ATOMIC ENERGY OF CANADA LIMITED
Power Projects, Sheridan Park, Ontario

Lecture 15

Nuclear power symposium

CONSTRUCTION

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ATOMIC ENERGY OF CANADA LIMITED
Power Projects

NUCLEAR POWER SYMPOSIUM

LECTURE NO. 15: IMPORTANT CONSIDERATIONS FROM A CONSTRUCTION POINT OF VIEW IN THE CONSTRUCTION OF A SINGLE UNIT, 600 MW CANDU PHWR NUCLEAR GENERATING STATION

by

V.A. Harrison

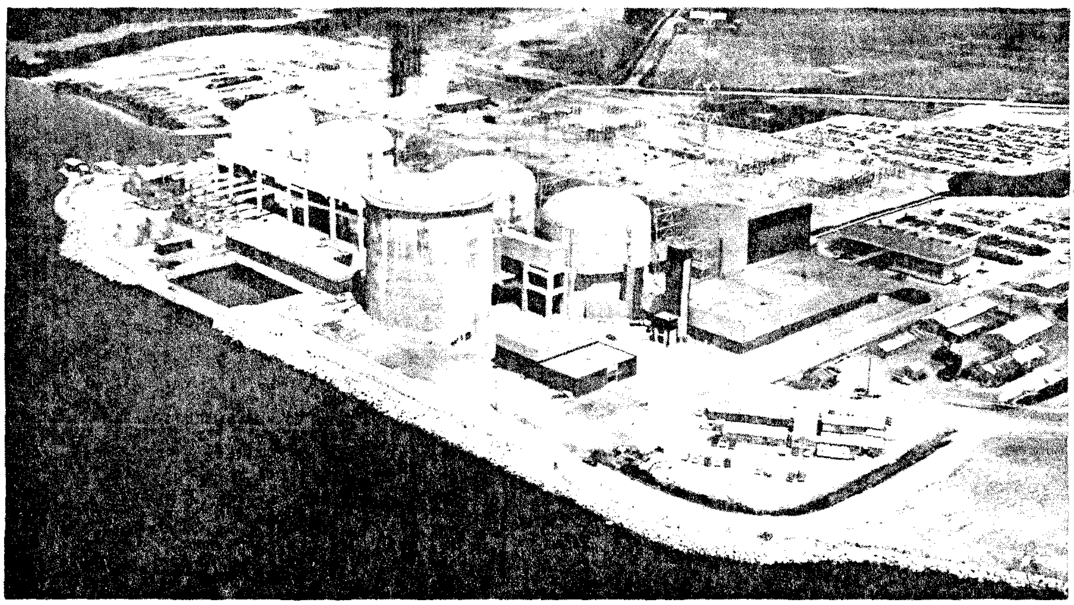


Figure 1 Pickering Generating Station

1. INTRODUCTION

1.1 Basis of Paper

In order to present as clear a picture as possible of construction phases, methods and progress, it is, of course, necessary to use progress pictures of the Pickering project. Recognizing, however, a very significant difference in scale between the construction of a four-unit plant and a single unit plant, all other data in this paper has been scaled down to represent the quantities and staff for a single unit plant with provision for a second unit later.

1.2 Background Regarding Ontario Hydro's Project Organization

As many of you will know, Ontario Hydro have their own engineering, design and construction organizations. For the Pickering project this meant that about 80% of the total field construction work was carried out by tradesmen supervised directly by Ontario Hydro personnel. The balance of the work was, of course, carried out by various unit price and lump sum contracts. The management for the entire project is carried out under two Managers reporting to the Director of Generation Projects, who is responsible for the design and construction of all generation facilities. The Manager of Engineering is responsible for all engineering design and project engineering service on the nuclear part of the plant. The Manager of Construction is responsible for all activities at site up to and including the construction testing of systems and equipment, until such systems are turned over to the commissioning teams under the Operations Station Manager.

As many of us in Ontario Hydro have experienced a transition from the construction of hydraulic generating stations to fossil fired and nuclear thermal generating facilities, we are aware of considerable differences in certain areas requiring particular attention, and as many of you may also be exposed to some aspects of the transition from hydraulic to nuclear, this paper will attempt to focus some attention on the most significant points requiring increased emphasis.

1.3 The Essence of Nuclear Construction

As a very general overall statement, we have found nuclear station construction to be much more detailed and exacting. This involved the acquisition, inspection and precise installation of a very large number of materials and specialized equipment. The emphasis here and throughout must be on excellent quality control of the materials and equipment supplied and of the workmanship of installation. This is achieved through education of all those involved and a high standard of engineering inspection and quality control. The increased complexity of this type of construction required much greater attention to detailed planning and scheduling, to overall co-ordination both on site and off and to greatly increased communications at a multiplicity of levels. I believe it is almost impossible to over-emphasize the importance of giving really adequate attention to these areas. Further reference is made to these areas in more specific terms later on in relation to the various functional aspects of construction.

2. COMMUNITY AND PUBLIC RELATIONS

Well in advance of the actual physical commencement of construction, it must be clearly recognized that considerable attention must be given to overcoming public misunderstanding concerning the hazards relating to nuclear plant construction and operation. This pertains in particular to the communities within, say, 30 miles of the site as well as to the public at large.

2.1 Pickering Project Location

When Ontario Hydro decided in 1964 to build a two million kilowatt nuclear electric station close to one of Canada's largest municipalities, it could have been asking for trouble. Though the station would be Ontario's - and Canada's - third, it would be the first in a densely populated area.

The location was a Lake Ontario site in Pickering Township, just south of and readily accessible from, the Province's multi- lane east-west freeway and barely four miles from the eastern limit of Metropolitan Toronto with over two million people.

Pickering Township had two distinct characteristics. One was residential. Of the Township's 27,000 people, 21,000 urban residential citizens occupied only 25% of the land area. Of these, 10,000 lived in Bay Ridges, a new sub-division immediately adjacent to the site. The remaining 6,000 included 5,000 farm dwellers and 1,000 non-farm rural people.

To this diverse and widespread audience, Hydro had to address itself on a little-known topic which, for the public, had frightening connotations. The utility was to put nuclear fission - to build an atomic plant - in their midst and within a stone's throw of middle class kitchens.

The challenge was three-fold: to prevent organized opposition, to head off the consolidation and exploitation of misconceptions and to have the installation accepted as a safe and good neighbour.

2.2 Background Concerns

Very early it became evident that the people in and around Pickering would be concerned about safety, the social and economic effects on the community and the possibility of air and water pollution. A factor of some significance was the 'spill-over' of scare material and anti-nuclear publicity from the United States.

Aware that misconceptions could be more easily prevented than corrected and knowing that the facts were indeed on its side, Hydro's policy was to be one of forthrightness. The guiding philosophy would be to initiate rather than react. Some things would be stated only in response to questions but the replies would be complete, prompt and clearly stated, and questions would be encouraged and solicited at every opportunity. Hydro would go to the people, using every means at its disposal.

2.3 Steps to Achieve the Objectives

A plan was formulated which identified four time divisions:

(a) from the initial announcement to the start of construction,

(b) the construction period,

(c) start-up,

(d) regular operation.

Personal contact with municipal officials in Pickering began on a confidential basis even before the station (then nameless) was announced. The implications for local municipal pride were intimated. Studies were made to show the nature and distribution of the public involved and the use of nuclear information material was stepped up.

A long-standing program of presentations to school groups was supplemented with nuclear information. There were more than 1,000 schools within 30 miles of the site.

Speakers went to the meetings of service clubs and citizens' groups, outlining the plan, explaining nuclear power and citing the successful and safe operation of NPD. References to international recognition and the possibility of prestige were mentioned. On each occasion there was a question period and each question was noted.

A similar full-scale presentation was made to employees and their families who lived in the area.

From the week in which the first soil test crew arrived on the site, progress reports, including contract awards, have been and are being issued.

Local opinion leaders and area press representatives were taken on tours conducted by Hydro, not only of the site but also of Douglas Point, some 150 miles away. Brief remarks by Hydro officials at luncheons afforded further opportunities to answer questions.

Having cited the plant as contributing to the municipality's prestige, the time was ideal for officially naming the plant "Pickering Generating Station".

Favourable comment came from many quarters, notably the local press, when this announcement was made.

A major ceremony was held on the site after land preparation was completed, to mark the formal start of construction. It provided national publicity and an opportunity for area citizens to visit the site.

When the Information Centre was completed and a film on nuclear power ready, an advance preview of the Centre was held for local officials and media representatives.

A Public Relations Officer and a chief guide were permanently assigned to the Centre, which is open for 52 week operation. During the summer, student guides are engaged. Attendance has been in the order of 100,000 visitors per year. Visitors are shown the film, taken through the 4,000 square foot exhibit area and then for a short tour of the site. There is also an observation deck overlooking the site.

Pamphlets on the station and its centre are placed in county fairs and larger exhibitions and sent with written replies to enquiries about the station or Hydro's nuclear program.

2.4 Results

To date, no organized opposition to the plant has formed. Not one letter-to-the-editor has been published expressing concern for the safety of the community.

Pickering Township has repeatedly mentioned the station in its advertising and its industrial promotion brochures as a matter of civic pride.

With misconceptions dispelled and prevented and with each enquiry of every form answered promptly, fully and honestly, the genuine co-operation of a previously hesitant and potentially hostile populace has been earned.

3. SALIENT POINTS RELATING TO FUNCTIONAL CONSTRUCTION PHASES

3.1 General

The following phases are presented in a general chronological order. Recognizing the familiarity of those reading this report with engineering construction of electrical generating facilities, no attempt has been made to present a complete picture of construction requirements. Rather, we have attempted to identify the salient points relating to each phase of nuclear construction; that is, those aspects peculiar to this type of plant and requiring special emphasis or attention.

