Conf-820705--3

CONF-820705--3

DE82 013030

CLINCH RIVER BREEDER REACTOR PLANT PROJECT

CONSTRUCTION SCHEDULE

W. J. PURCELL AND E. M. MARTIN
WESTINGHOUSE ELECTRIC CORPORATION

J. M. SHIVLEY
STONE & WEBSTER ENGINEERING CORPORATION

ABSTRACT

The construction schedule for the Clinch River Breeder Reactor Plant and its evolution are described. The initial schedule basis, changes necessitated by the evaluation of the overall plant design, and constructability improvements that have been effected to assure adherence to the schedule are presented. The schedule structure and hierarchy are discussed, as are tools used to define, develop, and evaluate the schedule.

INTRODUCTION

The methodology in the development of a technological base adequate for the realization of commercial LMFBR power plants has been the construction of a succession of fast breeder reactor facilities, each a conservative but significant extrapolation in size and engineering technology over its predecessor.[1] The effort began with the Experimental Breeder Reactor I (EBR-I) and was followed by the Experimental Breeder Reactor II (EBR-II), the Enrico Fermi Atomic Power Plant (Fermi), and most recently, the Fast Flux Test Facility (FFTF).[2] The FFTF achieved full power in December 1980. The Clinch River Breeder Reactor Plant (CRBRP) Project, which is now underway, is the next logical step toward commercial plant construction.

The purpose of this paper is to describe the development and evolution of one of the key elements of the overall CRBRP Project plan, the construction schedule. The construction schedule integrates the final efforts of all the Project participants that are required to actually build the plant.

THE CRBRP PROJECT

CRBRP, a joint effort of the U.S. Department of Energy and the nation's electrical utility industry, will be located on the Clinch River near Oak Ridge, Tennessee (Figure 1). The plant will have a generating capacity of 375 MWe, or enough power to provide the residential electric needs of a city of 200,000, and it will be operated as part of the Tennessee Valley Authority system. The Project team was established in 1973 with the initial task of firming up the design basis and providing realistic cost and schedule estimates. Organization of the team is shown in Figure 2. As can be seen, it is a complex structure requiring extensive technical and schedular interactions between participants. The Architect-Engineer, the Lead Reactor Manufacturer, and the Constructor are under contract to the Department of Energy, CRBRP Project Office.

REFERENCE BASELINE SCHEDULE DEVELOPMENT

System and component conceptual designs, including equipment lists, and design parameters were established by early 1974. Development of the equipment arrangements and building specifications was completed by the Architect-Engineer and approved by the systems designers. Those designs, arrangements, and specifications became the reference baseline designs from which reference construction quantities were developed for use in the Project schedule development.

The reference baseline construction schedule was developed primarily by using the experience of the Architect-Engineer and the Lead Reactor Manufacturer in the construction of Light Water Reactor (LWR) projects. In addition, recent FFTF experience relating to activity sequencing, durations, and productivity rates were factored into the reference schedule.

A top level Project logic diagram, including all major items of equipment and construction activities, was developed. Relationships of system and component designs, fabrication, and deliveries with construction installation and test activities were identified. Construction activity durations were based on the reference design construction quantities, economical crew sizes, and recent industry experience for installation rates. As the construction quantities of CRBRP

---

[1] "Element 1, Overall Plan, LMFBR Program Plan," WASH-1101, 2nd Edition, December 1973.

[2] The FFTF is an LMFBR test reactor operated by Westinghouse Electric Corporation for the Department of Energy in Richland, Washington.

