A PLANNING AND SCHEDULING SYSTEM
FOR
HIGH-RISE BUILDING CONSTRUCTION

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ABSTRACT

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Planning and control of time are crucial issues in any construction project, especially in times of high inflation rates and sky-rocketing costs of construction. Some progress was made in that field in the early 1960's, with the advent of computerized network techniques (PERT/CPM). However, these planning tools have not gained general acceptance in the entire construction industry, especially in high-rise building construction.

The purpose of this thesis is to develop a planning and scheduling system adapted to high-rise building construction. With the cooperation of Montreal-based medium-sized construction companies, the study of high-rise building construction process was performed, and led to the formulation of specification for the system. Then, all the existing scheduling tools and their algorithms were studied and analysed to see their suitability to satisfy these specifications.

That analysis led to the design of the system based on network (CPM) and linear planning chart algorithms. Other features include correction of durations because of learning curve and bad weather

effects, and the possibility of generating short cycle schedules and procurement reports. The algorithms were then incorporated in a computer program which was tested with an extensive example of use.

ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION

1.1 BACKGROUND

With the increasing density of population in urban areas and advances in building technology, the architecture of commercial and residential buildings has evolved towards the slim, high-rise structures that can be seen today in most modern cities. The increasing cost of land in central business districts has also reinforced the need to increase the rentable area of such buildings which in turn leads to high-rise architecture.

At the same time, the development industry has become very competitive and has exerted considerable pressure on the construction industry to deliver buildings as soon as possible. Of more than five years at the beginning of this century, the construction duration of building projects has decreased to one to four years, depending on scale and complexity.

In the last decade of high inflation rates, some developers became very cautious in their investments, because of the sky-rocketing wages of labour, cost of materials and interest rates. The completion of a project on time and within budget became more than ever a crucial issue for a successful investment.

The scope of these projects requires a tremendous work force of trade specialists in many different disciplines. Few companies can keep such a large work force. Over the years, more and more specialized trade subcontractors came into being. Currently, when a general contractor signs a contract with the owner, he subcontracts out a high proportion of the work which may reach 90-95 percent of the project value. Benefits are derived from this mode of operating (ref. 55): the highly specialized and experienced staff enables the subcontractors to perform the job more quickly and at less cost than the general contractor; the general contractor can earn a mark-up on the work of the subcontractor while keeping only a few of his own resources at stake; he can process a larger volume of work with minimal expansion of staff; the fact that the subcontractor is bonded to the general contractor enables the latter to share the risks of the job with the former, and perhaps to transfer them to the subcontractors.

However, such an approach has created an environment in which each group is highly skilled and competent in its own area but in which there is little perspective on how all the pieces fit together. This places the general contractor in a management role of controlling and integrating the work of the various subcontractors in a global process, thus creating an information processing problem.

This problem has been the main concern of a research project at the Centre for Building Studies of Concordia University. The goal of the research is to "develop a comprehensive concept for a Construction Project Management Information System (CPMIS) tailored to the needs and capabilities of the Canadian general building contractor who engages in the construction of high-rise buildings" (ref. 63). Several years ago, contractors were reluctant to use computerized information systems because of their high overhead costs and lack of flexibility. However, with the advent of cheap microcomputers and the possibility of having an information system designed for their specific needs, the use of such a CPMIS is becoming more attractive to general contractors.

Previous work in this research programme includes a thesis (ref. 30) focussing on the need for collecting, analysing and reporting information for use by the contractor's clients, bank and surety. Another thesis (ref. 62) focussed on the analysis of several building contracting firms with respect to the problem of project planning and control, and it recommended that some work be done on the design and development of a project management information system for the building contractor which is basic in nature and simple to understand and use.

This recommendation was acted upon by Russell, McGowan and Katsanis (ref. 55), at Concordia University, who developed a framework for a subcontractor control system for the general contractor. The goal of that system was to refine the present methods of managing subcontractors by formulating an integrated process for controlling their performance, especially in terms of cost and time. Further work by Waldman (ref. 63) led to a refinement of the system and to successful partial implementation on microcomputers of the cost control aspect as reflected in initial price breakdown, progress monitoring and monthly progress claim forms.

Some other field trials and refinements of the subcontractor control system are presently being done by Avichai Manelson, another member of the research team. His work consists of studying the operations of subcontractors and of seeing how the system fits into the mode of operations of general contractors and subcontractors.

One of the attributes of the system is that it must interface with a master plan and schedule for the project, and must allow for interplay between itself and the master planning and scheduling process (ref. 55). It is the purpose of this present study to devise a planning and scheduling process for high-rise building construction.

1.2 METHODOLOGY

The methodology employed to achieve the above goal consisted of a combination of direct observation of the construction process and of an in-depth review of the theory about current planning and scheduling techniques as described in the literature.

The examination of the construction process was made through exposure to the personnel of two general contracting firms and of some of their subcontractors, on two different sites in the Montreal area. It consisted of several formal and informal meetings with the project managers, the general contractors' superintendents and the subcontractors' foremen. For three months, the author visited weekly the construction site of an office tower in downtown Montreal, and studied how the job was progressing. Those weekly visits were also accompanied by informal discussions with three subcontractor's foremen, in order to get their view of the process.

On another job, in downtown Montreal, the author was given permission to attend the weekly subcontractor's coordination meetings at which the detailed execution of the job and the short term schedule were discussed. Those meetings highlighted the interfacing points between the subcontractors and the need for a good project plan.

Finally, for about six months, pictures of the two job sites were taken twice a week and studied carefully by the author. Some of these pictures are included in the thesis to illustrate some of the points explained in the description of the process.

This exposure to actual construction sites led the author to formulate specifications for a planning and scheduling model tailored to high-rise building construction.

The next step consisted of examining the literature to see how current planning and scheduling techniques could be used or adapted to satisfy the specifications developed. From that review, a model was proposed and implemented on a computer.

1.3 LITERATURE REVIEW

Previous work which pertains to the problem examined in this thesis is briefly described below and examined in more detail in chapters 3 and 4.

In a report prepared for the Canadian Construction Association about project planning and progress control practices in the Canadian Construction Industry, Revay and Associates Ltd. (ref. 50) suggested that new models suitable for project planning and progress control and which could be readily adaptable to the specific needs of industrial contractors be developed. It was also suggested that these models be tested on real jobs, in order to facilitate their design and their adoption by users.

Russell and Triassi (ref. 52) studied general contractor project control practices and found that the building contractors interviewed used bar charts for planning and scheduling. However, these charts were rarely updated and sometimes abandoned during the course of a job. However, controllable causes of over-runs could be correlated with identified deficiencies in planning and control practices, showing a need for more appropriate planning and scheduling methods.

Birell (ref. 8) stated that "the CPM/PERT concepts, while marginally useful, are comparatively foreign to the construction process which has heuristically evolved over centuries to satisfy the needs of the situation of construction: it follows that a planning concept for construction drawn from that heuristic analysis to the processes of construction can be a more realistic and thus more useful concept of planning for the construction process". While not suggesting alternate models, he sets out a methodology to design planning models, which is similar to the one of the present thesis.

Peer and Sellinger (ref. 44) suggested a model called Construction Planning Technique (CPT). This model is aimed at offering a practical solution to the problem of arranging the production process on site.

Such a model has been treated in several publications (refs. 7,21,27,35, 39,48) and is described in the third chapter of this thesis.

1.4 THESIS OVERVIEW

A study of the high-rise building construction process is described in Chapter II. Also included in the last section of the chapter is a general specification for the planning and scheduling model.

A review of various planning and scheduling techniques which could be used in developing a model is presented in Chapter III.

Details of the model formulated in response to the needs of high-rise construction are unveiled in Chapter IV.

Chapter V contains a description of how the model was computerized as well as an extensive example of its use.

Finally, the conclusion of the thesis and recommendations for future work are set forth in Chapter VI. Appendices contain part of a sample session on the terminal, the list of activities and dates for the last update of the example in Chapter V and the computer code listings.

CHAPTER II

THE BUILDING CONSTRUCTION PROCESS

2.1 INTRODUCTION

Most building projects are very similar in nature as to the components and the processes involved to put them together. It is clear, however, that a hotel or a luxury condominium building will not be done with the same quality standards as for a commercial office building or for an industrial facility.

However, the planning process used by a general contractor for all of these building types is similar. He has to coordinate the work of numerous subcontractors and sequence it properly in order to limit coordination problems. The detailed activities that constitute one job will obviously be different from job to job but the overall framework is the same.

The purpose of this chapter is to identify the kind of activities that are performed by the various trades during construction of a typical high-rise building. The various characteristics of these activities will be used as a basis for identifying the features that the scheduling system should have. Then, a rough description of the main activities performed by the various trades will be given. A section on the sequencing of activities will be presented along with the problems of coordination associated with it. Finally, specifications for a planning system will be put down according to the characteristics defined in the earlier parts of the chapter.

2.2 DESCRIPTION OF ACTIVITIES

Activities are described here by listing them and explaining the methods involved in each of them. Each trade is treated separately as a "sub-network" first and in the next section, the sequencing of activities and the interfaces between subcontractors is described.

2.2.1 Preliminary Work

Although not part of the construction itself, the preliminary work, as described below, should be included in the general contractor's schedule, especially if the owner chooses a general contractor at the front end and gives him the mandate to manage the project from start to finish. In a standard lumpsum price contract, in which the scope is known and the plans are virtually complete, the preliminary work is reduced considerably; the general contractor will be asked to start the work soon after award of the contract and many variables (soil conditions, processes required, etc.) will be known at this stage.

However, in a "fast track" or a "turn-key" job, the owner will involve the general contractor very quickly in the job and will ask him to contribute to the design by suggesting alternatives or methods which might reduce the cost and/or time of construction. Some demolition work is often required, especially on sites located in an old residential or commercial area. Specialized contractors can do such a job relatively quickly but it has to be included on the general contractor's master schedule.

Then research about the characteristics of the site and of the surroundings has to be carried out. A soil testing firm may prepare a geological report on the soil's condition by drilling bore holes and analysing the samples for use by the soil's and foundation's engineers in order for them to perform their design. Research will also include the gathering of data concerning the location of surrounding tunnels, electrical conduits, sewer and water pipes, etc. This information greatly influences the methods used to perform the excavation.

Finally, in a fast-track job, the design task has to be scheduled properly in order to minimize change orders due to problems of coordination and/or missing design information and tne resulting claims. Information from suppliers and subcontractors should be obtained so that lags between the awarding of the contract, the issuing of shop drawings and the start of the work itself, after all the required approvals, will be scheduled adequately.

Procedures for reporting progress in design and construction should be instituted at this stage along witn communication lines and the hierarchy of responsibilities of the various groups involved. All these operations could be labeled under a "general conditions" type of activity; even if they are not part of the operations on the buildings themselves (or direct costs), they constitute the basis of a successful start of the construction process.

Finally, the general contractor has to mobilize his staff and equipment to the site and organize it. He will need a "site office", usually a large mobile home, equipped with phones, clerical equipment, drafting tables and private rooms. This activity precedes any construction work on the site.

2.2.2 Excavation and Foundation

In high-rise building construction, the excavation work is usually extensive and requires several months. The depth of the excavation can vary from 1 or 2 floors (10 to 20 feet) to several floors (40 feet and more) that will be used as parking spaces for the users of the building, storage area, and possibly retail outlets. Such depths might require the use of earth retention techniques to hold the sides of the excavation. Sheet piling is widely used and is fairly simple to execute. The driving of the steel beams has to precede the actual excavation of material. If the excavation is so deep that it is impossible for a shovel to reach the bottom of it, the work should be planned to enable trucks to go down into the excavation where they will be loaded. When all the possible work will be done, the shovel from the top will excavate what it can and the rest will be lifted by crane.

Before reaching the bottom of the excavation or the surface of the bedrock, the beams of the sheet piling have to be held in place by tie backs or by lateral inclined supports. In order to avoid deformation and movement of the earth to be retained, the engineers usually require the beams to be braced every 8 to 10 feet in depth. If tie-backs are used, the most logical sequencing is the following: starting on one side of the site, the steel beams for the sheet piling are driven in the ground. When a sufficient number of them are done the shovel can start excavating on that side of the excavation up to a depth of 8 to 10 feet (or as mentioned in the specifications). While the shovel keeps on moving the same way as the driving equipment, the drilling macnine can start its work of installing the tie backs and follow the same path along the sides as his predecessors. Once there is enough room to operate, the excavation can continue at the starting point for another 8-10 feet to enable the drillers to install the next set of tie backs.

This sequence of activities should be used as a starting point for the excavation activities. The exact sequencing of the work of the shovel and of installing the tie backs will be variable depending on the job site characteristics: its size and shape, its accessibility and its quality.

If the nature of the surroundings of the site doesn't permit the use of tie-backs, lateral supports have to be used to hold the beams. The process of excavating differs in this case; the center of the hole has to be done in the first place up to the bottom of the excavation and earth has to be left on the sides, sloping downwards to the bottom. Once this is done, a small abutment is poured on the bottom of the excavation and the supporting beams are installed between the sides of the excavation and the abutment. The remaining material is taken out for another 8-10 feet and another lateral support, lying on the same abutment is installed, if necessary. This is done up to the bottom of the excavation. Tie backs are preferred to lateral supports when possible because it clears the interior part of the hole where the work will be done. Blasting, if required, is the next activity of the excavation work. Because of the stability of bedrock, no earth retention techniques are required when excavating bedrock.

Once the excavation work is completely finished, the foundations have to be done. On a high-rise building they usually consist of piles, caissons, mat or footings, depending on the bearing capacity of the soil. The stability of the soil will dictate if the caissons should be driven from the surface or from the bottom of the excavation; if the soil is unstable, the caissons should be driven from the surface in order to avoid equipment becoming stuck due to poor soil conditions. It costs more to do that but the risks are decreased considerably. Piles are driven from the bottom of the excavation. Such work should be started as soon as there is enough room for the driving machines to operate.

Because of the unpredictable nature of soils, in general, excavation and foundation will always remain difficult to plan accurately. However, the outlined sequence of activities will help to prevent errors of logic and it should be used as a check list when the planning is done. On big sites, the work could be broken down in different areas, which would be done by following the same sequence using several equipment spreads.

2.2.3 Structure

Among all the operations that have to be executed in a building job, erection of the structure will be the one setting the rhythm of the execution of the work for the remaining trades. Physically, the structural work has to be completed on any floor before any other trade can start its own operations. Three main types of high-rise structures are currently used in the industry: steel or concrete used separately and steel and concrete. The advantages and disadvantages of each are identified at the design stage by the structural engineers and the architects but the general contractor often suggests alternatives. For example, in the Montreal area, most contractors are experienced with poured-in place reinforced concrete structures and will often "sell" it to the owner and to the architect. In general, a steel structure can be erected faster than a concrete one, but it costs more. Beyond a certain number of stories (about 50), concrete becomes less advantageous because of the tremendous weight of the structure, so that tall structures are usually made of steel. But for medium-sized buildings (20-40 storeys) the trade-offs are made between the duration of construction, the initial capital investment and also, the skills of local general contractors.

The construction processes involved in concrete structure erection differ from the ones of steel structures. They will be outlined first. Once a suitable crane system is installed and working and the foundation work completed, the formwork can be started for the columns, the walls of the perimeter and for the first slab (Fig. 2.1). The plumbing subcontractor should be present at that stage in order to embed in the slab

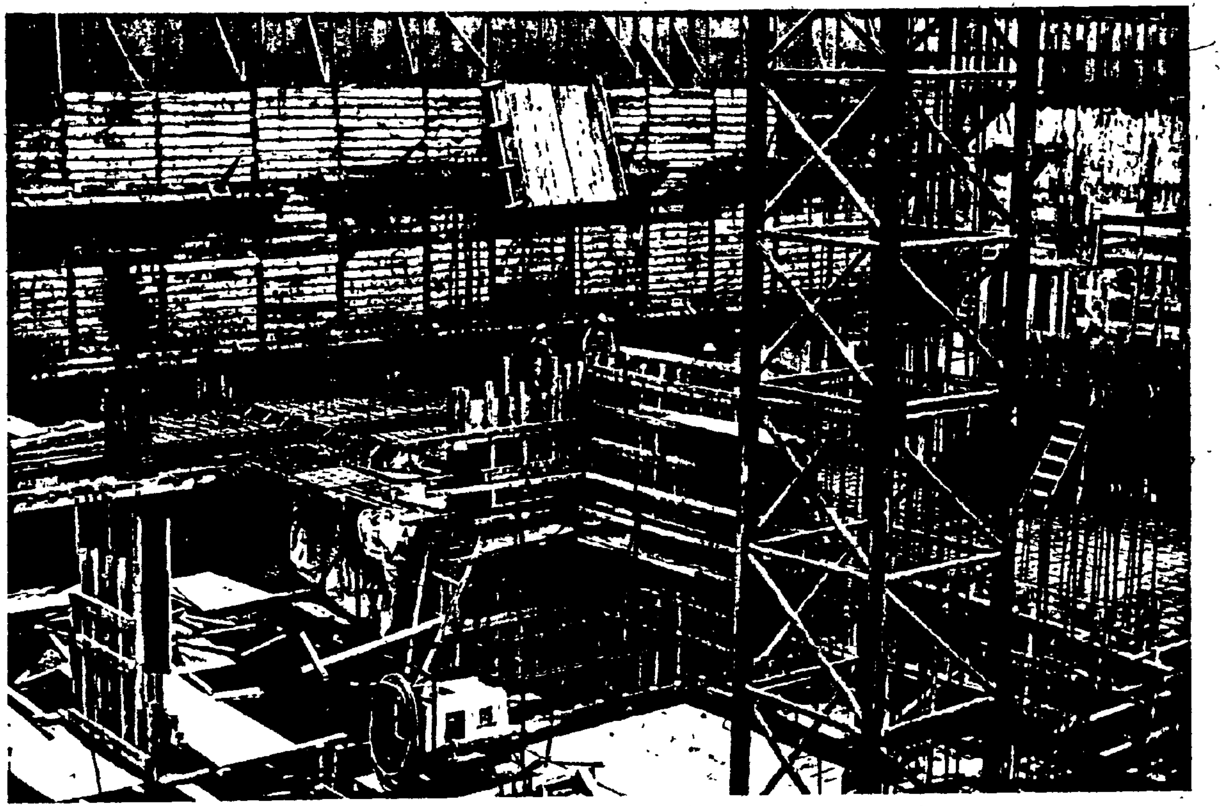

Fig. 2.1 Basement Structure

the sleeves for the drainage pipes. To speed up operations, the concrete of the perimeter walls and columns could be poured directly from the trucks or by using concrete pumps. Concrete for the remaining areas could be poured by using a crane and bucket system.

The basement usually houses various vital equipment for the building such as the main domestic water pumps, sprinkler pumps, sewer pumps, electrical transformers, switches and auxiliary generator, etc. Although the bulk of their work may be months away, those contractors have to follow closely all the concreting operations in order to be on site on time to embed their sleeves or leave holes open. For example, transformers cannot be delivered soon after the contract is given out. Usually, a hole is left in the slab to facilitate their installation later on during the job. Communication plays a big role in the execution of these special areas.

In general, all the basement floors will require more time than the typical upper floors of a building for several reasons: these floors may cover a greater area than the typical floor in order to minimize the depth of the excavation and the presence of concrete walls around the perimeter of the basement floors and the necessity of slopes between the floors to facilitate car movements increases the complexity and the volume of the concreting operations. Finally, the contractors are mobilizing their staff and are organizing themselves on the site; a few design details may also have to be reworked because they do not fit the actual job. All of these factors put together slow down the productivity of the structure of the basement floors.

Normally, the ground floor, in terms of quantities and complexity, cannot be grouped with the typical floors. Its area again may cover a greater surface than the typical floor. Its characteristics include accesses to the building, ramps for cars, loading and unloading docks, a security control panel, and special requirements for specific tenants (bank branch, restaurant, etc.). Ground floors are also often characterized by high ceilings and sometimes by an atrium (more than two storeys high). When separated from the tower(s) the atrium is often made of steel which facilitates its construction. Ground floor columns made of concrete add some difficulties to the process. They have to be poured in more than one step and scaffolding has to be used to install the formwork (Fig. 2.2) and to shore the forms for the slab of the second floor or of the mezzanine. Such a situation will always happen, no matter the kind of building, and the schedule should treat the situation accordingly.

The second floor represents usually the start of the typical floor arrangement for the tower. All the design corrections should be made at that stage in order to repeat exactly the same procedures on the remaining slabs. Again, the presence of the mechanical and electrical subcontractors during the installation of the formwork is crucial.

The general sequence of operations of the concreting of a floor is described as follows (Fig. 2.3). The pre-assembled column reinforcing steel is hoisted up and installed on the top of the previous columns;

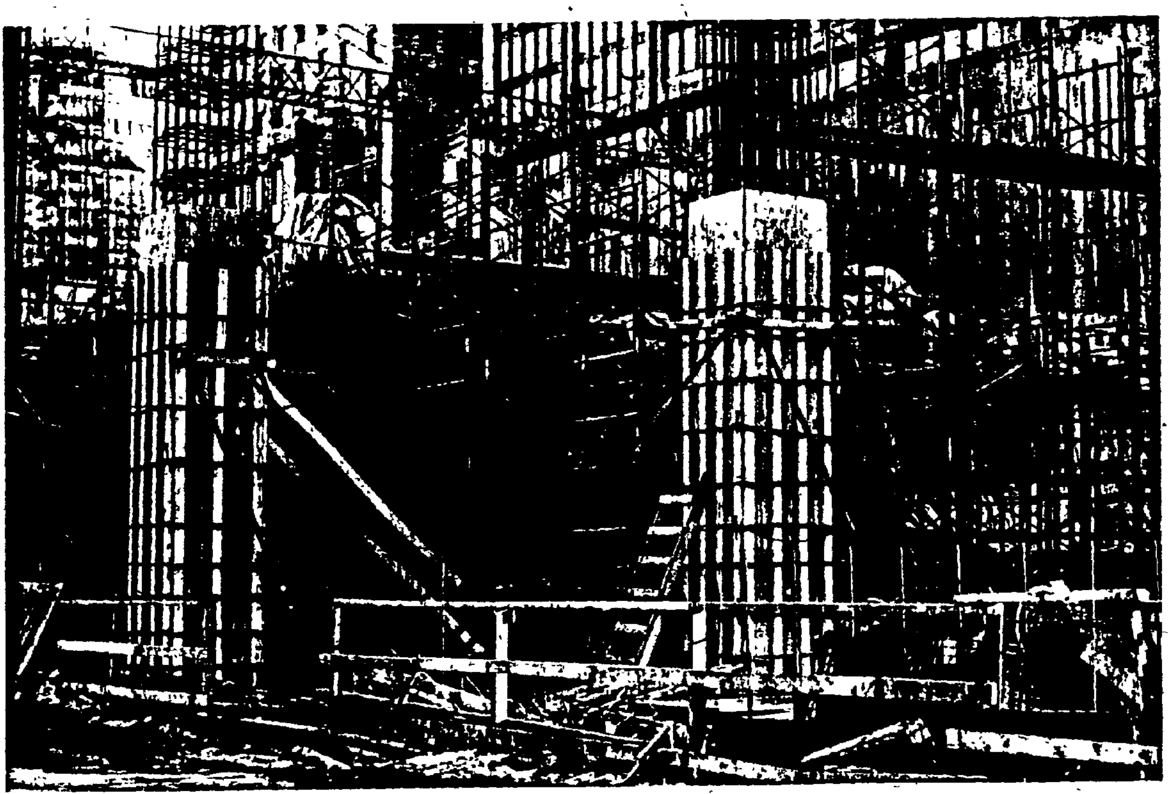

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Fig. 2.2 Ground Floor Structure

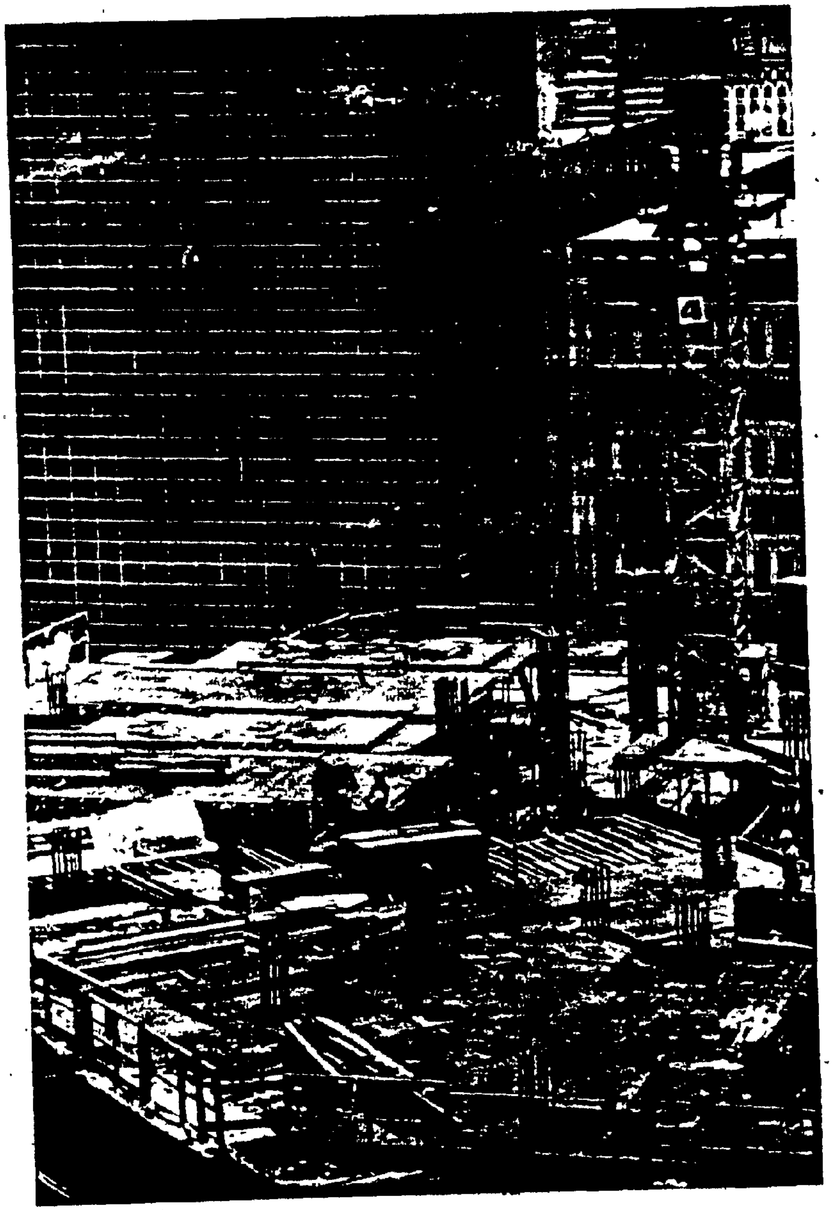

Fig. 2.3 Typical Floor Structure

formwork is done next and braced properly. The reinforcing steel and the forms for the walls of the core (if made of concrete) follow next. Then, the slab forms are installed, covering the whole area of the floor. When all the carpentry work is finished and levelled, the reinforcing bars can be installed, along with all the conduits, sleeves, steel angles, etc., that have to be embeded in the slab. The pouring of the columns and of the walls is done first, followed by the pouring of the slab. Overnight curing should enable the workers to start on the next floor the day after the pouring.

Normally, large floors are broken down in two or more sections (Fig. 2.4) which are handled separately as explained above. Completely independant crews work on their respective sections which are not necessarily executed exactly in parallel. It is preferable to have two or more pouring sessions for the same floor instead of having a big one for the whole floor. Cranes and access facilities to the site are therefore used more effectively and confusion on the floor itself is avoided.

The floor(s) which house(s) the mechanical equipment for heating and ventilation break(s) the repetitive cycle for typical floors. Thicker slabs, numerous electrical conduits, holes for pipes, and embedded bolts characterize them. The mechanical and electrical subcontractors might slow down the rhythm of the concreting operations because of the above-mentioned additional work.

Weather can influence substantially the progress of work on a

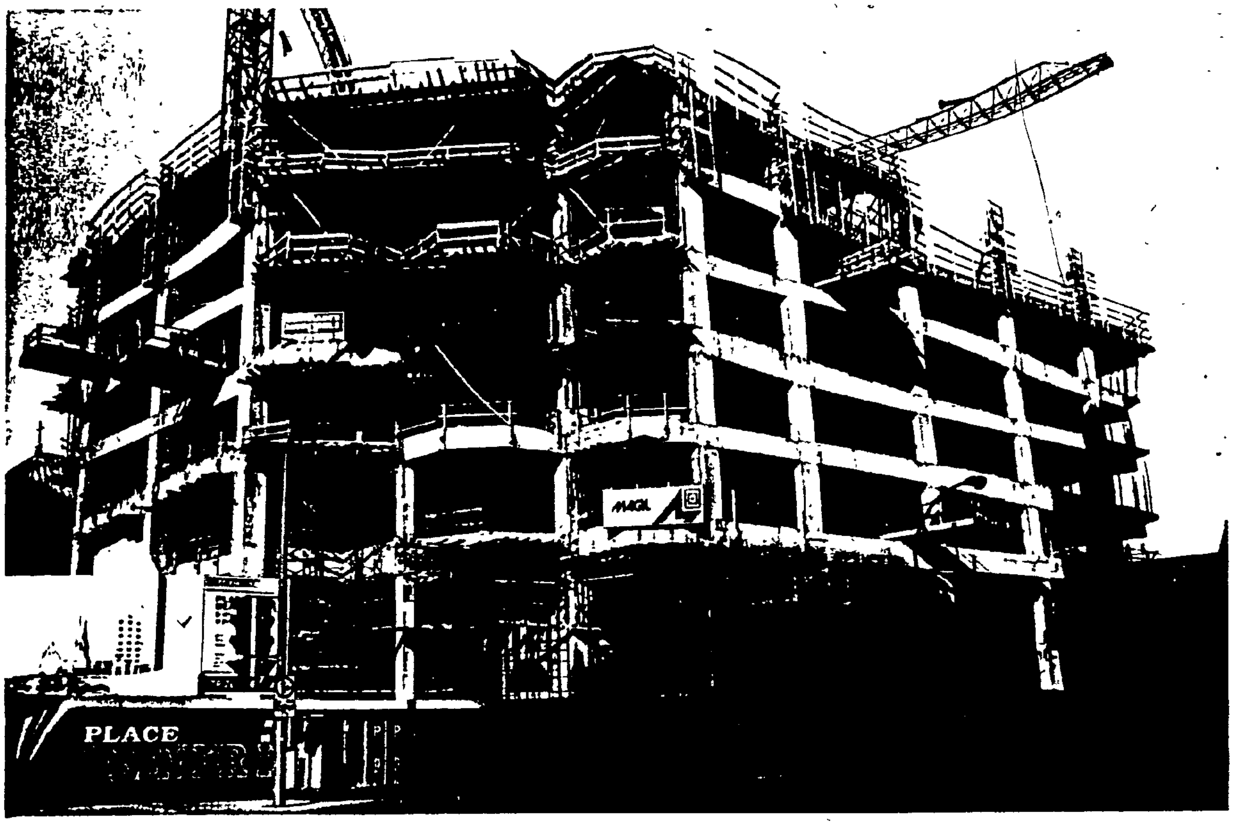

Fig. 2.4 Typical Floor poured in two sections.

reinforced concrete structure. In the summer months, the productivity of the structural work reaches it's peak because of the predominately good conditions and high temperatures. Only intense rain might stop the work but usually not for long periods of time. In fall, the probability of rainy days increases, but not dramatically. However, construction costs are increased by the necessity of heating the areas of the building where the concrete is poured and where it is still curing. Contractors normally use propane burners to generate the heat but the means to insulate those areas are very limited. Usually the heating has to be done for 7 days after the pour and 24 hours a day.

Winter months remain the most difficult ones for a construction job, especially in areas where cold temperatures and heavy snow falls predominate. Snow represents a major inconvenience because it always has to be removed from the forms, meaning time lost and delays. If the reinforcing bars are installed and it then snows, compressed air is often used to finish the cleaning job (Fig. 2.5). When it snows during the concrete pouring, one might prefer to cover it as soon as possible, but the finishing of the slab suffers. Extreme cold weather and high winds paralyze job sites because of safety reasons. And it should be remembered that the concrete has to be heated to a specific temperature for curing. All these factors taken together have discouraged more than one general contractor from working during the winter months. Although direct construction costs are decreased when work is done only in summer months, most owners prefer a shorter construction period (i.e. work all year long) because of the interest charges and of the quicker delivery

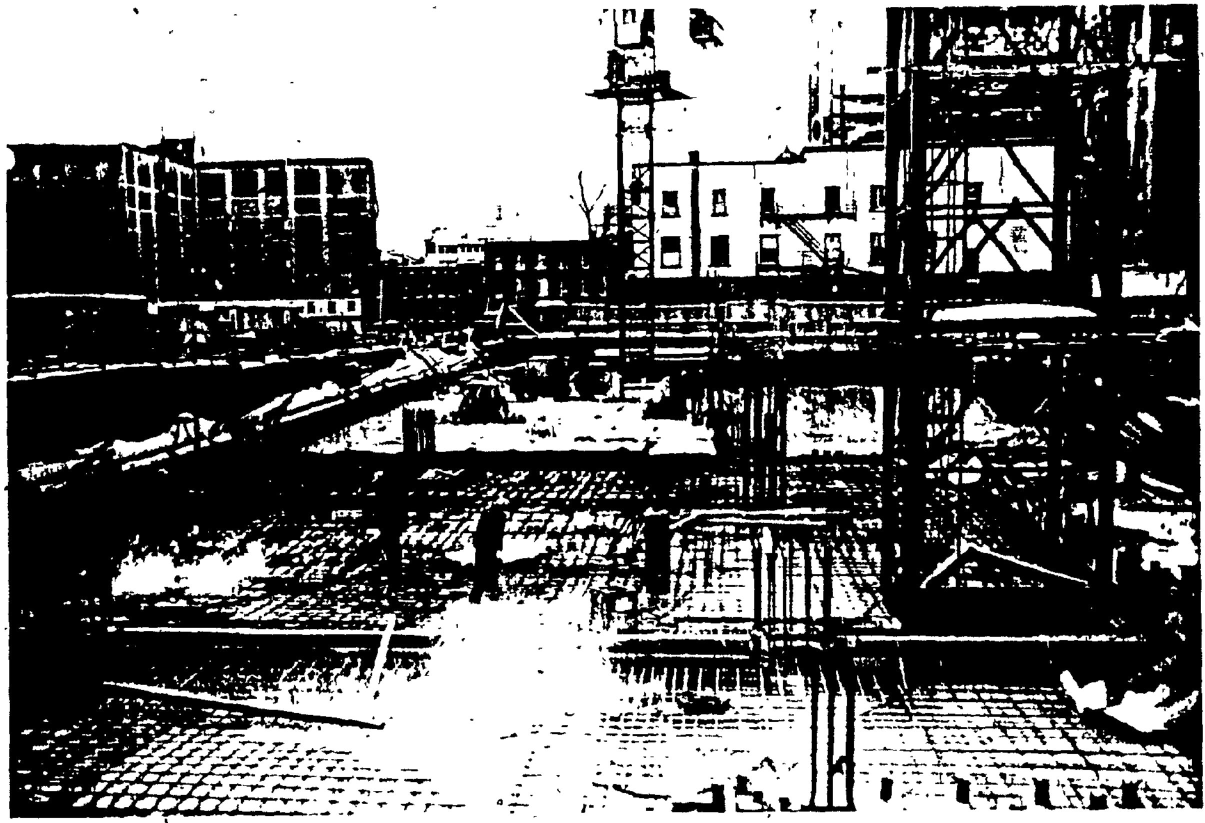

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Fig. 2.5 Clearing of snow during winter.

of the product which can generate funds.

So a subcontractor should be able to predict a rhythm of production for the structure erection, based on its area and complexity. Moreover, when the final schedule is prepared, some provision (contingency) for lost days should be included in order to evaluate better the real time needed to perform the construction work. From one or two days per month during the summer months, the provision for days lost increases to a peak of 4 or 5 days lost per month during the winter months.

The erection of a steel structure differs from a concrete one because it is performed with three different sets of operations, each usually done by a different subcontractor. The first of these activities consists of assembling the various columns, beams, joints, bracing, etc., that represent the skeleton of the building. These pieces of steel are prefabricated in the steel contractors shop and are shipped to the site where they will be lifted and bolted and/or welded together. Accurate shop drawings and corresponding fabrication are crucial to the successful erection of the structure. Everything has to fit perfectly in order to avoid creating unforeseen stresses in the structure.

The steel subcontractor usually assembles the structure in two steps. First, the "core", which consists of the main pillars of the structure, is erected. Sometimes, a crane system will be attached to it and will be used to lift the various pieces of the structure. Then, once the core is finished, the perimeter of the structure can be assembled (Fig. 2.6). The various elements are usually lighter in weight

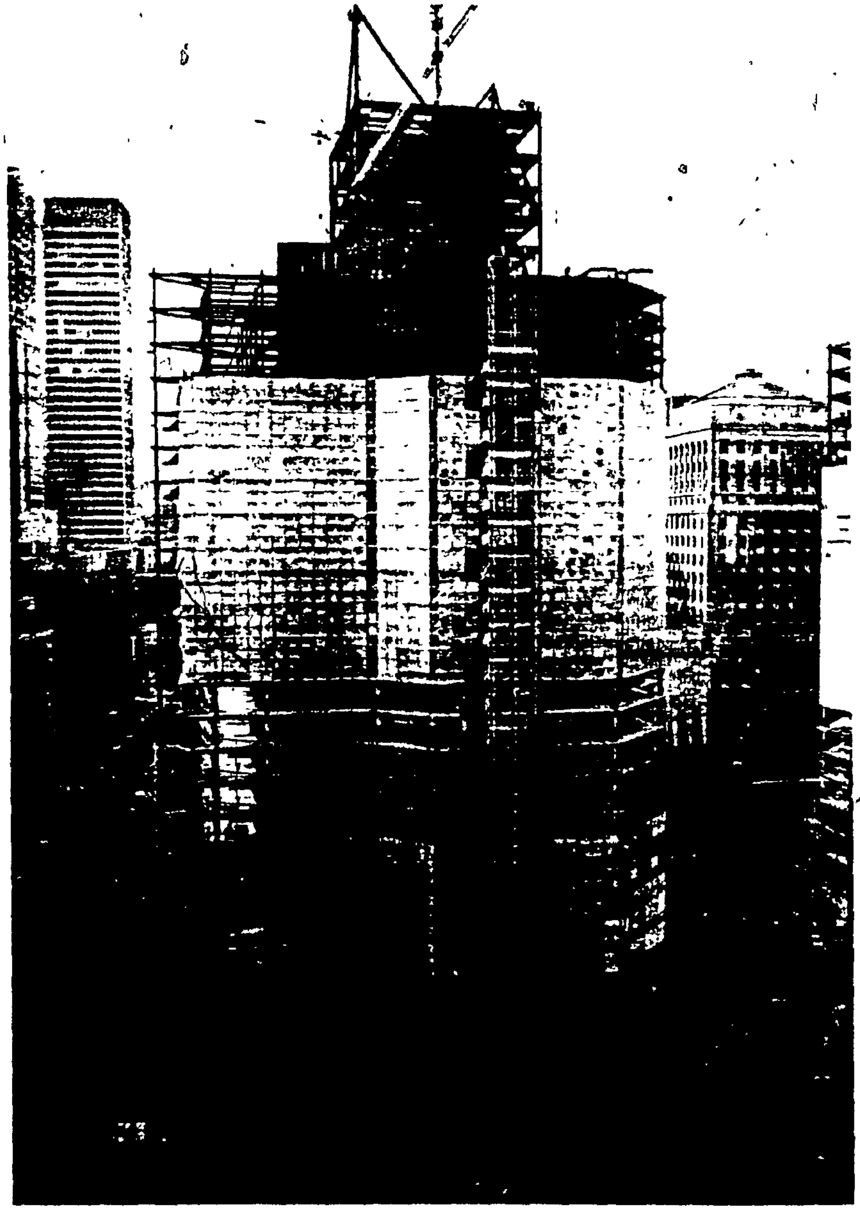


Fig. 2.6 Erection of a Steel Structure.

than the core's element because they don't have to bear the load of the mechanical systems and of the elevators. Once this is terminated, the steel work is considered done and the next set of operations can begin.

Performed by a different subcontractor, the pouring of the floor slabs follows the erection of the steel. It resembles the operations for a concrete structure except that only the deck has to be poured. The following sequence of operations describes the process involved: a metal deck is laid on the framing system and will stay there permanently. The various reinforcing steel bars and/or grid, sleeves for pipes and electrical conduits are then installed by the various subcontractors. The pouring and finishing of concrete follow. A detail worth mentioning is that usually the crane system is owned and operated by the steel subcontractor; because of the time required to haul and to install the various pieces of the frame, the other subcontractors cannot depend on it and should organize their work accordingly. In the case of the concrete, an alternative would be a pumping system from the ground instead of a crane and bucket one, depending on the height of the building. Time could definitely be saved and conflicts could be avoided.

Finally, the steel members have to be fire-proofed which involves the spraying of fire proof material. While this task does not involve the use of complex methods or equipment, it has to follow the rhythm set by the structural steel erection. However, fire-proofing has to be done at normal room temperature (20°C) in order for it to adhere properly to the metal. Therefore, when the work is performed during the cold winter months, the areas where the concrete is poured and cured and where the steel is fire proofed have to be heated. Because the steel beams are already installed, the plastic insulation sheets can be attached easily on the perimeter beams. In order to minimize the area exposed to the cold, it is preferable to execute the concreting and fire proofing activities back to back and to heat 3 or 4 consecutive floors instead of having a gap between the heated areas (Fig. 2.6).

While describing the activity sequencing of a reinforced concrete structure, all the different types of floor, ground floor, mezzanine, mechanical floors, typical floors, etc., were mentioned and their characteristics outlined. These characteristics still exist in the case of a steel structure and the planning operations should consider them. The sequencing for other structural configurations, such as a concrete core with a structural steel frame for the perimeter is not treated herein.

2.2.4 Mechanical Work

The mechanical work in building construction is usually broken down three distinct sections, which in some cases correspond to three different sub-contracts: ventilation, plumbing and heating and fire protection (sprinklers).

The ventilation work is mostly repetitive and present on each of the floors in the form of ductwork, diffusers and possibly a small mechanical room. Special mechanical floor(s) will contain components such as fresh air intake and "used air" evacuation along with the fans, cooling towers, chillers, filters, etc.

Because of the size and rigidity of the duct work, its installation immediately follows the structural work. After the shop drawings are ready, the fabrication of the duct work (sheet metal) will start in the shop of the subcontractor so that it will not delay the start of his work. This activity may not be specifically indicated on the construction schedule but it should be monitored. The installation of the duct work consists of a simple method: its location on the ceiling is determined by precise measurements; several metal hang rods are drilled at regular intervals in the ceiling along the way of the duct; the ducts are then suspended from on these supports and carefully linked one with the other (Fig. 2.7). The workers normally use a small scaffolding which is mounted on wheels so it can be easily moved over the whole floor area. The start of a subsequent floor is not governed by the finishing of a previous one. For example, when a tenant wants to modify the standard arrangement on floors he occupies or when some shoring is still in place to distribute the load of the tower crane, the duct work is not installed and work on the following floor is started.

Compared to work on the upper floors of the building, work on the basement floors (which may be used for parking) is far less extensive. It consists of a small network of ducts which diffuses fresh air and evacuates used air from the basement. This system is usually not connected with the control system that diffuses fresh air in the upper

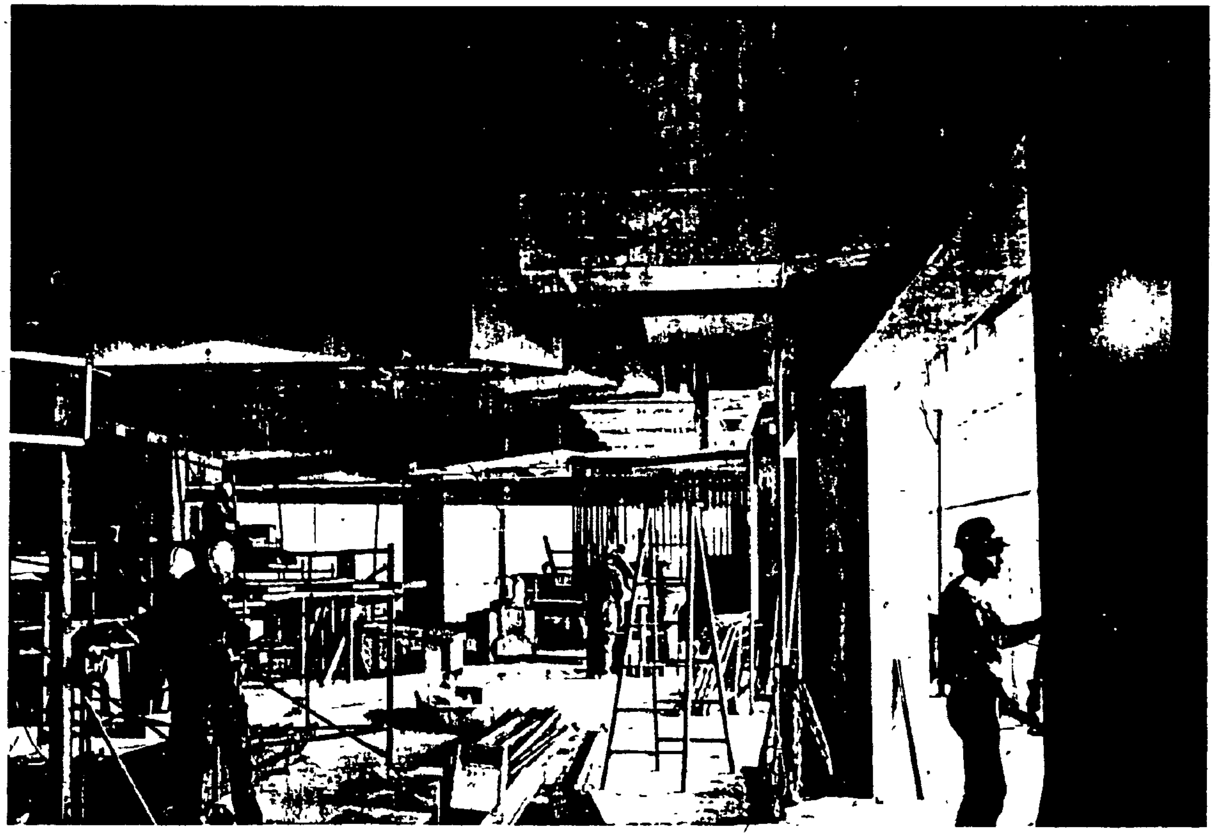


Fig. 2.7 Ventilation Ductwork Installation

floors and has its own fans, electrical coils and air intake and evacuation. The work on the ground floor and on the mezzanine represents more hours and more complicated processes because of the height of the ceiling and the normally special features of it. The ground floor is also often used as a storage area at the beginning of the job and so renders work in that area more complicated. Hence the roughing-in work of the ventilation subcontractor and of all subcontractors in general usually starts with the second floor.

The repetitive roughing-in work in ventilation also includes, in many cases for large buildings, a small mechanical room on each floor containing a fan and a heat exchanger (Fig. 2.8). Duct work will also be installed vertically for the fresh air and return air risers. The return air riser is usually located near the toilet area, where air is evacuated.

The mechanical floor(s) houses the heart of the ventilation system. The duct work consists of the intake of the atmospheric air and the evacuation of the impure air coming from the return air riser, with the main fans and filters. The ventilation subcontractor has usually to furnish the equipment for air conditioning, mainly the chillers and cooling towers. Although these items constitute a substantial portion of the contract amount in terms of value, the labour associated with them for the ventilation sub is usually very small. All that has to be done is to hoist them and put them at their respective locations. The work of connecting the pipes and wires is not included in the

Fig. 2.8 Floor Ventilation Unit

ventilation contract.

After the duct work is properly fixed to the ceiling, it has to be insulated by gluing around it fiberglass insulation or a material with similar properties. One important feature of this work is that the glue has to be applied at normal room temperature to be effective. Therefore, insulating work under winter conditions requires heating. As mentioned before, a trade-off has to be made between heating the floors (sometimes twice - once for concrete, once for finishing) and proceeding with the work, or waiting for warmer temperatures to execute the work.

Finally, the finishing work on each floor consists of installing the diffusers and the flexible ducts, if any, and linking them to the main duct work. Start-up, testing and balancing of the various components conclude the work of the ventilation subcontractor.

The plumbing work consists of the distribution of domestic water in the structure and of the evacuation of sewage water from the building. It also includes the transport of heating and chilled water through the building. As mentioned before, the plumbing subcontractor should be present on the job during the erection of the structure in order to put his sleeves in at the right place in the deck. This is crucial for the risers because they have to be plumbed.

Once the formwork is stripped, the various risers can be erected. They can be listed under several categories: domestic water (hot and cold); storm water; sewage; heating and chilled water; and oil or gas risers. Their installation remains relatively simple because of the vertical nature of the work. The accuracy of the embedded sleeves plays an important role in the progress of these activities.

In the basement of a building, the plumbing work consists of a network of drain pipes needed to evacuate the water on parking floors. Because those floors are located below the main-sewer of the city, the water has to be raised by drain pumps which are installed at the lowest point in the basement. Other equipment located in the basement are the booster pumps that increase the pressure of the city's domestic water network in order to guarantee a reasonable pressure at the highest level of the building.

The distribution of domestic water differs a lot depending on the type of building; on a typical floor of a high-rise commercial office building, the domestic water is used only for the washrooms and drinking fountains that are located in the core of the building. In a residential type of high-rise building, the network of distribution of domestic water (and evacuation of sewer) is far more extensive because of the numerous toilets, baths, showers and kitchens found on each floor. A hospital or highly-technical building (eg. university laboratories) requires extensive plumbing work because of the enormous and complex pipe network on each floor. Although the above-mentioned examples each require a different plan of work from the plumbing subcontractor, the ideas of keeping a constant production rate for the entire building and a constant workforce for the duration of the project are central to all. This is then accomplished by adjusting crew sizes so that the production rate agreed upon with the General Contractor can be maintained.

The mechanical floor(s) usually represent(s) a large quantity of work for the plumbing trades. Large pieces of equipment such as boilers, hot water reservoir, circulating pumps and chimneys have to be delivered and installed by this subcontractor. All the networks of pipes linking the various elements of the air conditioning system (cooling tower, chillers, condensors, etc.) have to be fabricated and installed by the same subcontractor. Coordination is very important at this stage between the ventilation and plumbing trades; the latter needs the exact dimensions and locations of the various units in order to issue his shop drawings so sleeves may be placed before the pouring of the deck. Poor coordination could affect the alignment of the pipes and therefore result in delays for everybody.

The finishing work consists of insulating the pipes and installing the toilets and the lavoratory equipment on each of the floors. The commissioning of the whole system is the last step before occupation.

With respect to the fire protection or sprinkler system, the work of the sprinkler subcontractor may start very early depending on the municipal laws for fire protection. For example, a municipality might require that a fire hose be located not more than 3 floors below the upper most floor of the structrue during its construction. Therefore the stand pipe has to follow the structure closely and a pipe has to link the riser to a connection at street level, to allow a pump-truck to produce the necessary pressure. Also, the subcontractor has to follow closely the structural erection in order to put his sleeves in at the right location.

In the basement, the sprinkler subcontractor has to furnish and install booster pumps that will provide the necessary pressure in the pipe network. It should be noted that the domestic water network and the sprinkler network are completely independent.

The roughing work consists of linking the already installed riser to a network of smaller diameter horizontal pipes present on each floor of the building. Its installation resembles the ductwork network; it is suspended to the ceiling of the structure by metal supports and it is installed by a crew using scaffolding mounted on wheels. After the network is properly installed, all the connections are tested to avoid any leaks in the system.

The sprinkler work is finished by the installation of the heads or pendants at the various locations along the network of pipes. It also includes the installation of hoses and extinguishers as required by local laws. At the street level, a cross-connection and valves are installed permanently in order to link the system to the pumps of the fire trucks in the case of a major fire.

2.2.5 Electrical Work

Among the trades present in a building construction job, the electrical work probably contains the most items. One just has to think about all the wiring, panels, switches, plugs, lights, etc., that have to be delivered and installed by this subcontractor. The breakdown and the planning of the electrical subcontractors job is therefore complex.

Actually, the electrical subcontractor shows up on the site right at the beginning of the construction because he usually supplies temporary power to the various facilities used by the general contractor and the subcontractors. He has to contact the local electrical power company in order to schedule suitable dates with them for the connection to the area's network. Temporary power is also provided for power cranes, outlets on each floor for the hand tools and equipment and, when the forms are stripped, temporary lighting.

As mentioned for the mechanical subcontractors, the electrical subcontractor has to follow daily the structural work in order to embed in the slab the conduits that will eventually contain wires. This operation requires more time than the work of the mechanical subcontractors because the path of the conduits has to be laid out carefully on the forms as compared to locating only a specific point for the sleeves.

Every major building has a main electrical room that contains the main transformers and switches along with auxiliary power units in case of failure of the area's network. This room is normally located in the basement near the incoming power location. Because of the size of the electrical elements and the long lead time necessary for their fabrication and delivery, the slab over the electrical room might not be poured until their installation is completed (Fig. 2.9). Close coordination between the electrical and formwork subcontractors is therefore crucial at this stage. Preferably, the final pouring should be done when all units are found to be properly working. Considerable work is required in the electrical room to connect the transformers and switch gear to the main feeders and bus duct. Agreements have to be reached with other subcontractors on dates at which they need permanent power for their use during the construction period (elevator motors, ventilation equipment, etc.) in order to avoid delays and conflicts between the various trades.

Large pieces of electrical equipment (control panels, switches) are also found in the main mechanical room and in the elevator control room(s). Again good lines of communication are essential between the electrical and concerned subcontractors in order to deliver electrical equipment at a suitable time for everybody. Information on the lead time necessary for this equipment should be available early in the project to avoid procurement problems for the electrical subcontractor.

As the structure goes up and is stripped, the repetitive roughing work can be executed. It consists of putting in place the vertical feeder conduits and the bus duct that will carry the power to the various floors and equipment. These elements run vertically through the building so their installation remains relatively simple. On each

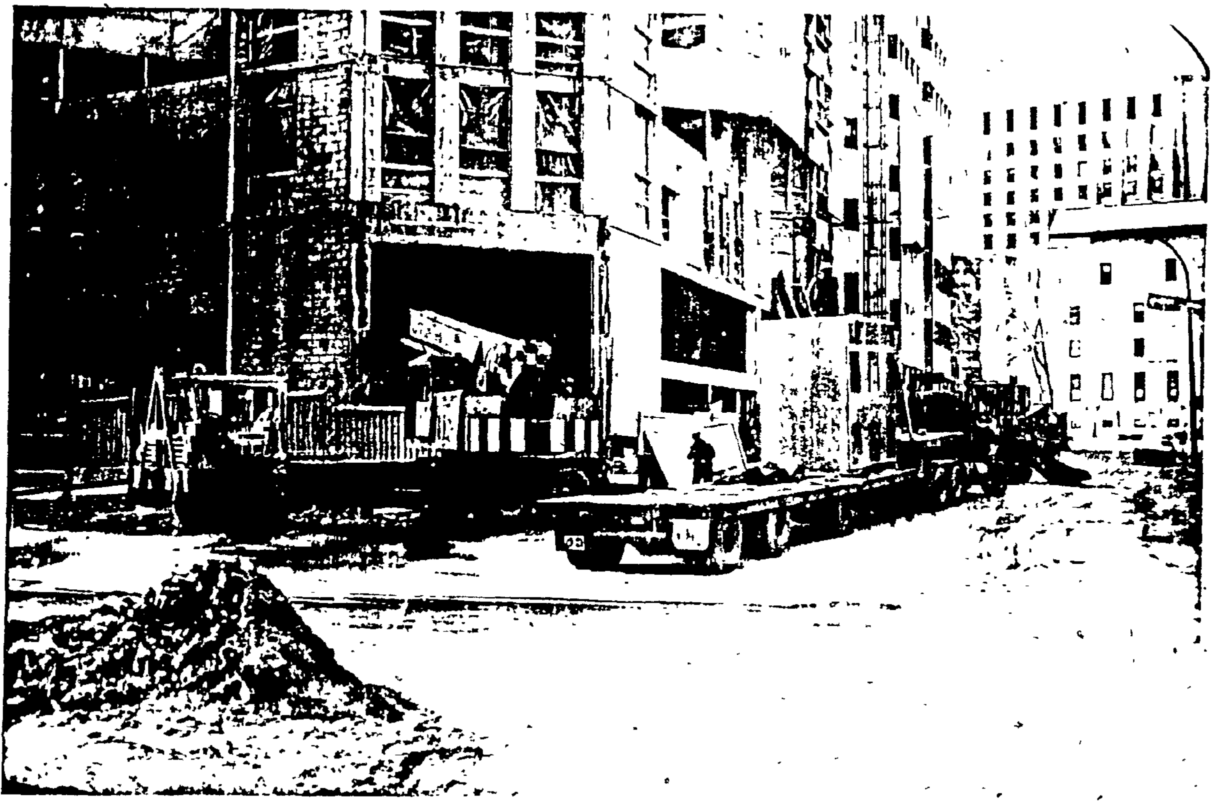


Fig. 2.9 Delivery of large transformers

floor, the branch wiring for the fixtures and the services has to be pulled in the conduits up to the breaker boxes where they all join. The panel containing the breakers themselves is installed later when the finishing is done. At the same time, the wiring for the various components of the fire alarm system (exit signs, bells, switches) can be installed.

Major electrical connections have to be made on each floor to various pieces of equipment depending on the level in the building. Switch gear for ventilation units, electrical heating, elevator motors and control rooms, etc. has to be connected and sometimes, as mentioned earlier at a specific date in order not to delay the progress of the various trades. For example, the elevator contractor will need permanent power in his motors in order for him to use his platform to do the finishing on each floor.

Finally, the finishing of the work on each floor can be summarized by installing fixtures and lamps on the ceiling grid and the various outlets (switches, lights, speakers). Because the room between the acoustic ceiling and the concrete slab is limited, close coordination between the ventilation shop drawings (duct work and diffusers) and the electrical shop drawings is of great importance if major problem in the arrangements in the ceiling is to be avoided. Fixtures have to be connected to the wires and breakers have to be properly installed on the above-mentioned boxes.

Meanwhile, the temporary power network is slowly dismantled as the finishing work progresses in the structure. The telephone system is usually installed by the local telephone company (although the slab conduit may be installed by the electrical subcontractor). The requirements of tenants (if they are known at the time of construction) might create several delays in both the electrical and communications networks. Their impact on the execution of the job might necessitate a rescheduling of the work.

2.2.6 Enclosure

Enclosure systems of buildings have changed considerably over the last half century. From heavy, thick, brick and /or stone bearing exterior walls they have evolved to systems of light precast concrete or metal curtain walls. The reasons for change include the increase in the costs of materials and labour and changes in architectural styles. New materials and techniques are filling in for previous ones. Prefabricated materials, like curtain walls and precast panels have a great advantage over traditional masonry walls in that they are fabricated in a controlled environment and on-site installation requires far less labour man-hours. The effects of bad weather on the progress of the enclosure are therefore diminished considerably.

The importance of the installation of the enclosure of a building depends largely on the severity of the climate and on the materials used for the interior finishing. In cold climates, it is preferable to speed up the installation of the enclosure to protect the workers from cold winds and to save on heating costs when necessary. In more rainy regions, the progress of the "dry trades" inside the building is directly linked with the "sealing" of the enclosure. Careful coordination is very important between those trades at the planning stage.

As mentioned for most of the previous trades, the enclosure subcontractor has to be present on the site when the ~~structure~~ is poured in order to embed in the slab the brackets or angles that will hold the wall to the structure. Sometimes, the subcontractor will only be responsible for the supplying of those brackets, the installation falling under the jurisdiction of the formwork subcontractor. However, the location in the slab of the brackets has to be known early in the job in order to put them exactly at the right place and to coordinate the sizes of the prefabricated items accordingly.

In the case of precast panels, the bulk of the work lies in the fabrication of the panels. Their installation represents less than 20% of the contract value. The sequence of operations for their installation depends on the hoisting equipment available. For example, if a mobile crane working from the sides of the building is used, it is preferable to do several floors on one side while the crane is there and to move around the building with the crane instead of working on one floor and doing it all around. However, if an overhead crane is used, it would be more practical to do one floor at a time all around to avoid carrying the welding equipment up and down. The installation of windows and the sealing (caulking) of the joints signal the end of the enclosure installation.

The installation of metal curtain walls involves a more detailed sequence of activities and requires more labour on site than for a precast concrete enclosure. The attachment of the grid to the structure leads off the sequence. The light material pieces of the grid are hoisted onto their respective floors and are then welded to the brackets embedded in the slab. Because of their light weight, no hoisting device is needed during the installation of the grid. The pattern of installation depends on various factors that are different on each job. For progress measurement purposes, the general contractor might prefer that the subcontractor installs everything that is possible on one floor before moving to the next one.

The installation of the rest of the curtain wall can be done by using light scaffolding suspended from upper floors. If the structural work is not completed, the enclosure subcontractor should install, prior to any work down below, security panels that would stop any falling object from hitting his workers. The curtain wall consists of basically three components: the insulation panel, the glass and the exterior panel covering the pans (could be glass or metal). The sequence of installation remains very flexible; clearly, the insulation pan has to precede the exterior panel, otherwise the pattern of installation is dictated only by the logic of the subcontractor's project manager or superintendent (Fig. 2.10).

However, through visual inspection on several sites in the Montreal

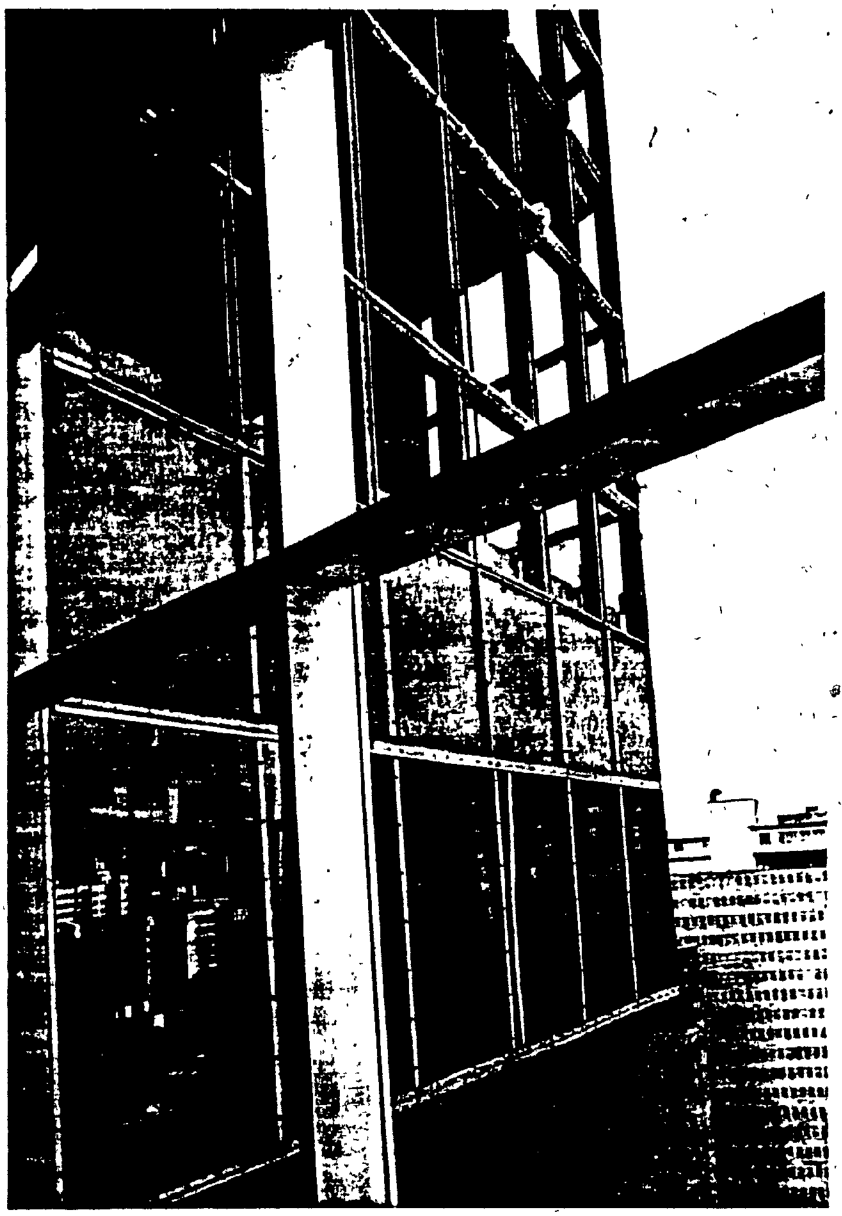


Fig. 2.10 View of a Curtain Wall

area, the work seemed to be done more vertically than horizontally. In fact, once the scaffolding was installed on one "face" of the building, the trend was to do several floors on that face and then move the scaffolding to another face in order to repeat the process (Fig. 2.11). Because the start of the next floor is not dependant on the completion of the previous one, the planning of the job and the process of progress measurement should be adapted accordingly. For example, if the desired rate is 1 floor/week, one would expect the enclosure subcontractor to produce an equivalent area of enclosure corresponding to 1 floor/week. Once again, caulking of the various joints would be the last activity for the curtain wall enclosure.

2.2.7 Vertical Transportation

All modern high rise buildings have fast, modern, motorized transportation systems composed of elevators (moved by electrical motors or hydraulic pistons) and escalators. Hydraulic elevators are very strong but very slow. One of their major characteristics (and inconvenience) lies in the fact that the cylinder containing the piston has to go as deep below the first elevation as the distance between the lowest and highest elevation of the cab's travel. As buildings became higher, hydraulic elevators were replaced by elevators moved by cables and electric motors for cost reasons. However, some hydraulic elevators are still used for short lifts requiring great load capacity. Motorized stairways (escalators) are used when a great number of individuals have

Fig. 2.11 Progress of Curtain Wall Erection

constantly to be moved for one floor or two. They are found especially in department stores, subway stations, etc. In high-rise buildings, elevators require the most attention at the planning stage compared to other vertical transportation facilities.

Elevator work is characterized by a long-lead time needed for fabrication and delivery of all the components, but especially the motors and the elements of the very complex control room. Therefore initial decisions as to the capacity, the number and the type of elevators have to be taken very early in the project's life to ensure the timely delivery of the above-mentioned items. The accuracy of shop drawings makes the difference between successful and unsuccessful installation. Those drawings have to be issued and accepted as the structure starts going up. As for several other trades, the elevator subcontractor has to follow the erection closely in order for him to embed and/or install precisely the beams that will hold the rails of the cab. Tremendous precision is required at that stage in order to avoid problems later.

Buildings composed of more than twenty floors often have several groups of elevators, each of them serving a section of the building (eg. low-rise, high-rise). This arrangement is preferable for several reasons. In terms of transportation efficiency, the tenants of the high rise portion are better served than with a conventional arrangement. For the owner and the tenants, such an arrangement produces a larger area on the upper floors because the location of the low-rise(s) shaft(s) is (are) replaced by rentable space area. Finally, the installation work is better spread over the life of the project and enables the elevator subcontractor to level his manpower requirements, especially for the installation of the control room's equipment which requires highly skilled and competent tradesmen.

The first activity in the installation of the elevators after the structure is finished is to install the rails in the shafts that guide the cabs and counterweights. The complexity of this operation lies in the tremendous precision required. The rails have to be perfectly plumbed to ensure proper travel of the cab and of the counterweight. Simultaneously, the oil buffers at the bottom of the shaft can be installed. These serve as "shock absorbers" in case the cab goes beyond the first floor.

As soon as the slab can receive the motors, they should be lifted so that their installation can start as soon as possible. Again great precision is required in order to ensure their proper operation. The structural frame of the cab and the platform which are actually the skeleton of the finished car, can be installed on the rails along with the cables and the counterweight. Meanwhile, work in the control room can be initiated as soon as the equipment is delivered in order to make the necessary connections required to operate the motors. When this is done, the platform is equipped with a simple switch to govern the movement of the platform in the shaft.

Using the platform, the workers can travel from floor to floor and install the frames and the doors on each of them. They can also prepare the wiring that will go from each call button and any overhead sign to the central control room. Once all the work on each floor is completed, the cab can be finished by installing all the walls, the ceiling with its lighting and ventilation system, the doors and the control panel with all the buttons. Last, but not least, all the components, especially the control room, have to be adjusted to work properly. The electronic work is performed by highly skilled technicians which might be hard to find in times of great volume of work. The idea of having control rooms in several locations in a building (low and hign-rise) facilitates the planning of the adjustment work and enables the low-rise elevators to be ready at a much earlier date than the higher ones.

Installation of the rails, the doors and the finishing on each floor are repetitive activities. The remaining activities of the elevator subcontractor are mainly non-repetitive and require substantial lead time. The characteristics of such a job should be reflected in the scheduling system.

2.2.8 Interior Finishing

Before describing the activities involved in the actual finishing of the interior of a building, it is appropriate to include in this section the activities that could be labeled under "Miscellaneous iron and architectural metal." These include all the iron and steel members that are supplied and installed by a contractor other than the structural (steel or concrete) subcontractor.

Metal stairs, if any, represent the most important items for the miscellaneous iron contractor. They are found in all structural steel framed building and sometimes in reinforced concrete ones where the architects decide not to have poured-in-place stairs. Sometimes local security laws will require that a functional stairway should be located within a certain number of floors from the last one during the erection of the structure. So this subcontractor has to follow carefully the progression of the structure in order to respect these rules. In the case of a concrete stairway, the iron work in the stairways is limited to the installation of the steel rails. However, sleeves have to be carefully located in the concrete in order to attach the rails; therefore, shop drawings for the rails, indicating the location of sleeves should be ready in advance. Other miscellaneous iron work includes frames, inserts and anchors that have to be installed before the concrete pouring. These activities have been mentioned before as falling under the jurisdiction of other contractors. Each job and contract breakdown is unique. The specific features and needs of a building will govern the delivery and installation of the miscellaneous iron items.

Architectural metals are used in the finishing of the interior and of the exterior of a building. A detailed description of the various possibilities would be useless at this stage because of the enormous differences between buildings (hotel versus commercial or residential). But the general approach to these items remains the same: shop drawings (if any) should be issued and approved early in the project's life; orders should be placed to suppliers in order to give them enough time to fabricate the required components; delivery and installation are then performed according to schedule.

The interior finishing as such can be divided in two categories labelled "wet trades" and "dry trades". According to Stillman (60) "basically, the meaning of 'wet' trade is a trade that erects or installs a material which requires water in the process." However, the problem with these trades is the amount of debris left by them and the humidity that goes along with the use of water. These two factors might become a source of coordination problems between "wet" and "dry" trades. Generally, "wet" trades include masonry, plaster, terrazzo and ceramic tile and possibly several other materials. For the purpose of this description, these four are adequate.

The masonry items mentioned at this stage do not include the enclosure although it could be performed by the same subcontractor. Concrete block walls are erected in several areas in a building in order to partition them. They are used extensively in the basement floors of the building because of the aesthetic and functional characteristics of these areas (packing, storage, equipment rooms) and because of the high level of humidity which could damage "dry" materials. On typical floors, masonry can be found in elevator shafts, equipment rooms, etc. in order to keep the transmission of noise and vibration through the walls to a minimum. In terms of planning, careful coordination is required between the masonry subcontractor and the contractors concerned with the rooms created by the masonry walls. In general, before enclosing a room for good, the subcontractors involved should make sure that all the major pieces of equipment are delivered in time.

Because of the increased use of easily installed and cheaper products, the use of plaster for walls and ceilings has decreased considerably along with the number of good plastering subcontractors. The sequence of work depends on the characteristics of the buildings and thus the planning should be done accordingly. It should be remembered that plaster has to be completely dry before any paint can be applied (more than 30 days). This time could be shortened by moving the air with fans and by applying moderate heat.

Terrazo is a nice and long lasting finishing material for slabs composed of marble chips and a binder which could be a Portland cement mixture or more recently an epoxy or an acrylic material. Although very attractive once finished, its installation remains a very messy process. Basically, the described mixture of terrazo is poured or cast on a base. After it is cured, the surface is ground and levelled with a grinding machine creating a great amount of unuseable "slurry" that has to be thrown away. Because of these characteristics, terrazo should only be used in the special areas of a building (ground floor lobby, luxury areas, etc.). The above-mentioned characteristics dictate at what stage it should be installed in order to diminish as much as possible the effects of its installation on other finishing work.

Ceramic tiles seem to be the only suitable material for the finishing of the walls and floors of toilet rooms and showers. The square pieces of tile are applied directly to the partitioning walls (gypsum board or masonry) and to the floor by using a waterproof tile cement. Those tiles are expensive so it is in the subcontractor's interest to minimize waste as much as possible. Soon after the tiles are installed, the entire room should be cleaned perfectly to avoid any debris drying and damaging permanently the tile and to clear the way for the plumber to undertake the last part of his work.

The activities labelled "dry" trades include dry-wall partitioning and studding, hollow metal doors and bucks, hardware, acoustic ceiling and wall covering.

Dry wall partitions are made of metal studs, which are set in a metal track, with gypsum board attached with special drive screws. Because of its cheap price and the lower skill level required to install it properly (compared to plaster) it has become very popular and is omnipresent in building construction. The structure and properties of the wall can differ depending on location. For example, partitioning between offices would only require one layer of board on each side of the stubs. In the case of walls separating toilets, mechanical rooms or corridors, the noise absorption level has to be increased in order to guarantee a good quality environment. This is done by putting a second layer of gypsum board on the initial ones and/or by adding some insulating material (e.g. fibreglass) between the vertical metal studs. When those boards are used in potentially "wet" areas (like showers), the "green" moisture resistant type is used. Besides the partitioning required by each tenant, which is unpredictable, dry wall is installed on the interior part of the enclosure, on the columns and on the various parts of the "core" (toilets, mechanical, and electrical rooms, elevator hall and shafts).

The process for installing a piece of gypsum board remains very simple: the exact location of the wall is outlined on the slab using a chalk line along which a metal track is carefully installed. The studs are then fixed to it along with the door bucks (prefabricated frames) which are described later. Once everything is carefully plumbed, the board is fixed to the studs by special screws and joints are taped and filled to make a uniform surface. Gypsum board has to be installed in a completely dry environment or it could be wasted. Work in colder months might necessitate heating for the joints, which have to be applicated at normal room temperature. The sequence of installation of the dry-wall remains discretionary. However, the preceding work has to be carefully identified in order to avoid conflicts during the execution of the work.

Hollow metal doors and bucks and hardware items should be approached the same way because of their similar characteristics. In terms of importance, the bucks (metal door frames) lead those items because of their required presence during the partitioning. The doors themselves can wait but their fabrication should get underway as soon as possible, especially if it is a large building. The process of issuing and approving shop drawings again plays a big role in the timely delivery of these items. Hardware includes many small items, like lock sets, hinges, door plates, door bumpers, etc. Close coordination between their shop drawing and the doors are crucial for timely finishing. Unless the architects asks for very special materials, these pieces should be readily available and even in stock. However, they should be ordered relatively soon in order to avoid delays in delivery.

Suspended acoustic ceilings are very popular in high-rise commercial office buildings. All the services (electricity, telephone, mechanical systems) are located in the space between the acoustic ceiling and the slab. This allows great flexibility for the partitioning, which is not part of the ceiling, in the case of changes in the arrangement of the floor. Residential buildings and hotels are usually designed with nicer, but less flexible ceiling. Moreover the partitions in such buildings seldom, if ever, change.

The process for installing a suspended ceiling remains fairly simple. The suspending device (either a wire or a thin rod) are located and fixed to the slab above. Along with being at the right elevation, the ceiling has to be levelled with great care. Formally done by using tapes and surveying instruments, elevations can now be given by a rotating laser beam set and levelled on a tripod. The resultant time savings are beneficial along with the increased precision. Once the structure (grid) of the ceiling is properly installed, room is given to various trades to perform their finishing work. The job of finishing the ceiling (installing tile or else) is then only a formality.

Wall covering and painting should be executed with great care because their quality will directly reflect on the appearance of the building. It is the last operation before occupancy so priority should be given to the areas with the earliest occupation dates. Good lines of communication should be established in order to avoid mistakes in colours, quality, material (if not paint) etc. If non-standard materials are used, an early order should be placed to the supplier in order to avoid delays which are unforgivable at this stage.

2.2.9 Testing and Commissioning

Once all the components of a building are installed and connected, they have to be started up and tested to ensure proper output and that the desired building environment can be obtained. Mechanical (ventilation, plumbing and sprinkler), electrical and elevator's work require the most attention especially in the equipment rooms. Although some work might be necessary on each floor, those activities cannot be considered repetitive and could not be included in the activities found on a "typical" floor. The duration and the costs associated with such an activity are highly variable and depend a lot on the quality of the work done in the early stages of the installation. Proper installation of the equipment should yield adequate time for its start up but any difference due to errors in fabrication, in handling or storage and/or in connections will appear at that stage and could create enormous delays in commissioning.

From the general contractor's point of view, some time should be allowed at the end of the project to correct the "latent defects" or deficiencies along with commissioning major equipment items. The exact duration cannot be properly evaluated because of the high level of uncertainity associated with it. His own experience will guide him in assessing suitable times for start up. Once again, the tenant's occupation date should be the target for complete and satisfactory operation of all equipment.

2.3 SEQUENCING OF ACTIVITIES

Once the above mentioned activities have been identified, they then must be put together in a plan of execution which will eventually be the reference or standard for the scheduling process. A review of their sequencing for the construction of high-rise buildings follows. At this point, it is relevant to define the concepts of preferential and theoretical (or absolute) logic as outlined by O'Brien (ref. 36): "When you prepare a network, there is an in-between logic which we could call preferential logic. Theoretical or absolute logic is a black or white situation. If absolute logic is referred to as the logical skeleton, which is, inflexible, then preferential logic could be considered to be the next of the project body."

2.3.1 Typical Floor Activities

As mentioned previously, we have to differentiate between repetitive activities that are found on all typical floors and non-repetitive activities that are specific only to one area or a few areas of the building. The main planning rules, as followed in the industry today will be identified here for the repetitive activities. The detailed logic of a typical floor is not treated because it varies from job to job.

Needless to say, the structure has to precede all other activities and the characteristics of the process required to build it narrow the number of possible alternatives for the schedule. The logic of the structure is absolute for the following relationships: The pouring has to be sequential (increasing floor number) and overlapping between floors is impossible (i.e. the floor above cannot start as long as the floor below is not completed). We have to understand that if the floor is broken down in sections, then each section would be treated separately and the relationships mentioned would still apply. The stripping of the forms (if applicable) is the next activity. After this, the skeleton of that floor is completed and the next sequence of activities can start.

In general, most of the trades have two phases in their work: roughing-in and finishing which are again absolute in logic, one to the other: roughing has to precede finishing. Also, the floors can be worked on in areas which are independent of each other but are ultimately linked together upon completion. For example, in a commercial high-rise office building, the areas could be divided as follows: the elevators (shaft and lobby), the ceiling in the rentable area, the toilet area, the mechanical room, the electrical room and the exterior walls (enclosure). In each of these areas (referred later as "work categories") the sequencing of the trades should be identified and a typical arrangement would look like this:

In the elevator area, the rails would be installed in the shaft, followed by the installation of the motors, cables and the platform which would permit the installation of the door frames; at this stage the masonry subcontractor could install the masonry shaft, followed by the gyproc and the ceiling in the lobby.

In the ceiling area, the ventilation, sprinkler and electrical subcontractors have to go one after the other to do the roughing work. The logic between these trades is usually decided before hand and is really preferential. Once all the roughing work is completed, the ceiling ties can be installed in the above slab, followed by the ceiling grid. Again, sprinkler, electrical and mechanical trades come one after the other to do the "finishing" before the ceiling tiles are put on.

In the toilet area, the domestic water risers have to be installed first along with the storm drain and sewer risers.

Fig. 2.12 Rough Plumbing in the Toilet Area.

This is followed by the rough plumbing in the toilet area (Fig. 2.12). Usually, the return air riser is located in the toilet along with a small amount of ductwork. For reasons of practicality the ventilation crew should come in first so that they will have room to move their scaffolding. The next activities occur in the following order: gyproc wall, ceramic tile, plumbing fixtures and finishing (ceiling,mirrors, etc.)

In the mechanical room, the heating and chilled water risers would be installed first, followed by the delivery of the ventilation unit; the plumber would then install the pipes between the risers and the unit and in the same fashion, the electricians would connect the fan motors to a control panel linked with the electrical network. Finally, the room has to be closed in usually by a masonry wall (Fig. 2.13), to cut down the noise transmission and then covered by gyproc boards for appearance. The characteristics of the mechanical design dictate the logic after the ventilation unit is delivered (i.e. between plumbing, electrical and masonry trades).

The electrical room area is often linked with one of the above mentioned areas. For example, in one of the jobs that the author followed, the electrical room was in the mechanical room, whereas in the other one, the electrical room was located between the men's and women's washrooms. In any

Fig. 2.13 Masonry Wall to close the mechanical room

event, the installation follows this absolute logic: The bus duct and switches first, followed by the installation of the panel. Depending on its location, the installation of the panel might be preceded by other activities: for example, a wall might be needed, etc. The logic between those activities will be dictated by the architectural design.

Installation of the enclosure system is important in countries working in a tough winter environment like Canada. Depending on the type of enclosure (metal curtain walls, precast etc.) the number and type of activities will differ. However, a general sequence could be as follows: enclosure "frame", glazing, caulking and dry-wall inside.

The merging point of most of these areas lies in the ceiling grid which is preceded by the installation of the gyproc on all the walls. Also, one should identify the areas where noise insulated partitions are used. In fact, those partitions have to precede installation of the ceiling because the walls are "slab to slab." A study of the architectural design specific to a job will clear up those situations.

Now that the main lines of the logic for one typical floor have been traced, the next step is to examine how these typical floors will be linked one to the other. Most of the items that are vertical in the building (structure, risers, bus-duct, rails) have to be done sequentially (floor by floor, without overlapping) whereas the other activities are not "absolutely" linked with the floors above or below. For example, the installation of the ventilation duct work could be done in any floor sequence without technological problems and this could be applied to all the other "non-vertical" activities.

But in practice, and this will be explained later, it is desirable to identify a floor sequence prior to the job start and this sequence is followed by all the trades. However, some trades might be allowed to overlap floors when they do their work and this is why a proper plan of execution becomes important. Overlapping of floors has been identified as a problem area by general contractors because too often a subcontractor will "jump" floors, disturbing the sequence of other trades and thus the overall job plan.

2.3.2 Scheduling of Non-Repetitive Activities

Non-repetitive activities were also identified in the first section of this chapter. Again, a complete analysis of the sequencing is not appropriate because of the different nature of projects; however, the most common ones are identified along with their various relationships with other activities.

All the work preceding the start of the structure on the 1st typical floor is non-repetitive, including mobilization, excavation, foundation and the basement floors up to the ground floor. The 2nd floor, depending on the architectural design would be the start of the repetitive typical sequence. Therefore, all activities below that first typical level, besides the structure do not need to be completed in order for the typical ones to start. In practice, activities like drains, ventilation and lighting are not definitively scheduled and are used mainly as "buffers". For example, if a trade is delayed on one of the repetitive activities on the upper floors (e.g. plumbing roughing-in), the workers, instead of staying idle, should come down in the basement to work (e.g. drain pipes) until they can keep on working upstairs. However, if the basement floors have to be completed by a specific date, proper scheduling should be done.

Along with the so-called "buffer" activities are the more important "equipment" activities whose monitoring is very important, especially if long lead times are required for design, construction and shipping. These activities are crucial for the timely completion of the mechanical, electrical, sprinkler and elevator trades in particular. Included in these activities are the booster pumps, one for plumbing and one for the sprinkler, the main electrical room equipment (transformers, emergency generators, switch gear, etc.), the elevator motors and control equipment along with the required transformers and switches, the main mechanical room components (chillers, pumps, furnaces, cooling towers, etc.), and the corresponding electrical panels and transformers. The work on site required to install those units is highly variable, ranging from a day or two to several weeks per item.

Of importance, therefore, is the identification of any logical connections between the non-repetitive activites themselves and between repetitive and non-repetitive activites. For example, the elevator subcontractor will have to wait before the forms are stripped before delivering his motors to the site and the cables, platforms and counterweights will not be installed before the rails are completed and the motors properly installed on their beams. Similarly, the installation of the door frames on each floor is preceded by the electrification and proper operation of the motors and of the cables, platforms, etc.

In general, the non-repetitive activities and the "equipment" activities should be identified along with the logic that ties them with the other activities of the overall plan. The procurement monitoring of activities is very crucial because delays in fabrication and/or delivery can become very difficult to recover.

2.3.3. Interfacing Between Subcontractors

The building construction industry is characterized by a large number of trades and usually a general contractor will award as many contracts as there are specialities. This leads to from 10 to 60 or more subcontractors trying to do their job the way they want and as profitably as possible at anyone time. This issue is discussed in ref. 55 as follows:

> Consequently he relinquishes direct control over most of the resources of which the six M's (men, machines, materials, money, methods and management) are comprised in favour of the advantages of subcontracting the work."

And the control over the resources of the subcontractors may lead to numerous coordination problems between the various trades. In fact, each subcontractor is trying to allocate and level his resources across several projects to cut down as much as possible hiring and firing and to keep the same men as long as he can. Therefore, it is very difficult for a general contractor to dictate to his subcontractors the resource levels they should employ or utilize on a particular job.

However, the general contractor is not reticent to "suggest" to a subcontractor to increase his productivity if his work is delaying other subcontractors or the project's timely completion as a whole. As seen in the previous section, in some areas, several activities have to be done sequentially and by different subcontractors. If for any reason, one of the subcontractors slows down his rate of production then the whole flow of the tradesmen in that area will be interrupted, resulting in delays and in potential claims.

Interfacing points happen also in the arrangement of all the pieces of the construction puzzle. Coordination is required before construction starts when the various shop drawings are produced by the subcontractor. For example, the ceiling area containing the ventilation ducts and diffusers, sprinkler system and electrical fixtures requires a lot of work, and even when everything is approved and fabricated, some problems will arise the first time that the components are put together in three dimensions. Each subcontractor has to compromise in order to solve the problem but in general, they will always try to have the others modify their arrangement which can lead to a fair degree of friction between them. In this case, the general has to act as a "mediator" in order to find the most appropriate solution.

Finally, unions play an important role in the process and the presence of shop stewards on the site can result in reduced efficiency and sometimes problems of jurisdiction over the work. One should deal with such problems with extreme care because unions are prepared to go to great lengths to gain respect and recognition.

Therefore, a realistic and detailed plan should be available well in advance so subcontractors can plan the use of their resources. If for valid reasons a given plan cannot be respected by one or more subcontractors, the general contractor usually tries to adjust his schedule. The problem of shop drawing coordination always exists. The best way to avoid major problems is to establish good lines of communication between the trades involved and to enforce regular meetings in order to exchange information and comment on it as soon as possible.

In a broad sense, the general contractor should stimulate the exchange of information between himself and the subcontractor and the subcontractors themselves in order to foresee and solve interfacing problems before they become too big.

2.4 SPECIFICATIONS OF THE SYSTEM

Now that we have a good idea of the kind of activities that a planning system for general contractors should handle, it is appropriate to set out a specification for the system. It is important to mention at this stage that the system will form part of a Project Management Information System (PMIS) under development at the Centre for Building Studies of Concordia University and that the scheduling system will be compatible with the PMIS. A description of the level of detail and of the characteristics required is described below.

2.4.1 Level of Detail Required

One of the objectives of the PMIS is to group together the functions of estimating, planning, scheduling and monitoring (cost control) of the various construction activities. In order to do so, one has to develop a work breakdown structure that will suit all of the management processes of the contractor. Although this is not part of the scope of this thesis, it is important to examine the level of detail required for planning and scheduling purposes and see how it compares to the level of detail required for the other functions.

From the experience of the research group in performing field trials of the subcontractor control part of the system, it was found that conflicts often arise between the detail needed to break down the job in terms of costs and in terms of time. For example, the dry-wall trades do their estimates by looking at the surface they have to cover and by the relative arrangement of the studs and gyproc boards in specific areas. Therefore, non-regular arrangements should cost more per square foot of wall than a straight forward covering of a masonry wall. Therefore, costs will be broken down according to studs, board and joints along with the labour associated with each. Monitoring will also follow a similar breakdown: a subcontractor will be paid according to the quantity of studs, board and joints he did over the last period and for cost control purposes, the general contractor will not be interested in knowing more than that.

For scheduling purposes, however, a more detailed breakdown is required because of the necessity of, having some areas ready before others. For example, in one of the projects that the author followed, the gyproc wall in the toilet area was needed very early in the job because it was a prerequisite to the roughing-in of the electrical room located between the ladies and men's washrooms. However, all the other areas of the typical floor did not require the gyproc that early as its only successor was the installation of the ceiling grid.

Situations such as the above happen in other trades and vary from job to job depending on the layout of the building. So in general, the level of detail required will be dictated by the need to identify smaller parts of the work which are crucial for the sequencing of trades. For cost purposes, the smaller parts would be aggregated in a larger one in order to suit the level of detail required at that stage.

2.4.2 Characteristics

The information required by the General Contractor from the subcontractors should meet his needs for planning and control of the job at hand and for feedback for use on future jobs but not require the subcontractor to divulge confidential information. In general, a subcontractor is not willing to commit himself to a firm delivery date for a piece of equipment and/or a production rate for a sequence of similar activities because he wishes to keep as much room to maneuver as possible. The important point however is to promote the communication of information between the general contractor and the subcontractors to force a little more discipline on the subcontractor and on the general contractor so that they have a shared view of what is expected from each party.

The user of the system would be the general contractor's project manager, although the input should be simple enough to be done by a clerk or a secretary. The system should screen all possible input mistakes in order to ease the interface between the user and the system's software. Various reports differing in format and in level of detail, but issued from the same data base should be available. It is understood that the site superintendant will require a greater level of detail and a shorter time frame than the contractor's vice-president or owner's representative. Therefore, the report formats available should be compatible with the purpose for which they are required.

The process of updating information should be simple and very functional. It should include changes in the logic or in the durations of the activities but should also track the progress of the activities and see if the trades are working at the desired rate. If not, there should be a possibility to modify the current information in order to update the schedule. Therefore, if an activity is delayed it should be noticed and then the activities downstream should be rescheduled accordingly in order to avoid large delays. Obviously, some corrective action should be taken by the general contractor to modify the situation such as asking a subcontractor to increase his productivity, increase manpower change suppliers, etc. The actual start and finishing dates should be part of the progress report in order to observe the actual rhythm of production of the trades and to keep historical records of the job.

More importantly, the scheduling model should reflect the construction process described in this chapter. It should differentiate between repetitive and non-repetitive activities and treat each of them separately according to their respective characteristics. A non-repetitive activity should be treated discretely and be related to its predecessors and successors. A repetitive activity should, if possible, be input only once in the system, along with the predecessors. Then, the system should by itself generate the schedule for all the floors of building, based on that single input of data. Furthermore, it should be designed to reflect all the possible relationships that were mentioned in the description of the process, and not limit itself to a simple sequence of repetitive activities. In fact, although the system should treat repetitive and non-repetitive activities differently, there should be a way of having precedence relationships between these two different types of activities.

Also, the relationship between the same activity on successive floors should promote work continuity and stable production rates for the trades. The system should therefore foresee conflicts between trades that are dependent on each other, but decided to work at different production rates, and schedule these activities accordingly.

The description of the activities also highlighted the fact that the progress of some activities was influenced by weather conditions. Those activities should be identified as such and there should be a routine that includes some contingency (extra days) on their execution, if the work is performed in bad weather months. Such a routine would obviously require the presence of a calendar in the system.

Large equipment activities, although not requiring extensive work on the site, require however, several months of work before they are actually delivered on site. Each of these has its own procurement sequence, which starts from a tender call, and finishes when the equipment is delivered on site. Proper monitoring of that sequence is desirable, so the system should have the possibility of preparing a special report pertaining to that issue.

A complete analysis of the planning tools available and their compatibility with the described specification is undertaken in the next chapter.

CHAPTER III

REVIEW OF PLANNING TOOLS AND THEORIES

3.1 INTRODUCTION

To come up with an appropriate scheduling system for high-rise building construction, several steps are necessary. First, the issue of productivity in building projects is reviewed along with an exploration of the features of repetitive work and learning curve theory. Treatment of these topics will help in seeing the differences between building projects and civil engineering and/or heavy construction ones. Also, the difference between working days and actual calendar time will be studied along with updating processes.

A complete investigation of the methods and processes used at the activity level is not required for this thesis. The scheduling system basically takes the information obtained at this level in the form of a duration, crew size, etc., and incorporates it into the overall schedule. Therefore, emphasis will be placed on a scheduling system that reflects as much as possible the manner in which construction progresses. Thus, a review of planning techniques currently used in the construction industry along with their usefulness for scheduling building projects provides a key focus for this chapter. From this analysis, it will be possible to identify the basic ingredients for a planning and scheduling algorithm tailored to the specific needs and features of high-rise construction.

3.2 CONCEPTS

3.2.1 Productivity and Production Rates in Building Projects

The American Association of Cost Engineers defines productivity as follows (ref. 3): "Relative measure of labour efficiency, either good or bad, when compared to an established base or norm as determined from an area of great experience, which may be either an increase or decrease in cost." Of little concern at the beginning of the 20th century, productivity in construction has become a major concern especially in times of high interest rates and increased labour and energy costs. Large nuclear jobs seem to have the worst productivity as only 32% of the worker's time was spent to do direct work while the remaining time was split between waiting, travelling, receiving instructions, etc. (ref. 4). In residential buildings projects, the percentage of productive time increases, reaching a value of 69.7% (ref. 26). This can be explained by the low complexity of housing projects and the experience of the tradesmen who know what they have to do, especially in mass housing projects where the learning curve effect (see next section) is significant in increasing productivity because of the high level of repetitive work.

The problem of worker productivity is beyond the scope of the present thesis. Of importance, however, are the characteristics of the execution of the work in building construction projects in comparison with other projects. As stated by O'brien (37): "Heavy construction is massed in the literal sense of the word; it can be accomplished in a wide variety of sequences, the overall schedule being determined by the resource of supply to the massive amount of work. High-rise construction is production type scheduling in the common mass-production sense of the word. Work must be accomplished in a definite sequence on each floor. Once a successful sequence has been established, it is repeated floor by floor, thus simulating the mass-production approach."

Some principles of industrial mass-production can therefore be applied to the construction of high-rise buildings. When designing an assembly-line, each task performed by the workers is calculated so that it will take the exact same amount of time so that the set of tasks required to assemble a specific item will be performed without interruption. If one task takes twice the time of another, there should be two crews working on it, thereby yielding the same production rate. This is called "assembly-line balancing" and has been identified as "vital to the economical completion of a high-rise project" by O'brien (ref. 37, p. 459).

In building construction, a task could be a repetitive activity of any one of the many trades involved. Trying to balance all of these production rates is unrealistic for the following reasons: (i) the different nature of construction work when compared to the manufacturing of goods (ref. 65, page. IV-223); (ii) the small size of most firms and the fact that they are different corporate entities having their own goals; (iii) some trades are influenced by weather problems; (iv) design is separate from construction and often not suited for effecient construction; and (v) resources are limited and are not under the control of one person and/or corporate entity.

Nevertheless, efforts should be made to come up with similar production rates for sequential trades in order to develop a rhythm for execution of the work. But, when balancing production rates, proper consideration should be given to the external factors affecting the possible alternatives. For example, in the province of Quebec, when a crew size goes beyond six for a specific trade, one of the crew members has to be a "shop steward" who is basically a union delegate that makes sure that all the security measures are enforced and that all the rights of the workers, negotiated in the collective agreement, are respected. Other factors might include the availability of materials delivered by suppliers, the capacity of the lifting equipment, the location of the storage area on site, the size of the working area and the availability of qualified tradesmen. When setting his crew size, the subcontractor takes into account all these factors. Also, because of these factors, the productivity is not directly proportional to the crew size; so the subcontractor will be reluctant to modify it.

A major difference between industrial production and "building" production is the number of cycles. In industrial production, the number of times a repetitive operation is performed is exceedingly large (10,000 to 1,000,000 times) whereas in building construction it is limited to the number of typical floors. Therefore, in industrial production if two successive activities have different production rates, it is not possible to schedule them so that their execution will not be interrupted and they will not interfere with each other. In building production, it is possible because of the small number of cycles. A useful analogy is the scheduling of two trains having different speeds on the same track. If the fast one leaves first, the slow one will leave as soon as it can and arrive at the destination with a lag; if the slow one leaves first, the fast one will wait until a sufficient lag between them enables it to travel at full speed until it reaches its destination. While this may appear simplistic, it is the basis of research of several individuals on linear and repetitive projects (Ref. 27, 35, 39, 43, 57). Their theories will be explained later in this chapter.

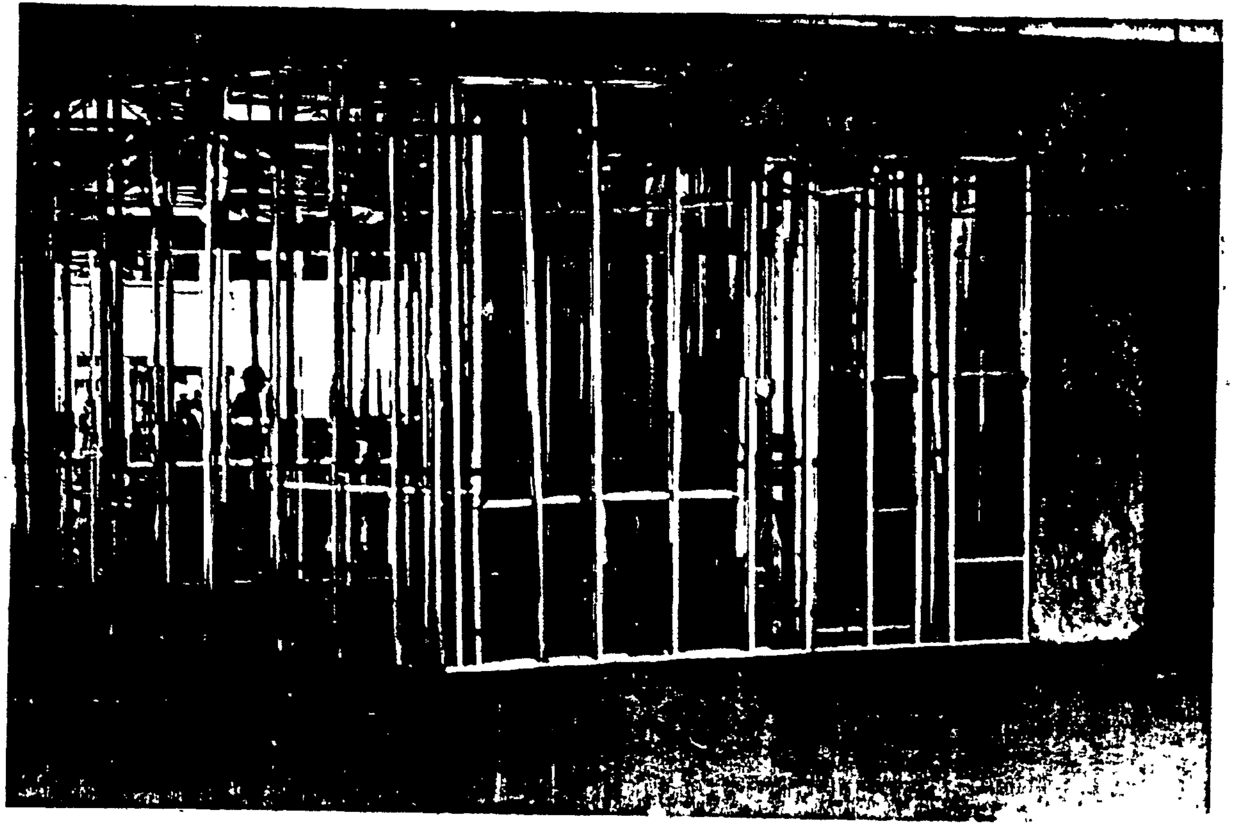
Finally, it is appropriate to explain the importance of the structure in a building project. Because of technological constraints, overlapping of the floors is impossible. And unless costs are not a constraint to the owner, it is almost impossible to speed up the rhythm of the structure because of the size of the working area, the number of operations that have to be done sequentially (shoring, column and slab formwork, placing of column and slab reinforcing steel and conduit, sleeving and pouring) and the capacity of the hauling equipment. Also, the structure leads everything and its production sets the rhythm of execution of the job. Ideally, all the trades that follow it should keep a similar production rate.

3.2.2 Repetition (Learning curve)

Most modern high-rise buildings are characterized by similar shape and arrangement for each of the floors. This saves both time and cost at the design stage and on the construction site. Architectural plans become much simpler; only one floor layout is required for several typical floors. Therefore, once a successful arrangement is designed, the work is completed for several floors at the time.

Similarly, on the construction site, considerable time is saved, especially in coordination of the installation of the various mechanical and electrical components. For example on the first typical floor, a mock-up (see Fig. 3.1(a) and (b)) of all the components of the ceiling and core will be put together to identify the several problems which usually occur such as a duct being on the path of a sprinkler pipe or a lighting fixture, etc.. So at that stage, corrections to the design will be made and those corrections will serve all subsequent typical floors, thus minimizing future coordination problems and the time spent solving them.

But besides costs and time saved in correcting errors only once, repetition of work can lead to increased productivity because of "learning curve" effects. The basic principle of the "learning curve" is that skill and productivity in performing tasks improves with experience and practice (ref. 41). The concept is far from new, and has been treated in numerous psychological studies dealing with the learning process. The construction industry has been evolving in such a way that there are



(a) Studding in the Toilet Area

Fig. 3.1 Examples of Mock-up

(b) Ceiling Grid and Tiles

Fig. 3.1 Examples of Mock-up

more and more specialized trades, each focussing on a specific operation. This is called the law of the division of work: "The less different activities labour must perform, the more of the same activities labour will perform in a unit of time. But this increase in the number of repetitions in a unit time also results in increased efficiency because of the routine-acquiring effect" (ref. 20).

Gates and Scarpa (ref. 20) described two types of increase in the degree of learning: the learning curve and the experience curve. The learning curve is used when a person is acquiring skills in doing a specific operation. The first time that a person uses a typewriter, it takes a long time to write a single sentence. But after a month or two of using it everyday, the person will have acquired greater skill and the time required to type a similar sentence should be reduced significantly. The term experience curve is used when we refer to a skilled person performing a similar operation several times. For example, if we ask an experienced secretary to type the same letter several times, she should type the last one in less time than the first one. Similarly, the tenth of ten identical concrete footing pours should take less time than the first one (see Fig. 3.2).

For high-rise construction, experience curve theory explains an increased efficiency in performing a similar operation several times because in general the workers have had previous experience. But if in the course of their execution, repetitive operations are interrupted, an "unlearning curve" effect can occur. In fact, when operations resume on

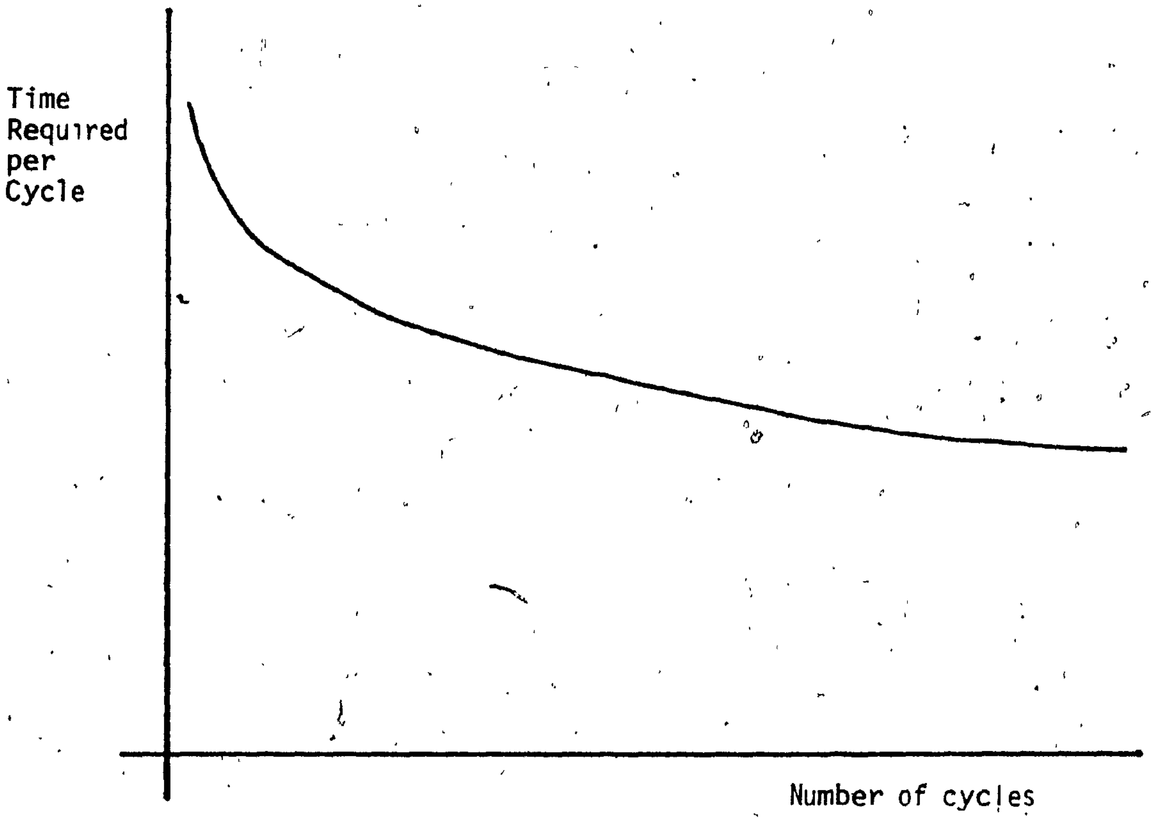


Fig. 3.2 Learning Curve Effects

that repetitive activity, it will take more time to be executed than before it was interrupted because the workers might have "forgotten" or "unlearned" parts of the process. So in order to maximize learning and experience, it is preferable to provide continuity of work on repetitive operations.

The purpose of this analysis is not to develop a model that would represent the learning curve of various building construction trades. In fact, Gates and Scarpa (ref. 20) included a mathematical model in their paper which was based on historical data. In the author's opinion, it is not terribly useful because of the deterministic nature of the model. To place too much emphasis on formulas may result in obscuring the true situation.

Therefore, in practical terms, estimates by subcontractors are based on a production rate per activity, calculated by taking into account the above mentioned external factors, but it is clear that such a production rate will only be achieved after a number of similar activities are performed and after the design deficiencies are resolved. So some allocation should be made to "correct" the production rate of an activity for the first few levels. This increased duration should be incorporated in the schedule so that it will be as realistic as possible. The degree of learning and number of corrections in the design is variable from activity to activity. A United Nations report (ref. 40) on costs of repetitive units shows that tasks that are more complex, like formwork erection have greater learning rates (reduced to

75% of cost) than concreting and form stripping (reduction to 90% of cost only) (see Fig. 3.3). So it is important to treat each individual activity and to include in the schedule some realistic allocation for learning and experience. Those allocations should be based on information gathered from previous similar projects.

3.2.3 Calendar Day Vs Working Day

The purpose of a scheduling system is to relate various activities with time; and a common frame of reference for everybody is a calendar. Therefore, it is crucial to have a final schedule of the works related to calendar dates so that all the subcontractors, suppliers, etc., will be on the same wave length as to promises, commitments, delivery dates, etc.

In general, durations of activities are expressed in working days and the various calculations required to obtain a complete schedule of activities are related to those working days. Translating a schedule from working days to calendar days requires the identification of holidays, weekends, annual vacations, etc., which are considered as "nonworkable" days.

A crucial aspect to be taken into account is the weather. Holidays and weekends are constant throughout the year and are predicted with certainty a long time before their occurence. But weather is not and it plays a significant role in delaying the schedule, especially in winter time. A contractor should not be blamed for being behind schedule

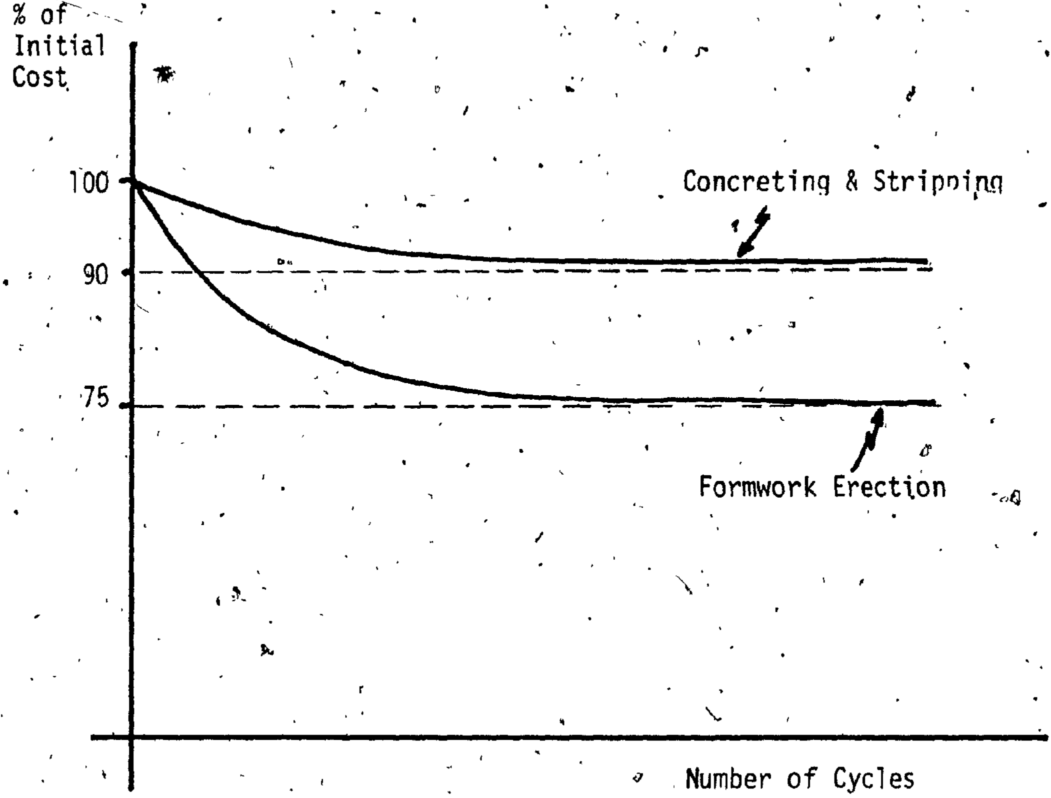


Fig. 3.3 Cost Reductions because of Learning and Improved Effeciency.

because of unforseeable weather but he should not take the weather as an excuse. Therefore, a realistic contingency allowance should be added to the schedule, but only for activities affected by the weather. For instance, all finishing trades are normally not affected by the weather, whereas the structure and enclosure are.

O'Shea (ref. 38) reviews some of the routines that were available at the time of his publication for taking the influence of weather into account (October 1968). Some planners will deliberately increase the duration of certain activities in order to make allowance for weather delays (ref. 5, p. 200). Although this helps in establishing a realistic project duration, it creates vagueness in establishing schedule dates for individual activities. Another method is called "by-passing": when the working days are switched to calendar days, some dates (or "pulled dates") are omitted on the assumption that they will be lost due to bad weather. O'Shea sees two weaknesses in this approach: it considers that all work performed in times of bad weather will be delayed, which is false, as mentioned above and it also creates "bias". The "pulled date" disappears from the calendar, as if it was a holiday or a weekend, which is not true. One of the general contractors that the author met was using a similar way to add contingency for weather, but he had the advantage of differientiating between activities affected by weather, and those that are not. The feature can be seen in the bar-chart format shown in Fig. 3.7, where the "shaded" days correspond to days lost because of bad weather.

O'Shea (ref. 38) and Schaffer (ref. 58) each have proposed their ways of including weather factors in the critical path method (CPM) calculations. While O'Shea identifies weather factors for each month and sensitivity factors for each activity, Schaffer assigns "efficiency factors" (a percentage by which the duration is divided to give a corrected duration) for each activity, which are in practice a combination of the two factors of O'Shea. Those factors are obviously subject to the location of the project: it is clear that Winter will bring more inclement weather in Canada than in Southern California. Therefore local statistics on rain and/or snow probabilities have to be obtained.

Referring to critical path method calculations and accounting for weather delays, two problems might occur when performing the "forward" and "backward" passes. First, if the time unit is big, like weeks or even days, the duration change for an activity of small duration might be negligible. For example, if the time unit is days and we have an activity with a duration of 5 days and which is influenced by weather, and the assigned "efficiency" factor is 80%, then the corrected duration would be 5 divided by 0.80 or 6.25 days. But if we do not want to split days into quarters, 6 would be the new duration. But in better times, the factor might be 95%, giving a corrected duration of 5.26 days. It would be useless to put 5, but exaggerated to put 6. So it is difficult to draw the line.

A possible solution could be the following: if an activity occurs only once (i.e. if it is non-repetitive), its duration should be rounded to the nearest integer. However, if it is repetitive, it would be preferable to truncate the decimal part for the first one and add it to the next repetition of the same activity. Therefore, the model would stay as close as possible to the monthly factor instead of truncating too much or adding too much in order to come back to the units used in the calculations.

The second problem arises in performing the "backward pass" and float calculations. If an activity is weather dependent but not critical, its early and late start dates will not be at the same period of the year and might therefore be calculated with different adjusted durations than with the "forward pass". The float calculations might then become confusing because of the fact that the "forward" and "backward" durations are not the same.

3.2.4 .Updating and Progress

The process of updating consists, in a first step, of recording the progress of the job, and in a second step of planning and scheduling the remaining work after some time interval has elapsed. If the job progressed as initially scheduled, the remaining work will not have to be rescheduled. However, one of the main characteristics of construction work is that it can be affected by several factors, many of which are beyond the control of the General Contractor (eg. changes in design, procurement delays, labour difficulties, accidents and severe weather). Thus the schedule should be adjusted in order to reallocate the time lost. It may be possible to update the schedule without going beyond the target date but very often it will not be possible. In general, it is important to update the schedule as soon as possible so that the trades affected by changes will know when they have to perform their work.

It is interesting to evaluate now a mechanism that could be used for updating. One simplistic way of doing this is to show the progress on the old schedule and to calculate the remaining dates according to "actual" start and finish dates. If delays were encountered especially on critical activities, the project target date might be changed and if possible, some corrective action should be undertaken. The duration of some activities could be shortened by requiring a bigger crew size or longer hours, or a change in the logic of the execution of the work might result in a new, shorter critical path.

Some problems may arise for activities having very long durations and which are partially complete at the time of progress assessment. How can one know if one activity is on schedule when it is not completed? Some will assume a linear relationship of progress with time i.e. 50% of the job should be performed when 50% of the time required is elapsed. This, however, is not always true. Barrie & Paulson (ref. 7, page 218) suggested a way of reporting progress which is not proportional with time. Scheduled progress percentages related to time were included on the schedule, along with the actual progress with respect to the time. Thus, one could readily see if actual progress was according to schedule or not.

This raises the question, however, of how can one arrive at scheduled percentages. One progress model is suggested in ref. 12. It involves data gathered on the progress of form-work on several jobs and the fitting of a model to the data. In order to establish a common framework for all projects, the equation was expressed in terms of physical percent complete as a function of the percentage of total activity time elapsed. The outcome was a model which was very similar to the "S" curve which is used to represent overall project progress versus time. Such models might be useful for heavy engineering projects like road construction where activities are of long duration. For building construction, however, it is more important to measure progress as a production rate per floor instead of taking each repetitive activity as one overall activity for all floors, as suggested in ref. 12.

Instead of updating the schedule by simply reallocating the remaining activities as mentioned previously, it would be useful to record the actual dates and derive production rates for the repetitive activities. Those production rates could then be used to forecast a trend to completion of the repetitive activities. If a specific activity had a slow start but seems to be regaining the time lost at the beginning, the forecasted rate of production might turn out to be higher than what was scheduled originally (Fig. 3.4). It would then be appropriate to develop a model that would use project data and produce from it forecasts of production rates up to the completion of the project, and

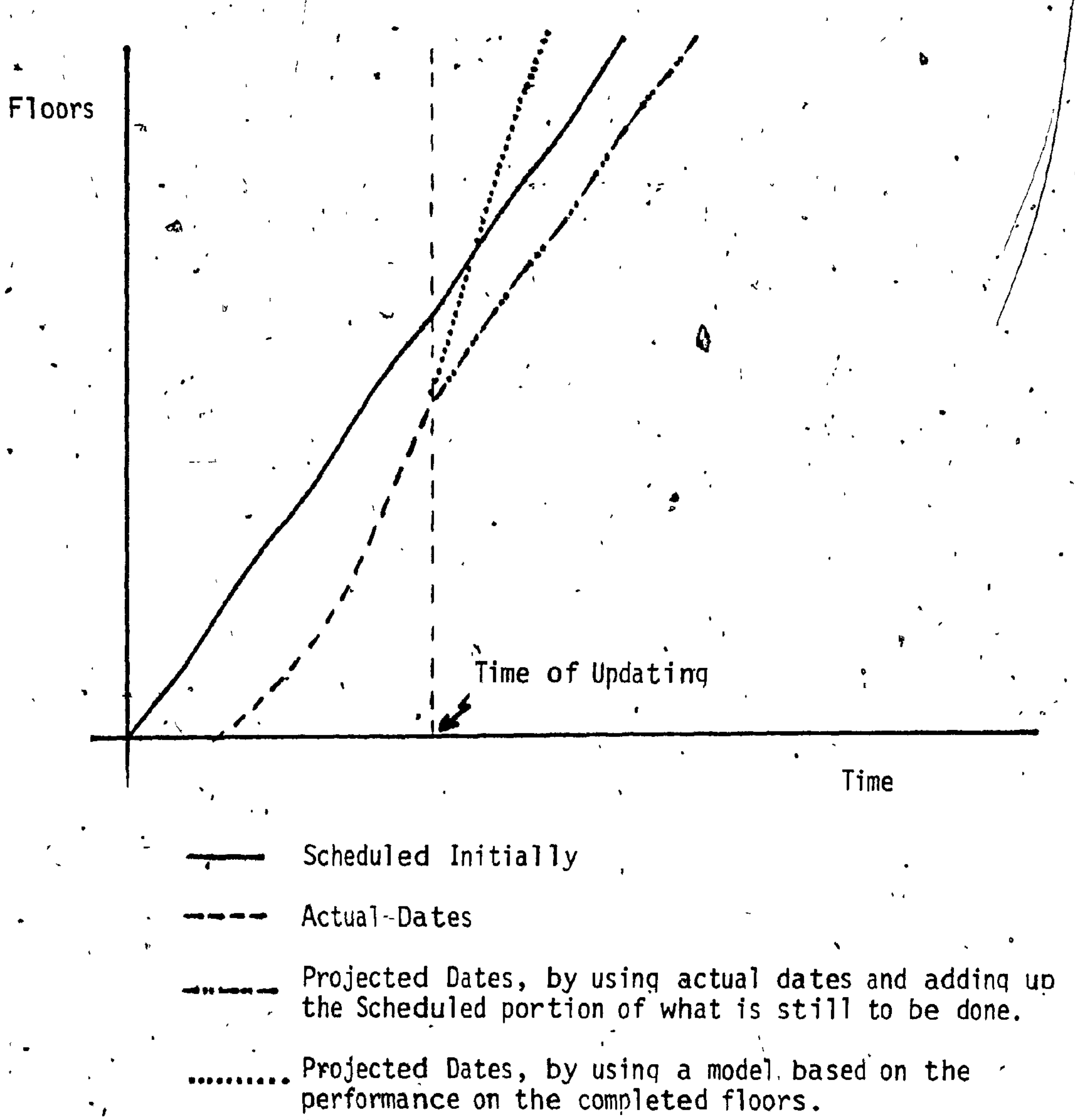


Fig. 3.4 Updating and Progress

therefore forecast the dates for the execution of the remaining activities. It would be a tool that would help the users of the system to better assess the status of the project and come up with more realistic predictions as to the completion of the work.