It may be helpful, before assessing specific phases in more detail, to look briefly at the relative contribution in dollars of the civil, mechanical and electrical features of construction. The following chart presents this for the first 2 units at Pickering and is generally representative of the broad overall cost breakdown as well as the major disciplines.

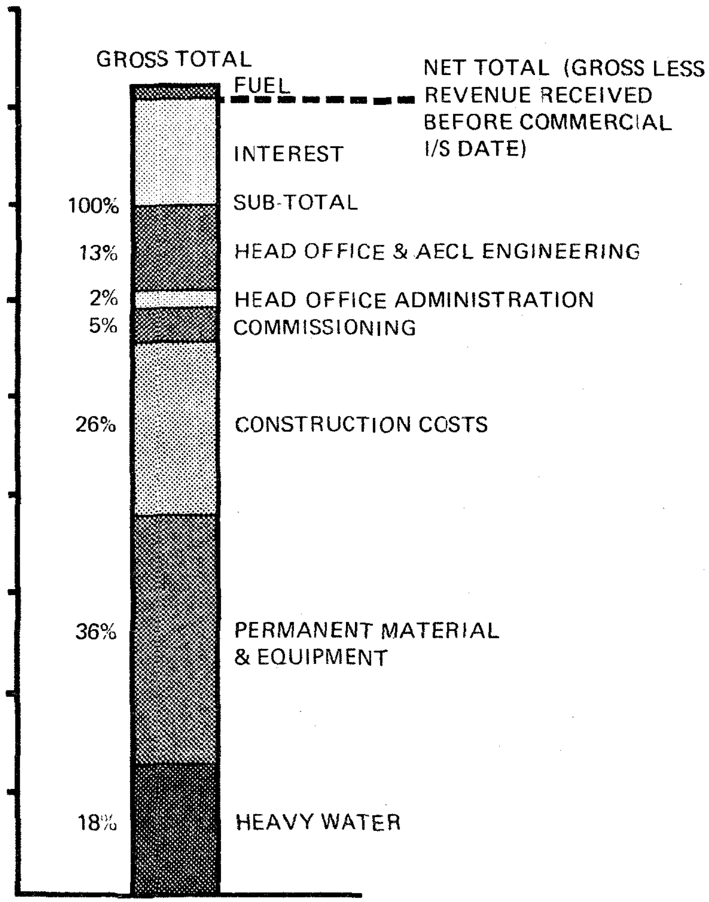
It is apparent that the civil construction costs, predominantly the concrete work, represent the largest portion of erection costs, while the mechanical materials and equipment are by far the largest proportion of supply costs.

"Other site construction costs" include such expenditures as Hydro field engineering and supervisory staff, materials control and handling costs and other similar indirect costs.

3.2 Planning of Construction Facilities

The layout of shops, offices, warehouse and storage facilities and construction air, water and power services, requires careful attention at the construction planning stage to integrate them with the permanent site layout.

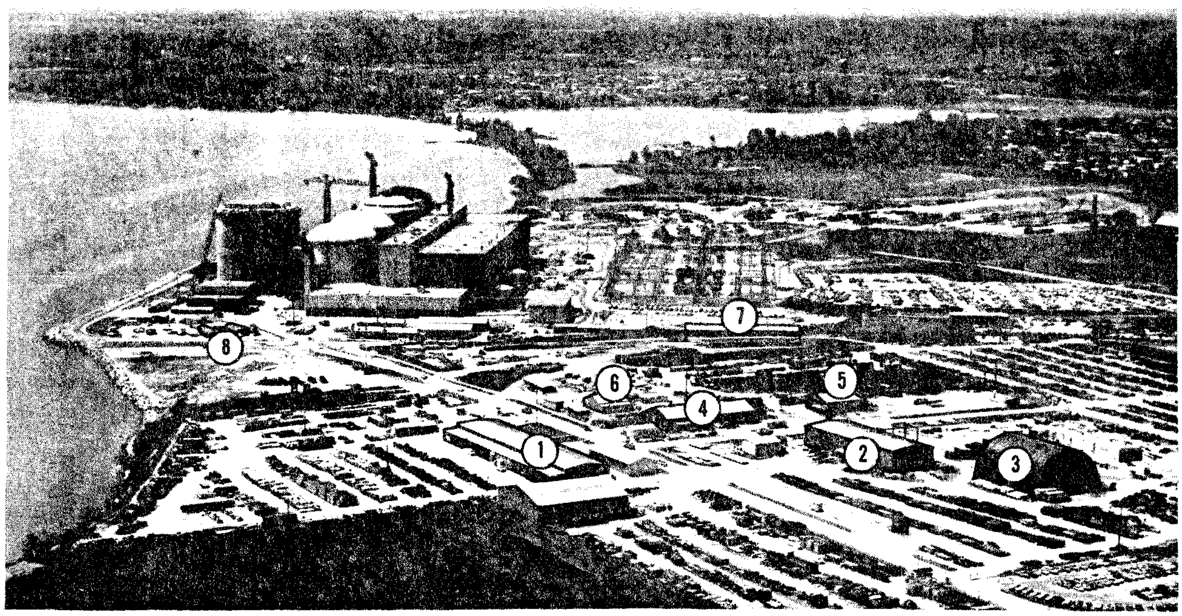
Particular attention needs to be given to the shop layout and equipment for pipe fabrication to optimize on-site fabrication of spool pieces, as well as pickling facilities for pipe and for radiographic inspection. An unexpectedly large volume of miscellaneous structural steel fabrication at site, possibly in the order of 1,100 tons, makes an adequate fabrication shop and sandblasting and painting facilities important. There will, of course, also be a considerable quantity of steel fabricated off the site. The machine shop must also be equipped to meet the exacting tolerances specified for certain nuclear components and to fabricate urgently needed parts or tools to avoid costly delays.



SUMMARY:- CONSTRUCTION & PERMANENT MATERIAL COSTS

DISCIPLINE		% OF SUB-TOTAL
MECHANICAL	CONSTRUCTION COSTS	4
	PERMANENT MATERIAL & EQUIP.	24
	TOTAL	28
CIVIL	CONSTRUCTION COSTS	8
	PERMANENT MATERIAL & EQUIP.	6
	TOTAL	14
ELECTRICAL	CONSTRUCTION COSTS	3
	PERMANENT MATERIAL & EQUIP.	6
	TOTAL	9
OTHER SITE CONSTRUCTION COSTS		11

Figure 2 Pickering G. S. Actual Project Expenditures



1. WAREHOUSE
2. PIPE FAB SHOP
3. FEEDER TUBE FAB SHOP
4. MACHINE SHOP
5. REPAIR GARAGE
6. CARPENTERS SHOP
7. PROJECT OFFICE
8. FIELD OFFICE

Figure 3 Construction Facilities

Needless to say, a very adequate warehousing and mechanized material handling arrangement is of considerable importance to adequately handle the multitude of diverse materials.

Also, the very large number of materials involved requires substantial indoor storage both heated and unheated and a considerable area for outdoor storage.

Influenced partly by the size of pump motors (up to 6,000 hp) and other equipment to be tested, construction power requirements are in the order of 5,000 kVA.

3.3 Excavation and Foundations

Very little can be said about excavation and foundations without knowing the sub-surface conditions for a particular site. The Pickering site required the excavation of more than 300,000 cubic yards of earth and the driving of 90,000 lineal feet of heavy steel H piling (12BP89 and 12BP74) of an average length of approximately 50 feet for the first unit, plus ancillary structures. It will be readily seen from the attached progress pictures that a significant portion of the site resulted from disposal of fill behind rock filled dykes as reclaimed areas.

An early start must be made on reactor building excavation and foundations owing to the critical position this building has in the construction schedule. The most complicated, long duration work is, of course, contained in this structure.

In making an early start on this excavation, due regard must be given to its relationship to the circulating water intake and discharge channels which may be adjacent to it and at the same or lower elevations.

3.4 Concrete Work

Total concrete required in the various structures for a single unit plant would likely be about 100,000 cubic yards. Of this, perhaps 2,000 cubic yards will be heavy concrete using ilmenite ore for aggregate to provide containment or shielding from radiation from the reactor.

To control the quality of the concrete, Ontario Hydro specified the mixing plant itself and all ingredients as well as the actual mixes. To meet placing temperature specifications, facilities were also included for adding ice to the mix and for cooling the aggregates.

The quality of the concrete, particularly for the perimeter walls and dome of the reactor building, is influenced by the requirement of air tightness as the structure will be operated under a small negative pressure. Minimum shrinkage is of prime importance and concrete specifications for this work specify close temperature differentials, waiting periods and pour sequences. Careful scheduling of the many pours involved is required as well as very close quality control on placing temperatures and methods.

The arrangement of the construction joints also has an important bearing on the leak tightness of the reactor building. Generally, a 10 foot lift has been built completely around the perimeter wall with 5 foot gaps left every 25 feet before the next vertical lift is started. Concreting of these small filler pours was delayed until the heat of hydration in the larger 25 foot sections had been dissipated and shrinkage had taken place. No staggering of joints took place in subsequent vertical lifts.