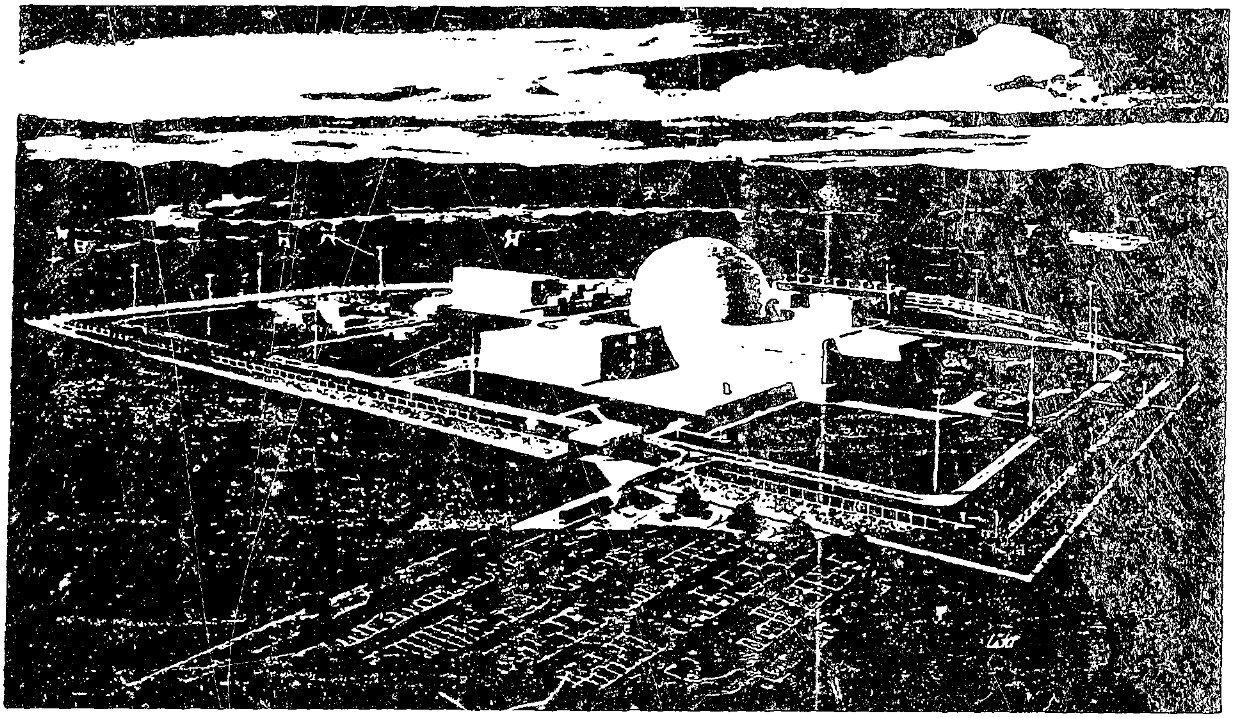

FIG. 1 ARTIST CONCEPT OF CRBRP

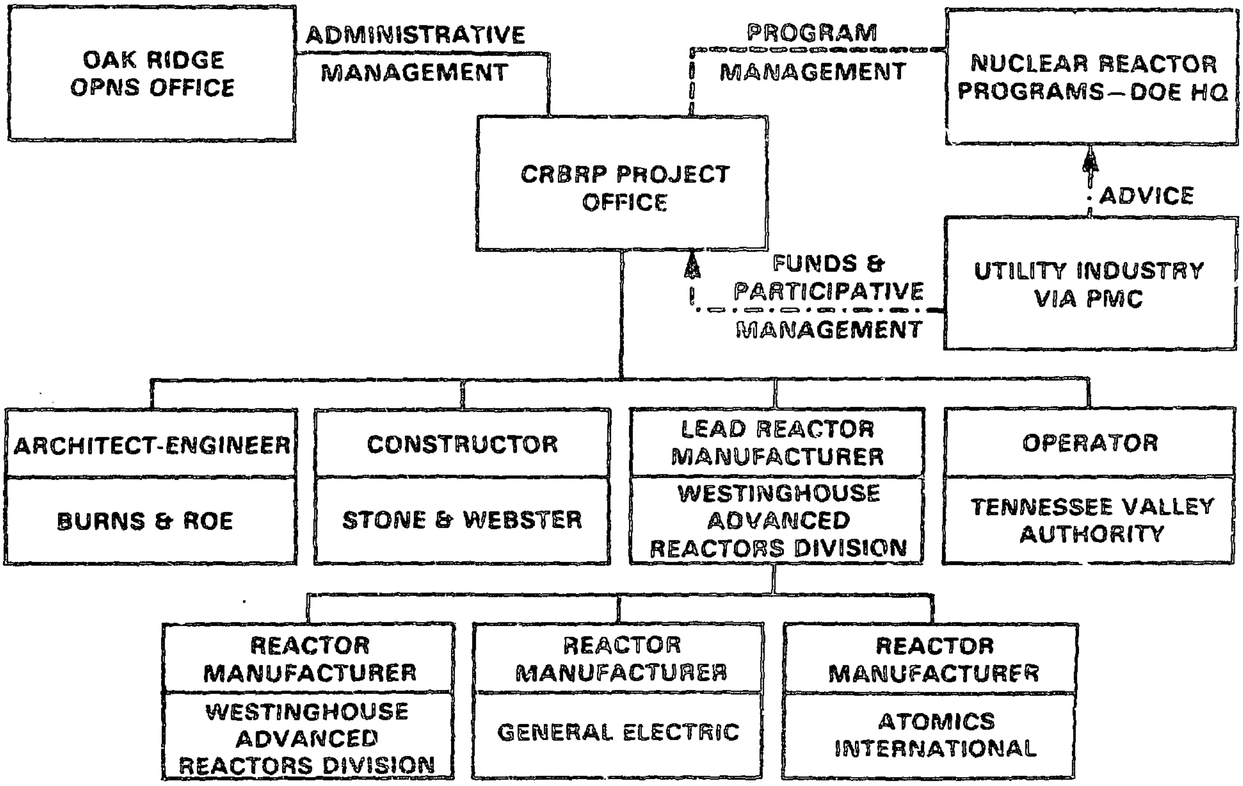

FIG. 2 THE PROJECT ORGANIZATION

compared favorably with those of 1100 to 1150 MWe LWRs, the overall construction periods for LWRs built in the United States were compared with the construction period estimated in the CRBRP reference schedule. The construction period for those LWRs, excluding site preparation and test, ranged from 30 months to 78 months and included the impact of many factors relating to licensing, regional labor availability, and site considerations. The Architect-Engineer's more recent experience indicated that the construction durations for similar size LWRs ranged in duration from 43 to 50 months.

On the basis of that comparison, and because the CRBRP would be slightly larger in volume of materials, a construction duration of 56 months was proposed. The overall CRBRP reference schedule depicted an 82-month duration from receipt of the Limited Work Authorization to criticality. This 82-month schedule was subdivided into site work of 16 months, construction activities of 56 months, and fuel loading and testing of 10 months (Figure 3).

