Cy. # 31a

NP-7331

A PROPOSAL FOR A NUCLEAR POWER STEAM GENERATING PLANT FOR THE RURAL COOPERATIVE POWER ASSOCIATION ELK RIVER, MINNESOTA

PREPARED FOR THE

U. S. ATOMIC ENERGY COMMISSION

BY

NUCLEAR PRODUCTS - ERCO
DIVISION OF ACF INDUSTRIES, INCORPORATED
WASHINGTON, D. C.

188-001

January 31, 1958

TABLE OF CONTENTS

188-002

LIST OF ILLUSTRATIONS

188-003

II

SUMMARY

This proposal is submitted by ACF Industries, Incorporated to the U. S. Atomic Energy Commission pursuant to the Commission's Invitation for Proposals dated October 11, 1957, for the design and construction of a boiling water nuclear reactor contemplated by the Rural Cooperative Power Association of Minnesota under the second round of the Atomic Energy Commission's Power Reactor Demonstration Program. This proposal is responsive to the Invitation without exception.

ACF Industries, Incorporated through its Nuclear Products-Erco Division will be responsible for the complete design, construction and operational testing of the nuclear reactor steam generating plant. In carrying out this work, ACF will use the Maxon Construction Company of Dayton, Ohio, as the construction subcontractor and Sargent & Lundy Engineers of Chicago, Illinois, as the architect engineer.

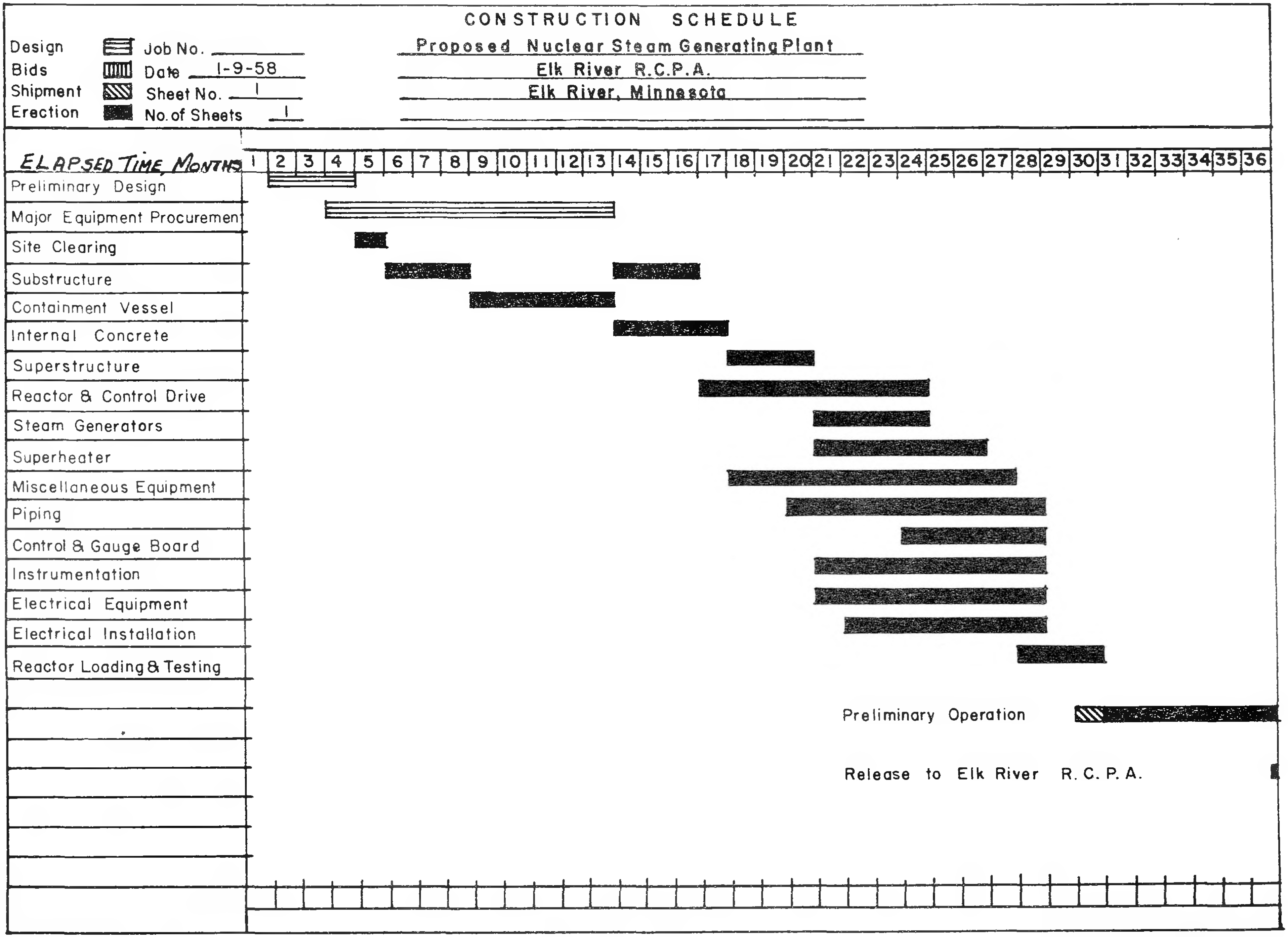
The plant proposed herein is characterized by a boiling-water type nuclear reactor operating at a thermal power of 58.2 megawatts, supplemented by a conventional coal-fired superheater of 14.8 megawatt capability. The rated output of the system is 225,000 lb per hour of 600 psig, 825 F steam, measured at the RCPA turbine throttle.

The nuclear reactor proposed herein may be most accurately described as a modified EBWR type machine, containing 148 specially designed fuel elements consisting of urania-thoria pellets in assemblies of stainless steel tubes. Cooling is by natural convection and boiling of the light water moderator, with control being effected by 9 cross-shaped absorber rods driven from the under-side of the reactor vessel. Circulation of the moderator-coolant outside the reactor vessel to suitable heat exchangers induces vaporization of pre-heated steam plant feed water, for subsequent introduction to the superheater, with all process equipment of the system except the superheater being housed in a suitable containment vessel type building. The estimated life of the fuel array proposed herein is twenty-seven months and whereas its thermal rating is 58.2 megawatts, current EBWR experience indicates an ultimate capability in the 80-100 megawatt range, which capability can be established in the proposed plant without major modification.

Included in this proposal are preliminary design data and physical concepts which were the basis of plant performance and cost predictions. Included also are the anticipated scope of work and the expected division of responsibilities among ACF, AEC and RCPA. It is expected that certain of the design concepts will undergo modification in the detail design; however, it is felt that the fundamental technical criteria developed herein will characterize the finished plant.

ACF proposes to initiate plant operation 29 months after official authorization to proceed by the AEC. Such authorization would of necessity be subject to the terms and conditions stated in the proposal and further amplified in the cover letter to this proposal. ACF proposes to transfer operating responsibility to RCPA 36 months after the authorization to proceed.

188-004


CONSTRUCTION SCHEDULE
Proposed Nuclear Steam Generating Plant
Elk River R.C.P.A.
Elk River, Minnesota
Design
Bids
Shipment
Erection
Job No.
Date 1-9-58
Sheet No. 1
No. of Sheets 1
ELAPSED TIME MONTHS
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Preliminary Design
Major Equipment Procurement
Site Clearing
Substructure
Containment Vessel
Internal Concrete
Superstructure
Reactor & Control Drive
Steam Generators
Superheater
Miscellaneous Equipment
Piping
Control & Gauge Board
Instrumentation
Electrical Equipment
Electrical Installation
Reactor Loading & Testing
Preliminary Operation
Release to Elk River R. C. P. A.

III

SCOPE

ACF Industries, Incorporated (ACF) through its Nuclear Products-Erco Division, proposes to enter into a contract with the U. S. Atomic Energy Commission (AEC) to provide the equipment and services required for the development, design and construction of a nuclear reactor for installation on the Rural Cooperative Power Association (RCPA) system.

1. ACF shall furnish the following services and equipment:

A. Services

(1) ACF will provide the complete design for the nuclear reactor proposed herein, including preparation of all drawings and specifications relating to the reactor components and systems as described elsewhere in this proposal.

(2) Performance of all nuclear and engineering calculations, analyses, and studies required for successful performance of the reactor.

(3) Revision of drawings and specifications as required during the course of the project and submission of one complete set of reproducible-transparencies of the project drawings revised to the "as-built" condition, with six sets of "as-built " prints.

(4) Procurement, scheduling, expediting, inspection and test of all materials, components, and systems to be supplied by ACF.

(5) Preparation of Hazard Reports as required.

(6) Preparation of design, cost, and procurement progress reports to AEC at regular intervals, to be specified by AEC, but in no event more frequently than once per month.

(7) Preparation of the required plant operating manuals.

(8) Performance of research, development, and engineering services as described in this proposal in order to establish a fuel element consistent with the requirements and specifications of the reactor proposed herein.

(9) Performance and supervision of the following test operations on the proposed reactor:

(a) Such pre-neutron operating tests as are necessary and practical prior to completion of construction of the proposed reactor plant.

(b) Upon completion of construction, further pre-neutron operating tests as in the opinion of ACF may be deemed appropriate or necessary.

(c) Upon completion of all cold (pre-neutron) tests, a criticality run and any further tests which in the opinion of ACF are appropriate or necessary. These would include a complete check of all nuclear and process instrumentation.

(d) Upon completion of tests in Section (c) above, step-wise elevation of reactor power to full rating of 225,000 lb/hr of steam at 600 psig and 825 F delivered at the turbine, with superheater in operation at rated capacity.

(e) Operation of the reactor for a period of 60 days by, or directly under the supervision of, ACF personnel, assisted as required by AEC designated personnel.

(f) Operation of the reactor for a period of 60 days by AEC designated personnel under direct supervision of and assisted by ACF personnel.

(g) During the periods described in Sections (e) and (f) above, personnel designated by the AEC will receive reactor operating training under ACF supervision to establish capability and proficiency required for licensing by the U. S. A.E.C. Reactor operating power levels during these periods will be at the discretion of ACF, but in no event will the reactor be operated at higher than full power rating. It is understood that AEC designated personnel, referred to herein will be in fact, employees of RCPA.

B. <u>Equipment</u>

The equipment to be provided by ACF is described, in detail, in Section IV of the proposal, "Technical Discussion". This equipment includes the following:

(1) Reactor and building complete.

(2) Reactor control and instrumentation systems complete.

(3) Steam generating unit.

(4) Reactor auxiliary systems.

(5) Reactor building ventilation system.

(6) Steam superheater and building complete.

(7) Steam delivery line to the turbine and a boiler feed line from RCPA's fourth stage heater.

(8) Fuel elements for the initial core loading plus 15% spares.

(9) Extension of existing water, steam, and electrical utilities required for connection with nuclear plant.

ACF's responsibilities under this proposal and under the proposed contract will terminate upon completion of the operating test program outlined under this section I or 200 days after the first reactor criticality, whichever occurs first, (except as to warranties of suppliers).

2. The items to be furnished by AEC or RCPA shall include, but not be limited to, the following:

A. AEC shall provide:

(1) Existing AEC owned technical data and other information required by ACF in carrying out ACF responsibilities herein.

(2) Fully enriched UF_6, without charge to ACF.

(3) Indemnification of ACF, its subcontractors and their suppliers against losses arising from nuclear hazards and incidents.

B. RCPA shall provide:

(1) All construction, erection and installation labor and labor supervision for items and equipment beyond the termination of the steam line.

(2) Plant auxiliary buildings, power, water and distribution systems for both construction and operating facilities, and all supporting facilities incident to plant operation.

(3) Reasonable space for erection of temporary construction and storage buildings and approximately 300 square feet of unencumbered floor area in the general vicinity of the turbine for the reactor control room.

(4) Site preparation to the extent required to permit direct excavation by ACF. In addition, the RCPA will provide access roads as required to the site, will remove any and all above-grade encumbrances such as utility lines, conveying equipment, etc., to permit direct excavation by ACF and will supply to ACF two sets of "as-built" drawings and plot plans from which excavation can be planned to insure against interruption of existing operations or disturbances of existing structures and equipment.

(5) Necessary office space for ACF and subcontractor personnel in the immediate vicinity of the proposed plant.

(6) Necessary alterations to the existing coal bunker so that it will be adjacent to the superheater and permit direct connection of a gravity fed coal chute to be provided by ACF.

IV

TECHNICAL DISCUSSION

A. DESCRIPTION OF OVERALL FACILITY

1. Proposed Cycle

The steam generating plant proposed for the Elk River RCPA facility will be designed to furnish a steam flow of 225,000 lb/hr of 600 psig, 825 F steam at the turbine throttle as specified by the requirements of the bid invitation.

The system for this plant is basically a two circuit steam generating unit operating with a boiling water nuclear reactor. The primary coolant circulation outside of the reactor and recirculation within the reactor are by natural convection. Both circuits are designed for future application of forced circulation for increased capacity if desired.

In the primary circuit, 258,000 lb/hr, saturated steam is generated within the reactor at 875 psig pressure at rated capacity and is passed from the reactor vessel to a primary heat exchanger where the steam condenses to give up its heat to a secondary coolant for the indirect production of steam. The resulting saturated primary liquid returns through a sub-cooler to the reactor at 449 F.

In the secondary circuit, 225,000 lb/hr feedwater from the operator's fourth stage heater is pumped through the shell side of the sub-cooler for preheating, then to the shell side of the primary heat exchanger, converted to steam, superheated in a coal fired superheater, and delivered to the turbine throttle at 600 psig 825 F.

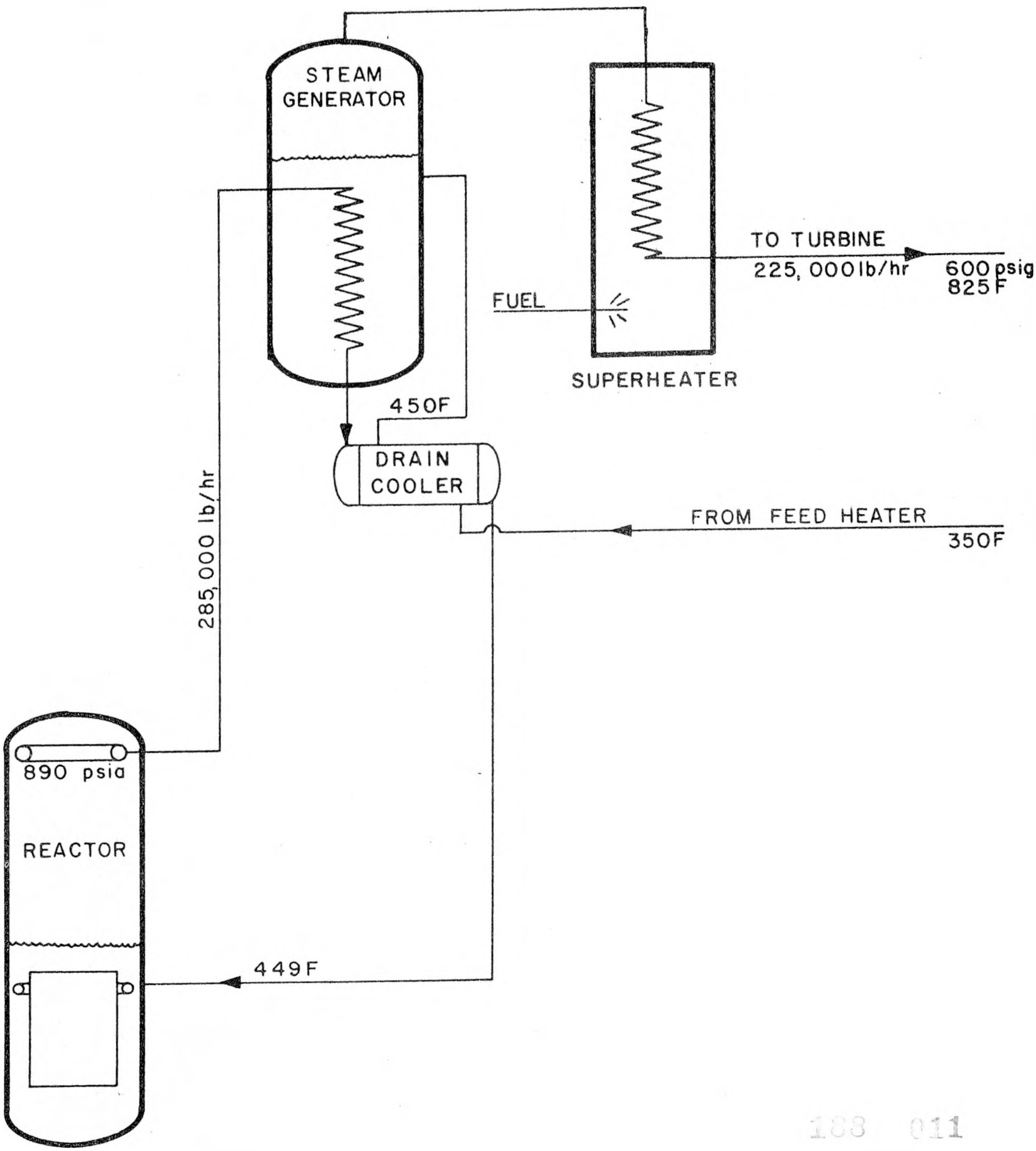
The main advantage of the indirect method for generating steam for electrical power production is the absence of radioactivity in secondary steam which permits continuous access to the electrical power plant.

The reactor produces 58.2 MW of heat and the separately fired (coal) superheater produces 14.8 MW of heat. The steam produced is fed to a turbine-generator operating at 22,000 KW electrical output.

A schematic diagram of the power plant is shown in Figure 1, "Flow Diagram" and a simplified flow diagram is shown in Figure 2.

SIMPLIFIED FLOW DIAGRAM

FIG. 2



188 011

BOILING WATER POWER REACTOR

ACF INDUSTRIES, INCORPORATED

2. General Arrangement

The general arrangement of the reactor and superheater installation are shown on Figure 3, General Arrangement Proposed Nuclear Steam Generating Plant, and Figure 4, Superheater General Arrangement and Plot Plan. The reactor, steam generators, and their auxiliaries will be located in a containment vessel while the superheater and its auxiliaries will be located in an enclosure located adjacent to the existing power plant. The control room will be located adjacent to existing plant controls.