3.3 PLANNING TOOLS

In this section a review of planning techniques currently used in the construction industry is presented. For each technique, an analysis of its advantages and disadvantages is made along with an assessment of how it can or cannot be applied to high-rise building construction, how it can be used by the various levels in the general contractor's firm and how different levels of detail can be interfaced.

Four techniques are investigated, these being the Barchart, network techniques (Precedence and Arrow), the line of balance and the Linear Planning Chart (or VPM scheduling, etc.).

3.3.1 Bar Chart

It was not until the 1900's that the first scientific consideration of the problem of work scheduling was initiated. At that time, Henry L. Gantt and Fredrick W. Taylor used a graphical representation of work versus time in order to schedule the output of fixed production equipment. It became an accepted tool for planning construction and recording its progress and is the basis of today's bar graphs or bar charts (ref. 36).

Statistics (ref. 50) show that the bar chart is still widely used in the construction industry. There are several reasons for its continued use: it is easily read and understood by all levels of management and supervision; one can superimpose progress on the chart and readily see the status of the project; any kind of sequence between activities is possible (complete, partial or no overlapping at all); it is easy to aggregate several activities into one; it is very useful at the early stages of a project because it traces broad lines and helps in estimating the project duration and therefore overhead requirements.

However, some of its weaknesses cast a shadow on the above-mentioned advantages. In a general sense, the bar chart is limited to what it can present, which is a link between the execution of a particular activity and time. When a scheduler or a planner prepares one, he is obviously influenced by some completion dates that are imposed and will arrange the schedule so that it meets those dates by shortening some durations and/or overlapping some activities with others. However, the plan may very well reflect more wishful thinking than actual rational planning. The main source of such freedom is the fact that activity interrelationships and interdependences are not shown on the bar chart, even if they are considered by the planner. It then becomes a poor communication tool of the planning process, because any individual looking at it is not able to go over the same thought process as the planner. Also, without dependences identified, there is no easy way of playing "what if" games in order to simulate the effects of a particular change in the plan.

Because it is not usually the result of extended calculations, and resides on paper (as opposed to computer memory), updating is a tedious process for the draftman which explains why bar charts are not updated frequently, if at all. Finally, their effectiveness of visually communicating a plan diminishes as the number of activities increases.

Melin and Whiteaker (ref. 33) described another version of the bar chart called "Fenced Bar Chart" which has the feature of showing the logic between the various activities. It is somewhat similar to a time-scaled arrow diagram. With the presence of highly sophisticated computer graphics equipment, the generation of such a chart might become very easy to do. The application of such a tool might erase some of the disadvantages mentioned earlier.

It is now appropriate to see how a bar chart could deal with the characteristics of high-rise building construction as described in the second chapter of this thesis. In total, between 25 and 35 repetitive activities were identified for each typical floor. If there are 15 floors in the building, it means that between 375 and 525 different activities would have to be shown on the chart. Each of these activities being of relatively short duration, the resulting chart would definitely not be visually appealing and thus hard to use as a management aid. Actually, on one of the construction projects that the author had a chance to follow, the General Contractor used such a format (see Fig. 3.5) and it was terrible: for a 26 floor job, there were about 150 activities only for structural work, and they were scheduled to take

1 of

```
                                                   J  J   A    S   O    N    D   J   F    M    A   M     J  J   A     S   O   N     D
                                                   U  U   U    E   C    O    E   A   E    A    P   A     U  U   U     E   C   O     E
                                                   N  L   G    P   T    V    C   N   B    R    R   Y     N  L   G     P   T   V     C
            SYMBOL     INDICATES
              *        CRITICAL ACT.               1  0   0    0   0    0    0   0   0    0    0   0     0  0   0     0   0   0     0
              +        NON-CRITICAL ACT.           5  6   3    7   5    2    7   4   1    1    5   3     7  5   2     6   4   1     6
              =        FREE FLOAT
              -        TOTAL FLOAT                 8  8   8    8   8    8    8   8   8    8    8   8     8  8   8     8   8   8     8
                                                   1  1   1    1   1    1    1   2   2    2    2   2     2  2   2     2   2   2     2

   NO  ACTIVITY DESCRIPTION
                                                   !  !   !    !   !    !    !   !   !    !    !   !     !  !   !     !   !   !     !
  1000 MOBILIZE JOB                                C
    20 PREPARATION TO 2ND FLR -SECT. A            CCCCCCCCCCCCC
    21 PREPARATION TO 2ND FLR -SECT. B.                          CCCCCCCCCCC
    22 PREPARATION TO 2ND FLR -SECT C                                       CCCCCCCCCCCCC
    30 START STRUCTURE - 2ND FLOOR                                                      C
 10020 R/F CONCRETE STR - 2ND FLR -SECT A                                                CCCC
 10021 R/F CONCRETE STR - 2ND FLR -SECT B                                                   CC
 10030 R/F CONCRETE STR - 3RD FLR -SECT. A                                                  CC
 10031 R/F CONCRETE STR - 3RD FLR -SECT. B                                                   C
 10022 R/F CONCRETE STR. - 2ND FLR -SECT C                                                   C
                                                   !  !   !    !   !    !    !   !   !    !    !   !     !  !   !     !   !   !     !
 10032 R/F CONCRETE STR. - 3RD FLR -SECT. C                                                   C
 10040 R/F CONCRETE STR. - 4TH FLR -SECT. A                                                   CC
 10041 R/F CONCRETE STR - 4TH FLR -SECT. B                                                       C
 10050 R/F CONCRETE STR - 5TH FLR -SECT. A                                                      CC
 10051 R/F CONCRETE STR. - 5TH FLR -SECT. B                                                      C
 10060 R/F CONCRETE STR - 6TH FLR -SECT. A                                                       P*
 10061 R/F CONCRETE STR. - 6TH FLR -SECT B                                                         *
 11020 STRIP & RESHORE- 2ND FLR -SECT. A                                                           +=-
   100 SLAB ON FILL                                                                                +*-
 10070 R/F CONCRETE STR. - 7TH FLR -SECT A                                                         *
                                                   !  !   !    !   !    !    !   !   !    !    !   !     !  !   !     !   !   !     !
   130 MASONRY BASEMENT                                                                            +++++++++==
   131 MASONRY IN CORE TO 17TH FLR                                                                 +++++++++++-------
   123 WATERPROOFING G F AT COLUMNS                                                                ++==-----
 10071 R/F CONCRETE STR. - 7TH FLR -SECT B                                                         **
 10080 R/F CONCRETE STR. - 8TH FLR -SECT A                                                          *
 11021 STRIP & RESHORE- 2ND FLR -SECT B                                                             +-
 11030 STRIP & RESHORE- 3RD FLR -SECT A                                                             +--
 10081 R/F CONCRETE STR. - 8TH FLR -SECT. B                                                         **
 11031 STRIP & RESHORE- 3RD FLR -SECT B                                                             +--
 10090 R/F CONCRETE STR. - 9TH FLR -SECT. A                                                         **
 11040 STRIP & RESHORE- 4TH FLR -SECT A                                                             +--
   380 START ELEVATOR SET-UP                                                                        ++++-
 11041 STRIP & RESHORE- 4TH FLR -SECT B                                                              +-
   120 PRECAST -GRD. FLR TO 3RD FLR                                                                  ++-------
 11050 STRIP & RESHORE- 5TH FLR -SECT. A                                                             +-
 10091 R/F CONCRETE STR. - 9TH FLR -SECT B                                                           **
 11051 STRIP & RESHORE- 5TH FLR -SECT. B                                                             +--
 10100 R/F CONCRETE STR -10TH FLR -SECT. A                                                           **
 11060 STRIP & RESHORE- 6TH FLR -SECT A                                                              +--
 11061 STRIP & RESHORE- 6TH FLR -SECT B                                                              +=-
                                                   !  !   !    !   !    !    !   !   !    !    !   !     !  !   !     !   !   !     !
 10101 R/F CONCRETE STR -10TH FLR -SECT. B                                                            *
 10110 R/F CONCRETE STR -11TH FLR -SECT. A                                                            **
 11070 STRIP & RESHORE- 7TH FLR -SECT. A                                                              +-
 11071 STRIP & RESHORE- 7TH FLR -SECT. B                                                              +=
 10111 R/F CONCRETE STR -11TH FLR -SECT. B                                                             *
   121 PRECAST -3RD TO 15TH FLR                                                                        +++++++++++-------
 10120 R/F CONCRETE STR -12TH FLR -SECT. A                                                             *
 11080 STRIP & RESHORE- 8TH FLR -SECT A                                                                +-
   142 CURTAIN WALL - WEST & NORTH                                                                     ++++++
 10121 R/F CONCRETE STR -12TH FLR -SECT B                                                              **
                                                   !  !   !    !   !    !    !   !   !    !    !   !     !  !   !     !   !   !     !
 11081 STRIP & RESHORE- 8TH FLR -SECT. B                                                               +-
   383 LO-RISE ELEVATOR INSTALLATION                                                                   +++++++++++++++++++++++++++=====
   161 TRIPLE GLAZING TO 15TH FLR                                                                      +++++++++++++-------
 10130 R/F CONCRETE STR -13TH FLR -SECT A                                                              *
 11090 STRIP & RESHORE- 9TH FLR -SECT A                                                                 +--------
   382 SHUTTLE ELEVATOR                                                                                 ++++++
 11091 STRIP & RESHORE- 9TH FLR -SECT B                                                                 +====----
 10131 R/F CONCRETE STR -13TH FLR -SECT B                                                               **
 10140 R/F CONCRETE STR -14TH FLR -SECT A                                                               **
 11100 STRIP & RESHORE-10TH FLR -SECT A                                                                 +---=====
                                                   !  !   !    !   !    !    !   !   !    !    !   !     !  !   !     !   !   !     !
 11101 STRIP & RESHORE-10TH FLR -SECT B                                                                  +===-----
 10141 R/F CONCRETE STR -14TH FLR -SECT B                                                                **
 10150 R/F CONCRETE STR -15TH FLR -SECT A                                                                **
 11110 STRIP & RESHORE-11TH FLR -SECT. A                                                                 +-------
 11111 STRIP & RESHORE-11TH FLR -SECT B                                                                  +=====---
  3700 DELIVERY ITE LOW VOLTAGE SWITCHGEAR                                                               *
 10151 R/F CONCRETE STR -15TH FLR -SECT B                                                                 **
 10160 R/F CONCRETE STR -16TH FLR -SECT. A                                                                **
 11120 STRIP & RESHORE-12TH FLR -SECT A                                                                   +-------
 11121 STRIP & RESHORE-12TH FLR -SECT. B                                                                  +===----
                                                   !  !   !    !   !    !    !   !   !    !    !   !     !  !   !     !   !   !     !
  3710 DELIVERY POLYGON TRANSFORMERS                                                                      *
 10161 R/F CONCRETE STR -16TH FLR -SECT B                                                                  **
 10170 R/F CONCRETE STR -17TH FLR -SECT. A                                                                 **
 11130 STRIP & RESHORE-13TH FLR -SECT. A                                                                   +-------
 11131 STRIP & RESHORE-13TH FLR -SECT B                                                                    +===----
 10171 R/F CONCRETE STR -17TH FLR -SECT. B                                                                 *
 10180 R/F CONCRETE STR -18TH FLR -SECT. A                                                                 **
 11140 STRIP & RESHORE-14TH FLR -SECT A                                                                    +------
  3720 DELIVERY MERLINE-GERIN SWITCHGEAR                                                                   *
 11141 STRIP & RESHORE-14TH FLR -SECT. B                                                                   +====---
                                                   !  !   !    !   !    !    !   !   !    !    !   !     !  !   !     !   !   !     !
   124 WATERPROOFING TRANSFORMER ROOM                                                                       **
 10181 R/F CONCRETE STR -18TH FLR -SECT. B                                                                  *
 10190 R/F CONCRETE STR -19TH FLR -SECT A                                                                   *
 11150 STRIP & RESHORE-15TH FLR -SECT A                                                                     +------
 11151 STRIP & RESHORE-15TH FLR -SECT B                                                                     +=====--
   132 MASONRY TO P/H                                                                                       ++++++++++++++++=====
 10191 R/F CONCRETE STR -19TH FLR -SECT B                                                                   ***
 10200 R/F CONCRETE STR -20TH FLR -SECT A                                                                     *
 11160 STRIP & RESHORE-16TH FLR -SECT A                                                                       +---
 11161 STRIP & RESHORE-16TH FLR -SECT B                                                                       +=--
 10201 R/F CONCRETE STR -20TH FLR -SECT B                                                                     **
 10210 R/F CONCRETE STR -21ST FLR -SECT A                                                                     **
 11170 STRIP & RESHORE-17TH FLR -SECT A                                                                       +---
 11171 STRIP & RESHORE-17TH FLR -SECT B                                                                        +=--
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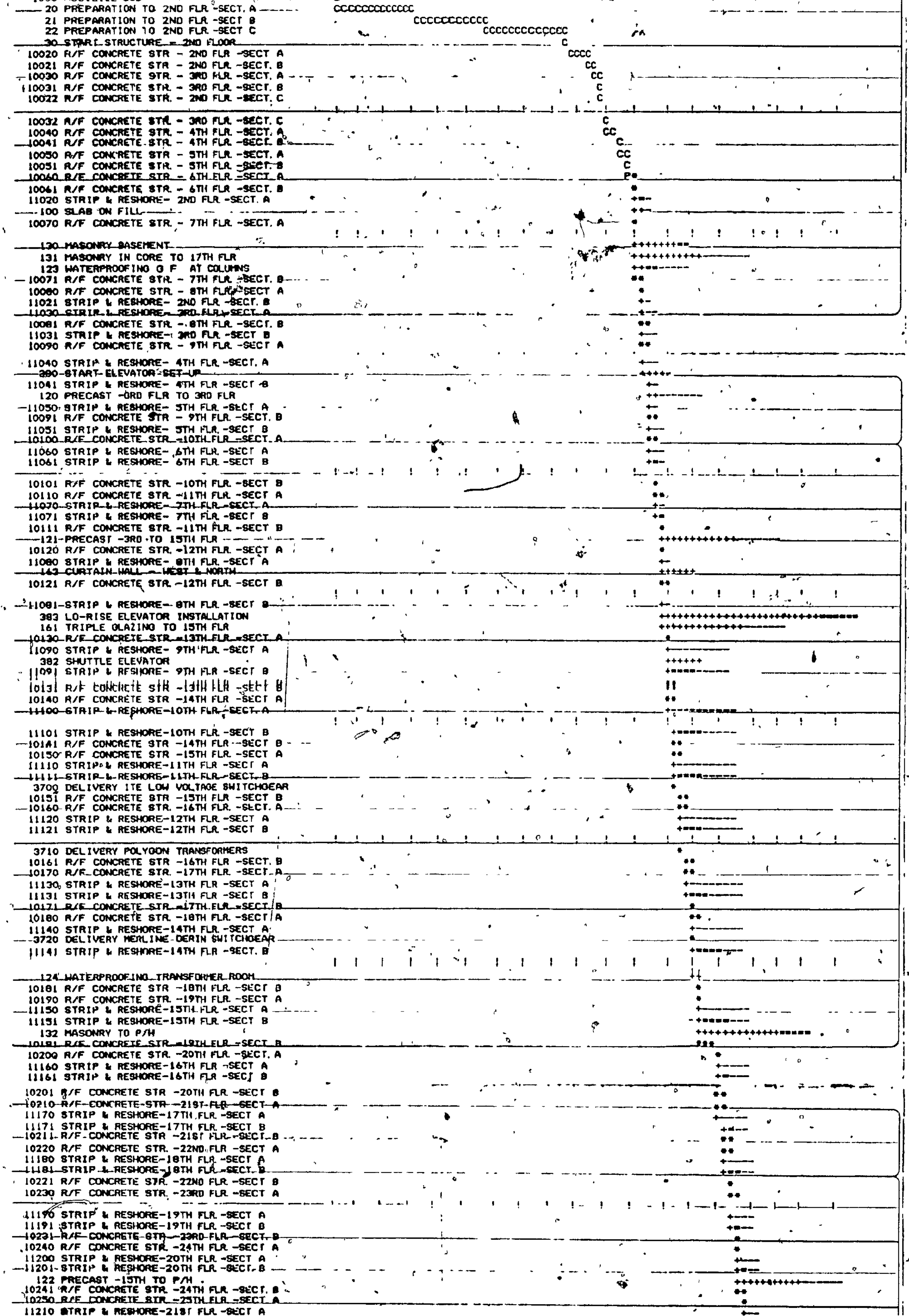


Fig. 3.5 Example of Use of Bar Chart Format (1st)

2 of 2

place in a short 7 month period.

On another job that the author followed, the General Contractor initially prepared a bar chart with about 70 activities (see Fig. 3.6). Some of these activities were non-repetitive, some were repetitive. However, no distinctions were made between the two activity types. For the repetitive activities, no indication of their location in the building and time frame per floor was given. Therefore, it could not show the logic between the various repetitive activities on a given floor. Thus the subcontractors had only a time frame in which to execute their job and could do it in any manner, within that time frame. Such a schedule could not be used to identify coordination problems between the trades.

This same General Contracting firm issued a new schedule with about 6 months to go in the project. It was again a bar chart format, but with a more detailed time-frame (units were days instead of weeks) and only repetitive activities were shown. This time, however, each bar corresponding to an activity was broken down so that each section corresponded to a floor of which the number was written on top of the bar. Although the logical relationships were not shown on the schedule, one could see that the planner had gone through an examination of the predecessor relationships for the activities. The format was visible too; there were 20 activities for 24 floors (total of 480 "bars") and they were grouped on one page (Fig. 3.7). However, the absence of non-repetitive activites on that chart made that schedule incomplete but certainly more useful to the trades.

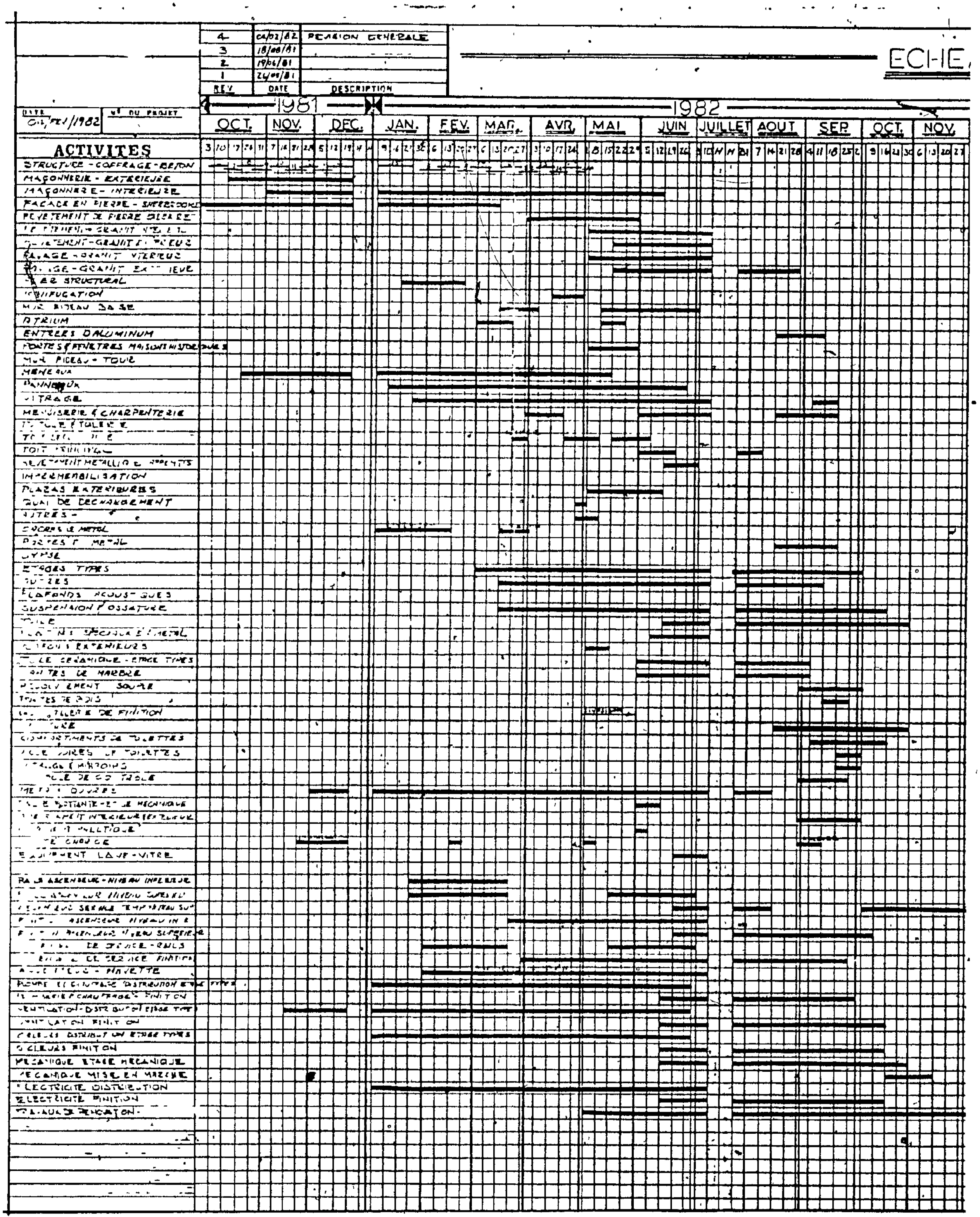


Fig. 3.6 Example of Use of Bar-Chart Format (2nd)

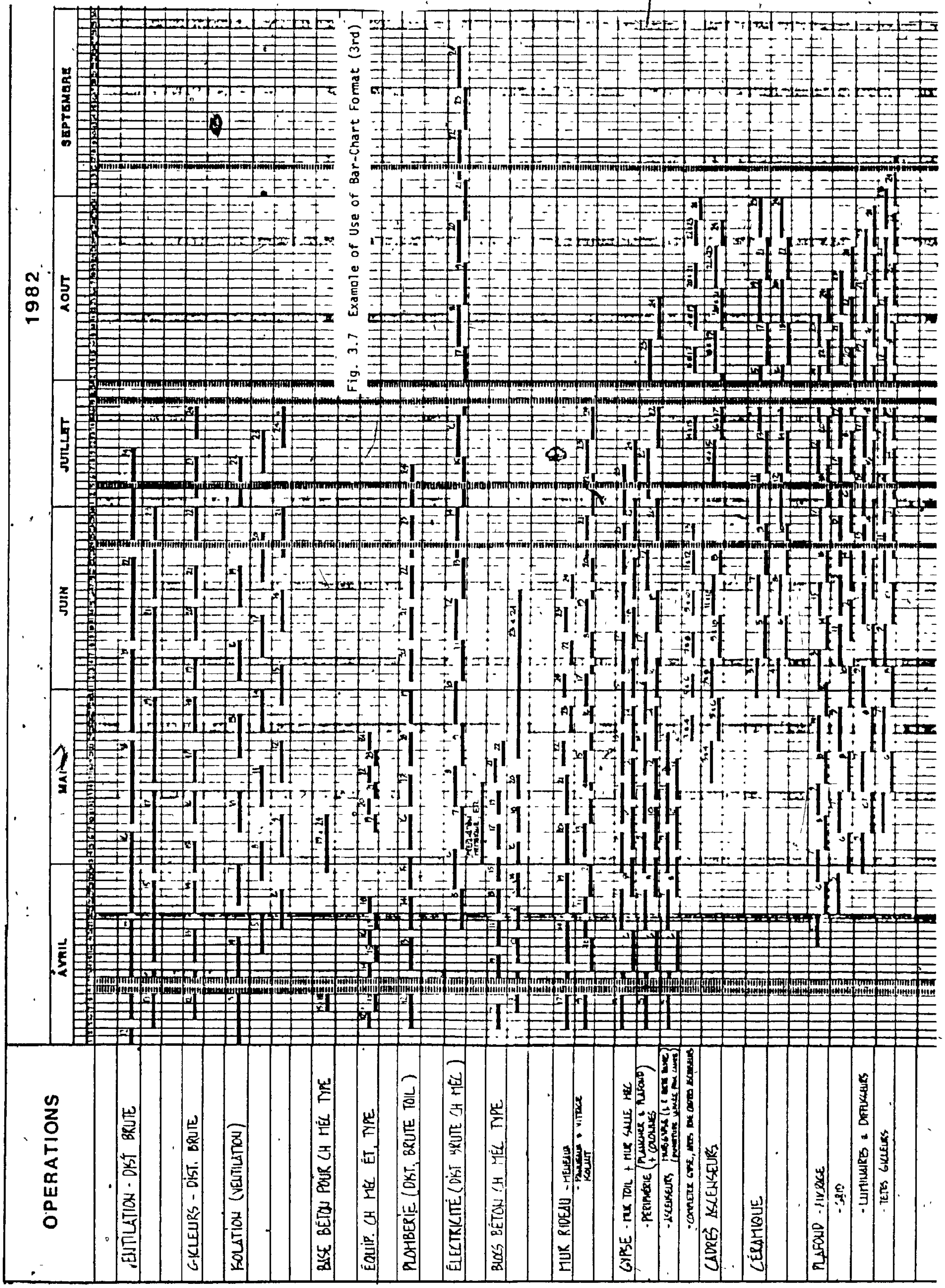


Fig. 3.7 Example of Use of Bar-Chart Format (3rd)

As mentioned earlier in this section, the updating process of such a schedule can be very long and arduous, especially because of its size and detail. However, the idea of going into floor by floor detail and to show each activity only once is useful to keep in mind.

In terms of its acceptability, there is no doubt that a bar chart is accepted at all levels of the project, from the site superintendant to the project manager to senior management and even the client. The detail present at the site level will definitely be different than the one in the president's office but that should not create any major problem because aggregation of several activities into one is easily done.

So the bar chart technique is an interesting option when we talk about output formats or a tool for communicating the schedule (although not the thought process behind it) to the various individuals. However, it is not adequate for deriving actual dates because of the previously mentioned disadvantages: lack of information on the interrelationships between the activities and very difficult to update.

Keeping in mind that it is advisable to computerize the system, the bar chart technique will not likely be used as a means to arrive at a schedule, but rather as a tool for output purposes of data calculated using a more comprehensive model of the construction process.

3.3.2 Network Techniques

Network planning techniques were originated during the years 1956-1958 to solve two different planning problems. In the first case, the firm E.I. duPont de Nemours was concerned about developing a better scheduling tool in order to improve the construction planning of several chemical plants. Some mathematicians developed the basic relationships for a schedule, given the sequence of work and the duration of each activity. In 1957, a special team which included James E. Kelley Jr. of Remington Rand, Morgan Walker of DuPont and later Dr. John W. Mauchly, was formed in order to find a way of using these principles. They came up with a routine which was called at that time the Kelly-Walker method and which forms the basis for current CPM techniques. Actually, Kelley is generally credited with having made improvements to the network representation which made the overall concept practical (ref. 37, p. 35). This team then compared the CPM technique with older planning methods and found out that to correct the schedule because of design changes, it took the old team 40% of the original effort to update whereas it took only 10% for the CPM team, a remarkable improvement (ref. 36, p. 6).

In the second case, in January 1958, the Special Project Office of the Navy Bureau of Ordinance was concerned about monitoring and controlling the Polaris Missile Program. It was however some time after the project started that this became a problem: there were more than 3,000 contractors or agencies working on the program and it was impossible to monitor them efficiently. They therefore established a task group to formulate a technique which became known as PERT (Program Evaluation Research Task and later Project Evaluation and Review Technique).

Less than a year after that, the group had developed detailed procedures: the first step was to identify "events that are planned to occur along the way to a successful conclusion of the project" (ref. 36 p. 97) or "milestones"; the second step was to link these events to graphically portray the dependences among them; and the third element was to estimate times to move from one event to the other, taking into account uncertainty. It was demonstrated by the group that a single estimate was not practical for research and development work. "They pointed out that circumstances are too flexible in R and D, unlike construction where time can be estimated with certainty" (ref. 36, p. 98). So, three time estimates were used: a most likely time, an optimistic time and a pessimistic time. These three times were assumed to be distributed along a Bell-shaped curve which, in turn, yielded an estimate of an "expected" duration. That duration was then used to perform calculations similar to the CPM mentioned above. It was also possible to evaluate the probability for completing a project within a defined time interval. In this case, the Polaris project finished ahead of schedule with the use of PERT.

PERT is very similar to CPM except for the time estimates. For purposes of this thesis, the author will treat both methods as one.

Basically, a CPM network is a graphic representation of a project.

At the present time, two formats are used to present the network: the activity on arrow and the activity on node or precedence diagram. The activity on arrow notation was the one used on the first versions of the CPM back in the late 1950's. The precedence diagram was suggested by John Fondahl later in 1961 (ref. 19). The author will assume that the readers have a basic knowledge of both approaches. They have been treated in various textbooks and publications (ref. 2,5,19,24,36,37). Each of the two notations have their pros and cons as described in the references.

Since the 1960's, CPM has been used more and more in the construction industry. Many owners require its use on their projects. Thus it is appropriate to identify some of the benefits of using CPM.

First of all, the CPM requires a careful study of the work logic: when identifying the various interdependences between the activities, the planner has to review the construction process and make sure that the sequence is right. However, the network presentation of the activities enables anybody to see and understand the interdependencies between the activities. So there is a clear and shared vision of the logic of the work. This might be one reason why owners like CPM: they know that the planners had to review in detail the logic and they can easily see it in the network presentation.

CPM also splits planning and scheduling. Referring to a concept mentioned earlier in this thesis, the planner has to identify in the first place, the theoretical logic which has to be respected. This logic forms a skeleton on which the other activities, which have preferential logic, are distributed. This constitutes the planning part. For the scheduling task, durations for the activities are estimated, based on the resources available, equipment use, space constraints, etc. These durations, along with the interdependences, form the basis for the simple calculations that generate the schedule. It is only at this stage that a look at the time frame will be made, therefore diminishing the tendency of "fitting the dates" that an owner may have set.

Because most CPM calculations are usually done on computer, updating of the plan and schedule is possible, although it is difficult in most network processors. Activities can be deleted or added, the logic can be changed as can the activity durations.

If for any reasons, the project duration has to be shortened, a CPM presentation imposes more discipline than a bar chart, especially with respect to the logic. Theoretical logic will not be changed under any circumstances, but a shorter project duration could be obtained by reducing the duration of such activities or by shifting some of the logic which is preferential, only if they are on the critical path. But again, a careful study of the implications of such changes is explicitly done, therefore yielding a more realistic plan.

The CPM calculations also determine which activities are critical, and which are not. Often, a contractor will orient his efforts to keep those critical activities on schedule and will worry about the others if they encounter long delays and thus become critical. Notwithstanding the importance of their execution in the overall project, he will manage them "by exception" and give priority to the critical activities.

Finally, CPM networks are good for showing how progress affects the schedule. If an activity is delayed for any reason, the updated schedule will readily show the downstream effects of the slow progress and if possible, revised logic could be adopted to compensate for the delay. More generally, CPM networks enable their users to play "what if" games thereby identifying the effects of schedule deviations on the overall project.

In 1962, an editorial in the Engineering News Records said that "the use of the CPM technique by construction firms would be necessary for survival in the future" (ref. 14). On the other hand, numerous software development companies designed and commercialized various CPM packages which, in general, have the same characteristics. Nevertheless, in 1974, only 22% of the senior managers of the top 400 construction companies in the United States mentioned that CPM was very important to their success (ref. 14). Similarly, in Canada, a study made in 1974 (ref. 50) revealed that only 27% of the respondents and 44% of those with a yearly volume of more than $10M used CPM during the job. The reasons for this low usage might be found in the disadvantages of the CPM model.

One of the limitations of the CPM model lies in the fact that it is a deterministic system which treats some probabilistic data (durations, logical connections). Birell (ref. 8) states that the lack of success of CPM models is due to "their incompatibility to the essence of the construction process". John Fondahl (ref. 17) mentions that "any model or mathematical system involves certain approximations and compromises with reality". In the case of the network model, the durations of the activities are more an approximation than anything else. It might take more or less time so the number represents an average. In the case of the interrelationships between the activities, one must be very careful when interpreting them; the model assumes that an activity is 100% complete before the following activities may be started. In order for that statement to be true, one should increase the level of detail of the activities to show all the exceptions to the 100% complete rule. For example, if some jacks have to be left in place to transmit the load of the tower crane, some ductwork might not be installed until the crane is removed. However, when the ventilation subcontractor has done all his work on the floor, he will move to the next one even if the activity is only 95% complete. In Fondahl's terms, some approximation, based on judgement, is made that "the substantial commencement of one activity will follow the substantial completion of another" (not necessarily 100% complete) (ref. 17).

Another problem lies in the fact that often scheduling calculations account only for technological restraints and assume unlimited resources that can be hired and fired freely during the construction period. Thus, the solution obtained from the model turns out to be infeasible because of resource constraints. Some software packages have resource levelling algorithms which allocate non-critical activities in such a way that the resource requirements are as constant as possible during the length of the project. However, the assumption that non-critical activities can be shifted anywhere between their early start date and late finish date is not always realistic. Network techniques have to be used in combination with personal judgement. If bad assumptions are made, bad results come out (GIGO principle: Garbage In Garbage Out!).

In fact, on jobs with a great number of activities, the CPM calculations can result in a tremendous volume of data about early and late dates and various kinds of floats, which might never be used at the job level by the construction people. For example, one of the general contractors that the author consulted tried to use a CPM package; the level of detail was such that 450 activities comprised the plan and a "Time Analysis Report" consisted of 29 pages of output which could not be used at all levels of management, although it was appropriate for the project manager.

Now that we know more about CPM networks, it is appropriate to evaluate their suitability for high-rise building projects. As in any application there are always general rules and exceptions to the rules. Two articles published in the early 1960's (ref. 16 and 31) described very successful applications of CPM networks to high-rise building construction. However, it would be simplistic to advocate the adoption of the critical path method simply on the basis of these publications. Of importance is the ability of this model to reflect accurately the construction process.

Two types of activities present in Building construction were identified earlier: repetitive activities executed on typical floors and non-repetitive activities which are performed only once. Network formats are useful when determining the sequence of non-repetitive and repetitive activities on a typical floor. However, showing all the activities for every floor on the same network would turn out to be very clumsy, especially if we are dealing with a great number of floors. Drawing the network for a 30 storey building with each floor having 30 activities (900 activities ...) would be a very painful task on the drafting table and also at the computer terminal.

When designing the network, one would like to include precedence relationships to sequence the crews as much as possible from floor to floor. For example, fig. 3.8 shows part of an arrow diagram for a high-rise sequence. Although it is not a technological constraint, the start of the lath on the 16th floor would be preceded by the finish of the lath on the 15th floor because of the presence of only one crew. In high-rise building construction, most of the trades move from floor to floor in this fashion. So a tremendous number of precedence relationships would have to be added to an already very tight presentation, creating overlapping arrows, arrows referring to a previous page, etc.. This obviously is not a desirable format.

Moreover, even if these relationships were added to sequence the crews properly, the CPM algorithm would not take into account the timing of the activities of each floor nor would it allow for the benefits of

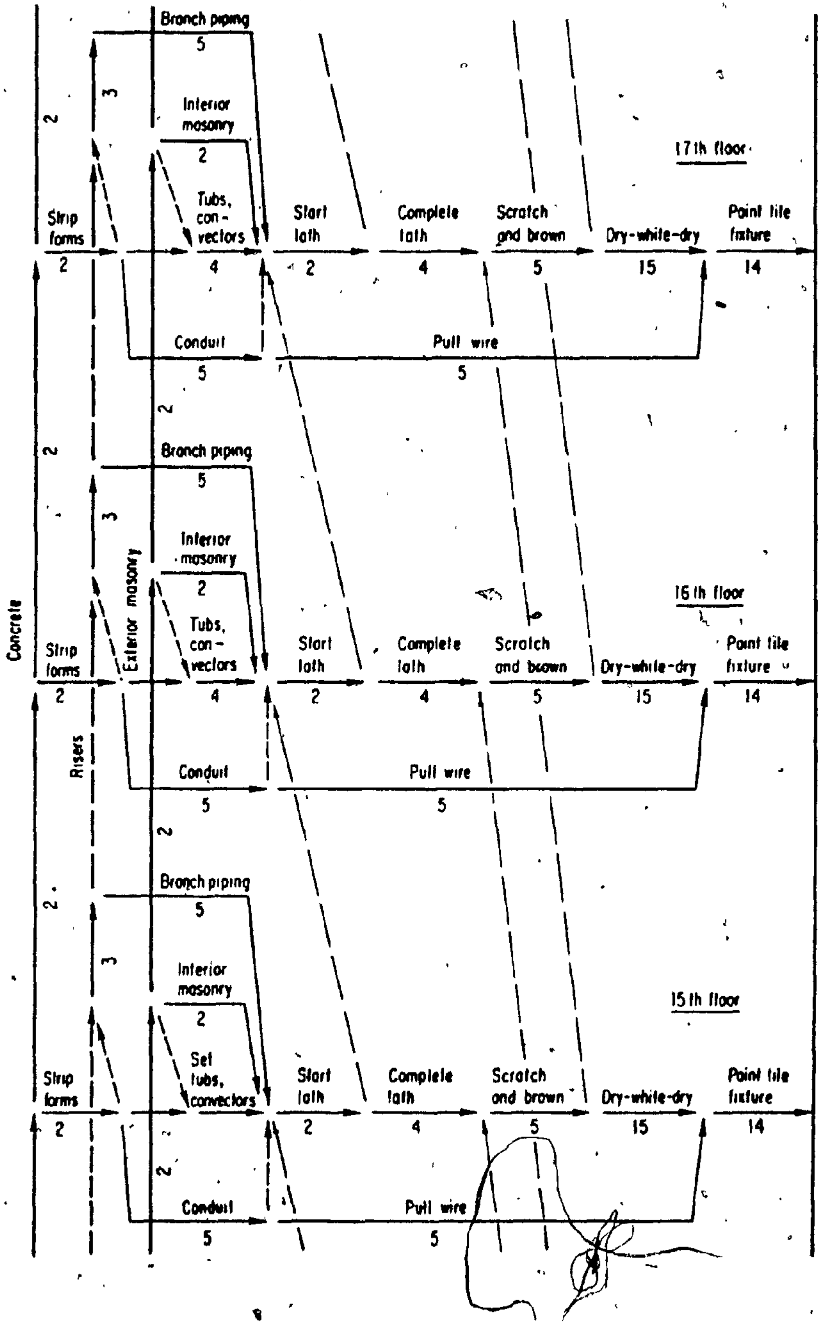


Fig. 3.8 Arrow Diagram for a High-rise Sequence (ref. 36, p. 130)

continuity and learning effects as mentioned previously in this chapter. For example, if the structure is slower than the rough-in work for plumbing, the plumbing subcontractor will let the structure go for several floors before starting in order to work continuously from floor to floor. The CPM calculations do not explicitly account for this; the rough-in work for plumbing will end up having a lot of float, but there is no indication as to where he should start his work in order to move smoothly from floor to floor without interruption.

As to their usefulness at the various management levels in a General Contracting firm, it is variable; top management and the client are more interested in seeing key milestones, rather than precedence relationships. A network format might not prove very useful to them. However, the project manager and the superintendant, who are interested in the coordination of the various trades and activities should find CPM networks useful in designing a successful sequence for the non-repetitive activities and for the typical floor repetitive activities. However, the extension of the sequence of one typical floor to all the others does not appear easily possible by using network techniques.

For the aggregation of a fine level of detail into a more general activity or subnetwork, it is possible to do it as long as the activities of the subnetwork do not have links with activities outside of the subnetwork. For example, grouping ventilation roughing-in, floor mechanical unit and air distribution (diffusers) under one activity called "ventilation" is not possible in a network because roughing-in is a prerequisite to ceiling ties, floor unit is a prerequisite to plumbing and electrical connections etc. However, "structure" could be an aggregated activity which includes column formwork and rebar, slab form and rebar, sleeving, pouring, and concrete finishing, which are not related to other activities.

So in general, CPM network techniques have some qualities which make them very attractive: definition of activities and their relationships which can be shown in a clear format (for one floor ..); and the possibility of computer usage for the scheduling calculations. However, some of the characteristics of high-rise construction, especially repetition and continuity of the work cannot be easily handled by such a technique. Keeping these qualities in mind, what is required is to find a way to include the characteristics described. The next sections will reveal some models that may be interesting to consider for this task.

3.3.3 Line of Balance

The line of balance technique was developed by the Navy Special Projects Office in 1951 and was approved in its present form in 1962. It is based upon the establishment of a required delivery program for completed units and was aimed at planning and monitoring the manufacture of many similar units. The repetitive floors of high-rise building can be considered as separate units that have to be assembled one after the other in the exact same sequence. Thus, their construction can be compared to a manufacturing process and that is why the line of balance technique might be interesting to analyse.

A line of balance (LOB) model consists basically of three components: (1) a unit cycle network showing all the activities performed, their dependences and the time required between activity and unit completion; (2) an objective chart showing a calendar schedule for the completion of the units; (3) a progress chart showing the completion of the activities for each unit. A brief explanation of each of the components and their interrelation is given below.

The unit cycle network is very similar to a CPM network as described in the previous section. With the information mentioned in the previous paragraph, it is possible to evaluate the total time required to produce one unit, the critical path, etc. However, the LOB network is calculated differently: instead of calculating the time at which the activities are performed after the start of the first activity, calculations are made by evaluating the time required before unit completion (see Fig. 3.9). It is actually making forward pass calculations, but starting from the last activity and using on late activity times.

The objective chart is basically a desired completion schedule. It shows the number of units on the y-axis and the time on the x-axis (fig. 3.10). It is determined by the expectations of the owner and/or contractor rather than by the LOB model itself. It reflects one of the assumptions of the LOB technique: a target is set and all the activities are scheduled by going backwards from the target, instead of starting from a point and evaluating at which time it is possible to finish. The unit network and the objective chart represents the "planning" aspect.

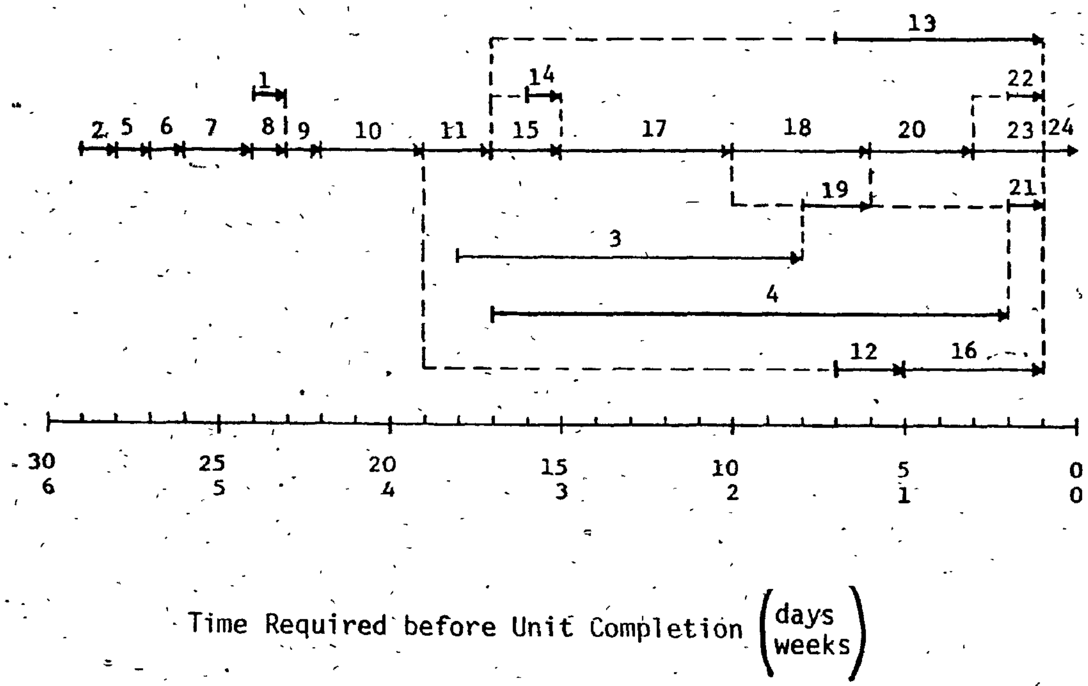
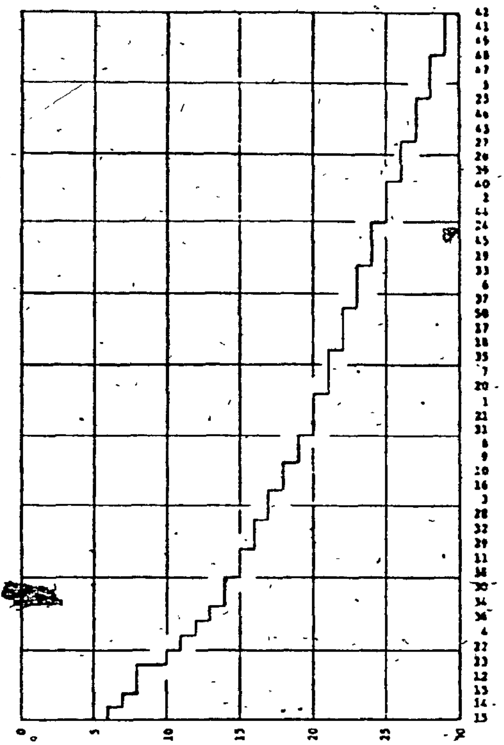


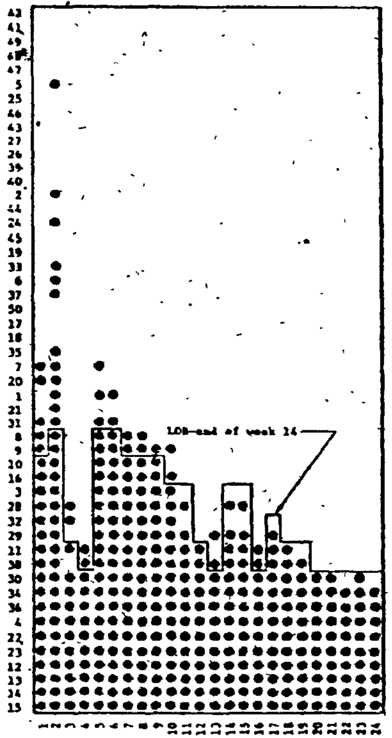
Fig. 3.9 Unit Cycle Network (ref. 11)

Units



Time from Project Start (weeks)

Fig. 3.10 Objective Chart
(ref.11)



Activities

Fig. 3.11 Progress Chart
(Ref. 11)

The progress chart (Fig. 3.11) is a two-dimensional chart with the number of units on the y-axis and activity numbers on the x-axis. Both variables are discrete and are shown on the chart by a dot or other symbol. When an activity for a specific unit is completed, the corresponding location on the progress chart is "darkened". It is on that chart that the line of balance is shown and it enables one to compare the current status of an activity relative to its scheduled status and therefore initiate corrective action to bring the work back on schedule.

The line of balance is shown on the progress chart by showing the activities which must be completed by a certain date (or"date of LOB") in order to meet the unit completion schedule (objective chart) according to the dependences and duration of the unit network (ref. 11). The calculation of the LOB uses the objective chart and the unit network in the following way: First a date has to be chosen for which to do the calculation. A segment of the LOB will be calculated for each activity using the following principle: the time required between the completion of the activity and a unit completion is determined from the unit network which was calculated backward previously. This time is then added to the LOB date chosen and at that resulting time, the number of completed units required is read from the objective chart. In order to be on schedule, that specific activity has to have been completed for that number of units, and it determines where the "line of balance" is. This operation is repeated for all the activities of the unit cycle network and the LOB is shown on the progress chart. Any activity that is not completed below the line of balance is late and will most likely delay completion of the unit. If activities are completed above the line of balance, they are ahead of schedule.

For purposes of this thesis, it is not necessary to review in detail the various applications of this technique. It has been used mostly in the manufacturing industry (ref. 37,56) and also in the construction of similar housing units (ref. 11,29). Of importance here are the strengths and weaknesses of this technique and an evaluation of its suitability for scheduling high-rise building construction.

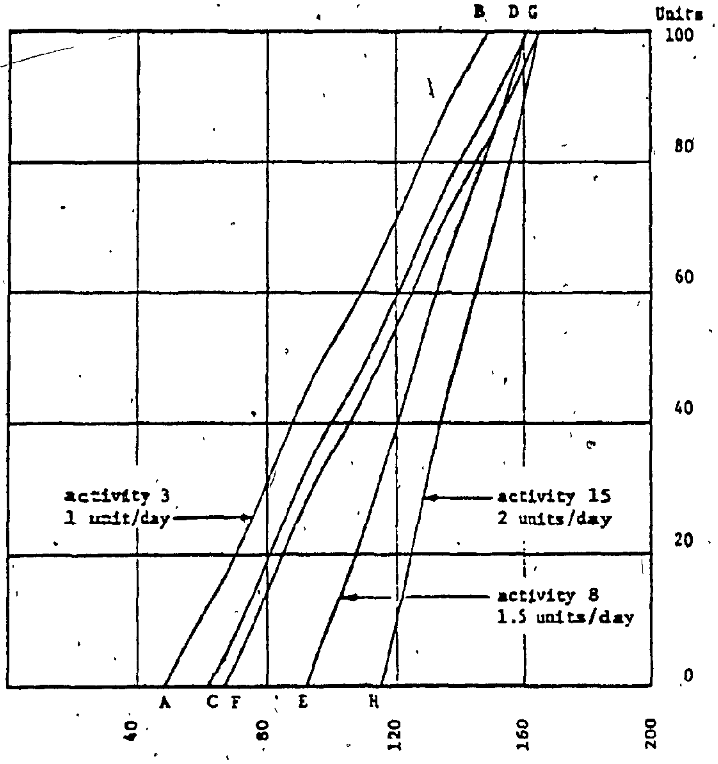
One of the main qualities of this technique is its simple presentation and also its clarity. Only three documents are needed to show the schedule of the work, the relation between the activities and the status (progress) of the work. One can readily see if the activities are on schedule or not and corrective action, if required, can be initiated as soon as the line of balance is drawn on the progress chart.

The fact that there is a network designed to show the activities forces the user to develop a logical plan, as mentioned in the characteristics of CPM networks (see previous section), and this helps in arriving at the most efficient sequence of work. The objective chart shows clearly when each of the units will be completed and indicates well the flow of work from unit to unit.

However the line of balance technique has several limitations: at any point in time it doesn't indicate the schedule of work of a particular trade (or activity) from unit to unit. The objective chart shows the schedule of the last activity of the unit network but does not include the other activities. In order to get such a schedule, one would have to subtract from the dates of the objective chart the time gap between the completion of the activity and the completion of the whole unit, obtained from the unit network. Thus one could derive an objective chart for each and every activity.

The previous sentence illustrates a key assumption of the line of balance technique which is that all the activities are performed at the same rhythm of production. For industrial mass production and even for housing projects this may be feasible, but for high-rise building construction, it is an onerous constraint. From the description of the construction processes involved in building construction (see Chapter II), we realize that some trades might have different rates of production than others, might be affected by weather or have a longer learning period. The LOB assumption would force planners to have the construction processes fit the model rather than the opposite. Also the LOB model assumes independence between the units, which is not necessarily the case for high-rise building construction.

Carr and Meyer (ref. 11) realized the limitation of different production rates and tried to modify the model so it would allow for varying rates. Their solution was to show on the objective chart not only the line representing the completion of the units, but also the lines showing the desired completion dates of the activities having different production rates (fig. 3.12). These lines were placed on the



Time from Project Start (days)

Fig. 3.12 Objective Chart with Different Production Rates (ref. 11) chart so that they could move continuously at their rhythm, without interfering with the others. The line of balance is then calculated by looking at the scheduled progress as per the line that concerns each of the activities. Although this solution accounts for variable production rates, the objective chart becomes more complicated to interpret and the calculations of the LOB have to be done more carefully.

The LOB is designed to monitor repetitive tasks and it was shown previously that one of the characteristics of high-rise construction was non-repetitive activities that have some interdependences with some repetitive activities. The LOB technique cannot in any way account for such a characteristic and would therefore miss the most important requirement of the system, which is to have a model that is as close as possible to the actual construction process.

Other limitations are the lack of scheduling information revealed by the LOB model; it is good at showing progress, but says very little about the relation between the activities of each unit and the time of their execution.

In summary the LOB technique has some features which promote the continuity of work and account for learning phenomena, but it lacks flexibility when the production rates are different for the various activities and cannot allow for the presence of non-repetitive activities. The presence of several activities on the objective chart has great similarities with the next model that is explained.

3.3.4 Linear Planning Charts

Linear Planning charts have been the subject of several publications but under different appellations. It was referred to as the "chain method" by Popescu (ref. 48), the "linear balance chart" by Barrie and Paulson (ref. 7), the "Construction Planning Technique" by Peer and Selinger (ref. 44), the "Trade Progress Chart" by Goldhalder, Ha and Macedo (ref. 21), the "Linear Scheduling Method" by Johnston (ref. 27), the "Vertical Production Method" by O'brien (ref. 35) and the "Time-space Scheduling Method" by Stradal and Cacha (ref. 39). It is not essential here to review in detail the characteristics of each version of the technique. Instead, a description of the general characteristics and assumptions is presented by aggregating the information present in these publications.

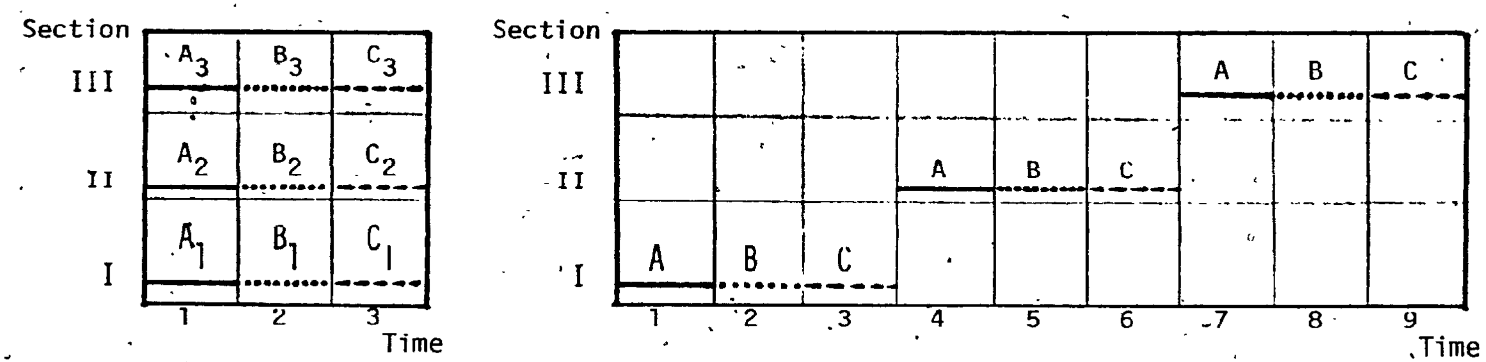
The exact origins of the linear planning chart are not evident. The chart itself has some similarities with the objective chart of the line of balance in that there are units on the y-axis versus time on the x-axis. The units are in fact any measure of production, depending on the field of application. In the case of high-rise buildings, the units correspond to "floors".

One of the basic assumptions of the linear representation of the work is that realization of the overall construction project has to be divided into production crews (ref. 43) and that each "work-squad" will proceed on each segment (floor in our case) one after the other in a sequence established by technological or preferential constraints (ref.

8). There are various types of relationships between the execution of the work on each segment. Stradal and Cacha (ref. 39) have described three work sequence types. The first is simultaneous work, where each section is done simultaneously. The linear planning chart does not apply in this case because no relationships exist between the segments. The second is successive work, where all activities possible are performed on one segment before any activity is started on the next one. The third is the flow line method, in which each task is performed from section to section, without interruption and is started as soon as the previous squad has completed its work (see Fig. 3.13).

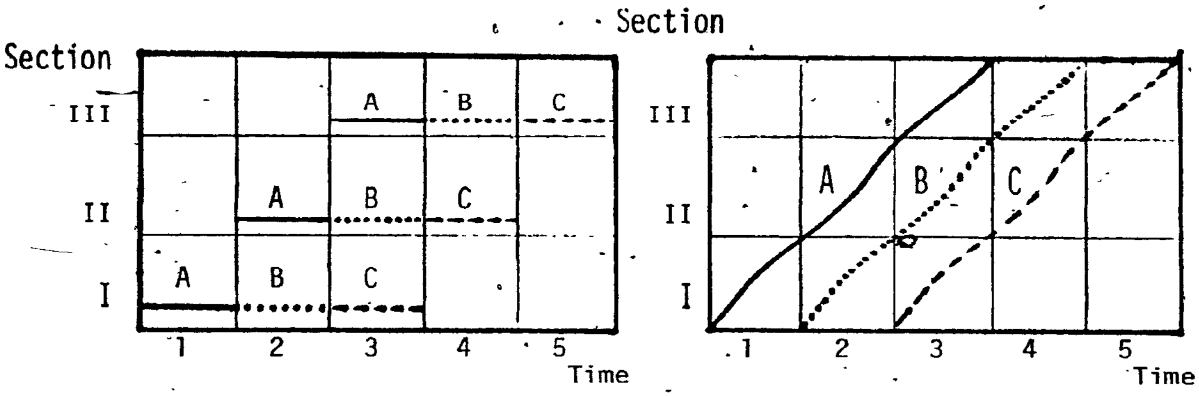
The linear chart is suited to represent the latter type of relationship, which is the most desirable to efficiently execute the various activities. While simultaneous work becomes feasible after the structure is completed (see section 2.3.1 of present thesis) it is highly undesirable because of the lack of continuity, the great number of crews required (the extreme case being 1 per floor), the probable lack of equipment and site congestion. The successive method is definitely "technically" possible but would result in an extremely long project duration and tremendous lack of work continuity.

After a successful breakdown of the work into activities is established for each typical segment (e.g. floor), a "rate of production" is defined for each of these activities. The activities are then projected over all the floors at the anticipated rate of production in a linear (simplest) relationship. The basic mathematical relationships are as



Simultaneous Proceeding

Successive Proceeding



Flow Line Proceeding

Fig. 3.13 Types of Work Sequences (Ref. 39) follows:

i = Floor number

j = activity number

$S(i)$ = start date of the i^{th} floor

$F(i)$ = finish date of the i^{th} floor

P = production rate (days/floor)

$$F_j(i) = S_j(i) + P - 1 \qquad (3.1)$$

$$S_j(i+1) = F_j(i) + 1 \qquad (3.2)$$

Note: The finish date is at the end of the day and the start date is at the beginning of the day.

It is clear that this mathematical relationship is very simplistic because all the relationships between the floors are Finish-Start type with no lag and constant production rate for each floor. All the publications mentioned had such a model as the basis of their theory and it will be used herein.

Equation 3.1 however has some unknown on the first level: S(1) is not calculated anywhere in these equations. There are two possibilities: either it is the first activity calculated and S(1) is simply the starting date of the project, or, if the activity has a predecessor, it is the earliest time that it can start.

If the production rates of two activities are the same, the relationship will be:

$$S_j(i) = F_{j-1}(i) + 1 \qquad (3.3)$$

However, if the production rates are different, this relationship might or might not be true depending on the production rate of the predecessor. The two activities should be synchronized so that they will be continuous and executed at their earliest possible time. When the production rates are different there is normally only one floor for which the above relationship will apply, and this floor will be the basis for the calculation of all the other floors. This is commonly called the "bottleneck point" (ref. 39). If a slower rate follows a fast one, it will start as soon as it can and some lag will accumulate as it goes on (fig. 3.14) and if a fast one follows a slow one, it will wait and start at the appropriate time so that the bottleneck is on the last floor (fig. 3.15). It is similar to the two trains on the same track analogy mentioned earlier in this chapter.

O'Brien identified these situations in his paper on VPM (ref. 35) when he discusses planning alternatives: the assumption of work continuity requirements might end up creating a longer project duration if a slow rate of production follows a fast one. On fig. 3.16, we can see that for the upper floors, there is room to work but nobody is there yet because of the slow pace of the activity j+1. Also, we can see that activity j+1 is on stand by for several days before starting because of the bottleneck at the top between activities j-1 and j. If the fast pace of activity j (fig. 3.17) was decreased a bit, the project would be shortened by several days. So the alternatives suggested by O'Brien are either to adjust the rates so that they are as similar as possible, or to keep different production rates and schedule the activities according to the bottlenecks. In fact, Barrie and Paulson (ref. 7) identified the

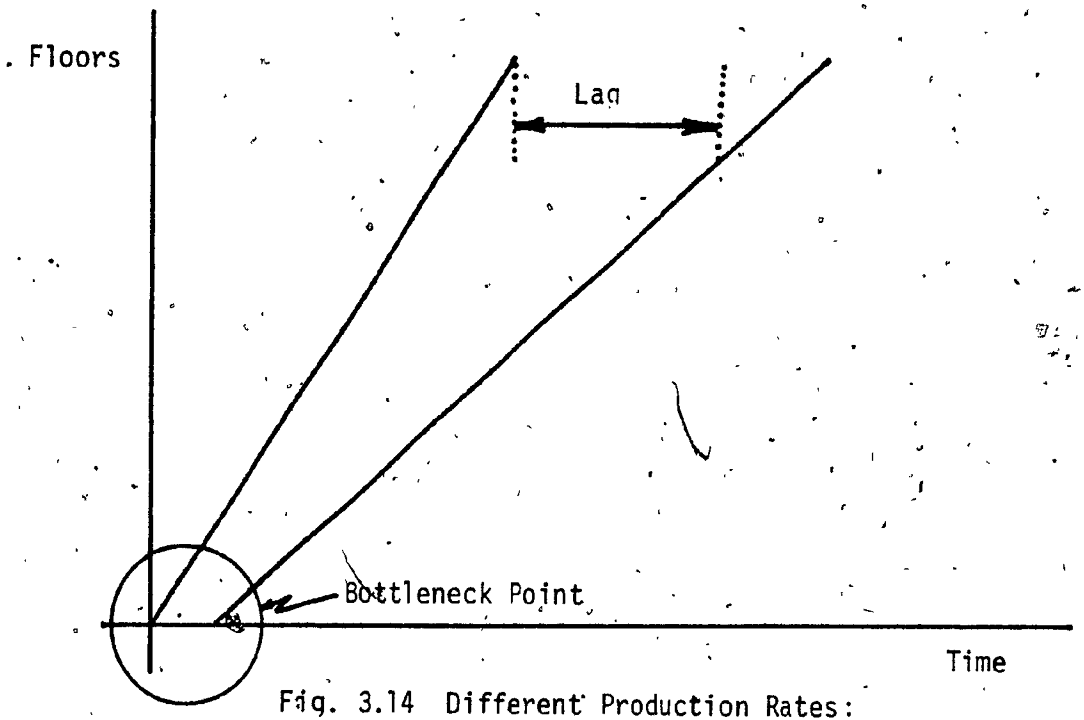


Fig. 3.14 Different Production Rates: Bottleneck at the Bottom.

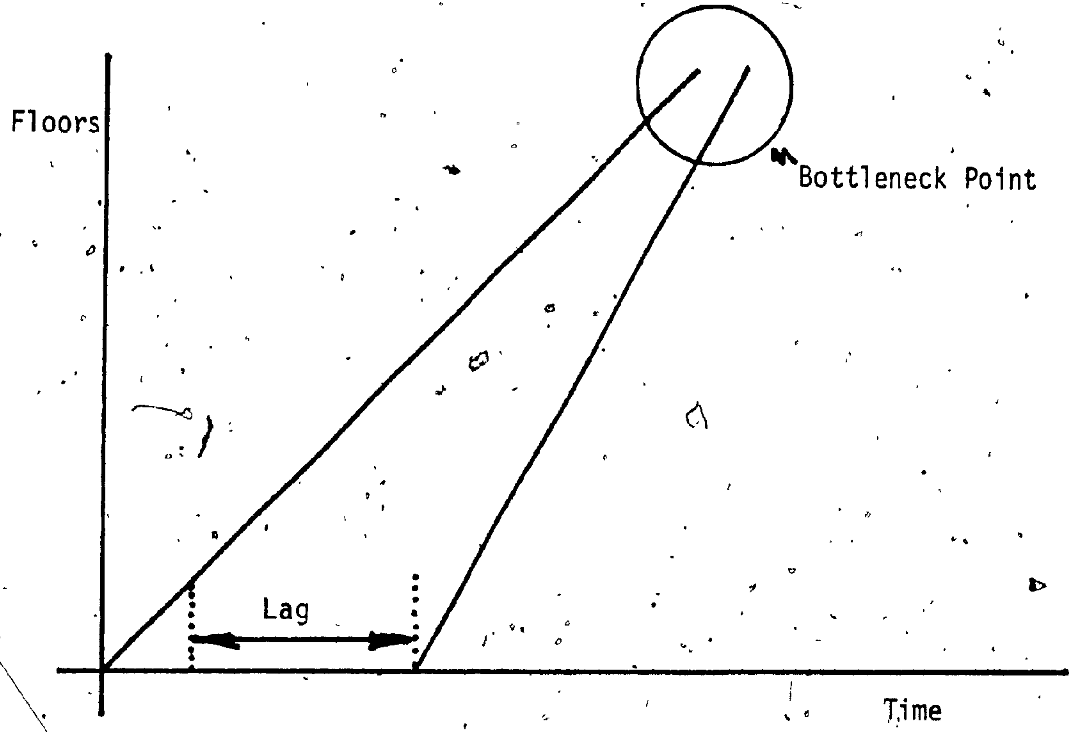


Fig. 3.15 Different Production Rates: Bottleneck at the Top

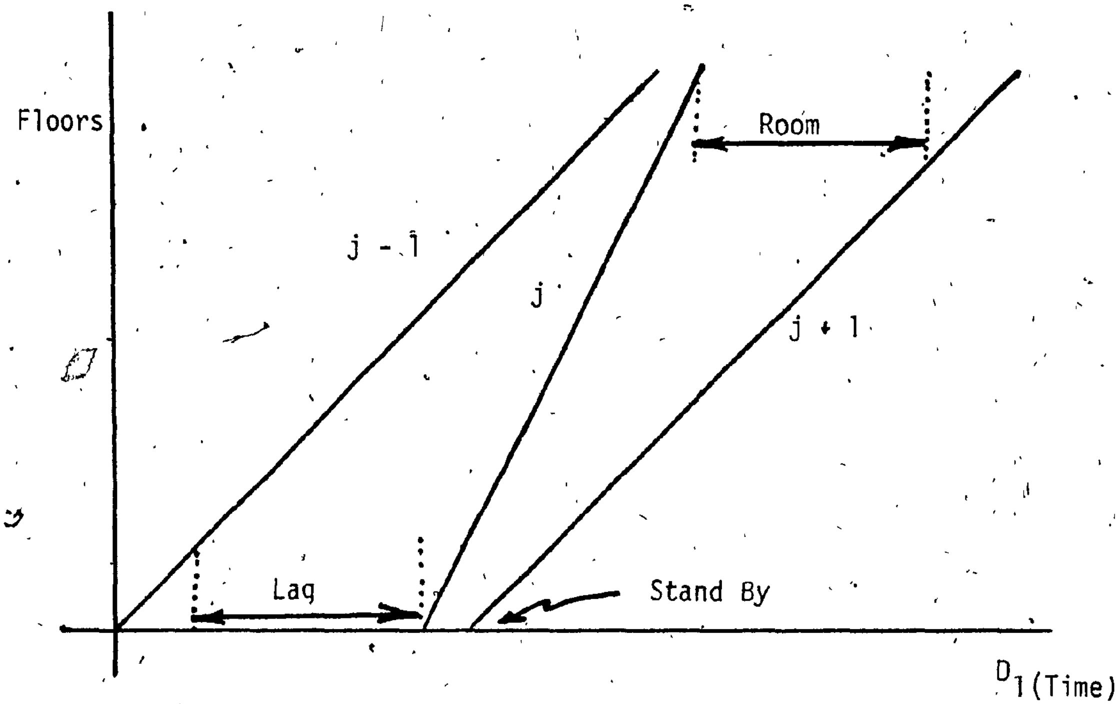


Fig. 3.16 Sequential Activities with Different Production Rates

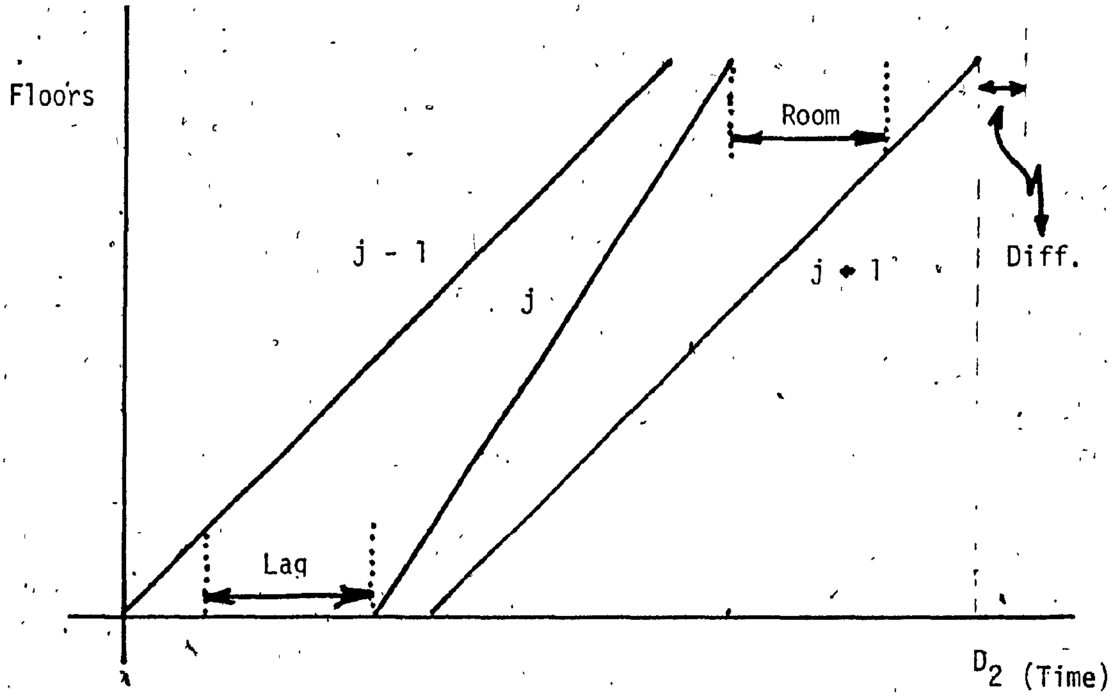


Fig. 3.17 Same as fig. 3.16, but with a shorter "Project" duration ($D_2 < D_1$).

principle that "slopes (or production rates) should be equal or decreasing as one moves along". This statement is appropriate in order to have bottlenecks on the first unit (or floor) only; however, with the idea of keeping the project's duration as short as possible, the statement should be read as follows: production rates should be equal or increasing as one moves along.

Shlomo Sellinger (ref. 57) developed algorithms to find the optimal production rate of several activities and his model allowed for non-linear relationships. In fact, each activity of each segment had its own man-hour requirements, which, when divided by different number of men would yield different duration for the segment. His model has some good features which are explained further along but one of its basic limitations is the assumption that production increases linearly with crew size. This is not necessarily true and has already been treated earlier in this chapter (section 3.2.1). However, some of the algorithms are of interest to this work.

His model applies for several activities that have to be executed in a sequence, one after the other. The first activity of the sequence is first calculated by simply using the start date as the start of the first level and by applying the same kind of mathematical relationships as in equations 3.1 and 3.2. However, in this case, the production rate, P, will not be the same for each level, because of different man-hour requirements and equation 3.3. should be as follows:

$$F_j(i) = S_j(i) + P(i) - 1 \qquad (3.4)$$

Then, the next activity is calculated by assigning an arbitrary number for the start of the first level and by again using equation 3.4. Now to find the real start date of that production line, the precedence relationship with the first activity should be studied level by level to find the one or more levels where bottlenecks will be present. Therefore, the difference between the starting date of the second activity and the finish date of the first activity are calculated for each level, and the smallest difference will be the amount by which the arbitrarily calculated dates will be subtracted to become the real scheduled start and finish dates for that activity (equations 3.5 through 3.7).

n = number of floors

$$\Delta = \min [S_j(1) - F_{j-1}(1), S_j(2) - F_{j-1}(2), \ldots S_j(n) - F_{j-1}(n)] \qquad (3.5)$$

$$S_j(i) = S_j(i) - \Delta \qquad (3.6)$$

$$F_j(i) = F_j(i) - \Delta \qquad (3.7)$$

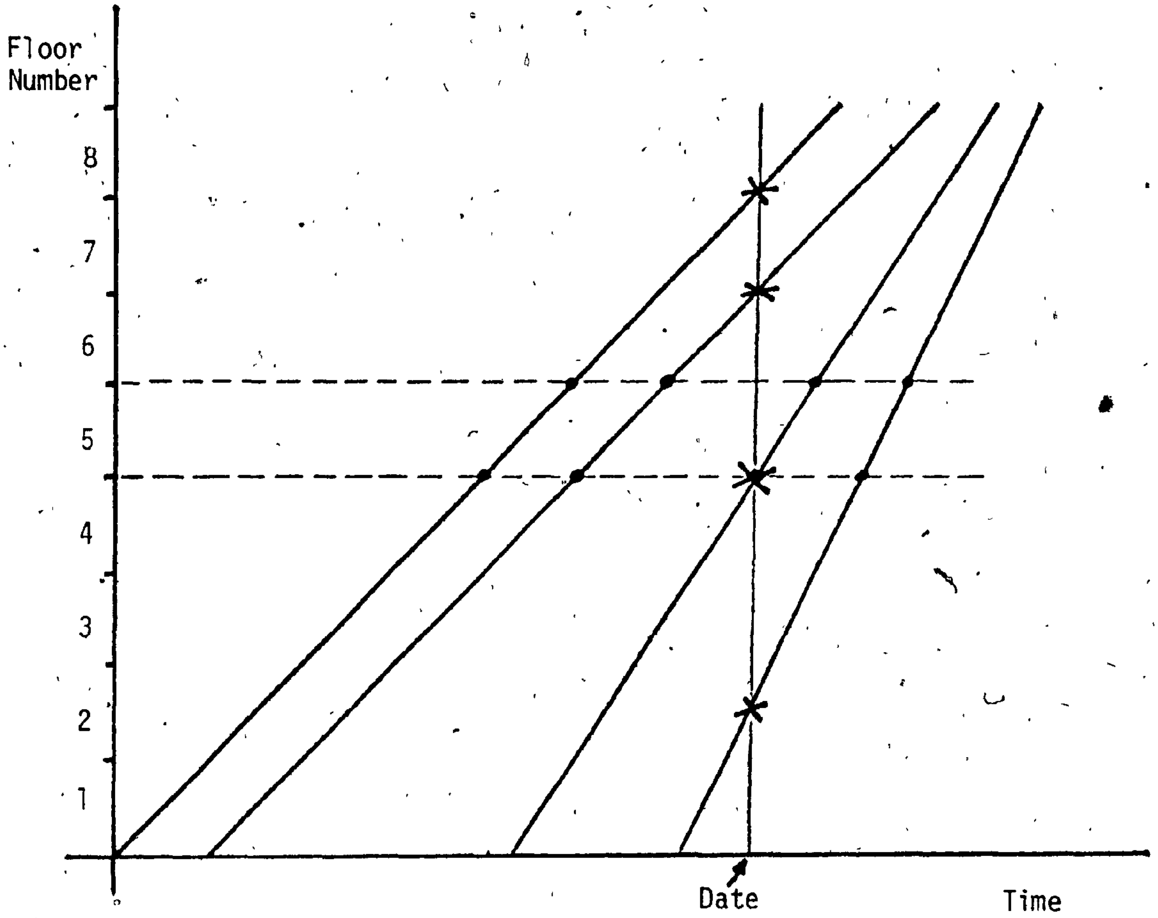
But the main characteristic of his algorithm lies in the fact that there might be various alternatives for the production rate of a given floor for a given activity and that, by comparing all the possible combinations, one optimal solution, that would yield the shortest project duration, can be found. A detailed explanation of the algorithm can be found in refs. 44 and 57.

The linear planning chart has advantages and disadvantages; it is directly aimed at showing the relation between "units" which are produced one after the other and time. It shows very clearly the order of execution of the activities, their production rate and the bottleneck points. Therefore, simply by looking at it, one can see if some activities are slower than others and can suggest alternatives that could better synchronize the work between activities and between subcontractors.

Without having to scan through numerous pages of numbers and dates, one can quickly find the schedule information for a given activity on a given floor because of the simplicity of presentation. In the same manner, one can easily develop a schedule for one given floor by scanning horizontally and picking out the start and finish dates for a floor, or see what the status is of each floor, at a given date by drawing a vertical line and looking where each of the trades is (Fig. 3.18).

Its main advantage, which is also its main characteristic is the fact that it promotes continuity of work for the various trades and therefore the possibility of increased efficiency because of learning effects and repetition. Although most models base their algorithms on the fact that the floors cannot overlap, some more general models have been suggested by Popescu (ref. 48) and Stradal and Cacha (ref. 39) to allow for several crews working in parallel or for one activity having several processes performed by different specialists which, sequentially, move from level to level.

However, the linear planning chart model has some limitations. All the writers on the technique used the model to show a sequence of activities done in series, one after the other. But the linear chart cannot



× Status of Activity as at "Date"

● Start and Finish Times of each Activity for the 5th floor.

Fig. 3.18 Ways of Finding Information on a Linear Planning Chart.

show in two dimensions activities in parallel. Moreover, each activity, as described in the models, could not have more than one predecessor. From the description of the previous chapter, six areas were identified on each floor and they were executed in parallel. Also, several activities, like the installation of the ceiling grid, have more than one predecessor which would complicate the application of the linear planning chart.

O'Brien (ref. 35) developed a network for a typical floor (Fig. 3.19) which formed the basis for "vertical production lines". However, on the final chart, only seven activities out of 24 activities on the network were shown on the chart (Fig. 3.20). The chart was used to show the coordination between the "critical" trades and did not show the trades that were working at the same pace as the one shown on the chart, nor the ones which were "non critical". It was suggested that the chart be used for planning the coordination of the work and not for generating a schedule for each activity of the network.

The same author also suggested that the possibility should exist of having other kinds of dependences than just the preceding repetitive activity. For example, one activity, the masonry enclosure, required that the structure for the eleventh floor be completed before it could start on the first floor which requires a greater lag than the finish to start relationship only. It is possible to show such relationships graphically and this was done in some publications (ref. 21, 35) (Fig. 3.21). However, no general mathematical relationships were derived and

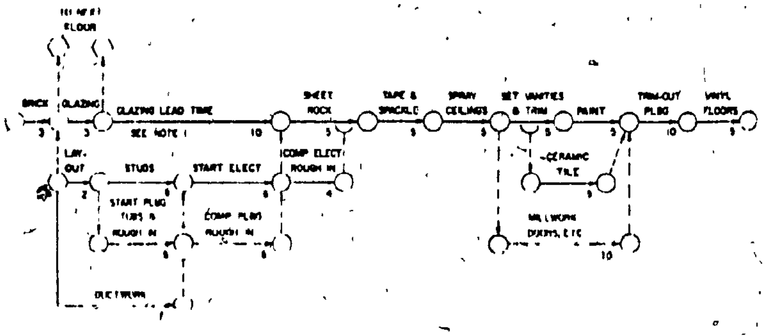


Fig. 3.19 Network for a Typical Floor (ref. 35)

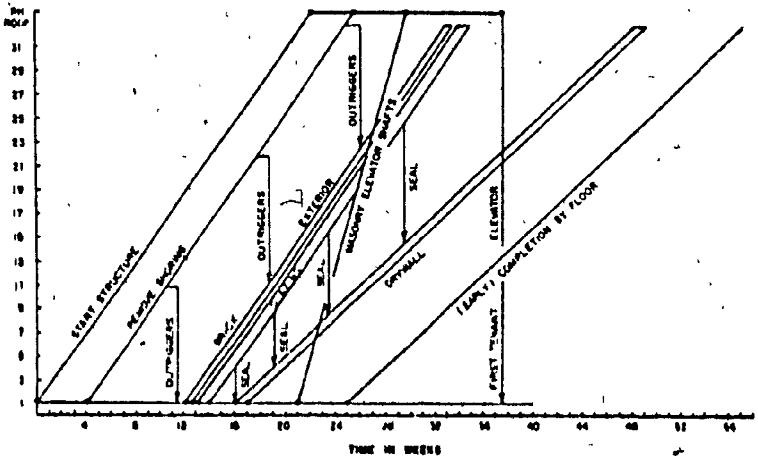
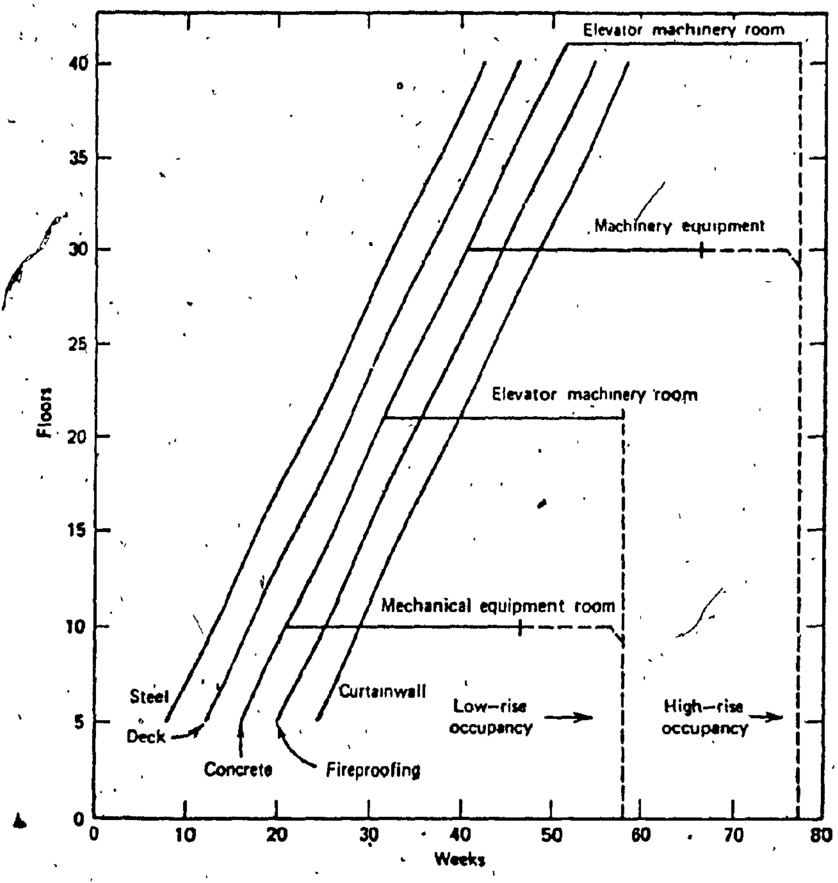
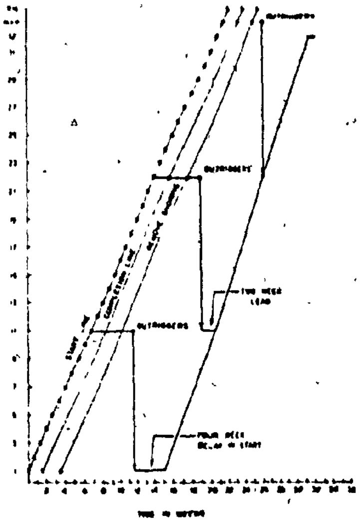


Fig. 3.20 Linear Chart for Seven Activities of the Network (ref. 35).



(a) From ref. 21



(b) From ref. 35

Fig. 3.21 Charts with Other kinds of Dependences included in the models proposed.

As for the aggregation of several activities, the linear chart would lose its usefulness. The linear chart is designed to show the relationships between several sequential activities. If several activities were to be grouped under one activity, some overlapping would be required between the floors. We have mentioned previously that overlapping can be shown on the linear chart. However, if too much overlapping results from such an aggregation, the concept of "Flow lines" and the good visual presentation that the chart has would disappear. If the activities are not sequential on the chart, this would result in cross-overs with other activities, yielding a very bad presentation. Too much overlapping would also complicate the mathematical relationships; some of the variables of the model would have to be derived in order to be able to come up with the same schedule. Finally, its good presentation could make it attractive to upper levels of management and owners, even if it has enough detail to be used at the site level.

However, the mathematical models derived from these techniques are very limited and do not have provisions for some characteristics of high-rise construction, like non-repetitive activities, or other kinds of precedence relationships than a finish start relationship with the preceding repetitive activity. The model of O'Brien (ref. 35) is probably the most appropriate found in the literature, but it was not explicit enough in dealing with the above-mentioned limitations.

3.4 EXTENSION AND COMBINATION OF TOOLS

So far the most common planning tools used in the construction industry have been described individually along with some of the assumptions upon which they are based. It is of interest to see how some of these theories can be combined together.

It was shown that a standard Critical Path Method model was not suitable for high-rise building construction because of its inability to allow for learning and repetition and the effort required to extend the network to treat all floors. However, the model proved to be good for planning the sequence of non-repetitive activities and the one of repetitive activities for one typical floor.

On the other hand, the linear planning chart proved to be useful at showing a sequence of repetitive activities, taking into account work continuity requirements, and therefore improved productivity through learning curve effects, but was very limited in the structure of the predecessors, because it allowed only for one predecessor per activity, and that activity had to be a repetitive activity.

The problem of having only one predecessor per activity on the linear chart could be overcome by incorporating a network structure to link the repetitive activities one to the other. Therefore, an activity could have one or more predecessors, and to calculate the scheduled start and finish date of an activity, one would have to compare all the floors of all the predecessors and find the one(s) that is (are) governing. Therefore, equation 3.5 could be applied as many times as there are predecessors, and the smallest difference found would be the one used in equations 3.6 and 3.7. Such a model could handle a network of repetitive activities like the one shown on Fig. 3.19.

The problem of non-repetitive activities, however still exists. Because of the nature of non-repetitive activities (no work-continuity nor learning curve effects), they cannot be scheduled by using a linear planning chart but could be, by using a normal CPM structure. So, non-repetitive activities, between themselves, could be presented and scheduled by using a network model.

But from the study of the construction process (Chapter II), it was shown that the repetitive and non-repetitive activities were often dependent one to the other, and that the scheduling model should include precedence relationships between the two types of activities. Two types of interfaces seem therefore possible: (i) a non-repetitive activity could be a predecessor to a specific floor of a repetitive activity, like having the first typical floor of the superstructure being preceded by the completion of the basement structure; (ii) or a specific floor of a repetitive activity could be a predecessor to a non-repetitive activity, like having the start of the work in the main mechanical room being preceded by the completion of the last typical floor of the superstructure, where it is located. Therefore, the predecessor of repetitive and non-repetitive activities could be structured in order to accomodate these kinds of precedence relationships.

A graphical representation of such a combination would require three dimensions: one for time, one for location (unit) and a third one to show the activities in parallel. Just as the representation of a sequence of activities in series requires only one dimension for a CPM network, the representation of activities in parallel would require another dimension.

It was mentioned previously that there are two possible ways of showing a CPM network: the "arrow" diagram and the "precedence" diagram. Because of the increased complexity of the relationships between the activities and their two different characteristics (repetitive and non-repetitive), the arrow diagram would become more complicated, and computerization would be very messy. Whereas by using a precedence diagram, each activity would be identified as repetitive or non-repetitive, have its production rate or its duration, and have its precedessors for all levels or for only specific levels.

From this description, it seems that a combination of the CPM and linear planning chart models might give a very realistic planning model for high-rise building construction. A more detailed description of the model and its algorithms is explained in the next chapter.

CHAPTER IV

DESIGN OF THE SYSTEM

4.1 INTRODUCTION

It was mentioned in the previous chapter that a combination of the linear planning chart and precedence diagram could possibly yield a suitable model to represent high-rise building construction. It is now appropriate to better define the structure of the model, its characteristics and more importantly its algorithms which will form the basis for a computerized planning system.

The description of the characteristics of the system will include the difference between repetitive (or typical) and non-repetitive activities, along with the assumption of continuity for the repetitive activities. The importance of a good user interface and presentation of the results will be explained in the following section. A general outline of how the planning system may be interfaced with the existing subcontractor control system (63) will also be presented.

The next section of this chapter consists of an enumeration of the features of the scheduling system and the corresponding algorithms: precedence relationships; calculation mechanism; learning effects; weather effects; procurement schedule; short cycle schedule; and updating mechanism.

4.2 CHARACTERISTICS

4.2.1 Repetitive Activities and Continuity

At the planning stage, the repetitive activities should be identified and sequenced together as described in the second chapter of this thesis. To be considered repetitive, an activity should be present on more than one floor, but doesn't have to be on all typical floors. Also, the floors on which it is present should be sequential.

For example, an activity like the rails on the low-rise portion of the elevator doesn't appear on all the floors, but it is repetitive because it is present on sequential floors. If there are several mechanical floors in the building they could not be considered repetitive activities because the floors are not sequential. However, such activities could be linked one to the other with precedence relationships, but the system would not recognize them as "repetitive activities", because they are not performed on sequential floors and their execution does not require the "continuity" of the activities present on several or all typical floors.

But the word continuity has to be elaborated upon more because it has a great impact on the model and it is a key assumption of the mathematical relationships that will be explained in the third section of this chapter. Because each repetitive activity will usually be performed by the same crew on all the floors, and this crew will usually only be assigned to that specific work, it is important that it works at a set rhythm or production rate and that it moves to the next floor as soon as the previous one is completed. This will also have some effects on the efficiency of the execution of the work, as stated by Ashley (ref. 6): "Maintaining a continuous flow of work for each of the identifiable crews, especially on repetitive tasks, provides stimulus for the crews to perform well and allows maximum opportunity to experience learning curve effects on production."

Most network models applied to high-rise construction fail to recognize the importance of continuity, which is not part of the CPM algorithm. Although the repetitive activities can be broken down for each of the floors, they are treated discretely, with precedence relationships with different activities on the same floor, or with that same activity but on the floor below. Consequently, there could be float between the completion of one floor and the start of the next one, which has to be avoided for continuity. Sellinger (ref. 57) mentioned such a problem by saying that: "Such a requirement (work-continuity) is ruled out in network and related methods, where relations of 'greater-than-or-equal-to' between times of activities are feasible."

The proposed model will therefore allow for continuity requirements by designing the mathematical relationships in order to eliminate float between the floors of a repetitive activity. Each repetitive activity will be extended to all the floors it concerns, but the relationship will be such that the times computed for each of them will respect the assumption that there is no float between them. In practical terms, a repetitive activity will be input only once, along with the floors it concerns and the time required to do one floor or production rate per floor. Then the model would itself generate the time for each floor.

A repetitive activity on a given floor might be preceded by another repetitive activity on the same floor, by another repetitive activity, but from a different floor, or by any non-repetitive activity. These precedence relationships constitute the basis for determining the exact time at which an activity can be performed. They will be explained in a further section. Of importance now is the identification of the kind of relationships that can exist between floors of a repetitive activity.

In the previous chapters, several equations (3.1 to 3.7) were stated. Their main limitation was that the start of a subsequent floor was ruled by the finish of the previous one, or the continuity requirement, and that any other combination was not possible. However, it might be possible that more than one crew could work in parallel, meaning that two floors are executed at the same time. Moreover, those two crews might proceed on those floors with some lag factor. For example, the floor above might start only 2 days after the floor below is started, for all sorts of reasons. Finally, the relationship between the move to a next floor for a crew might not be "finish to start equal to zero". Keeping these issues in mind, a general model can be formulated in the following way with the variables below and as illustrated in figure 4.1.

n = number of crews

p = production rate (days/floor)

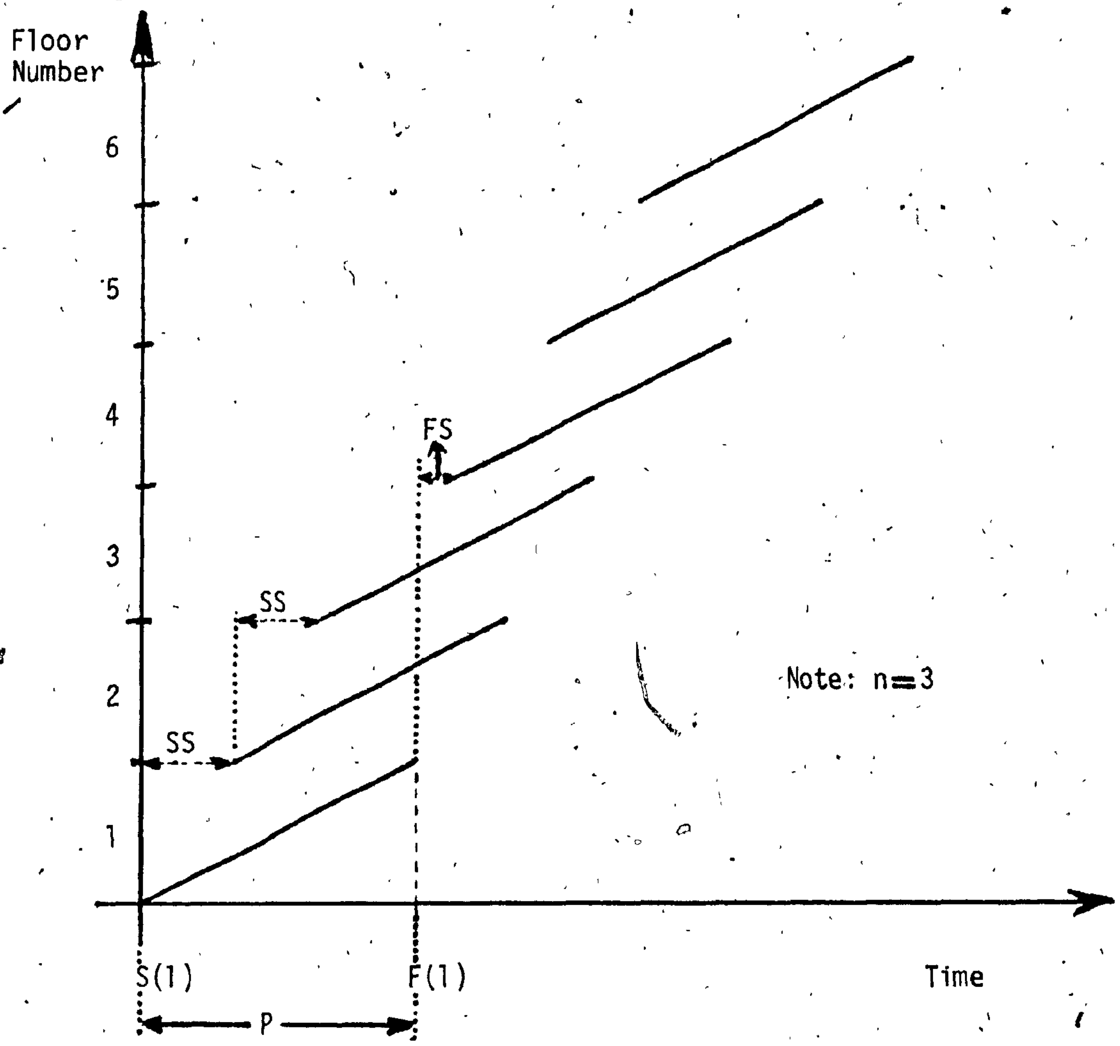


Fig. 4.1 General Variables for a Repetitive Activity

SS = start to start relationship between successive floors of activities having more than one crew

FS = finish to start relationship between the next floor that an individual crew has to move to

$S(i)$ = start of i^{th} floor

$F(i)$ = Finish of i^{th} floor

The relationships would be as follows:

$$F(i) = S(i) + P - 1 \qquad (4.1)$$

$$S(i) = F(i-1) + FS + 1 \text{ (if } n = 1) \qquad (4.2)$$

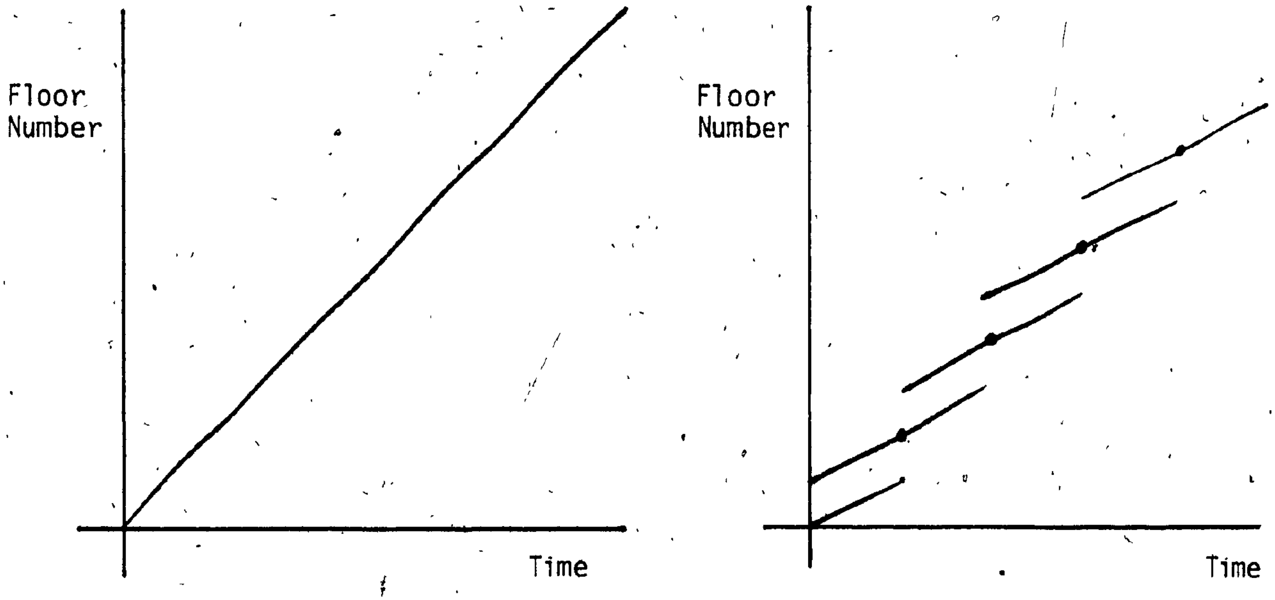
$$S(i) = S(i-1) + SS \qquad \text{(if } n > 1) \qquad (4.3)$$

$$S(i+n) = F(i) + FS + 1 \text{ (when } i = nk+1 \text{ where } k = 0,1,2,3...) \qquad (4.4)$$

These equations only concern one activity at a time and serve only to define the quantitative relationships between the floors of that repetitive activity. Again, a starting value is required in order to generate the values for all floors. This will be explained in the calculation mechanism in the next section of this chapter. It should be mentioned that equation 4.3 is assumed to be used only if "n" is greater than one.

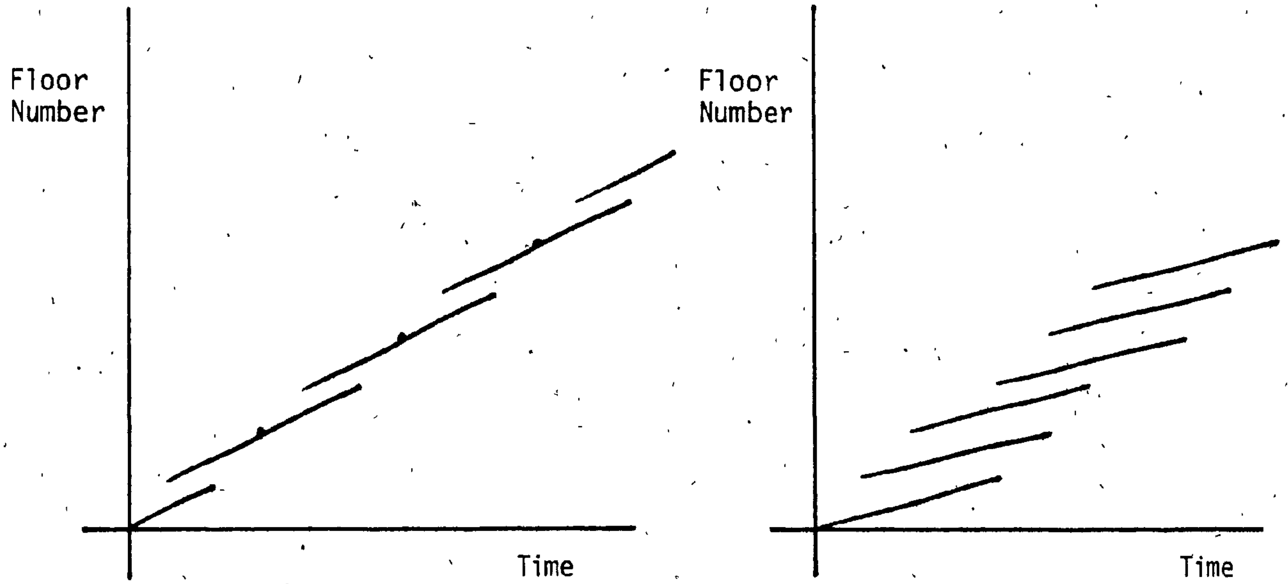
Most models seen in the literature to date had a linear relationship linking floors with time. This corresponds to the situation of $n = 1$, and $FS = 0$ and as depicted in Figure 4.2 (a). Other combinations of these variables (n, SS, FS) are shown in Figs. 4.2 (b)(c)(d).

Therefore, once the repetitive activities are identified, each one has to be described as to the levels on which it is performed, its



(a) n=1, FS=0.

(b) n=2, FS=0, SS=0.



(c) n=2, FS=1, SS=1.

(d) n=~~3, FS=~~0, SS=1.

Fig. 4.2 Various Combinations of Variables production rate per floor, the number of crews (or number of floors in parallel), the start to start relationship between the parallel floors (if applicable) or the finish to start relationship between the floors performed by the same crew. This information provides the basis for generating the data relative to an activity's timing on each floor. It was mentioned previously that float between floors should be eliminated for continuity. In the foregoing model, a finish to start relationship different than zero would therefore mean a lag between the finish and the start of successive floors. The basic principle of the model is to respect the relationships between the floors. If a lag is needed for any reason, it will be added; but after the scheduling computations are performed, all the start to start and finish to start conditions between the floors will be maintained (i.e. priority is given the relationship between sequential floors) and in that sense it can be said that the work-continuity requirements are respected.

4.2.2 Non-Repetitive Activities

Non-repetitive activities only concern one floor, or one specific area and will be characterised by a duration only, and not by all the variables defined in the previous section.

This is mainly due to the fact that non-repetitive activities are not part of a continuous process as the others are; the process involved will only be done once or twice so the work could not be made more efficient by learning effects or work continuity. However, those activities have to be part of the same scheduling system because their execution might be a prerequisite for the start of a repetitive activity, or the completion of a repetitive activity for a given floor might influence their starting dates.

Most planning and scheduling models for repetitive operations have never incorporated non-repetitive activities. Any high-rise building has non-repetitive activities that influence the execution of the repetitive portion of the work. O'brien (ref. 35) described high-rise construction as "hybrid" because of the clear distinction between operations before the start of the typical levels and the construction of these typical levels. However, he did not generalize his model to include non-repetitive activities in the repetitive portion of the work.

As explained in the next section, the proposed model will allow for the presence of non-repetitive activities that might precede or succeed non-repetitive or repetitive activities at any stage during the job execution. Each activity will be characterized by start and finish dates, and also by a duration. Also included will be milestones. They will be used when a specific activity has to be started by a given date. An example of such a situation is when some trades, like dry wall installation, have to work in warmer periods in order to save heating costs. So although there would not be any technological constraint limiting a start before, say, April 1st, the work would not be scheduled to start until that date. So a milestone date would in fact become a predecessor to the start of any activity. It would be characterized only by that date, and would obviously not have any predecessor, its date being fixed.

In order to avoid the possibility of having negative float, milestones will not be allowed to have predecessors. Therefore, if a section of the building is required to be completed before the completion date of the project, adjustments should be made to the logic, or the durations of the activities to meet a date set by the owner or another party. Improvements to the system should include the possibility of having milestones as "desired" intermediary completion dates, but it will not be part of the present work.

4.2.3 User Interface

In order to be applicable and understood by its potential users, the proposed model should be presented in a way that will facilitate the input of activities and any subsequent changes that might be required. It is important at this stage to identify the kind of functions that should be available to the user in order to link the mathematical relationships to the various activities and to facilitate changes in the data required for each activity.

Depending on the kind of construction that a contractor is performing, the facility should exist to minimize the effort required to input information by using a standard network (ref.22). High-rise commercial or residential buildings are usually designed with similar building systems and thus the sequence of execution of a typical floor will be very similar from building to building unless some highly advanced techniques or elements are used.

But assuming that all projects are identical would be unrealistic, and thus some new activities or a rearrangement of existing ones may have to be contemplated. In order to limit the input data and to eliminate redundant information, each activity needs only the following information: its number, which will include a responsibility code (i.e. general contractor or a given subcontractor), its description, its predecessors and its duration or production rate plus lag factors (SS, FS, etc.) if it is repetitive. It is not necessary to input the successors of any activity because they can be derived from the predecessors. So, inputting new activities would only require the abovementioned variables. It should also be possible to delete an activity by simply "erasing" all the information describing it. Care should be taken when doing such a thing so that adjustments to other activities are made because of the deletion.

Further, the capability should exist to make changes to the data relative to one activity, without having to delete and re-input everything; so there should be a mechanism that enables one to change information such as the activity's description, its variables (duration or production rate, etc.) and its predecessors. For the latter item, it should be possible to delete or to add any predecessor.

So a good user interface is required in order to facilitate the communication between the users of the system and its algorithms.

4.2.4 Presentation of Results

The usefulness of the presentation of the calculations of any system is the key to its success and acceptance by its various users. Poor presentation of the results of network analysis is one reason why construction personnel have been scared off its use.

It was mentioned in the previous chapter that the bar chart is widely accepted in the construction industry at all levels of management. Most scheduling packages based on network methods have a "bar chart option" that prints the results of the calculations in such a format. Thus, it is appropriate that the proposed model use such a technique as one way of presenting results. Example formats were shown in figures 3.5,3.6 and 3.7 and the latter seemed to be very appropriate for showing repetitive activities. Non-repetitive activities could be shown in a standard way, as long as they are not too numerous. Of importance also is the presence of calendar dates as a time reference.

So one possibility of presenting the results would be by the following bar-chart option: it would show the dates horizontally on the top and bottom and the activity names and descriptions written vertically. The non-repetitive activities would be represented by one single bar going from its start and finish dates, as seen in normal bar charts. The repetitive activities would be listed on as many lines as there are crews (which means the simultaneous execution on several floors) and the floor number would be written on the top of the bar, at the starting date of the floor. The float of the non-critical activities could be shown by another means on the portion between the early finish date and the late finish date of an activity. A fenced bar chart would be an interesting alternative to study but its design goes go beyond the scope of the present thesis. An example of the proposed format is shown on fig. 4.3.

Although it would not be used as a schedule document, the various dates for each non-repetitive activity and for each floor of each repetitive activity should be available in tabular form. Therefore, another format possibility would be to present the early start and finish dates and the late start and finish dates and the float, along with the activity name and number. Such a format is useful for office work or as a document to back up other kinds of presentation. See Figure 4.4 for an example format.

The linear planning chart as a presentation format should be included because of its ability to show the continuous flow of trades and "collision points" as defined in the previous section. As mentioned in the previous chapter, linear charts cannot show activities in parallel. So one way of using this graphical model would be to show only the sequential activities that are part of a specific work category of the building. Referring to chapter two, six work categories (elevator, mechanical room, toilet, enclosure, ceiling and electrical room) had been defined for a typical high-rise building. Each category is comprised of a set of specific repetitive activities. It is the relationship between those activities that have to be modelled. For

