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ENGINEERING SUPPORT – FACILITY STUDIES

by
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ABSTRACT

The Ralph M. Parsons Company provided architectural-engineering services in support of the General Atomic Company in the next-step fusion program (TNS). Parsons, having long recognized the importance of fusion technology as a viable energy option in the country's overall energy program, has been actively involved in supporting fusion programs such as the conceptual design study of an experimental power reactor (EPR) facility as well as this TNS engineering support study.

In this conceptual scoping study, Parsons has arranged a supporting facility around a baseline 3.8m ignition test reactor (ITR) designed by the General Atomic Company (GAC). During the study, Parsons conceptually designed and estimated the constructed costs of the balance-of-plant (BOP) supporting buildings and systems necessary for the ITR operation.

In addition to facility design and cost estimate, this scoping study also includes the program planning and quality assurance for the TNS program. In terms of BOP functional design assurance, schedule implication, and preliminary cost tradeoff, Parsons has examined the potential impacts evolving from developmental changes to the tokamak parameters and from various ITR upgrade scenarios. Recommendations have been made in this study suggesting areas of consideration which may lead to further cost savings in the TNS program.

FOREWORD

This is Volume X of an eleven-volume report constituting the TNS Scoping Studies performed during the 1977 fiscal year. The complete volume list is as follows:

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III.	REACTOR PHYSICS	General Atomic Company
IV.	REACTOR ENGINEERING	General Atomic Company
V.	SUPPORT ENGINEERING, TRITIUM AND NEUTRONICS	Argonne National Laboratory/General Atomic Company
VI.	PLASMA CHAMBER	McDonnell-Douglas Astronautics Company-East
VII.	REMOTE MAINTENANCE SYSTEM	Aerojet Manufacturing Company
VIII.	MAINTAINABILITY STUDIES	Battelle Columbus Laboratories
IX.	ENGINEERING SUPPORT STUDIES — SAFETY, REGULATORY CONSIDERATIONS	Nuclear Services Corporation
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XI.	POLOIDAL COIL SYSTEM — POWER SUPPLY AND TRANSFER	Los Alamos Scientific Laboratory

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10.1. SUMMARY

10.1.1. PROJECT DESCRIPTION

The TNS studies conducted for the General Atomic Company by the Ralph M. Parsons Company consist of engineering support for the TNS program in the area of program planning, facility, conceptual design for the 3.8m ITR, quality assurance, and cost estimate. The main objectives of the TNS studies are to provide the services required (1) to assist in formulating broad scenarios which will indicate the direction(s) future TNS work efforts will take, (2) to ascertain the impact on TNS, and (3) to assist in establishing policy for future fusion power devices as well as for TNS.

Although TNS studies are of scoping nature, the facility design, as presented in this report, includes all the engineering elements for an ignition test reactor (ITR) such as cryogenic cooling for maintaining superconducting B and E coils, electrical power supply systems for coil systems, and neutral-beam injectors to support 30-second deuterium-tritium (D-T) burns. An alternate facility design is provided to accommodate the ITR upgrade option to EPR status. The time and budget of TNS scoping studies, as well as the unavailability of detailed tokamak system information, do not permit optimization of the facility design, and, as such, this facility design is not intended as a final design. However, it does provide a reference BOP facility on which a reasonable cost estimate can be based, and in which high-cost items can be identified. Accordingly, it may serve also as a logical guide to further cost-saving measures.

Because fusion is in the first-of-a-kind stage of technological development, the tokamak fusion system is undergoing constant design improvement. Therefore, the BOP design is subject to more risks in providing a firm design of functional support systems which are necessarily based on an incomplete definition of the tokamak parameters. Furthermore, the flexibility of providing upgradable options in the TNS program would also complicate the program planning. Three studies are presented to assist the program planning. The first study identifies the BOP-fusion device system interface factors/areas and examines the system interaction from the viewpoint of how to maximize the BOP functional assurance. The second study looks into the major components, which constitute the 3.8m ITR base schedule, and assesses the potential schedule impact due to several TNS scenarios including upgradable considerations. The third study deals with cost implication. A preliminary cost tradeoff is presented to identify the items which have significant cost impact on the facility. In addition, a cost comparison is made between the previous experimental fusion power reactor (EPR) facility and this 3.8m ITR facility.

Quality assurance requirements for TNS are broadly assessed on the basis of (1) what is best for fusion technology development and necessary assurance in management, engineering, procurement, manufacture, and construction, and (2) the necessity of implementing a program for a fusion technology which is of substantial difference in physics principles, as well as in environmental and public safety implication, from fission technology.

10.1.2. SCOPE OF WORK

The following subsections 10.1.2.1. through 10.1.2.5. describe the scope of work given to Parsons by General Atomic Company.

10.1.2.1. Program Planning

- How far can work proceed with the definition and design of the new facility without possessing exact knowledge of all the tokamak design parameters (assume bounding envelope is provided)? What are the effects of schedules, costs, overall program planning and direction, quality assurance, etc.?

- How would an upgradable or staged device affect the facility (initially designed as an ITR only) in terms of costs, schedules, etc.? How might the upgrade be accomplished, and what are the risks, advantages, penalties, etc.?

10.1.2.2. Facility Conceptual Design

This activity will be varied and closely related to the efforts of program planning. Alternatives to be considered are as follows:

- Develop an overall conceptual design of the facility for the baseline ITR. Include the identity of the major systems, their relative size and location, plus a plot plan layout of all major items.

- Consider the design of the facility (BOP) without having a complete definition of the tokamak parameters and the resulting risks and impact on cost, schedules, etc. Identify the major systems which would be common to the various options TNS might develop into, the impact resulting from the late addition or elimination of items required to satisfy the final purpose(s) of TNS, and finally the advantages/penalties of designing/constructing TNS in this manner.

10.1.2.3. Quality Assurance

Broadly establish/define the quality assurance requirements for TNS, while recognizing the necessity of implementing a program which is divorced from fission requirements. Consider also the impact of the TNS quality assurance requirements becoming the basis for future fusion devices (principally as they affect costs and schedules).

10.1.2.4. Functional Assurance

Assuming the accomplishment of facility design without complete definition of the tokamak parameters and the complications of upgrading, what functional risks can be identified relative to the physics mission of the device?

10.1.2.5. Cost Estimates

Develop a BOP cost estimate for a "minimum requirement" type ITR facility including the impacts on cost for the various studies above using mid-1977 dollars. Identify the costs required for engineering and construction services, the major elements/systems in the BOP, high-risk items, and contingencies.

10.1.3. FACILITY CONCEPTUAL DESIGN

The facilities conceptual design summarized here includes a description of the facility arrangement (Drawing P-1), followed by a brief review of the balance-of-plant systems. The design is based on preliminary parameters for a 3.8m ITR as furnished by the General Atomic Company. It represents a minimum cost, i.e. "bare bones," approach. However, throughout the architectural layout work, careful consideration has been given to the possibility of a 4.2m upgradable facility being carried forward.

10.1.3.1. Facility Arrangement

The site plan arrangement (Drawing AR-1) shows an access road and railroad spur entering the ITR facility from the west, raw-water supply from the northwest, and electrical power from the north. Personnel parking is provided outside the perimeter security fence, and a guard station is located nearby to control incoming and outgoing personnel, truck and railcar traffic. The plant cooling tower is located in the northwest corner of the fenced compound. The property line is located a minimum of 800 meters from the tokamak building to provide allowable radiation levels at the plant boundary during normal operations.

The tokamak building (Drawing AR-2) contains the fusion device, a hot cell for remote maintenance of activated components, and an inspection and assembly cell on the ground floor. The tritium- and deuterium-handling areas, radwaste and cryogenic systems are located in the basement of the tokamak building (Drawing AR-3). This building, designed to provide the required personnel shielding, is constructed of reinforced concrete and will also withstand the effects of the design-basis earthquake and tornado to prevent the potential release of tritium to the atmosphere in the event of these natural phenomena.

The auxiliary building containing the process cooling-water systems, the electrical equipment building, the shipping and receiving building, and the laboratory and administration building are constructed with a steel frame, insulated metal siding exterior walls and metal roof deck with rigid insulation, and built-up composition roofing. The one exception is the control room and standby power supply system area of the administration building, which is "hardened" similar to the tokamak building.

These support buildings are clustered around the tokamak building in an arrangement which minimizes the length of power conductors, instrumentation wiring, piping, ductwork, and personnel and material traffic. Further optimization investigations will be required in subsequent conceptual and Title I design efforts.

The upgradable 4.2m ITR facility arrangement (Drawings AR-5, AR-6, and AR-7) is included to assess the impact on costs and schedule of providing a facility that can be upgraded to produce power. The basic layout is similar to the 3.8 ITR facility, but, based on a much higher duty factor for the fusion cycle burn, more stringent maintenance requirements, and larger equipment, more space has been provided for those areas affected.

10.1.3.2. Balance-of-Plant (BOP) Support Systems

The following BOP systems are required to support the basic 3.8m ITR facility:

- Water supply and cooling systems
- Cryogenic cooling systems

- Normal HVAC systems
- Radwaste systems
- Plant utility systems
- Remote handling systems
- Electrical power supply systems

Drawing ME-1 shows the water supply and cooling systems. Facilities include a raw-water reservoir, cooling tower, direct tower cooling-water loops, closed-circuit deionized water-cooling loops, and standard services such as potable water and fire water.

The cryogenic cooling systems provide both liquefied helium and liquefied nitrogen services, plus nitrogen gas service as required. This system is shown on Drawing ME-2. Helium is stored on gas to facilitate maintenance of the helium cryogenic cooling system. Nitrogen supply requirements are met by using a liquefied nitrogen storage package.

The heating, ventilation, and air conditioning (HVAC) systems are shown on Drawing ME-3. In addition to conventional HVAC service, the systems are designed to ensure negligible release of tritium to the environment under all operating conditions. This includes design features to shift normal HVAC service to tritium-cleanup systems (study performed by Argonne National Laboratory) if tritium release to the HVAC system is detected.

Since no fission products are produced in this facility, the radwaste system, as shown on Drawing ME-4, is a small system. Essentially, it consists of five tanks, two pumps, and a small, remotely operated cement mixer to solidify high-tritium-contaminated liquids for subsequent disposal.

Plant utility systems consist of a small steam system to handle HVAC heating needs, plant and instrument air, vacuum, argon, and hydrogen services as required.

The scope of work for remote-handling systems by Parsons includes only bridge cranes in the tokamak cell, hot cell, and inspection and assembly cell to lift and move some of the major components of the tokamak device, plus rails for a bridge-crane-mounted shielded cab in the tokamak cell. These are shown in Drawing AR-2. Other remote-handling systems are being studied by AMCO Division of Aerojet-General Corporation. No other cranes of any significance are provided in the facility.

Drawing EE-1 outlines the electrical systems to be furnished for this facility. Power is to be received from an outside source at 138 kV and transformed as required to meet plant requirements. Energy storage devices will be used for pulsed-type loads to ease peak demands and load fluctuations. Two diesel-driven on-site generators and a battery-type power supply (for uninterruptible loads) are furnished to meet standby needs.

10.1.4. COST

Based on the conceptual facility layout and BOP systems developed in Sections 10.2 and 10.3, Parsons has provided a cost estimate for the 3.8m ITR facility. The cost of the BOP portion of the facility is estimated at $120M. Parametric methods were used, for the most part, in the development of quantities and combined with gross quantity takeoffs where practicable. Impacting factors which have not been addressed or incorporated into the total capital cost mentioned above are constructibility, reliability, and time relationship. Interest during construction and escalation have not been included in the figure presented. It is noted that extraordinary design problems associated with first-of-a-kind technology could potentially result in a high cost impact.

Preliminary tradoff considerations were conducted to identify major high-cost components in the facility to recommend areas of potential cost savings. The tokamak building stands out as one of the major items in which potential cost savings may be realized if further design tradeoff studies are performed. Other plasma heating technology (such as RF heating) in lieu of neutral-beam injection appears to offer great cost saving potentials because it makes possible the reduction of the size of the tokamak building.

To illustrate the overall cost relationship between the fusion device concepts, cost comparison was prepared between the current 3.8m ITR facility and Parsons' previous GAC EPR facility. Also, in order to obtain better TNS program planning, a preliminary evaluation was conducted to determine the potential cost implications of an upgradable ITR program.

The upgradable 4.2m ITR facility, which includes a steam generation system, associated power production systems, and a turbine building, will result in an incremental capital expenditure of approximately $60 to $70 million in the BOP portion of the facility.

10.1.5. PROGRAM PLANNING

In program planning, Parsons has examined major factors which will affect the BOP functional assurance, the potential cost, and schedule impacts, also taking the upgradable option into consideration. To minimize BOP design uncertainty brought about by changes of the tokamak parameters during the TNS program's BOP engineering phase, the BOP/fusion machine interface was evaluated and recommendations were made to (1) highlight areas of great impact, and (2) to identify the key relationship in the major segment in a baseline ITR schedule so that the overall program schedule may be expedited.

Results of the BOP/fusion machine study indicate the need of:

1. Early site selection

2. Identification of regulatory requirements related to structure design and safety-related systems

3. A tradeoff study on size of the tokamak building with respect to the fusion machine assembly/disassembly approach as well as remote-handling philosophy.

4. Facility integration coordination in order to facilitate timely design information exchange among various subcontractors.

Site-related information, such as cooling-water source, geotechnical data, stiffness of electrical grid system in the site region, etc. are required for the BOP design. In addition, major tokamak component heat load and power supply requirements would be required.

Results of the schedule evaluation indicate a 10-year schedule for a baseline 3.8m ITR facility. This 10-year schedule includes the front-end scoping study, conceptual design, Title I and II engineering effort, procurement, construction, and startup activities. Major schedule impacts due to factors such as delay in site selection, extension of scoping study, and upgradable consideration were assessed. An overall schedule for TNS with upgradable scenarios would depend largely on how the upgradable option is implemented. The shortest schedule would be achieved by the design and construction of the 4.2m ITR with blanket structure and its associated BOP systems including the turbine building as an integral package. This would result in an overall schedule of 11 years.

Results of the cost study revealed the major cost components in the 3.8m ITR facility. The cost estimate was based on the mid-1977 dollars and on the conceptual facility scoping design as presented in Sections 10.2 and 10.3. The results indicate the need of further tradeoff study in high-cost items, particularly the means of reducing costs of the tokamak building which has a cost tag of $26 million in the overall 3.8 facility cost estimate. In this regard, the cost and benefit analysis of the plasma beam heating methods, such as RF vs. neutral-beam heating, would be a major cost-saving step as the neutral-beam system is one of the major factors in determining the size of the tokamak building.

In general, it would favorably impact the TNS program planning if, in developing fusion device technology, the BOP systems are also given due consideration in the area of high-cost items. Additionally, because of intricate interface requirements, the BOP and fusion device schedule planning should be a closely integrated package rather than two loosely coupled packages.

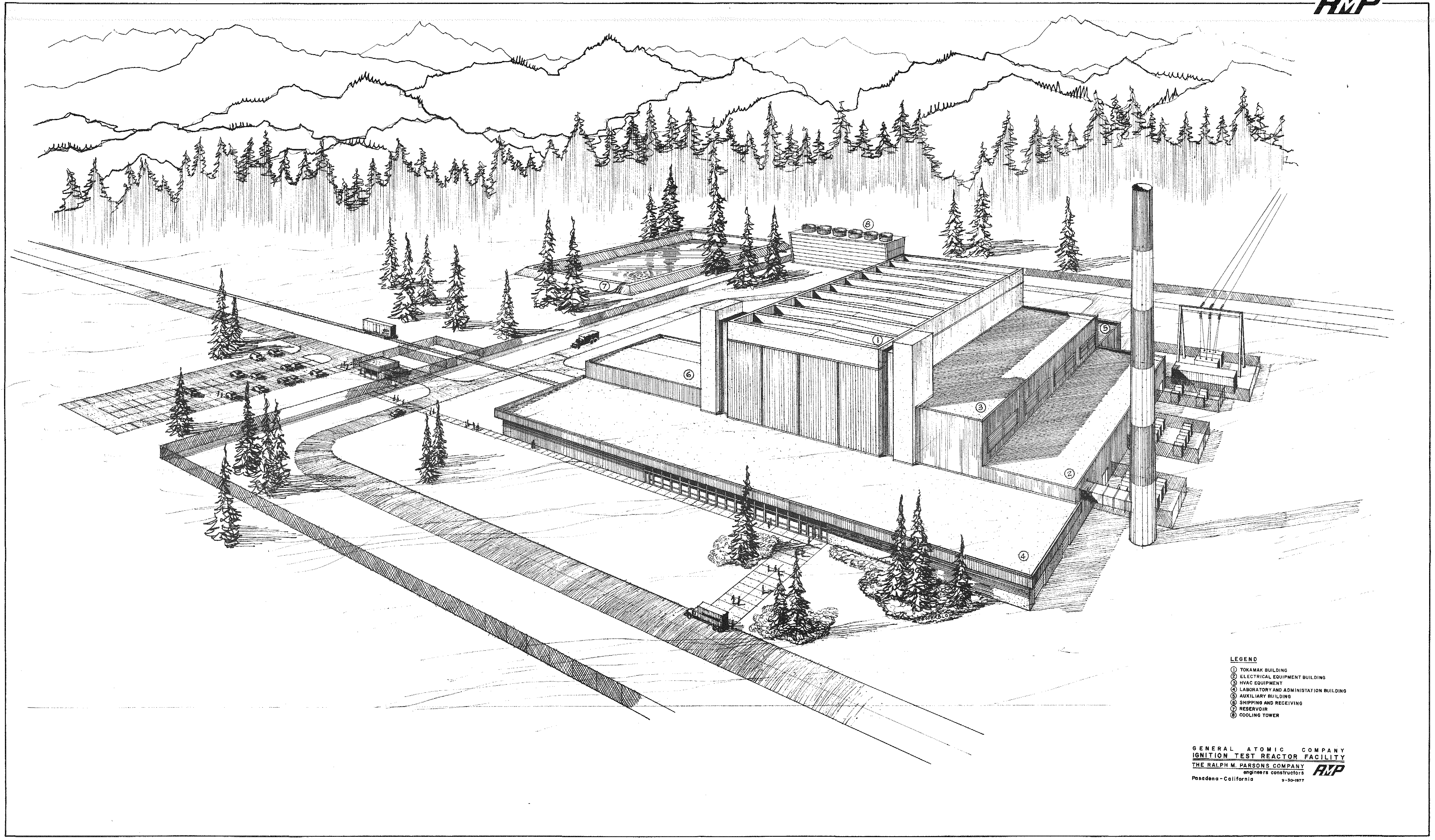
10.1.6. QUALITY ASSURANCE

Parsons developed an initial approach to the quality assurance philosophy for the ITR facility. Recognizing that the ITR is to be one of the earlier demonstration plants in the fusion program, the approach was to consider quality assurance requirements to the fusion demonstration plants in general, and then highlight those aspects that would be considered for the ITR. In delineating these highlights, it was assumed that the ITR was to be an experimental facility with a primary function of obtaining research and development data for use in future fusion demonstration plants.

The initial concept of quality assurance philosophy for fusion plants, including the ITR, took cognizance of the fact that fusion, in general, does not represent the same scope or depth of safety problems that one attributes to fission plants. Consequently, there may, or may not, be specific regulatory requirements related to quality assurance in the demonstration and commercial fusion plants of the future. With such a philosophy, it would not be necessary to reference a quality assurance program such as 19 CFR 50 Appendix B specifically; on the other hand, it was accepted that criteria such as 19 CFR 50 Appendix B, ANSI N45.2, ASME Code, etc., do have certain quality assurance elements within them that one would want to incorporate into any project which embodied a sophisticated technology and in which reliability or maintenance of onstream performance would be extremely important objectives.

From this framework, a set of quality assurance requirements were developed for ITR and fusion in general, that were based on specific criteria that should be adapted in fusion plants of the future with the degree and depth of application determined by (1) the type of fusion facility involved, (2) the importance of safety, (3) the environment and reliability, and (4) the nature of the organization and interfaces providing the design and construction activities for a given facility. The QA philosophy covered management control between the quality assurance function and the performing functions of the project, engineering and design control requirements, procurement and manufacturing control requirements, and construction control requirements. As part of the philosophy, an initial establishment was made of typical quality levels that would apply to a fusion project, and of the type of QA activity that would be conducted for each level. In addition, the philosophy of adapting standard industry codes to fusion was delineated.

As part of the philosophy, organizational interfaces for a typical project (ITR) were shown to demonstrate the QA interface philosophy that could be applied to these types of plants. Also discussed is whether the consideration of safeguard and security features warrants special attention in terms of quality classification.



LEGEND

① TOKAMAK BUILDING
② ELECTRICAL EQUIPMENT BUILDING
③ HVAC EQUIPMENT
④ LABORATORY AND ADMINISTATION BUILDING
⑤ AUXILIARY BUILDING
⑥ SHIPPING AND RECEIVING
⑦ RESERVOIR
⑧ COOLING TOWER

GENERAL ATOMIC COMPANY
IGNITION TEST REACTOR FACILITY
THE RALPH M. PARSONS COMPANY
engineers constructors
Pasadena - California
9-30-1977

Drawing P-1.
Ignition Test Reactor Facility - Perspective

10.2. CONCEPTUAL LAYOUT FOR THE 3.8 m ITR FACILITY

10.2.1. INTRODUCTION

This section describes the siting and general arrangement of the building elements of the 3.8m Ignition Test Reactor Facility Conceptual Design. Included at the end of this section are site plan, floor plans, and section drawings referenced to the descriptions in this section.

10.2.2. SITE PLAN

10.2.2.1. Design Considerations

Since the site for this facility was not selected during this conceptual design phase, certain site-related assumptions have been established as follows:

1. A sufficient water supply adjacent to the facility site is available.

2. A minimum area of 600 acres is available to allow for a distance of approximately 800m (2625 ft) from the center of the tokamak device to the plant boundary. This distance is assumed to be required to reduce radiation dosage to 5 mr/yr at the boundary during normal operation.

3. A railroad spur is adjacent to the plant property.

4. Adequate electrical power is delivered to the transformer yard.

5. Sanitary sewage system is available for tie-in at plant-site boundary.

6. Plant steam supply is not available for this facility. An independent steam boiler is provided as part of this facility design.

7. Radwaste systems and plant utility systems including compressed air, vacuum, argon, and compressed hydrogen supplies are not presently available at plant-site, and therefore will be provided as part of the facility design.

8. Personnel parking shall be located outside the facility perimeter fence. A guard station is provided at the fence to control incoming and outgoing personnel, vehicles, and railcars.

9. Space for future expansion should be allowed for a steam conversion building and turbine building under the "upgradable" consideration.

10.2.2.2. Conceptual Design Description

Drawing AR-1 shows the facility site arrangement, with the access road and railroad spur on the west, with parking space provided for approximately 90 cars. After parking, operating personnel walk through the guard station at the facility perimeter fence, and proceed to the personnel entry which leads to the change areas, laboratory and administration offices.

The perimeter fence encloses an area of approximately 270m by 270m. An access road encircles the ITR facility, and driveways are provided to areas of the building requiring vehicular access, such as the loading dock at the shipping - receiving building, the standby generators, steam boiler, and helium and nitrogen storage areas.

The electrical service is shown entering the transformer yard in the northeastern corner of the ITR facility. Other outdoor transformer areas are located adjacent to the associated electrical switchgear in the electrical building.

Future expansion for upgradable considerations is provided adjacent to and west of the tokamak building.

The cooling tower is located in the northwestern corner of the fenced area, with the raw-water reservoir located nearby. The raw-water intake structure, or deep-well is presumed to be located to the northwest.

10.2.2.3. Design Alternatives

A major design alternative is the adoption of the "upgradable" ignition test reactor facility for the TNS program. A larger tokamak building is recommended, a future steam-generation building and turbine building would be required, and an expanded cooling tower capacity would be needed.

Roadwork costs could be reduced by eliminating the eastern portion of the perimeter road.

If the raw-water supply was of sufficient size, such as a large river or lake, the reservoir could be eliminated by pumping water from the intake structure directly into the cooling-tower basin, thereby saving the cost of the reservoir and a pair of pumps.

10.2.3. TOKAMAK BUILDING

10.2.3.1. Design Considerations

The tokamak building design must accommodate the following considerations:

1. Provide an enclosure to house the tokamak device with sufficient space and handling systems to allow for construction operation and maintenance of the device.

2. Provide shielding adequate to protect plant personnel inhabiting adjacent building spaces during the fusion reaction, and to protect the public at the plant boundaries, or in the airspace above the facility within altitude limits to be defined.

3. Provide a hot cell for remote maintenance on activated components and for decontamination service.

4. Provide space for those support systems that should be located in close proximity to the tokamak device, i.e., cryosorption vacuum pumps, tritium-handling, deuterium-handling, cryogenic systems, and radwaste systems. Personnel circulation for access to these spaces is, of course, required.

The personnel shielding requirements proposed herein result in a building which is also configured to resist the effects of the design-basis earthquake and tornado, and tornado-generated missiles. The structure serves as a confinement against the accidental release of the tritium inventory to the atmosphere.

10.2.3.2. Conceptual Design Description

Drawings AR-2, AR-3, and AR-4 show the general arrangement of the facility. The tokamak cell is 36m wide by 55m long by 25m high. The enclosing shielding walls are 1.5m thick standard-weight concrete. The roof is also constructed of concrete and is 1.5m thick at the ridge, and 1.2m thick at the edges. Deep concrete beams, spaced approximately 8.5m on center, span the 36m width to support the roof.

A hot cell measuring 17m by 18m with a ceiling height of 17m is located adjacent to the tokamak cell, and has a two-story, 5m-wide remote-maintenance gallery along two sides, separated from the hot cell with a 1.2m-thick concrete shielding wall provided with shielding windows and master-slave manipulators (described and estimated by Amco Division of Aerojet-General in Volume VII).

An inspection and assembly cell measuring 12m by 24m by 17m high is located next to the hot cell, and is used for hands-on maintenance of "cold" components for final inspection and decontamination of items leaving the facility, and to provide an airlock between the hot cell and the

Sliding shielding doors are provided between the tokamak cell and the hot cell, and between the hot cell and the inspection and assembly cell.