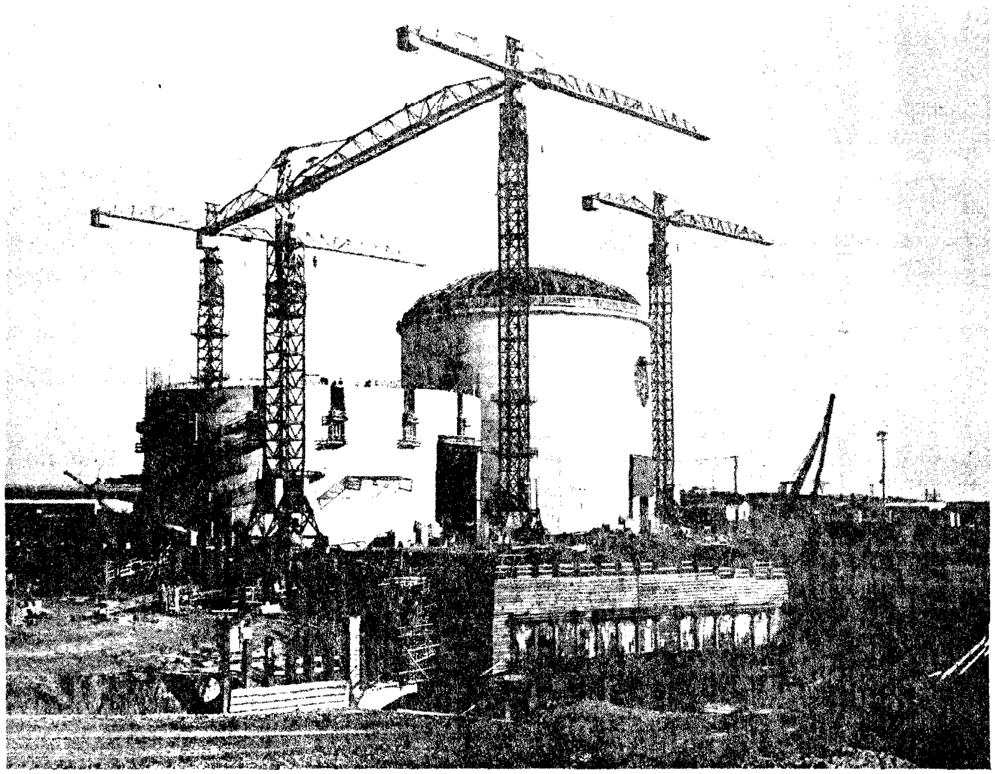


Figure 4 Reactor Buildings Nos. 1 and 2 Showing Tower Crane Placement and Filler Pours

As a further aid to minimizing shrinkage and cracking in the perimeter wall, the maximum placing temperature of the concrete for the filler sections was specified at 50°F. This was achieved by substituting shaved ice for all or part of the mixing water. To reduce the heat of hydration, 20% of the cement was replaced by flyash or low heat cement in the concrete used in filler pours.

Close tolerances are generally required throughout the reactor building requiring well designed formwork.

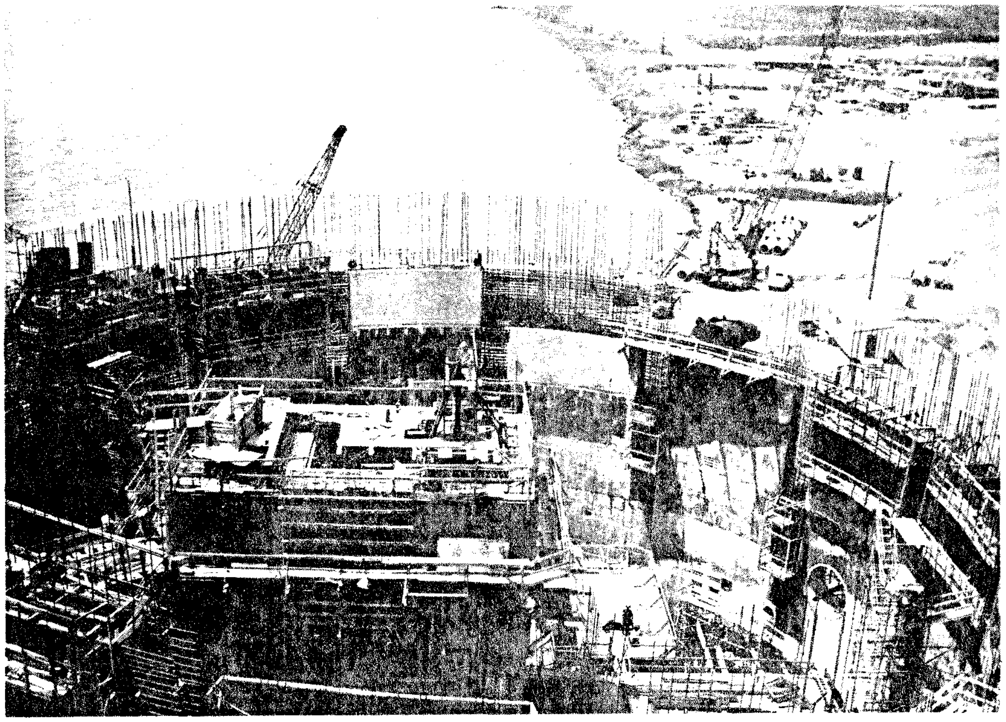


Figure 5 Reactor Building Perimeter Wall Forms
and Calandria Vault Construction

Multiple sets of steel forms were designed to take the full liquid head of concrete so that placing of the 4 foot thick perimeter wall was not restricted by the rate of rise.

The calandria vault inside the reactor building is constructed of concrete having a density of 240 lb per cubic foot to provide shielding from calandria radiation. This density was obtained by using ilmenite coarse aggregate and hematite fine aggregate. Placing methods were the same as for regular concrete but with an approximate 50% reduction in the loading of concrete handling equipment.

The reinforced concrete dome of the reactor building is elliptical in shape, 2 feet thick at the springline and 18 inches thick at the crown. The rise to the crown is 35 feet 9 inches.

To support the concrete during pouring, 44 equally spaced, bolted, structural steel trusses were used. The lower ends were supported on the top of the perimeter wall and the tops were connected to a horizontal compression ring supported from the permanent structural steel inside the reactor building.

Most concrete is heavily reinforced, a total of about 8,000 tons for a one-unit plant. Many carefully welded imbedments are also involved to preserve the leak tightness of the perimeter walls around various penetrations.

It is also essential to recognize the importance of tower cranes for concrete placing, steel erection and for handling materials and equipment. The nature of the internals of the reactor building makes it essential to work from outside the perimeter of this 148 foot diameter building. This requires two sizable tower cranes. Those used at Pickering had a capacity of 6 tons at 164 feet.

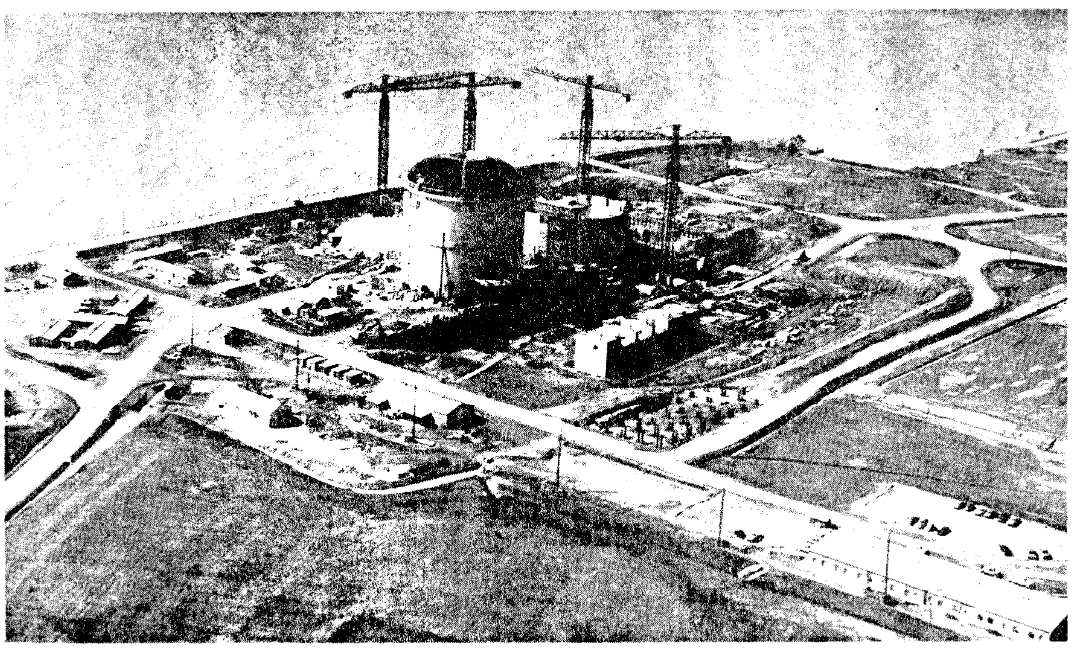


Figure 6 Progress 15 Months After Start of Construction

In referring to concrete, it is worth making reference to the epoxy coatings used as internal surface finishes in much of the reactor building as well as in various concrete and steel storage tanks. These require knowledgable and careful application as numerous coats are often involved to achieve the desired surface finish.

The sequence of such work, as well as internal painting generally, requires close co-ordination to complete this work without allowing wet paint and fumes to interfere unduly with the many other trades completing work within confined areas to a tight schedule.

Cleanliness, particularly in the reactor building, is a more stringent requirement than on a normal type of construction job. The sophisticated equipment can be adversely affected by dust during construction and dust which would become radioactive needs to be removed towards the end of construction. Very large industrial heavy duty vacuum cleaners have been found to have a real application here.

3.5 Structural Steel and Architectural Work

Steel for a single unit plant would be in the order of 5,000 tons. The sequence of erection relative to turbine block construction warrants consideration. There are economic advantages to block construction first. Early completion of concrete floors in the reactor and turbine auxiliary bays is dependent on early erection and torquing of steel in these areas. Steel 'Q' deck was found to greatly expedite floor construction by acting as formwork for the underside of floor slabs. Installation of other equipment and systems is, of course, dependent on placement of floors.