```
                        I83  83   83   83   83   83   83   83  83   83   83   83  83  83   83   83   83   83   83   83   83
                        IAPR APR  APR  APR  MAY  MAY  MAY  MAY MAY  JUN  JUN  JUN JUN JUL  JUL  AUG  AUG  AUG  AUG  AUG  SEP
NO.    DESCRIPTION      I5   11   18   25   2    9    16   24  30   6    13   20  27  4    11   1    8    15   22   29   6
-------------------------------------------------------------------------------------------------------------------------------
                        I
 18100 MILEST. NO.1     IM
                        I.   .    .    .    .    .    .    .   .    .    .    .   .   .    .    .    .    .    .    .    .
                        I1
 12201 NON-REP. NO.2    ISCCCF
                        I.   .    .    .    .    .    .    .   .    .    .    .   .   .    .    .    .    .    .    .    .
                        I1                                                             **************************************************
 12101 NON-REP. NO.1    ISCCCCCCCCF                                                    *                                                *
                        I.   .    .    .    .    .    .    .   .    .    .    .   .    * LEGEND:                                        *
                        I          1           4                                       *                                                *
 10100 REPET. NO.1      I          SCCCCCCCCCCFS********F                              *        *  CRITICAL ACTIVITY                    *
                        I               2         5                                    *        X  NON-CRITICAL ACTIVITY                *
 10100 REPET. NO.1      I               S********FS********F                           *        M  MILESTONE DATE                       *
                        I                  3         6                                 *        -  TOTAL FLOAT                          *
 10100 REPET. NO.1      I                  S********FS********F                        *        C  COMPLETED ACTIVITY                   *
                        I.   .    .    .    .    .    .    .   .    .    .    .   .    *        S  START DATE OF AN ACTIVITY            *
                        I                         1         3         5                *        F  FINISH DATE OF AN ACTIVITY           *
 10400 REPET. NO 4      I                         S********FS********FS********F       *                                                *
                        I                         2         4         6                **************************************************
 10400 REPET. NO 4      I                         S********FS********FS********F
                        I.   .    .    .    .    .    .    .   .    .    .    .   .   .    .    .    .    .    .    .    .
                        I                      1    2    3    4    5    6
 10300 REPET. NO.3      I                      SXXXFSXXXFSXXXFSXXXFSXXXFSXXXF--
                        I.   .    .    .    .    .    .    .   .    .    .    .   .   .    .    .    .    .    .    .    .
                        I                      1    2    3    4    5    6
 10200 REPET. NO.2      I                      SXXXFSXXXFSXXXFSXXXFSXXXFSXXXF--
                        I.   .    .    .    .    .    .    .   .    .    .    .   .   .    .    .    .    .    .    .    .
                        I                           1    2    3    4    5    6
 10500 REPET. NO.5      I                           SXXXFSXXXFSXXXFSXXXFSXXXFSXXXF--
                        I.   .    .    .    .    .    .    .   .    .    .    .   .   .    .    .    .    .    .    .    .
                        I                                       1   2   3   4   5   6
 10600 REPET. NO.6      I                                       S**FS**FS**FS**FS**FS**F
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                        I                                                               6
 12406 NON-REP. NO.4    I                                                               S*****F
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 12300 NON-REP. NO.3    I                                                               SXXXF--
                        I.   .    .    .    .    .    .    .   .    .    .    .   .   .    .    .    .    .    .    .    .
                        I                                                                       6
 12506 LAST ACT.        I                                                                       S**F
                        I.   .    .    .    .    .    .    .   .    .    .    .   .   .    .    .    .    .    .    .    .
                        ------------------------------------------------------------------------------------------------------
                         5   11   18   25   2    9    16   24  30   6    13   20  27  4    11   1    8    15   22   29   6
                         APR APR  APR  APR  MAY  MAY  MAY  MAY MAY  JUN  JUN  JUN JUN JUL  JUL  AUG  AUG  AUG  AUG  AUG  SEP
                         83  83   83   83   83   83   83   83  83   83   83   83  83  83   83   83   83   83   83   83   83
```

Fig. 4.3 Bar-Chart Format

			EARLY		LATE		ACTUAL			DURATION	
NO.	DESCRIPTION	FLOOR	START	FINISH	START	FINISH	START	FINISH	FLOAT	SCHED.	ACT.
10100	REPET. NO.1	1	19APR83	2 MAY83	19APR83	2 MAY83	19APR83	4 MAY83	0	10	12
10100	REPET. NO.1	2	26APR83	9 MAY83	26APR83	9 MAY83			0	10	0
10100	REPET. NO.1	3	29APR83	12MAY83	29APR83	12MAY83			0	10	0
10100	REPET. NO.1	4	5 MAY83	18MAY83	5 MAY83	18MAY83			0	10	0
10100	REPET. NO.1	5	10MAY83	24MAY83	10MAY83	24MAY83			0	10	0
10100	REPET. NO.1	6	13MAY83	27MAY83	13MAY83	27MAY83			0	10	0
10200	REPET. NO.2	1	5 MAY83	11MAY83	9 MAY83	13MAY83			2	5	0
10200	REPET. NO.2	2	12MAY83	18MAY83	16MAY83	20MAY83			2	5	0
10200	REPET. NO.2	3	19MAY83	26MAY83	24MAY83	30MAY83			2	5	0
10200	REPET. NO.2	4	27MAY83	2 JUN83	31MAY83	6 JUN83			2	5	0
10200	REPET. NO.2	5	3 JUN83	9 JUN83	7 JUN83	13JUN83			2	5	0
10200	REPET. NO.2	6	10JUN83	16JUN83	14JUN83	20JUN83			2	5	0
10300	REPET. NO.3	1	5 MAY83	11MAY83	9 MAY83	13MAY83			2	5	0
10300	REPET. NO.3	2	12MAY83	18MAY83	16MAY83	20MAY83			2	5	0
10300	REPET. NO.3	3	19MAY83	26MAY83	24MAY83	30MAY83			2	5	0
10300	REPET. NO.3	4	27MAY83	2 JUN83	31MAY83	6 JUN83			2	5	0
10300	REPET. NO.3	5	3 JUN83	9 JUN83	7 JUN83	13JUN83			2	5	0
10300	REPET. NO.3	6	10JUN83	16JUN83	14JUN83	20JUN83			2	5	0
10400	REPET. NO 4	1	10MAY83	24MAY83	10MAY83	24MAY83			0	10	0
10400	REPET. NO 4	2	10MAY83	24MAY83	10MAY83	24MAY83			0	10	0
10400	REPET. NO 4	3	25MAY83	7 JUN83	25MAY83	7 JUN83			0	10	0
10400	REPET. NO 4	4	25MAY83	7 JUN83	25MAY83	7 JUN83			0	10	0
10400	REPET. NO 4	5	8 JUN83	21JUN83	8 JUN83	21JUN83			0	10	0
10400	REPET. NO 4	6	8 JUN83	21JUN83	8 JUN83	21JUN83			0	10	0
10500	REPET. NO.5	1	12MAY83	18MAY83	16MAY83	20MAY83			2	5	0
10500	REPET. NO.5	2	19MAY83	26MAY83	24MAY83	30MAY83			2	5	0
10500	REPET. NO.5	3	27MAY83	2 JUN83	31MAY83	6 JUN83			2	5	0
10500	REPET. NO.5	4	3 JUN83	9 JUN83	7 JUN83	13JUN83			2	5	0
10500	REPET. NO.5	5	10JUN83	16JUN83	14JUN83	20JUN83			2	5	0

Fig. 4.4 List of Dates Format

example, the installation of the gyproc board on the exterior wall (enclosure) will never enter in conflict with the installation of the toilet fixtures. So, for sequencing and coordination purposes, only interdependent activities part of the same working category should appear on the same chart.

As in the bar chart presentation, the horizontal axis represents the time frame and is indicated with dates, again to refer to a standard time frame. The vertical axis represents the floors; in order to stress the appearance of levels, lines should separate each floor which corresponds to the space between two horizontal lines. Then each activity, with some identification code to differentiate them, is drawn on the chart, with the slope corresponding to the production rate. In order to show better the "flow through" the floors, the intersection of the flow line with the lower line of a floor corresponds to the start date and the finish date corresponds to the intersection with the upper line; repetitive activities having more than one crew, or with a lag would then appear clearly.

Non-repetitive activities are also shown on the chart at their corresponding level (if applicable). The activity is shown horizontally to highlight its non-repetitive nature. Thus, it is presented in a way very similar to the standard bar chart, but is not shaded in between the start and finish dates, in case one or more repetitive activities "pass through."

Criticality can be shown by a simple sign, like an asterisk.

Showing floats for non-critical activities can turn out to be very messy. One way of solving the problem is to simply compare the linear chart with a bar chart presentation of those activities, on which the float can be readily seen. Showing an early and late "line" for each repetitive activity would create some overlapping of lines, and while adding information, the chart would loose much of its clarity and readability. So float is not shown on the chart. An example of the proposed format is shown on figure 4.5.

4.2.5 Interface with Subcontractor Control System

As mentioned previously, the proposed scheduling system will eventually form part of a Project Management Information System (PMIS) now under development at the Centre for Building Studies of Concordia University. Part of this PMIS consists of a subcontractor control system (SUCS) which is aimed at better monitoring the operations of subcontractors in terms of costs, progress payments and the schedule of their activities. The planning and scheduling system developed by the author will be part of SUCS and its function will be to generate the schedule of the activities and also to update it as the project evolves. A complete description of SUCS may be found in references 54,55,62,63.

It is important, however, to evaluate where the scheduling system comes into play in SUCS, and what kind of interfaces are required. The first interface deals with the activity breakdown. Ideally, a standard work breakdown of all possible activities should be done, and any build-

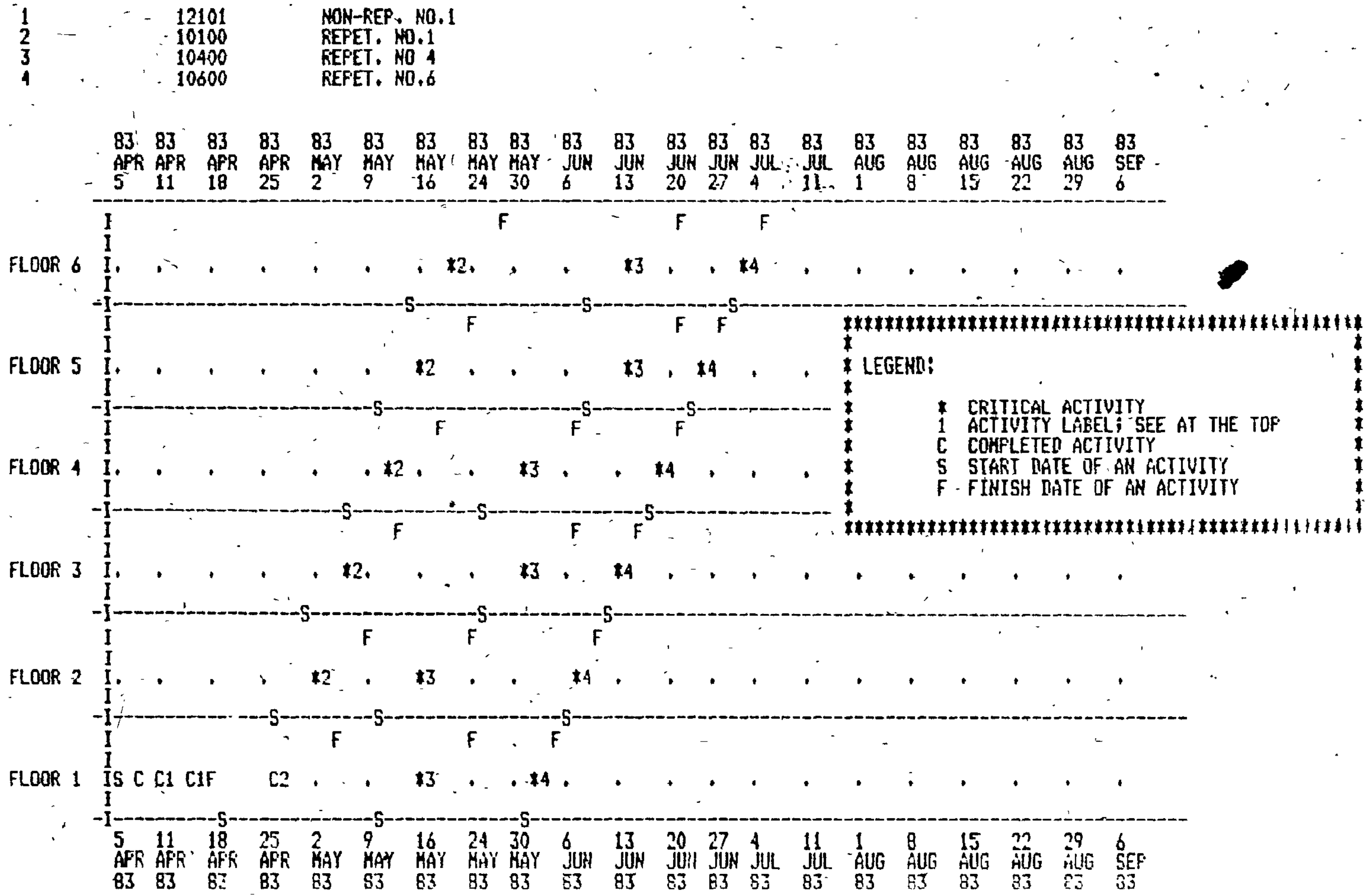

Fig. 4.5 Linear Chart Format

ing project could be broken down into activities by choosing from this exhaustive list. This breakdown should be suitable both for cost and time control purposes in order to avoid differing breakdowns for each which would eliminate the possibility of an integrated time, cost and physical progress control system. Observation of current industry practices shows that different breakdowns are used for time and cost purposes, and this leads to some problems in control. This problem is presently being studied by the research team and some conclusions should be published before the end of 1983.

Other interface points occur when it is time to produce two of the SUCS reports. The first is the subcontractor schedule and progress chart (see fig. 4.6). This matrix format enables one to quickly find the information for each activity on a given floor. The information found in each "cell" is the scheduled start and finish dates, the actual start and finish dates and the percent complete of that activity at the time of the report. The "scheduled dates" come directly from the scheduling system data base and corresponds to the early start and finish date in order to show the subcontractors at which date they can be on site, even if the activity is not critical. The actual start and finish dates are used in the updating process. So the scheduling system's database should be structured in the same way as the SUCS database in order to render possible an exchange of information.

The matrix schedule is thus another way of presenting results and focuses directly on the work of a particular subcontractor. Although

PMIS CONTRACTORS

SUBCONTRACTOR SCHEDULE AND PRO RESS CHART
FOR PERIOD ENDIN : ____________

KEY	
SCH STRT -------- ACT STRT	SCH FIN -------- ACT FIN
%COMPLETE	

PROJECT: PLACE CBS
DATE: ____________

SUBCONTRACTOR: RNLWMM CONTRACTIN
SPECIALTY: SPECIALITY 1
CONTRACT NO. 0010

REPETITIVE ACTIVITIES

LEVEL	ACT.1		ACT.2		ACT.3		ACT.4		ACT.5		REMARKS
16	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	
15	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	
14	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	
13	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	
12	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	
11	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	
10	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	
9	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	
8	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	
7	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	
************											
6	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	
5	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	
4	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	
3	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	
2	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	
************											
L	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	
************											
B1	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	
B2	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	--------	--------	-------- S%	-------- I%	

1 of

EQUIPMENT & NON-REPETITIVE ACTIVITIES

ITEM	ENR.1	ENR.2	ENR.3	ENR.4	ENR.5

	S% ☐☐☐	I% ☐☐☐		☐☐☐	S% ☐☐☐	I% ☐☐☐		☐☐☐	S% ☐☐☐	I% ☐☐☐
15	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
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14	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
	S% ☐☐☐	I% ☐☐☐		☐☐☐	S% ☐☐☐	I% ☐☐☐		☐☐☐	S% ☐☐☐	I% ☐☐☐
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12	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
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11	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
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EQUIPMENT & NON-REPETITIVE ACTIVITIES

ITEM		ENR.1		ENR.2		ENR.3		ENR.4		ENR.5	
LOCATION		PH		BAS1		17		BAS1		PH	
QUANTITY											
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%SUPPL'D	%INST'D	S% ☐☐☐	I% ☐☐☐	S% ☐☐☐	I% ☐☐☐	S% ☐☐☐	I% ☐☐☐	S% ☐☐☐	I% ☐☐☐	S% ☐☐☐	I% ☐☐☐

Fig. 4.6 Subcontractor Schedule and Progress Chart (ref. 55)

2 of 2

this format does not show the interfacing between the activities, it provides an immediate comparison of the scheduled and actual status of the activities on any given floor and enables management to monitor the activities in detail and to initiate corrective action, if required.

Another document is the subcontractor milestone chart (Fig. 4.7) which portrays the information of the matrix schedule in a graphical way, in a kind of linear planning chart. The usefulness and suitability of this format has not been tested yet with a construction company. However, the initial concepts of scheduling as first outlined in references 55 and 63 have since evolved to the approach presented in this thesis. One of the main differences lies in how the generation of the linear representation is performed; in the previous publications (ref. 55, 63), the scheduling process was based on the assumption that milestones were first established and then individual dates for each of the floors would be obtained by interpolating between the milestone dates. But, the question of setting milestones became very ambiguous, because in practice they seem to be determined by experience on previous jobs or simply by wishful thinking in order to please the owner. It was shown previously that such an approach can be the cause of the non-acceptance of schedules. Instead, each repetitive activity should be assigned a realistic production rate and each non-repetitive one, a duration, and the schedule should then be calculated using these values. If the resulting schedule is not acceptable, changes in the logic of execution (if possible) and in the duration could be suggested and implemented, yielding a shorter schedule. But it should be remembered that the

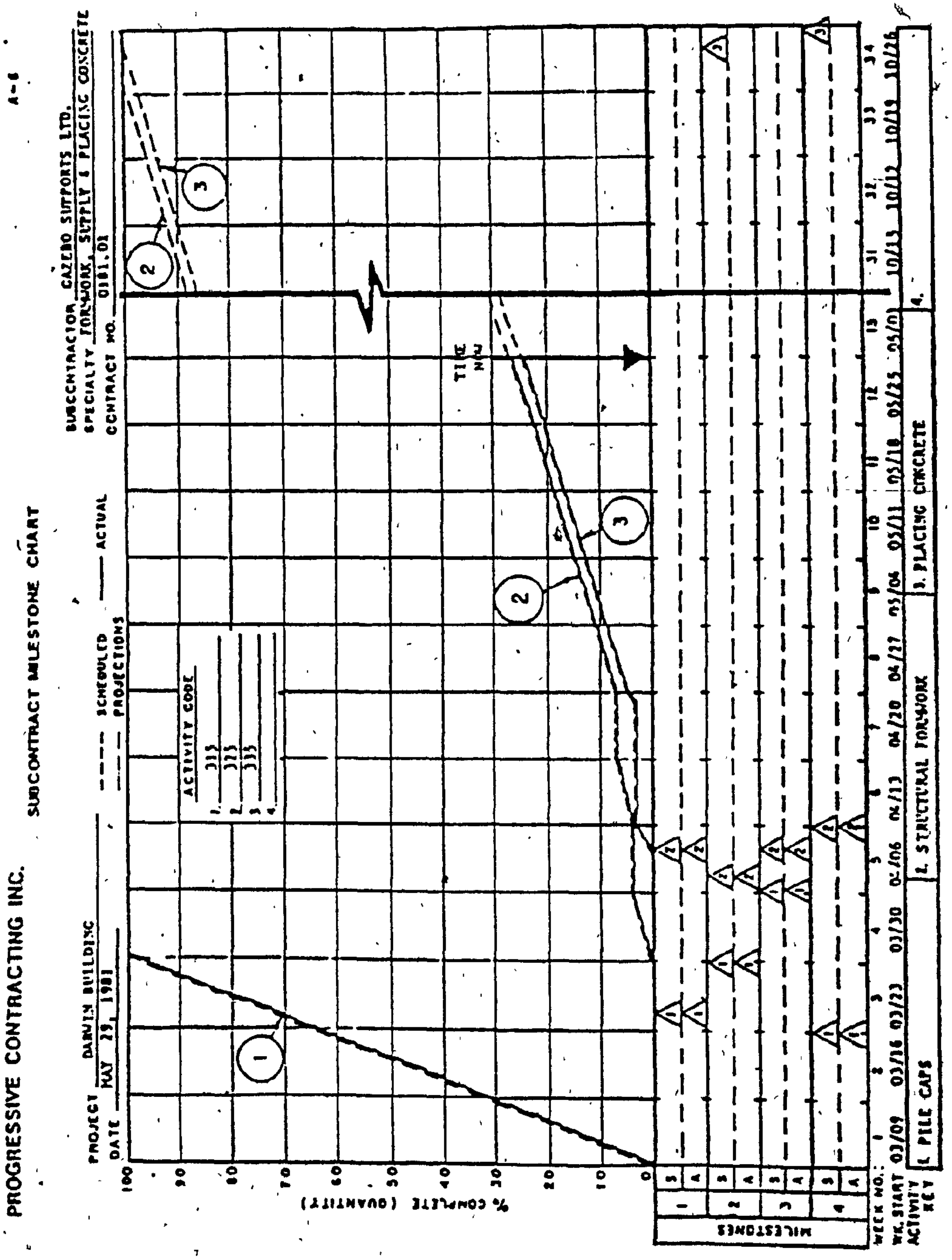


Fig. 4.7 Subcontractor Milestone Chart (ref. 55)

production rates should be determined rationally, instead of being derived by interpolating between already defined milestones.

Actually, the subcontract milestone chart should eventually be replaced by the linear planning chart as previously described by modifying the following characteristics: on the y-axis the percent complete should be replaced by the floor number, in order to see a direct relationship between the activity, the floor on which it should be at and the date at which it is scheduled to be there. This would provide more information about what is expected from the subs and therefore would enhance communication with the General Contractor. Another modification would be the presentation of the non-repetitive activities. On Fig. 4.7, activity 1 is non-repetitive but still appears on the chart as a two-dimensional "line", which cannot be differentiated from the other repetitive activities. Also, there is no indication of the location of that activity, which creates confusion. Such a format was designed probably to put more emphasis on the monitoring aspect, i.e. on progress, rather than on the planning aspect. It appears unnecessary to present a non-repetitive activity in two dimensions which means elimination of the floor number, which is very important information to have. So floor number should replace percent complete on the y-axis, and a non-repetitive activity should be presented horizontally, its y-coordinate corresponding to the floor number where it is executed. Hence the chart would become a better format for presenting the schedule of the subcontractor's activities as mentioned in the section on presentation of the results.

Some functions of the subcontractor control system, dealing with price breakdown, progress assessment and progress claim generation have already been implemented and tested satisfactorily on a major building construction site in Montreal. The actual interface of the scheduling system with SUCS is beyond the scope of the present work. The remaining part of this thesis deals with algorithms of the scheduling system and its computerization as an independent system.

4.3 FEATURES AND ALGORITHMS

4.3.1 Precedence Relationships

The precedence relationships of a standard precedence diagram are very straight forward; each activity can have any number of predecessors, or zero if it is a starting activity or a milestone. These precedence relationships simply indicate the activities whose completion is required in order for the current activity to start.

However, the proposed model has both repetitive and non-repetitive activities, and the type of precedence relationships possible necessitate a different approach than the one explained in the previous paragraph.

It is appropriate to recall here that although a repetitive activity is only entered once into the system for all the floors, it is possible to identify start and finish dates for each floor, and that this information could be treated discretely, as if there were no relationship between the floors. We will see later that the calculation mechanism treats all the floors together in a very strict way, but that once the calculation is done for each floor of a repetitive activity, the dates of a specific floor can be looked upon independently of the other floors.

The precedence relationships are different for repetitive and non-repetitive activities. For repetitive activities, two kinds of predecessors are possible and will be referred to as "typical" and "non-typical" predecessors.

A typical predecessor can be a repetitive activity only and when such a predecessor is specified, ~~it,~~ means that there will be a precedence "link" between all the common floors of the activities joined through precedence relationships. In other words, a typical precedence link between two repetitive activities will mean that for each floor, the predecessor has to be completed before the activity on that specific floor can start; this precedence relationship is of "Finish to Start" type only, with no lag (precedence diagram terminology). However, because of the work continuity requirements, only one of these floors might govern, if the activities have different production rates; therefore the start and finish dates of this floor will influence the scheduled start and finish dates of all the floors of that repetitive activity. So, a floor that doesn't govern will not start as soon as the typical predecessor on the same floor is completed, but will rather start with a "lag" dictated by the floor that governs (see fig. 3.14 and 3.15).

For example, the installation of the ceramic tile in the toilets has to follow the erection of the gyproc walls in the toilet area. So, the ceramic tile, a repetitive activity, will have as a typical predecessor the repetitive activity gyproc walls and this relationship will mean that on all the floors where both activities are present, the gyproc walls will have to be done before the ceramic tile can start. (See Fig. 4.8). So by inputting only two activities and one precedence relationship, we get, say for a 20 storey building, 40 activities and 20 precedence relationships. In the case where the two linked activities are not present on all floors, relationships will only exist for the floors that both are present. For example, a special ceiling performed by a different subcontractor, present only on bottom half of the building cannot be started before the insulation on the ductwork is completed; so the insulation would be a typical predecessor for the special ceiling, meaning that on all floors where the special ceiling and the insulation are present, there will be a precedence link. However, the insulation completion on the upper half of the building will not influence the start of the special ceiling (See Fig. 4.9).

A non-typical predecessor can be a non-repetitive activity, a milestone, or a specific floor of a repetitive activity, and will mean that there is a precedence link between one or more activities and a specific floor of the current activity (each non-typical predecessor "precedes" its own specific floor of the repetitive activity). In other words, the non-typical predecessor has to be completed (or "happened" if a milestone) in order for the specified floor of the repetitive activity to

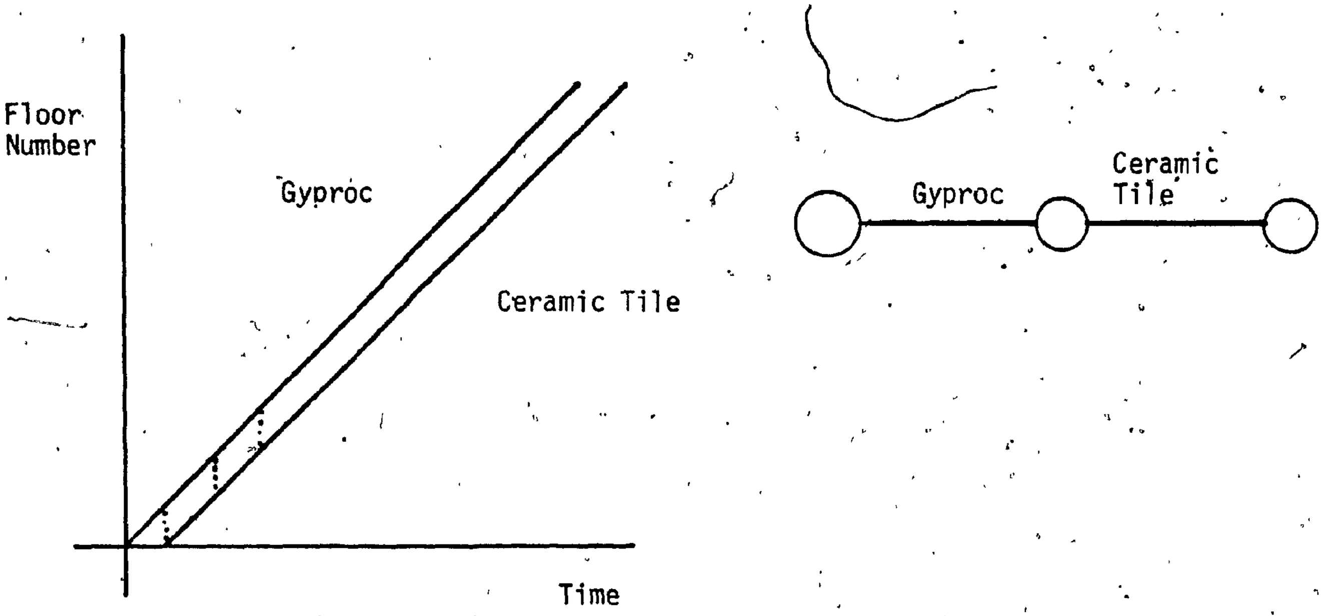


Fig. 4.8 Typical Predecessor

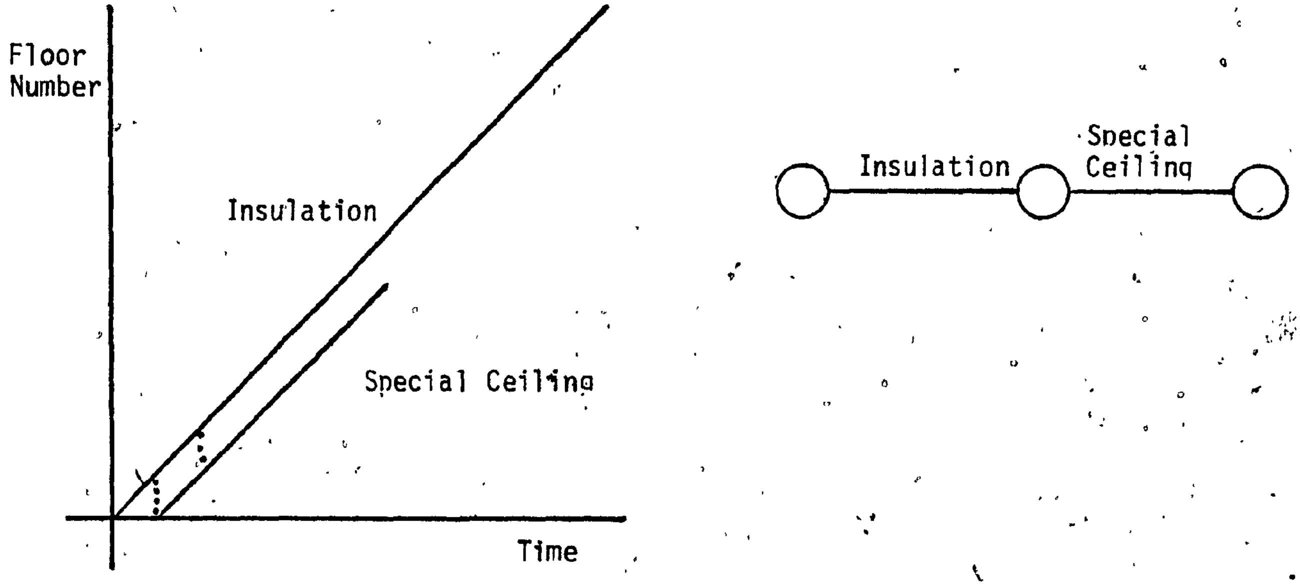


Fig. 4.9 Typical Predecessor (diff. number of floors)

start. Once again, this relationship is of finish to start type with no lag.

For example, the start of the installation of the high-rise elevator's doors and frames is preceded by the installation of motors, cables and platform, a non-repetitive activity. So the first floor of the repetitive activity called "doors and frames" will have as non-typical predecessor the non-repetitive activity "motors, cables, and platform" (see Fig. 4.10). Another example is simply the start of the structure for the typical floor: it is preceded by the completion of the structure for the basement floors, considered a non-repetitive activity. So the structure for the typical floors, a repetitive activity, will not have any "typical" predecessors because it is the first repetitive structural activity of the construction phase. But it will have as "non-typical predecessor" the non-repetitive activity called "Basement structure" and the dependency will be for the first floor only, as shown in fig. 4.11.

When a milestone is a non-typical predecessor, a "date" becomes the constraint for a given floor. For example, the start of the gyproc wall installation might have to wait until April 1st, as mentioned before. So the installation of gyproc walls will have as a non-typical predecessor, for the 1st floor, the date April 1st, as shown in Fig. 4.12.

Finally, a non-typical predecessor can be a repetitive activity on a specific floor. For example, in order to plumb the rails properly, and for safety reasons, elevator rails will not be started until the

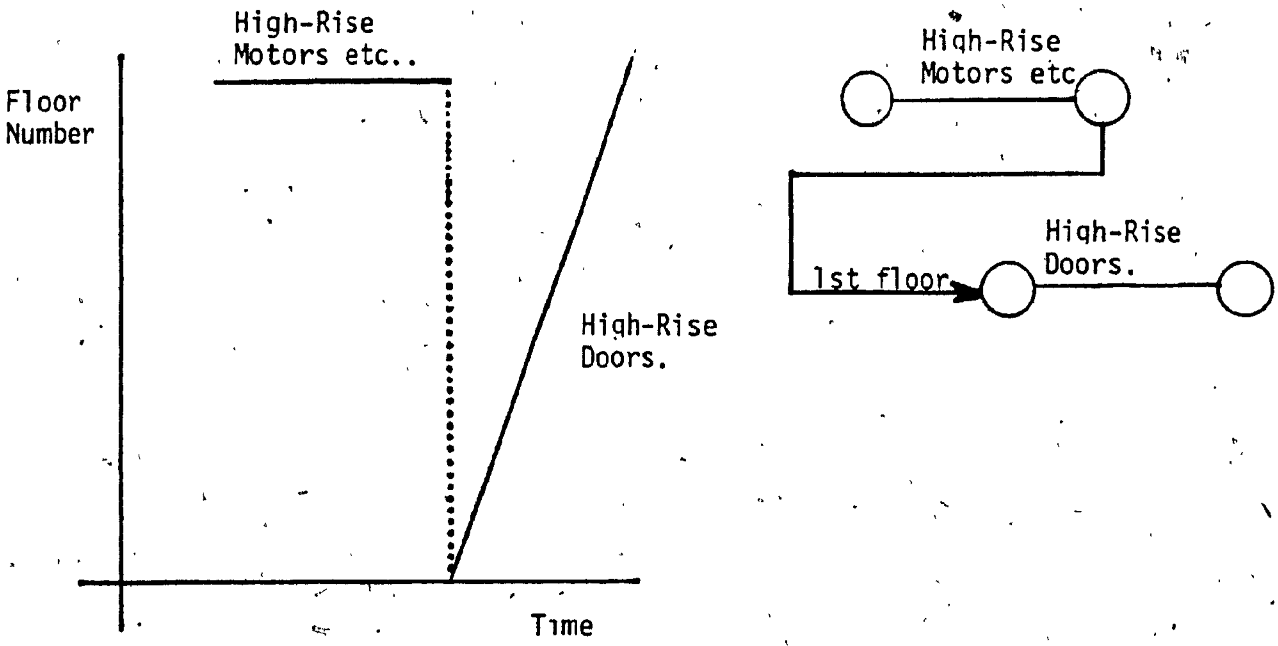


Fig. 4.10 Non-typical Predecessor

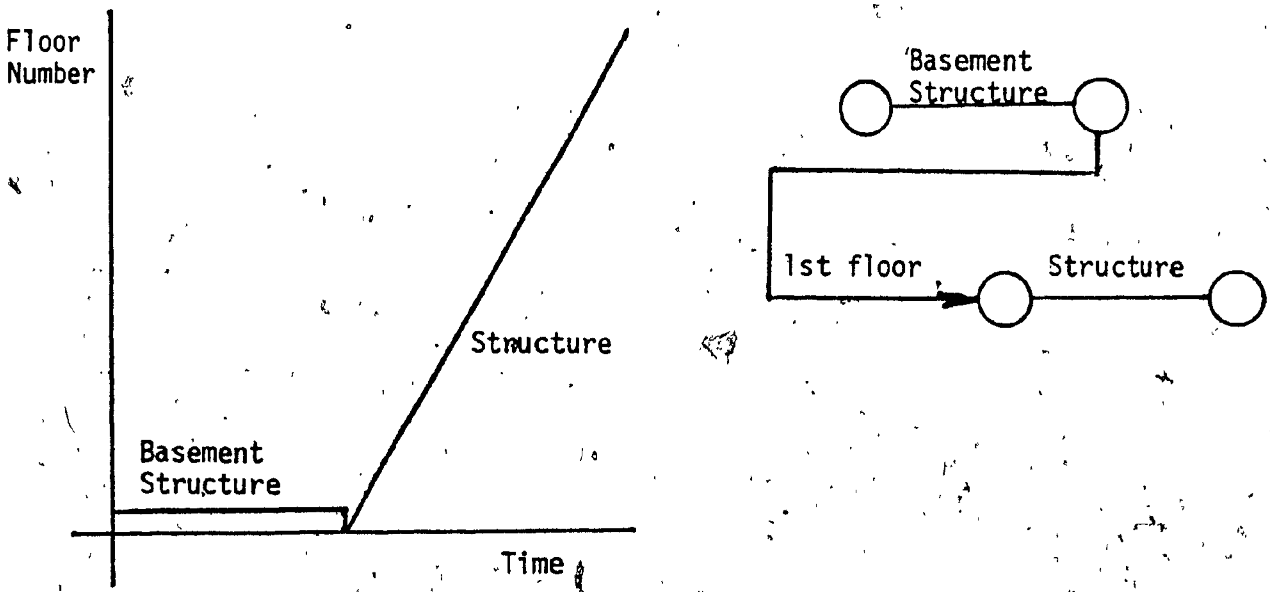


Fig. 4.11 Non-typical Predecessor (diff. case)

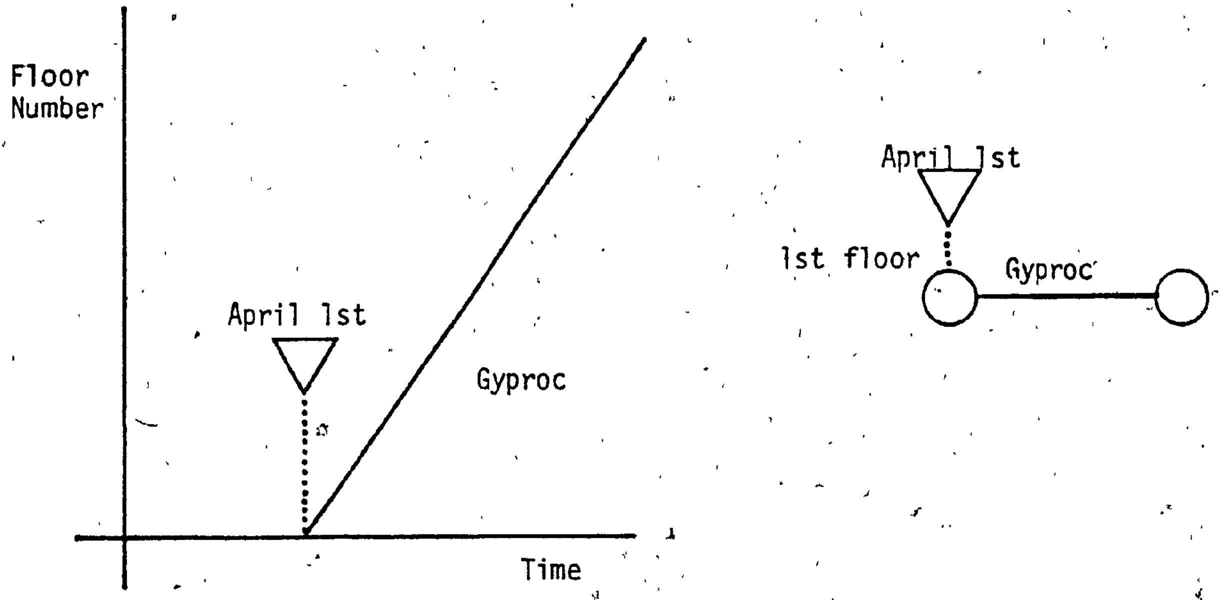


Fig. 4.12 A Milestone as a Non-typical Predecessor

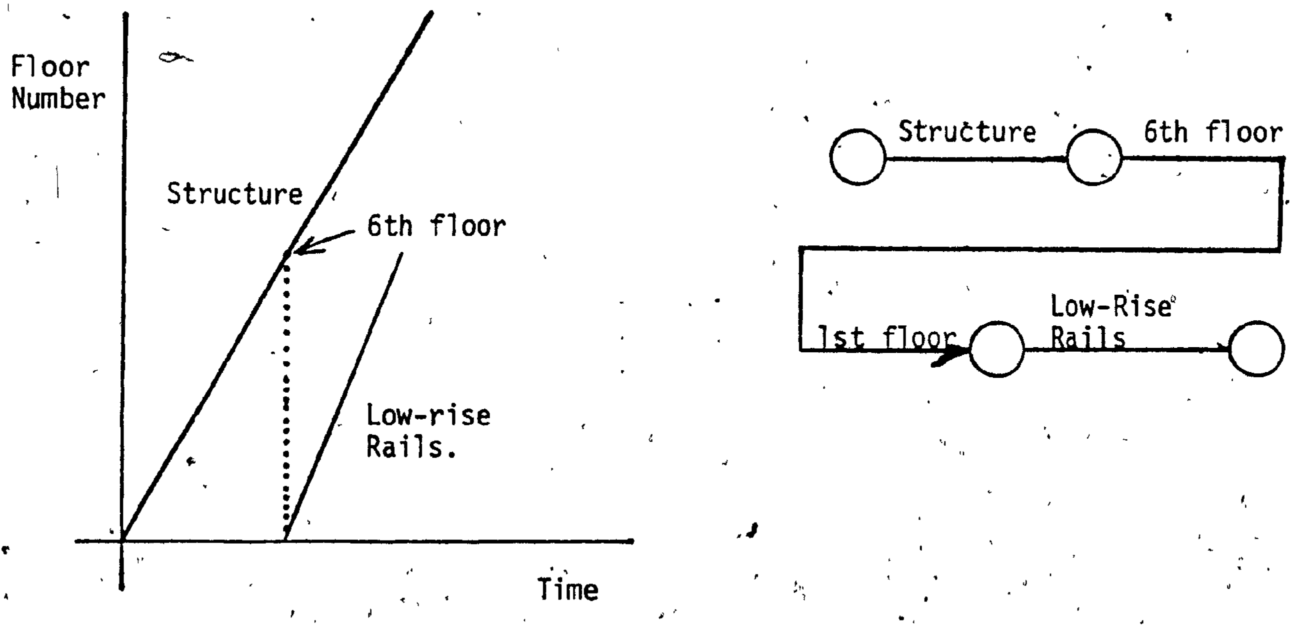


Fig. 4.13 A Specific Floor of a Repetitive Activity as a Non-typical Predecessor

structure is completed on the floor where its motors are. If the motors are on the 6th floor, it means that the rails on the first floor cannot be started until the structure is completed on the 6th floor. So the low-rise rails on the first floor will have as a non-typical predecessor, the completion of the sixth floor of the structure, as shown in fig. 4.13. Another example of such relationships is when a subtrade wants to level its resources. For example, the plumbing subcontractor might prefer to start the installation of the toilet fixtures only when the roughing-in is completed for all the floors. So the installation of the fixtures on the first floor will have as a non-typical predecessor, the completion of the plumbing roughing on the last floor, as shown in Fig. 4.14. The typical and non-typical predecessors are only applicable for repetitive activities and should handle any kind of possible dependencies.

There is only one kind of predecessor for a non-repetitive activity, and it is similar to the non-typical predecessor for the repetitive activities explained above. A non-repetitive activity could be dependent on another non-repetitive activity, on a milestone or on a repetitive activity of one given floor.

For example, the pouring of the footings follows the completion of the excavation. So the "footings" activity will have as predecessor the "excavation" and both of these activities are non-repetitive (one could look at footings as a repetitive activity, but in the horizontal plane, a refinement we need not consider here). A milestone could also precede

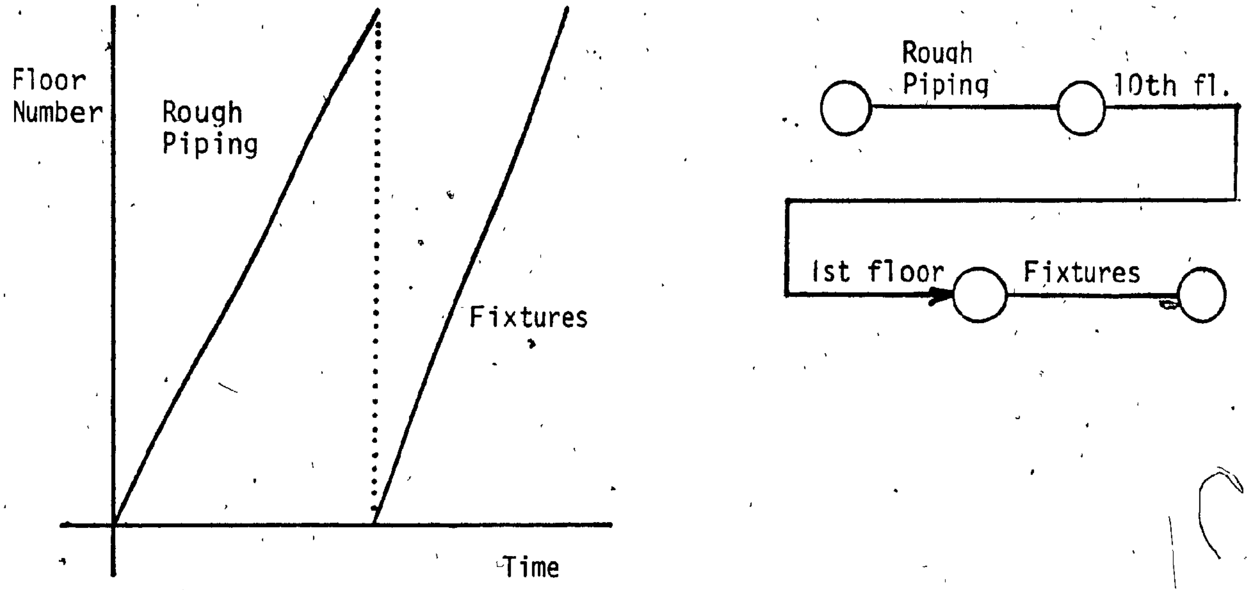


Fig. 4.14 A Specific Floor of a Repetitive Activity as a Non-typical Predecessor (other case).

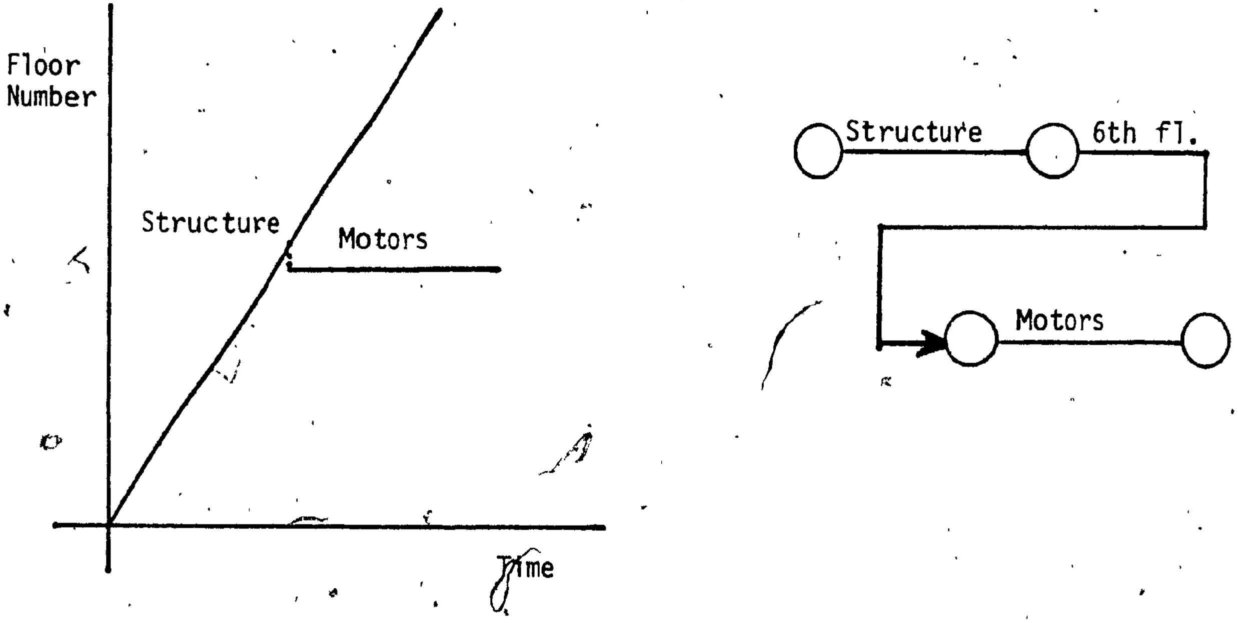


Fig. 4.15 A Specific Floor of a Repetitive Activity as a Predecessor to a Non-Repetitive Activity.

a non-repetitive activity. As we will see later, procurement activities do not form part of the construction network, but rather are treated in a specific report. Therefore, milestones will be used to schedule the delivery on site of large equipment, and the procurement report will be based on the delivery date. So if a large piece of equipment cannot be delivered to the site before a given date, that date could be entered as a milestone preceding that activity. For example, if the transformers for the main electrical room cannot be delivered before, say, June 15th, a milestone would be entered as a predecessor of the installation of those transformers. Finally, a repetitive activity of a given floor can precede a non-repetitive activity; for example, the installation of the low-rise motors for the elevator will not start until the structure is completed on the floor where they are, say the 6th floor, as shown in Fig. 4.15.

So any kind of dependencies possible between the activities for high-rise building construction can be handled by the kind of precedence relationships described in this section.

4.3.2 Calculation Mechanism

Before explaining the mathematical relationships used to generate the schedule of activities, some preliminary operations have to be performed. It was said previously that the information that would be input for a given activity was its number, its name, its predecessors and its duration or production rate and some lag factors (SS,FS) if repetitive. The proposed model will follow a procedure similar to that for network models to arrange the activities in the order in which they will be calculated, or what could be referred to as "sequence step order" (ref. 24).

The first operation for each activity is to generate the list of its successors. This is done by going from activity to activity, one by one, and assigning to each predecessor, a successor that is the current activity. For example, if activity 2 has as predecessor activity 1, activity 1 will obviously have activity 2 as a successor.

The activities can be put into sequence order once their successors have been identified. This is done by first counting for each activity the number of predecessors of every kind. Those with a count of zero will be the first in the order, because they do not have any predecessor. For the first activity(ies), the successors will be looked at and the counter of the number of predecessors will be decreased by one for each successor. If, after decreasing it, the counter becomes zero, that activity will be put at the end of the list of the activities with a count of zero and will be next in the order. When all the successors are looked at for the first activity, the next activity in the order will be studied by doing the same thing, until no more activities are left. The order in which the counter became zero for each activity will be the sequence step order. A flow chart of this algorithm is presented in fig. 4.16.

N(A) : Number of Predecessors of Activity No. A
O(I) : Ith Activity (its number) in the order of input.
S(I) : Ith Activity (its number) in the Sequential Step Order
N : Number of Activities.

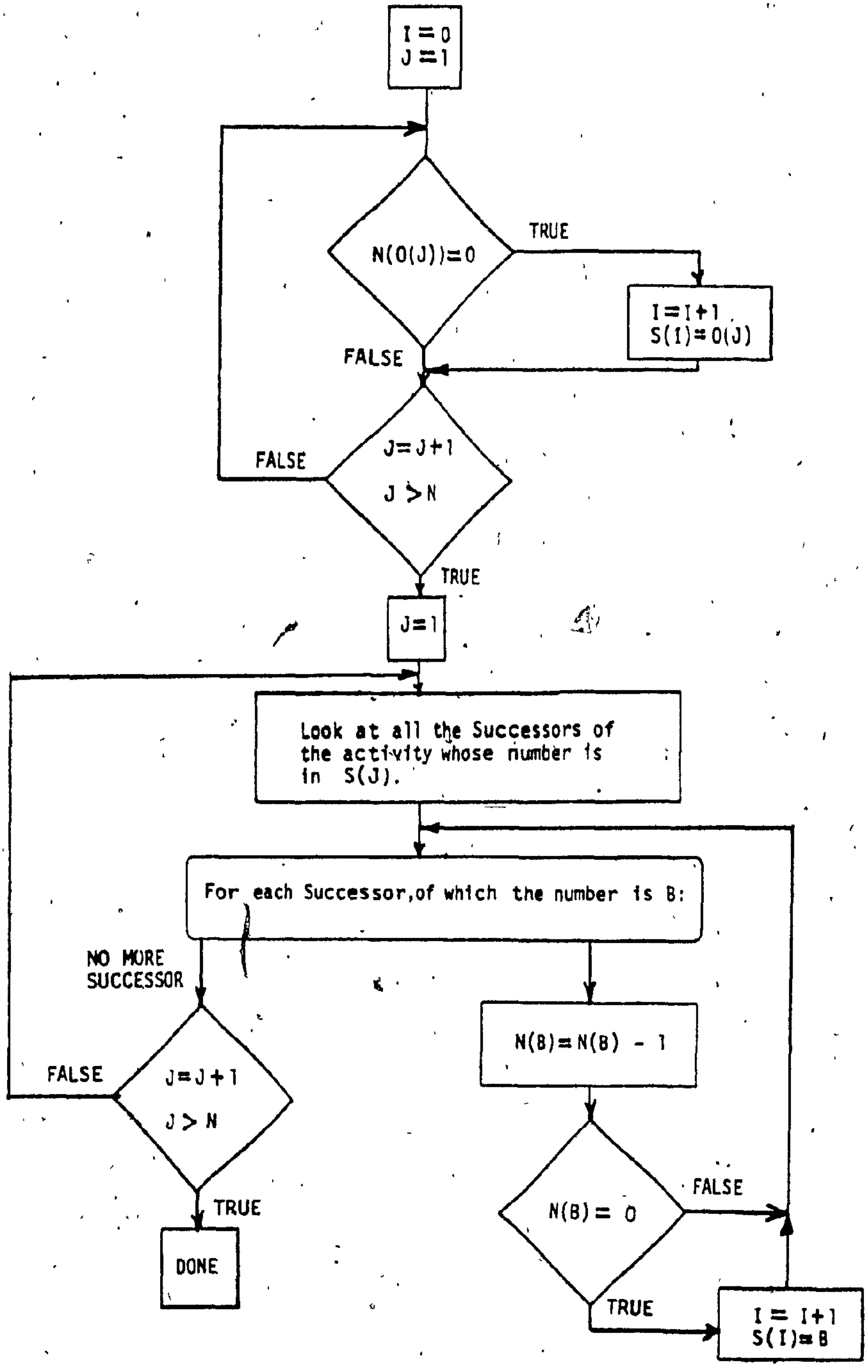


Fig. 4.16 Sequential Step Algorithm

The calculation algorithm is very different for the repetitive activities, compared to the non-repetitive ones, even if, when put in sequence step order, no difference is made between the two. It should be noted that all the following relationships use working days as the basic time unit.

The algorithm for non-repetitive activities is explained first. When calculations are to be made for a non-repetitive activity one has to look at its predecessors. The early start and finish dates of its predecessors (repetitive, non repetitive and milestone) are assumed to have already been computed. Then among those predecessors, the one that governs must be identified as follows. First, define the following items:

S = start of activity
F = finish of activity
D = duration of activity
F_i = finish time of i^{th} predecessor
M = milestone date
n = number of predecessors
m = number of milestones

Note: A start date is always at the beginning of the day and a finish date, at the end of the day.

Then, the earliest start date and earliest finish date of the activity at hand are given by:

$$S = \max [F_1+1, F_2+1, F_3+1, \ldots., F_n+1, M_1, M_2, \ldots. M_m] \qquad (4.5)$$

$$F = S + D - 1 \qquad (4.6)$$

So the start date of any non-repetitive activity will be either the greatest finish date of any predecessor +1 or the greatest milestone date, as shown in equation 4.5. The finish date of that activity is then calculated by standard CPM calculations, i.e. the finish date of the activity is equal to the summation of its starting date and its duration minus 1 in order to satisfy beginning and end of day conventions (eq. 4.6).

The calculation of the dates for a repetitive activity is more complicated and follows a three step procedure. In order to respect work continuity requirements, arbitrary dates for all the floors of the repetitive activity are calculated first by choosing an arbitrary date for the first floor, and then computing times for the remaining floors by applying the type of relationships defined previously. In the second step, each of the floors is compared to its corresponding predecessors and the smallest difference found for all the floors will be the one by which the arbitrarily calculated dates are decreased in the third step, to yield the actual scheduled dates. Such a procedure is very similar to the one used by Shlomo Sellinger (ref. 57) but for a different application: he was comparing alternatives, instead of comparing predecessors.

Here is a more detailed explanation of the mathematical relationships involved in the three steps. Recalling equations 4.1 to 4.4. of section 4.2.1., a set of arbitrary dates which satisfy the continuity requirements stipulated by the various variables that characterize each repetitive activity is calculated. The following information is required to describe each repetitive activity (see Fig. 4.1):

n = number of crews
P = production rate (days/floor)
SS = start to start relationships between successive floors, when there is more than one crew
FS = finish to start relationship between the next floor that a crew has to move to.
$F1$ = first floor on which the activity is present
FL = last floor on which the activity is present
$S(i)$ = start time of i^{th} floor
$F(i)$ = finish time of i^{th} floor
A = arbitrary chosen date (any number)

The following equations provide the basis for calculating arbitrary start and finish dates for each floor:

$S(F1) = A$ (eq. 4.7)
for any floor $F(i) = S(i) + P - 1$ (eq. 4.1)
if $n = 1$ $S(i) = F(i-1) + FS + 1$ (eq. 4.2)
if $n > 1$ $S(i) = S(i-1) + SS$ (eq. 4.3)
when $i = nk+1$ $S(i+n) = F(i) + FS + 1$ (eq. 4.4)
where $k=0,1,2,3,\ldots, FL/n$

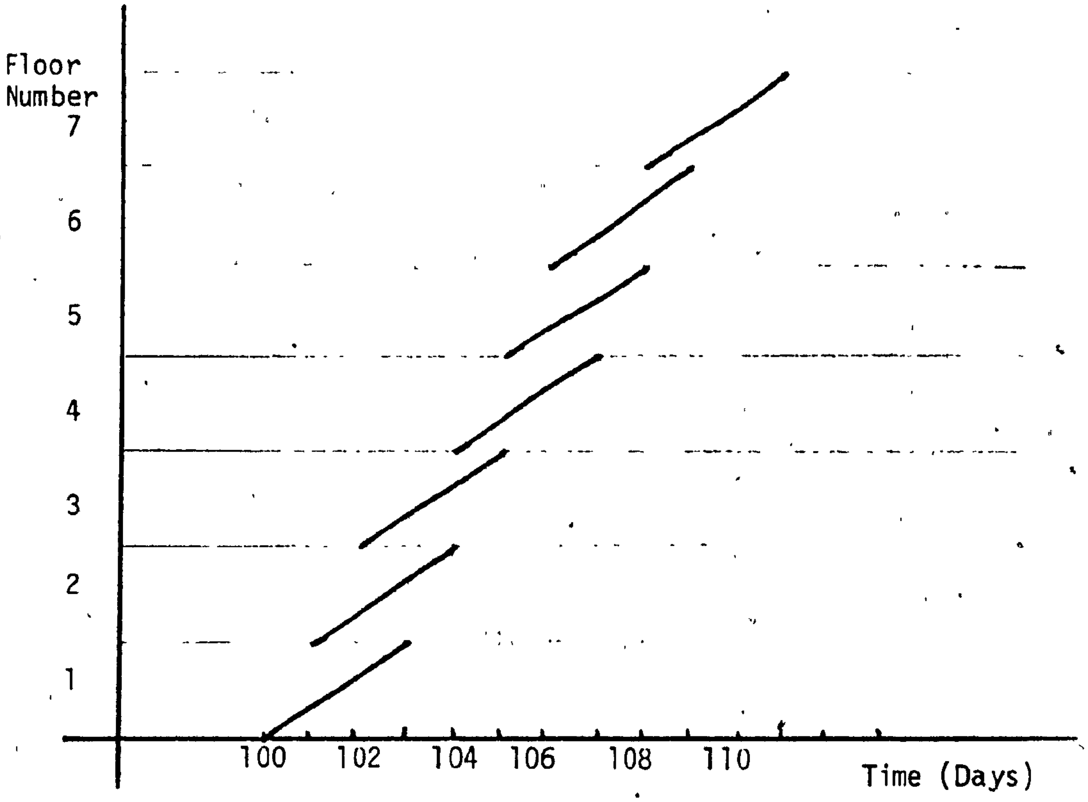
These relationships are evaluated for i = F1 to FL to determine arbitrary start and finish dates for each floor. An example of the use of those equations is shown on figure 4.17.

Now, the dates generated for an activity using the foregoing equations have to be compared with all the predecessors of that activity. The comparison mechanism is different for typical versus non-typical predecessors. For each typical predecessor, the comparison is made for each of the common floors of the predecessor and of the activity under consideration. A difference is calculated for each floor, and the smallest difference found equals the difference (or spread) for that typical predecessor. This process may be represented as follows. Let:

Δ_k = difference for k^{th} typical predecessor
F_{ik} = finish date of the i^{th} floor of k^{th} predecessor
S_i = start date on i^{th} floor of the current activity
F1 = first common level
FL = last common level

$$\text{Then } \Delta_k = \min [S_{F1} - F_{F1k},\ S_{(F1+1)} - F_{(F1+1)k},\ S_{(F1+2)} - F_{(F1+2)k} \cdots\cdots$$
$$\cdots\cdots,\ S_{FL} - F_{FLk}] \qquad \text{(eq. 4.8)}$$

This difference has to be calculated for each of the k typical predecessors. The non-typical predecessors must also be compared with the start date of the specific floor they are preceding. This is done through the following relationships:



In this case: n=3, SS=1, FS=0, P=4.

S(1) = 100 (4.7)

F(1) = S(1)+P-1 = 100+4-1 = 103 (4.1)

S(2) = S(1)+SS = 100+1 = 101 (4.3)

F(2) = S(2)+P-1 = 101+4-1= 104 (4.1)

S(3) = S(2) + SS = 101+1 = 102 (4.3)

F(3) = S(3)+P-1 = 102+4-1 = 105 (4.1)

S(4) = F(1)+FS+1 = 103+0+1 = 104 (4.4)

F(4) = S(4)+P-1 = 104+4-1 = 107 (4.1)

⋮

S(7) = F(4)+FS+1 = 107+0+1 = 108 (4.4)

Fig. 4.17 Example of use of Equations

Δ_{NT} : difference for the non-typical predecessors

F_k : finish date of the k^{th} non-typical predecessor

Note: if the k^{th} non-typical predecessor is a milestone date, the following relationship should be applied:

F_k = date - 1 eq. 4.9

S_k = start date of the specific floor that the k^{th} non-typical predecessor is preceding

m = number of non-typical predecessors.

$$\Delta_{NT} = \min \; [S_1-F_1,\; S_2-F_2,\; \ldots,\; S_m-F_m] \qquad \text{(eq. 4.10)}$$

Now that the arbitrary dates have been compared with all possible predecessors, the one that will set the actual dates has to be determined, by finding the smallest difference of all, as shown in equation 4.11.

$$\Delta = \min \; [\Delta_1, \Delta_2, \ldots, \Delta_K, \Delta_{NT}] \qquad \text{eq. 4.11}$$

Thus value of delta (Δ) is the smallest difference found by comparing the start times of the activity with the finish times of each predecessor; it is therefore the amount by which the arbitrary dates, for each floor, can be subtracted in order to arrive at the actual schedule dates. The last mathematical relationship to get schedule dates is the subtraction of Δ from the arbitrary dates to obtain start and finish times, as expressed in equation 4.12:

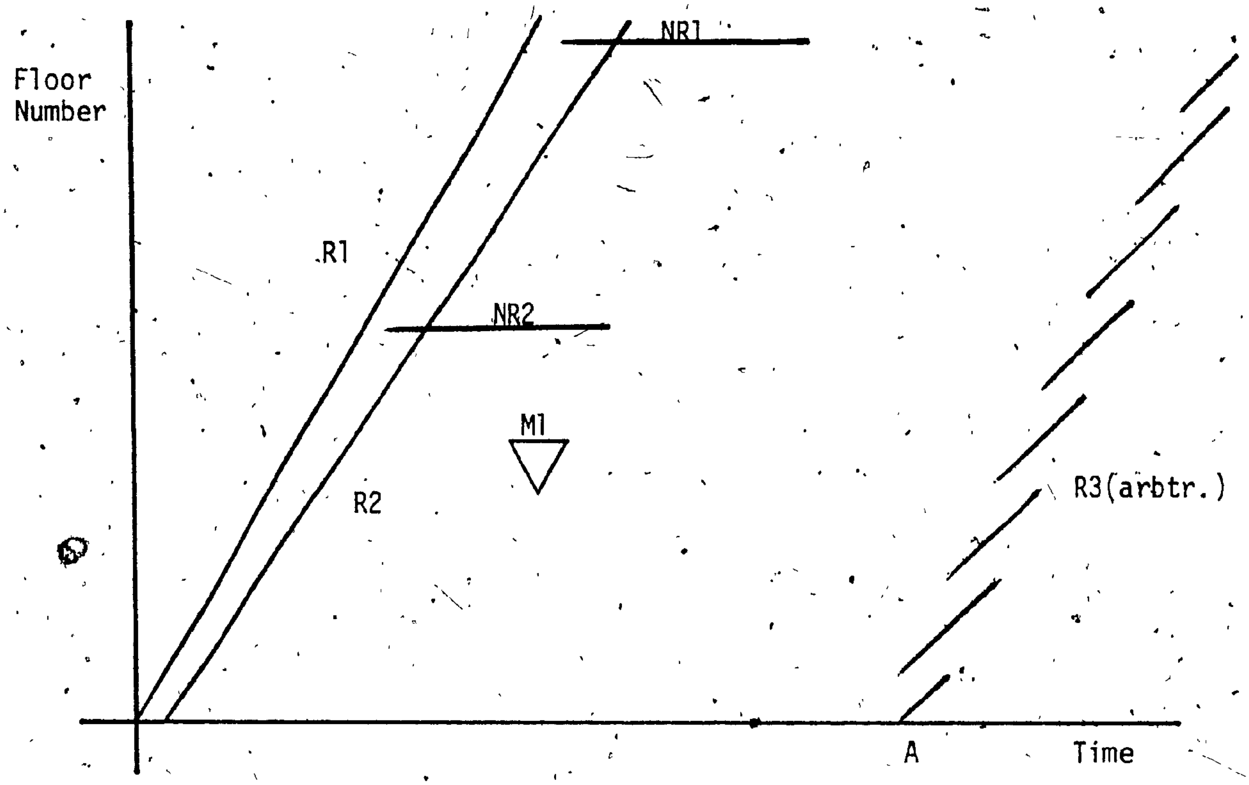
$$S_S(i) = S_A(i) - \Delta + 1$$
$$F_S(i) = F_A(i) - \Delta + 1 \qquad \text{eq. 4.12}$$

where subscripts s and A mean scheduled and arbitrary, respectively.

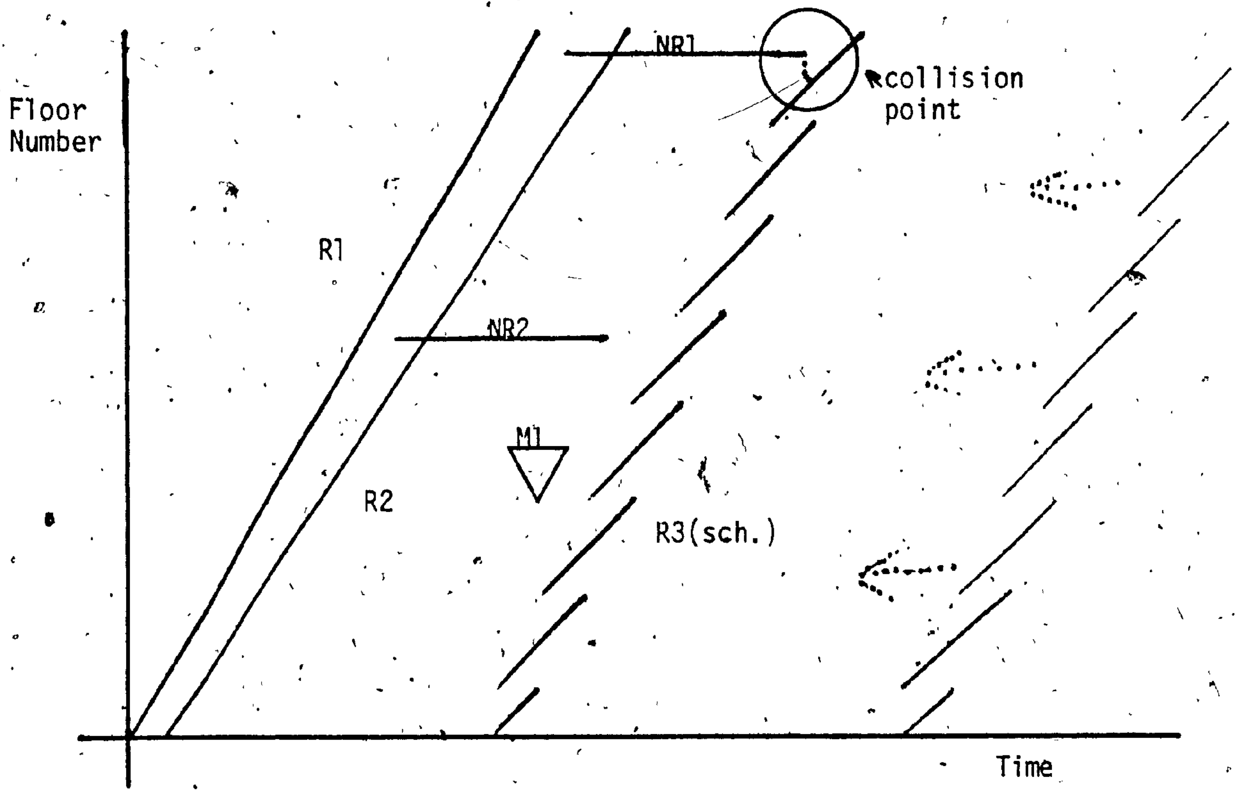
Because the dates of each floor are reduced by the same amount, they keep exactly the same relationships as defined by equations 4.1 to 4.4 which ensure continuity of the work. In fact, the smallest difference found will be the "collision point" as defined in the previous chapter.

Fig. 4.18 shows graphically the mathematical relationships. The repetitive activity R3 is the current candidate for scheduling. By using equations 4.1 to 4.4 and an arbitrary starting date A, we obtain arbitrary start and finish dates, as shown on Fig. 4.18 (a). Also shown are the predecessors of R3; there are two "typical predecessors", R1 and R2 and three non-typical predecessors: non-repetitive activites NR1 and NR2, and the milestone M1. Applying the mathematical relationships explained before results in "shifting" activity R3 to the left of the graph until it "hits" one of its predecessors, namely NR1 in this case. The point where activity R3 stops becomes its actual schedule.

Once the calculations are performed for all the activities, the latest finish date will be the completion date of the project. Using CPM terminology, these calculations would be described as the "forward pass computations". When developing the model, activities in parallel are allowed, and therefore the notions of criticality and float exist.



(a) R3, with arbitrary dates.



(b) R3, at its "scheduled" position (after shifting).

Fig. 4.18 Graphical Explanation of the Calculation Mechanism

A backward pass should be performed in order to identify critical activities and float times for non-critical ones. These two notions are crucial for monitoring the job and planning resource requirements.

The backward pass algorithms are very similar to the forward pass ones. The sequence step order defined earlier is used, except that the order of the activities is from the last activity to the first one.

For the non-repetitive activities, the dates are determined by the successors. If an activity does not have any successors, it means that it is the last one of the network, and its finish date corresponds to the completion date of the project. Because of the convention of having milestones as predecessors only, it is not possible to have a milestone as a successor. For activities other than the last one, all the successors have to be looked at in order to find which one governs.

Using the same definitions as before, we have the following relationships:

$$LF = \min. [LS_1-1, LS_2-1 \ldots\ldots, LS_n-1] \qquad \text{eq. 4.13}$$

$$LS = LF - D + 1 \qquad \text{eq. 4.14}$$

where LS_i = late start date of i^{th} successor

LF = late finish date of the activity

LS = late start date of the activity

D = duration of the activity

n = number of successors

The computations for the repetitive activities are again done in three separate steps. For the first one, an arbitrary date is selected and arbitrary dates for each floor are generated using equations 4.1 to 4.4 and 4.7. After this is done, these dates have to be compared with all the successors. Because there are typical and non-typical predecessors, there are also typical and non-typical successors, which are structured exactly the same way. For all typical successors, the difference is found by the following equation (4.15):

Δ_k = difference for the k^{th} typical sucessor

F_i = finish of the i^{th} floor of the calculated activity

LS_{ik} = late start date of the i^{th} floor of the k^{th} successor

$F1$ = first common level

FL = last common level

$$\Delta_k = \min [LS_{F1k} - F_{F1}, LS_{(F1+1)k} - F_{(F1+1)}, \ldots, LS_{FLk} - F_{FL}] \quad \text{eq. 4.15}$$

For the non-typical successors, their dates have to be compared with the finish date of the specific floor they succeed; the special case of milestones that was present in the forward pass is not present here, because of the previously mentioned assumption. So the difference for these non-typical successors is calculated as follows:

Δ_{NS} = difference for non typical successors

LS_k = start date of the k^{th} non-typical successor

F_k = finish date of the specific floor for the k^{th} non-typical successor

m = number of non-typical successors.

Then,

$$\Delta_{NS} = \min \; [LS_1 - F_1 \; LS_2 - F_2, \; \ldots\ldots, \; LS_m - F_m] \qquad \text{eq. 4.16}$$

and the smallest difference is determined by equation 4.17.

$$\Delta = \min \; [\Delta_1, \Delta_2, \Delta_3, \; . \; . \; . \; . \; ., \Delta_{NS}] \qquad \text{eq. 4.17}$$

To find the actual late start and finish dates of the current activity, the value of "Δ" has to be subtracted, as shown in equation 4.18:

$$\begin{aligned} LS(i) &= S(i) - \Delta + 1 \\ LF(i) &= F(i) - \Delta + 1 \end{aligned} \qquad \text{eq. 4.18}$$

This process is repeated for all activities. No more calculations are required to obtain dates. The other features of the system make use the data from these calculations.

For example, by computing the difference between the early start and late start dates, the value of the total float can be obtained. If it is zero, the activity is critical and should be identified as such. Most CPM models also output values for free float, interfering float and independent float (ref. 24). Because of the assumptions of continuity for the repetitive activity, some of these calculations might yield incorrect results. For example, if two repetitive activities follow one another and have different production rates, there will only be one "collision point, as shown on fig. 4.19. If the network consists of only those two activities, early and late dates would be the same for each activity and both would be critical; therefore, the total float

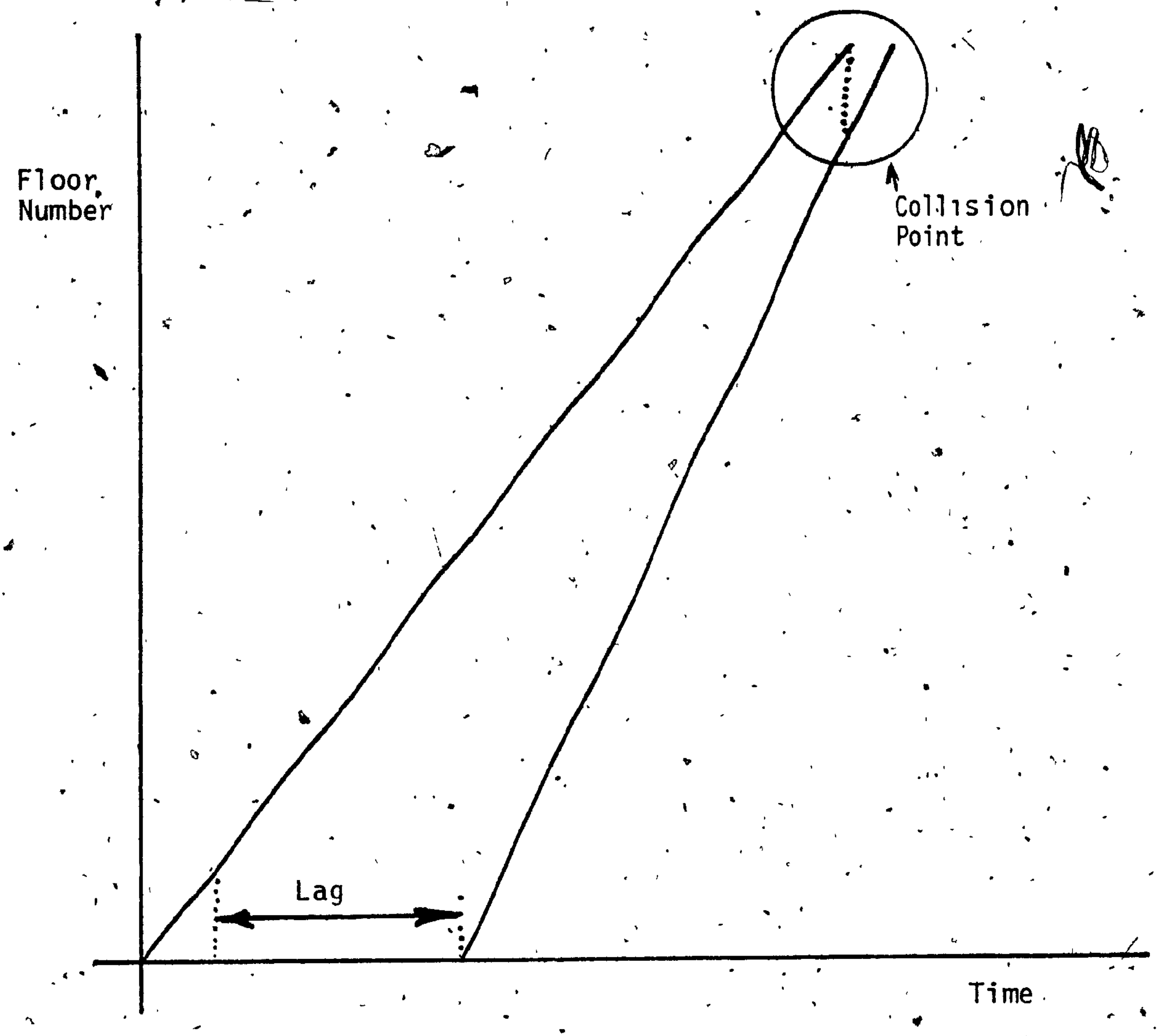


Fig. 4.19 Lag and Float for Two Critical Activities.

would be zero for all floors. However, the definition of free float is as follows (ref. 24):

$$FF = ESD_{i+1} - EFD_i. \qquad \text{eq. 4.19}$$

i = activity number

In our example, the free float, on the first floor, would be different than zero, and would in fact be equal to the "lag" between the two activities on that first floor. But the lag cannot be considered as float in the proposed model if continuity is to be maintained. It is recommended that the issue of float in linear planning algorithms be investigated in more detail in follow-up work to this thesis. Only the total float will be calculated in the present work.

4.3.3 Learning Effects

So far, the production rate of a repetitive activity was assumed to be the same for all the floors. For example, if the production rate was set at 4 days per floor, with one crew and a finish to start relationship between floors of 0, it would take 40 days to do 10 floors for that specific activity.

However, as explained in the previous chapter, learning curve effects are present in such a sequence. Consideration of these effects should form part of the proposed scheduling system for repetitive activities especially if the work is assumed to be continuous. This consideration differentiates the planning system described herein from those described in the literature.

Most learning curve models have been developed for manufacturing industries where the cycle time of an operation is very small and the number of units produced is very high. The application of such models to the construction industry remains doubtful and is not pursued in the present research.

But one does not really need a mathematical model to include learning effects in a scheduling system. In fact, the use of estimated coefficients of efficiency for the first few floors of a repetitive activity could yield a good approximation for a learning curve. Because a different learning curve would be required for each repetitive activity, such an approach would be very simple and easy to use.

The meaning of production rate has therefore to be refined at this stage: it is taken to mean the "expected" production rate, or the production rate that will be reached when the learning time is passed. For example, if an activity has a production rate of 4 days per floor, the first few floors might require 6,7 or even 8 days to be performed, depending on the degree of complexity of the operation and the skills required to perform it. Coefficients of efficiency could be estimated in advance by the persons responsible for executing the activity and the production rates for the first few floors would be determined by adjusting the initially estimated production by the coefficients.

These coefficients are probably best expressed as percentages: a 50% value for the coefficient would mean that the production rate for that specific floor would be multiplied by 2 (1/.5). Therefore, a value of 100% means that the learning period is over.

Because only a few floors are affected by a learning period, most floors of a repetitive activity will have a coefficient of efficiency of 100%. In order to limit the input of data, all the floors of a repetitive activity will be assumed to have a value of 100%, unless otherwise noted. So only the coefficients that are different than 100% have to be input.

In terms of mathematical relationships, only equation 4.1 requires modification, by the addition in the equation of the coefficient of efficiency:

$F(i)$ = finish of i^{th} floor

$S(i)$ = start of i^{th} floor

P = "expected" production rate (days/floor)

$L(i)$ = coefficient of efficiency of i^{th} floor (in percent)

$$F(i) = S(i) + \frac{P}{L(i)} \times 100 - 1 \qquad \text{eq. 4.20}$$

So equation 4.20 replaces equation 4.1 in the previously explained calculation mechanism. This calculation might give non-integer results for a Finish date. For this case, the date should be rounded to the next integer, but with some care, as explained in the next chapter.

4.3.4 Calendar Days and Weather Effects

Although all the calculations are performed with "working days", the schedule has to be presented in a calendar day framework in order to be communicable, as explained in the previous chapter. This requires that a calendar of working days be generated, by eliminating weekends, holidays and vacation so that each working day corresponds to a calendar day.

The only other input required is the determination of the actual starting date of construction. Once known, it corresponds to the first working day. And then, the second working day corresponds to the next "workable" day, the third, to the next, etc., until the number of working days corresponds to the project's duration. Although all the relationships are in working days, the results would be presented by finding the equivalent calendar day using the process just described.

As explained in the previous chapter, the conversion of working days to calendar days is important for communications purposes, but also to add some contingency when work is performed during winter months. In fact each month of the year would have its own "weather factor" that would adjust the duration or the production rate according to the time of the year an activity is performed. An example of such coefficients is shown in table 4.1. The factors shown are used in the present thesis for illustrative purposes but should not be considered as standard. In fact, different activities should have different factors, but this is not treated in the present model.

The procedure for adjusting the durations of non-repetitive activities affected by weather differs from the one for the production rates of repetitive activities. However, in both cases, the early start and finish dates are calculated using the previously mentioned mechanism before any adjustments are made to the values.

For each non-repetitive activity affected by weather, the calendar date corresponding to the early start date, which is in working days, is found first. The month of that date is then used to find the weather factor from table 4.1. If the duration of the activity is greater than

MONTH	FACTOR
January	70%
February	70%
March	75%
April	80%
May	90%
June	100%
July	100%
August	100%
September	90%
October	80%
November	75%
December	70%

Table 4.1

Weather Factors for the 12 months of the year

20 working days (or 1 calendar month), the execution of the activity will be spread over more than one month, and therefore over possibly different weather factors. So the weather factor that is used to adjust the duration should be an average of the factors of the months during which the activity is performed. So equation 4.6 would be replaced by equation 4.21:

F = finish date of activity

S = start date of activity

D = duration of activity

n = number of months over which activity is spread

W = weather factor for the month of the start date.

where $$W = \frac{W_1 + W_2 + W_3 + \ldots + W_n}{n}$$

$$F = S + \frac{D}{W} \times 100 - 1 \qquad \text{eq. 4.21}$$

For the repetitive activities, the adjustment procedure is more complicated. Once the dates are determined by the calculation algorithms mentioned before, each floor has to be taken one by one, and adjusted accordingly. But, after each successive floor is adjusted, the dates of the remaining floors have to be increased by the adjustment amount for the current floor, in order for the weather factors to be consistent with the months in which the activities will be performed. Thus for the activity at hand:

$$F(i) = S(i) + \frac{P}{L(i) x W} \times 10000 - 1 \qquad \text{eq. 4.22}$$

and, if the difference between the adjusted finish date and the original one is "d", this should be added to all the remaining floors, as in eq. 4.23.

For all i's $\geqslant$ i+1 up to the number of levels:

$$\begin{aligned} S(i) &= S(i) + d \\ F(i) &= F(i) + d \end{aligned} \qquad \text{eq. 4.23}$$

For these calculations, the fractions should be carried forward in order for the results to be as meaningful as possible. When all iterations are complete, the dates obtained should be rounded to the nearest integer.

After the activity's schedule dates have been adjusted, a check has to be made of the activity's position vis-a-vis its predecessors. Consider the situation shown on fig. 4.20: activity 2 is a successor to activity 1 and the unadjusted calculations have found a "collision point" on the last floor, and a set of dates represented as 2a. Then, by performing the routine explained above, the dates are adjusted, and the new schedule is shown as 2b. It can readily be seen that there is no longer a collision point on the last floor, and that the activity could start at a much earlier date. So the dates have to be adjusted again.

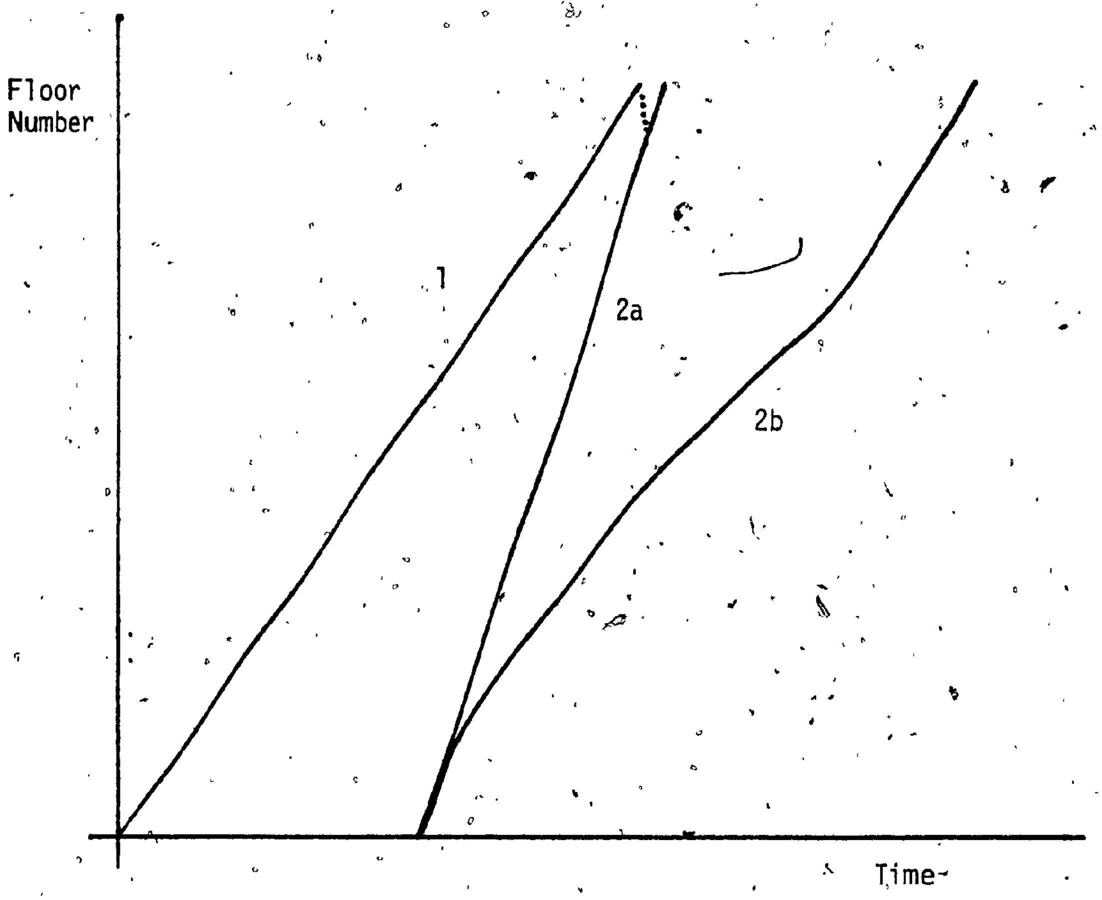


Fig. 4.20 Weather Effects on the Production Rate and Scheduling of a Repetitive Activity.

Therefore, The next step is to compare the activity with all its predecessors, to find a new "collision point" and to modify its schedule dates. It is the same as treating the schedule dates denoted by 2b as "arbitrary dates", as before, and then finding the smallest difference by which they have to be modified. Therefore, equations 4.8 to 4.12 are used again to come up with the results.

However, if the difference by which the dates are modified is relatively big, the weather factors by which the dates have been adjusted might not be the ones corresponding to the month in which the activity is now scheduled, yielding again unsatisfactory results. Therefore, a new set of computations should be performed. The starting date of the first floor is kept and used as an arbitrary starting date as in the first step of the calculations for the repetitive activities. Thus, equations 4.1 to 4.4, 4.7 and 4.20 are used to generate a new set of arbitrary dates. The next step consists of adjusting those dates by using the corresponding weather factors, and therefore use again equations 4.22 and 4.23.

The resulting dates are then compared with all the predecessors, as before, and adjusted accordingly. However, this time, the difference should be very small, and therefore the scheduled dates will be correct. Although this second series of operation seems to be redundant, it has to be done in order for the schedule to be accurate.

4.3.5 Procurement Schedule

As seen in the second chapter of this thesis, some activities are very labour intensive, and their timely completion depends on the productivity of the men on site. However, other activities, mainly non-repetitive, require few labour hours on site, but depend on the timely delivery of some pieces of equipment. Examples of such activities are major electrical equipment (main transformers and switches), mechanical equipment (pumps, chillers, boilers, etc.); transportation equipment (escalators, elevators, etc.), and many others, depending on the characteristics of the building. So in order to be delivered on site at required dates, it is important to monitor their procurement activities, from the time a decision is made on the supplier up to when the final product arrives on site. The procurement activities prior to delivery at the site do not form part of the network but should be derived by backtracking in time from the moment that the equipment is needed on the site.

The actual tasks that properly describe a procurement sequence might differ from activity to activity, but they should be chosen from a list of all possible ones. Each of these tasks would be associated with a duration, so that, by subtracting from the start date on site, one might derive a procurement schedule. In order to simplify the model, all these tasks are treated as sequential and would not have any overlapping. In fact, this model resembles the line of balance theory (see previous chapter) where a schedule is derived by knowing the date of the last activity of a sequence, the dates of the others being derived by backtracking in time.

Here is a list of the kind of tasks that might be part of a procurement sequence (ref. 7):

1) Preparation of bid documents
2) Call for Tenders
3) Examination of bids and contract award
4) Vendor's preparation and submission of shop drawings
5) Review and approval of shop drawings
6) Fabrication by the vendor or subcontractor
7) Shipping
8) Custom clearances
9) Delivery and inspection.

Obviously, some activities will not require all of these tasks and some very special pieces of equipment might require the addition of very specialized tasks such as inspection and expediting in a manufacturers plant. Of importance here is the treatment of the procurement function and its integration into the scheduling system.

The algorithm for generating the procurement schedule is very similar to the backward pass explained earlier in this chapter. However, in order to simplify the quantity of information that appears on the report, each of the tasks will be associated only with a start date, instead of with early and late start and finish dates, as in the schedule. Because all the tasks are sequential, one can readily find the finish date by looking at the start of the next task. Also, the notions of criticality and float are not appropriate in this case.

From the author's experience on two sites in the city of Montreal, it became evident that repetitive activities do not require formal treatment of a procurement sequence because of low-complexity of the material or equipment that are associated with them; therefore only the non-repetitive activities will have the option of having such a sequence associated with them. This assumption is very important in the computerization of the model (see next chapter).

When an activity has a procurement sequence, some information has to be input: the tasks that will form the sequence have to be chosen from the list mentioned before and each of them will be assigned a duration. Once the dates are calculated for that activity, dates of the procurement tasks can be evaluated by starting from the last task in the chronological sequence, and finding its start date by the following relationship (eq. 4.24):

SP(i) : start date of i^{th} procurement task

NP : number of procurement tasks

D(i) : duration of i^{th} procurement task

ES : early start of the activity for which this sequence is calculated

$$SD(NP) = ES - D(NP) \qquad \text{eq. 4.24}$$

$$SD(i) = SD(i+1) - D(i) \qquad \text{eq. 4.25}$$

The other task times of the procurement sequence would be calculated by subtracting the duration of the task from the date of its successor, as shown in equation 4.25. As in all calculations presented before, all these times are in working days and should be changed to calendar dates for presenting the report.

Such a procurement status report will be mainly used as a checklist by the general contractor and the subcontractor. Therefore any deviation from the planned schedule will be detected early and corrective action could be initiated as soon as possible to diminish or eliminate the impact of procurement delays on the construction site schedule. However, if a delay occurs, the impact on the overall schedule can be readily determined.

4.3.6 Short Cycle Schedules

Short cycle schedules have been widely used in the manufacturing industry as a tool for short term planning and monitoring of mainly routine operations. Smith (ref. 59) defined short cycle scheduling in the following way: "Simply stated, short interval scheduling is a method for assigning a planned quantity of work to be completed by a specific time and is a means to determine that the quantity of work has been completed within the specific time limit". Actual application of such procedure in construction is limited, and very few articles have been published on this subject (ref. 28 47 and 51).

The objectives of using short cycle schedules are three-fold (ref. 10):

1) To encourage site management to look ahead, to foresee immediate requirements, and hence avoid delays;
2) To review the actual progress achieved, to check performance, and either to take corrective action for short-comings or take advantage of any gains; and
3) To incorporate any design modifications (change orders) or to facilitate improved production techniques in the light of fuller information or further investigation, such as that obtained from work study methods.

Ponce-Campos and Pawley (ref. 47) and Kelley (ref. 28) described short cycle schedules as a tool to control construction operations and processes on a day-to-day basis, at a level of detail beyond that reached in network models. These authors asserted that a short cycle schedule had to include work assignments and short term work goals for line supervision. The planning and scheduling system proposed in this thesis is to be used by a General Contractor who is interested in controlling the work of his subcontractors but not to the level of detail of work assignments. Thus, a short cycle schedule would simply pickup from the overall detailed schedule, only the activities that are to be done over the next week, for example, and on which he could put emphasis. Such a document could be very useful at the regular site meetings. The activities that are listed would be the center of interest of the meeting as to what each subcontractor has to do over the next period. If anyone foresees problems, it could be raised at the meeting in order to avoid delays.

The second objective of short cycle schedules is to review the progress achieved and check performance. Therefore, the activities that should have been done during that last week should also be present on the schedule so they can be examined at the site meeting to determine if everything was executed as per what was on the schedule. So the schedule should contain the activities of the week before, the ones for the present week and probably the ones for the coming week, in order to have a better window on the future.

Practically, the short cycle schedule would consist of inputting a calendar date, say the beginning of a week; then, a window would be set as one week before that date and two weeks after that date, and all the activities having a part or all of their execution over that three week period would be listed on the short order schedule. So its algorithm would consist of taking all the activities, one by one to see if it is executed during that three week period. A possible format for presenting the results would be as on Fig. 4.4. However, this report might be improved by refining the format or the information appearing on it; although not part of the present thesis, a good starting point for future work is found in refs. 47 and 51.

4.3.7 Updating

As mentioned before, updating of the schedule is a very important feature in order for the system to be used on a real construction project. As the job is executed, it is crucial to evaluate if the activities are performed according to the plan, and if not, how the time delays or gains affect the remaining activities. Simply stated, updating consists of "planning and scheduling the remaining work after some time has elapsed" (ref. 24). In the proposed model, updating would be done in a sequence of three steps.

The first step is to record the actual start and finish dates of the activities. This should be done on a very regular basis, and would not have any effect on the schedule; it is a scorekeeping task in order to get an image of how the job is performed. Therefore, each non-repetitive activity, and each floor of a repetitive activity would eventually be assigned "actual" start and finish dates. Those dates would appear on the matrix format (fig. 4.6) or eventually on the bar chart or the linear chart presentations, in order to show a graphical comparison of the scheduled versus actual dates.

At that stage, one could assess the performance on these activities by comparing the dates with the scheduled dates, and also by studying if the completed activities have followed the logic established in the initial plan. This is crucial for evaluating the impact of slippages on the remaining activities and also, for keeping historical records for use on similar future jobs.

The second step consists of generating a new "updated" schedule incorporating all these actual start and finish dates in the calculation, but keeping intact the logic and the durations of the activities which have not been executed yet. The link with actual dates in the calculation of the updated schedule will be different for repetitive versus non-repetitive activities.

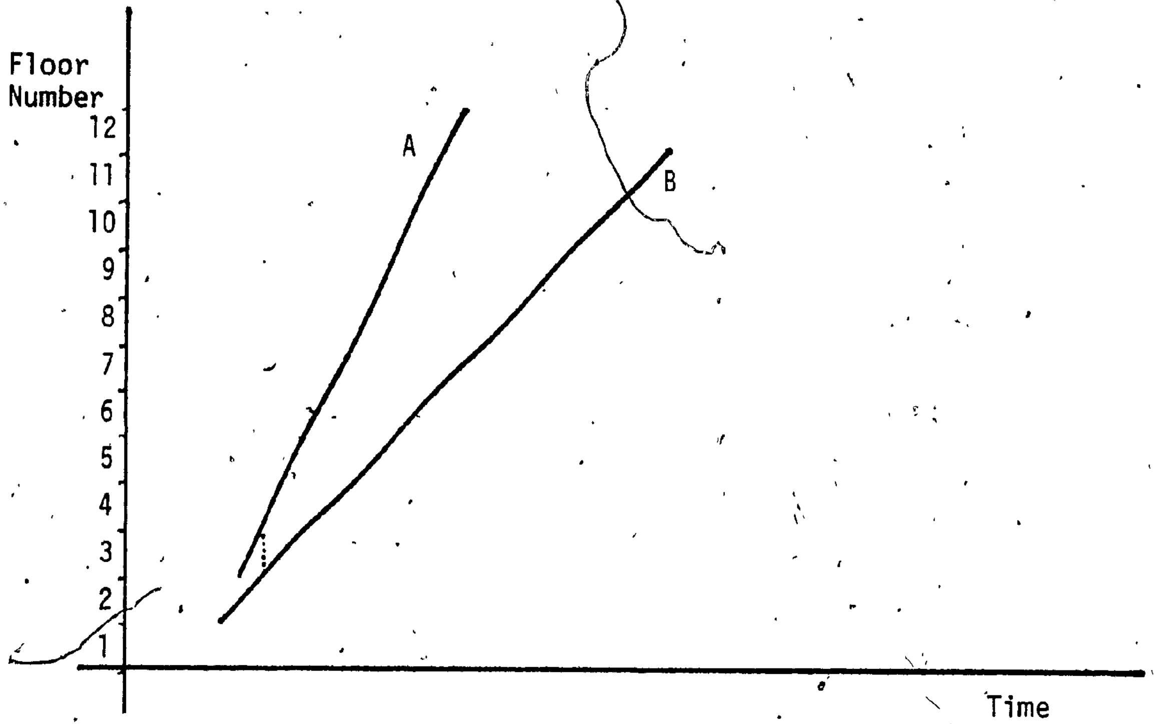
For the non-repetitive activities, if a predecessor is a completed activity (as indicated by its status), the comparison is not made with the early finish date, but rather with the actual finish date. So, a verification would be made before any calculation to see if the activity is completed or not. The relationships and equations to do this will be the same as the ones explained before (eq. 4.5 and 4.6).

For the repetitive activities, the calculation for the non-typical predecessor will be the same as explained in the previous paragraph. However, things are different when it is time to compare the arbitrary dates with the typical predecessors. An additional piece of information that has to be included for each repetitive activity is the "current level". At the beginning of a job, the current level corresponds to the first level for that repetitive activity. But as the job progresses and lower levels are completed, the current level becomes the level following the last completed level. For example, if 5 floors of the structure are completed at the end of the month, and the sixth one has started, the current level will be 6. If all the levels of a repetitive activity are completed, the current level is equal to one plus the last level: for example, if a repetitive activity is completed on all levels, and that the last one is 12, the current level is set to be 13.

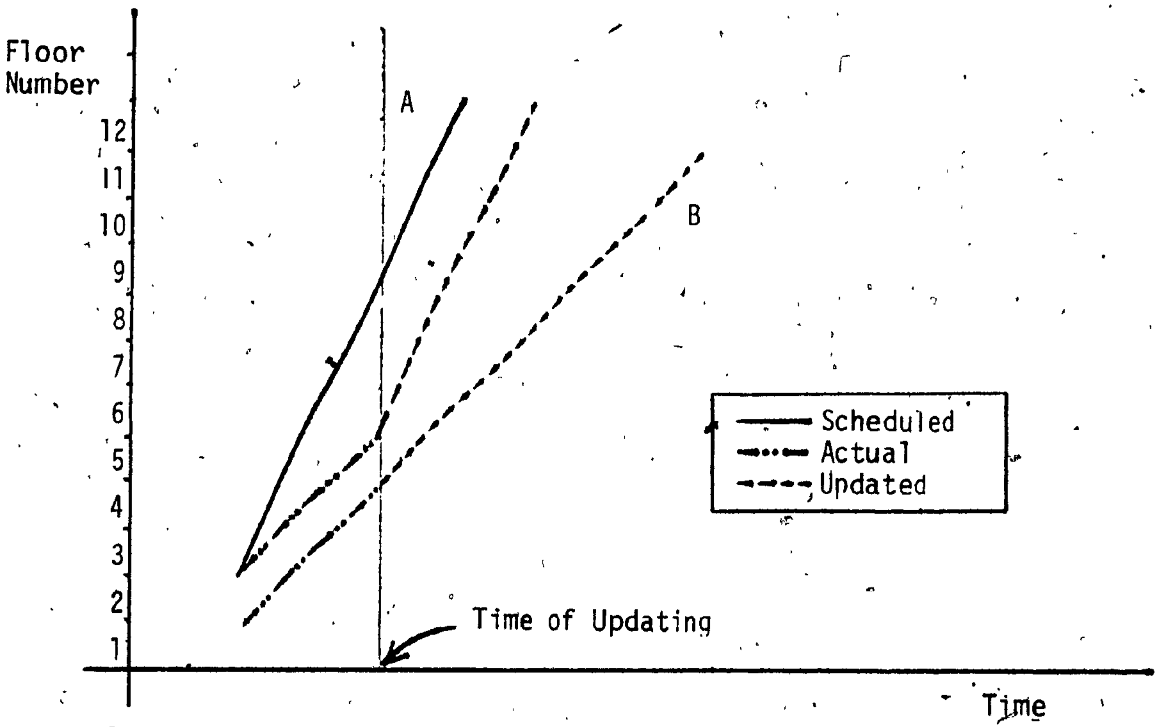
So as explained in the calculations section, the arbitrary dates will be calculated again, using equations 4.1 to 4.4 and 4.7. Now, instead of comparing all the levels of the activity with the ones of its predecessors, only the common levels between the current one and the last one will be compared. Moreover, a new dependency will exist: the current level will have as a predecessor the actual finish of the preceding level, in order to "update" that repetitive activity. Again all the calculations are in working days.

For example, consider the situation shown in Fig. 4.21: repetitive activity B is to be done on floors 2 to 10 of an 11 storey building; its predecessor, A, is to be done on floors 3 to 11. After the job is started, the schedule is updated and the current level of activity A is the 6th Floor and the one of B is the 4th floor. When compared to the mentioned predecessor, only floors 4 to 10 will be updated, because they are common to both, and above the current level of B. The 4th floor will also be compared to the actual finish date of the third floor. When a comparison is made, if the floor is completed (i.e. it is below the current level), comparison will be made with the actual start and finish dates, rather than with the early start and finish dates, like in the case of the 4th and 5th floor of B being compared with the 4th and 5th of A, which are completed (below the current level) at the time of the calculation.

All these calculations lead to the production of a new updated schedule, incorporating the actual start and finish dates of the completed activities. The impact on the remaining activities of delays or changes in the work execution will readily be shown.



(a) Scheduled Production Rates



(b) Actual Dates and Updating

Fig. 4.21 Updating Process

The third step of the updating process will consist of taking corrective action and revising the schedule by changing durations or logic, where possible, in order to meet (if possible) the project's target date. Moreover, up dating should also include corrections to duration or logic because of poor planning, unforeseen conditions or poor productivity. If one realizes that a planned production rate or duration is unrealistic, it should be reassessed and incorporated in the calculations. The "final" updated schedule issued from this process will then show a forecast of the time required to completion of the project.

It was mentioned in the previous chapter that it would be useful to develop a routine that could predict the production rates of the remaining floors of a repetitive activity by studying the performance on the completed floors, instead of using the production rates decided upon at the planning stage, for the process of forecasting time to complete, as explained above. Such a routine would have to consider several factors in order to be realistic: the nature of the activity, its complexity, its learning curve, the time of the year at which it has been performed, if it was subject to any external factors (slow deliveries of materials, union problems, etc.), the location of the site, etc. However, several of these variables are hard to quantify. The issue of using trend data for updating and forecasting is left for future work by others.

CHAPTER V

COMPUTERIZATION OF THE SYSTEM

5.1 INTRODUCTION

All the mathematical relationships described in the previous chapter were incorporated into a computer program, the design of which is described in this chapter. A part of the subcontractor control system (ref. 55, 63) has already been programmed on a micro-computer and the results have been satisfactory. In theory, the scheduling system should have been programmed on the same microcomputer, in order to interface it with the subcontractor control system. However, because of the low accessibility of the microcomputer, the author decided to do the program development on the Centre for Building Studies mini-computer, a Perkin-Elmer 3220.

In the early stages of the research project, the team analysed several computer languages and a decision was taken in favour of BASIC (ref. 63). In order to remain as close as possible to the existing programs, the Basic Level II version, available on tne Perkin-Elmer 3220, was used for programming the scheduling system.

In the first section, the fundamentals of the computer programs are explained: the data structure and the organization of the files, the structure of the program through a series of menus, the input, changes to existing data, the processing and the output. Programs are not explained step by step, but are listed in Appendix III.

In another section, the operation of the system is explained by the use of a simple example of a 16 storey building. First, all the data are input and compiled so that a first schedule can be generated. The logic and activity data are then adjusted slightly and a new run done, to show the approach of a project manager trying to get the "best arrangement" of the activities. Then some actual start and finish dates are input, to simulate the construction work in progress, and a new "updated" schedule, showing the completed activities is generated. In fact, the example simulates the use of the system, as if it was actively used for a job.

5.2 DATA STRUCTURE

5.2.1 Coding System

Each activity is designated by a unique number, composed of six digits:

xxyyzz

in which xx: identifies a subcontractor number
yy: identifies an activity number for subcontractor xx
zz: is a level number for activity yy of subcontractor xx.

The activity number, yy, determines the type of activity:

For a repetitive activity	:	from 1 to 20
For a non-repetitive activity	:	from 21 to 80
For a milestone	:	from 81 to 99

When a repetitive activity is referred to as a whole entity, for example at the time of input or when mentioned as a typical predecessor or when it is time to print, etc., the zz digits have to be 00. However, if a reference is made to a specific floor of that repetitive activity, as in the case of a specific floor of a repetitive activity being a non-typical predecessor, or being a predecessor to a non-repetitive activity, etc., the zz digits are set equal to the corresponding floor number.

In the case of a non-repetitive activity, the zz digits equal the floor number, if applicable. For example, excavation is not done on a specific floor, so the last two digits should be 00. However, the mechanical equipment of the 26th Floor should have as its last two digits 26. Table 5.1 shows some examples of activity numbers and their meaning.

Creating a file with as many records as there are possible activity numbers would waste a lot of file space. Therefore, the six-digit activity number is reduced to a number between 0 to 200 by means of a hashing routine, and this number corresponds to the record of that specific activity. It should be understood that the 200 limit for the number of records is arbitrary, and that if more records are needed, this number could be increased as long as the hashing routine is modified accordingly (see Appendix III). The file containing the various start and finish dates of the activities will require more space than the activity file, mainly because each repetitive activity requires as many records as there are floors; therefore the number of records for that file has been chosen to be 1700, which is again arbitrary. The flow-chart of the algorithm of the hashing routine is shown on Fig. 5.1.

Activity Number	Meaning
010100	Repetitive activity number one of subcontractor no. 1. Treated as a whole entity.
020101	Repetitive activity no. 1 of subcontractor no. 2, referring to the first level only.
062100	Non-repetitive activity no. 21 of the subcontractor No. 6. Not located on a specific level.
098100	A milestone for subcontractor no. 9.
012116	Non-repetitive activity no. 21 of the subcontractor no. 1, located on the 16th Floor.

Table 5.1 Example of Activity Numbers

5.2.2. Activity Files

All the activities of a project are written on one file, containing 200 records, for a possibility of 200 activities. The record number for an activity is computed from the activity's number by using a hashing routine as explained previously. In order to keep track of the activities as they are input, one item of the record consists of a pointer to

H : Record Number
HO : Hashing Number (199 or 1699 in our case)
N : Activity Number

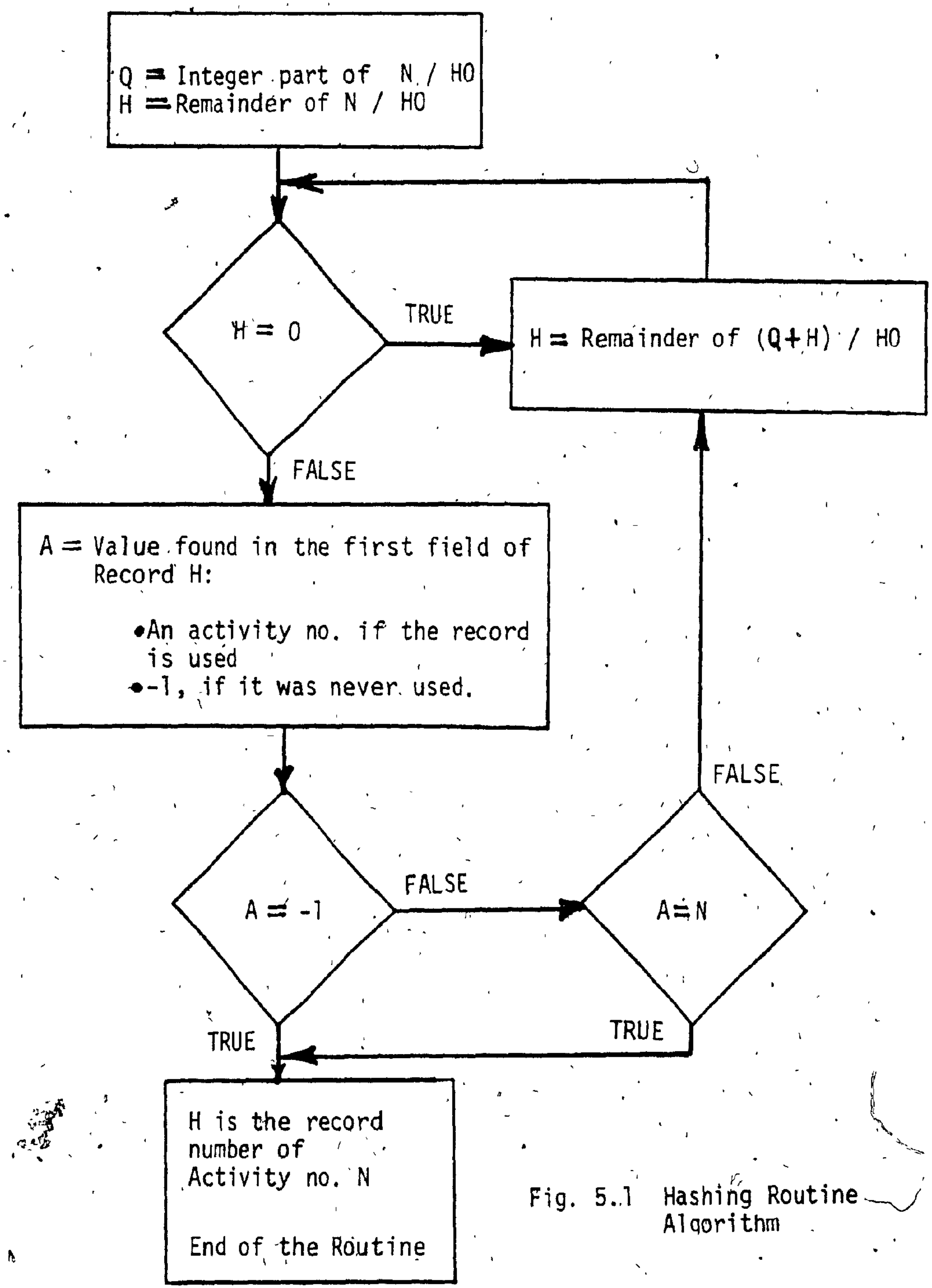


Fig. 5.1 Hashing Routine Algorithm

the record where the next activity is located, in the order of input. The record "0" of the file contains the number of activities, and the location of the first activity; the last activity has "-1" as a pointer. The explanation of the linkage of the activities is shown in fig. 5.2.

The structure of the data of one activity is very similar to one used by Tong (ref. 61). He designed a precedence network processor, in partial fulfilment of his master's degree at the Center for Building Studies of Concordia University. He suggested that the information

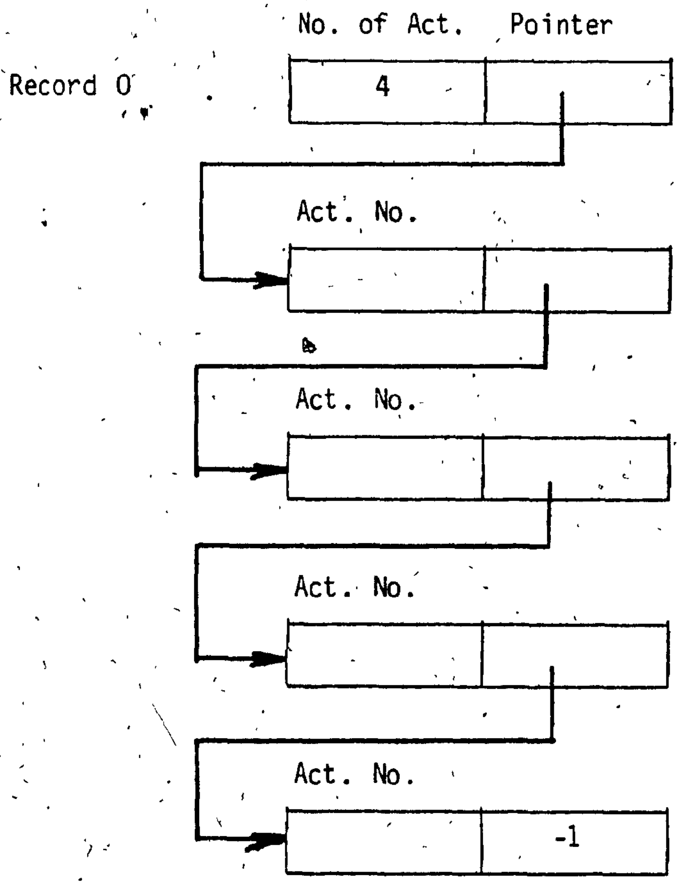


Fig. 5.2: Linkage of Activities

pertinent to one activity should be minimal and consist only of a number, a description, a duration, the number of predecessors, and those predecessors. From that information, all the processing and output could be done without adding further data.

The principle of minimal information still applies in this case, but each activity needs more than the five variables mentioned in the previous paragraph to describe it fully. In fact, a repetitive activity needs a minimum of 16 variables, in order for all the previously mentioned features to be present. At the time of the design of the system, these variables were spread over two files, although they could have been put into one larger file. In the actual version of the system, the data is still spread over two files, which contain different information depending on the type of activity (repetitive, non-repetitive, milestone).

<u>Repetitive Activity:</u>

<u>1st File:</u>

A	B	C	D	E	F	G	H	I

Where:

A: Activity number

B: Pointer to the record containing the next activity in the order of input

C: Number of typical predecessors

D: Pointer to the linked list of typical predecessors

E: Pointer to the linked list of typical successors (not part of input: derived from predecessors)

F: Number of non-typical predecessors

G: Pointer to the linked list of non-typical predecessors

H: Pointer to the linked list of non-typical successors (not part of input: derived from predecessors)

I: Description of activity (character string).

<u>2nd File:</u>

A	B	C	D	E	F	G	H	I

A: Starting Level

B: Current level

C: Ending level

D: Number of crews

E: Production rate

F: Start to start relationship between floors

G: Finish to start relationship between floors performed by the same crew

H: Pointer to the linked list of coefficients of efficiency

I: Weather factor (0 or 1 for no or yes).

Non-repetitive Activity:

1st File:

A	B	C	D	E	F

A: Activity number

B: Pointer to record containing the next activity in the order of input

C: Number of predecessors

D: Pointer to the linked list of predecessors

E: Pointer to the linked list of successors (not input but derived from predecessors)

F: Description of activity (character string)

2nd File:

A	B	C	D

A: Duration

B: Pointer to the linked list of the procurement activities

C: Weather factor (1 or 0 for yes or no)

D: Status (1 or 0 for completed or not)

Milestones:

1st. File:

A	B	C	D

A: Number of the milestone

B: Pointer to the record containing the next activity in the order of input

C: Pointer to the linked list of successors

D: Description (character string)

2nd File:

A

A: date (the input is a date, but it is immediately changed to its working day equivalent, from the calendar).

Two other files (the 3rd and 4th) are used to store the various linked lists mentioned in the above description. One of these files has two fields (the 3rd), and the other one (the 4th) will have three fields in order to suit the different applications. Each link list requiring the use of one of these two files will now be explained. The mechanism by which the record number is chosen from the list of available records and by which a record that is no longer needed is returned to the list of available records will not be explained here. More information on this issue can be found in any book on data structures (ref. 25, page 114).

5.2.2.1 Repetitive Activity:

1st File:

A	B	C	D	E	F	G	H	I

Recall: D, E, G and H were pointers to linked lists.

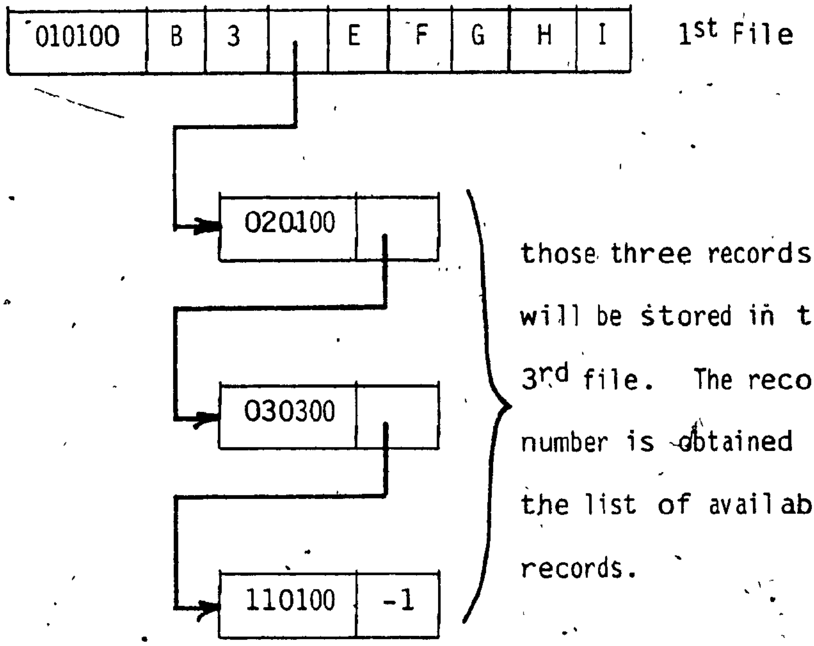
D is a pointer to the linked list of typical predecessors. If there is no typical predecessor, D is set equal to -1. If predecessors exist, D will be the number of the record in file 3 in which the activity number of the first predecessor is located.

For example, suppose activity No. 010100 has three predecessors, activity numbers 020100, 030300 and 110100. The data is assigned as shown in Figure 5.3. One field of the record contains the activity number of the predecessor, and the other field contains a pointer to the next predecessor. The last predecessor has a pointer of -1. As we can see, there is no limit to the number of predecessors that an activity can have.

E is also a pointer to a linked list, but this time to one of the typical successors of that activity, which is derived from the predecessors. The structure of the list is exactly the same as in Fig. 5.3, i.e. one field contains the activity number, and the other field, a pointer to the next record.

G is a pointer to the list of non-typical predecessors. This time however, three fields are required, so the records of file #4 have to be used. As before, one field contains the activity number of the predecessor, and the other, a pointer to the record where the next non-typical predecessor is located (if any). However, a non-typical predecessor imposes a dependence on only a specific floor of a repetitive activity; so the other field contains the floor number which is dependent on that non-typical predecessor.

For example, assume that activity 010100, a repetitive activity has 3 non-typical predecessors: the first one is a milestone, No. 098100,



those three records will be stored in the 3rd file. The record number is obtained from the list of available records.

Fig. 5.3 Typical Predecessor Arrangement

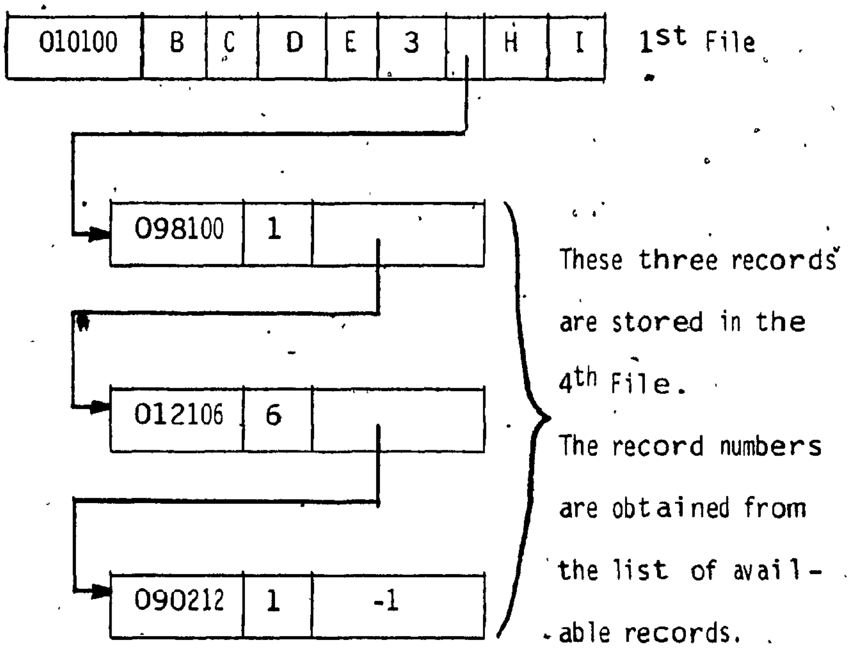
which precedes the first floor of 010100, the second one is a non-repetitive activity, No. 012106, which precedes the 6th floor, and the last one is the 12th floor of activity 090200, a repetitive activity, which precedes the 1st Floor of activity 010100. The arrangement of these non-typical predecessors is shown in Fig. 5.4(a).

Finally, H is a pointer to the linked list of the non-typical successors of that activity, which are derived from the predecessors of the activities. The structure is again similar, but this time, the floor number is the one which is followed by that successor. For example, in Fig. 5.4(a) activity 010100 is preceded by the 12th floor of the repetitive activity 090200; therefore, activity 090200 should have among its non-typical successors, the 1st Floor of activity 010100, and this successor will follow floor No. 12. This situation is shown in Fig. 5.4(b).

2nd File:

A	B	C	D	E	F	G	H	I

"H" is a pointer to the linked list of coefficients of efficiency. The coefficients are used to increase the production rate of some floors of a repetitive activity to account for learning effects (see section 4.3.3). Each record in the list should contain three fields: one for the floor number, one for its coefficient of efficiency



These three records are stored in the 4th File. The record numbers are obtained from the list of available records.

Note: reference is made to the 12th floor of repetitive activity 090200

Fig. 5.4(a) Non-typical Predecessor Arrangement

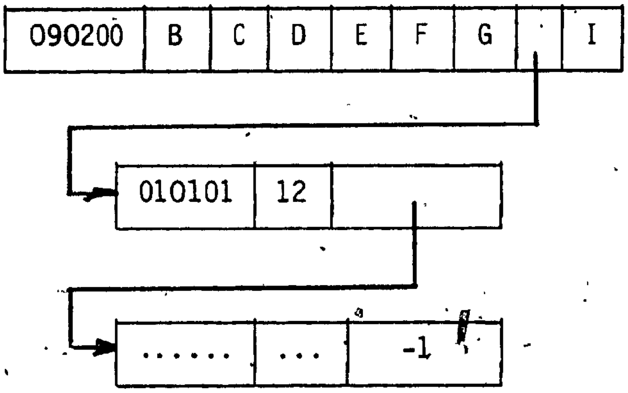


Fig. 5.4(b) Non-typical Successor Arrangement

(as a percentage) and the last one is a pointer. If there are no learning effects, H is set equal to -1. For example, assume floors 1, 2, 3 and 4 have coefficients of 50%, 60%, 75% and 90%, respectively. The linked list structure would then be arranged as in Fig. 5.5. As in the case of the predecessors, there is no limit to the number of items that the list can contain.

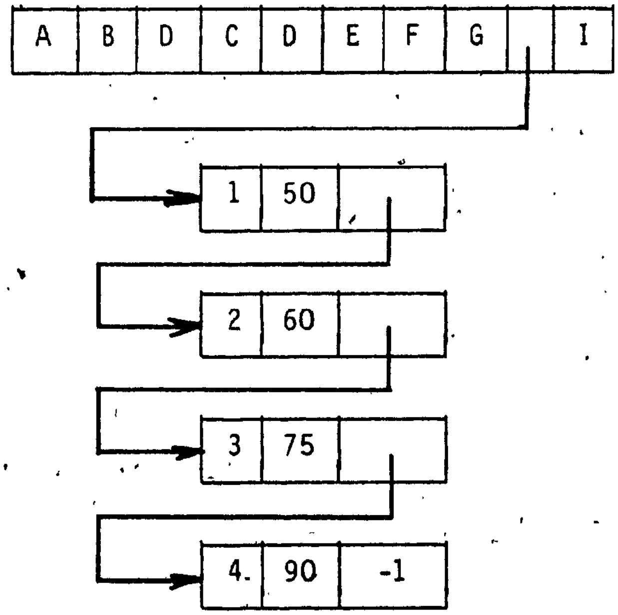


Fig. 5.5 Arrangement of List of Production Coefficients

5.2.2.2 Non-Repetitive Activites

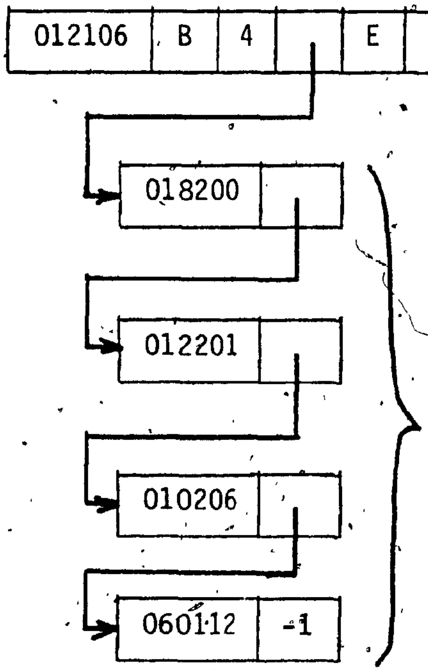
1st File:

A	B	C	D	E	F

Non-repetitive activities have only one kind of predecessor, and the only information that is required is an activity number. Therefore, the list of predecessors contains only 2 fields: one for the activity number, and the other for the pointer to the next activity on the list. So the list is formed by using the records of file #3; "D" is its pointer.

For example, assume activity 012106, a non-repetitive activity, has 4 predecessors: the first one is milestone No. 018200, the second, non-repetitive activity 012201, the third, floor No. 6 of the repetitive activity 010200 and finally, floor No. 12 of the repetitive activity 060100. The linked list structure would be arranged as in Fig. 5.6.

Moreover, the field "E" is also a pointer to a linked list. But this time it points to the list of the successors of activity number "A". The structure of the list is identical to the one for the predecessors, and the records, requiring only 2 fields, are stored in the 3rd file. Again this list is not input, but rather derived from the predecessors.



The four records are stored in the 3rd file. The record number is obtained from the list of available records.

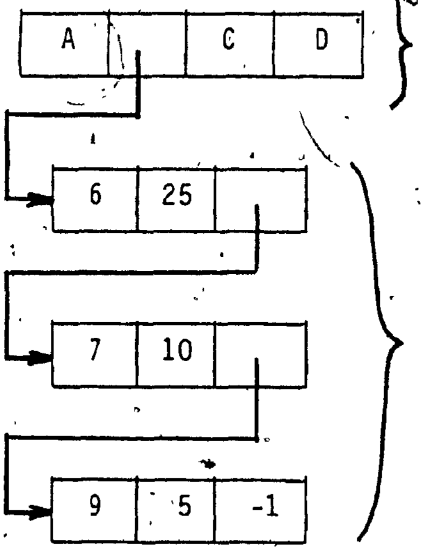
Fig. 5.6 Arrangement of Predecessors of a Non-Repetitive Activity

2nd File:

A	B	C	D

The field "B" of the second file for a non-repetitive activity also contains a pointer to a linked list. This one contains the sequence of procurement activities, which are chosen from a menu of 9 tasks, as mentioned in the previous chapter (section 4.3.5). The records of this list require three fields: one for the number of the procurement task, one for its duration (in working days) and the third one is a pointer to the next item of the procurement sequence. If an activity does not have a procurement sequence, the field "B" will have a value of -1.

For example, assume activity number 012106, has 3 items in its procurement sequence, which correspond to numbers 6,7 and 9 of the list of the procurement activities (i.e. fabrication by the vendor, shipping and delivery/inspection, respectively). These tasks have durations of 25,10 and 5 days, respectively. They would therefore be arranged in a linked list as shown in fig. 5.7.



2nd File
Record corresponding to required activity

These records are stored in the 4th file

Record numbers are obtained from the list of available records

Fig. 5.7 - Arrangement of the Procurement Sequence of a Non-Repetitive Activity

5.2.2.3 Milestones

1st File:

A	B	C	D

The field "C" corresponds to a pointer to a linked list, containing its successors. The successors of a milestone are basically similar to the successors of a non-repetitive activity. Therefore, the structure of the items is identical: one field for the activity number, and another one for the pointer to the next item on the list. Once again, the successors are not part of the input routine, but rather derived from the predecessors. The arrangement of the successors of a milestone is very similar to the arrangement shown in fig. 5.6, except that the pointer is in the 3rd field, instead of the 4th one.

5.2.3 Other Files

The scheduling system, as programmed by the author accesses also three other files: one contains the record numbers of the activity sorted in two different ways: increasing activity number, and sequential step order; another one contains all the activity start and finish dates; and the last one contains the equivalent of working days to calendar days. Besides the holidays that are input to generate the "working" calendar days, and the start and finish dates that are input as the job goes along, the fields only contain information which has been calculated by the various programs of the system. They are mainly used to save time, when one wants to reproduce an output or only recalculate the dates, without changing the logic.

5.2.3.1 File of Sorted Activity Numbers

Record No: i

A	B

The record number i of the file contains 2 fields: A is the record number of the i^{th} activity in the sequential step order and B is the record number of the i^{th} activity in the increasing activity number order.

For example, assume that a network has 5 activities whose numbers are: 010100, 010200, 062100, 098100, 012216. After all the information is entered, stored in the activity files and compiled, it is found that the sequential step order is (say): 098100, 010100, 010200, 012216 and 062100. Suppose also that the activity data is stored (respectively) in the following records of files 1 and 2 (obtained from hashing routine): 192, 150, 51, 77 and 12. Therefore, this file would contain the following information (Table 5.2).

Record	Sequential Step (A)	Increasing Activity Number (B)
1	192	150
2	150	51
3	51	77
4	77	12
5	12	192

Table 5.2 - File of Sorted Activity Numbers

5.2.3.2 File of Dates

A	B	C	D	E	F	G

This file contains the most records, because each non-repetitive activity has one record, and each floor of a repetitive activity also has a record. So, for example, if a network has 20 non-repetitive activities, and 30 repetitive activities over 25 floors, a total of 770 (20 + 25 x 30) records will be required to store all the dates that will eventually be computed. This is why this file has presently a size of 1700 records.

Each record of the file has seven fields, described as follows:

A: activity number (XXYYZZ)

Note: if the activity is repetitive ZZ will be the floor number that is specified.

B: Early start date
C: Early finish date
D: Late start date } computed
E: Late finish date
F: Actual start date } input by user
G: Actual finish date

In order to facilitate the calculation mechanism, all the dates are expressed in "working days after the start of the project". They are converted to calendar dates for output purposes, by accessing the "calendar dates" file. Even the actual start and finish dates, which are input by the user in a calendar date format (year/month/day) are changed to working days at the time they are input.

The record numbers are again determined by a hashing routine, which generates this time a number between 0 and 1700. In order to avoid confusion, the two files containing the activity data (file 1 and 2) and this file of dates should be considered completely independent.

5.2.3.3 File of Calendar Dates

Record i:

A	B.

Each record of this file corresponds to one working day and contains two fields: the first one (A) is a number from 1 to 5, representing the day of the week (1 = Monday, 2 = Tuesday, etc.), the second one (B) contains a six digit number, representing a date (YYMMDD) where YY is the year, MM is the month and DD the day. So March 1st, 1983, would be represented as 830301. This notation has been chosen in order to facilitate generation of the calendar.

The only information that is required to generate the calendar is a start date, which corresponds to the first working day, and all the holidays, other than weekends (Saturdays and Sundays). The program then finds, for each working day the next available "workable" day of the calendar. A slight modification to the algorithm could treat weekends as "workable day", but changes in the software are required (see Program "Calendar" in appendix III).

For example, if a project starts on August 29th, 1983 (Monday), the first 10 records of the calendar file correspond to the first 10 working days. In fact, the ith record of the calendar file has the calendar date of the ith working day. Knowing that September 5, 1983 is a holiday because of labour day, the first ten calendar dates corresponding to the first ten working days are shown in table 5.3.

Record No.	Day of the Week	Date
1	1	830829
2	2	830830
3	3	830831
4	4	830901
5	5	830902
6	2	830906
7	3	830907
8	4	830908
9	5	830909
10	1	830912

TABLE 5.3: File of Calendar Dates

5.3 FUNDAMENTALS OF THE SYSTEM

The scheduling system is composed of ten programs, of which nine are called by a main program labeled "main". This program is similar to a main program calling nine different subroutines, depending on the requirements of the user. The programs have been designed to facilitate as much as possible the use of the system. For decisions that have to be made by the user, there is a menu that outlines the possible alternatives. The program "main" contains the first menu in the hierarchy which contains the following options:

MENU

1) Start a new project
2) Input new activities
3) Delete activities
4) Change precedence
5) Change activity name
6) List activities
7) Compile data
8) Execute data
9) Print results
10) Input or change activity data
11) Short cycle schedule
12) Procurement status report
13) Prepare calendar
14) Quit

Each of these options has its own submenu, orienting the user towards his needs. Whenever the program "main" calls one of the subprograms, a "Name of File?" question will appear before any operations are performed. This question will not be included in the explanation of the various menus, although it appears in almost every case. Fig. 5.8 shows the structure of the main menu. Each of these options is explained below, along with the related submenus. They are grouped under five main headings: starting a new project, input of data, processing, changes to the data and output of data.

5.3.1 Starting A New Project

When starting a new project, two options of the menu have to be executed: the files have to be created (item 1, main menu) and the calendar has to be prepared (item 13, main menu).

5.3.1.1. Start A New Project

This option calls the program "new". The user is asked if he wants a standard network, previously stored in a file, to be copied into the new file as a starting point. The program then creates all the required files and indexes them properly so that they can be used in the other programs. Once these operations are completed, execution returns to the main program and the main menu reappears. Fig. 5.9 shows the structure of that first option of the main menu.

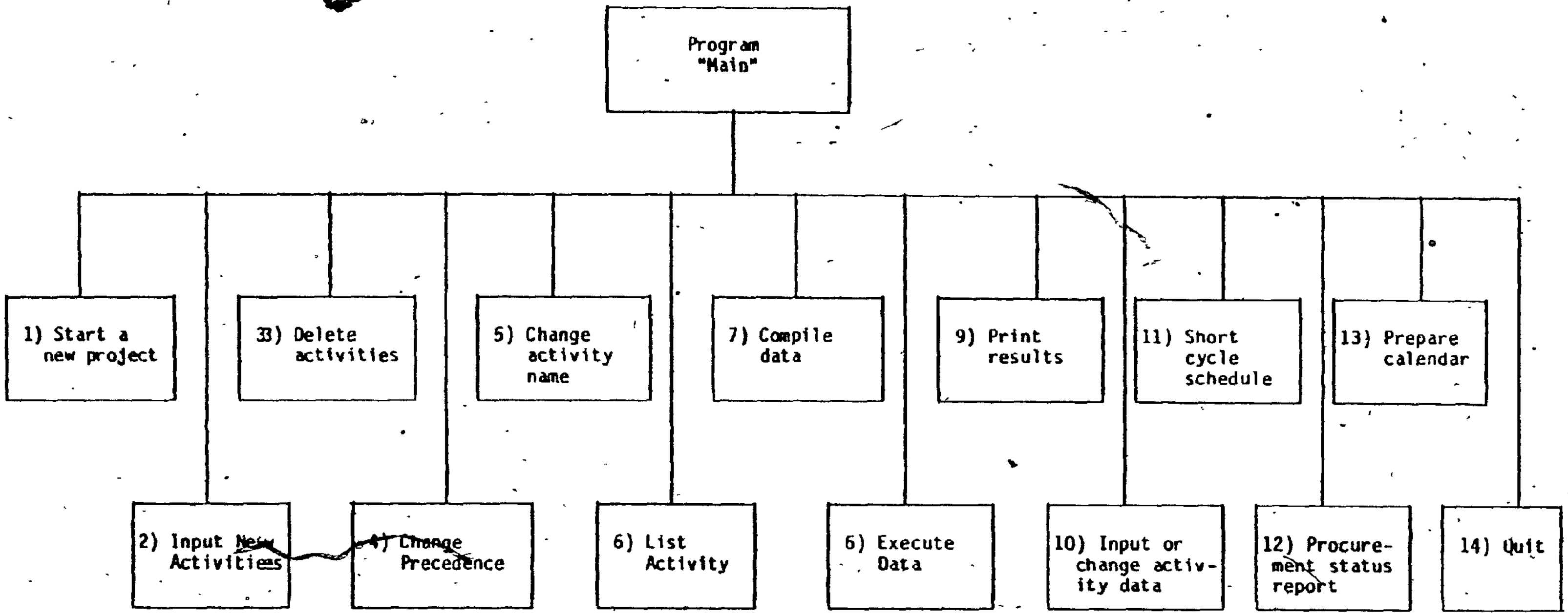


Fig. 5.8 - Structure of the Main Menu

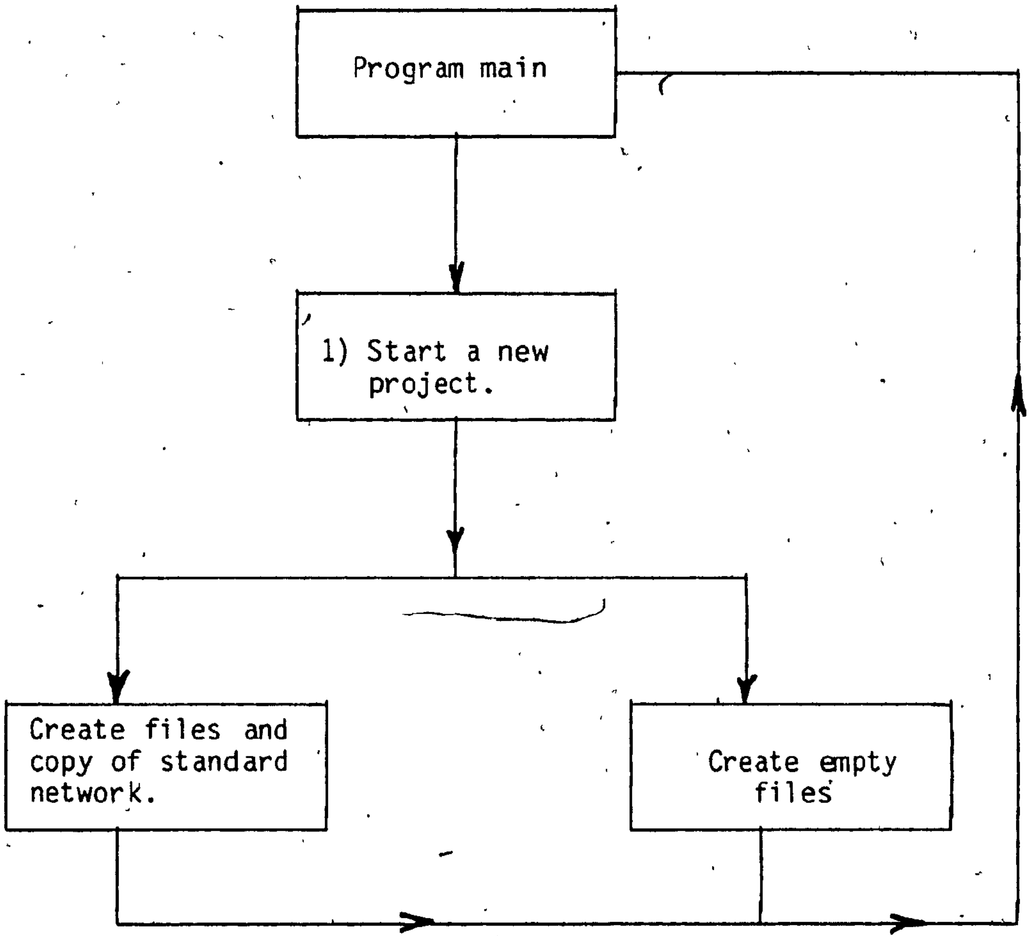


Fig. 5.9 Start a New Project

5.3.1.2 Prepare the Calendar

This is the 13th option of the menu and it calls the program "Calendar". This routine first asks for the starting date of the project and the day of the week that date corresponds to. Then, all the holidays during the construction period are input along with the number of working days for which calendar dates should be determined. The order of input of these holidays is of no importance, because the program orders them before starting the computations.

Starting at day 1 and going up to the number of working days required by the user (could be a very large number), the program finds the corresponding calendar date. After execution is completed, it is transferred back to the main program and the main menu reappears. The structure of the program is shown in Fig. 5.10.

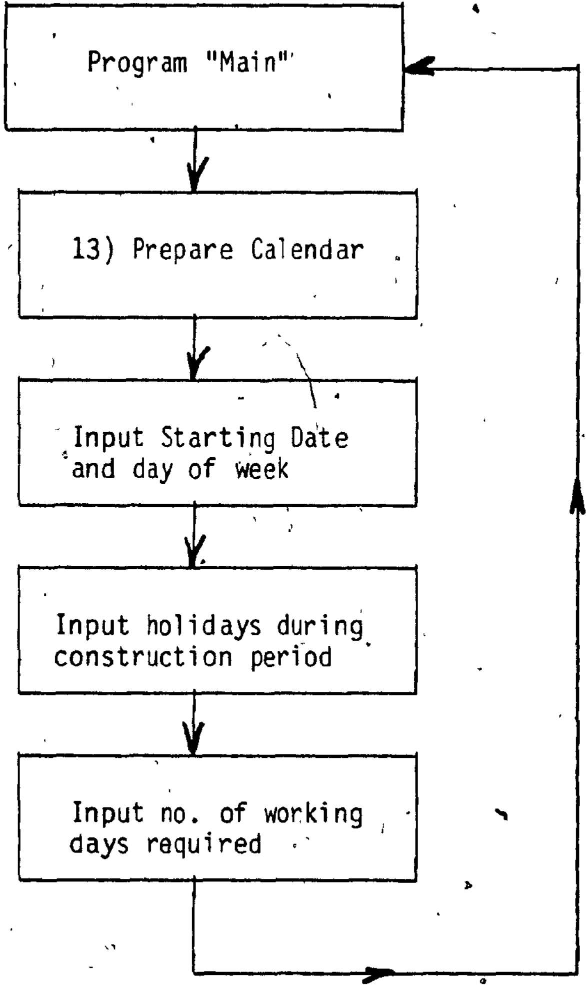


Fig. 5.10 Prepare Calendar

5.3.2 Input of Data

The input of data is done using two options of the menu which correspond to the two activity files mentioned in the data structure. One of these files contains the information about the activity and its relation with others: Activity number, predecessors (typical or non-typical), and the description of the activity. The other file, contains information about the activity itself: the duration (production rate), weather effects, learning effects; etc. The structure of these options is now explained.

5.3.2.1. Input New Activities

This is the 2nd option of the menu and is part of the main program. It is used whenever new activities have to be input into the system, either at the beginning of a job or midway through a job, when some activities have to be added. The main identifier of an activity is its number, so great care must be taken when it is input. The following rules apply: the two middle digits define the type of activity, as mentioned in the coding system (see section 5.2.1). If an activity is repetitive, the last two digits have to be 00.

The first item input by the user is the activity number. This number defines the type of activity and is used to direct the execution of the program through one of three different sequences of statements depending on whether the activity is repetitive, non-repetitive or a milestone. The description of the activity is entered after the activity number.

If the activity is repetitive, the number of typical predecessors is the next item input, followed by the activity numbers of the predecessors. Then the number of non-typical predecessors is entered, followed by the activity number of each predecessor, and in each case, the level that it precedes. Following this input, execution of the program returns to the top of the program to read another activity number.

If the activity is non-repetitive, only the number of predecessors and those predecessors is input, because there is only one type of predecessor. In the case of a milestone, it does not have any predecessor by definition, so execution returns to the top to read another number. A value of zero (0) as an activity number stops the input and returns execution to the main menu. Before printing the menu, the total number of activities is shown on the screen. Fig. 5.11 shows the structure of this option. It should be noted that there is no specific order for the input of the activities, or of their predecessors. It is only when the data is compiled, that the suitability of the relationships is checked.

5.3.2.2. Input or Change Activity Data

This is the 10th option of the menu and it calls the program "DATA". Because this program is used to enter new information and update old information, it first asks the user if he wants to enter new information or update. The difference between the two is that in the

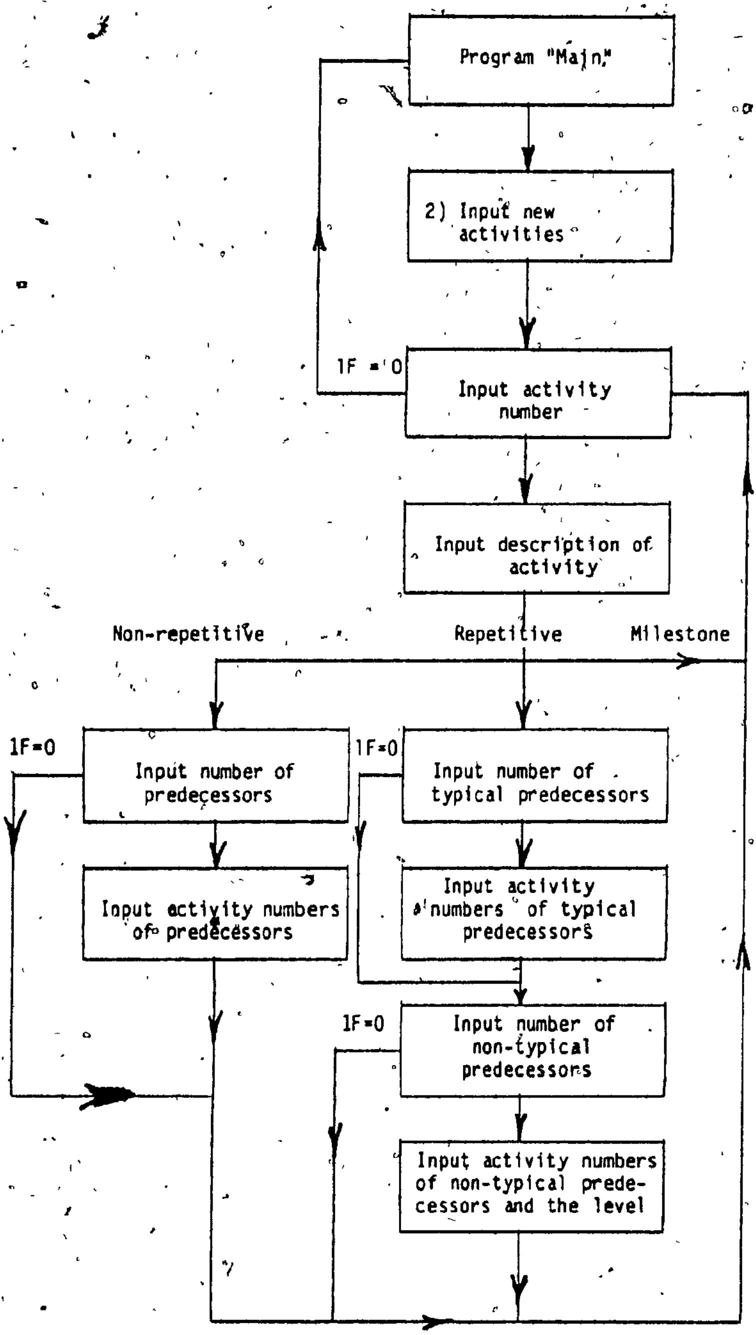


Fig. 5.11 Input New Activities

case of updating, the old information is shown first, whereas in the case of new information, the data is input right away. This mechanics is used to input the weather factors, which are used in correcting the durations of activities influenced by weather, and actual start and finish dates of activities as the job is executed. Treatment of the input for updating is done in a later section, although the input of actual start and finish dates is explained herein.

When inputting activity data, the user has two choices: either to input it randomly (i.e. the user picks the activity number he wants to refer to) or to input it sequentially. In this case the user selects the sequence in which he would like to enter activity data: in the order of input, the sequential step order or the increasing activity numbers. The operations required to input the activity data are independent of how the activities are sequenced.

For a repetitive activity, the program asks the user to input, one after the other, the following nine items: the starting level, the current level (equal to the starting level in the case of new data), the last level, the number of crews, the production rate per floor, the start to start relationship, the finish to start relationship, the production coefficient sequence and the weather factor. All these variables require the input of only one numerical value except for the sequence of production coefficients. In this case, two values are entered per floor: the floor number and the production coefficient. The program keeps prompting for these two values until two zeros (0,0) are entered. In the case of no floors requiring adjustment, zeros are entered as the first item and the list will be empty.

Once all the values have been input, they reappear on the screen (Fig. 5.12 (b)) in order for the user to check them; if any modifications are required, the user just has to input the number corresponding to the item he would like to modify; in the case of the production coefficient sequence, only the pointer appears; if it is minus one, it means that the list is empty; if it is different than minus one, choosing that item leads to the list being displayed followed by the user being asked for changes; asking for changes will delete all the old list, and thus a new sequence should be input. If everything is correct, choosing 10 (quit) will get the next activity if it is sequential, or ask the user for another activity if it is randomly accessed. Putting a value of zero for the starting level at any time stops the input and sends the execution up to the first menu, without storing any values. This enables the user to get out of the sequential input without having to go down to the last activity.

For a non-repetitive activity, only four items have to be input: the duration of the activity, the procurement sequence, the weather factor and the status. All these variables, except the procurement sequence require the input of only one value. The case of procurement activities is very similar to the sequence of production coefficients explained previously. First, the nine procurement tasks appear on the screen in order to guide the user; then, the procurement tasks are input in chronological sequence by entering item number and the duration. Entering 0,0 will stop the input. If an activity does not have a procurement sequence, 0,0 should be input as the first two entries.

After the four items are entered, they reappear on the screen as a check point (fig. 5.12 (b)) and any item could be modified by inputting the number corresponding to it; again, in the case of the list of procurement activities, only the pointer appears; if it is minus one, the list is empty; if it is greater than zero, it means that there is a list of procurement activities that can be displayed by choosing the item number 2. Once it is printed, the user asks if he wants changes (Fig. 5.12 (b)); again, asking for changes will delete the old list and a new procurement sequence should be input. Choosing item 5, quit, results in that activity being left and the next one obtained. At any time, inputting a negative value for the duration stops the input and sends the execution to the top of the first menu.

In the case of a milestone, only one variable, the date, has to be input. It is entered in the following format: YYMMDD where YY is the year, MM the month and DD the day. For example, April 3rd, 1983 would be input as 830403. After it is input, the program checks with the calendar to see if that date exists, and if so, stores the equivalent working day. If that date does not correspond to a working day, an error message is written asking the user to input a new date. Inputting zero as a date sends execution of the program to the first menu.

Part of that first menu includes the input of weather factors and actual start and finish dates; the input of weather factors simply consists of inputting sequentially 12 values between 0 and 100, corresponding to the percentage of efficiency for each month starting with January. Suggested percentages were shown in Table 4.1 and are used in this thesis.

Finally, the input of actual start and finish dates which are really part of the updating process, starts by asking the user to input an activity number. It should be remembered that in this case, repetitive activities are input with the last two digits being the level number, because a repetitive activity as a whole entity cannot have a start and finish date; therefore, the specific level has to be identified. The next step is to enter two dates which are checked to make sure that they correspond to working days. The input of these dates is terminated by entering zero as an activity number.

Figure 5.12 (a) and 5.12 (b) show the configuration of this option of the main menu.

5.3.3. Processing

The processing part of this program does not require any input by the user and is separated into two parts which correspond to two items of the menu: compile data and execute data. Both of these procedures could have been put together in one program, but one part would have been redundant in the case of minor changes to the data. So, in order to save execution time, the programs have been kept distinct.

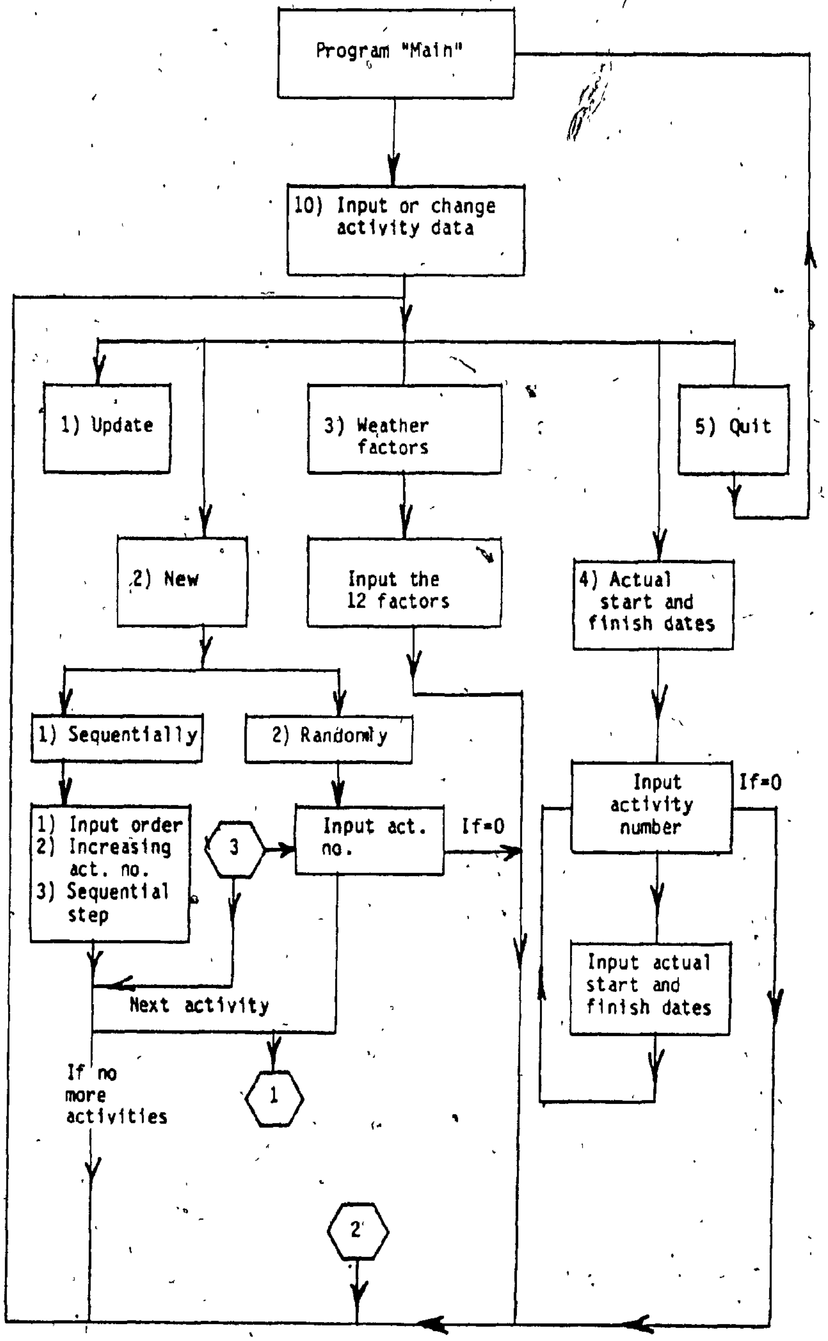


Fig. 5.12(a) - Input or Change Activity Data

⬡ : represents a transfer to fig. 5.12(b) or fig. 5.15

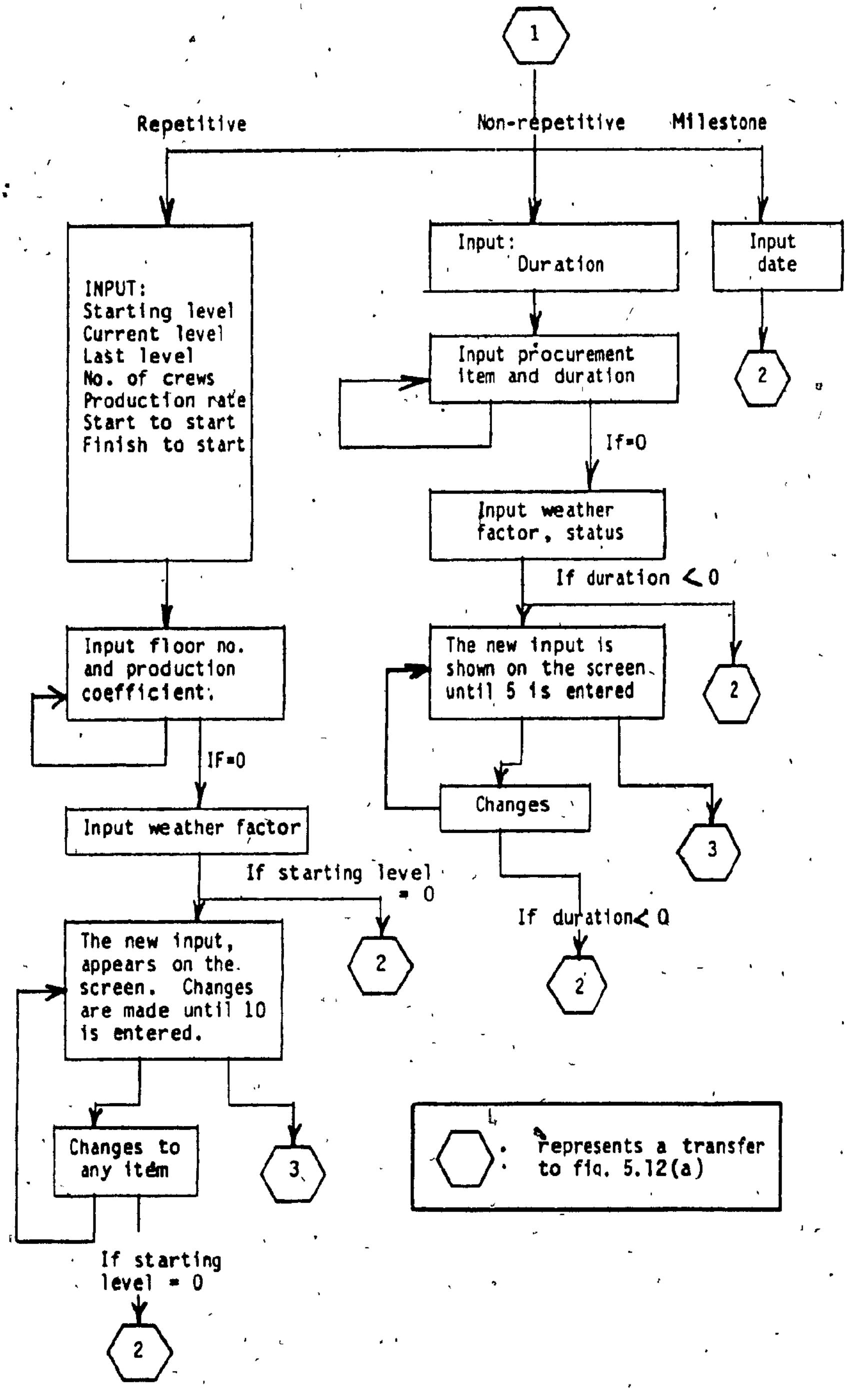


Fig. 5.12(b) - Input or Change Activity Data (cont'd)

5.3.3.1 Compile Data

This is the seventh option of the main menu and it calls the program "SUCS". This routine performs several operations which include checking the validity of the precedence links and sorting the activities. Only the data contained in the first activity file, activity number, number of predecessors and predecessor identities are required at this stage. Therefore, this routine can be executed without inputting the activity data of the second file (option 10 of the menu).

The program first deletes all the previously generated successors of the activities, if any, and returns the records to the list of available records (this was done by the author to facilitate the programming of that section). Then, all the predecessors are checked to make sure that they refer to an existing activity number; if such an activity number does not exist, the predecessor is deleted, but the program does not warn the user about it. Then, a new list of successors is formed by looking at the predecessors of each activity.

Now that each activity has a list of successors, the activities are put in sequential step order, as explained before and finally, the activity numbers are sorted in increasing order for output purposes. The results of the last two operations are stored in a file in order to avoid repeating them whenever one of the foregoing sequences of activities is required.

Note that none of these operations require the use of the activity data of the second file. Therefore, if no change in the number of activities or their logic is made, it is not necessary to compile the data again. Once a job is started and the logic is well defined and "frozen", one is more likely to change the duration or production rates, not the logic. In this case, only the "execute data" option needs to be performed. The structure of the "compile data" option is self explanatory, because it does not require any input. After it is executed, the program is transferred to the main menu.

5.3.3.2 Execute Data

This is the eighth option of the menu and it calls the program "COMP". This program uses data which is found in the various files, but does not require any input by the user, except before the start of execution: a question will appear on the screen: "REARRANGE FILE? Yes or No". Answering yes to that question eliminates all obsolete data, such as dates of activities that do not exist, etc. This procedure is not required if no changes were made to the activities.

This program requires that the procedure "SUCS" be done previously and that all data specific to any activity has been already input. It is the program in which all the previously explained algorithms (section 4.3.2) are executed. Without going in further detail, a forward pass is done by accessing each activity, one by one in the sequential step order, followed by a backward pass using the latest finish date computed as the project duration. This is done by accessing each activity in the reverse of the sequential order (i.e. last one = first one). Also included in this program are the adjustments for weather (which requires generation of the calendar) and learning effects for the repetitive activities.

The results of the calculations are stored in the file of dates which are accessed later for output presentations. After execution, the program returns to the main menu.

5.3.4. CHANGES TO EXISTING DATA

The ability to modify easily the data base of the system is essential for its application in a real situation. As it is now, any information in the files can be modified, but the interaction with the user could be improved (this might represent future work). Four options of the menu enable the user to modify information: delete activities, change precedence, change activity name and input or change activity data. Each of these options is now explained.

5.3.4.1 Delete Activities

This is the third option of the menu and its code is included in the program "main". This routine is used to delete activities from the network. If an activity number has to be modified for any reason, the activity should first be deleted, and then re-input with its new number.

The program first asks the user to input the activity number that is to be deleted; then the program returns all the records of the various linked lists to the list of available records and adjusts the linked list of the activities between themselves. The counter of the number of activities is also decreased by one. The program then asks the user to input another activity number that is to be deleted. Entering zero as an activity number stops the process and brings the execution to the main menu. It should be mentioned that when an activity is deleted, no modification is made to the activities that had that activity as a predecessor; therefore great care should be taken in checking the required adjustments.

5.3.4.2 Change Precedence

This is the fourth option of the menu, and it calls the program "CHPRE". In this option, the user can either delete a predecessor or add a predecessor to any activity. The linked list structure, besides being efficient in terms of storage requirements also facilitates addition or deletion of any element in the list (ref. 25, pages 26 and 27).

In any case, the user will be asked to input an activity number and a predecessor number; if the activity number corresponds to a repetitive activity, the user will be asked to specify if the predecessor is typical or non-typical. This is used to designate the pointer to the right linked list.

For the case of deleting a predecessor, the action of the program consists of verifying if the activity number exists and then screening linked list of predecessors to see where it is located. If the number is not found an error message "Predecessor not found" appears and execution returns to the top of the program. If the number is found, the record is deleted from the list, returned to the list of available records, and the linked list of predecessors is adjusted. Again, execution of the program continues at the start of the program.

In the case of adding a predecessor, the program inserts the new predecessor in the previous list of predecessors. In the case of a non-typical predecessor for a repetitive activity, the user also has to input the level that it precedes, as when a new activity is input. The program asks the user "For which level?" at that stage. When the lists are adjusted, the execution again moves to the top of the program.

The third choice of the sub menu is "Quit", and it brings the user back to the main menu. The structure of that option is shown on Fig. 5.13.

5.3.4.3 Change Activity Name

This is the third option of the menu and its code is included in the program "main". This routine is used to modify the name of any activity. The activity number is input, and the current name is printed on the screen. Then the user inputs the new name and execution returns to the initial point to get another activity number. Entering zero as an activity number stops the input and returns the execution to the top of the main menu. The simple structure of this option is shown in Fig. 5.14.

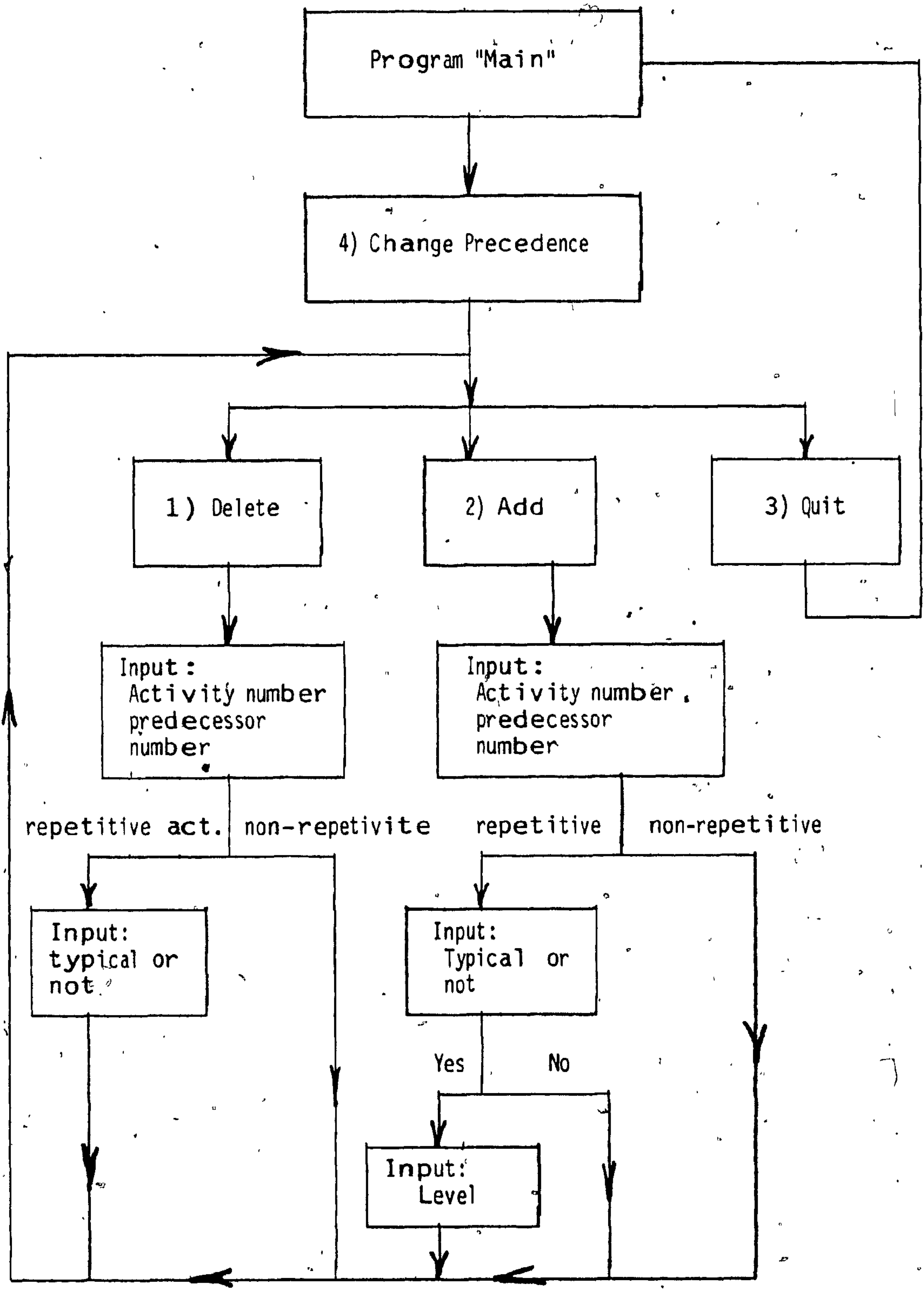


Fig. 5.13 Change Precedence

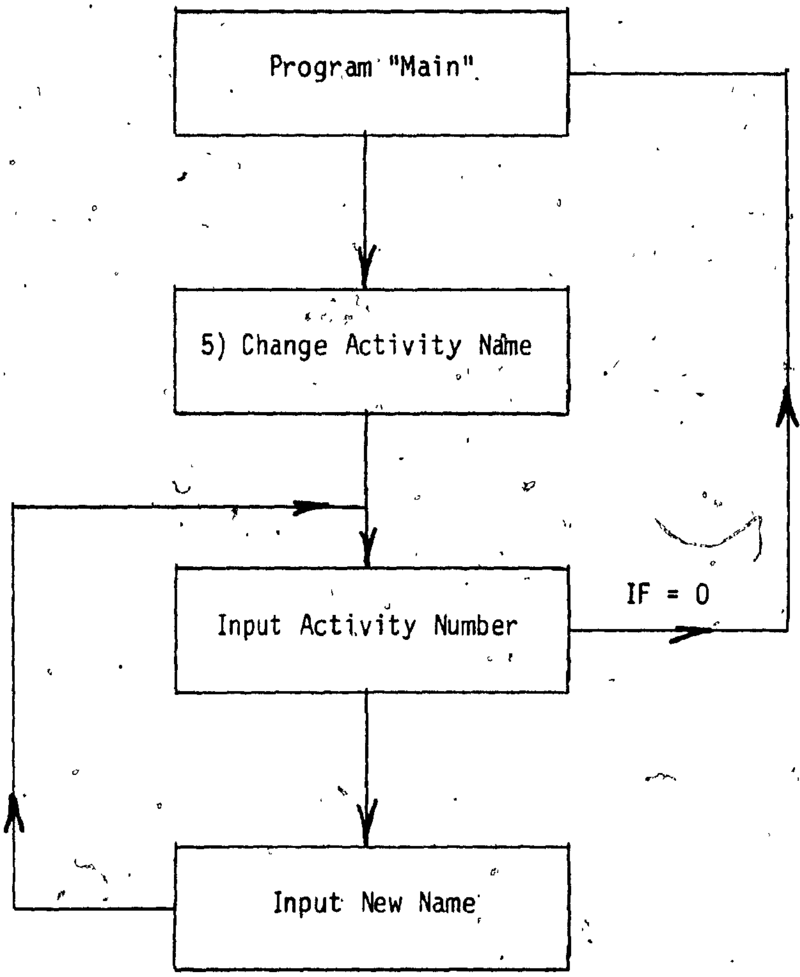


Fig. 5.14 Change Activity Name

5.3.4.4 Input or Change Activity Data

This option of the menu has already been treated in section 5.3.2.2 for the case of the input of new activity data. But one item of the submenu (see Fig. 5.12(a)), "update" had been deliberately left aside for treatment in this part of the description, because of its characteristics. The sequence of the "submenus" of the option "update" is exactly the same as for the option new, up to the point where activity data is to be input. So, the program asks the user if he wants to go through the activities sequentially or randomly. In the case of the former, it asks the user to specify the type of sequence (order of input, increasing activity number or sequential step order), and for the latter, it asks for an activity number.

The main difference between the "new" and "update" option is that in the "update"option, the old data readily appears on the screen, and the user has the choice to access the item he wishes, without having to go through each of them. From this point on, the program execution is identical to the "new" option, and the corresponding section (5.3.2.2) should be referred to. The structure of the option is shown in Fig. 5.15.

5.3.5 OUTPUT OF DATA

In this section the various output options available in the system are explained. In fact, four options of the menu produce hard copy output: list activities, print results, short cycle schedule and

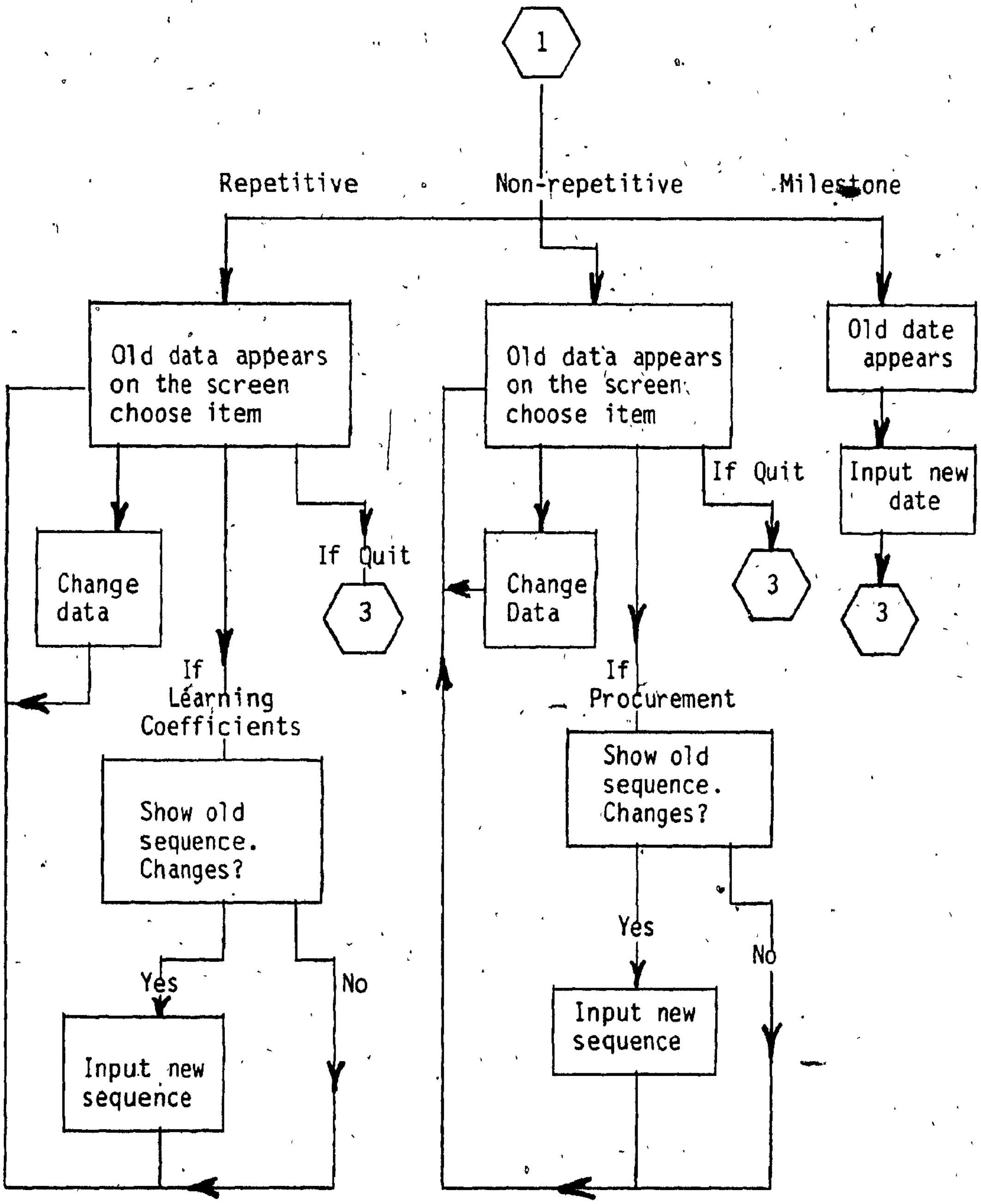


Fig. 5.15 - Update Information (refer to Fig. 5.12(a) and (b))

⬡ : represents a transfer to fiq. 5.12(a) procurement status report. It should be understood that the various output formats have been designed by the author to be functional, and that some improvements to them might be required, especially if the system is eventually tested on a real job. This could be the subject of further research. The formats, as they are now, will be shown in the example of the next section.

5.3.5.1 List Activities

This is the sixth option of the menu and its statements form part of the program "main". It consists of showing the data that describe each of the activities and which were input by the user. Therefore, no computed dates as such are shown on this report. First, the user is asked the sequence in which he would like to see the activities appear: the order of input, the sequential step order or the increasing activity number order. Then the program searches the files and prints all the data relevant to each activity.

The activities are presented in three main blocks: repetitive activities, non-repetitive activities and milestones. For the repetitive activities, the data shown are: the starting, current and last levels, the number of crews, the production rate, their start to start and finish to start relationships, the learning sequence and the weather influence (0 or 1). Also shown is the list of typical predecessors and the list of non-typical predecessors and their corresponding levels.

For the non-repetitive activities, the duration, the procurement status (0 or 1 is written for no or yes), the weather influence (0 or 1) and the status (1 or 0 for completed or not). Also included is the list of the predecessors of each activity. Finally, the milestones are printed out and the only information associated with them is their dates. A short statement ends this report by saying "For a total of X activities" where x is the number of activities.

5.3.5.2 Print Results

This is the ninth option of the menu and it calls the program "OUT". This program enables the user to print the results of the computations in three different ways, as explained in the previous chapter (section 4.2.4): a list of dates; a linear planning chart; and a bar chart. Before any computations are performed by the program, the user is asked to enter the number of levels of the project. This information could eventually be included in a "project" file which would have information that could appear on the headings of the above reports. However, the author did not inlcude this aspect in the present version of the system.

When choosing the "list of dates" option, the user is asked in which order he would like to see the activities printed out: increasing activity number; sequential steps; and randomly. The latter option then asks the user to input the activity numbers he would like to see on the print out. Then for each activity, the early, late and actual (if any) start and finish dates is printed along with the float and the scheduled and actual durations (if any) of the activity. The scheduled duration includes corrections for learning and weather, if applicable.

The linear planning chart option is used to show very specific activities; therefore each time that one is generated, the user has to input the activity numbers one by one. First, the user inputs the number of activities that he would like to see on the chart and then he enters the activity numbers, one by one. After a chart is printed, the program asks again for a number of activities. If no additional charts are required, inputting zero returns the execution to the initial menu of the printing options.

The bar chart option prints all the activities in sequential step order in bar chart form. Critical activities, non-critical activities and their floats, and completed activities all appear. In the present version of the system, no sorting alternatives exist for printing the bar chart, such as early start or early finish date, criticality etc. This could be done in future work.

Actual outputs of the system are shown in the next section. The structure of this option is shown in Fig. 5.16.

5.3.5.3 Short Cycle Schedule

This is the eleventh option of the menu, and it calls the program "SHORT". Given a specific date, the program looks in the file of dates and prints out any activity for which the early start or early finish

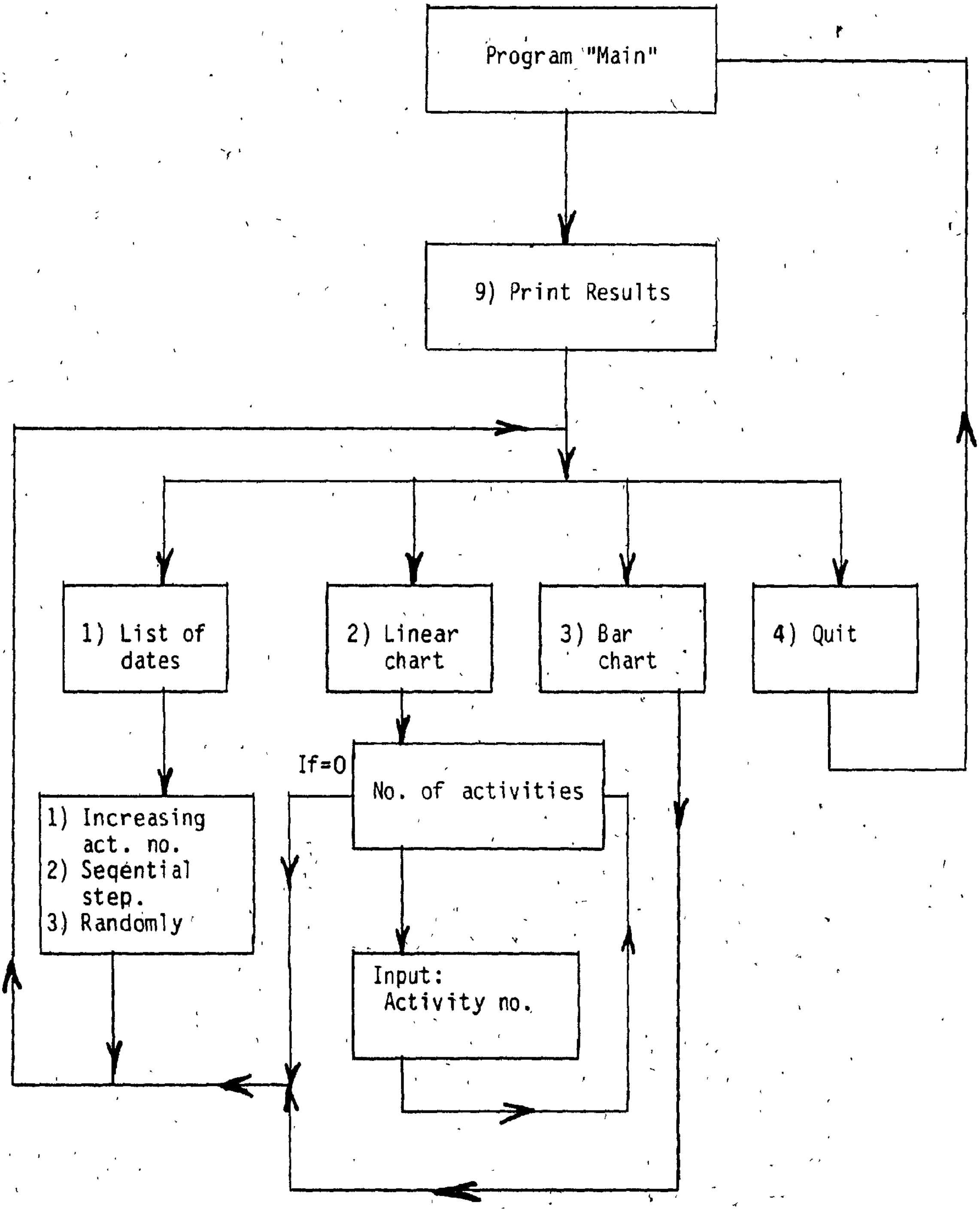


Fig. 5.16 - Print Results

dates are in a window one week before that date and two weeks after that date. The presentation of the data is done in a way exactly similar to the "list of dates" option mentioned earlier.

The heading of the print out will be "short cycle schedule as of XX MMM YY" and the activities follow. It should be mentioned that the activities will appear in a totally random order, which corresponds to the order in which they appear in the file. A sample output is shown in the example of the next section.

5.3.5.4 Procurement Status Report

This is the twelfth option of the menu, and it calls the program "PROC". This program generates the procurement status report for the activities input by the user. The heading consists of the nine activities mentioned in section 4.3.5, in chronological order.

For each activity, the program scans the list of procurement tasks and calculates the date at which each task should start, according to the duration of each specific task. Because each activity has its own procurement sequence, blanks are left in the case of one or several of the procurement tasks not being part of the procurement sequence.

The program then asks for activity numbers until a 0 is entered. Then, the report is printed, and execution returns to the main menu.

5.4 EXAMPLE OF USE

It is now appropriate to go through an example in order to understand how to use the various features mentioned in the previous section. The author considered a hypothetical building project: a sixteen storey building, with a reinforced concrete frame and a precast enclosure (see Fig. 5.17 for details). The activities, the logic of execution and the durations have been designed by the author, and should not be considered as coming from a specific job although the problem definition has benefited from the author's experience with office building projects in Montreal, as described previously. Because most building projects have very similar activities, it is clear that most of the logical relationships between the activities in the example could be applicable to other jobs.

5.4.1 The Activities and Their Relationships

Referring to the description of Chapter 2, the author defined a series of activities that would be considered as "repetitive". It is not appropriate at this stage to explain the various dependences, especially because they are very straight forward. The graphical representation of the network of repetitive activities per level is shown on Fig. 5.18. Some activities are preceded or followed by non-repetitive activities which are shown on subsequent figures. It should be mentioned however, that high-rise and low-rise elevator activities have been split, because each of them have their own dependences and their own specific floors.

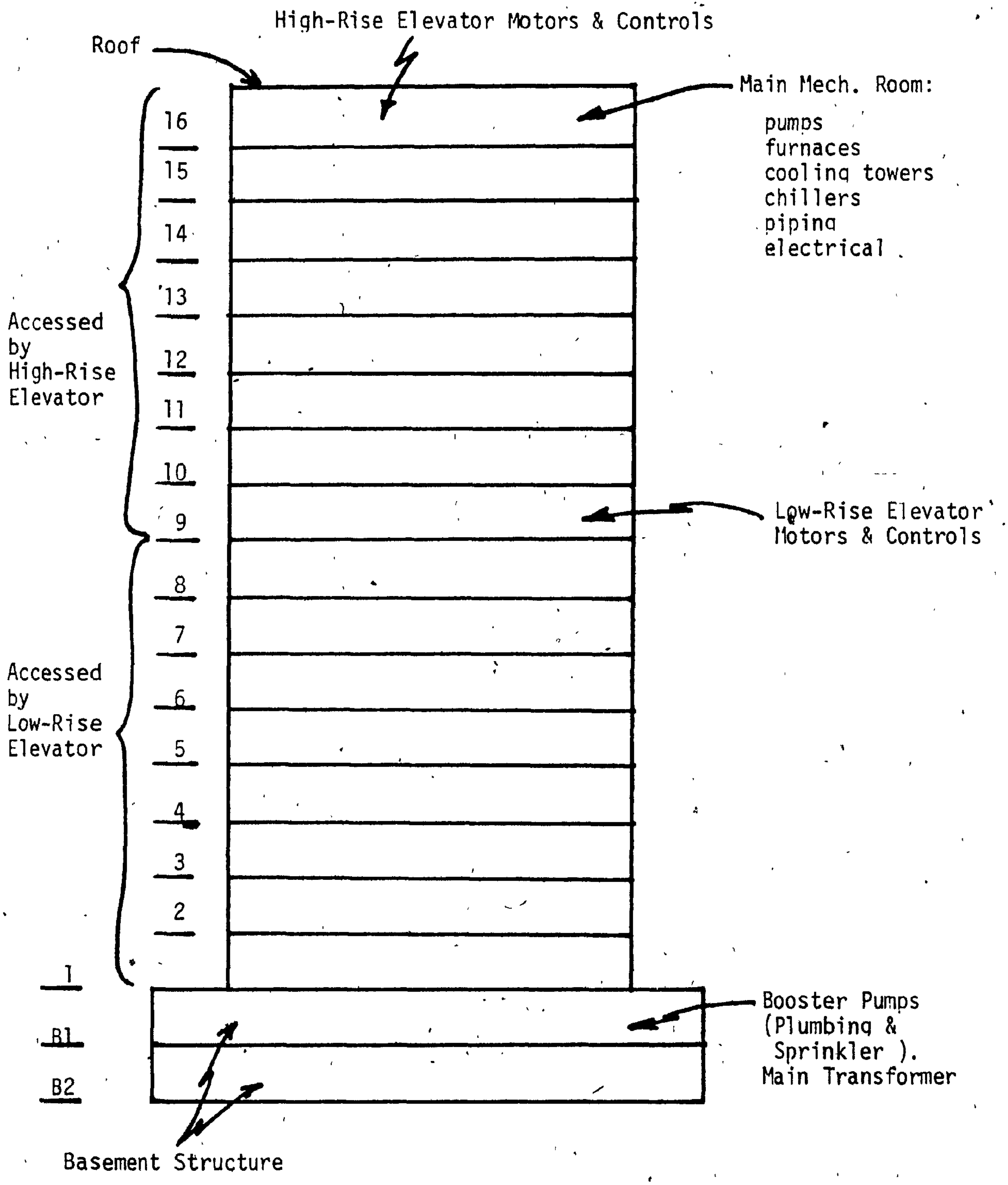


Fig. 5.17 Sketch of Hypothetical Building

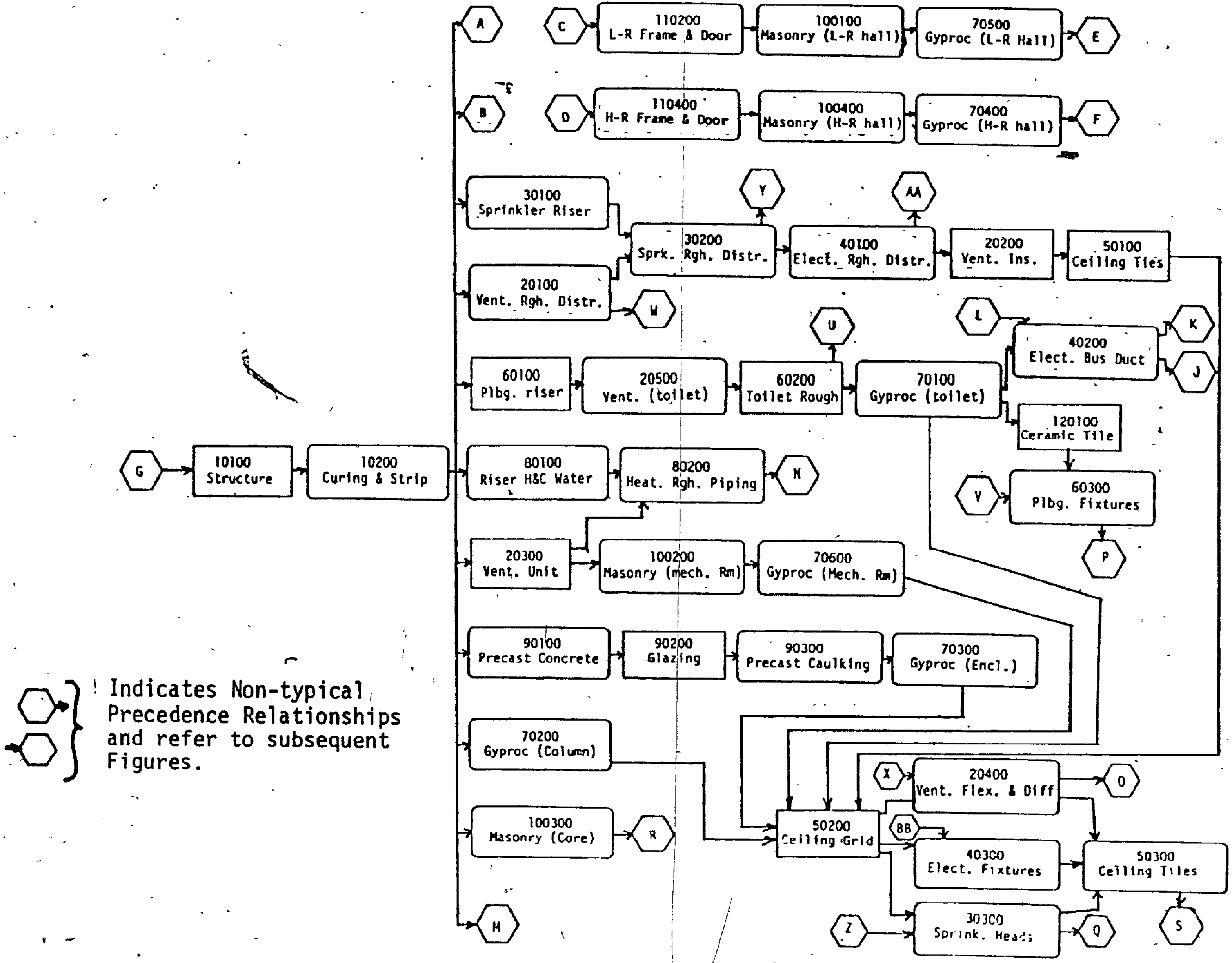


Fig. 5.18 Precedence Diagram of Repetitive Activities

Before the structure starts on the first typical floor, some non-repetitive activities have to be performed: mobilization; excavation; foundation; and basement structure. Mobilization is preceded by a milestone, to specify the start of the project. Also included at this stage are some of the equipment items that are located in the basement, e.g. the booster pumps for the sprinkler system and the domestic water, and the main transformers in the electrical room. The arrangement of these activities is shown in Fig. 5.19.

Another series of non-repetitive activities is the elevator's activities, which include the motors, cables and platform and finish and test. It should be mentioned that in order to be plumbed properly, the installation of the rails cannot be started until the floor, on which the motors are located is completed. Therefore, instead of having the structure as a typical predecessor, the low-rise and high rise rails will have as predecessors the 9th floor and the 16th floor of the structure, respectively. These floors house the elevator's machine rooms.

Also important for this non-repetitive sequence is the presence of electric power to operate the platform: transformer and bus duct are therefore required at this stage. Finally, after the testing is satisfactorily done, the next activity is elevator crew demobilization. The sequence of activities, for high-rise and low-rise are shown in Fig. 5.20.

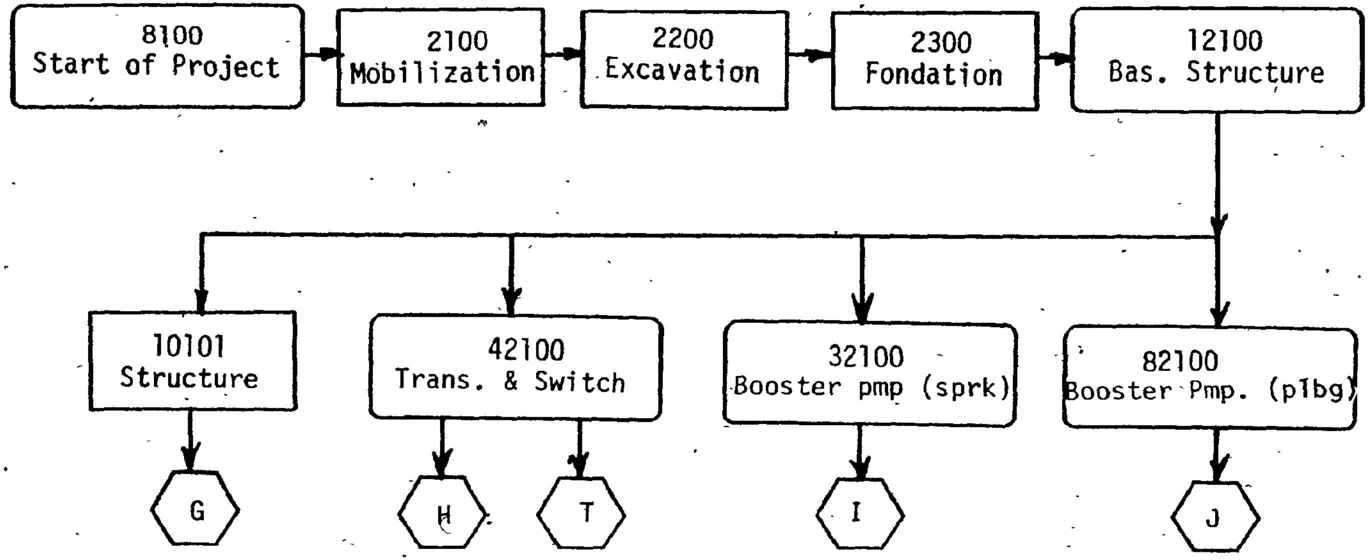


Fig. 5.19 Precedence Diagram of Non-repetitive Activities before the Structure.

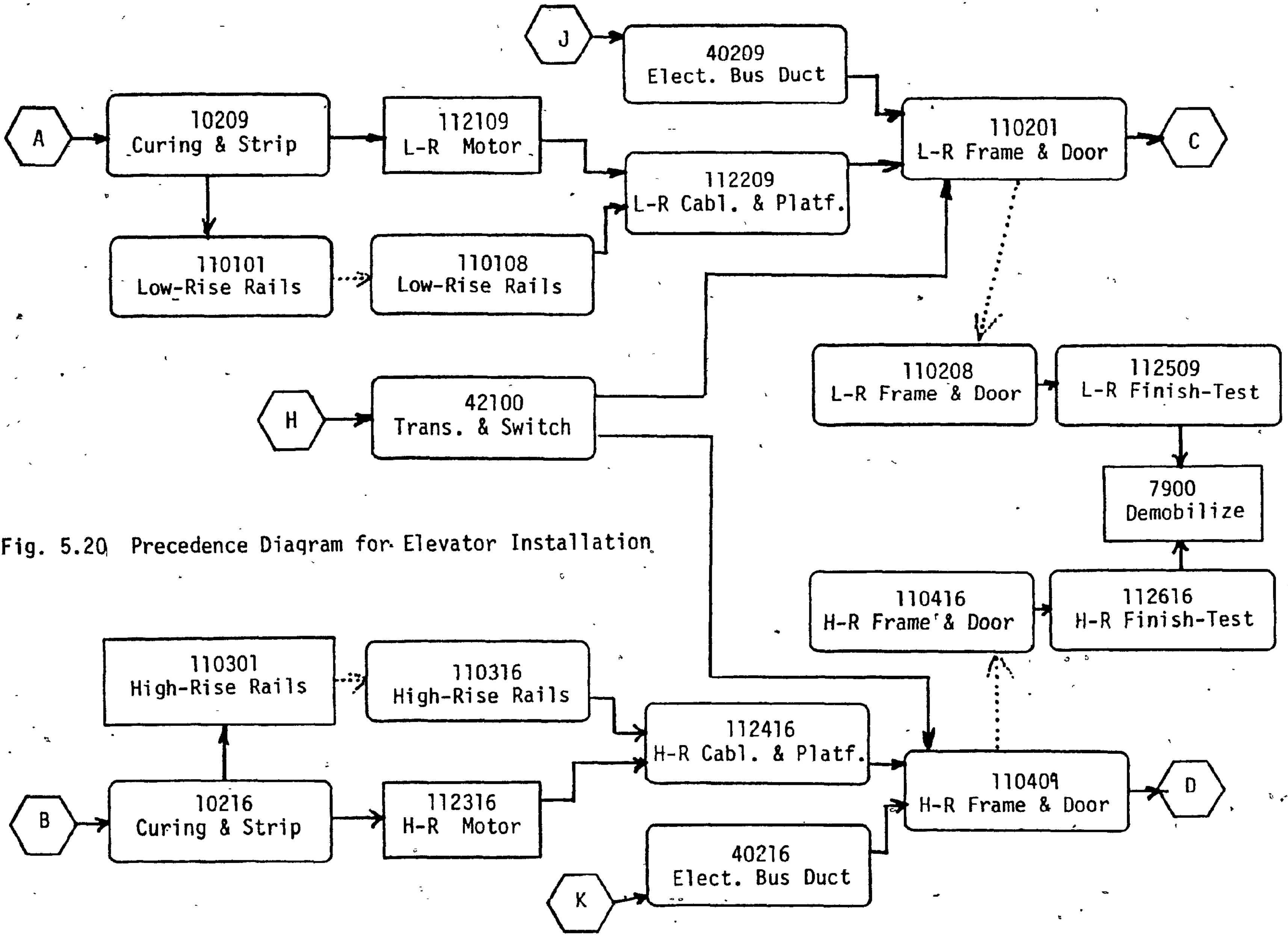


Fig. 5.20 Precedence Diagram for Elevator Installation

Another area of attention is the main mechanical room, located on the sixteenth floor. As soon as the structure is stripped, the slab can receive the various items like the pumps, furnaces, cooling towers and the chillers. When those are in, the electricity and the piping in that room are done, followed by the balancing, which requires the completion of the air distribution system and the circulation of hot and cold water. Following the stripping of the last floor is also the roof, which precedes the arrival of the bus-duct on the last floor; the sequence is shown in Fig. 5.21.

Other components of the building have to be tested, like the plumbing and the sprinkler system. Both activities require the installation of all the piping in both cases, and finishing (plumbing fixtures and sprinkler heads). Normally, the fire alarm is tested with the sprinkler system, but for purposes of this example, it has not been included. Finally, an activity labelled miscellaneous finish follows four interior finishing activities, and the last activity of the network is demobilize. These sequences are shown in Fig. 5.22.

Finally, some of the finishing activities require that the finishing on the first floor only starts when the roughing is completed on the last floor for resource levelling purposes. Such activities are: toilet rough piping and plumbing fixtures; sprinkler rough and sprinkler heads, ventilation roughing and ventilation flexible duct and diffusers, electrical roughing and electrical fixtures. Those would be non-typical predecessors, as explained in the previous section (see Fig. 5.23).

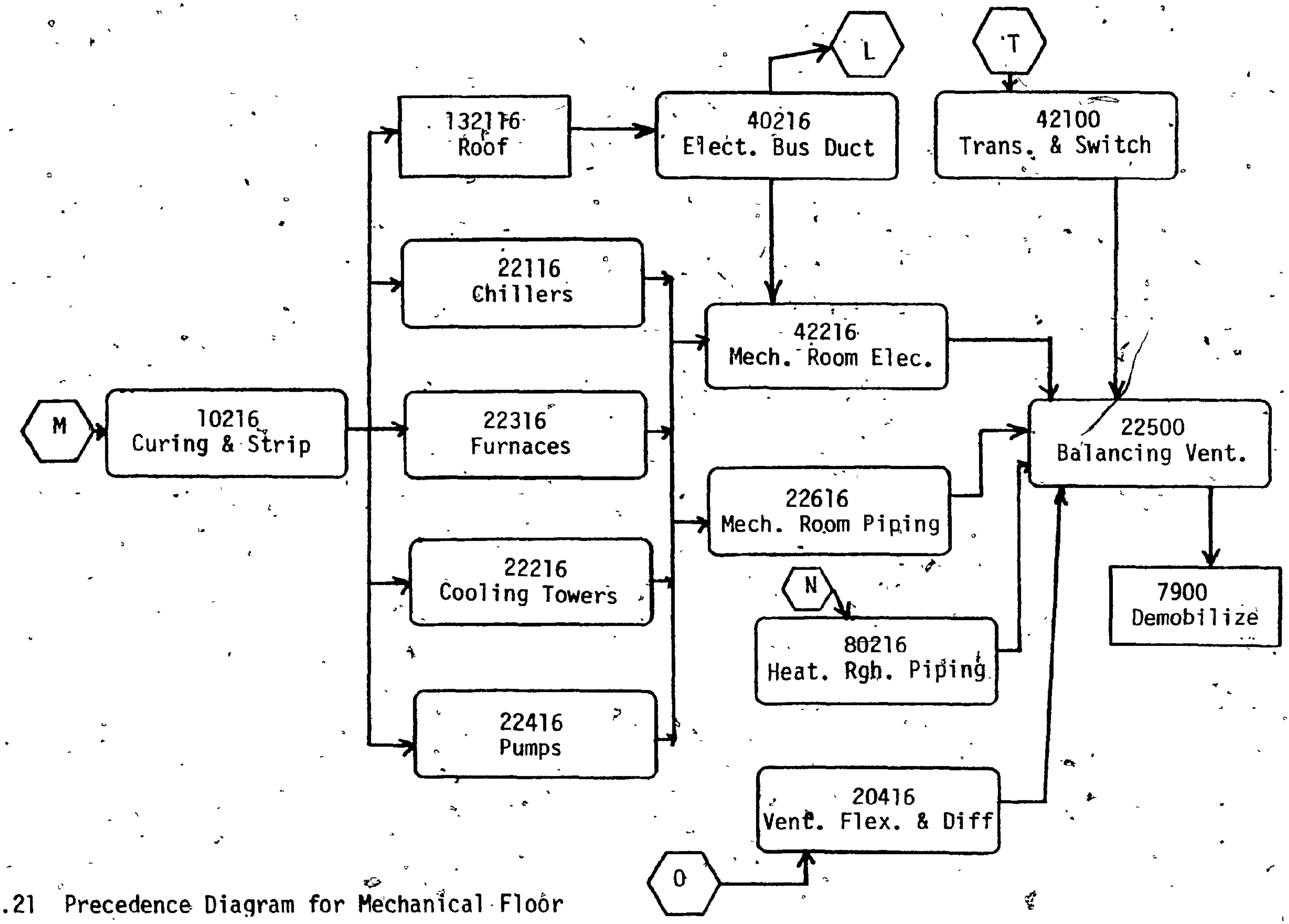


Fig. 5.21 Precedence Diagram for Mechanical Floor

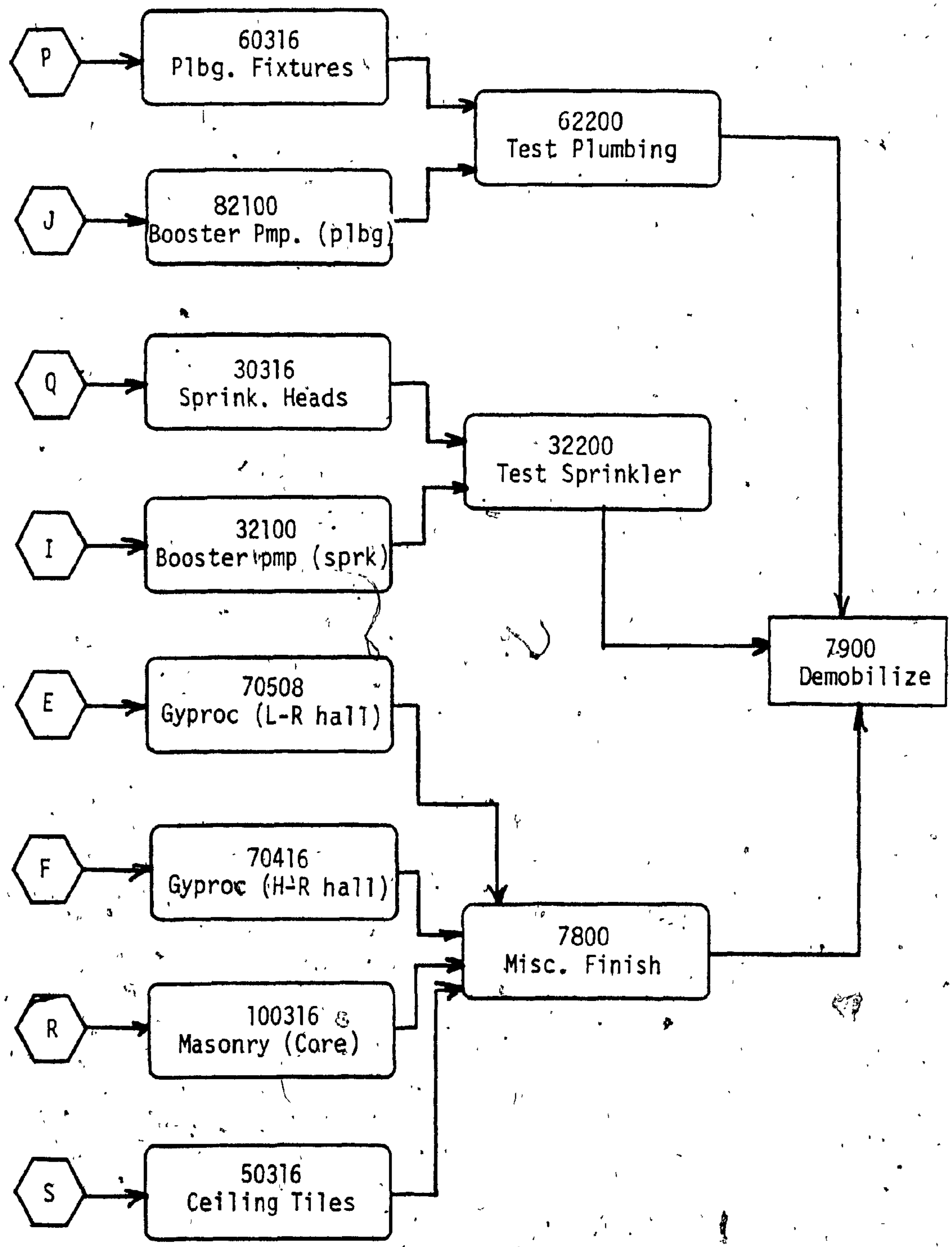


Fig. 5.22 Precedence Diagram for Finishing Activities

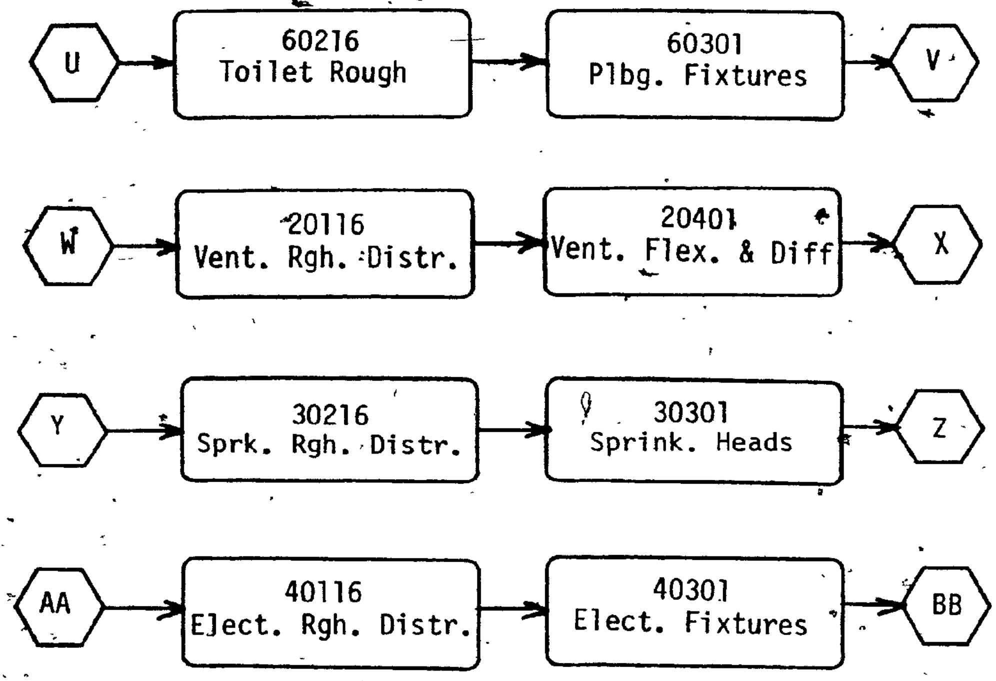


Fig. 5.23 Diagram of Other Non-typical Predecessors

5.4.2 Start, Input of Data and A First Run

Once signed on the Perkin Elmer 3220, the user has to type BASIC and then RUN "MAIN". A complete terminal sequence of all the steps described in this section is shown in the appendix at the end of this chapter which is broken into sections for easy reference.

As mentioned in the previous section, the first thing to do is to create the files for the project; in our case, the name "JOB" which is less than 4 characters will be used. Because there is no standard network in the system now, we cannot copy it. Instead empty files are created.

As a second step, the calendar has to be prepared for the project. It starts right after the Easter break, on the Tuesday (day 2), April 5, 1983. Holidays are input up to the end of 1984, in order to cover the entire project. For this case they consist of all fixed holidays (Easter, Victoria day, St. Jean-Baptiste, Canada day, Labour day, Thanksgiving day and Christmas) and two weeks vacation in the summer and during Christmas. This sequence is shown in part A of the Appendix I.

Finally, the weather factors for each of the months have to be input once for the project, so it is preferable to do it now. They are input sequentially, from January to December. The factors that have been input correspond to the ones of table 4.1 and are again arbitrary.

Activities can now be input one by one. Because of the great quantity of data and the redundancy of listing the information now, one should refer to the list of activities in figures 5.24 (a) and (b). The sequence of the input of the number, description and predecessors is done first and is shown in the Appendix IB. Although 65 activities were input for that project, only 21 are shown in the Appendix in order to understand how to input the data.

Also to be input is all the activity data as described in the previous section. Again, the detailed data is not listed here, but can be found in the list of activities in Fig. 5.24. In Appendix IC, the sequence on the terminal, as it would appear to the user is presented. Input for several activities is not shown in order to minimize the extent of the presentation. The activities shown were chosen to represent each of the possible options.

After all the data is input, it is appropriate to list all the activities, in the order of input, to see if there were any errors or ommisions. The table is shown in Fig. 5.24. In this case everything is correct. So the next step is to compile and execute the data and print a first bar chart to see the schedule generated by the set of data.

The sequence of the input of the remaining data, the listing of the activities, the compiling, execution and print out of a bar chart (Fig. 5.25) is shown in Appendix ID. The list of activities and the bar chart do not appear on the screen, but are assigned to a line-printer hooked up to the computer.

