1984

Industry Reference Document (3) of (32)

St. Lucie 2: Doing It Right in Nuclear Construction

18 pages

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American Society of Civil Engineers, Spring Conference

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DOING IT RIGHT IN NUCLEAR CONSTRUCTION

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ASCE - 1984 SPRING CONVENTION

ATLANTA, GEORGA

MAY 15, 1984

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DOING IT RIGHT IN NUCLEAR CONSTRUCTION

One measure of success in building any power plant is how well the project sticks to its construction schedule.

At Florida Power & Light Company's St Lucie Nuclear Power Plant Unit No 2 (890 MWe) construction proceeded according to the original schedule and plan called for when its construction permit was issued in June 1977. The project has virtually been on target for every major construction milestone (Chart 1).

Furthermore, St Lucie 2 achieved an annual rate of 27 percent completion in 1980 and 23 percent in 1981, a record for any nuclear plant under construction in the United States at that time. As can be seen on Chart 2 (Progress Versus Industry Performance), the accomplishments at St Lucie 2 are equal to those achieved in the early 1970's.

Ebasco provided engineering, construction and related services to Florida Power & Light Company (FP&L), who built St Lucie 2 on Hutchinson Island, about 45 miles north of West Palm Beach, Florida. It is an extension to and a duplicate slide-along arrangement of St Lucie 1 for which Ebasco provided similar services. This second unit achieved a 74-month time span from start of concrete to commercial operation, 3 1/2 years better than current industry averages - a rare accomplishment in today's nuclear industry.

St Lucie 2 is an 890 MWe Class Nuclear Power Plant which utilizes a Combustion Engineering Pressurized Water Reactor with associated nuclear steam supply and auxiliary systems and a Westinghouse turbine generator.

I HISTORY

Originally, construction of both St Lucie 1 and 2 was able to proceed concurrently, but then FP&L decided to delay construction of the second unit. St Lucie 1 started with Ebasco construction forces moving on site in late March 1969. The Atomic Energy Commission, predecessor of the Nuclear Regulatory Commission (NRC), issued the construction permit on June 30, 1970, and first concrete placement for the reactor containment building took place a week later. Installation of the nuclear steam supply system began in September 1973 and core loading in March 1976. St Lucie 1 began commercial operation in December 1976.

Work began on St Lucie 2 in 1971, with initial efforts directed toward preparing the Preliminary Safety Analysis Report (PSAR), Environmental Report and antitrust information required by the NRC before construction start. Although the PSAR was submitted for review in April, 1973 (Chart 3), subsequent meetings and site visits were conducted with the NRC staff to resolve such questions as site characteristics, radiological assessment, hydrology, geology and seismology. Other discussions probed emergency planning, industrial security and design features of the nuclear power plant. In response to these requests and discussions, an additional 44 amendments were eventually docketed to the PSAR.

The NRC issued its Safety Evaluation Report in November 1974, and in March 1975 awarded the Limited Work Authorization. Construction work started in June 1976, but the terms and limitations imposed by the Limited Work Authorization permitted only excavation and foundation work up to existing grade level.

Four months later, however, most construction work ceased and the work force was laid off. A regulation specified that the NRC must study a number of potential sites before allowing any work to begin, whereas the staff of the licensing board had studied a hypothetical alternative to the St Lucie site. After various appeals and site hearings, the NRC eventually granted a construction permit in June 1977, but not before $71 million was added to the plant cost as a result of the work stoppage.

II PROJECT DEVELOPMENT

The following discussion indicates some of the early steps that were taken to enable the project to proceed as well as it did.

In organizing our Ebasco project team, a number of things were done that proved to be a definite asset in conducting and controlling the engineering, design and licensing efforts.

First, the overall project team organization was under the direction of the Ebasco Project Manager (Chart 4). Reporting to him were the Project Engineer and Assistant Project Manager, as well as liaison with the Ebasco Project Superintendent. All of the related service functions were put under the direction of the Assistant Project Manager (Chart 5). This included Purchasing, Expediting, Estimating, Services Cost, Planning, Scheduling and Vendor Quality Assurance.

The advantages of this arrangement, especially in the critical areas of material procurement and expediting, were that vendor technical, commercial and subvendor problems received immediate management visibility. This enabled project resources to be brought to bear to resolve these problems and maintain critical material delivery dates. It also enabled close liaison with the construction site to be established on required at-site dates for materials and jobsite priorities to be addressed in a timely manner.

The Project Engineer had the Engineering, Design and Licensing groups report to him, as well as the Site Engineering Group (Chart 6). The advantage of this arrangement was that priorities could be established and controlled from among the numerous engineering and licensing items to be performed to support the schedule. It also enabled us to maintain excellent control of service workdays and schedules.

The Ebasco Project Superintendent reported to the FP&L Site Manager in the integrated construction organization and maintained liaison with the Ebasco Project Manager.

Another significant factor which contributed to the work was the decision to locate all our home office project team personnel into one project grouping (Chart 7). This had decided benefits in communications, improved interface amongst disciplines and enhanced project team goal congruence. It also insured full-time participation from assigned project personnel.

III PROJECT PLANNING

During the period October 1976 to March 1977, a team of Ebasco and FP&L construction supervisors developed what became the Project Master Schedule. A 65-month schedule for the project (start of concrete to start of fuel load) was established and major milestones were identified and fixed. This set the stage for all future planning. This schedule consisted of an integrated engineering and construction plan and included summary start-up logic.

The schedule philosophy adopted by the project was to schedule and monitor all activities and material delivery dates to the "early start" date requirements. This approach provided some valuable additional margin which proved useful in minimizing impact to the construction schedule caused by factors outside project control.

In addition, special priority was placed on engineering, design and delivery of piping and hangers. These were scheduled for delivery a full 18 months prior to the "early start" dates. The result was that hanger installation preceded pipe erection and minimized the need for temporary pipe support devices to a large degree. This resulted in an orderly pipe installation program.

Although uncertainty existed about St Lucie 2's future when the limited work authorization was withdrawn in October 1976, a bold decision was made to proceed without delay in accordance with previously established engineering, design and procurement schedules. As a result, when the construction permit was granted in June 1977, approximately 75 percent of the original scope of engineering and design was completed and 40 percent of the engineered materials were delivered. In retrospect, this decision typified the total commitment and support this project had received from its inception from both FP&L and Ebasco executive management.