Other principal equipment in the reactor building will include reactor water purification equipment, air conditioning equipment, emergency condenser, fuel storage and waste disposal tanks, and biological shielding. All radioactivity is therefore confined to the reactor building.

Ample compartmentalization for major equipment is provided in order that maintenance may be performed while the remainder of the plant is operating at reduced capacity.

3. Containment Vessel

A containment vessel is required to prevent the spread of radioactive material in the event of a circuit rupture. This containment vessel may be occupied during normal operation. The design pressure for the containment vessel will be 27 psig and the design will be in accordance with Section VIII of the A.S.M.E. Boiler and Pressure Vessel Code with certain exceptions, e.g., no pressure relief valve. Upon completion of the erection of the containment vessel, a thorough testing program will be performed to insure the integrity of the shell.

Normal access for personnel into the containment vessel will be provided by an airlock consisting of two manually operated doors in series with an interlocking arrangement which assures that one door is closed at all times. A large bolted freight door will be provided to permit removal of large pieces of equipment; however, as this will not be an airlock, its use will be restricted to periods when the reactor is not operating.

Temporary steel columns will be required to support the structure during erection and testing of the vessel. Upon completion of this phase of the project, a concrete foundation will be poured under the vessel for the purpose of carrying the internal equipment and shielding loads.

4. Biological Shielding

Biological shielding is provided as protection against radiation consisting of neutrons from the reactor core and gamma rays. Corrosion products from the entire system, induced activity from materials which have captured neutrons, fragments of fuel elements, and contributions from N^{16} and O^{19} make up the sources of gamma rays. Levels of radiation entering the primary system will have sufficient magnitude to require biological shielding. The design of the shielding will incorporate compartmentalized arrangements to make it possible to service equipment during operation of the remainder of the plant.

5. Air Conditioning System

Several heating and ventilating units located within the containment vessel will provide normal ventilation. These units will draw outside air into the vessel, circulate the air within the vessel, and exhaust air from the vessel through the vent stack, as shown on Figure 3. Both the inlet and exhaust ducts will have quick-closing valves actuated by a radiation monitoring system. The exhaust stack contains sufficient volume before the valve to serve as a hold-up tank for a period long enough to allow the valve to close, thus preventing the escape of radioactive gas to the atmosphere.

6. Electrical Distribution System

All process and control information will be fed into a centralized control room located within the existing building from which all major operational decisions will be made. An auxiliary instrument area close to the control area will be required to house the equipment associated with indicators or recorders on the control boards.

Where radiation problems exist, shielding and equipment arrangements will be designed so that standard control devices can be used to their fullest extent.

The auxiliary power supply for the reactor and superheater plant is indicated on Figure 5, Single Line Diagram. The auxiliary power supply will be from two auxiliary power transformers. One full-size auxiliary power transformer will be connected to the generator leads through a disconnect switch. The reserve auxiliary transformer, also full size, will be connected to an existing 13.8 kv bus through an oil circuit breaker. The plant auxiliary voltage will be 440 volts, 3 phase, 60 cycle.

The station auxiliaries will be fed from 440 volt unit substations of standard indoor metal clad type with air circuit breakers. Switchgear and motor control centers will feed the remaining auxiliaries which are not essential to the safe shutdown of the reactor. Additional motor control centers are located in the existing building to serve the superheater auxiliaries.

B. REACTOR COMPLEX

1. Reactor Vessel

The reactor vessel is approximately 84 inches internal diameter, 23 feet high, 3-3/8 inches thick and conforms to the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII. It is fabricated of carbon steel and is internally clad with a 3/32 inch layer of type 304 stainless steel. Fig. 6a shows the reactor vessel arrangement.

A thermal shield of 1 inch thick stainless steel containing 1 percent Boron surrounds the core area and is spaced 1 inch from the vessel wall. This design provides an annulus for the flow of water to cool both the shield and vessel wall.

The core is centered in the pressure vessel. An 11 inch annulus between the core and thermal shield serves as a downcomer for natural water circulation. Feedwater at 449F enters the reactor through two 6 inch nozzles and a distributing ring above the downcomer. The feedwater cools the water in the reactor as it enters the downcomer with the result that the water entering the fuel elements is subcooled about 3F. A light, louvered shock shield 1/8 inch thick is installed above the water level line to prevent thermal shock to the pressure vessel as a result of impingement by cold boric acid solution.

The steam dome above the water level is approximately 7 feet, 6 inches high and designed to provide low steam velocity for good steam - water separation and low steam radioactivity. A "dry pipe" collects the steam for discharge from the vessel through two 8 inch steam nozzles at near 100% steam quality.

The design of the reactor vessel also incorporates inlet and exit nozzles for future increase in heat output to be obtained by forced circulation. The water would enter below the core, rise through the core, flow downward peripherally and leave the reactor by a side outlet at the base. Provisions are made for future installation of a shroud to surround the core and bottom grid for the forced circulation water up through the core elements for increased power at a later date.

2. Core Structure

The reactor core structure consists basically of a lower support grid and upper guide plate fastened together by means of tie rods and encased in a shroud which extends from the lower grid to a point two feet above the upper guide plate. There are 164 fuel element spaces in the lower grid plate, and under normal conditions 148 of these will be occupied with elements. The lower plate will bear the entire weight of the fuel and will transmit this load to the pressure vessel by means of six legs attached to the bottom of the grid and resting on the pressure vessel. The upper guide plate will locate the fuel elements and prevent any lateral motion. Each fuel element is constructed so that the upper portion forms a spring padded box which can be centered into the guide plate. All structural parts, as described above, are of AISI Type 304 stainless steel.

The proposed core arrangement is shown on Fig. 6. The active core height is 60 inches and the active radius is 28.45 inches.

The reactor core is reflected on all sides by about 10.5 inches of light water. This is the coolant water surrounding the reactor core and gives a good reflector savings to the core in the radial direction. The reflectors on top and below the core are made up of water and steel. This offers additional reflector savings although somewhat less than pure water.

3. Reactor Core Performance

The hydraulic characteristics of the Elk River Core were examined for the proposed design of 148 elements each consisting of a 5 x 5 array of 0.450 inch diameter tubes on a 0.75 inch pitch. The heat balance employed gave a division between heating the water and boiling:

Heat absorbed in boiling	173,000,000 BTU/hr
Heat absorbed in heating the water	24,800,000
Total reactor heat	197,800,000 BTU/hr (58.2 MW)

Boiling commences on the average approximately 0.944 feet from the bottom of the active element and occurs over a length of 4.056 feet. The average inlet water velocity is 4.05 feet per second for 58.2 TMW operation. The recirculation ratio is 28.2 to 1 giving 2.9F of subcooling at core inlet and a recirculation of 18,900 gpm of water.

The resulting performance parameters for the core are tabulated below:

Average power density in the coolant - 39.6 KW/liter
Average inlet velocity - 4.05 feet/second
Average Reynolds number - 320,000
Average exit quality - 0.036
Average exit void fraction - 0.312
Average void fraction over boiling length - 0.237
Average void fraction in the core - 0.192

Average heat flux - 89,800 BTU/hr. ft.^{2}
Total steam rate - 258,000 lb/hr.
System pressure - 875 psig
Boiling temperature - 531F
Inlet water temperature - 528.1F
Feedwater return temperature - 449F

The calculations were based on the use of a 2 foot shroud above the core. In addition, allowance is made for scaling as observed in the Experimental Boiling Water Reactor at Argonne.

On the basis of Borax IV and recent EBWR tests, the core as presently designed will operate without any evidence of boiling instabilities. Recent EBWR operation at an average power density of 62.5 KW/liter and 40 to 50% exit voids produced no instability or reactor oscillation. These conditions are both more severe than proposed here.

A total core life of 27 months may be obtained by inserting the 22 spare elements, each of double uranium loading, at the end of a 15-month core period. In this arrangement, the 22 center elements are withdrawn and are replaced by 22 peripheral elements. The 22 spare elements are inserted in the now vacant peripheral positions. The burnout distribution is shown in Fig. 7; the diagram supposes 15 months operation without disturbing the element arrangement, then transfer of elements as outlined above for an additional 12-month period.

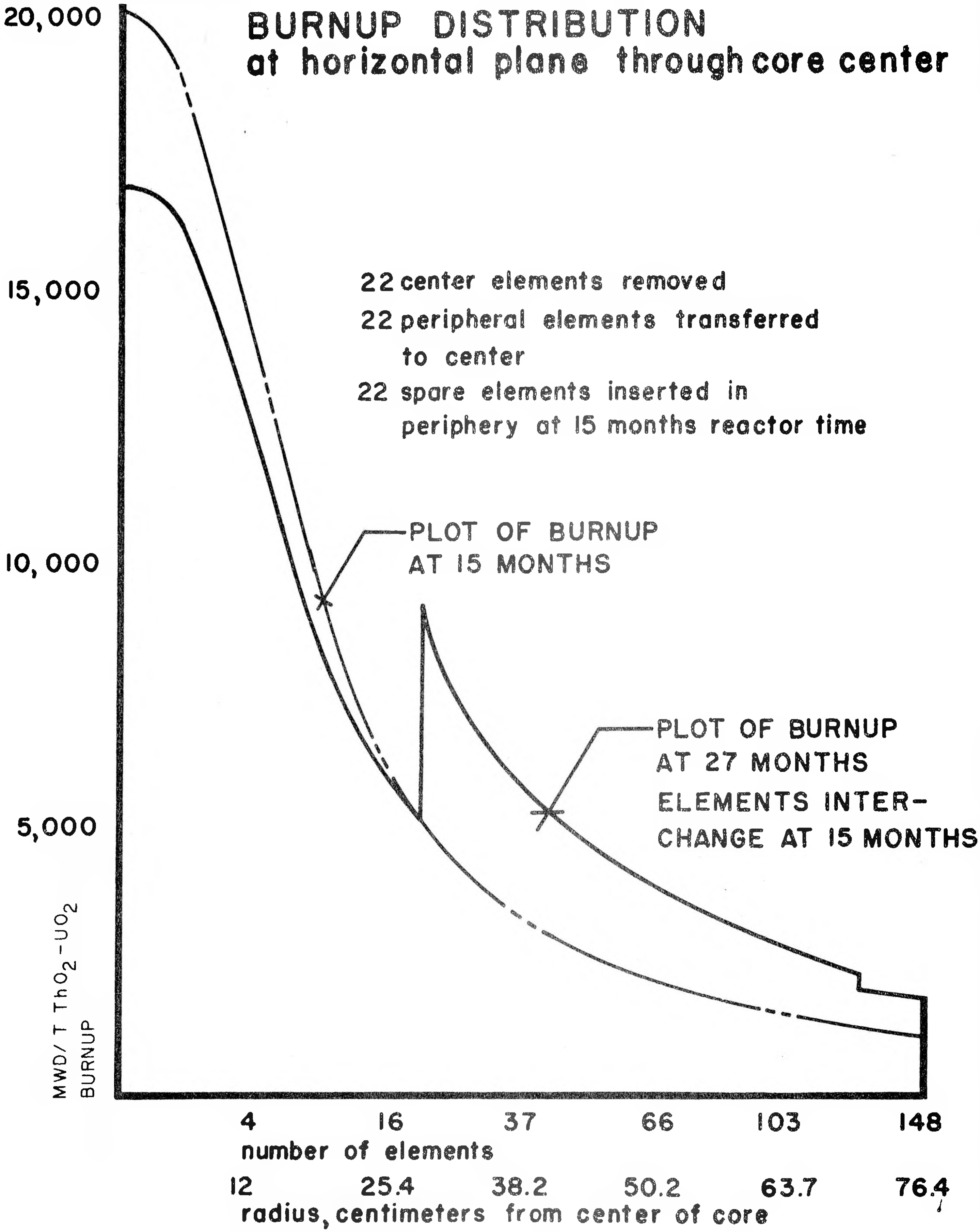
The proposed Elk River fuel element consisting of urania-thoria pellets clad in stainless steel has been evaluated to determine possible temperatures and stresses. The fuel element consists of a stainless steel tube containing a stack of pellets according to the following specifications.

Dimensional Data

Tube I.D. - 0.410"
Tube wall thickness - 0.020"
Thoria-urania pellet diameter - 0.407"
Total effective pellet length - 5 feet
Number of rods per element - 25
Total number of fuel elements - 148
Total number of rods - 3700

Material Data

Pellet composition-thoria + 90% or better enriched uranium
Thoria density - 95% theoretical
Urania density - 95% theoretical
Steel tube composition - 304 stainless steel ELC



BOILING WATER POWER REACTOR

ACF INDUSTRIES, INCORPORATED

FIGURE 7

For a reactor power of 58.2 MWT and a maximum to average local power distribution of 3.45 the local heat flux was found to be:

Average - 89,800 BTU/hr. ft.^{2}
Maximum - 310,000 BTU/hr.ft.^{2}
Burnout - 900,000 BTU/hr.ft.^{2}

The heat flux can thus be seen to be well below the burnout point at all locations in the reactor core. Numerous correlations exist for the boiling heat transfer burnout heat flux. The lowest value calculated from these correlations was selected as given above.

The burnup of fuel and accumulation of fission products is based on 450 days of operation between refueling and a 100% plant factor.

Average metal atom percent burnup - 0.815
Average total atom percent burnup - 0.271
Average MWD/Ton (Thoria and Urania) - 5870
Maximum metal atom percent burnup - 2.82
Maximum total atom percent burnup - 0.938
Maximum MWD/Ton (Thoria and Urania) - 20200

The temperatures and stresses incurred in a fuel pin located in various regions of the core were examined. A pin operating in the region of average flux with nominal clearances gave the following performance:

Heat flux - 89,800 BTU/hr.ft.^{2}
Boiling fluid temperature - 531F
Stainless steel outside surface temperature - 545F
Stainless steel inside surface temperature - 560F
Surface temperature of thoria-urania pellet - 1396F
Center temperature of thoria-urania pellet - 1830F
Compressive stress in the S. S. tube - 9820 psi
Thermal stress in the S. S. tube - 2520 psi

A pin operating in the region of maximum flux and having nominal clearances gave the following performance:

Heat flux - 310,000 BTU/hr. ft.^{2}
Boiling fluid temperature - 531F
Stainless steel outside surface temperature - 566F
Stainless steel inside surface temperature - 618F
Surface temperature of thoria-urania pellet - 1421F
Center temperature of thoria-urania pellet -3420F
Compressive stress in the S. S. tube - 4910 psi
Thermal stress in the S. S. tube -8700 psi

The pin specifications do not under any of the circumstances considered, lead to temperatures in excess of the melting point of the mixture. The stresses resulting from a combination of thermal stresses and tensile stresses are all within the 14000 psi yield strength of 304 ELC stainless steel. The proposed pin therefore satisfies both thermal and structural limitations under the most adverse conditions.

4. Reactor Fuel

(a) General Description

The fuel element proposed for this reactor is shown by the drawing (Fig. 8) and photographs (Figs. 9 & 10) included in a later portion of this proposal. To better understand the manufacturing techniques and to insure the design characteristics, ACF has fabricated a full scale dummy element as shown in these photographs. The element consists of a 5 by 5 square array of fuel tubes complete with a lower fuel guide adapter and an upper fuel handling adapter. Each AISI Type 304 ELC stainless steel tube is 0.410" inside diameter and 0.020" minimum wall thickness. The tube is closed on both ends with slotted end pieces which are welded into the support grids of the lower and upper adapters. Each fuel tube contains 120 fuel pellets, 2 thermal insulators and a hold-down spring.

The UO_2 is a compound of uranium of greater than 90 percent uranium-235. The thorium contained in the ThO_2 acts as the fertile material and is converted into uranium-233 in the reactor core.