Architectural work is considered to be in line with normal requirements. However, a good sized work force is required to achieve prompt and early completion of the building exterior to provide economical housing for internal work. There is also a substantial requirement for laying heavy concrete blocks as shielding walls, which is somewhat unusual.

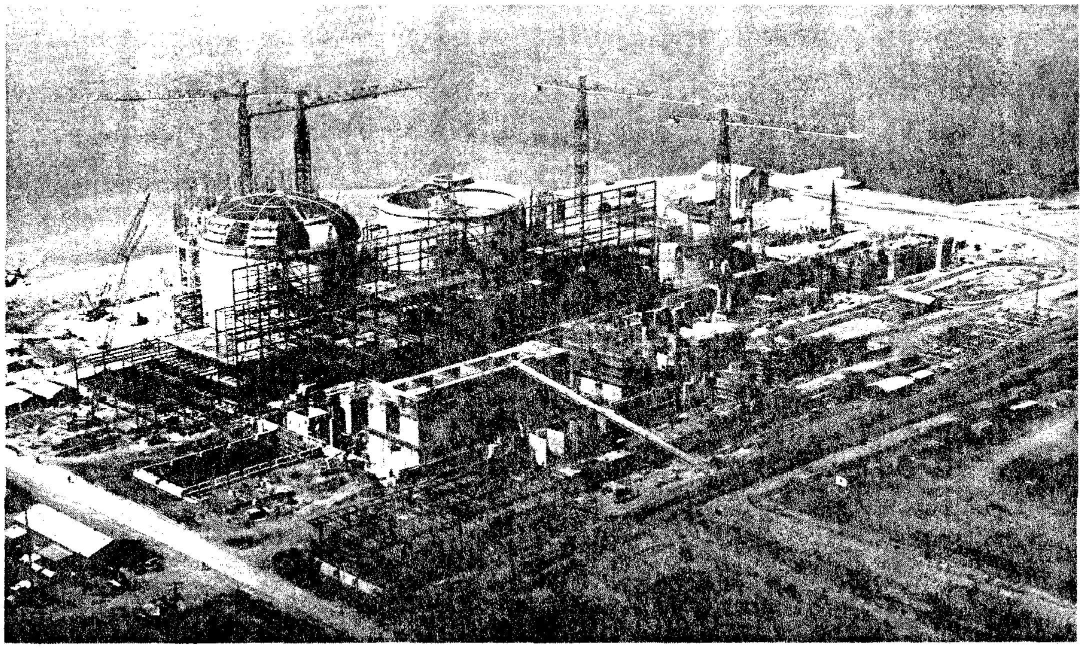


Figure 7 Progress 30 Months After Start of Construction

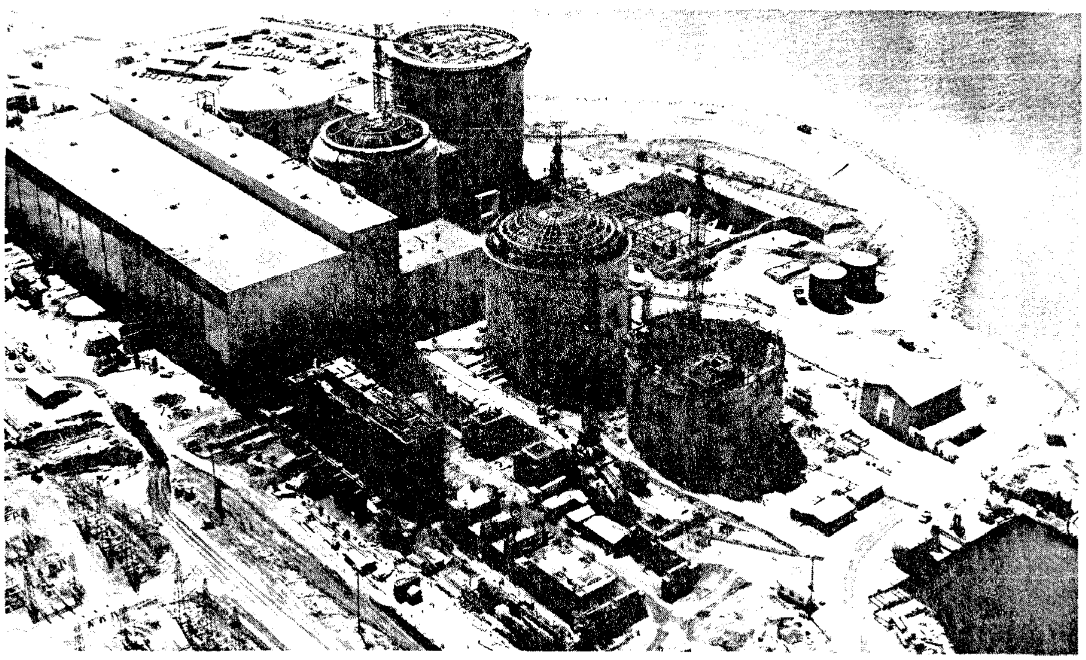


Figure 8 Progress 42 Months After Start of Construction

3.6 Mechanical Installations

3.6.1 Reactor Components

The installation of the reactor components requires special procedures and some special skills. A knowledge of the compatability of the materials used and an understanding of the function and relationship of the various components is needed by the professional engineer responsible for this installation.

A fully-engineered system for receiving, transporting and placing the major reactor components has been found to be essential and economical considering their weight, size and importance.

An unloading dock, possibly constructed alongside the circulating water outfall channel, is a requirement for unloading barge-transported components such as the calandria, dump tank and end shields.

End shields weighing 280 tons, including the shipping ring, were skidded off the barge which had been sunk for stability, and transported on a rail system to the calandria vault. The 20 foot lift up into position was made using a system of centre-hole jacks and threaded rods.

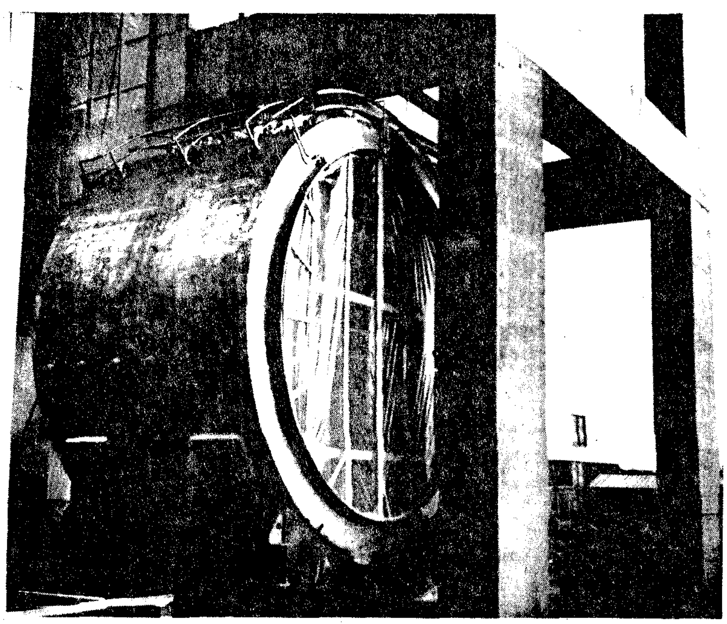


Figure 9 Calandria Being Moved into the Reactor Building

The calandria shells, weighing 45 tons each, were off-loaded by floating derrick and skidded into the temporary reactor components building nearby. Internal thermal shields were installed by the manufacturer and spray cooling piping by Hydro trades forces before the calandria, now weighing 180 tons, was moved by the rail track into the reactor building and lifted into place using the same system as for the end shields.

The end shield rings which had been previously installed and the dump tank were also received by barge and handled by floating derrick and delivered to the building by truck float. Some turbine generator components were handled in the same way.

End shields held by the support rods are lined up in their final position, allowing for weld gap and shrinkage. The calandria, accurately measured and with weld preparation machined on both ends, is accurately aligned for welding to the end shields. This is a manual TIG weld involving significant shrinkage problems due to the stainless steel material. All welds are fully radiographed.

The installation of the Zircaloy calandria tubes, pressure tubes and stainless steel end fittings is carried out from temporary adjustable platforms in the reactor vaults.

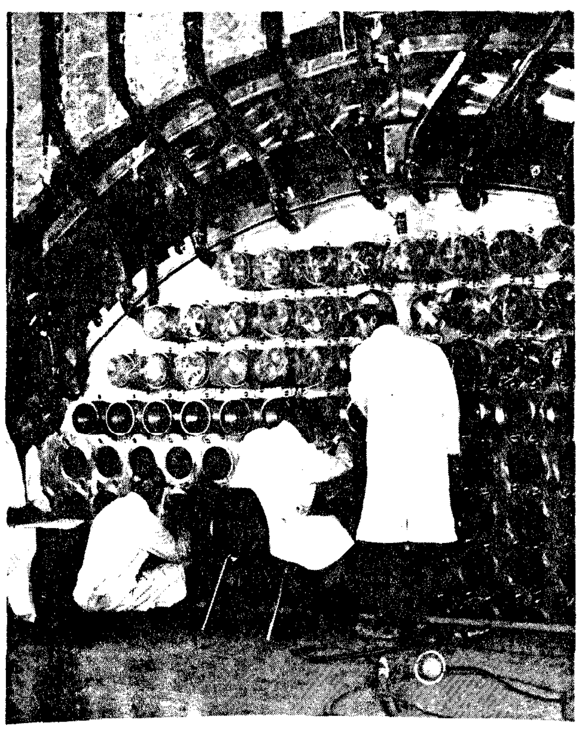


Figure 10 Calandria Tube Sheets Showing Bellows Seal

Figure 11 Installing Calandria Tube End Fittings

To join the thin calandria tube to the tube sheet, the calandria tube is sandwiched between a stainless steel insert and the tube sheet. The insert is then roll-expanded using conventional type boiler tube expanders. The pressure tube to end fitting joint is roll-expanded directly into the stainless steel end fitting. The sealing of the ends of the calandria and primary coolant tubes must be of high integrity to prevent the leakage of heavy water. After rolling, all joints must be capable of passing a helium leak test based on leakage at the rate of a few cubic centimeters per year.