PROJECT-WIDE SCHEDULING SYSTEM AND SCHEDULE HIERARCHY DEVELOPMENT

The CRBRP planning and schedule control system is designed to integrate the activities of all Project participants to assure a coordinated and controlled effort directed toward the design, fabrication, and construction of the plant. Project scheduling comprises a hierarchy of schedules that expands the level of schedule detail as one progresses to lower level schedules (Figure 4).

The Project Level 1 schedule graphically depicts the overall Project milestones together with the interrelationships of each major contractors' work within the total Project. It is established and controlled by the Project Office and contains milestones selected by the Project Office to control Project performance. The Level 2 schedules are computerized logic networks that display activity and activity durations for all components and systems within a participant's scope of work. All CRBRP Level 2 schedules are computerized using the IBM Project Management System Version IV (PMS-IV) extended network processor and are updated at least monthly. The Level 3 schedules represent the contractors' detailed work sequence and schedule to support the Level 2 schedules and usually cover durations of 6 months to a year. The lowest level of planning in the schedule hierarchy is the set of weekly and daily schedules that participants may elect to initiate. All milestone events appearing on the higher levels of schedules appear on the lower levels of schedules.

In 1976 and 1977, each participant's (except the Constructor's) schedule system, as well as other elements of their management control systems, were validated by Department of Energy teams as meeting the Department of Defense Cost Schedule Control System Criteria (C/SCSC).[3] Each participant has retained its validation through eight systems surveillances conducted by the Department of Energy.

---

[3] DOE Order 2250.1 "Cost and Schedule Control System (C&SCS) Criteria for Contract Performance Measurement."