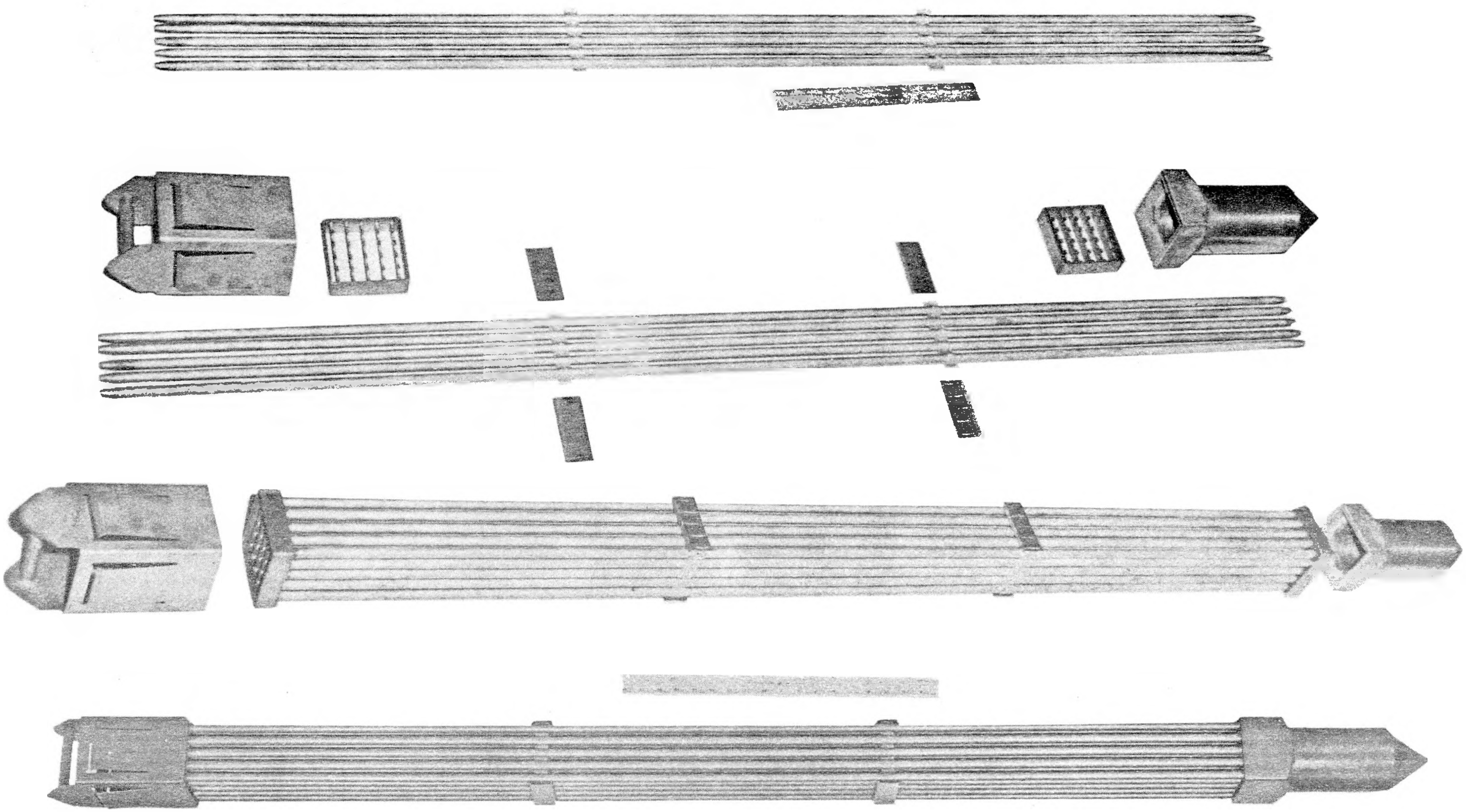
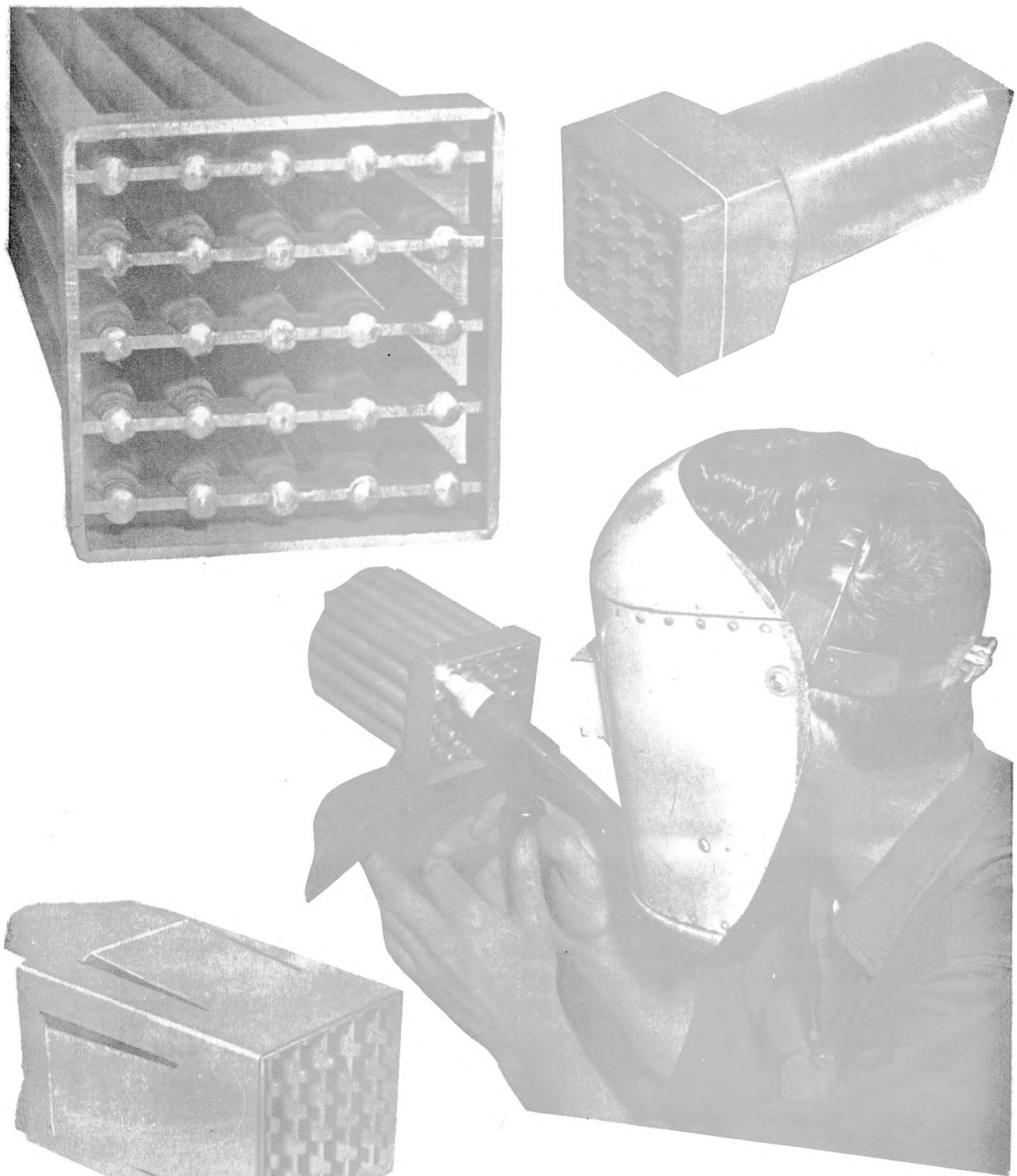


FIG. 9

BOILING WATER POWER REACTOR
PROPOSED FUEL ELEMENT ASSEMBLY,
ACF INDUSTRIES, INCORPORATED



188 021

BOILING WATER POWER REACTOR
PROPOSED FUEL ELEMENT FABRICATION
ACF INDUSTRIES, INCORPORATED

The pellets are 0.407" diameter and 0.500" long, and are specified to be of a minimum of 90% of theoritical density. The 148 regular fuel elements are loaded with pellets each containing .349 grams uranium-235. Twenty-two spare fuel elements are provided which are loaded with pellets, each containing 0.833 grams uranium-235. Helium gas at 1 atmosphere standard temperature and pressure furnishes the heat transfer bond between the pellet and the tubing wall. A thermal insulating wafer of sintered magnesium oxide is placed at the ends of the fuel pellets to prevent overheating with resulting thermal stresses of the end closures. The hold-down spring placed in the fission gas space above the pellets is provided to assure mechanical stability of the core.

The individual fuel tubes are joined by AISI Type 304 stainless steel tabs at positions one-third and two-thirds of the distance along the length. The separate tabs are brazed to the tubes and spot welded together. The end tab of each row of tubes is welded into a short side plate which thus holds the rows of tubes firmly in position.

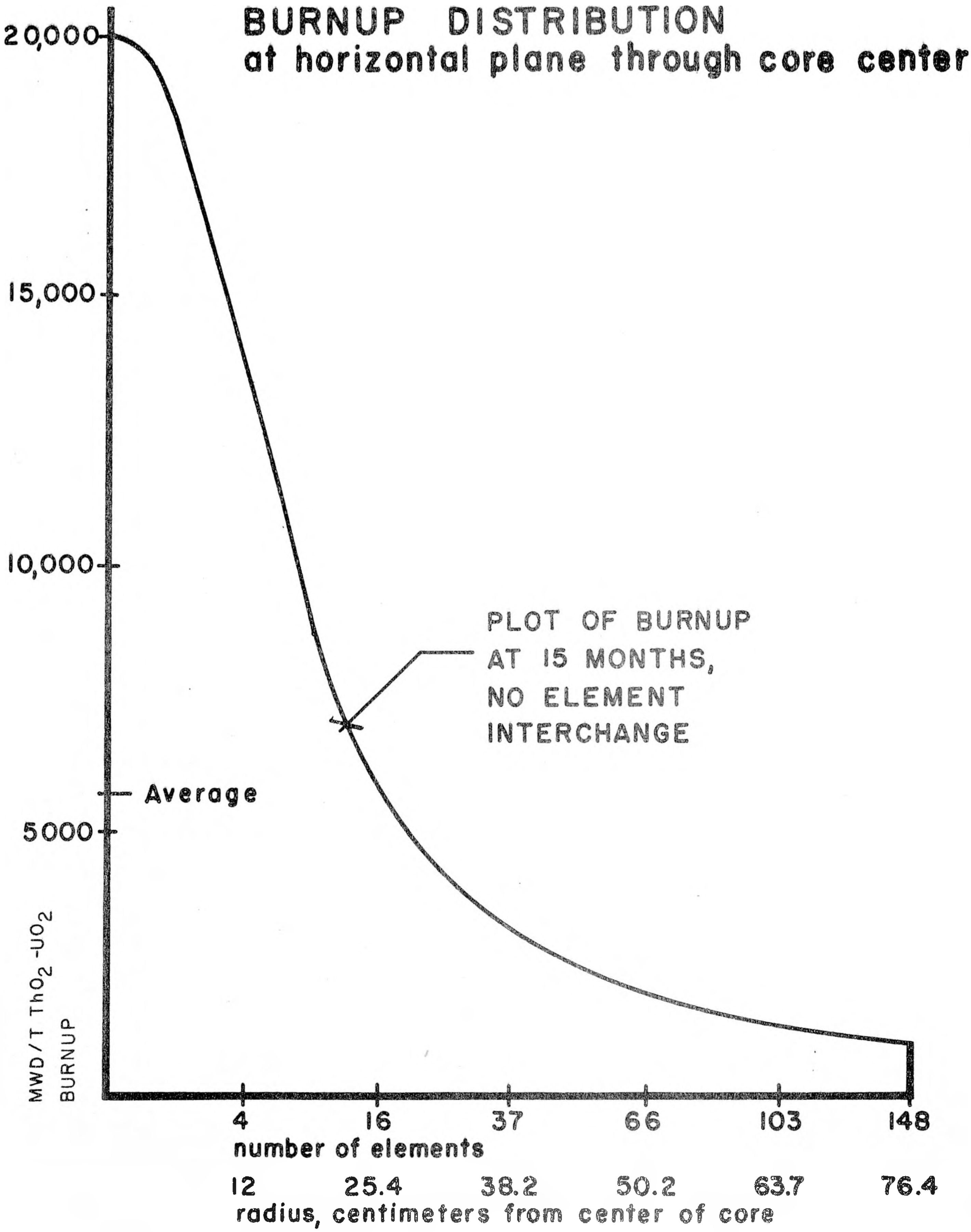
(b) Fuel Rotation Program

Enough fuel is contained in the normal loading of 148 fuel elements to allow fifteen months continuous reactor operation. At this time the highest burnup, approximately 20,000 megawatt days per ton of UO_2-ThO_2, occurs in the central pellets of the four center fuel elements. A contemplated research and development program to prove the validity of this design burnup is described under Section IV-D2. Fig. 11 approximates an idealized distribution of the burnup horizontally through the core at center. Note that the maximum unit burnup occurs in the center 24 elements.

An interchange of elements sometime before the end of the cycle would substantially reduce the total burnup in the center 24 elements. Figs. 11a and 12 elaborate this idea to show burnout distribution for fuel cycles involving a 24 element interchange at 12 months and 7-1/2 months, respectively.

5. Reactor Physics

The reactor core physics calculations are presented in this section in tabular and graphic form and describe the core condition as a function of reactor operating time. The general characteristics of the core have been described earlier in this proposal and will not be repeated here. Since the core is similar in size and shape to the EBWR at Argonne National Laboratory, use has been made of existing information established at that facility.

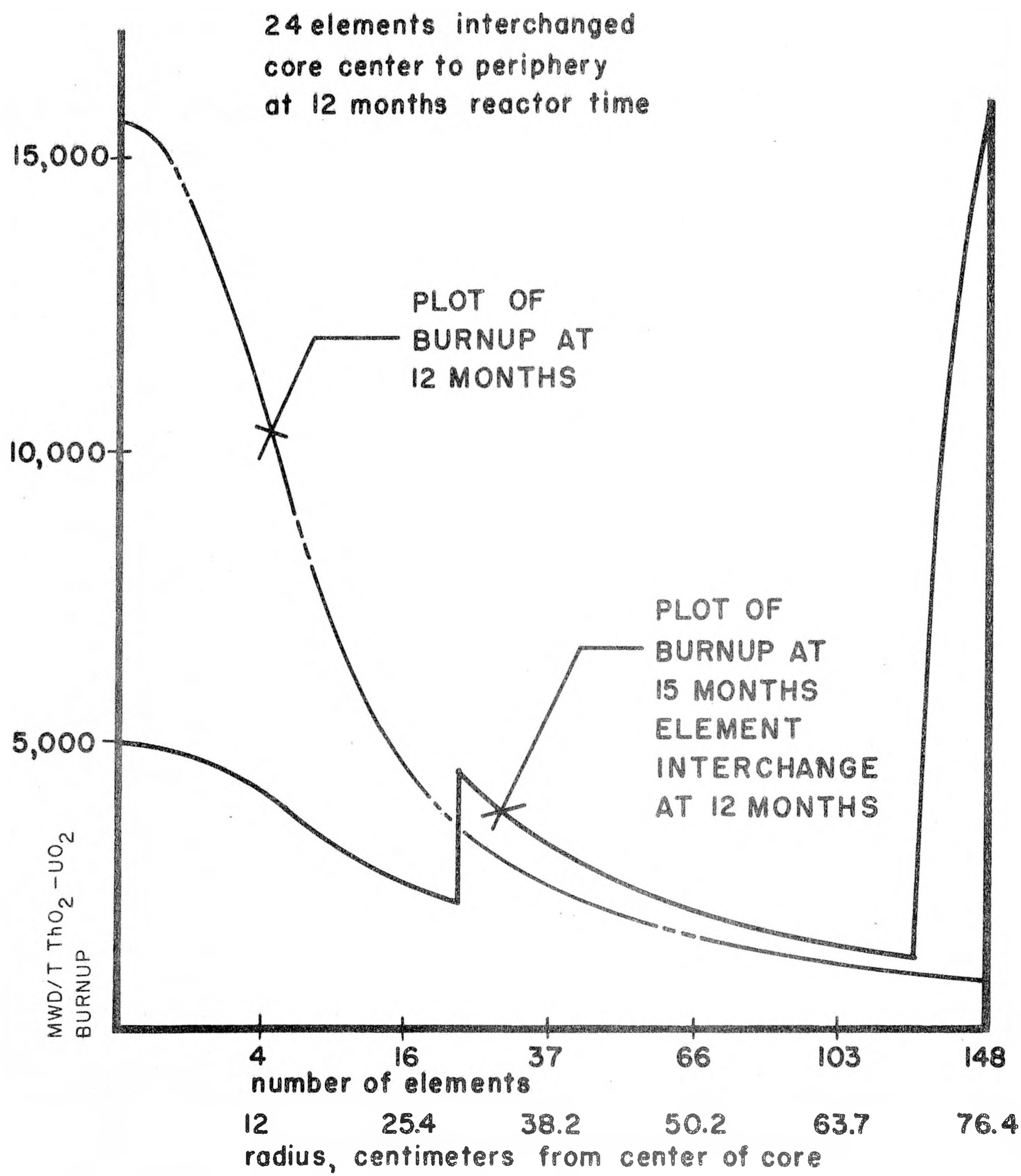


BOILING WATER POWER REACTOR

ACF INDUSTRIES, INCORPORATED

FIGURE 11

BURNUP DISTRIBUTION
at horizontal plane through core center



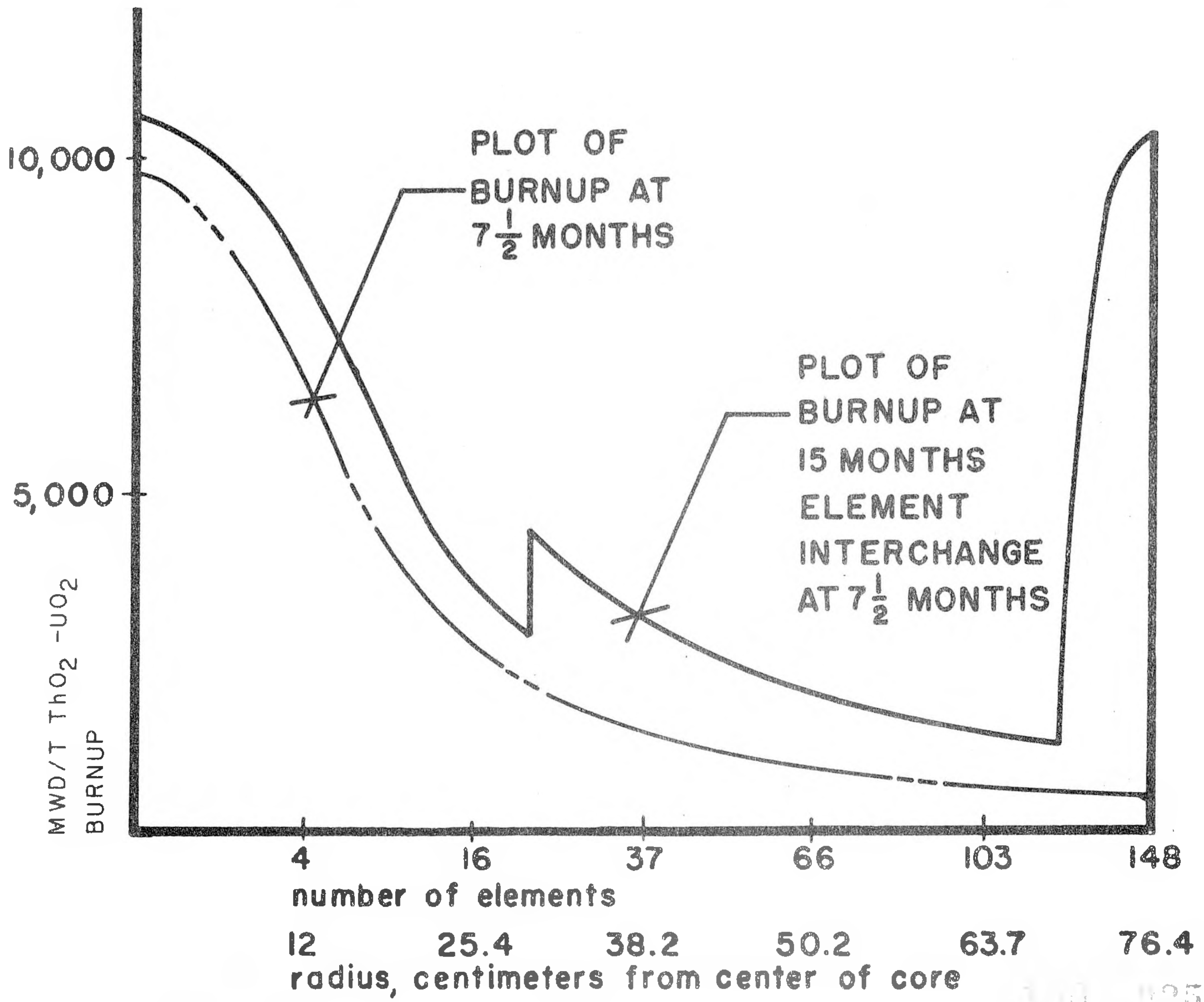
BOILING WATER POWER REACTOR

ACF INDUSTRIES, INCORPORATED

FIGURE 11a

BURNUP DISTRIBUTION
at horizontal plane through core center

24 elements interchanged
core center to periphery
at $7\frac{1}{2}$ months.