Another factor which contributed to the success of the construction effort at St Lucie 2 was the performance of a detailed review of the design from St Lucie 1 by construction personnel. The objective of this review was to recommend areas where design enhancements could be made to improve construction productivity and costs. As a result, approximately 250 items were addressed and incorporated into the design. In addition, a Design Problem Review (DPR) program was initiated. This was a comprehensive review by engineering of all St Lucie changes; i.e., backfit changes, operations enhancements, regulatory requirements etc., in order to ensure their consideration and disposition for St Lucie 2. Over 1000 items were considered with approximately 350 incorporated into the St Lucie 2 design.

IV CONSTRUCTION SITE ORGANIZATION

The construction site organization utilized an innovative integrated approach which proved quite effective (Chart 8). It consisted of both Ebasco and FP&L personnel integrated into one organization. In this organization, Ebasco's supervisory construction staff, under the overall direction of the FP&L site manager, managed and directed construction activities of craft work forces and subcontractors according to the schedules established. The organizational functions which FP&L wished to influence directly were under the utility supervisors, reporting also to the site manager (Chart 9). These included quality control and quality assurance; construction cost control, planning and scheduling; and services such as area stores site purchasing, contract and office administration. The control tools - cost control and accounting and payroll systems - were standard Ebasco systems on all Ebasco construction jobsites.

Although in these areas the lead person was an FP&L supervisor, most supervisory and other nonmanual personnel were Ebasco employees. The ratio of FP&L to Ebasco personnel in these areas (excluding quality control inspectors) were 29 percent FP&L to 71 percent Ebasco, for a total of 145 nonmanual personnel. With this integration, the utility achieved desired visibility of job progress and became an integral part of the decision-making process.

The functions involved in the everyday construction operations, engineering and testing functions were under the direction of Ebasco supervisors who, in turn, reported to the FP&L Site Manager (Chart 10). Although these organizations were essentially comprised of Ebasco supervisory and nonmanual personnel, the owner integrated into these groups several utility personnel. The personnel ratio for these was 3 percent FP&L personnel to 97 percent Ebasco employees, for a total of 225 individuals. Integrating a limited number of utility personnel into these groups allowed these individuals to gain considerable insight into the engineer/construction operations and experience of considerable future value to the utility.

V CONSTRUCTION PLANNING AND IMPLEMENTATION

The optimization of the construction effort was the result, to a large degree, of the early planning and innovative thinking that went into the formulation of the overall construction plan and schedule for this project.

A. Reactor Auxiliary Building "Stair Stepping" Concept

One of the innovative ideas that went into the initial plan and schedule was the "stair stepping" concept for the construction of the reactor auxiliary building. In this plan, the building was constructed with emphasis placed on early completion of the west end of the building. The philosophy being that early completion of this end of the structure provided an early start to installation of the more critical areas of equipment installation in the reactor auxiliary building; i.e., the control room and the reactor auxiliary control boards, the cable vault area, and NSSS auxiliary equipment.

As a result, the building during construction took on a "stair step" appearance, and as each elevation was completed, all major equipment and appurtenances were moved into that level prior to the roof being installed. Considerable amount of Q deck construction was also utilized in an effort to minimize forming and shoring requirements. The net result was that critical areas were completed earlier and key crafts started their work sooner.

B. Reactor Containment Building

Foundation design considerations were finalized when plans called for both St Lucie 1 and 2 to be built simultaneously. Subsurface exploration borings indicated poorly consolidated sand with thin layers of clay to a depth of 65 feet below existing grade. To meet seismic criteria, a plant island was constructed by excavating the unsuitable material, back-filling with well-graded sand and them compacting to required specifications. This plant island resulted in a compacted Class 1 fill measuring 780 by 920 feet and 78-1/2 feet deep. For economic reasons, the plant island was sized as small as possible by spacing the plant structures at minimum distances apart. When FP&L decided to delay construction of St Lucie 2, these plans were technically feasible, but subsequently they did require unique design and construction efforts for the second unit.

One of these special provisions, Ebasco believes was the first nuclear safety Class 1 cofferdam ever to be engineered and constructed. It was necessary to protect the safe shutdown ability of St Lucie 1 under all foreseeable circumstances, including earthquakes.

A circular sheetpile cofferdam for the reactor containment building was braced with internal compression beams and sized to allow excavation, concreting of the base mat and walls up-to-grade elevation, and subsequent back-fill operations.

The 180-foot diameter circular cofferdam was constructed by driving 500 tons of sheetpiling in 72-foot lengths through compacted sand with electrical vibratory hammers. The 900 tons of horizontal bracing (walers) consisted of wide-flange beams 36 inches deep and weighing 230 pounds to the foot, installed every five feet on vertical centers. To allow dewatering of the cofferdam, 18 deep wells were installed along the periphery. Driving of the sheeting started in June 1976, and the mudmat (working surface) was placed in late September of that year.

C. Slipforming

Another innovative construction accomplishment at St Lucie 2 was the "slip-forming" of the concrete containment shield wall for the reactor containment building, in lieu of the traditional "step-form" method. This concrete cylinder has a three-foot-thick reinforced wall, approximately 190-1/2 feet high with an inside radius of 74 feet. It is supported by a ring wall (9 feet thick and 4 feet high) which, in turn, rests on the base mat. The shield wall contains more than 1000 tons of reinforcing steel with another 23 tons of embedded materials such as electrical conduits, grounding cables and anchor bolts.

Wall placement through slipforming of 10,000 cubic yards of concrete averaged 11-1/2 feet per day, and the operation took place without interruption in only 16-1/2 days in November 1977. Manpower for slipforming averaged 398 craft workers, and the crafts worked three shifts a day, seven days a week until completion. Ebasco engineering and construction supervisory personnel also provided around-the-clock support and technical assistance. Immediately after completion of slipforming, construction on the steel containment vessel started inside the shield building.

VI HURRICANE DAVID

When the project was 26 percent completed, a severe storm seriously jeopardized the project's continued ability to meet its objectives and be ready for start of fuel load in November 1982. The high winds of Hurricane David struck on September 3, 1979, toppling a 150-ton construction derrick being used to supply materials to both the reactor containment building and the reactor auxiliary building. The storm completely destroyed the derrick, composed of a 180-foot tower with a 256-foot mast resting on top of the tower, and a 200-foot boom. More importantly, the falling derrick severely damaged the reactor auxiliary building under construction. Initially, lost schedule time to repair the damage and replace equipment was estimated at 13 weeks.

Immediately, Ebasco and FP&L engineering and construction supervisors formulated recovery plans. A task force of construction and site engineering personnel pinpointed all damage on design drawings. Ebasco engineers assessed this damage, developed repair procedures and determined the extent of necessary nondestructive testing of adjoining areas. Concurrently, Ebasco reviewed equipment damage with vendor representatives and expedited orders for replacement equipment. Construction plans called for additional overtime of crafts and construction supervisors to make up the additional hours required for repairs. As the recovery operation proceeded, site activity unaffected by the derrick collapse maintained its previous schedule.