A crane maintenance mezzanine is located over the hot cell and inspection and assembly cell area. Access to this space is by means of stairways on either side of the mezzanine, or by the elevator located on the left side.

The lower level of the tokamak building contains the cryosorption vacuum pumps (located directly below the tokamak device), the tritium handling area, the liquid helium and nitrogen cryogenic systems, the liquid radwaste tanks, utility systems, and deuterium-handling area. Access to these areas is by means of a perimeter corridor system linking three stairways and the elevator.

The ceiling height for this basement area is tentatively established at 9m. The foundation mat is approximately 2.5m thick and the first floor and vacuum pump area wall approximately 2.0m thick to provide shielding during the fusion burn cycle.

10.2.3.3. Design Alternatives

Many design alternatives hinge on the size, number, arrangement and maintenance space requirements of the neutral-beam injectors. The possibility exists that they may be supplanted by some other technology, such as RF heating, requiring much less space.

The building arrangement shown in Drawing AR-2 provides adequate space for retracting an individual neutral-beam injector into a shielded enclosure for transfer to the hot cell for remote maintenance. Space in the cell could be reduced by devising another maintenance philosophy such as moving an entire double-deck enclosure containing two neutral-beam injectors, into the hot cell. Further tradeoff studies should be conducted to see if possible adverse effects might be encountered in remote maintenance from using this scheme.

Another design approach would be to provide movable local shielding close to the tokamak device, and thereby reduce the thickness of the confinement enclosure structure. The disadvantage here is that heavy shielding blocks would have to be removed for any and all maintenance operations.

The major design alternative in the tokamak building is the provision for upgrading the ignition test reactor into an experimental power reactor. In this case, a 4.2m major-radius tokamak design is used as the basis for an upgradable ITR facility. Upgradable considerations are discussed in detail in Section 10.5.5. of this report, and the proposed arrangement is shown on Drawing AR-5.

10.2.4. THE AUXILIARY BUILDING

10.2.4.1. Design Considerations

The auxiliary building, containing the cooling-water support systems for the tokamak, the chillers and pumps for the air-cooling part of the building ventilation systems, and the plant boiler, should be located near the tokamak device, the cryogenic systems area, the electrical building and the HVAC area to minimize the length of pipe runs. For the same reason, the cooling tower should be located nearby.

10.2.4.2. Conceptual Design Description

The auxiliary building construction consists of a steel frame with open web steel roof joists, insulated metal siding walls, metal roof deck covered by rigid insulation and built-up composition roofing. It is located adjacent to the tokamak building and the electrical building. Access to the auxiliary building from the other areas of the facility is via a 3.6m-wide corridor. The overall building size is 62m by 26m with a clear height of 7.5m. The helium storage tanks and liquefied nitrogen storage system are located outside this building in a fenced yard.

10.2.4.3. Design Alternatives

In the interests of economy, the building construction is not "hardened" against tornadoes or tornado-generated missiles, since the facility is primarily a research facility. A breach of the walls or roof of this building will not result in a release of radioactive material to the environment.

For the upgradable version of the ITR, the space required for the cooling-water systems equipment will be larger since the longer burn time results in greater heat removal capacity.

10.2.5. THE ELECTRICAL EQUIPMENT BUILDING

10.2.5.1. Design Considerations

The electrical equipment building contains the electrical equipment that cannot be located outside in the transformer yards. It should be located as close as possible to the tokamak device, and, to minimize the length of conductors and instrumentation wiring, near the auxiliary building, HVAC equipment area, and the control room and standby power supply. The HVAC equipment has been located on the second floor of this building for similar reasons; i.e., to minimize the length of ductwork to the areas served. The incoming power supply terminates in the transformer yard adjacent to the north side of the electrical equipment building.

10.2.5.2. Conceptual Design Description

The electrical equipment building construction consists of a steel frame with open-web steel roof joists, steel frame second floor with metal floor decking and concrete topping, insulated metal siding walls, metal roof deck covered by rigid insulation and built-up composition roofing. It is located adjacent to the tokamak building between the auxiliary building and the laboratory and administration building. The first floor contains, in addition to electrical panels and switchgear, two motor generator sets in floor pits to reduce the danger of missiles being generated if the flywheel should disintegrate.

Access to the electrical equipment building from the other areas of the facility is via the same corridor that leads to the auxiliary building. Two stairways provide direct access to the second floor HVAC equipment area, with another corridor providing access to the elevator. The overall size of the electrical building is 36m by 80m, with a clear height of 7.5m on both floors.

Transformers associated with the indoor electrical equipment are located adjacent to the building in fenced, outdoor transformer yards in order to reduce enclosed space within the building.

10.2.6. THE LABORATORY AND ADMINISTRATION BUILDING

10.2.6.1. Design Considerations

The laboratory and administration building is designed to house instrumentation and laboratory functions, administrative offices, toilet, shower, and locker facilities, laundry storage, health-physics decontamination, storage and office facility, orientation room, data acquisition and control room, and the standby power supply system.

There should be direct access from the hot cell to the shower and locker rooms, and the health-physics facility, in case of accidental contamination of operating personnel.

To minimize the length of instrumentation wiring, the control room should be located as closely as possible to the tokamak, the electrical building, and the HVAC equipment areas, and close to the other support facilities to minimize travel time for control room personnel. The control room should be designed to withstand the effects of a design-basis earthquake and tornado, and be shielded for magnetic flux influence on the control panel instruments.

10.2.6.2. Conceptual Design Description

The laboratory and administration building is located adjacent to the tokamak building hot cell and the inspection and assembly cell for direct personnel access to these areas as well as to the remote maintenance gallery, the shipping and receiving building, and the corridor leading to the electrical equipment and auxiliary buildings. Stairways and the elevator leading to the lower level of the tokamak building, the second level of the remote maintenance gallery, the HVAC equipment area on the electrical equipment building upper level, and the crane maintenance mezzanine of the tokamak building are directly accessible from the laboratory and administration building.

The control room and standby power supply portion of this building is constructed of concrete, and designed to withstand the effects of the design-basis earthquake and tornado, and tornado generated missiles to allow for the orderly shutdown of the facility. Only those safety related systems, such as the tritium cleanup portion of the HVAC system and the data acquisition and control systems will require standby power supply.

The remainder of the laboratory and administration building will utilize the same construction as the auxiliary building; steel frame, insulated metal siding walls and roof deck with builtup composition roofing.

Interior partitions will be metal studs and gypsum board, painted with rubber base. Vinyl asbestos tile is proposed for the floors, with the laboratory receiving acid- and grease-resistant resilient flooring. Suspended acoustical-tile ceilings are proposed throughout the laboratory and administration building, with the exception of the standby generator rooms.

In the control room, the computer floor system is elevated to provide underfloor space for cable raceways.

Toilet rooms will have ceramic mosaic tile floors and glazed ceramic title wainscot walls. Ceilings and walls above the tile wainscoting will be water-resistant gypsum board, with gloss enamel finish.

10.2.6.3. Design Alternatives

If the selected site already has some or all of the support areas provided in the laboratory and administration building, such as laboratory space, offices, toilet, shower and locker facilities, etc., the building may be reduced accordingly.

For the upgradable ITR facility, the number of operating personnel required for the steam conversion and turbine building would increase and would require a small increase in the support areas.

10.2.7. THE SHIPPING AND RECEIVING BUILDING

10.2.7.1. Design Considerations

The shipping and receiving building must accommodate the handling of incoming and outgoing material and equipment shipped by rail or truck. Storage space and a foreman's office for logging shipments in and out will be required.

This area should have direct access to the inspection and assembly cell and the elevator, and should be near the personnel support area.

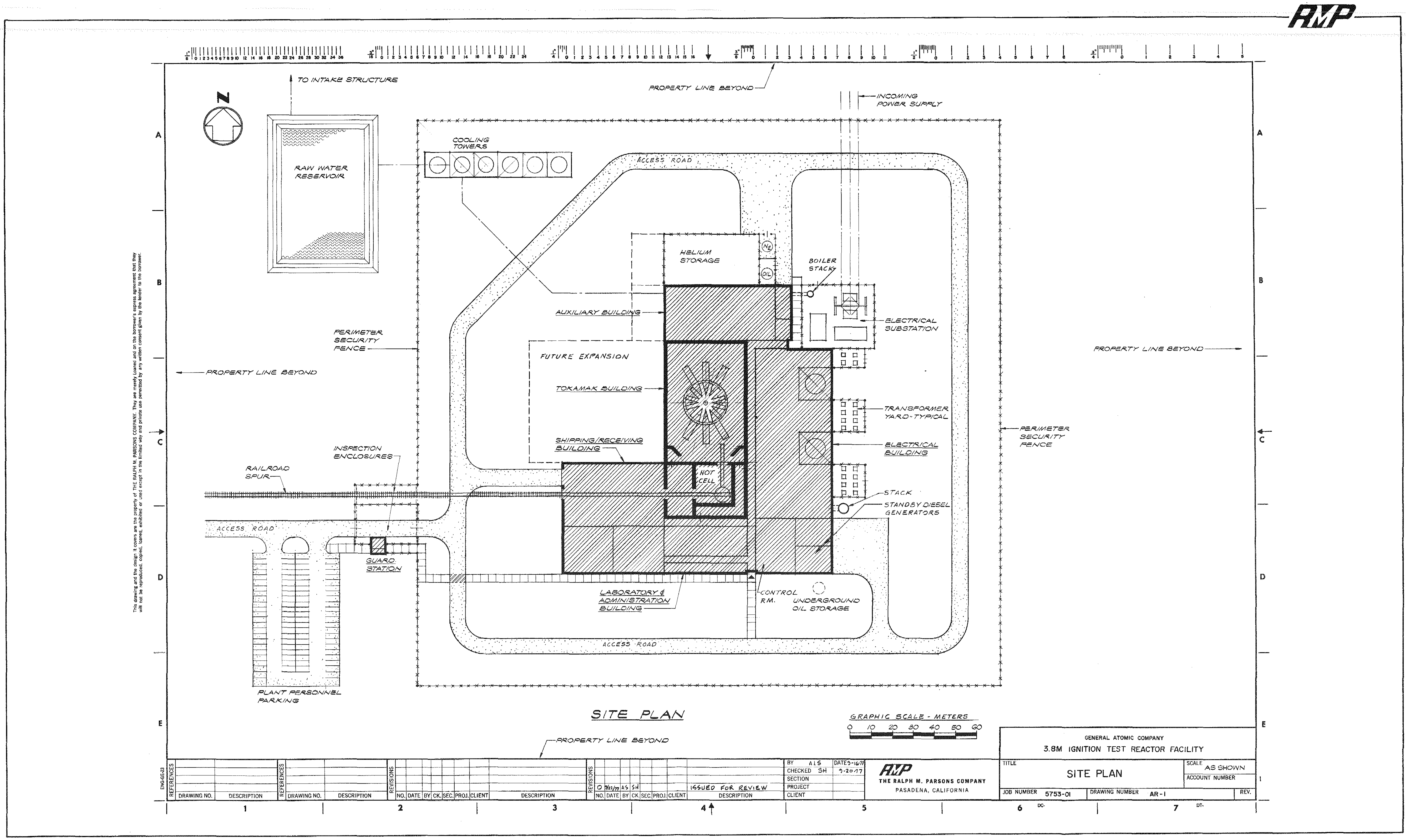
10.2.7.2. Conceptual Design Description

The shipping and receiving building will utilize the same construction as the auxiliary building; steel frame with open web joists, insulated metal siding walls and metal roof deck with insulation and built-up composition roofing. The shipping and receiving area receives a rail spur from off-site, and has a truck loading dock and a foreman's office. The elevator and a stairway giving access to the lower and upper levels of the facility are also located in this area. It measures 30m by 50m with a clear height of 7.5m. The storage area is 25m by 22m.

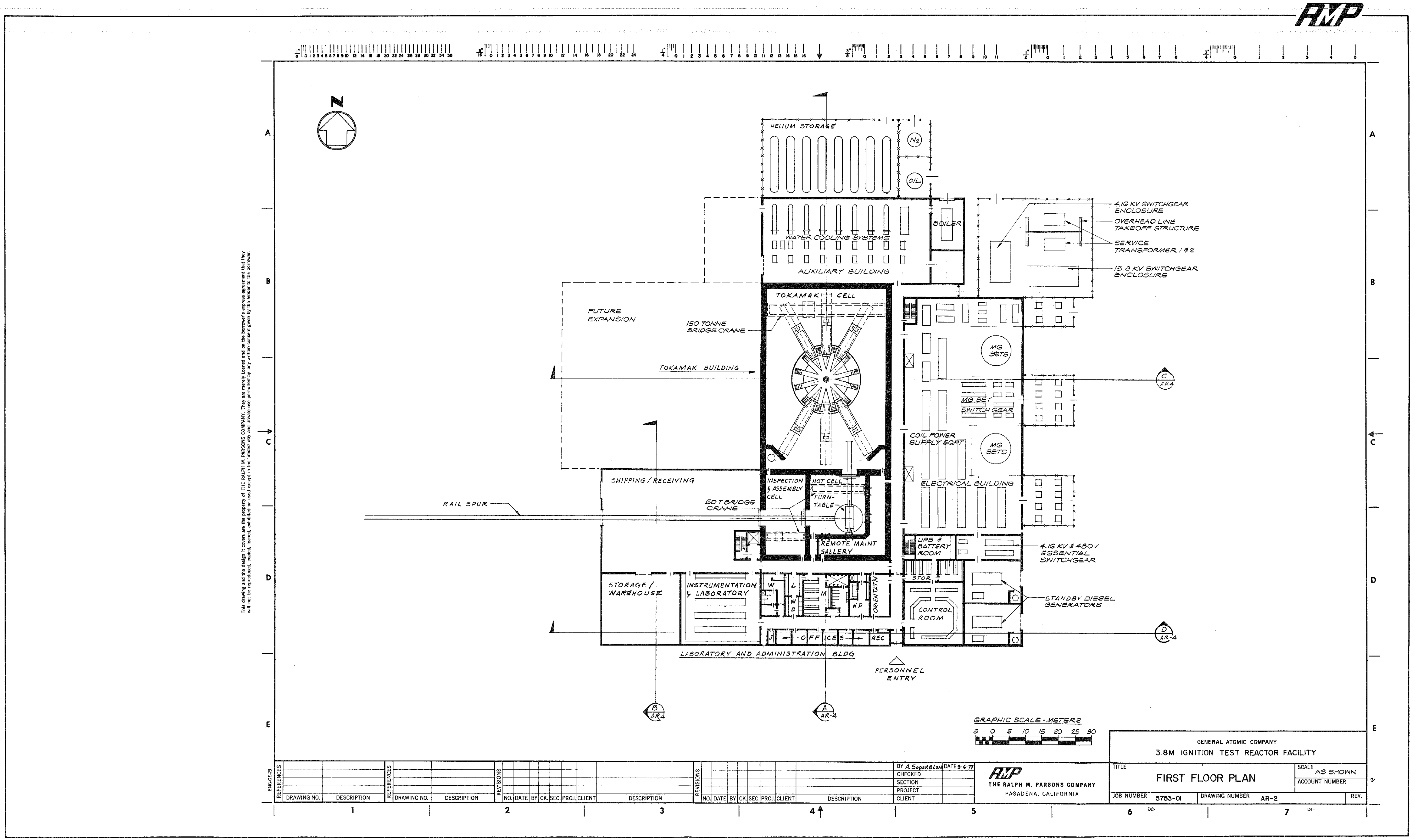
It is proposed that the western portion of the shipping-receiving and the storage area be built prior to the start of construction of the tokamak building. The enclosure could then be used for fabrication and warehousing during the construction phase.

10.2.7.3. Design Alternatives

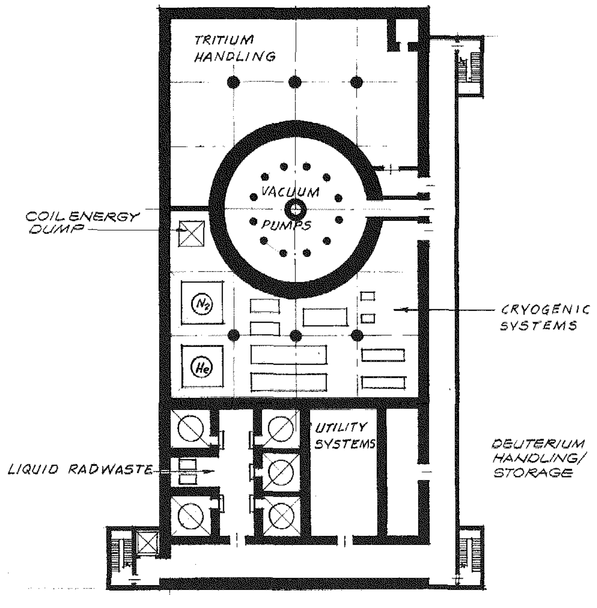
In the interest of economy, the shipping and receiving area has not been provided with a bridge crane. It is anticipated that the handling of material and equipment in this area be done with forklifts or hydrocranes. Further tradeoff studies should be investigated to see if the handling requirements in this area justify the installation of a bridge crane, or, at least, the provision for the future installation of one.



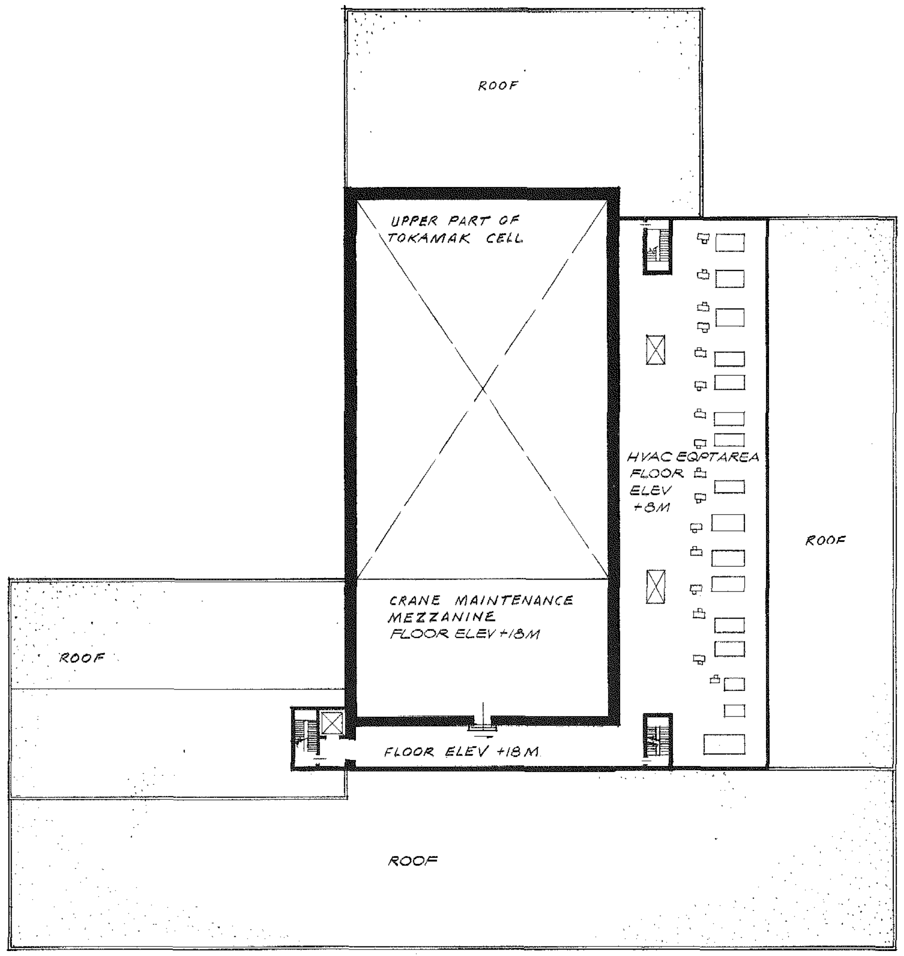
Drawing Ar-1.
3.8m Ignition Test Reactor Facility - Site Plan



Drawing AR-2.
3.8m Ignition Test Reactor Facility - First Floor Plan



LOWER LEVEL PLAN



PLAN OF UPPER LEVELS

GRAPHIC SCALE-METERS
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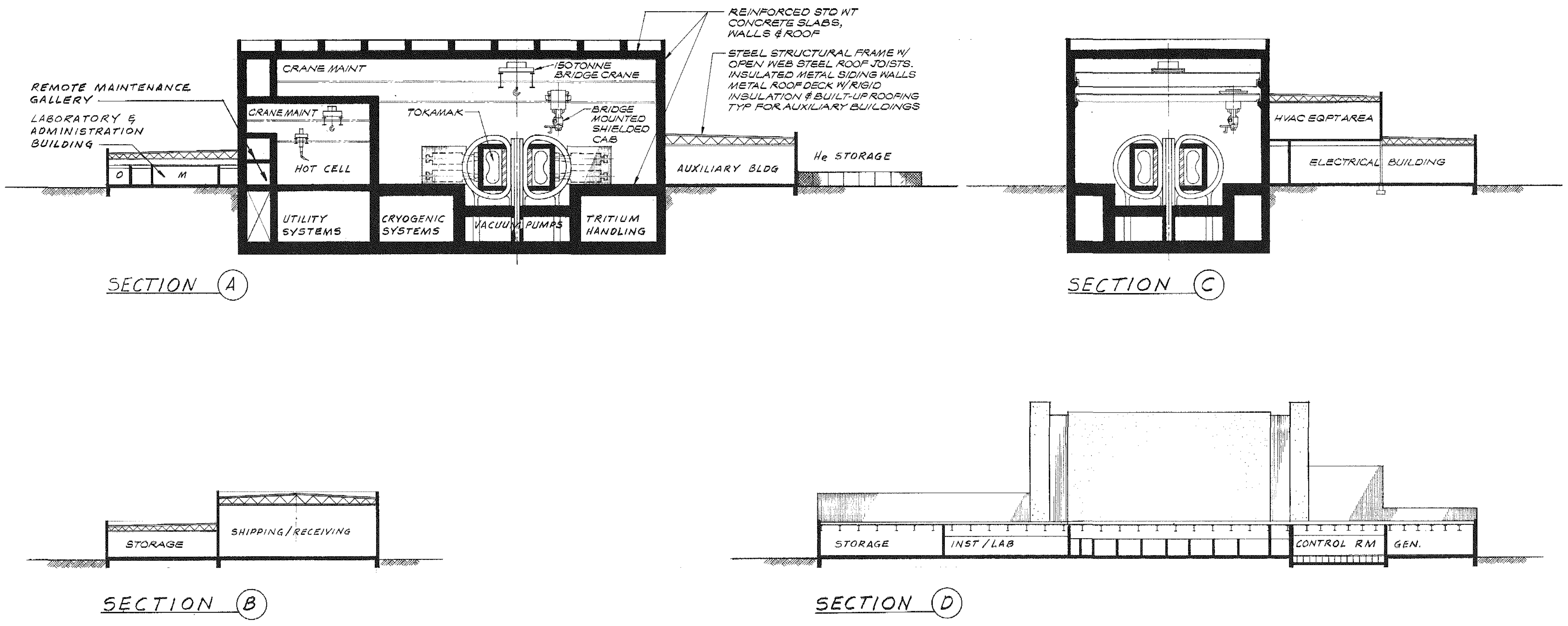
GENERAL ATOMIC COMPANY
3.8M IGNITION TEST REACTOR FACILITY
TITLE LOWER & UPPER LEVEL PLANS
SCALE AS SHOWN
ACCOUNT NUMBER
JOB NUMBER 5753-01
DRAWING NUMBER AR-3
REV.

Drawing AR-3.
3.8m Ignition Test Reactor Facility - Lower and Upper Levels Plans



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GRAPHIC SCALE-METERS
5 0 5 10 15 20 25 30

GENERAL ATOMIC COMPANY
3.8M IGNITION TEST REACTOR FACILITY

TITLE SECTIONS
SCALE AS SHOWN
ACCOUNT NUMBER
JOB NUMBER 5753-01
DRAWING NUMBER AR-4
REV.

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Drawing AR-4.
3.8m Ignition Test Reactor Facility - Sections

10.3. BALANCE OF PLANT SYSTEMS FOR 3.8 m ITR FACILITY

10.3.1. INTRODUCTION

This section includes the principal balance of plant (BOP) systems expected to be required for a 3.8m ignition test reactor (ITR). All of the work is at the preliminary conceptual scoping level.

Each subsection is outlined by first presenting the design considerations, then describing the design. This is followed by mention of design alternatives, and concludes with remarks concerning upgradable considerations. There are seven such subsections grouped, in each case, on the basis of similar use or similar type of service.

10.3.2. WATER SUPPLY AND COOLING SYSTEMS

The water supply and cooling systems, shown in Drawing ME-1, represent a major element in the BOP systems. It furnishes all the cooling-water makeup, potable-water, and fire-water requirements for the entire facility. A conventional cooling-tower system is used to satisfy the plant cooling-water requirements.

10.3.2.1. Design Considerations

Primary design considerations for the water supply and cooling systems are as follows:

1. Facility site is still to be selected, thus specifics on the availability of a water supply are not known. A plentiful water supply source such as river, lake etc., has been assumed to be a site requirement.

2. For the tokamak fusion system, deionized cooling water is required in order to avoid activation of contaminants and/or corrosion products, and conductance of electricity.

3. Separate cooling-water loops are provided for cooling the tokamak device components to reduce the possibility of tritium contact with a large volume of water.

4. Adequate water must be furnished for orderly shut down of the facility in case of interruption of usual services.

5. Adequate water must be furnished for plant fire protection.

10.3.2.2. Conceptual Design Description

Source of water for this TNS project is expected to be from a lake, or a river, or deep wells. Two source-water pumps are provided so that routine maintenance can be performed without interrupting normal supply. The source-water pumps discharge to a raw-water supply reservoir on the plant site. Raw-water pumps, drawing from the water-supply reservoir, are used to furnish cooling-tower makeup water, cooling-tower water-treatment water supply, makeup water deionization package water supply, electric power supply system and HVAC system cooling-water deoxygenation-package water supplies, and potable-water treatment-package water supply. Two raw-water pumps are furnished, again for routine maintenance reasons. The raw-water supply reservoir also serves as a fire-water supply source. Two fire-water pumps are used, one with an electric driver on the standby electric service bus and the other employing an independent diesel driver.