3.6.2 Piping

As one would expect, piping and welding are predominant items, involving an estimated 170,000 lineal feet of piping for a single unit plant, excluding feeder tubes. A well-equipped pipe fabrication shop is essential for economical assembly and welding of spool pieces, making as much use as possible of automatic welding equipment such as hot wire TIG for quality and economy of welds. An automatic welder was also jointly developed and used very successfully for making the field welds joining the feeder piping which connects the headers and the reactor coolant channels in the primary heat transport system. There are roughly 30,000 lineal feet of feeder tubing per unit.

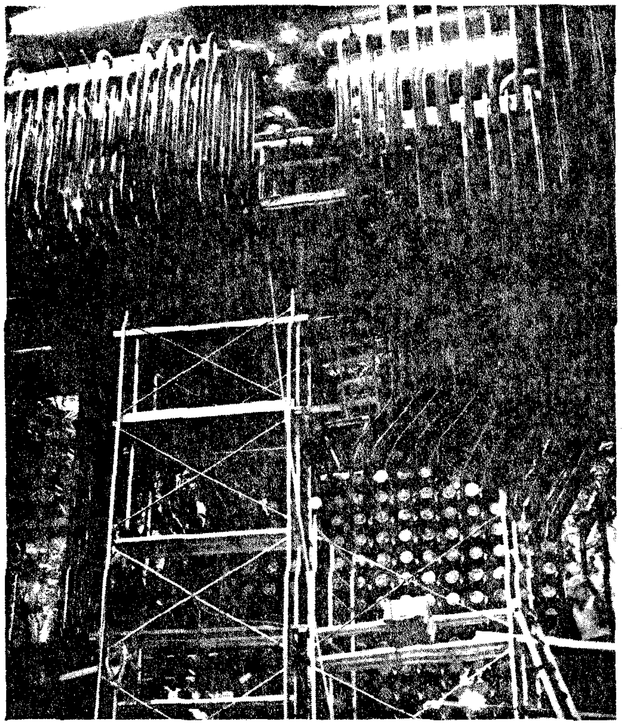


Figure 12 Feeder Tube Installation

The welding of nuclear piping requires a high level of integrity. This involves extensive use of radiography, helium leak testing and ultrasonic equipment in the inspection of welded joints. The large volume of radiographic inspection is such that several certified radiographers would be required. Helium leak testing is not difficult but does require special equipment and the training of operators.

Insulation of piping in particular, as well as boilers and tanks, is a major undertaking. The timing is quite critical, particularly on the boiler and primary heat transport system, and cleanliness at later stages is difficult and needs concentrated attention.

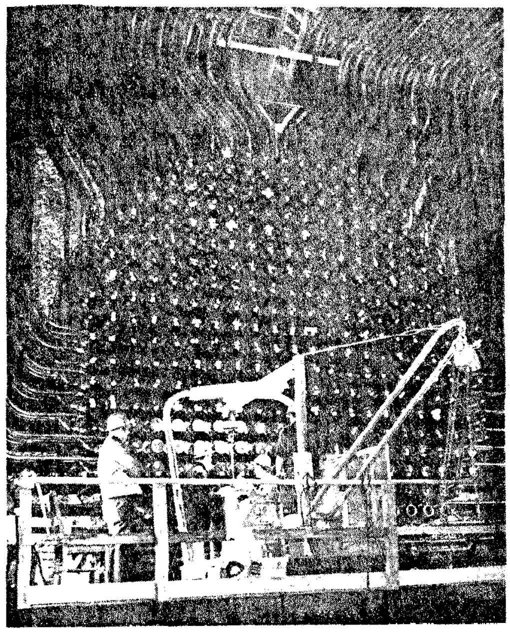


Figure 13 Installing Closure Plugs

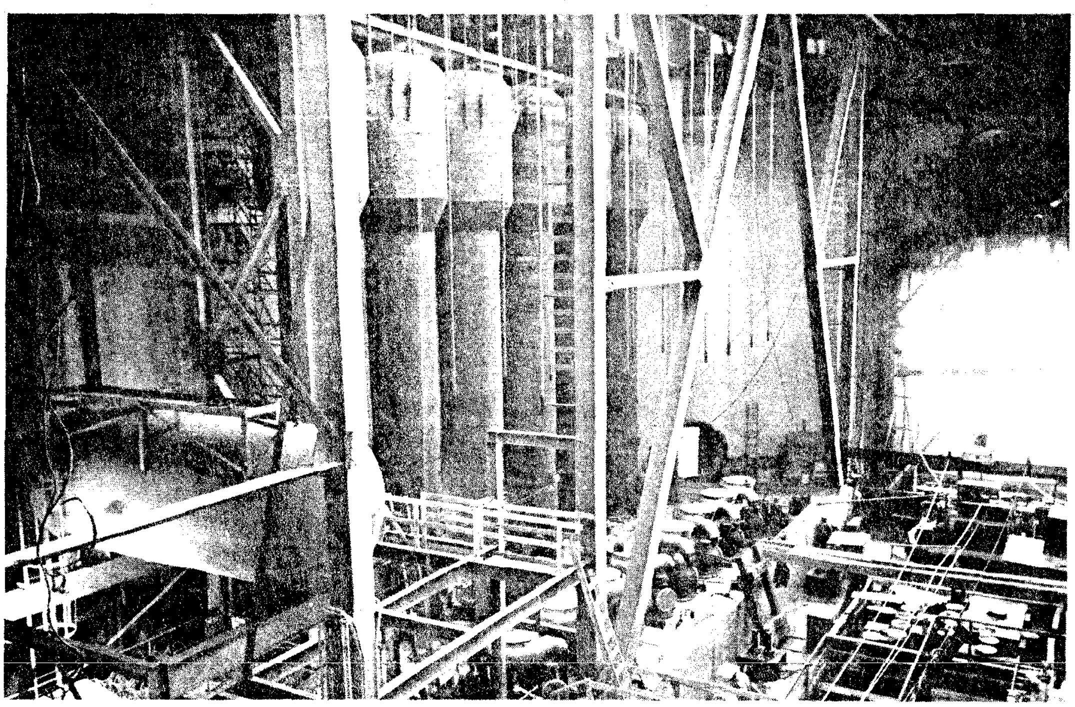


Figure 14 Boilers and Primary Pump Bowls

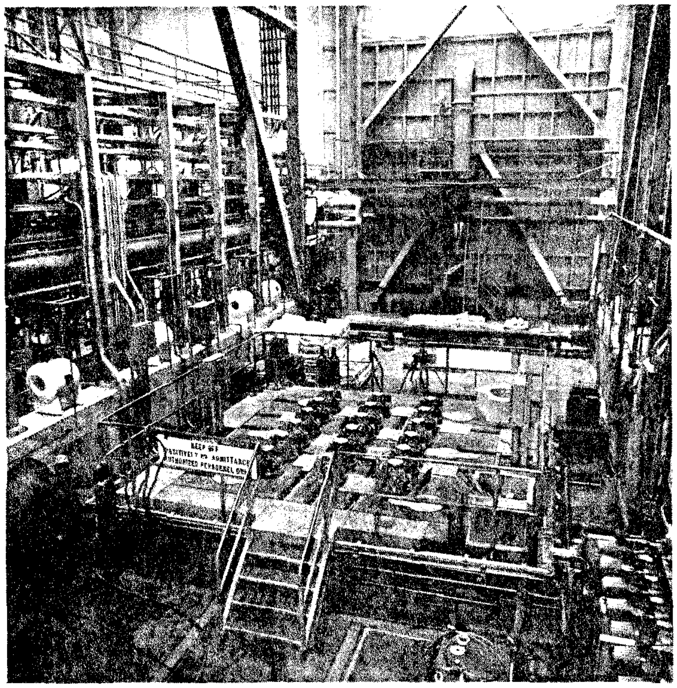


Figure 15 Reactivity Mechanism Louvers
to Pressure Relief Duct in Background

3.7 Electrical Installations

While electrical equipment and materials are reasonably standard relative to power and control requirements in fossil fired generating stations, this work in a nuclear plant is characterized by very large quantities to be installed in restricted areas and must be closely co-ordinated with many other trades. Control cable, for example, would likely be in the order of one million lineal feet, power cable about 300,000 lineal feet and cable pan 60,000 lineal feet. An estimated 5,000 indoor lights and fixtures are installed.

The electrical power systems are complicated by a variety of standby power systems and power transfer systems not found in other thermal generating stations. Complexity and sophistication are imposed on the control instrumentation and wiring by triplication and channel separation of the protection and regulating systems and the computer of the major processes.