The net result: By November 1980, the teamwork factor - so important in St Lucie 2's progress - was able to make up the 13-week loss on the critical path schedule.

VII NSSS INSTALLATION

An important benchmark in the NRC's assessment of nuclear plant construction is the installation of the nuclear steam supply system's major equipment; i.e., reactor vessel, steam generators and pressurizer. The project was able to meet this milestone on a progressive schedule by adopting two innovative ideas.

First was early planning and the decision to erect the containment steel vessel started utilizing the "tops-off" approach. Basically, this method provided post weld heat treatment of the vessel erection before erecting the dome. Because of thinner plates the dome did not require heat treatment and could be erected at a later time. As a result, interior concrete work started months earlier than otherwise possible and ensured that support structures were ready for NSSS installation.

Secondly, the interior concrete was not brought up to the operating level before setting the nuclear vessel. Instead, Ebasco engineering and construction personnel, in conjunction with the heavy rigging subcontractor and the polar crane manufacturer, simplified the "posting" arrangement for utilizing the polar crane in setting the vessels. Using a two-shore (instead of six-shore) polar crane girder support system saved considerable schedule time and enabled construction forces to meet the target date of June-July 1980.

VIII OCEAN DISCHARGE PIPE

Construction of St Lucie 2's discharge headwall and installation of a 3,345-foot-long ocearn discharge pipe was completed as scheduled in October 1981. The discharge headwall is located just south of Unit 1's headwall at the dune line to the Atlantic Ocean. The structure funnels circulating discharge water into a discharge diffuser pipe which measures 16 feet in diameter.

This pipe connects at the discharge headwall under the beach dune line, and running beneath the ocean floor it stretches 3,345 feet into the Atlantic Ocean. To disperse the discharge water evenly and at a constant rate of flow, the last 1,368 feet of pipe contains fifty eight 48-inch diameter risers which project through the ocean floor at 24-foot intervals.

IX START-UP PLANNING AND IMPLEMENTATION

One of the major contributing factors in the completion of St Lucie 2 at or near schedule was the ability to turn over components and systems to FP&L's operating department in an orderly and timely manner. The success of this phase of the project was due to the early planning, scheduling and implementation of a start-up program, and probably more importantly to FP&L's overall philosophy concerning acceptance and testing of equipment and systems.

This overall philosophy had as its primary objective the earliest possible acceptance of equipment, components and partial systems, in order to enable early testing and problem identification of system components.

First, FP&L developed an overall start-up program plan and schedule which required early on-site presence of operating department personnel 35 months prior to the scheduled "start of fuel load" date. This was not just a token work force, but rather a sizable commitment of manpower numbering approximately 64 people. Their early work consisted of a number of tasks, the highlights being to:

a) Define start-up system boundaries.

b) Prepare preoperation test procedures.

c) Establish construction turnover sequence.

d) Establish preoperational test requirements.

e) Determine start-up (construction and operations) manpower levels.

f) Establish target milestone dates.

X CONSTRUCTION/START-UP SCHEDULE INTEGRATION

The detailed start-up schedule and logic was then integrated with the construction schedule to develop one combined schedule that the jobsite worked to and home office engineering and design also supported.

XI IMPLEMENTATION

With the establishment of the target milestones for start-up, the "SCAT" Program (Start-Up/Construction Accelerated Turnover Program) was initiated to expedite the turnover of systems from construction to operations. Essentially, this program identified portions of total systems PTO's (Partial Turnovers) which were then completed and turned over to Operations, allowing early testing and problem identification of system components. Approximately 488 "packages" were identified and scheduled for turnover in priority sequence to support established start-up milestones. In addition, computerized listings of all system components were developed which were used by the construction test group to "punch list" the systems for completeness. In addition to the PTO's established, conditional turnovers were also established, whereby operations accepted systems on a conditional basis, with an agreed upon list of exemptions, but sufficiently complete whereby testing and checkout could proceed. Again, this was in keeping with FP&L's start-up philosophy, whereby early acceptance of components and partial systems enabled sufficient time to identify and resolve equipment and start-up test performance problems with minimal impact to the overall scheduled core load objective for the project.

In the course of the start-up phase of the project, the construction organization objectives gradually shifted from a bulk quantity installation effort and area concept of control to total support of start-up turnover requirements and work performed on discipline basis.

XII OTHER PROJECT EFFORTS

Concurrent with this ongoing effort, it was recognized by project management from both companies, that continual increases to the scope of the project would make any milestone dates established very elusive targets.

XIII CHANGE REVIEW BOARD

It was decided to establish a change review board comprised of project team management personnel of both companies from engineering, construction, operations and project management. The objective of this group was to review changes arising out of licensing commitments, system enhancements and operations improvements. This review was to determine whether it was best to implement the item prior to core load or defer to a backfit status (post core load) in order not to impact construction, turnover and start-up schedules.

In general, the criteria employed by the group was that if the item was needed in order to operate the system, or if it was a licensing commitment promised for completion prior to core load, it would then be worked on for implementation prior to core load date. Those items not meeting this criteria were designated for backfit. This insured a defined scope and helped assure realistic schedule dates.

XIV FSAR PREPARATION AND REVIEW CYCLE BY THE NRC

A significant threat to the project schedule occurred in 1980 during the Nuclear Regulatory Commission's caseload forecast panel review of the site and project schedule. The NRC estimate of project completion generally follows a statistical schedule model shown in Chart 11. This model was developed prior to TMI and includes three curves showing the lower, medium and upper quartile. Using this model and other data obtained during their on-site visit in February and September of 1980, the NRC projected a fuel load date of December 1983, which was 13 months later than that established by the project. Since the NRC schedule for review of the Final Safety Analysis Report (FSAR) was based on this later date, it was necessary to convince then that the project could meet our schedule. Through concerted FP&L upper management efforts, the NRC accepted the project schedule and completed the FSAR review in record time of 9 months. The project successfully completed Advisory Committee for Reactor Safety (ACRS) hearings and did not encounter any regulatory delays.

To insure that the licensing effort was supportive of the project objectives an overall plan was developed for this phase of the project.