The main heat sink for the entire plant cooling-water requirements is a conventional cooling-tower system which includes a cooling-tower water-treatment package and three main cooling-water circulation pumps. Use of a three-pump arrangement in this case, i.e. two pumps operating with one 50% spare, is dictated mainly by economic factors regarding pump size. An added advantage is flexibility in operation. This main loop serves five closed-loop deionized cooling-water systems and furnishes direct cooling water to six major heat loads in the facility.

The five closed-loop deionized cooling-water systems are:

- Plasma vacuum chamber
- "F" coil
- Shield
- Neutral-beam injectors
- Cryogenic components and HVAC tritium-cleanup equipment

The water used in each of these loops is deionized to minimize activation of impurities in the water due to the neutron flux from the tokamak device. In each case, a small amount of the deionized water is processed through a loop bypass in order to continuously remove corrosion products in the loops as they occur. Since the ITR is not contemplated as a power-generation facility, the pumps used in each of these loops are not spared. Breaking the requirements into five separate loops was done with the thought of minimizing the amount of tritiated-water type of radwaste that would have to be handled in case of unanticipated technicalities, misoperation, or accident.

The cryogenic components and tritium cleanup, deionized-cooling-water loop include a standby refrigeration package which is serviced by the standby electric service bus. The objective in this case is to furnish uninterrupted cooling-water service for standby operation of tritium-cleanup facilities.

The six major heat loads using cooling water on a direct basis are:

- Electric power supply
- Heating, ventilation, and air conditioning (HVAC)
- Motor-generator room air cooling
- Standby power supply system

- Toroidal field coil dump
- Miscellaneous small services

Recognizing that some of these services will be required during standby conditions which may be void of cooling-tower capabilities, plans are to size the raw-water supply reservoir plus the cooling-tower basin so that an orderly shut-down of the plant can be accomplished by using cooling water on a once-through basis and then discharging it into the environment.

10.3.2.3. Design Alternatives

If site selection should reveal an abundant acceptable water supply, there is the possibility of eliminating the raw-water supply reservoir. If the water source is from a pressured main furnished by others, even source water pumps could be eliminated. Although it is not likely, nevertheless, there is the possibility of using an abundant water source on a once-through basis and eliminating the cooling tower with its large water basin and large main cooling-water recirculation pumps.

Another alternative to cooling requirements is the use, either in part or in full, of air cooling. A study delineating the maximum allowable temperatures for cooling services throughout the facility would serve to reveal the extent to which such a concept might have some economic value.

Within the tokamak device itself, GAC personnel have suggested combining deionized cooling-water services. This is the outcome of a very recent examination of these systems revealing that the possibility of tritium contamination is quite remote. Thus, combining a number of these service plus using a surge system to reduce cooling-tower requirements merits further consideration.

10.3.2.4. Upgradable Consideration

Considering the point that, as the ITR is upgraded, having an abundant and acceptable water supply is less likely, starting with a cooling-tower system as a heat sink for the 3.8m tokamak fusion device is advantageous. There is the possibility that add-on heat sink needs could take the form of air cooling as the system is upgraded. However, this would require designing the initial water cooling system at a higher cooling water outlet temperature to take advantage of air cooling. The advantage of this approach would be to reduce additional cooling tower capacity requirements for upgradable ITR.

Sizing and installation of cooling-water headers to allow for future expansion should be of primary consideration at the outset, and the allowance of sufficient plot areas for additional raw-water reserve, cooling-tower facilities, and other cooling-water services should be provided.

10.3.2.5. Equipment List

The reference drawing for this equipment list is Drawing ME-1, 3.8m Ignition Test Reactor Facility - Water Supply and Cooling Systems.

1. Heat Exchangers

Quantity	Description
1	WE-1, Cooling Tower, 180-MWt, 2590-ℓ/sec cooling-water rate, 41.6°C inlet, 29.4°C outlet, $762m^2$ area, 6 cells 10.7m each, standard materials. Located where practical on site. (Based on 24°C wet-bulb temperature 95% of the time.)
1	WE-2, Plasma Vacuum Cooling-Water Exchanger, 13.5-MWt, $1,380m^2$ area. Vertical stock of two horizontal shells in series. Each shell 1.2m dia by 7.3m long, 0.46m between shells. Tubes and channel stainless steel (SS), shells carbon steel (CS). Located in auxiliary building.

Quantity	Description
1	WE-3, "F" Coil Cooling-Water Exchanger, 40.1 MWt, 4,120m^2 area. Two vertical stacks in parallel. Each stack consists of two horizontal shells in series, each shell 1.2m dia by 7.3m long, 0.46m between shells. Tubes and channel SS, shells CS. Located in auxiliary building.
1	WE-4, Shield Cooling-Water Exchanger, 25.2-MWt, 2,570m^2 area. Remaining details as outlined for WE-3 above.
1	WE-5, Cryogenic Components and Tritium-Cleanup Cooling-Water Exchanger, 7.0-MWt, 2,220m^2 area. Vertical stack of three horizontal shells in series. Each shell 1.3m dia by 7.3m long, 0.51m between shells. Tubes and channel SS, shells, CS. Located in auxiliary building.
1	WE-6, Neutral-Beam Cooling-Water Exchanger, 18.2-MWt, 1,850m^2 area. Two vertical stacks in parallel. Each stack consists of two horizontal shells in series. Each shell 1.1m dia by 7.3m long, 0.41m between shells. Tubes and channel SS, shells, CS. Located in auxiliary building.

2. Pumps

Quantity	Description
1	Wp-1, Source-Water Pump No. 1, 44.2-ℓ/sec, 28.2m total dynamic head (TDH), 37.2-kW electric-driven, vertical submersible centrifugal, CS. Located at source of water supply.

Quantity	Description
1	WP-2, Source-Water Pump No. 2, identical spare for WP-1.
1	WP-3, Fire-Water Pump No. 1, 158-ℓ/sec, 88.0m TDH, 374-kW electric-driven, vertical submersible centrifugal, CS. Located at water supply pond.
1	WP-4, Fire-Water Pump No. 2, identical to WP-3, except 560-kW diesel-driven.
1	WP-5, Raw-Water Pump No. 1, 37.9-ℓ/sec, 35.2m TDH, 37.3-kW electric-driven, vertical submersible centrifugal, CS. Located at water supply pond.
1	WP-6, Raw-Water Pump No. 2, identical spare for WP-5.
1	WP-7, Main Cooling-Water Circulation Pump No. 1, 884-ℓ/sec, 42.2m TDH, 560-kW electric-driven, vertical submersible centrifugal, CS. Located at water supply pond.
1	WP-8, Main Cooling-Water Circulation Pump No. 2, identical to WP-7.
1	WP-9, Plasma Vacuum Chamber Cooling-Water Circulation Pump, 75.7-ℓ/sec, 35.2m TDH, 67.1-kW electric-driven, horizontal centrifugal, SS. Located in auxiliary building.
1	WP-10, "F" Coils Cooling-Water Circulation Pump, 221-ℓ/sec, 35.2m TDH, 187-kW electric-driven,

Quantity	Description
	horizontal centrifugal, SS. Located in auxiliary building.
1	WP-11, Shield Cooling-Water Circulation Pump, 133-ℓ/sec, 35.2m TDH, 131-kW electric-driven, horizontal centrifugal, SS. Located in auxiliary building.
1	WP-12, Cryogenic Components and Tritium-Cleanup Cooling-Water Circulation Pump, 114-ℓ/sec, 35.2m TDH, 112-kW electric-driven, horizontal centrifugal, SS. Located in auxiliary building.
1	WP-13, Main Cooling-Water Circulation Pump No. 3, identical spare for WP-7 and WP-8.
1	WP-14, Neutral-Beam Cooling-Water Circulation Pump, 101-ℓ/sec, 35.2m TDH, 74.6-kW electric-driven, horizontal centrifugal, SS. Located in auxiliary building.

3. Package Units

Quantity	Description
1	WX-1, Cooling-Tower Water-Treatment Package, two 380-ℓ tanks; two 1.26 ℓ/sec, 35.2m TDH, 0.75-kW electric-driven piston-type pumps. All material SS. Located in 3.7m by 6.1m simple, heated shed near cooling tower.
1	WX-2, Makeup Water Deionization Package, 6.31-ℓ/sec size. All material SS. Skid-mounted, 2.4m by 4.8m by 3.0m high. Located in auxiliary building.

Quantity	Description
1	WX-3, Plasma VAcuum Chamber Cooling-Water Polishing Package, 1.26-ℓ/sec size. All materials SS. Includes inlet filter, deoxidation vessel, mixed-bed type deionization vessel, and outlet filter. Skid-mounted, 1.2m by 2.4m by 2.4m high. Located in auxiliary building.
1	WX-4, "F" Coil Cooling-Water Polishing Package, use two units in parallel as described for WX-3 above to provide 2.52 ℓ/sec size.
1	WX-5 Shield Cooling-Water Polishing Package, identical to WX-3.
1	WX-6, Cryogenic Components and Tritium-Cleanup Cooling-Water Polishing Package, identical to WX-3.
1	WX-7, Cryogenic Components and Tritium Cleanup Standby Refrigeration Package, 0.352-MWt size, 74.6-kW electric-driven compressors, 11.2-kW electric-driven foil. Skid-mounted chilling unit, 2.4m by 7.6m by 2.4m high; located in cooling-water service room. Air interchanger 4.6m by 4.6m by 0.91m deep; located on building roof.
1	WX-8, Electric Power Conversion System Cooling-Water Deoxygenation Package, one 380-ℓ tank; one 1.26-ℓ/sec 35.2m head, 0.75-kW electric-driven horizontal centrifugal pump, and one small 0.37 kW electric-driven piston-type pump. All material CS. Located in auxiliary building.

Quantity	Description
1	WX-9, HVAC System Cooling-Water Deoxygenation Package, identical to WX-8.
1	WX-10, Potable-Water Treatment Package, 3.16-ℓ/sec rating, filtration and chlorination units. All standard materials. Skid-mounted, 1.8m by 2.4m by 2.4m high. Located near WX-2 in auxiliary building.
1	WX-11, Sewage Treatment Package, 3.16-ℓ/sec rating, standard unit. All standard materials. Located in 3.7m by 6.1m simple, heated shed where convenient on plant site.
1	WX-12, Neutral-Beam Cooling-Water Polishing Package, identical to WX-3.

10.3.3. CRYOGENIC COOLING SYSTEMS

The cryogenic cooling systems, shown on Drawing ME-2, represent a considerable portion of the BOP systems. They furnish all the extremely low temperature cooling requirements for the tokamak fusion device. There are two services; liquefied helium and liquefied nitrogen. The helium services include gaseous helium storage, helium liquefaction, and liquefied helium storage Dewar. The nitrogen services include a liquefied nitrogen storage package, nitrogen liquefaction, and liquefied nitrogen storage Dewar. Pressurized nitrogen gas service is also furnished.

10.3.3.1. Design Considerations

Primary design considerations for the liquefied helium service include cryogenic cooling requirements for:

- Neutral-beam injectors
- Plasma vacuum chamber cryosorption pumps

- Fuel preparation
- Detritiation
- Cooling for superconducting "B" coils
- Cooling for superconducting "E" coils and their electrical leads

Primary design considerations for the liquefied nitrogen service include cryogenic cooling requirements for:

- Neutral-beam injectors
- Plasma vacuum chamber cryosorption pumps
- Fuel preparation
- Detritiation
- Diagnostics

A final major design consideration taken into account was the need to conserve the helium requirements of the facility.

10.3.3.2. Conceptual Design Description

The primary elements of the helium liquefaction system include helium storage vessels, a helium liquefaction package with compression systems, and a liquefied helium storage Dewar. The storage system is essentially a number of vessels designed to receive and store the helium inventory of the facility during those times when it is not in operation. The compression facilities which are included in the helium liquefaction package will be used for the pressurization work. The helium liquefaction package essentially consists of a series of exchangers and expanders enclosed in a double-walled Dewar type housing. It is furnished as a package unit from a manufacturer highly experienced in the design and fabrication of specialized cryogenic facilities. The compression service which is used in conjunction with this liquefaction package is divided into two 50% services in order to provide reliability to the entire system, since one of these compressors will always be required for helium storage operations. The function of the liquefied helium Dewar is to adequately meet the immediate demands of the various facility operational modes or, in other words, smooth out system operations.

The primary elements of the nitrogen liquefaction system include liquefied nitrogen storage, a nitrogen liquefaction package including compression systems, and a liquefied nitrogen storage Dewar and pumps. The liquefied nitrogen storage routinely furnishes gaseous nitrogen on a makeup basis to the nitrogen liquefaction package to replace the nitrogen furnished on a non-recycle basis by the compression system in this latter package. When this nitrogen usage falls below the minimum boiloff rate of the storage package and the storage Dewar is full, the excess boiloff is vented to the atmosphere. The nitrogen liquefaction package and storage Dewar are similar to the helium liquefaction package and storage Dewar described above, except that there is no need for split compression service, and liquefied nitrogen output is distributed to the services via pump.

10.3.3.3. Design Alternatives

Design alternatives requiring further study are:

- Combining helium and nitrogen liquefaction systems into a single package
- Combining helium and nitrogen compression services into a single system

10.3.3.4. Upgradable Considerations

As this ITR is upgraded, the primary consideration is space and power requirements for installation of additional cryogenic facilities. Additionally, there is the probability that, as liquefied helium service requirements increase, a point will be reached when helium storage needs will increase to such an extent that, in place of gaseous helium storage, liquefied helium storage with its attendant standby refrigeration system will become economically justified. Such storage facilities have an added advantage in that the immediate availability of the helium in liquefied form may permit accelerated cooldown during startup operations. Operational experience of this nature would be very valuable as a selling point when the time approaches to start a project designed to deliver power into a utility power network.

10.3.3.5. Equipment List

The reference drawing for this equipment list is Drawing ME-2, 3.8m Ignition Test Reactor Facility - Cryogenic Cooling Systems.

Quantity	Description
1	CV-1, Helium Storage Vessels, 8 vessels on a common header. Each vessel 8-ft dia by 45-ft T-T, 2:1 semi-elliptical heads, design pressure 275 psig, design temperature 120°F, materials CS. Located outdoors.
1	CV-2, Liquefied Helium Storage Dewar, 2,000-gal capacity. Space envelope 8-ft dia by 18-ft long. Located near services.

Quantity	Description
1	CV-3, Liquefied Nitrogen Storage Dewar, 2,000-gal capacity. Space envelope 8-ft dia by 18-ft long. Located near services.

2. Pumps

Quantity	Description
1	CP-1, Liquefied Nitrogen Pump No. 1, 50-gpm, 60-psi head, 2-hp electric-driven, vertical centrifugal, 316 SS. Located near and below CV-3.
1	CP-2, Liquefied Nitrogen Pump No. 2, identical spare for CP-1.

3. Package Units

Quantity	Description
1	CX-1, Liquefied Nitrogen Storage Package, 2,000-gal capacity. Space envelope - Dewar, 8-ft dia by 18-ft long; delivery pad with vaporizer 20 ft by 20 ft, fenced; driveway. Located outside building near CV-3.
1	CX-2, Helium Liquefaction Package, 3,000- /hr capacity. Compressors included. Vertical cold box 8 ft dia by 36 ft high. Two reciprocating multistage compression systems with intercoolers and aftercoolers, 1,500-hp electric drivers, space requirement 8 ft by 30 ft by 8 ft high. Allow space below cold box for dropping shell. Entire package to be located in basement of main building.

Quantity	Description
1	CX-3, Nitrogen Liquefaction Package, 1,600 ℓ/hr capacity. Compressors included. Vertical cold box 8-ft dia by 36-ft high. Two reciprocating multistage compression systems with intercoolers and aftercoolers, 150-hp electric driven, space requirement 8-ft by 10-ft by 6-ft high. Allow space below cold box for dropping shell. Entire package to be located in basement of main building.

10.3.4. HEATING, VENTILATION, AND AIR CONDITIONING (HVAC) SYSTEMS

The ignition test reactor facility will be provided with a controlled environment designed to ensure negligible release of tritium to the atmosphere under all operating conditions. To accomplish this, all areas, including the tokamak cell itself, are maintained under a slight negative pressure relative to the surrounding environment. Additionally, an air-cleanup unit is employed in the tokamak cell to maintain a low level of atmospheric particulates in the cell during normal operation. The design is limited to normal plant operations and does not include tritium-handling and -cleanup systems which are being studied by Argonne National Laboratory. A composite HVAC diagram, shown on Drawing ME-3, describes the systems.

10.3.4.1. Design Considerations

Primary design considerations for the HVAC systems are:

1. To provide a conventional HVAC system for the tokamak cell, maintaining slightly subatmospheric pressure.

2. To provide sufficient recirculation of air in the tokamak cell to continuously remove 0.3-MW of heat and minimize airborne particulate.

3. In case of abnormal operations, to prevent release of tritium from the facility by directing any high-level exhaust air through tritium cleanup systems.

10.3.4.2. Conceptual Design Description

Drawing ME-3 shows the general arrangement of HVAC components for normal plant operations. It is comprised of:

- Outdoor air-purge supply and exhaust systems
- Tokamak building pressure-control system
- Tokamak building air-cleanup system
- Tokamak building recirculating-air system
- Auxiliary systems

Under normal operating conditions, all HVAC systems draw in outdoor air through filtration and tempering facilities and exhaust this air through high-efficiency particulate air (HEPA) filters back to the environment.

For the tokamak cell, a pressure control system is used to keep the cell at a slight negative pressure with respect to the environment. A similar pressure-control system is used to serve the inspection and assembly cell, the maintenance gallery, and the hot cell. In both cases the objective is to assure that all exhaust-air passes through a roughing filter and then two stages of HEPA filters before returning to the environment. In addition, instrumentation is provided (1) to detect any above-normal concentration of tritium in the exhaust air, (2) to lock out the normal inlet--and exhaust air-routes, and (3) to shift all exhaust-air volume required for maintaining cell negative pressure through a tritium-cleanup system which is being studied by Argonne National Laboratory.

The tokamak cell also contains an air-cleanup unit which serves to continuously collect particulates from the cell atmosphere during normal operation. This system is designed to maintain a very low level of particulate in the tokamak cell atmosphere since, during the fusion burn cycle, this particulate might possibly become activated. A set of four recirculating-air coolers augments the air-cleanup unit. These coolers serve to continuously remove the 0.3-MW of heat the fusion device is expected to release during normal operations.

Air purge systems, using outdoor air on a once-through basis, are also used in the following areas under normal operation conditions:

- Liquid radwaste and tokamak vacuum pump areas
- Tritium-handling area with process enclosures

As in the tokamak cell area, the liquid radwaste and tokamak vacuum pump areas and tritium-handling area with process enclosures are equipped with instrumentation to detect any above-normal concentration of tritium in the exhaust air, and designed to lock out the normal inlet- and exhaust-air routes and shift all exhaust air volume required for maintaining area negative pressure through a tritium cleanup system which is also being studied by Argonne National Laboratory. In addition, for the process enclosures in the tritium-handling area an exhaust system is provided to maintain these enclosures at a pressure slightly negative to the general tritium-handling working area. This is a routine precautionary measure used whenever materials such as tritium are handled.

In the cryogenics area, the control room, and laboratory and administration building, standard air-conditioning units employing partial recirculation of air and unfiltered exhaust are utilized.

Throughout the plant, such as in the inspection and assembly cell, the maintenance gallery, and the control room, internal recirculating air-conditioning units are used for personal comfort.

10.3.4.3. Design Alternatives

As the structures for this tokamak facility become more specific and the limits for tritium contamination become better defined, a number of economies may surface. For example, the number of purge air inlet and exhaust systems can be reduced.

Details on the capabilities of the tritium-handling and -cleanup system tems will reflect on the design parameters required for the normal HVAC systems. This is especially significant for the tokamak cell and may materially affect the need for and/or size of the recirculating-air coolers and the air-cleanup unit.

10.3.4.4. Upgradable Considerations

Heat load and air-cleanup requirements in the tokamak cell are the key points which must be considered in upgrading the ITR. In this respect, employing recirculating-air coolers and an air cleanup unit in an initial design may be advantageous from the point of view of operating experience alone. The value of such experience should be taken into account in making any cost tradeoff studies on this subject.

10.3.4.5. Equipment List

The reference drawing for this equipment list is Drawing ME-3, 3.8m Ignition Test Reactor Facility - Composite HVAC Diagram.

1. Tokamak Cell

a. Outdoor Air Purge Supply

Quantity	Description
2	Fan type : Centrifugal
	Fan capacity : 2.83m^3/sec
	Fan motor : 7.5 kW
	Cooling-water coil: 1.1m^2
	Heating-water coil: 0.84m^2
	Prefilter : Low efficiency
	Final Filter : High efficiency

b. Purge Air Exhaust

Quantity	Description
2	Fan type : Centrifugal
	Fan capacity : 2.83m^3/sec
	Fan motor : 11.2 kW
	Prefilter : Low efficiency
	Intermediate filter: High efficiency
	Final filter : 2-stage HEPA

c. Pressure Control

Quantity	Description	
2	Fan type	Centrifugal W/VIV
	Fan capacity	$2.36m^3$/sec
	Fan motor	15 kW
	Filter train	1 required
	Prefilter	Low efficiency
	Intermediate filter	High efficiency
	Final filter	2-stage HEPA

d. Recirculating Air Coolers

Quantity	Description	
4	Fan type	Centrifugal
	Fan capacity	$5.67m^3$/sec
	Fan motor	23 kW
	Cooling-water coil	$2.2m^2$
	Filter	Low Efficiency

e. Air Cleanup Unit

Quantity	Description	
1	Fan type	Centrifugal
	Fan capacity	$4.25m^3$/sec
	Fan motor	15 kW
	Prefilter	Low efficiency
	Intermediate filter	High efficiency
	Final filter	2-stage HEPA

2. Tritium-Handling Area Air System

a. Outdoor Air System

Quantity	Description
1	Fan type : Centrifugal
	Fan capacity : $4.72m^3$/sec
	Fan Motor : 11.2 kW
	Prefilter : Low efficiency
	Final filter : High efficiency
	Cooling-water coil: $1.9m^2$
	Heating-water coil: $1.6m^2$

b. General Supply Air System

Quantity	Description
2	Fan type : Centrifugal
	Fan capacity : $11.8m^3$/sec
	Fan motor : 37 kW
	Prefilter : High efficiency
	Final filter : 1-stage HEPA
	Water-cooling coil: $4.7m^2$

c. Return Air System

Quantity	Description
2	Fan type : Centrifugal
	Fan capacity : $9.44m^3$/sec
	Fan motor : 37 kW
	Refilter : Low efficiency
	Intermediate filter: High efficiency
	Final filter : 1-stage HEPA

d. Exhaust System

Quantity	Description
2	Fan type : Centrifugal W/VIV (Variable inlet vanes)
	Fan capacity : $4.72m^3$/sec
	Fan motor : 19 kW
	Prefilter : Low efficiency
	Intermediate filter: High efficiency
	Final filter : 2-stage HEPA

3. Liquid Radwaste and Vacuum Pump Area Air System

a. Supply Air System

Quantity	Description
2	Fan type : Centrifugal W/VIV
	Fan capacity : $9.44m^3$/sec
	Fan motor : 37 kW
	Plenum section : 1 required
	Prefilter : Low efficiency
	Final filter : High efficiency
	Cooling-water coil: $3.7m^2$
	Heating-water coil with integral pace and bypass : $3.7m^2$

b. Exhaust Air System

Quantity	Description
2	Fan type : Centrifugal W/VIV
	Fan capacity : 9.44m^3/sec
	Fan motor : 37 kW
	Filter train : 1
	Prefilter : Low efficiency
	Intermediate filter: High efficiency
	Final filter : 2-stage HEPA

4. Cryogenic Area Air Cooling System

Quantity	Description
1	Fan type : Centrifugal
	Fan capacity : 7.8m^3/sec
	Fan motor : 23 kW
	Prefilter : Low efficiency
	Final filter : High efficiency
	Cooling-water coil : 2.8m^2

5. Hot Cell/Assembly and Inspection Cell Air System

a. Recirculating Air Unit

Quantity	Description
2	Fan type : Centrifugal
	Fan capacity : 4.72m^3/sec
	Fan motor : 11.2 kW
	Filter : Low efficiency
	Cooling-water coil : 1.9m^2

b. Outdoor Air Supply System

Quantity	Description	
1	Fan type	: Centrifugal
	Fan capacity	: 1.39m^3/sec
	Fan motor	: 3.7 kW
	Prefilter	: Low efficiency
	Final filter	: High efficiency
	Cooling-water coil	: 0.75m^2
	Electric heating	: 65 kW

c. Exhaust Air System

Quantity	Description	
1	Fan type	: Centrifugal W/VIV
	Fan capacity	: 2.36m^3/sec
	Fan motor	: 7.5 kW
	Prefilter	: Low efficiency
	Intermediate filter	: High efficiency
	Final filter	: 2-stage HEPA

10.3.5. RADWASTE SYSTEMS

Radwaste is not expected to be a large part of the BOP systems because no fission product is produced in this facility. The major radwastes generated are tritium-contaminated substances, waste from hot-cell operations, hot change, shower, and neutron-activated equipment. The radwaste systems are shown on Drawing ME-4. Major items in the system are five tanks, two pumps, and a small cement-mixing-type solidification system. The tritium-handling and -cleanup systems are being studied by others.

10.3.5.1. Design Considerations

The principal design consideration for the radwaste system is the handling of tritiated water that might arise from problems encountered in one of the deionized cooling-water loops near to the tokamak device itself due to misoperation, accident, or other unanticipated event. Gaseous radwaste from the fuel-handling facility is expected to be handled by a separate tritium cleanup system. Likewise, tritium release, which might possibly occur under abnormal conditions within the tokamak building will be handled by the building tritium-cleanup system. Handling of solid wastes will be done in the hot cell using the remote handling facilities related thereto plus a proposed remotely operated cement-mixing machine.