```
REPETITIVE ACTIVITIES

NO.     DESCRIPTION          I START  CURRENT  LAST  CREWS  RATE   SS    FS    LEARN  WEATHER TYPICAL NON-TYP
-----------------------------------------------------------------------------------------------------------------
                             I
 10100  STRUCTURE            I   1       1      16     1      6     0     0    6  90     1      0      1  12100
                             I                                                 3  75            0      0  0
                             I                                                 2  60            0      0  0
                             I                                                 1  50            0      0  0
                             I
 70200  GYPROC (COLUMN)      I   1       1      16     1      4     0     0    0  0      0      10200  0  0
                             I
110100 L-R ELEV. RAILS       I   1       1       8     1      3     0     0    1  80     0      0      1  10209
                             I
110200 L-R ELEV. FR. & DOORI I   1       1       8     1      2     0     0    1  90     0      0      1  112209
                             I                                                 0  0             0      1  42100
                             I                                                 0  0             0      1  40209
                             I
100100 MASONRY (L-R HALL)    I   1       1       8     1      4     0     0    1  90     0      110200 0  0
                             I
 70500  GYPROC (L-R HALL)    I   1       1       8     1      3     0     0    0  0      0      100100 0  0
                             I
110300 H-R ELEV. RAILS       I   1       1      16     1      2     0     0    2  75     0      0      1  10216
                             I                                                 1  50            0      1  110108
                             I
110400 H-R ELEV. FR. & DOORI I   9       9      16     1      3     0     0    0  0      0      0      9  110205
                             I                                                 0  0             0      9  112416
                             I                                                 0  0             0      9  42100
                             I                                                 0  0             0      9  40216
                             I
100400 MASONRY (H-R HALL)    I   9       9      16     1      4     0     0    0  0      0      110400 0  0
                             I
 70400  GYPROC (H-R HALL)    I   9       9      16     1      3     0     0    0  0      0      100400 0  0
                             I
 30100  SPRINKLER RISER      I   1       1      16     1      6     0     0    2  90     1      10200  0  0
                             I                                                 1  75            0      0  0
                             I
 20100  VENT. RGH DISTR.     I   1       1      16     1      5     0     0    1  80     0      10200  0  0
                             I
 30200  SPRINK. RGH DISTR.   I   1       1      16     1      5     0     0    1  80     0      30100  0  0
                             I                                                 0  0             20100  0  0
                             I
 40100  ELECTR. RGH DISTR.   I   1       1      16     1      5     0     0    1  80     0      30200  0  0
                             I
 20200  VENT. INSULATION     I   1       1      16     1      4     0     0    1  75     0      40100  0  0
                             I
 50100  CEILING TIES         I   1       1      16     1      4     0     0    0  0      0      20200  0  0
                             I
 60100  RISER (DOM. WATER)   I   1       1      16     1      2     0     3    1  50     0      10200  0  0
                             I
 20500  VENT RGH (TOILET)    I   1       1      16     1      2     0     3    1  80     0      60100  0  0
                             I
 60200  TOILET RGH PIPING    I   1       1      16     1      5     0     0    1  80     0      20500  0  0
                             I
 70100  GYPROC (TOILET)      I   1       1      16     1      5     0     0    1  75     0      60200  0  0
                             I
 40200  EL. BUS DUCT & PAN.  I   1       1      16     1      5     0     0    2  90     0      70100  16  132116
                             I                                                 1  75            0      0  0
                             I
120100 CERAMIC TILE          I   1       1      16     1      3     0     0    1  90     0      70100  0  0
                             I
 60300  PLUMBING FIXTURES    I   1       1      16     1      4     0     0    1  80     0      120100 1  60216
                             I
 80100  RISER (H & C WATER)  I   1       1      16     1      2     0     3    1  90     0      10200  0  0
                             I
 20300  VENT. UNIT           I   1       1      16     1      4     0     0    1  75     0      10200  0  0
                             I
 80200  HEAT. ROUGH PIPING   I   1       1      16     1      4     0     0    1  80     0      80100  0  0
                             I                                                 0  0             20300  0  0
                             I
100200 MASONRY (MECH. RM)    I   1       1      16     1      4     0     0    0  0      0      20300  0  0
                             I
 70600  GYPROC (MECH RM)     I   1       1      16     1      3     0     0    0  0      0      100200 0  0
                             I
 90100  PRECAST PANELS       I   1       1      16     3     15     0     0    6  90     1      10200  0  0
                             I                                                 5  90            0      0  0
                             I                                                 4  90            0      0  0
                             I                                                 3  70            0      0  0
                             I                                                 2  70            0      0  0
                             I                                                 1  70            0      0  0
                             I
 90200  GLAZING              I   1       1      16     1      5     0     0    1  90     1      90100  0  0
                             I
 90300  PRECAST CAULKING     I   1       1      16     1      5     0     0    1  80     0      90200  0  0
                             I
 70300  GYPROC (ENCLOSURE)   I   1       1      16     1      4     0     0    0  0      0      90300  0  0
                             I
100300 MASONRY ( CORE )      I   1       1      16     1      4     0     0    0  0      0      10200  0  0
                             I
 50200  CEILING GRID         I   1       1      16     1      4     0     0    2  90     0      70200  0  0
                             I                                                 1  70            50100  0  0
                             I                                                 0  0             70100  0  0
                             I                                                 0  0             70600  0  0
                             I                                                 0  0             70300  0  0
                             I
 40300  ELECT. FIXTURES      I   1       1      16     1      3     0     0    2  85     0      50200  1  40116
                             I                                                 1  60            0      0  0
                             I
 20400  VENT FLEX. & DIFF.   I   1       1      16     1      3     0     0    2  85     0      50200  1  20116
                             I                                                 1  60            0      0  0
                             I
 30300  SPRINKLER HEADS      I   1       1      16     1      3     0     0    2  85     0      50200  1  30216
                             I                                                 1  60            0      0  0
                             I
 50300  TILES (CEILING)      I   1       1      16     1      3     0     0    0  0      0      40300  0  0
                             I                                                 0  0             20400  0  0
                             I                                                 0  0             30300  0  0
                             I
 10200  CURING & STRIP.      I   1       1      16     1      6     0     0    3  90     1      10100  0  0
                             I                                                 2  75            0      0  0
                             I                                                 1  60            0      0  0
```

EXPLANATION OF THE HEADINGS:

Start : Starting level of the repetitive activity
Current : Current level of the repetitive activity
Last : Last level of the repetitive activity
Crews : Number of crews (or floors in parrallel)

1 of

```
110300 H-R ELEV. RAILS     I   1   1   16   1   2   0   0   2 75   0   0       1 10216
                           I                                1 50       0       1 110108
                           I
110400 H-R ELEV. FR. & DOORI   9   9   16   1   3   0   0   0 0    0   0       9 110205
                           I                                0 0        0       9 112416
                           I                                0 0        0       9 42100
                           I                                0 0        0       9 40216
                           I
100400 MASONRY (H-R HALL)  I   9   9   16   1   4   0   0   0 0    0   110400 0 0
                           I
70400  GYPROC (H-R HALL)   I   9   9   16   1   3   0   0   0 0    0   100400 0 0
                           I
30100  SPRINKLER RISER     I   1   1   16   1   6   0   0   2 90   1   10200  0 0
                           I                                1 75       0      0 0
                           I
20100  VENT. RGH DISTR.    I   1   1   16   1   5   0   0   1 80   0   10200  0 0
                           I
30200  SPRINK. RGH DISTR.  I   1   1   16   1   5   0   0   1 80   0   30100  0 0
                           I                                0 0        20100  0 0
                           I
40100  ELECTR. RGH DISTR.  I   1   1   16   1   5   0   0   1 80   0   30200  0 0
                           I
20200  VENT. INSULATION    I   1   1   16   1   4   0   0   1 75   0   40100  0 0
                           I
50100  CEILING TIES        I   1   1   16   1   4   0   0   0 0    0   20200  0 0
                           I
60100  RISER (DOM. WATER)  I   1   1   16   1   2   0   3   1 50   0   10200  0 0
                           I
20500  VENT RGH (TOILET)   I   1   1   16   1   2   0   3   1 80   0   60100  0 0
                           I
60200  TOILET RGH PIPING   I   1   1   16   1   5   0   0   1 80   0   20500  0 0
                           I
70100  GYPROC (TOILET)     I   1   1   16   1   5   0   0   1 75   0   60200  0 0
                           I
60200  EL. BUS DUCT & PAN. I   1   1   16   1   5   0   0   2 90   0   70100  16 132116
                           I                                1 75       0      0 0
                           I
120100 CERAMIC TILE        I   1   1   16   1   3   0   0   1 90   0   70100  0 0
                           I
60300  PLUMBING FIXTURES   I   1   1   16   1   4   0   0   1 80   0   120100 1 60216
                           I
80100  RISER (H & C WATER) I   1   1   16   1   2   0   3   1 90   0   10200  0 0
                           I
20300  VENT. UNIT          I   1   1   16   1   4   0   0   1 75   0   10200  0 0
                           I
80200  HEAT. ROUGH PIPING  I   1   1   16   1   4   0   0   1 80   0   80100  0 0
                           I                                0 0        20300  0 0
                           I
100200 MASONRY (MECH. RM)  I   1   1   16   1   4   0   0   0 0    0   20300  0 0
                           I
70600  GYPROC (MECH RM)    I   1   1   16   1   3   0   0   0 0    0   100200 0 0
                           I
90100  PRECAST PANELS      I   1   1   16   3   15  0   0   6 90   1   10200  0 0
                           I                                5 90       0      0 0
                           I                                4 90       0      0 0
                           I                                3 70       0      0 0
                           I                                2 70       0      0 0
                           I                                1 70       0      0 0
                           I
90200  GLAZING             I   1   1   16   1   5   0   0   1 90   1   90100  0 0
                           I
90300  PRECAST CAULKING    I   1   1   16   1   5   0   0   1 80   0   90200  0 0
                           I
70300  GYPROC (ENCLOSURE)  I   1   1   16   1   4   0   0   0 0    0   90300  0 0
                           I
100300 MASONRY ( CORE )    I   1   1   16   1   4   0   0   0 0    0   10200  0 0
                           I
50200  CEILING GRID        I   1   1   16   1   4   0   0   2 90   0   70200  0 0
                           I                                1 70       50100  0 0
                           I                                0 0        70100  0 0
                           I                                0 0        70600  0 0
                           I                                0 0        70300  0 0
                           I
40300  ELECT. FIXTURES     I   1   1   16   1   3   0   0   2 85   0   50200  1 40116
                           I                                1 60       0      0 0
                           I
20400  VENT FLEX. & DIFF.  I   1   1   16   1   3   0   0   2 85   0   50200  1 20116
                           I                                1 60       0      0 0
                           I
30300  SPRINKLER HEADS     I   1   1   16   1   3   0   0   2 85   0   50200  1 30216
                           I                                1 40       0      0 0
                           I
50300  TILES (CEILING)     I   1   1   16   1   3   0   0   0 0    0   40300  0 0
                           I                                0 0        20400  0 0
                           I                                0 0        30300  0 0
                           I
10200  CURING & STRIP.     I   1   1   16   1   6   0   0   3 90   1   10100  0 0
                           I                                2 75       0      0 0
                           I                                1 60       0      0 0
```

EXPLANATION OF THE HEADINGS:

Start : Starting level of the repetitive activity
Current : Current level of the repetitive activity
Last : Last level of the repetitive activity
Crews : Number of crews (or floors in parrallel)
Rate : Production Rate (Days/floor)
SS : Start to start relationship between successive floors done by different crews (when crew is one, SS does not apply and is enterd as zero).
FS : Finish to start relationship between two floors done by the same crew.
Learn : Sequence of learning coefficients: the first number is the floor number and the second, the corresponding "coefficient of effeciency"(in %)
Weather : Weather Factor (1 or 0 for yes or no)
Typical : Activity number(s) of the typical predecessor(s)
Non-typ : Consists of two numbers: the first one is the level preceded by the "predecessor", and the second, the activity number of that predecessor(s).

Fig. 5.24(a) List of Activities (1st version)

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```
NON-REPETITIVE ACTIVITIES

NO.    DESCRIPTION          I  DURATION  PROCUREMENT  WEATHER  STATUS   PREDECESSORS
------------------------------------------------------------------------------------
                            I
2100   MOBILIZATION         I   10          0            0        0       8100
                            I
2200   EXCAVATION           I   40          0            1        0       2100
                            I
2300   FOUNDATION           I   20          0            1        0       2200
                            I
12100  BASEMENT STRUCT.     I   30          0            1        0       2300
                            I
42100  TRANSF. & SWITCH     I   20          1            0        0       12100
                            I
32100  BOOSTER PUMP (SPRK)  I   10          1            0        0       12100
                            I
62100  BOOSTER PUMP (PLMBG) I   20          1            0        0       12100
                            I
112109  LOW-RISE MOTOR      I   20          1            0        0       10209
                            I
112209 L-R CABLES & PLATF.  I   20          1            0        0       110108
                            I                                             112109
                            I
112316 HIGH-RISE MOTOR      I   20          1            0        0       10216
                            I                                             112109
                            I
112416 H-R CABLES & PLATF.  I   20          1            0        0       112209
                            I                                             110316
                            I                                             112316
                            I
112509 L-R FINISH & TEST    I   30          0            0        0       110208
                            I
112616 H-R FINISH & TEST    I   30          0            0        0       112509
                            I                                             110416
                            I
132116 ROOF                 I   20          0            1        0       10216
                            I
22116  CHILLERS             I   10          1            0        0       10216
                            I
22216  COOLING TOWERS       I   10          1            0        0       10216
                            I
22316  FURNACES             I   20          1            0        0       10216
                            I
22416  PUMPS                I   10          1            0        0       10216
                            I
22500  BALANCING VENT.      I   20          0            0        0       42100
                            I                                             42216
                            I                                             22616
                            I                                             80216
                            I                                             20416
                            I
22616  MECH ROOM PIPING     I   15          0            0        0       22116
                            I                                             22216
                            I                                             22316
                            I                                             22416
                            I
42216  MECH ROOM ELECTR.    I   15          1            0        0       22116
                            I                                             22216
                            I                                             22316
                            I                                             22416
                            I                                             40216
                            I
62200  TEST PLUMBING        I   20          0            0        0       62100
                            I                                             60316
                            I
32230  TEST SPRINKLER       I   15          0            0        0       30316
                            I                                             32100
                            I
7800   MISCELL. FINISH      I   15          0            0        0       70508
                            I                                             70416
                            I                                             100316
                            I                                             50316
                            I
7900   DEMOBILIZ.           I   10          0            0        0       112616
                            I                                             7800
                            I                                             62200
                            I                                             32200
                            I                                             22500

MILESTONES

NO.    DESCRIPTION          I        DATE
--------------------------------------------
                            I
8100   START OF PROJECT     I   830405

FOR A TOTAL OF [illegible] ACTIVITIES
```

EXPLANATION OF THE HEADINGS:

Duration : Duration of the activity (days)
Procurement : 1 or 0 for yes or no.
Weather : 1 or 0 for yes or no.
Predecessors : Activity number(s) of the predecessor(s) of the activity.

Fig. 5.24(b) List of Activities (1st version) (cont'd)

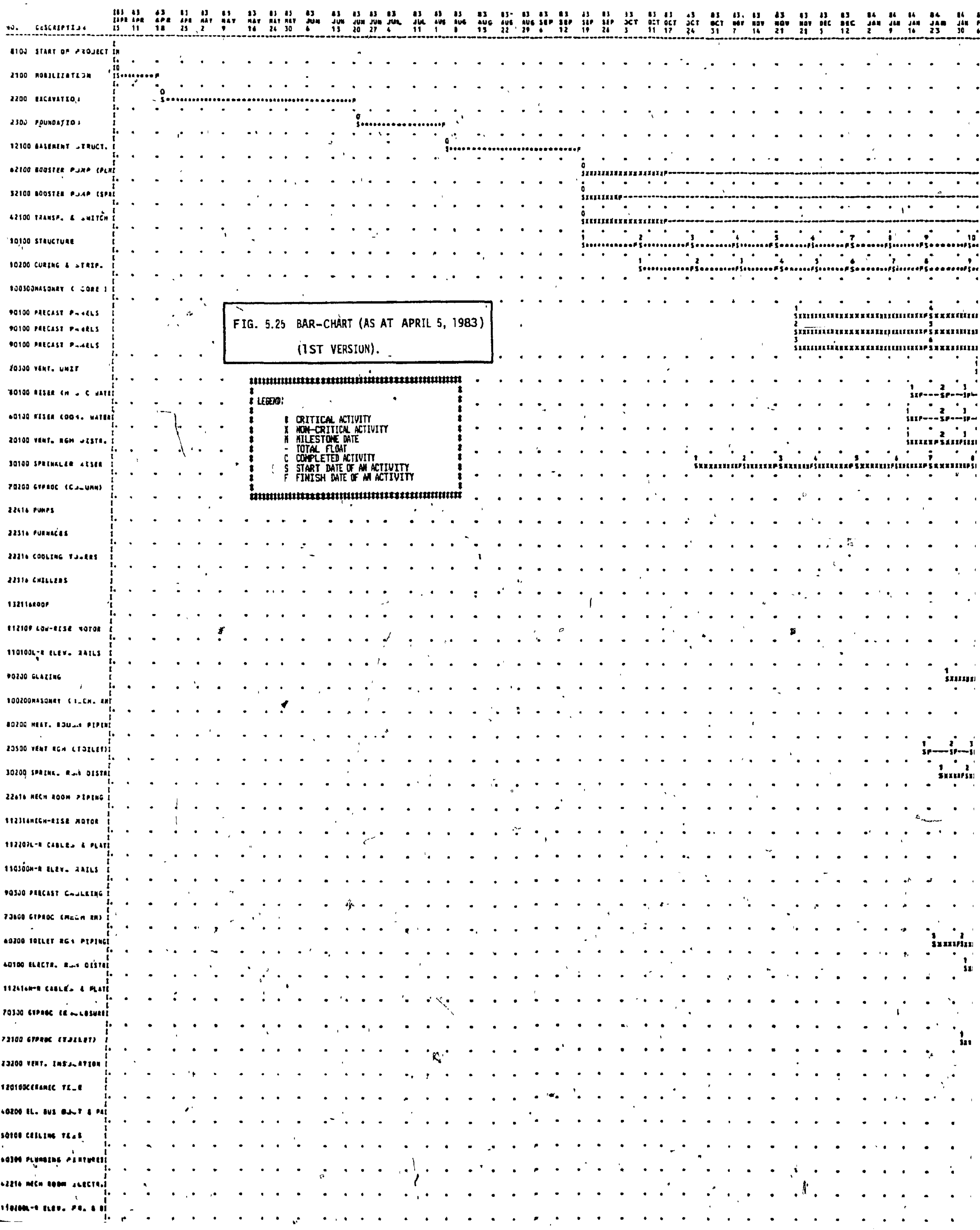
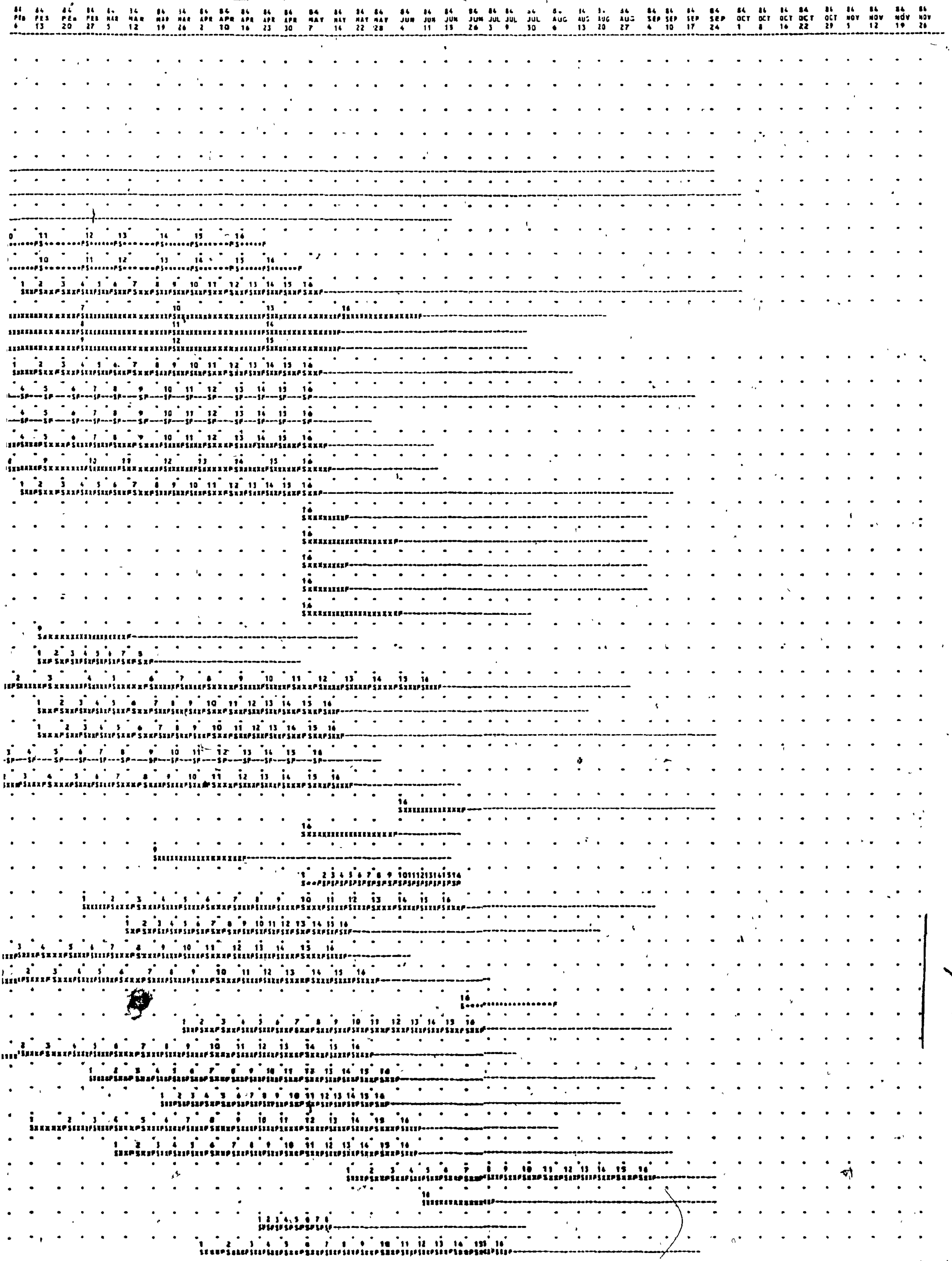
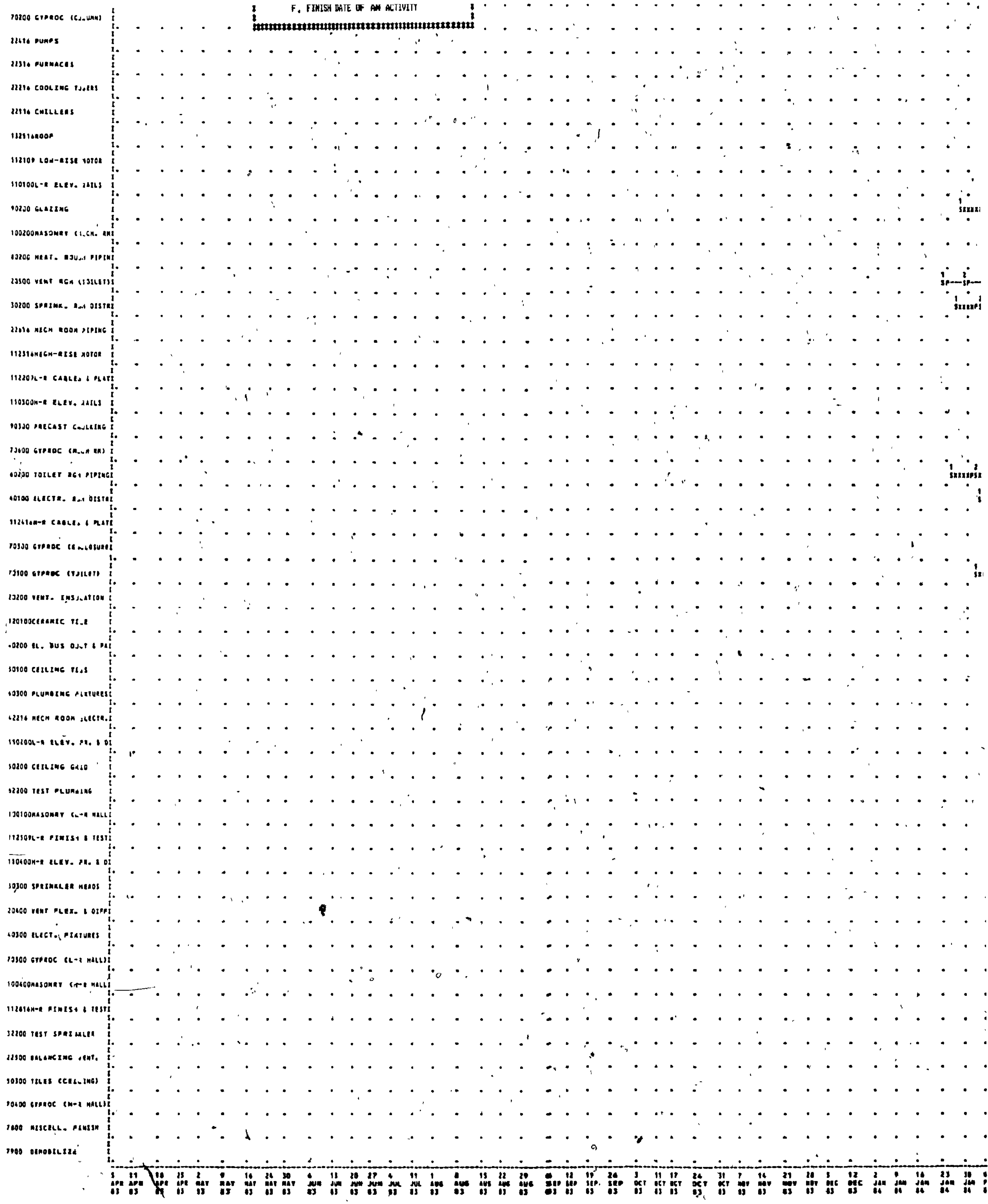
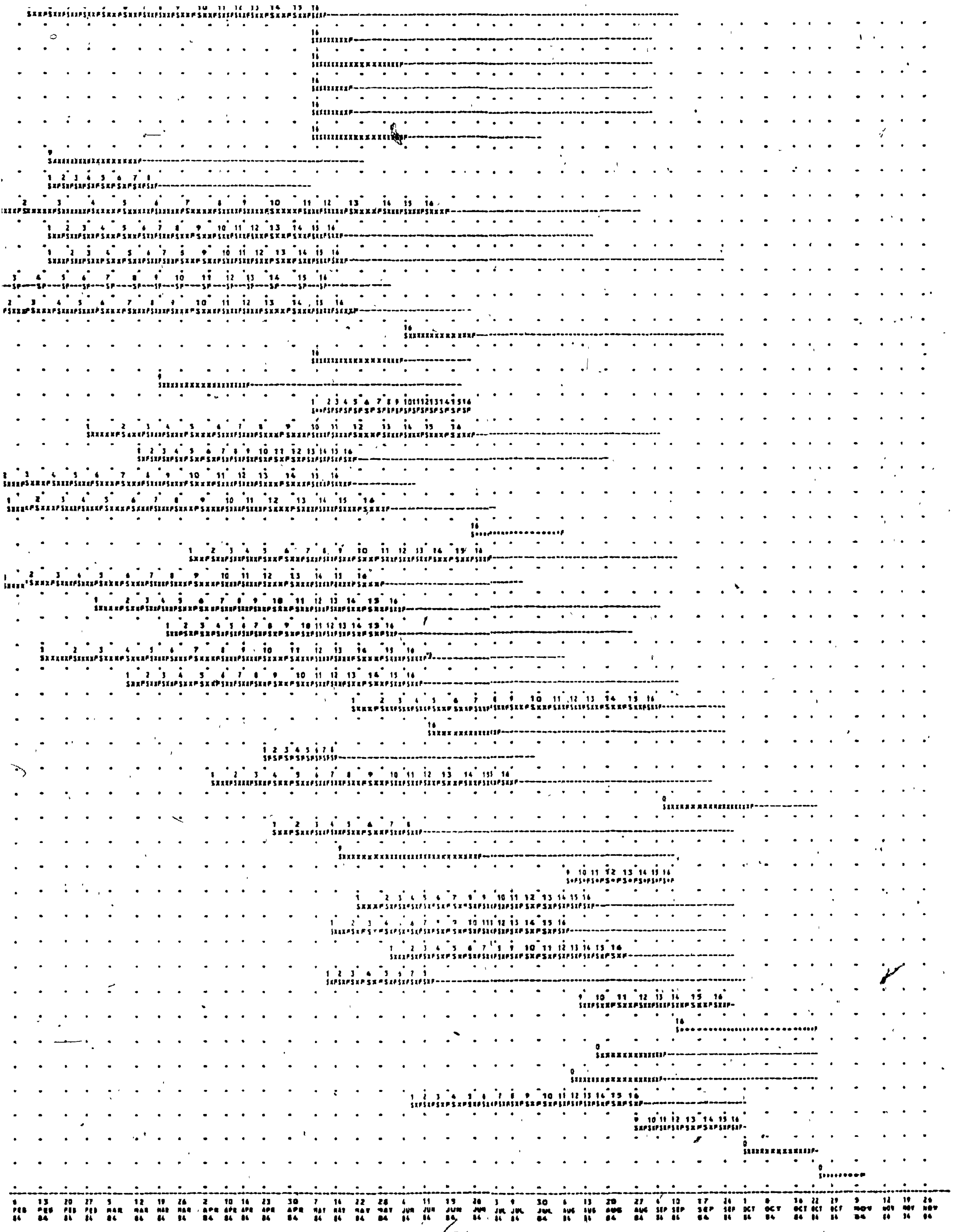


FIG. 5.25 BAR-CHART (AS AT APRIL 5, 1983)
(1ST VERSION).


84 FEB 6
84 FEB 13
84 FEB 20
84 FEB 27
84 MAR 5
84 MAR 12
84 MAR 19
84 MAR 26
84 APR 2
84 APR 10
84 APR 16
84 APR 23
84 APR 30
84 MAY 7
84 MAY 14
84 MAY 22
84 MAY 28
84 JUN 4
84 JUN 11
84 JUN 18
84 JUN 26
84 JUL 3
84 JUL 9
84 JUL 30
84 AUG 6
84 AUG 13
84 AUG 20
84 AUG 27
84 SEP 4
84 SEP 10
84 SEP 17
84 SEP 24
84 OCT 1
84 OCT 8
84 OCT 16
84 OCT 22
84 OCT 29
84 NOV 5
84 NOV 12
84 NOV 19
84 NOV 26

1 of


F, FINISH DATE OF AN ACTIVITY
70200 GYPROC (COLUMN)
22416 PUMPS
22316 FURNACES
22216 COOLING TOWERS
22116 CHILLERS
132516ROOF
112109 LOW-RISE MOTOR
110100L-R ELEV. RAILS
90230 GLAZING
100200MASONRY (LCH. RM
43200 HEAT. ROUGH PIPIN
23500 VENT RGH (TOILETS)
30200 SPRINK. R. DISTR
22616 MECH ROOM PIPING
112316HIGH-RISE MOTOR
112207L-R CABLES & PLAT
110300H-R ELEV. RAILS
90330 PRECAST CAULKING
73600 GYPROC (MECH RM)
60200 TOILET RGH PIPING
40100 ELECTR. R. DISTR
112416H-R CABLES & PLAT
70330 GYPROC (ENCLOSURE
73100 GYPROC (TOILET)
23200 VENT. INSULATION
120100CERAMIC TILE
40200 EL. BUS DUCT & PA
50100 CEILING TILES
60300 PLUMBING FIXTURES
42216 MECH ROOM ELECTR.
110200L-R ELEV. FR. & D
50200 CEILING GRID
62200 TEST PLUMBING
130100MASONRY (L-R HALL
112509L-R FINISH & TEST
110400H-R ELEV. FR. & D
30300 SPRINKLER HEADS
20400 VENT FLEX. & DIFF
40300 ELECT. FIXTURES
70500 GYPROC (L-R HALL)
100400MASONRY (H-R HALL
112616H-R FINISH & TEST
32200 TEST SPRINKLER
22500 BALANCING VENT.
50300 TILES (CEILING)
70400 GYPROC (H-R HALL)
7800 MISCELL. FINISH
7900 DEMOBILIZE
S
SP---SP--
SXXXXPS
SXXXXPS
S
5 APR 83
11 APR 83
18 APR 83
25 APR 83
2 MAY 83
9 MAY 83
16 MAY 83
24 MAY 83
30 MAY 83
6 JUN 83
13 JUN 83
20 JUN 83
27 JUN 83
4 JUL 83
11 JUL 83
1 AUG 83
8 AUG 83
15 AUG 83
22 AUG 83
29 AUG 83
6 SEP 83
12 SEP 83
19 SEP 83
26 SEP 83
3 OCT 83
11 OCT 83
17 OCT 83
24 OCT 83
31 OCT 83
7 NOV 83
14 NOV 83
21 NOV 83
28 NOV 83
5 DEC 83
12 DEC 83
2 JAN 84
9 JAN 84
16 JAN 84
23 JAN 84
30 JAN 84


6 FEB 84
13 FEB 84
20 FEB 84
27 FEB 84
5 MAR 84
12 MAR 84
19 MAR 84
26 MAR 84
2 APR 84
9 APR 84
16 APR 84
23 APR 84
30 APR 84
7 MAY 84
14 MAY 84
21 MAY 84
28 MAY 84
4 JUN 84
11 JUN 84
18 JUN 84
25 JUN 84
3 JUL 84
9 JUL 84
30 JUL 84
6 AUG 84
13 AUG 84
20 AUG 84
27 AUG 84
4 SEP 84
10 SEP 84
17 SEP 84
24 SEP 84
1 OCT 84
8 OCT 84
15 OCT 84
22 OCT 84
29 OCT 84
5 NOV 84
12 NOV 84
19 NOV 84
26 NOV 84

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5.4.3 Changes In The Data And A Second Run

A first glance at the bar-chart points out that the current completion date is November 6th 1984 and it is satisfactory to the owner. However, a lot of the wet trades, masonry, gyproc and ceramic tile, have start dates in the winter months, meaning a lot of heating required. So a milestone called "no heating required", with number 8200, and representing the date April 2nd 1984 is input and precedes several of the wet trades, mainly : 70200 Gyproc (column), 100100 masonry (L-R Hall), 100400 masonry (H-R Hall), 120100 ceramic tile, 100200 masonry (mech. room), 70300 Gyproc (enclosure), 100300 Masonry (core).

Also, the three main pieces of equipment that are located in the basement, the two pumps and the electrical equipment, cannot be delivered before April 2nd 1984. Therefore, milestone 8200 also becomes a predecessor to those three main pieces of equipment (a different milestone could have been used if the dates did not coincide). Therefore, the completion of the basement structure is no longer needed for those three activities, and that precedence can be deleted.

Appendix IE presents the sequence on the terminal to add all the above-mentioned predecessors, to delete the predecessor "Basement structure" to the three pieces of equipment and to input the new milestone and its date.

Now, everything is set up for a new run. Because some changes were made to the precedence relationships, the data has to be compiled again, by calling number 7 on the main menu. Then, the results are calculated by calling the "execute data" command.

Again, the results are printed on a bar chart; the user wants a linear chart for each of the five areas mentioned in the second chapter of this thesis: the branch mechanical room, the elevator, the enclosure, the toilets and the ceiling. For each of these areas, specific activities are to be shown on the chart. They are listed in table 5.4.

AREA	NUMBER OF ACTIVITIES	ACTIVITY NO.
Branch Mechanical Room	9	10100, 10200, 80100, 80200, 22316, 22616, 20300, 100200, 70600
Elevator	16	10100, 10200, 110100, 110200, 70500, 110300, 110400, 70400, 112109, 112209, 112316, 112416, 112509, 112616, 100100, 100400
Enclosure	6	10100, 10200, 90100, 90200, 90300, 70300
Toilet	9	10100, 10200, 60100, 20500, 60200, 70100, 120100, 40200, 60300
Ceiling	11	10100, 10200, 20100, 30100, 30200, 40100, 20200, 50100, 50200, 50300, 30300

TABLE 5.4

Activities corresponding to the five areas

The sequence on the terminal to produce the linear charts is shown in Appendix IF. Although only 3 sequences are shown, the five linear charts were actually printed. Also required at this stage is the procurement status report for the non-repetitive activities that have a procurement sequence. The sequence on the terminal is also shown in Appendix IF.

Two other reports could have been produced: the list of dates and the short cycle schedule. Because it is the beginning of the project, and only one activity (mobilization) has to be monitored, a short cycle schedule would contain only that activity; therefore the author decided not to print it. The list of dates has not been printed out this time simply because of its size (21 pages of output).

The various outputs are shown in the following pages: the list of activities (Fig. 5.26), the bar-chart (Fig. 5.27), the five linear charts (Fig. 5.28 (a) to (e)), and the procurement status report (5.29).

5.4.4. Progress and Updating

It is assumed here that an update is made on December 16th, 1983, just before the Christmas vacation.