BOILING WATER POWER REACTOR
ACF INDUSTRIES, INCORPORATED

FIGURE 12

The following data are given for the reactor core which operates at an average temperature of 531F. The core lifetime is 15 months and there is an 18 percent boiling void in the H_2O coolant during operation.

a. Fuel Requirements (15 months operation)

	Kgm	
Cold clean critical mass	90.0	
Temperature and voids	18.0	
Fuel burnup	34.2	
Burnable poisons	8.6	
Equilibrium Xenon and Samarium	8.2	
Fuel needed	159.0	
U-233 buildup equivalent	11.0	(U-235)
Total U-235 loading	148.0	kgm

Fuel	Mass (kgm)	Mass per pin (gm)
U-235	148.0	40.00
UO_2(90% or better U-235)	180.0	48.65
ThO_2	4,219.0	1,140.27

b. Control Requirement

The worth of the 9 control rods when fully inserted in the core of the reactor is 15 percent δk/k at 68F. In order for the reactor to be critical at the end of the 15 month cycle with burnout poisons, xenon and samarium buildup and 18 percent void in the coolant water, 58 kilograms of enriched uranium are required. In order to determine the amount of control required for the reactor at the clean cold condition the excess reactivity due to the 58 extra kgs was used.

Reactivities at startup are as follows:

	Mass Kgm Added	Reactivity δk/k percent
Temperature and void for 68F to 531 F, 0 to 18 percent void	18.0	5.64

	Mass Kgms Added	Reactivity δk/k percent
Fuel burnout 1.3 g per mwd 26,325 mwd	34.2	10.71
Fission product poisons	8.6	2.69
Equilibrium xenon and samarium	8.2	2.57
Uranium-233 production equivalent -	11.0	- 3.45
	58.0	18.16

Mass coefficient of reactivity at reactor startup is 0.3131 percent per kgm of U-235.

Since the reactivity control of the 9 control rods is 15 percent, in order to have sufficient safety in the control rods it is necessary to obtain an additional 8.2 percent excess reactivity by burnable poisons built into the core of the reactor. To obtain this amount of control will require 2.7 x 10^{-4} grams of Boron-10 per cubic centimeter of core. The method of getting this amount of poison into the core may be determined later, but for best results it should be included in the meat of the fuel elements. The over-all control of the rods will be 1.5 times the excess reactivity at clean cold startup.

c. Poisons

At end of core life:	Percent Reactivity
Fission product poisons	2.7
Samarium poisons	0.6
Xenon poisoning (equilibrium)	2.0
Maximum xenon after shutdown	2.9

d. Uranium-233 Buildup

$\frac{\text{Atoms U-233}}{\text{Atoms U-235}}$	Percent
One year operation	7.8
End of core life (15 months)	10.1
Reactivity worth of U-233 at end of core life	3.5

e. Reactivity Coefficients

Mass coefficient	$\delta k/k$ per kgm.
Hot critical	0.22
End of core life	0.34
Temperature coefficient	$\delta k/k$ per ^{o}C
For cold to operating	-9.6×10^{-3}
Void coefficient	$\delta k/k$ per percent void
At operating temperature	-1.444×10^{-2}

f. Miscellaneous Data

Average thermal flux in core:	
Clean operating core (58.5 MW)	1.19×10^{13} n/cm^2/sec
End of core life (58.5 MW)	1.55×10^{13} n/cm^2/sec
Volume fraction of UO_2 to ThO_2	
at startup	3.79
at end of core life	2.91
Percent Burnup of U-235 (15 months)	23.1
Conversion ratio	
at startup	0.47
at end of core life (15 months)	0.55

Percent of Materials in Core

Material	Percent by Volume
Steel	5.9
Void	.4
Zr.	4.1
H_2O	67.1
Fuel (UO_2 + ThO_2)	22.5
	100.0

$$\frac{\text{Water}}{\text{Metal}} = 2.07$$

$$\frac{\text{Water}}{\text{Fuel } (UO_2 + ThO_2)} = 2.98$$

g. Figures

Data was computed as a function of reactor lifetime, so that one may estimate the maximum possible lifetime of the reactor before shutdown is necessary.

FIGURE 13. Fuel Requirement vs Lifetime: Mass of U-235, including enough to override U-235 burnup and permanent poison buildup. Xe and Sm poisoning which are constant with time are not included. These would add approximately 8.2 kg U-235. Buildup of U-233 is also not included. At 15 months lifetime this would save 11 kg. U-235.

FIGURE 14. This figure gives the percent burnup of U-235 at end of life as a function of lifetime. It also gives the percent burnup of total atoms of U plus Th which determines the structural lifetime of the fuel elements. Values of percent burnup of U-235 are very nearly correct, but do not allow for an increase in the fuel inventory to account for poison buildup, and should therefore be multiplied by approximately (0.97) to obtain a better approximation.

FIGURE 15. This figure gives the control needed as a function of reactor lifetime. For a lifetime of 15 months values are about 1.4 percent reactivity too high.

FIGURE 16. The percentage of the original U-235 atom is given for U-233 buildup as a function of operating time. The effect on reactivity is also given. These calculations are based on a reactor lifetime of 15 months.

FIGURE 17. Effect on reactivity of Xe buildup due to reactor shutdown from full power at the end of life.

FIGURE 18. The amount of B^{10} needed for burnable poisons. Assuming all boron is subject to the average core flux then the prescribed amounts are given to change the reactivity by a given percentage for the cold critical core or hot critical core.

6. Reactor Shielding

The thermal shield surrounding the reactor will consist of a sheet of steel 1 inch thick. This will be composed of 1 percent boron to reduce the number of thermal neutrons striking the materials surrounding the core. Following the 1 inch thickness of borated steel is the reactor vessel which is 3-3/8 inches of steel. The vessel is followed by a 6 inch thickness of cooled steel. This amount of thermal shielding is sufficient to reduce the temperature of the concrete below 150F.