10.3.5.2. Conceptual Design Descriptions

A total of five large cone-bottom tanks are provided for radwaste in shielded rooms in the basement of the tokamak building. The first of these tanks is used for initial receipt and checking of material from sumps in the tokamak, hot-cell, hot change, shower, tritium-handling facility and other areas. All tanks are vertical with cone-bottom to minimize retention of entrained solids. The next tank is used for storage of high-level tritium waste, recirculating same via a pump followed by filter and deionizer cartridges, and retaining such high-level waste for disposal via the solidification system if the cartridges do not lower the liquid radwaste to an acceptable level for routine discharge. The last three tanks are reserved for low-level tritium waste service and include similar pumped recirculation facilities with filter and deionizer. A second use for this latter system is to accept any overflow that might occur from the high-level tritium waste system.

10.3.5.3. Design Alternatives

If the site selection includes an existing radwaste system which has spare capacity and can accept tritiated water, then a radwaste facility for this facility would not be needed. However, a properly encased radwaste pipeline to the existing system would have to be included in the ITR plant cost.

10.3.5.4. Upgradable Considerations

Upgrading the ITR is not expected to have any impact on the radwaste systems other than possible increase in use. In fact, as operating experience accumulates it is expected that design changes will be made in the upgraded systems to reduce radwaste and consequent use of the radwaste facilities.

10.3.5.5. Equipment List

The reference drawing for this equipment list is Drawing ME-4, 3.8m Ignition Test Reactor Facility - Radwaste Systems.

1. Tanks

Quantity	Description
1	RT-1, High-Level Tritium Radwaste Tank No. 1, 37,900-ℓ capacity, 3.7m diameter by 3.7m straight side with 30° conical bottom. Design pressure nominal, design temperature ambient, materials SS. Located in basement of tokamak building.
1	RT-2, High-Level Tritium Radwaste Tank No. 2, identical to RT-1 above.
1	RT-3, Low-Level Tritium Radwaste Tank No. 1, identical to RT-1 above.
1	RT-4, Low-Level Tritium Radwaste Tank No. 2, identical to RT-1 above.

Quantity	Description
1	RT-5, Low-Level Tritium Radwaste Tank No. 3, identical to RT-1 above.

2. Pumps

Quantity	Description
1	RP-1, High-Level Tritium Radwaste Pump, 3.2-ℓ/sec, 35.2m TDH, 3.73-kW electric-driven, horizontal centrifugal, materials SS. Located near and below radwaste tanks.
1	RP-2, Low-Level Tritium Radwaste Pump, identical to RP-1 above.

3. Package Units

Quantity	Description
1	RX-1, Solidification System, custom-built device, materials SS. Includes drum-cover-mounted geared cement-mixing device with armored flexible tritium radwaste line, plus framework and facilities to raise and lower same electrically. Drum size to be handled 208 ℓ.

10.3.6. PLANT UTILITY SYSTEMS

Plant utility systems are not expected to constitute a major portion of the BOP systems for this facility, nor to be of any unusual nature. Facilities required include steam, compressed air, vacuum, argon, and hydrogen.

10.3.6.1. Design Considerations

The major use for steam is for the heating, ventilating and air conditioning (HVAC) system heating load. Both plant air and instrument air are provided as routine plant needs. Also provided are vacuum, argon, and hydrogen services.

10.3.6.2. Conceptual Design Description

The steam requirement is satisfied by a package boiler as shown on Drawing AR-2 and defined in the HVAC requirements. Conventional plant equipment is used to provide the plant air and the dry oil-free instrument air needs. Since little is known about the vacuum requirements, something similar to the compressed air system is assumed as a temporary guideline. For the present, both the argon and the hydrogen service are assumed to include high-pressure cylinders for supply via a laboratory-type pressure-reducing regulator followed by a small (13-mm) diameter pipe distribution system.

10.3.6.3. Design Alternatives

Design alternatives are site dependent. There is the possibility that the selected site will have excess steam and/or compressed air facilities available. It is doubtful that vacuum, argon, and hydrogen services will be available regardless of plant site selection.

10.3.6.4. Upgradable Considerations

The major consideration now, to provide facilities that may be upgraded later, is to furnished oversize headers for these services.

10.3.7. REMOTE-HANDLING SYSTEMS

Parsons' scope in the area of remote-handling systems includes only some of the facilities to move the major components of the tokamak device.

Since this is a minimum cost facility, no cranes are provided for maintenance operations in the auxiliary building, shipping and receiving building, or in the electrical equipment building. In the tokamak building, the principal items involved are shield blocks, coil support structure, and the neutral-beam injectors. The principal pieces of equipment to be furnished in the BOP for servicing such items include one 150-tonne bridge crane and two 50-tonne bridge cranes, rails for a shielded cab on a 50-tonne bridge in the tokamak cell, rails for a bridge-mounted manipulator in the hot cell, and rails for a dolly in the floors of the inspection and assembly cell, hot cell, and tokamak cell. Other items of equipment required for remote maintenance are described by Amco Division of Aerojet-General in Volume VII, and include the manned, shielded cab on a 50-tonne bridge in the tokamak cell, a powered dolly used for transporting equipment between the tokamak cell, hot cell, inspection and assembly cell, and the shipping and receiving building. Also included in Amco's scope are master-slave manipulators used in conjunction with shielding/viewing windows, and a turntable for the powered dolly, all in the hot cell.

10.3.7.1. Design Considerations

Within the tokamak cell itself, the major design consideration is the capability to remove and transport one or more of the twelve 40-tonne neutral-beam-injector assemblies, complete with shielded enclosure, to a point in the cell where they can be easily transported to the hot cell for maintenance. Other considerations include the capability of handling items weighing up to 50 tonnes from the entrance to the inspection and assembly cell through the hot cell to the tokamak cell.

10.3.7.2. Conceptual Design Description

The above design considerations within the tokamak cell are satisfied by use of a 150-tonne bridge crane which is capable of lifting one or more of the neutral-beam-injector assemblies from any location in the cell and transporting them to the entrance of the hot cell. Lifting requirements in the hot cell and in the inspection and assembly cell are met by use of a 50-tonne bridge crane in each of these areas.

A rail system utilizing a dolly, for transport of tokamak parts weighing up to 100 tonnes, augments the cranes described above. This rail system extends from outside the inspection and assembly cell, where incoming items may be transferred from railroad cars onto the dolly, through the hot cell to the tokamak cell. In the hot cell, the rail system intercepts a turntable, provided by others, which may be used for rotating tokamak parts either for remote maintenance or for transport between the hot cell and the tokamak cell.

10.3.7.3. Design Alternatives

There are three design alternatives within Parsons scope of work. First, additional remote-handling studies may reveal that the tokamak cell main bridge crane may be reduced in capacity from its present 150 tonnes. Second, use of air-lift-type pallets instead of the dolly and floor rails presently suggested may be acceptable and less expensive. Last, it may be found of value to add bridge cranes for maintenance service in the auxiliary building, shipping and receiving building, and in the electrical equipment building.

10.3.7.4. Upgradable Considerations

The key point involved in considering upgradable facilities is whether or not such a step would require a bridge crane in the tokamak cell larger than the currently proposed 150-tonne capacity. In this respect, the need to lift and transport a large piece of equipment, such as a single-piece top structure on an upgradable tokamak machine, should be carefully analyzed.

10.3.7.5. Equipment List

1.0 Cranes

Quantity	Description
1	Bridge crane, tokamak cell, 150-tonne capacity
1	Bridge crane, hot cell, 50-tonne capacity
1	Bridge crane, inspection and assembly cell, 50-tonne capacity

10.3.8. ELECTRICAL POWER SUPPLY AND DISTRIBUTION

The purpose of the electrical power supply and distribution is to supply reliable electrical power continuously for the TNS tokamak device and for all its electrical auxiliaries during normal, abnormal, and standby operating conditions.

The energy requirements of the ITR will be satisfied by transmitting electrical power from a public utility system having a transmission voltage of 138 kV. The electrical power distribution system receives power at 138 kV, transforms it to 13.8 kV and 4.16 kV, and distributes it to equipment. The system will be designed to accommodate the load schedule of the ITR. Energy-storage devices will be used for pulsed-type loads to ease the peak demands and load fluctuations on the utility system.

The electrical power supply and distribution system is shown on the single-line diagram, Drawing EE-1.

10.3.8.1. Design Considerations

The functions of the electrical power supply and distribution system are:

- To provide reliable electrical power to the tokamak device and to its auxiliaries from the utility system.

- To provide two separate standby on-site generators capable of furnishing standby power to essential equipment.

- To provide power to the energy-storage equipment of the pulsed-type loads of the tokamak device.

The system design is based on the following criteria:

1. One full-capacity 138-kV transmission line will be provided.

2. One full-capacity 13.8-kV and one full-capacity 4.16-kV distribution transformer will be provided.

3. The on-site standby ac electrical power source will consist of two (2) full-capacity diesel-driven generators, each sized to supply adequate power to the tokamak device essential auxiliary loads during intervals of loss of power from the utility supply.

4. The major equipment such as transformers and switchgear, etc., will be utility-grade, and standard voltages and ratings will be used to meet schedule and cost objectives.

5. Power supply to essential circuits, to safety-related instrumentation and to control functions will have the highest reliability and service continuity and the design for these will be based on the single-failure criteria.

6. The system design will incorporate provisions to ensure safety of personnel and protection of equipment from damage during all operating conditions.

7. The 3-phase short circuit capacity of the electrical system will be sufficient so that the largest motor-driven equipment can be started directly across the line.

10.3.8.2. Conceptual Design Description

The electrical power supply and distribution system is shown on the single-line diagram, Drawing EE-1, and consists of the following major electrical equipment.

- 138-kV switchyard
- Two station service power transformers
- One 15-kV switchgear assembly in outdoor enclosure
- Two 5-kV normal switchgear assemblies No. 1 and 2 in outdoor enclosure
- Two 480-V normal switchgear assemblies No. 1 and 2 with two 1500-kVA 4.16/0.48-kV transformers
- Two 5-kV essential switchgear assemblies No. 1E and 2E
- Two 4.16-kV standby diesel-driven generators
- Two 480-V essential switchgear assemblies No. 1E and 2E, each with a 4.16 - 0.48-kV transformer.

The transformers associated with the electrical power systems are connected as follows:

- Service transformer No. 1, 2 winding, 138 to 13.8 kV, delta-wye connected
- Service transformer No. 2, 2 winding, 138 to 4.16 kV, delta-wye connected
- Unit substation transformers, 2 winding, 4.16 to 0.48 kV, delta-wye connected.

Each neutral point of each 480-V wye connection is connected directly to the ground.

With the transformers connected as listed above, the various voltage systems will be operating as follows:

- Both the 13.8-kV and 4.16-kV systems are grounded through the neutral by a resistor with sufficient ground currents available for the operation of protective devices.
- The 480-V system is a solidly grounded wye system with ground currents available for the operation of protective relays and devices.

10.3.8.2.1. Normal Power Supply. During normal conditions power to the machine and to its essential auxiliaries will be furnished from the local utility's 138-kV offsite transmission network through the 138-kV switchyard and the service transformers. There are two transformers provided, one to supply the 13.8-kV switchgear and the other to supply the two 4.16-kV switchgear.

The large loads (approximately 2,000 hp and above) are supplied power from the 13.8-kV switchgear assembly. Such loads will include the refrigerators, vacuum system, and coil power supplies. Loads, such as the neutral-beam injectors and coil power supplies, which operate in a pulsed mode, will be fed from motor-generator sets of the energy-storage type. The "E" coil power supplies are currently being studied by Argonne National Laboratory and are outside Parsons scope of work. Energy-storage type motor-generator sets are used to supply power to pulsed-type loads to minimize the peak-power demands and voltage dips on the 137-kV utility power supply system. The 13.8-kV loads are fed from a 138 - 13.8-kV transformer which is separate from the 4.16-kV supply transformer to minimize voltage drops on the 4.16-kV system due to the high peak-power demands of the pulsed-type loads.

Equipment with motor drives from 187 kW (250 hp) to 1500 kW (2,000 hp) are supplied power from the 4.16-kV switchgear assemblies No. 1 and 2. These two 4.16-kV switchgear assemblies are separated and both of these are fed from the secondary winding of the 4.16-kV service transformer. The loads on the 4,160-V normal busses will consist of the main cooling-water pumps, "F" coil cooling-water circulation pump, and liquefied-helium-system package equipment. These 4.16-kV loads have been divided into two duplicate groups between the two 4.16-kV busses so that the loss of either bus will interrupt the power to only one group.

Equipment with motor drives 150 kW (200 hp) and less but greater than 75 kW (100 hp) are supplied power from the two 480-V switchgear assemblies. These are each supplied power from the 4.16-kV system through a 1500-kVA OA, 4.16 - 0.48-kV transformer.

All loads with motor drives 75 kW (100 hp) and less, including lighting transformers and other miscellaneous auxiliaries, will be furnished power from 480-V motor control centers, which are supplied power from the two 480-V switchgear assemblies.

10.3.8.2.2. Essential Standby Power Supply. The standby electric power (Class 1E) system for the tokamak device starts with the 4.16-kV switchgear assemblies No. 1E and 2E. These two switchgear assemblies are completely separated and each can be supplied with power from the 4.16-kV service transformer, through the 4.16-kV normal busses.

In addition to the above, each switchgear assembly can also be supplied power from an onsite diesel-driven standby generator. The transfer from one power supply to the other for these switchgear assemblies will be automatic.

The essential auxiliaries, with motor drives 187-kW (250 hp) and larger, have been divided into two completely separate redundant groups between these two 4.16-kV busses so that the loss of either of these busses will interrupt the power to only one group, but would leave the redundant group in operation. When either of these 4.16-kV busses is being supplied power from only its associated on-site standby diesel-driven generator, the starting of the essential motor-driven auxiliary loads will be sequential and automatic.

The essential auxiliaries with motor drives less than 187 kW (250 hp), together with the 480-V motor control centers supplying power to the 125-Vdc system batteries and the station uninterruptible power supply panels, are supplied power from these two 480-V assemblies. Each of these is supplied power from the 4.16-kV essential power system through a 750-kVA OA, 4.16 - 0.48-kV transformer. These two assemblies are also completely separated.

All essential loads with motor drives 75-kW (100 hp) and smaller, including battery chargers and emergency AC lighting, will be furnished power from 480-V essential motor control centers, which are supplied power from the respective standby 480-V switchgear assemblies. The essential motor control centers will be physically separated to two redundant groups.

The four station batteries, each with its associated 125-Vdc panel, its 125-Vdc to 120-Vac inverter, and associated uninterruptible power panel, are for the purpose of supplying the 125-Vdc and uninterruptible 120-Vac essential (emergency Class IE) loads associated with the instrumentation and protection of the tokamak device. The rating of each of these pieces of equipment will be:

- Battery charger - 200-A, 125 Vdc
- Battery - 800-Ah, 125 Vdc
- Inverter - 15 kVA, 208-120 Vdc.

10.3.8.2.3. Safety and Reliability. The electric power system for the tokamak device has been designed to provide a power system which can be operated with complete safety. The major features of the system are:

1. Isolating air break switches have been provided around all 138-kV oil circuit breakers.

2. All of the 13.8-kV, 4.16-kV and 480-V switchgear assemblies are of metal-enclosed construction with draw-out type air-circuit breakers.

3. All power circuit interrupting devices have been specified with sufficient interrupting capacity to safely interrupt any short circuit current that can be developed.

4. All power circuit interrupting devices have been specified with sufficient momentary withstand capacity to tolerate the forces that can be developed by the largest possible short circuit currents.

5. All auxiliaries have been provided with air circuit breakers which can provide isolation for each device during maintenance periods.

6. Essential (Class 1E) components are duplicated and their power supplies and distribution systems are arranged to ensure that neither a failure of a bus, nor the failure of equipment connected to a bus (including the diesel-generator), will prevent proper operation of the essential systems.

7. The standby diesel-generator units are physically isolated and their feeders are run separately. The engines require no outside power for starting other than 125-Vdc for control logic, field flashing, and breaker control. One of the station's vital batteries supplies 125-Vdc to one diesel, with another battery supplying the second diesel via separated cable routings.

10.3.8.3. Design Alternatives

The system as described above has been selected for the following reasons:

- Simplicity and ease of operation
- Adequate reliability
- Adequate flexibility
- Meets the economic and schedule objectives of the program
- Upgradable from ITR to EPR

However, other alternative power distribution systems have been considered with a breaker-and-a-half scheme for the 138-kV switchyard, two off-site power supplies to essential loads, double-bus arrangement for the 13.8-kV system. The use of 6.9-kV distribution for the largest loads and with a secondary selective system (double bus with a tie breaker) for the 480-V distribution.

Another alternative 13.8-kV system, where the pulsed-type loads are directly connected to the 13.8-kV switchgear bus without the utilization of energy-storage type motor-generators, has also been considered. The possibility exists to employ such a system. However, more data would be required with respect to the "stiffness", and acceptable load steps and voltage variations of the utility power system as well as the acceptable input voltage variations of the load power supplies to determine the economic advantages of such a system.

10.3.8.4. Upgradable Considerations

The basic power distribution system is upgradable to serve the requirements of the EPR. The basic voltage levels of 138 kV, 13.8 kV, 4.16 kV and 480 V are adequate to supply the loads of the EPR. The 138-kV switchyard could be extended with another double breaker bay or developed to a breaker-and-a-half scheme to provide another 138-kV feeder to the plant. Transformers and switchgear could be scaled up in rating as required. Another 13.8-kV bus could be added if required.

10.3.8.5. Equipment List

The reference drawing for this equipment list is Drawing EE-1, 3.8M Ignition Test Reactor Facility - Electrical Single-Line Diagram.

1. 138-kV Switchyard

Quantity	Description
1	Outdoor, 138-kV, 3-pole oil circuit breaker, rated at 1600-A, 60-Hz, with a 3-cycle interrupting time, and a 3-phase interrupting capacity of 10,000 MVA.
2	Outdoor, 138-kV, 3-pole, single-throw, group-operated, 1600-A, isolating switches, with a momentary rating of 40,000 A.
2	Outdoor, 138-kV, 3-pole, single-throw, motor-group-operated, 1,200-A, isolating switches, with a momentary rating of 40,000 A.
12	138-kV dead-end assemblies, including strain insulators, consisting of 20 units 5-3/4 x 10 in.; strain clamp, eye-bolt, and clevis.

Quantity	Description
24	Connectors, taps from busses to isolating switches, oil circuit breakers, and transformers.
1 lot	Grounding system for switchyard.
1	Major steel takeoff structures, "A" frame construction.
2	138-kV isolating-switch steel structures.
1	Dead-end steel "A" frame construction structures with supports for two motor-operated isolating switches for high-voltage service transformers.
2	Lightning arrestors, 122 kV
1	Switchyard indoor control and relay board
1	Switchyard 125-V battery rated at 200-Ah, 60-cells, complete with battery rack, intercell connectors and a 300-A fused, 2-pole disconnect switch
1	Battery charger, indoor, 3-phase, 480-Vac to 125 Vdc, with a 60-A, 125-Vdc rating.
1	Indoor, dry-type, 25-kVA station and control transformer, 3-phase, 400/120-V, with 120-V distribution panel.

2. Power Distribution

Quantity	Description
1	Service transformer, oil-immersed, 3-phase, 60-Hz, 2 winding. 22.5/30-MVA, OA/FA, 138-kV delta primary, and wye secondary. 65°C temperature rise; standard impedance.
1	Service transformer, oil-immersed, 3-phase, 60-Hz, 2 winding. 10/12.5-MVA, OA/FA 138-kV delta primary, and wye secondary. 65° temperature rise; standard impedance.
1 lot	15-kV, 2000-A outdoor, nonsegregated bus, 3-phase, 3 conductors.
1 lot	5-kV, 1200-A outdoor, nonsegregated bus, 3-phase, 3 conductors.
1	3-phase, 60-Hz, 500-MVA, 15-kV metal-clad switchgear assemblies in outdoor, weather-protected enclosure, with 2000-A and 1200-A air circuit breakers, as required, including grounding transformer and potential transformer cubicle.
2	3-phase, 60-Hz, 250-MVA, 5-kV metal-clad emergency switchgear assemblies in outdoor, weather-protected enclosure, with 1200-A air circuit breakers, as required, including grounding transformer and potential transformer cubicle.

Quantity	Description
2	3-phase, 60-Hz, 250-MVA, 5-kV metal-clad emergency switchgear assemblies in outdoor weather-protected enclosure, and with 1200-A air circuit breakers as required.
2	Unit substation transformers, outdoor, oil-type, OA/FA, 3-phase, 60-Hz, 1500 kVA, 13.8/0.48-kV delta-wye connected with standard impedance.
2	Indoor, 3-phase, 60-Hz, 480-V metal-clad switchgear, consisting of one 2000-A incoming-air circuit breaker. 1600- and 600-A feeder air circuit breakers as required.
	All air circuit breakers to have a 22,000 symmetrical ampere interrupting rating, minimum.
6	Indoor, 3-phase, 480-V, 60-Hz motor control centers, each to be furnished with molded-case air circuit breakers, and combination starters as required.
2	Unit substation transformers, indoor, dry-type, air-cooled, 3-phase, 60-Hz, 750 kVA, 4.16/0.48 kV delta-wye connected, with standard impedance.
2	Indoor, 3-phase, 480-V metal-clad switchgear, each consisting of one 1600-A incoming air circuit breaker and 600-A air circuit feeder breakers as required. All circuit breakers to have a 22,000 symmetrical ampere interrupting rating, minimum.

Quantity	Description
5	Indoor transformers, dry-type, air-cooled, 1-phase, 60-Hz, 15-kVA, 480 to 120-V.
5	Indoor investers, 1-phase, 2-wire, 15-kVA, 120-Vac, 60-Hz, from 125-Vdc. Each to be furnished with an incoming molded-case air circuit breaker and a static-type transfer switch, and manual by-pass switch.
5	Indoor battery chargers, 3-phase, 480- to 125-Vdc with a 200-A, 125-Vdc rating.
5	Indoor 125-Vdc distribution panels.
5	Dc batteries, each rated at 125-Vdc, 800-Ah, 60 cells. Complete with battery rack, intercell connectors and a 1000-A fused, 2-pole disconnect switch.
2	Diesel engine-driven generators, each rated 3-phase, 60-Hz, 2500-kVA, 4.16-kV, 0.8 P.F., with voltage regulators, field control, and engine control equipment.
5	Indoor, uninterruptible power supply panels.
2	Indoor diesel-driven generator neutral grounding transformers, rated 4.16-0.24/0.12 kV, 10-kVA with a 2-Ω, 240-V, resistor unit.

3. Penetrations into the Tokamak Building

Quantity	Description
2	Penetrations for B-coils, superconductor, rated at 10,000-A, dc continuous.
26	Penetrations for F-coils, rated 1,100 to 22,000-A, 15 kVdc.
2	Penetrations for neutral-beam injectors, rated 1,580-A, 200-kVdc.
2	Penetrations for E-coils, superconductor 4000-kA, 400 Vdc peak.

4. 15-kV, 5-kV and 600-V Power Cables

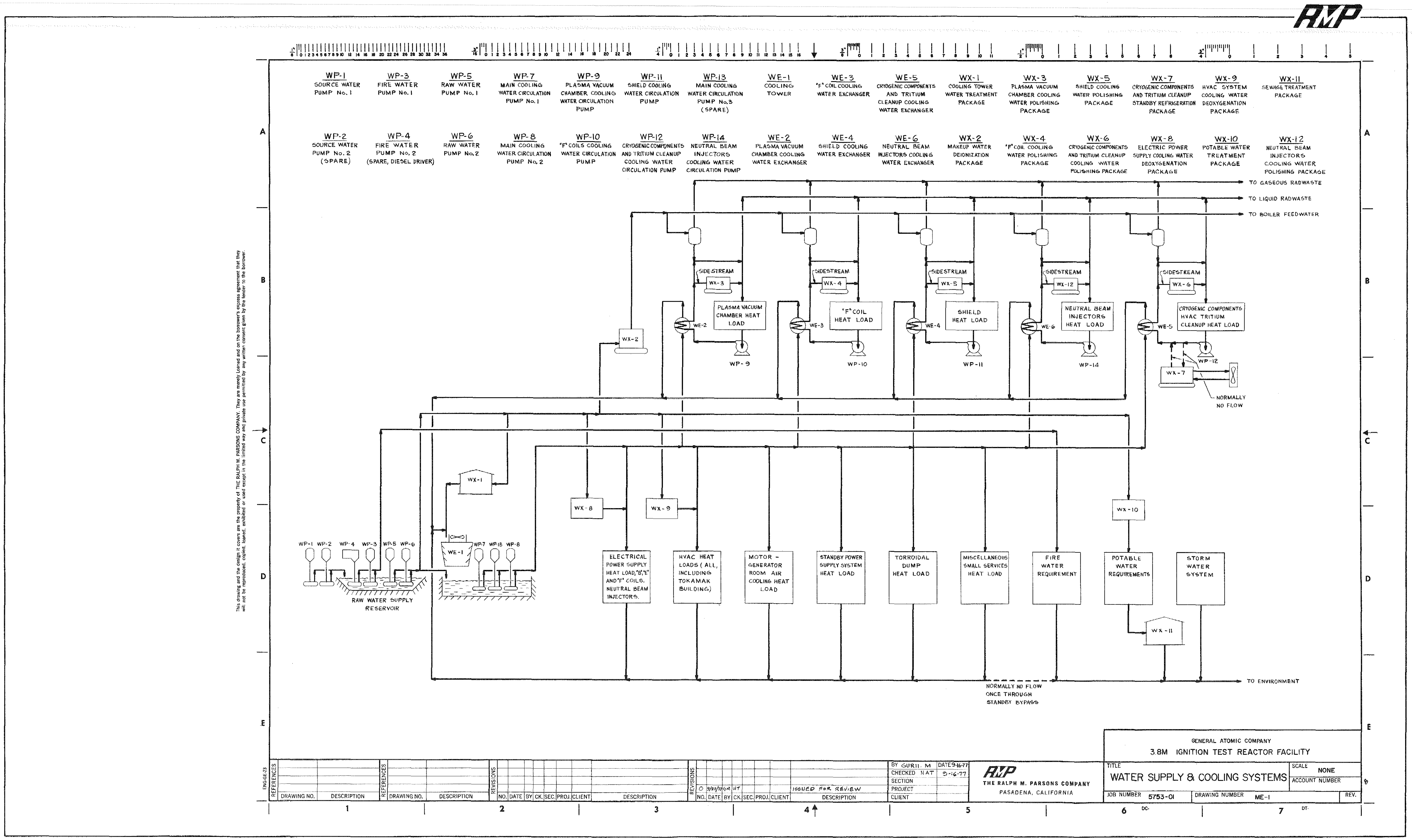
Quantity	Description
1 lot	5-kV, 15-kV and 600-V single- and three-conductor power cables, as required.