The plan developed for the project called for the preparation of what was designated as the Design Defense/FSAR Interface Document. A well known problem in meeting nuclear power plant schedules is the "ratcheting" that occurs during the licensing review cycle and results in additional unforeseen additions to the project scope and an increase in schedule. To minimize that from occurring on St Lucie 2, a documented three-party review (Ebasco, FP&L and Combustion Engineering) of the St Lucie Unit 2 design against the NRC Standard Review Plans was conducted to document the degree of compliance and identify possible areas of contention. The Design Defense Documents also served to organize and develop in a rational manner the Final Safety Analysis Report (FSAR) for the St Lucie 2 plant.

In conjunction with this effort, a detailed three-party (Ebasco, FP&L and Combustion Engineering) integrated schedule indicating preparation and review of primary and secondary responsibilities of all sections of the FSAR was prepared with Ebasco responsible for the control and production of the document.

The Environmental Report-Operating License was a two-party (Ebasco and FP&L) effort and unique in that the ER-OL presented only an update to the initial Environmental Report and did not duplicate information previously submitted.

A 25-month time span from start of DD/FSAR/ER (Design Defense/Final Safety Analysis Report/Environmental Report) to tendering of these documents was achieved as per the schedule established (Chart 12).

The NRC finally docketed the FSAR and ER in February 1981, which left a very short period of time for the FSAR review cycle by the NRC.

Again, the combined efforts of Ebasco, FP&L and Combustion Engineering established a unique organization for conducting what had to be an accelerated review process. The review process itself was established as an informal process whereby meetings were conducted with the different NRC branches, all questions answered during the meeting and followed up with formal responses in a subsequent time frame. This allowed the review to proceed expeditiously without the tedious rounds of formal questions, answers and clarifications which in the past tended to stretch the process ad infinitum.

Seventeen integrated licensing teams were organized in 1980 with representatives from the three major participants, Ebasco, Florida Power & Light Company and Combustion Engineering, in order to provide total support for the many tasks required in the licensing effort. These tasks included accelerated licensing review methods, normal licensing processes, Environmental Report-Operating License, TMI and others. The team manager was selected from the organization with primary responsibility for the task. All team managers reported to an Engineering Management team made up of the Ebasco Project Engineer, FP&L Engineering Project Manager and the Combustion Engineering Project Manager.

As a result of these efforts and team approach with the NRC and the informal review approach worked out, licensing was removed from the critical path of the project by reducing the time span of "Docketing of FSAR" to ACRS letter recommending operating license to 9 months versus 19 to 21 months pre-TMI days.

XV CONCLUSIONS

I have presented just some of the highlights of the project and summary overview of the means by which these things were accomplished. The results are quite evident. We were able to essentially maintain our progress in accordance with the schedule established at the start of construction in June 1977. The project costs were kept within budget and forecasts. Start-up and initial preoperation of systems revealed only a minimum of problems, a strong indication of a quality effort. The plant availability is currently at 89.3 percent since commercial operation.

REASONS WHY

Certainly the careful planning, scheduling and innovative thinking that went into the project contributed to its success. The carrying out of these plans is attributed to the excellent teamwork and personnel in both companies associated with this Project. Excellent communications were maintained which enabled us to identify potential problem areas early and take corrective action with project resources.

The net result is that Florida Power & Light Company was able to begin to realize a fuel savings of $20 million/month and add 802 MW to their system in 1983. Both Florida Power & Light Company and Ebasco take considerable pride in being cooperative partners in the "Spirit of St Lucie."

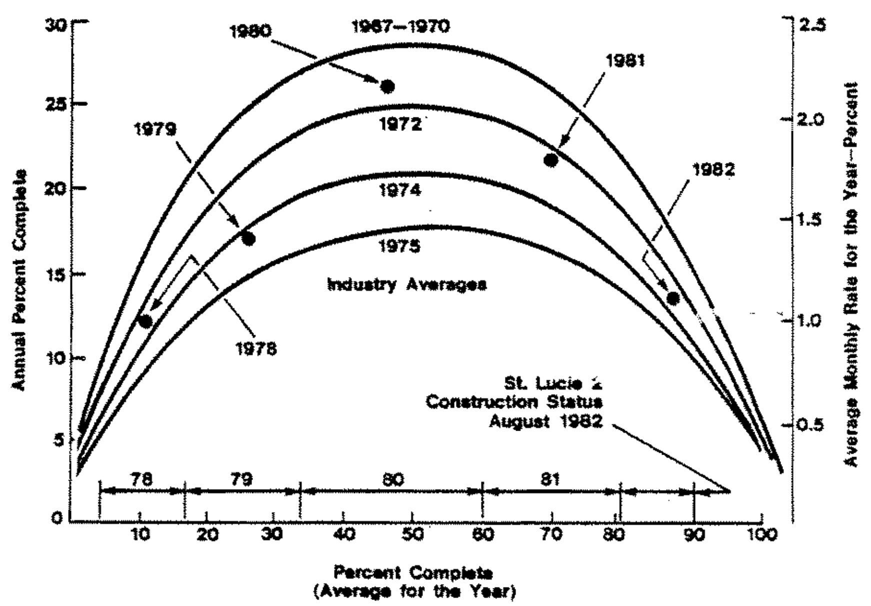
CHART 1

ST. LUCIE UNIT NO. 2
COMPLETED MILESTONE ANALYSIS

	SCHEDULED	ACTUAL
CONSTRUCTION PERMIT	June, 1977	
START RCB BASEMAT CONCRETE	07/06/77	07/07/77
START INTAKE STRUCT BASEMAT-CONCRETE	10/15/77	10/01/77
START T.G. PEDESTAL MAT CONCRETE	12/15/77	10/25/77
START ERECT STEEL CONTAINMENT	01/18/78	12/21/77
START RAB BASEMAT CONCRETE	02/10/78	02/10/78
COMPLETE POST WELD HEAT TREATMENT	12/06/78	01/22/79
START M.S.T. STEEL ERECTION	12/28/78	02/12/79
START RCB INT. CONCRETE	01/17/79	11/07/78
START FHB BASEMAT CONCRETE	05/05/79	06/05/79
START PREOPERATIONAL TESTING	04/20/80	03/19/80
START SETTING NSSS MAJOR EQUIPMENT	06/18/80	06/22/80
COMPLETE RCB OPER FLOOR CONCRETE	09/23/80	10/17/80
SET CONTAINMENT VESSEL DOME	09/26/80	10/04/80
COMPLETE RAB EXT. CONCRETE	12/15/80	12/18/80
COMPLETE LOOP LARGE BORE PIPING	03/14/81	02/06/81
COMPLETE REFUELING WATER STORAGE TANK	04/30/81	04/28/81
COMPLETE RCB EXTERIOR SHIELD WALL CONCRETE	09/06/81	08/11/81
INTAKE COOLING WATER INT. MTR RUN	09/25/81	09/23/81
COMPLETE OCEAN DISCHARGE PPG (KIEWIT)	12/25/81	10/14/81
TURBINE ON TURNING GEAR	12/15/81	12/16/81
ECCS FLOW TEST	01/04/82	01/13/82
SECONDARY HYDRO	02/04/82	02/04/82
COLD HYDRO	03/17/82	05/19/82
HOT OPERATIONAL TESTING	11/30/82	05/07/83
FUEL LOADING	10/28/82	04/06/83
COMMERCIAL OPERATION	05/28/83	08/08/83