BOILING WATER POWER REACTOR

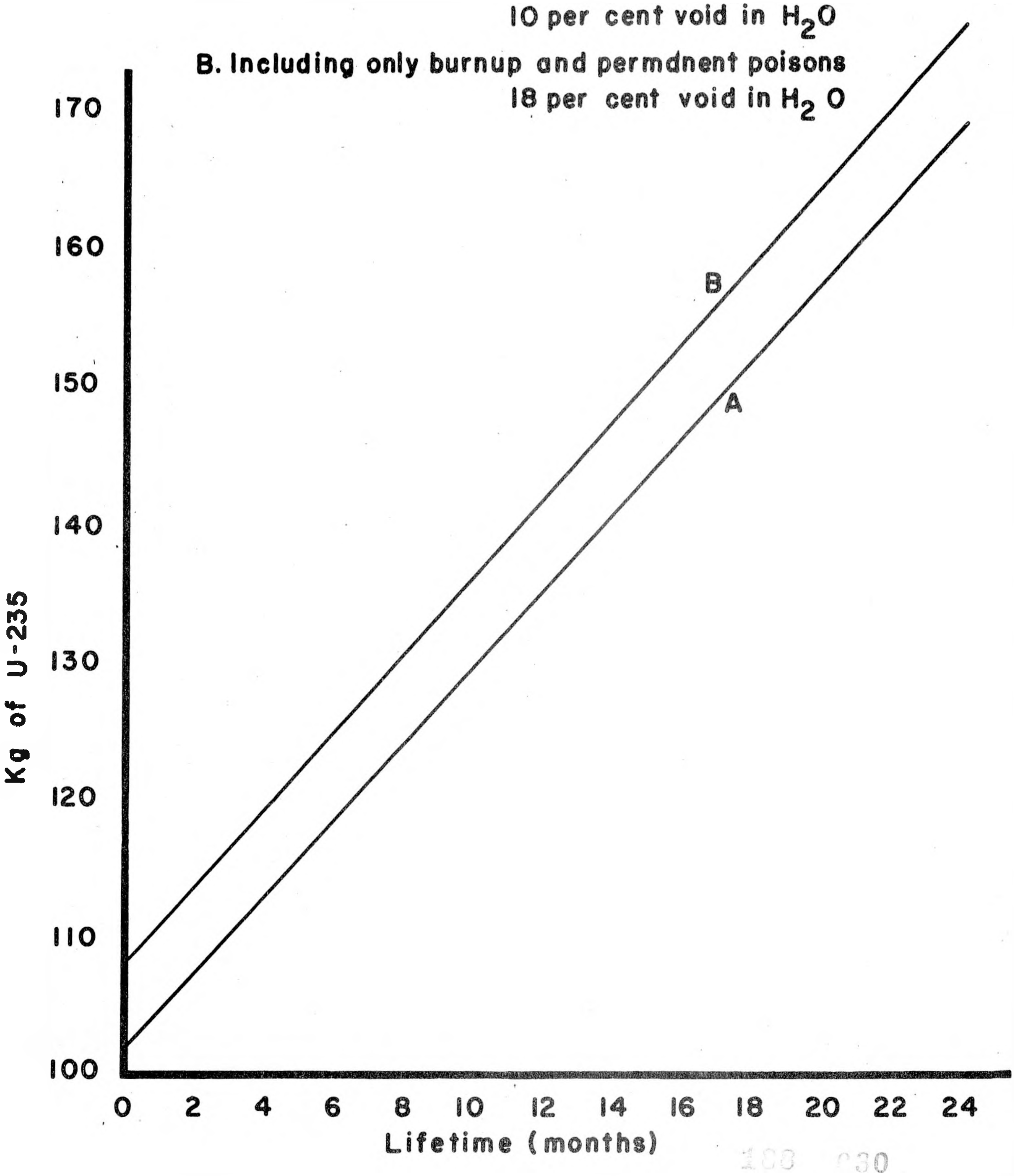
FIGURE 13

ACF INDUSTRIES, INCORPORATED

Fuel U-235 Requirement vs Lifetime

A. Including only burnup and permanent poisons
10 per cent void in H_2O

B. Including only burnup and permdnent poisons
18 per cent void in H_2O



188 030

BOILING WATER POWER REACTOR FIGURE 14

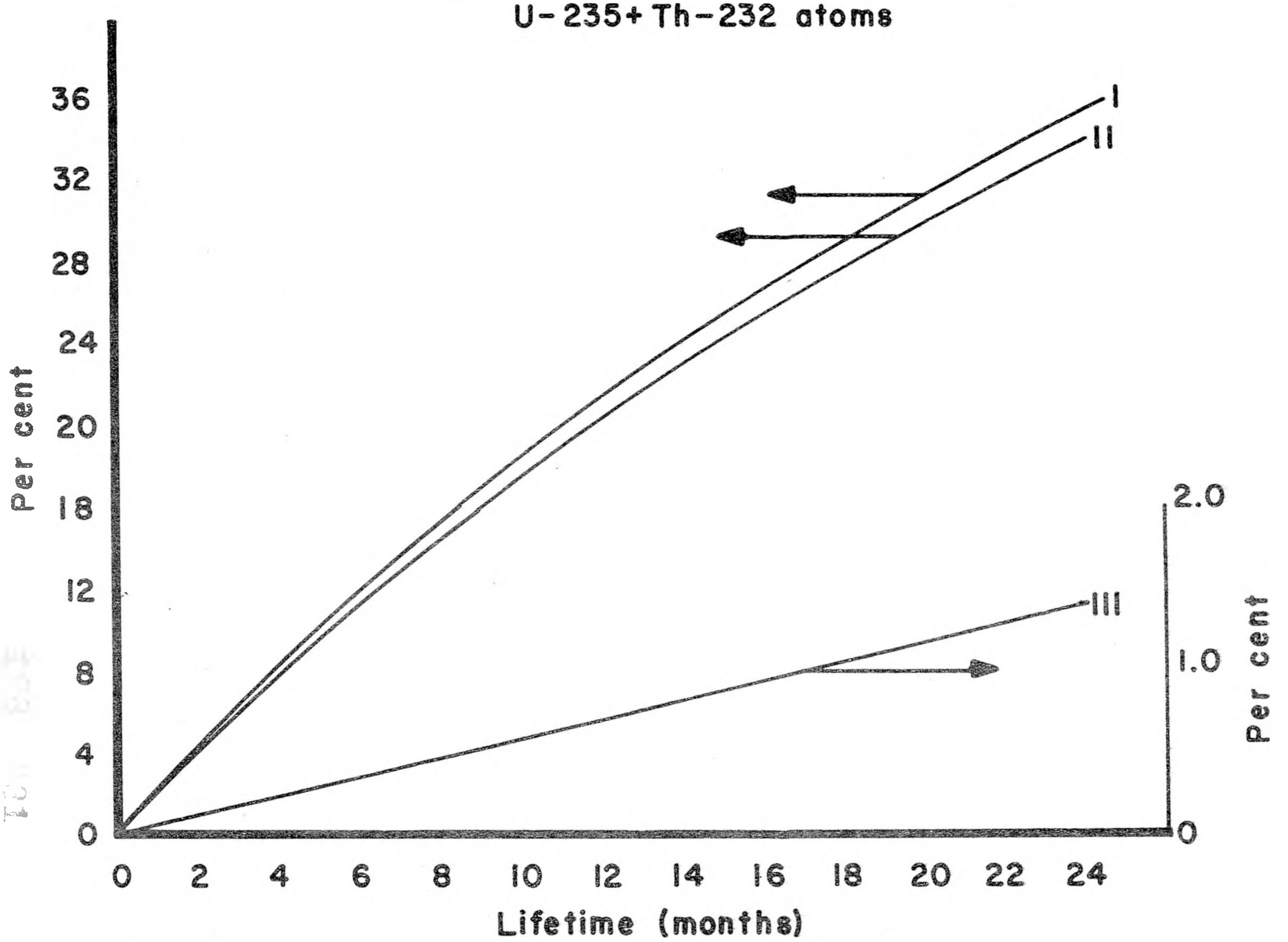
ACF INDUSTRIES, INCORPORATED

Per cent Burnup of U-235 vs Lifetime

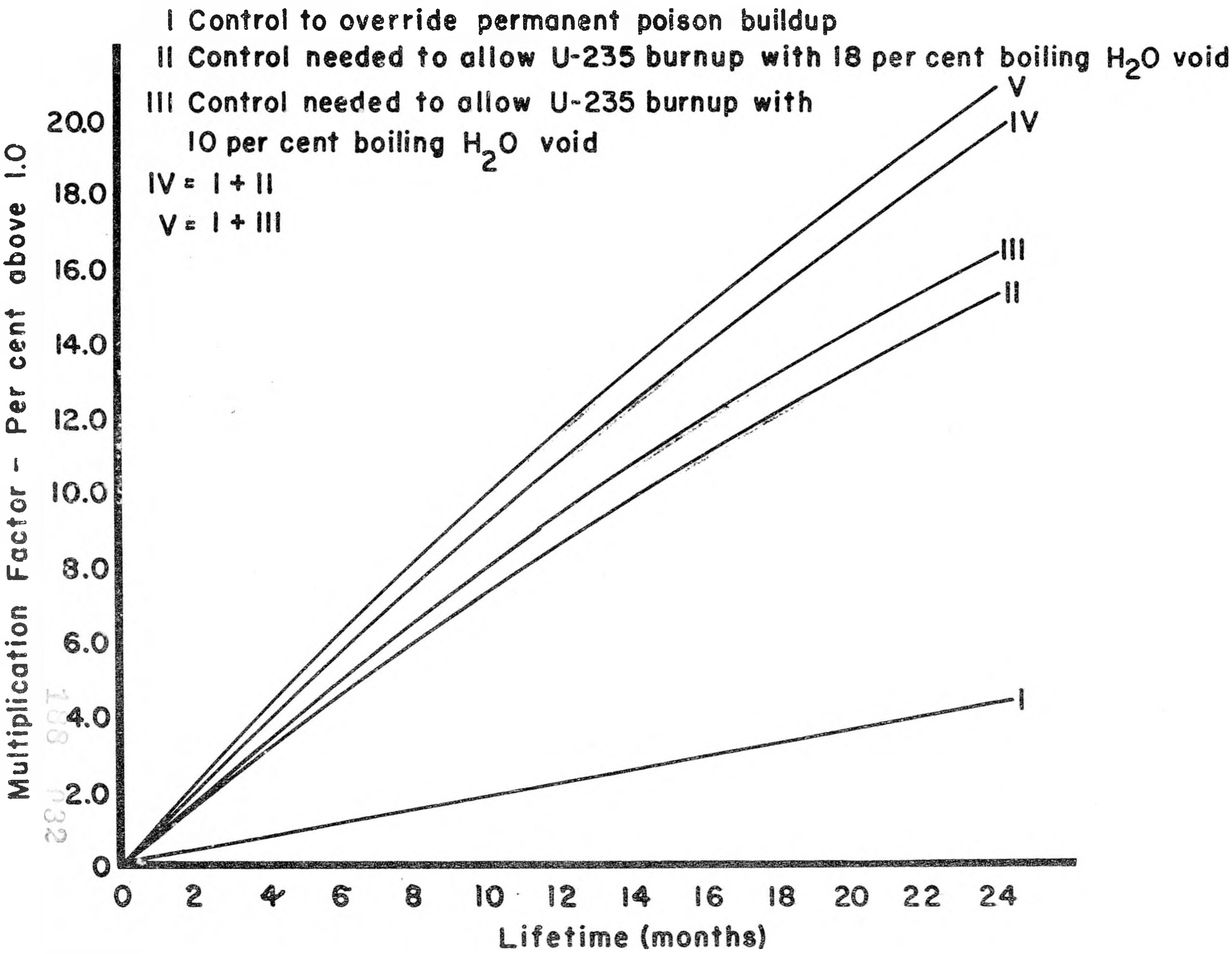
for: I 10 per cent boiling H_2O void

II 18 per cent boiling H_2O void

III Per cent burnup U-235 of total U-235+ Th-232 atoms

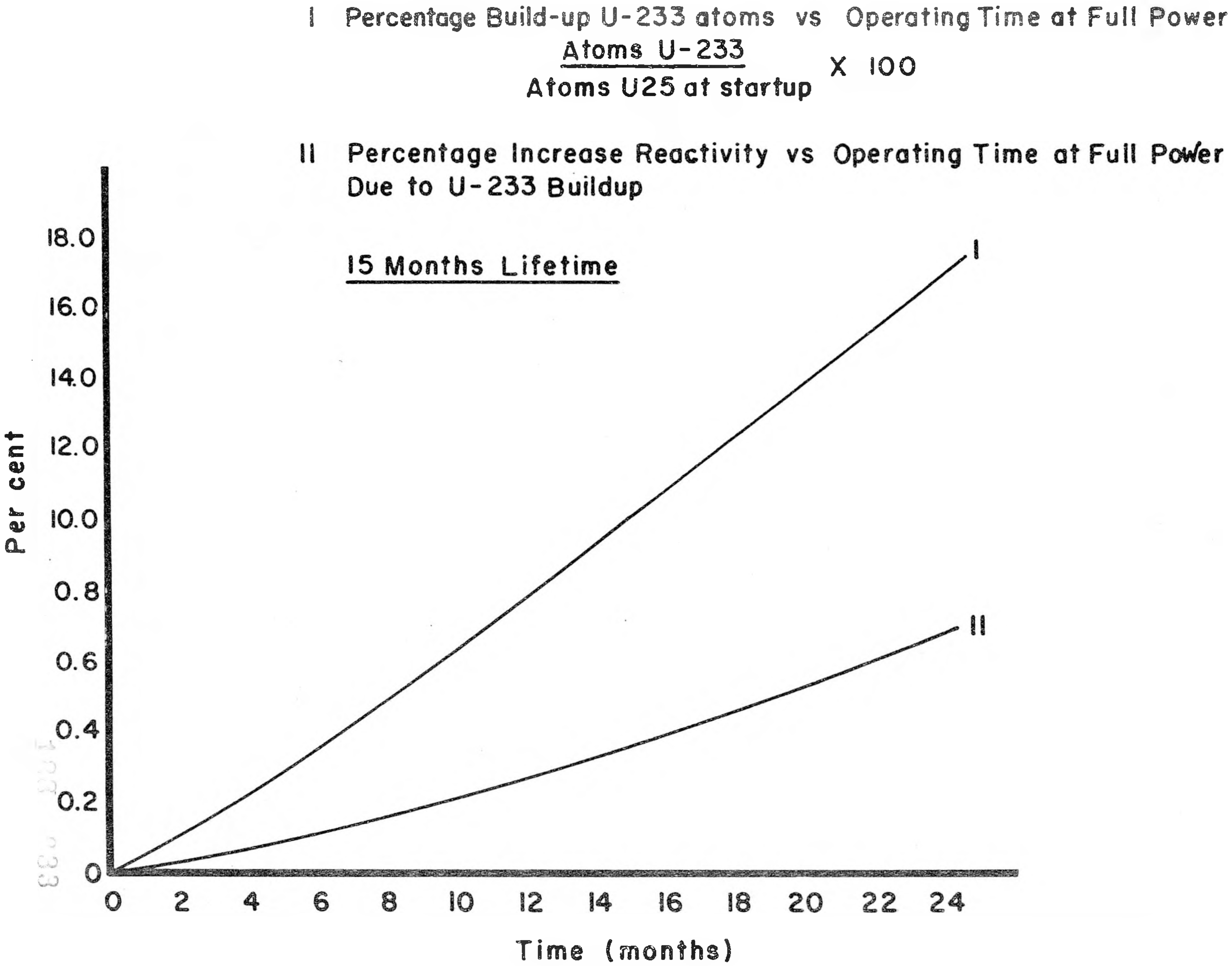


APPROXIMATE REQUIRED CONTROL vs LIFETIME (at operating temperature)



BOILING WATER POWER REACTOR FIGURE 15

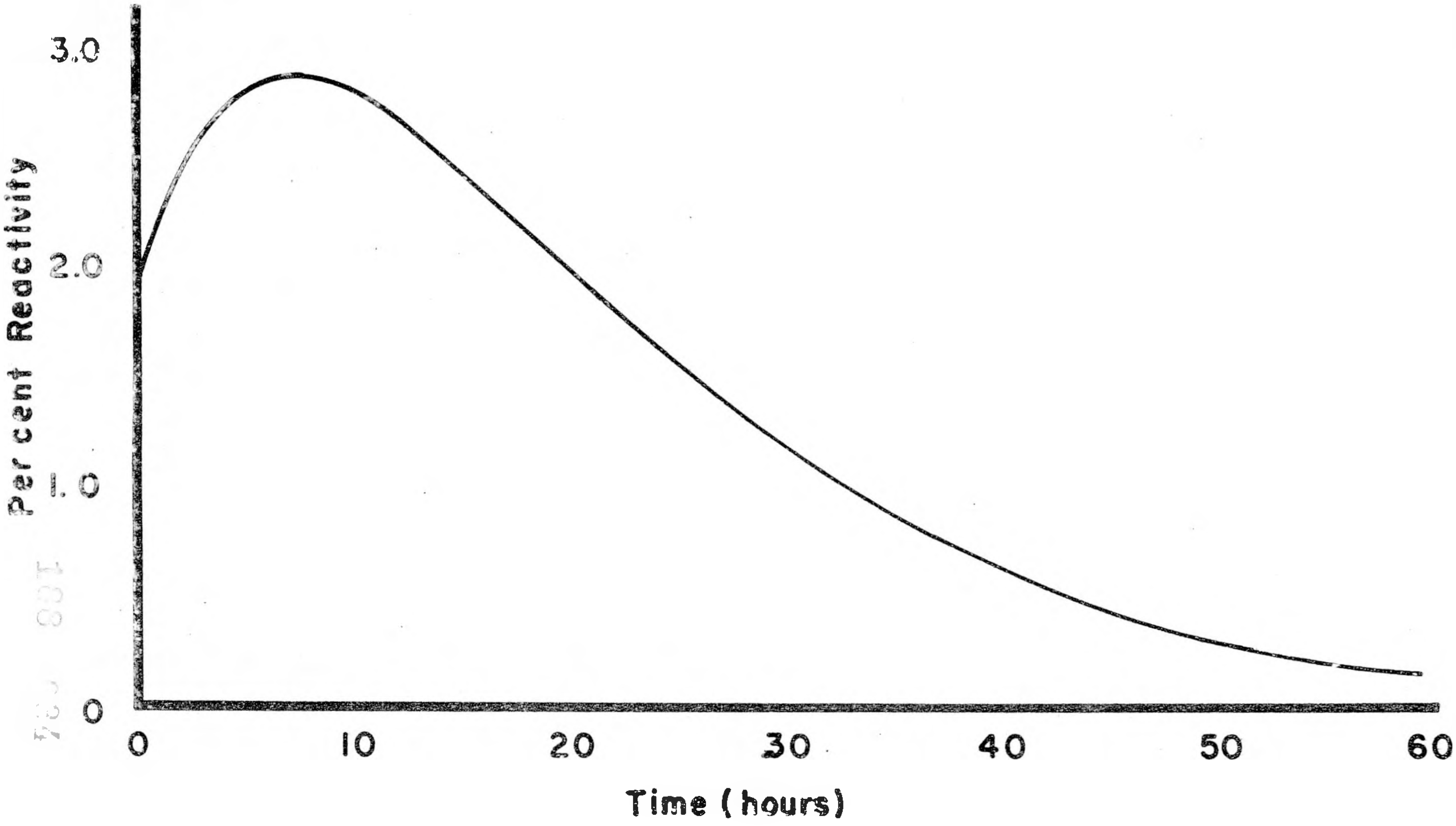
ACF INDUSTRIES, INCORPORATED



BOILING WATER POWER REACTOR
ACF INDUSTRIES, INCORPORATED

FIGURE 16

Loss Per cent Reactivity vs Time Due to Xe Buildup After Shutdown, after 58.5 Megawatt Operation



BOILING WATER POWER REACTOR
ACF INDUSTRIES, INCORPORATED

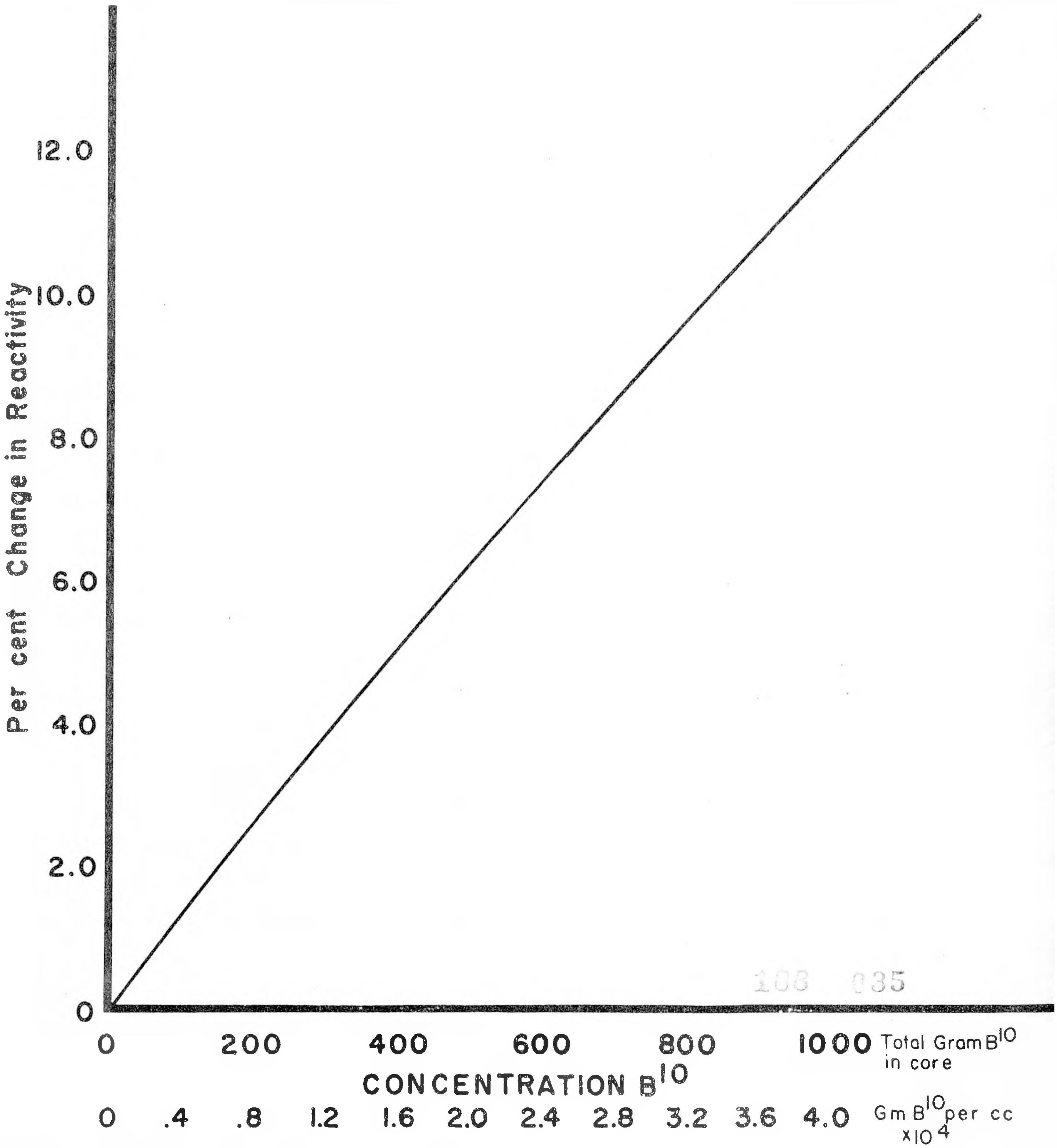
FIGURE 17

BOILING WATER POWER REACTOR

FIGURE 18

ACF INDUSTRIES, INCORPORATED

Per cent Change Reactivity vs B^{10} Concentration
(at room or operating temperature)



108 035

The biological shield surrounding the reactor and other sources of radiation will be of sufficient thickness to reduce the dose-rate at the outside surface of the shields to 1/10 of acceptable tolerance (0.75 mr/hr) in all operating areas. Where access is permitted on a limited time basis, the allowable dose rate will be considerably higher. Limited access areas would be areas such as the sub-reactor room.

For the concrete shield surrounding the reactor, fuel storage area and steam lines ordinary concrete is used. The composition of the concrete is as follows:

Portland cement	15.0 percent
Sand	34.2 percent
Gravel	43.3 percent
Water	7.5 percent
Density	2.4 grams/cm^3(150 lb ft^3)

The heavy concrete, which is used to shield the sub-reactor room and above the reactor vessel, will be of the following composition:

Portland cement	775 lb/cu yd
Magnetite or equivalent	2450 "
Steel punchings	4130 "
Water	340 "
Total	7695 lb/cu yd
Density	4.26 gms/cm^3 (280 lb/ft^3)

The shield thicknesses for the reactor are as follows:

Radial Shield Surrounding Core	Thickness (inches)
Water (reflector)	10
Steel (2 percent boron)	1
Water	2
Steel (tank wall)	3
Insulation	3
Air gap	3
Steel	6
Concrete, ordinary (ρ = 2.4 g/cm^3)	108

Below Core	
Water (in vessel)	33
Steel (tank bottom)	3
Insulation	3
Air gap	6
Steel	6
Heavy concrete (ρ = 4.2 gm/cm^3)	48
Steel	4

	Thickness (inches)
Above Reactor	
Steam ($\rho = 3.402 \times 10^{-2}$ g/cm^3)	185
Steel (2 percent boron tank cover)	5
Insulation	5
Heavy concrete ($\rho = 4.25$ g/cm^3)	66
Fuel Storage Tank	
Ordinary concrete + 4" lead	60
Evaporators	
Ordinary concrete ($\rho = 2.4$ g/cm^3)	18

7. Reactor Control Rods and Drive Mechanisms

The proposed reactor will be controlled by nine cross shaped control rods. The upper section of the rods will contain material having high neutron absorption and the lower or follower section will be low neutron absorbing material. Thus the rods, when raised, will permit reactivity increase and, when lowered, will reduce reactivity.

The rod drives and seals are attached to thimbles extending down from the underside of the reactor vessel. An arrangement drawing of the proposed drive is shown in Fig. 19. The drive incorporates an attachment to the control rod and a pressure breakdown seal similar to that utilized on the EBWR. The drive itself consists of an air balancing cylinder and piston, and a lead screw and thrust plate system for controlling the motion of the air piston. The top supply to the air cylinder is supplied continuously with air pressure sufficient to create a downward force of approximately 100 lbs. in addition to the reactor pressure force. An accumulator will be provided in this line to maintain pressure in the event of supply failure. If the pressure falls below a safe value, the rod will scram. The bottom supply to the air cylinder is provided with a controlled pressure source sufficient to counterbalance the reactor pressure force on the drive and the weight of the rod. A quick acting valve is provided to close off this supply and vent the bottom supply of the air cylinder to atmosphere. In normal operation the bottom of the cylinder is pressurized, thus exerting a positive upward force on the thrust plate. The control rods are raised or lowered by energizing the drive motor which raises or lowers the thrust plate through ball bearing lead screws and chain drive. The control rod is scrammed by exhausting the bottom of the air cylinder to the atmosphere. The "drive locked" switch prevents re-pressurizing the cylinder until the thrust plate has been lowered into engagement.

Rod position indication is obtained from a synchro transmitter and receiver system coupled to the rod drive.

Scram action of the drive system will be fail safe since air pressure will always be present on the upper side of the air piston and can thereby force the drive down. The balancing pressure on the lower side of the air piston will be supplied by a spring and air loaded valve, actuated by a solenoid. Thus an electrical failure will cause this valve to open, exhausting the balancing pressure. This drive mechanism has been proven and tested on the BORAX and SPERT reactors.

8. Reactor Control and Instrumentation

When the reactor is shut down the neutron density is between 10^{-8} and 10^{-7} of the full power density. The reactor will deliver power to the coolant and cause the water to boil when the neutron density is about 10^{-2} of the rated power density. At this neutron density, the reactor control is based entirely upon the steam power delivered, but below this value it is necessary to rely upon neutron flux sensitive instruments located in the biological shield which surrounds the reactor for control of reactor power. Control and operation therefore is based on neutron flux until steam power is produced, at which point process instruments in the external circuit are used with the flux only as a limiting parameter.

Neutron Flux Instrumentation

The neutron flux will be monitored by nine independent instrument channels. There are four different types of channels as shown in attached "Nuclear Instrumentation Block Diagram" Fig. 20.

Startup Channels

For initial startup and very low power operation (1 watt to 10^4 watts) a duplicate system will be provided which will include:

a. Neutron counter which will provide an electrical signal proportional to the neutron flux. This detector will have a sensitivity of 4.5 counts/ neutron/cm^2/sec.

b. Preamplifier that will be capable of providing driving power for cables back to the control room. The rated gain factor will be 40 - stabilized.

c. Amplifier that will increase the signal to the level required. The amplifier will be non-overloading with a gain of 2500. Its response time will be 1 sec. This amplifier chassis will have a power supply capable of supplying the necessary plate and filament power to the preamplifier and a pulse generator for checking amplifier operation. There will be two outputs from this chassis, a pulse output to drive a scaler and a current output to drive a logarithmic current meter.