5. Control and Instrumentation Tables

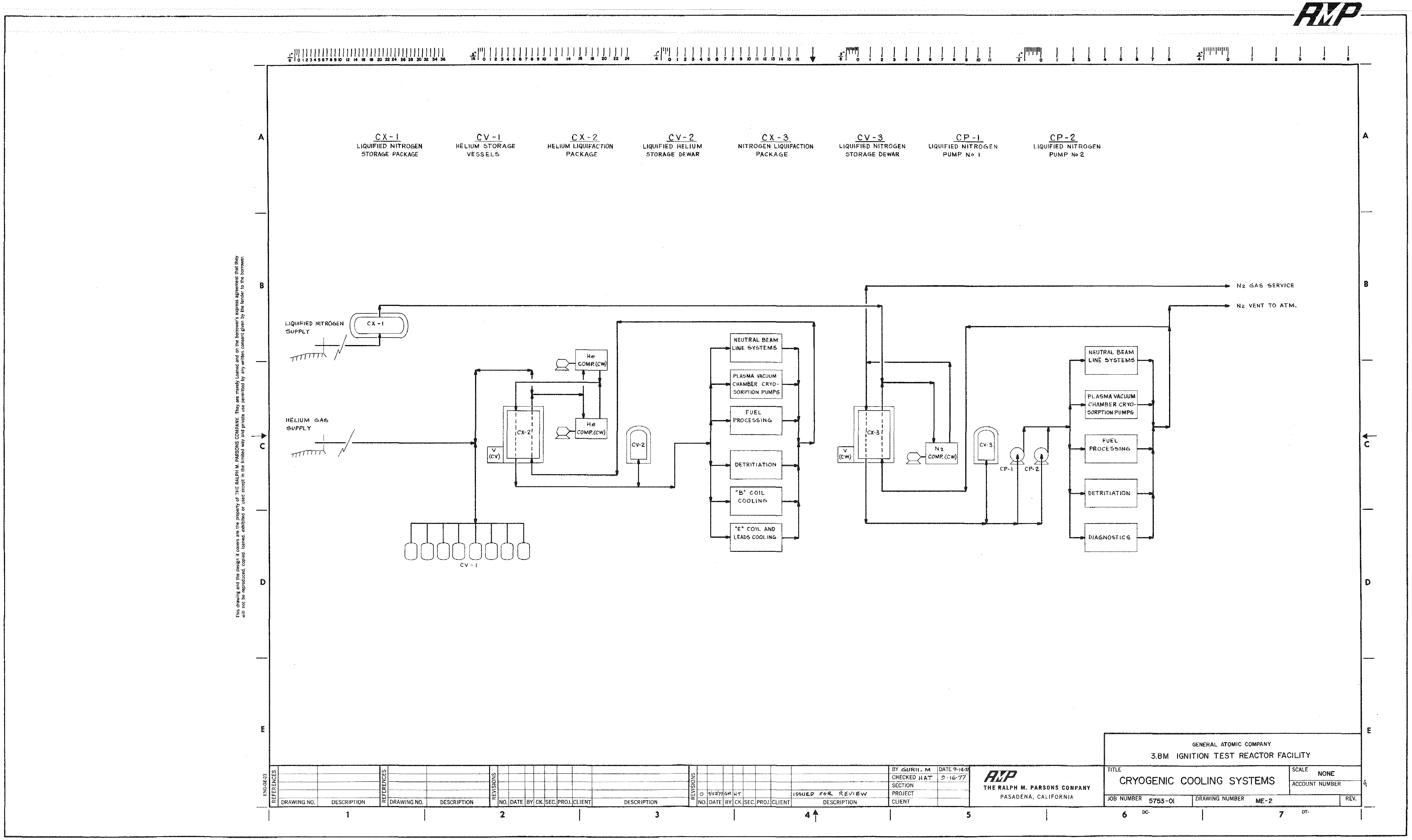
Quantity	Description
1 lot	Control and instrumentation cables as required.

6. Raceways - Conduit and Trays for Power, Control, and Instrumentation Cables

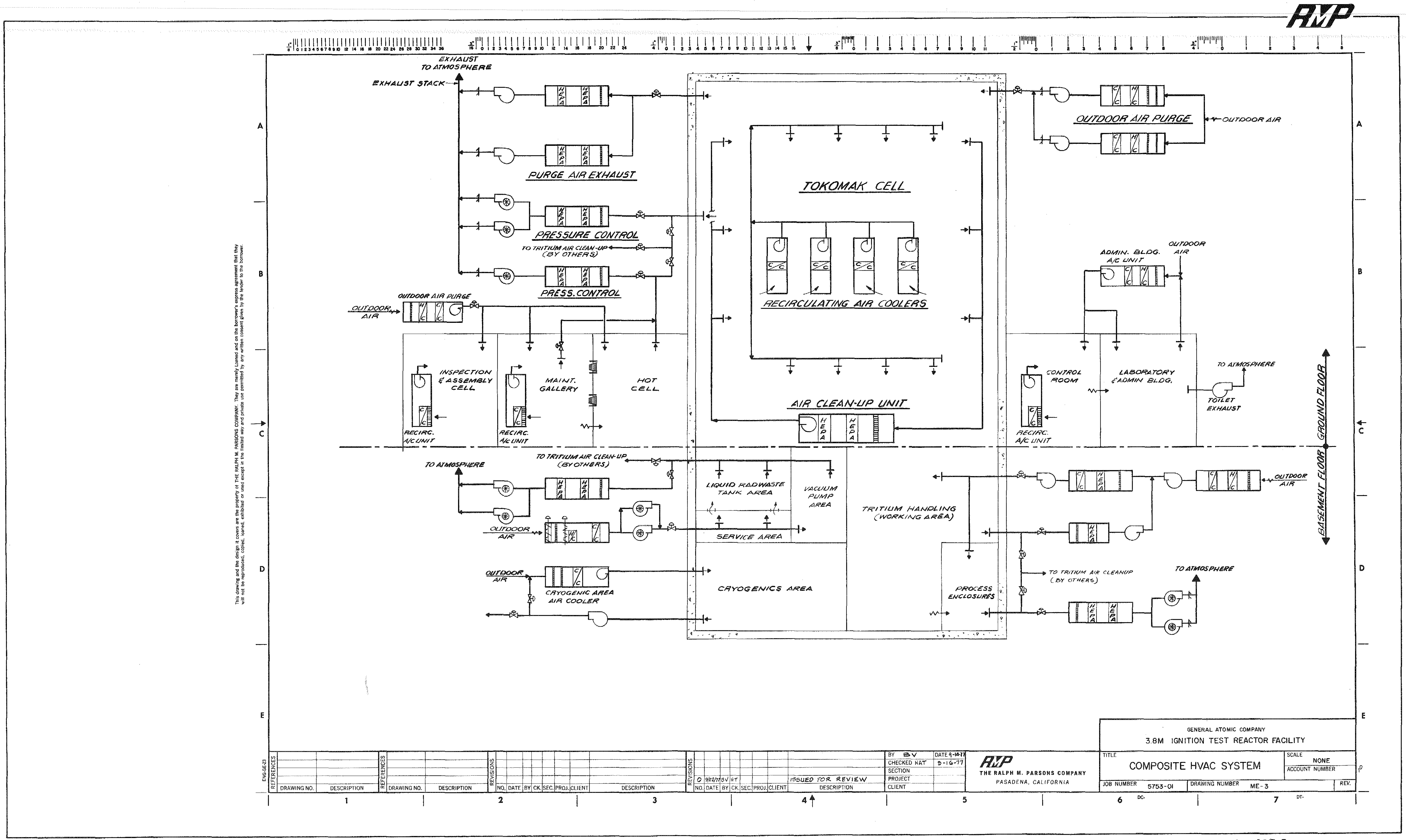
Quantity	Description
1 lot	Raceway systems as required.
1 lot	Cathodic protection.



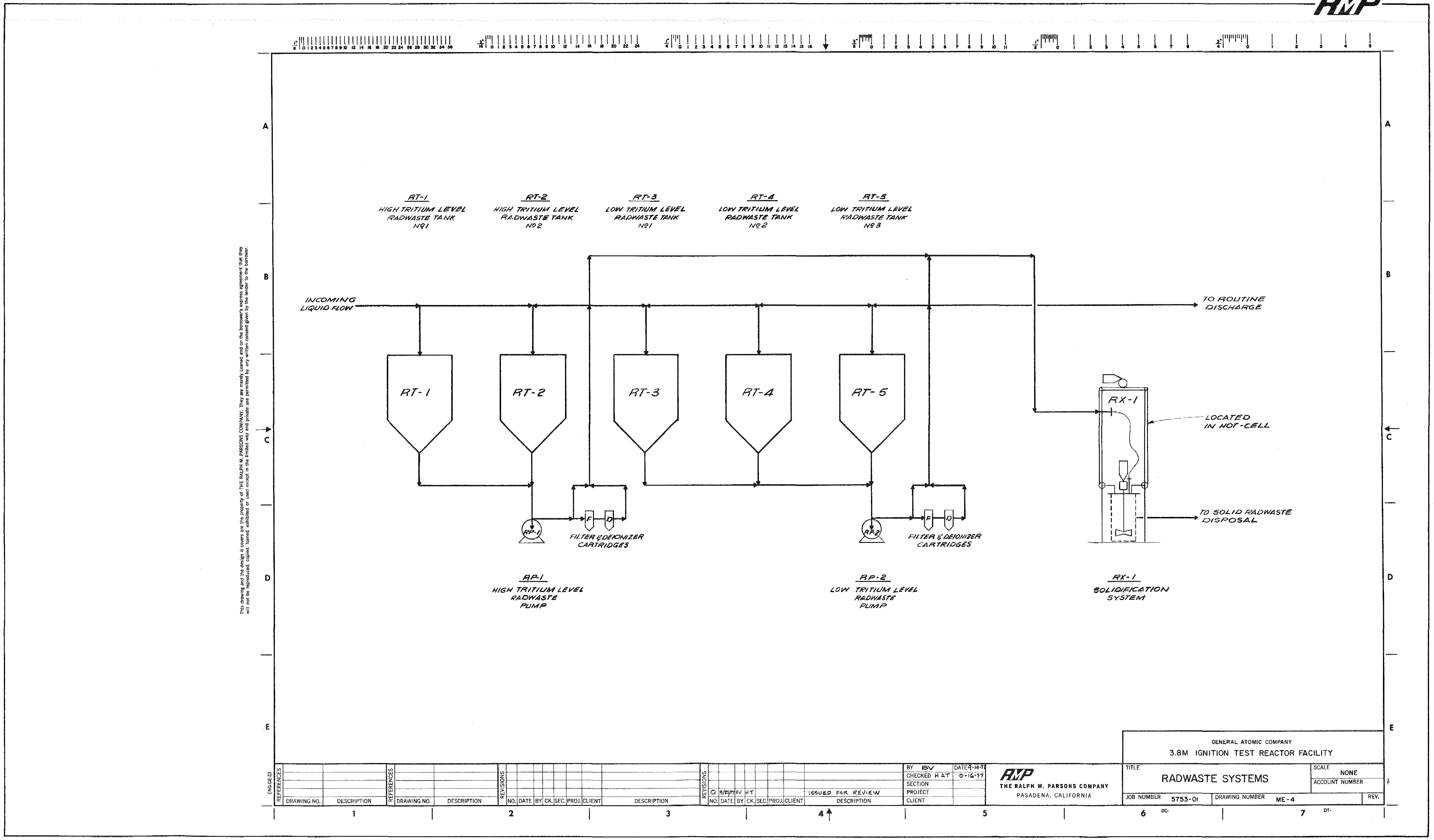
Drawing ME-1.
3.8m Ignition Test Reactor Facility - Water Supply and Cooling Systems



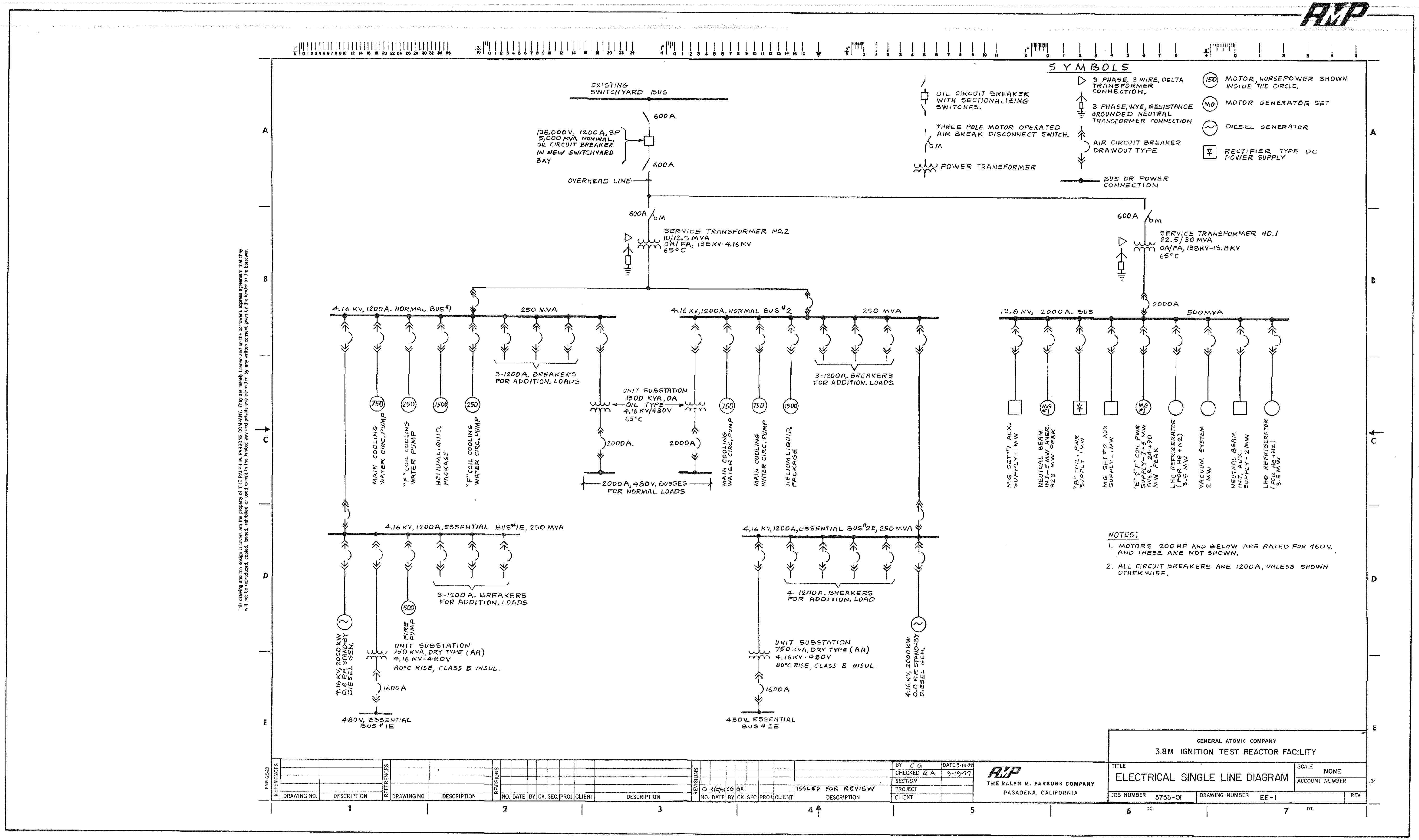
Drawing ME-2.
3.8m Ignition Test Reactor Facility - Cryogenic Cooling Systems



Drawing ME-3.
3.8m Ignition Test Reactor Facility - Composite HVAC Diagram



Drawing ME-4.
3.8m Ignition Test Reactor Facility - Radwaste Systems



Drawing EE-1.
3.8m Ignition Test Reactor Facility - Electrical Single-Line Diagram

10.4. COST ESTIMATE FOR THE 38.8 m ITR FACILITY

10.4.1. INTRODUCTION

In order to provide a valid basis for the TNS program planning, it is important to assess potential cost implications of the various scenarios that may be used in formulating the TNS program. The cost estimate aspect of the TNS program is of particular significance in view of the large extension of program scope required from the Doublet III experimental apparatus to a fusion experimental power reactor facility. Thus, one of the main objectives of this phase of the TNS scoping study is to obtain the facility cost for the baseline ITR facility.

The approach taken is to perform a cost estimate of a "bare-bones" minimum cost facility. The results of this cost estimate and the associated facility layout and BOP system information may then furnish a basis on which further decisions to optimize the TNS program can be made.

The cost estimate as presented in the following subsection is limited to the balance of plant portion of the 3.8m ITR facility. Costs for the tokamak device, tritium-handling system, and the remote-handling equipment such as manipulators, shielded vehicle, etc., are outside Parsons scope of work.

Level of effort of this cost estimate is comparable to the design description as presented in Sections 10.2 and 10.3 and, hence is of preliminary scoping nature. However, special effort has been placed to examine the major cost components in reasonable detail so that a realistic total facility cost can be obtained.

10.4.2. METHODOLOGY

The cost estimate for the facility has utilized the facility layout shown in Drawings AR-1, AR-2, AR-3, AR-4, and the BOP system design as described in Section 10.3. Because the site was not selected at the time of this cost estimate, the land and land rights have been excluded from the estimate. Furthermore, an average site in the Continental United States such as St. Louis, Missouri, has been used to estimate construction services. This same locale was also used as a reference site for the previous EPR cost estimate.

The cost of the facility has been structured into the following six major accounts in accordance with NUS-531, Guide for Economic Evaluation of Reactor Plant Design, NUS Corporation, January, 1969:

- Structures and site facilities - includes the in-place cost of structures and improvements used and useful in connection with fusion power generation.

- Reactor plant equipment - includes the installed cost of the tokamak device, cryogenic cooling equipment, cooling charging equipment, purification and discharging equipment, radioactive waste treatment and disposal equipment, boilers, instrumentation and control, and other fusion plant equipment.

- Electric plant equipment - includes the cost installed of auxiliary generating apparatus, conversion equipment, and equipment used primarily in connection with the control and switching of electric energy, and the protection of electric circuits and equipment, except electric motors used to drive equipment included in other accounts. Such motors are included in the account in which the equipment with which they are associated is included.

- Miscellaneous plant equipment - includes the cost installed of miscellaneous equipment in and about the fusion generating plant devoted to general station use, and which is not properly includable in any of the foregoing accounts.

- Construction facilities, equipment, and services - includes field cost items which cannot be directly identified with any specific construction operation for the permanent facilities.

- Engineering services - includes all costs for design engineering; estimating and cost control; purchasing, expediting and inspection; other home office services; and fees.

Each of the above accounts has further breakdowns. The basic account definition is given in NUS-530, with necessary modification to reflect the special characteristics of fusion facilities.

In costing the structure and site facilities, special attention was given to the tokamak building because of its size and the large amount of concrete required for its construction due to the radiation shielding requirement. Concrete takeoff was performed to obtain a realistic cost estimate. For the BOP system, efforts have been made to estimate each BOP system separately so that the cost of each system may be assessed. It should be noted that the 3.8m ITR does not have the blanket structure with its associated cooling system and hence there is no steam cycle equipment such as steam generators, condensers, etc., in the BOP systems.

10.4.3. COSTING ESTIMATE BASIS

The conceptual design study cost estimate as presented in Table 10.4-1 is based on:

1. The conceptual facility arrangement and BOP systems as described in Section 10.2 and Section 10.3.

2. Preliminary engineering and construction schedule for the 3.8m ITR facility as shown in Figure 10.5-1.

TABLE 10.4-1

PRELIMINARY ESTIMATE SUMMARY - BALANCE OF PLANT FOR 3.8M IGNITION TEST REACTOR FACILITY

Account No.		Amount (k$)	Amount (k$)
20	Land and Land Rights		Excluded
	Land and privilege acquisition		
	Relocation of buildings, utilities, highways, and other services		
21	Structures and Site Facilities		31,210
	Site improvements and facilities	761	
	Tokamak building	26,312	
	Intake and discharge structures	134	
	Miscellaneous buildings	3,703	
	Stacks (when separable from buildings)	300	
22	Reactor Plant Equipment		32,812
	Tokamak device	GAC	
	Cryogenic cooling systems	13,142	
	Water supply and cooling systems	13,313	
	Radioactive waste systems	2,559	
	Other reactor plant equipment	1,359	
	Instrumentation and control (for BOP Systems only)	1,680	
	Fossil-fueled boiler	759	
24	Electric Plant Equipment		20,220
	Switchgear 230-kV switchyard	1,800	
	Power distribution system	18,000	
	Electrical penetrations	420	
25	Miscellaneous Plant Equipment		2,429
	Transportation and lifting equipment	315	
	Air and water service systems	330	
	Communications equipment	237	
	Furnishings and fixtures	1,547	
91	Construction Facilities, Equipment, and Services		21,384
92	Engineering Services		12,150
93	Other Costs		Excluded
94	Interest During Construction		Excluded
	Total present-day cost (August, 1977) balance of Plant*		120,205

*See Clarifications and Qualifications

3. Supplementary data compiled on the previous EPR facility conceptual design.

4. Cost base as of August, 1977 (Present Day).

10.4.4. COSTING BASIS

The costing basis for this scoping study is as follows:

1. Major equipment costs are based on vendor quotations or on historical data pertaining to similar equipment. Quotations were received on the helium refrigeration systems including cryogenic piping. The cost of other applicable major items of equipment was extrapolated from the estimate of the experimental power reactor facility.

2. Concrete quantities were developed from takeoffs of the conceptual design drawings. Electrical and piping quantities were estimated utilizing EPR estimate ratios where applicable.

3. Pricing of bulk materials is based on the St. Louis, Missouri, area in a present day time frame of August, 1977.

4. The manual labor wage rate is a job average composite based on labor agreement in effect in the St. Louis, Missouri area as of August, 1977 and includes travel, fringe benefits, payroll taxes, and insurance. Labor costs are based on a straight-time, standard single-shift work week (40 hours) with casual overtime included.

5. Labor productivity included in the estimate reflects Parsons standards for power plant construction in the St. Louis, Missouri, area.

6. Indirect field costs reflect past experience on other similar projects in the Continental United States.

7. Engineering costs reflect Parsons best estimate of the effort required to completely design an operating facility as "first of a kind."

8. Contingency and fee have not been identified specifically but have been accommodated in the general unit pricing and structuring of the costing.

10.4.5. CLARIFICATIONS AND QUALIFICATIONS

In establishing the basis of this cost estimate, certain elements require clarification. Also, certain elements are excluded or are qualified in the cost estimate. The more significant elements are as follows:

1. General Atomic Company will provide independent cost estimates, including installation costs where applicable, for the following items. These costs must be added to the Parsons estimate to determine total facility cost.

    a. Tokamak fusion system

    b. Remote-handling system (w/exceptions as indicated in estimate)

    c. Tritium-handling system and associated HVAC

    d. Emergency tritium cleanup system

    e. Computer and data acquisition

    f. Hot-cell shielding windows (6)

  g. Deuterium storage
  h. Deuterium and tritium gas supply
  i. Garage and warehouse
  j. Account 20, Land and Land Rights
  k. Account 93, Other Costs
  l. Account 94, Interest During Construction

2. Escalation has not been included in this estimate.

3. Special site investigation and licensing costs are not included in this estimate.

4. Quality Assurance Costs relative to Engineering and Procurement are included in Accounts 921 and 922, Engineering Services.

5. Quality Assurance Costs relative to construction are included in Account 910, Engineering Construction and Field Supervision.

10.5. PROGRAM PLANNING

10.5.1. INTRODUCTION

Because fusion technology is in a state of rapid advancement, there are inherent risks in providing functional assurance of BOP systems which are based on tokamak parameters that are not completely defined. This is particularly evident if the development of the technology necessitates designing both the fusion device system and the BOP system concurrently to expedite the overall project schedule.

The term "functional assurance" as used here refers to the risk involved in the BOP design to provide necessary facility support to the physics mission of the fusion device, assuming the accomplishment of facility design without complete definition of the tokamak parameters and the complications of upgrading ITRs.

Recognizing the complexity of the problems involved, the program planning phase of the TNS project is to examine the following two areas with emphasis on evaluating potential impacts to the overall fusion program in terms of design, schedule, and cost. Additional objectives are to provide a logistic base upon which recommendation can be made as to direction(s) of the TNS program. In question form, the two particular areas are:

- How far can work proceed with the definition and design of the new facility without possessing exact knowledge of all the tokamak design parameters (assume bounding envelope is provided) and what are the affects on schedules, costs, overall program and direction, quality assurance, etc.?
- How would an upgradable or staged device affect the facility (initially designed as an ITR only) in terms of costs, schedules, etc., how might the upgrade be accomplished, and what are the risks, advantages, penalties, etc.?

Three studies have been devised to gain a better understanding of the intricate relationship of various segments associated with the TNS project. Study 1, BOP design interface, examines the BOP-Fusion system interface areas with emphasis on identifying which items have significant impact on the design, so that the subsequent impact to the schedule (Study 2) and cost tradeoff (Study 3) can be broadly assessed. It is noted that due to the scoping nature of the studies, not all relevant factors have been evaluated in detail. Nor do the studies cover every aspect of the risk assessment. Rather, the studies, as presented in the subsequent sections of this report, are intended to give an overall indication of the risks involved in terms of the BOP functional supporting requirements to the fusion device, and of the penalties incurred in the area of schedule and cost due to evolving tokamak fusion design parameters.

10.5.2. STUDY 1 - BOP DESIGN INTERFACE

To provide a qualitative evaluation of the functional assurance of the BOP system, the interface between the fusion device and the BOP system must first be identified. From the interface requirements, the question of which tokamak design change or which TNS project decisions would have major impact to the BOP functional support systems can then be identified. For purposes of this evaluation, the 3.8m ITR has been used as a reference case.