In the first place, the actual start and finish dates of the completed activities have to be input, one by one. (See Appendix IG). Note that for the repetitive activities, the activity number should have the floor number as its last two digits.

```
REPETITIVE ACTIVITIES

NO.    DESCRIPTION         I START  CURRENT  LAST   CREWS  RATE   SS     FS     LEARN  WEATHER  TYPICAL  NON-TYP
-------------------------------------------------------------------------------------------------------------------
                           I
10100  STRUCTURE           I   1       1      16      1      6      0      0     4  90     1      0        1  12100
                           I                                                     3  75            0        0  0
                           I                                                     2  60            0        0  0
                           I                                                     1  30            0        0  0
                           I
10200  CURING & STRIP.     I   1       1      16      1      6      0      0     3  90     1      10100    0  0
                           I                                                     2  75            0        0  0
                           I                                                     1  60            0        0  0
                           I
20100  VENT. RGH DISTR.    I   1       1      16      1      5      0      0     1  80     0      10200    0  0
                           I
20200  VENT. INSULATION    I   1       1      16      1      4      0      0     1  75     0      40100    0  0
                           I
20300  VENT. UNIT          I   1       1      16      1      4      0      0     1  75     0      10200    0  0
                           I
20400  VENT FLEX. & DIFF.  I   1       1      16      1      3      0      0     2  85     0      50200    1  20116
                           I                                                     1  60            0        0  0
                           I
20500  VENT RGH (TOILET)   I   1       1      16      1      2      0      3     1  80     0      60100    0  0
                           I
30100  SPRINKLER RISER     I   1       1      16      1      6      0      0     2  90     1      10200    0  0
                           I                                                     1  75            0        0  0
                           I
30200  SPRINK. RGH DISTR.  I   1       1      16      1      5      0      0     1  80     0      30100    0  0
                           I                                                     0  0             20100    0  0
                           I
30300  SPRINKLER HEADS     I   1       1      16      1      3      0      0     2  85     0      50200    1  30216
                           I                                                     1  60            0        0  0
                           I
40100  ELECTR. RGH DISTR.  I   1       1      16      1      5      0      0     1  80     0      30200    0  0
                           I
40200  EL. BUS DUCT & PAN. I   1       1      16      1      5      0      0     2  90     0      70100    16 132116
                           I                                                     1  75            0        0  0
                           I
40300  ELECT. FIXTURES     I   1       1      16      1      3      0      0     2  85     0      50200    1  40116
                           I                                                     1  60            0        0  0
                           I
50100  CEILING TIES        I   1       1      16      1      4      0      0     0  0      0      20200    0  0
                           I
50200  CEILING GRID        I   1       1      16      1      4      0      0     2  90     0      70200    0  0
                           I                                                     1  70            50100    0  0
                           I                                                     0  0             70100    0  0
                           I                                                     0  0             70600    0  0
                           I                                                     0  0             70300    0  0
                           I
50300  TILES (CEILING)     I   1       1      16      1      3      0      0     0  0      0      40300    0  0
                           I                                                     0  0             20400    0  0
                           I                                                     0  0             30300    0  0
                           I
60100  RISER (DOM. WATER)  I   1       1      16      1      2      0      3     1  50     0      10200    0  0
                           I
60200  TOILET RGH PIPING   I   1       1      16      1      5      0      0     1  80     0      20500    0  0
                           I
60300  PLUMBING FIXTURES   I   1       1      16      1      4      0      0     1  80     0      120100   1  60216
                           I
70100  GYPROC (TOILET)     I   1       1      16      1      5      0      0     1  75     0      60200    0  0
                           I
70200  GYPROC (COLUMN)     I   1       1      16      1      4      0      0     0  0      0      10200    1  8200
                           I
70300  GYPROC (ENCLOSURE)  I   1       1      16      1      4      0      0     0  0      0      90300    1  8200
                           I
70400  GYPROC (H-R HALL)   I   9       9      16      1      3      0      0     0  0      0      100400   0  0
                           I
70500  GYPROC (L-R HALL)   I   1       1      8       1      3      0      0     0  0      0      100100   0  0
                           I
70600  GYPROC (MECH RM)    I   1       1      16      1      3      0      0     0  0      0      100200   0  0
                           I
80100  RISER (H & C WATER) I   1       1      16      1      2      0      3     1  90     0      10200    0  0
                           I
80200  HEAT. ROUGH PIPING  I   1       1      16      1      4      0      0     1  80     0      80100    0  0
                           I                                                     3  0             20300    0  0
                           I
90100  PRECAST PANELS      I   1       1      16      3      15     0      0     6  90     1      10200    0  0
                           I                                                     5  90            0        0  0
                           I                                                     4  90            0        0  0
                           I                                                     3  70            0        0  0
                           I                                                     2  70            0        0  0
                           I                                                     1  70            0        0  0
                           I
90200  GLAZING             I   1       1      16      1      5      0      0     1  90     1      90100    0  0
                           I
90300  PRECAST CAULKING    I   1       1      16      1      5      0      0     1  80     0      90200    0  0
                           I
100100 MASONRY (L-R HALL)  I   1       1      8       1      4      0      0     1  90     0      110200   1  8200
                           I
100200 MASONRY (MECH. RM)  I   1       1      16      1      4      0      0     0  0      0      20300    1  8200
                           I
100300 MASONRY ( CORE )    I   1       1      16      1      4      0      0     0  0      0      10200    1  8200
                           I
100400 MASONRY (H-R HALL)  I   9       9      16      1      4      0      0     0  0      0      110400   9  8200
                           I
110100 L-R ELEV. RAILS     I   1       1      8       1      3      0      0     1  80     0      0        1  10209
                           I
110200 L-R ELEV. FR. & DOORI   1       1      8       1      2      0      0     1  90     0      0        1  112209
                           I                                                     3  0             0        1  42100
                           I                                                     0  0             0        1  40209
                           I
110300 H-R ELEV. RAILS     I   1       1      16      1      2      0      0     2  75     0      0        1  10216
                           I                                                     1  50            0        1  110108
                           I
110400 H-R ELEV. FR. & DOORI   9       9      16      1      3      0      0     0  0      0      0        9  110208
                           I                                                     0  0             0        9  112416
                           I                                                     0  0             0        9  42100
                           I                                                     0  0             0        9  40216
                           I
120100 CERAMIC TILE        I   1       1      16      1      3      0      0     1  90     0      70100    1  8200
```

1af

```
20100  VENT. RGH DISTR.     I   1    1    16    1    5    0    0    1 80    0    10200  0  0
                            I
20200  VENT. INSULATION     I   1    1    16    1    4    0    0    1 75    0    40100  0  0
                            I
20300  VENT. UNIT           I   1    1    16    1    4    0    0    1 75    0    10200  0  0
                            I
20400  VENT FLEX. & DIFF.   I   1    1    16    1    3    0    0    2 85    0    30200  1  20116
                            I                                       1 60         0      0  0
                            I
20500  VENT RGH (TOILET)    I   1    1    16    1    2    0    3    1 80    0    40100  0  0
                            I
30100  SPRINKLER RISER      I   1    1    16    1    4    0    0    2 90    1    10200  0  0
                            I                                       1 75         0      0  0
                            I
30200  SPRINK. RGH DISTR.   I   1    1    16    1    5    0    0    1 80    0    30100  0  0
                            I                                       0 0          20100  0  0
                            I
30300  SPRINKLER HEADS      I   1    1    16    1    3    0    0    2 85    0    30200  1  30216
                            I                                       1 60         0      0  0
                            I
40100  ELECTR. RGH DISTR.   I   1    1    16    1    5    0    0    1 80    0    30200  0  0
                            I
40200  EL. BUS JCT & PAN.   I   1    1    16    1    5    0    0    2 90    0    70100  14 132116
                            I                                       1 75         0      0  0
                            I
40300  ELECT. FIXTURES      I   1    1    16    1    3    0    0    2 85    0    30200  1  40116
                            I                                       1 60         0      0  0
                            I
50100  CEILING TIES         I   1    1    16    1    4    0    0    0 0     0    20200  0  0
                            I
50200  CEILING GRID         I   1    1    16    1    4    0    0    2 90    0    70200  0  0
                            I                                       1 70         30100  0  0
                            I                                       0 0          70100  0  0
                            I                                       0 0          70600  0  0
                            I                                       0 0          70300  0  0
                            I
50300  TILES (CEILING)      I   1    1    16    1    3    0    0    0 0     0    40300  0  0
                            I                                       0 0          20400  0  0
                            I                                       0 0          30300  0  0
                            I
60100  RISER (DOM. WATER)   I   1    1    16    1    2    0    3    1 50    0    10200  0  0
                            I
60200  TOILET RGH PIPING    I   1    1    16    1    5    0    0    1 80    0    20500  0  0
                            I
60300  PLUMBING FIXTURES    I   1    1    16    1    4    0    0    1 80    0    120100 1  60216
                            I
70100  GYPROC (TOILET)      I   1    1    16    1    5    0    0    1 75    0    60200  0  0
                            I
70200  GYPROC (COLUMN)      I   1    1    16    1    4    0    0    0 0     0    10200  1  8200
                            I
70300  GYPROC (ENCLOSURE)   I   1    1    16    1    4    0    0    0 0     0    90300  1  8200
                            I
70400  GYPROC (H-R HALL)    I   9    9    16    1    3    0    0    0 0     0    100400 0  0
                            I
70500  GYPROC (L-R HALL)    I   1    1    8     1    3    0    0    0 0     0    100100 0  0
                            I
70600  GYPROC (MECH RM)     I   1    1    16    1    3    0    0    0 0     0    100200 0  0
                            I
80100  RISER (H & C WATER)  I   1    1    16    1    2    0    3    1 90    0    10200  0  0
                            I
80200  HEAT. ROUGH PIPING   I   1    1    16    1    4    0    0    1 80    0    80100  0  0
                            I                                       0 0          20300  0  0
                            I
90100  PRECAST PANELS       I   1    1    16    3    15   0    0    6 90    1    10200  0  0
                            I                                       5 90         0      0  0
                            I                                       4 90         0      0  0
                            I                                       3 70         0      0  0
                            I                                       2 70         0      0  0
                            I                                       1 70         0      0  0
                            I
90200  GLAZING              I   1    1    16    1    5    0    0    1 90    0    90100  0  0
                            I
90300  PRECAST CAULKING     I   1    1    16    1    5    0    0    1 80    0    90200  0  0
                            I
100100 MASONRY (L-R HALL)   I   1    1    8     1    4    0    0    1 90    0    110200 1  8200
                            I
100200 MASONRY (MECH. RM)   I   1    1    16    1    4    0    0    0 0     0    20300  1  8200
                            I
100300 MASONRY ( CORE )     I   1    1    16    1    4    0    0    0 0     0    10200  1  8200
                            I
100400 MASONRY (H-R HALL)   I   9    9    16    1    4    0    0    0 0     0    110400 9  8200
                            I
110100 L-R ELEV. RAILS      I   1    1    8     1    3    0    0    1 80    0    0      1  10209
                            I
110200 L-R ELEV. FR. & DOORI   1    1    8     1    2    0    0    1 90    0    0      1  112209
                            I                                       0 0          0      1  42100
                            I                                       0 0          0      1  40209
                            I
110300 H-R ELEV. RAILS      I   1    1    16    1    2    0    0    2 75    0    0      1  10216
                            I                                       1 50         0      1  110108
                            I
110400 H-R ELEV. FR. & DOORI   9    9    16    1    3    0    0    0 0     0    0      9  110208
                            I                                       0 0          0      9  112416
                            I                                       0 0          0      9  42100
                            I                                       0 0          0      9  40216
                            I
120100 CERAMIC TILE         I   1    1    16    1    3    0    0    1 90    0    70100  1  8200
```

Fig. 5.26(a) List of Activities (2nd version)

(see fig. 5.24(a) for explanation of the headings).

2 of 2

```
NON-REPETITIVE ACTIVITIES
NO.    DESCRIPTION        I DURATION PROCUREMENT WEATHER STATUS PREDECESSORS
-----------------------------------------------------------------------------
                          I
2100   MOBILIZATION       I   10         0          0       0       8100
                          I
2200   EXCAVATION         I   40         0          1       0       2100
                          I
2300   FOUNDATION         I   20         0          1       0       2200
                          I
7800   MISCELL. FINISH    I   15         0          0       0       70508
                          I                                         70416
                          I                                         100316
                          I                                         50316
                          I
7900   DEMOBILIZ.         I   10         0          0       0       112616
                          I                                         7800
                          I                                         62200
                          I                                         32200
                          I                                         22500
                          I
12100  BASEMENT STRUCT.   I   30         0          1       0       2300
                          I
22116  CHILLERS           I   10         1          0       0       10216
                          I
22216  COOLING TOWERS     I   10         1          0       0       10216
                          I
22316  FURNACES           I   20         1          0       0       10216
                          I
22416  PUMPS              I   10         1          0       0       10216
                          I
22500  BALANCING VENT.    I   20         0          0       0       42100
                          I                                         42216
                          I                                         22616
                          I                                         80216
                          I                                         20416
                          I
22616  MECH ROOM PIPING   I   15         0          0       0       22116
                          I                                         22216
                          I                                         22316
                          I                                         22416
                          I
32100  BOOSTER PUMP (SPRK) I  10         1          0       0       8200
                          I
32200  TEST SPRINKLER     I   15         0          0       0       30316
                          I                                         32100
                          I
42100  TRANSF. & SWITCH   I   20         1          0       0       8200
                          I
42216  MECH ROOM ELECTR.  I   15         1          0       0       22116
                          I                                         22216
                          I                                         22316
                          I                                         22416
                          I                                         40216
                          I
62100  BOOSTER PUMP (PLMBG)I  20         1          0       0       8200
                          I
62200  TEST PLUMBING      I   20         0          0       0       62100
                          I                                         60316
                          I
112109  LOW-RISE MOTOR    I   20         1          0       0       10209
                          I
112209 L-R CABLES & PLATF. I  20         1          0       0       110108
                          I                                         112109
                          I
112316 HIGH-RISE MOTOR    I   20         1          0       0       10216
                          I                                         112109
                          I
112416 H-R CABLES & PLATF. I  20         1          0       0       112209
                          I                                         110316
                          I                                         112316
                          I
112509 L-R FINISH & TEST  I   30         0          0       0       110208
                          I
112616 H-R FINISH & TEST  I   30         0          0       0       112509
                          I                                         110416
                          I
132116 ROOF               I   20         0          1       0       10216
MILESTONES
NO.    DESCRIPTION        I      DATE
----------------------------------------------------
                          I
8100   START OF PROJECT   I   830405
                          I
8200   NO HEATING REQ'D   I   840402

FOR A TOTAL OF [illegible] ACTIVITIES
```

(see fig. 5.24(b) for explanation of the headings)

Fig.5.26(b) List of Activities (2nd version) (cont'd)

1 of 1

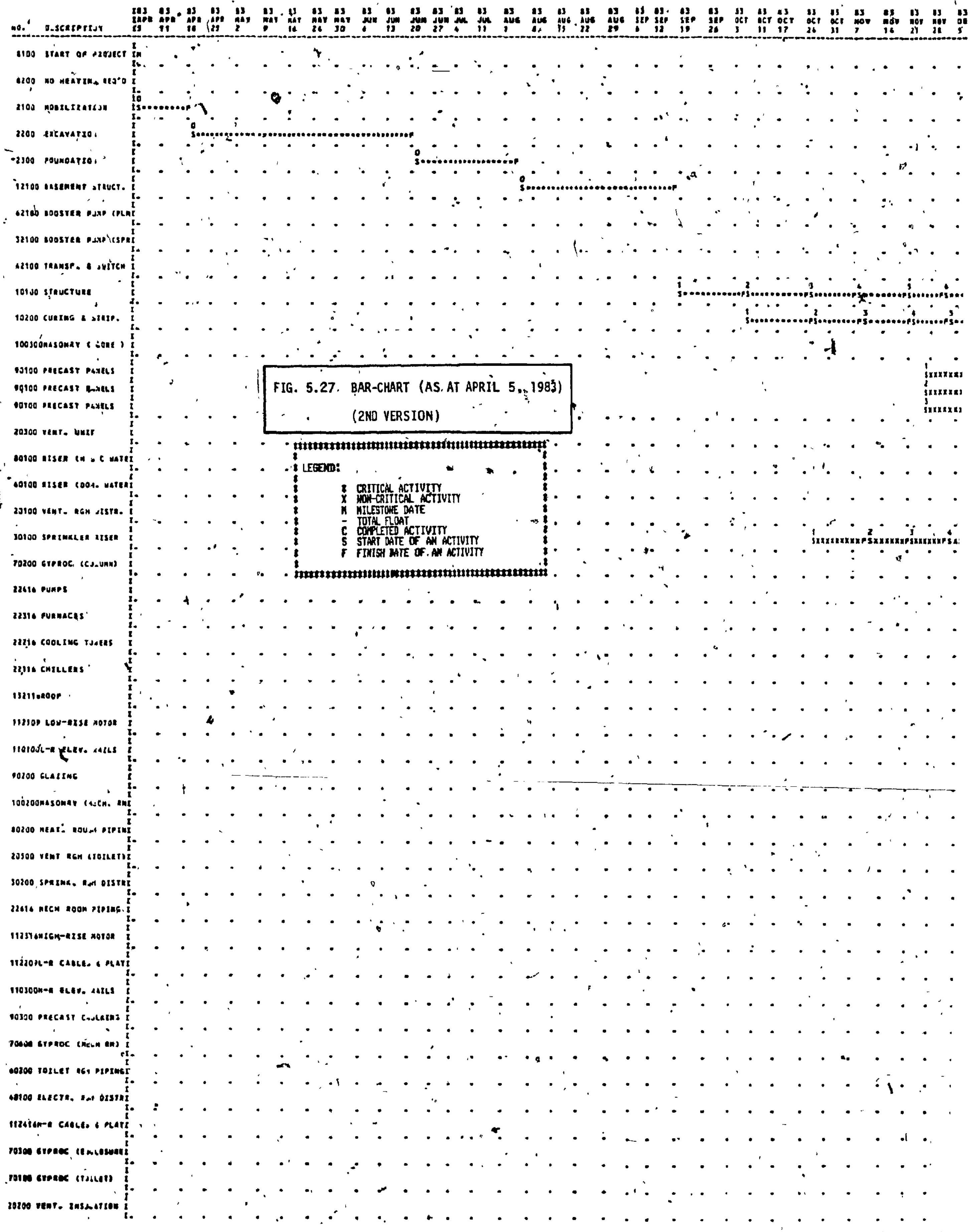
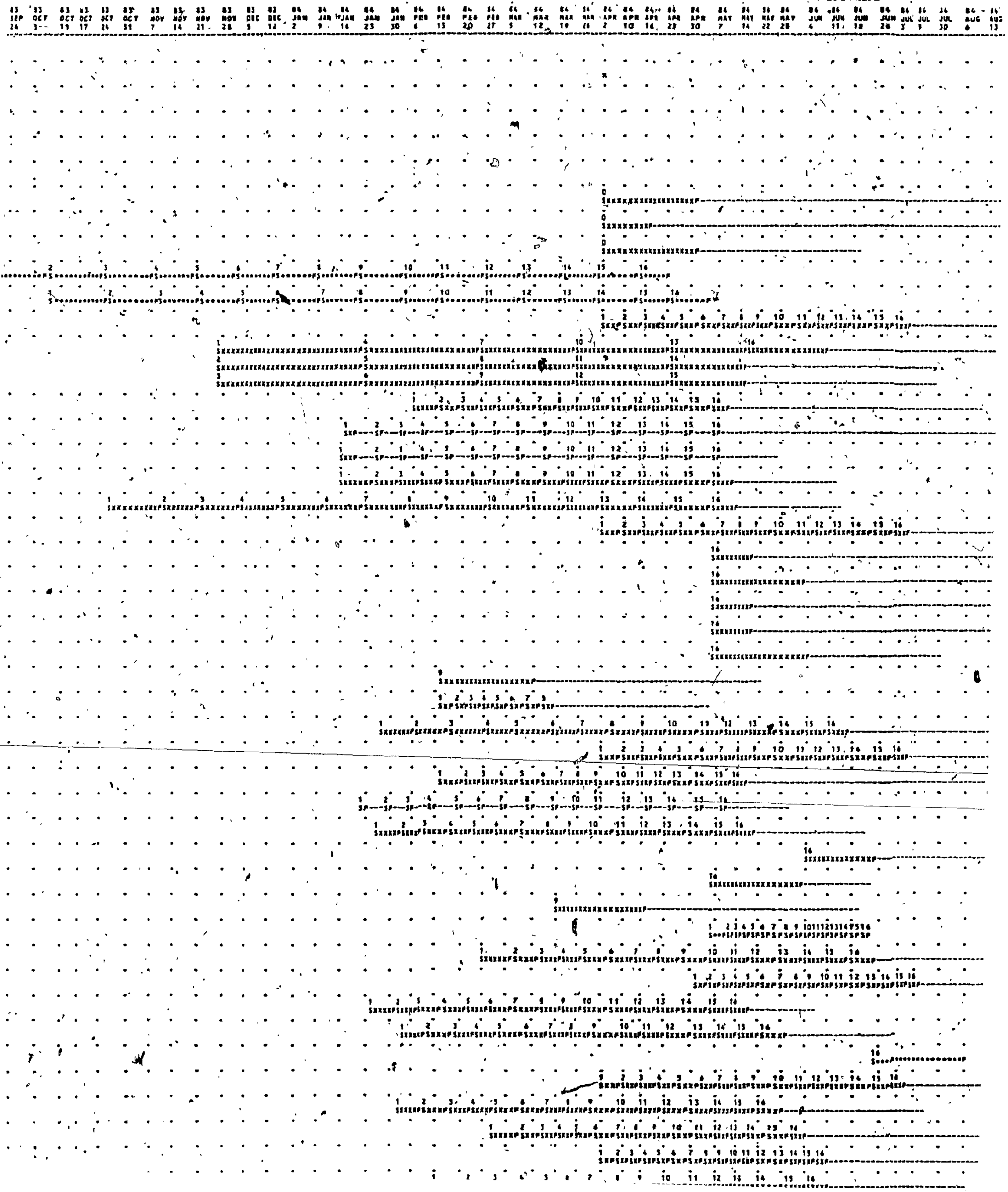


FIG. 5.27. BAR-CHART (AS AT APRIL 5, 1983)

(2ND VERSION)

2 of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83 OCT 11
83 OCT 17
83 OCT 24
83 OCT 31
83 NOV 7
83 NOV 14
83 NOV 21
83 NOV 28
83 DEC 5
83 DEC 12
84 JAN 2
84 JAN 9
84 JAN 16
84 JAN 23
84 JAN 30
84 FEB 6
84 FEB 13
84 FEB 20
84 FEB 27
84 MAR 5
84 MAR 12
84 MAR 19
84 MAR 26
84 APR 2
84 APR 10
84 APR 16
84 APR 23
84 APR 30
84 MAY 7
84 MAY 14
84 MAY 22
84 MAY 28
84 JUN 4
84 JUN 11
84 JUN 18
84 JUN 25
84 JUL 3
84 JUL 9
84 JUL 30
84 AUG 6
84 AUG 13

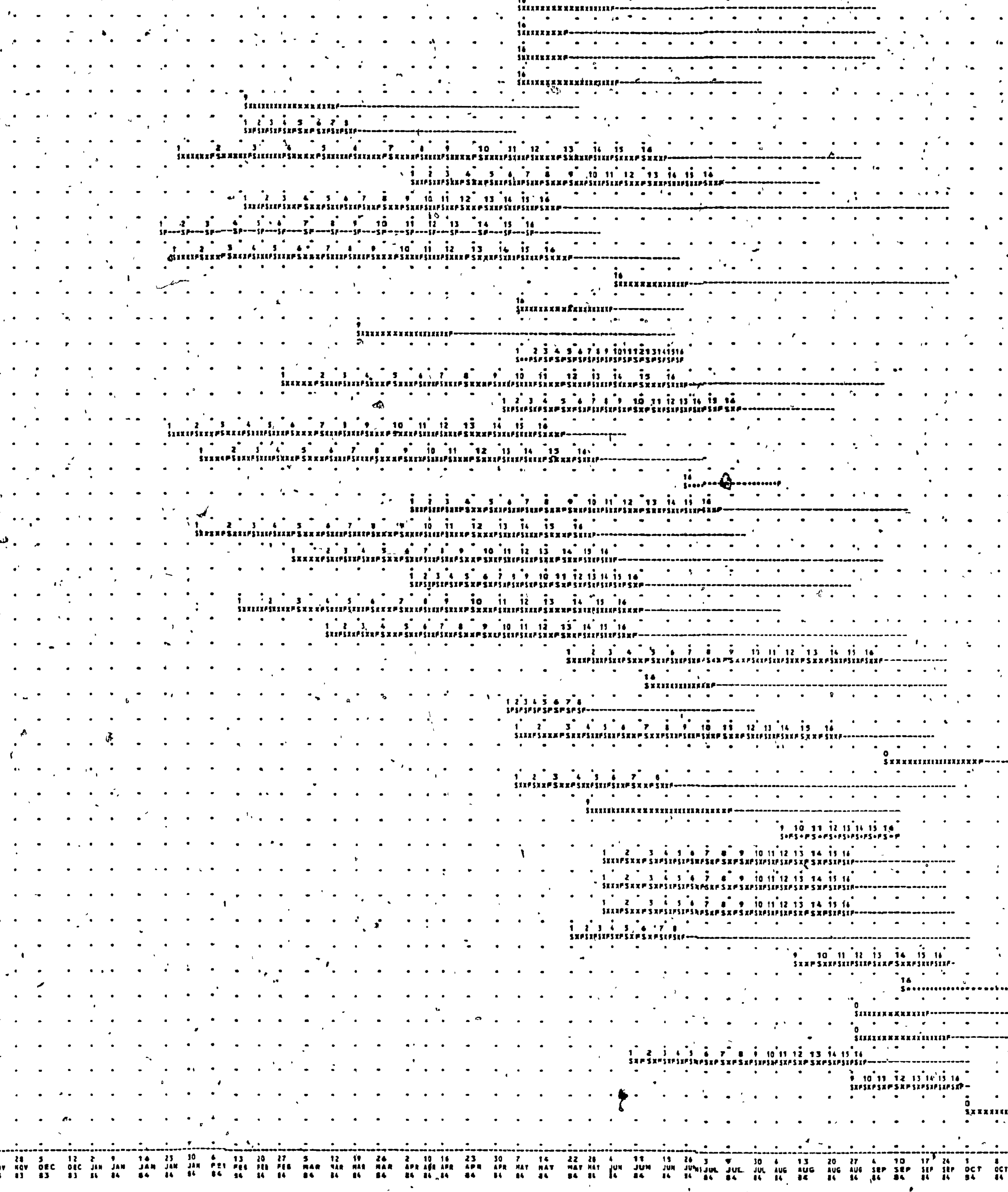
3 of

```
 84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84
MAR MAR MAR APR APR APR APR APR MAY MAY MAY MAY JUN JUN JUN JUN JUL JUL JUL AUG AUG AUG AUG SEP SEP SEP SEP OCT OCT OCT OCT OCT NOV NOV NOV NOV
 12  19  26   2  10  16  23  30   7  14  22  28   4  11  18  26   3   9  30   6  13  20  27   4  10  17  24   1   8  16  22  29   5  12  19  26
-----------------------------------------------------------------------------------------------------------------------------------------------

 0
 SXXXXXXXXXXXXXXXXXP---------------------------------------------------
 0
 SXXXXXXXXP---------------------------------------------------------------
 0
 SXXXXXXXXXXXXXXXXXP----------------------------
3      14      15      16
------FS------FS------FS------F
2      13      14      15      16
------FS------FS------FS------FS------P
      1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16
      SXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXP--------------------------------
    10                   13                16
XXXXXXXXFSXXXXXXXXXXXXXXXXXXFSXXXXXXXXXXXXXFSXXXXXXXXXXXXXXXP----------------------------
    11                   14
XXXXXXXXFSXXXXXXXXXXXXXXXXXXFSXXXXXXXXXXXXXXXP---------------------------
    12                   15
XXXXXXXXFSXXXXXXXXXXXXXXXXXXFSXXXXXXXXXXXXXXXP---------------------------
 7   8   9   10  11  12  13  14  15  16
XPSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXF--------------------------------
  9    10    11    12    13    14    15    16
---SF---SF---SF---SF---SF---SF---SF---SF-------------------------------------------------------
  9    10    11    12    13    14    15    16
---SF---SF---SF---SF---SF---SF---SF---SF------------
  9    10    11    12    13    14    15    16
XXPSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXP---------------------
11     12     13     14     15     16
SXXXXXFSXXXXXXFSXXXXXFSXXXXXXFSXXXXXFSXXXP-----------------
      1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16
      SXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXFSXXP-------------------------------
                16
                SXXXXXXXP-------------------------------------------------------------
                16
                SXXXXXXXXXXXXXXXXXXP-------------------------------------------------
                16
                SXXXXXXXP-------------------------------------------------------------
                16
                SXXXXXXXP-------------------------------------------------------------
                16
                SXXXXXXXXXXXXXXXXXXP--------------------------------
XP---------------------------------------------------
7  8
SXPSXP-----------------------------------
    6     7     8     9    10    11  12   13     14  15  16
XXXXPSXXXXPSXXXXPSXXXXPSXXXXPSXXXXPSXXXXPSXXXXPSXXXXPSXXXXPSXXXXP------------------------------------
      1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16
      SXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXP--------------------
  6   7   8   9   10  11  12  13  14  15  16
XXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXP---------------------------------------------------------
8    9    10   11   12   13   14   15   16
SP---SP---SP---SP---SP---SP---SP---SP---SP-------------
  8    9    10   11   12   13   14   15   16
XXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXP------------------
                         16
                         SXXXXXXXXXXXXP-----------------------------------------
                16
                SXXXXXXXXXXXXXXXXXXP----------------------
  9
  SXXXXXXXXXXXXXXXXXXXP--------------------------------------------
                1 2 3 4 5 6 7 8 9 10111213141516
                S--PSPSPSPSPSPSPSPSPSPSPSPSPSPSP
  3    4    5    6    7    8    9    10   11   12   13   14   15   16
XXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXP------------------------------------
               1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16
               SXPSXPSXPSXPSXPSXPSXPSXPSXPSXPSXPSXPSXPSXPSXPSXP---------------------
  8    9    10   11   12   13   14   15   16
XXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXP--------------
6   7    8    9    10   11   12   13   14   15   16
SXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXP-------------
                              16
                              S---P---------------P
      1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16
      SXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXP------------------------------
6   7   8   9    10   11   12   13   14   15   16
SXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXP----------------
2   3   4   5   6   7   8   9   10  11  12  13  14  15  16
SXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXP------------------------------
      1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16
      SXPSXPSXPSXPSXPSXPSXPSXPSXPSXPSXPSXPSXPSXPSXPSXP--------------------
```

```
22316 FURNACES          I
22216 COOLING TOWERS    I
22116 CHILLERS          I
132110ROOF              I
112109 LOW-RISE MOTOR   I
110100L-R ELEV. RAILS   I
90200 GLAZING           I
100200MASONRY (MECH. RMI
80200 HEAT. ROUGH PIPINI
20300 VENT RGH (TOILETSI
30200 SPRINK. RGH DISTRI
22416 MECH ROOM PIPING  I
112310HIGH-RISE MOTOR   I
112200L-R CABLE. & PLATI
110300H-R ELEV. RAILS   I
90300 PRECAST CAULKING  I
70600 GYPROC (MECH RM)  I
60200 TOILET RGH PIPINGI
40100 ELECTR. RGH DISTRI
112410H-R CABLES & PLATI
70300 GYPROC (ENCLOSUREI
70100 GYPROC (TOILETS)  I
20200 VENT. INSULATION  I
120100CERAMIC TILE      I
40200 EL. BUS DUCT & PAI
50100 CEILING TILES     I
60300 PLUMBING FIXTURESI
42216 MECH ROOM ELECTR.I
110200L-R ELEV. FR. & DI
50200 CEILING GRID      I
62200 TEST PLUMBING     I
100100MASONRY (L-R HALLI
112500L-R FINISH & TESTI
110400H-R ELEV. FR. & DI
30300 SPRINKLER HEADS   I
20400 VENT FLEX. & DIFFI
40300 ELECT. FIXTURES   I
70500 GYPROC (L-R HALL)I
100400MASONRY (H-R HALLI
112610H-R FINISH & TESTI
32200 TEST SPRINKLER    I
22500 BALANCING VENT.   I
50300 TILES (CEILING)   I
70400 GYPROC (H-R HALL)I
7800  MISCELL. FINISH   I
7900  DEMOBILIZE        I
                        I
                        --------------------------------------------------------------------------------------------------------------------------------
                        5   11  18  25  2   9   16  24  30  6   13  20  27  4   11  1   8   15  22  29  6   12  19  26  3   11  17   24  31  7   14  21  28  5   12  2   9
                        APR APR APR APR MAY MAY MAY MAY MAY JUN JUN JUN JUN JUL JUL AUG AUG AUG AUG AUG SEP SEP SEP SEP OCT OCT OCT. OCT OCT NOV NOV NOV NOV DEC DEC JAN JA
                        83  83  83  83  83  83  83  73  83  83  83  83  83  83  83  83  83  83  83  83  83  83  83  83  83  83  83   83  83  83  83  83  83  83  83  84  84
```

4 of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9 JAN 84
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30 JAN 84
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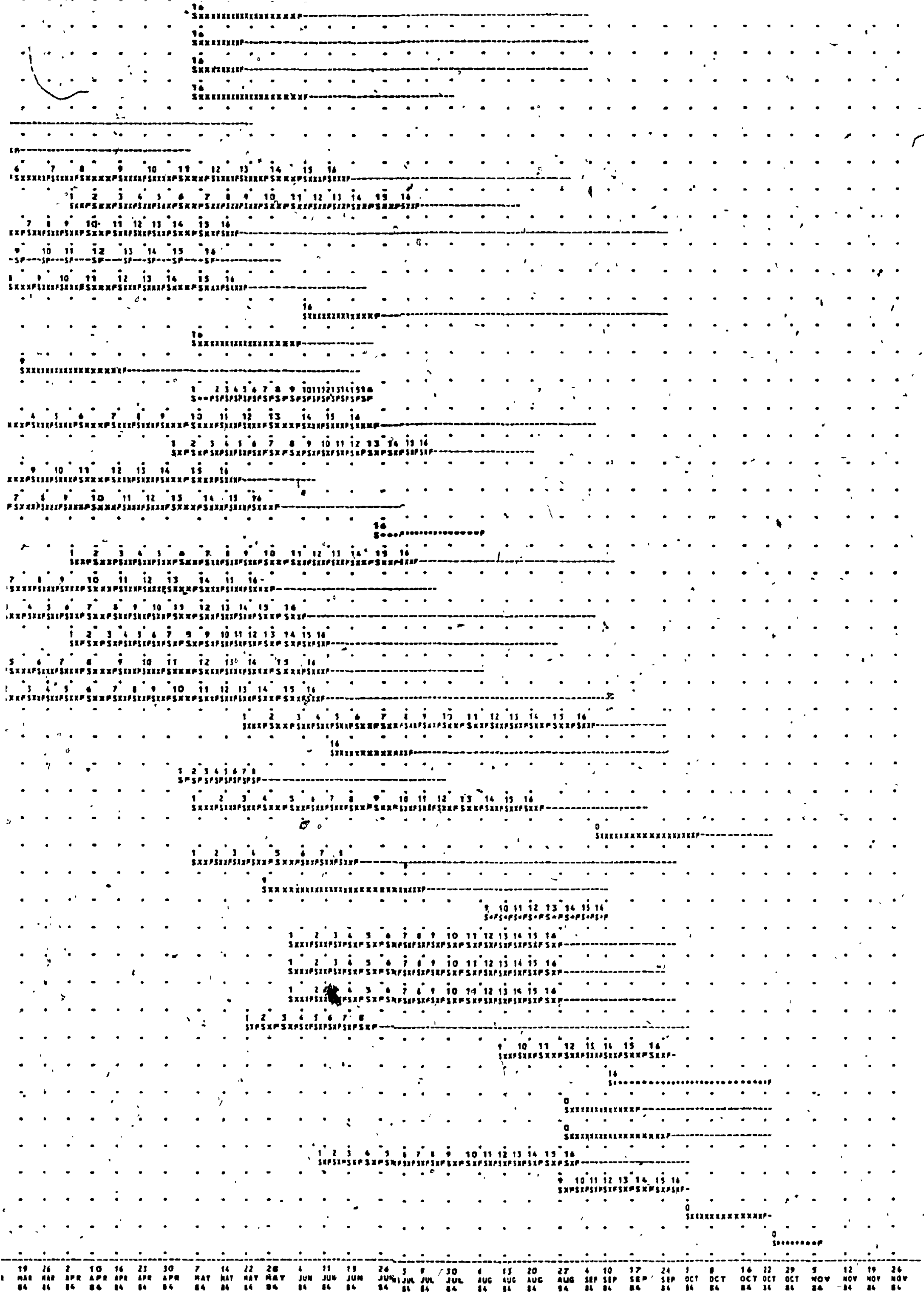
13 FEB 84
20 FEB 84
27 FEB 84
5 MAR 84
12 MAR 84
19 MAR 84
26 MAR 84
2 APR 84
10 APR 84
16 APR 84
23 APR 84
30 APR 84
7 MAY 84
14 MAY 84
22 MAY 84
28 MAY 84
4 JUN 84
11 JUN 84
19 JUN 84
26 JUN 84
3 JUL 84
9 JUL 84
30 JUL 84
6 AUG 84
13 AUG 84
20 AUG 84
27 AUG 84
4 SEP 84
10 SEP 84
17 SEP 84
24 SEP 84
1 OCT 84
8 OCT 84

5 of


19 MAR 84
26 MAR 84
2 APR 84
10 APR 84
16 APR 84
23 APR 84
30 APR 84
7 MAY 84
14 MAY 84
22 MAY 84
28 MAY 84
4 JUN 84
11 JUN 84
19 JUN 84
26 JUN 84
3 JUL 84
9 JUL 84
30 JUL 84
6 AUG 84
13 AUG 84
20 AUG 84
27 AUG 84
4 SEP 84
10 SEP 84
17 SEP 84
24 SEP 84
1 OCT 84
8 OCT 84
16 OCT 84
22 OCT 84
29 OCT 84
5 NOV 84
12 NOV 84
19 NOV 84
26 NOV 84

6 of 6

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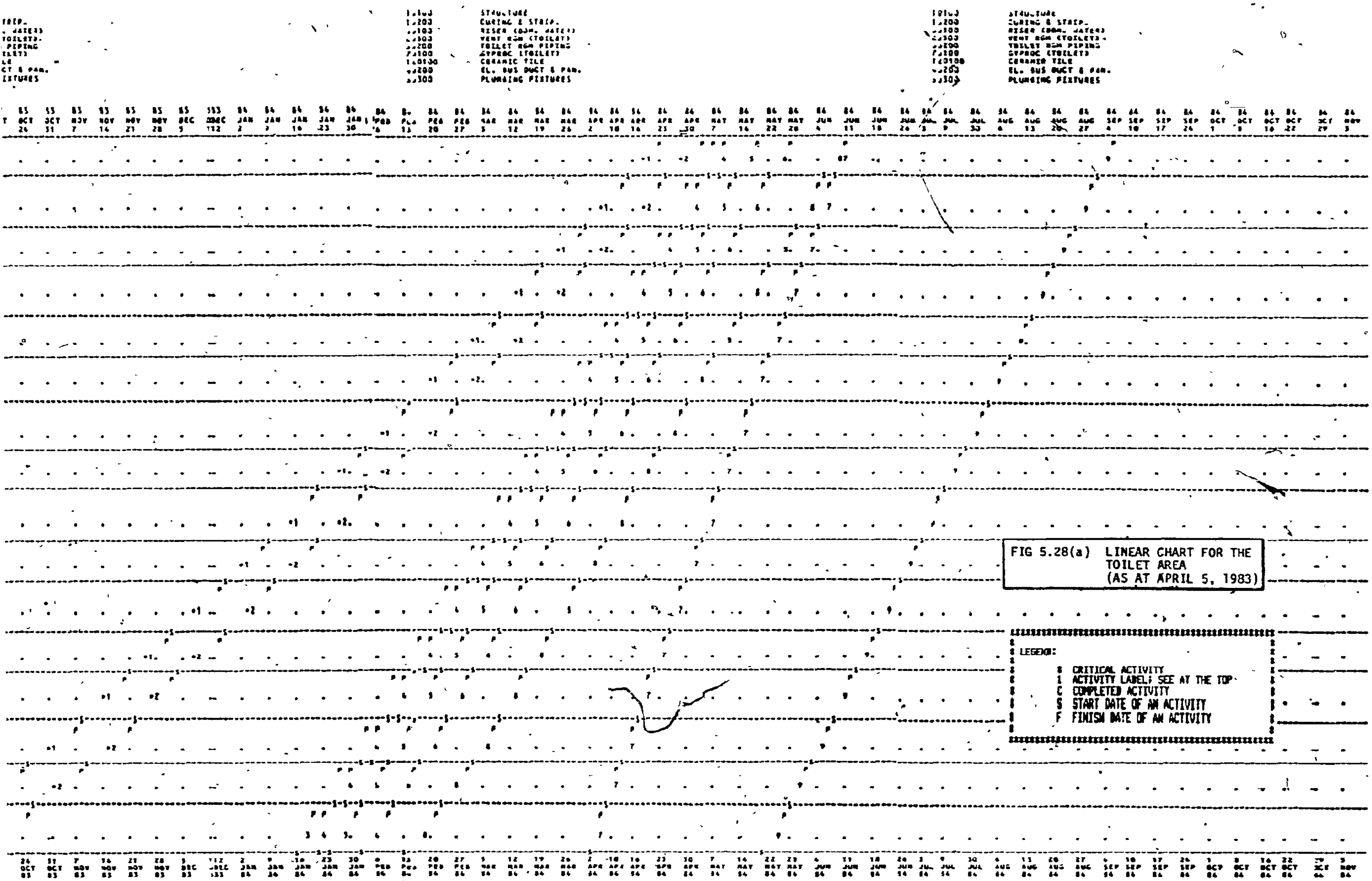

FIG 5.28(a) LINEAR CHART FOR THE TOILET AREA (AS AT APRIL 5, 1983)

1af

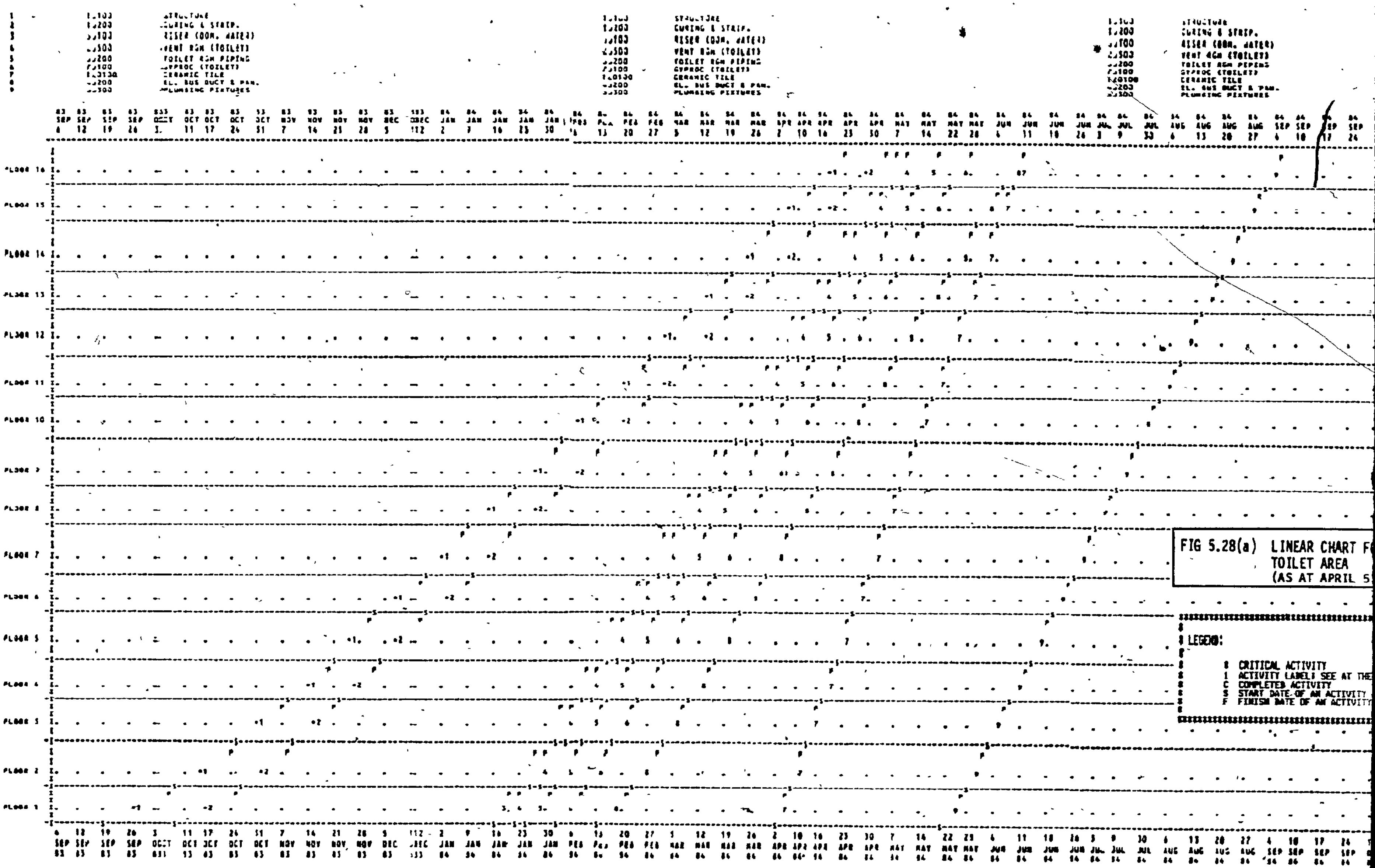

FIG 5.28(a) LINEAR CHART F
TOILET AREA
(AS AT APRIL 5

2 of 2

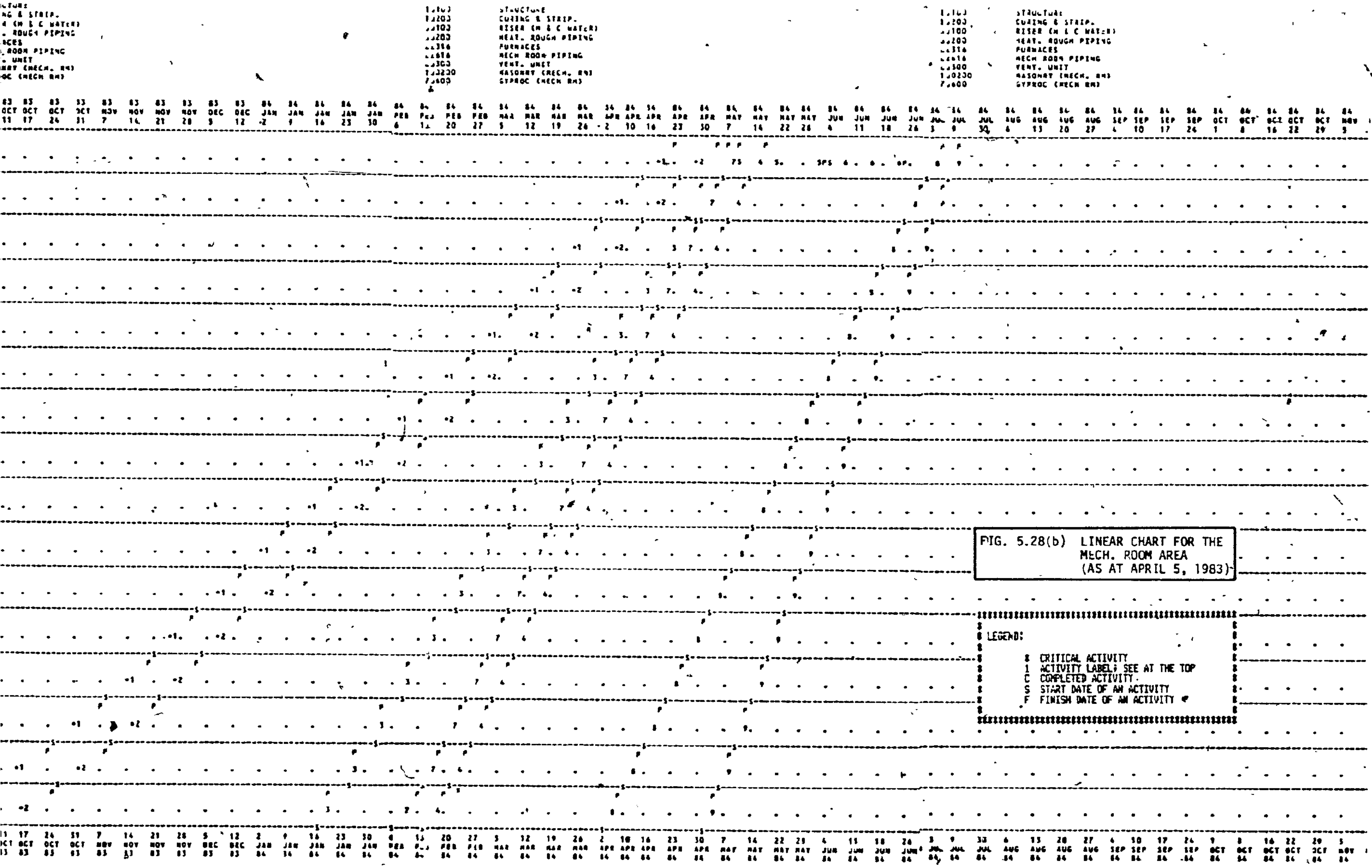

FIG. 5.28(b) LINEAR CHART FOR THE MECH. ROOM AREA (AS AT APRIL 5, 1983)

1af

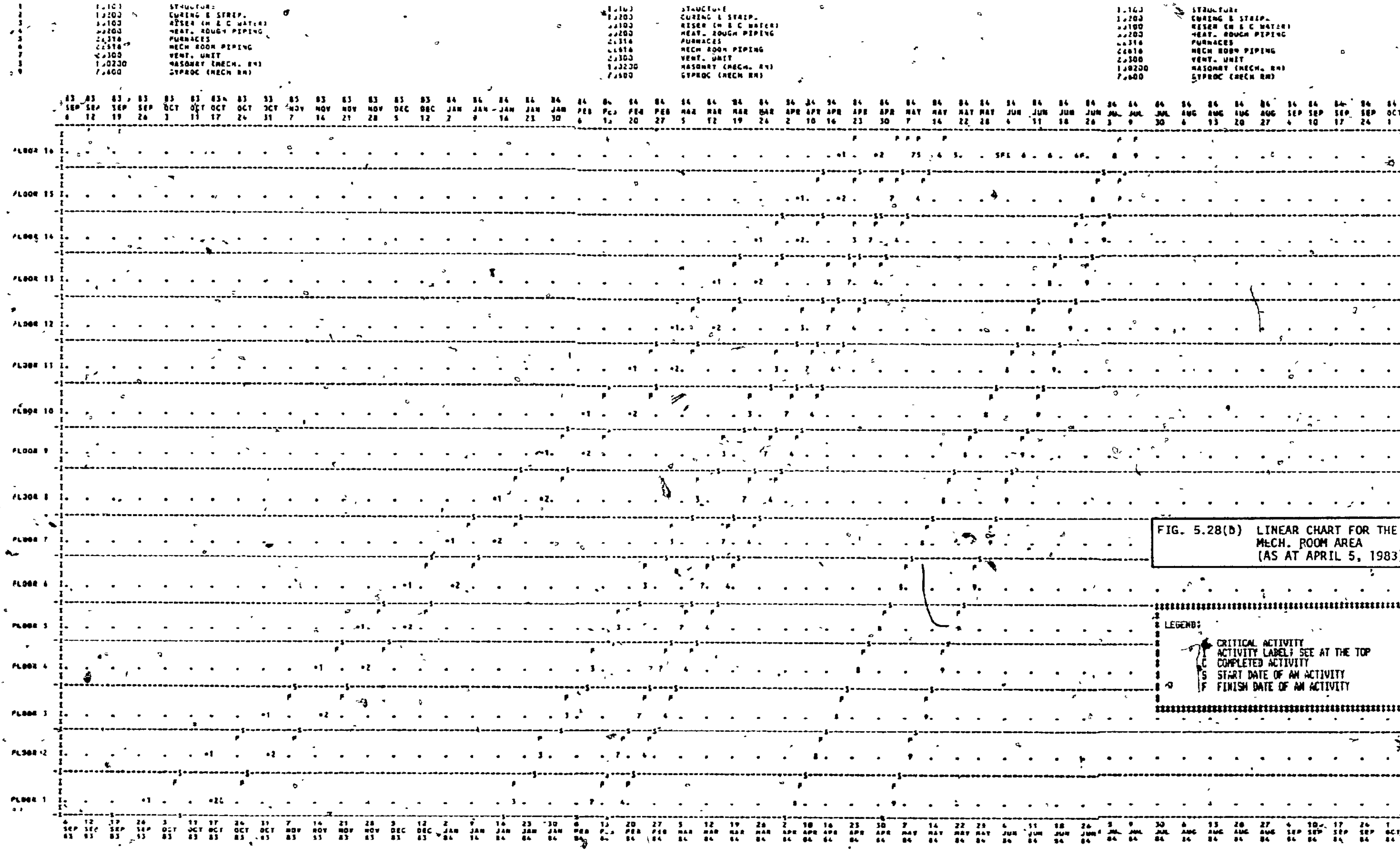

FIG. 5.28(b) LINEAR CHART FOR THE MECH. ROOM AREA (AS AT APRIL 5, 1983)

2 of 2

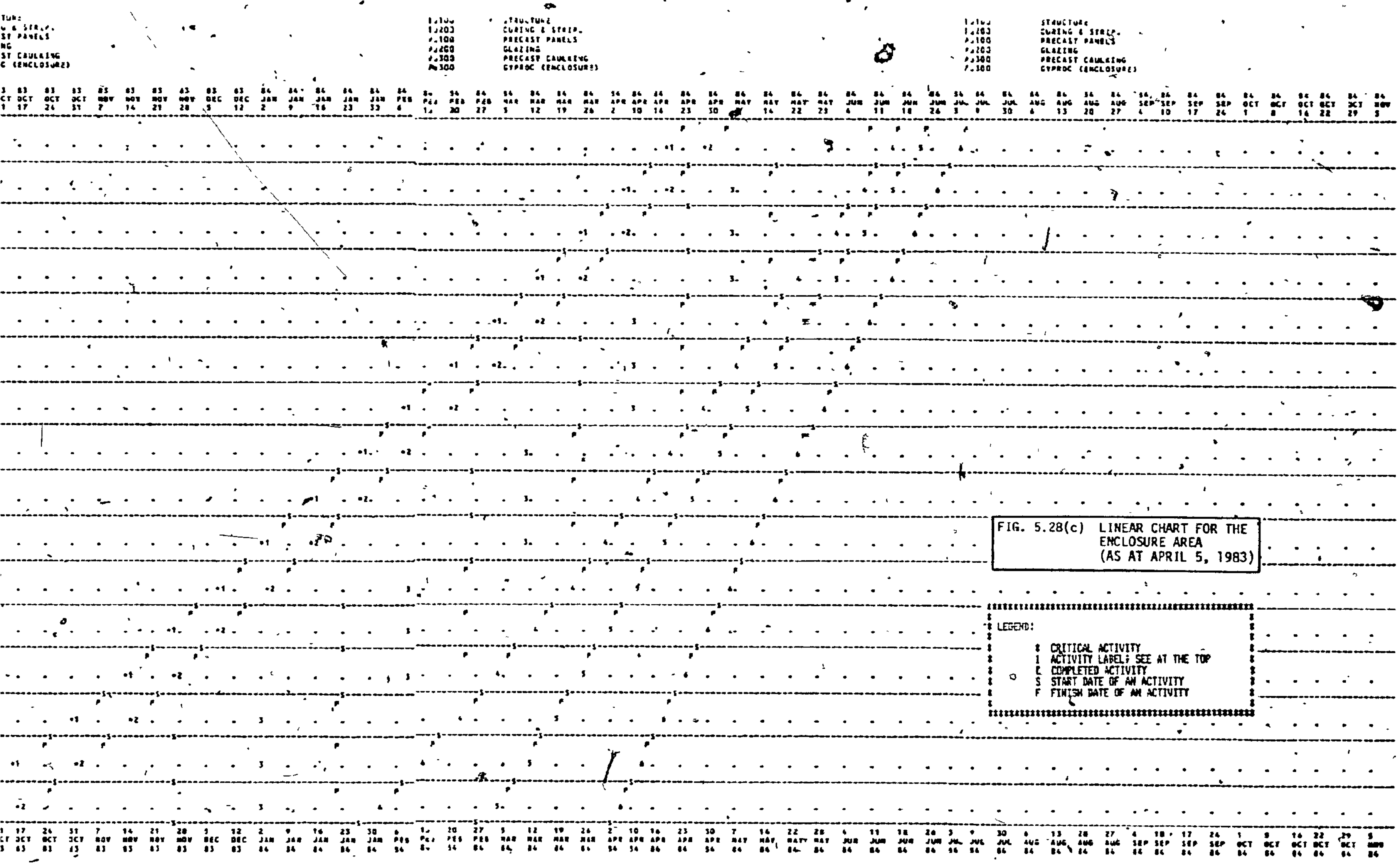

FIG. 5.28(c) LINEAR CHART FOR THE ENCLOSURE AREA (AS AT APRIL 5, 1983)

1af

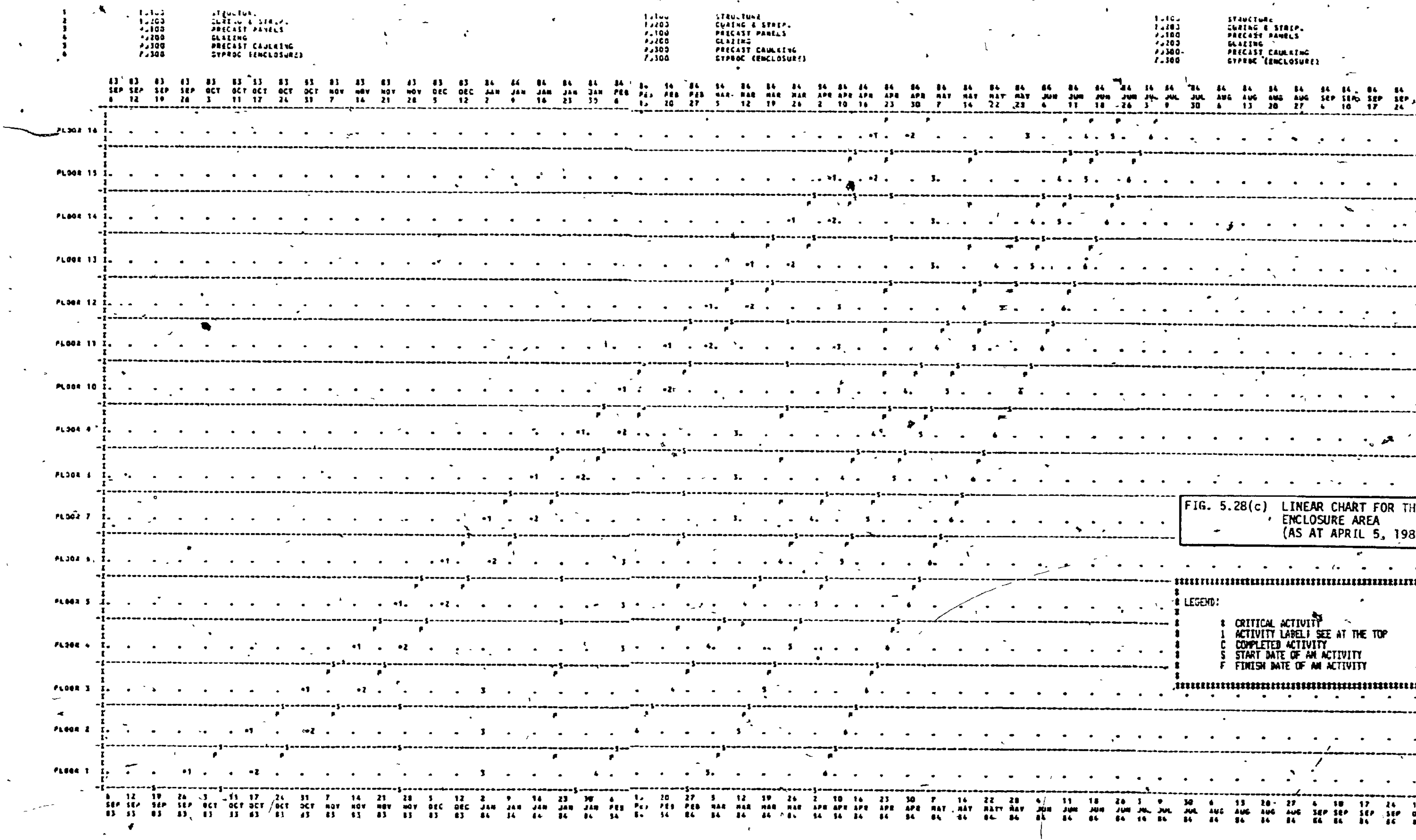

FIG. 5.28(c) LINEAR CHART FOR TH
ENCLOSURE AREA
(AS AT APRIL 5, 198

2of2

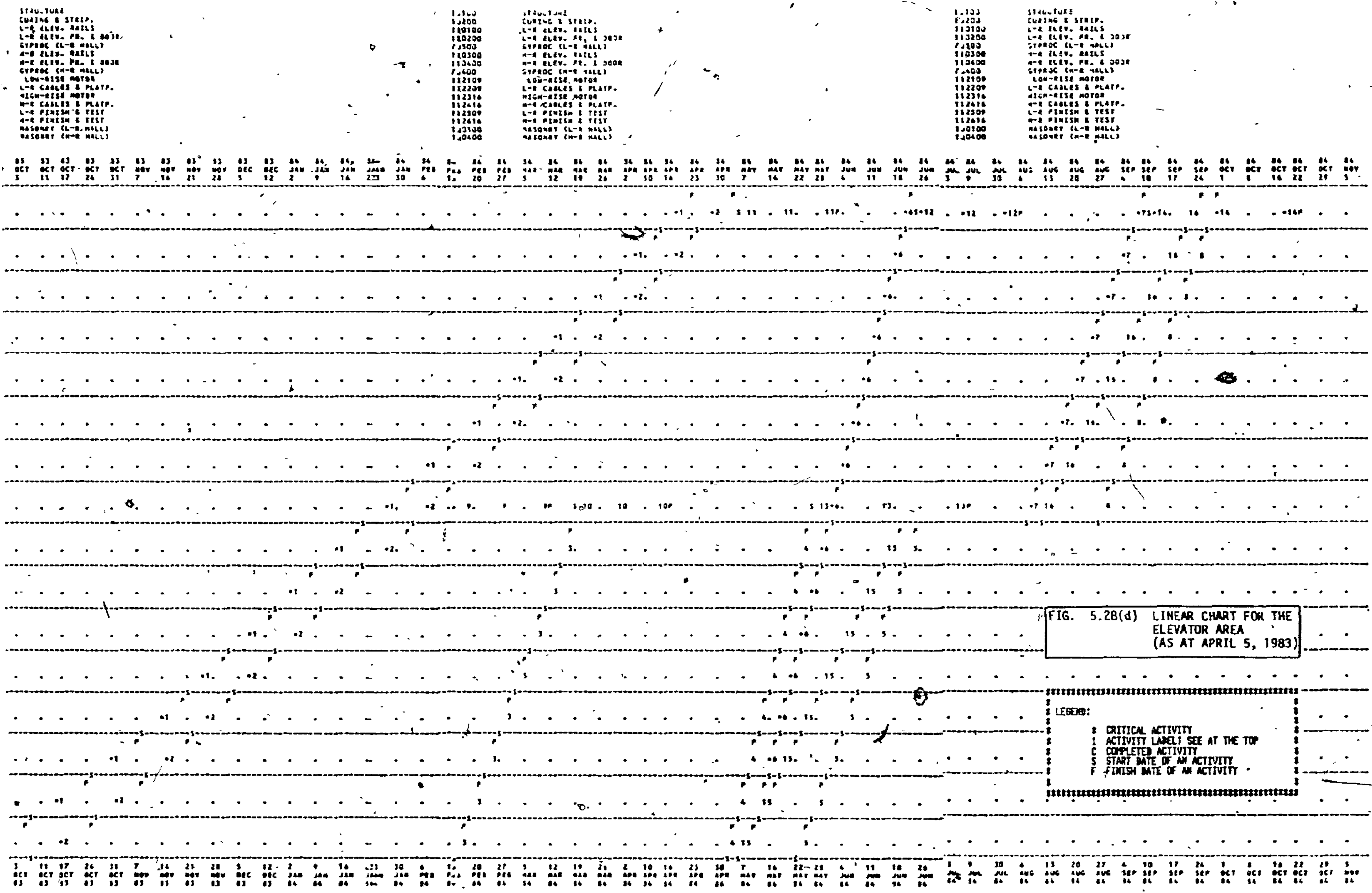

FIG. 5.28(d) LINEAR CHART FOR THE ELEVATOR AREA (AS AT APRIL 5, 1983)

LEGEND:

- $ CRITICAL ACTIVITY
- 1 ACTIVITY LABEL; SEE AT THE TOP
- C COMPLETED ACTIVITY
- S START DATE OF AN ACTIVITY
- F FINISH DATE OF AN ACTIVITY

1 af

1	1.103	STRUCTURE
2	1.200	CURING & STRIP.
3	110100	L-R ELEV. RAILS
4	110200	L-R ELEV. FR. & DOOR
5	7.500	GYPROC (L-R HALL)
6	110300	H-R ELEV. RAILS
7	110400	H-R ELEV. FR. & DOOR
8	7.600	GYPROC (H-R HALL)
9	112109	LOW-RISE MOTOR
10	112209	L-R CABLES & PLATF.
11	112316	HIGH-RISE MOTOR
12	112416	H-R CABLES & PLATF.
13	112509	L-R FINISH & TEST
14	112616	H-R FINISH & TEST
15	140100	MASONRY (L-R HALL)
16	140400	MASONRY (H-R HALL)

1.103 STRUCTURE
1.200 CURING & STRIP.
110100 L-R ELEV. RAILS
110200 L-R ELEV. FR. & DOOR
7.500 GYPROC (L-R HALL)
110300 H-R ELEV. RAILS
110400 H-R ELEV. FR. & DOOR
7.600 GYPROC (H-R HALL)
112109 LOW-RISE MOTOR
112209 L-R CABLES & PLATF.
112316 HIGH-RISE MOTOR
112416 H-R CABLES & PLATF.
112509 L-R FINISH & TEST
112616 H-R FINISH & TEST
140100 MASONRY (L-R HALL)
140400 MASONRY (H-R HALL)

1.103 STRUCTURE
1.200 CURING & STRIP.
110100 L-R ELEV. RAILS
110200 L-R ELEV. FR. & DOOR
7.500 GYPROC (L-R HALL)
110300 H-R ELEV. RAILS
110400 H-R ELEV. FR. & DOOR
7.600 GYPROC (H-R HALL)
112109 LOW-RISE MOTOR
112209 L-R CABLES & PLATF.
112316 HIGH-RISE MOTOR
112416 H-R CABLES & PLATF.
112509 L-R FINISH & TEST
112616 H-R FINISH & TEST
140100 MASONRY (L-R HALL)
140400 MASONRY (H-R HALL)

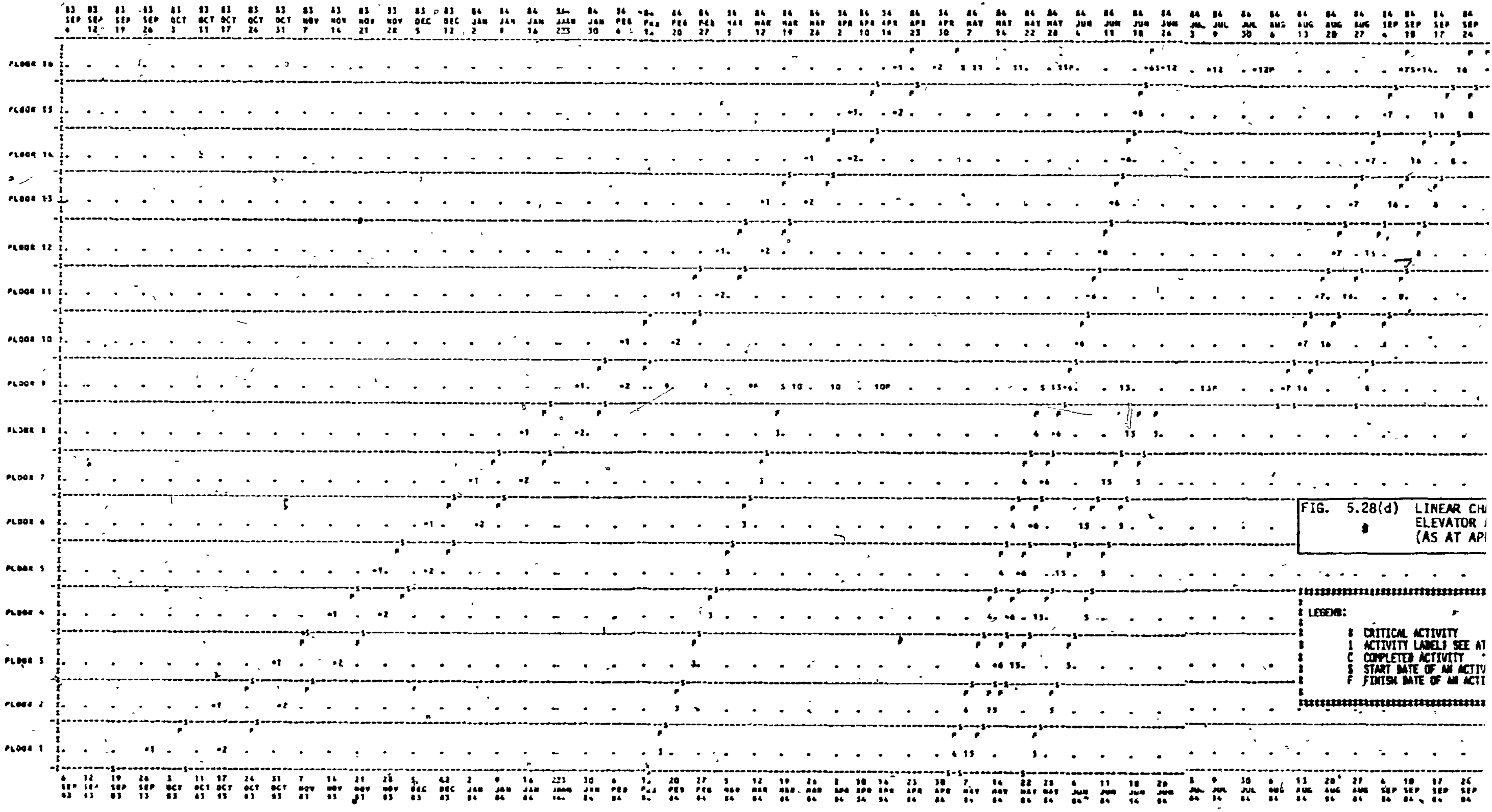

FIG. 5.28(d) LINEAR CH
$
ELEVATOR
(AS AT AP

LEGEND:

$ CRITICAL ACTIVITY
1 ACTIVITY LABEL) SEE AT
C COMPLETED ACTIVITY
S START DATE OF AN ACTIV
F FINISH DATE OF AN ACTI

2 of 2

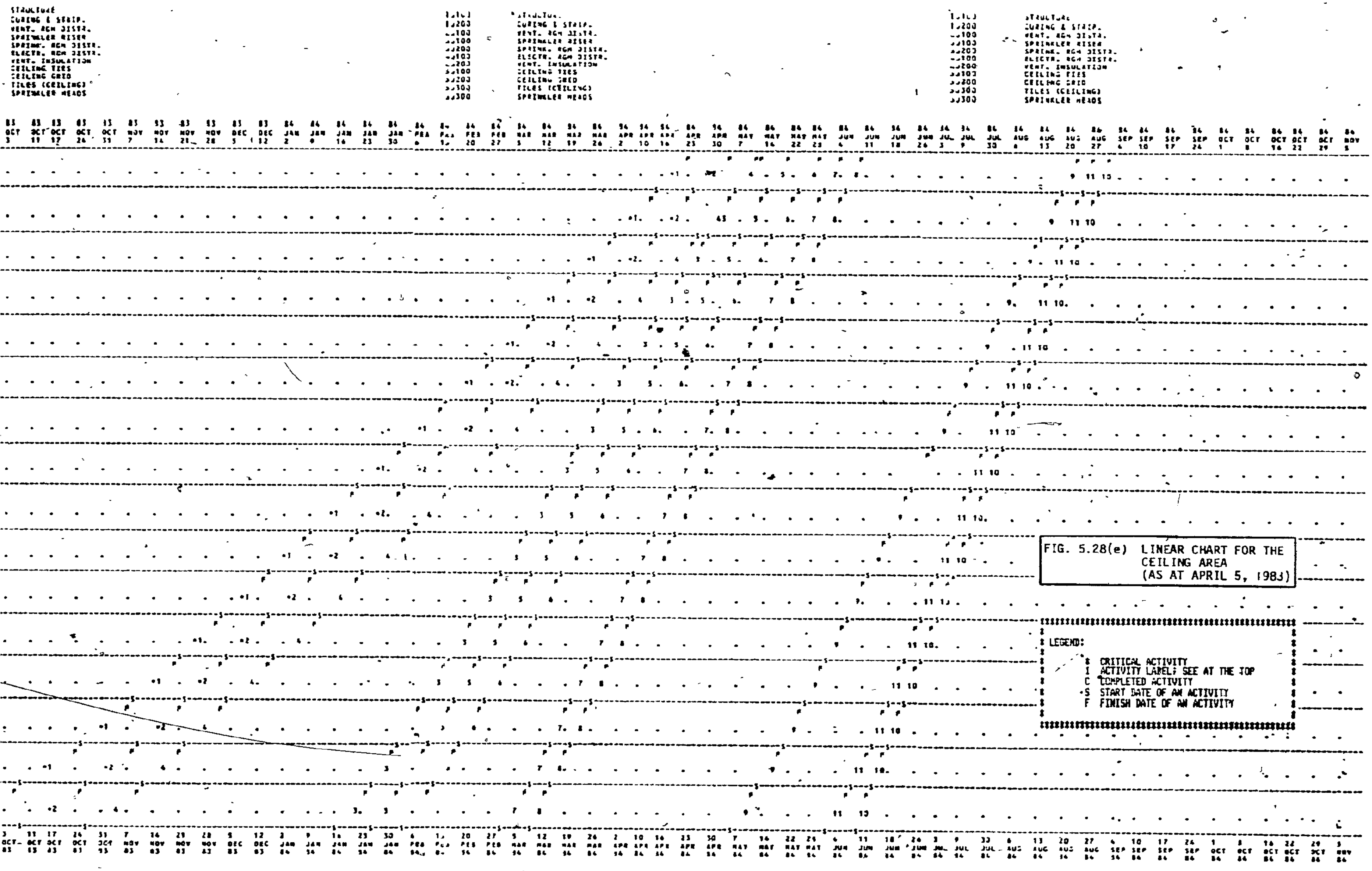

FIG. 5.28(e) LINEAR CHART FOR THE CEILING AREA (AS AT APRIL 5, 1983)

1af

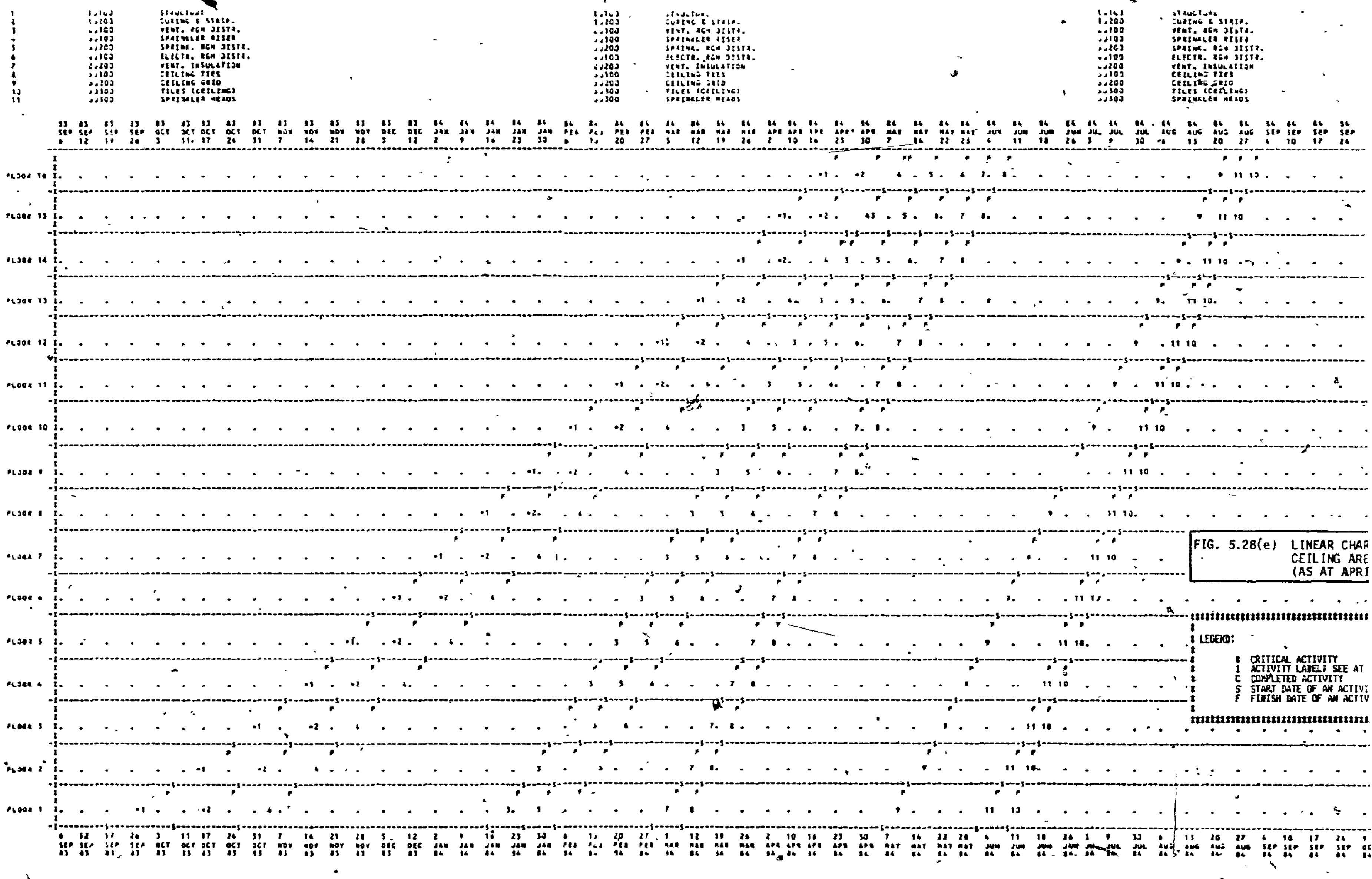

FIG. 5.28(e) LINEAR CHAR
CEILING ARE
(AS AT APRI

LEGEND:

$ CRITICAL ACTIVITY
1 ACTIVITY LABEL; SEE AT
C COMPLETED ACTIVITY
S START DATE OF AN ACTIVI
F FINISH DATE OF AN ACTIV

2 of 2

```
 PROCUREMENT STATUS REPORT

                         PREPAR.   TENDER    CONTRACT  SHOP DWG  SHOP DWG  FABRIC.   SHIPPING  CUSTOM    DELIVERY
  NO.    DESCRIPTION   I BID DOC.  CALL      AWARD     SUBMIT    APPROV.   EQUIP.    EQUIP.    CLEAR     INSPECT.
------------------------------------------------------------------------------------------------------------------
                       I
62100  BOOSTER PUMP (PLI                     25JAN84                       1 FEB84   14MAR84             28MAR84
                       I
32100  BOOSTER PUMP (SPI                     23JAN84                       6 FEB84   19MAR84   26MAR84   29MAR84
                       I
42100  TRANSF. & SWITCHI 9 JAN84   16JAN84   26JAN84                       30JAN84   12MAR84             26MAR84
                       I
22416  PUMPS           I                               24FEB84   9 MAR84   13MAR84   12APR84   26APR84   1 MAY84
                       I
22316  FURNACES        I                                                   29FEB84   13APR84             27APR84
                       I
22216  COOLING TOWERS  I 26JAN84   9 FEB84   23FEB84   28FEB84   13MAR84   16MAR84   17APR84             1 MAY84
                       I
22116  CHILLERS        I 5 JAN84   19JAN84   2 FEB84   7 FEB84   21FEB84   24FEB84   10APR84   24APR84   1 MAY84
                       I
112109 LOW-RISE MOTOR  I                               2 DEC83   16DEC83   6 JAN84   3 FEB84             10FEB84
                       I
112316 HIGH-RISE MOTOR I                               20FEB84   19MAR84   26MAR84   18APR84             2 MAY84
                       I
112209 L-R CABLES & PLAI                                                   15FEB84   29FEB84             14MAR84
                       I
112416 H-R CABLES & PLAI                                                   10MAY84   8 JUN84             19JUN84
                       I
42216  MECH ROOM ELECTRI                                                   24APR84   23MAY84             6 JUN84
                       I
```

Fig. 5.29 Procurement Status Report

After those dates are input, the status of the non-repetitive activities and the current levels of the repetitive activities have to be updated: non-repetitive activities 2100, 2200, 2300, and 12100 now have a status of completed (or (1)). Repetitive activity 10100, the structure, is now completed on 6 floors; therefore the current level is 7. Repetitive activities 10200 and 30100 are now completed on floors 4 and 5 respectively; therefore their current levels are 5 and 6 respectively.

Also, a change in the design of the ventilation units on each of the floors will delay their delivery by one month so that activity cannot start before March 5th, 1984, necessitating a new activity, milestone No. 8300, called "START DEL. OF VENT", which precedes activity 20300 on the first floor.

Also delayed was the start of the precast panel erection, promised now for January 2nd 1984. So another milestone, No. 8400, called "START PANELS", and bearing that date, would be input and precede the start of activity 90100 on the first floor. Finally, milestone 8100, "START OF THE PROJECT" is no longer needed and can be deleted.

After all this input is performed, the data has to be compiled again, because changes were made in the predecessors. It is then executed and the results printed on a bar-chart (Fig. 5.30). The sequence on the terminal for all these changes is shown in Appendix IG. Because one activity was deleted, the file should be rearranged when the data is executed (option 8 of menu).

1 of 1

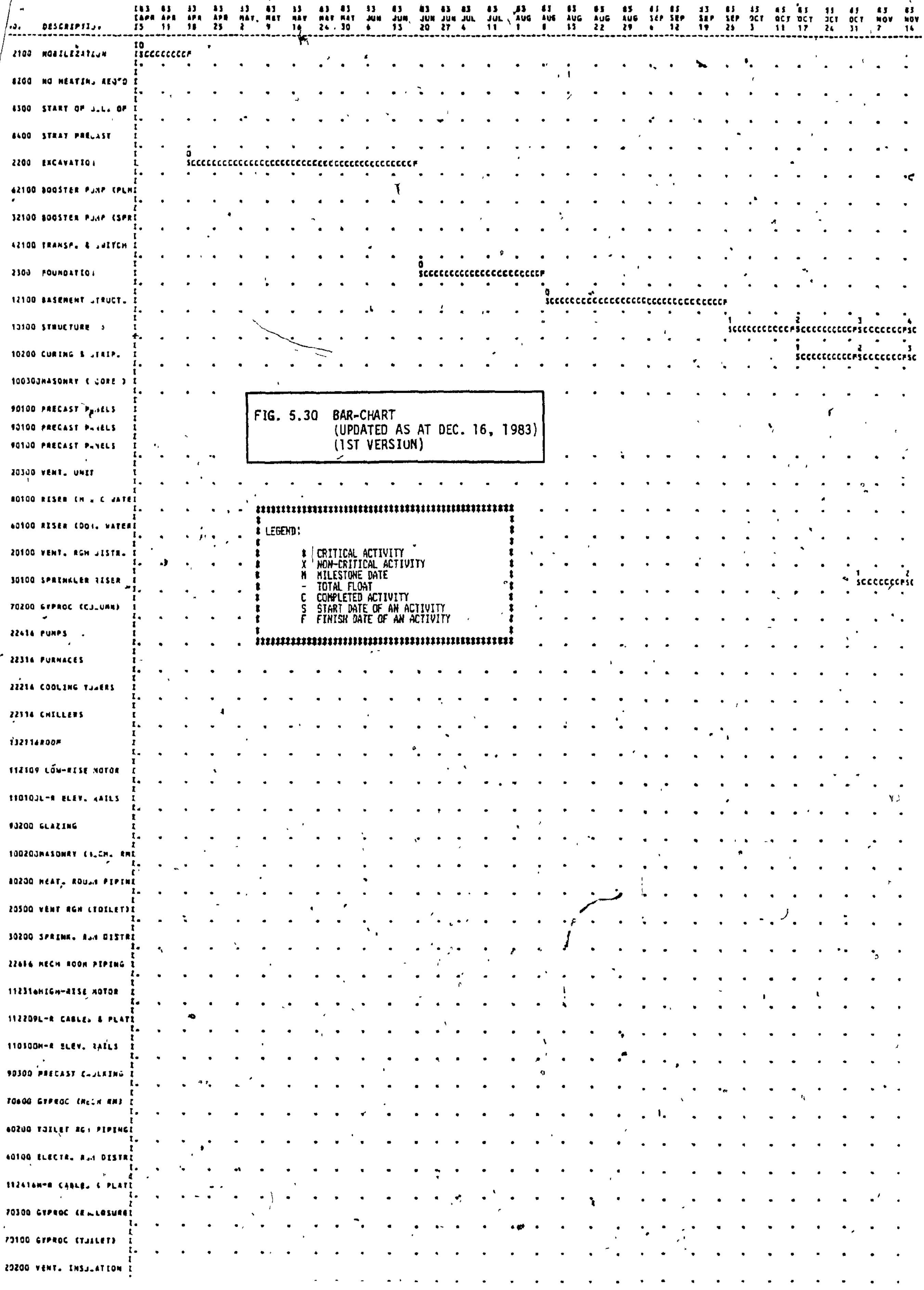

FIG. 5.30 BAR-CHART
(UPDATED AS AT DEC. 16, 1983)
(1ST VERSION)

LEGEND:

- $ CRITICAL ACTIVITY
- X NON-CRITICAL ACTIVITY
- M MILESTONE DATE
- \- TOTAL FLOAT
- C COMPLETED ACTIVITY
- S START DATE OF AN ACTIVITY
- F FINISH DATE OF AN ACTIVITY

2 of 1

```
  83  83  83  83  83  83  83  83  83  83 | 84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84  84
T OCT OCT OCT OCT NOV NOV NOV NOV DEC DEC | JAN JAN JAN JAN JAN FEB FEB FEB FEB MAR MAR MAR MAR APR APR APR APR APR MAY MAY MAY MAY JUN JUN JUN JUN JUL JUL JUL AUG AUG AUG A
  11  17  24  31  7   14  21  28  5   12  | 2   9   16  23  30  6   13  20  27  5   12  19  26  2   10  16  23  30  7   14  22  28  4   11  19  26  3   9   30  6   13  20  2
----------------------------------------------------------------------------------------------------------------------------------------------------------------------------
                                                                                         0
                                                                                         SXXXXXXXXXXXXXXXXXP-------------------------------------------------------------
                                                                                         0
                                                                                         SXXXXXXXXP----------------------------------------------------------------------
                                                                                         0
                                                                                         SXXXXXXXXXXXXXXXXP------------------------------------------
      2       3       4       5      6      7       8       9      10      11      12      13      14      15      16
CCCCCCPSCCCCCCCCCCPSCCCCCCCPSCCCCCCCPSCCCCCPSCCCCCCPS******FS******PS******PS******PS*****FS*****PS******PS******PS******PS*****P
      1       2       3       4       5      6       7       8       9      10      11      12      13      14      15     16
      SCCCCCCCCCCPSCCCCCCCPSCCCCCCCPSCCCCCPSCCCCCCPS******FS******PS******PS******PS*****FS*****PS******PS******PS******PS*****P
                                                                                         1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16
                                                                                         SXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXP-------------------
                                         1                 4                 7                 10                13                16
                                         SXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXPSXXXXXXXXXXXXXXXXXXXXXXXPSXXXXXXXXXXXXXXXXXXXXXXXXXXXXPSXXXXXXXXXXXXXXP--------------------
                                         2                 5                 8                 11                14
                                         SXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXPSXXXXXXXXXXXXXXXXXXXXXXXPSXXXXXXXXXXXXXXXXXXXXXXXXXXXXPSXXXXXXXXXXXXXXP----------
                                         3                 6                 9                 12                15
                                         SXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXPSXXXXXXXXXXXXXXXXXXXXXXXPSXXXXXXXXXXXXXXXXXXXXXXXXXXXXPSXXXXXXXXXXXXXXP----------
                                                                         1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16
                                                                         SXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXP--------------------
                                                  1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16
                                                  SXP---SP---SP---SP---SP---SP---SP---SP---SP---SP---SP---SP---SP---SP---SP---SP--------------------------
                                                  1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16
                                                  SXXP---SP---SP---SP---SP---SP---SP---SP---SP---SP---SP---SP---SP---SP---SP---SP-----------
                                                  1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16
                                                  SXXXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXXP--------------------
               1       2       3       4       5      6       7       8      9      10      11      12      13      14      15      16
               SCCCCCCPSCCCCCCCCPSCCCCCPSCCCCCCCPSXXXXXXPSXXXXXXPSXXXXXXPSXXXXXXPSXXXXXXPSXXXXXXPSXXXXXXPSXXXXXXPSXXXXXXPSXXXXXXPSXXXXXXPSXXXXXXP-------
                                                                                         1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16
                                                                                         SXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXP-------------------
                                                                                                          16
                                                                                                          SXXXXXXXP--------------------------------------------------
                                                                                                          16
                                                                                                          SXXXXXXXXXXXXXXXXP-----------------------------------------
                                                                                                          16
                                                                                                          SXXXXXXXP--------------------------------------------------
                                                                                                          16
                                                                                                          SXXXXXXXP--------------------------------------------------
                                                                                                          16
                                                                                                          SXXXXXXXXXXXXXXXXP------------------------
                                                                    9
                                                                    SXXXXXXXXXXXXXXXXP------------------------------------------
                                                                    1 2 3 4 5 6 7 8
                                                                    SXPSXPSXPSXPSXPSXPSXPSXP---------------------------
                                                                    1       2       3       4       5       6       7       8       9       10      11      12      13      14      15      16
                                                                    SXXXXXPSXXXXPSXXXXXPSXXXXXPSXXXXXPSXXXXPSXXXXPSXXXXPSXXXXPSXXXXPSXXXXPSXXXXPSXXXXPSXXXXPSXXXXPSXXXXP---------
                                                                                         1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16
                                                                                         SXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXP--------------------
                                                                            1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16
                                                                            SXXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXP-------------------------------
                                                   1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16
                                                   SP---SP---SP---SP---SP---SP---SP---SP---SP---SP---SP---SP---SP---SP---SP---SP----------
                                                      1      2      3      4      5      6      7      8      9      10     11     12     13     14     15     16
                                                      SXXXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXP-----------------------
                                                                                                                           16
                                                                                                                           SXXXXXXXXXXXXXP-------------------
                                                                                                          16
                                                                                                          SXXXXXXXXXXXXXXXXP-----------------
                                                                                   9
                                                                                   SXXXXXXXXXXXXXXXXP----------------------------------
                                                                                                          1 2 3 4 5 6 7 8 9 10111213141516
                                                                                                          S--PSPSPSPSPSPSPSPSPSPSPSPSPSPSPSP
                                                                           1     2     3     4     5     6     7     8     9     10    11    12    13    14    15    16
                                                                           SXXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXP-------------
                                                                                                    1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16
                                                                                                    SXPSXPSXPSXPSXPSXPSXPSXPSXPSXPSXPSXPSXPSXPSXPSXP------------------
                                                 1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16
                                                 SXXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXP-------------
                                                         1     2     3     4     5     6     7     8     9     10    11    12    13    14    15    16
                                                         SXXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXP------------------
                                                                                                                                   16
                                                                                                                                   S*****************P
                                                                                              1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16
                                                                                              SXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXPSXXP--------------
                                                      1     2     3     4     5     6     7     8     9     10    11    12    13    14    15    16
                                                      SXXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXP---------------------
                                                                          1   2   3   4   5   6   7   8   9   10  11  12  13  14  15  16
                                                                          --------PSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXPSXXXP-
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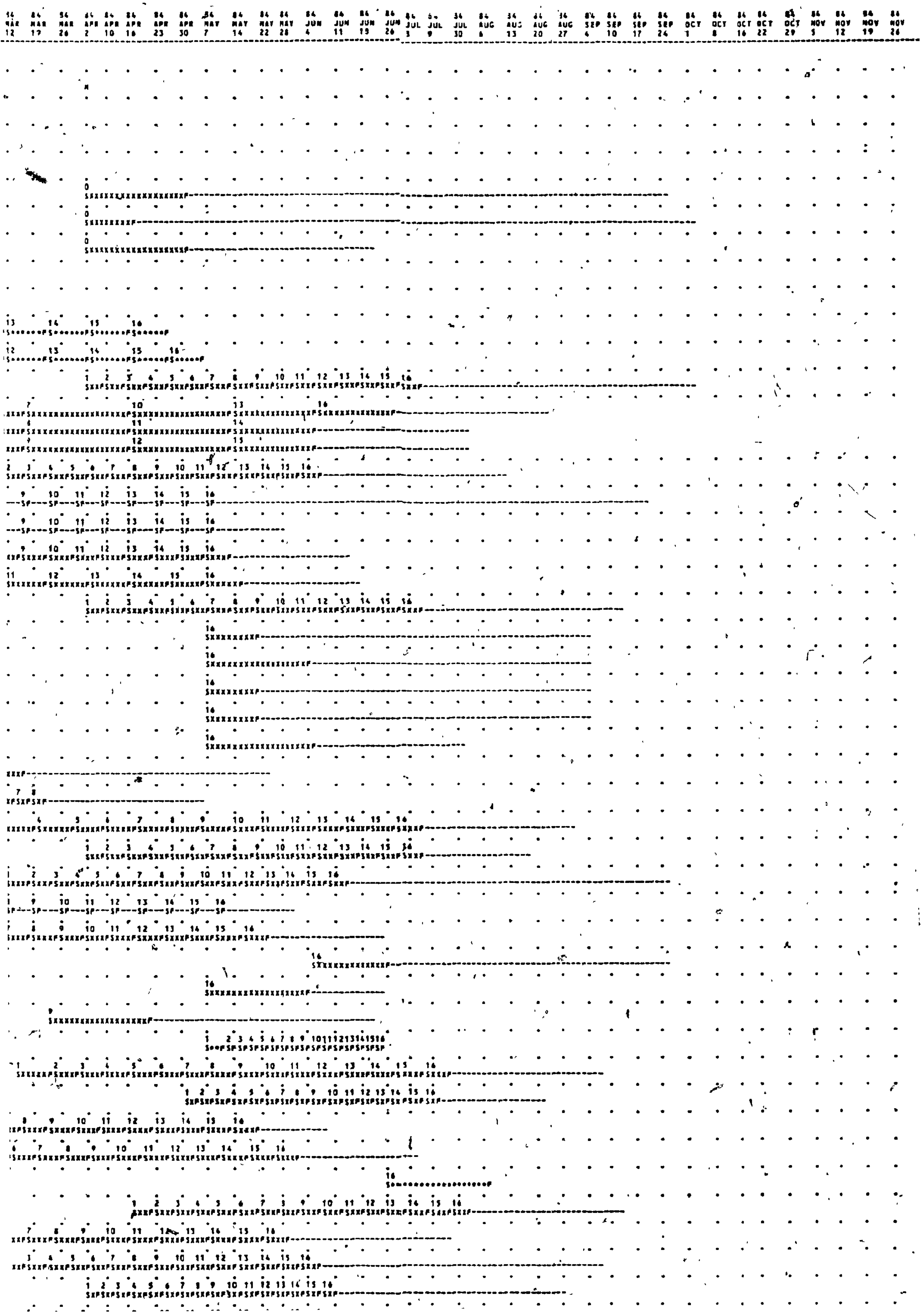
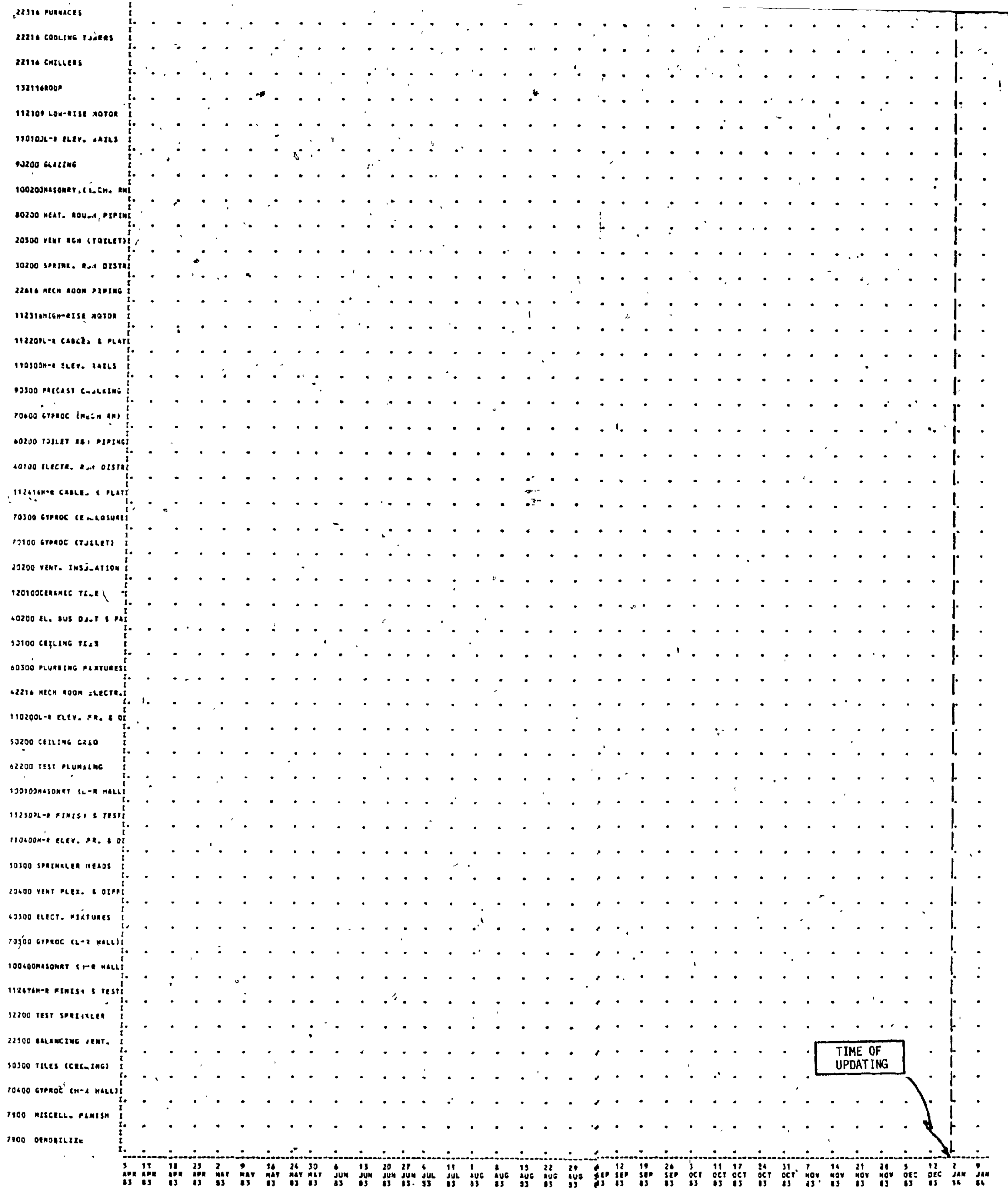
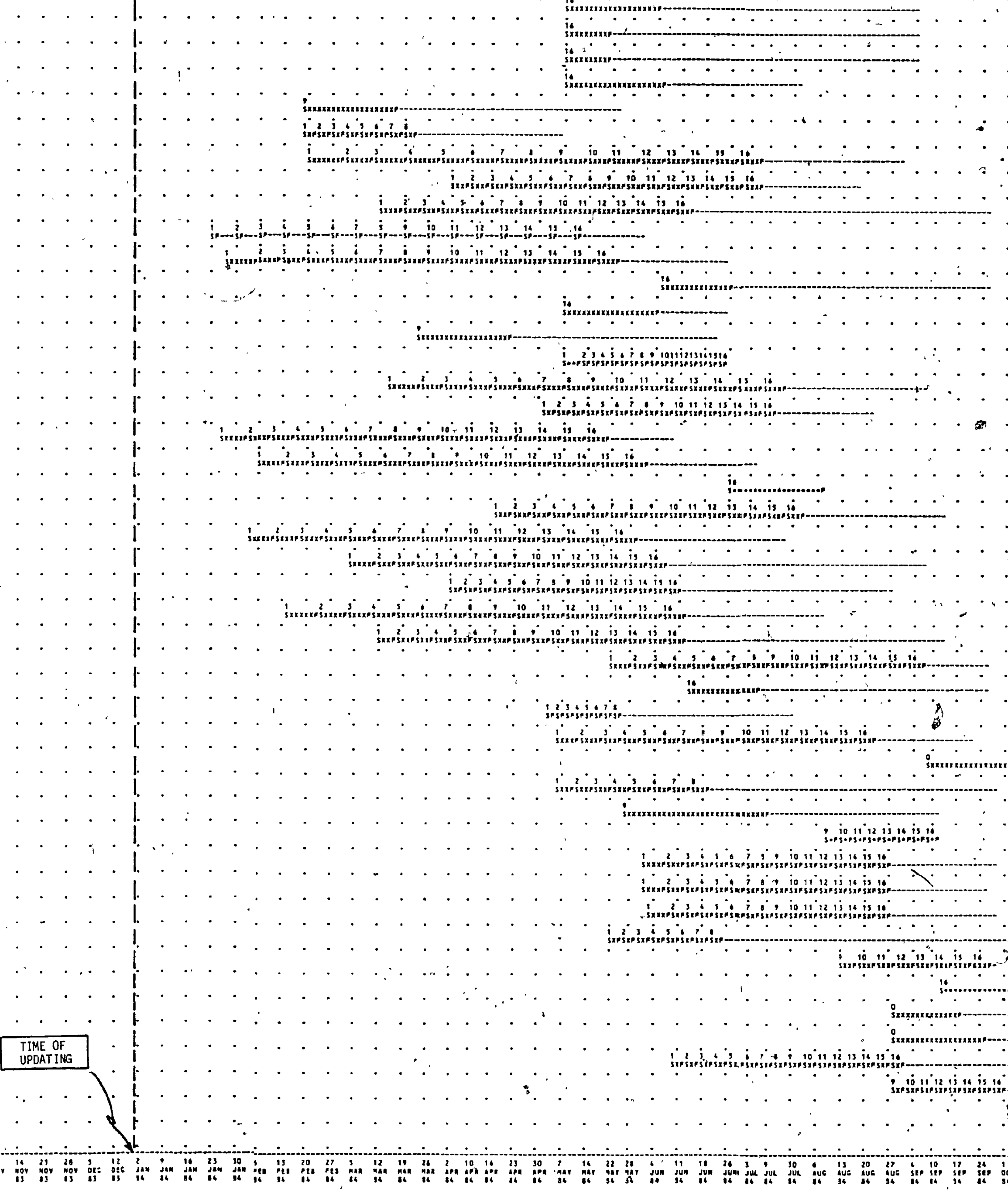

84 MAR 12
84 MAR 19
84 MAR 26
84 APR 2
84 APR 10
84 APR 16
84 APR 23
84 APR 30
84 MAY 7
84 MAY 14
84 MAY 22
84 MAY 28
84 JUN 4
84 JUN 11
84 JUN 19
84 JUN 26
84 JUL 3
84 JUL 9
84 JUL 30
84 AUG 6
84 AUG 13
84 AUG 20
84 AUG 27
84 SEP 4
84 SEP 10
84 SEP 17
84 SEP 24
84 OCT 1
84 OCT 8
84 OCT 16
84 OCT 22
84 OCT 29
84 NOV 5
84 NOV 12
84 NOV 19
84 NOV 26

3 of


22316 FURNACES
22216 COOLING TOWERS
22116 CHILLERS
132116ROOF
112109 LOW-RISE MOTOR
110100L-R ELEV. RAILS
90200 GLAZING
100200MASONRY,(EL.CH. RM
80200 HEAT. ROUGH PIPING
20500 VENT RGH (TOILET)
30200 SPRINK. R.H DISTR
22616 MECH ROOM PIPING
112316HIGH-RISE MOTOR
112209L-R CABLES & PLAT
110300H-R ELEV. RAILS
90300 PRECAST CAULKING
70600 GYPROC (MECH RM)
60200 TOILET RG. PIPING
40100 ELECTR. R.H DISTR
112416H-R CABLES & PLAT
70300 GYPROC (ENCLOSURE
70100 GYPROC (TOILET)
20200 VENT. INSULATION
120100CERAMIC TILE
40200 EL. BUS DUCT & PA
53100 CEILING TEES
60300 PLUMBING FIXTURES
42216 MECH ROOM ELECTR.
110200L-R ELEV. FR. & D
53200 CEILING GRID
62200 TEST PLUMBING
100100MASONRY (L-R HALL
112509L-R FINISH & TEST
110400H-R ELEV. FR. & D
30300 SPRINKLER HEADS
20400 VENT FLEX. & DIFF
40300 ELECT. FIXTURES
70500 GYPROC (L-R HALL)
100400MASONRY (H-R HALL
112616H-R FINISH & TEST
32200 TEST SPRINKLER
22500 BALANCING VENT.
50300 TILES (CEILING)
70400 GYPROC (H-R HALL)
7300 MISCELL. FINISH
7900 DEMOBILIZE
5 APR 83
11 APR 83
18 APR 83
25 APR 83
2 MAY 83
9 MAY 83
16 MAY 83
24 MAY 83
30 MAY 83
6 JUN 83
13 JUN 83
20 JUN 83
27 JUN 83
4 JUL 83
11 JUL 83
1 AUG 83
8 AUG 83
15 AUG 83
22 AUG 83
29 AUG 83
6 SEP 83
12 SEP 83
19 SEP 83
26 SEP 83
3 OCT 83
11 OCT 83
17 OCT 83
24 OCT 83
31 OCT 83
7 NOV 83
14 NOV 83
21 NOV 83
28 NOV 83
5 DEC 83
12 DEC 83
2 JAN 84
9 JAN 84
TIME OF UPDATING

| 4 of |


TIME OF UPDATING
14 NOV 83
21 NOV 83
28 NOV 83
5 DEC 83
12 DEC 83
2 JAN 84
9 JAN 84
16 JAN 84
23 JAN 84
30 JAN 84
6 FEB 84
13 FEB 84
20 FEB 84
27 FEB 84
5 MAR 84
12 MAR 84
19 MAR 84
26 MAR 84
2 APR 84
10 APR 84
16 APR 84
23 APR 84
30 APR 84
7 MAY 84
14 MAY 84
22 MAY 84
28 MAY 84
4 JUN 84
11 JUN 84
18 JUN 84
26 JUN 84
3 JUL 84
9 JUL 84
30 JUL 84
6 AUG 84
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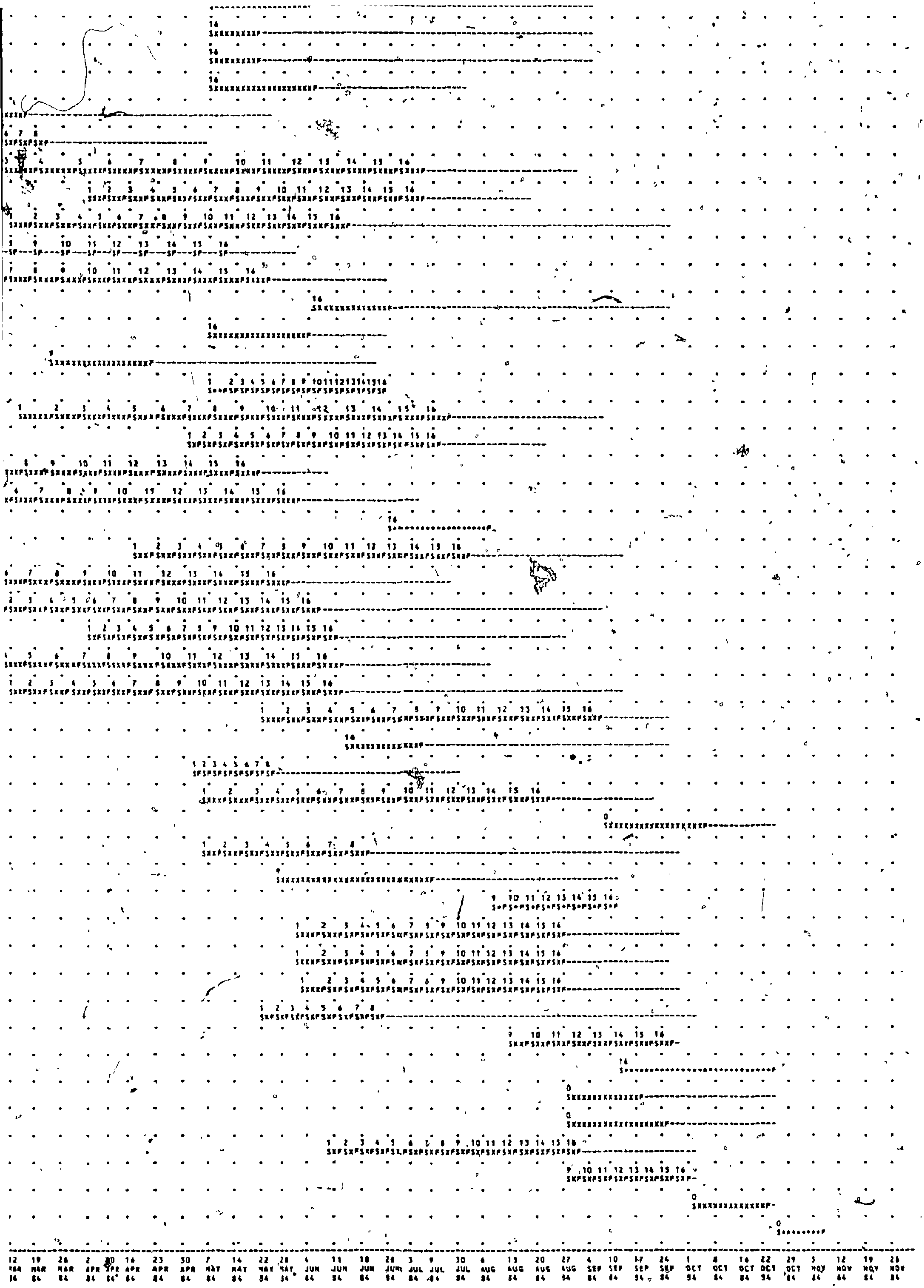
20 AUG 84
27 AUG 84
4 SEP 84
10 SEP 84
17 SEP 84
24 SEP 84

5 of


12 MAR 84
19 MAR 84
26 MAR 84
2 APR 84
10 APR 84
16 APR 84
23 APR 84
30 APR 84
7 MAY 84
14 MAY 84
22 MAY 84
28 MAY 84
4 JUN 84
11 JUN 84
18 JUN 84
26 JUN 84
3 JUL 84
9 JUL 84
30 JUL 84
6 AUG 84
13 AUG 84
20 AUG 84
27 AUG 84
4 SEP 84
10 SEP 84
17 SEP 84
24 SEP 84
1 OCT 84
8 OCT 84
16 OCT 84
22 OCT 84
29 OCT 84
5 NOV 84
12 NOV 84
19 NOV 84
26 NOV 84

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A first look at the bar-chart shows that, although the foundations and basement structure were delayed by a total of 6 working days, the structure was executed very well and recovered 3 working days by having a faster rate than scheduled (see list of dates in appendix II). Also two other days were recovered because the structure finishes in better weather months, March and April, which have better weather coefficients than January and February. Thus, as of December 16, 1983, the schedule is only one day off the initial one and the current completion date is now November 7th 1984.

However, after discussing the schedule with the subcontractors, further modifications were discovered: the elevator subcontractor said that he could do the high-rise elevator rails at a rythm of 2 days per floor, instead of 3 as input. So activity No. 110400 would have to be updated by changing its production rate.

Similarly, the masonry subcontractor said that he would work on 2 floors at the time, in parallel, for the high-rise masonry wall with two crews. So the "number of crews" of activity 100400, which is now 1 would be modified to 2. The start to start and finish to start relationships remain at zero.

After entering these changes, the data can be executed again. Because no changes were made to the predecessors, it is not necessary to compile the data again. Also, several reports will be produced: the list of activities in increasing activity number for quicker reference (Fig. 5.31), a bar-chart (Fig. 5.32), a list of dates in increasing activity number (appendix II), the 5 linear charts (Fig. 5.33(a) to (e)), a short cycle schedule for January 2nd, 1984 (Fig. 5.34) and the procurement status report (Fig. 5.35). Appendix IH show the sequence on the terminal to execute the above mentioned options.

A quick look at these reports shows us that the projected completion date is now October 29th, 1984, more than a week earlier than the previous one, and that the critical path is modified slightly. The masonry and the gyproc of the high-rise elevator hall are now critical. However, the high-rise elevator finish and test activity is very important and hard to "crash" so it should be considered as critical. In fact, it has a total float of only 1 day which is very small.

The procurement status report shows that the transformers and switch and the chillers should have their bid documents started very soon (January 9 and 6, 1984, respectively), and that the shop drawings for the low-rise elevator motors should be completed within the coming week (January 4th, 1984). The short cycle schedule gives the superintendant an idea of the activities to be performed at this stage: the structure is on the 7th floor, and the 6th floor is stripped; the precast panels should start on the first three floors.

Finally, a study of the list of dates (appendix II) enables the project manager to compare actual and scheduled start and finish dates, but also to compare the scheduled and actual durations. This might indicate to him that one subcontractor is really below the expected productivity and should initiate corrective action.