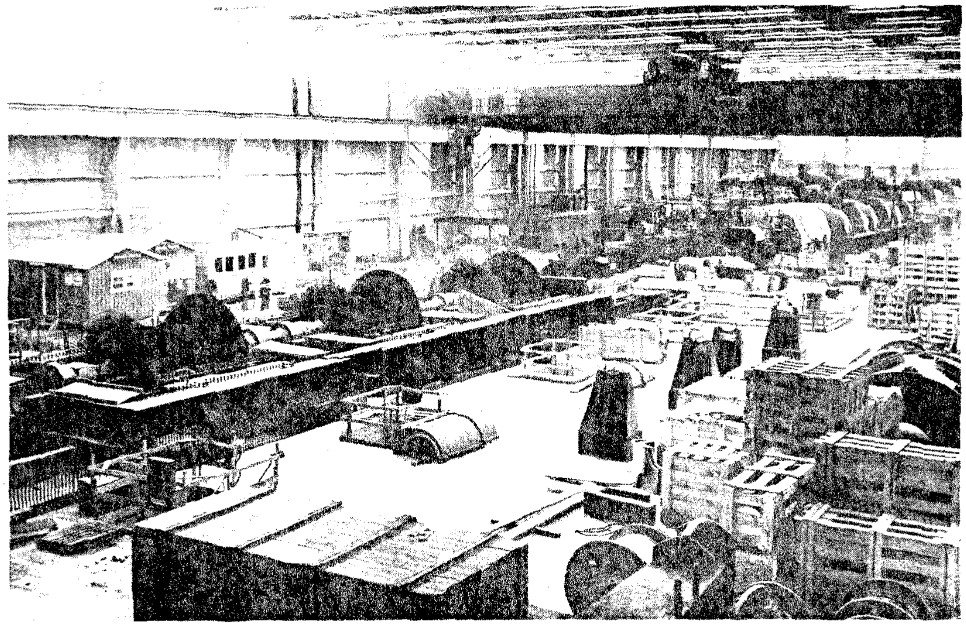


Figure 16 Turbine Hall Showing Units Nos. 1 and 2

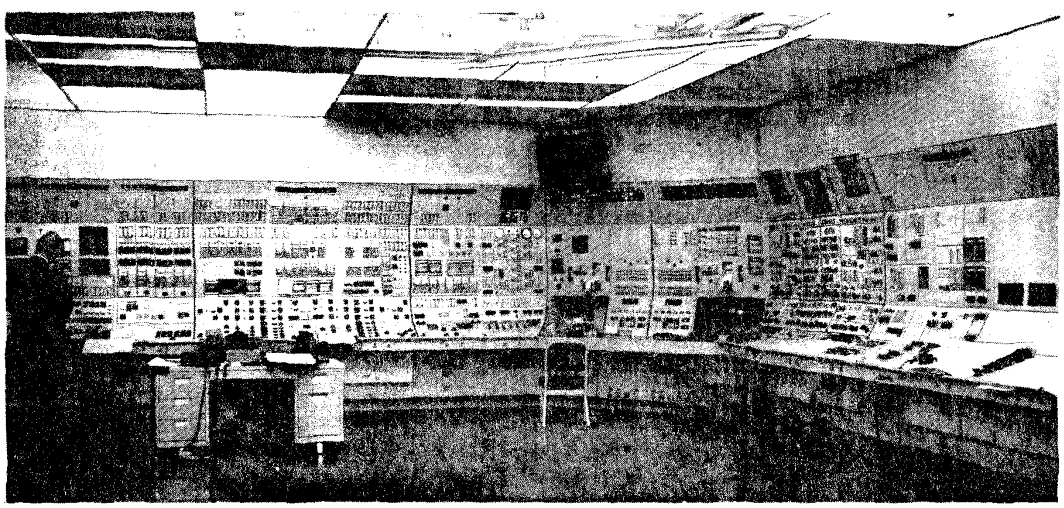


Figure 17 Control Room, Unit No. 1 Quadrant

3.8 Instrumentation

From an instrumentation viewpoint, the main difference between nuclear and conventional power stations is that a nuclear station has a significantly larger volume of complex, sophisticated instrumentation (approximately five times that of a fossil station of similar capacity). To satisfy Atomic Energy Control Board licensing requirements, these systems require extensive, certified, operational testing during the construction and commissioning phases. To accomplish this, a highly skilled, experienced group of instrumentation specialists is required. This group should be formed 2 to 3 years before the unit goes critical. Initially, the emphasis should be on special training in areas such as:

nuclear instrumentation
radiation control procedures
nuclear systems (design involvement)
computer wiring program

As construction progresses, the emphasis would shift from formal training to contract co-ordination and quality control of the instrumentation installations. Construction testing and commissioning would follow as the contracts are completed and systems are turned over to operating personnel. We see advantages in transferring the instrumentation technicians who do the engineering checkout of construction to the Operations staff for maintenance of the control systems.

Variations in training requirements for control maintainers, some variations in rates and conditions and an on-going need for these technicians in our construction program, limit the opportunity for doing this in Ontario Hydro.

As other work on the approximately 200 various systems must be virtually 100% complete before some of the instrumentation work can be completed and checked out, a large amount of exacting work must be carried out in a short time. About 2,700 instruments are involved and probably 130,000 lineal feet of stainless steel tubing and perhaps 325,000 terminations.

New automatic tube welding equipment has been developed by AECL from commercial models. This ensures a consistently higher standard of tube weld at very much lower cost than manually. Over 9,000 such joints can be made by machine and another 3,000 must be done manually.

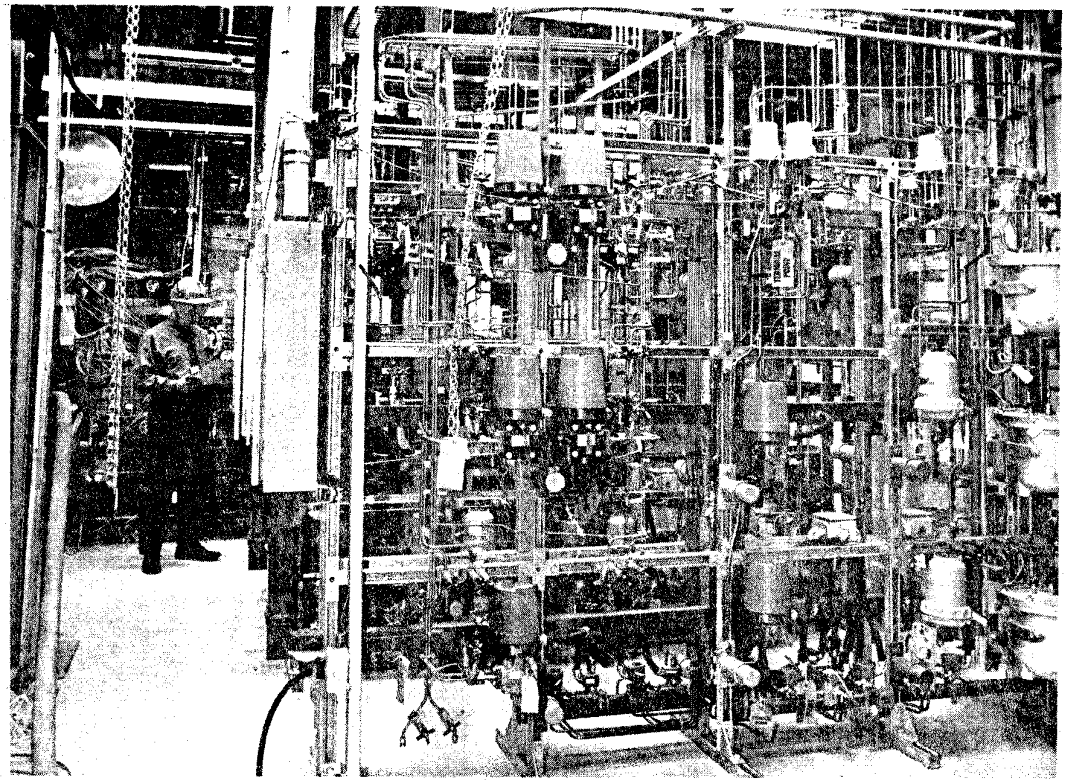


Figure 18 Typical Instrumentation Showing
Channel Flow Monitoring System in the Foreground

The very large number of control cables and terminations has been handled very expeditiously and at substantially lower costs through the use of information supplied by a computer wiring program developed for Pickering. Cable routing and wiring printouts replace conventional wiring diagrams. While there were considerable development and implementation problems initially, this system has proved to be highly successful.

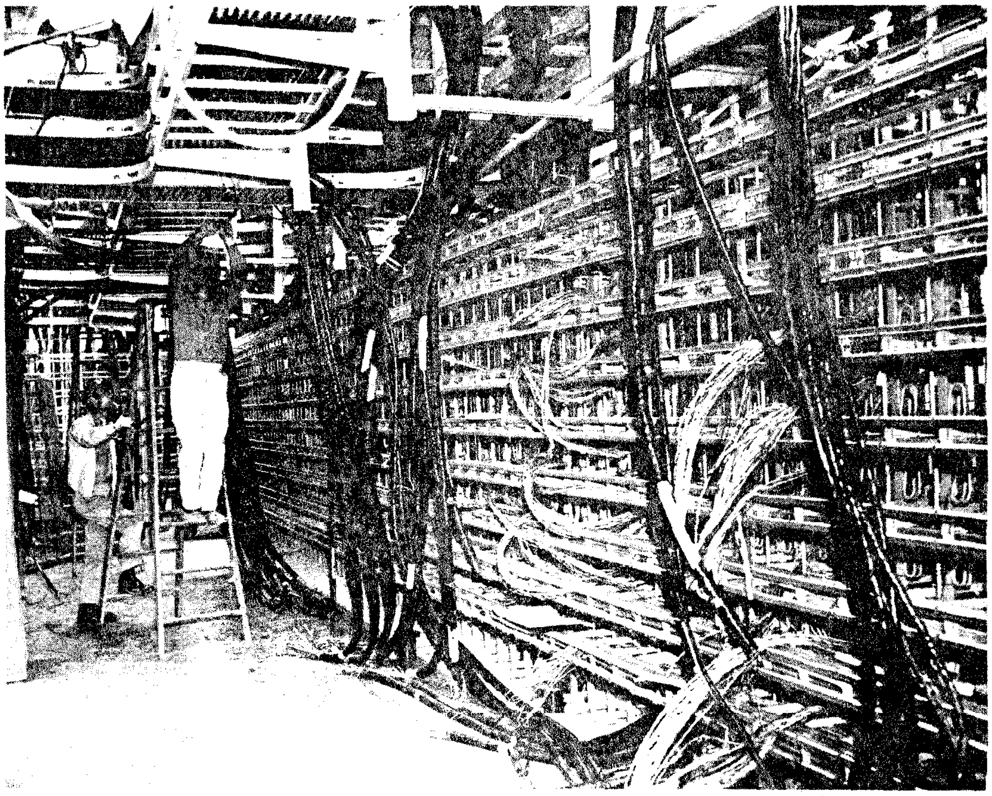


Figure 19 Control Distribution Frames
Control Equipment Room

3.9 System Checkout and Turnover to the Commissioning Group

After installation, the mechanical engineering group co-ordinate and carry out the final check on each system for correctness and completeness and then perform those running tests which can conveniently be done by them. This is mainly hydrostatic testing and demonstrating the operation of individual components. They do not normally operate systems and do not handle heavy water. After completion of checkout and the construction testing, the system is formally turned over to the Commissioning group along with fairly complete documentation of the state of the system and the tests performed.