10.5.2.1. Methodology

By means of each tokamak device component, the BOP functional supports were first identified as shown in Table 10.5-1. Major tokamak device components are;

- Plasma vacuum vessel/vacuum pump system
- Water cooled magnetic coils
- Superconducting magnetic coils
- Shields

TABLE 10.5-1.
IGNITION TEST REACTOR FACILITY SUPPORT REQUIREMENTS

3.8m ITR Component/System	BOP Requirement (Primary Interface)	BOP Requirement (Secondary Interface)
Plasma Vacuum Vessel	- vessel water cooling - vacuum pumping - remote handling - solid radwaste (decommissioning)	- vessel cooling water cleanup - heat rejection to the plant cooling towers - tokamak building
Shields	- cooling - remote handling - laydown space for shields	- cooling-water cleanup - heat rejection to the plant cooling tower
F-Coils	- cooling for F coils - remote handling - hot cell - electric power supplies to coil power conversion - cooling for F coils power conversion - solid radwaste (decommissioning)	- cooling-water cleanup - hot storage - heat rejection to the plant cooling towers
E-Coils	- cryogenic refrigeration - remote handling for E-coil supporting frame - laydown space - electrical power supplies to E-coils power conversion - emergency energy dumping	- helium, nitrogen supply/ storage - crane support - water cooling to electric power supplies - tokamak building

TABLE 10.5-1.
IGNITION TEST REACTOR FACILITY SUPPORT REQUIREMENTS (continued)

3.8m ITR Component/System	BOP Requirement (Primary Interface)	BOP Requirement (Secondary Interface)
B-Coils	- cryogenic refrigeration - electric power supplies to B-coils power conversion - emergency energy dumping	- helium, nitrogen supply/ storage - tokamak building - electrical equipment building - switchyard - standby power supply - water cooling to cryogenic refrigeration equipment
Neutral-Beam Injectors	- cryogenic pumping - water cooling for ion dump - remote handling - hot cell - hot storage	- shielding evaluation - same as B-coils
Tritium Handling	- tritium storage - building space for tritium generation/delivery system - tritium cleanup system (HVAC) - radwaste system	- water cooling to HVAC equipment

TABLE 10.5-1.
IGNITION TEST REACTOR FACILITY SUPPORT REQUIREMENTS (continued)

3.8m ITR Component/System	BOP Requirement (Primary Interface)	BOP Requirement (Secondary Interface)
3.8m ITR	general facility support - fire protection - potable water - compressed air, inert gases - water treatment - sewage - auxiliary boiler - laboratory - offices - restrooms - showers and lockers - receiving/shipping control room administration parking	

RMP

- Neutral-beam injector system
- Fusion device supporting structure
- Electrical power conversion
- Tritium-handling systems

From Table 10.5-1, the BOP support requirements were used to derive major BOP systems which were required to provide necessary functional support.

Major BOP support items are;

- Building structure design
- Plant layout and building size
- Cooling-water systems
- Cryogenic refrigeration systems
- Heating, ventilation, and air-conditioning systems
- Remote-handling/hot cell
- Radwaste systems
- Electrical power supply
- Facility support systems - compressed gases, plant air, sewage system, etc.

After the identification of major BOP interface systems, a matrix (Table 10.5-2) was formulated with the preceding lists of the BOP systems and the fusion device systems as heading for the rows and columns, respectively. Each of the discipline engineers participating in the study was requested to evaluate the relationship between the fusion device systems and the BOP systems by filling out Table 10.5-2 with "large", "medium", "small", "nil" to indicate degree of impact according to his experience in the conceptual facility design for the 3.8m ITR. Although the results, as shown in Table 10.5-2, are still of a subjective nature, it nevertheless provides a base to identify the major factors interfacing the fusion and BOP systems.

TABLE 10.5-2.
TOKAMAK DEVICE - BOP SYSTEMS INTERFACE

TOKAMAK Device / BOP	Plasma Vacuum Vessel/ Pumps	Water-Cooled Magnetic Coils	Superconducting Magnetic Coils	Shields	Neutral-Beam Injectors	Fusion Device Supporting Structure	Electrical Power Conversion	Tritium-Handling Systems	Operation and Maintenance Philosophy	Safety and Reliability	Regulatory Consideration
Building Structure Design	Nil	Nil	Nil	Nil	Small	Medium	Nil	Medium	Small	Large	Large
Plant Layout and Building Sizes	Small	Small	Medium	Medium	Large	Large	Large	Medium	Large	Large	Large
Cooling Water Systems	Medium	Medium	Medium	Medium	Medium	Nil	Medium	Medium	Small	Small	Nil
Cryogenic Refrigeration Systems	Medium	Nil	Large	Nil	Large	Nil	Nil	Large	Small	Medium	Nil
HVAC	Small	Small	Nil	Small	Small	Nil	Medium	Large	Large	Large	Medium
Remote Handling/ Hot Cell	Large	Large	Nil	Large	Large	Large	Nil	Large	Large	Large	Medium
Radwaste Systems	Medium	Small	Small	Small	Small	Nil	Nil	Large	Large	Small	Large
Electrical Power Supply	Small	Large	Medium	Nil	Large	Nil	Large	Small	Small	Medium	Medium
Facility Support Systems	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Medium	Medium	Small

Based on Table 10.5-2, major impact areas were further analyzed for each important BOP system. The results are presented below.

10.5.2.2. Analysis

10.5.2.2.1. Building Structure Design. Structure design is strongly affected by radiation shielding required to protect the facility operation personnel and the public. Major building structures which require shielding consideration are the tokamak cell, radwaste area, and the hot cell. Radiation shielding considerations would affect the structure wall and roof thickness which in turn depends upon the tokamak parameters such as burn time, materials chosen for fusion device components (activation consideration), and shield design for magnetic coils, etc. In addition, the building structure design is also determined by site-related geotechnical information and tornado, seismic, and flood design criteria.

10.2.2.2.2. Building Size. The major building structures which comprise the 3.8m ITR facility include the tokamak building, the electrical equipment building, the auxiliary building and the laboratory and office building, and the shipping and receiving building.

For the tokamak building, the floor area must accommodate the tokamak device with its radial neutral-beam injectors. Clearance must be provided between the neutral-beam injectors and the building walls to allow for removal of the neutral-beam injector for hot-cell maintenance. Major factors which affect the size of the tokamak building are the arrangement of neutral-beam injectors around the tokamak device, and the maintenance philosophy for the neutral-beam injectors and the fusion device. For example, the laydown space in the tokamak building is determined by the largest component to be removed from the fusion device.

The floor area of the electrical equipment building must accommodate all the electrical equipment with reasonable access space to allow for removal and maintenance of components. The auxiliary building must provide space for all of the process cooling water systems and other mechanical support systems for the tokamak fusion device. The size of the laboratory and administration building depends upon the number of staff members to be housed in the building and the associated office support requirements such as orientation rooms, etc. The size of the laboratory and administration building is independent of changes in the tokamak parameters.

10.5.2.2.3. Layout. Relative positions of various plant building structures and systems are determined by the functional support requirements. Major criteria underlying this consideration are:

1. All essential facility services should be as close as possible to the place where the service is needed. Examples are the locations of the hot cell and the cryogenic cooling systems in the tokamak building.

2. Potential for spreading radioactive contaminants should be minimized.

3. Ease of personnel and material flow to facilitate maintenance and operations should be considered. This also includes allocation of equipment laydown space for maintenance.

4. Major equipment should be located away from a potential missile projectile due to failure of rotating equipment such as motor-generator flywheels.

5. Allow for expansion such as addition of heat removal capacity, additional power supply equipment, and an add-on turbine building.

General plant layout considerations are not subject to changes in the tokamak parameters. However, change of the tokamak device remote-handling approach and provision for upgradable ITR power generation capability would have major impacts on the facility layout.

10.5.2.2.4. Cooling Water Systems. Plant site selection will be the major factor affecting the BOP cooling-water systems, since site water conditions will directly affect the size of all items, i.e., exchangers, piping, and lines in the cooling water circuit including design of systems at the point of heat load. Beyond this point, direct changes in cooling-water requirements are not of great impact on the design. Provision for some changes can be handled by initially furnishing additional space in the auxiliary building, and slightly oversizing the main lines, pumps, and pump drivers in the cooling-water tower circuit.

10.5.2.2.5. Cryogenic Cooling Systems. Changes in cryogenic requirements will have a significant impact on BOP design since the gas liquefaction systems are highly sophisticated package units employing large compression systems which specifically limit maximum outputs. Added requirements would mean installation of additional package unit(s) and compressors which might not synchronize with the originally planned capacity on an operational basis. Accurate initial assessments of the locations of all requirements and the size of the more significant loads, particularly "B" Coil and "E" Coil plus leads for liquefied helium, and the neutral-beam line systems for liquefied nitrogen are essential. Liquefied helium requirements are the most important since they impact liquefied nitrogen requirements and, although to a lesser extent, cooling-water and power requirements.

10.5.2.2.6. HVAC Systems. Normal building HVAC systems depend upon the size of the building, heat load, and the plant site selection. The HVAC system design will have to incorporate the functional requirement of tritium-cleanup under abnormal operation conditions. The standby tritium cleanup HVAC systems are affected by the cleanup rate, amount of tritium inventory which may be released in the postulated accident, and the system redundancy requirements. This tritium-cleanup HVAC system design is outside Parsons' scope of work.

10.5.2.2.7. Remote Handling/Hot Cell. Due to high radiation caused by 14 Mev fusion neutrons, remote handling plays a very crucial role in the design of the 3.8m ITR facility. Major factors affecting remote handling are operation and maintenance philosophy, availability of access space to the tokamak device components, frequency of equipment maintenance and functional requirements of special remote-handling equipment. Remote-handling approach is affected more from the hardware size, weight and assembly/disassembly requirements than the change of tokamak physics parameters.

Since remote handling was handled by AMCO in the BOP conceptual scoping study for the 3.8m ITR, close coordination with Aerojet was necessary to get a consistent facility design with various remote-handling approaches. Hot-cell design is generally determined by the tokamak component service requirements as well as facility decommissioning considerations. However, the design of the hot cell is not very sensitive to the change of tokamak parameters. Envelope definition of equipment and components to be serviced in a hot cell will be adequate.

10.5.2.2.8. Radwaste Systems. Since liquid radwaste tankage size is based on the largest volume of cooling water that could become sufficiently activated or tritium-contaminated to require storage before release to the environment, or disposed of by solidification, a decision concerning the ultimate size of the largest closed-loop demineralized-water cooling system is required. Radwastes, regardless of form, i.e., solid, liquid, or gas are not expected in any significant proportion. Thus other decisions regarding this system are not critical.

10.5.2.2.9. Electrical Power Supply Systems. Electrical power supply systems are closely related to the tokamak coils electrical power requirements. Any major deviation of the tokamak parameters in electrical power requirements will significantly impact the functional assurance of the electrical power supply systems. Other significant factors are definition of the systems which will require standby power supply, and upgradable considerations for future expansion.

Due to large parasitic power needs and the requirements to furnish large surges of power during the burn-time periods, the facility site selection will also have substantial impact on the electrical power supply system.

10.5.2.2.10. Facility Support Systems. Facility support systems such as compressed air vacuum, steam, etc., are rather insensitive to changes in the tokamak parameters. Design of the facility support systems for the 3.8m ITR is not expected to be different from most R&D facilities. Early identification of the site will, however, expedite the determination of the general facility conditions, such as availability of sewage treatment, etc., and, hence, minimize any gross assumptions on the site conditions.

10.5.2.3. Recommendation

Based on the preceding assessment, summarized below is a list of major factors which will significantly impact the design of the BOP system and hence affect the BOP functional assurance to support the 3.8m ITR facility. Early determination of the information as recommended will facilitate the BOP system design and will minimize any potential design impact due to changes in the tokamak parameters.

- Site selection and site-related information such as cooling water sources, geotechnical data, and availability of electric power to support 3.8m ITR coil systems.

- Identification of regulatory requirements in the area of radiation protection and environmental concerns. For example, tritium-handling and -release criteria.

10.5.3.1. 3.8 m ITR Schedule

Figure 10.5-1 shows a base schedule for the 3.8m ITR facility. It is a 10-year schedule from the scoping study through site selection, engineering, procurement, construction and startup testing of the facility. It is noted that the BOP portion if just one of the factors affecting the overall TNS schedule. Other major components of the TNS schedule are scoping studies, site selection/survey, environmental report preparation, and takamak fusion device design, fabrication, installation and testing.

Major features of the base schedule are:

- One year of scoping studies
- Engineering of the tokamak fusion systems will take 3.5 years with the first 18 months for the conceptual design and the subsequent 24 months for the preliminary and final design.
- Engineering for the BOP systems will take 4.5 years including 1 year for conceptual design and 3.5 years total for the title I and title II design efforts.
- Four years for procurement and construction of the BOP facility and 5 years for procurement, fabrication, and installation of the tokamak device components.

- Remote handling, plant maintenance and operation philosophy such as the assembly/disassembly of the tokamak device; particularly, the neutral-beam injector system or other plasma beam heating system.

- Major tokamak component cooling requirements such as type of coolant, heat load characteristics, flow rate requirements.

- Major tokamak component electric power loads, and characteristics.

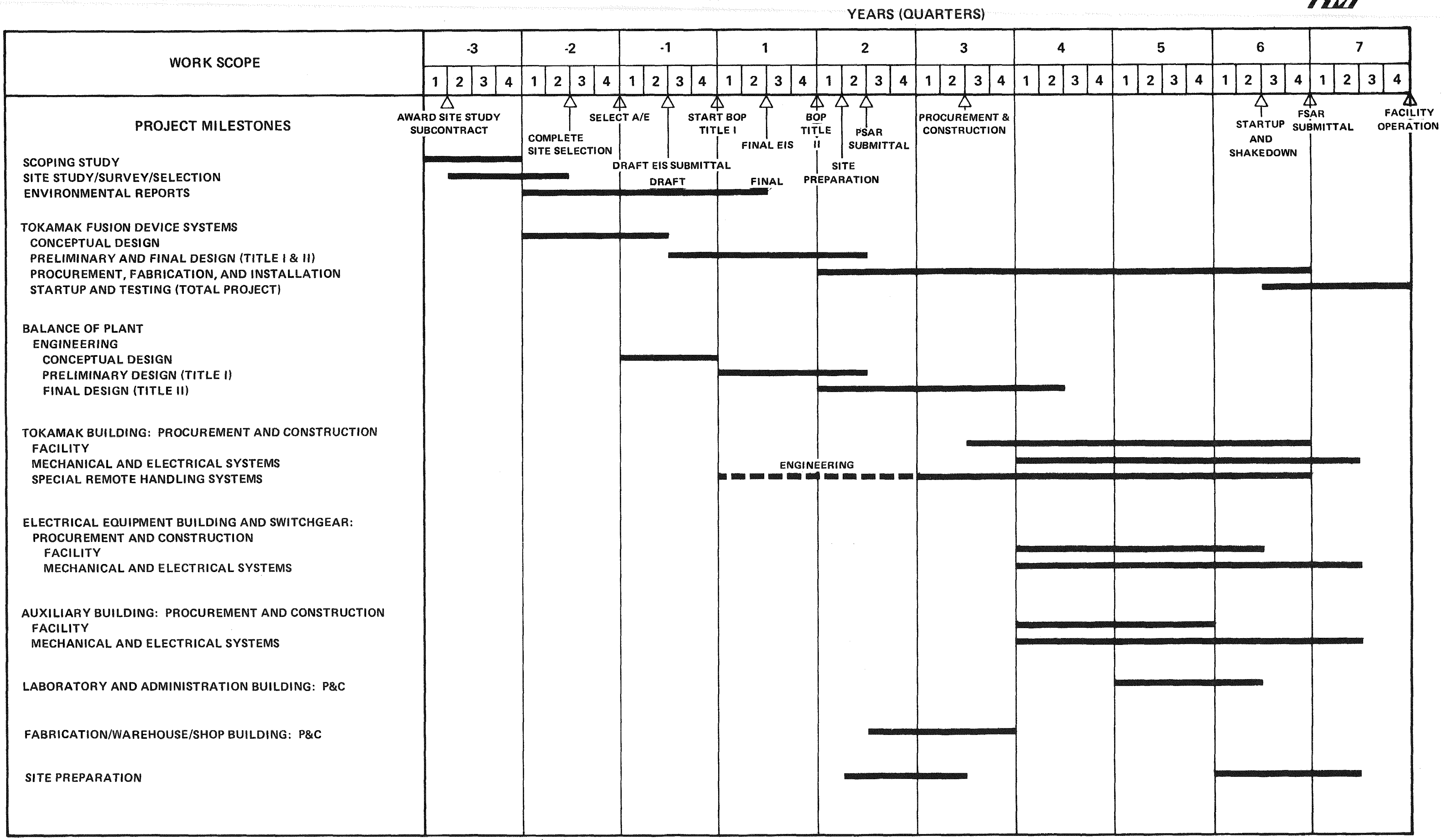
- Identification of safety-related systems and any redundancy facility support requirement such as dual systems/components, standby power supply, etc.

- Facility integration coordination to permit timely exchange of information among various subcontractors and parties involved in the TNS project and to allow orderly design of the BOP system.

10.5.3. STUDY 2 - SCHEDULE

The purpose of this study was to evaluate the potential impact on the TNS schedule due to facility design which is based upon envelope tokamak parameters. Before the schedule impact can be assessed, major components which constitute the TNS schedule must first be identified and their overall time sequence relationship examined.

For purpose of this study, it has been assumed that ERDA funding availability and facility licensing would not constitute major constraints in the TNS schedule. On the other hand, the schedule has been structured on a relative time frame without designating the calendar year to accommodate any change in the assumptions.



3.8 m Ignition Test Reactor Facility
Preliminary Schedule
Figure 10.5-1

- Eighteen months for component testing and startup activities before the start of ITR facility operation.

10.5.3.2. Analysis

In examining the base 3.8m ITR schedule, time sequential relationships exist among major activities of the schedule. Of particular importance are the interface requirements between the BOP system design and the tokamak device component design, and between site selection and BOP design.

10.5.3.2.1. Scoping Study. The scoping studies are to be followed by the conceptual design phase of the tokamak fusion systems which would last 1.5 years. Changes in time duration of the scoping study would not affect the schedule if the scoping study and the conceptual design are overlapped in such a way that the total time period of 2.5 years for the two items is not changed.

10.5.3.2.2. Site Selection. As determined in Study 1, site-related information is required for the BOP system design. Duration of time required for site selection/survey is definitely related to the type of land (private or federal reservation) considered for the ITR facility. Siting on private lands takes longer time as it involves negotiation of access right for survey and the transfer of land title if it is selected for the facility siting.

In the base schedule, the site selection/survey is concurrent with the scoping study to expedite the overall schedule. Siting the ITR on a federal reservation is preferred because of scheduling advantages as well as the possibility of utilizing existing site-related information. In any event, a negative impact on the overall TNS schedule will result if the site selection and survey is not completed before the starting of the BOP conceptual design.

10.5.3.2.3. Interface Between Tokamak Fusion Systems and BOP Systems. Because this is a first-of-a-kind technological development, the engineering, procurement, fabrication and installation of the fusion device components occupy a very important segment in the overall sequence of events in the TNS program. While portions of the BOP facility may be divided into design/construction packages to expedite the overall schedule, it should be recognized that the BOP portion of the TNS program may not necessarily be the governing factor for the overall program schedule. In addition, any accelerated schedule for the engineering of the BOP systems without more refined definition of the tokamak fusion system parameters would certainly decrease BOP functional support assurance and hence increase probability of a system redesign or retrofit situation. In this regard, to minimize the design risk associated with tokamak parameter uncertainties, the major BOP design interface factors as identified in Study 1 should be incorporated into the detailed overall program schedule planning.

In the base schedule for the 3.8m ITR, the BOP conceptual design starts at 1 year after the conceptual design of the fusion systems. Although the conceptual design of the BOP systems may start earlier than the time frame, as indicated in Fig. 10.5-1, it is noted that this would not shorten the overall program schedule. In any event, it would certainly be beneficial to the TNS program if the basic design information such as site condition, basic remote-handling approach, fusion system envelope parameters and regulatory considerations related to safety-related systems and tritium release can be identified or defined in the scoping studies.

10.5.3.2.4. Upgradable ITR. From the BOP design standpoint, the major differences in the ITR and upgradable ITR facilities are the heat removal system from the blanket, the associated steam conversion, and the electric power production system. The base facility layout for the 3.8m ITR has provisions for upgradable considerations such as the addition of a plant area to handle the additional heat generation. Details of upgradable considerations were presented in the 3.8m ITR conceptual design section in this report.

From the aspect of scheduling considerations, the basic impacts will be the time requirements in engineering, procurement, and construction of these added facilities. Overall schedule for TNS with upgradable option depends upon how the upgradable option is implemented. For example, one scenario would be to design and construct the 4.2m ITR with blanket and its associated BOP systems including these added facilities as an integral package. This would offer the least impact, estimated to be 6 to 12 months, to the base schedule.

An alternate approach would be to build the 4.2m ITR with minimum blanket heat removal equipment only. Heat rejection is accomplished through the cooling tower loop. This approach would provide building space to add steam generators and other facilities later.

Another approach would be to provide the steam generation system for the 4.2m ITR and leave the turbine building for future expansion. The steam dump to the atmosphere or to a condenser may be utilized in this approach. The facility can be designed to provide such an option. The impact to schedule in this approach depends largely upon when addition of these facilities is exercised. The main advantage of this approach is that there is less risk in funding commitment now while the physics test of fusion ignition is carried out. The major disadvantages will be to compromise the facility operation while the construction of the additional facilities is in progress and possibly the relatively long down time of the upgradable ITR to allow for connection of these additions.

10.5.3.3. Recommendations

Based on the preceding analysis on the impact to the overall TNS schedule, the following items stand out as major decisions and considerations which would expedite the overall project schedule.

- Site selection and survey work should be initiated as early as possible. Siting the ITR on federal reservation land is recommended.
- Early selection of an A/E firm to perform integral facility planning will benefit the overall TNS program. The schedule planning for the tokamak fusion systems and for the BOP systems should be an integral package rather than two separate loosely coupled packages.
- Early decision as to if, how, and when the upgradable option is to be implemented, taking into consideration the availability of funding and commitment to fusion energy as a viable energy option.

10.5.4. STUDY 3 - COST

The objectives of this cost study are to evaluate the major components which make up the overall cost for the 3.8m ITR facility, to evaluate the potential cost impact due to an upgradable design alternative and to identify and recommend potential cost saving measures for the TNS program. In performing this cost evaluation, it is recognized that Parsons' scope of work and consequently the cost investigation has been limited to the balance-of-plant portion of the ITR facility. Hence, this study does not reflect any necessary tradeoff consideration in the tokamak fusion device systems.

10.5.4.1. The 3.8 m ITR Cost Estimate Evaluation

The balance-of-plant costs as outlined in Table 10.4-1 were based on the reference design described in Sections 10.2 and 10.3. Because of the time and budgetary constraints of these TNS scoping studies, the 3.8m ITR facility design has not been optimized. The cost evaluation is therefore of conceptual nature and is subject to further design refinement.

10.5.4.1.1. Major High Cost Components. The cost of the BOP portion of the facility is estimated to be around $120M in August 1977 dollars. The following items constitute the major cost components in this estimate.

1. Structures and Site Facilities - $31.2M. The $31.2M structure and site facilities cost represents approximately 26% of the BOP cost. Of this $31.2M, more than four-fifths of the cost, or $26.3M is contributed by the tokamak building.

2. Reactor Plant Equipment - $32.8M. The cryogenic cooling systems and the water supply and cooling systems cost approximately $13M, each. It should be noted that the cost value is based upon a "bare-bones" minimum cost facility approach without the luxury of providing system and/or component redundancy.

3. Electric Plant Equipment - $20.2M. The major cost components are the 230 kV switchyard and the power distribution system. The relatively low cost, percentagewise, of the electric plant equipment is partially due to low duty factor and partially due to the absence of the power production requirement in this 3.8m ITR facility.

4. Construction Facilities, Equipment, and Services - $21.4M.

5. Engineering Services - $12.2M.

10.5.4.1.2. Tradeoff Considerations. Based upon the high cost components in the 3.8m ITR facility, the preliminary tradeoff considerations are highlighted below:

1. The tokamak building housing the fusion device has to provide many interface support requirements such as maintenance laydown space and lifting clearance for fusion device components, radiation shielding, space for cryogenic and vacuum pumping equipment, tritium-handling, and remote-handling accommodations, etc. The current design described in Sections 10.2 and 10.3 reflects a design which has taken into consideration these major interface requirements. However, other design alternatives exist, and the design concepts outlined below require further investigation as to their feasibility and cost implication.

   a. The width and length of the tokamak building is determined by the arrangement of the neutral-beam irjectors around the fusion device. A tradeoff study investigating neutral-beam injector maintenance alternatives and other beam-heating options such as RF heating versus the size and hence the cost of the tokamak building, definitely presents a potential for major cost savings.

   b. The current design reflects a tokamak cell recessed into the earth with heavy walls and slabs. If this same design were elevated to ground level, considerable savings could be attained in excavation and backfill operation. However, the seismic requirements and the vacuum pump and cryogenic refrigeration requirements would have to be evaluated closely. Other tradeoff areas may involve the comparison of the monolithic poured concrete roof of the tokamak building versus the use of precast, post-stressed "T" sections or stressed slabs welded together. The shielding requirement over the tokamak device must still be provided, however.

c. Another alternative would involve disassociation of the tokamak building from the rest of the supporting building so that lesser wall thickness may be required for radiation shielding. However, the engineering feasibility for such a concept and its cost implication on the electrical, piping, and operating personnel travel would have to be carefully evaluated.

2. The ancillary structures. The ancillary structures are steel frame design, utilizing open web steel roof joists with insulated metal siding and metal roof deck with insulation and buildup roofing. The costs for the ancillary structures have been minimized from a structural standpoint by the actual cubic footage required, but further investigation will be required to optimize space required for economy and operating efficiency.

   The associated building services required in the ancillary structures will be affected parametrically as the volume of the structure is increased or decreased. The building services include HVAC, fire protection, lighting, potable water, communications, and laboratory and office space which have a direct relationship to the total cubic footage of the structure.

3. The BOP systems. The piping systems in the current configuration appears to be as optimum as can be conceived. The tritium-handling and cryogenic systems are located as close as possible, to support the tokamak device, and any further optimization in any refined layout will most likely not result in any subsequent economic savings.