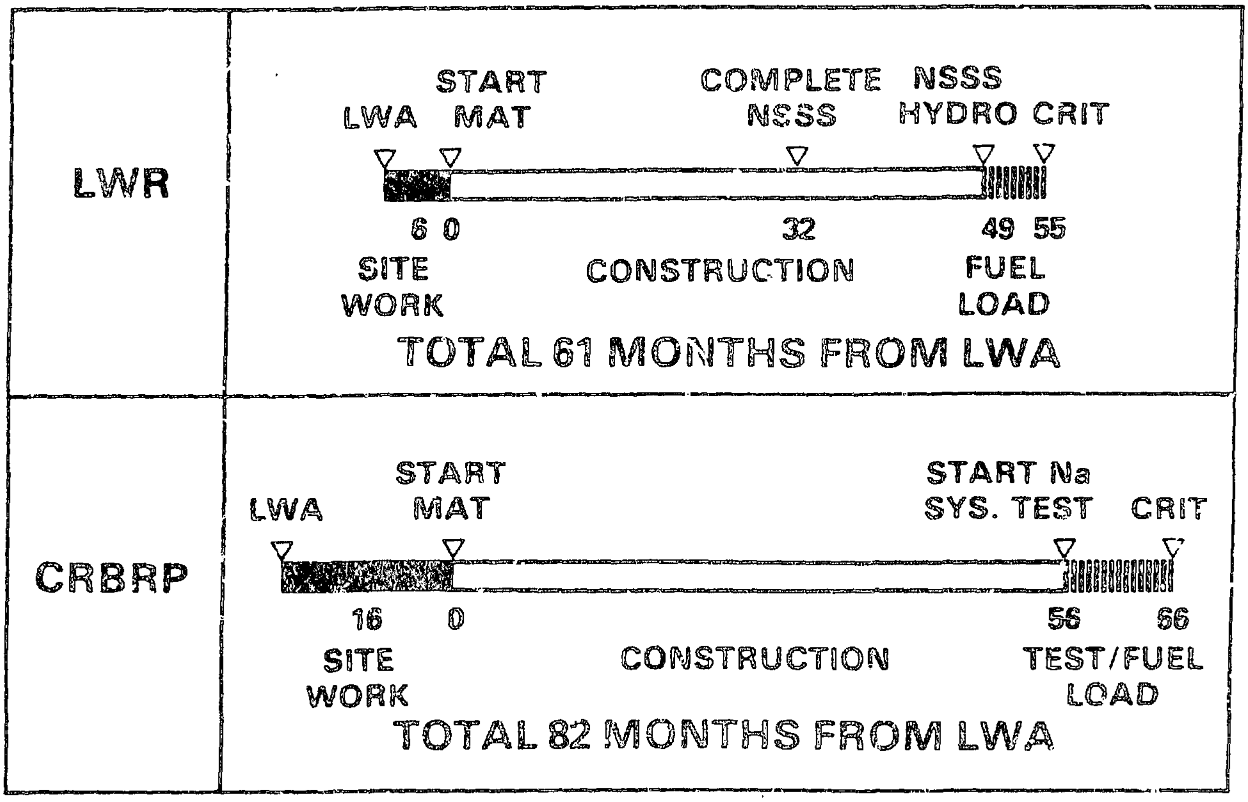

FIG. 3 COMPARISON OF CRBRP AND LWR CONSTRUCTION SCHEDULE

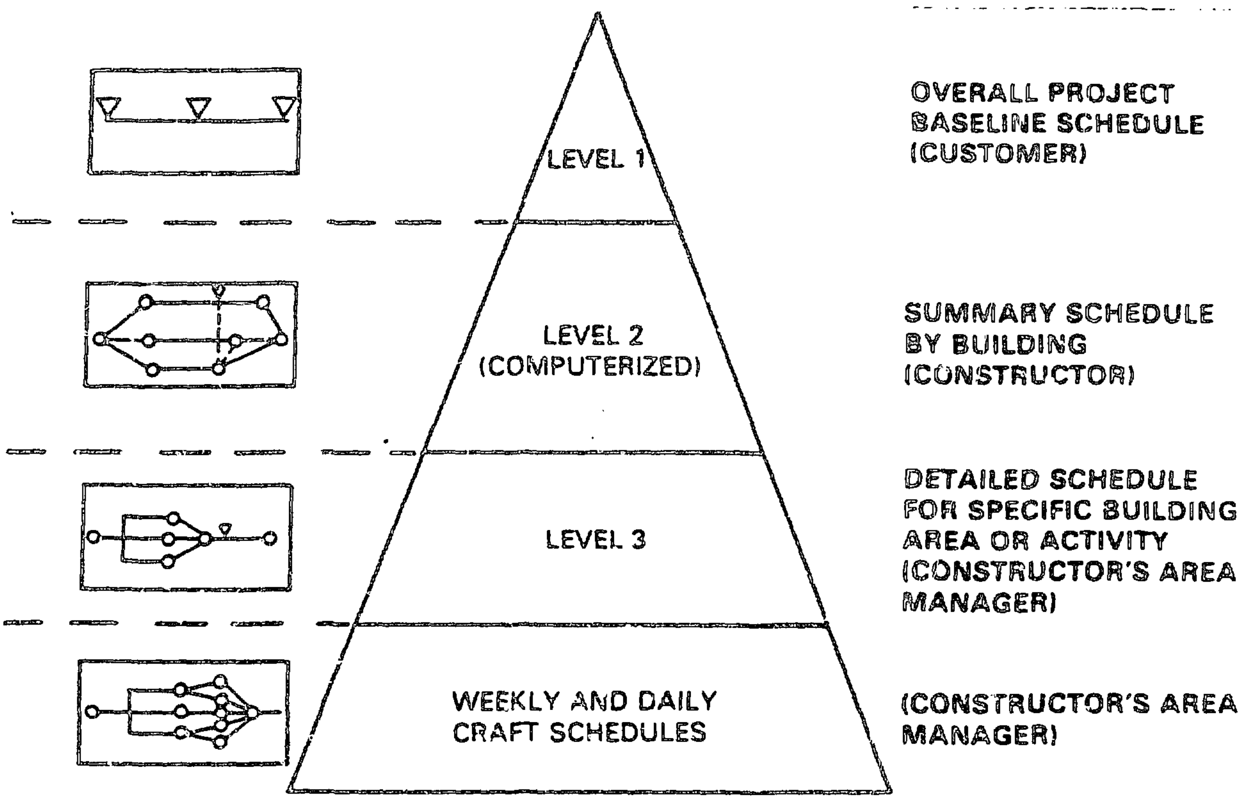

FIG. 4 SCHEDULE HIERARCHY

DETAILED SCHEDULE DEVELOPMENT AND ANALYSIS

Significant progress was made toward completing the preliminary CRBRP design by the time the Constructor joined the team in January 1976. In addition, certain long-lead components, such as the reactor vessel, primary and intermediate pumps, and intermediate heat exchangers were placed on order. Also during the period between completion of the Reference design in 1974 and the addition of the Constructor to the team, changes to design requirements had significant construction impact. Those design changes included:

1. An increase in the containment building diameter from 150 feet to 186 feet.
2. The addition of a concrete confinement vessel around and over the top of the containment vessel.
3. Revision of the plant seismic requirements requiring increased mat thickness and structural supports.

In addition to those changes, other interactions with the Nuclear Regulatory Commission (NRC) regarding safety and licensing issues resulted in design modifications that affected construction quantities and construction sequences to varying degrees. Although the reference schedule was being updated and maintained by the Architect-Engineer, a lack of detail available in the construction schedule made it impossible to separately evaluate the net impact of the changes on construction sequencing and time durations. It was estimated, however, that the design changes had increased the Construction period to at least 57 1/2 months.

Immediately after receipt of a contract the Constructor initiated a thorough construction reference schedule analysis. Schedule assumptions, construction quantities, sequencing, and specification requirements were reviewed and, in general, thought to be acceptable considering the stage of design and schedule detail available. Activity durations, however, were considered to be optimistic and the schedule impacts of recent design changes appeared not to have been adequately addressed. The full impact on the construction quantities was just then being identified. Concrete, for example, had increased from 208,530 yd^3 to more than 300,000 yd^3, and excavation had increased from 1.8 million yd^3 to approximately 3 million yd^3. Corresponding increases in forming, reinforcing steel, and backfill were identified. In addition, the maturing of component designs and hardening of fabrication estimates revealed that some components might not meet the desired construction site need date. The constructability of several of the conceptual design features, such as the cell liners, appeared to be questionable from a schedule and cost point of view.

The Constructor, with the assistance of the other participants, immediately instituted a plan designed to develop an achievable, detailed construction schedule aimed at completing the Project within the original time frame.

Senior construction managers with associated planning staff reviewed current designs with each of the Project participants for the purpose of better understanding the installation sequence, constraints, and critical areas in construction. On the basis of the reviews, detailed construction working schedules were developed. Those schedules, which forecast that it would take between 9 and 18 months longer for construction activities than estimated in the reference baseline schedule, became the basis for subsequent actions taken to effect schedule recovery. The actions included constructability design reviews, resequencing to reduce the critical path, and redesign to reduce the critical path.