188-038

d. Logarithmic current meter which will provide rough indication of flux level and voltage signal proportional to the logarithm of the neutron flux to the period circuit. Its range will be 1 - 10^5 counts per second. This unit will also supply the voltage required for the detector.

e. Period meter which will provide indication of the reactor period (-30 to + 3 sec.)

f. A scaler that will accurately measure the counting rate. Scaling factors 10, 100, and 1000 may be selected. The register will be electromagnetic, 4 digit.

g. A switching arrangement that will turn off the pulse circuits after a counting rate of 3 x 10^4 is reached.

Linear Power Channels

This channel will be used to aid in startup and to indicate neutron level at full power. It will be therefore supplied in duplicate. The signal from either channel will be continuously displayed on a strip chart recorder. The reading from both channels will be continuously displayed on indicating meters. As the neutron density in the reactor increases, the current in these channels rises; therefore, range change switches will be used to follow the flux over eight decade changes.

The linear power channel will consist of:

a. Compensated ionization chamber which will provide a signal proportional to neutron flux. Its sensitivity will be approximately 10^{-14} amps/ n/cm^2/sec.

b. Linear current amplifier which will provide a dc voltage to the recorder proportional to the neutron flux. Its range will be 10^{-13} to 10^{-4} amps.

Log N and Period Channel

Period channels will be used when the reactor is being brought from low-power levels to operating power levels.

Progressively shorter periods will cause the following actions to occur:

a. Prohibit further withdrawal of control rods.

b. The control rods will free fall into the core (scram).

188-039

The period scram circuit may be blocked out at the operator's discretion while operating at a fixed power level. This is done to eliminate all scrams due to noise pickup by the sensitive period circuits. The response of level safeties and period safeties are approximately the same when operating close to a level safety point, and since the period circuits are very noise-sensitive, they give an additional source of false scrams without any additional safety.

The duplicate Log N and period channels will consist of the following:

a. Compensated ion chamber which will provide current proportional to the neutron flux and possess a sensitivity of approximately 10^{-14} amp/n/cm^2/sec. The neutron sensing material will be boron, approximately 1 mg/cm^2, enriched to 96% B_{10}

b. Logarithmic amplifier which will provide a dc voltage proportional to Log NV. Its range will be 10^{-10} to 10^{-4} amp.

c. Period circuit which will compute the reactor's period and provide the signal to be used for tripping the scram bus when the period becomes too short. The range of the instrument will be -30 sec to +3 sec. The scram signal will be set for periods less than 10 sec.

d. Period and Log NV recorders which can be switched to either of the two channels.

e. Log NV and period indicators will be located on the operator's console. These meters will be switched together with the recorders to either of the two channels.

Level Safety Channels

The level safety channels will be supplied in triplicate for the purpose of setting an upper limit on neutron flux.

During startup and lower power operation, the level trips may be set at a level one decade below full power, thus terminating any transients before the reactor power may rise significantly during startup.

To improve reliability of power production, by eliminating false shutdown due to circuit failure, a two out of three circuit trip will be used to scram the reactor on high flux level.

The level safety channels will consist of the following:

a. Uncompensated ionization chamber which will provide a current proportional to neutron flux. Its sensitivity will be approximately 10^{-14} amps/neutron/cm^2/sec.

188-040

b. Amplifier that will convert the current from the ionization chamber to a voltage signal required to vary the scram bus as required to scram the reactor. The response time of this circuit will be less than 50 milliseconds.

Reactor Startup

To show how the instrumentation is used, reactor startup will be described and the function of each unit of the nuclear block diagram is pointed out.

A source of neutrons is built into the reactor and as a result, the startup channels give a reading of 30 to 60 counts per minute (cmp). The linear power circuits read about .4 of full scale on the most sensitive range setting. The Log N channels are reading their base or lowest value. The level safety channels are reading zero. As an added safety feature, there is a range switch on the safety channels through which the trip set point may be lowered on the electronic portion of the circuit to a setting near 0.1 of the normal full power value. The effectiveness of this setting is explained later.

Control circuit interlocks are cleared by pre-heating the reactor system and startup is begun by raising the control rods until all have been moved about 0.1 of their total travel. During this process, the operator notes the output of the counting channels and watches the flux reading on the linear channel recorder. The counting rate will nearly double reaching some 100 to 140 cpm, and a very small reading change will be seen on the linear power level recorder. The readings are recorded on the startup record sheet when it is observed that they are steady. The same procedure is followed in steps of rod withdrawal at .15 and .20 of full travel. At this point, the flux reading will show a definite increase and the counting rate will be near 1000 cpm. The readings will still be steady showing a sub-critical reactivity condition, but the increase in flux indicates that the rods are near the critical position.

The center rod is now left stationary while the other rods are raised in increments of a few inches each. After each rod is raised, the linear flux recorder is examined for a moment to see if a sustained flux rise with time is evident. The range of the linear channel amplifier is changed as soon as the instrument reads more than .7 of full scale. When a gradual sustained rise in flux is evident, the counting rate will have gone up to about 2000 or 3000 cpm. The logarithmic channel will begin to show a small increase.

The operator now concentrates on manipulation of the center rod alone, which has been provided with an individual control switch. This rod is raised until the flux doubling time is about 35 seconds. The Log N channel period meter control is effective at this point and prevents raising any rod if the doubling time is shorter than 20 seconds. Should the period become very short (about 5 seconds), the reactor will scram. When a suitable doubling time or period

188-041

is obtained, the rods are left alone. The range of the flux instrument is changed to keep the reading on scale. At about 50 KW of heat in the reactor core, the period will become longer as the reactor heats up and begins to control itself. In about one or two minutes, this self-controlling feature of the boiling reactor will change the period to infinity. At this point, the period meter is of no value on the boiling reactor because a period cannot be sustained. The period meter interlock is removed from the shutdown circuit by opening a key switch. When the flux begins to decrease, due to the negative reactivity effect of heating the water, the over flux trips are switched to the full power setting. At the lower setting, these trips served two functions. One was the simple over flux protection, but the other was to reinforce the period protection during startup. Had too short a period been selected, the power at which the reactor controlled itself would have been higher - possibly high enough to have caused undesirable thermal stresses in the pressure vessel. This method of control insures the maximum of protection with the minimum of equipment by making all operating instruments function as protection throughout the startup process.

Automatic Control System

The automatic control system for coordinating reactor output with turbine generator demand is outlined on Fig. 22. The basic sensing device is a pressure controller located in the secondary steam system at the superheater outlet. This pressure sensing device transmits a signal to the master controller. Any deviation from the normal or null signal will result in an immediate change of the fine control rod position, thus effecting a change in reactor power level. Therefore, changes in load or other incidents which result in secondary pressure changes will automatically be compensated for by the resultant correction in reactor power. This mechanism permits the reactor to follow the turbine generator load. Minor fluctuations in pressure will be corrected by a negative temperature coefficient inherent in the reactor design.

A pressure limit switch is located in each primary steam loop to limit the pressure rise within the primary loop. This action is considered desirable in order to back up the basic pressure sensing device in the secondary system in case of its inoperability or in a situation where the primary system pressure rises without an accompanying secondary pressure rise. The limit switches will be set at an appropriate point in order not to interfere with the normal operating controls.

A three element feedwater control system will be installed on each secondary feedwater loop to maintain water level in each steam generator within limits. To accomplish this, the feedwater flow is balanced against the steam flow in the secondary steam line, with the liquid level system furnishing a signal for final adjustment of the feedwater regulating valve. Deviations in level result in position changes in the feedwater regulating valve. A three-pen recorder will be supplied for each control system, recording secondary steam flow, feedwater flow and water level.

the superheater outlet steam temperature will be maintained constant by utilizing a temperature controller. Corrections in steam temperature will be initiated by signals emitted by this controller thereby adjusting the position of the butterfly control valves in the coal feed lines and the dampers in the combustion air lines. Loss of fuel will be annunciated to the control room, alerting the operator, but will not require automatic shutdown of the reactor. Loss of combustion air would result in dangerous conditions. To avoid this, the combustion air supply is interlocked with the fuel control valves. Therefore, any loss of combustion air will shut off the fuel supply to the superhecter. Interlocks will be provided to purge the superheater furnace before coal is re-introduced into the firing chamber after a failure of the air supply.

Safety valves will be provided as a final backup to relieve the primary steam system.

Emergency Conditions

A full study of emergency conditions and the automatic corrective action is not included here. Appropriate protective automatic control action will be built into the system during detailed design.

Only very dangerous conditions will result in complete shutdown. Some examples of conditions in this category are as follows:

a. High neutron flux at two of the three over flux trip circuits.

b. High water level; inherent shutdown ability by water expulsion is lost.

c. Low reactor water level; danger of exposing core.

d. Very high primary system pressure; indicates loss of heat balance or improper operation of the plant.

e. Very low primary system pressure; indicates a possible large steam leak or broken pipe in the primary system.

f. Building radioactivity high.

188 043 -043

Some conditions merely require cut-back in power since they do not indicate dangerous reactor conditions. An important example of this is the loss of the turbo-generator load. This may result in a rapid increase in primary system pressure. The rate of increase will be too fast for the normal control system to handle. If the turbine load is lost and the main turbine valve closes, a fixed number of rods (1 or 2) are fully inserted into the reactor immediately to cut back reactor power to about 5% of rated output.

This action puts the reactor on "hot" standby and when plant conditions are corrected, startup can be effected quickly. A full re-start of the reactor would require at least one hour if all rods were fully inserted.

Details of the full or partial shutdown conditions will be worked out in a complete hazard analysis.

In general, the plan of operation in emergencies will provide for power reduction, partial or complete, and for controlled cooling of the plant to prevent thermal shock stresses.

Radiation Monitors

The radiation monitoring system will provide a record of radiation level throughout the building, in the ventilation exhaust duct, and sewer effluent. A fission product monitor will also be provided to detect fuel element ruptures.

The radiation monitoring system is shown in block diagram form on Fig. 21. A brief description of each channel is given below.

Area Monitors

The area monitor system consists of ten gamma sensitive remote units which will be connected to a common control unit located in the control room. The remote sensing units contain the ionization chamber and an electrometer tube. The output of this unit is proportional to the log of radiation intensity. This enables monitoring of three decades (0.1 to 100 MR/Hr.)

The output of each remote unit is recorded and an alarm is given when the radiation level rises above tolerance.

Stack Monitors

The stack radiation monitor system will include a particulate monitor and a gas monitor. The radiation level will be recorded continuously. The exhaust dampers will be closed and the reactor shut down when the activity released to the atmosphere is above tolerance.

The particulate monitor pulls a continuous sample of air into a detection chamber where it passes through filter paper which is monitored by a Balogen-filled Geiger-Mueller tube. The output of this tube is fed through a preamplifier to a 3-decade log count rate meter. This unit detects high energy betas and gammas.

The gas monitor consists of a balogen-quenched Geiger-Mueller tube mounted in a stack probe. The Geiger-Mueller tube output is fed through a pre-amplifier to a 3-decade log count ratemeter.

Sewer Effluent Monitor

The sewer effluent monitor will consist of a self-quenched Geiger-Mueller tube with stainless steel cathode to allow complete immersion in water. The output of the Geiger-Mueller tube is fed through a preamplifier to a 3-decade log count rate meter.

The output of the log count rate meter is continuously recorded and an alarm is given when the radioactivity of the effluent is above tolerance.

Fission Product Monitor

The function of the monitor will be to measure the ratio of portions of the gamma spectrum in the primary coolant stream of the reactor. The monitor will be positioned along the stream from the reactor core at a suitable distance and corresponding delay time such that adequate discrimination can be accomplished between induced power, corrosion activity, (ie., N^{16}, Mg^{27}, Na^{24}, Al^{28}, etc.), and fuel rupture deposits such as I^{135}.

The system will discriminate two portions of the spectrum corresponding to a variable window in the region of 1 mev and an integral corresponding to all energies above 4.5 mev. Normal coolant activity will give a constant value to the ratio of the above channels with the possible exception of corrosion buildup. When a rupture occurs, additional activity in the spectral region of 1 mev will be released into the stream causing the ratio to be disturbed. The ratio detector circuit is provided with a discriminator and an alarm to give indications of the disturbance.

9. Fuel Handling System

In normal operation, spent fuel is removed to the spent fuel element cooling pit by means of the inclined chute connecting the pit with the reactor vessel. A powered carriage in the chute allows transfer of fuel from the pit back into the core. Fresh fuel is lowered into the vessel from above. Hand operated chain hoists assure "operator feel" when inserting and withdrawing fuel elements.

Refueling operations are conducted under visual surveillance from the floor above the core, the depth of water over the core providing sufficient shielding.

The refueling sequence follows:

a. Any radioactive particles present in the core water are removed by cycling the water through the filter and demineralizer, after which the core is purged twice with clean water.

b. Access is obtained to the lid hold-down bolts by removing the two upper layers of the upper shield plug and the small, individual plugs, concentric with the lid bolts, in the lowest layer of the shielding plug. The lowest plug layer shields personnel during removal of the lid bolts.

c. The water level in the core is raised to flood the space vacated by the upper layers of the shielding plug.

d. The lower plug layer, with the reactor core lid, is raised through the water shield.

e. Entrance to the chute is accomplished by removing a plug in the mouth of the chute and an access section in the shroud extension. Actual chute entrance to the cooling pit is obtained when the chute gate valve is opened pneumatically.

f. Fresh elements are lowered into the vessel from the floor above the core.

Storage pit water is circulated for heat removal and cleanup. Cadmium in the pit storage racks assures non-criticality among spent elements. The pit is large enough to accommodate a shipping cask and loading tools. Cask loading and element surveillance is accomplished from the floor above the core.

10. Reactor Auxiliary Systems

a. Reactor Startup Heater

The startup heater is used to preheat the reactor water initially to about 325 F (95 psig). It is a conventional shell and tube heat exchanger and is connected between the base of the reactor vessel and the feedwater inlet line. Plant steam is used for the heat source and condenses on the outside of the tubes. The reactor water is heated inside the tubes and flows by natural convection to heat the bulk of the water in the reactor vessel.

b. Low Pressure Boric Acid System

Provisions were made for automatically spraying water over the core to cool the fuel elements in the case pressure and water level were lost simultaneously. Two solenoid operated valves sensed from the water column on the reactor vessel open at a 20 psig pressure and water level 6 inches above the core. In order to prevent reaching possible fuel criticality by the addition of water, the water is first sent through a tank containing boric acid crystals. The resulting boric acid solution (0.2%) is introduced above the core through a spray ring. An alarm is provided to give warning in case flow of boric acid solution does not take place when operator attempts to actuate the solenoid valves. The two solenoid valves are provided to ensure that back pressure from the reactor vessel does not occur. Check valves are also provided for the same reason.

c. High Pressure Boric Acid System

A standby emergency boric acid injection system was provided to reduce core reactivity below criticality in the event control rods failed to enter the core assembly after a scram. The system consists of a high pressure tank containing 215 gallons of an 0.25% solution of boric acid under an air cushion maintained at 1600 psig pressure by an air compressor. The tank and discharge line are constructed of type 304 stainless steel and connected to one of four forced circulation inlet nozzles at the base of the reactor. Two solenoid trip valves are located in the discharge line which may be actuated automatically, or manually by a trip valve. A valve is located between the two solenoid valves as a means of detecting possible leakage of boric acid solution past the first valve. Early remedial action may then be taken to prevent possible poisoning of fuel elements during normal operation if the second solenoid valve were to leak.

d. Reactor Shield Cooling

Cooling is provided for the thermal shield surrounding the reactor vessel, the shield tanks surrounding the removable plugs, the sleeves surrounding the control rod nozzles and the sleeves surrounding the non-used forced circulation nozzles. The cooling coils are nominally 1/2" ID copper tubing and installed for thirteen circuits in duplicate, one operating and one spare.

The heat to be removed is approximately 52 KW (180,000 Btu/hr) at a 35 gpm water rate and 10 F temperature difference.

The cooling circuit constitutes a closed loop comprised of a pump, heat exchanger and expansion tank. The expansion tank is of 175 gallon capacity and contains water at 50% level. Demineralized water is used for the shielding circuit. The heat from the shield circuit is absorbed by river cooling water in the heat exchanger and eventually returned to the river.

Two pumps are provided, one operating and one spare. Filters are installed at the discharge of each pump to remove particulate matter from the water. Pressure indication preceding the filter will serve as a measure of filter operating efficiency.

Flow indicators (Rotometer type) and throttle valves are provided in each cooling circuit to permit water flow adjustment for optimum conditions. Flow alarms are provided at the exit of each cooling circuit.

Temperature measurements are recorded for each cooling circuit. One temperature recording serving the shield cooling pumps also serves the exit of the shield cooler and the inlet to the cooling circuits.

e. Primary Water Purification and Normal Shutdown Cooling System

(1) Water Purification

The purification system is designed to maintain reactor water quality at 1 megohm specific resistance. The ion-exchange effluent will have a specific resistance of about 12 megohms/cm and a pH about 7.

Two parallel circuits are provided which permits the use of one unit while resins and filter cartridges are being replaced in the other unit. Each circuit is comprised of a regenerative heat exchanger, secondary cooler, prefilter, mixed-bed ion-exchange unit, after-filter and circulating pump. Both circuits can be operated simultaneously for maximum clean-up capacity.

The reactor water at 449 F is piped from the bottom of the reactor vessel to the regenerative heat exchanger where it is cooled to 250 F, then through the secondary cooler for cooling to 110 F. The water continues through the prefilter, ion-exchange unit, after-filter, and circulating pump. The discharge from the pump enters the regenerative heat exchanger where the water temperature is increased to 310 F and returned to the reactor.

"Fulflo" filter units are provided upstream and downstream of the ion-exchange units. The upstream filter removes non-ionized particulate matter from the water and protects the ion-exchange resins against major radioactive contamination. The downstream filter removes minute attrition particles which may escape the ion-exchange beds. Nonregenerative units are provided from which cotton thread cartridges (2 micron size) may be removed in a cage assembly. The filter units are fabricated of type 304 stainless steel.