CHART 2

ST. LUCIE UNIT NO. 2
PROGRESS VS. INDUSTRY PERFORMANCE



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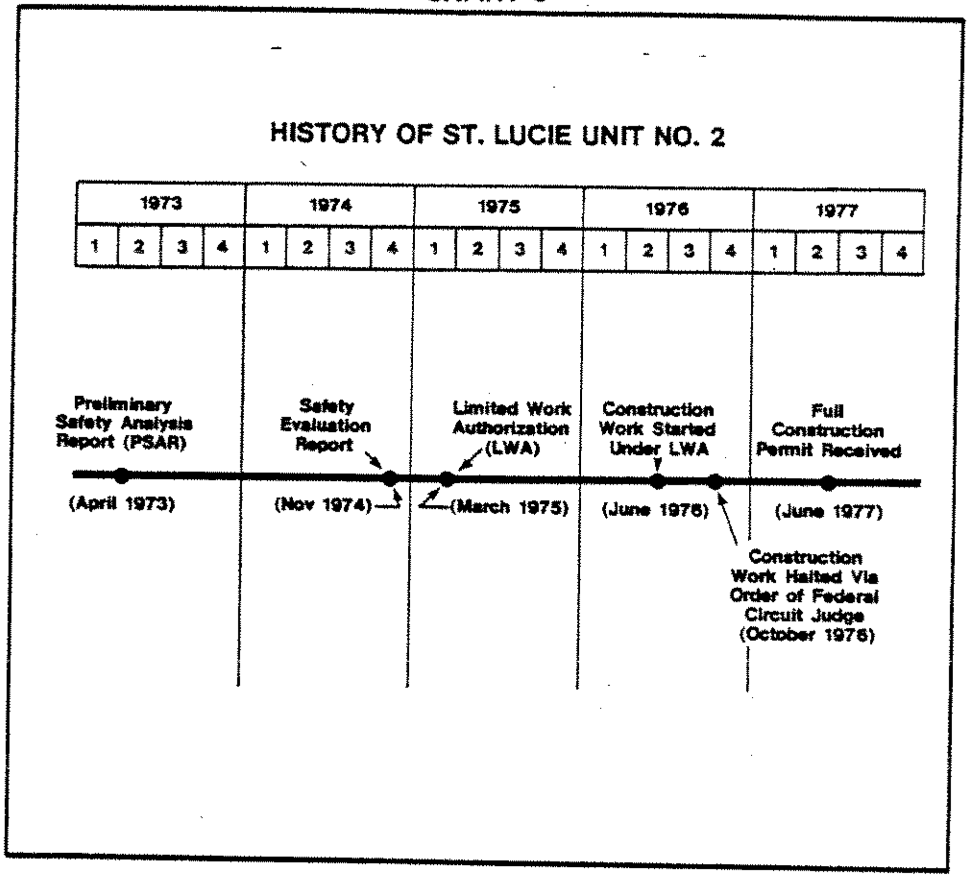

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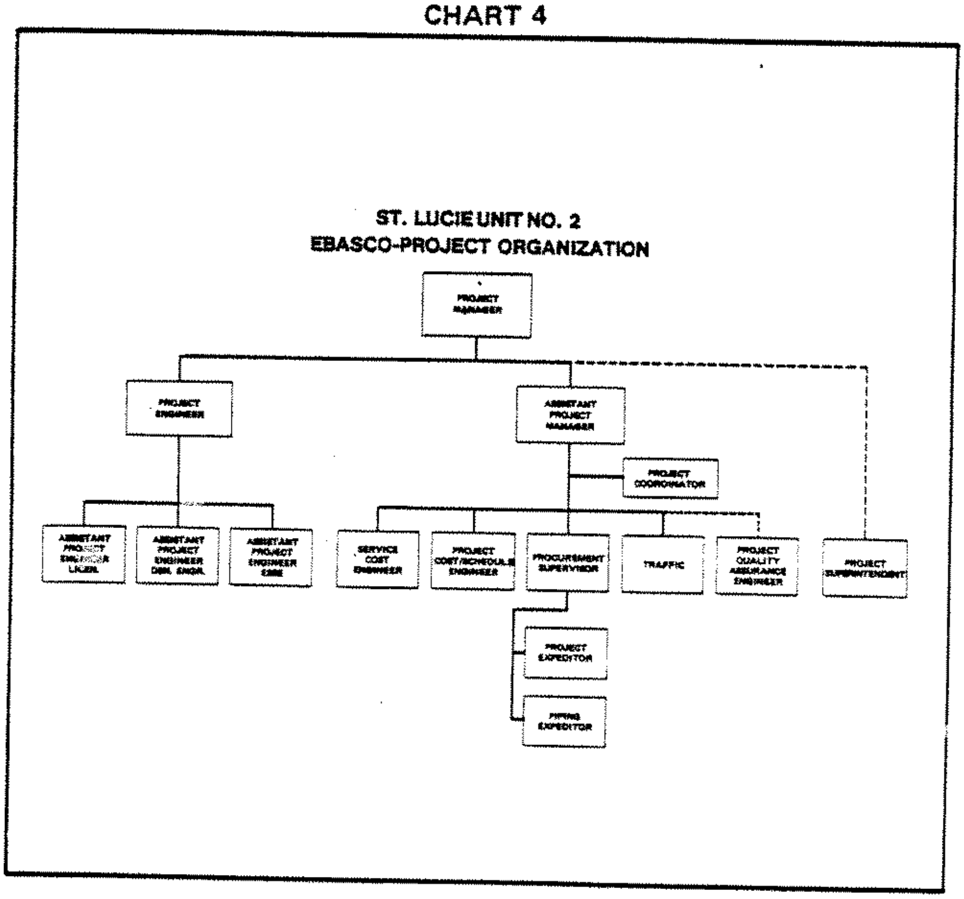