CONSTRUCTABILITY DESIGN REVIEWS

Comprehensive equipment and building design reviews were conducted by the contractor with the cooperation of all participants. Specifications and drawings were reviewed to assure that the design could be fabricated and installed. Piping and similar components were reviewed to maximize the prefabrication of items into the largest modules practical to handle and install. Each building was reviewed to assure adequate entry through hatches, blockouts, etc. Component sequencing and the interrelationships with adjacent work were reviewed to eliminate potential conflicts. Alternate approaches that might reduce cost, facilitate erection and construction or improve the schedule were pursued. The most recent FFTF experience was re-examined in an effort to avoid repetition of errors and to identify any actions that could improve the CRBRP schedule.

By use of the extensive design reviews, discussions with the designers, and the experience and expertise of the constructor's management team, the working detailed schedules were replanned. Typically the changes consisted of:

1. Resequencing construction activities.
2. Paralleling critical path activities.
3. Recommending design changes to improve schedule and avoid costs.
4. Identifying work-arounds or resequencing to accommodate late component deliveries.
5. Developing alternate construction methods for added flexibility.
6. Identifying areas where prefabrication, either on-site or off-site, could eliminate critical path work.
7. Double-shifting of critical path work.

RESEQUENCING TO REDUCE CRITICAL PATH

The constructability reviews and detailed construction schedule development resulted in several decisions that reduced the construction schedule critical path. Several of the decisions resulted in paralleling critical path activities that had previously been in series. An example of such activities is the installation of the reactor vessel lower internals. The initial schedule sequence required the reactor vessel to be set followed by installation of the lower internals assemblies. A decision to pre-install the lower internals into the reactor vessel prior to its installation at the site improved that critical path area by several weeks.

Cell liner design modifications were completed to allow prefabrication and assembly on-site. This resulted in removal of several thousand linear feet of welding from the Reactor Containment Building, reduction of cell congestion, and the additional benefit of having the cells themselves function as forms during concrete pouring operations. Off-site pre-assembly and checkout of several components, such as the ex-vessel transfer machine and sodium pump internals, offered benefits similar to those realized in the prefabrication of cell liners.

The reference schedule logic for pouring concrete in the Nuclear Island was to start at the periphery working toward the center in order to allow the early completion of exterior wall construction (and backfill), with erection of the reactor containment vessel to start only after completion of the Nuclear Island mat pours. The detailed construction schedule developed by the contractor indicated that insufficient time had been allotted to containment vessel erection and to the completion of interior concrete. Consequently, the logic was revised with early start of mat concrete in the reactor containment area and secondary attention given to the periphery to provide for outside walls and early start of backfill. This sequence provides for start of containment vessel erection several months before completion of the Nuclear Island mat.

The reference construction schedule required the containment vessel to be stopped at grade level until concrete was brought to the operating floor level. At that time, large equipment such as the reactor vessel guard vessel, reactor vessel, and intermediate heat exchangers would be set with savings to rigging costs. The detailed construction schedule analysis indicated that this would extend the construction schedule an unacceptable period of time with attendant increases in construction cost. The schedule was first revised to provide a construction opening, together with a construction bridge, that would not require stopping vessel erection nor require completion of the operating floor before setting the reactor vessel. This plan was further improved with the development of large lift equipment (Transi-Lift), which made possible handling of the steel reactor vessel support and other heavy component lifts over the reactor containment vessel during erection operations. The plan has minimal adverse effect on the containment vessel erector, allows set of the reactor vessel eight months before completion of the operating floor, and, as a side benefit, allows the dome of the containment vessel to be ground-assembled and set in two pieces providing a cover over the reactor building approximately four months earlier than originally planned.

REDESIGN TO REDUCE CRITICAL PATH

The redesign of certain components and plant areas also contributed to the reduction in critical path. One of the major reductions resulted from the redesign of the reactor vessel support. The initial design was a concrete support with a "Z" ring girder placed on top on a concrete support ledge. Reviews indicated that a complete redesign of the concrete ledge would be necessary to resolve certain technical issues and to provide a constructable design. Further, the use of concrete dictated that concrete around the head access area must be essentially complete to the operating floor level before the reactor vessel could be set. A design change to replace the concrete reactor support with a steel support was strongly recommended. The resultant steel ledge support was made more attractive by the development of the large lift crane (Transi-Lift) previously mentioned. This crane, developed by the a Pacific northwest rigging and equipment contractor, has the capability of handling 1000 tons at radial distances of 165 feet from the crane base. The reactor vessel support ledge design change resulted in a steel support that rests on concrete 36 feet (elevation 780) below the operating floor. Resequencing the concrete pours to expedite concrete placement around the reactor cavity base, setting the reactor vessel support ledge when elevation 780 is reached, and immediately proceeding to set the reactor vessel guard vessel and the reactor vessel will release the large sodium piping operations in the reactor cavity and subsequent work in the reactor vessel assembly areas about eight months earlier than originally scheduled.

Another design change that resulted in overall schedule improvement is the substantial decrease in the amount of cable required through the use of signal multiplexing. Multiplexing is an electronic advance that is relatively new to the nuclear industry. It enables thousands of signals to be transmitted simultaneously along one circuit. Multiplexing will save more that a million and a half feet of cable in the plant and, as a result, reduce the construction schedule while improving reliability and substantially decreasing costs.