The mixed bed ion exchange units contain highly basic anion resin (IRA-400) and strongly acid cation resin (IR-120). The nuclear grade resin designated as XE-150 is mixed in stoichiometric proportions and contains 60% highly purified IRA-400 and 40% highly purified IR-120 resins on a volume basis. The resins are enclosed in a removable basket for ease in recharging. The units are of type 304 stainless steel construction and are mounted on movable carriages for removal to the resin disposal area.

The two circulating pumps are single stage impeller pumps with a capacity of 50 gpm each. The drive and pump components in contact with reactor water are of type 304 stainless steel construction. One pump is electrically driven by a 3 hp motor and the second is steam turbine driven. This feature provides water circulation for shutdown cooling in the event of electrical power failure.

(2) Normal Shutdown Cooling

Cooling for normal shutdown may be obtained by selectively valving off the regenerative heat exchanger, filters and ion-exchange units and utilizing only the secondary coolers and circulating pumps. The secondary coolers and pumps are designed for 50 gpm capacity each and will adequately fulfill normal shutdown requirements.

f. Auxiliary Shielding - Purification System

The pre-filters and ion-exchange units are equipped with 4 inches of lead shielding to protect personnel against radioactivity. Should additional shielding be required, a space was provided for the erection of a 2 ft. concrete or concrete block wall.

g. <u>Make-up Water Injection Pump</u>

Under normal operation make-up demineralized water will not be required. However, in the event make-up water were required, an injection pump of low capacity and high pressure was provided. A piston-type motor operated pump of 10 gpm capacity and 1000 psig pressure will feed water from the plant water demineralizer into the primary water purification line. The pump is fabricated of type 304 stainless steel.

h. <u>Fuel Element Storage Well</u>

The fuel element storage well, approximately 18,000 gallon water capacity, is located along the side of the reactor. The well is supplied with water from the plant demineralizer and the over-flow drains to the waste disposal tanks. Nozzles are provided for a future recirculating ion-exchange system in the event conditions warrant minimizing water activity or to maintain water purity.

i. <u>Waste Disposal System</u>

All liquid waste from the reactor building will be monitored before discharge to the municipal sewer system. The system is shown in Fig. 22, and it is identical to the waste disposal system now installed on the reactor for the Massachusetts Institute of Technology presently under construction by ACF, which is located in the city of Cambridge, Massachusetts. This system has been examined and approved by the AEC safeguards committee.

The discharge tolerances of the liquid waste will be 1×10^{-13} curies/cc for alphas and 1×10^{-15} curies/cc for Betas and Gammas. The procedure will be to fill one tank, monitor it, and then discharge the contents to the sewer. During the discharge a monitor will continuously monitor and record the activity of the effluent. The piping and the sewerage discharge pump will be designed to allow the tank contents to be stirred by circulation. The system will be provided with shutoff valves between the reactor building and the tanks, and also transfer lines and a pump for transferring the contents of one tank to the other.

C. STEAM GENERATING PLANT

1. Steam Generator

The steam generator is designed to produce 225,000 lb/hr of dry saturated steam at the pressure necessary to supply steam to the turbine throttle at 600 psig. Heat will be provided by 285,000 lb/hr saturated steam from the reactor at a pressure of about 875 psig.

The steam generator shown is a two-shell, horizontal, closed heat exchanger unit in which the primary steam is condensed in the tubes, and secondary steam is generated in the shell. The tubes are stainless steel, welded into stainless steel clad tube sheets. A dry pipe is provided in the shell for separation of moisture and delivery of high quality steam to the secondary system.

A two-shell design provides extra plant reliability in that the plant can be operated at reduced capacity in case of a tube failure in either shell. Access openings in the tube bundle headers, isolating valves and biological shielding around each shell permit plugging a failed tube without shutting down the entire plant.

An alternate steam generator design has been considered and may be substituted, with the buyer's and operator's approval, in the final plant design. This consists of a single shell, vertical heat exchanger with primary steam condensed in the shell and secondary steam generated in the tubes. The vapor-water mixture from the evaporator is discharged into a separate, horizontal steam drum containing a battery of cyclone separators. The tubes will be stainless steel welded into stainless steel clad tube-sheets. The top tube-sheet will be fixed and the bottom tube-sheet floating to provide for differential expansion between tubes and shell.

The vertical evaporator has the advantage of more positive drainage of the primary condensate and lower pressure drop, thereby facilitating natural circulation of the primary fluid. It also permits the inclusion of means for the separation and removal of dissociated gases carried over from the reactor with the steam. The single-shell design does not provide the flexibility of a two-shell unit but special provisions for extra reliability is probably not warranted due to the relatively low temperature of the heating fluid. The single evaporator also avoids parallel operation of units, thereby simplifying controls and operation.

A continuous drainer or other approved means will be provided for maintaining the desired primary water level in or immediately following the steam generator(s).

188 051

2. Sub-cooler

A drain cooler is provided to sub-cool the condensate leaving the steam generator to about 450F before re-entering the reactor. This is desirable for better reactor performance. Cooling is provided by the evaporator feedwater of the secondary system, the feed being heated to a temperature about 50F below its saturation temperature.

The cooler is a single pass tube-and-shell heat exchanger, with the primary water in the tubes and secondary water in the shell. The tubes are stainless steel, welded into stainless steel clad tube sheets.

3. Gas Recombiner System

A recombiner is provided to recombine the hydrogen and oxygen resulting from dissociation of the primary water in the reactor and carried over with the steam to the secondary steam generator. The recombiner consists of a stainless steel vessel containing a bed approximately 6 inches diameter by 12 inches deep of platinized alumina pellets.

The steam evolved by the recombination of the gases, and the steam carried over with the gases from the steam generator, will be condensed in a small condenser and returned to the primary system.

4. Steam Superheater

The superheater will receive essentially dry and saturated steam from the steam generator and superheat it for delivery to the turbine throttle at 825F.

The superheater is designed for initial operation with pulverized coal, with provision for adding oil or gas burners at a later date. The superheater installation will include all equipment necessary for the efficient operation of the plant such as pulverizers, blowers, burners, induced draft fan, forced draft fan, air preheater, dust collector, etc., housed in a separate building adjacent to the existing power plant. A gravity fed coal chute will be provided to transfer the coal from the bunker to the superheater as shown on Fig. 4.

A pulverized coal furnace has been chosen in order that the superheater can be adequately protected against damage resulting from loss of steam. It is believed that such protection cannot be provided with a stoker furnace.

5. Emergency Condenser

An emergency condenser is provided to receive steam from the reactor through a suitable relief valve system in case the reactor pressure reaches a predetermined value due to a sudden dropping of load or malfunctioning of the controls. The condenser is designed to condense the entire normal steam output of the reactor and is provided with a drain cooler section for sub-cooling the condensate for return to the reactor. Cooling water will be supplied from the river or from the main condenser circulating water system by a separate circulating pump.

This condenser may also be used as a heat sink for testing the reactor at higher than design output. During these tests, the condenser will be run in parallel with the primary steam generators to dissipate surplus heat over that required for operation of the power generating plant. It is believed that, based on recent EBWR tests, these tests will prove the reactor to be capable of operating continuously at 80 to 100 megawatts.

In the remote event of a pressure build-up, the condenser shell is protected by safety valves set at the design pressure of 1200 psig, which discharge into the containment vessel.

6. Emergency and Control Power

Emergency standby power will be provided by a 25 KW diesel engine generating set. Direct current power for control of all electrically operated air circuit breakers and for instrumentation and control is provided by a 125 volt battery located in the turbine generator building.

188 053

D. RESEARCH AND DEVELOPMENT

1. Exponential and Critical Assembly

In the opinion of the engineering staff of ACF, it will not be necessary to construct a critical facility or an exponential experiment facility to establish required design characteristics of the proposed Elk River core design. There are two major factors upon which this opinion is based.

First of all, the reactor core design which ACF proposes is one that contains built-in flexibility by virtue of variably loaded fuel elements and flexible core lattice. There are 16 extra spaces in the grid plate for additional fuel above the normal 148 elements as specified for the core. In order to be assured of sufficient fissionable material at reactor startup, 22 spare fuel elements will have a heavy loading of U-235 which will be more than double the normal loading. By doing this, over 7% additional reactivity can be obtained and by the addition of 16 normal elements into the outer space of the grid plate, about 2% reactivity can be gained; thus, a total of 9% reactivity is available which is well above the margin of error in physics calculations.

Secondly, the design, fabrication, construction, and operation of a suitable critical facility would be a significantly high expenditure. The main purpose of a critical assembly is to establish the measurements of clean cold critical mass and the neutron flux distribution and lattice constants to a good degree of accuracy. These properties are of very great importance in establishing the procedure for bringing the reactor from a cold start to operating conditions. It is felt, however, that the state of technology concerning boiling water reactors is such that a great deal of data on this type of core is available and this data along with presently developed calculating methods could be applied in order to accurately determine the same information as we would get by running critical assemblies. In addition, the void distribution conditions in a boiling water reactor cannot be simulated in a critical assembly. This information must be arrived at using already available information from EBWR and BORAX -IV, and supporting calculations.

ACF feels that the technical data and information realized from the con- structure of critical and exponential assemblies does not justify the expenditures involved. By designing the reactor with sufficient flexibility built into the core, critical assemblies can in-effect be conducted in the reactor itself. The resulting economic gain which is significant, will be passed on to the buyer.

2. Fuel Irradiation Test Program

The object of the irradiation test program is to obtain design and performance information for the proposed fuel elements.

188 054

In considering the use of ThO_2-3 w/o UO_2 as fuel material for the proposed reactor, the following factors appear to be most important:

(a) Expected rate of release of fission gas
(b) Density to be specified for the fuel
(c) Feasibility of projected fuel burnup
(d) Supporting research and development

These topics will be discussed in the following sections using such available experimental data as are presently available. As will be shown, however, there is little published information pertaining to the actual ThO_2-UO_2 composition which has been specified. As a matter of fact, many of the conclusions regarding the performance of any ThO_2-UO_2 fuel must be based at the present time on information obtained on UO_2, since this material has been subjected to much more intensive study.

a. Fission Gas Release

It is in this area that information is particularly lacking for ThO_2 fuels. Both Chalk River and Argonne are preparing to make quantitative studies of fission gas release from ThO_2 fuels during irradiation, but no data has been obtained as yet.

ThO_2 has a crystal lattice very similar to UO_2, so that a solid solution is formed in all proportions between the two oxides. (1) Therefore, since considerable information is available on the factors which control fission gas release from UO_2, one can suppose that these same factors will likely be effective in the case of ThO_2, or solid solutions of UO_2 and ThO_2.

Most of the data obtained on fission gas release from UO_2 have been reported by WAPD personnel in connection with PWR development. (2,3) These investigators have shown that solid state diffusion controls the release of fission gases from UO_2 and that, as expected, the amounts of fission gas released are very sensitive to the density of the oxide, since this will determine the length of diffusion path. An additional feature is that above about 95% theoretical density, the ratio of open to closed porosity becomes very small. Thus, gas atoms in high density oxide must not only diffuse a greater distance before reaching a void, but will also likely emerge into a closed pore which will not permit the gas to reach the annulus about the fuel.

Based on data in reference 2, the following conclusions may be drawn with regard to gas release from UO_2:

(1) UO_2, 93% dense, taken to 12,000 MWD/T of oxide at a heat flux of 900,000 BTU/hr-ft.^{2}, and with the center molten, releases only about 15% of fission krypton.

(2) Increasing the density of UO_2 from 94% of theoretical to 97% decreases the rate of krypton release by a factor of 10.

Thus, allowing considerable uncertainty in applying the above information to the ThO_2-3 w/o UO_2, one may conclude that fission gas release will not constitute a serious problem with the reference fuel under design conditions.

b. Specified Fuel Density

The above section notes the importance of high density in lowering fission gas release from oxide fuels. The specified fuel density, therefore, should be as high as is consistent with manufacturers' capabilities. Table I lists theoretical densities reported for ThO_2-UO_2 by a number of investigators. Table II lists bulk densities of pellets produced at a number of different sites. The beneficial effect of the addition of 0.5 w/o CaO, CaF_2, or V_2O_5 is readily apparent in promoting high sintered density.

In specifying the fuel density, the best value of the theoretical density of ThO_2-3 w/o UO_2 must first be decided upon. A density of 10.03 gm/cm^3, calculated from lattice parameter data in reference I, is considered to be the best available value. From data in Table II, it appears that a density of 95% of theoretical should be readily obtainable by normal industrial practice with the proposed 0.4 w/o CaO addition. It is suggested that density be specified as 94.0 - 96.0% of theoretical (10.03 gm/cm^3). By way of comparison, the reference density of PWR UO_2 fuel is 93 - 95% of theoretical.

c. Feasibility of Design Burnup

Data on the effects of irradiation on ThO_2-UO_2 composition are at present limited to a few specimens prepared and irradiated by Argonne National Laboratory. (10,12) In these experiments, irradiation of ThO_2-2.5 w/o UO_2 to 0.9% metal atom burnup (6700 MWD/T oxide), showed no discernible volume or dimensional changes. Maximum fuel irradiation temperatures, however, did not exceed 932F.

In other experiments, ThO_2-10 w/o UO_2 was irradiated to 1.3% burnup of the metal atoms (9700 MWD/T oxide) at maximum fuel temperatures ranging from 1184F to above the melting point. All specimens in the group were aluminum-jacketed, and the annulus was filled with either lead or a helium-argon mixture. Although jacket failures were experienced in the higher burnup specimens because of overheating, it was shown that specimens taken to 0.64% metal atom burnup (4800 MWD/T oxide) with a maximum fuel temperature of 3524 F and a heat flux of 425,000 $BTU/hr\text{-}ft^2$ showed negligible dimensional changes.

WAPD observes negligible dimensional changes in UO_2 after burnups of 25,000 MWD/T oxide (2) and their people believe that UO_2 may be stable dimensionally and will release minor amounts of fission gas to burnups up to 50,000 MWD/T oxide, (13) provided melting does not occur.

On the basis of the above experimental evidence, it is believed that the design burnup of a maximum of 20,000 MWD/T oxide is quite feasible from the standpoint of possible deleterious fission gas release and dimensional changes.

d. Supporting Research and Development

Since no irradiation data exist at present on the reference fuel with the maximum contemplated heat fluxes, burnups, and fuel temperatures, it is proposed that this data be obtained with pellets in the reference cladding and with a helium annulus. For determining the ultimate capabilities of the fuel, some specimens should also be taken to relatively high burnups.

The least costly method would be to irradiate short prototype elements in NaK capsules.

Also, it may be assumed that fission gas release will be strongly dependent on density of the oxide. Balanced against the advantage of little gas release, with thinner tube walls then being feasible, is the probable higher cost of high-density pellets. In any event, it appears worthwhile to determine the effect of density on fission gas release so that an evaluation can be made of the optimum oxide density from the economic standpoint. This information will be obtained in conjunction with the prototype elements mentioned above.

Two series of tests are required as follows:

(1) With pellet density held constant at 94% of theoretical density, burnup of 15,000 MWD/T, 20,000 MWD/T, and 35,000 MWD/T are made on prototype fuel elements.

188 057

(2) With burnup of 20,000 MWD/T held constant, prototype fuel elements are irradiated with densities of theoretical of 90%, 94%, and 97%.

Data to be obtained from the program includes the effect of irradiation on pellet length, pellet diameter, pellet volume or density, fission gas release into the helium annulus, determination of per cent open pores and per cent closed pores in the pellets (pre-irradiation only), and determination of pellet reactivity change due to fuel burnup. The information on pellet reactivity change as a function of burnup will be used to verify reactor operation physics calculations. Each series of tests has three variables and one prototype fuel element, containing three pellets each, will be tested for each variable. Burnup is defined as Megawatt Days per Ton fissioned of ThO_2-UO_2 mixture. Proof of burnup in the test program is obtained from both activation of a thermal neutron flux monitor and a Cesium-137 chemical analysis from the irradiated pellets. The irradiation testing program is scheduled to start April, 1958, and will be completed approximately one year from that date.

3. Control Rod Drive Mechanism Development

A laboratory development and test program will be conducted on the proposed control rod drive mechanism. The program will consist of construction of a complete prototype drive assembly and a test stand, to be arranged to simulate all operating conditions. Tests will then be conducted to verify design specifications such as scram release time, total scram time, positioning accuracy, operation of all switches and interlocks, packing leakage, etc. Following these tests the assembly will be subjected to a simulated life test of 1000 scram cycles and 5000 normal operating cycles.

In addition to the prototype program discussed above, each production drive assembly will be set up and operated for 100 cycles to demonstrate satisfactory performance prior to installation in the proposed reactor.

In addition to preparing complete specifications and establishing the working parameters for the control mechanisms, ACF intends to survey the current field and review the many control rod drive mechanisms which have been developed and are available. In the event that it should prove to be more economical and expeditious to purchase control drive mechanisms directly, which will meet in every detail the specifications established for the Elk River Power Plant, such action may be taken.

188 058

Table I Theoretical Densities of ThO_2 and ThO_2-UO_2

Density, gm/cm^3	Composition	Reference
10.15	ThO_2	4
10.05	ThO_2	5
10.03	ThO_2	6
10.01 (a)	ThO_2	1
10.0	ThO_2	7
10.03 (a)	ThO_2-3 w/o UO_2	1
10.06 (b)	ThO_2-3 w/o UO_2	8

(a) Calculated from data in reference 1.
(b) Taken from estimated curve in reference 8.

Table II Bulk Densities of ThO_2 and ThO_2-UO_2

Per Cent of Theoretical	Composition	Reference
90-96	ThO_2	4
81	ThO_2	7
97	ThO_2-0.5 w/o CaO	9
97	ThO_2-1 w/o CaO	5
97	ThO_2-.5 w/o CaF_2	7
97	ThO_2-1 w/o CaF_2	5
83	ThO_2-1 w/o Al_2O_3	5
78	ThO_2-1 w/o MgO	5
78	ThO_2-2.5 w/o UO_2	7
79	ThO_2-2.5 w/o UO_2	10
93 (a)	ThO_2-2.5 w/o UO_2	10
97	ThO_2-2.5 w/o $UO_2$0.4 w/o V_2O_5	7
83	ThO_2-6.35 w/o UO_2	8
86 (a)	ThO_2-10 w/o UO_2	11
98 (a)	ThO_2-10 w/o UO_2	10

(a) These values are not bulk densities but are for comparison purposes only, as they are specimens whose densities were determined by water immersions so that the effect of open pores is not present.