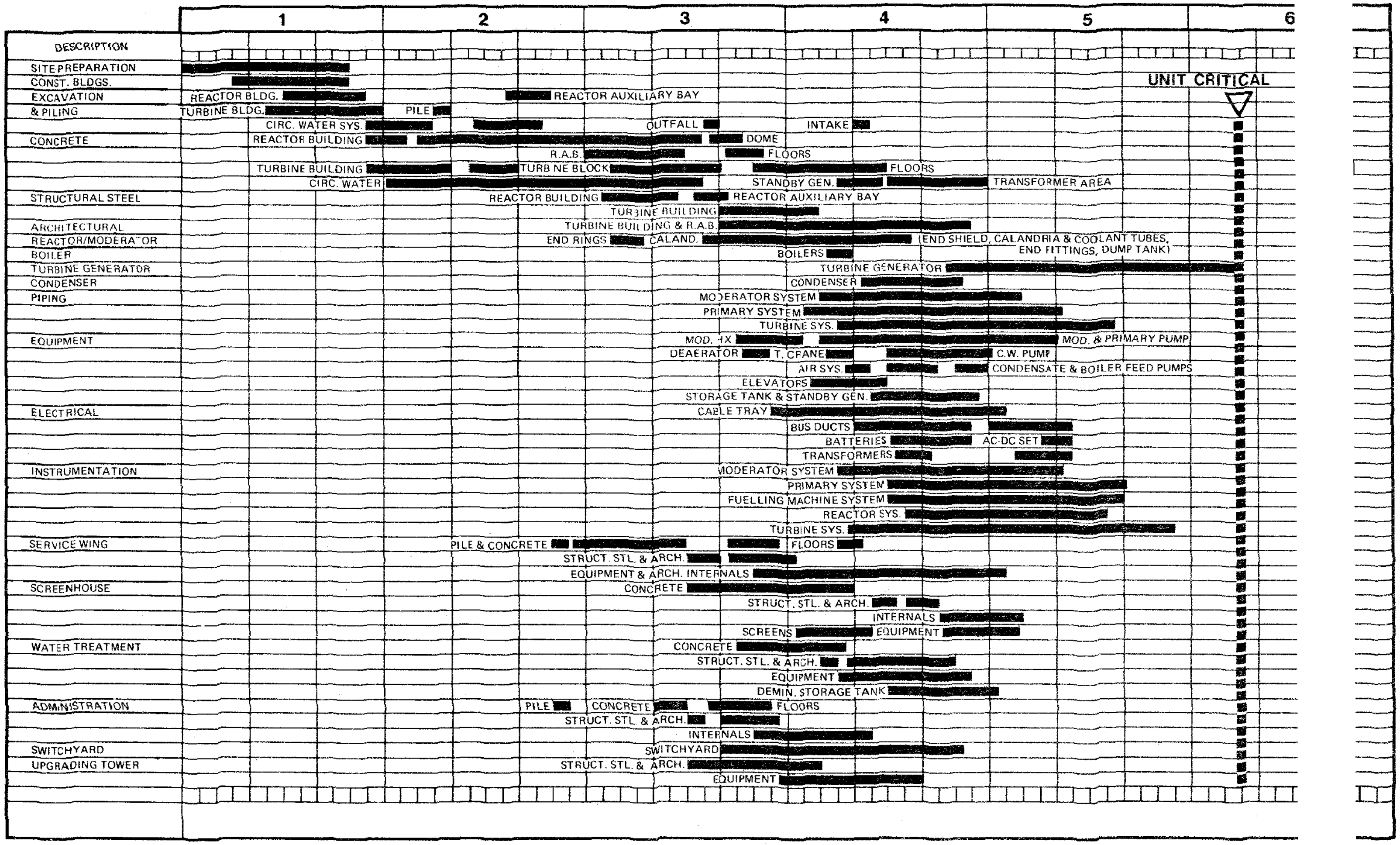


Figure 20 Field Construction Program

4. CHANGES AND MODIFICATIONS

Although many modifications have been incorporated in the design and construction of the CANDU PHWR plant through close liaison between Hydro design, construction and Operations personnel and AECL, experience at Douglas Point and Pickering indicates that a considerable number of design changes are still likely to be found beneficial as a result of further operating experience. A number of tradesmen and engineering personnel will likely be involved in this kind of work for perhaps a year or so after the plant is in operation.

5. *PERSONNEL REQUIREMENTS*

5.1 Engineering, Technical and Supervisory Staff

Until the early 1960's, Ontario Hydro was engaged mainly in the construction of hydraulic generating plants. At the time the Douglas Point Nuclear Power Station was commenced, it became apparent that technical skills were not sufficient to meet the increased demands. It was therefore necessary to provide retraining for a number of regular employees. At the same time, due to the increased number of skilled technicians required, a number of technicians and technologists with Community College training in Canada and the United Kingdom were recruited. While their experience varied considerably, these employees were sufficiently qualified to respond quickly to training.

The staff of the Resident Engineer on a nuclear station is made up of civil, mechanical, electrical, instrumentation and control sections. Each group is headed by a professional engineer and may ave one or more assistant professional engineers. The other staff of these sections are engineering technicians. Engineering technicians and technologists who have completed the course of study given in the Community Colleges of Ontario are well qualified for this work. Our experience indicates that people with this kind of background have a better understanding of the requirements and are generally more appropriately trained and better suited for this type of work than the construction tradesmen.

5.2 Construction Tradesmen

As mentioned briefly earlier, the standard of workmanship throughout a nuclear plant is particularly important in terms of its safe, reliable operation as a base load plant with high availability. To achieve the high standards required, construction trades forces will not only require close inspection but must be schooled and encouraged to produce top quality work.

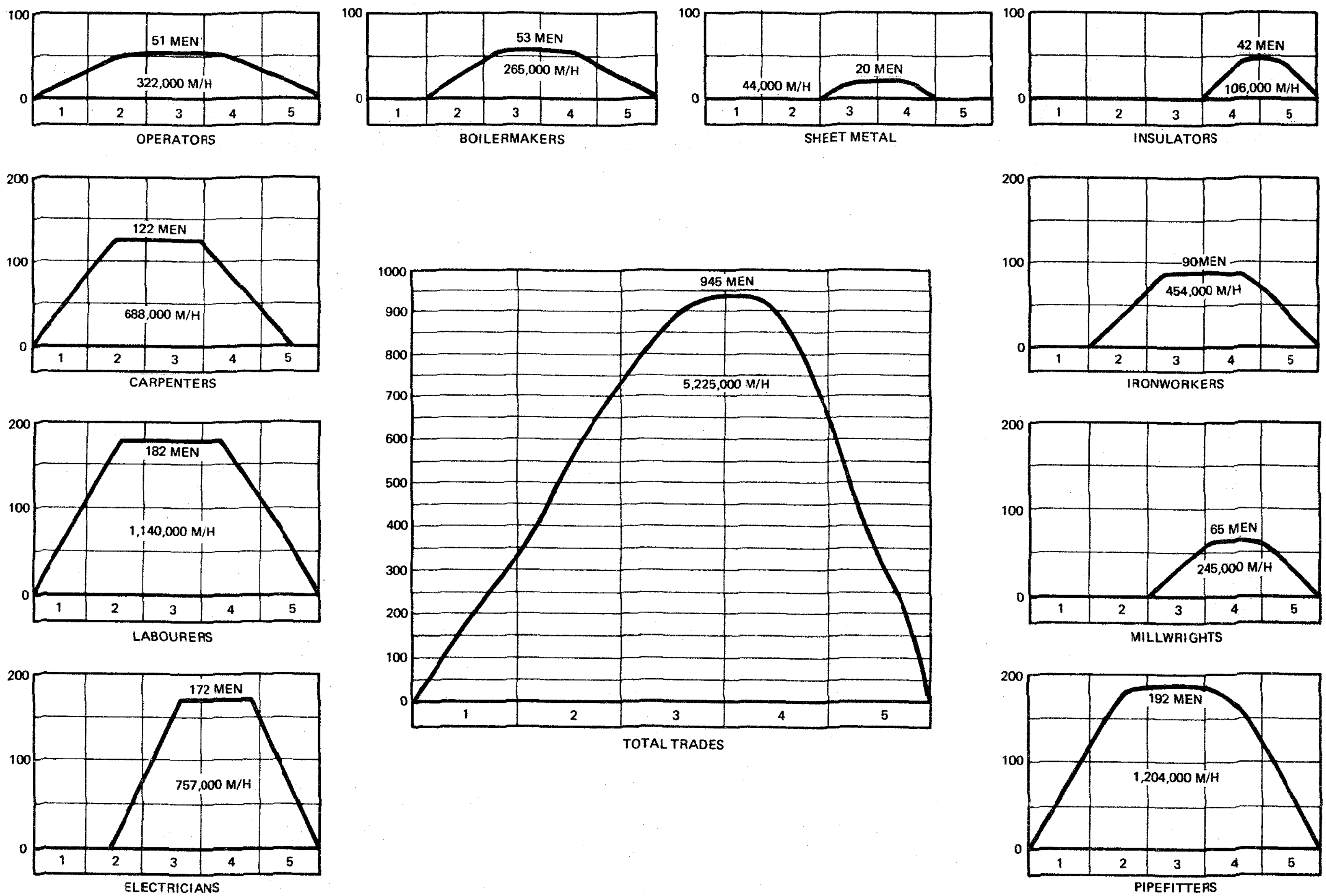


Figure 21 Trades Force Requirements

Skilled welders in the pipefitting, ironworking and boilermaking trades in particular were generally not available and a welder training program was necessary to upgrade existing skills in new welding procedures. Electricians and pipefitters were retrained to install the complex electrical and pneumatic instrumentation systems. Millwrighting skills had to be upgraded. An extensive Trades Apprenticeship Program was introduced in co-operation with the Construction Trades Unions and the Ontario Department of Labour.