Other design decisions resulted in the standardization of piping and equipment nozzle weld end preparations. This standardization resulted in the adaptation of semi-automatic field pipe welders and simplified pipe spooling fabrication, with savings of both cost and schedule.

OTHER PLANNING AIDS USED IN CONSTRUCTION SCHEDULE DEVELOPMENT

An example of the integrated systems approach employed in the CRBRP Project is the use of a detailed model (one-half inch to the foot) for the entire plant (Figure 5). It is used in all phases of the plant design, including pipe routing, equipment location, interference determination, constructability and equipment removability. The model is detailed down to

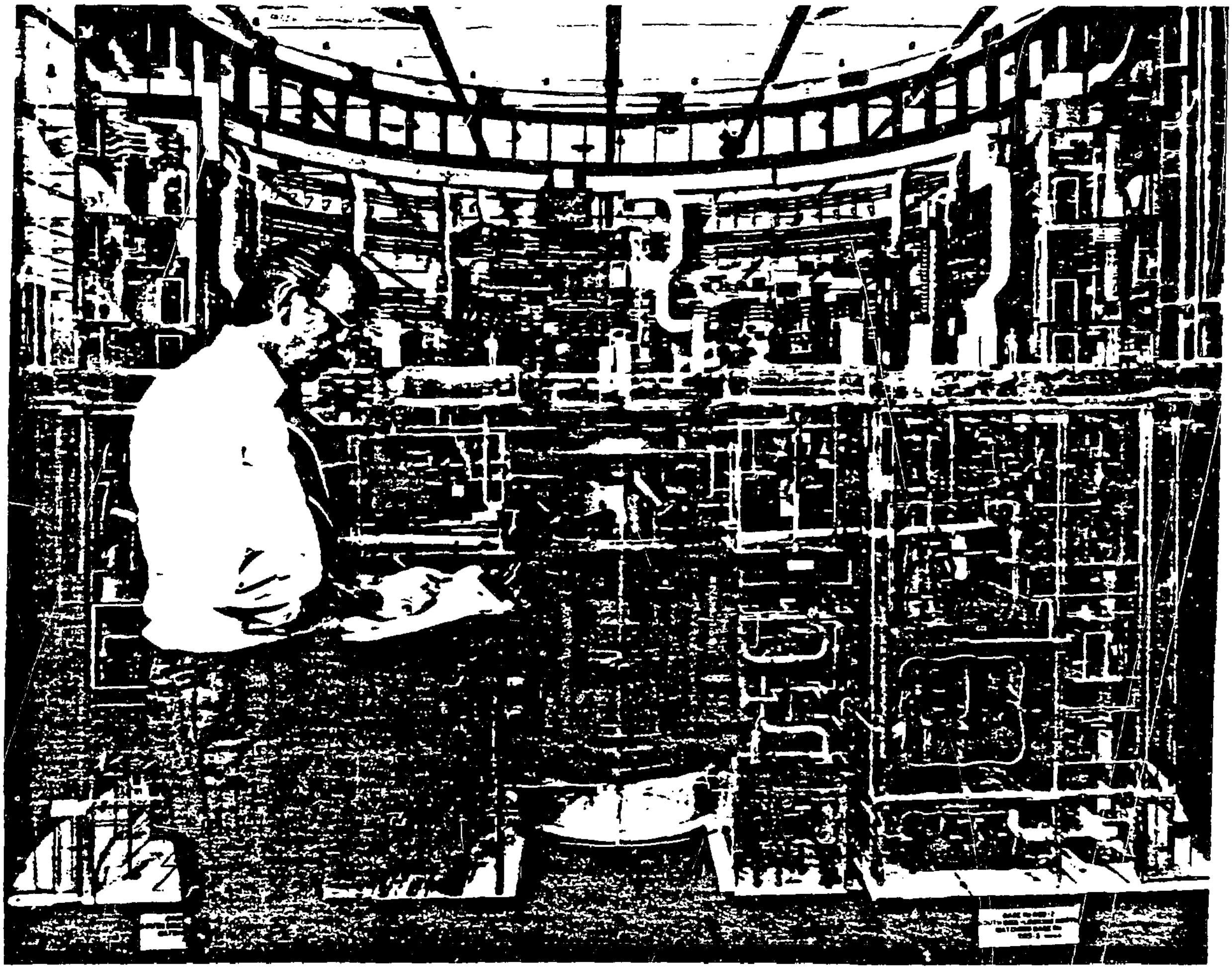

FIG. 5 SECTION OF DETAILED PLANT MODEL (1/2" TO THE FOOT)

one-inch pipe and was instrumental in determining construction sequences, particularly in determining work arounds for components that would not meet site need dates. In addition, the model was used extensively to optimize pipe spooling lenghts and configurations, which resulted in reduction of many field welds. The model was built by, and is currently located at, the Architect-Engineer's facility and is available to all Project participants. With the start of mechanical and electrical installation, the model will be moved to the CRBRP site for use as a planning tool during construction.

A second model used in construction planning is a topographical model of the site (one-fourth inch to the foot). This model can be disassembled to represent the various stages of site clearance, excavation, backfill, and concrete operation to grade level (Figure 6). It has been used extensively for sequencing site activities, for scheduling large earthmoving equipment into and out of the site, and for solicitation of bids from subcontractors.