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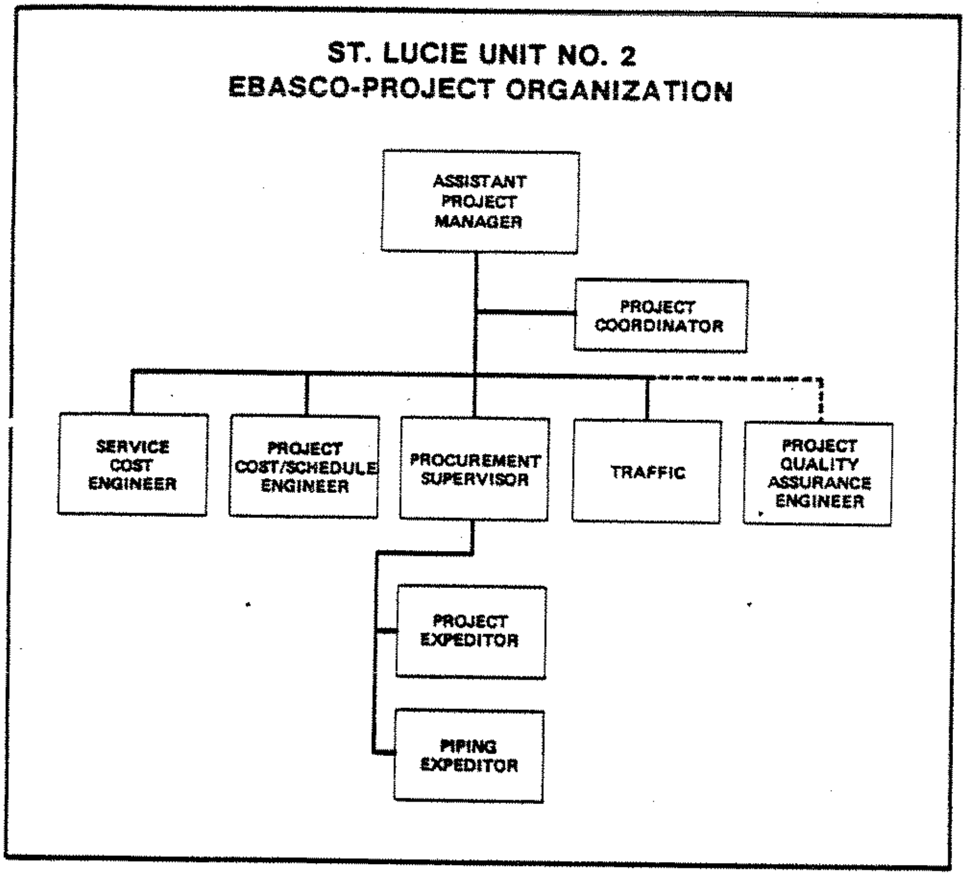

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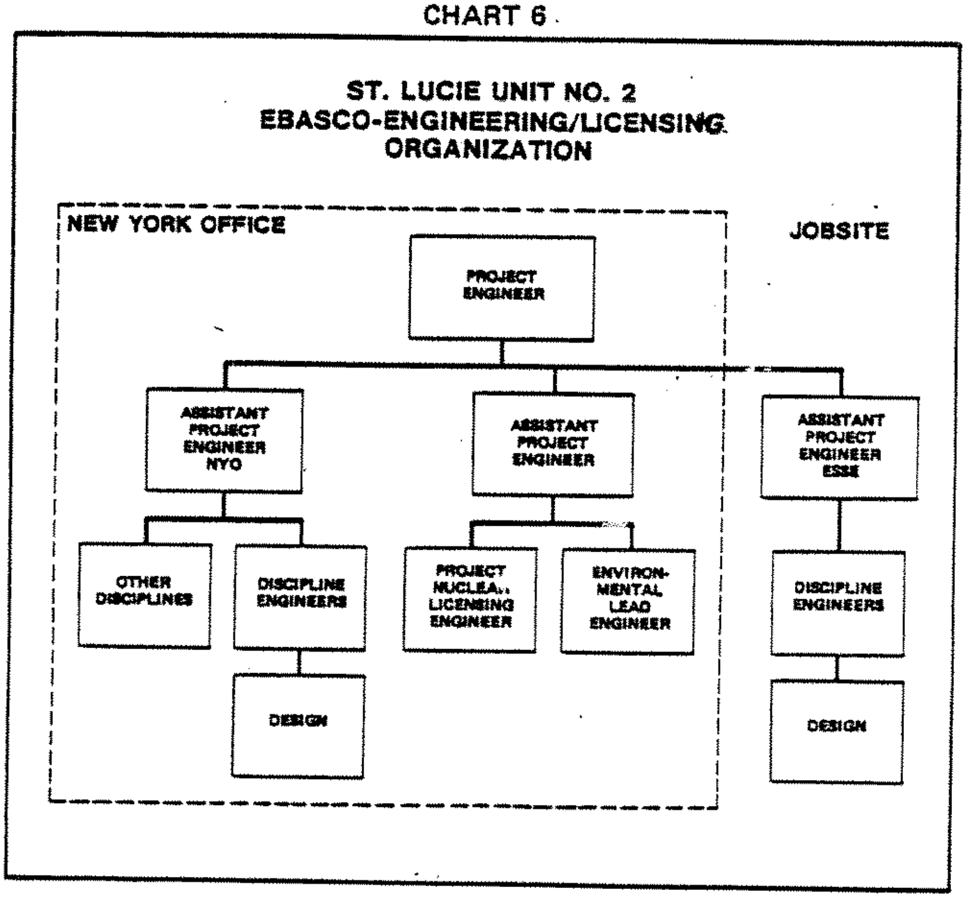