   Cooling water, service water, and domestic water, depend on site location and these factors could be significant in the total plant cost.

Optimization of the electrical requirements does not appear to offer savings, as the electrical building, standby generators, and control room are located in very close proximity to the tokamak cell. The runs of conduit, cable tray, raceway, etc., in the current configuration will be difficult to reduce in quantity.

One factor which could possibly reduce the quantity of electrical bulk material required, would be a raceway tunnel adjacent to the tokamak cell, channeling all the electrical runs into one area. This tunnel concept is worth exploring as the concept defines itself more specifically.

The building services including HVAC, fire protection, service water, communications, lighting, laboratory, and office space will be little affected by any major configuration change or optimization study. These items are governed by the square footage of usable floor area and will remain relatively constant in any concept change. The total square footage by floor of the existing arrangement will remain relatively unchanged because of the total requirement for usable operating floor space.

10.5.4.2. Comparison Between the 3.8 m ITR and the 4.5 m EPR Facilities

For comparison purposes, the balance of plant estimate for the 4.5m Experimental Power Reactor prepared by Parsons in mid-1976 has been escalated from January 1976 to August 1977, present day costing basis, and is presented in Table 10.5-3.

The 3.8m alternative, although not truly comparable, has resulted in a reduction of approximately $185M, or 60%. When the necessary cost adjustments are made in the EPR estimate, such as the elimination of the turbine building and turbine plant equipment, a projected reduction in capital expenditures of approximately $135M or 53% is still realized.

A comparison of the two alternatives is compiled below:

Account		PERCENTAGE OF TOTAL 4.5m EPR	 3.8m ITR
21	Structures and site facilities	33	26
22	Reactor plant equipment	24	27
23	Turbine plant equipment	9	0
24	Electric plant equipment	10	17
25	Miscellaneous plant equipment	1	2
91	Construction facilities, equipment, and services	13	18
92	Engineering services	10	10

The overall reduction in structures and site facilities has primarily been the result of decreased support facility costs.

From a practical standpoint, a direct comparison of the EPR with the ITR is difficult due to the concepts involved and their specific stage of development and generating capacity. However, the cost associated with the EPR facility as presented here should provide a better overall cost relationship for the TNS program management.

10.5.4.3. Upgradable ITR Considerations

Drawings AR-5 through AR-7 present a facility arrangement for a 4.2m ITR facility with the capability of being upgraded to EPR status by adding a blanket structure to the basic ITR tokamak device and providing a blanket cooling system, steam conversion and power generation. The larger tokamak building is designed to accommodate AMCO's

TABLE 10.5-3

PRELIMINARY ESTIMATE SUMMARY - BALANCE OF PLANT FOR 4.5M EPR

Account No.		Amount (k$)	Amount (k$)
20	Land and Land Rights		Excluded
201	Land and Privilege Acquisition		
202	Relocation of Buildings, Utilities, Highways and Other Services		
21	Structures and Site Facilities		101,748
	Site Improvements and Facilities	2,701	
	Reactor Building	38,187	
	Turbine Building	11,308	
	Intake and Discharge Structures	245	
	Reactor Auxiliaries Building	16,510	
	Radioactive Waste Building	20,084	
	Miscellaneous Buildings	12,229	
	Stacks (when separable from buildings)	484	
22	Reactor Plant Equipment		72,599
	Nuclear Island	GAC	
	Main Heat Transfer and Transport Systems	30,656	
	Safeguards Cooling Systems	17,410	
	Radioactive Waste Treatment and Disposal	5,991	
	Other Reactor Plant Equipment	13,142	
	Instrumentation and Control	4,143	
	Fossil-Fueled Boilers and Superheaters	1,257	
23	Turbine Plant Equipment		27,911
	Turbine-Generators	9,545	
	Heat Rejection Systems	8,059	
	Condensing Systems	2,530	
	Feed-Heating System	2,709	
	Other Turbine-Plant Equipment	2,837	
	Instrumentation and Control	2,231	
24	Electric Plant Equipment		29,625
	Switchgear	5,063	
	Station Service Equipment	8,388	
	Switchboards	2,951	
	Protective Equipment	2,406	
	Electrical Structures and Wiring Containers	1,457	
	Power and Control Wiring	9,360	

TABLE 10.5-3 (CONTINUED)

Account No.		Amount (k$)	Amount (k$)
25	Miscellaneous Plant Equipment		3,693
	Transportation and Lifting Equipment	373	
	Air and Water Service Systems	293	
	Communications Equipment	237	
	Furnishings and Fixtures	2,790	
91	Construction Facilities, Equipment, and Services		39,329
	Engineering Construction and Field Supervision	17,728	
	Temporary Facilities	5,521	
	Construction Equipment	5,646	
	Construction Services	10,434	
92	Engineering Services		28,925
	Reactor Engineering	16,932	
	Plant Engineering	11,993	
93	Other Costs		Excluded
	Taxes and Insurance		
	Staff Training and Plant Startup		
	Owners G. and A.		
94	Interest During Construction		Excluded
	Physical Plant and Associated Indirect Costs		
	Land and Land Rights		
	Special Materials		
*Total Present Day Cost (August, 1977), Balance of Plant			303,830

*See clarifications and qualifications

remote-handling concept of removing the tokamak top coil support structure in one piece in order to facilitate overall maintainability and to increase the access to the top portion of the fusion device.

Overall cost implications of upgrading the ITR would depend upon the upgradable scenarios. That is, how the upgrade package is to be implemented. Potential factors which affect the base schedule of the 3.8m ITR facility and potential effects due to various ITR upgradable alternatives have been discussed in the previous section (Study 2). While the level of effort in this scoping studies does not permit the obtaining of a cost breakdown, preliminary cost assessment indicates an incremental cost to be, in present day dollars, approximately $60-70M. This includes a steam generation system, associated power production systems and a turbine building. It should be emphasized that this cost figure does not represent an optimized design but merely an attempt to qualify the concept and provide a reference point for further studies and investigation.

The following cost-related observations are made to highlight the areas for potential cost savings and for further tradeoff considerations.

1. The tokamak building for the upgradable ITR as outlined in Section 10.5.5. would result in an additional cost outlay of approximately $13M. The larger tokamak building provides the necessary laydown space for the top coil support structure, space to accommodate the anticipated addition of the cooling piping for the blanket structure, and space for the addition of cryogenic and vacuum piping equipment etc. Further investigations of the detailed space requirements for the upgradable ITR would optimize the size of the tokamak building and if the building size could be reduced, large cost savings would be realized.

2. Another major cost addition item for the upgradable ITR will be the addition of cooling capacity and the steam cycle systems to accommodate the operation of ITR in the power production demonstration mode.

   Detailed cost implication of increased cooling capacity and steam cycle system package will depend upon the parameters such as design thermal output, the duty factor, and the steam conditions, etc. In addition, the design and construction of a turbine building will also be required. All these factors indicate a need for further optimization studies in the configuration of steam cycle systems and associated supporting facilities.

10.5.5. UPGRADABLE CONSIDERATION

One of the options in the TNS program is to design and build a fusion machine which can operate as an ITR initially and be upgraded into a net power device for EPR operation by changing and adding components and systems outside the basic fusion machine. Basic additions in the facility portion will be the scale up of electrical power supply systems to support longer burn times and a higher duty factor, and the expansion of cryogenic and water-cooling systems to remove extra heat generation in various components; and eventually installation of steam generators and related systems plus addition of the power generation system.

Drawing AR-5 shows a facility first floor plan for the 4.2m upgradable ITR. The facility consists of a tokamak building with hot cell/decontamination cell, an electrical equipment building, an auxiliary building which houses the water-cooling system equipment, switchyard, a laboratory and office building, and the add-on turbine building. Major differences between this layout and that shown in Drawing AK-2 are discussed below:

- The neutral-beam injectors are arranged symmetrically in each 60-degree sector to provide better access space for remote handling and for the accommodation of helium coolant piping.

- A larger tokamak cell is provided to accommodate withdrawal of a neutral-beam injector into a shielded enclosure for removal into the hot cell for maintenance and to allow more laydown space and space for the operation of the shielded cab vehicle.

- The AMCO remote-handling concept of retrieving the tokamak top structure in one piece is accommodated. This approach would increase the fusion device top access and would expedite maintenance/repair service to the top portion of the fusion machine.

Drawing AR-6 shows the lower and upper level plans for a 4.2m upgradable ITR. A mezzanine is provided for fusion device top structure laydown space and for temporary hot storage. There is one 250-tonne bridge crane in the tokamak cell to service the fusion machine components, including the top structure, and a separate bridge-mounted shielded cab for remote maintenance of the upper half of the fusion machine.

Upgradable considerations include an add-on steam conversion building and a turbine building (see Drawing AR-5). The steam conversion building houses the steam generating system components including steam generators. For the upgradable ITR, the blanket is not part of the plasma vacuum boundary and hence the probability of tritium migration into the primary helium coolant loop and the subsequent steam loop is very small. The steam conversion building is not a confinement building.

The facility layout as shown in Drawings AR-5 to AR-7 indicate a concept which has not been optimized due to the budgetary and time constraints of this scoping study.

The upgradable consideration for the BOP systems are discussed in Section 10.3. The potential schedule impact and cost implication are presented in subsections 10.5.3 and 10.5.4.

10.5.6. RECOMMENDATIONS

Based on the studies performed in the program planning area, it is recommended that:

1. The scoping studies segment of TNS project be expanded to include further tradeoff studies on the potential high-cost components of the ITR facility. This should include a tradeoff study on the size of the tokamak building with respect to different heating technology such as RF heating versus the neutral-beam injector system.

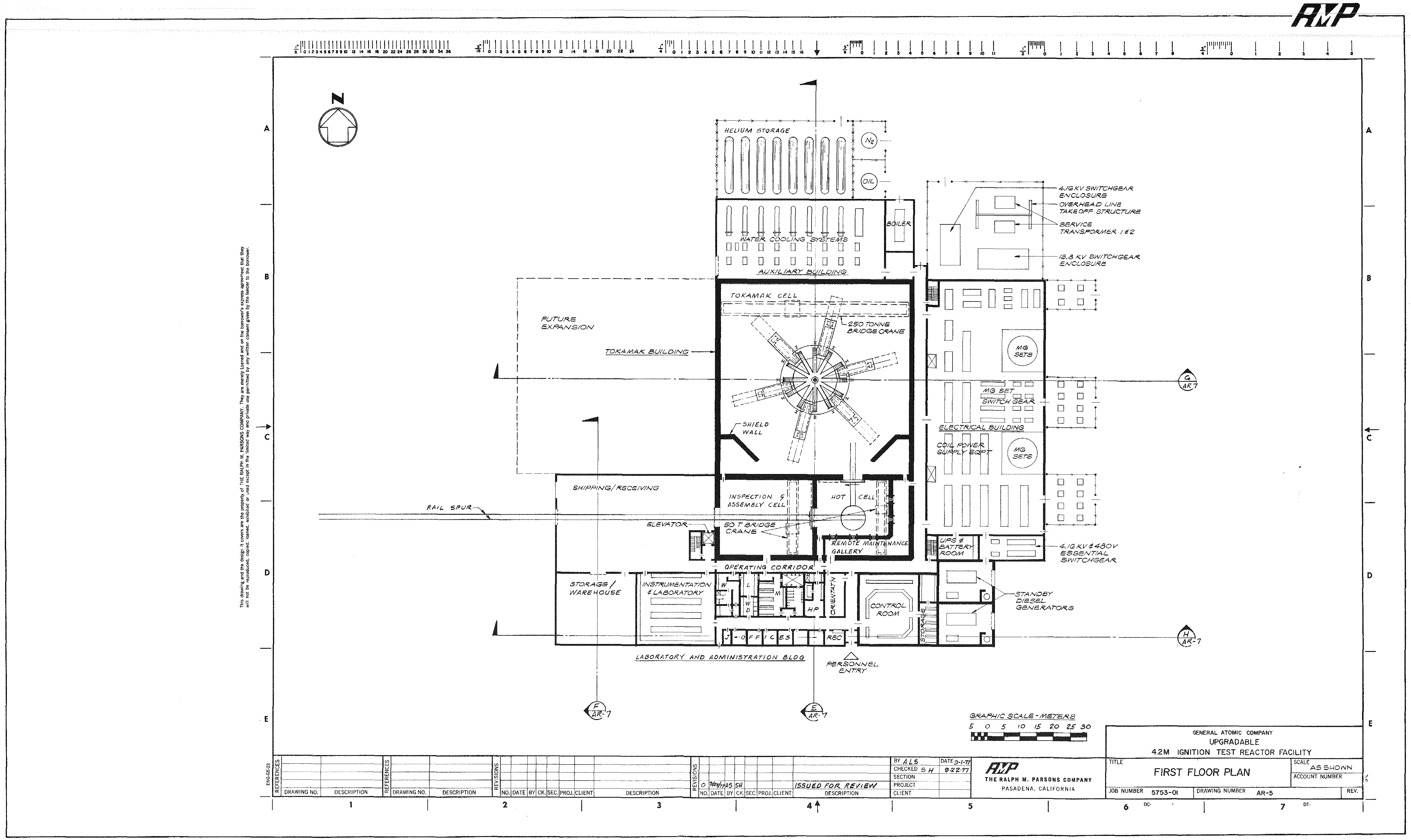
2. The site should be selected early with due consideration for the large electric power supply requirements and availability of site-related required information to facilitate BOP design.

3. In developing fusion device parameters, due consideration should be placed also on the BOP-fusion interface requirements as identified in this report.

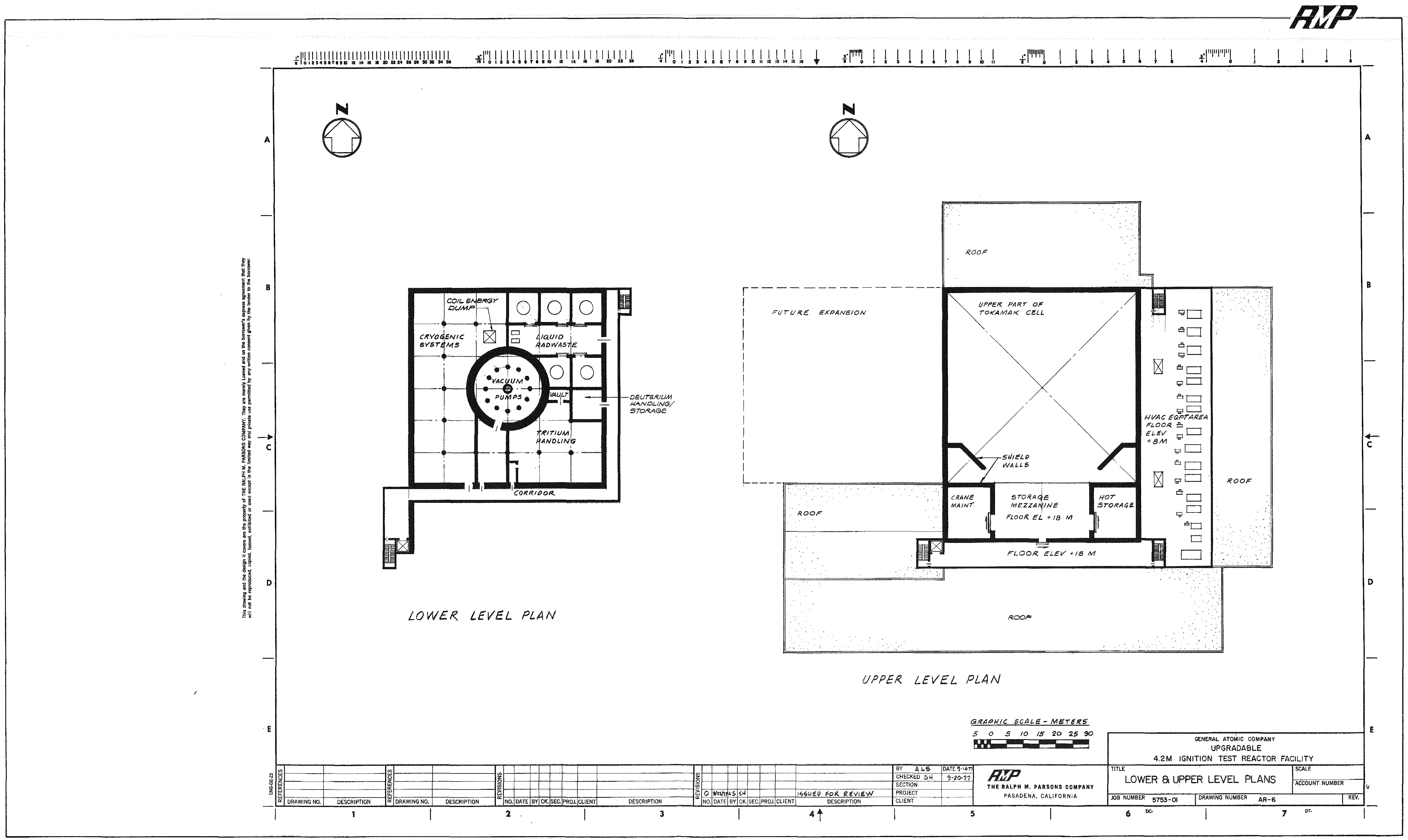
4. Early identification of regulatory requirements and general design criteria for fusion technology should be established.

5. Early selection of an A/E firm should be made to work in the TNS program so that there will be integral facility planning which will include both tokamak device component development and BOP planning.

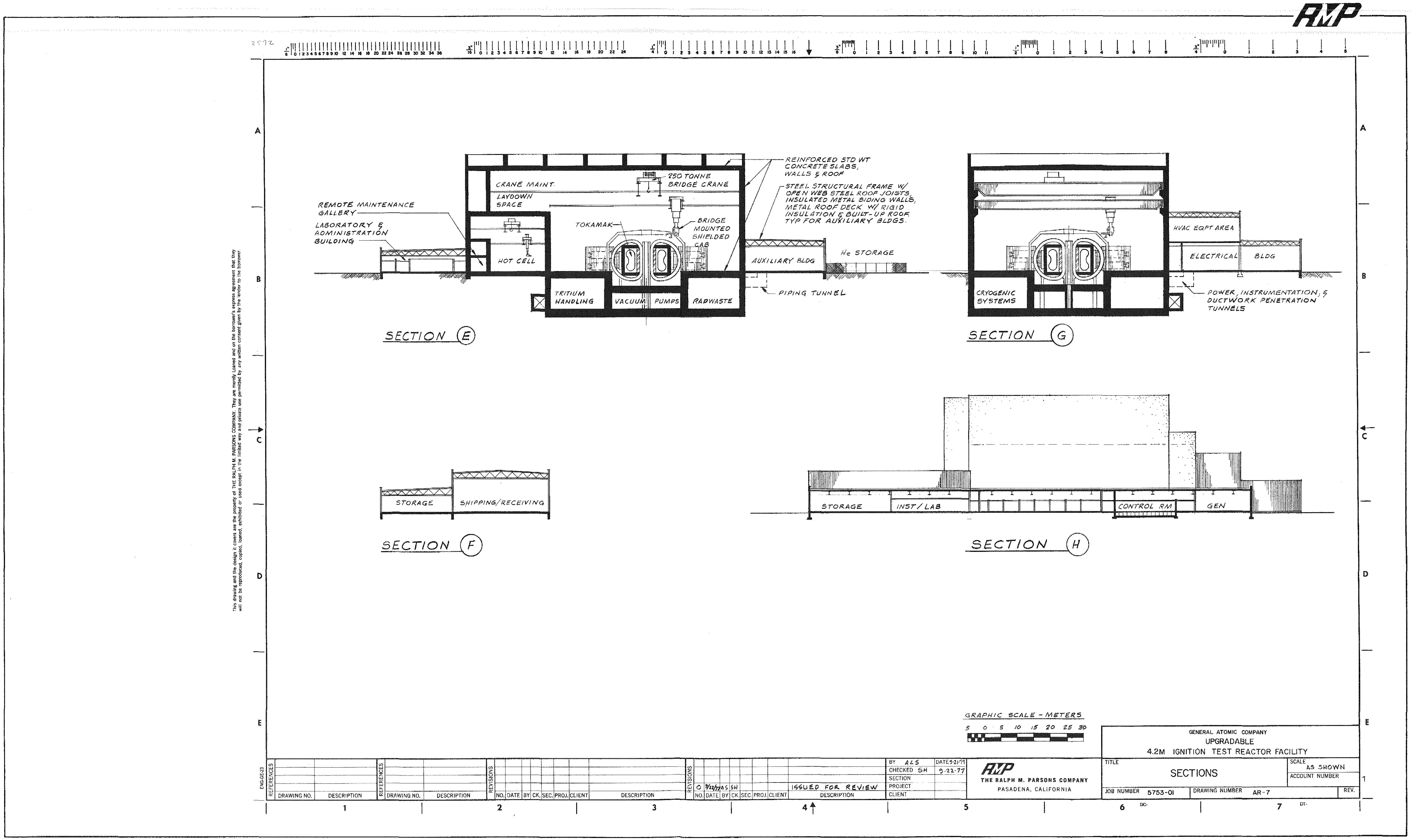
6. The necessary organization and procedure to facilitate coordination among various subcontractors and parties responsible for the TNS program should be established as soon as practical.



Drawing AR-5.
Upgradable 4.2m Ignition Test Reactor Factility - First Floor Plan



Drawing AR-6.
Upgradable 4.2m Ignition Test Reactor Facility - Lower and Upper Levels Plans



Drawing AR-7.
Upgradable 4.2m Ignition Test Reactor Facility - Sections

10.6. QUALITY ASSURANCE

10.6.1. INTRODUCTION

The establishment of quality assurance requirements for the design, fabrication, and construction of the ITR is based on the philosophy that quality assurance work elements shall be applied to systems, components, and structures commensurate with the importance of these items to the following objectives:

- Safety of the public beyond the site boundaries
- Safety of plant operating personnel
- Requirement for on-line reliability and investment protection

Consequently, the ITR Quality Assurance Program will impose a high degree of surveillance and control on certain items in the plant and a lesser degree of surveillance and control on other items. The impact of this philosophy will be to apply a classification system to all components, systems, and structures in the ITR, using the above delineated objectives as the basis for establishing the specific degree of importance within this classification system. In establishing the specific classification system for ITR, recognition will be given to the premise that there are no specific regulatory requirements currently imposed on fusion plants, as is currently the case for fission plants. Consequently, there are considerably less safety requirements that are needed for ITR, as compared to a nuclear reactor. However there are generic quality elements that should be embodied in any classification system that gradates the importance of the various items in the plant and, in so far as possible these elements will be considered. A basic concept in the development of ITR is that it is one of the first major fusion plants to be built and that its QA requirements will probably establish a baseline for quality assurance programs for future fusion plants. Accordingly, elements of quality assurance and quality control practices will be selected from existing industry codes and standards that are judged to be applicable to the objectives delineated above and which conform to the specific requirements of the individual classifications for ITR components, systems and structures.

It must be noted that in light of the operational reliability requirements of ITR as a physics experiment, it is anticipated that there may be certain systems or components within the ITR that represent first-of-a-kind items or design approaches. Consequently, these items will have a classification applied which relates to their "newness" or unique function in the ITR plant. Subsequent, or future fusion plants may, however, not consider these items unique and thus, the items may have different classifications chosen commensurate with their importance or uniqueness to the future plants in which they are contained.

The sections of this document delineate the quality assurance requirements to be invoked on the various participants involved in the design and construction of the ITR. It is assumed that the point of applicability of the program is the start of Preliminary Design work, or as currently defined in ERDA's system, the start of Title I; the termination of the applicability of this program is assumed to be completion of construction activities or the end of Title III. It is further assumed the preoperational testing, startup, and operation will be covered by a quality assurance program for operation, delineated by the contractor or the agent that is assigned by ERDA to operate the ITR.

All of the participants in the design and construction of the ITR will have appropriate quality assurance criteria imposed on them commensurate with the specific classification assigned to the work they perform in accordance with their contractual responsibilities. The overall quality assurance criteria for ITR is included in this document as Appendix A; as indicated previously, some participants in the project will have all of these criteria invoked on them while others will have less. The generation of Appendix A has been based on a philosophy that there should be a level of baseline quality assurance criteria generically applicable to fusion plants. The specific application, however, to the ITR project is delineated within the QA sections of this document, subject to more specific criteria being developed in future design development work on ITR. It is noted that the nineteenth criterion has been identified and appropriately included in the quality assurance criteria. Although training and qualification is by no means a new concept, its role and significance in this project is paramount, especially when ITR and fusion represent a significant new and sophisticated technology. It is recognized that refinements in this generic QA philosophy will probably occur as the ITR project development proceeds and certainly the specific application of QA to ITR will be more apparent during this project development.

10.6.2. MANAGEMENT CONTROL

In order to define interfaces and QA responsibilities at both the management and lower tier levels, it is useful to delineate a management and major contractor functional organizational philosophy for ITR: In terms of one concept, Appendix B shows the overall ITR project in terms of organizations or companies, interfaces and major responsibilities. The management control of the ITR, shown in Appendix B, starting with Preliminary Design (Title I), is predicated on the concept that a selected ERDA Project Office will utilize the GAC ITR Program staff as the overall ITR Project Management function for design and construction. It is assumed that a separate organization chart would be generated by GAC for the startup and operational phases of the project.

Reporting to the GAC ITR Program Director is the GAC QA staff responsible for the overall QA program for the complete engineering, design, and construction of the ITR project. They, in turn, would monitor the QA programs and QA functions in each of the contractor's organizations but the ITR QA function in these organizations would have a single direct line of reporting to the GAC through their respective Project Management staffs. Internally, within each organization, it would be required (as delineated in Appendix A), to have a separate line of reporting between the Project Management staff and the organization's management, and the QA function and the organization's management.