```
REPETITIVE ACTIVITIES

NO.    DESCRIPTION          I START  CURRENT  LAST  CREWS  RATE   SS    FS    LEARN   WEATHER TYPICAL  NON-TYP
-----------------------------------------------------------------------------------------------------------------
                            I
10100  STRUCTURE            I   1      7       16     1      6     0     0    4  90     1     0        1  12100
                            I                                                 3  75           0        0  0
                            I                                                 2  60           0        0  0
                            I                                                 1  50           0        0  0
                            I
10200  CURING & STRIP.      I   1      6       16     1      6     0     0    3  90     1     10100    0  0
                            I                                                 2  75           0        0  0
                            I                                                 1  60           0        0  0
                            I
20100  VENT. RGH DISTR.     I   1      1       16     1      5     0     0    1  80     0     10200    0  0
                            I
20200  VENT. INSULATION     I   1      1       16     1      4     0     0    1  75     0     40100    0  0
                            I
20300  VENT. UNIT           I   1      1       16     1      4     0     0    1  75     0     10200    1  8300
                            I
20400  VENT FLEX. & DIFF.   I   1      1       16     1      3     0     0    2  85     0     50200    1  20116
                            I                                                 1  60           0        0  0
                            I
20500  VENT RGH (TOILET)    I   1      1       16     1      2     0     3    1  80     0     60100    0  0
                            I
30100  SPRINKLER RISER      I   1      5       16     1      6     0     0    2  90     1     10200    0  0
                            I                                                 1  75           0        0  0
                            I
30200  SPRINK. RGH DISTR.   I   1      1       16     1      5     0     0    1  80     0     30100    0  0
                            I                                                 0  0            20100    0  0
                            I
30300  SPRINKLER HEADS      I   1      1       16     1      3     0     0    2  85     0     50200    1  30216
                            I                                                 1  60           0        0  0
                            I
40100  ELECTR. RGH DISTR.   I   1      1       16     1      5     0     0    1  80     0     30200    0  0
                            I
40200  EL. BUS DUCT & PAN.  I   1      1       16     1      5     0     0    2  90     0     70100    16 132116
                            I                                                 1  75           0        0  0
                            I
40300  ELECT. FIXTURES      I   1      1       16     1      3     0     0    2  85     0     50200    1  40116
                            I                                                 1  60           0        0  0
                            I
50100  CEILING TIES         I   1      1       16     1      4     0     0    0  0      0     20200    0  0
                            I
50200  CEILING GRID         I   1      1       16     1      4     0     0    2  90     0     70200    0  0
                            I                                                 1  70           30100    0  0
                            I                                                 0  0            70100    0  0
                            I                                                 0  0            70600    0  0
                            I                                                 0  0            70300    0  0
                            I
50300  TILES (CEILING)      I   1      1       16     1      3     0     0    0  0      0     40300    0  0
                            I                                                 0  0            20400    0  0
                            I                                                 0  0            30300    0  0
                            I
60100  RISER (DOM. WATER)   I   1      1       16     1      2     0     3    1  50     0     10200    0  0
                            I
60200  TOILET RGH PIPING    I   1      1       16     1      5     0     0    1  80     0     20500    0  0
                            I
60300  PLUMBING FIXTURES    I   1      1       16     1      4     0     0    1  80     0     120100   1  60216
                            I
70100  GYPROC (TOILET)      I   1      1       16     1      5     0     0    1  75     0     60200    0  0
                            I
70200  GYPROC (COLUMN)      I   1      1       16     1      4     0     0    0  0      0     10200    1  8200
                            I
70300  GYPROC (ENCLOSURE)   I   1      1       16     1      4     0     0    0  0      0     90300    1  8200
                            I
70400  GYPROC (H-R HALL)    I   9      9       16     1      3     0     0    0  0      0     100400   0  0
                            I
70500  GYPROC (L-R HALL)    I   1      1       8      1      3     0     0    0  0      0     100100   0  0
                            I
70600  GYPROC (MECH RM)     I   1      1       16     1      3     0     0    0  0      0     100200   0  0
                            I
80100  RISER (H & C WATER)  I   1      1       16     1      2     0     3    1  90     0     10200    0  0
                            I
80200  HEAT. ROUGH PIPING   I   1      1       16     1      4     0     0    1  80     0     80100    0  0
                            I                                                 0  0            20300    0  0
                            I
90100  PRECAST PANELS       I   1      1       16     3      15    0     0    6  90     1     10200    1  8400
                            I                                                 5  90           0        0  0
                            I                                                 4  90           0        0  0
                            I                                                 3  70           0        0  0
                            I                                                 2  70           0        0  0
                            I                                                 1  70           0        0  0
                            I
90200  GLAZING              I   1      1       16     1      5     0     0    1  90     1     90100    0  0
                            I
90300  PRECAST CAULKING     I   1      1       16     1      5     0     0    1  80     0     90200    0  0
                            I
100100 MASONRY (L-R HALL)   I   1      1       8      1      4     0     0    1  90     0     110200   1  8200
                            I
100200 MASONRY (MECH. RM)   I   1      1       16     1      4     0     0    0  0      0     20300    1  8200
                            I
100300 MASONRY ( CORE )     I   1      1       16     1      4     0     0    0  0      0     10200    1  8200
                            I
100400 MASONRY (H-R HALL)   I   9      9       16     2      4     0     0    0  0      0     110400   9  8200
                            I
110100 L-R ELEV. RAILS      I   1      1       8      1      3     0     0    1  80     0     0        1  10209
                            I
110200 L-R ELEV. FR. & DOORI    1      1       8      1      2     0     0    1  90     0     0        1  112209
                            I                                                 0  0            0        1  42100
                            I                                                 0  0            0        1  40209
                            I
110300 H-R ELEV. RAILS      I   1      1       16     1      2     0     0    2  75     0     0        1  10216
                            I                                                 1  50           0        1  110108
                            I
110400 H-R ELEV. FR. & DOORI    9      9       16     1      2     0     0    0  0      0     0        9  110208
                            I                                                 0  0            0        9  112416
                            I                                                 0  0            0        9  42100
                            I                                                 0  0            0        9  40216
                            I
120100 CERAMIC TILE         I   1      1       16     1      3     0     0    1  90     0     70100    1  8200
```

1af

```
20100  VENT. RGH DISTR.       I    1    1    16    1    5     0    0    1  80    0    10200  0   0
20200  VENT. INSULATION       I    1    1    16    1    4     0    0    1  75    0    40100  0   0
                              I
20300  VENT. UNIT             I    1    1    16    1    4     0    0    1  75    0    10200  1   8300
                              I
20400  VENT FLEX. & DIFF.     I    1    1    16    1    3     0    0    2  85    0    50200  1   20116
                              I                                         1  60         0      0   0
                              I
20500  VENT RGH (TOILET)      I    1    1    16    1    2     0    3    1  80    0    60100  0   0
                              I
30100  SPRINKLER RISER        I    1    1    16    1    6     0    0    2  90    1    10200  0   0
                              I                                         1  75         0      0   0
                              I
30200  SPRINK. RGH DISTR.     I    1    1    16    1    5     0    0    1  80    0    30100  0   0
                              I                                         0  0          20100  0   0
                              I
30300  SPRINKLER HEADS        I    1    1    16    1    3     0    0    2  85    0    50200  1   30216
                              I                                         1  60         0      0   0
                              I
40100  ELECTR. RGH DISTR.     I    1    1    16    1    5     0    0    1  80    0    30200  0   0
                              I
40200  EL. BUS DUCT & PAN.    I    1    1    16    1    5     0    0    2  90    0    70100  16  132116
                              I                                         1  75         0      0   0
                              I
40300  ELECT. FIXTURES        I    1    1    16    1    3     0    0    2  85    0    50200  1   40116
                              I                                         1  60         0      0   0
                              I
50100  CEILING TIES           I    1    1    16    1    4     0    0    0  0     0    20200  0   0
                              I
50200  CEILING GRID           I    1    1    16    1    4     0    0    2  90    0    70200  0   0
                              I                                         1  70         50100  0   0
                              I                                         0  0          70100  0   0
                              I                                         0  0          70600  0   0
                              I                                         0  0          70300  0   0
                              I
50300  TILES (CEILING)        I    1    1    16    1    3     0    0    0  0     0    40300  0   0
                              I                                         0  0          20400  0   0
                              I                                         0  0          30300  0   0
                              I
60100  RISER (DOM. WATER)     I    1    1    16    1    2     0    3    1  50    0    10200  0   0
                              I
60200  TOILET RGH PIPING      I    1    1    16    1    5     0    0    1  80    0    20500  0   0
                              I
60300  PLUMBING FIXTURES      I    1    1    16    1    4     0    0    1  80    0    120100 1   60216
                              I
70100  GYPROC (TOILET)        I    1    1    16    1    5     0    0    1  75    0    60200  0   0
                              I
70200  GYPROC (COLUMN)        I    1    1    16    1    4     0    0    0  0     0    10200  1   8200
                              I
70300  GYPROC (ENCLOSURE)     I    1    1    16    1    4     0    0    0  0     0    90300  1   8200
                              I
70400  GYPROC (H-R HALL)      I    9    9    16    1    3     0    0    0  0     0    100400 0   0
                              I
70500  GYPROC (L-R HALL)      I    1    1    8     1    3     0    0    0  0     0    100100 0   0
                              I
70600  GYPROC (MECH RM)       I    1    1    16    1    3     0    0    0  0     0    100200 0   0
                              I
80100  RISER (H & C WATER)    I    1    1    16    1    2     0    3    1  90    0    10200  0   0
                              I
80200  HEAT. ROUGH PIPING     I    1    1    16    1    4     0    0    1  80    0    80100  0   0
                              I                                         0  0          20300  0   0
                              I
90100  PRECAST PANELS         I    1    1    16    3    15    0    0    6  90    1    10200  1   8400
                              I                                         5  90         0      0   0
                              I                                         4  90         0      0   0
                              I                                         3  70         0      0   0
                              I                                         2  70         0      0   0
                              I                                         1  70         0      0   0
                              I
90200  GLAZING                I    1    1    16    1    5     0    0    1  90    1    90100  0   0
                              I
90300  PRECAST CAULKING       I    1    1    16    1    5     0    0    1  80    0    90200  0   0
                              I
100100 MASONRY (L-R HALL)     I    1    1    8     1    4     0    0    1  90    0    110200 1   8200
                              I
100200 MASONRY (MECH. RM)     I    1    1    16    1    4     0    0    0  0     0    20300  1   8200
                              I
100300 MASONRY ( CORE )       I    1    1    16    1    4     0    0    0  0     0    10200  1   8200
                              I
100400 MASONRY (H-R HALL)     I    9    9    16    2    4     0    0    0  0     0    110400 9   8200
                              I
110100 L-R ELEV. RAILS        I    1    1    8     1    3     0    0    1  80    0    0      1   10209
                              I
110200 L-R ELEV. FR. & DOOR   I    1    1    8     1    2     0    0    1  90    0    0      1   112209
                              I                                         0  0          0      1   42100
                              I                                         0  0          0      1   40209
                              I
110300 H-R ELEV. RAILS        I    1    1    16    1    2     0    0    2  75    0    0      1   10216
                              I                                         1  50         0      1   110108
                              I
110400 H-R ELEV. FR. & DOOR   I    9    9    16    1    2     0    0    0  0     0    0      9   110208
                              I                                         0  0          0      9   112416
                              I                                         0  0          0      9   42100
                              I                                         0  0          0      9   40216
                              I
120100 CERAMIC TILE           I    1    1    16    1    3     0    0    1  90    0    70100  1   8200
```

Fig. 5.31(a) List of Activities (Updated as Dec. 16, 1983)

(See fig. 5.24(a) for the explanation of the headings)

2 of 2

```
NON-REPETITIVE ACTIVITIES
NO.     DESCRIPTION          I  DURATION  PROCUREMENT  WEATHER  STATUS  PREDECESSORS
------------------------------------------------------------------------------------
                             I
2100    MOBILIZATION         I    10          0           0        1       0
                             I
2200    EXCAVATION           I    40          0           1        1       2100
                             I
2300    FOUNDATION           I    20          0           1        1       2200
                             I
7300    MISCELL. FINISH      I    15          0           0        0       70508
                             I                                             70416
                             I                                             100316
                             I                                             50316
                             I
7900    DEMOBILIZE           I    10          0           0        0       112616
                             I                                             7800
                             I                                             62200
                             I                                             32200
                             I                                             22500
                             I
12100   BASEMENT STRUCT.     I    30          0           1        1       2300
                             I
22116   CHILLERS             I    10          1           0        0       10216
                             I
22216   COOLING TOWERS       I    10          1           0        0       10216
                             I
22316   FURNACES             I    20          1           0        0       10216
                             I
22416   PUMPS                I    10          1           0        0       10216
                             I
22500   BALANCING VENT.      I    20          0           0        0       42100
                             I                                             42216
                             I                                             22616
                             I                                             80216
                             I                                             20416
                             I
22616   MECH ROOM PIPING     I    15          0           0        0       22116
                             I                                             22216
                             I                                             22316
                             I                                             22416
                             I
32100   BOOSTER PUMP (SPRK)  I    10          1           0        0       8200
                             I
32200   TEST SPRINKLER       I    15          0           0        0       30316
                             I                                             32100
                             I
42100   TRANSF. & SWITCH     I    20          1           0        0       8200
                             I
42216   MECH ROOM ELECTR.    I    15          1           0        0       22116
                             I                                             22216
                             I                                             22316
                             I                                             22416
                             I                                             40216
                             I
62100   BOOSTER PUMP (PLMBG) I    20          1           0        0       8200
                             I
62200   TEST PLUMBING        I    20          0           0        0       62100
                             I                                             60316
                             I
112109  LOW-RISE MOTOR       I   -20          1           0        0       10209
                             I
112209 L-R CABLES & PLATF.   I    20          1           0        0       110108
                             I                                             112109
                             I
112316 HIGH-RISE MOTOR       I    20          1           0        0       10216
                             I                                             112109
                             I
112416 H-R CABLES & PLATF.   I    20          1           0        0       112209
                             I                                             110316
                             I                                             112316
                             I
112509 L-R FINISH & TEST     I    30          0           0        0       110208
                             I
112516 H-R FINISH & TEST     I    30          0           0        0       112509
                             I                                             110416
                             I
132116 ROOF                  I    20          0           1        0       10216
MILESTONES
NO.     DESCRIPTION          I       DATE
--------------------------------------------------
                             I
8200    NO HEATING REQ'D     I    840402
                             I
8300    START OF DEL. OF VENI    840305
                             I
8400    STRAT PRECAST        I    840102

FOR A TOTAL OF  37  ACTIVITIES
```

(See fig. 5.24(b) for the explanation of the headings)

Fig. 5.31(b) List of Activities (cont'd)
(Updated as at Dec 16, 1983)

1 of 1

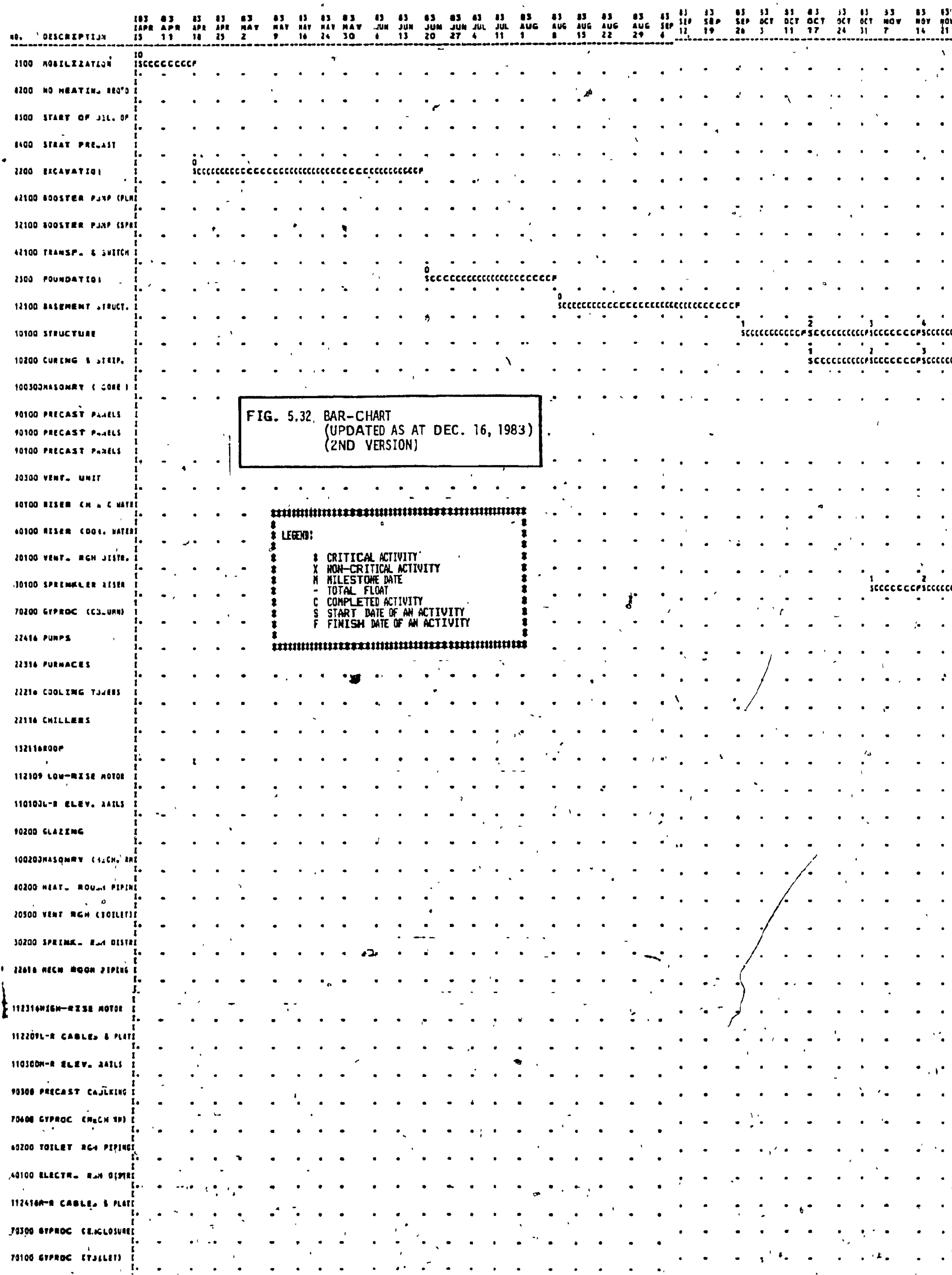
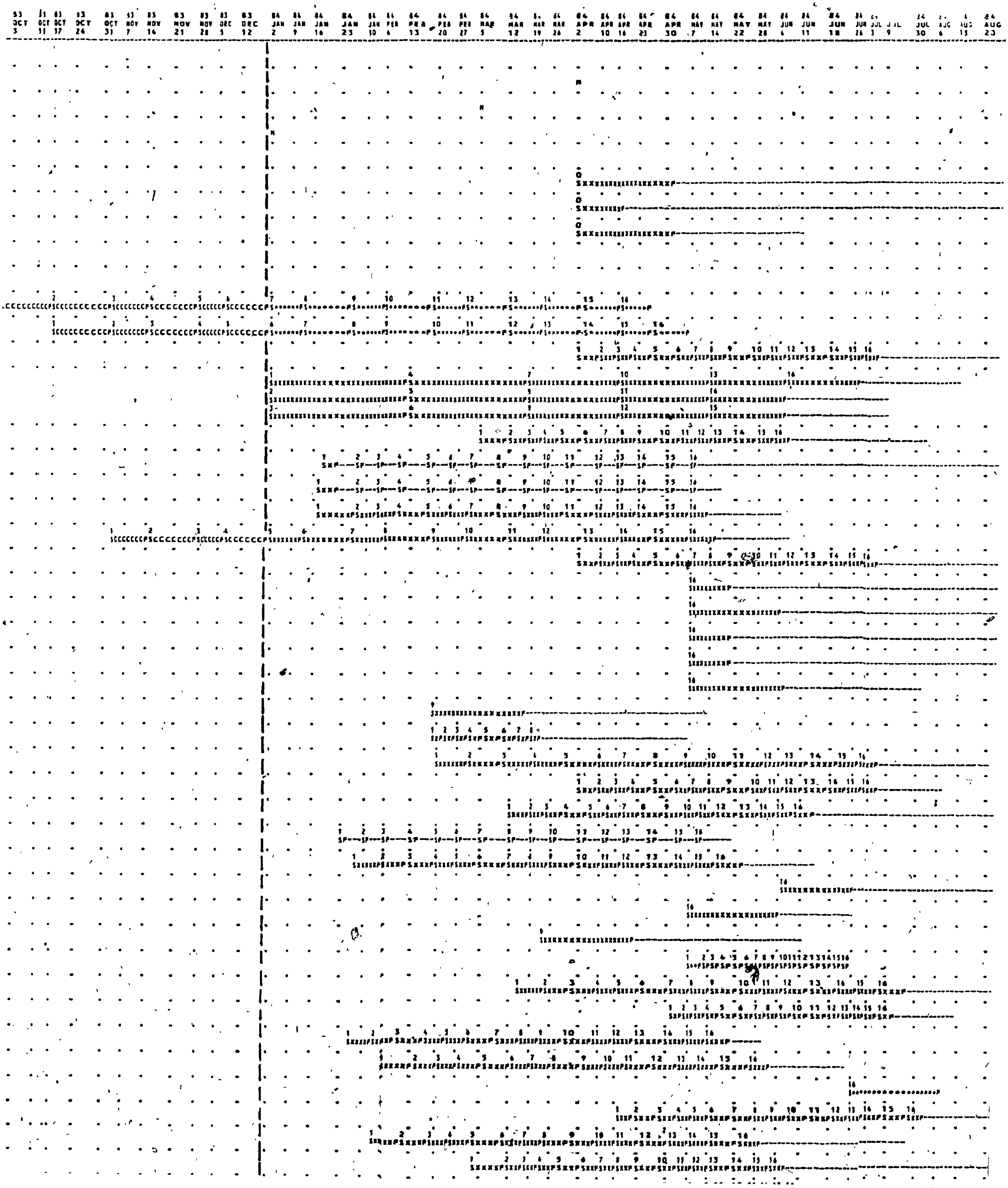


FIG. 5.32 BAR-CHART
(UPDATED AS AT DEC. 16, 1983)
(2ND VERSION)

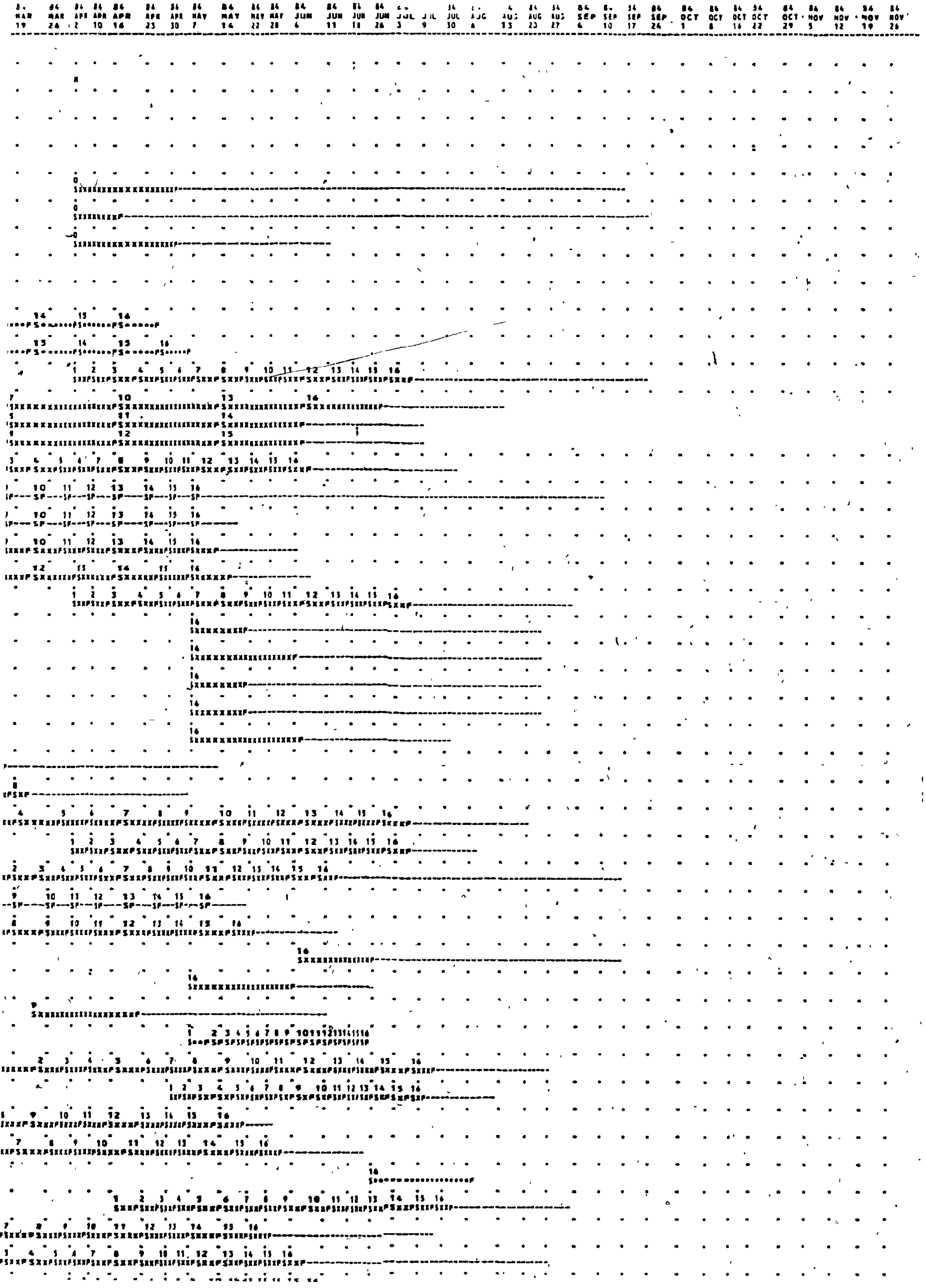
LEGEND:

- $ CRITICAL ACTIVITY
- X NON-CRITICAL ACTIVITY
- M MILESTONE DATE
- \- TOTAL FLOAT
- C COMPLETED ACTIVITY
- S START DATE OF AN ACTIVITY
- F FINISH DATE OF AN ACTIVITY

2 of 1


83 OCT 3
83 OCT 11
83 OCT 17
83 OCT 24
83 OCT 31
83 NOV 7
83 NOV 14
83 NOV 21
83 NOV 28
83 DEC 5
83 DEC 12
84 JAN 2
84 JAN 9
84 JAN 16
84 JAN 23
84 JAN 30
84 FEB 6
84 FEB 13
84 FEB 20
84 FEB 27
84 MAR 5
84 MAR 12
84 MAR 19
84 MAR 26
84 APR 2
84 APR 10
84 APR 16
84 APR 23
84 APR 30
84 MAY 7
84 MAY 14
84 MAY 22
84 MAY 28
84 JUN 4
84 JUN 11
84 JUN 18
84 JUN 26
84 JUL 3
84 JUL 9
84 JUL 30
84 AUG 6
84 AUG 13
84 AUG 23

3 of


84 MAR 19
84 MAR 26
84 APR 2
84 APR 10
84 APR 16
84 APR 23
84 APR 30
84 MAY 7
84 MAY 14
84 MAY 22
84 MAY 28
84 JUN 4
84 JUN 11
84 JUN 18
84 JUN 26
84 JUL 3
84 JUL 9
84 JUL 30
84 AUG 6
84 AUG 13
84 AUG 23
84 AUG 27
84 SEP 4
84 SEP 10
84 SEP 17
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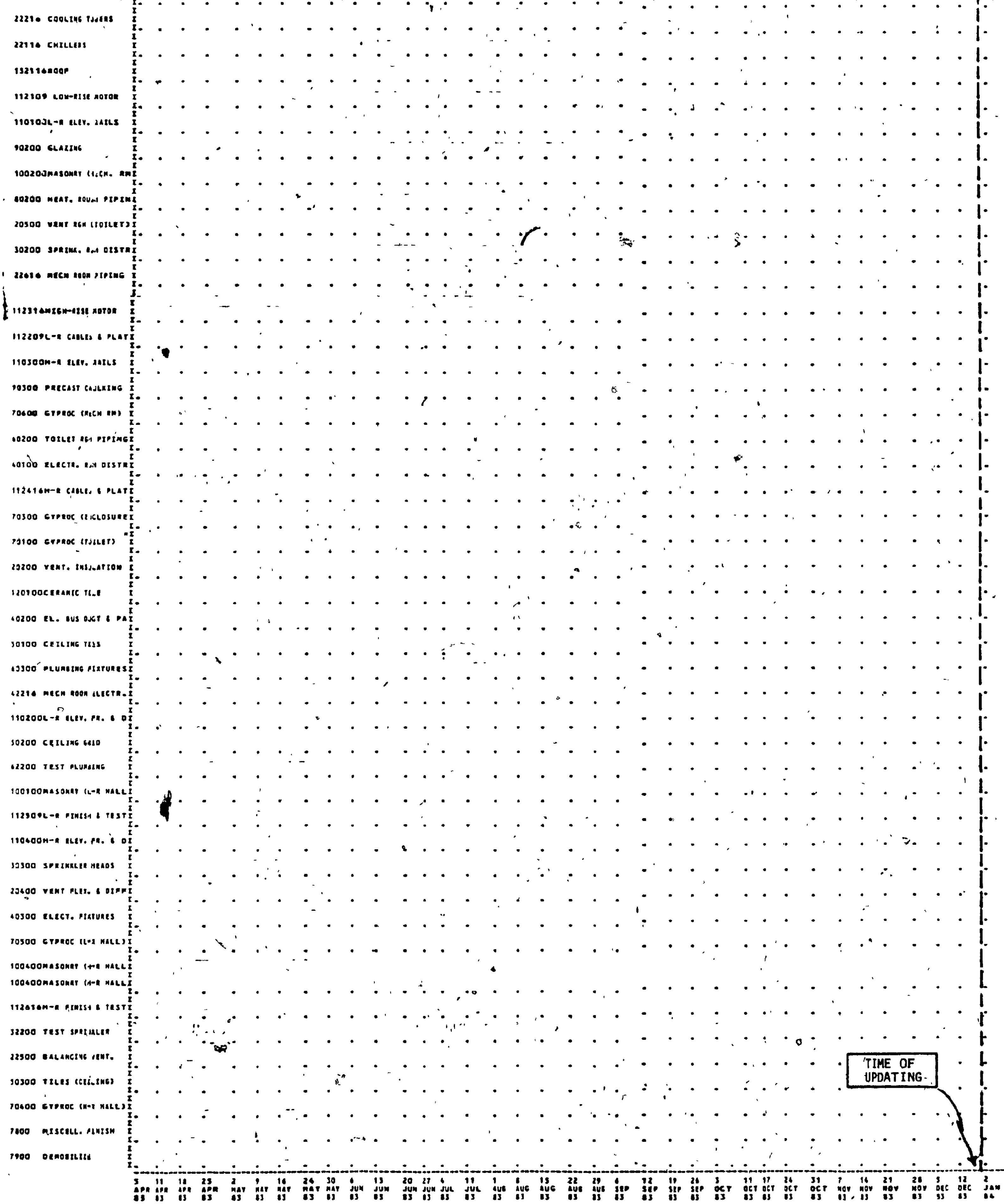
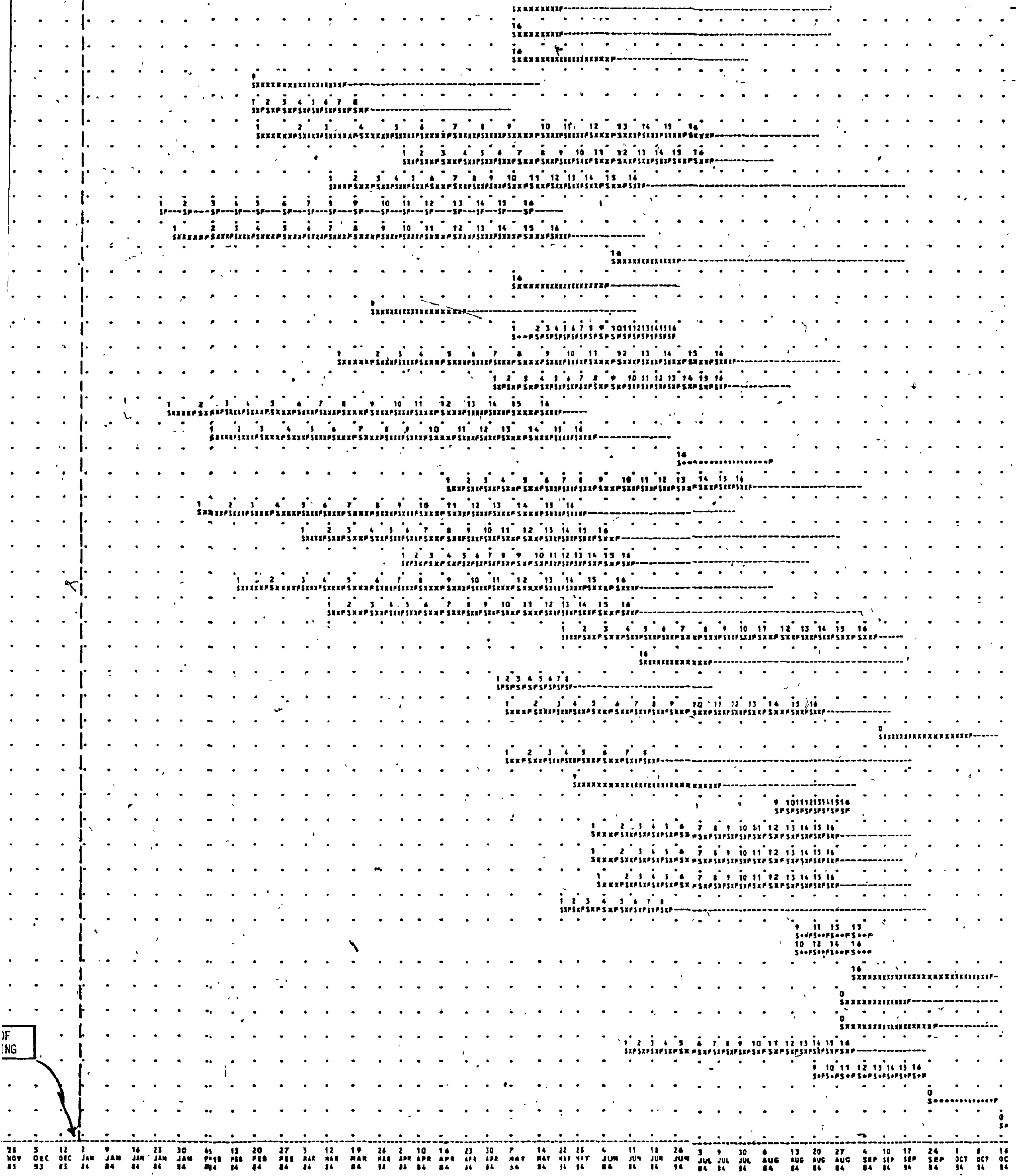
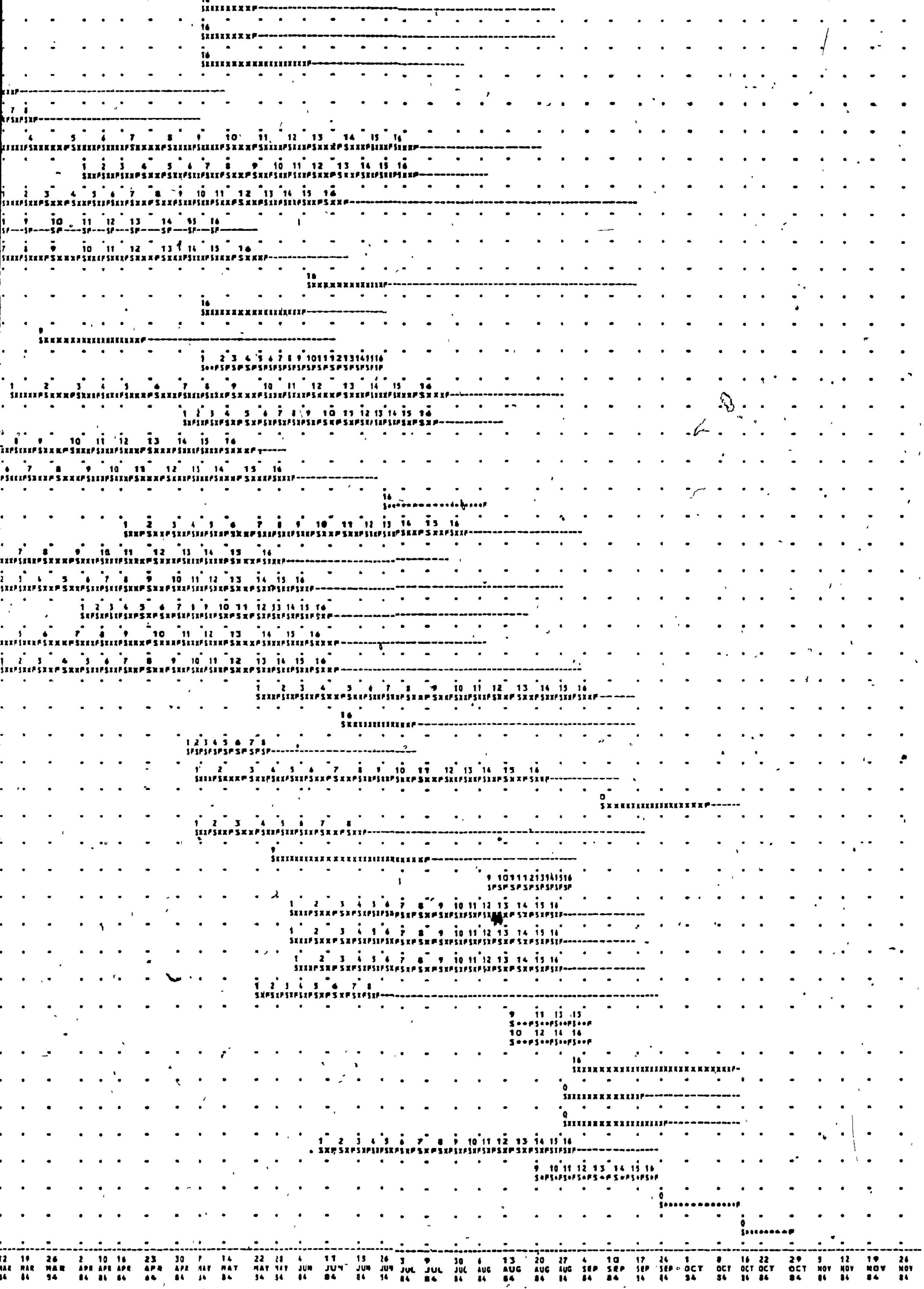
84 NOV 5
84 NOV 12
84 NOV 19
84 NOV 26


222116 COOLING TOWERS
22116 CHILLERS
132116ROOF
112109 LOW-RISE MOTOR
110103L-R ELEV. RAILS
90200 GLAZING
100203MASONRY (MECH. RM
80200 HEAT. ROUGH PIPING
20500 VENT RGH (TOILET)
30200 SPRINK. RGH DISTR
22616 MECH ROOM PIPING
112316HIGH-RISE MOTOR
112209L-R CABLES & PLAT
110300H-R ELEV. RAILS
90300 PRECAST CAULKING
70600 GYPROC (MECH RM)
60200 TOILET RGH PIPING
40100 ELECTR. RGH DISTR
112416H-R CABLES & PLAT
70300 GYPROC (ENCLOSURE
70100 GYPROC (TOILET)
20200 VENT. INSULATION
120100CERAMIC TILE
40200 EL. BUS DUCT & PA
50100 CEILING TEES
63300 PLUMBING FIXTURES
42216 MECH ROOM ELECTR.
110200L-R ELEV. FR. & D
50200 CEILING GRID
62200 TEST PLUMBING
100100MASONRY (L-R HALL
112509L-R FINISH & TEST
110400H-R ELEV. FR. & D
30300 SPRINKLER HEADS
20400 VENT FLEX. & DIFF
40300 ELECT. FIXTURES
70500 GYPROC (L-R HALL)
100400MASONRY (H-R HALL
100400MASONRY (H-R HALL
112616H-R FINISH & TEST
32200 TEST SPRINKLER
22500 BALANCING VENT.
50300 TILES (CEILING)
70400 GYPROC (H-R HALL)
7800 MISCELL. FINISH
7900 DEMOBILIZE
5 APR 83
11 APR 83
18 APR 83
25 APR 83
2 MAY 83
9 MAY 83
16 MAY 83
24 MAY 83
30 MAY 83
6 JUN 83
13 JUN 83
20 JUN 83
27 JUN 83
4 JUL 83
11 JUL 83
1 AUG 83
8 AUG 83
15 AUG 83
22 AUG 83
29 AUG 83
6 SEP 83
12 SEP 83
19 SEP 83
26 SEP 83
3 OCT 83
11 OCT 83
17 OCT 83
24 OCT 83
31 OCT 83
7 NOV 83
14 NOV 83
21 NOV 83
28 NOV 83
5 DEC 83
12 DEC 83
2 JAN 84
TIME OF UPDATING

4 of


OF
ING
26 NOV 83
5 DEC 83
12 DEC 83
2 JAN 84
9 JAN 84
16 JAN 84
23 JAN 84
30 JAN 84
6 FEB 84
13 FEB 84
20 FEB 84
27 FEB 84
5 MAR 84
12 MAR 84
19 MAR 84
26 MAR 84
2 APR 84
10 APR 84
16 APR 84
23 APR 84
30 APR 84
7 MAY 84
14 MAY 84
22 MAY 84
28 MAY 84
4 JUN 84
11 JUN 84
18 JUN 84
26 JUN 84
3 JUL 84
9 JUL 84
30 JUL 84
6 AUG 84
13 AUG 84
20 AUG 84
27 AUG 84
4 SEP 84
10 SEP 84
17 SEP 84
24 SEP 84
1 OCT 84
8 OCT 84
14 OC 84

5 of


12 MAR 84
19 MAR 84
26 MAR 84
2 APR 84
10 APR 84
16 APR 84
23 APR 84
30 APR 84
7 MAY 84
14 MAY 84
22 MAY 84
28 MAY 84
4 JUN 84
11 JUN 84
18 JUN 84
26 JUN 84
3 JUL 84
9 JUL 84
30 JUL 84
6 AUG 84
13 AUG 84
20 AUG 84
27 AUG 84
4 SEP 84
10 SEP 84
17 SEP 84
24 SEP 84
1 OCT 84
8 OCT 84
16 OCT 84
22 OCT 84
29 OCT 84
5 NOV 84
12 NOV 84
19 NOV 84
26 NOV 84

6 of 6

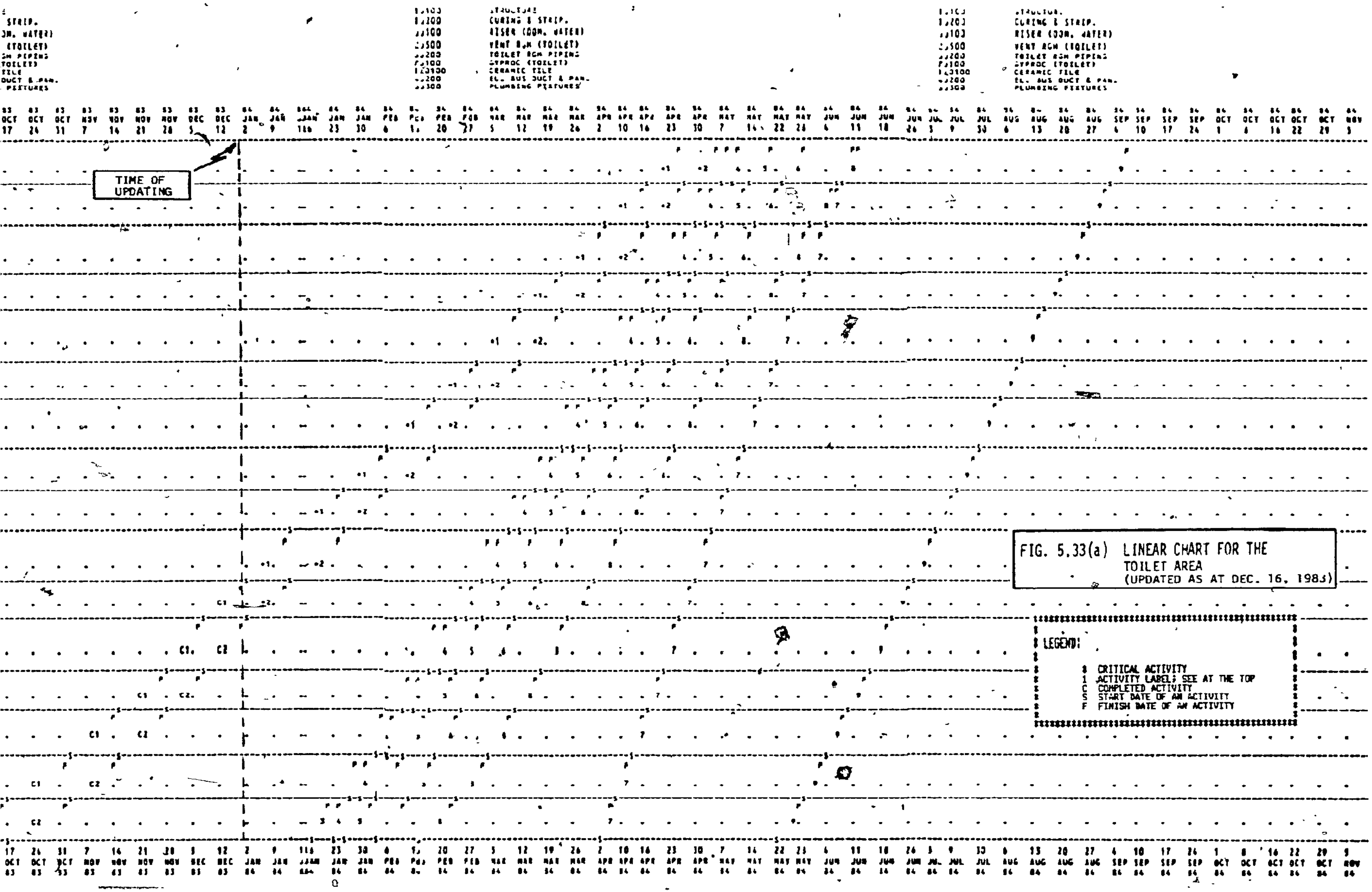


FIG. 5.33(a) LINEAR CHART FOR THE TOILET AREA (UPDATED AS AT DEC. 16, 1983)

1af

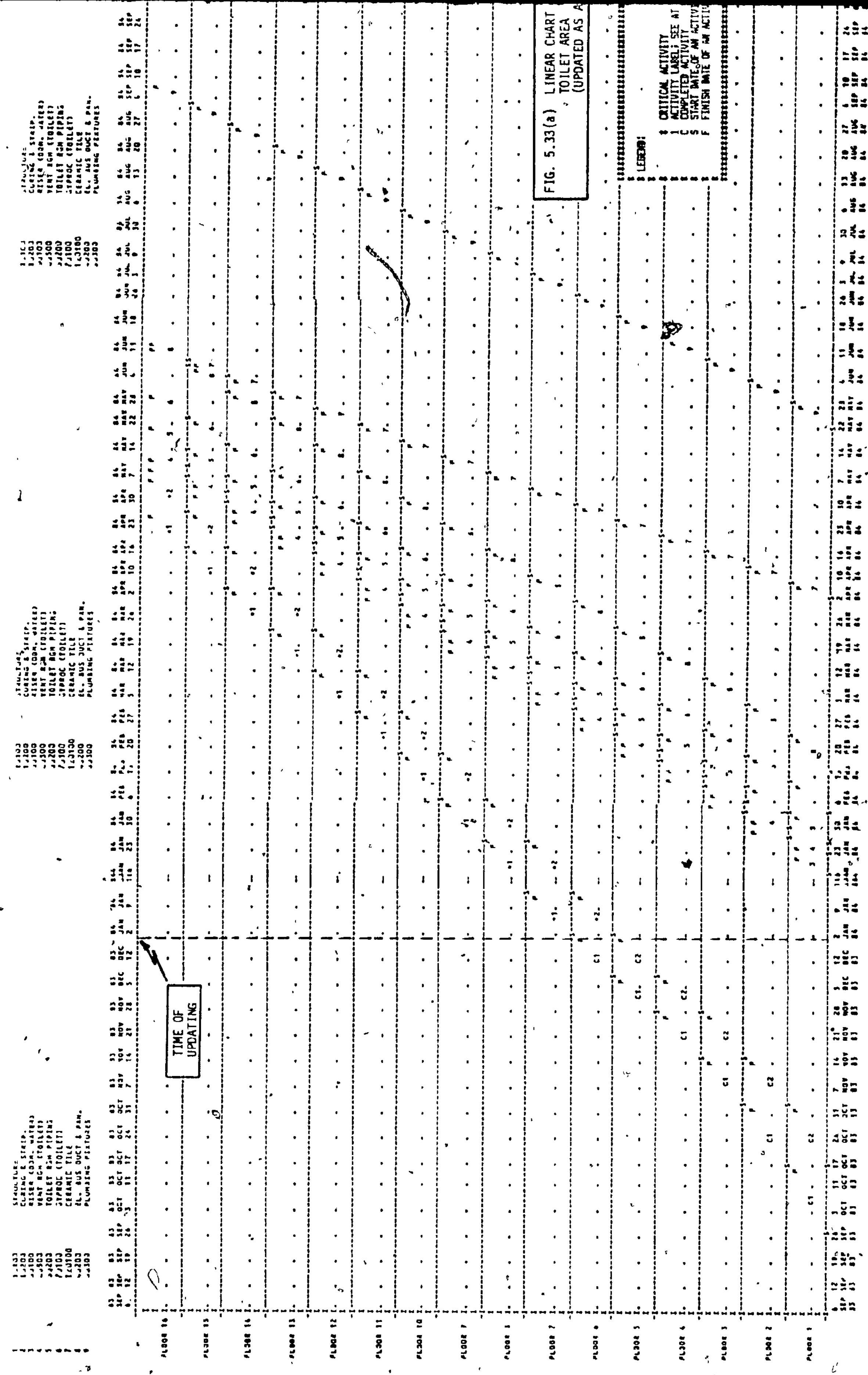


FIG. 5.33(a) LINEAR CHART
TOILET AREA
(UPDATED AS A

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2 of 2

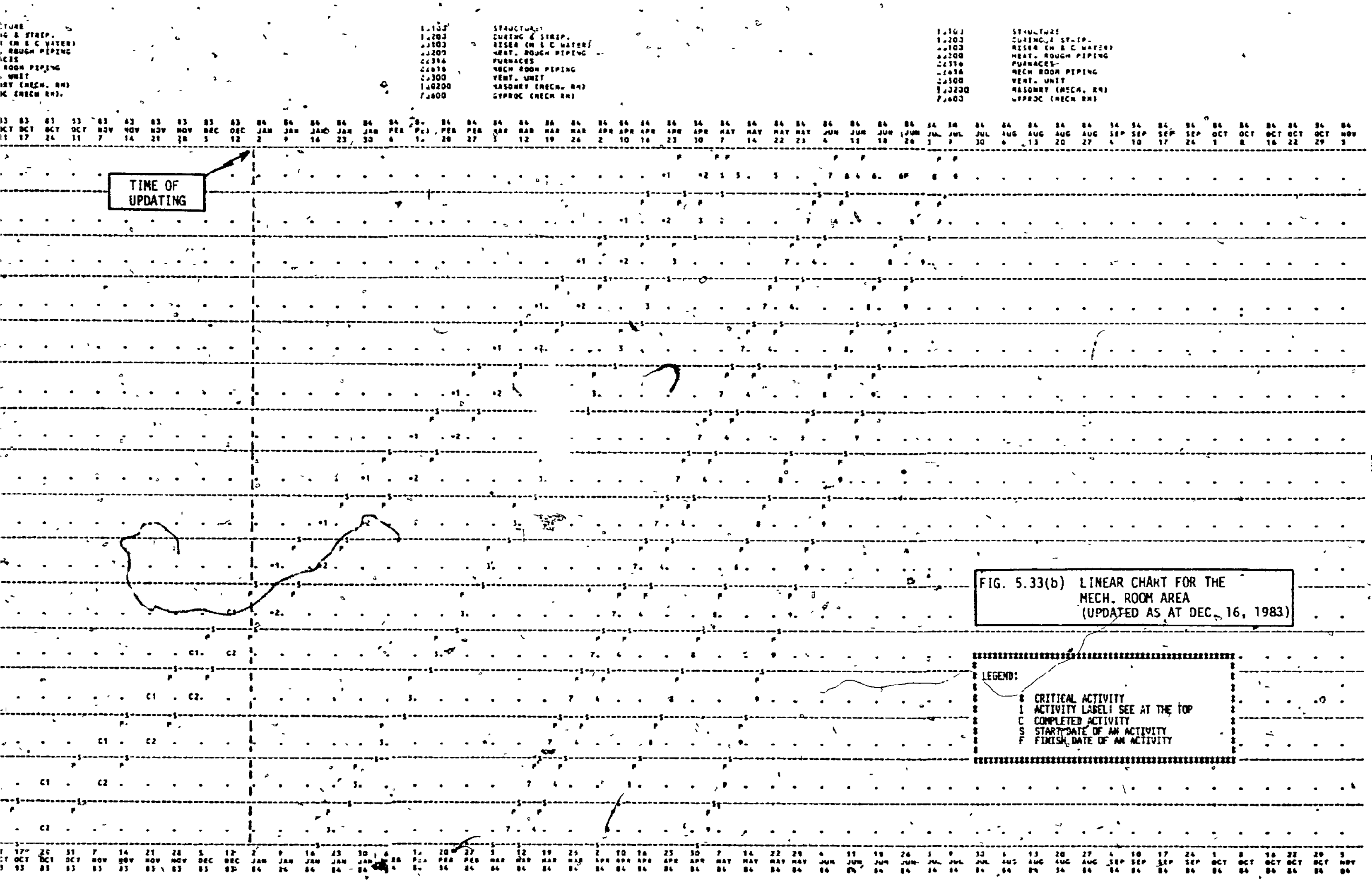

FIG. 5.33(b) LINEAR CHART FOR THE MECH. ROOM AREA (UPDATED AS AT DEC. 16, 1983)

POOR COPY
COPIE DE QUALITEE INFERIEURE

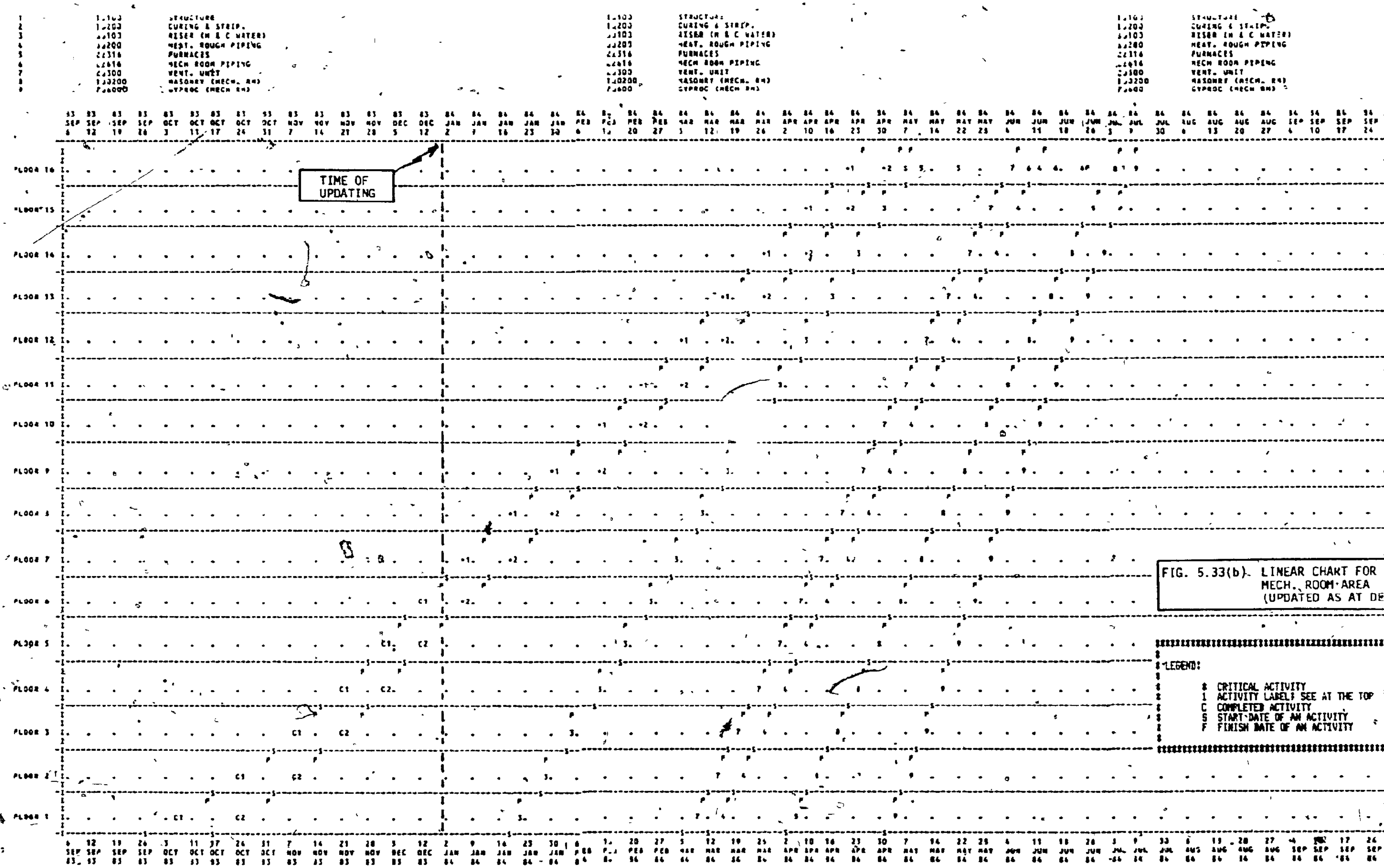

FIG. 5.33(b). LINEAR CHART FOR MECH. ROOM AREA (UPDATED AS AT DE

2 of 2

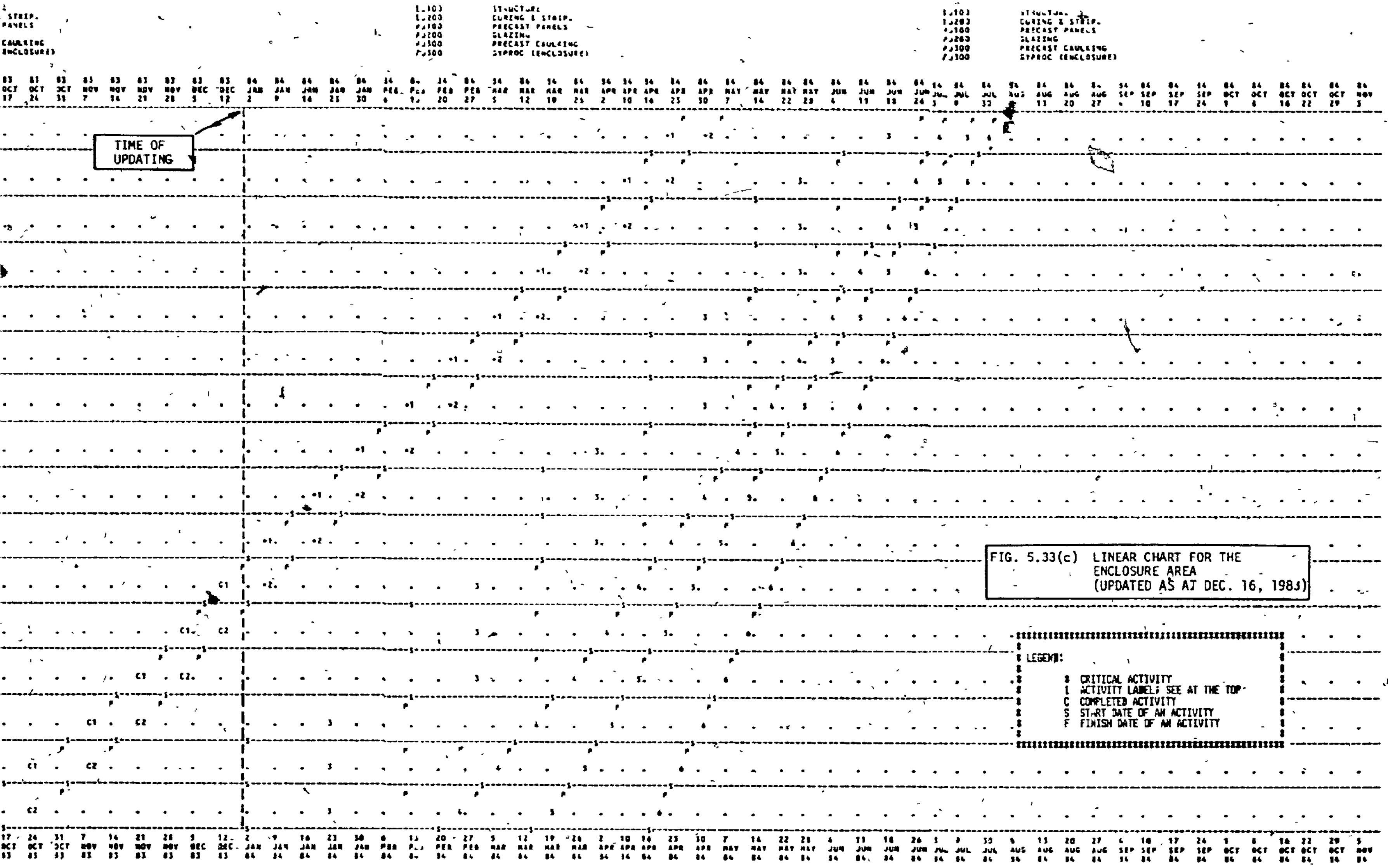

FIG. 5.33(c) LINEAR CHART FOR THE ENCLOSURE AREA (UPDATED AS AT DEC. 16, 1983)

1 of

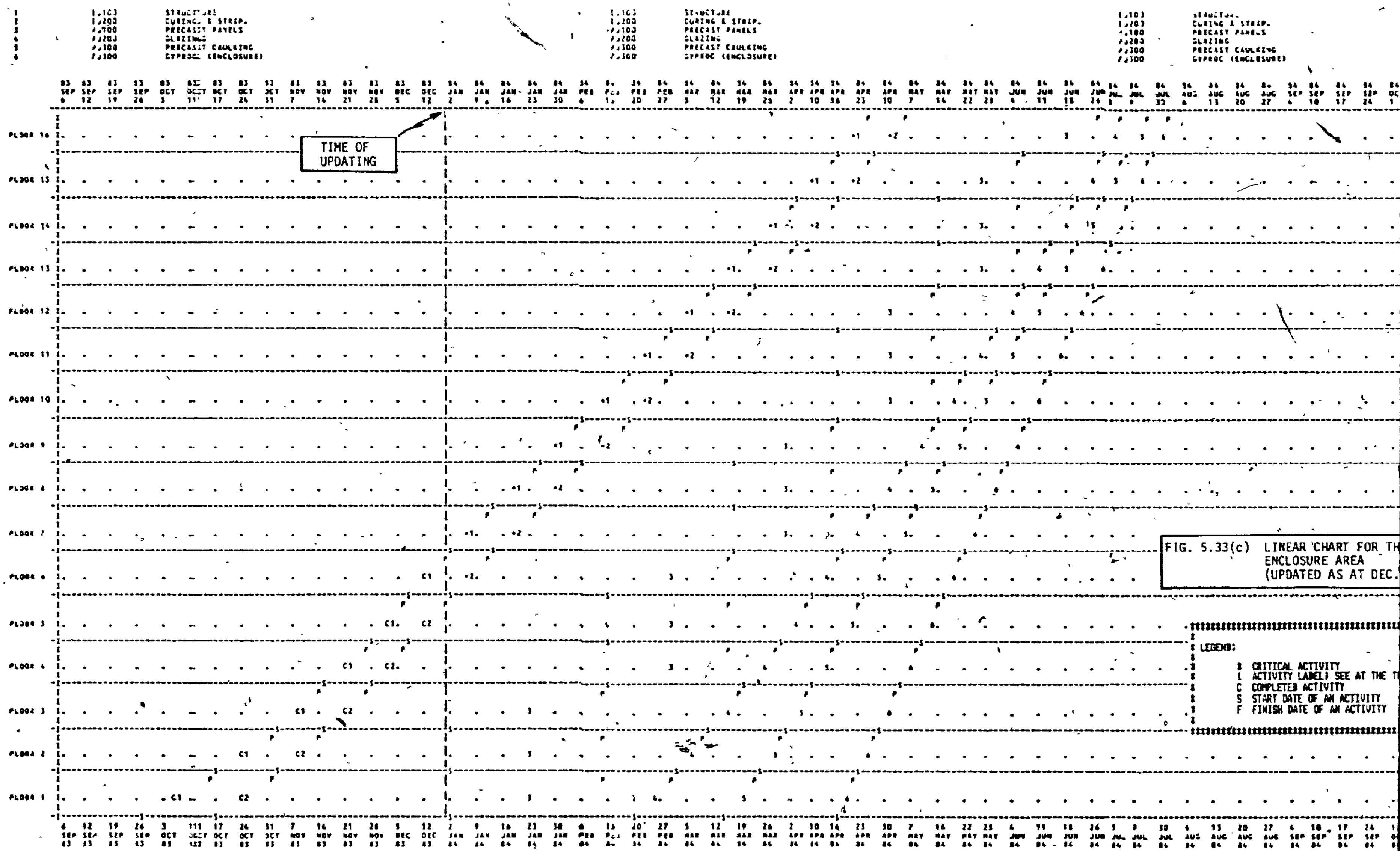

FIG. 5.33(c) LINEAR CHART FOR TH
ENCLOSURE AREA
(UPDATED AS AT DEC.

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2 of 2

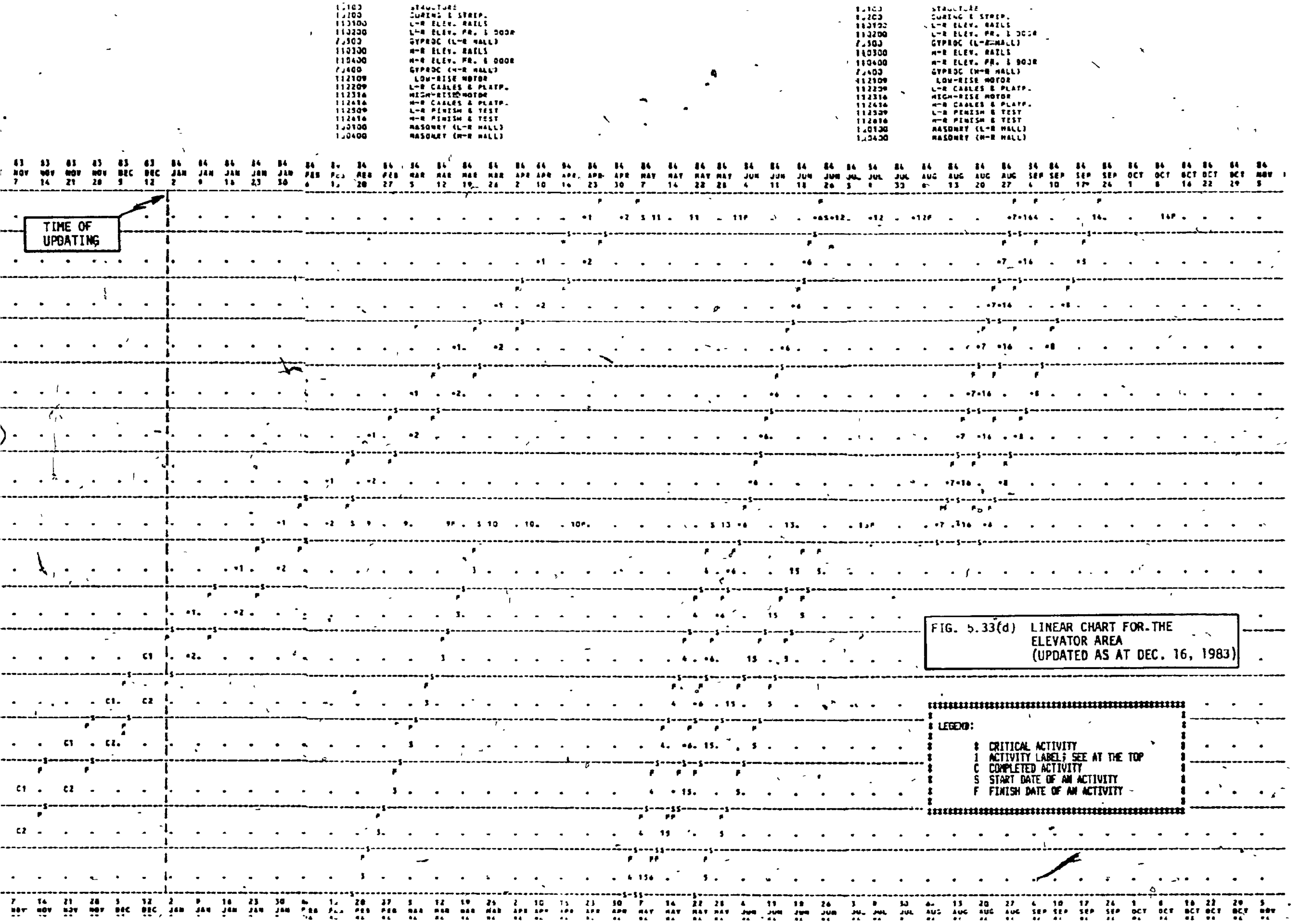

FIG. 5.33(d) LINEAR CHART FOR THE ELEVATOR AREA (UPDATED AS AT DEC. 16, 1983)

1af

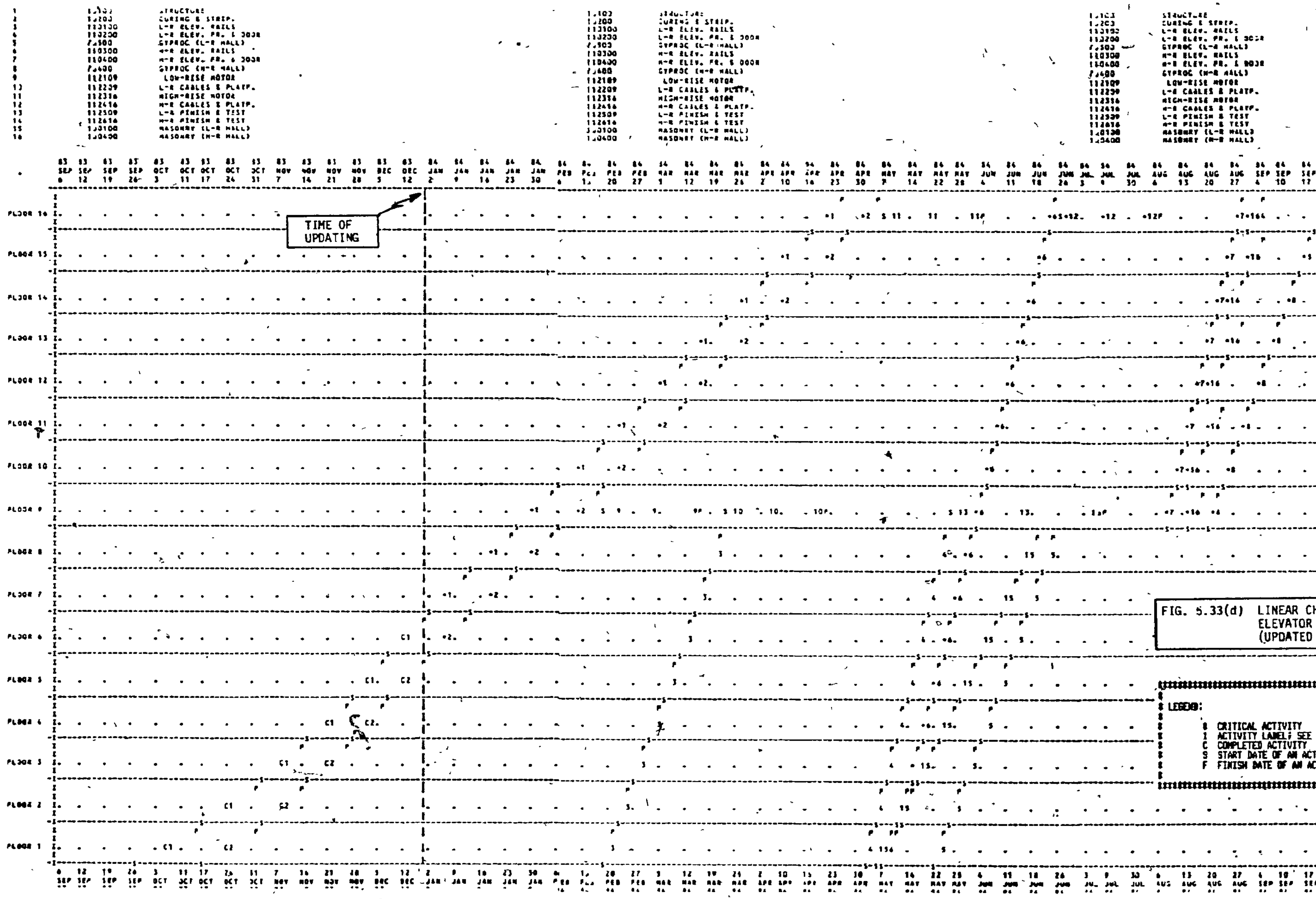

FIG. 5.33(d) LINEAR CH
ELEVATOR
(UPDATED

2 of 2

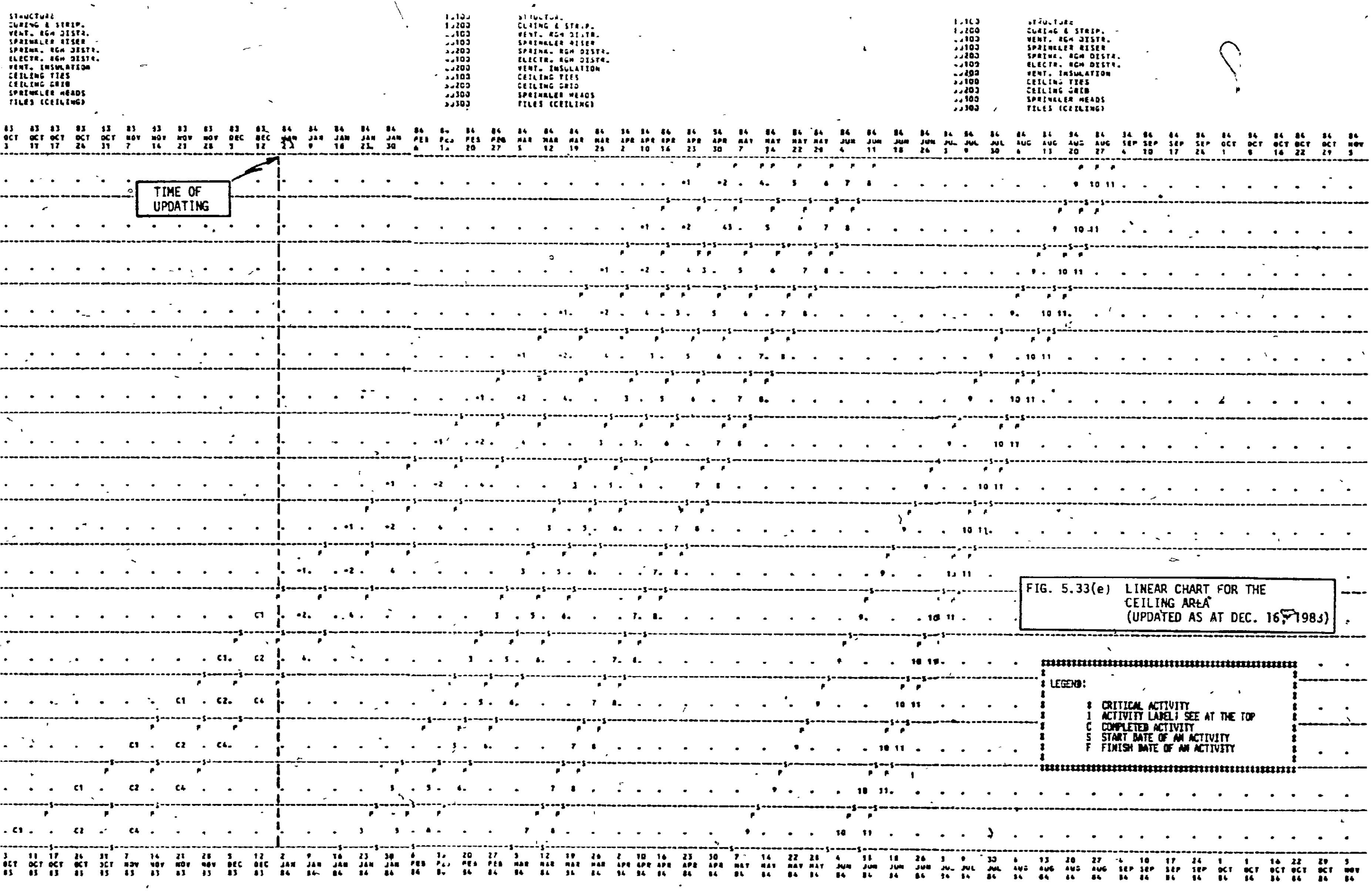

FIG. 5.33(e) LINEAR CHART FOR THE CEILING AREA (UPDATED AS AT DEC. 16, 1983)

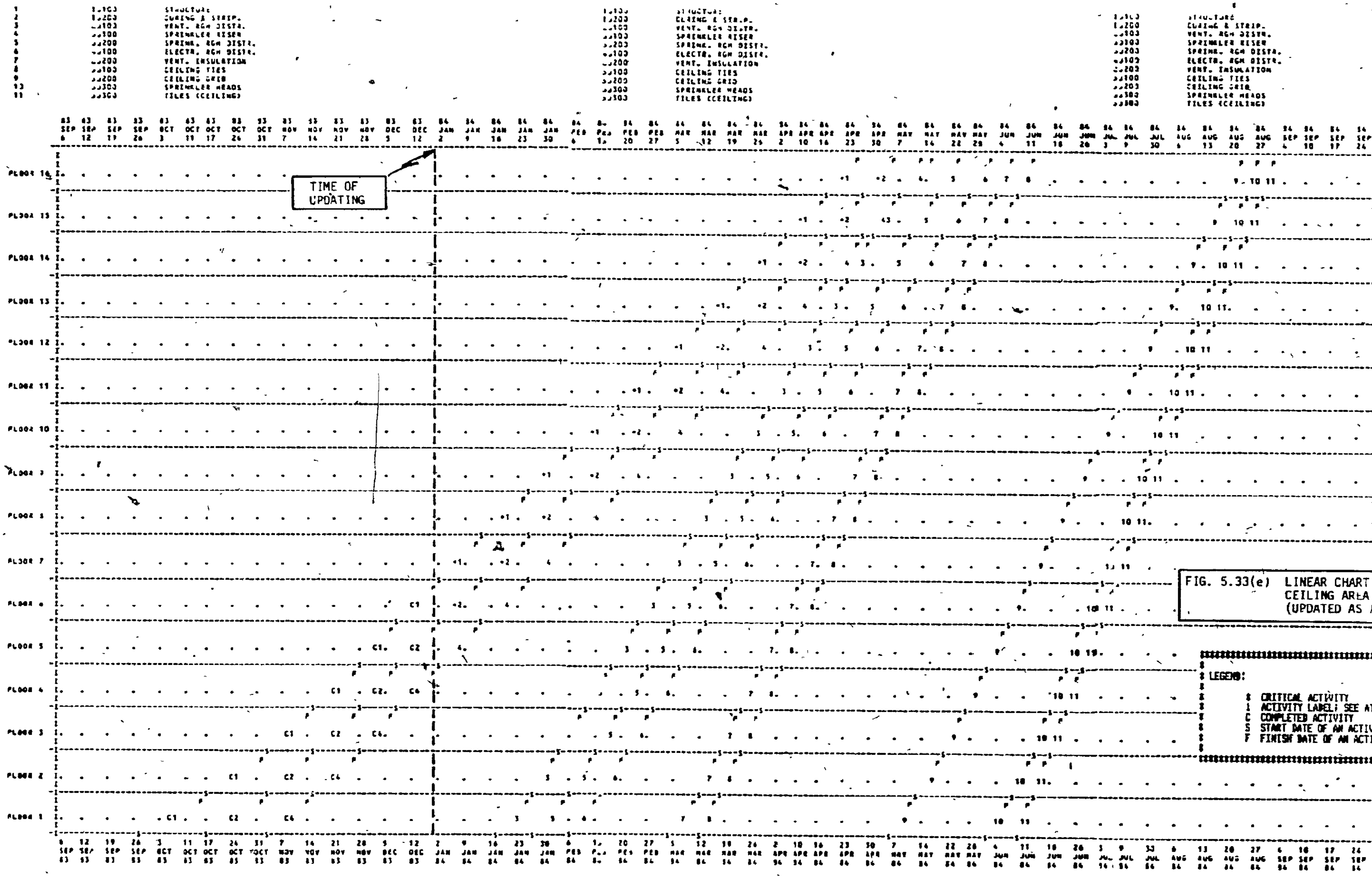

FIG. 5.33(e) LINEAR CHART
CEILING AREA
(UPDATED AS

2of2

```
SHORT CYCLE SCHEDULE AS OF  2 JAN 84

                                     I     E A R L Y             L A T E            A C T U A L                   DURATION
NO.     DESCRIPTION         FLOOR I   START     FINISH     START     FINISH     START     FINISH     FLOAT    SCHED.  ACTUAL
-------------------------------------------------------------------------------------------------------------------------------
                                     I
10200   CURING & STRIP.         5   I   2 DEC83   13DEC83    2 DEC83   13DEC83    7 DEC83   16DEC83     0        8       8
                                     I
10200   CURING & STRIP.         6   I   2 JAN84   11JAN84    2 JAN84   11JAN84                         0        8       0
                                     I
10200   CURING & STRIP.         7   I   12JAN84   24JAN84    12JAN84   24JAN84                         0        9       0
                                     I
90100   PRECAST PANELS          1   I   2 JAN84   10FEB84    1 FEB84   13MAR84                        22       30       0
                                     I
90100   PRECAST PANELS          2   I   2 JAN84   10FEB84    1 FEB84   13MAR84                        22       30       0
                                     I
90100   PRECAST PANELS          3   I   2 JAN84   10FEB84    1 FEB84   13MAR84                        22       30       0
                                     I
30100   SPRINKLER RISER         2   I   10NOV83   21NOV83    12DEC83   4 JAN84    15NOV83   25NOV83    22        8       9
                                     I
30100   SPRINKLER RISER         3   I   22NOV83   1 DEC83    5 JAN84   16JAN84    28NOV83   6 DEC83    22        8       7
                                     I
30100   SPRINKLER RISER         4   I   2 DEC83   14DEC83    17JAN84   27JAN84    7 DEC83   16DEC83    22        9       8
                                     I
30100   SPRINKLER RISER         5   I   2 JAN84   11JAN84    23JAN84   1 FEB84                        15        8       0
                                     I
30100   SPRINKLER RISER         6   I   12JAN84   24JAN84    2 FEB84   14FEB84                        15        9       0
                                     I
8400    STRAT PRECAST           0   I             2 JAN84                                              0        0       0
                                     I
10100   STRUCTURE               6   I   1 DEC83   13DEC83    1 DEC83   13DEC83    7 DEC83   16DEC83     0        9       5
                                     I
10100   STRUCTURE               7   I   2 JAN84   11JAN84    2 JAN84   11JAN84                         0        8       0
                                     I
10100   STRUCTURE               8   I   12JAN84   24JAN84    12JAN84   24JAN84                         0        9       0
```

Fig. 5.34 Short Cycle Schedule (as at Jan. 2, 1984)

PROCUREMENT STATUS REPORT

NO.	DESCRIPTION	PREPAR. BID DOC.	TENDER CALL	CONTRACT AWARD	SHOP DWG SUBMIT	SHOP DWG APPROV.	FABRIC. EQUIP.	SHIPPING EQUIP.	CUSTOM CLEAR	DELIVERY INSPECT.
62100	BOOSTER PUMP (PL			25JAN84			1 FEB84	14MAR84		28MAR84
32100	BOOSTER PUMP (SP			23JAN84			6 FEB84	19MAR84	26MAR84	29MAR84
42100	TRANSF. & SWITCH	9 JAN84	16JAN84	26JAN84			30JAN84	12MAR84		26MAR84
22416	PUMPS				27FEB84	12MAR84	14MAR84	13APR84	27APR84	2 MAY84
22316	FURNACE						1 MAR84	16APR84		30APR84
22216	COOLING TOWERS	27JAN84	10FEB84	24FEB84	29FEB84	14MAR84	19MAR84	18APR84		2 MAY84
22116	CHILLERS	6 JAN84	20JAN84	3 FEB84	8 FEB84	22FEB84	27FEB84	11APR84	25APR84	2 MAY84
112109	LOW-RISE MOTOR				7 DEC83	4 JAN84	11JAN84	8 FEB84		15FEB84
112316	HIGH-RISE MOTOR				21FEB84	20MAR84	27MAR84	19APR84		3 MAY84
112209	L-R CABLES & PLA						20FEB84	5 MAR84		19MAR84
112416	M-R CABLES & PLA						11MAY84	11JUN84		20JUN84
42216	MECH ROOM ELECTR						25APR84	24MAY84		7 JUN84

Fig. 5.35 Procurement Status Report(as at Dec. 16, 1983)

5.5 SUGGESTIONS FOR IMPROVEMENT TO THE PROGRAMS

All the computer code has been programmed by the author in order to test the algorithms of the planning and scheduling system. Even if the basic mathematical relationships and the data processing are handled satisfactorily by the present code, improvements are necessary to facilitate an immediate use of the system.

First, file space should be allocated to store information about the project: the name of the project; the number of levels (floors); the name of the owner; the number of subcontractors, their trade, etc. Then, the output formats (bar-chart, linear chart, list of dates, list of activities, short-cycle schedule and procurement status report) should be modified to include headings containing that information, where relevant and also data like the date the report was printed or updated, the current project completion date, a key, explaining the meaning of the characters used on the formats, etc.

Second, some formats require some adjustments. For the bar chart, it should be possible to print the activities in different orders: sorted by early start or sorted by criticality. It should also be possible to print selective activities like for a given subcontractor or trade. For the linear chart, one could find a way around the input of each activity number that appears on a chart. The activities being part of a "work category" or area should be identified as such, and then the user would have just to specify the area, and not all the activities to get the chart printed out. Also, the presence of overlapping of activities on a linear chart creates problems of interpretation: on Fig. 5.28 (a), activity No. 3 is very close to activity No. 4 on the chart and the result is that the label "3" disappear on floors 2 to 16; on Fig. 5.28 (b), the start of activity No. 5 is at the same time than the execution of activity 7 on the 16th floor, which makes the start of 5 disappear from the chart. Some improvements are required to get around this difficulty. The procurement status report should also show the actual dates that the tasks occurred for monitoring. File space should be allocated to store that data, and the format should be modified accordingly.

Third, improvements could be done to facilitate the delay of the start of an activity. In the present version of the system, if the start of an activity is delayed because of external factors, a new milestone has to be introduced, and precedence relationships have to be added. On the long run, such a procedure might require a lot of file space for milestones which contain only a date as information. Therefore, as a suggestion, each activity might have another field called "earliest possible start date", which would be input by the user and would depend on external factors. During the forward pass calculations, such a date would become a predecessor, like a milestone, and this would avoid the use of file space. So, in the case of the delay of the start of precast panels, in the example of use of the previous section, the date "January 2nd 1984", would be input in that field.

Finally, some improvements are required to the software itself: all possible user input errors should be screened in order to avoid getting a system error that might affect the files and in general previous input in the system. This is crucial for a successful use of the system by a "non-computer" person. Also, the data structure was designed to minimize the amount of memory space required to operate the system (less than 25 K bytes). Moreover, computer time is affected because data never stays in primary memory but is constantly "read" and "written" to a secondary storage device (disk drive in the case of the Perkin Elmer 3220), which takes a considerable amount of time. Witn the increased primary memory of microcomputers (256 K and more ..) it might be possible to have enough space to avoid using a secondary storage device during the execution, which would considerably cut computing time.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The need for a planning and scheduling system for high-rise building construction was identified when the attributes of a Construction Project Management Information System (CPMIS) were examined. The main objective of the present thesis was to develop such a planning and scheduling system.

However, in order for it to be useful, it had to be designed by incorporating into its specification input gained from the study of the construction process and feedback from the construction people who would eventually end up using it. Of importance also was an extensive review of all possible planning techniques in order to develop a system with the most realistic algorithms possible.

This goal has been met. Based on the specification built up by studying the construction process, a planning and scheduling model has been designed and its algorithms have been included in a computer program. The programs have been designed to facilitate the interface between the user and the machine, both for the initial planning process and for updating, once construction has started.

The algorithms include salient characteristics of high-rise building construction, such as the repetitiveness of several activities on typical floors, the work continuity concept for those activities, learning curve effects and the influence of inclement weather on activity progress. These characteristics are not handled adequately by current planning techniques.

The example presented showed that even if only 64 activities were used to model the construction process of a sixteen storey building, a good level of detail was obtained, and would be comparable to inputting about 500 activities in a standard CPM system. The bar chart and linear chart formats proved to be readable and should be useful to a general contractor. The capability of producing a short cycle schedule should prove valuable to site level management which is interested in short term tasks. The procurement status report is useful for reminding subcontractors to work on the delivery of major items, even if their arrival on the site is months away. Finally, the updating and the generation of a new updated schedule showed the flexibility of the system and its suitability for high-rise building construction.

6.2 RECOMMENDATION FOR FUTURE WORK

Topics which could be treated in future work include:

i) A field trial of the system on a job from beginning to end, to see what modifications and refinements in the algorithms and/or presentation formats are required (see section 5.5);

ii) A refinement of the software in order to make the program "fool-proof". Further, some analysis should be undertaken to see how computing time could be reduced and how the program could be implemented on a microcomputer;

iii) An integration of the system with the subcontractor control system, in order to tie into the matrix format for schedule and physical progress control and to facilitate cash flow planning;

iv) An investigation on the possibility of having other kinds of relationships between the activities, like finish to finish, or start to start with lag factors; or comparing two repetitive activities by looking at the floors discretely, and not all together as the current model assumes, etc;

v) The development of learning curve models, for the various types of repetitive activity; and

vi) The development of a model to forecast time to complete, for a repetitive activity, based on the performance of the completed floors and on historical data.

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APPENDIX I

Sample Session on the Terminal for the Example in Chapter V

Note: What follows a ">" is input by the user.

```
NAME OF FILE ? (4 CHAR.)
>JOB

            MENU

1) START  A NEW PROJECT
2) INPUT  NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY  NAME
6) LIST  ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT  RESULTS
10) INPUT OR CHANGE ACTIVITY  DATA
11) SHORT CYCLE  SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>1
```

Menu displayed by terminal

```
NAME OF  FILE ? (4  CHAR.)
>JOB

COPY OF  STANDARD NETWORK ? (1) YES OR  (2) NO
>2

NAME OF  FILE ? (4  CHAR.)
>JOB
```

Creation of job file called "JOB".

```
            MENU

1) START  A NEW PROJECT
2) INPUT  NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY  NAME
6) LIST  ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY  DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>13

INPUT DAY OF WEEK  AND DATE THAT PROJECT STARTS
>2,830405
```

Start date of the project

```
INPUT HOLIDAYS (0  TO END)
>830523
>830624
>830701
>830718
>830719
>
   :
   :
 841231
>850101
>850102
>850103
>850104
>0
```

Input of holidays (one at a time)

Format is important:YYMMDD

```
INPUT NO OF WORKING DAYS
>500
```

Estimated by the user (arbitrary)

```
NAME OF FILE ? (4 CHAR.)
>JOB

            MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER!
>10

NAME OF FILE ? (4 CHAR.)
>JOB


1) UPDATE
2) NEW
3) WEATHER FACTORS
4) ACTUAL START AND FINISH DATES
5) QUIT
>3

INPUT WEATHER FACTORS
>70,70,75,80,90,100,100,100,90,80,75,70

1) UPDATE
2) NEW
3) WEATHER FACTORS
4) ACTUAL START AND FINISH DATES
5) QUIT
>5
```

Input of weather factors;

done once .

The first number corresponds to January, the second, to February, etc...

```
NAME OF FILE ? (4 CHAR.)
>JOB

            MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER!
>14

  STOP 370
>
```

End of the session.

App. I(B).

```
NAME OF FILE ? (4 CHAR.)
>JOB

            MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE  SCHEDULE
12) PROCUREMENT  STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>2
```

New activities are input in the system

```
ENTER ACTIVITY NO.
>10100
ENTER DESCRIPTION (MAX. 20) OF ACTIVITY  10100
>STRUCTURE
ENTER NO. OF TYPICAL PREDECESSORS FOR ACTIVITY
 10100
>0
ENTER NO. OF NON-TYPICAL PREDECESSORS
>1
ENTER ACT.NO AND LEVEL IT PRECEDES
>12100,1
```

Repetitive activity: the last two digits of the number have to be 00.

```
ENTER ACTIVITY NO.
>70200
ENTER DESCRIPTION (MAX. 20) OF ACTIVITY  70200
>GYPROC (COLUMN)
ENTER NO. OF TYPICAL PREDECESSORS FOR ACTIVITY
 70200
>1
ENTER ACT. NO. OF THE PREDECESSORS
>10200
ENTER NO. OF NON-TYPICAL PREDECESSORS
>0
```

Repetitive without non-typical predecessor.

```
ENTER ACTIVITY NO.
>110100
ENTER DESCRIPTION (MAX. 20) OF ACTIVITY  110100
>L-R ELEV. RAILS
ENTER NO. OF TYPICAL PREDECESSORS FOR ACTIVITY
 110100
>0
ENTER NO. OF NON-TYPICAL PREDECESSORS
>1
ENTER ACT.NO AND LEVEL IT PRECEDES
>10209,1
```

A repetitive activity as a non-typical predecessor; the last two digits are the floor number.

```
ENTER ACTIVITY NO.
>110200
ENTER DESCRIPTION (MAX. 20) OF ACTIVITY  110200
>L-R ELEV. FR. & DOOR
ENTER NO. OF TYPICAL PREDECESSORS FOR ACTIVITY
 110200
>0
```

Repetitive activity without typical predecessor

```
ENTER NO. OF NON-TYPICAL PREDECESSORS
>3
ENTER ACT.NO AND LEVEL IT PRECEDES
>112209,1
>42100,1
>40209,1
```

For non-typical predecessors, activity number and level are input together, for each predecessor.

```
ENTER ACTIVITY NO.
>100100
ENTER DESCRIPTION (MAX. 20) OF  ACTIVITY   100100
>MASONRY (L-R HALL)
ENTER NO. OF TYPICAL  PREDECESSORS FOR ACTIVITY
 100100
>1
ENTER ACT.  NO. OF THE PREDECESSORS
>110200
ENTER NO. OF NON-TYPICAL PREDECESSORS
>0
ENTER ACTIVITY NO.
>70500
ENTER DESCRIPTION (MAX. 20) OF  ACTIVITY   70500
>GYPROC (L-R HALL)
ENTER NO. OF TYPICAL  PREDECESSORS FOR ACTIVITY
 70500
>1
ENTER ACT.  NO. OF THE PREDECESSORS
>100100
ENTER NO. OF NON-TYPICAL PREDECESSORS
>0

ENTER ACTIVITY NO.
>110300
ENTER DESCRIPTION (MAX. 20) OF  ACTIVITY   110300
>H-R ELEV.  RAILS
ENTER NO. OF TYPICAL  PREDECESSORS FOR ACTIVITY
 110300
>0
ENTER NO. OF NON-TYPICAL PREDECESSORS
>2
ENTER ACT.NO AND LEVEL IT PRECEDES
>10216,1
>110108,1

ENTER ACTIVITY NO.
>110400
ENTER DESCRIPTION (MAX. 20) OF  ACTIVITY   110400
>H-R ELEV.  FR & DOOR
ENTER NO. OF TYPICAL  PREDECESSORS FOR ACTIVITY
 110400
>0
ENTER NO. OF NON-TYPICAL PREDECESSORS
>4
ENTER ACT.NO AND LEVEL IT PRECEDES
>110208,9
>112416,9
>42100,9
>40216,9
  .
  .
  .
  .
ENTER ACTIVITY NO.
>50200
ENTER DESCRIPTION (MAX. 20) OF  ACTIVITY   50200
>CEILING GRID
ENTER NO. OF TYPICAL  PREDECESSORS FOR ACTIVITY
 50200
>5
ENTER ACT.  NO. OF THE PREDECESSORS
>70200
>50100
>70100
>70600
>70300
ENTER NO. OF NON-TYPICAL PREDECESSORS
>0
```

Typical predecessors are input one by one.

```
ENTER ACTIVITY NO.
>40300
ENTER DESCRIPTION (MAX. 20) OF ACTIVITY  40300
>ELECT. FIXTURES
ENTER NO. OF TYPICAL PREDECESSORS FOR ACTIVITY
 40300
>1
ENTER ACT. NO. OF THE PREDECESSORS
>50200
ENTER NO. OF NON-TYPICAL PREDECESSORS
>1
ENTER ACT.NO AND LEVEL IT PRECEDES
>40116,1
ENTER ACTIVITY NO.
>20400
ENTER DESCRIPTION (MAX. 20) OF ACTIVITY  20400
>VENT FLEX. & DIFF.
ENTER NO. OF TYPICAL PREDECESSORS FOR ACTIVITY
 20400
>1
ENTER ACT. NO. OF THE PREDECESSORS
>50200
ENTER NO. OF NON-TYPICAL PREDECESSORS
>1
ENTER ACT.NO AND LEVEL IT PRECEDES
>20116,1

ENTER ACTIVITY NO.
>30300
ENTER DESCRIPTION (MAX. 20) OF ACTIVITY  30300
>SPRINKLER HEADS
ENTER NO. OF TYPICAL PREDECESSORS FOR ACTIVITY
 30300
>1
ENTER ACT. NO. OF THE PREDECESSORS
>50200
ENTER NO. OF NON-TYPICAL PREDECESSORS
>1
ENTER ACT.NO AND LEVEL IT PRECEDES
>30216,1

ENTER ACTIVITY NO.
>50300
ENTER DESCRIPTION (MAX. 20) OF ACTIVITY  50300
>TILES (CEILING)
ENTER NO. OF TYPICAL PREDECESSORS FOR ACTIVITY
 50300
>3
ENTER ACT. NO. OF THE PREDECESSORS
>40300
>20400
>30300
ENTER NO. OF NON-TYPICAL PREDECESSORS
>0

ENTER ACTIVITY NO.
>2100
ENTER DESCRIPTION (MAX. 20) OF ACTIVITY  2100
>MOBILIZATION
ENTER NO OF PREDECESSOR FOR ACTIVITY  2100
>1
ENTER ACT. NO. OF THE PREDECESSORS
>8100
```

Non-repetitive activity:
21 > 20.

```
ENTER ACTIVITY NO.
>2200
ENTER DESCRIPTION (MAX. 20) OF ACTIVITY  2200
>EXCAVATION
ENTER NO OF PREDECESSOR FOR ACTIVITY  2200
>1
ENTER ACT. NO. OF THE PREDECESSORS
>2100
```

```
ENTER ACTIVITY NO.
>22116
ENTER DESCRIPTION (MAX. 20) OF ACTIVITY  22116
>CHILLERS
ENTER NO OF PREDECESSOR FOR ACTIVITY  22116
>1
ENTER ACT. NO. OF THE PREDECESSORS
>10216

ENTER ACTIVITY NO.
>22216
ENTER DESCRIPTION (MAX. 20) OF ACTIVITY  22216
>COOLING TOWERS
ENTER NO OF PREDECESSOR FOR ACTIVITY  22216
>1
ENTER ACT. NO. OF THE PREDECESSORS
>10216

ENTER ACTIVITY NO.
>22316
ENTER DESCRIPTION (MAX. 20) OF ACTIVITY  22316
>FURNACES
ENTER NO OF PREDECESSOR FOR ACTIVITY  22316
>1
ENTER ACT. NO. OF THE PREDECESSORS
>10216
    :
    :
    :
    :
ENTER ACTIVITY NO.
>7800
ENTER DESCRIPTION (MAX. 20) OF ACTIVITY  7800
>MISCELL. FINISH
ENTER NO OF PREDECESSOR FOR ACTIVITY  7800
>4
ENTER ACT. NO. OF THE PREDECESSORS
>70508
>70416
>100316
>50316
```

Predecessors are input one by one.

```
ENTER ACTIVITY NO.
>7900
ENTER DESCRIPTION (MAX. 20) OF ACTIVITY  7900
>DEMOBILIZE
ENTER NO OF PREDECESSOR FOR ACTIVITY  7900
>5
ENTER ACT. NO. OF THE PREDECESSORS
>112616
>7800
>62200
>32200
>22500


ENTER ACTIVITY NO.
>8100
ENTER DESCRIPTION (MAX. 20) OF ACTIVITY  8100
>START OF PROJECT
```

Milestone : 81 > 80
No predecessor

```
ENTER ACTIVITY NO.
>0
  END OF INPUT
FOR A TOTAL OF   65   ACTIVITIES
```

"0" stops the input.

Back to the main menu.

```
          MENU.....
```

```
         MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>10

NAME OF FILE ? (4 CHAR.)
>JOB

1) UPDATE
2) NEW
3) WEATHER FACTORS
4) ACTUAL START AND FINISH DATES
5) QUIT
>
 2
```

New activity data is input here.

```
1) SEQUENTIALLY
2) RANDOMLY
>1

1) ORDER OF INPUT
2) INCREASING ACTIVITY NO.
3) SEQUENTIAL STEP ORDER
>1
```

...in the order of input.

```
ACTIVITY NO. 10100
STARTING LEVEL ?
>1
CURRENT LEVEL ?
>1
LAST LEVEL ?
>16
NO. OF CREWS ?
>1
PRODUCTION RATE ?
>6
START TO START ?
>0
FINISH TO START ?
>0
```

Input one number for each of these variables.

```
ENTER FLOOR NO. AND PRODUCTION COEFFICIENT
>1,50
>2,60
>3,75
>4,90
>0,0
```

Floor number and production coefficient are input two by two, until "0,0" is entered.

```
WEATHER ? (1)YES OR (0) NO
>1

1) STARTING LEVEL:  1
2) CURRENT  LEVEL:  1
3) LAST     LEVEL:  16
4) NO. OF CREWS  :  1
5) PRODUCTION RATE: 6
6) START TO START:  0
7) FINISH TO FIN.:  0
8) LEARNING      :  18
9) WEATHER       :  1
10) QUIT
>10
```

Data reappears for a quick check;

"Quit"(10) moves to the next activity.

Learning is "18", which is different than "-1". (18 is in fact the pointer to the first record of the list.)

```
ACTIVITY NO. 70200
STARTING LEVEL ?
>1
CURRENT LEVEL ?
>1
LAST LEVEL ?
>16
NO. OF CREWS ?
>1
PRODUCTION RATE ?
>4
START TO START ?
>0
FINISH TO START ?
>0
ENTER FLOOR NO. AND PRODUCTION COEFFICIENT
>0,0
WEATHER ? (1)YES OR (0) NO
>0
```

If no learning , "0,0" is input right away, and the list is empty.

```
1) STARTING LEVEL:  1
2) CURRENT  LEVEL:  1
3) LAST     LEVEL:  16
4) NO. OF CREWS   :  1
5) PRODUCTION RATE: 4
6) START TO START:  0
7) FINISH TO FIN.:  0
8) LEARNING       : -1
9) WEATHER        :  0
10) QUIT
```

"-1" means that the list is empty (no learning)

```
>10
ACTIVITY NO. 110100
STARTING LEVEL ?
>1
CURRENT LEVEL ?
>1
LAST LEVEL ?
>8
NO. OF CREWS ?
>1
PRODUCTION RATE ?
>4
START TO START ?
>0
FINISH TO START ?
>0
ENTER FLOOR NO. AND PRODUCTION COEFFICIENT
>1,90
>0,0
WEATHER ? (1)YES OR (0) NO
>0

1) STARTING LEVEL:  1
2) CURRENT  LEVEL:  1
3) LAST     LEVEL:  8
4) NO. OF CREWS   :  1
5) PRODUCTION RATE: 4
6) START TO START:  0
7) FINISH TO FIN.:  0
8) LEARNING       :  19
9) WEATHER        :  0
10) QUIT
>
 5
PRODUCTION RATE ?
>3
```

Production rate was not entered properly; choosing "5" will allow the user to modify it.

```
1) STARTING LEVEL:  1
2) CURRENT  LEVEL:  1
3) LAST     LEVEL:  8
4) NO. OF CREWS   :  1
5) PRODUCTION RATE: 3
6) START TO START:  0
7) FINISH TO FIN.:  0
8) LEARNING       :  19
9) WEATHER        :  0
```

Data is displayed again.

```
ACTIVITY NO. 110400
STARTING LEVEL ?
>9
CURRENT LEVEL ?
>9
LAST LEVEL ?
>16
NO. OF CREWS ?
>1
PRODUCTION RATE ?
>3
START TO START ?
>0
FINISH TO START ?
>0
ENTER FLOOR NO. AND PRODUCTION COEFFICIENT
>0,0
WEATHER ? (1)YES OR (0) NO
>0

1) STARTING LEVEL:  9
2) CURRENT  LEVEL:  9
3) LAST     LEVEL:  16
4) NO. OF CREWS  :  1
5) PRODUCTION RATE: 3
6) START TO START:  0
7) FINISH TO FIN.:  0
8) LEARNING      : -1
9) WEATHER       :  0
10) QUIT
>10
        :
        :
        :
ACTIVITY NO. 50300
STARTING LEVEL ?
>1
CURRENT LEVEL ?
>1
LAST LEVEL ?
>16
NO. OF CREWS ?
>1
PRODUCTION RATE ?
>3
START TO START ?
>0
FINISH TO START ?
>0
ENTER FLOOR NO. AND PRODUCTION COEFFICIENT
>0,0
WEATHER ? (1)YES OR (0) NO
>0

1) STARTING LEVEL:  1
2) CURRENT  LEVEL:  1
3) LAST     LEVEL:  16
4) NO. OF CREWS  :  1
5) PRODUCTION RATE: 3
6) START TO START:  0
7) FINISH TO FIN.:  0
8) LEARNING      : -1
9) WEATHER       :  0
10) QUIT
>10
        :
ACTIVITY NO. 2100
ENTER DURATION
>10
1) PREPARATION OF BID DOCUMENTS
2) CALL FOR TENDERS
3) EXAMINATION OF BIDS AND CONTRACT AWARD
4) VENDOR'S PREPARATION AND SUBMISSION OF SHOP DRAWINGS
5) REVIEW AND APPROVAL OF SHOP DRAWINGS
6) FABRICATION BY THE VENDOR
7) SHIPPING
8) CUSTOM CLEARANCES
9) DELIVERY AND INSPECTION
```

} Non-repetitive activity

} The possible procurement tasks appear to guide the user in choosing them.

```
 >0,0
WEATHER ? (1)YES OR (0) NO
>0
STATUS  (1) COMPLETED  (0) NOT
>0

1) DURATION    :  10
2) PROCUREMENT: -1
3) WEATHER     :  0
4) STATUS      :  0
5) QUIT
>
 5
```

no procurement

```
ACTIVITY NO. 2200
ENTER DURATION
>40
1) PREPARATION OF BID DOCUMENTS
2) CALL FOR TENDERS
3) EXAMINATION OF BIDS AND CONTRACT AWARD
4) VENDOR'S PREPARATION AND SUBMISSION OF SHOP DRAWINGS
5) REVIEW AND APPROVAL OF SHOP DRAWINGS
6) FABRICATION BY THE VENDOR
7) SHIPPING
8) CUSTOM CLEARANCES
9) DELIVERY AND INSPECTION

ENTER ITEM NUMBER AND DURATION
>0,0
WEATHER ? (1)YES OR (0) NO
>1
STATUS  (1) COMPLETED  (0) NOT
>0

1) DURATION    :  40
2) PROCUREMENT: -1
3) WEATHER     :  1
4) STATUS      :  0
5) QUIT
>5
```

Data reappear.

```
            :

ACTIVITY NO. 22116
ENTER DURATION
>10
1) PREPARATION OF BID DOCUMENTS
2) CALL FOR TENDERS
3) EXAMINATION OF BIDS AND CONTRACT AWARD
4) VENDOR'S PREPARATION AND SUBMISSION OF SHOP DRAWINGS
5) REVIEW AND APPROVAL OF SHOP DRAWINGS
6) FABRICATION BY THE VENDOR
7) SHIPPING
8) CUSTOM CLEARANCES
9) DELIVERY AND INSPECTION

ENTER ITEM NUMBER AND DURATION
>1,10
>2,10
>3,3
>4,10
>5,3
>6,30
>7,10
>8,5
>9,3
>0,0
```

Item number and duration of the task corresponding to that number are input one by one, in chronological order

"0,0" stops the input.

```
WEATHER ? (1)YES OR (0) NO
>0
STATUS  (1) COMPLETED  (0) NOT
>0

1) DURATION    :  10
2) PROCUREMENT:  28
3) WEATHER     :  0
4) STATUS      :  0
5) QUIT
>5
```

A number different than "-1" means that there is a procurement sequence. (in fact, 28 is a pointer to the first record of the list).

```
ACTIVITY NO. 22216
ENTER DURATION
>10
1) PREPARATION OF BID DOCUMENTS
2) CALL FOR TENDERS
3) EXAMINATION OF BIDS AND CONTRACT AWARD
4) VENDOR'S PREPARATION AND SUBMISSION OF SHOP DRAWINGS
5) REVIEW AND APPROVAL OF SHOP DRAWINGS
6) FABRICATION BY THE VENDOR
7) SHIPPING
8) CUSTOM CLEARANCES
9) DELIVERY AND INSPECTION

ENTER ITEM NUMBER AND DURATION
>1,10
>2,10
>3,3
>4,10
>5,3
>6,20
>7,10
>9,3
>0,0
WEATHER ? (1)YES OR (0) NO
>0
STATUS  (1) COMPLETED  (0) NOT
>0

1) DURATION    :  10
2) PROCUREMENT:  36
3) WEATHER     :  0
4) STATUS      :  0
5) QUIT
>5

ACTIVITY NO. 22316
ENTER DURATION
>20
1) PREPARATION OF BID DOCUMENTS
2) CALL FOR TENDERS
3) EXAMINATION OF BIDS AND CONTRACT AWARD
4) VENDOR'S PREPARATION AND SUBMISSION OF SHOP DRAWINGS
5) REVIEW AND APPROVAL OF SHOP DRAWINGS
6) FABRICATION BY THE VENDOR
7) SHIPPING
8) CUSTOM CLEARANCES
9) DELIVERY AND INSPECTION

ENTER ITEM NUMBER AND DURATION
>9,5
>0,0
WEATHER ? (1)YES OR (0) NO
```

Can input any of these tasks, but it has to be in chronoligal order.

```
>0
STATUS  (1) COMPLETED  (0) NOT
>0

1) DURATION    :  20
2) PROCUREMENT:  37
3) WEATHER     :  0
4) STATUS      :  0
5) QUIT
>2
1) PREPARATION OF BID DOCUMENTS
2) CALL FOR TENDERS
3) EXAMINATION OF BIDS AND CONTRACT AWARD
4) VENDOR'S PREPARATION AND SUBMISSION OF SHOP DRAWINGS
5) REVIEW AND APPROVAL OF SHOP DRAWINGS
6) FABRICATION BY THE VENDOR
7) SHIPPING
8) CUSTOM CLEARANCES
9) DELIVERY AND INSPECTION

ENTER ITEM NUMBER AND DURATION
>6,30
>7,10
>9,5
>0,0
        :
```

```
1) DURATION    :  20
2) PROCUREMENT:  40
3) WEATHER     :  0
4) STATUS      :  0
5) QUIT
>5
ACTIVITY NO. 7800
ENTER DURATION
>15

1) PREPARATION OF BID DOCUMENTS
2) CALL FOR TENDERS
3) EXAMINATION OF BIDS AND CONTRACT AWARD
4) VENDOR'S PREPARATION AND SUBMISSION OF SHOP DRAWINGS
5) REVIEW AND APPROVAL OF SHOP DRAWINGS
6) FABRICATION BY THE VENDOR
7) SHIPPING
8) CUSTOM CLEARANCES
9) DELIVERY AND INSPECTION

ENTER ITEM NUMBER AND DURATION
>0,0
WEATHER ? (1)YES OR (0) NO
>0
STATUS  (1) COMPLETED  (0) NOT
>0

1) DURATION    :  15
2) PROCUREMENT: -1
3) WEATHER     :  0
4) STATUS      :  0
5) QUIT
>5

ACTIVITY NO. 7900
ENTER DURATION
>10
1) PREPARATION OF BID DOCUMENTS
2) CALL FOR TENDERS
3) EXAMINATION OF BIDS AND CONTRACT AWARD
4) VENDOR'S PREPARATION AND SUBMISSION OF SHOP DRAWINGS
5) REVIEW AND APPROVAL OF SHOP DRAWINGS
6) FABRICATION BY THE VENDOR
7) SHIPPING
8) CUSTOM CLEARANCES
9) DELIVERY AND INSPECTION

ENTER ITEM NUMBER AND DURATION
>0,0
WEATHER ? (1)YES OR (0) NO
>0
STATUS  (1) COMPLETED  (0) NOT
>0

1) DURATION    :  10
2) PROCUREMENT: -1
3) WEATHER     :  0
4) STATUS      :  0
5) QUIT
>5

MILESTONE NO. 8100
INPUT NEW DATE
>830405
```

Case of a milestone: only a date (YYMMDD) is input.

```
1) UPDATE
2) NEW
3) WEATHER FACTORS
4) ACTUAL START AND FINISH DATES
5) QUIT
>5
```

When all the activities have been accessed, the menu is displayed.

```
            MENU

 1) START A NEW PROJECT
 2) INPUT NEW ACTIVITIES
 3) DELETE ACTIVITIES
 4) CHANGE PRECEDENCE
 5) CHANGE ACTIVITY NAME
 6) LIST ACTIVITIES
 7) COMPILE DATA
 8) EXECUTE DATA
 9) PRINT RESULTS
 10) INPUT OR CHANGE ACTIVITY DATA
 11) SHORT CYCLE SCHEDULE
 12) PROCUREMENT STATUS REPORT
 13) PREPARE CALENDAR
 14) QUIT

CHOOSE ANY NUMBER:
>6

 1)ORDER OF INPUT
 2)SEQUENTIAL STEP
 3)INCREASING ACTIVITY NO.
>1
```

Activities are listed in the order of Input.

```
            MENU

 1) START A NEW PROJECT
 2) INPUT NEW ACTIVITIES
 3) DELETE ACTIVITIES
 4) CHANGE PRECEDENCE
 5) CHANGE ACTIVITY NAME
 6) LIST ACTIVITIES
 7) COMPILE DATA
 8) EXECUTE DATA
 9) PRINT RESULTS
 10) INPUT OR CHANGE ACTIVITY DATA
 11) SHORT CYCLE SCHEDULE
 12) PROCUREMENT STATUS REPORT
 13) PREPARE CALENDAR
 14) QUIT

CHOOSE ANY NUMBER:
>7

NAME OF FILE ? (4 CHAR.)
>JOB
```

Data are compiled

```
START CALCULATION
START SORTING
```

Displayed

```
NAME OF FILE ? (4 CHAR.)
>JOB
            MENU

 1) START A NEW PROJECT
 2) INPUT NEW ACTIVITIES
 3) DELETE ACTIVITIES
 4) CHANGE PRECEDENCE
 5) CHANGE ACTIVITY NAME
 6) LIST ACTIVITIES
 7) COMPILE DATA
 8) EXECUTE DATA
 9) PRINT RESULTS
 10) INPUT OR CHANGE ACTIVITY DATA
 11) SHORT CYCLE SCHEDULE
 12) PROCUREMENT STATUS REPORT
 13) PREPARE CALENDAR
 14) QUIT
```

```
>8
NAME OF FILE ? (4 CHAR.)
>JOB
```

Data are calculated

```
REARRANGE FILE ? YES (1) OR NO (2)
>2
```

It is the first run; The file does not need to be rearranged.

```
NAME OF FILE ? (4 CHAR.)
>JOB

           MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>9

NAME OF FILE ? (4 CHAR.)
>JOB
```

Printing results

```
NO. OF LEVELS FOR THE PROJECT ?
>16
```

Number of levels (floors) is input now and every time this option is chosen.

```
1) LIST OF DATES
2) LINEAR CHART
3) BAR CHART
4) QUIT
>3
```

The bar-chart is printed.

```
1) LIST OF DATES
2) LINEAR CHART
3) BAR CHART
4) QUIT
>4

NAME OF FILE ? (4 CHAR.)
>JOB

           MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>14
  STOP 370
```

End of Session.

```
NAME OF FILE ? (4 CHAR.)
>JOB

               MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>4

NAME OF FILE ? (4 CHAR.)
>JOB
```

Modifications are required to the precedence relationships.

```
1) DELETE PRECEDENCE
2) ADD PRECEDENCE
3) QUIT
>2
ACTIVITY NO. AN PREDECESSOR NO.?
>70200,8200
IS THE PREDECESSOR TYPICAL (1) OR NOT (2)
>2
FOR WHICH LEVEL
>1
```

Addition of non-typical predecessor 8200 to the first floor of Activity 70200.

```
1) DELETE PRECEDENCE
2) ADD PRECEDENCE
3) QUIT
>2
ACTIVITY NO. AN PREDECESSOR NO.?
>100100,8200
IS THE PREDECESSOR TYPICAL (1) OR NOT (2)
>2
FOR WHICH LEVEL
>1
```

Activity number and predecessor number are input together.

```
1) DELETE PRECEDENCE
2) ADD PRECEDENCE
3) QUIT
>2
ACTIVITY NO. AN PREDECESSOR NO.?
>100400,8200
IS THE PREDECESSOR TYPICAL (1) OR NOT (2)
>2
FOR WHICH LEVEL
>1
 9
1) DELETE PRECEDENCE
2) ADD PRECEDENCE
3) QUIT
>2
ACTIVITY NO. AN PREDECESSOR NO.?
>120100,8200
IS THE PREDECESSOR TYPICAL (1) OR NOT (2)
>2
FOR WHICH LEVEL
>1
1) DELETE PRECEDENCE
2) ADD PRECEDENCE
3) QUIT
>2
ACTIVITY NO. AN PREDECESSOR NO.?
>100200,8200
IS THE PREDECESSOR TYPICAL (1) OR NOT (2)
>2
FOR WHICH LEVEL
```

```
>1
1) DELETE PRECEDENCE
2) ADD PRECEDENCE
3) QUIT
>2
ACTIVITY NO. AN PREDECESSOR NO.?
>70300,8200
IS THE PREDECESSOR TYPICAL (1) OR NOT (2)
>2
FOR WHICH LEVEL
>1
1) DELETE PRECEDENCE
2) ADD PRECEDENCE
3) QUIT
>2
ACTIVITY NO. AN PREDECESSOR NO.?
>100300,8200
IS THE PREDECESSOR TYPICAL (1) OR NOT (2)
>2
FOR WHICH LEVEL
>1
1) DELETE PRECEDENCE
2) ADD PRECEDENCE
3) QUIT
>2
ACTIVITY NO. AN PREDECESSOR NO.?
>42100,8200
1) DELETE PRECEDENCE
2) ADD PRECEDENCE
3) QUIT
```

Addition of predecessor no. 8200 to non-repetitive activity 42100.

```
> 2
ACTIVITY NO. AN PREDECESSOR NO.?
>32100,8200
1) DELETE PRECEDENCE
2) ADD PRECEDENCE
3) QUIT
>8
ACTIVITY NO. AN PREDECESSOR NO.?
>62100,8200
1) DELETE PRECEDENCE
2) ADD PRECEDENCE
3) QUIT
>1
ACTIVITY NO. AN PREDECESSOR NO.?
>32100,12100
PRECEDENCE 12100 IS DELETED
```

Predecessor no. 12100 of activity no. 32100 is deleted.

```
1) DELETE PRECEDENCE
2) ADD PRECEDENCE
3) QUIT
>1
ACTIVITY NO. AN PREDECESSOR NO.?
>42100,12100
PRECEDENCE 12100 IS DELETED
1) DELETE PRECEDENCE
2) ADD PRECEDENCE
3) QUIT
>1
ACTIVITY NO. AN PREDECESSOR NO.?
>62100,12100
PRECEDENCE 12100 IS DELETED
1) DELETE PRECEDENCE
2) ADD PRECEDENCE
3) QUIT
>3
```

Return to main menu.

```
NAME OF FILE ? (4 CHAR.)
>JOB
```

```
              MENU
 1) START A NEW PROJECT
 2) INPUT NEW ACTIVITIES
 3) DELETE ACTIVITIES
 4) CHANGE PRECEDENCE
 5) CHANGE ACTIVITY NAME
 6) LIST ACTIVITIES
 7) COMPILE DATA
 8) EXECUTE DATA
 9) PRINT RESULTS
 10) INPUT OR CHANGE ACTIVITY DATA
 11) SHORT CYCLE SCHEDULE
 12) PROCUREMENT STATUS REPORT
 13) PREPARE CALENDAR
 14) QUIT

CHOOSE ANY NUMBER:
>2

ENTER ACTIVITY NO.
>8200
ENTER DESCRIPTION (MAX. 20) OF ACTIVITY  8200
>NO HEATING REQ'D
ENTER ACTIVITY NO.
>0
END OF INPUT
FOR A TOTAL OF  66  ACTIVITIES
```

Milestone no. 8200 is
added to the activities
in the system.

```
              MENU

 1) START A NEW PROJECT
 2) INPUT NEW ACTIVITIES
 3) DELETE ACTIVITIES
 4) CHANGE PRECEDENCE
 5) CHANGE ACTIVITY NAME
 6) LIST ACTIVITIES
 7) COMPILE DATA
 8) EXECUTE DATA
 9) PRINT RESULTS
 10) INPUT OR CHANGE ACTIVITY DATA
 11) SHORT CYCLE SCHEDULE
 12) PROCUREMENT STATUS REPORT
 13) PREPARE CALENDAR
 14) QUIT

CHOOSE ANY NUMBER:
>10

NAME OF FILE ? (4 CHAR.)
>JOB

1) UPDATE
2) NEW
3) WEATHER FACTORS
4) ACTUAL START AND FINISH DATES
5) QUIT
>2

1) SEQUENTIALLY
2) RANDOMLY
>2
```

Randomly accessed because only the date
of 8200 is entered.

```
ACTIVITY NO.
>8200
MILESTONE NO. 8200
INPUT NEW DATE
>840402

ACTIVITY NO.
>0
```

"O" stops the input

```
1) UPDATE
2) NEW
3) WEATHER FACTORS
4) ACTUAL START AND FINISH DATES
5) QUIT
>5
```

App. I(F).

```
          MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>9

NAME OF FILE ? (4 CHAR.)
>JOB

NO. OF LEVELS FOR THE PROJECT ?
>16

1) LIST OF DATES
2) LINEAR CHART
3) BAR CHART
4) QUIT
>2
```

Printing the results.

in a linear chart format:

```
NO. OF ACTIVITIES TO PRINT ON THE SAME CHART ?
>9
```

First, input the number of activities to print on the same chart.

```
INPUT ACTIVITY NO.
>10100
INPUT ACTIVITY NO.
>10200
INPUT ACTIVITY NO.
>80100
INPUT ACTIVITY NO.
>80200
INPUT ACTIVITY NO.
>22316
INPUT ACTIVITY NO.
>22616
INPUT ACTIVITY NO.
>20300
INPUT ACTIVITY NO.
>100200
INPUT ACTIVITY NO.
>70600
```

Activity numbers are input one by one.

```
NO. OF ACTIVITIES TO PRINT ON THE SAME CHART ?
>16
INPUT ACTIVITY NO.
>10100
INPUT ACTIVITY NO.
>10200
INPUT ACTIVITY NO.
>110100
INPUT ACTIVITY NO.
>110200
INPUT ACTIVITY NO.
>70500
INPUT ACTIVITY NO.
>110300
INPUT ACTIVITY NO.
>110400
INPUT ACTIVITY NO.
>70400
INPUT ACTIVITY NO.
>112109
```

Another chart...

⋮

```
NO. OF ACTIVITIES TO PRINT ON THE SAME CHART ?
>6
INPUT ACTIVITY NO.
>10100
INPUT ACTIVITY NO.
>10200
INPUT ACTIVITY NO.
>90100
INPUT ACTIVITY NO.
>90200
INPUT ACTIVITY NO.
>90300
INPUT ACTIVITY NO.
>70300
 :
NO. OF ACTIVITIES TO PRINT ON THE SAME CHART ?
>0
```

"0" stops the input and execution goes to the printing menu.

```
1) LIST OF DATES
2) LINEAR CHART
3) BAR CHART
4) QUIT
>4

NAME OF FILE ? (4 CHAR.)
>JOB

           MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>12

NAME OF FILE ? (4 CHAR.)
>JOB
```

Production of the procurement status report.

```
ACTIVITY NO. ?
>62100
ACTIVITY NO. ?
>32100
ACTIVITY NO. ?
>42100
ACTIVITY NO. ?
>22416
ACTIVITY NO. ?
>22316
ACTIVITY NO. ?
>22216
ACTIVITY NO. ?
>22116
ACTIVITY NO. ?
>112109
ACTIVITY NO. ?
>112316
ACTIVITY NO. ?
>112209
ACTIVITY NO. ?
>112416
ACTIVITY NO. ?
>42216
ACTIVITY NO. ?
>0
```

Activity numbers, that are to appear on the report are input one by one.

"0" stops the input and execution returns to the main menu.

App. I(G):

UPDATING:

First: input actual start and finish dates (option 10).

```
          MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>10

NAME OF FILE ? (4 CHAR.)
>JOB

1) UPDATE
2) NEW
3) WEATHER FACTORS
4) ACTUAL START AND FINISH DATES
5) QUIT
>4

INPUT ACTIVITY NO.
>2100
INPUT ACTUAL START AND FINISH DATES
>830405,830418
```

Input activity number and then both actual start and finish dates.(YYMMDD)

```
INPUT ACTIVITY NO.
>2200
INPUT ACTUAL START AND FINISH DATES
>830418,830617

INPUT ACTIVITY NO.
>2300
INPUT ACTUAL START AND FINISH DATES
>830620,830808

INPUT ACTIVITY NO.
>12100
INPUT ACTUAL START AND FINISH DATES
>830809,830926

INPUT ACTIVITY NO.
>10101
INPUT ACTUAL START AND FINISH DATES
>830927,831014

INPUT ACTIVITY NO.
>10102
INPUT ACTUAL START AND FINISH DATES
>831017,831101
```

For a repetitive activity, the last two digits are the floor number.

```
INPUT ACTIVITY NO.
>10103
INPUT ACTUAL START AND FINISH DATES
>831102,831114

INPUT ACTIVITY NO.
>10104
INPUT ACTUAL START AND FINISH DATES
>831115,831125

INPUT ACTIVITY NO.
>10105
INPUT ACTUAL START AND FINISH DATES
>831128,831206
```

```
INPUT ACTIVITY NO.
>10106
INPUT ACTUAL START AND FINISH DATES
>831207,831216

INPUT ACTIVITY NO.
>10201
INPUT ACTUAL START AND FINISH DATES
>831017,831101

INPUT ACTIVITY NO.
>10202
INPUT ACTUAL START AND FINISH DATES
>831102,831114

INPUT ACTIVITY NO.
>10203
INPUT ACTUAL START AND FINISH DATES
>831115,831125

INPUT ACTIVITY NO.
>10204
INPUT ACTUAL START AND FINISH DATES
>831128,831206

INPUT ACTIVITY NO.
>10205
INPUT ACTUAL START AND FINISH DATES
>831207,831216

INPUT ACTIVITY NO.
>30101
INPUT ACTUAL START AND FINISH DATES
>831102,831114

INPUT ACTIVITY NO.
>30102
INPUT ACTUAL START AND FINISH DATES
>831115,831125

INPUT ACTIVITY NO.
>30103
INPUT ACTUAL START AND FINISH DATES
>831128,831206

INPUT ACTIVITY NO.
>30104
INPUT ACTUAL START AND FINISH DATES
>831207,831216

INPUT ACTIVITY NO.
>0
```

"0" stops the input of dates

```
1) UPDATE
2) NEW
3) WEATHER FACTORS
4) ACTUAL START AND FINISH DATES
5) QUIT
>1
```

Here, the status of non-repetitive activities that are completed and the current floor of the repetitive activities are modified.

```
1) SEQUENTIALLY
2) RANDOMLY
>2
```

Randomly accessed...