5.3 Jurisdictional Assignments

Of particular significance in the building of nuclear plants is the matter of jurisdictional assignments of trades work. Many work procedures occur for which records of prior agreements are either non-existent or not pertinent. However, Ontario Hydro has, at this point in time, completed the Douglas Point nuclear plant, nearly completed Pickering G. S. and has commenced Bruce G. S. Sufficient precedent has been established so that serious jurisdictional disputes have been minimal for the past two years or more. Prior to that many contentious issues arose.

We have found the following procedures to be beneficial.

(1) Establishment of a fairly comprehensive record of significant work procedures and jurisdictional disputes (Ontario Hydro Trade Work Assignments Manual).

(2) Establishment of a co-operative working relationship between supervisory levels and labour union representatives, especially at the local levels (Chief Stewards, Business Agents and/or Managers).

(3) Hold "mark-up" meetings at the international representative level where new work processes are involved or where agreement has not been reached at the local level. Such meetings require careful consideration and preparation.

(4) Follow a standard, consistent procedure when making work assignments.

6. MATERIAL PROCUREMENT, RECEIPT, STORAGE AND HANDLING

In recent years, Ontario Hydro has found it advantageous for thermal and nuclear construction projects to establish a separate Materials Department on site, as part of the Construction Manager's staff, headed by a senior engineer. This department has overall responsibility for procurement of site ordered materials and equipment, contracts and expediting, receipt, storage, issue, handling and delivery to the powerhouse of ALL materials and disposal of scrap and surplus material.

This centralizing of responsibility at the site has proved to be very effective and well suited to the large volume of sophisticated material and equipment involved in nuclear plant construction in particular. It also greatly facilitates communication on materials matters with Hydro engineering design departments, AECL, Hydro's purchasing and shop inspection personnel and suppliers, and ensures the close integration of procurement and erection essential for economical construction.

While there is probably an option regarding the supply of conventional materials and equipment, responsibility for the supply of nuclear components and materials should definitely rest with AECL and the owner's engineering department. This would include procurement, inspection and expediting as well as site facilities for receiving, storing and reissuing. This would involve some 7,000 to 8,000 stock code items with a widely variable quantity of each stock code.

A system involving the preparation at a design stage of complete bills of material for all design work is a definite requirement. These must define clearly the responsibility for supply action between AECL, the owner's engineering and purchasing organizations and contractors.

In conjunction with this, a simple material control system based on stock codes, has been found to greatly facilitate ensuring the availability of materials and equipment at the right time.

Reference has been made elsewhere to warehousing facilities. Experience has clearly shown the pronounced advantage of centralized warehousing, storage and material records and of mechanized material handling. The matter of jurisdictional assignments relating to material handling is a matter deserving early and careful attention, as the precedents established have a substantial impact on costs.

7. PLANNING, SCHEDULING, CO-ORDINATION

As referred to in very general terms at the beginning of this paper, the more detailed nature of nuclear construction, involving a great many systems and separate components and their installation in close proximity to one another in fairly confined spaces, requires a dynamic system of planning, scheduling and co-ordination. We in Ontario Hydro have adopted a three-level system for all major projects. Level I is an overall master schedule which commits the various managers involved to basic key dates. Level II schedules are primarily used to co-ordinate design, procurement, construction and commissioning. Level III schedules are developed by each contributing department as detailed working schedules to ensure the achievement of the dates established.

Frequent monitoring and updating of detailed schedules is required owing to the flexibility needed in adjusting logic to absorb changes in deliveries in particular and from other sources and still maintain the key dates of Level I and Level II schedules. Roughly 150 CPM diagrams and some 3,000 activities were used to adequately schedule and co-ordinate the work on a single unit. A combination of manual and computer updating was found to be most suitable.

Very close liaison between construction installation and testing, and commissioning is essential to optimize the schedule towards the "reactor critical" date. Key dates were established for the turnover of 200 systems for the beginning of their commissioning. Weekly reviews were held jointly to assess the co-ordination of commissioning with construction and almost daily liaison was maintained between the construction test engineers responsible for various systems and their commissioning engineer counterpart on the Operations staff.

8. SAFETY

From the nature of the heavy construction involving a great deal of handling of heavy components of awkward shapes in confined spaces, the need for attention to safety is apparent. Schedule demands involve many trades working in close proximity with a variety of tools and materials. Staff co-ordination of an overall safety program has been found to be essential to ensure adequate and reasonably uniform attention to this important area. With an estimated 5,250,000 manhours of skilled trades required in the construction of a single unit plant, a program instructing, informing and involving all trades as well as all levels of supervision, is clearly warranted and a sound investment.

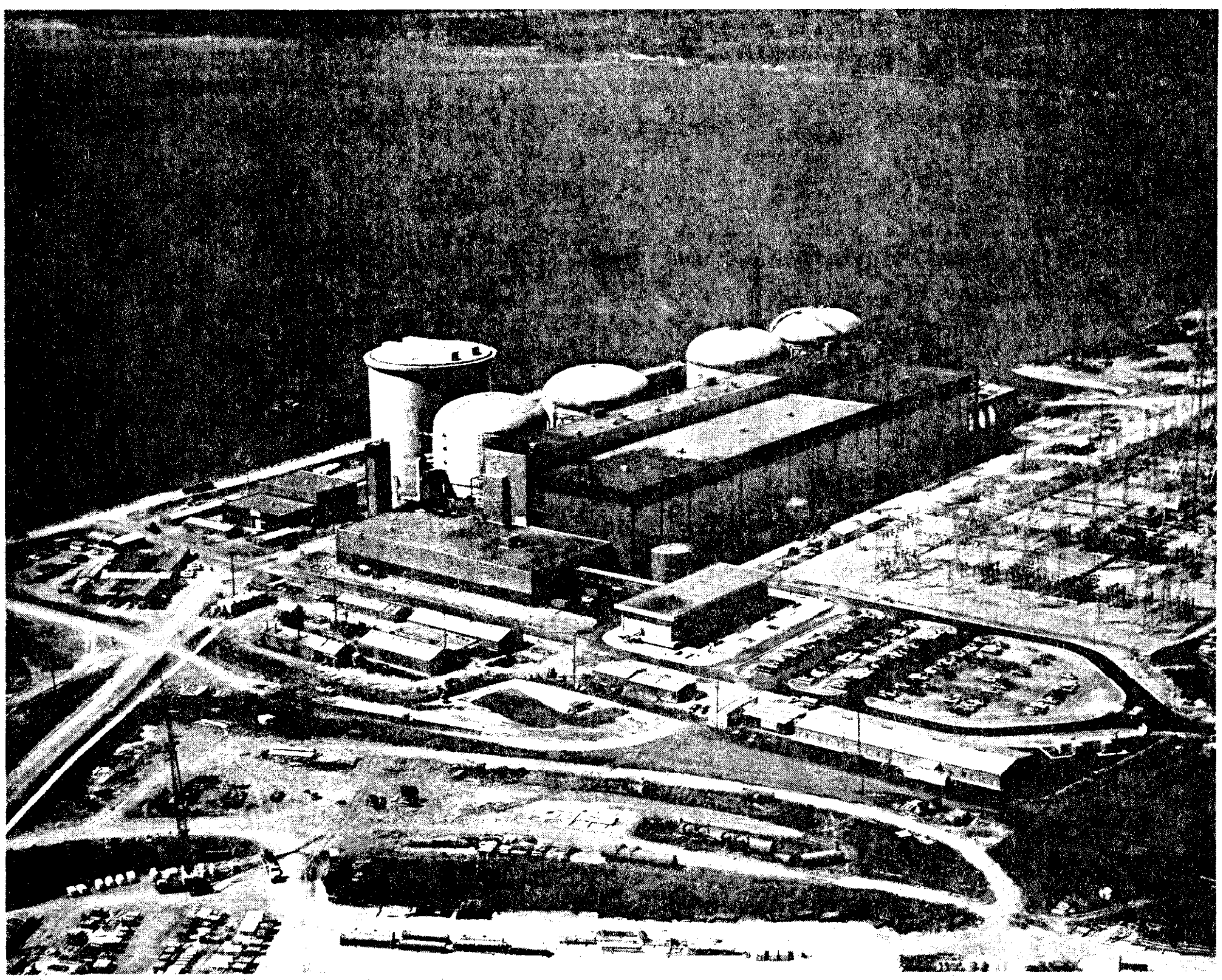


Figure 22 Pickering Generating Station