The GAC QA function for ITR would be responsible for developing an overall QA plan for the project. The purpose of the policies would be to set the guidelines for each of the contractors in developing their own QA procedures over the work for which they are contractually responsible. The ITR QA Plan would also define the type of QA activities each contractor would be expected to perform, the classification levels selected for the project, and the general guidelines for quality assurance activity to be applied to the various classification levels. It is not intended that the GAC/ITR/QA function define the details of how the QA function is to be carried out in each contractor organization; this is to be developed by each contractor himself and submitted to GAX/ITR/QA for approval. If a contractor's scope is large, then GAC/ITR/QA may request the development of a QA Plan first from that contractor, prior to the development of the QA procedures or the operating or project procedures that describe how the contractually responsible work is to be carried out. The advantage of having QA Plans from each of the major contractors is to utilize them in an overall QA Plan for the project, if one is required; the combination of the GAC/ITR/QA Plan, and those of the major contractors, should adequately describe the total QA Program for ITR.

For subtier contractors, vendors, and suppliers, it will be the responsibility of the major contractors to determine the need and extent of the QA/QC programs required from those lower tier organizations. The major contractors, as purchasers, will be required to determine the classification of work to be performed by the lower tier organizations and evaluate the quality of the work of those organizations including their QA/QC Programs, to perform to ITR requirements. Included is the responsibility for selecting, qualifying, and approving vendors and contractors for their scope of work. This fundamental quality assurance practice cannot be overemphasized since it is at these interfaces where control of quality has generally been subject to breakdown.

During the course of work by each contractor, it will be the responsibility of the QA function within each organization to provide the required surveillance over the work performed under the specific contract through inspections and examinations at prescribed frequencies and by formal audits. Such surveillance also includes examining the proper qualification and certification of personnel as required by company procedures and industry Codes, Standards, any regulatory requirements which might be imposed in the future. Qualification of personnel also includes training and orientation in the technical discipline in which an individual is involved, and in the methods and techniques used by an organization to control and demonstrate, by objective evidence, the adherence to quality requirements.

10.6.3. ENGINEERING AND DESIGN CONTROL

Those contractor design organizations, responsible for performing engineering and design work, as required by contract, shall have their design control system documented and approved prior to inception of the work. It shall cover the control of design input, control of the design process, control of design changes to approved design documents, and verification of the design. Verification shall include checking of design document such as drawings, specifications, calculations, and special testing, fabrication and erection documents, by individuals other than those who prepared or originated the design. In addition, Design Reviews shall be performed on a system, building, or design package basis. Such reviews shall normally be conducted by the contractor responsible for that part of the design work but where complex interfaces exist, GAC/ITR/QA may elect to conduct a combined design review, covering the work of several contractors.

At the current time there are no specific regulatory requirements or industry Codes and Standards specifically denoted as applying to fusion plants. There are, however, Codes and Standards that do apply to classes of equipment and components relative to the required performance of these items, and these should be used where their applicability in a fusion plant, or the ITR, is very similar to their application in other industrial fields or other types of plants. Examples of this would be Sections I and VIII of the ASME Code for equipment and components that function in a high pressure environment, but not having radioactive material contained within them; Section III - Division 1 of the ASME Code and ANS1 B31.1 for items that contain radioactive material, such as tritium, (care, however, should be given to utilizing proper Code Class); IEEE Electrical Standards for critical or extremely reliable electrical equipment; SNT-TC-1A for nondestructive examination, when it is felt necessary to conduct such examinations. Where other standards and industry practices used in sophisticated technology plants, are to be applied to a fusion plant, then that portion of the industry Standards and practices should be incorporated directly into design specifications or a generic fusion standard should be generated (if it applies beyond just ITR). When it is recognized that such existing codes, standards and practices are nonexistent or inadequate to meet the needs of this new technology project, an organization responsibility should be identified to coordinate the development of new or supplemental codes, standards and practices.

This responsibility should include the establishment of an interface between contractors and the applicable material standards writing organization.

In view of the experimental nature of the ITR, the engineering effort in each contractor's organization should include the development of specific inspection and examination points, which the engineering function determines are important and should be inspected by the purchaser, or some other organization designated by the management contractor. The responsible QA function over that area of work should review and augment, as required, these engineering recommendations to assure that the expenditure is commensurate with the benefits to be gained by the inspection or examination effort.

One of the main functions of the engineering effort is the identification of the various items in the plant as to a specific quality level (QL) classification. In order to accomplish this it is necessary to define the various ITR quality levels so that systems, components and structures can be identified and thus meaningful, but not excessive, quality assurance program elements or activities can be applied to the design, procurement and construction work, associated with these plant items. The quality level classification chosen for ITR, is as follows:

1. Quality Level 1 (QL-1) - This level applies to components, systems and structures whose failure can cause an unacceptable release of radioactive material to the public at the site boundary; or whose failure can cause a shutdown of the ITR in excess of (TBD), even allowing for the ability to perform maintenance and repair operations.

2. Quality Level 2 (QL-2) - This level applies to components, systems and structures whose failure can cause a release of radioactive material inside the plant boundary to an unacceptable level to plant operating personnel, or whose failure can cause a shutdown of the ITR in excess of (TBD), even allowing for the ability to perform maintenance and repair operations.

3. Quality Level 3 (QL-3) - This level applies to components, systems and structures which are not classified as QL-1 or 2 because their satisfactory performance has negligible impact on safety and is not required to maintain satisfactory operation of the ITR, allowing for the ability to perform rapid maintenance and repair operations.

The final design documents, issued by the responsible contractor, will indicate the QL of the item under consideration. The broad identification of QL designation will be nominally accomplished by designated engineering personnel within the contractor's organization, based on the system classification approved by GAC. The contractor's QA function would perform detailed verification of the selection, with spot checking performed, as required, by GAC/QA. It should be noted that the above definitions for each of the three QL's can be considered as generic for fusion plants. However, it is anticipated the time elements chosen for limiting plant shutdown is more specifically directed towards ITR, as a physics experiment, rather than the values that might be chosen for a future fusion plant whose mission would be to produce electrical power.

Another main function of the engineering effort is to clearly identify those items which require traceability. It should be noted that item A.8. of the quality assurance criteria, "Identification and Control of Items" is not intended to imply traceability and is not required for all items. It is the responsibility of the designing organization to identify those items requiring traceability.

10.6.4. PROCUREMENT AND MANUFACTURING CONTROL

Most of the major contractors (Appendix B) under the ITR Program Director are expected to be responsible for the procurement of material, equipment, components and services. This activity shall be controlled to an extent consistent with the importance of the item or service being procured, as noted by the appropriate QL classification.

One of the initial important steps in the procurement process is the evaluation of the procurement document, prior to submission of that document to suppliers for bidding. The QA function in the appropriate Purchasing Organization shall assure that the following information has been incorporated, as required:

- Scope of work to be performed by supplier
- Technical requirements including all necessary design document
- Quality assurance/quality control requirements to be placed on supplier commensurate with QL classification
- Right of access to supplier's shop for purchaser and ERDA
- Documentation requirements to be provided to purchaser and the required timing
- Identification of nonconformances and purchaser's requirements as to disposition and approval

Another element in the selection of an acceptable supplier is the evaluation of his bid response from a management, technical and quality standpoint. While the engineering function in the purchaser's organization is responsible for determining technical adequacy of the supplier, the QA function should review the supplier's quality program (response to bid request), past history of inspection or examinations of supplier, or as an alternative, conduct a quality survey. Suppliers with industry Code, Standard, or recognized authority certifications may have these certifications used as a basis for establishing the quality performance of the supplier. Suppliers, judged to be marginal performers, should only be selected when the purchaser's inspection program is planned to provide sufficient surveillance to assure that marginal performance will not occur on the ITR Purchase Order under consideration; otherwise suppliers judged to be marginal performers should be avoided. Concerns or questions over the supplier's QA/QC Program should be resolved at a very early date, preferably prior to placement of the purchase order.

During the course of vendor fabrication or supply of services, inspection programs shall be planned and carried out in a documented manner. As an important step in this activity, early contact between the purchaser and the supplier should be implemented to assure that the supplier understands the quality requirements of the purchase order and the methods, techniques, and procedures the supplier intends to follow in meeting these quality requirements. During this initial inspection planning phase, the purchaser shall evaluate the quality control or inspection program inherent to the supplier's organization and operation. The philosophy of purchasing on the ITR is to primarily select those companies that have adequate QC and/or inspection programs within their own organization, so as to minimize the extent and depth of the purchaser's inspection requirements; however, because of the first-of-a-kind potential for some items in the ITR, it may not always be possible to fully depend on the supplier's inspection program and consequently the purchaser may have to add inspection depth of his own to the purchase order; this is an assessment that should be made by the purchaser's staff. In general, however, the philosophy that should be followed for generic fusion plants is to provide purchaser inspection activities primarily to examine the quality control program of the suppliers and perform spot inspection over the implementation of that program including checking of the vendor's own inspection program. Where the product items are unique or marginal vendors are required, then the purchaser should increase his inspection and vendor audit activities.

10.6.5. CONSTRUCTION CONTROL

The philosophy shown in Appendix B, covering the organizational approach to the construction effort is to utilize the services of an on-site Construction Management Contractor who directs the activities of the various construction contractors, the exact number of which depends on just how the major design contractors break up their design packages. The ITR Construction Management (CM) Contractor would be responsible for the procurement activity associated with selecting construction contractor sources, evaluating their quality program capabilities, and preparing the bid requirements and documents for specific construction packages. In this latter area there is an interface with the design contractors, since these organizations will be responsible for preparing the design documents that are to be used by the CM in procuring the services of the various construction contractors.

The CM will have a QA staff function attached to its site organization to assist in delineating the proper quality control requirements (depending on the appropriate QL) to the contractors who are bidding, and to evaluate the QC program of the selected contractor as meeting the overall QA Plan requirements. The CM/QA function will also be responsible for providing surveillance and audits of the site construction contractors, as well as auditing the activities of the other CM organizational elements participating in the ITR project. Again the emphasis in selecting construction contractors will be to concentrate on those organizations having documented and practical QC and inspection programs of their own, so as to minimize the CM/QA activity; if the construction contractor has a good QC and inspection program of his own, the inspection and surveillance of the CM/QA staff, over that contractor, is minimized. Where Code certifications and stamps are required of the construction contractor, the CM/QA will pay particular attention to the quality requirements involved and the collection, on schedule, of appropriate Code Data Reports.

Another major interface between the CM and the design contractors is in the area of field change control. It is inevitable that because of many reasons, changes will have to be considered to prior approved design documents. The construction contractor will have to have rapid decisions from the CM field engineering personnel when it appears that a design change must be considered because of the inability to construct an item(s) at the site, or because correcting a construction deficiency will severely delay schedule and increase cost. In many cases the CM's field engineering staff may not be able to make decisions of design change because it may have impact on many facets of the design, or may even affect several design contractors. The CM/QA function will have to work out a feasible method with the design contractor's QA function for quickly responding to requests for design changes when they have been identified and documented at the construction site.

There are numerous test laboratories which normally will be expected to provide site test and examination services, i.e: concrete, steel, NDE, etc. In the formulation of the organization in Appendix B, consideration will have to be given to whether the CM/QA function maintains these services in a centralized manner to support the work of the construction contractors, or whether the individual contractors provide their own services, as part of their QC program, which would be subject to surveillance and audit by the CM/QA function. It would not be prudent to specifically delineate, at this time, the philosophy for ITR because, to a large degree, it depends on the size of the design packages which, in turn, dictate the scope of services of an individual construction contractor. In general, it would be anticipated that large construction contractors, who would require extensive laboratory test services, may, in the interests of efficient construction services and minimum schedule delays, have their own laboratory test services. For small contractors, with minimum laboratory service requirements, the CM/QA function could maintain a centralized activity. This approach, however, may result in several different laboratory services, located at the site, performing the same type of services. This issue should be examined in detail by the CM/QA function as a construction planning activity.

As part of the CM's responsibility at the site, a receiving inspection activity shall be set up as part of the overall receiving and warehousing function. The purpose of this activity is to assure that equipment and material received at site is not damaged and the software required to support its acceptance is on file at the site. If such is not the case, then these items should be either rejected, and returned, or segregated as required. In accordance with Appendix A criteria, nonconformances would be generated and sent to the procuring agency to effect resolution. Additionally, those items that had not been inspected at the source should be inspected at the site, to the degree necessary, beyond just the examination of possible shipping damage.

10.6.6. APPLICATION OF QA ACTIVITY TO QUALITY LEVEL CLASSIFICATIONS

As indicated earlier, the scope and depth of QA activity for the most part, will depend on the classification level selected for the system, component or structure, which, for ITR, is described as QL 1, 2, 3. It is obvious that the QL-1 items are the most important, while QL-3 items are the least important. In order to provide a framework and philosophy for defining the extent of the QA program for these various levels, we describe herein examples of gradations of QA activity which would be applied to the various levels; we have broken down these example activities to the design, procurement, and construction phases of the project.

During the engineering and design phase, it is anticipated that all plant systems, components, and structures will be designated as QL-1, 2, or 3. For these items, normal design checking within, and external to the design element responsible, will be performed in accordance with the basic operating procedures of the design contractor involved. However, in addition it would be anticipated that QL-1 items would receive a formal design review with a singular individual selected for directing this review, and utilizing other individuals as necessary. It could be accomplished individually within each design contractor's organization or among several organizations. It is anticipated that QL-2 items would receive a level of design review, somewhat less than QL-1, perhaps in specific areas, by specific people. QL-3 items are considered as industry standard items, requiring no design review. The QA function would maintain in-process recording of these design reviews and assure that recommendations for changes were incorporated into the design (recycling of design documents) or were resolved as required by the Project Director organization. To the extent that these additional reviews and checks are performed on QL-1 items, compared to QL-3 items, the greater the requirement for quality verification (the lower the QL number), the greater is the requirement for maintaining quality records.

In the procurement phase, for QL-1 and 2 items, vendor selection and evaluation would be reviewed by the QA staff and detailed inspection plans prepared. In addition, vendor QC programs would be evaluated prior to placement of a purchase order. If an unusual unique item was involved, or a vendor selected who was generally unknown to the equipment involved, then a pre-award survey could be conducted. For QL-3 items it would not be necessary to develop detailed inspection plans or perhaps even perform source inspection (receiving inspection would suffice), unless the design contractor specified such requirements because of uniqueness.

In the construction phase it is intended that the site QA function, attached to the CM organization, provide specific surveillance over the QC activities for QL-1 and 2 items. Such surveillance would include reviewing the construction contractor inspection reports for completeness and adequacy. The CM-QA activity would perform specific spot inspections, on a scheduled basis, of QL-1 activities by the construction contractors, and random unscheduled (except for special unique areas in (ITR) inspections of QA-2 areas. Generally QL-3 areas of work by the construction contractor would not require CM-QA surveillance unless requested by the design contractor. In nonconformance reporting, resolution, and followup, it would be required that CM-QA activity control the overall process for QL-1 and 2 items, but would not be required to follow up on QL-3 nonconformances. However, an audit of QL-3 construction work would be conducted by the CM-QA staff semi-annually to assure that ERDA is obtaining work in accordance with contractual commitments, and suggestions for improvement will be noted.

The above discussion, and the classification system delineated for ITR, has not considered the requirement for QA surveillance in the plant that would nominally fall into QL-3, but which can be construed as providing security or safeguards features to the plant (i.e: guard houses, floodlights, fencing, intrusion systems and alarms, etc.) This is an area that may well have to be considered so as to provide generic security and safeguard features to fusion plants of the future, especially fusion power demonstration plants or production plants. In this consideration, it will be necessary to determine whether these items can fit into the existing classification for a specific plant, or whether a special classification level (QL-4) would have to be delineated, together with a philosophy of what QA activity would be applied to this level. For the ITR, however, as an experimental facility, on a government owned or controlled site, we do not believe that QA requirements related to security and safeguards features should be considered.

APPENDIX A

ITR QUALITY ASSURANCE CRITERIA

A.1. ORGANIZATION

The design and construction organizations required to comply with this criterion shall have a documented organizational structure, with responsibilities, authorities, and lines of communication clearly delineated in writing, for performing activities affecting quality in accordance with the classification system imposed on ITR. These activities include both the performing functions of attaining quality objectives and the functions of assuring that an appropriate quality assurance program is established and verifying that activities affecting quality have been correctly performed. Persons or organization of elements responsible for ensuring that an appropriate quality assurance program is established and for verifying that activities affecting quality have been correctly performed shall have sufficient authority and organizational freedom to (1) identify quality problems; (2) initiate, recommend, or provide solutions to quality problems through designated channels; (3) verify implementation of solutions; and (4) control further processing, delivery or installation until proper disposition of a nonconformance, deficiency, or unsatisfactory condition has occurred. Such persons or organizational elements shall have direct access to responsible management at a level where appropriate action can be effected. Such persons or organizational elements shall report to a management level such that required authority and organizational freedom are provided.

A.2. QUALITY ASSURANCE PROGRAM

A documented quality assurance program shall be planned, implemented, and maintained in accordance with specified requirements of this appendix, a classification system developed for the particular facility involved, and the contractual scope of work assigned to the project participants. The program shall identify the activities and items to which it applies. The establishment of the program shall include consideration of the technical aspects of the activities affecting quality to an extent consistent with their importance as defined in the classification system. The program shall be established at the earliest time consistent with the schedule for accomplishing the activities.

The program shall provide for the planning and accomplishment of activities affecting quality under suitably controlled conditions.

Controlled conditions include the use of appropriate equipment, suitable environmental conditions for accomplishing the activity, and assurance that prerequisites for the given activity have been satisfied. The program shall take into account the need for special controls, processes, test equipment, tools, and skills to attain the required quality and the need for verification of quality by inspection, examination, or test.

Management of those organizations responsible for implementing the quality assurance program or portions thereof, shall regularly assess the adequacy of that part of the program for which they have designated responsibility and assure its effective implementation.

A.3. DESIGN CONTROL

The design shall be defined, controlled, and verified. Applicable design inputs shall be appropriately specified on a timely basis, and correctly translated into design documents. Design interfaces shall be identified and controlled. Design adequacy shall be verified by competent persons other than those who designed the item. Design changes, including field changes, shall be governed by design control measures commensurate with those applied to the original design.

A.4. PROCUREMENT DOCUMENT CONTROL

Applicable design bases and other requirements necessary to ensure adequate quality shall be included or referenced in documents for procurement of items and services. To the extent necessary, procurement documents shall require contractors to provide a quality assurance program consistent with the pertinent requirements of this attachment, the classification system, and their contractual scope of work.

A.5. INSTRUCTIONS, PROCEDURES, AND DRAWINGS

Activities affecting quality shall be prescribed by, and performed in accordance with, documented instruction, procedures, or drawings, of a type appropriate to the circumstances. These documents shall contain appropriate quantitative or qualitative criteria for determining that such activities have been satisfactorily accomplished.

A.6. DOCUMENT CONTROL

The preparation, issue and change of documents which prescribe activities to be performed that require quality considerations and those documents that prescribe the quality considerations and requirements themselves shall be controlled to ensure that correct documents are being employed. Such documents, including changes thereto, shall be reviewed for adequacy and approved for release by authorized personnel.

A.7. CONTROL OF PURCHASED ITEMS AND SERVICES

The procurement of items and services shall be controlled to ensure conformance with specified requirements. Such control shall provide, as appropriate, for source evaluation and selection, evaluation of objective evidence of quality furnished by the supplier, source inspection or audit, and examination of items upon delivery.

A.8. IDENTIFICATION AND CONTROL OF ITEMS

Controls shall be established to ensure that only correct and accepted items are used or installed. Identification shall be maintained on items or in documents traceable to these items.

A.9. CONTROL OF PROCESSES

Processes affecting quality of items and services shall be controlled in accordance with specified requirements. Special processes such as welding, heat-treating, and nondestructive examination shall be performed by qualified personnel using qualified procedures.

A.10. INSPECTION

Inspections shall be planned and executed by, or for, the organization performing activities affecting quality to verify conformance to documented instructions, procedures and drawings for accomplishing the activities. Scope of inspections and methods to be employed, to determine conformance with specified requirements, shall be defined. Inspection results shall be documented. Inspection for acceptance shall be performed by appropriately qualified persons other than those who performed or directly supervised the work.

A.11. TEST CONTROL

Testing required to demonstrate that items conform to specified requirements and will perform satisfactorily in service shall be identified, controlled and documented. Tests shall be performed in accordance with written procedures which incorporate or reference test acceptance criteria based on the applicable design documents. Test results shall be recorded and their adequacy evaluated.

A.12. CONTROL OF MEASURING AND TEST EQUIPMENT

Tools, gages, instruments, and other measuring and test equipment used for activities affecting quality shall be controlled and calibrated and adjusted at specified periods to maintain accuracy within necessary limits.

A.13. HANDLING, STORAGE, AND SHIPPING

Handling, storage, cleaning, packaging, shipping, and preservation of items shall be controlled to prevent damage or loss, and to minimize deterioration.

A.14. INSPECTION, TEST, AND OPERATING STATUS

The status of inspection and test activities shall be indicated either on the items or in records traceable to the items where necessary to assure that required inspections and tests are performed. The authority for application and removal of status indicators shall be defined. The inadvertent operation of systems and components shall be prevented by use of controls such as by tagging.

A.15. CONTROL OF NONCONFORMING ITEMS AND SERVICES

Items and services which do not conform to specified requirements shall be controlled. Controls shall provide for identification, documentation, evaluation, segregation when practical, and disposition of nonconformances and notification to affected organizations.

A.16. CORRECTIVE ACTION

Conditions adverse to quality shall be promptly identified, investigated, documented, evaluated and corrected. In the case of a significant condition adverse to quality, the cause of the condition shall be determined and corrective action taken to preclude reoccurrence. The identification, cause and corrective action planned and taken for significant conditions shall be documented and reported to appropriate levels of management. Followup action shall be taken to verify implementation of corrective action.

A.17. QUALITY ASSURANCE RECORDS

Records shall be specified and maintained to furnish documentary evidence of activities affecting quality. Records shall be legible, identifiable, and retrievable. Records shall be protected against damage, deterioration, or loss. Requirements and responsibilities for record transmittal, distribution, retention, maintenance, and disposition shall be established and documented.

A.18. AUDITS

Planned and scheduled audits shall be performed to verify compliance with all aspects of the quality assurance program, and to determine its effectiveness. These audits shall be performed in accordance with written procedures or checklists by appropriately trained personnel who do not have direct responsibility for performing the activities being audited. Audit results shall be documented, reported to and reviewed by responsible management. Followup action shall be taken where indicated.

A.19. TRAINING

Personnel, whose activities affect quality, shall be appropriately indoctrinated, trained and qualified as required to develop their competence for performing their activities. Measures shall be implemented to assure that suitable proficiency is achieved and maintained.

APPENDIX B

ITR PROJECT FUNCTION ORGANIZATION INTERFACES

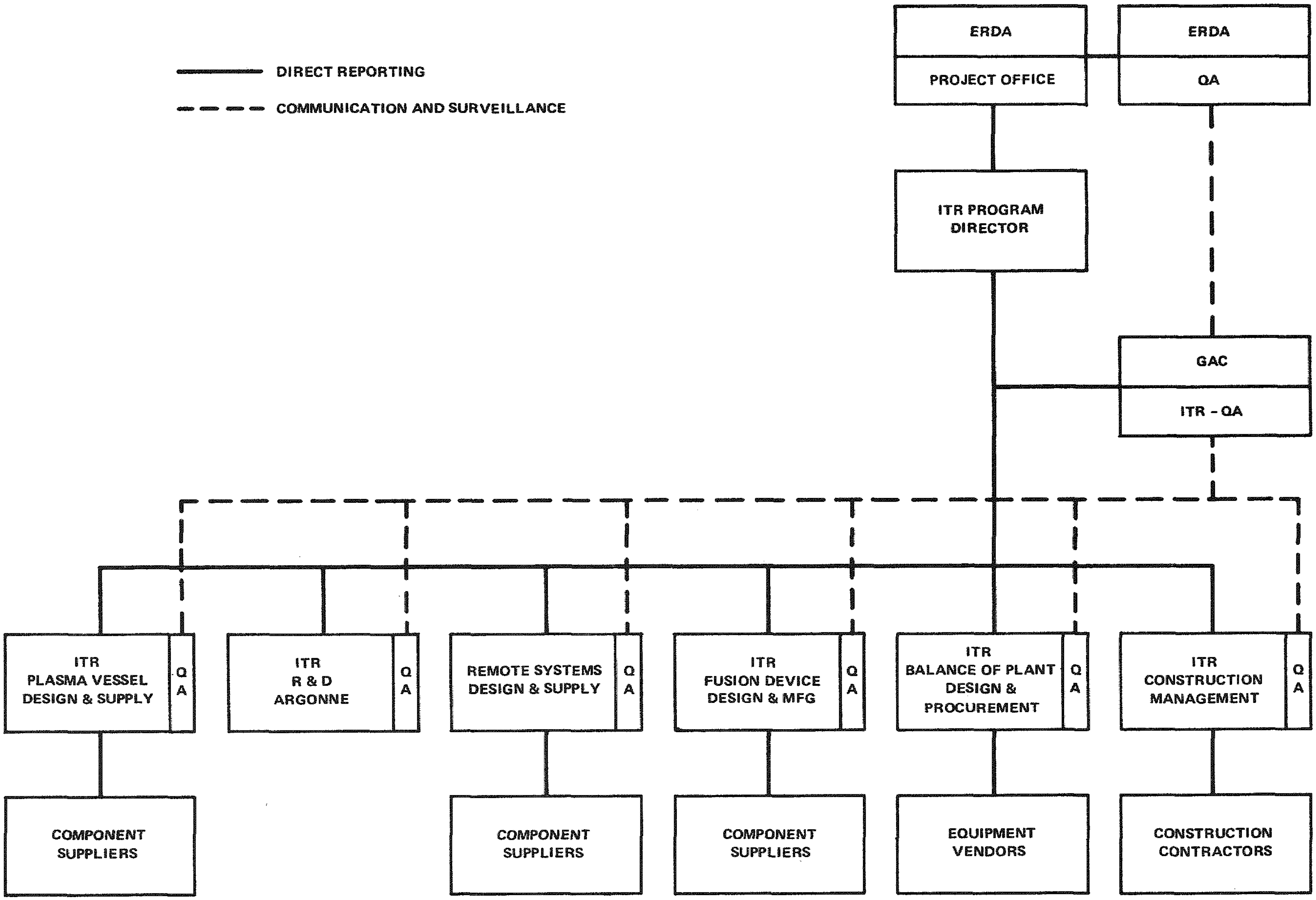


Figure B-1. ITR Project Functional Organization Interfaces