PRE-OPERATIONAL AND START-UP TEST SCHEDULE DEVELOPMENT

The CRBRP reference baseline schedule depended heavily on FFTF test planning for sequencing and durations. By 1975, it became clear that test planning for the FFTF had been started too late and was insufficiently integrated with the construction schedule. To assure that similar problems did not carry over to the CRBRP Project test planning was initiated in 1975. The planning paralleled the conceptual, preliminary, and final design phases of systems and components. System and component test requirements were developed as part of the conceptual design phase and were continually updated as the designs matured.

The current CRBRP acceptance test program is made up of three classifications of tests - Construction, Pre-operational, and Start-up.

Construction tests will be performed by the constructor based on *requirements* supplied by the system and component designers. These tests, such as continuity checks, hydrostatic tests, etc., are to be made to ensure that equipment is properly installed.

Pre-operational tests are designed to check out system design and safety functions prior to fuel loading and will be conducted by the Tennessee Valley Authority (TVA), the reactor operator. There are two types of pre-operational tests: the first is conducted at ambient temperature, and the second after sodium has been loaded into the primary and secondary heat transport systems. Requirements for the tests are defined by the system and component designers, and are in turn developed into test procedures by the test performer, TVA. The system designers approve the test procedures and monitor actual test operations.

The start-up test phase also is composed of two

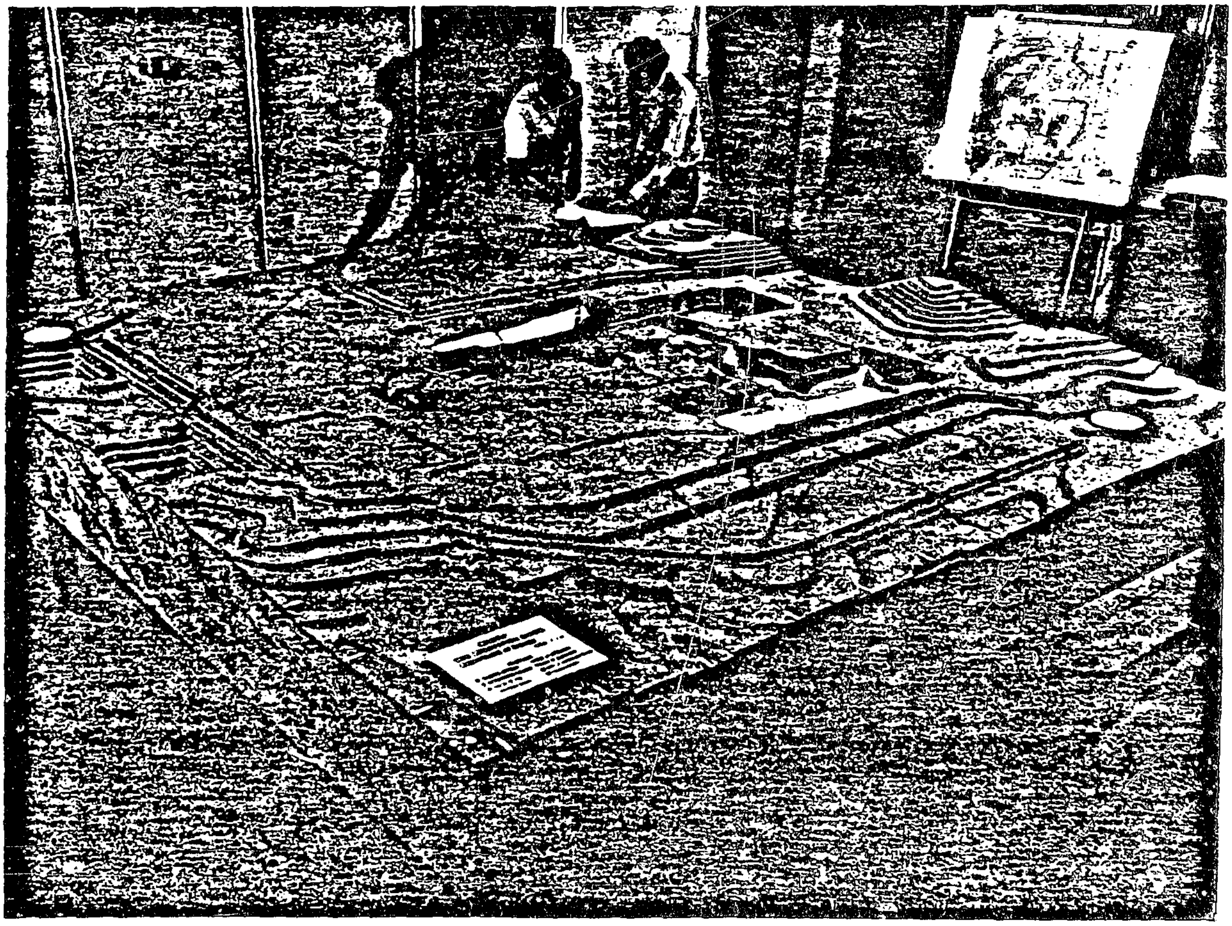

FIG. 6 SITE EXCAVATION MODEL

test sequences: the first from core load to 5 percent power, and the second from 5 percent power to full power. Test requirements and test specifications are prepared by the systems designer and TVA respectively, with TVA conducting the tests and the systems designer providing an overview function. To meet the overall CRBRP schedule goal, the test program must be planned in sufficient detail and integrated into the construction schedule such that necessary equipment is installed and checked out consistent with the prescribed test sequence. Test planning, therefore, may dictate the installation sequence for some equipment; installation sequence in turn determines site need dates, and site need dates determine purchase order placement dates, etc., back through the design process.