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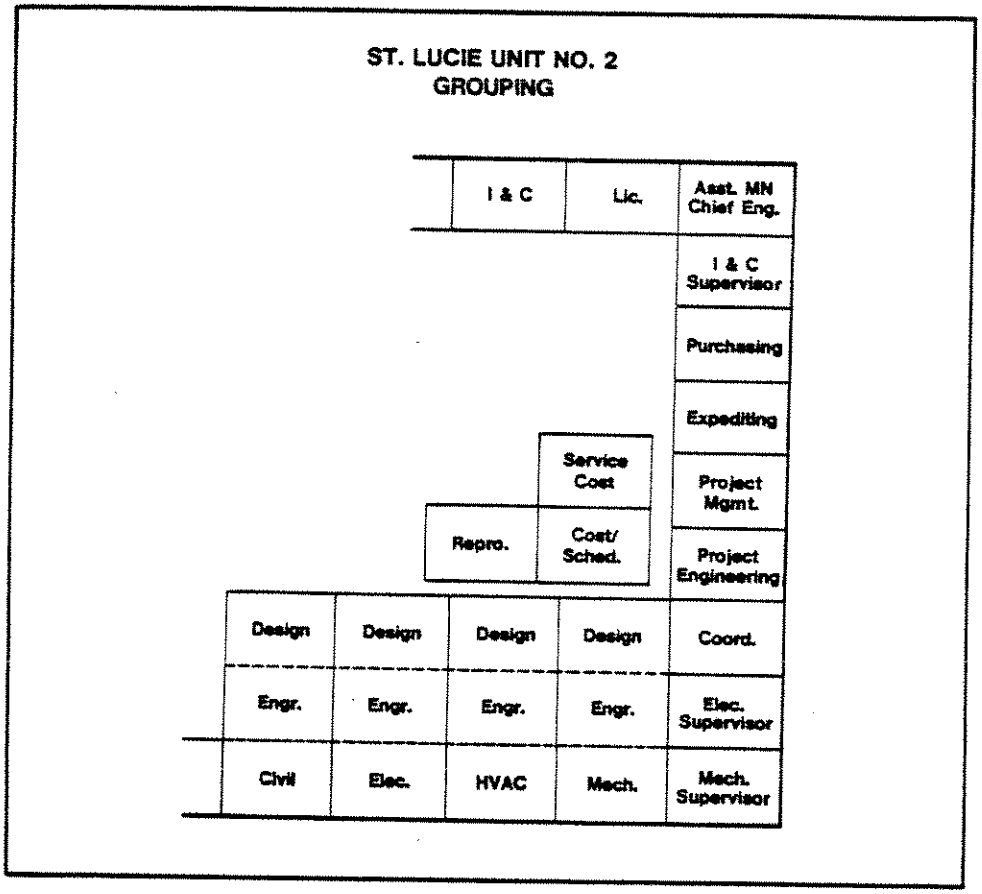

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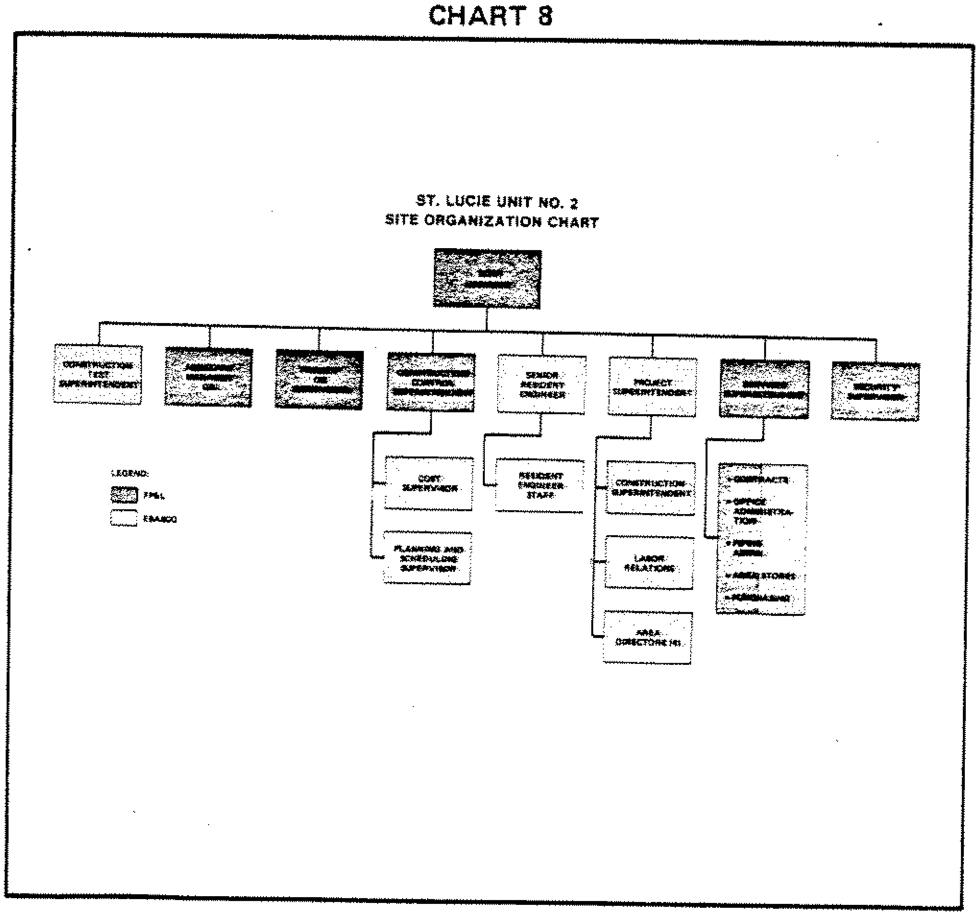

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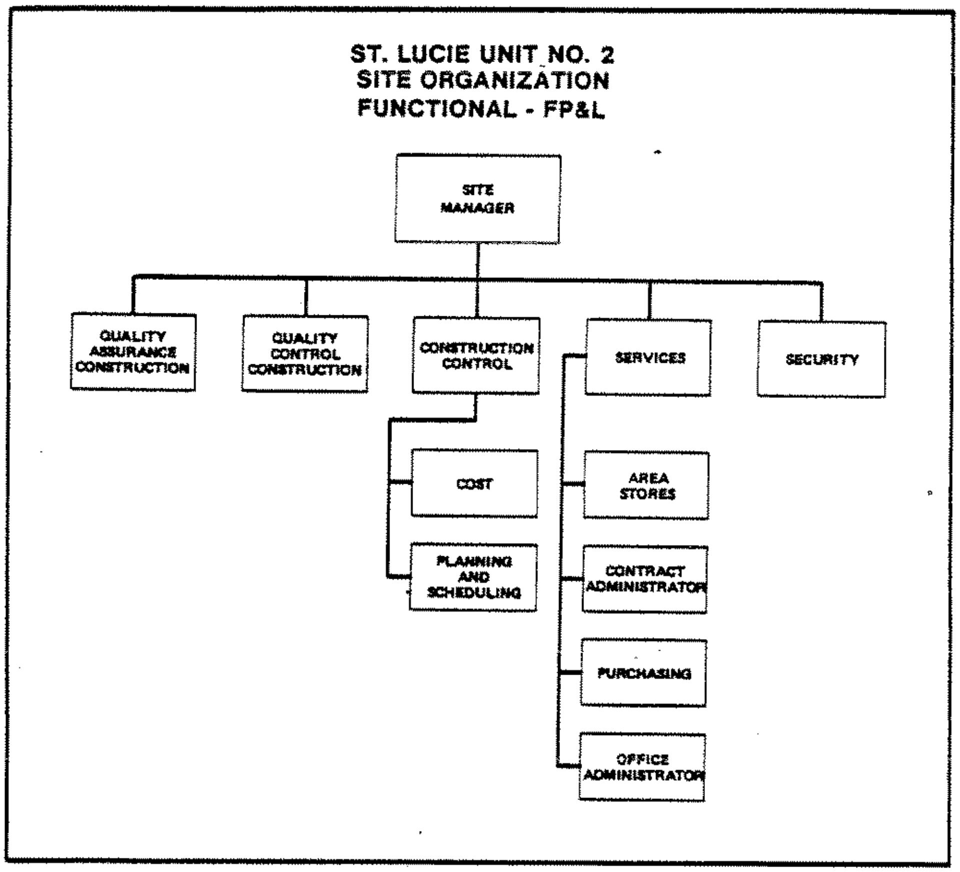