```
ACTIVITY NO.
>2100
ACTIVITY NO. 2100
```

Number is input by user

```
1) DURATION    :  10
2) PROCUREMENT: -1
3) WEATHER     :  0
4) STATUS      :  0
5) QUIT
>4
```

Data is displayed

```
STATUS  (1) COMPLETED  (0) NOT
>1
```

Status is modified

```
1) DURATION    :  10
2) PROCUREMENT: -1
3) WEATHER     :  0
4) STATUS      :  1
5) QUIT
>5
```

Data reappears for a check.

```
ACTIVITY NO.
>2200
ACTIVITY NO. 2200

1) DURATION    :  40
2) PROCUREMENT: -1
3) WEATHER     :  1
4) STATUS      :  0
5) QUIT
>4
STATUS  (1) COMPLETED  (0) NOT
>1

1) DURATION    :  40
2) PROCUREMENT: -1
3) WEATHER     :  1
4) STATUS      :  1
5) QUIT
>5

ACTIVITY NO.
>2300
ACTIVITY NO. 2300

1) DURATION    :  20
2) PROCUREMENT: -1
3) WEATHER     :  1
4) STATUS      :  0
5) QUIT
>4
STATUS  (1) COMPLETED  (0) NOT
>1

1) DURATION    :  20
2) PROCUREMENT: -1
3) WEATHER     :  1
4) STATUS      :  1
5) QUIT
>5

ACTIVITY NO.
>12100
ACTIVITY NO. 12100

1) DURATION    :  30
2) PROCUREMENT: -1
3) WEATHER     :  1
4) STATUS      :  0
5) QUIT
>4
STATUS  (1) COMPLETED  (0) NOT
>1

1) DURATION    :  30
2) PROCUREMENT: -1
3) WEATHER     :  1
4) STATUS      :  1
5) QUIT
>5

ACTIVITY NO.
>10100
```

```
ACTIVITY NO. 10100

1) STARTING LEVEL:  1
2) CURRENT  LEVEL:  1
3) LAST     LEVEL:  16
4) NO. OF CREWS  :  1
5) PRODUCTION RATE: 6
6) START TO START:  0
7) FINISH TO FIN.:  0
8) LEARNING      :  37
9) WEATHER       :  1
10) QUIT
```

For a repetitive activity, the user has to modify the current level.

```
>2
CURRENT LEVEL ?
>7
```

Activity no. 10100 is completed up to and including floor no. 6; therefore the current level is now 7.

```
1) STARTING LEVEL:  1
2) CURRENT  LEVEL:  7
3) LAST     LEVEL:  16
4) NO. OF CREWS  :  1
5) PRODUCTION RATE: 6
6) START TO START:  0
7) FINISH TO FIN.:  0
8) LEARNING      :  37
9) WEATHER       :  1
10) QUIT
>10

ACTIVITY NO.
>10200
ACTIVITY NO. 10200

1) STARTING LEVEL:  1
2) CURRENT  LEVEL:  1
3) LAST     LEVEL:  16
4) NO. OF CREWS  :  1
5) PRODUCTION RATE: 6
6) START TO START:  0
7) FINISH TO FIN.:  0
8) LEARNING      :  161
9) WEATHER       :  1
10) QUIT
>2
CURRENT LEVEL ?
>6

1) STARTING LEVEL:  1
2) CURRENT  LEVEL:  6
3) LAST     LEVEL:  16
4) NO. OF CREWS  :  1
5) PRODUCTION RATE: 6
6) START TO START:  0
7) FINISH TO FIN.:  0
8) LEARNING      :  161
9) WEATHER       :  1
10) QUIT
>10
```

Data always reappears for a check.

```
ACTIVITY NO.
>30100
ACTIVITY NO. 30100

1) STARTING LEVEL:  1
2) CURRENT  LEVEL:  1
3) LAST     LEVEL:  16
4) NO. OF CREWS  :  1
5) PRODUCTION RATE: 6
6) START TO START:  0
7) FINISH TO FIN.:  0
8) LEARNING      :  163
9) WEATHER       :  1
10) QUIT
>2
```

```
CURRENT LEVEL ?
>5
1) STARTING LEVEL:  1
2) CURRENT  LEVEL:  5
3) LAST     LEVEL:  16
4) NO. OF CREWS  :  1
5) PRODUCTION RATE: 6
6) START TO START:  0
7) FINISH TO FIN.:  0
8) LEARNING      :  163
9) WEATHER       :  1
10) QUIT
>10

ACTIVITY NO.
>0
```

No more modification is required.

```
1) UPDATE
2) NEW
3) WEATHER FACTORS
4) ACTUAL START AND FINISH DATES
5) QUIT
>5
```

Return to the main menu.

```
NAME OF FILE ? (4 CHAR.)
>JOB

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>2
```

In the updating, 2 milestones have to be added.

```
ENTER ACTIVITY NO.
>8300
ENTER DESCRIPTION (MAX. 20) OF ACTIVITY  8300
>START OF DEL. OF VENT
ENTER ACTIVITY NO.
>8400
ENTER DESCRIPTION (MAX. 20) OF ACTIVITY  8400
>STRAT PRECAST
```

They are input here.

```
ENTER ACTIVITY NO.
>0
END OF INPUT
FOR A TOTAL OF  68  ACTIVITIES

              MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>3
ACTIVITY NUMBER ? (0 TO QUIT)
>8100
```

```
ACTIVITY NO.  8100  IS DELETED
ACTIVITY NUMBER ? (0 TO QUIT)
>0
```

Milesone 8100 is deleted here.

```
          MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>4

NAME OF FILE ? (4 CHAR.)
>JOB

1) DELETE PRECEDENCE
2) ADD PRECEDENCE
3) QUIT
>2

ACTIVITY NO. AN PREDECESSOR NO.?
>20300,8300

IS THE PREDECESSOR TYPICAL (1) OR NOT (2)
>2
FOR WHICH LEVEL
>1

1) DELETE PRECEDENCE
2) ADD PRECEDENCE
3) QUIT
>2
ACTIVITY NO. AN PREDECESSOR NO.?
>90300,8400
IS THE PREDECESSOR TYPICAL (1) OR NOT (2)
>2
FOR WHICH LEVEL
>1
```

Milestones 8300 and 8400 are entered as predecessor to activities 20300 and 90300, respectively to delay their start.

Both are non-typical predecessors.

```
1) DELETE PRECEDENCE
2) ADD PRECEDENCE
3) QUIT
>3

NAME OF FILE ? (4 CHAR.)
>JOB

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>10
```

```
NAME OF FILE ? (4 CHAR.)
>JOB

1) UPDATE
2) NEW
3) WEATHER FACTORS
4) ACTUAL START AND FINISH DATES
5) QUIT
>2

1) SEQUENTIALLY
2) RANDOMLY
>2

ACTIVITY NO.
>8300
MILESTONE NO. 8300
INPUT NEW DATE
>830305
```

Dates of the new milestones are input here.

```
DATE NOT FOUND
INPUT NEW DATE
>840305
```

The program checks if the date exists.

```
ACTIVITY NO.
>8400
MILESTONE NO. 8400
INPUT NEW DATE
>840102

ACTIVITY NO.
>0

1) UPDATE
2) NEW
3) WEATHER FACTORS
4) ACTUAL START AND FINISH DATES
5) QUIT
>5

NAME OF FILE ? (4 CHAR.)
>
 JOB

            MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>7

NAME OF FILE ? (4 CHAR.)
>JOB
    START CALCULATION
START SORTING
```

Data are compiled again, because changes were made to the precedence relationships.

```
NAME OF FILE ? (4 CHAR.)
>JOB

           MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>8

NAME OF FILE ? (4 CHAR.)
>JOB
```

Compute the dates

```
REARRANGE FILE ? YES (1) OR NO (2)
>1
```

Rearrange the file because an activity was deleted.

```
NAME OF FILE ? (4 CHAR.)
>JOB

           MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>9

NAME OF FILE ? (4 CHAR.)
>JOB

NO. OF LEVELS FOR THE PROJECT ?
>16

1) LIST OF DATES
2) LINEAR CHART
3) BAR CHART
4) QUIT
>3
```

A Bar-chart (updated) is printed here.

```
1) LIST OF DATES
2) LINEAR CHART
3) BAR CHART
4) QUIT
>4

          MENU........
```

```
          MENU
1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>10

NAME OF FILE ? (4 CHAR.)
>JOB

1) UPDATE
2) NEW
3) WEATHER FACTORS
4) ACTUAL START AND FINISH DATES
5) QUIT
>1
```

Change activity data of two activities

```
1) SEQUENTIALLY
2) RANDOMLY
>2
```

Number of crews of 100400

```
ACTIVITY NO.
>100400
ACTIVITY NO. 100400

1) STARTING LEVEL:  9
2) CURRENT  LEVEL:  9
3) LAST     LEVEL:  16
4) NO. OF CREWS   :  1
5) PRODUCTION RATE: 4
6) START TO START:  0
7) FINISH TO FIN.:  0
8) LEARNING       : -1
9) WEATHER        :  0
10) QUIT
>4
NO. OF CREWS ?
>2

1) STARTING LEVEL:  9
2) CURRENT  LEVEL:  9
3) LAST     LEVEL:  16
4) NO. OF CREWS   :  2
5) PRODUCTION RATE: 4
6) START TO START:  0
7) FINISH TO FIN.:  0
8) LEARNING       : -1
9) WEATHER        :  0
10) QUIT
>10

ACTIVITY NO.
>110400

ACTIVITY NO. 110400

1) STARTING LEVEL:  9
2) CURRENT  LEVEL:  9
```

⋮

```
>5
PRODUCTION RATE  ?
>2

1) STARTING LEVEL:  9
2) CURRENT  LEVEL:  9
3) LAST     LEVEL:  16
4) NO. OF CREWS   :  1
5) PRODUCTION RATE: 2
6) START TO START:  0
7) FINISH TO FIN.:  0
8) LEARNING       : -1
9) WEATHER        :  0
10) QUIT
>10
```

Production rate of 110400

```
ACTIVITY NO.
>0

1) UPDATE
2) NEW
3) WEATHER FACTORS
4) ACTUAL START  AND FINISH  DATES
5) QUIT
>5

NAME OF FILE ? (4 CHAR.)
>JOB

            MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE  SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE  ANY NUMBER:
>8

NAME OF  FILE ? (4  CHAR.)
>JOB

REARRANGE FILE ?  YES (1) OR  NO (2)
>2

NAME OF  FILE ? (4  CHAR.)
>JOB
```

Reexecute data; do not need to compile because the precedence relationships are the same as the previous run.

```
            MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>6
```

Activities are listed..

```
 1)ORDER OF INPUT
 2)SEQUENTIAL STEP
 3)INCREASING ACTIVITY NO.
>3
```

In increasing activity number

```
            MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>9

NAME OF FILE ? (4 CHAR.)
>JOB

NO. OF LEVELS FOR THE PROJECT ?
>16
```

New schedules are printed

```
1) LIST OF DATES
2) LINEAR CHART
3) BAR CHART
4) QUIT
>3
```

A bar-chart....

```
1) LIST OF DATES
2) LINEAR CHART
3) BAR CHART
4) QUIT
>1
```

The list of dates (see Appendix II)

```
1) INCREASING ACTIVITY NO.
2) SEQUENTIAL STEP
3) RANDOMLY
>1
```

In increasing activity number

```
1) LIST OF DATES
2) LINEAR CHART
3) BAR CHART
4) QUIT
>2
```

The 5 linear charts...

```
NO. OF ACTIVITIES TO PRINT ON THE SAME CHART ?
>16
      •
      •
      •
      •
      •
      •
      •

1) LIST OF DATES
2) LINEAR CHART
3) BAR CHART
4) QUIT
>4


NAME OF FILE ? (4 CHAR.)
>JOB
```

```
          MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>11
NAME OF FILE ? (4 CHAR.)
>JOB

FOR WHICH DATE ?
>840102
```

Short cycle schedule

as at Jan. 2, 1984 (840102)

```
NAME OF FILE ? (4 CHAR.)
>JOB

          MENU

1) START A NEW PROJECT
2) INPUT NEW ACTIVITIES
3) DELETE ACTIVITIES
4) CHANGE PRECEDENCE
5) CHANGE ACTIVITY NAME
6) LIST ACTIVITIES
7) COMPILE DATA
8) EXECUTE DATA
9) PRINT RESULTS
10) INPUT OR CHANGE ACTIVITY DATA
11) SHORT CYCLE SCHEDULE
12) PROCUREMENT STATUS REPORT
13) PREPARE CALENDAR
14) QUIT

CHOOSE ANY NUMBER:
>12

NAME OF FILE ? (4 CHAR.)
>JOB

ACTIVITY NO. ?
>
  .
  .
  .
  .
  .
  .
  .
ACTIVITY NO. ?
>0


       MENU..........
```

and the procurement status report...

End of the Session.

APPENDIX II

List of Dates for the Last Run in the Example in Chapter V.

```
                                 I      E A R L Y            L A T E           A C T U A L                      DURATION     PAGE  1
NO.     DESCRIPTION      FLOOR   I   START     FINISH     START     FINISH    START     FINISH     FLOAT    SCHED.  ACTUAL
-------------------------------------------------------------------------------------------------------------------------------
                                 I
2100    MOBILIZATION         0   I   5 APR83   18APR83    5 APR83   18APR83   5 APR83   18APR83      0        10      10
                                 I
2200    EXCAVATION           0   I   19APR83   20JUN83    19APR83   20JUN83   18APR83   17JUN83      0        44      44
                                 I
2300    FOUNDATION           0   I   21JUN83   3 AUG83    21JUN83   3 AUG83   20JUN83   8 AUG83      0        20      24
                                 I
7800    MISCELL. FINISH      0   I   24SEP84   12OCT84    24SEP84   12OCT84                          0        15       0
                                 I
7900    DEMOBILIZE           0   I   16OCT84   29OCT84    16OCT84   29OCT84                          0        10       0
8200    NO HEATING REQ'D     0   I             2 APR84                                               0         0       0
                                 I
8300    START OF DEL. OF V   0   I             5 MAR84                                               0         0       0
                                 I
8400    STRAT PRECAST        0   I             2 JAN84                                               0         0       0
                                 I
10100   STRUCTURE            1   I   19SEP83   5 OCT83    19SEP83   5 OCT83   27SEP83   14OCT83      0        13      13
                                 I
10100   STRUCTURE            2   I   6 OCT83   24OCT83    6 OCT83   24OCT83   17OCT83   1 NOV83      0        12      12
                                 I
10100   STRUCTURE            3   I   25OCT83   7 NOV83    25OCT83   7 NOV83   2 NOV83   14NOV83      0        10       9
                                 I
10100   STRUCTURE            4   I   8 NOV83   18NOV83    8 NOV83   18NOV83   15NOV83   25NOV83      0         9       9
                                 I
10100   STRUCTURE            5   I   21NOV83   30NOV83    21NOV83   30NOV83   28NOV83   6 DEC83      0         8       7
                                 I
10100   STRUCTURE            6   I   1 DEC83   13DEC83    1 DEC83   13DEC83   7 DEC83   16DEC83      0         9       8
                                 I
10100   STRUCTURE            7   I   2 JAN84   11JAN84    2 JAN84   11JAN84                          0         8       0
                                 I
10100   STRUCTURE            8   I   12JAN84   24JAN84    12JAN84   24JAN84                          0         9       0
                                 I
10100   STRUCTURE            9   I   25JAN84   3 FEB84    25JAN84   3 FEB84                          0         8       0
                                 I
10100   STRUCTURE           10   I   6 FEB84   16FEB84    6 FEB84   16FEB84                          0         9       0
                                 I
10100   STRUCTURE           11   I   17FEB84   28FEB84    17FEB84   28FEB84                          0         8       0
                                 I
10100   STRUCTURE           12   I   29FEB84   9 MAR84    29FEB84   9 MAR84                          0         8       0
                                 I
10100   STRUCTURE           13   I   12MAR84   21MAR84    12MAR84   21MAR84                          0         8       0
                                 I
10100   STRUCTURE           14   I   22MAR84   2 APR84    22MAR84   2 APR84                          0         8       0
                                 I
10100   STRUCTURE           15   I   3 APR84   16APR84    3 APR84   16APR84                          0         8       0
                                 I
10100   STRUCTURE           16   I   17APR84   25APR84    17APR84   25APR84                          0         7       0
                                 I
10200   CURING & STRIP.      1   I   6 OCT83   25OCT83    6 OCT83   25OCT83   17OCT83   1 NOV83      0        13      12
                                 I
10200   CURING & STRIP.      2   I   26OCT83   8 NOV83    26OCT83   8 NOV83   2 NOV83   14NOV83      0        10       9
                                 I
10200   CURING & STRIP.      3   I   9 NOV83   21NOV83    9 NOV83   21NOV83   15NOV83   25NOV83      0         9       9
                                 I
10200   CURING & STRIP.      4   I   22NOV83   1 DEC83    22NOV83   1 DEC83   28NOV83   6 DEC83      0         8       7
                                 I
10200   CURING & STRIP.      5   I   2 DEC83   13DEC83    2 DEC83   13DEC83   7 DEC83   16DEC83      0         8       8
```

```
                                  I     E A R L Y          L A T E           A C T U A L                  DURATION     PAGE  2
NO.     DESCRIPTION       FLOOR I  START    FINISH     START    FINISH     START     FINISH     FLOAT   SCHED.  ACTUAL
-----------------------------------------------------------------------------------------------------------------------
                                  I
10200  CURING & STRIP.       6  I  2 JAN84   11JAN84   2 JAN84   11JAN84                        0       8       0
                                  I
10200  CURING & STRIP.       7  I  12JAN84   24JAN84   12JAN84   24JAN84                        0       9       0
                                  I
10200  CURING & STRIP.       8  I  25JAN84   3 FEB84   25JAN84   3 FEB84                        0       8       0
                                  I
10200  CURING & STRIP.       9  I  6 FEB84   16FEB84   6 FEB84   16FEB84                        0       9       0
                                  I
10200  CURING & STRIP.      10  I  17FEB84   28FEB84   17FEB84   28FEB84                        0       8       0
                                  I
10200  CURING & STRIP.      11  I  29FEB84   9 MAR84   29FEB84   9 MAR84                        0       8       0
                                  I
10200  CURING & STRIP.      12  I  12MAR84   21MAR84   12MAR84   21MAR84                        0       8       0
                                  I
10200  CURING & STRIP.      13  I  22MAR84   2 APR84   22MAR84   2 APR84                        0       8       0
                                  I
10200  CURING & STRIP.      14  I  3 APR84   16APR84   3 APR84   16APR84                        0       5       0
                                  I
10200  CURING & STRIP.      15  I  17APR84   25APR84   17APR84   25APR84                        0       7       0
                                  I
10200  CURING & STRIP.      16  I  26APR84   4 MAY84   26APR84   4 MAY84                        0       7       0
                                  I
12100  BASEMENT STRUCT.      0  I  4 AUG83   16SEP83   4 AUG83   16SEP83   9 AUG83   26SEP83    0      31      34
                                  I
20100  VENT. RG1 DISTR.      1  I  17JAN84   25JAN84   7 FEB84   15FEB84                       15       7       0
                                  I
20100  VENT. RG1 DISTR.      2  I  26JAN84   1 FEB84   16FEB84   22FEB84                       15       5       0
                                  I
20100  VENT. RG1 DISTR.      3  I  2 FEB84   8 FEB84   23FEB84   29FEB84                       15       5       0
                                  I
20100  VENT. RG1 DISTR.      4  I  9 FEB84   15FEB84   1 MAR84   7 MAR84                       15       5       0
                                  I
20100  VENT. RG1 DISTR.      5  I  16FEB84   22FEB84   8 MAR84   14MAR84                       15       5       0
                                  I
20100  VENT. RG1 DISTR.      6  I  23FEB84   29FEB84   15MAR84   21MAR84                       15       5       0
                                  I
20100  VENT. RG1 DISTR.      7  I  1 MAR84   7 MAR84   22MAR84   28MAR84                       15       5       0
                                  I
20100  VENT. RG1 DISTR.      8  I  8 MAR84   14MAR84   29MAR84   4 APR84                       15       5       0
                                  I
20100  VENT. RG1 DISTR.      9  I  15MAR84   21MAR84   5 APR84   13APR84                       15       5       0
                                  I
20100  VENT. RG1 DISTR.     10  I  22MAR84   28MAR84   16APR84   20APR84                       15       5       0
                                  I
20100  VENT. RG1 DISTR.     11  I  29MAR84   4 APR84   23APR84   27APR84                       15       5       0
                                  I
20100  VENT. RG1 DISTR.     12  I  5 APR84   13APR84   30APR84   4 MAY84                       15       5       0
                                  I
20100  VENT. RG1 DISTR.     13  I  16APR84   20APR84   7 MAY84   11MAY84                       15       5       0
                                  I
20100  VENT. RG1 DISTR.     14  I  23APR84   27APR84   14MAY84   18MAY84                       15       5       0
                                  I
20100  VENT. RG1 DISTR.     15  I  30APR84   4 MAY84   22MAY84   28MAY84                       15       5       0
                                  I
20100  VENT. RG1 DISTR.     16  I  7 MAY84   11MAY84   29MAY84   4 JUN84                       15       5       0
                                  I
20200  VENT. INSULATION      1  I  2 MAR84   9 MAR84   7 MAY84   16MAY84                       46       6       0
```

```
                                      I      E A R L Y           L A T E            A C T U A L                          DURATION      PAGE  3
NO.      DESCRIPTION         FLOOR I    START     FINISH     START    FINISH     START      FINISH      FLOAT   SCHED.  ACTUAL
-----------------------------------------------------------------------------------------------------------------------------------
                                      I
20200   VENT. INSULATION       2   I    12MAR84   15MAR84    17MAY84   23MAY84                            46       4        0
                                      I
20200   VENT. INSULATION       3   I    16MAR84   21MAR84    24MAY84   29MAY84                            46       4        0
                                      I
20200   VENT. INSULATION       4   I    22MAR84   27MAR84    30MAY84   4 JUN84                            46       4        0
                                      I
20200   VENT. INSULATION       5   I    28MAR84   2 APR84    5 JUN84   8 JUN84                            46       4        0
                                      I
20200   VENT. INSULATION       6   I    3 APR84   10APR84    11JUN84   14JUN84                            46       4        0
                                      I
20200   VENT. INSULATION       7   I    11APR84   16APR84    15JUN84   20JUN84                            46       4        0
                                      I
20200   VENT. INSULATION       8   I    17APR84   20APR84    21JUN84   27JUN84                            46       4        0
                                      I
20200   VENT. INSULATION       9   I    23APR84   26APR84    28JUN84   4 JUL84                            46       4        0
                                      I
20200   VENT. INSULATION      10   I    27APR84   2 MAY84    5 JUL84   10JUL84                            46       4        0
                                      I
20200   VENT. INSULATION      11   I    3 MAY84   3 MAY84    11JUL84   30JUL84                            46       4        0
                                      I
20200   VENT. INSULATION      12   I    9 MAY84   14MAY84    31JUL84   3 AUG84                            46       4        0
                                      I
20200   VENT. INSULATION      13   I    15MAY84   18MAY84    6 AUG84   9 AUG84                            46       4        0
                                      I
20200   VENT. INSULATION      14   I    22MAY84   25MAY84    10AUG84   15AUG84                            46       4        0
                                      I
20200   VENT. INSULATION      15   I    28MAY84   31MAY84    16AUG84   21AUG84                            46       4        0
                                      I
20200   VENT. INSULATION      16   I    1 JUN84   6 JUN84    22AUG84   27AUG84                            46       4        0
                                      I
20300   VENT. UNIT             1   I    5 MAR84   9 MAR84    16APR84   20APR84                            28       5        0
                                      I
20300   VENT. UNIT             2   I    12MAR84   15MAR84    23APR84   26APR84                            28       4        0
                                      I
20300   VENT. UNIT             3   I    16MAR84   21MAR84    27APR84   2 MAY84                            28       4        0
                                      I
20300   VENT. UNIT             4   I    22MAR84   27MAR84    3 MAY84   8 MAY84                            28       4        0
                                      I
20300   VENT. UNIT             5   I    28MAR84   2 APR84    9 MAY84   14MAY84                            28       4        0
                                      I
20300   VENT. UNIT             6   I    3 APR84   10APR84    15MAY84   18MAY84                            28       4        0
                                      I
20300   VENT. UNIT             7   I    11APR84   16APR84    22MAY84   25MAY84                            28       4        0
                                      I
20300   VENT. UNIT             8   I    17APR84   20APR84    28MAY84   31MAY84                            28       4        0
                                      I
20300   VENT. UNIT             9   I    23APR84   26APR84    1 JUN84   6 JUN84                            28       4        0
                                      I
20300   VENT. UNIT            10   I    27APR84   2 MAY84    7 JUN84   12JUN84                            28       4        0
                                      I
20300   VENT. UNIT            11   I    3 MAY84   8 MAY84    13JUN84   18JUN84                            28       4        0
                                      I
20300   VENT. UNIT            12   I    9 MAY84   14MAY84    19JUN84   22JUN84                            28       4        0
                                      I
20300   VENT. UNIT            13   I    15MAY84   18MAY84    26JUN84   29JUN84                            28       4        0
                                      I
20300   VENT. UNIT            14   I    22MAY84   25MAY84    3 JUL84   6 JUL84                            28       4        0
```

```
                                     I      E A R L Y           L A T E           A C T U A L                     DURATION    PAGE  4
NO.     DESCRIPTION          FLOOR I   START     FINISH     START.   FINISH    START       FINISH     FLOAT   SCHED.  ACTUAL
------------------------------------------------------------------------------------------------------------------------------
                                     I
20300   VENT. UNIT              15 I   28MAY84   31MAY84    9 JUL84  12JUL84                           28      4       0
                                     I
20300   VENT. UNIT              16 I   1 JUN84   6 JUN84    13JUL84  1 AUG84                           28      4       0
                                     I
20400   VENT FLEX. & DIFF. 1       I   31MAY84   6 JUN84    19JUN84  26JUN84                           13      5       0
                                     I
20400   VENT FLEX. & DIFF. 2       I   7 JUN84   12JUN84    27JUN84  3 JUL84                           13      4       0
                                     I
20400   VENT FLEX. & DIFF. 3       I   13JUN84   15JUN84    4 JUL84  6 JUL84                           13      3       0
                                     I
20400   VENT FLEX. & DIFF. 4       I   18JUN84   20JUN84    9 JUL84  11JUL84                           13      3       0
                                     I
20400   VENT FLEX. & DIFF. 5       I   21JUN84   26JUN84    12JUL84  30JUL84                           13      3       0
                                     I
20400   VENT FLEX. & DIFF. 6       I   27JUN84   29JUN84    31JUL84  2 AUG84                           13      3       0
                                     I
20400   VENT FLEX. & DIFF. 7       I   3 JUL84   5 JUL84    3 AUG84  7 AUG84                           13      3       0
                                     I
20400   VENT FLEX. & DIFF. 8       I   6 JUL84   10JUL84    8 AUG84  10AUG84                           13      3       0
                                     I
20400   VENT FLEX. & DIFF. 9       I   11JUL84   13JUL84    13AUG84  15AUG84                           13      3       0
                                     I
20400   VENT FLEX. & DIFF. 10      I   30JUL84   1 AUG84    16AUG84  20AUG84                           13      3       0
                                     I
20400   VENT FLEX. & DIFF. 11      I   2 AUG84   6 AUG84    21AUG84  23AUG84                           13      3       0
                                     I
20400   VENT FLEX. & DIFF. 12      I   7 AUG84   9 AUG84    24AUG84  28AUG84                           13      3       0
                                     I
20400   VENT FLEX. & DIFF. 13      I   10AUG84   14AUG84    29AUG84  31AUG84                           13      3       0
                                     I
20400   VENT FLEX. & DIFF. 14      I   15AUG84   17AUG84    4 SEP84  6 SEP84                           13      3       0
                                     I
20400   VENT FLEX. & DIFF. 15      I   20AUG84   22AUG84    7 SEP84  11SEP84                           13      3       0
                                     I
20400   VENT FLEX. & DIFF. 16      I   23AUG84   27AUG84    12SEP84  14SEP84                           13      3       0
                                     I
20500   VENT RGH (TOILET)  1       I   23JAN84   24JAN84    31JAN84  1 FEB84                           6       2       0
                                     I
20500   VENT RGH (TOILET)  2       I   30JAN84   31JAN84    7 FEB84  8 FEB84                           6       2       0
                                     I
20500   VENT RGH (TOILET)  3       I   6 FEB84   7 FEB84    14FEB84  15FEB84                           6       2       0
                                     I
20500   VENT RGH (TOILET)  4       I   13FEB84   14FEB84    21FEB84  22FEB84                           6       2       0
                                     I
20500   VENT RGH (TOILET)  5       I   20FEB84   21FEB84    28FEB84  29FEB84                           6       2       0
                                     I
20500   VENT RGH (TOILET)  6       I   27FEB84   28FEB84    6 MAR84  7 MAR84                           6       2       0
                                     I
20500   VENT RGH (TOILET)  7       I   5 MAR84   6 MAR84    13MAR84  14MAR84                           6       2       0
                                     I
20500   VENT RGH (TOILET)  8       I   12MAR84   13MAR84    20MAR84  21MAR84                           6       2       0
                                     I
20500   VENT RGH (TOILET)  9       I   19MAR84   20MAR84    27MAR84  28MAR84                           6       2       0
                                     I
20500   VENT RGH (TOILET)  10      I   26MAR84   27MAR84    3 APR84  4 APR84                           6       2       0
                                     I
20500   VENT RGH (TOILET)  11      I   2 APR84   3 APR84    12APR84  13APR84                           6       2       0
```

NO.	DESCRIPTION	FLOOR	EARLY START	EARLY FINISH	LATE START	LATE FINISH	ACTUAL START	ACTUAL FINISH	FLOAT	DURATION SCHED.	DURATION ACTUAL
20500	VENT RGM (TOILET)	12	11APR84	12APR84	19APR84	20APR84			6	2	0
20500	VENT RGM (TOILET)	13	18APR84	19APR84	26APR84	27APR84			6	2	0
20500	VENT RGM (TOILET)	14	25APR84	26APR84	3 MAY84	4 MAY84			6	2	0
20500	VENT RGM (TOILET)	15	2 MAY84	3 MAY84	10MAY84	11MAY84			6	2	0
20500	VENT RGM (TOILET)	16	9 MAY84	10MAY84	17MAY84	18MAY84			6	2	0
22116	CHILLERS	16	7 MAY84	18MAY84	10AUG84	23AUG84			56	10	0
22216	COOLING TOWERS	16	7 MAY84	18MAY84	10AUG84	23AUG84			56	10	0
22316	FURNACES	16	7 MAY84	4 JUN84	13JUL84	23AUG84			46	20	0
22416	PUMPS	16	7 MAY84	18MAY84	10AUG84	23AUG84			56	10	0
22500	BALANCING VENT.	0	28AUG84	25SEP84	17SEP84	12OCT84			13	20	0
22616	MECH ROOM PIPING	16	5 JUN84	26JUN84	24AUG84	14SEP84			46	15	0
30100	SPRINKLER RISER	1	26OCT83	9 NOV83	25NOV83	9 DEC83	2 NOV83	14NOV83	22	11	9
30100	SPRINKLER RISER	2	10NOV83	21NOV83	12DEC83	4 JAN84	15NOV83	25NOV83	22	8	9
30100	SPRINKLER RISER	3	22NOV83	1 DEC83	5 JAN84	16JAN84	28NOV83	6 DEC83	22	8	7
30100	SPRINKLER RISER	4	2 DEC83	14DEC83	17JAN84	27JAN84	7 DEC83	16DEC83	22	9	3
30100	SPRINKLER RISER	5	2 JAN84	11JAN84	23JAN84	1 FEB84			15	8	0
30100	SPRINKLER RISER	6	12JAN84	24JAN84	2 FEB84	14FEB84			15	9	0
30100	SPRINKLER RISER	7	25JAN84	3 FEB84	15FEB84	24FEB84			15	8	0
30100	SPRINKLER RISER	8	6 FEB84	16FEB84	27FEB84	8 MAR84			15	9	0
30100	SPRINKLER RISER	9	17FEB84	28FEB84	9 MAR84	20MAR84			15	8	0
30100	SPRINKLER RISER	10	29FEB84	9 MAR84	21MAR84	30MAR84			15	8	0
30100	SPRINKLER RISER	11	12MAR84	21MAR84	2 APR84	13APR84			15	8	0
30100	SPRINKLER RISER	12	22MAR84	2 APR84	16APR84	25APR84			15	8	0
30100	SPRINKLER RISER	13	3 APR84	16APR84	26APR84	7 MAY84			15	8	0
30100	SPRINKLER RISER	14	17APR84	25APR84	8 MAY84	16MAY84			15	7	0
30100	SPRINKLER RISER	15	26APR84	4 MAY84	17MAY84	28MAY84			15	7	0
30100	SPRINKLER RISER	16	7 MAY84	15MAY84	29MAY84	6 JUN84			15	7	0
30200	SPRINK. R.M DISTR.	1	26JAN84	3 FEB84	16FEB84	24FEB84			15	7	0
30200	SPRINK. R.M DISTR.	2	6 FEB84	10FEB84	27FEB84	2 MAR84			15	5	0

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                                    I      E A R L Y          L A T E          A C T U A L                    DURATION      PAGE  6.
NO.     DESCRIPTION          FLOOR I   START    FINISH    START    FINISH    START    FINISH    FLOAT  SCHED.  ACTUAL
-------------------------------------------------------------------------------------------------------------------------------
                                    I
30200   SPRINK. RGH DISTR.  3  I   13FEB84   17FEB84   5 MAR84   9 MAR84                        15      5       0
                                    I
30200   SPRINK. RGH DISTR.  4  I   20FEB84   24FEB84   12MAR84   16MAR84                        15      5       0
                                    I
30200   SPRINK. RGH DISTR.  5  I   27FEB84   2 MAR84   19MAR84   23MAR84                        15      5       0
                                    I
30200   SPRINK. RGH DISTR.  6  I   5 MAR84   9 MAR84   26MAR84   30MAR84                        15      5       0
                                    I
30200   SPRINK. RGH DISTR.  7  I   12MAR84   16MAR84   2 APR84   10APR84                        15      5       0
                                    I
30200   SPRINK. RGH DISTR.  8  I   19MAR84   23MAR84   11APR84   17APR84                        15      5       0
                                    I
30200   SPRINK. RGH DISTR.  9  I   26MAR84   30MAR84   18APR84   24APR84                        15      5       0
                                    I
30200   SPRINK. RGH DISTR. 10  I   2 APR84   10APR84   25APR84   1 MAY84                        15      5       0
                                    I
30200   SPRINK. RGH DISTR. 11  I   11APR84   17APR84   2 MAY84   8 MAY84                        15      5       0
                                    I
30200   SPRINK. RGH DISTR. 12  I   18APR84   24APR84   3 MAY84   15MAY84                        15      5       0
                                    I
30200   SPRINK. RGH DISTR. 13  I   25APR84   1 MAY84   16MAY84   23MAY84                        15      5       0
                                    I
30200   SPRINK. RGH DISTR. 14  I   2 MAY84   8 MAY84   24MAY84   30MAY84                        15      5       0
                                    I
30200   SPRINK. RGH DISTR. 15  I   9 MAY84   15MAY84   31MAY84   6 JUN84                        15      5       0
                                    I
30200   SPRINK. RGH DISTR. 16  I   16MAY84   23MAY84   7 JUN84   13JUN84                        15      5       0
                                    I
30300   SPRINKLER HEADS      1  I   31MAY84   6 JUN84   21JUN84   28JUN84                        15      5       0
                                    I
30300   SPRINKLER HEADS      2  I   7 JUN84   12JUN84   29JUN84   5 JUL84                        15      4       0
                                    I
30300   SPRINKLER HEADS      3  I   13JUN84   15JUN84   6 JUL84   10JUL84                        15      3       0
                                    I
30300   SPRINKLER HEADS      4  I   18JUN84   20JUN84   11JUL84   13JUL84                        15      3       0
                                    I
30300   SPRINKLER HEADS      5  I   21JUN84   26JUN84   30JUL84   1 AUG84                        15      3       0
                                    I
30300   SPRINKLER HEADS      6  I   27JUN84   29JUN84   2 AUG84   6 AUG84                        15      3       0
                                    I
30300   SPRINKLER HEADS      7  I   3 JUL84   5 JUL84   7 AUG84   9 AUG84                        15      3       0
                                    I
30300   SPRINKLER HEADS      8  I   6 JUL84   10JUL84   10AUG84   14AUG84                        15      3       0
                                    I
30300   SPRINKLER HEADS      9  I   11JUL84   13JUL84   15AUG84   17AUG84                        15      3       0
                                    I
30300   SPRINKLER HEADS     10  I   30JUL84   1 AUG84   20AUG84   22AUG84                        15      3       0
                                    I
30300   SPRINKLER HEADS     11  I   2 AUG84   6 AUG84   23AUG84   27AUG84                        15      3       0
                                    I
30300   SPRINKLER HEADS     12  I   7 AUG84   9 AUG84   28AUG84   30AUG84                        15      3       0
                                    I
30300   SPRINKLER HEADS     13  I   10AUG84   14AUG84   31AUG84   5 SEP84                        15      3       0
                                    I
30300   SPRINKLER HEADS     14  I   15AUG84   17AUG84   6 SEP84   10SEP84                        15      3       0
                                    I
30300   SPRINKLER HEADS     15  I   20AUG84   22AUG84   11SEP84   13SEP84                        15      3       0
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NO.	DESCRIPTION	FLOOR	EARLY START	EARLY FINISH	LATE START	LATE FINISH	ACTUAL START	ACTUAL FINISH	FLOAT	DURATION SCHED.	DURATION ACTUAL
30300	SPRINKLER HEADS	16	23AUG84	27AUG84	14SEP84	18SEP84			15	3	0
32100	BOOSTER PUMP (SPRK	0	2 APR84	17APR84	10SEP84	21SEP84			99	10	0
32200	TEST SPRINKLER.	0	28AUG84	18SEP84	24SEP84	12OCT84			18	15	0
40100	ELECTR. R&M DISTR.	1	6 FEB84	13FEB84	27FEB84	5 MAR84			15	6	0
40100	ELECTR. R&M DISTR.	2	14FEB84	20FEB84	6 MAR84	12MAR84			15	5	0
40100	ELECTR. R&M DISTR.	3	21FEB84	27FEB84	13MAR84	19MAR84			15	5	0
40100	ELECTR. R&M DISTR.	4	28FEB84	5 MAR84	20MAR84	26MAR84			15	5	0
40100	ELECTR. R&M DISTR.	5	6 MAR84	12MAR84	27MAR84	2 APR84			15	5	0
40100	ELECTR. R&M DISTR.	6	13MAR84	19MAR84	3 APR84	11APR84			15	5	0
40100	ELECTR. R&M DISTR.	7	20MAR84	26MAR84	12APR84	18APR84			15	5	0
40100	ELECTR. R&M DISTR.	8	27MAR84	2 APR84	19APR84	25APR84			15	5	0
40100	ELECTR. R&M DISTR.	9	3 APR84	11APR84	26APR84	2 MAY84			15	5	0
40100	ELECTR. R&M DISTR.	10	12APR84	18APR84	3 MAY84	9 MAY84			15	5	0
40100	ELECTR. R&M DISTR.	11	19APR84	25APR84	10MAY84	16MAY84			15	5	0
40100	ELECTR. R&M DISTR.	12	26APR84	2 MAY84	17MAY84	24MAY84			15	5	0
40100	ELECTR. R&M DISTR.	13	3 MAY84	9 MAY84	25MAY84	31MAY84			15	5	0
40100	ELECTR. R&M DISTR.	14	10MAY84	16MAY84	1 JUN84	7 JUN84			15	5	0
40100	ELECTR. R&M DISTR.	15	17MAY84	24MAY84	5 JUN84	14JUN84			15	5	0
40100	ELECTR. R&M DISTR.	16	25MAY84	31MAY84	15JUN84	21JUN84			15	5	0
40200	EL. BUS DUCT & PAN	1	14FEB84	22FEB84	23MAR84	2 APR84			28	7	0
40200	EL. BUS DUCT & PAN	2	23FEB84	1 MAR84	3 APR84	12APR84			28	6	0
40200	EL. BUS DUCT & PAN	3	2 MAR84	8 MAR84	13APR84	19APR84			28	5	0
40200	EL. BUS DUCT & PAN	4	9 MAR84	15MAR84	20APR84	26APR84			28	5	0
40200	EL. BUS DUCT & PAN	5	16MAR84	22MAR84	27APR84	3 MAY84			28	5	0
40200	EL. BUS DUCT & PAN	6	23MAR84	29MAR84	4 MAY84	10MAY84			28	5	0
40200	EL. BUS DUCT & PAN	7	30MAR84	5 APR84	11MAY84	17MAY84			28	5	0
40200	EL. BUS DUCT & PAN	8	10APR84	16APR84	18MAY84	25MAY84			28	5	0
40200	EL. BUS DUCT & PAN	9	17APR84	23APR84	28MAY84	1 JUN84			28	5	0
40200	EL. BUS DUCT & PAN	10	24APR84	30APR84	4 JUN84	8 JUN84			28	5	0

NO.	DESCRIPTION	FLOOR	EARLY START	EARLY FINISH	LATE START	LATE FINISH	ACTUAL START	ACTUAL FINISH	FLOAT	DURATION SCHED.	DURATION ACTUAL
40200	EL. BUS JJCT & PAN	11	1 MAY84	7 MAY84	11JUN84	15JUN84			28	5	0
40200	EL. BUS JJCT & PAN	12	8 MAY84	14MAY84	18JUN84	22JUN84			28	5	0
40200	EL. BUS JJCT & PAN	13	15MAY84	22MAY84	26JUN84	3 JUL84			28	5	0
40200	EL. BUS JJCT & PAN	14	23MAY84	29MAY84	4 JUL84	10JUL84			28	5	0
40200	EL. BUS JJCT & PAN	15	30MAY84	5 JUN84	11JUL84	31JUL84			28	5	0
40200	EL. BUS JJCT & PAN	16	6 JUN84	12JUN84	1 AUG84	7 AUG84			28	5	0
40300	ELECT. FIXTURES	1	1 JUN84	7 JUN84	22JUN84	29JUN84			15	5	0
40300	ELECT. FIXTURES	2	8 JUN84	12JUN84	3 JUL84	5 JUL84			15	3	0
40300	ELECT. FIXTURES	5	13JUN84	15JUN84	6 JUL84	10JUL84			15	3	0
40300	ELECT. FIXTURES	4	18JUN84	20JUN84	11JUL84	13JUL84			15	3	0
40300	ELECT. FIXTURES	5	21JUN84	26JUN84	30JUL84	1 AUG84			15	3	0
40300	ELECT. FIXTURES	6	27JUN84	29JUN84	2 AUG84	6 AUG84			15	3	0
40300	ELECT. FIXTURES	7	3 JUL84	5 JUL84	7 AUG84	9 AUG84			15	3	0
40300	ELECT. FIXTURES	8	6 JUL84	10JUL84	10AUG84	14AUG84			15	3	0
40300	ELECT. FIXTURES	9	11JUL84	13JUL84	15AUG84	17AUG84			15	3	0
40300	ELECT. FIXTURES	10	30JUL84	1 AUG84	20AUG84	22AUG84			15	3	0
40300	ELECT. FIXTURES	11	2 AUG84	6 AUG84	23AUG84	27AUG84			15	3	0
40300	ELECT. FIXTURES	12	7 AUG84	9 AUG84	28AUG84	30AUG84			15	3	0
40300	ELECT. FIXTURES	13	10AUG84	14AUG84	31AUG84	5 SEP84			15	3	0
40300	ELECT. FIXTURES	14	15AUG84	17AUG84	6 SEP84	10SEP84			15	3	0
40300	ELECT. FIXTURES	15	20AUG84	22AUG84	11SEP84	13SEP84			15	3	0
40300	ELECT. FIXTURES	16	23AUG84	27AUG84	14SEP84	18SEP84			15	3	0
42100	TRANSF. & SWITCH	0	2 APR84	1 MAY84	14MAY84	11JUN84			28	20	0
42216	MECH ROOM ELECTR.	16	13JUN84	5 JUL84	24AUG84	14SEP84			40	15	0
50100	CEILING TIES	1	12MAR84	15MAR84	17MAY84	23MAY84			46	4	0
50100	CEILING TIES	2	16MAR84	21MAR84	24MAY84	29MAY84			46	4	0
50100	CEILING TIES	3	22MAR84	27MAR84	30MAY84	4 JUN84			46	4	0
50100	CEILING TIES	4	28MAR84	2 APR84	5 JUN84	8 JUN84			46	4	0
50100	CEILING TIES	5	3 APR84	10APR84	11JUN84	14JUN84			46	4	0

NO.	DESCRIPTION	FLOOR	EARLY		LATE		ACTUAL		FLOAT	DURATION	
			START	FINISH	START	FINISH	START	FINISH		SCHED.	ACTUAL
50100	CEILING TILES	6	11APR84	16APR84	15JUN84	20JUN84			46	4	0
50100	CEILING TILES	7	17APR84	20APR84	21JUN84	27JUN84			46	4	0
50100	CEILING TILES	8	23APR84	26APR84	28JUN84	4 JUL84			46	4	0
50100	CEILING TILES	9	27APR84	2 MAY84	5 JUL84	10JUL84			46	4	0
50100	CEILING TILES	10	3 MAY84	8 MAY84	11JUL84	30JUL84			46	4	0
50100	CEILING TILES	11	9 MAY84	14MAY84	31JUL84	3 AUG84			46	4	0
50100	CEILING TILES	12	15MAY84	18MAY84	6 AUG84	9 AUG84			46	4	0
50100	CEILING TILES	13	22MAY84	25MAY84	10AUG84	15AUG84			46	4	0
50100	CEILING TILES	14	28MAY84	31MAY84	16AUG84	21AUG84			46	4	0
50100	CEILING TILES	15	1 JUN84	6 JUN84	22AUG84	27AUG84			46	4	0
50100	CEILING TILES	16	7 JUN84	12JUN84	28AUG84	31AUG84			46	4	0
50200	CEILING GRID	1	4 MAY84	10MAY84	24MAY84	30MAY84			13	5	0
50200	CEILING GRID	2	11MAY84	17MAY84	31MAY84	6 JUN84			13	5	0
50200	CEILING GRID	3	18MAY84	24MAY84	7 JUN84	12JUN84			13	4	0
50200	CEILING GRID	4	25MAY84	30MAY84	13JUN84	18JUN84			13	4	0
50200	CEILING GRID	5	31MAY84	5 JUN84	19JUN84	22JUN84			13	4	0
50200	CEILING GRID	6	6 JUN84	11JUN84	26JUN84	29JUN84			13	4	0
50200	CEILING GRID	7	12JUN84	15JUN84	3 JUL84	6 JUL84			13	4	0
50200	CEILING GRID	8	18JUN84	21JUN84	9 JUL84	12JUL84			13	4	0
50200	CEILING GRID	9	22JUN84	28JUN84	13JUL84	1 AUG84			13	4	0
50200	CEILING GRID	10	29JUN84	5 JUL84	2 AUG84	7 AUG84			13	4	0
50200	CEILING GRID	11	6 JUL84	11JUL84	5 AUG84	13AUG84			13	4	0
50200	CEILING GRID	12	12JUL84	31JUL84	14AUG84	17AUG84			13	4	0
50200	CEILING GRID	13	1 AUG84	6 AUG84	20AUG84	23AUG84			13	4	0
50200	CEILING GRID	14	7 AUG84	10AUG84	24AUG84	29AUG84			13	4	0
50200	CEILING GRID	15	13AUG84	16AUG84	30AUG84	5 SEP84			13	4	0
50200	CEILING GRID	16	17AUG84	22AUG84	6 SEP84	11SEP84			13	4	0
50300	TILES (CEILING)	1	8 JUN84	12JUN84	3 JUL84	5 JUL84			15	3	0
50300	TILES (CEILING)	2	13JUN84	15JUN84	6 JUL84	10JUL84			15	3	0

NO.	DESCRIPTION - FLOOR		I	EARLY START	EARLY FINISH	LATE START	LATE FINISH	ACTUAL START	ACTUAL FINISH	FLOAT	DURATION SCHED.	DURATION ACTUAL
50300	TILES (CEILING)	3	I	18JUN84	20JUN84	11JUL84	13JUL84			15	3	0
50300	TILES (CEILING)	4	I	21JUN84	26JUN84	30JUL84	1 AUG84			15	3	0
50300	TILES (CEILING)	5	I	27JUN84	29JUN84	2 AUG84	6 AUG84			15	3	0
50300	TILES (CEILING)	6	I	3 JUL84	5 JUL84	7 AUG84	9 AUG84			15	3	0
50300	TILES (CEILING)	7	I	6 JUL84	10JUL84	10AUG84	14AUG84			15	3	0
50300	TILES (CEILING)	8	I	11JUL84	13JUL84	15AUG84	17AUG84			15	3	0
50300	TILES (CEILING)	9	I	30JUL84	1 AUG84	20AUG84	22AUG84			15	3	0
50300	TILES (CEILING)	10	I	2 AUG84	6 AUG84	23AUG84	27AUG84			15	3	0
50300	TILES (CEILING)	11	I	7 AUG84	9 AUG84	28AUG84	30AUG84			15	3	0
50300	TILES (CEILING)	12	I	10AUG84	14AUG84	31AUG84	5 SEP84			15	3	0
50300	TILES (CEILING)	13	I	15AUG84	17AUG84	6 SEP84	10SEP84			15	3	0
50300	TILES (CEILING)	14	I	20AUG84	22AUG84	11SEP84	13SEP84			15	3	0
50300	TILES (CEILING)	15	I	23AUG84	27AUG84	14SEP84	18SEP84			15	3	0
50300	TILES (CEILING)	16	I	28AUG84	30AUG84	19SEP84	21SEP84			15	3	0
60100	RISER (DOM. WATER)	1	I	17JAN84	20JAN84	25JAN84	30JAN84			6	4	0
60100	RISER (DOM. WATER)	2	I	26JAN84	27JAN84	3 FEB84	6 FEB84			6	2	0
60100	RISER (DOM. WATER)	3	I	2 FEB84	3 FEB84	10FEB84	13FEB84			6	2	0
60100	RISER (DOM. WATER)	4	I	9 FEB84	10FEB84	17FEB84	20FEB84			6	2	0
60100	RISER (DOM. WATER)	5	I	16FEB84	17FEB84	24FEB84	27FEB84			6	2	0
60100	RISER (DOM. WATER)	6	I	23FEB84	24FEB84	2 MAR84	5 MAR84			6	2	0
60100	RISER (DOM. WATER)	7	I	1 MAR84	2 MAR84	9 MAR84	12MAR84			6	2	0
60100	RISER (DOM. WATER)	8	I	8 MAR84	9 MAR84	16MAR84	19MAR84			6	2	0
60100	RISER (DOM. WATER)	9	I	15MAR84	16MAR84	23MAR84	26MAR84			6	2	0
60100	RISER (DOM. WATER)	10	I	22MAR84	23MAR84	30MAR84	2 APR84			6	2	0
60100	RISER (DOM. WATER)	11	I	29MAR84	30MAR84	10APR84	11APR84			6	2	0
60100	RISER (DOM. WATER)	12	I	5 APR84	10APR84	17APR84	18APR84			6	2	0
60100	RISER (DOM. WATER)	13	I	16APR84	17APR84	24APR84	25APR84			6	2	0
60100	RISER (DOM. WATER)	14	I	23APR84	24APR84	1 MAY84	2 MAY84			6	2	0
60100	RISER (DOM. WATER)	15	I	30APR84	1 MAY84	8 MAY84	9 MAY84			6	2	0

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                                    I       E A R L Y            L A T E            A C T U A L                      DURATION      PAGE 11
NO.      DESCRIPTION        FLOOR I    START     FINISH      START     FINISH     START      FINISH     FLOAT    SCHED.  ACTUAL
-----------------------------------------------------------------------------------------------------------------------------------
                                    I
60100  RISER (DOM. WATER) 16 I   7 MAY84    8 MAY84    15MAY84    16MAY84                            6        2       0
                                    I
60200  TOILET R.M PIPING   1 I   25JAN84    1 FEB84    2 FEB84    9 FEB84                            6        6       0
                                    I
60200  TOILET R.M PIPING   2 I   2 FEB84    8 FEB84    10FEB84    16FEB84                            6        5       0
                                    I
60200  TOILET R.M PIPING   3 I   9 FEB84    15FEB84    17FEB84    23FEB84                            6        5       0
                                    I
60200  TOILET R.M PIPING   4 I   16FEB84    22FEB84    24FEB84    1 MAR84                            6        5       0
                                    I
60200  TOILET R.M PIPING   5 I   23FEB84    29FEB84    2 MAR84    8 MAR84                            6        5       0
                                    I
60200  TOILET R.M PIPING   6 I   1 MAR84    7 MAR84    9 MAR84    15MAR84                            6        5       0
                                    I
60200  TOILET R.M PIPING   7 I   8 MAR84    14MAR84    16MAR84    22MAR84                            6        5       0
                                    I
60200  TOILET R.M PIPING   8 I   15MAR84    21MAR84    23MAR84    29MAR84                            6        5       0
                                    I
60200  TOILET R.M PIPING   9 I   22MAR84    28MAR84    30MAR84    5 APR84                            6        5       0
                                    I
60200  TOILET R.M PIPING  10 I   29MAR84    4 APR84    10APR84    16APR84                            6        5       0
                                    I
60200  TOILET R.M PIPING  11 I   5 APR84    13APR84    17APR84    23APR84                            6        5       0
                                    I
60200  TOILET R.M PIPING  12 I   16APR84    20APR84    24APR84    30APR84                            6        5       0
                                    I
60200  TOILET R.M PIPING  13 I   23APR84    27APR84    1 MAY84    7 MAY84                            6        5       0
                                    I
60200  TOILET R.M PIPING  14 I   30APR84    4 MAY84    3 MAY84    14MAY84                            6        5       0
                                    I
60200  TOILET R.M PIPING  15 I   7 MAY84    11MAY84    15MAY84    22MAY84                            6        5       0
                                    I
60200  TOILET R.M PIPING  16 I   14MAY84    18MAY84    23MAY84    29MAY84                            6        5       0
                                    I
60300  PLUMBING FIXTURES   1 I   22MAY84    28MAY84    30MAY84    5 JUN84                            6        5       0
                                    I
60300  PLUMBING FIXTURES   2 I   29MAY84    1 JUN84    6 JUN84    11JUN84                            6        4       0
                                    I
60300  PLUMBING FIXTURES   3 I   4 JUN84    7 JUN84    12JUN84    15JUN84                            6        4       0
                                    I
60300  PLUMBING FIXTURES   4 I   8 JUN84    13JUN84    18JUN84    21JUN84                            6        4       0
                                    I
60300  PLUMBING FIXTURES   5 I   14JUN84    19JUN84    22JUN84    28JUN84                            6        4       0
                                    I
60300  PLUMBING FIXTURES   6 I   20JUN84    26JUN84    29JUN84    5 JUL84                            6        4       0
                                    I
60300  PLUMBING FIXTURES   7 I   27JUN84    3 JUL84    6 JUL84    11JUL84                            6        4       0
                                    I
60300  PLUMBING FIXTURES   8 I   4 JUL84    9 JUL84    12JUL84    31JUL84                            6        4       0
                                    I
60300  PLUMBING FIXTURES   9 I   10JUL84    13JUL84    1 AUG84    6 AUG84                            6        4       0
                                    I
60300  PLUMBING FIXTURES  10 I   30JUL84    2 AUG84    7 AUG84    10AUG84                            6        4       0
                                    I
60300  PLUMBING FIXTURES  11 I   3 AUG84    8 AUG84    13AUG84    16AUG84                            6        4       0
                                    I
60300  PLUMBING FIXTURES  12 I   9 AUG84    14AUG84    17AUG84    22AUG84                            6        4       0
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NO.	DESCRIPTION	FLOOR	EARLY START	EARLY FINISH	LATE START	LATE FINISH	ACTUAL START	ACTUAL FINISH	FLOAT	DURATION SCHED.	DURATION ACTUAL
60300	PLUMBING FIXTURES	13	15AUG84	20AUG84	23AUG84	28AUG84			6	4	0
60300	PLUMBING FIXTURES	14	21AUG84	24AUG84	29AUG84	4 SEP84			6	4	0
60300	PLUMBING FIXTURES	15	27AUG84	30AUG84	5 SEP84	10SEP84			6	4	0
60300	PLUMBING FIXTURES	16	31AUG84	6 SEP84	11SEP84	14SEP84			6	4	0
62100	BOOSTER PUMP (PLMB	0	2 APR84	1 MAY84	17AUG84	14SEP84			94	20	0
62200	TEST PLUMBING	0	7 SEP84	4 OCT84	17SEP84	12OCT84			6	20	0
70100	GYPROC (TOILET)	1	2 FEB84	9 FEB84	15MAR84	22MAR84			30	6	0
70100	GYPROC (TOILET)	2	10FEB84	16FEB84	23MAR84	29MAR84			30	5	0
70100	GYPROC (TOILET)	3	17FEB84	23FEB84	30MAR84	5 APR84			30	5	0
70100	GYPROC (TOILET)	4	24FEB84	1 MAR84	10APR84	16APR84			30	5	0
70100	GYPROC (TOILET)	5	2 MAR84	8 MAR84	17APR84	23APR84			30	5	0
70100	GYPROC (TOILET)	6	9 MAR84	15MAR84	24APR84	30APR84			30	5	0
70100	GYPROC (TOILET)	7	16MAR84	22MAR84	1 MAY84	7 MAY84			30	5	0
70100	GYPROC (TOILET)	8	23MAR84	29MAR84	8 MAY84	14MAY84			30	5	0
70100	GYPROC (TOILET)	9	30MAR84	5 APR84	15MAY84	22MAY84			30	5	0
70100	GYPROC (TOILET)	10	10APR84	16APR84	23MAY84	29MAY84			30	5	0
70100	GYPROC (TOILET)	11	17APR84	23APR84	30MAY84	5 JUN84			30	5	0
70100	GYPROC (TOILET)	12	24APR84	30APR84	6 JUN84	12JUN84			30	5	0
70100	GYPROC (TOILET)	13	1 MAY84	7 MAY84	13JUN84	19JUN84			30	5	0
70100	GYPROC (TOILET)	14	8 MAY84	14MAY84	20JUN84	27JUN84			30	5	0
70100	GYPROC (TOILET)	15	15MAY84	22MAY84	28JUN84	5 JUL84			30	5	0
70100	GYPROC (TOILET)	16	23[illegible]Y84	29MAY84	6 JUL84	12JUL84			30	5	0
70200	GYPROC (COLUMN)	1	2 APR84	5 APR84	17MAY84	23MAY84			31	4	0
70200	GYPROC (COLUMN)	2	10APR84	13APR84	24MAY84	29MAY84			31	4	0
70200	GYPROC (COLUMN)	3	16APR84	19APR84	30MAY84	4 JUN84			31	4	0
70200	GYPROC (COLUMN)	4	20APR84	25APR84	5 JUN84	8 JUN84			31	4	0
70200	GYPROC (COLUMN)	5	26APR84	1 MAY84	11JUN84	14JUN84			31	4	0
70200	GYPROC (COLUMN)	6	2 MAY84	7 MAY84	15JUN84	20JUN84			31	4	0
70200	GYPROC (COLUMN)	7	8 MAY84	11MAY84	21JUN84	27JUN84			31	4	0

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                                       I      E A R L Y           L A T E          A C T U A L                   DURATION      PAGE 13
NO.       DESCRIPTION          FLOOR I  START     FINISH     START     FINISH     START     FINISH     FLOAT  SCHED.  ACTUAL
--------------------------------------------------------------------------------------------------------------------------------
                                       I
70200  GYPROC (COLUMN)           8   I  14MAY84   17MAY84   28JUN84    4 JUL84                          31      4       0
                                       I
70200  GYPROC (COLUMN)           9   I  18MAY84   24MAY84    5 JUL84   10JUL84                          31      4       0
                                       I
70200  GYPROC (COLUMN)          10   I  25MAY84   30MAY84   11JUL84   30JUL84                          31      4       0
                                       I
70200  GYPROC (COLUMN)          11   I  31MAY84    5 JUN84   31JUL84    3 AUG84                          31      4       0
                                       I
70200  GYPROC (COLUMN)          12   I   6 JUN84   11JUN84    6 AUG84    9 AUG84                          31      4       0
                                       I
70200  GYPROC (COLUMN)          13   I  12JUN84   15JUN84   10AUG84   15AUG84                          31      4       0
                                       I
70200  GYPROC (COLUMN)          14   I  18JUN84   21JUN84   16AUG84   21AUG84                          31      4       0
                                       I
70200  GYPROC (COLUMN)          15   I  22JUN84   28JUN84   22AUG84   27AUG84                          31      4       0
                                       I
70200  GYPROC (COLUMN)          16   I  29JUN84    5 JUL84   28AUG84   31AUG84                          31      4       0
                                       I
70300  GYPROC (ENCLOSURE)  1   I  17APR84   20APR84   17MAY84   23MAY84                          22      4       0
                                       I
70300  GYPROC (ENCLOSURE)  2   I  23APR84   26APR84   24MAY84   29MAY84                          22      4       0
                                       I
70300  GYPROC (ENCLOSURE)  3   I  27APR84    2 MAY84   30MAY84    4 JUN84                          22      4       0
                                       I
70300  GYPROC (ENCLOSURE)  4   I   3 MAY84    8 MAY84    5 JUN84    8 JUN84                          22      4       0
                                       I
70300  GYPROC (ENCLOSURE)  5   I   9 MAY84   14MAY84   11JUN84   14JUN84                          22      4       0
                                       I
70300  GYPROC (ENCLOSURE)  6   I  15MAY84   18MAY84   15JUN84   20JUN84                          22      4       0
                                       I
70300  GYPROC (ENCLOSURE)  7   I  22MAY84   25MAY84   21JUN84   27JUN84                          22      4       0
                                       I
70300  GYPROC (ENCLOSURE)  8   I  28MAY84   31MAY84   28JUN84    4 JUL84                          22      4       0
                                       I
70300  GYPROC (ENCLOSURE)  9   I   1 JUN84    6 JUN84    5 JUL84   10JUL84                          22      4       0
                                       I
70300  GYPROC (ENCLOSURE) 10   I   7 JUN84   12JUN84   11JUL84   30JUL84                          22      4       0
                                       I
70300  GYPROC (ENCLOSURE) 11   I  13JUN84   18JUN84   31JUL84    3 AUG84                          22      4       0
                                       I
70300  GYPROC (ENCLOSURE) 12   I  19JUN84   22JUN84    6 AUG84    9 AUG84                          22      4       0
                                       I
70300  GYPROC (ENCLOSURE) 13   I  26JUN84   29JUN84   10AUG84   15AUG84                          22      4       0
                                       I
70300  GYPROC (ENCLOSURE) 14   I   3 JUL84    6 JUL84   16AUG84   21AUG84                          22      4       0
                                       I
70300  GYPROC (ENCLOSURE) 15   I   9 JUL84   12JUL84   22AUG84   27AUG84                          22      4       0
                                       I
70300  GYPROC (ENCLOSURE) 16   I  13JUL84    1 AUG84   28AUG84   31AUG84                          22      4       0
                                       I
70400  GYPROC (1-R HALL)         9   I  20AUG84   22AUG84   20AUG84   22AUG84                           0      3       0
                                       I
70400  GYPROC (1-R HALL)        10   I  23AUG84   27AUG84   23AUG84   27AUG84                           0      3       0
                                       I
70400  GYPROC (1-R HALL)        11   I  28AUG84   30AUG84   28AUG84   30AUG84                           0      3       0
                                       I
70400  GYPROC (1-R HALL)        12   I  31AUG84    5 SEP84   31AUG84    5 SEP84                           0      3       0
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NO.	DESCRIPTION	FLOOR	EARLY START	EARLY FINISH	LATE START	LATE FINISH	ACTUAL START	ACTUAL FINISH	FLOAT	DURATION SCHED.	DURATION ACTUAL
70400	GYPROC (H-R HALL)	13	6 SEP84	10SEP84	6 SEP84	10SEP84			0	3	0
70400	GYPROC (H-R HALL)	14	11SEP84	13SEP84	11SEP84	13SEP84			0	3	0
70400	GYPROC (H-R HALL)	15	14SEP84	18SEP84	14SEP84	18SEP84			0	3	0
70400	GYPROC (H-R HALL)	16	19SEP84	21SEP84	19SEP84	21SEP84			0	3	0
70500	GYPROC (L-R HALL)	1	22MAY84	24MAY84	20AUG84	22AUG84			52	3	0
70500	GYPROC (L-R HALL)	2	25MAY84	29MAY84	23AUG84	27AUG84			52	3	0
70500	GYPROC (L-R HALL)	3	30MAY84	1 JUN84	28AUG84	30AUG84			52	3	0
70500	GYPROC (L-R HALL)	4	4 JUN84	6 JUN84	31AUG84	5 SEP84			52	3	0
70500	GYPROC (L-R HALL)	5	7 JUN84	11JUN84	6 SEP84	10SEP84			52	3	0
70500	GYPROC (L-R HALL)	6	12JUN84	14JUN84	11SEP84	13SEP84			52	3	0
70500	GYPROC (L-R HALL)	7	15JUN84	19JUN84	14SEP84	18SEP84			52	3	0
70500	GYPROC (L-R HALL)	8	20JUN84	22JUN84	19SEP84	21SEP84			52	3	0
70600	GYPROC (1:CH RM)	1	1 MAY84	3 MAY84	18MAY84	23MAY84			13	3	0
70600	GYPROC (1:CH RM)	2	4 MAY84	8 MAY84	24MAY84	28MAY84			13	3	0
70600	GYPROC (1:CH RM)	3	9 MAY84	11MAY84	29MAY84	31MAY84			13	3	0
70600	GYPROC (1:CH RM)	4	14MAY84	16MAY84	1 JUN84	5 JUN84			13	3	0
70600	GYPROC (1:CH RM)	5	17MAY84	22MAY84	6 JUN84	8 JUN84			13	3	0
70600	GYPROC (1:CH RM)	6	23MAY84	25MAY84	11JUN84	13JUN84			13	3	0
70600	GYPROC (1:CH RM)	7	28MAY84	30MAY84	14JUN84	18JUN84			13	3	0
70600	GYPROC (1:CH RM)	8	31MAY84	4 JUN84	19JUN84	21JUN84			13	3	0
70600	GYPROC (1:CH RM)	9	5 JUN84	7 JUN84	22JUN84	27JUN84			13	3	0
70600	GYPROC (1:CH RM)	10	8 JUN84	12JUN84	28JUN84	3 JUL84			13	3	0
70600	GYPROC (1:CH RM)	11	13JUN84	15JUN84	4 JUL84	6 JUL84			13	3	0
70600	GYPROC (1:CH RM)	12	18JUN84	20JUN84	9 JUL84	11JUL84			13	3	0
70600	GYPROC (1:CH RM)	13	21JUN84	26JUN84	12JUL84	30JUL84			13	3	0
70600	GYPROC (1:CH RM)	14	27JUN84	29JUN84	31JUL84	2 AUG84			13	3	0
70600	GYPROC (1:CH RM)	15	3 JUL84	5 JUL84	3 AUG84	7 AUG84			13	3	0
70600	GYPROC (1:CH RM)	16	6 JUL84	10JUL84	8 AUG84	10AUG84			13	3	0
80100	RISER (H & C WATER	1	18JAN84	20JAN84	4 MAY84	8 MAY84			75	3	0

NO.	DESCRIPTION	FLOOR	EARLY START	EARLY FINISH	LATE START	LATE FINISH	ACTUAL START	ACTUAL FINISH	FLOAT	DURATION SCHED.	DURATION ACTUAL
80100	RISER (H & C WATER	2	26JAN84	27JAN84	14MAY84	15MAY84			75	2	0
80100	RISER (H & C WATER	3	2 FEB84	3 FEB84	22MAY84	23MAY84			75	2	0
80100	RISER (H & C WATER	4	9 FEB84	10FEB84	29MAY84	30MAY84			75	2	0
80100	RISER (H & C WATER	5	16FEB84	17FEB84	5 JUN84	6 JUN84			75	2	0
80100	RISER (H & C WATER	6	23FEB84	24FEB84	12JUN84	13JUN84			75	2	0
80100	RISER (H & C WATER	7	1 MAR84	2 MAR84	19JUN84	20JUN84			75	2	0
80100	RISER (H & C WATER	8	8 MAR84	9 MAR84	27JUN84	28JUN84			75	2	0
80100	RISER (H & C WATER	9	15MAR84	16MAR84	5 JUL84	6 JUL84			75	2	0
80100	RISER (H & C WATER	10	22MAR84	23MAR84	12JUL84	13JUL84			75	2	0
80100	RISER (H & C WATER	11	29MAR84	30MAR84	2 AUG84	3 AUG84			75	2	0
80100	RISER (H & C WATER	12	5 APR84	10APR84	9 AUG84	10AUG84			75	2	0
80100	RISER (H & C WATER	13	16APR84	17APR84	16AUG84	17AUG84			75	2	0
80100	RISER (H & C WATER	14	23APR84	24APR84	23AUG84	24AUG84			75	2	0
80100	RISER (H & C WATER	15	30APR84	1 MAY84	30AUG84	31AUG84			75	2	0
80100	RISER (H & C WATER	16	7 MAY84	8 MAY84	7 SEP84	10SEP84			75	2	0
80200	HEAT. ROUGH PIPING	1	12MAR84	16MAR84	30MAY84	5 JUN84			54	5	0
80200	HEAT. ROUGH PIPING	2	19MAR84	22MAR84	6 JUN84	11JUN84			54	4	0
80200	HEAT. ROUGH PIPING	3	23MAR84	28MAR84	12JUN84	15JUN84			54	4	0
80200	HEAT. ROUGH PIPING	4	29MAR84	3 APR84	18JUN84	21JUN84			54	4	0
80200	HEAT. ROUGH PIPING	5	4 APR84	11APR84	22JUN84	28JUN84			54	4	0
80200	HEAT. ROUGH PIPING	6	12APR84	17APR84	29JUN84	5 JUL84			54	4	0
80200	HEAT. ROUGH PIPING	7	18APR84	23APR84	6 JUL84	11JUL84			54	4	0
80200	HEAT. ROUGH PIPING	8	24APR84	27APR84	12JUL84	31JUL84			54	4	0
80200	HEAT. ROUGH PIPING	9	30APR84	3 MAY84	1 AUG84	6 AUG84			54	4	0
80200	HEAT. ROUGH PIPING	10	4 MAY84	9 MAY84	7 AUG84	10AUG84			54	4	0
80200	HEAT. ROUGH PIPING	11	10MAY84	15MAY84	13AUG84	16AUG84			54	4	0
80200	HEAT. ROUGH PIPING	12	16MAY84	22MAY84	17AUG84	22AUG84			54	4	0
80200	HEAT. ROUGH PIPING	13	23MAY84	28MAY84	23AUG84	28AUG84			54	4	0
80200	HEAT. ROUGH PIPING	14	29MAY84	1 JUN84	29AUG84	4 SEP84			54	4	0

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                                   I      E A R L Y           L A T E           A C T U A L                  DURATION    PAGE 16
NO.    DESCRIPTION         FLOOR I   START    FINISH     START    FINISH    START    FINISH    FLOAT  SCHED.  ACTUAL
-----------------------------------------------------------------------------------------------------------------------
                                   I
80200  HEAT. ROUGH PIPING 15 I   4 JUN84   7 JUN84    5 SEP84  10SEP84                       54       4       0
                                   I
80200  HEAT. ROUGH PIPING 16 I   8 JUN84  13JUN84   11SEP84  14SEP84                       54       4       0
                                   I
90100  PRECAST PANELS       1 I   2 JAN84  10FEB84    1 FEB84  13MAR84                       22      30       0
                                   I
90100  PRECAST PANELS       2 I   2 JAN84  10FEB84    1 FEB84  13MAR84                       22      30       0
                                   I
90100  PRECAST PANELS       3 I   2 JAN84  10FEB84    1 FEB84  13MAR84                       22      30       0
                                   I
90100  PRECAST PANELS       4 I  13FEB84  15MAR84   14MAR84  18APR84                       22      24       0
                                   I
90100  PRECAST PANELS       5 I  13FEB84  15MAR84   14MAR84  18APR84                       22      24       0
                                   I
90100  PRECAST PANELS       6 I  13FEB84  15MAR84   14MAR84  18APR84                       22      24       0
                                   I
90100  PRECAST PANELS       7 I  16MAR84  16APR84   19APR84  16MAY84                       22      20       0
                                   I
90100  PRECAST PANELS       8 I  16MAR84  16APR84   19APR84  16MAY84                       22      20       0
                                   I
90100  PRECAST PANELS       9 I  16MAR84  16APR84   19APR84  16MAY84                       22      20       0
                                   I
90100  PRECAST PANELS      10 I  17APR84  11MAY84   17MAY84  13JUN84                       22      19       0
                                   I
90100  PRECAST PANELS      11 I  17APR84  11MAY84   17MAY84  13JUN84                       22      19       0
                                   I
90100  PRECAST PANELS      12 I  17APR84  11MAY84   17MAY84  13JUN84                       22      19       0
                                   I
90100  PRECAST PANELS      13 I  14MAY84   5 JUN84   14JUN84   9 JUL84                       22      16       0
                                   I
90100  PRECAST PANELS      14 I  14MAY84   5 JUN84   14JUN84   9 JUL84                       22      16       0
                                   I
90100  PRECAST PANELS      15 I  14MAY84   5 JUN84   14JUN84   9 JUL84                       22      16       0
                                   I
90100  PRECAST PANELS      16 I   6 JUN84  27JUN84   10JUL84  13AUG84                       22      15       0
                                   I
90200  GLAZING              1 I  20FEB84  29FEB84   21MAR84  30MAR84                       22       8       0
                                   I
90200  GLAZING              2 I   1 MAR84   8 MAR84    2 APR84  11APR84                       22       6       0
                                   I
90200  GLAZING              3 I   9 MAR84  19MAR84   12APR84  20APR84                       22       7       0
                                   I
90200  GLAZING              4 I  20MAR84  28MAR84   23APR84   1 MAY84                       22       7       0
                                   I
90200  GLAZING              5 I  29MAR84   5 APR84    2 MAY84   9 MAY84                       22       6       0
                                   I
90200  GLAZING              6 I  10APR84  17APR84   10MAY84  17MAY84                       22       6       0
                                   I
90200  GLAZING              7 I  18APR84  25APR84   18MAY84  28MAY84                       22       6       0
                                   I
90200  GLAZING              8 I  26APR84   3 MAY84   29MAY84   5 JUN84                       22       6       0
                                   I
90200  GLAZING              9 I   4 MAY84  11MAY84    6 JUN84  13JUN84                       22       6       0
                                   I
90200  GLAZING             10 I  14MAY84  18MAY84   14JUN84  20JUN84                       22       5       0
                                   I
90200  GLAZING             11 I  22MAY84  29MAY84   21JUN84  29JUN84                       22       6       0
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                               I   E A R L Y         L A T E         A C T U A L                  DURATION      PAGE 17
NO.     DESCRIPTION      FLOOR I  START   FINISH   START   FINISH   START    FINISH   FLOAT   SCHED.  ACTUAL
----------------------------------------------------------------------------------------------------------------
                               I
90200  GLAZING              12 I  30MAY84  5 JUN84  3 JUL84  9 JUL84                     22      5       0
                               I
90200  GLAZING              13 I  6 JUN84 12JUN84  10JUL84  30JUL84                      22      5       0
                               I
90200  GLAZING              14 I  13JUN84 19JUN84  31JUL84  6 AUG84                      22      5       0
                               I
90200  GLAZING              15 I  20JUN84 27JUN84  7 AUG84  13AUG84                      22      5       0
                               I
90200  GLAZING              16 I  28JUN84  5 JUL84 14AUG84  20AUG84                      22      5       0
                               I
90300  PRECAST CAULKING      1 I  14MAR84 22MAR84  17APR84  25APR84                      22      7       0
                               I
90300  PRECAST CAULKING      2 I  23MAR84 29MAR84  26APR84  2 MAY84                      22      5       0
                               I
90300  PRECAST CAULKING      3 I  30MAR84  5 APR84  3 MAY84  9 MAY84                     22      5       0
                               I
90300  PRECAST CAULKING      4 I  10APR84 16APR84  10MAY84  16MAY84                      22      5       0
                               I
90300  PRECAST CAULKING      5 I  17APR84 23APR84  17MAY84  24MAY84                      22      5       0
                               I
90300  PRECAST CAULKING      6 I  24APR84 30APR84  25MAY84  31MAY84                      22      5       0
                               I
90300  PRECAST CAULKING      7 I  1 MAY84  7 MAY84  1 JUN84  7 JUN84                     22      5       0
                               I
90300  PRECAST CAULKING      8 I  9 MAY84 14MAY84   8 JUN84 14JUN84                      22      5       0
                               I
90300  PRECAST CAULKING      9 I  15MAY84 22MAY84  15JUN84  21JUN84                      22      5       0
                               I
90300  PRECAST CAULKING     10 I  23MAY84 29MAY84  22JUN84  29JUN84                      22      5       0
                               I
90300  PRECAST CAULKING     11 I  30MAY84  5 JUN84  3 JUL84  9 JUL84                     22      5       0
                               I
90300  PRECAST CAULKING     12 I  6 JUN84 12JUN84  10JUL84  30JUL84                      22      5       0
                               I
90300  PRECAST CAULKING     13 I  13JUN84 19JUN84  31JUL84  6 AUG84                      22      5       0
                               I
90300  PRECAST CAULKING     14 I  20JUN84 27JUN84  7 AUG84  13AUG84                      22      5       0
                               I
90300  PRECAST CAULKING     15 I  28JUN84  5 JUL84 14AUG84  20AUG84                      22      5       0
                               I
90300  PRECAST CAULKING     16 I  6 JUL84 12JUL84  21AUG84  27AUG84                      22      5       0
                               I
100100 MASONRY (L-R HALL)    1 I  4 MAY84  9 MAY84  3 AUG84  8 AUG84                     52      4       0
                               I
100100 MASONRY (L-R HALL)    2 I  10MAY84 15MAY84   9 AUG84 14AUG84                      52      4       0
                               I
100100 MASONRY (L-R HALL)    3 I  16MAY84 22MAY84  15AUG84  20AUG84                      52      4       0
                               I
100100 MASONRY (L-R HALL)    4 I  23MAY84 28MAY84  21AUG84  24AUG84                      52      4       0
                               I
100100 MASONRY (L-R HALL)    5 I  29MAY84  1 JUN84 27AUG84  30AUG84                      52      4       0
                               I
100100 MASONRY (L-R HALL)    6 I  4 JUN84  7 JUN84 31AUG84  6 SEP84                      52      4       0
                               I
100100 MASONRY (L-R HALL)    7 I  5 JUN84 13JUN84   7 SEP84 12SEP84                      52      4       0
                               I
100100 MASONRY (L-R HALL)    8 I  14JUN84 19JUN84  13SEP84  18SEP84                      52      4       0
```

```
                                   I      E A R L Y          L A T E          A C T U A L                    DURATION     PAGE 18
NO.     DESCRIPTION       FLOOR I   START    FINISH    START    FINISH    START     FINISH    FLOAT   SCHED.  ACTUAL
-------------------------------------------------------------------------------------------------------------------------
                                  I
100200 MASONRY (MECH. RM) 1  I   2 APR84   5 APR84   23APR84   26APR84                       13      4       0
                                  I
100200 MASONRY (MECH. RM) 2  I   10APR84   13APR84   27APR84   2 MAY84                       13      4       0
                                  I
100200 MASONRY (MECH. RM) 3  I   16APR84   19APR84   3 MAY84   8 MAY84                       13      4       0
                                  I
100200 MASONRY (MECH. RM) 4  I   20APR84   25APR84   9 MAY84   14MAY84                       13      4       0
                                  I
100200 MASONRY (MECH. RM) 5  I   26APR84   1 MAY84   15MAY84   18MAY84                       13      4       0
                                  I
100200 MASONRY (MECH. RM) 6  I   2 MAY84   7 MAY84   22MAY84   25MAY84                       13      4       0
                                  I
100200 MASONRY (MECH. RM) 7  I   8 MAY84   11MAY84   28MAY84   31MAY84                       13      4       0
                                  I
100200 MASONRY (MECH. RM) 8  I   14MAY84   17MAY84   1 JUN84   6 JUN84                       13      4       0
                                  I
100200 MASONRY (MECH. RM) 9  I   18MAY84   24MAY84   7 JUN84   12JUN84                       13      4       0
                                  I
100200 MASONRY (MECH. RM) 10 I   25MAY84   30MAY84   13JUN84   18JUN84                       13      4       0
                                  I
100200 MASONRY (MECH. RM) 11 I   31MAY84   5 JUN84   19JUN84   22JUN84                       13      4       0
                                  I
100200 MASONRY (MECH. RM) 12 I   6 JUN84   11JUN84   26JUN84   29JUN84                       13      4       0
                                  I
100200 MASONRY (MECH. RM) 13 I   12JUN84   15JUN84   3 JUL84   6 JUL84                       13      4       0
                                  I
100200 MASONRY (MECH. RM) 14 I   18JUN84   21JUN84   9 JUL84   12JUL84                       13      4       0
                                  I
100200 MASONRY (MECH. RM) 15 I   22JUN84   28JUN84   13JUL84   1 AUG84                       13      4       0
                                  I
100200 MASONRY (MECH. RM) 16 I   29JUN84   5 JUL84   2 AUG84   7 AUG84                       13      4       0
                                  I
100300 MASONRY ( CORE )   1  I   2 APR84   5 APR84   7 JUN84   12JUN84                       45      4       0
                                  I
100300 MASONRY ( CORE )   2  I   10APR84   13APR84   13JUN84   18JUN84                       45      4       0
                                  I
100300 MASONRY ( CORE )   3  I   16APR84   19APR84   19JUN84   22JUN84                       45      4       0
                                  I
100300 MASONRY ( CORE )   4  I   20APR84   25APR84   26JUN84   29JUN84                       45      4       0
                                  I
100300 MASONRY ( CORE )   5  I   26APR84   1 MAY84   3 JUL84   6 JUL84                       45      4       0
                                  I
100300 MASONRY ( CORE )   6  I   2 MAY84   7 MAY84   9 JUL84   12JUL84                       45      4       0
                                  I
100300 MASONRY ( CORE )   7  I   8 MAY84   11MAY84   13JUL84   1 AUG84                       45      4       0
                                  I
100300 MASONRY ( CORE )   8  I   14MAY84   17MAY84   2 AUG84   7 AUG84                       45      4       0
                                  I
100300 MASONRY ( CORE )   9  I   18MAY84   24MAY84   8 AUG84   13AUG84                       45      4       0
                                  I
100300 MASONRY ( CORE )   10 I   25MAY84   30MAY84   14AUG84   17AUG84                       45      4       0
                                  I
100300 MASONRY ( CORE )   11 I   31MAY84   5 JUN84   20AUG84   23AUG84                       45      4       0
                                  I
100300 MASONRY ( CORE )   12 I   5 JUN84   11JUN84   24AUG84   29AUG84                       45      4       0
                                  I
100300 MASONRY ( CORE )   13 I   12JUN84   15JUN84   30AUG84   5 SEP84                       45      4       0
```

NO.	DESCRIPTION	FLOOR	EARLY START	EARLY FINISH	LATE START	LATE FINISH	ACTUAL START	ACTUAL FINISH	FLOAT	DURATION SCHED.	DURATION ACTUAL
100300	MASONRY (CORE)	14	18JUN84	21JUN84	6 SEP84	11SEP84			45	4	0
100300	MASONRY (CORE)	15	22JUN84	28JUN84	12SEP84	17SEP84			45	4	0
100300	MASONRY (CORE)	16	29JUN84	5 JUL84	18SEP84	21SEP84			45	4	0
100400	MASONRY (M-R HALL)	9	14AUG84	17AUG84	14AUG84	17AUG84			0	4	0
100400	MASONRY (M-R HALL)	10	14AUG84	17AUG84	14AUG84	17AUG84			0	4	0
100400	MASONRY (M-R HALL)	11	20AUG84	23AUG84	20AUG84	23AUG84			0	4	0
100400	MASONRY (M-R HALL)	12	20AUG84	23AUG84	20AUG84	23AUG84			0	4	0
100400	MASONRY (M-R HALL)	13	24AUG84	29AUG84	24AUG84	29AUG84			0	4	0
100400	MASONRY (M-R HALL)	14	24AUG84	29AUG84	24AUG84	29AUG84			0	4	0
100400	MASONRY (M-R HALL)	15	30AUG84	5 SEP84	30AUG84	5 SEP84			0	4	0
100400	MASONRY (M-R HALL)	16	30AUG84	5 SEP84	30AUG84	5 SEP84			0	4	0
110100	L-R ELEV. RAILS	1	17FEB84	21FEB84	30MAR84	3 APR84			30	3	0
110100	L-R ELEV. RAILS	2	22FEB84	24FEB84	4 APR84	10APR84			30	3	0
110100	L-R ELEV. RAILS	3	27FEB84	29FEB84	11APR84	13APR84			30	3	0
110100	L-R ELEV. RAILS	4	1 MAR84	5 MAR84	16APR84	18APR84			30	3	0
110100	L-R ELEV. RAILS	5	[illegible] MAR84	5 MAR84	19APR84	23APR84			30	3	0
110100	L-R ELEV. RAILS	6	[illegible] MAR84	13MAR84	24APR84	26APR84			30	3	0
110100	L-R ELEV. RAILS	7	14MAR84	16MAR84	27APR84	1 MAY84			30	3	0
110100	L-R ELEV. RAILS	8	19MAR84	21MAR84	2 MAY84	4 MAY84			30	3	0
110200	L-R ELEV. FR. & DO	1	2 MAY84	3 MAY84	12JUN84	13JUN84			28	2	0
110200	L-R ELEV. FR. & DO	2	4 MAY84	7 MAY84	14JUN84	15JUN84			28	2	0
110200	L-R ELEV. FR. & DO	3	8 MAY84	9 MAY84	18JUN84	19JUN84			28	2	0
110200	L-R ELEV. FR. & DO	4	10MAY84	11MAY84	20JUN84	21JUN84			28	2	0
110200	L-R ELEV. FR. & DO	5	14MAY84	15MAY84	22JUN84	26JUN84			28	2	0
110200	L-R ELEV. FR. & DO	6	16MAY84	17MAY84	27JUN84	28JUN84			28	2	0
110200	L-R ELEV. FR. & DO	7	18MAY84	22MAY84	29JUN84	3 JUL84			28	2	0
110200	L-R ELEV. FR. & DO	8	23MAY84	24MAY84	4 JUL84	5 JUL84			28	2	0
110300	H-R ELEV. RAILS	1	7 MAY84	10MAY84	7 MAY84	10MAY84			0	4	0
110300	H-R ELEV. RAILS	2	11MAY84	14MAY84	11MAY84	14MAY84			0	2	0

```
                                    I       E A R L Y           L A T E           A C T U A L                      DURATION     PAGE 20
NO.    DESCRIPTION          FLOOR I   START    FINISH     START    FINISH     START     FINISH     FLOAT  SCHED.  ACTUAL
--------------------------------------------------------------------------------------------------------------------------
                                    I
110300 H-R ELEV. RAILS          3 I   15MAY84  16MAY84    15MAY84  16MAY84                          0       2       0
                                    I
110300 H-R ELEV. RAILS          4 I   17MAY84  18MAY84    17MAY84  18MAY84                          0       2       0
                                    I
110300 H-R ELEV. RAILS          5 I   22MAY84  23MAY84    22MAY84  23MAY84                          0       2       0
                                    I
110300 H-R ELEV. RAILS          6 I   24MAY84  25MAY84    24MAY84  25MAY84                          0       2       0
                                    I
110300 H-R ELEV. RAILS          7 I   28MAY84  29MAY84    28MAY84  29MAY84                          0       2       0
                                    I
110300 H-R ELEV. RAILS          8 I   30MAY84  31MAY84    30MAY84  31MAY84                          0       2       0
                                    I
110300 H-R ELEV. RAILS          9 I    1 JUN84  4 JUN84    1 JUN84  4 JUN84                         0       2       0
                                    I
110300 H-R ELEV. RAILS         10 I    5 JUN84  6 JUN84    5 JUN84  6 JUN84                         0       2       0
                                    I
110300 H-R ELEV. RAILS         11 I    7 JUN84  8 JUN84    7 JUN84  8 JUN84                         0       2       0
                                    I
110300 H-R ELEV. RAILS         12 I   11JUN84  12JUN84    11JUN84  12JUN84                          0       2       0
                                    I
110300 H-R ELEV. RAILS         13 I   13JUN84  14JUN84    13JUN84  14JUN84                          0       2       0
                                    I
110300 H-R ELEV. RAILS         14 I   15JUN84  18JUN84    15JUN84  18JUN84                          0       2       0
                                    I
110300 H-R ELEV. RAILS         15 I   19JUN84  20JUN84    19JUN84  20JUN84                          0       2       0
                                    I
110300 H-R ELEV. RAILS         16 I   21JUN84  22JUN84    21JUN84  22JUN84                          0       2       0
                                    I
110400 H-R ELEV. FR. & DO 9       I    8 AUG84  9 AUG84    8 AUG84  9 AUG84                         0       2       0
                                    I
110400 H-R ELEV. FR. & DO 10      I   10AUG84  13AUG84    10AUG84  13AUG84                          0       2       0
                                    I
110400 H-R ELEV. FR. & DO 11      I   14AUG84  15AUG84    14AUG84  15AUG84                          0       2       0
                                    I
110400 H-R ELEV. FR. & DO 12      I   16AUG84  17AUG84    16AUG84  17AUG84                          0       2       0
                                    I
110400 H-R ELEV. FR. & DO 13      I   20AUG84  21AUG84    20AUG84  21AUG84                          0       2       0
                                    I
110400 H-R ELEV. FR. & DO 14      I   22AUG84  23AUG84    22AUG84  23AUG84                          0       2       0
                                    I
110400 H-R ELEV. FR. & DO 15      I   24AUG84  27AUG84    24AUG84  27AUG84                          0       2       0
                                    I
110400 H-R ELEV. FR. & DO 16      I   28AUG84  29AUG84    28AUG84  29AUG84                          0       2       0
                                    I
112109  LOW-RISE MOTOR          9 I   17FEB84  15MAR84    16APR84  11MAY84                         39      20       0
                                    I
112209 L-R CABLES & PLATF       9 I   22MAR84  20APR84    14MAY84  11JUN84                         35      20       0
                                    I
112316 HIGH-RISE MOTOR         16 I    7 MAY84  4 JUN84   28MAY84  22JUN84                         14      20       0
                                    I
112416 H-R CABLES & PLATF      16 I   26JUN84   7 AUG84   26JUN84   7 AUG84                         0      20       0
                                    I
112509 L-R FINISH & TEST        9 I   25MAY84   9 JUL84    6 JUL84  30AUG84                        28      30       0
                                    I
112616 H-R FINISH & TEST       16 I   30AUG84  11OCT84    31AUG84  12OCT84                          1      30       0
                                    I
120100 CERAMIC TILE             1 I    2 APR84  4 APR84   25MAY84  29MAY84                         36       3       0
```

```
                                   I       E A R L Y           L A T E            A C T U A L                  DURATION      PAGE 21
NO.      DESCRIPTION       FLOOR I    START     FINISH      START     FINISH     START      FINISH     FLOAT  SCHED.  ACTUAL
--------------------------------------------------------------------------------------------------------------------------------
                                   I
120100 CERAMIC TILE            2 I    5 APR84   11APR84     30MAY84   1 JUN84                            36      3        0
                                   I
120100 CERAMIC TILE            3 I    12APR84   16APR84     4 JUN84   6 JUN84                            36      3        0
                                   I
120100 CERAMIC TILE            4 I    17APR84   19APR84     7 JUN84   11JUN84                            36      3        0
                                   I
120100 CERAMIC TILE            5 I    20APR84   24APR84     12JUN84   14JUN84                            36      3        0
                                   I
120100 CERAMIC TILE            6 I    25APR84   27APR84     15JUN84   19JUN84                            36      3        0
                                   I
120100 CERAMIC TILE            7 I    30APR84   2 MAY84     20JUN84   22JUN84                            36      3        0
                                   I
120100 CERAMIC TILE            8 I    3 MAY84   7 MAY84     26JUN84   28JUN84                            36      3        0
                                   I
120100 CERAMIC TILE            9 I    8 MAY84   10MAY84     29JUN84   4 JUL84                            36      3        0
                                   I
120100 CERAMIC TILE           10 I    11MAY84   15MAY84     5 JUL84   9 JUL84                            36      3        0
                                   I
120100 CERAMIC TILE           11 I    16MAY84   18MAY84     10JUL84   12JUL84                            36      3        0
                                   I
120100 CERAMIC TILE           12 I    22MAY84   24MAY84     13JUL84   31JUL84                            36      3        0
                                   I
120100 CERAMIC TILE           13 I    25MAY84   29MAY84     1 AUG84   3 AUG84                            36      3        0
                                   I
120100 CERAMIC TILE           14 I    30MAY84   1 JUN84     6 AUG84   8 AUG84                            36      3        0
                                   I
120100 CERAMIC TILE           15 I    4 JUN84   6 JUN84     9 AUG84   13AUG84                            36      3        0
                                   I
120100 CERAMIC TILE           16 I    7 JUN84   11JUN84     14AUG84   16AUG84                            36      3        0
                                   I
132116 ROOF                   16 I    7 MAY84   5 JUN84     15JUN84   31JUL84                            28     21        0
```

APPENDIX III

Computer Code Listings

Following is the computer code listings as they were for the example in chapter V. It is appropriate, however, to list the most important variables. Unfortunately, some of these variables do not have the same meaning in different programs.

A : Pointer to the first record in which the first activity in the order of input is stored.

C1 : Current level of a repetitive activity

D : Date for the short cycle schedule

D$: Description of the activity

D1 : Duration of a non-repetitive activity or Date of a milestone.

D2 : Date

E1 : Last level of a repetitive activity.

F(I) : Finish date of the ith floor of a repetitive activity.

F1 : Finish to finish relationship for a repetitive activity.

F2 : Early finish date.

F3 : Actual finish date.

F4 : Late finish date.

F8,F9 : Project's latest date.

H : Record number obtained from the hashing routine.

H0 : Hashing number.

H1 : Pointer to the next activity in the order of input

H2 : Pointer to the next activity in the order of input

L : Level preceded by a non-typical predecessor

L1 : Level preceded by a non-typical predecessor (in "main") or the first level of a repetitive activity

L1 : or coefficient of effeciency
or duration of a procuremnt task for a non-repetitive activity.

L9 : Level preceded by a non-typical predecessor.

M1$ to M7$: Arrays of characters used for printing data.

N : Total number of activities.

N0 : Pointer to the list of coefficients of effeciency

N1 : Activity number
or number of crews.

N2 : Activity number (in "main")
or pointer to the next activity in the order of input (others).

N9 : Activity number (argument for the hashing routine).

P : Next available record in the pool for the linked lists.

P(I) : Production rate for the ith floor of a repetitive activity.

P0 : Number of predecessor(s) for a non-repetitive activity
or number of typical predecessor(s) for a repetitive activity.

P1 : Production rate of a repetitive activity
or pointer to the linked list of the procurement sequence.

P5 : Number of non-typical predecessor(s) for a repetitive activity.

P7 : Predecessor number to be changed or added (in "chpre")
or -1 to see if a predecessor exists (in "sucs")

P8 : Pointer to the next record in the linked list of predecessors
(or list of coefficients of effeciency, or list of procurement tasks.)

P9 : Activity number of a predecessor
or floor number for the coefficient of effeciency
or procurement task number.

Q : Quotient of N9 divided by H0 (in the hashing routine)

R1 : Record number in the file of dates.

R2 : Record number in the file of dates.

S : Next available record in the pool for the linked lists
or status of a non-repetitive activity.

S(I) : Start date of the ith floor of a repetitive activity.

S0 : Arbitrary start date.

S1 : Starting level of a repetitive activity or start to start relationship for a repetitive activity.

S2 : Early start date

S3 : Actual Start date.

S4 : Late start date.

S8 : Successor number.

S9 : Pointer to the next record in the linked list of successors.

T1 : Pointer to the linked list of typical predecessors for a repetitive activity or to the list of predecessors for a non-repetitive activity.

T2 : Same as T1, but for the list of successors.

T5 : Pointer to the linked list of non-typical predecessors for a repetitive activity.

T6 : Pointer to the linked list of non-typical successors for a repetitive activity.

T9 : First field of the record H, from the hashing routine.

W : Weather factor (0 or 1).

W(I) : Weather correction factor for the Ith month of the year.

W0 : pointer to the list of coefficient of effeciency.

W8 : Weather factor (0 or 1).

X : Difference substracted from arbitrary dates to get scheduled dates.

In the explanation of the data structure, six files were mentionned; here is some information about the way they appear in the programs (see table on the next page). Assume the user inputs "JOB" as the "Name of File".

FILE NAME	LOGICAL UNIT *	NUMBER OF RECORDS PER FILE	NUMBER OF FIELDS PER RECORD	DESCRIPTION
JOB	7	200	9	Activity data (1st file)
JOB1	1	1000	2	Contains records of linked lists (3rd file)
JOB2	2	1000	3	Contains records of linked lists (4th file)
JOB3	3	200	2	File of sorted activity numbers.
JOB4	4	1700	7	File of dates
JOB5	5	200	9	Activity data (2nd file)
CAL	6	Working days Required	3	File of Calendar dates
PR:	6	-	-	Line Printer

* under which the file is normally opened.

Table III.1 Information on Files

As seen in the previous table, the files have a limited number of records of 200, for the activity data, of 1000 for the files of records of linked lists, and of 1700 for the file of dates. These numbers appear in several places in the programs; if modifications are required to the sizes of the files, here is where changes would be required:

PROGRAM NAME	LINE NUMBER (Basic) TO BE MODIFIED	NUMBER TO BE CHANGED
MAIN	1230 1310	199 199
NEW	260 370 480 520 530 540 592	199 1000 999 1000 1000 199 1699
CHPRE	160	199
SUCS	160 1840 2510	199 200 199
COMP	250 2950 3030 3130 3390	1699 199 1699 200 1699
OUT	1880 1960	199 1699
DATA	620 2320 2400	200 199 1699
SHORT	500 940	1699 199
PROC	780 990	199 1699