CRBRP test planning not only provides the identification, logic sequence, and schedule for all tests but also identifies the prerequisites for each test such as service equipment, test equipment, safety requirements, and prerequisite construction tests. The test logic sequence has been computerized to assure continuity throughout the test program and to simplify planning resulting from changing system or test requirements. The program also provides various sorting of data and the capability to provide solutions rapidly to logic alternatives. A resource allocation feature of the program provides the capability to optimize resources needed to specifically meet a schedule or to evaluate the resource change should the schedule change.

CURRENT CRBRP CONSTRUCTION SCHEDULE

A simplified representation of the CRBRP construction schedule and major Project milestones which existed in December 1981 are shown in Figure 7. Since January 1982, the Constructor, in an effort to provide assurance that the construction schedule can be met, has been investigating the concept of "Rolling-Four-Ten" shifting. This concept involves establishing two first-shift work crews who will alternate working four days, ten hours per day, then having four days off. Similarily, second-shift crews would be established for maintenance of equipment and to complete some critical work. Except for holidays, this concept will provide construction effort seven days per week. Although the overall Project schedule may not appreciably change, this innovative concept is expected to provide additional contingency for the Project schedule.

SUMMARY

The current CRBRP construction schedule is vastly changed from the original reference baseline schedule. Although there have been increases in construction quantities, increases in the number of components to be installed, and expansion of the test program, the CRBRP construction schedule continues to meet the Project requirements. This is primarily due to the dedication and cooperation between participants directed toward a common Project goal. Design or fabrication changes can now be quickly analyzed and their impacts identified, allowing management to focus attention and provide direction for problem resolutions.

Although the schedule remains very ambitious, continuation of the high caliber of detailed planning, including the ongoing examination of the Rolling-Four-Ten concept and the spirit of cooperation between Project participants are expected to result in achieving the current Project goal.

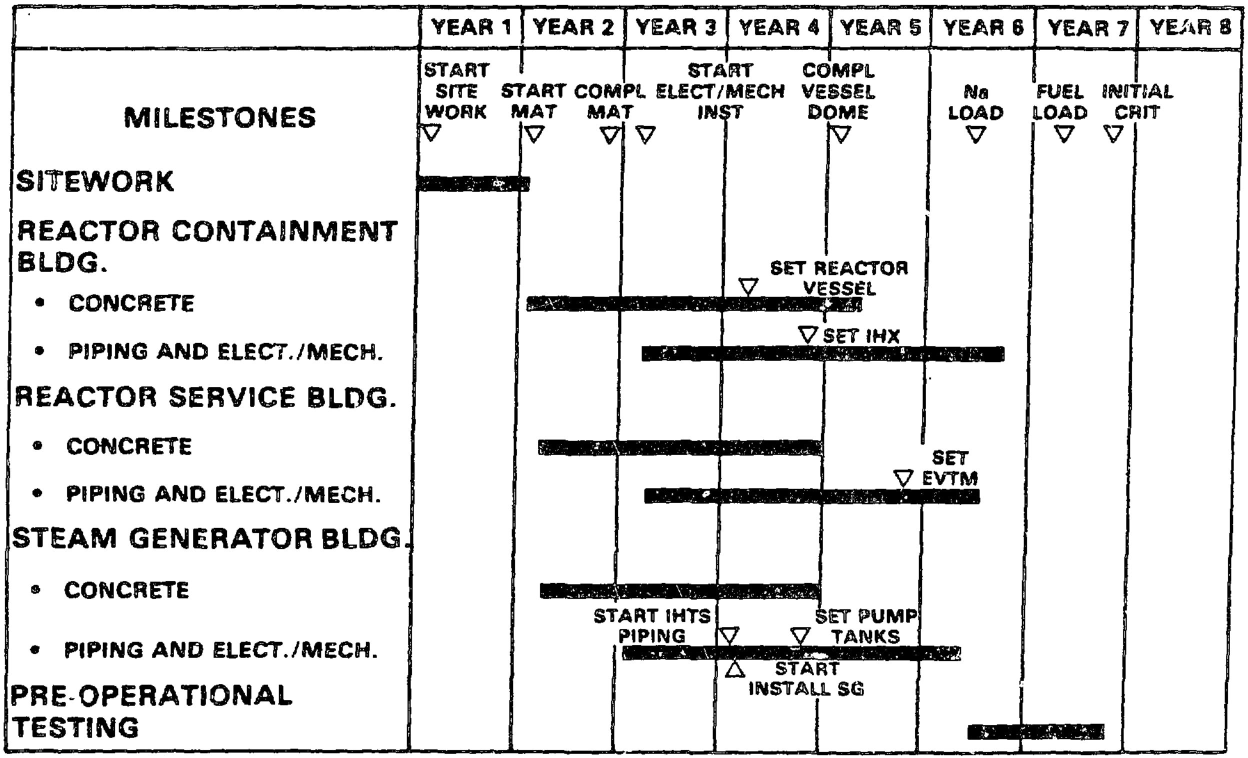

FIG. 7 CRBRP CONSTRUCTION SCHEDULE - DECEMBER 1981