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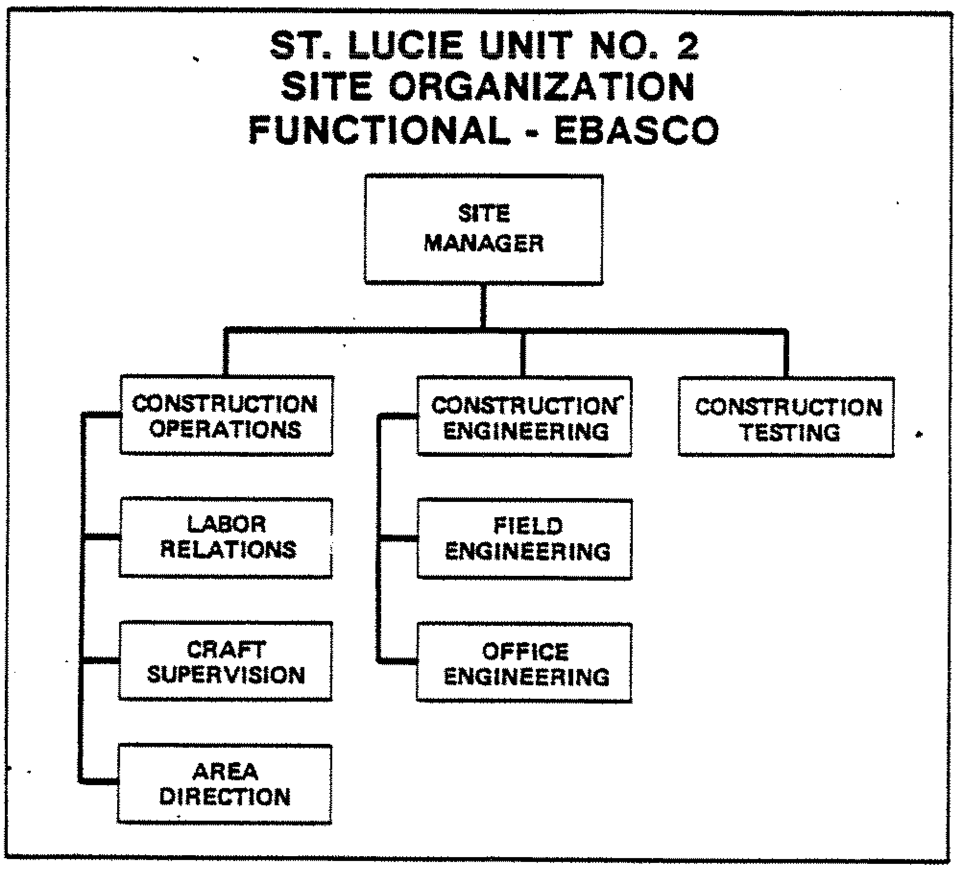

CHART 11

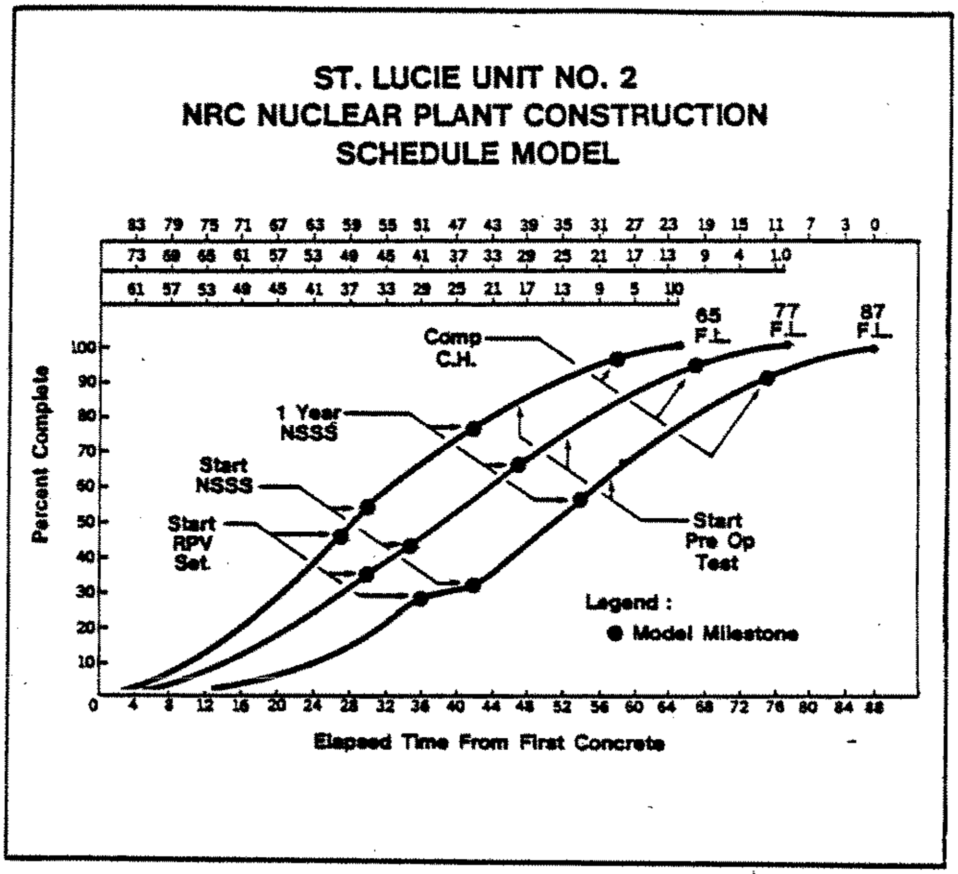

CHART 12