Table III.2 Modifications required to change sizes of files

```
1 REM
2 REM          PROGRAM "MAIN"
3 REM          AUTHOR: JEAN B. LARAMEE.
4 REM          CENTER FOR BUILDING STUDIES
5 REM          CONCORDIA UNIVERSITY
6 REM          FEBRUARY 1983.
7 REM
8 REM        "A SCHEDULING SYSTEM FOR HIGH-RISE BUILDING CONSTRUCTION"
9 REM
18 REM         DECLARE VARIABLES AND FUNCTIONS
19 REM
20 DIM F$(4),F1$(5),F2$(5),F3$(5),F4$(5),F5$(5)
30 DIM D$(20)
37 REM
38 REM   FNM:  MOD FUNCTION
39 REM
40 DEF FNM(X,Y)=INT((X/Y-INT(X/Y))*Y+.5)
47 REM
48 REM   FNA:  GET THE MIDDLE DIGITS OF NUMBER A WHICH HAS 6 DIGITS
49 REM
50 DEF FNA(A)=INT(INT(A/100)-(INT(A/10000)*100)+.5)
57 REM
58 REM   FNS:  GET THE FIRST TWO DIGITS OF A WHICH HAS 6 DIGITS
59 REM
60 DEF FNS(A)=INT(A/10000)
67 REM
68 REM   FNL:  GET THE LAST TWO DIGITS OF A WHICH HAS 6 DIGITS
69 REM
70 DEF FNL(A)=INT(A-(INT(A/100)*100)+.5)
77 REM
78 REM   INPUT THE NAME OF THE FILE
79 REM
80 PRINT "NAME OF FILE ? (4 CHAR.)"
90 INPUT F$
97 REM
98 REM   GENERATE THE NAMES OF ALL THE FILES
99 REM
100 F1$=F$+"1"
110 F2$=F$+"2"
120 F3$=F$+"3"
130 F4$=F$+"4"
140 F5$=F$+"5"
150 PRINT ""
160 PRINT "            MENU"
170 PRINT ""
180 PRINT "1) START A NEW PROJECT"
190 PRINT "2) INPUT NEW ACTIVITIES"
200 PRINT "3) DELETE ACTIVITIES"
210 PRINT "4) CHANGE PRECEDENCE"
220 PRINT "5) CHANGE ACTIVITY NAME"
230 PRINT "6) LIST ACTIVITIES"
240 PRINT "7) COMPILE DATA"
250 PRINT "8) EXECUTE DATA"
260 PRINT "9) PRINT RESULTS"
270 PRINT "10) INPUT OR CHANGE ACTIVITY DATA"
280 PRINT "11) SHORT CYCLE SCHEDULE"
290 PRINT "12) PROCUREMENT STATUS REPORT"
300 PRINT "13) PREPARE CALENDAR"
310 PRINT "14) QUIT"
320 PRINT ""
330 PRINT "CHOOSE ANY NUMBER:"
340 INPUT A9
350 ON A9 GOTO 390,400,1390,1930,1940,2080,2700,2710,2720,2730,2740,
2750
360 ON (A9-12) GOTO 380
367 REM
368 REM    EXECUTION OF PROGRAM "MAIN" STOPS HERE
369 REM
370 STOP
380 CHAIN "CALENDAR"
390 CHAIN "NEW"
396 REM
397 REM    IN THIS SECTION, NEW ACTIVITIES ARE INPUT IN THE SYSTEM.
398 REM    OPEN THE FILES
399 REM
400 OPEN F$,7,0
```

```
410 OPEN F1$,1,0
420 OPEN F2$,2,0
430 INFILE ON (7,0) N,A
437 REM
438 REM   SEE IF THERE ARE SOME ACTIVITIES IN THE FILE
439 REM
440 IF A=0 GOTO 490
447 REM
448 REM   SCAN THE LIST OF THE ACTIVITIES TO FIND THE LAST ONE
449 REM
450 INFILE ON (7,A) N2,H1,P0,T1,T2,P5,T5,T6,D$
460 IF H1>0 THEN A=H1: GOTO 450
470 H2=A
480 GOTO 570
487 REM
488 REM   THERE IS NO ACTIVITY: INPUT THE FIRST ONE
489 REM
490 PRINT 'ENTER ACTIVITY NO.'
500 INPUT N1
510 N9=N1
520 GOSUB 1310
530 IF T9<1 THEN GOSUB 1230 ELSE PRINT 'PLEASE REENTER NO.': GOTO 50
0
537 REM
538 REM   STORE IN RECORD '0' THE POINTER(H) TO THE FIRST ACTIVITY
539 REM
540 OUTFILE ON (7,0) N,H
550 H1=H
560 GOTO 650
567 REM
568 REM   ASK FOR ANOTHER NUMBER
569 REM
570 PRINT 'ENTER ACTIVITY NO.'
580 INPUT N1
590 N9=N1
597 REM
598 REM   A VALUE OF ZERO AS ACTIVITY NUMBER WILL STOP THE INPUT
599 REM
600 IF N1>0 THEN GOSUB 1310 ELSE H=0: GOTO 630
607 REM
608 REM   CHECK IF NUMBERS ARE DUPLICATED
609 REM
610 IF T9>=0 OR N1=N2 THEN PRINT 'CHOOSE ANOTHER NUMBER': GOTO 580
620 GOSUB 1230
621 OUTFILE ON (7,H) N1
630 H1=H
637 REM
638 REM   STORE THE INFORMATION ON THE FILE
639 REM
640 OUTFILE ON (7,H2) N2,H1,P0,T1,-1,P5,T5,-1,D$
650 IF N1<=0 GOTO 1150
657 REM
658 REM   READJUST THE POINTERS AND INCREASE COUNTER OF ACTIVITIES
659 REM
660 N=N+1
670 N2=N1
680 H2=H1
687 REM
688 REM   ENTER THE INFORMATION ABOUT THIS ACTIVITY
689 REM
690 PRINT 'ENTER DESCRIPTION (MAX. 20) OF ACTIVITY ';N1
700 INPUT D$
707 REM
708 REM   FIND THE TYPE OF THE ACTIVITY BY ITS NUMBER
709 REM
710 Y=FNA(N1)
720 IF Y>20 THEN 730 ELSE 930
730 IF Y<80 THEN 740 ELSE 1120
737 REM
738 REM   CASE OF A NON-REPETITIVE ACTIVITY
739 REM
740 PRINT 'ENTER NO OF PREDECESSOR FOR ACTIVITY ';N1
750 INPUT P0
760 IF P0>=1 THEN 770 ELSE T1=-1: GOTO 920
770 PRINT 'ENTER ACT. NO. OF THE PREDECESSORS'
777 REM
```

```
778 REM   GET NEXT AVAILABLE RECORD
779 REM
780 INFILE ON (1,0) P
790 T1=P
800 FOR I=1 TO P0
810   INFILE ON (1,P) P9,P8
820   INPUT P9
830   L9=P
837   REM
838   REM   STORE THE PREDECESSORS IN THE LINKED LIST
839   REM
840   OUTFILE ON (1,P) P9,P8
850   P=P8
860 NEXT I
870 INFILE ON (1,L9) P9,P8
877 REM
878 REM   THE LAST ITEM OF THE LIST HAS A POINTER OF -1
879 REM
880 OUTFILE ON (1,L9) P9,-1
890 OUTFILE ON (1,0) P
900 P5=0
910 T5=-1
916 REM
917 REM   FIND WHERE TO GO AFTER
918 REM   THE SAME SEQUENCE IS USED FOR REP. AND NON-REP. ACT.
919 REM
920 IF Y>20 THEN 570 ELSE 950
927 REM
928 REM   CASE OF A REPETITIVE ACTIVITY
929 REM
930 PRINT 'ENTER NO. OF TYPICAL PREDECESSORS FOR ACTIVITY ';N1
940 GOTO 750
950 PRINT 'ENTER NO. OF NON-TYPICAL PREDECESSORS'
960 INPUT P5
970 IF P5=0 THEN T5=-1: GOTO 570
980 PRINT 'ENTER ACT.NO AND LEVEL IT PRECEDES'
990 INFILE ON (2,0) P
1000 T5=P
1010 FOR I=1 TO P5
1020   INFILE ON (2,P) P9,L1,P8
1027   REM
1028   REM   INPUT NON-TYPICAL PREDECESSORS AND THE LEVEL PRECEDED
1029   REM
1030   INPUT P9,L
1040   L9=P
1047   REM
1048   REM   STORE ON THE FILE
1049   REM
1050   OUTFILE ON (2,P) P9,L,P8
1060   P=P8
1070 NEXT I
1080 INFILE ON (2,L9) P9,L1,P8
1090 OUTFILE ON (2,L9) P9,L1,-1
1100 OUTFILE ON (2,0) P
1110 GOTO 570
1117 REM
1118 REM   CASE OF A MILESTONE; NO PREDECESSOR
1119 REM
1120 P0=0:P5=0
1130 T1=-1:T5=-1
1140 GOTO 570
1150 INFILE ON (7,0) A1,N1
1157 REM
1158 REM   STORE THE NUMBER OF ACTIVITIES IN RECORD '0'
1159 REM
1160 OUTFILE ON (7,0) N,N1
1170 PRINT 'END OF INPUT'
1180 PRINT 'FOR A TOTAL OF ';N;' ACTIVITIES'
1190 CLOSE 1
1200 CLOSE 2
1210 CLOSE 7
1217 REM
1218 REM   RETURN TO THE MENU
1219 REM
1220 GOTO 150
```

```
1227 REM
1228 REM   SUBROUTINE TO FIND IF THE NUMBER N9 IS AVAILABLE
1229 REM
1230 H0=199
1240 Q=INT(N9/H0)
1250 H=FNM(N9,H0)
1260 IF H=0 THEN H=FNM((Q+H),H0): GOTO 1260
1270 INFILE ON (7,H) T9
1280 IF T9<=1 THEN RETURN
1290 IF T9=N9 THEN T9=2: RETURN
1300 H=FNM((Q+H),H0): GOTO 1260
1306 REM
1307 REM   HASHING ROUTINE:
1308 REM   SUBROUTINE TO FIND THE RECORD NUMBER (H) OF ACTIVITY N9
1309 REM
1310 H0=199
1320 Q=INT(N9/H0)
1330 H=FNM(N9,H0)
1340 IF H=0 THEN H=FNM((Q+H),H0): GOTO 1340
1350 INFILE ON (7,H) T9
1360 IF T9<0 THEN RETURN
1370 IF T9=N9 THEN T9=0: RETURN
1380 H=FNM((Q+H),H0): GOTO 1340
1386 REM
1387 REM   THIS SECTION OF THE PROGRAM IS TO DELETE ACTIVITIES
1388 REM
1390 OPEN F$,7,0
1400 OPEN F1$,1,0
1410 OPEN F2$,2,0
1411 OPEN F5$,5,0
1420 PRINT "ACTIVITY NUMBER ? (0 TO QUIT)"
1430 INPUT N1
1440 IF N1=0 GOTO 1890
1450 N9=N1
1460 GOSUB 1310
1467 REM
1468 REM   CHECK IF ACTIVITY EXISTS
1469 REM
1470 IF T9<0 THEN PRINT "ACTIVITY ";N1;" DOES NOT EXIST": GOTO 1420
1480 INFILE ON (7,H) N1,H2,P0,T1,T2,P5,T5,T6,D$
1490 INFILE ON (1,0) P
1500 IF T1<0 GOTO 1540
1507 REM
1508 REM   RETURN THE RECORDS OF THE LINKED LIST TO THE POOL
1509 REM
1510 OUTFILE ON (1,0) T1
1520 INFILE ON (1,T1) P8,P9
1530 IF P9<0 THEN OUTFILE ON (1,T1) T1,P ELSE T1=P9: GOTO 1520
1540 INFILE ON (2,0) P
1550 IF T5<0 GOTO 1590
1560 OUTFILE ON (2,0) T5
1570 INFILE ON (2,T5) P8,L1,P9
1580 IF P9<0 THEN OUTFILE ON (2,T5) T5,0,P ELSE T5=P9: GOTO 1570
1587 REM
1588 REM   FIND THE TYPE OF ACTIVITY
1589 REM
1590 Y=FNA(N1)
1600 IF Y>20 GOTO 1680
1606 REM
1607 REM   CASE OF A REPETITIVE ACTIVITY:
1608 REM   RETURN THE RECORDS OF THE LIST OF PRODUCTION COEFF.
1609 REM
1610 INFILE ON (5,H) Z1,Z2,Z3,Z4,Z5,Z6,Z7,Z8
1620 IF Z8<.1 GOTO 1750
1630 INFILE ON (2,0) P
1640 OUTFILE ON (2,0) Z8
1650 INFILE ON (2,Z8) P8,L1,P9
1660 IF P9<0 THEN OUTFILE ON (2,Z8) Z8,0,P ELSE Z8=P9: GOTO 1650
1670 GOTO 1750
1680 IF Y>80 GOTO 1750
1685 REM
1686 REM   CASE OF A NON-REPETITIVE ACTIVITY
1687 REM   RETURN THE RECORDS OF THE LIST OF PROCUREMENT ACTIVITIES
1688 REM
1690 INFILE ON (5,H) Z1,Z2
```

```
1700 IF Z2<.1 GOTO 1750
1710 INFILE ON (2,0) P
1720 OUTFILE ON (2,0) Z2
1730 INFILE ON (2,Z2) P8,L1,P9
1740 IF P9<0 THEN OUTFILE ON (2,Z2) Z2,0,P ELSE Z2=P9: GOTO 1730
1747 REM
1748 REM   FIND WHERE THE ACTIVITY IS IN THE LIST OF ACTIVITIES
1749 REM
1750 INFILE ON (7,0) N,A
1760 IF A=H THEN 1770 ELSE 1800
1767 REM
1768 REM   CASE WHEN THE ACTIVITY IS THE FIRST OF THE LINKED LIST
1769 REM
1770 INFILE ON (7,A) N9,H2
1780 OUTFILE ON (7,A)1
1790 A=H2: GOTO 1860
1800 INFILE ON (7,A) N9,A1,P0,T1,T2,P5,T5,T6,D$
1810 IF A1=H GOTO 1830
1820 A=A1: GOTO 1800
1827 REM
1828 REM   MODIFY THE POINTER OF THE PRECEDING ACT. IN THE LIST
1829 REM
1830 OUTFILE ON (7,A) N9,H2,P0,T1,T2,P5,T5,T6,D$
1840 OUTFILE ON (7,H)1
1847 REM
1848 REM   DECREASE THE COUNTER OF ACTIVITIES
1849 REM
1850 INFILE ON (7,0) N,A
1860 OUTFILE ON (7,0)(N-1),A
1870 PRINT 'ACTIVITY NO. ';N1;' IS DELETED'
1877 REM
1878 REM   RETURN TO GET ANOTHER ACTIVITY
1879 REM
1880 GOTO 1420
1890 CLOSE 1
1900 CLOSE 2
1901 CLOSE 5
1910 CLOSE 7
1917 REM
1918 REM   RETURN TO THE MENU
1919 REM
1920 GOTO 150
1930 CHAIN 'CHPRE'
1937 REM
1938 REM   THIS PART OF THE PROGRAM IS TO CHANGE THE ACTIVITY NAME
1939 REM
1940 OPEN F$,7,0
1950 PRINT 'ACTIVITY NO.?'
1960 INPUT N1
1970 IF N1=0 GOTO 2060
1980 N9=N1
1990 GOSUB 1310
2000 IF T9<0 THEN PRINT 'ACTIVITY NO.';N1;'DOESN'T EXIST': GOTO 1950
2010 INFILE ON (7,H) N2,H2,P0,T1,T2,P5,T5,T6,D$
2020 PRINT 'OLD NAME IS';D$;' INPUT NEW ONE'
2030 INPUT D$
2040 OUTFILE ON (7,H) N2,H2,P0,T1,T2,P5,T5,T6,D$
2050 GOTO 1950
2060 CLOSE 7
2067 REM
2068 REM   RETURN TO THE MENU
2069 REM
2070 GOTO 150
2076 REM
2077 REM   THIS SECTION OF THE PROGRAM IS TO LIST THE ACTIVITIES
2078 REM   AND THEIR RESPECTIVE DATA
2079 REM
2080 OPEN F$,7,0
2090 OPEN F1$,1,0
2100 OPEN F2$,2,0
2110 OPEN F3$,3,0
2120 OPEN 'CAL',4,0
2130 OPEN F5$,5,0
2140 OPEN 'PR:',6,1
2150 INFILE ON (7,0) N,A
```

```
2157 REM
2158 REM   PRINT THE HEADING
2159 REM
2160 PRINT ON (6)'REPETITIVE ACTIVITIES'
2170 PRINT ON (6)
2180 PRINT ON (6)' NO.     DESCRIPTION';TAB(29),'I  START   CURRENT
';
2190 PRINT ON (6)'  LAST    CREWS   RATE     SS      FS    ';
2200 PRINT ON (6)'  LEARN   WEATHER  TYPICAL  NON-TYP'
2210 FOR I=1 TO 125: PRINT ON (6)'-';: NEXT I
2220 PRINT ON (6)'-'
2227 REM
2228 REM   CHOOSE THE ORDER OF PRINTING
2229 REM
2230 PRINT ' 1)ORDER OF INPUT'
2240 PRINT ' 2)SEQUENTIAL STEP'
2250 PRINT ' 3)INCREASING ACTIVITY NO.'
2260 INPUT A1
2267 REM
2268 REM   SCAN FOR REPETITIVE ACTIVITY  (C=1)
2269 REM
2270 C=1
2280 ON A1 GOTO 2290,2350,2350
2287 REM
2288 REM   ORDER OF INPUT: FOLLOW THE LINKED LIST
2289 REM
2290 INFILE ON (7,0) N,A
2300 INFILE ON (7,A) N2,H2,P0,T1,T2,P5,T5,T6,D$
2310 GOSUB 2760
2320 A=H2
2330 IF A>0 GOTO 2300
2340 GOTO 2410
2347 REM
2348 REM   SEQUENTIAL STEP OR INCREASING ACT. NO: REFER TO THE FILE
2349 REM
2350 FOR I=1 TO N
2360   INFILE ON (3,I) Z1,Z2
2370   IF A1=2 THEN A=Z1 ELSE A=Z2
2380   INFILE ON (7,A) N2,H2,P0,T1,T2,P5,T5,T6,D$
2390   GOSUB 2760
2400 NEXT I
2407 REM
2408 REM   SCAN FOR NON-REPETITIVE ACTIVITIES (C=2): DO IT OVER
2409 REM
2410 C=C+1
2420 ON C GOTO 2440,2440,2520,2590
2430 PRINT ON (6)
2440 PRINT ON (6)
2450 PRINT ON (6)' NON-REPETITIVE ACTIVITIES'
2460 PRINT ON (6)
2470 PRINT ON (6)' NO.    DESCRIPTION';TAB(29),'I  DURATION ';
2480 PRINT ON (6)' PROCUREMENT  WEATHER  STATUS  PREDECESSORS'
2490 FOR I=1 TO 80: PRINT ON (6)'-';: NEXT I
2500 PRINT ON (6)'-'
2510 GOTO 2280
2517 REM
2518 REM   SCAN FOR MILESTONES (C=3)
2519 REM
2520 PRINT ON (6)
2530 PRINT ON (6)'MILESTONES'
2540 PRINT ON (6)
2550 PRINT ON (6)'NO.    DESCRIPTION';TAB(29),'I          DATE'
2560 FOR I=1 TO 60: PRINT ON (6)'-';: NEXT I
2570 PRINT ON (6)'-'
2580 GOTO 2280
2590 PRINT ON (6)
2600 PRINT ON (6)
2610 PRINT ON (6)'FOR A TOTAL OF ';N;' ACTIVITIES'
2620 CLOSE 1
2630 CLOSE 2
2640 CLOSE 3
2650 CLOSE 7
2660 CLOSE 4
2670 CLOSE 5
2680 CLOSE 6
2687 REM
```

```
2688 REM   RETURN TO THE MENU
2689 REM
2690 GOTO 150
2700 CHAIN "SUCS"
2710 CHAIN "COMP"
2720 CHAIN "OUT"
2730 CHAIN "DATA"
2740 CHAIN "SHORT"
2750 CHAIN "PROC"
2755 REM
2756 REM   THIS SUBROUTINE EXTRACT THE DATA FROM THE FILES AND
2757 REM   PRINTS IT.  IT GOES THROUGH EACH LINKED LISTS.
2758 REM   CHECK FOR C(1,2 OR 3) TO GET THE RELEVANT DATA
2759 REM
2760 Y=FNA(N2)
2770 ON C GOTO 2780,3030,3190
2780 IF Y>20 THEN RETURN
2787 REM
2788 REM   CASE OF A REPETITIVE ACTIVITY: 3 LINKED LISTS TO CHECK
2789 REM
2790 Z=0
2800 INFILE ON (5,A) S1,C1,L1,N4,P1,S2,F2;L3,W
2810 IF L3<.1 THEN N7=0:C2=0: GOTO 2840
2820 INFILE ON (2,L3) N7,C2,D9
2830 L3=D9
2840 IF T1<0 THEN N8=0: GOTO 2870
2850 INFILE ON (1,T1) N8,D8
2860 T1=D8
2870 IF T5<0 THEN N9=0:L=0: GOTO 2900
2880 INFILE ON (2,T5) N9,L,D7
2890 T5=D7
2900 TO=N7+N8+N9
2910 IF Z>0 GOTO 2980
2917 REM
2918 REM   PRINT THE DATA
2919 REM
2920 PRINT ON (6)TAB(29),"I"
2930 PRINT ON (6) N2,TAB(9),D$;TAB(29),"I";TAB(33),S1;TAB(40),C1;
2940 PRINT ON (6)TAB(48),L1;TAB(57),N4;TAB(66),P1;TAB(75),S2;
2950 PRINT ON (6)TAB(84),F2;TAB(90),N7;C2;TAB(102),W;TAB(109),N8;
2960 PRINT ON (6)TAB(116),L;N9
2970 IF TO<=0 THEN RETURN ELSE 3010
2980 IF TO<=0 THEN RETURN
2990 PRINT ON (6)TAB(29),"I",TAB(90),N7;C2;TAB(109),N8;
3000 PRINT ON (6)TAB(116),L;N9
3010 Z=Z+1
3020 GOTO 2810
3030 IF Y<20 OR Y>80 THEN RETURN
3037 REM
3038 REM   CASE OF A NON-REPETITIVE ACTIVITY
3039 REM
3040 INFILE ON (5,A) D1,P1,W1,S
3050 Z=0
3057 REM
3058 REM   2 LINKED LISTS TO CHECK
3059 REM
3060 IF T1<0 THEN N8=0: GOTO 3090
3070 INFILE ON (1,T1) N8,D8
3080 T1=D8
3090 IF P1<.1 THEN P1=0 ELSE P1=1
3100 IF Z>0 GOTO 3150
3110 PRINT ON (6)TAB(29),"I"
3120 PRINT ON (6) N2,TAB(9),D$;TAB(29),"I",TAB(32),D1;
3130 PRINT ON (6)TAB(43);P1;TAB(56),W1;TAB(65),S;TAB(75),N8
3140 IF N8=0 THEN RETURN ELSE 3170
3150 IF N8=0 THEN RETURN
3160 PRINT ON (6)TAB(29),"I";TAB(75),N8
3170 Z=Z+1
3180 GOTO 3060
3190 IF Y<80 THEN RETURN
3197 REM
3198 REM   CASE OF A MILESTONE
3199 REM
3200 INFILE ON (5,A) D
3210 INFILE ON (4,D) Q,D1
```

```
3220 PRINT ON (6)TAB(29),'I'
3230 PRINT ON (6) N2,TAB(9),D$;TAB(29),'I',TAB(32),D1
3240 RETURN
3247 REM
3248 REM   END OF PROGRAM 'MAIN'
3249 REM
3250 END
```

```
1 REM
2 REM     PROGRAM 'NEW'
3 REM     CREATES AND INITIALIZE FILES FOR A NEW PROJECT
4 REM     POSSIBILITY OF COPYING A FILE (STANDARD NETWORK )
5 REM
6 REM     AUTHOR: JEAN B. LARAMEE
7 REM     CENTER FOR BUILDING STUDIES
8 REM     CONCORDIA UNIVERSITY
9 REM     FEBRUARY 1983
10 REM
11 REM    THIS PROGRAM IS CALLED BY THE PROGRAM 'MAIN' AND RETURNS
12 REM    TO IT AFTER ITS EXECUTION
13 REM
18 REM    DECLARE VARIABLES
19 REM
20 DIM F$(4),F1$(5),F2$(5),F3$(5),F4$(5),F5$(5)
30 DIM D$(20)
40 PRINT 'NAME OF FILE ? (4 CHAR.)'
50 INPUT F$
60 F1$=F$+'1'
70 F2$=F$+'2'
80 F3$=F$+'3'
90 F4$=F$+'4'
100 F5$=F$+'5'
107 REM
108 REM   CREATES THE 6 FILES REQUIRED
109 REM
110 CREATE F$,2,90
120 CREATE F1$,2,16
130 CREATE F2$,2,24
140 CREATE F3$,2,16
150 CREATE F4$,2,56
160 CREATE F5$,2,72
170 OPEN F$,2,0
180 OPEN F1$,3,0
190 OPEN F2$,4,0
197 REM
198 REM   POSSIBILITY OF COPYING
199 REM
200 PRINT 'COPY OF STANDARD NETWORK ? (1) YES OR (2) NO'
210 INPUT A9
220 ON A9 GOTO 230,470
227 REM
228 REM   THE STANDARD NETWORK IS IN FILE 'STAN'
229 REM
230 OPEN 'STAN',1,0
231 OPEN F5$,5,0
237 REM
238 REM COPY THE DATA
239 REM
240 INFILE ON (1,0) N,A
250 OUTFILE ON (2,0) N,A
251 OUTFILE ON (5,0)0
260 FOR I=1 TO 199
270   INFILE ON (1,I) N1
271   IF N1<0 THEN OUTFILE ON (2,I) N1: GOTO 281
272   INFILE ON (1,I) N1,N2,P0,T1,T2,P5,T5,T6,D$
280   OUTFILE ON (2,I) N1,N2,P0,T1,T2,P5,T5,T6,D$
281   OUTFILE ON (5,I)0
290 NEXT I
300 CLOSE 1
301 CLOSE 5
310 OPEN 'STAN1',1,0
320 OPEN 'STAN2',5,0
330 INFILE ON (1,0) S
340 OUTFILE ON (3,0) S
350 INFILE ON (5,0) P
360 OUTFILE ON (4,0) P
370 FOR I=1 TO 1000
380   INFILE ON (1,I) S1,S2
390   OUTFILE ON (3,I) S1,S2
400   INFILE ON (5,I) P5,T5,T6
410   OUTFILE ON (4,I) P5,T5,T6
420 NEXT I
430 PRINT 'NETWORK COPIED'
```

```
440 CLOSE 1
450 CLOSE 5
460 GOTO 590
467 REM
468 REM   INITIALIZE THE LINKED LIST OF AVAILABLE RECORDS
469 REM
470 OPEN F5$,5,0
480 FOR I=0 TO 999
490    OUTFILE ON (3,I)(I+1),(I+1)
500    OUTFILE ON (4,I)(I+1),0,(I+1)
510 NEXT I
520 OUTFILE ON (3,1000)0,-1
530 OUTFILE ON (4,1000)0,0,-1
537 REM
538 REM   INITIALIZE THE FILES CONTAINING ACTIVITY DATA
539 REM
540 FOR I=0 TO 199
550    OUTFILE ON (2,I)-1
560    OUTFILE ON (5,I)0
570 NEXT I
580 OUTFILE ON (2,0)0,0
590 CLOSE 2
591 OPEN F4$,2,0
592 FOR I=0 TO 1699
593    OUTFILE ON (2,I)-1,0,0,0,0,0,0
594 NEXT I
595 CLOSE 2
600 CLOSE 3
610 CLOSE 4
620 CLOSE 5
627 REM
628 REM   RETURN TO THE PROGRAM 'MAIN'
629 REM
630 CHAIN 'MAIN'
637 REM
638 REM   END OF PROGRAM 'NEW'
639 REM
640 END
```

```
1 REM
2 REM      PROGRAM 'CHPRE'
3 REM      CHANGES THE PREDECESSORS OF AN ACTIVITY
4 REM      POSSIBILITY OF ADDING OR DELETING A PREDECESSOR
5 REM
6 REM      AUTHOR: JEAN B. LARAMEE
7 REM      CENTER FOR BUILDING STUDIES
8 REM      CONCORDIA UNIVERSITY
9 REM      FEBRUARY 1983
10 REM
11 REM     THIS PROGRAM IS CALLED BY THE PROGRAM 'MAIN' AND
12 REM     RETURN TO IT AFTER ITS EXECUTION
13 REM
18 REM     DECLARES VARIABLES AND FUNCTIONS
19 REM
20 DIM F$(4),F1$(5),F2$(5),F3$(5),F4$(5),F5$(5)
30 DIM D$(20)
40 DEF FNM(X,Y)=INT((X/Y-INT(X/Y))*Y+.5)
50 DEF FNA(A)=INT(INT(A/100)-(INT(A/10000)*100)+.5)
60 DEF FNS(A)=INT(A/10000)
70 DEF FNL(A)=INT(A-(INT(A/100)*100)+.5)
80 PRINT 'NAME OF FILE ? (4 CHAR.)'
90 INPUT F$
100 F1$=F$+"1"
110 F2$=F$+"2"
120 F3$=F$+"3"
130 F4$=F$+"4"
140 F5$=F$+"5"
150 GOTO 240
157 REM
158 REM  SUBROUTINE THAT GETS THE RECORD NUMBER: HASHING ROUTINE
159 REM
160 H0=199
170 Q=INT(N9/H0)
180 H=FNM(N9,H0)
190 IF H=0 THEN H=FNM((Q+H),H0): GOTO 190
200 INFILE ON (7,H) T9
210 IF T9<0 THEN RETURN
220 IF T9=N9 THEN T9=0: RETURN
230 H=FNM((Q+H),H0): GOTO 190
237 REM
238 REM  START THE PROGRAM: OPEN THE FILES
239 REM
240 OPEN F1$,1,0
250 OPEN F2$,2,0
260 OPEN F$,7,0
267 REM
268 REM  ASK THE USER FOR THE OPTION HE WANTS
269 REM
270 PRINT '1) DELETE PRECEDENCE'
280 PRINT '2) ADD PRECEDENCE'
290 PRINT '3) QUIT'
300 INPUT A1
310 IF A1=3 GOTO 1320
320 PRINT 'ACTIVITY NO. AN PREDECESSOR NO.?'
330 INPUT N1,P7
340 N9=N1
350 GOSUB 160
360 H9=H
367 REM
368 REM  GET THE ACTIVITY DATA
369 REM
370 IF T9<0 THEN PRINT "ACTIVITY NOT FOUND": GOTO 270
380 INFILE ON (7,H) N2,H2,P0,T1,T2,P5,T5,T6,D$
390 Y=FNA(N1)
400 IF Y>20 THEN Z=1: GOTO 430
406 REM
407 REM  CASE OF A REPETITIVE ACTIVITY
408 REM  IDENTIFY IF THE PREDECESSOR IS TYPICAL OR NOT
409 REM
410 PRINT 'IS THE PREDECESSOR TYPICAL (1) OR NOT (2)'
420 INPUT Z
430 ON A1 GOTO 440,1170
437 REM
438 REM  CASE OF DELETING A PREDECESSOR
```

```
439 REM
440 ON Z GOSUB 470,820
450 IF A2=1 THEN PRINT "PREDECESSOR NOT FOUND": GOTO 270
460 IF A2=2 THEN PRINT "PRECEDENCE";P7;"IS DELETED": GOTO 270
465 REM
466 REM.  THIS SUBROUTINE LOOKS FOR THE PREDECESSOR
467 REM   AND DELETES IT FROM THE LINKED LIST
468 REM   IF IT DOESN'T FIND IT, IT SENDS AN ERROR MESSAGE: LINE 450
469 REM
470 IF T1<0 THEN A2=1: RETURN
480 T3=T1
490 INFILE ON (1,T3) P8,P9
500 N9=P8
510 Y1=FNA(N9)
515 REM
516 REM   CASE OF A NON-REPETITIVE ACTIVITY THAT HAS A REPETITIVE
517 REM   ACTIVITY AS A PREDECESSOR: FIND THE ACTIVITY NUMBER BY
518 REM   SUBSTRACTING THE LEVEL NUMBER
519 REM
520 IF Y1<20 THEN N9=N9-FNL(P8)
530 GOSUB 160
540 IF T9<0 THEN P8=-1
546 REM
547 REM   CHECK IF THIS PREDECESSOR IS THE ONE WE LOOK FOR
548 REM
550 IF P8=P7 THEN T1=P9: GOTO 750
556 REM
557 REM   THE PREDECESSOR WE LOOK FOR IS NOT THE FIRST OF THE LIST
558 REM
560 T1=T3
570 T3=P9
577 REM
578 REM   KEEP SCANNING THE LIST UNTIL WE FIND IT OR UNTIL THE END
579 REM
580 IF P9<0 THEN A2=1: RETURN
590 INFILE ON (1,T3) P8,P9
600 N9=P8
610 Y1=FNA(N9)
620 IF Y1<20 THEN N9=N9-FNL(P8)
630 GOSUB 160
640 IF T9<0 THEN P8=-1
650 IF P8=P7 THEN 660 ELSE 560
657 REM
658 REM   THE PREDECESSOR IS FOUND: ITS RECORD IS RET. TO THE POOL
659 REM
660 INFILE ON (1,0) P
670 OUTFILE ON (1,0) T3
680 OUTFILE ON (1,T3) T3,P
690 INFILE ON (1,T1) P8,Z
700 OUTFILE ON (1,T1) P8,P9
710 INFILE ON (7,H9) N2,H2,P0,T1,T2,P5,T5,T6,D$
717 REM
718 REM   DECREASE THE NUMBER OF PREDECESSORS BY ONE
719 REM
720 OUTFILE ON (7,H9) N2,H2,(P0-1),T1,T2,P5,T5,T6,D$
730 IF P7>0 THEN A2=2: RETURN
740 GOTO 570
747 REM
748 REM   CASE WHEN THE PREDECESSOR IS THE FIRST OF THE LIST
749 REM
750 INFILE ON (7,H9) N2,H2,P0
760 OUTFILE ON (7,H9) N2,H2,(P0-1),T1,T2,P5,T5,T6,D$
770 INFILE ON (1,0) P
780 OUTFILE ON (1,0) T3
790 OUTFILE ON (1,T3) T3,P
800 IF P7>0 THEN A2=2: RETURN
810 GOTO 470
817 REM
818 REM   CASE OF A NON-TYPICAL PREDECESSOR OF A REPETITIVE ACT.
819 REM
820 IF T5<0 THEN A2=1: RETURN
830 T3=T5
840 INFILE ON (2,T3) P8,L1,P9
850 N9=P8
860 Y1=FNA(N9)
```

```
867 REM
868 REM   CHECK IF THE PREDECESSOR IS A REPETITIVE ACTIVITY
869 REM
870 IF Y1<20 THEN N9=N9-FNL(P8)
880 GOSUB 160
890 IF T9<0 THEN P8=-1
900 IF P8=P7 THEN T5=P9: GOTO 1100
907 REM
908 REM   KEEP ON SCANNING THE LIST
909 REM
910 T5=T3
920 T3=P9
930 IF P9<0 THEN A2=1: RETURN
940 INFILE ON (2,T3) P8,L,P9
950 N9=P8
960 Y1=FNA(N9)
970 IF Y1<20 THEN N9=N9-FNL(P8)
980 GOSUB 160
990 IF T9<0 THEN P8=-1
997 REM
998 REM   CHECK IF WE HAVE FOUND THE PREDECESSOR
999 REM
1000 IF P8=P7 THEN 1010 ELSE 910
1007 REM
1008 REM   RETURN THE RECORD TO THE LIST OF AVAILABLE RECORDS
1009 REM
1010 INFILE ON (2,0) P
1020 OUTFILE ON (2,0) T3
1030 OUTFILE ON (2,T3) T3,0,P
1040 INFILE ON (2,T5) P8,L,Z
1050 OUTFILE ON (2,T5) P8,L,P9
1060 INFILE ON (7,H9) N2,H2,P0,T1,T2,P5,T5,T6,D$
1067 REM
1068 REM   ADJUST THE ACTIVITY DATA
1069 REM
1070 OUTFILE ON (7,H9) N2,H2,P0,T1,T2,(P5-1),T5,T6,D$
1080 IF P7>0 THEN A2=2: RETURN
1090 GOTO 920
1097 REM
1098 REM   CASE WHEN THE PREDECESSOR IS THE FIRST OF THE LIST
1099 REM
1100 INFILE ON (7,H9) N2,H2,P0,T1,T2,P5
1110 OUTFILE ON (7,H9) N2,H2,P0,T1,T2,(P5-1),T5,T6,D$
1120 INFILE ON (2,0) P
1130 OUTFILE ON (2,0) T3
1140 OUTFILE ON (2,T3) T3,0,P
1150 IF P7>0 THEN A2=2: RETURN
1160 GOTO 820
1167 REM
1168 REM   CASE OF ADDING A PREDECESSOR TO THE LIST
1169 REM
1170 ON Z GOTO 1180,1240
1177 REM
1178 REM   CASE OF A TYPICAL PREDECESSOR OR ONE OF A NON-REPET. ACT.
1179 REM
1180 INFILE ON (1,0) P
1190 INFILE ON (1,P) P8,P9
1200 OUTFILE ON (1,0) P9
1210 OUTFILE ON (1,P) P7,T1
1217 REM
1218 REM   ADD THE PREDECESSOR TO THE LIST AND ADJUST ACTIVITY DATA
1219 REM
1220 OUTFILE ON (7,H9) N2,H2,(P0+1),P,T2,P5,T5,T6,D$
1230 GOTO 270
1237 REM
1238 REM  CASE OF A NON-TYPICAL PREDECESSOR
1239 REM
1240 INFILE ON (2,0) P
1250 INFILE ON (2,P) P8,L,P9
1260 OUTFILE ON (2,0) P9
1267 REM
1268 REM   ASK FOR THE LEVEL IT PRECEDES
1269 REM
1270 PRINT 'FOR WHICH LEVEL'
1280 INPUT L1
```

```
1290 OUTFILE ON (2,P) P7,L1,T5
1297 REM
1298 REM   ADD THE PREDECESSOR TO THE LIST AND ADJUST THE DATA
1299 REM
1300 OUTFILE ON (7,H9) N2,H2,P0,T1,T2,(P5+1),P,T6,D$
1307 REM
1308 REM   RETURN TO THE TOP OF THE PROGRAM
1309 REM
1310 GOTO 270
1320 CLOSE 1
1330 CLOSE 7
1337 REM
1338 REM   RETURN TO THE PROGRAM "MAIN"
1339 REM
1340 CHAIN "MAIN"
1347 REM
1348 REM   END OF PROGRAM 'CHPRE"
1349 REM
1350 END
```

```
1 REM
2 REM          PROGRAM 'SUCS'
3 REM          CHECKS IF THE PREDECESSORS NUMBERS CORRESPOND TO
4 REM          ACTIVITY NUMBERS; CREATE THE LINKED LIST OF SUC-
5 REM          CESSORS; DETERMINE THE SEQUENTIAL STEP ORDER OF
6 REM          THE ACTIVITIES; SORT THE ACTIVITY BY THEIR NUM-
7 REM          BERS.
8 REM
9 REM          AUTHOR: JEAN B. LARAMEE
10 REM         CENTER FOR BUILDING STUDIES
11 REM         CONCORDIA UNIVERSITY
12 REM         FEBRUARY 1983
13 REM
14 REM         THIS PROGRAM IS CALLED BY THE PROGRAM 'MAIN' AND
15 REM         RETURNS TO IT AFTER ITS EXECUTION
16 REM
17 REM         DECLARES VARIABLES AND FUNCTIONS
18 REM
20 DIM F$(4),F1$(5),F2$(5),F3$(5),F4$(5),F5$(5)
30 DIM D$(20)
40 DEF FNM(X,Y)=INT((X/Y-INT(X/Y))*Y+.5)
50 DEF FNA(A)=INT(INT(A/100)-(INT(A/10000)*100)+.5)
60 DEF FNS(A)=INT(A/10000)
70 DEF FNL(A)=INT(A-(INT(A/100)*100)+.5)
80 PRINT 'NAME OF FILE ? (4 CHAR.)'
90 INPUT F$
100 F1$=F$+'1'
110 F2$=F$+'2'
120 F3$=F$+'3'
130 F4$=F$+'4'
140 F5$=F$+'5'
147 REM
148 REM    THE EXECUTION OF THE PROGRAM STARTS AT LINE 940
149 REM
150 GOTO 940
157 REM
158 REM    SUBROUTINE THAT GETS A RECORD NUMBER : HASHING ROUTINE
159 REM
160 H0=199
170 Q=INT(N9/H0)
180 H=FNM(N9,H0)
190 IF H=0 THEN H=FNM((Q+H),H0): GOTO 190
200 INFILE ON (7,H) T9
210 IF T9<0 THEN RETURN
220 IF T9=N9 THEN T9=0: RETURN
230 H=FNM((Q+H),H0): GOTO 190
234 REM
235 REM    THIS SUBROUTINE CHECKS IF THE PREDECESSORS NUMBERS
236 REM    EXIST: IF THEY DON'T THEY ARE DELETED.
237 REM    IT IS EXACTLY SIMILAR TO THE SUBROUTINE IN PROGRAM
238 REM    'CHPRE' THAT LOOKS FOR A PREDECESSOR (THIS TIME P7=-1)
239 REM
240 IF T1<0 THEN A2=1: RETURN
250 T3=T1
260 INFILE ON (1,T3) P8,P9
270 N9=P8
280 Y1=FNA(N9)
290 IF Y1<20 THEN N9=N9-FNL(P8)
300 GOSUB 160
307 REM
308 REM   CASE WHEN A PREDECESSOR DOESN'T EXIST.
309 REM
310 IF T9<0 THEN P8=-1
317 REM
318 REM    IT IS DELETED (LINE 520)
319 REM
320 IF P8=P7 THEN T1=P9: GOTO 520
330 T1=T3
340 T3=P9
347 REM
348 REM    THE END OF THE LIST IS REACHED: RETURN
349 REM
350 IF P9<0 THEN A2=1: RETURN
360 INFILE ON (1,T3) P8,P9
370 N9=P8
```

```
380 Y1=FNA(N9)
390 IF Y1<20  THEN N9=N9-FNL(P8)
400 GOSUB 160
410 IF T9<0  THEN P8=-1
417 REM
418 REM   A PREDECESSOR DOESN'T EXIST: IT IS DELETED.
419 REM
420 IF P8=P7  THEN 430  ELSE 330
430 INFILE ON  (1,0) P
440 OUTFILE ON  (1,0)  T3
450 OUTFILE ON  (1,T3)  T3,P
460 INFILE ON  (1,T1)  P8,Z
470 OUTFILE ON  (1,T1)  P8,P9
480 INFILE ON  (7,H9)  N2,H2,P0,T1,T2,P5,T5,T6,D$
490 OUTFILE ON  (7,H9)  N2,H2,(P0-1),T1,T2,P5,T5,T6,D$
500 IF P7>0  THEN A2=2:  RETURN
510 GOTO 340
520 INFILE ON  (7,H9)  N2,H2,P0
530 OUTFILE ON  (7,H9)  N2,H2,(P0-1),T1,T2,P5,T5,T6,D$
540 INFILE ON  (1,0)  P
550 OUTFILE ON  (1,0)  T3
560 OUTFILE ON  (1,T3)  T3,P
570 IF P7>0  THEN A2=2:  RETURN
577 REM
578 REM   EVEN IF A PRED. IS DELETED, HAVE TO REACH END OF LIST
579 REM
580 GOTO 240
587 REM
588 REM   CHECK THE NON-TYPICAL  PREDECESSORS
589 REM
590 IF T5<0  THEN A2=1:  RETURN
600 T3=T5
610 INFILE ON  (2,T3)  P8,L1,P9
620 N9=P8
630 Y1=FNA(N9)
640 IF Y1<20  THEN N9=N9-FNL(P8)
650 GOSUB 160
660 IF T9<0  THEN P8=-1
670 IF P8=P7  THEN T5=P9: GOTO 870
680 T5=T3
690 T3=P9
700 IF P9<0  THEN A2=1:  RETURN
710 INFILE ON  (2,T3)  P8,L,P9
720 N9=P8
730 Y1=FNA(N9)
740 IF Y1<20  THEN N9=N9-FNL(P8)
750 GOSUB 160
760 IF T9<0  THEN P8=-1
770 IF P8=P7  THEN 780  ELSE 680
780 INFILE ON  (2,0)  P
790 OUTFILE ON  (2,0)  T3
800 OUTFILE ON  (2,T3)  T3,0,P
810 INFILE ON  (2,T5)  P8,L,Z
820 OUTFILE ON  (2,T5)  P8,L,P9
830 INFILE ON  (7,H9)  N2,H2,P0,T1,T2,P5,T5,T6,D$
840 OUTFILE ON  (7,H9)  N2,H2,P0,T1,T2,(P5-1),T5,T6,D$
850 IF P7>0  THEN A2=2:  RETURN
860 GOTO 690
870 INFILE ON  (7,H9)  N2,H2,P0,T1,T2,P5
880 OUTFILE ON  (7,H9)  N2,H2,P0,T1,T2,(P5-1),T5,T6,D$
890 INFILE ON  (2,0)  P
900 OUTFILE ON  (2,0)  T3
910 OUTFILE ON  (2,T3)  T3,0,P
920 IF P7>0  THEN A2=2:  RETURN
930 GOTO 590
936 REM
937 REM   START OF THE PROGRAM "SUCS"
938 REM   OPEN THE FILES.
939 REM
940 OPEN F$,7,0
950 OPEN F1$,1,0
960 OPEN F2$,2,0
970 INFILE ON  (7,0)  N,A
980 INFILE ON  (7,A)  N2,H2,P0,T1,T2,P5,T5,T6,D$
990 H9=A
```

```
1000 P7=-1
1007 REM
1008 REM   CHECK IF PREDECESSORS EXIST
1009 REM
1010 IF P0>0 THEN GOSUB 240
1020 IF P5>0 THEN GOSUB 590
1030 INFILE ON (7,A) N1,N2,P0,T1,T2,P5,T5,T6,D$
1036 REM
1037 REM   ELIMINATE THE PREVIOUS LISTS OF SUCCESSORS
1038 REM   RETURN THE RECORDS TO THE LIST OF AVAILABLE RECORDS
1039 REM
1040 IF T2<0 GOTO 1110
1050 INFILE ON (1,0) S
1060 OUTFILE ON (1,0) T2
1070 INFILE ON (1,T2) S8,S9
1080 IF S9>0 THEN T2=S9: GOTO 1070
1090 OUTFILE ON (1,T2) S8,S
1100 OUTFILE ON (7,A) N1,N2,P0,T1,-1,P5,T5,T6,D$
1107 REM
1108 REM   NON-TYPICAL SUCCESOR
1109 REM
1110 IF T6<0 GOTO 1180
1120 INFILE ON (2,0) S
1130 OUTFILE ON (2,0) T6
1140 INFILE ON (2,T6) S8,L,S9
1150 IF S9>0 THEN T6=S9: GOTO 1140
1160 OUTFILE ON (2,T6) T6,0,S
1170 OUTFILE ON (7,A) N1,N2,P0,T1,-1,P5,T5,-1,D$
1176 REM
1177 REM   NEXT ACTIVITY IN THE ORDER OF INPUT
1178 REM   DO THE SAME THING OVER: LINE 980
1179 REM
1180 IF N2>0 THEN A=N2: GOTO 980
1187 REM
1188 REM   BUILD THE LIST OF SUCC. BY LOOKING AT EACH ACT.'S PRED.
1189 REM
1190 INFILE ON (7,0) N,A
1200 IF A<=0 GOTO 1810
1210 INFILE ON (7,A) N1,N2,P0,T1,T2,P5,T5,T6
1220 Y=FNA(N1)
1230 IF Y>20 GOTO 1390
1237 REM
1238 REM   LOOK AT THE TYPICAL PREDECESSORS
1239 REM
1240 IF T1<0 GOTO 1300
1250 INFILE ON (1,T1) N8,P8
1260 L1=0
1270 GOSUB 1600
1280 T1=P8
1290 GOTO 1240
1297 REM
1298 REM   LOOK AT THE NON-TYPICAL PREDECESSORS
1299 REM
1300 IF T5<0 GOTO 1530
1310 INFILE ON (2,T5) N8,L1,P8
1320 Y1=FNA(N8)
1330 IF Y1>20 GOTO 1370
1340 GOSUB 1690
1350 T5=P8
1360 GOTO 1300
1370 GOSUB 1600
1380 GOTO 1350
1387 REM
1388 REM   LOOK AT PREDECESSORS OF NON-REPETITIVE ACTIVITIES
1389 REM
1390 IF T1<0 GOTO 1530
1400 INFILE ON (1,T1) N8,P8
1410 Y1=FNA(N8)
1420 IF Y1>20 GOTO 1470
1430 L1=0
1440 GOSUB 1690
1450 T1=P8
1460 GOTO 1390
1470 L1=0
1480 GOSUB 1600
```

```
1490 GOTO 1450
1530 INFILE ON (7,A) N1,N2
1540 A=N2
1547 REM
1548 REM   GO GET THE NEXT ACTIVITY
1549 REM
1550 GOTO 1200
1596 REM
1597 REM.  THIS SUBROUTINE ADDS A SUCCESSOR TO ONE ACT. (2 FIELDS)
1598 REM
1600 N9=N8
1610 GOSUB 160
1620 INFILE ON (1,0) S
1630 INFILE ON (1,S) S9,S8
1640 OUTFILE ON (1,0) S8
1650 INFILE ON (7,H) X1,X2,X3,X4,T2,X5,X6,X7,D$
1656 REM
1657 REM   THE LEVEL HAS TO BE CORRECT...
1658 REM
1660 OUTFILE ON (1,S)(N1+L1),T2
1670 OUTFILE ON (7,H) X1,X2,X3,X4,S,X5,X6,X7,D$
1680 RETURN
1686 REM
1687 REM   THIS SUBROUTINE ADDS A NON-TYPICAL SUCCESSOR TO A
1688 REM   REPETITIVE ACTIVITY.
1689 REM
1690 N9=N8-FNL(N8)
1700 GOSUB 160
1710 INFILE ON (2,0) S
1720 INFILE ON (2,S) S9,L0,S8
1730 OUTFILE ON (2,0) S8
1740 INFILE ON (7,H) X1,X2,X3,X4,X5,X6,X7,T6,D$
1745 REM
1746 REM   THE LEVEL WHICH IS SUCCEEDED BY THIS "SUCCESSOR" IS THE
1747 REM   LEVEL WHICH WAS INDICATED IN THE PREDECESSOR...
1748 REM
1750 OUTFILE ON (2,S)(N1+L1),FNL(N8),T6
1760 OUTFILE ON (7,H) X1,X2,X3,X4,X5,X6,X7,S,D$
1770 RETURN
1799 REM
1800 REM   START PUTTING THE ACTIVITIES IN SEQUENTIAL STEP ORDER
1801 REM
1810 OPEN F3$,3,0
1820 INFILE ON (7,0) N,A
1830 OUTFILE ON (3,0) N
1840 DIM C(200),K(N),Q(N)
1850 I=1
1860 IF A<=0 GOTO 1930
1870 INFILE ON (7,A) N1,N2,P0,T1,T2,P5,T5,T6
1875 REM
1876 REM   K(I) CONTAINS THE Ith RECORD NUMBER IN THE ORDER OF INPUT
1877 REM
1880 K(I)=A
1886 REM
1887 REM   C(I) CONTAINS THE NUMBER OF PREDECESSORS OF ACTIVITY
1888 REM   STORED IN RECORD I.
1889 REM
1890 C(A)=P0+P5
1900 A=N2
1910 I=I+1
1920 GOTO 1860
1930 I=0
1940 FOR J=1 TO N
1946   REM
1947   REM   LOOK FOR ACTIVITIES THAT DO NOT HAVE ANY PREDECESSOR
1948   REM   THEY WILL BE THE FIRST IN THE SEQUENTIAL STEP ORDER
1949   REM
1950   IF C(K(J))>0 GOTO 1980
1960   I=I+1
1966   REM
1967   REM   Q(I) CONTAINS THE RECORD NUMBER OF THE Ith ACTIVITY IN
1968   REM   THE SEQUENTIAL STEP ORDER
1969   REM
1970   Q(I)=K(J)
1980 NEXT J
```

```
1986 REM
1987 REM   O CONTAINS THE SEQUENTIAL STEP NUMBER
1988 REM
1990 O=1
2000 PRINT 'START CALCULATION'
2010 FOR J=1 TO N
2016   REM
2017   REM   FOR EACH ACTIVITY FROM Q, GET THE SUCCESSORS AND
2018   REM   DECREASE THEIR COUNTER OF PREDECESSORS (C) BY ONE.
2019   REM
2020   INFILE ON (7,Q(O)) N1,N2,P0,T1,T2,P5,T5,T6
2030   IF T2<0 GOTO 2150
2040   INFILE ON (1,T2) S8,S9
2050   T2=S9
2060   Y=FNA(S8)
2070   IF Y>20 THEN N9=S8 ELSE N9=S8-FNL(S8)
2080   GOSUB 2510
2090   S8=H
2100   C(S8)=C(S8)-1
2110   IF C(S8)>=1 GOTO 2030
2116   REM
2117   REM   WHEN C=0, THAT ACT. IS THE NEXT IN THE SEQUENTIAL STEP
2118   REM   ORDER (I.E. ALL ITS PREDECESSORS HAVE BEEN REFERRED TO)
2119   REM
2120   I=I+1
2130   Q(I)=S8
2140   GOTO 2030
2146   REM
2147   REM   NOW LOOK AT THE NON-TYPICAL SUCCESSORS, IF ANY.
2148   REM
2150   IF T6<0 GOTO 2270
2160   INFILE ON (2,T6) S8,L,S9
2170   Y=FNA(S8)
2180   IF Y>20 THEN N9=S8 ELSE N9=S8-FNL(S8)
2190   GOSUB 2510
2200   S8=H
2210   T6=S9
2217   REM
2218   REM   DECREASE C THE SAME WAY AND CHECK IF IT IS ZERO.
2219   REM
2220   C(S8)=C(S8)-1
2230   IF C(S8)>=1 GOTO 2150
2240   I=I+1
2250   Q(I)=S8
2260   GOTO 2150
2267   REM
2268   REM   NO MORE SUCCESSORS FOR THAT ACTIVITY: NEXT ONE.
2269   REM
2270   O=O+1
2280 NEXT J
2287 REM
2288 REM   ACT. ARE IN SEQUENTIAL STEP ORDER: TRANSFER TO THE FILE
2289 REM
2290 FOR J=1 TO N
2300   OUTFILE ON (3,J) Q(J),Q(J)
2310 NEXT J
2320 PRINT 'START SORTING'
2330 I9=0
2337 REM
2338 REM   USE OF A BUBBLE SORT ALGORYTHM TO SORT THE ACT. NUMBERS
2339 REM
2340 FOR I=1 TO N-1
2350   INFILE ON (3,I) Z1,O1
2360   INFILE ON (3,I+1) Z2,O2
2370   INFILE ON (7,O1) N1
2380   INFILE ON (7,O2) N2
2390   IF N1<N2 GOTO 2430
2400   OUTFILE ON (3,I) Z1,O2
2410   OUTFILE ON (3,I+1) Z2,O1
2420   I9=1
2430 NEXT I
2440 N=N-1
2450 IF I9=1 GOTO 2330
2460 CLOSE 1
2470 CLOSE 2
```

```
2480 CLOSE 3
2490 CLOSE 7
2497 REM
2498 REM   RETURN TO THE PROGRAM 'MAIN'
2499 REM
2500 CHAIN 'MAIN'
2507 REM
2508 REM   SUBROUTINE THAT GETS A RECORD NUMBER: HASHING ROUTINE
2509 REM
2510 H0=199
2511 IF N9=0 THEN RETURN
2520 Q=INT(N9/H0)
2530 H=FNM(N9,H0)
2540 IF H=0 THEN H=FNM((Q+H),H0): GOTO 2540
2550 INFILE ON (7,H) T9
2560 IF T9<0 THEN RETURN
2570 IF T9=N9 THEN T9=0: RETURN
2580 H=FNM((Q+H),H0): GOTO 2540
2587 REM
2588 REM   END OF THE PROGRAM 'SUCS'
2589 REM
2590 END
```

```
1 REM
2 REM         PROGRAM 'COMP'
3 REM         AUTHOR: JEAN B. LARAMEE
4 REM         CENTER FOR BUILDING STUDIES
5 REM         CONCORDIA UNIVERSITY
6 REM         FEBRUARY 1983
7 REM
8 REM         THIS PROGRAM PERFORMS THE FORWARD AND BACKWARD
9 REM         PASS TO CALCULATE THE START AND FINISH DATES
10 REM        OF ALL THE ACTIVITIES.
11 REM
12 REM        IT IS CALLED BY THE PROGRAM 'MAIN' AND RETURNS
13 REM        TO IT AFTER ITS EXECUTION.
14 REM
18 REM        DECLARE VARIABLES AND FUNCTIONS
19 REM
20 DIM F$(4),F1$(5),F2$(5),F3$(5),F4$(5),F5$(5)
30 DIM F(40),S(40),P(40),W(13)
40 DIM D$(20)
50 DEF FNM(X,Y)=INT((X/Y-INT(X/Y))*Y+.5)
60 DEF FNA(A)=INT(INT(A/100)-(INT(A/10000)*100)+.5)
70 DEF FNL(A)=INT(A-(INT(A/100)*100)+.5)
80 PRINT 'NAME OF FILE ? (4 CHAR.)'
90 INPUT F$
100 F1$=F$+'1'
110 F2$=F$+'2'
120 F3$=F$+'3'
130 F4$=F$+'4'
140 F5$=F$+'5'
150 OPEN F$,7,0
160 OPEN F1$,1,0
170 OPEN F2$,2,0
180 OPEN F3$,3,0
190 OPEN F4$,4,0
200 OPEN F5$,5,0
210 OPEN 'CAL',6,0
217 REM
218 REM   ASK THE USER IF HE NEEDS TO RESTRUCTURE THE FILE
219 REM
220 PRINT 'REARRANGE FILE ? YES (1) OR NO (2) '
230 INPUT A
240 ON A GOTO 250,610
246 REM
247 REM   SCAN ALL THE RECORDS AND SEE IF THEY ARE OCCUPIED
248 REM   BY AN EXISTING ACTIVITY.  IF NOT PUT '1' AS THE KEY.
249 REM
250 FOR I=1 TO 1699
260   INFILE ON (4,I) A
270   IF A<>1 GOTO 350
280   Y=FNA(A)
290   IF Y>20 THEN A9=A ELSE A9=A-FNL(A)
300   GOSUB 2950
310   IF T9<0 THEN OUTFILE ON (4,I)1,0,0,0,0,0,0: GOTO 350
320   IF Y>20 GOTO 350
330   INFILE ON (5,H) S1,C1,L1
340   IF FNL(A)<S1 OR FNL(A)>L1 THEN OUTFILE ON (4,I)1,0,0,0,0,0,0
350 NEXT I
360 INFILE ON (7,0) N
365 REM
366 REM   FOR EACH ACTIVTY, SEE IF A DELETED DATE RECORD
367 REM   WAS ON THE PATH TO THAT RECORD.  IF SO, EXCHANGE
368 REM   THE RECORDS.
369 REM
370 FOR I=1 TO N
380   INFILE ON (3,I) A
390   INFILE ON (7,A) N1
400   Y=FNA(N1)
410   IF Y<20 THEN 420 ELSE 480
420   INFILE ON (5,A) S1,C1,L1
430   FOR J=S1 TO L1
440     R9=N1+J
450     GOSUB 520
460   NEXT J
470   GOTO 500
480   R9=N1
```

```
490   GOSUB 520
500 NEXT I
510 GOTO 610
515 REM
516 REM   THIS SUBROUTINE CHECKS IF A DELETED RECORD WAS ON
517 REM   THE PATH TO AN ACTIVITY RECORD.  IF SO, IT CHANGES
518 REM   THE ADDRESS OF THAT ACTIVITY DATA.
519 REM
520 GOSUB 3390
530 R1=H
540 GOSUB 3030
550 R2=H
560 IF R1=R2 THEN RETURN
570 INFILE ON (4,R2) Z,Z1,Z2,Z3,Z4,Z5,Z6
580 OUTFILE ON (4,R1) Z,Z1,Z2,Z3,Z4,Z5,Z6
590 OUTFILE ON (4,R2)1,0,0,0,0,0,0
600 RETURN
610 INFILE ON (3,0) N
617 REM
618 REM   START OF THE FORWARD PASS CALCULATIONS
619 REM
620 F2=0:S0=1
630 FOR I1=1 TO N
631   REM
632   REM   GET THE NEXT ACTIVITY IN THE SEQUENTIAL STEP ORDER
633   REM
640   INFILE ON (3,I1) A
650   INFILE ON (7,A) N1,N2,P0,T1,T2,P5,T5,T6
660   Y=FNA(N1)
661   REM
662   REM   CHECK THE TYPE OF ACTIVITY
663   REM
670   IF Y>80 GOTO 2010
680   IF Y>20 GOTO 1610
681   REM
682   REM   CASE OF A REPETITIVE ACTIVITY
683   REM
690   INFILE ON (5,A) L1,C1,E1,N1,P1,S1,F1,W0,W8
691   REM
692   REM   CHECK IF ACTIVITY IS COMPLETED
693   REM
700   IF C1>E1 GOTO 2050
701   REM
702   REM   FIND THE PRODUCTION RATE FOR EACH FLOOR
703   REM
710   FOR I=L1 TO E1
720     P(I)=P1
730   NEXT I
740   IF W0<0 GOTO 790
750   INFILE ON (2,W0) W1,W2,W3
760   W0=W3
770   P(W1)=100*P1/W2
780   GOTO 740
781   REM
782   REM   CALCULATE START AND FINISH DATES WITH ARBITRARY START
783   REM   DATE OF S0, WHICH IS EQUAL TO 1 IN THIS CASE.
784   REM
790   S(L1)=S0
800   FOR I=L1 TO E1 STEP N1
810     FOR J=0 TO N1-1
820       F(I+J)=S(I+J)+P(I+J)-1
830       S(I+J+1)=S(I+J)+S1
840     NEXT J
850     S(I+N1)=F(I)+F1+1
860   NEXT I
870   F9=0
871   REM
872   REM   CHECK IF THE ACTIVITY HAS PREDECESSORS
873   REM
880   IF T1<0 AND T5<0 THEN X=1 ELSE X=1000
881   REM
882   REM   LOOK AT THE LIST OF TYPICAL PREDECESSORS
883   REM
890   IF T1<0 GOTO 1060
900   INFILE ON (1,T1) P9,P8
```

```
910    T1=P8
920    A9=P9
930    GOSUB 2950
931    REM
932    REM   FIND THE LEVELS COMMON TO BOTH ACTIVITIES
933    REM
940    INFILE ON (5,H) L2,C2,E2
950    IF C1<L2 THEN C3=L2 ELSE C3=C1
960    IF E2<E1 THEN E3=E2 ELSE E3=E1
961    REM
962    REM   COMPARE EACH COMMON LEVELS AND FIND THE SMALLEST DIFF.
963    REM
970    FOR J=C3 TO E3
980      R9=P9+J
990      GOSUB 3030
1000     R1=H
1010     INFILE ON (4,R1) Z,S1,F1,S4,F4,S3,F3
1020     IF J<C2 THEN X1=S(J)-F3 ELSE X1=S(J)-F1
1030     IF X1<X THEN X=X1
1040   NEXT J
1041   REM
1042   REM   GO TO THE NEXT PREDECESSOR IN THE LIST
1043   REM
1050   GOTO 890
1051   REM
1052   REM   CHECK THE LIST OF NON-TYPICAL PREDECESSORS
1053   REM
1060   IF T5<0 GOTO 1240
1070   INFILE ON (2,T5) P9,L9,P8
1080   T5=P8
1081   REM
1082   REM   CHECK IF THE LEVEL SPECIFIED IS BELOW THE CURRENT LEV.
1083   REM
1090   IF L9<C1 GOTO 1060
1100   R9=P9
1110   GOSUB 3030
1120   R1=H
1130   Y1=FNA(P9)
1131   REM
1132   REM   CHECK THE TYPE OF ACTIVITY OF THE PREDECESSOR
1133   REM
1140   IF Y1<20 THEN A9=P9-FNL(P9) ELSE A9=P9
1150   GOSUB 2950
1160   INFILE ON (4,R1) Z,S1,F1,S4,F4,S3,F3
1170   INFILE ON (5,H) Z1,Z2,Z3,Z4
1171   REM
1172   REM   CHECK IF THE PREDECESSOR IS COMPLETED
1173   REM
1180   IF Y1<20 THEN IF FNL(P9)<Z2 THEN F5=F3 ELSE F5=F1
1190   IF Y1>80 THEN F5=F1
1200   IF Y1>20 AND Y1<80 THEN IF Z4=1 THEN F5=F3 ELSE F5=F1
1201   REM
1202   REM   CALCULATE THE DIFFERENCE AND COMPARE IT WITH THE
1203   REM   SMALLEST ONE COMPUTED SO FAR
1204   REM
1210   X1=S(L9)-F5
1220   IF X1<X THEN X=X1
1221   REM
1222   REM   GO GET THE NEXT NON-TYPICAL PREDECESSOR IN THE LIST
1223   REM
1230   GOTO 1060
1231   REM
1232   REM   SEE IF THAT REPETITIVE ACTIVITY HAS SOME LEVELS
1233   REM   COMPLETED.  IF SO, FIND THE DIFFERENCE.
1234   REM
1240   IF L1=C1 GOTO 1440
1250   INFILE ON (7,A) A1
1260   INFILE ON (5,A) L1,C1,E1,N1,P1,S1,F1
1270   X0=FNM(C1-1,N1)
1280   IF X0=0 THEN 1290 ELSE 1340
1290   R9=A1+C1-N1
1300   GOSUB 3030
1310   INFILE ON (4,H) Z,Z1,Z2,Z3,Z4,S3,F3
1320   X1=S(C1)-F3-F1
1330   GOTO 1430
```

```
1340    R9=A1+C1-1
1350    GOSUB 3030
1360    INFILE ON (4,H) Z,Z1,Z2,Z3,Z4,S3,F3
1370    X1=S(C1)-S3-S1
1380    R9=A1+C1-X0
1390    GOSUB 3030
1400    INFILE ON (4,H) Z,Z1,Z2,Z3,Z4,S3,F3
1410    X2=S(C1+N1-X0)-F3-F1
1420    IF X2<X1 THEN X1=X2
1430    IF X1<X THEN X=X1
1431    REM
1432    REM   ADJUST THE ARBITRARY DATES BY SUBSTRACTING THE DIFF.
1433    REM
1440    INFILE ON (7,A) A1
1450    FOR J=L1 TO E1
1460      S(J)=S(J)-X+1
1470      F(J)=F(J)-X+1
1480    NEXT J
1481    REM
1482    REM   LOOK IF THE ACTIVITY HAS TO BE ADJUSTED FOR WEATHER
1483    REM
1490    IF F9<=1 AND W8>0 GOTO 3110
1491    REM
1492    REM   STORE THE RESULTS IN THE FILE OF DATES
1493    REM
1500    FOR J=C1 TO E1
1510      R9=A1+J
1520      GOSUB 3030
1530      R=H
1540      INFILE ON (4,R) Z,S1,F1,S4,F4,S3,F3
1541      REM
1542      REM   ROUND OFF THE VALUES OF S1 AND F1
1543      REM
1550      S1=INT(S(J))
1560      F1=INT(F(J))
1570      OUTFILE ON (4,R) R9,S1,F1,S4,F4,S3,F3
1580      F8=F1
1590    NEXT J
1591    REM
1592    REM   CALCULATE NEXT ACTIVITY
1593    REM
1600    GOTO 2050
1601    REM
1602    REM   CASE OF A NON-REPETITIVE ACTIVITY
1603    REM   INITIALIZE THE START AND FINISH VARIABLES
1604    REM
1610    S2=0:F2=0
1620    INFILE ON (5,A) Z1,Z2,Z3,Z4
1621    REM
1622    REM   CHECK THE STATUS OF THE ACTIVITY (COMPLETED ?)
1623    REM
1630    IF Z4>0 GOTO 2050
1631    REM
1632    REM   COMPARE WITH THE PREDECESSORS
1633    REM
1640    IF T1<0 GOTO 2050
1650    INFILE ON (1,T1) P9,P8
1660    Y1=FNA(P9)
1670    IF Y1<20 THEN A9=P9-FNL(P9) ELSE A9=P9
1680    T1=P8
1690    R9=P9
1700    GOSUB 3030
1710    R1=H
1711    REM
1712    REM   EXAMINE THE DATES OF THE PREDECESSOR
1713    REM
1720    INFILE ON (4,R1) Z,S1,F1,S4,F4,S3,F3
1730    GOSUB 2950
1740    INFILE ON (5,H) Z1,Z2,Z3,Z4
1741    REM
1742    REM   CHECK THE STATUS OF THE PREDECESSOR
1743    REM
1750    IF Y1<20 THEN IF FNL(P9)<Z2 THEN F5=F3 ELSE F5=F1
1760    IF Y1>80 THEN F5=F1
1770    IF Y1>20 AND Y1<80 THEN IF Z4=1 THEN F5=F3 ELSE F5=F1
```

```
1780   INFILE ON (5,A) D1,D2,W3
1781   REM
1782   REM   CHECK IF THE ACTIVITY IS WEATHER DEPENDANT
1783   REM
1790   IF W3>.1 THEN GOSUB 3120 ELSE 1910
1800   IF F5=0 THEN INFILE ON (6,1) Z,W ELSE INFILE ON (6,F5) Z,W
1801   REM
1802   REM   FIND THE MONTH OF THE YEAR IN WHICH IT STARTS
1803   REM   AND THE NUMBER OF MONTHS OVER WHICH IT IS EXECUTED
1804   REM
1810   M0=FNA(W)
1820   K=INT(D1/20)+1
1830   K2=0
1840   FOR K1=0 TO K-1
1850     M1=M0+K1
1860     IF M1=13 THEN M1=1 ELSE M1=FNM(M1,13)
1870     K2=K2+W(M1)
1880   NEXT K1
1881   REM
1882   REM   EVALUATE THE WEATHER FACTOR OVER THE DURATION
1883   REM
1890   W=K2/K
1900   D1=INT(100*D1/W)
1901   REM
1902   REM   SEE IF THE PREDECESSOR RULES
1903   REM
1910   IF S2<(F5+1) THEN S2=F5+1
1920   IF F2<(S2+D1-1) THEN F2=S2+D1-1
1921   REM
1922   REM   PUT THE RESULTS IN THE FILE OF DATES
1923   REM
1930   INFILE ON (7,A) N1
1940   R9=N1
1950   GOSUB 3030
1960   R2=H
1970   INFILE ON (4,R2) Z,S1,F1,S4,F4,S3,F3
1980   OUTFILE ON (4,R2) R9,S2,F2,S4,F4,S3,F3
1990   F9=F2
1991   REM
1992   REM   CHECK THE NEXT PREDECESSOR
1993   REM
2000   GOTO 1640
2001   REM
2002   REM   CASE OF A MILESTONE
2003   REM
2010   INFILE ON (5,A) D1
2020   INFILE ON (7,A) R9
2030   GOSUB 3030
2031   REM
2032   REM   PUT ON FILE THE DATE-1 TO SATISFY END OF DAY ASSUMPT.
2033   REM
2040   OUTFILE ON (4,H) R9,D1,(D1-1)
2041   REM
2042   REM   END OF LOOP: GO CALCULATE THE NEXT ACTIVITY
2043   REM
2050 NEXT I1
2051 REM
2052 REM   FIND THE LATEST DATE OF THE PROJECT AND START
2053 REM   THE BACKWARD PASS CALCULATIONS.
2054 REM
2060 IF F9<F8 THEN S0=F8 ELSE S0=F9
2070 FOR I1=N TO 1 STEP -1
2080   INFILE ON (3,I1) A
2090   INFILE ON (7,A) N1,N2,P0,T1,T2,P5,T5,T6
2100   Y=FNA(N1)
2101   REM
2102   REM   CHECK THE TYPE OF THE ACTIVITY
2103   REM
2110   IF Y>80 GOTO 2870
2120   IF Y>20 GOTO 2650
2121   REM
2122   REM   CASE OF A REPETITIVE ACTIVITY
2123   REM
2130   INFILE ON (5,A) L1,C1,E1
2131   REM
```

```
2132      REM   CHECK IF THE ACTIVITY IS COMPLETED
2133      REM
2140      IF C1>E1 GOTO 2870
2141      REM
2142      REM   USE THE EARLY START AND FINISH DATES AND SHIFT
2143      REM   THE ACTIVITY AS FAR 'RIGHT' AS POSSIBLE
2144      REM
2150      FOR I=C1 TO E1
2160        R9=N1+I
2170        GOSUB 3030
2180        INFILE ON (4,H) Z1,S1,F1
2190        S(I)=S1
2200        F(I)=F1
2210      NEXT I
2220      X=1000
2230      FOR J=C1 TO E1
2240        X1=S0-F(J)
2250        IF X1<X THEN X=X1
2260      NEXT J
2270      FOR J=C1 TO E1
2280        S(J)=S(J)+X
2290        F(J)=F(J)+X
2300      NEXT J
2301      REM
2302      REM   CHECK IF THE ACTIVITY HAS SUCCESSORS
2303      REM
2310      IF T2<0 AND T6<0 THEN X=-1 ELSE X=-500
2311      REM
2312      REM   CHECK THE TYPICAL SUCCESORS
2313      REM
2320      IF T2<0 GOTO 2440
2330      INFILE ON (1,T2) S9,S8
2340      T2=S8
2350      FOR J=C1 TO E1
2360        R9=S9+J
2370        GOSUB 3030
2380        R1=H
2381        REM
2382        REM   COMPARE WITH THE LATE START OF THE SUCESSOR
2383        REM
2390        INFILE ON (4,R1) Z,Z1,Z2,S1,F1
2400        X1=F(J)-S1
2410        IF X1>X THEN X=X1
2420      NEXT J
2430      GOTO 2320
2431      REM
2432      REM   CHECK THE NON-TYPICAL SUCCESSORS
2433      REM
2440      IF T6<0 GOTO 2530
2450      INFILE ON (2,T6) S9,L9,S8
2460      T6=S8
2470      R9=S9
2480      GOSUB 3030
2490      INFILE ON (4,H) Z,Z1,Z2,S1,F1
2491      REM
2492      REM   COMPUTE THE DIFFERENCE AND SEE IF IT RULES.
2493      REM
2500      X1=F(L9)-S1
2510      IF X1>X THEN X=X1
2520      GOTO 2440
2521      REM
2522      REM   COMPUTE THE LATE DATES AND STORE IN THE FILE
2523      REM
2530      INFILE ON (7,A) A1
2540      FOR J=C1 TO E1
2550        R9=A1+J
2560        GOSUB 3030
2570        R=H
2580        IF X<0 THEN X=-1
2590        S1=S(J)-X-1
2600        F1=F(J)-X-1
2610        INFILE ON (4,R) Z,Z1,Z2,Z3,Z4,Z5,Z6
2620        OUTFILE ON (4,R) Z,Z1,Z2,S1,F1,Z5,Z6
2630      NEXT J
2640      GOTO 2870
```

```
2641   REM
2642   REM   CASE OF A NON-REPETITIVE ACTIVITY
2643   REM
2650   S2=S0:F2=S0
2660   INFILE ON (5,A) Z1,Z2,Z3,Z4
2661   REM
2662   REM   CHECK THE STATUS OF THE ACTIVITY
2663   REM
2670   IF Z4>.1 GOTO 2870
2680   INFILE ON (7,A) N1
2690   R9=N1
2700   GOSUB 3030
2710   R2=H
2720   INFILE ON (4,R2) Z9,S6,F6
2721   REM
2722   REM   EVALUATE DURATION OF ACTIVITY
2723   REM
2730   D1=F6-S6+1
2731   REM
2732   REM   CHECK THE SUCCESSORS OF THE ACTIVITY
2733   REM
2740   IF T2<0 GOTO 2630
2750   IF T2<0 GOTO 2870
2760   INFILE ON (1,T2) S9,S8
2770   T2=S8
2780   R9=S9
2790   GOSUB 3030
2800   R1=H
2801   REM
2802   REM   COMPARE WITH THE LATE START OF THE SUCCESSOR
2803   REM
2810   INFILE ON (4,R1) Z,Z1,Z2,S1,Z2
2820   IF F2>(S1-1) THEN F2=S1-1
2830   IF S2>(F2-D1+1) THEN S2=F2-D1+1
2840   INFILE ON (4,R2) Z,Z1,Z2,Z3,Z4,Z5,Z6
2850   OUTFILE ON (4,R2) Z,Z1,Z2,S2,F2,Z5,Z6
2860   GOTO 2750
2861   REM
2862   REM   END OF THE LOOP OF THE BACKWARD PASS
2863   REM
2870 NEXT I1
2880 CLOSE 2
2890 CLOSE 3
2900 CLOSE 4
2910 CLOSE 5
2920 CLOSE 6
2930 CLOSE 7
2931 REM
2932 REM   RETURN TO THE PROGRAM "MAIN"
2933 REM
2940 CHAIN "MAIN"
2941 REM
2942 REM   HASHING ROUTINE TO GET THE ACTIVITY RECORD
2943 REM
2950 H0=199
2960 Q=INT(A9/H0)
2970 H=FNM(A9,H0)
2980 IF H=0 THEN H=FNM((Q+H),H0): GOTO 2980
2990 INFILE ON (7,H) T9
3000 IF T9<0 THEN RETURN
3010 IF T9=A9 THEN RETURN
3020 H=FNM((Q+H),H0): GOTO 2980
3021 REM
3022 REM   HASHING ROUTINE TO GET THE RECORD OF THE DATES
3023 REM
3030 H0=1699
3040 Q=INT(R9/H0)
3050 H=FNM(R9,H0)
3060 IF H=0 THEN H=FNM((Q+H),H0): GOTO 3060
3070 INFILE ON (4,H) T9
3080 IF T9<0 THEN RETURN
3090 IF T9=R9 THEN RETURN
3100 H=FNM((Q+H),H0): GOTO 3060
3101 REM
3102 REM   THIS SECTION ADJUSTS THE PRODUCTION RATES FOR THE
```

```
3103 REM  REPETITIVE ACTIVITIES AFFECTED BY WEATHER.
3104 REM
3110 IF F9=1 GOTO 3300
3111 REM
3112 REM  GO GET THE WEATHER FACTORS
3113 REM
3120 INFILE ON (5,0) W(1),W(2),W(3),W(4),W(5),W(6),W(7),W(8)
3130 INFILE ON (5,200) W(9),W(10),W(11),W(12)
3131 REM
3132 REM   IN THE CASE OF A NON-REPETITIVE ACT.:RETURN
3133 REM
3140 IF Y>20 THEN RETURN
3141 REM
3142 REM   CORRECT THE PRODUCTION RATES DEPENDING ON THE
3143 REM   MONTH IN WHICH THE ACTIVITY IS EXECUTED.
3144 REM
3150 FOR J=C1  TO E1
3160   INFILE ON (6,S(J)) Z,W
3170   Y2=FNA(W)
3180   Z=F(J)
3190   F(J)=S(J)+100*(F(J)-S(J)+1)/W(Y2)-1
3200   D9=F(J)-Z
3210   IF J+N1>E1 GOTO 3260
3220   FOR J1=J+N1 TO E1 STEP N1
3230     F(J1)=F(J1)+D9
3240     S(J1)=S(J1)+D9
3250   NEXT J1
3260 NEXT J
3270 INFILE ON (7,A) N1,N2,P0,T1,T2,P5,T5,T6
3271 REM
3272 REM   RETURN TO THE TOP AND COMPARE AGAIN WITH THE
3273 REM   PREDECESSORS TO SEE IF IT CHANGES ITS START.
3274 REM
3280 F9=F9+1
3290 GOTO 880
3291 REM
3292 REM   SECOND TIME AROUND:FIND THE NEW DATES
3293 REM
3300 INFILE ON (5,A) L1,C1,E1,N1,P1,S1,F1
3310 FOR I=L1  TO E1  STEP N1
3320   FOR J=0  TO N1-1
3330     F(I+J)=S(I+J)+P(I+J)-1
3340     S(I+J+1)=S(I+J)+S1
3350   NEXT J
3360   S(I+N1)=F(I)+F1+1
3370 NEXT I
3371 REM
3372 REM   AND FIND THE NEW WEATHER FACTORS....
3373 REM
3380 GOTO 3120
3381 REM
3382 REM   HASHING ROUTINE USED TO READJUST THE RECORDS
3383 REM   OF THE FILE OF DATES
3384 REM
3390 H0=1699
3400 Q=INT(R9/H0)
3410 H=FNM(R9,H0)
3420 IF H=0 THEN H=FNM((Q+H),H0): GOTO 3420
3430 INFILE ON (4,H) T9
3440 IF T9<=1 THEN RETURN
3450 IF T9=R9 THEN RETURN
3460 H=FNM((Q+H),H0): GOTO 3420
3461 REM
3462 REM   END OF THE PROGRAM "COMP"
3463 REM
3470 END
```

```
  1 REM
  2 REM        PROGRAM 'OUT'
  3 REM        AUTHOR: JEAN B. LARAMEE
  4 REM        CENTER FOR BUIDING STUDIES
  5 REM        CONCORDIA UNIVERSITY
  6 REM        FEBRUARY 1983
  7 REM
  8 REM        THIS PROGRAM TAKES THE FILE OF DATES
  9 REM        AND PRINTS IT IN THREE DIFFERENT FOR-
 10 REM        MATS: LIST OF DATES, LINEAR CHART AND
 11 REM        BAR CHART.
 12 REM
 13 REM        IT IS CALLED BY THE PROGRAM 'MAIN' AND
 14 REM        RETURNS TO IT AFTER ITS EXECUTION.
 15 REM
 16 REM        DECLARE VARIABLES AND FUNCTIONS.
 17 REM
 20 DIM F$(4),F1$(5),F2$(5),F3$(5),F4$(5),F5$(5)
 30 DIM M1$(103),M2$(103),M3$(103),M4$(103),M5$(103),M6$(103)
 40 DIM M7$(103),D$(20),A$(3)
 50 DEF FNM(X,Y)=INT((X/Y-INT(X/Y))*Y+.5)
 60 DEF FNA(A)=INT(INT(A/100)-(INT(A/10000)*100)+.5)
 70 DEF FNL(A)=INT(A-(INT(A/100)*100)+.5)
 80 DEF FNS(A)=INT(A/10000)
 90 PRINT 'NAME OF FILE ? (4 CHAR.)'
 100 INPUT F$
 110 F1$=F$+'1'
 120 F2$=F$+'2'
 130 F3$=F$+'3'
 140 F4$=F$+'4'
 150 F5$=F$+'5'
 160 OPEN F$,7,0
 170 OPEN 'CAL',1,0
 180 OPEN F3$,3,0
 190 OPEN F4$,4,0
 200 OPEN F5$,5,0
 210 OPEN 'PR:',6,2
 211 REM
 212 REM    INPUT THE NUMBER OF LEVELS FOR THE PROJECT
 213 REM
 220 PRINT 'NO. OF LEVELS FOR THE PROJECT ?'
 230 INPUT N9
 240 DIM C(30),F(50)
 241 REM
 242 REM    ASK THE USER FOR THE OPTION HE WANTS
 243 REM
 250 PRINT '1) LIST OF DATES'
 260 PRINT '2) LINEAR CHART'
 270 PRINT '3) BAR CHART'
 280 PRINT '4) QUIT'
 290 INPUT Z0
 300 ON Z0 GOTO 930,310,2040,1800
 301 REM
 302 REM    CASE OF THE LINEAR PLANNING CHART
 303 REM    ASK THE USER TO INPUT THE NUMBER OF
 304 REM    ACTIVITIES HE WANTS TO SEE ON THE SAME CHART.
 305 REM
 310 PRINT 'NO. OF ACTIVITIES TO PRINT ON THE SAME CHART ?'
 320 INPUT N
 321 REM
 322 REM    ZERO WILL STOP THE INPUT AND RETURN TO THE MENU
 323 REM
 330 IF N<=0 GOTO 250
 340 FOR I=1 TO N
 350   PRINT 'INPUT ACTIVITY NO.'
 360   INPUT A
 370   A9=A
 380   GOSUB 1880
 390   IF T9<0 THEN PRINT 'ACTIVITY NOT FOUND': GOTO 350
 400   C(I)=H
 410 NEXT I
 420 W=0
 421 REM
 422 REM    INITIALIZE THE FLAG THAT SAYS IF AN ACTIVITY WAS PRINTED
 423 REM
```

```
430 FOR I=1 TO N9
440   F(I)=1
450 NEXT I
451 REM
452 REM   PRINT THE HEADING AND THE CALENDAR DATES
453 REM
460 PRINT ON (6)'<12>'
470 FOR I=1 TO N
480   INFILE ON (7,C(I)) N1,N2,P0,T1,T2,P5,T5,T6,D$
490   PRINT ON (6) I,N1,D$
500 NEXT I
510 PRINT ON (6)
520 PRINT ON (6)
530 GOSUB 2130
540 PRINT ON (6)TAB(11),M5$
550 PRINT ON (6)TAB(11),M4$
560 PRINT ON (6)TAB(11),M3$
570 M1$='-'
580 FOR J=1 TO 102
590   M1$=M1$+'-'
600 NEXT J
610 PRINT ON (6)TAB(9);M1$
611 REM
612 REM   GET THE 'POINTS' FOR EACH FLOOR AND PRINT IT
613 REM
620 FOR I=N9 TO 1 STEP -1
621   REM
622   REM   INITIALIZE THE CHARACTER ARRAYS
623   REM
630   M3$=M1$
640   M4$=M6$
650   M5$=M7$
651   REM
652   REM   TAKE THE ACTIVITIES ONE BY ONE
653   REM
660   FOR J=1 TO N
670     INFILE ON (7,C(J)) N1
680     Y=FNA(N1)
690     IF Y>20 GOTO 750
691     REM
692     REM   CASE OF A REPETITIVE ACTIVITY
693     REM
700     R9=N1+I
710     A$=STR$(J)
720     GOSUB 3180
730   NEXT J
740   GOTO 780
741   REM
742   REM   CASE OF A NON-REPETITIVE ACTIVITY
743   REM
750   Y1=FNL(N1)
751   REM
752   REM   CHECK IF THE ACTIVITY IS ON THE LEVEL THAT IS PRINTED
753   REM
760   IF Y1=I THEN R9=N1: GOTO 710
770   GOTO 730
771   REM
772   REM   PRINT THAT FLOOR
773   REM
780   PRINT ON (6)TAB(10),'I';M5$
790   PRINT ON (6)TAB(10),'I';M7$
800   PRINT ON (6)'FLOOR';I;TAB(10),'I';M4$
810   PRINT ON (6)TAB(10),'I';M7$
820   PRINT ON (6)TAB(9),'-I';M3$
830 NEXT I
840 GOSUB 2130
841 REM
842 REM   PRINT THE BOTTOM CALENDAR DATES
843 REM
850 PRINT ON (6)TAB(11),M3$
860 PRINT ON (6)TAB(11),M4$
870 PRINT ON (6)TAB(11),M5$
880 K=0
881 REM
882 REM   CHECK IF ALL THE ACTIVITIES WERE PRINTED ENTIRELY
```

```
883 REM
890 FOR I=1 TO N9
900   K=K+F(I)
910 NEXT I
911 REM
912 REM   IF NOT, PRINT ON NEXT PAGE AND RESTART
913 REM
920 IF K<1 THEN 310 ELSE W=B9-1: GOTO 460
921 REM
922 REM   CASE IF THE LIST OF DATES: ASK FOR THE ORDER
923 REM
930 PRINT '1) INCREASING ACTIVITY NO.'
940 PRINT '2) SEQUENTIAL STEP'
950 PRINT '3) RANDOMLY'
960 INPUT A1
961 REM
962 REM   INITILIALIZE THE CHARACTER ARRAY
963 REM
970 M2$=' '
980 FOR K=1 TO 60
990   M2$=' '+M2$
1000 NEXT K
1001 REM
1002 REM   INITIALIZE THE NUMBER OF PAGES AND PRINT THE HEADING
1003 REM
1010 P1=-1:P=1
1020 GOSUB 1040
1030 GOTO 1170
1031 REM
1032 REM   THAT SUBROUTINE PRINTS THE HEADING ON THE TOP OF THE PAGE
1033 REM
1040 PRINT ON (6)'<12>'
1050 PRINT ON (6)TAB(31),'I';TAB(38),'E A R L Y';
1060 PRINT ON (6)TAB(59),'L A T E';TAB(77),'A C T U A L';
1070 PRINT ON (6)TAB(105),'DURATION     PAGE ';
1080 PRINT ON (6) USING '@@',P
1090 PRINT ON (6)' NO.      DESCRIPTION    FLOOR',TAB(31),'I';
1100 PRINT ON (6)'   START      FINISH     START     FINISH    ';
1110 PRINT ON (6)' START      FINISH    FLOAT   SCHED.  ACTUAL'
1120 FOR I1=1 TO 120
1130 PRINT ON (6)'-';
1140 NEXT I1
1150 PRINT ON (6)'-'
1160 RETURN
1170 ON A1 GOTO 1180,1180,1490
1171 REM
1172 REM   CASE OF THE INCR. ACT. NO. OR THE SEQUENT. STEP ORDER
1173 REM
1180 INFILE ON (3,0) N
1190 FOR I=1 TO N
1200   INFILE ON (3,I) Z1,Z2
1201   REM
1202   REM   CHOOSE THE RIGHT ONE...
1203   REM
1210   IF A1=1 THEN Z=Z2 ELSE Z=Z1
1220   INFILE ON (7,Z) N1,N2,P0,T1,T2,P5,T5,T6,D$
1230   Y=FNA(N1)
1240   IF Y>20 GOTO 1380
1241   REM
1242   REM   CASE OF A REPETITIVE ACTIVITY
1243   REM
1250   FOR J=1 TO N9
1260     R9=N1+J
1270     GOSUB 1960
1280     IF T9<0 GOTO 1360
1290     P1=P1+1
1300     IF P1>28 THEN P1=0:P=P+1: GOSUB 1040
1310     M1$=M2$
1311     REM
1312     REM   GO GET THE VARIOUS DATES
1314     REM
1320     GOSUB 3610
1321     REM
1322     REM   PRINT THE DATES
1323     REM
```

```
1330      PRINT ON (6)TAB(31),'I'
1340      PRINT ON (6) N1,TAB(9),D$;TAB(27),J;TAB(31),'I    ';M1$;F9;
1350      PRINT ON (6)TAB(104),F8;TAB(112),F7
1360    NEXT J
1370    GOTO 1470
1371    REM
1372    REM   CASE OF A NON-REPRTITIVE ACTIVITY
1373    REM
1380    R9=N1
1390    GOSUB 1960
1400    P1=P1+1
1410    IF P1>28 THEN P1=0:P=P+1: GOSUB 1040
1420    M1$=M2$
1430    GOSUB 3610
1440    PRINT ON (6)TAB(31),'I'
1450    PRINT ON (6) N1,TAB(9),D$;TAB(27),FNL(N1);TAB(31),'I    ';M1$;
F9;
1460    PRINT ON (6)TAB(104),F8;TAB(112),F7
1470 NEXT I
1480 GOTO 250
1481 REM
1482 REM   CASE OF RANDOMLY INPUTTING THE ACTIVITIES
1483 REM
1490 PRINT 'ACTIVITY NO.'
1500 INPUT A9
1501 REM
1502 REM   ZERO WILL STOP THE INPUT
1503 REM
1510 IF A9=0 GOTO 250
1520 GOSUB 1880
1530 IF T9<0 THEN PRINT 'ACTIVITY NOT FOUND': GOTO 1490
1540 INFILE ON (7,H) N1,N2,P0,T1,T2,P5,T5,T6,D$
1550 Y=FNA(N1)
1551 REM
1552 REM   SIMILAR PROCEDURE AS ABOVE...
1553 REM
1560 IF Y>20 GOTO 1700
1570 FOR J=1 TO N9
1580   R9=N1+J
1590   GOSUB 1960
1600   IF T9<0 GOTO 1680
1610   P1=P1+1
1620   IF P1>28 THEN P1=0:P=P+1: GOSUB 1040
1630   M1$=M2$
1640   GOSUB 3610
1650   PRINT ON (6)TAB(31),'I'
1660   PRINT ON (6) N1,TAB(9),D$;TAB(27),J;TAB(31),'I    ';M1$;F9;
1670   PRINT ON (6)TAB(104),F8;TAB(112),F7
1680 NEXT J
1690 GOTO 1490
1700 R9=N1
1710 GOSUB 1960
1720 P1=P1+1
1730 IF P1>28 THEN P1=0:P=P+1: GOSUB 1040
1740 M1$=M2$
1750 GOSUB 3610
1760 PRINT ON (6)TAB(31),'I'
1770 PRINT ON (6) N1,TAB(9),D$;TAB(27),FNL(N1);TAB(31),'I    ';M1$;F9
;
1780 PRINT ON (6)TAB(104),F8;TAB(112),F7
1790 GOTO 1490
1800 CLOSE 1
1810 CLOSE 2
1820 CLOSE 3
1830 CLOSE 4
1840 CLOSE 5
1850 CLOSE 6
1860 CLOSE 7
1861 REM
1862 REM   RETURN TO THE PROGRAM 'MAIN'
1863 REM
1870 CHAIN 'MAIN'
1871 REM
1872 REM   HASING ROUTINE TO GET THE ACTIVITY NUMBER
1873 REM
1880 H0=199
1890 Q=INT(A9/H0)
```

```
1900 H=FNM(A9,H0)
1910 IF H=0 THEN H=FNM((Q+H),H0): GOTO 1910
1920 INFILE ON (7,H) T9
1930 IF T9<0 THEN RETURN
1940 IF T9=A9 THEN T9=0: RETURN
1950 H=FNM((Q+H),H0): GOTO 1910
1951 REM
1952 REM   HASHING ROUTINE TO GET THE RECORD OF THE DATES
1953 REM
1960 H0=1699
1970 Q=INT(R9/H0)
1980 H=FNM(R9,H0)
1990 IF H=0 THEN H=FNM((Q+H),H0): GOTO 1990
2000 INFILE ON (4,H) T9
2010 IF T9<0 THEN RETURN
2020 IF T9=R9 THEN RETURN
2030 H=FNM((Q+H),H0): GOTO 1990
2031 REM
2032 REM   CASE OF THE BAR-CHART
2033 REM
2040 INFILE ON (3,0) N
2060 W=0
2061 REM
2062 REM   INITIALIZE THE FLAG
2063 REM
2070 FOR I=1 TO N
2080   F(I)=1
2090 NEXT I
2091 REM
2092 REM   PRINT THE CALENDAR DATES ON THE TOP
2093 REM
2100 PRINT ON (6)"<12>"
2110 GOSUB 2130
2120 GOTO 2570
2121 REM
2122 REM   THIS SUBROUTINE GETS THE DATE OF THE START OF THE WEEK
2123 REM
2130 M1$=" "
2140 FOR I=1 TO 101
2150   M1$=M1$+" "
2160 NEXT I
2170 M2$=M1$
2180 M3$=M1$
2190 M4$=M1$
2200 M5$=M1$
2210 M6$=M1$
2220 M7$=M1$
2230 FOR J=(W+1) TO (W+100)
2240   IF J=W+1 THEN 2250 ELSE 2260
2250   INFILE ON (1,J) A2,B2: GOTO 2300
2260   INFILE ON (1,J-1) A1,B1
2270   INFILE ON (1,J) A2,B2
2280   IF A2>A1 GOTO 2550
2290   B9=J
2300   D1=FNL(B2)
2310   M1=FNA(B2)
2320   Y1=FNS(B2)
2330   I=J-W
2340   M3$(I,(I+1))=STR$(D1)
2350   GOSUB 2370
2360   GOTO 2520
2361   REM
2362   REM   THIS SUBROUTINE CHANGES THE MONTH NUMBER INTO ITS NAME
2363   REM
2370   ON M1 GOTO 2390,2400,2410,2420,2430,2440
2380   ON (M1-6) GOTO 2450,2460,2470,2480,2490,2500
2390   A$="JAN": GOTO 2510
2400   A$="FEB": GOTO 2510
2410   A$="MAR": GOTO 2510
2420   A$="APR": GOTO 2510
2430   A$="MAY": GOTO 2510
2440   A$="JUN": GOTO 2510
2450   A$="JUL": GOTO 2510
2460   A$="AUG": GOTO 2510
2470   A$="SEP": GOTO 2510
```

```
2480   A$="OCT": GOTO 2510
2490   A$="NOV": GOTO 2510
2500   A$="DEC": GOTO 2510
2510   RETURN
2520   M5$(I,(I+1))=STR$(Y1)
2530   M4$(I,(I+2))=A$
2531   REM
2532   REM   A DOT "." WILL IDENTIFY THE START OF THE WEEK
2533   REM
2540   M6$(I,I)="."
2550 NEXT J
2560 RETURN
2561 REM
2562 REM   PRINT THE HEADING OF THE BAR-CHART
2563 REM
2570 PRINT ON (6)TAB(25),"I";M5$
2580 PRINT ON (6)TAB(25),"I";M4$
2590 PRINT ON (6)"NO.    DESCRIPTION",TAB(25),"I";M3$
2600 FOR I=1 TO 126
2610   PRINT ON (6)"-";
2620 NEXT I
2630 PRINT ON (6)"-"
2631 REM
2632 REM   START PRINTING THE ACTIVITY ONE AFTER THE OTHER
2633 REM
2640 FOR I=1 TO N
2650   M1$=M7$
2660   M2$=M7$
2661   REM
2662   REM   THAY ARE PRINTED IN SEQUENTIAL STEP ORDER
2663   REM
2670   INFILE ON (3,I) Z
2680   INFILE ON (7,Z) Z1,N3,P0,T1,T2,P5,T5,T6,D$
2690   Y=FNA(Z1)
2700   IF Y>20 GOTO 2800
2701   REM
2702   REM   CASE OF A REPETITIVE ACTIVITY
2703   REM
2710   INFILE ON (5,Z) L1,C1,E1,N8
2711   REM
2712   REM   PRINT THE FLOOR IN PARALLEL ON SEPARATE LINES
2713   REM
2720   FOR U=1 TO N8
2730     FOR J=L1+U-1 TO E1 STEP N8
2740       R9=Z1+J
2750       Y2=J
2760       A$="X"
2770       GOSUB 3180
2780     NEXT J
2790     GOTO 2930
2800     IF Y>80 GOTO 2860
2801     REM
2802     REM   CASE OF A NON-REPETITIVE ACTIVITY
2803     REM
2810     R9=Z1
2820     Y2=FNL(R9)
2830     A$="X"
2840     GOSUB 3180
2850     GOTO 2930
2851     REM
2852     REM   CASE OF A MILESTONE
2853     REM
2860     IF F(I)=0 GOTO 2930
2870     R9=Z1
2880     GOSUB 1960
2890     INFILE ON (4,H) Z1,D,D1
2900     D1=D1+1
2910     IF D1>(W+101) THEN 2930 ELSE F(I)=0
2920     M1$((D1-W),(D1-W))="M"
2921     REM
2922     REM   PRINT THAT LINE
2923     REM
2930     PRINT ON (6)TAB(25),"I";M2$
2940     PRINT ON (6) Z1;TAB(8),D$;TAB(25),"I";M1$
2950     IF Y>20 GOTO 2990
```

```
2960        M1$=M7$
2970        M2$=M7$
2980      NEXT U
2990      PRINT ON (6)TAB(25),'I';M6$
3000      GOTO 3040
3010      PRINT ON (6)TAB(25),'I'
3020      PRINT ON (6)TAB(25),'I'
3030      PRINT ON (6)TAB(25),'I';M6$
3040 NEXT I
3041 REM
3042 REM   PRINT THE CALENDAR AT THE BOTTOM
3043 REM
3050 FOR I=1 TO 100
3060    PRINT ON (6)TAB(I+25),'-';
3070 NEXT I
3080 PRINT ON (6)'-'
3090 PRINT ON (6)TAB(26),M3$
3100 PRINT ON (6)TAB(26),M4$
3110 PRINT ON (6)TAB(26),M5$
3120 K=0
3121 REM
3122 REM   CHECK IF THE ACTIVITIES WERE COMPLETELY PRINTED
3123 REM
3130 PRINT 'NEXT PAGE'
3140 FOR I=1 TO N
3150    K=K+F(I)
3160 NEXT I
3170 IF K<1 THEN 250 ELSE W=B9-1: GOTO 2100
3171 REM
3172 REM   THIS SUBROUTINE PUTS IN THE ARRAYS OF CHARACTER
3173 REM   THE SIGNS ('*','X','C',ETC...) AT THEIR RESPECTIVE
3174 REM   DATES.  IT ALSO MODIFIES THE FLAG TO ENABLE THE
3175 REM   ACTIVITIES TO BE PRINTED ON THE RIGHT PAGE.
3176 REM
3180 GOSUB 1960
3190 IF T9<>0 THEN RETURN
3200 INFILE ON (4,H) R,S,F,S3,F3,S4,F4
3201 REM
3202 REM   CHECK IF THE ACTIVITY IS COMPLETED
3203 REM
3210 IF S4<>0 AND F4<>0 THEN A$='C'+A$ ELSE 3240
3220 IF Z0=2 THEN IF J<10 THEN A$=' '+A$
3230 S=S4:F=F4: GOTO 3360
3231 REM
3232 REM   CHECK IF THE ACTIVITY IS CRITICAL
3233 REM
3240 IF S3=S THEN A$='*'+A$ ELSE A$=' '+A$
3250 IF Z0=3 AND S3<>S THEN A$='X'
3260 IF Z0=2 THEN IF J<10 THEN A$=' '+A$
3270 IF Z0=2 OR S3=S GOTO 3360
3271 REM
3272 REM   PRINT THE FLOAT ON THE BAR-CHART
3273 REM
3280 S3=F
3290 IF S3>=(W+101) THEN F(I)=1: GOTO 3360
3300 IF F3<=(W+101) THEN F(I)=0 ELSE F(I)=1:F3=W+101
3310 IF F3<=W GOTO 3360
3320 IF S3<=W THEN S3=W+1
3330 FOR K=S3 TO F3
3340    M1$((K-W),(K-W))='-'
3350 NEXT K
3360 S1=S:F1=F
3361 REM
3362 REM   CHECK IF THE ACTIVITY HAS TO BE PRINTED ON THAT PAGE
3363 REM
3370 IF S>=(W+101) THEN F(I)=1: RETURN
3380 IF F<=(W+101) AND S3=S AND Z0=3 AND S4=0 THEN F(I)=0: GOTO 3400
3390 IF F<=(W+101) THEN F(I)=0 ELSE F(I)=1:F=W+101
3400 IF F<=W THEN RETURN
3410 IF S<=W THEN S=W+1: GOTO 3440
3420 IF Z0=2 GOTO 3510
3421 REM
3422 REM   PUT THE FLOOR NUMBER OVER THE BAR
3423 REM
3430 M2$((S-W),(S-W+1))=STR$(Y2)
```

```
3440 IF Z0=2 GOTO 3510
3441 REM
3442 REM   PUT THE CHARACTERS IN THE ARRAY TO FORM THE BAR
3443 REM
3450 FOR K=S TO F
3460   IF K=S THEN IF S1>=W+1 THEN M1$((K-W),(K-W))='S': GOTO 3490
3470   IF K=F THEN IF F1<=W+101 THEN M1$((K-W),(K-W))='F': GOTO 3490
3480   M1$((K-W),(K-W))=A$
3490 NEXT K
3500 RETURN
3501 REM
3502 REM   CASE OF THE LINEAR PLANNING CHART
3503 REM
3510 IF Y>80 THEN M4$((S1-W),(S1-W+1))=A$: RETURN
3520 IF Y>20 THEN 3530 ELSE 3560
3521 REM
3522 REM   CASE OF A NON-REPETITIVE ACTIVITY
3523 REM
3530 IF F1<=W+101 THEN M4$((F1-W-3),(F1-W))=A$+'F'
3540 IF S1>=W+1 THEN M4$((S1-W),(S1-W+3))='S'+A$
3550 GOTO 3580
3551 REM
3552 REM   CASE OF A REPETITIVE ACTIVITY
3553 REM
3560 IF S1>=W+1 THEN M3$((S1-W),(S1-W))='S'
3570 IF F1<W+101 THEN M5$((F1-W),(F1-W))='F'
3580 K=INT((S1+F1)/2)
3590 IF K<=W+101 AND K>W+1 THEN M4$((K-W-1),(K-W+1))=A$
3600 RETURN
3601 REM
3602 REM   THIS SUBROUTINE PUTS THE DATES IN A CHARACTER STRING
3603 REM
3610 INFILE ON (4,H) Q,D(0),D(1),D(2),D(3),D(4),D(5)
3620 IF Y>80 THEN K=1:D(1)=D(1)+1: GOTO 3640
3630 FOR K=0 TO 5
3640   IF D(K)<=0 GOTO 3730
3650   INFILE ON (1,D(K)) D,D1
3660   A=FNL(D1)
3670   M1$((K*10+1),(K*10+2))=STR$(A)
3680   M1=FNA(D1)
3690   GOSUB 2370
3700   M1$((K*10+3),(K*10+5))=A$
3710   A=FNS(D1)
3720   M1$((K*10+6),(K*10+7))=STR$(A)
3730   IF Y>80 THEN F9=0:F8=0:F7=0: GOTO 3780
3740 NEXT K
3750 F9=D(2)-D(0)
3760 F8=D(1)-D(0)+1
3770 IF D(5)<>0 AND D(4)<>0 THEN F7=D(5)-D(4)+1 ELSE F7=0
3780 RETURN
3781 REM
3782 REM   END OF PROGRAM 'OUT'
3783 REM
3790 END
```

```
1 REM
2 REM       PROGRAM 'DATA'
3 REM       AUTHOR: JEAN B. LARAMEE
4 REM       CENTER FOR BUILDING STUDIES
5 REM       CONCORDIA UNIVERSITY
6 REM       FEBRUARY 1983
7 REM
8 REM       THIS PROGRAM ENABLES THE USER TO INPUT NEW ACTIVITY
9 REM       DATA OR TO UPDATE IT.  HE CAN ALSO INPUT THE WEATHER
10 REM      FACTORS AND THE ACTUAL START AND FINISH DATES.
11 REM
12 REM      IT IS CALLED BY THE PROGRAM 'MAIN' AND RETURNS TO
13 REM      IT AFTER ITS EXECUTION.
14 REM
18 REM      DECLARE VARIABLES AND FUNCTIONS.
19 REM
20 DIM F$(4),F1$(5),F2$(5),F3$(5),F4$(5),F5$(5)
30 DEF FNM(X,Y)=INT((X/Y-INT(X/Y))*Y+.5)
40 DEF FNA(A)=INT(INT(A/100)-(INT(A/10000)*100)+.5)
50 PRINT 'NAME OF FILE ? (4 CHAR.)'
60 INPUT F$
70 F2$=F$+'2'
80 F3$=F$+'3'
90 F4$=F$+'4'
100 F5$=F$+'5'
110 OPEN F$,7,0
120 OPEN F2$,2,0
130 OPEN F3$,3,0
140 OPEN F4$,4,0
150 OPEN F5$,5,0
160 OPEN 'CAL',6,0
161 REM
162 REM   ASK THE USER FOR THE OPTION HE WANTS
163 REM
170 PRINT '1) UPDATE'
180 PRINT '2) NEW'
190 PRINT '3) WEATHER FACTORS'
200 PRINT '4) ACTUAL START AND FINISH DATES'
210 PRINT '5) QUIT'
220 INPUT Z
230 ON Z GOTO 240,240,590,2480,640
240 PRINT '1) SEQUENTIALLY'
250 PRINT '2) RANDOMLY'
260 INPUT A
270 ON A GOTO 280,490
280 PRINT '1) ORDER OF INPUT'
290 PRINT '2) INCREASING ACTIVITY NO.'
300 PRINT '3) SEQUENTIAL STEP ORDER'
310 INPUT A1
320 ON A1 GOTO 330,400,400
321 REM
322 REM   CASE OF THE ORDER OF INPUT
323 REM
330 INFILE ON (7,0) N,A
340 INFILE ON (7,A) N1,N2
350 GOSUB 700
360 IF L1=0 THEN GOTO 170
370 A=N2
380 IF A=0 GOTO 170
390 GOTO 340
391 REM
392 REM   CASE OF THE INCREASING ACT. NO OR THE SEQUENTIAL STEP
393 REM
400 INFILE ON (7,0) N
410 I=1
420 INFILE ON (3,I) Z1,Z2
430 IF A1=2 THEN A=Z2 ELSE A=Z1
440 INFILE ON (7,A) N1
450 GOSUB 700
460 IF L1=0 GOTO 170
470 I=I+1
480 IF I>N THEN 170 ELSE 420
481 REM
482 REM   CASE OF RANDOMLY ACCESSING THE ACTIVITIES
483 REM
```

```
490 PRINT 'ACTIVITY NO.'
500 INPUT N9
501 REM
502 REM   INPUTTING ZERO WILL RETURN TO THE MENU.
503 REM
510 IF N9=0 THEN GOTO 170
520 GOSUB 2320
530 IF T9<>0 THEN PRINT 'ACTIVITY NOT FOUND': GOTO 490
540 INFILE ON (7,H) N1
550 A=H
560 GOSUB 700
570 IF L1=0 GOTO 170
580 GOTO 490
581 REM
582 REM   CASE OF INPUTTING THE WEATHER FACTORS
583 REM
590 PRINT 'INPUT WEATHER FACTORS'
600 INPUT W,W1,W2,W3,W4,W5,W6,W7,W8,W9,W0,Z
610 OUTFILE ON (5,0) W,W1,W2,W3,W4,W5,W6,W7
620 OUTFILE ON (5,200) W8,W9,W0,Z
630 GOTO 170
640 CLOSE 2
650 CLOSE 3
660 CLOSE 4
670 CLOSE 5
680 CLOSE 7
681 REM
682 REM   RETURN TO THE PROGRAM 'MAIN'
683 REM
690 CHAIN 'MAIN'
691 REM
692 REM   THIS SUBROUTINE ENABLES THE USER TO INPUT OR MODIFY
693 REM   THE DATA FOR A SPECIFIC ACTIVITY.
694 REM
700 Y=FNA(N1)
710 IF Y>80 GOTO 1190
720 IF Y>20 GOTO 980
721 REM
722 REM   CASE OF A REPETITIVE ACTIVITY
723 REM
730 PRINT 'ACTIVITY NO.';N1
731 REM
732 REM   IF IT IS A NEW ACTIVITY, GO RIGHT AWAY TO THE INPUT.
733 REM   IF NOT, SHOW EXISTING DATA.
734 REM
740 IF Z=2 GOTO 920
750 INFILE ON (5,A) L1,C1,E1,N1,P1,S1,F1,N0,W
760 PRINT
770 PRINT '1) STARTING LEVEL: ';L1
780 PRINT '2) CURRENT  LEVEL: ';C1
790 PRINT '3) LAST     LEVEL: ';E1
800 PRINT '4) NO. OF CREWS  : ';N1
810 PRINT '5) PRODUCTION RATE:';P1
820 PRINT '6) START TO START: ';S1
830 PRINT '7) FINISH TO FIN.: ';F1
840 PRINT '8) LEARNING      : ';N0
850 PRINT '9) WEATHER       : ';W
860 PRINT '10) QUIT'
861 REM
862 REM   THE USER SPECIFIES THE ITEM HE WANTS TO MODIFY.
863 REM
870 INPUT Z1
880 ON Z1 GOSUB 1360,1390,1420,1450,1480,1510,1540,1600,1570
881 REM
882 REM   INPUTTING ZERO AS STARTING LEVEL WILL STOP THE INPUT.
883 REM
890 IF L1=0 THEN RETURN
900 OUTFILE ON (5,A) L1,C1,E1,N1,P1,S1,F1,N0,W
910 IF Z1=10 THEN RETURN ELSE GOTO 750
911 REM
912 REM   CASE OF NEW DATA:GO THROUGH EACH ITEM
913 REM
920 FOR I1=1 TO 9
930   ON I1 GOSUB 1360,1390,1420,1450,1480,1510,1540,1600,1570
940 NEXT I1
```

```
950 IF L1=0 THEN RETURN
960 OUTFILE ON (5,A) L1,C1,E1,N1,P1,S1,F1,N0,W
970 GOTO 750
971 REM
972 REM   CASE OF A NON-REPETITIVE ACTIVITY
973 REM
980 PRINT 'ACTIVITY NO.';N1
990 L1=1
1000 IF Z=2 GOTO 1130
1010 INFILE ON (5,A) D1,P1,W,S
1020 PRINT
1030 PRINT '1) DURATION    : ';D1
1040 PRINT '2) PROCUREMENT: ';P1
1050 PRINT '3) WEATHER     : ';W
1060 PRINT '4) STATUS      : ';S
1070 PRINT '5) QUIT'
1080 INPUT Z1
1090 ON Z1 GOSUB 1870,1930,1570,1900
1100 IF D1<0 THEN L1=0: RETURN
1110 OUTFILE ON (5,A) D1,P1,W,S
1120 IF Z1=5 THEN RETURN ELSE 1010
1130 FOR I1=1 TO 4
1140   ON I1 GOSUB 1870,1930,1570,1900
1150 NEXT I1
1160 IF D1<0 THEN L1=0: RETURN
1170 OUTFILE ON (5,A) D1,P1,W,S
1180 GOTO 1010
1181 REM
1182 REM   CASE OF A MILESTONE
1183 REM
1190 PRINT 'MILESTONE NO.';N1
1200 L1=1
1210 IF Z=2 GOTO 1250
1220 INFILE ON (5,A) D
1230 INFILE ON (6,D) D1,D2
1240 PRINT 'DATE';D2
1250 PRINT 'INPUT NEW DATE'
1260 INPUT D2
1270 IF D2<=0 THEN L1=0: RETURN
1271 REM
1272 REM   VERIFY IF THE DATE IS IN THE CALENDAR
1273 REM
1280 I9=1
1290 INFILE ON (6,I9) D1,D3
1300 IF D2=D3 THEN D1=I9: GOTO 1340
1310 I9=I9+1
1320 IF I9>600 THEN PRINT 'DATE NOT FOUND': GOTO 1250
1330 GOTO 1290
1340 OUTFILE ON (5,A) D1
1350 RETURN
1351 REM
1352 REM   FOLLOWING IS A SERIES OF SUBROUTINES TO INPUT THE DATA.
1353 REM
1360 PRINT 'STARTING LEVEL ?'
1370 INPUT L1
1380 RETURN
1390 PRINT 'CURRENT LEVEL ?'
1400 INPUT C1
1410 RETURN
1420 PRINT 'LAST LEVEL ?'
1430 INPUT E1
1440 RETURN
1450 PRINT 'NO. OF CREWS ?'
1460 INPUT N1
1470 RETURN
1480 PRINT 'PRODUCTION RATE ?'
1490 INPUT P1
1500 RETURN
1510 PRINT 'START TO START ?'
1520 INPUT S1
1530 RETURN
1540 PRINT 'FINISH TO START ?'
1550 INPUT F1
1560 RETURN
1570 PRINT 'WEATHER ? (1)YES OR (0) NO '
```

```
1580 INPUT W
1590 RETURN
1591 REM
1592 REM   THIS SUBROUTINE IS TO INPUT THE LEARNING EFFECTS
1593 REM
1600 IF Z=2 GOTO 1770
1601 REM
1602 REM   PRINT THE OLD SEQUENCE (IF ANY).
1603 REM
1610 IF NO<.1 GOTO 1770
1620 INFILE ON (2,NO) W8,W9,Z3
1630 PRINT 'FLOOR','COEFFICIENT'
1640 ZO=NO
1650 PRINT W8,W9
1660 IF Z3<0 GOTO 1700
1670 ZO=Z3
1680 INFILE ON (2,ZO) W8,W9,Z3
1690 GOTO 1650
1691 REM
1692 REM   ASK THE USER IF HE WANTS CHANGES
1693 REM
1700 PRINT 'CHANGES ?(1) YES (2) NO'
1710 INPUT Z4
1720 ON Z4 GOTO 1740
1730 RETURN
1731 REM
1732 REM   IF SO, DELETE THE OLD FACTORS AND INPUT A NEW SET.
1733 REM
1740 INFILE ON (2,0) P
1750 OUTFILE ON (2,0) NO
1760 OUTFILE ON (2,ZO)0,0,P
1770 NO=-1
1780 PRINT 'ENTER FLOOR NO. AND PRODUCTION COEFFICIENT'
1790 INPUT W1,W2
1800 IF W1<=0 THEN RETURN
1810 INFILE ON (2,0) ZO
1820 INFILE ON (2,ZO) W8,W9,Z3
1830 OUTFILE ON (2,0) Z3
1840 OUTFILE ON (2,ZO) W1,W2,NO
1850 NO=ZO
1860 GOTO 1790
1861 REM
1862 REM   SUBROUTINES FOR DATA OF NON-REPETITIVE ACTIVITIES.
1863 REM
1870 PRINT 'ENTER DURATION'
1880 INPUT D1
1890 RETURN
1900 PRINT 'STATUS  (1) COMPLETED  (0) NOT'
1910 INPUT S
1920 RETURN
1921 REM
1922 REM   THIS SUBROUTINE IS TO INPUT THE PROCUREMENT SEQUENCE
1923 REM
1930 IF Z=2 GOTO 2100
1931 REM
1932 REM   PRINT THE OLD SEQUENCE, IF ANY.
1933 REM
1940 IF P1<.1 GOTO 2100
1950 INFILE ON (2,P1) W8,W9,Z3
1960 PRINT 'ITEM','DURATION'
1970 ZO=P1
1980 PRINT W8,W9
1990 IF Z3<0 GOTO 2030
2000 ZO=Z3
2010 INFILE ON (2,ZO) W8,W9,Z3
2020 GOTO 1980
2021 REM
2022 REM   ASK THE USER IF HE WANTS CHANGES.
2023 REM
2030 PRINT 'CHANGES ? (1) YES (2) NO'
2040 INPUT Z9
2050 ON Z9 GOTO 2070
2060 RETURN
2061 REM
2062 REM   IF SO, DELETE THE OLD SEQUENCE AND INPUT A NEW ONE.
```

```
2063 REM
2070 INFILE ON (2,0) P
2080 OUTFILE ON (2,0) P1
2090 OUTFILE ON (2,Z0)0,0,P
2100 PRINT '1) PREPARATION OF BID DOCUMENTS'
2110 PRINT '2) CALL FOR TENDERS'
2120 PRINT '3) EXAMINATION OF BIDS AND CONTRACT AWARD'
2130 PRINT '4) VENDOR'S PREPARATION AND SUBMISSION OF SHOP DRAWINGS'
2140 PRINT '5) REVIEW AND APPROVAL OF SHOP DRAWINGS'
2150 PRINT '6) FABRICATION BY THE VENDOR'
2160 PRINT '7) SHIPPING'
2170 PRINT '8) CUSTOM CLEARANCES'
2180 PRINT '9) DELIVERY AND INSPECTION'
2190 PRINT
2200 N0=-1
2210 PRINT 'ENTER ITEM NUMBER AND DURATION'
2220 INPUT W1,W2
2221 REM
2222 REM   ZERO WILL STOP THE INPUT
2223 REM
2230 IF W1<=0 GOTO 2300
2240 INFILE ON (2,0) Z0
2250 INFILE ON (2,Z0) W8,W9,Z3
2260 OUTFILE ON (2,0) Z3
2270 OUTFILE ON (2,Z0) W1,W2,N0
2280 N0=Z0
2290 GOTO 2220
2300 P1=N0
2310 RETURN
2311 REM
2312 REM   HASHING ROUTINE FOR THE ACTIVITY NUMBERS
2313 REM
2320 H0=199
2330 Q=INT(N9/H0)
2340 H=FNM(N9,H0)
2350 IF H=0 THEN H=FNM((Q+H),H0): GOTO 2350
2360 INFILE ON (7,H) T9
2370 IF T9<>0 THEN RETURN
2380 IF T9=N9 THEN T9=0: RETURN
2390 H-FNM((Q+H),H0): GOTO 2350
2391 REM
2392 REM   HASHING ROUTINE FOR THE RECORDS OF DATES
2393 REM
2400 HQ=1699
2410 Q=INT(R9/H0)
2420 H=FNM(R9,H0)
2430 IF H=0 THEN H=FNM((Q+H),H0); GOTO 2430
2440 INFILE ON (4,H) T9
2450 IF T9<>0 THEN RETURN
2460 IF T9=R9 THEN RETURN
2470 H=FNM((Q+H),H0): GOTO 2430
2471 REM
2472 REM   THIS PART IS TO INPUT ACTUAL START AND FINISH DATES.
2473 REM
2480 PRINT 'INPUT ACTIVITY NO.'
2490 INPUT R9
2500 IF R9=0 GOTO 170
2510 GOSUB 2400
2520 IF T9<>0 THEN PRINT 'ACTIVITY NOT FOUND': GOTO 2480
2521 REM
2522 REM   PRINT OLD DATES, IF ANY.
2523 REM
2530 INFILE ON (4,H) Z,Z1,Z2,Z3,Z4,Z5,Z6
2540 IF Z5=0 AND Z6=0 GOTO 2620
2550 INFILE ON (6,Z5) D2,D8
2560 INFILE ON (6,Z6) D2,D9
2570 PRINT D8,D9
2580 PRINT 'CHANGES ? (1) YES (2) NO'
2590 INPUT Z8
2600 ON Z8 GOTO 2620
2610 GOTO 2480
2620 PRINT 'INPUT ACTUAL START AND FINISH DATES'
2630 INPUT D8,D9
2631 REM
2632 REM   SEE IF THE DATES ARE IN THE CALENDAR.
```

```
2633 REM
2640 IF D8=0 AND D9=0 GOTO 2760
2650 I=1
2660 INFILE ON (6,I) D2,D3
2670 IF D8=D3 THEN D8=I: GOTO 2730
2680 I=I+1
2690 IF I>500 THEN PRINT "DATE NOT FOUND": GOTO 2620
2700 GOTO 2660
2710 INFILE ON (6,I) D2,D3
2720 IF D9=D3 THEN D9=I: GOTO 2760
2730 I=I+1
2740 IF I>500 THEN PRINT "DATE NOT FOUND": GOTO 2620
2750 GOTO 2710
2751 REM
2752 REM   STORE THE DATES
2753 REM
2760 INFILE ON (4,H) Z,Z1,Z2,Z3,Z4,Z5,Z6
2770 OUTFILE ON (4,H) Z,Z1,Z2,Z3,Z4,D8,D9
2780 GOTO 2480
2781 REM
2782 REM    END OF THE PROGRAM 'DATA"
2783 REM
2790 END
```

```
1 REM
2 REM          PROGRAM 'SHORT'
3 REM          AUTHOR :JEAN  B. LARAMEE
4 REM          CENTER FOR BUILDING STUDIES
5 REM          CONCORDIA UNIVERSITY
6 REM          FEBRUARY 1983
7 REM
8 REM          THIS PROGRAM PRODUCES THE SHORT  CYCLE SCHEDULE
9 REM          FOR A SPECIFIC DATE.
10 REM
11 REM         IT IS CALLED BY THE PROGRAM 'MAIN' AND RETURNS TO
12 REM         IT AFTER ITS EXECUTION.
13 REM
14 REM         DECLARE VARIABLES AND FUNCTIONS.
19 REM
20 DIM  F$(4),F1$(5),F2$(5),F3$(5),F4$(5),F5$(5)
30 DIM  D$(20),M1$(60),M2$(60),S(200),D(6),A$(3)
40 DEF  FNM(X,Y)=INT((X/Y-INT(X/Y))*Y+.5)
50 DEF  FNA(A)-INT(INT(A/100)-(INT(A/10000)*100)+.5)
60 DEF  FNL(A)=INT(A-(INT(A/100)*100)+.5)
70 DEF  FNS(A)=INT(A/10000)
80 PRINT 'NAME OF FILE ? (4 CHAR.)'
90 INPUT F$
100 F1$=F$+'1'
110 F2$=F$+'2'
120 F3$=F$+'3'
130 F4$=F$+'4'
140 F5$=F$+'5'
150 OPEN F$,7,0
160 OPEN 'CAL',1,0
170 OPEN F3$,3,0
180 OPEN F4$,4,0
190 OPEN F5$,5,0
200 OPEN 'PR:',6,2
210 M2$=' '
220 FOR  I=1 TO 60
230    M2$=M2$+' '
240 NEXT I
241 REM
242 REM    ASK THE USER TO INPUT THE DATE HE WANTS
243 REM
250 PRINT 'FOR WHICH DATE ?'
260 INPUT D
270 I*0
280 I=I+1
290 IF  I.500 THEN PRINT 'DATE NOT FOUND': GOTO 250
300 INFILE ON (1,I) Z,D1
310 IF  D=D1 THEN  320 ELSE  280
311 REM
312 REM    SET THE LIMITS OF  THE WINDOW
313 REM
320 I1=I-5
330 IF  I1:0 THEN  I1=1
340 I2=I+10
350 M=FNA(D)
360 GOSUB 1020
361 REM
362 REM    PRINT THE HEADING
363 REM
370 PRINT ON (6)"SHORT CYCLE SCHEDULE AS OF ";FNL(D);A$;FNS(D)
380 PRINT ON (6)
390 PRINT ON (6)TAB(31),'I';TAB(38),'E A R L Y';
400 PRINT ON (6)TAB(59),'L  A T E',TAB(77),'A C  T U A L';
410 PRINT ON (6)TAB(105),'DURATION'
420 PRINT ON (6)" NO.      DESCRIPTION     FLOOR",TAB(31),"I";
430 PRINT ON (6)"    START       FINISH      START     FINISH    ";
440 PRINT ON (6)" START      FINISH     FLOAT   SCHED. ACTUAL'
450 FOR  I=1 TO 120
460   PRINT ON (6)'-';
470 NEXT  I
480 PRINT ON (6)'-'
490 N=0
491 REM
492 REM    SCAN THE FILE OF DATES AND PICK THE ACTIVITIES LOCATED
493 REM    WITHIN THE LIMITS: EARLY, LATE OR ACTUAL DATES.
```

```
494 REM
500 FOR I=1 TO 1699
510    INFILE ON (4,I) Z,S1,F1,S2,F2,S3,F3
520    IF F1<I1  GOTO 540
530    IF S1>I2  THEN 540  ELSE 580
540    IF F2<I1  GOTO 560
550    IF S2>I2  THEN 560  ELSE 580
560    IF S3<I1  GOTO 600
570    IF F3>I2  GOTO 600
580    N=N+1
581 REM
582 REM   ARRAY S CONTAINS THE RECORD NUMBERS OF THE PICKED ACT.
583 REM
590    S(N)=I
600 NEXT I
601 REM
602 REM   PRINT THE ACTIVITIES IN THE ORDER THEY WERE FOUND
603 REM
610 FOR I=1 TO N
620    M1$=M2$
621    REM
622    REM   THIS PROCEDURE IS SIMILAR TO THE ONE USED TO PRINT
623    REM   THE LIST OF DATES OF THE PROGRAM 'OUT'.
624    REM
630    INFILE ON (4,S(I)) Z,D(0);D(1),D(2),D(3),D(4),D(5)
640    Y=FNA(Z)
650    IF Y>20  THEN A9=Z  ELSE A9=Z-FNL(Z)
660    GOSUB 940
670    INFILE ON  (7,H) N1,N2,P0,T1,T2,P5,T5,T6,D$
680    IF Y>80  THEN K=1:D(1)=D(1)+1: GOTO 700
690    FOR K=0  TO 5
700      IF D(K)<=0 GOTO 790
710      INFILE  ON (1,D(K)) D,D1
720      A=FNL(D1)
730      M1$((K*10+1),(K*10+2))=STR$(A)
740      M=FNA(D1)
750      GOSUB  1020
760      M1$((K*10+3),(K*10+5))=A$
770      A=FNS(D1)
780      M1$((K*10+6),(K*10+7))=STR$(A)
790      IF Y>80  THEN F9=0:F8=0:F7=0: GOTO 840
800    NEXT K
810    F9=D(2)-D(0)
820    F8=D(1)-D(0)+1
830    IF D(5)<>0 AND D(4)<>0 THEN  F7=D(5)-D(4)+1 ELSE F7=0
840    PRINT ON  (6)TAB(31),'I'
850    PRINT ON  (6) N1,TAB(9),D$;TAB(27),FNL(Z);TAB(31),'I    ';M1$;F9
;
860    PRINT ON  (6)TAB(104),F8;TAB(112),F7
870 NEXT I
880 CLOSE 1
890 CLOSE 4
900 CLOSE 5
910 CLOSE 6
920 CLOSE 7
921 REM
922 REM  'RETURN TO THE PROGRAM 'MAIN'
923 REM
930 CHAIN 'MAIN'
931 REM
932 REM   HASHING ROUTINE FOR THE ACTIVITY NUMBERS RECORDS
933 REM
940 HO=199
950 Q=INT(A9/HO)
960 H=FNM(A9,HO)
970 IF  H=0 THEN  H=FNM((Q+H),H0):  GOTO 970
980 INFILE ON  (7,H) T9
990 IF  T9<0 THEN  RETURN
1000  IF T9=A9  THEN RETURN
1010  H=FNM((Q+H),H0): GOTO 970
1011  REM
1012  REM   SUBROUTINE THAT CONVERTS THE MONTH NUMBER INTO ITS NAME
1013  REM
1020  ON M GOTO  1040,1050,1060,1070,1080,1090,1100,1110,1120,1130
1030  ON (M-10)  GOTO 1140,1150
1040  A$='JAN':  RETURN
```

```
1050 A$="FEB": RETURN
1060 A$="MAR": RETURN
1070 A$="APR": RETURN
1080 A$="MAY": RETURN
1090 A$="JUN": RETURN
1100 A$="JUL": RETURN
1110 A$="AUG": RETURN
1120 A$="SEP": RETURN
1130 A$="OCT": RETURN
1140 A$="NOV": RETURN
1150 A$="DEC": RETURN
1151 REM
1152 REM   END OF THE PROGRAM "SHORT"
1153 REM
1160 END
```

```
1 REM
2 REM          PROGRAM "PROC"
3 REM          AUTHOR: JEAN B. LARAMEE
4 REM          CENTER FOR BUILDING STUDIES
5 REM          CONCORDIA UNIVERSITY
6 REM          FEBRUARY 1983
7 REM
8 REM          THIS PROGRAM PRODUCES THE PROCUREMENT STATUS
9 REM          REPORT FOR THE ACTIVITIES INPUT BY THE USER.
10 REM
11 REM         IT IS CALLED BY THE PROGRAM "MAIN" AND RETURNS TO
12 REM         IT AFTER ITS EXECUTION.
13 REM
18 REM         DECLARE VAIABLES AND FUNCTIONS
19 REM
20 DIM F$(4),F1$(5),F2$(5),F3$(5),F4$(5),F5$(5)
30 DIM D$(20),M$(110),M1$(110)
40 DIM A$(3)
50 DEF FNM(X,Y)=INT((X/Y-INT(X/Y))*Y+.5)
60 DEF FNA(A)=INT(INT(A/100)-(INT(A/10000)*100)+.5)
70 DEF FNL(A)=INT(A-(INT(A/100)*100)+.5)
80 DEF FNS(A)=INT(A/10000)
90 PRINT "NAME OF FILE ? (4 CHAR.)"
100 INPUT F$
110 F1$=F$+"1"
120 F2$=F$+"2"
130 F3$=F$+"3"
140 F4$=F$+"4"
150 F5$=F$+"5"
160 OPEN F$,7,0
170 OPEN "CAL",1,0
180 OPEN F2$,2,0
190 OPEN F4$,4,0
200 OPEN F5$,5,0
210 OPEN "PR:",6,2
211 REM
212 REM   PRINT THE HEADING
213 REM
220 PRINT ON (6)"<12>"
230 PRINT ON (6)"       PROCUREMENT STATUS REPORT    "
240 PRINT ON (6)""
250 M1$=" "
260 FOR I=1 TO 102
270   M1$=M1$+" "
280 NEXT I
290 M$="  PREPAR.   TENDER   CONTRACT  SHOP DWG  SHOP DWG "
300 M$=M$+"  FABRIC.  SHIPPING   CUSTOM   DELIVERY "
310 PRINT ON (6)TAB(26),M$
320 M$=M1$
330 M$=" BID DOC.    CALL      AWARD      SUBMIT   APPROV.  "
340 M$=M$+"  EQUIP.    EQUIP.    CLEAR    INSPECT.  "
350 PRINT ON (6)"    NO.     DESCRIPTION";TAB(25),"I";M$
360 FOR I=1 TO 120
370   PRINT ON (6)"-";
380 NEXT I
390 PRINT ON (6)"-"
400 PRINT ON (6)TAB(25),"I"
401 REM
402 REM   ASK THE USER TO INPUT THE ACTIVITIES HE WANTS TO SEE.
403 REM
410 PRINT "ACTIVITY NO. ?"
420 INPUT A9
430 IF A9<=0 GOTO 710
440 GOSUB 780
450 INFILE ON (5,H) A2,A3
451 REM
452 REM   VERIFY IF IT HAS A PROCUREMENT SEQUENCE
453 REM
460 IF A3<0 OR A3>2000 THEN PRINT "NO PROCUREMENT": GOTO 410
470 R9=A9
480 GOSUB 990
481 REM
482 REM   GET THE DATE AT WHICH THE ACTIVITY STARTS ON THE SITE.
483 REM
490 INFILE ON (4,H) R9,S
```

```
500 M$-M1$
510 IF A3<0 GOTO 660
520 INFILE ON (2,A3) Z1,Z2,Z3
530 A3=Z3
531 REM
532 REM   CALCULATE THE DATE AT WHICH THAT ITEM STARTS
533 REM
540 D=S-Z2
550 S=D
560 INFILE ON (1,D) J,D1
570 L=Z1*10-8
580 J1=FNL(D1)
581 REM
582 REM   PUT THAT UNDER THE RIGHT HEADING
583 REM
590 M$(L,L+1)=STR$(J1)
600 M=FNA(D1)
610 GOSUB 860
620 M$(L+2,L+4)=A$
630 Y=FNS(D1)
640 M$(L+5,L+6)=STR$(Y)
650 GOTO 510
660 GOSUB 780
670 INFILE ON (7,H) N1,N2,P0,T1,T2,P5,T5,T6,D$
671 REM
672 REM   PRINT FOR THAT ACTIVITY
673 REM
680 PRINT ON (6) N1,TAB(9),D$;TAB(25),'I';M$
690 PRINT ON (6)TAB(25),'I'
691 REM
692 REM   GO GET ANOTHER ONE
693 REM
700 GOTO 410
710 CLOSE 1
720 CLOSE 2
730 CLOSE 4
740 CLOSE 5
750 CLOSE 6
760 CLOSE 7
761 REM
762 REM   RETURN TO THE PROGRAM 'MAIN'
763 REM
770 CHAIN 'MAIN'
771 REM
772 REM   HASHING ROUTINE FOR THE ACTIVITY NUMBERS
773 REM
780 H0=199
790 Q=INT(A9/H0)
800 H=FNM(A9,H0)
810 IF H=0 THEN H=FNM((Q+H),H0): GOTO 810
820 INFILE ON (7,H) T9
830 IF T9<0 THEN RETURN
840 IF T9=A9 THEN RETURN
850 H=FNM((Q+H),H0): GOTO 810
851 REM
852 REM   THIS SUBROUTINE CONVERTS MONTH NUMBER INTO ITS NAME
853 REM
860 ON M GOTO 870,880,890,900,910,920,930,940,950,960,970,980
870 A$='JAN': RETURN
880 A$='FEB': RETURN
890 A$='MAR': RETURN
900 A$='APR': RETURN
910 A$='MAY': RETURN
920 A$='JUN': RETURN
930 A$='JUL': RETURN
940 A$='AUG': RETURN
950 A$='SEP': RETURN
960 A$='OCT': RETURN
970 A$='NOV': RETURN
980 A$='DEC': RETURN
981 REM
982 REM   HASHING ROUTINE FOR THE DATES RECORDS.
983 REM
990 H0=1699
1000 Q=INT(R9/H0)
```

```
1010 H=FNM(R9,HO)
1020 IF H=0 THEN H=FNM((Q+H),HO): GOTO 1020
1030 INFILE ON (4,H) T9
1040 IF T9<0 THEN RETURN
1050 IF T9=R9 THEN RETURN
1060 H=FNM((Q+H),HO): GOTO 1020
1061 REM
1062 REM   END OF THE PROGRAM "PROC"
1063 REM
1070 END
```

```
1 REM
2 REM       PROGRAM 'CALENDAR'
3 REM       AUTHOR: JEAN B. LARAMEE
4 REM       CENTER FOR BUILDING STUDIES
5 REM       CONCORDIA UNIVERSITY
6 REM       FEBRUARY 1983
7 REM
8 REM       THIS PROGRAM PREPARES THE EQUIVALENT OF WORKING
9 REM       DAYS TO CALENDAR DAYS AND STORES IT IN FILE 'CAL'.
10 REM
11 REM      THIS PROGRAM IS CALLED BY THE PROGRAM 'MAIN' AND
12 REM      RETURNS TO IT AFTER ITS EXECUTION.
13 REM
18 REM      DECLARE VARIABLES AND FUNCTIONS
19 REM
20 DEF FNM(X,Y)=INT((X/Y-INT(X/Y))*Y+.5)
30 DEF FNA(A)=INT(INT(A/100)-(INT(A/10000)*100)+.5)
40 DEF FNS(A)=INT(A/10000)
50 DEF FNL(A)=INT(A-(INT(A/100)*100)+.5)
60 OPEN 'CAL',1,0
61 REM
62 REM   THE DAY OF THE WEEK IS A NUMBER (MON=1, TUE=2, ETC...)
63 REM
70 PRINT 'INPUT DAY OF WEEK AND DATE THAT PROJECT STARTS'
80 INPUT D,S
90 I=1
91 REM
92 REM   INPUT THE DATES IN THE FORMAT YYMMDD (ALL NUMBERS).
93 REM
100 PRINT 'INPUT HOLIDAYS (0 TO END)'
110 INPUT H
120 OUTFILE ON (1,I)0,0,H
130 IF H=0 GOTO 160
140 I=I+1
150 GOTO 110
160 OUTFILE ON (1,0) I
170 I=I-2
180 I9=0
181 REM
182 REM   SORT THE HOLIDAYS
183 REM
190 FOR J=1 TO I
200   INFILE ON (1,J) A1,B1,C1
210   INFILE ON (1,J+1) A2,B2,C2
220   IF C1<C2 GOTO 260
230   OUTFILE ON (1,J) A1,B1,C2
240   OUTFILE ON (1,J+1) A2,B2,C1
250   I9=1
260 NEXT J
270 I=I-1
280 IF I9=1 GOTO 180
290 PRINT 'INPUT NO OF WORKING DAYS'
300 INPUT N
301 REM
302 REM   STORE THE START DATE IN THE FIRST RECORD
303 REM
310 INFILE ON (1,1) A,B,C
320 OUTFILE ON (1,1) D,S,C
330 I1=1
340 S1=S
350 D1=D
351 REM
352 REM   FOR THE NUMBER OF WORKING DAYS, GO THROUGH THE CALENDAR
353 REM   AND ELIMINATE THE HOLIDAYS AND THE WEEKENDS.
354 REM
360 FOR I=2 TO N
361   REM
362   REM   NEXT DATE
363   REM
370   D1=D1+1
380   S1=S1+1
390   D9=FNL(S1)
391   REM
392   REM   CHECK IF IT IS THE END OF THE MONTH
393   REM
```

```
400   IF D9 25 GOTO 530
401   REM
402   REM   CHECK IF IT IS AN HOLIDAY
403   REM
410   IF S1-C THEN 420 ELSE 450
411   REM
412   REM   GET THE NEXT HOLIDAY AND GO GET THE NEXT CALENDAR DAY
413   REM
420   I1 I1+1
430   INFILE ON (1,I1) A,B,C
440   GOTO 370
441   REM
442   REM   CHECK IF IT IS DURING A WEEKEND
443   REM   HERE IS WHERE ONE COULD MODIFY THE SOFTWARE
444   REM   TO GENERATE A CALENDAR FOR WHICH ONE WORKS
445   REM   ON WEEKENDS.  (REPLACE 5 BY 6 OR 7)
446   REM
450   IF D1 5 THEN 460 ELSE 480
451   REM
452   REM   IF SO JUMP THAT DATE AND ADJUST THE DAY OF THE WEEK
453   REM
460   IF D1=7 THEN D1=0
470   GOTO 370
480   INFILE ON (1,I) A,B,Z
481   REM
482   REM   STORE THAT DATE IN THE Ith RECORD OF THE FILE
483   REM
490   OUTFILE ON (1,I) D1,S1,Z
500 NEXT I
510 CLOSE 1
511 REM
512 REM   RETURN TO THE PROGRAM 'MAIN'
513 REM
520 CHAIN 'MAIN'
521 REM
522 REM   THIS PROCEDURE GETS THE FIRST DATE OF THE NEXT MONTH
523 REM
530 M=FNA(S1)
540 ON M GOTO 550,570,550,630,550,630,550,550,630,550,630,650
541 REM
542 REM   CASE OF MONTHS OF 31 DAYS; EXCEPT DECEMBER
543 REM
550 IF D9 31 THEN S1=S1+68: GOTO 380
560 GOTO 410
561 REM
562 REM   CASE OF FEBRUARY: CHECK FOR LEAP YEAR
563 REM
570 Y-FNB(S1)
580 Y1=FNM(Y,4)
590 IF Y1=0 THEN 600 ELSE 620
600 IF D9 29 THEN S1=S1+70: GOTO 380
610 GOTO 410
620 S1=S1+71: GOTO 380
621 REM
622 REM   CASE OF MONTHS OF 30 DAYS
623 REM
630 IF D9 30 THEN S1=S1+69: GOTO 380
640 GOTO 410
641 REM
642 REM   CASE OF DECEMBER: CHANGE YEAR
643 REM
650 IF D9 31 THEN S1-S1+8868: GOTO 380
660 GOTO 410
661 REM
662 REM   END OF THE PROGRAM 'CALENDAR'
663 REM
670 END
```