REFERENCES

1. W. A. Lambertson, M. H. Mueller and F. H. Gunzel, Jr., "Uranium Oxide Phase Equilibrium Systems: IV, UO_2-ThO_2." J. Am. Ceram. Soc., 36, 397-399 (1953).

2. J. D. Eichenberg, et al, "Effects of Irradiation on Bulk UO_2," WAPD-183 (1957).

3. B. Lustman, "Release of Fission Gases from UO_2," WAPD-173 (1957).

4. P. Murray and D. T. Livey, "The Technology of Urania and Thoria," Progress in Nuclear Energy, 1, Series V, 448-478, Pergamon Press (1956).

5. C. E. Curtis and J. R. Johnson, "Properties of Thorium Oxide Ceramics," J. Am. Ceram. Soc., 40, 63-68 (1957).

6. Hdbk. Chem. and Physics, 37th ed., 611 (1955).

7. C. A. Arenberg, et al, "Thoria Ceramics," Bull, Am. Ceram. Soc., 36, 302-306 (1957).

8. J. H. Handwerk, C. L. Hoenig and R. C. Lied, "Manufacture of the ThO_2-UO_2 Ceramic Fuel Pellets for Borax IV," ANL-5678 (1957).

9. J. R. Johnson and C. E. Curtis, "Note on Sintering of ThO_2," J. Am. Ceram. Soc., 37, 611 (1954).

10. J. H. Handwerk and R. A. Noland, "Oxide Fuel Elements for High Temperatures," Chem. Eng. Prog., 53, No. 2, 60-62 (1957).

11. J. H. Handwerk, L. L. Abernethy and R. A. Bach, "Thoria and Urania Bodies," Bull. Am. Ceram. Soc., 36, 99-101, (1957).

12. J. H. Kittel and J. H. Handwerk, "Effects of Irradiation on the Ceramic Fuels ThO_2-UO_2 and UO_2," ANL-5675 (to be published).

13. R. Fillnow at High Temperatures Fuels Committee Meeting Dec. 12, 1957.

PROPOSED DESIGN DRAWINGS

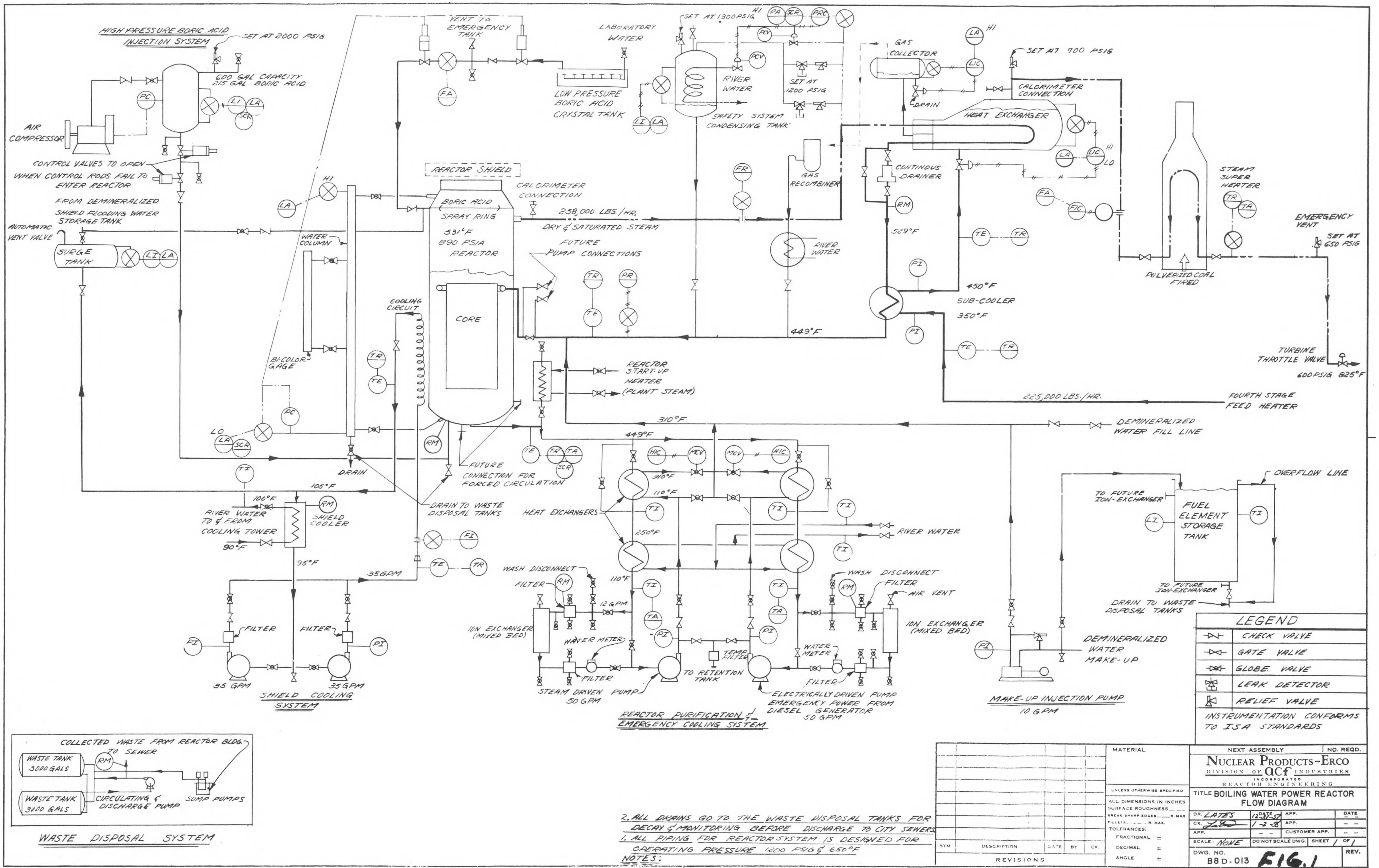
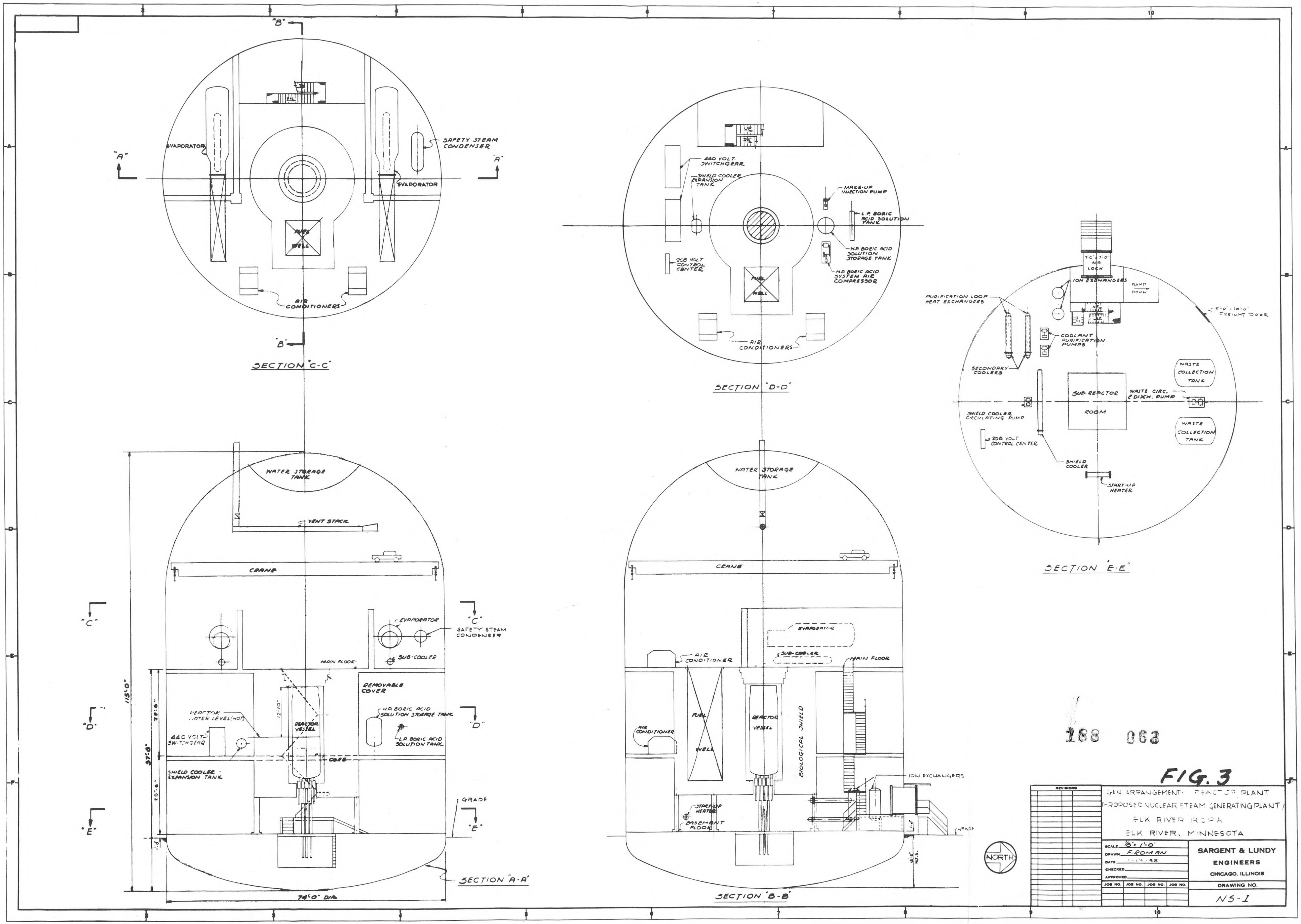

HIGH PRESSURE BORIC ACID INJECTION SYSTEM
SET AT 2000 PSIG
600 GAL CAPACITY 215 GAL BORIC ACID
AIR COMPRESSOR
CONTROL VALVES TO OPEN WHEN CONTROL RODS FAIL TO ENTER REACTOR
FROM DEMINERALIZED SHIELD FLOODING WATER STORAGE TANK
AUTOMATIC VENT VALVE
SURGE TANK
VENT TO EMERGENCY TANK
LABORATORY WATER
LOW PRESSURE BORIC ACID CRYSTAL TANK
SET AT 1300 PSIG
RIVER WATER
SET AT 1200 PSIG
SAFETY SYSTEM CONDENSING TANK
GAS COLLECTOR
DRAIN
SET AT 700 PSIG
CALORIMETER CONNECTION
HEAT EXCHANGER
REACTOR SHIELD
BORIC ACID SPRAY RING
531°F
890 PSIA
REACTOR
CALORIMETER CONNECTION
258,000 LBS./HR.
DRY & SATURATED STEAM
FUTURE PUMP CONNECTIONS
GAS RECOMBINER
CONTINOUS DRAINER
529°F
RIVER WATER
450°F
SUB-COOLER
350°F
449°F
STEAM SUPER HEATER
PULVERIZED COAL FIRED
EMERGENCY VENT
SET AT 650 PSIG
WATER COLUMN
BI-COLOR GAGE
COOLING CIRCUIT
CORE
REACTOR START-UP HEATER (PLANT STEAM)
TURBINE THROTTLE VALVE
600 PSIG 825°F
225,000 LBS./HR.
FOURTH STAGE FEED HEATER
310°F
DEMINERALIZED WATER FILL LINE
DRAIN
FUTURE CONNECTION FOR FORCED CIRCULATION
DRAIN TO WASTE DISPOSAL TANKS
105°F
100°F
RIVER WATER TO & FROM COOLING TOWER
SHIELD COOLER
90°F
95°F
35GPM
FILTER
35 GPM
SHIELD COOLING SYSTEM
HEAT EXCHANGERS
449°F
310°F
110°F
250°F
RIVER WATER
WASH DISCONNECT
12 GPM
ION EXCHANGER (MIXED BED)
WATER METER
TEMP. FILTER
TO RETENTION TANK
AIR VENT
STEAM DRIVEN PUMP 50 GPM
ELECTRICALLY DRIVEN PUMP EMERGENCY POWER FROM DIESEL GENERATOR 50 GPM
REACTOR PURIFICATION & EMERGENCY COOLING SYSTEM
OVERFLOW LINE
TO FUTURE ION-EXCHANGER
FUEL ELEMENT STORAGE TANK
DRAIN TO WASTE DISPOSAL TANKS
DEMINERALIZED WATER MAKE-UP
MAKE-UP INJECTION PUMP 10 GPM
LEGEND
CHECK VALVE
GATE VALVE
GLOBE VALVE
LEAK DETECTOR
RELIEF VALVE
INSTRUMENTATION CONFORMS TO ISA STANDARDS
COLLECTED WASTE FROM REACTOR BLDG.
TO SEWER
WASTE TANK 3000 GALS
CIRCULATING & DISCHARGE PUMP
SUMP PUMPS
WASTE DISPOSAL SYSTEM
2. ALL DRAINS GO TO THE WASTE DISPOSAL TANKS FOR DECAY & MONITORING BEFORE DISCHARGE TO CITY SEWERS
1. ALL PIPING FOR REACTOR SYSTEM IS DESIGNED FOR OPERATING PRESSURE 1200 PSIG & 650°F
NOTES:
REVISIONS
MATERIAL
NEXT ASSEMBLY
NO. REQD.
NUCLEAR PRODUCTS-ERCO
DIVISION OF ACF INDUSTRIES INCORPORATED
REACTOR ENGINEERING
TITLE BOILING WATER POWER REACTOR FLOW DIAGRAM
SCALE NONE
DO NOT SCALE DWG.
SHEET 1 OF 1
DWG. NO. B8D-013

FIG. 1



168 063

FIG. 3

GEN. ARRANGEMENT - REACTOR PLANT
PROPOSED NUCLEAR STEAM GENERATING PLANT
ELK RIVER RCPA
ELK RIVER, MINNESOTA

SCALE 1/8" = 1'-0"
DRAWN F. ROMAN
DATE 1-1?-58
CHECKED
APPROVED

SARGENT & LUNDY ENGINEERS
CHICAGO, ILLINOIS

DRAWING NO. NS-1

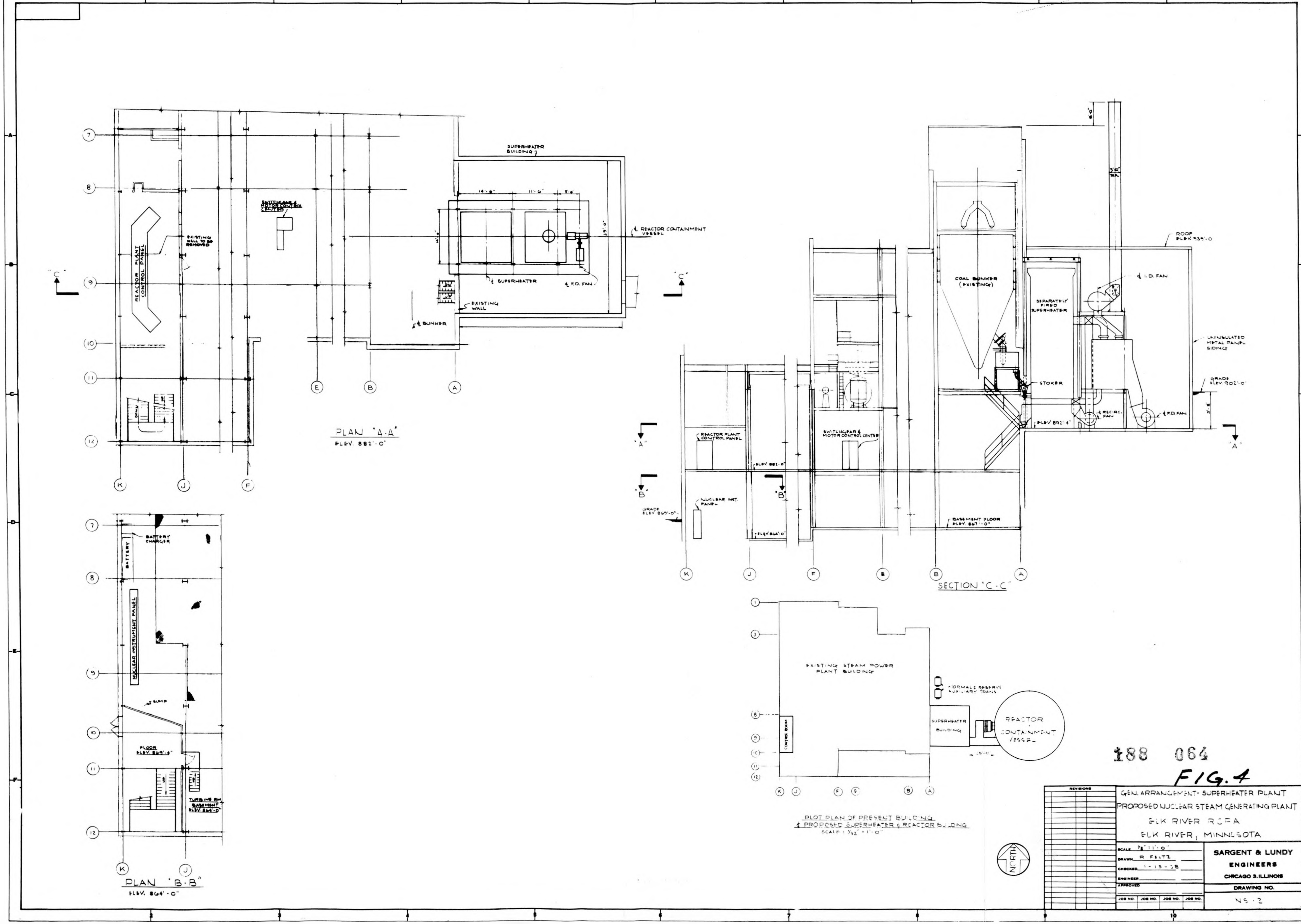
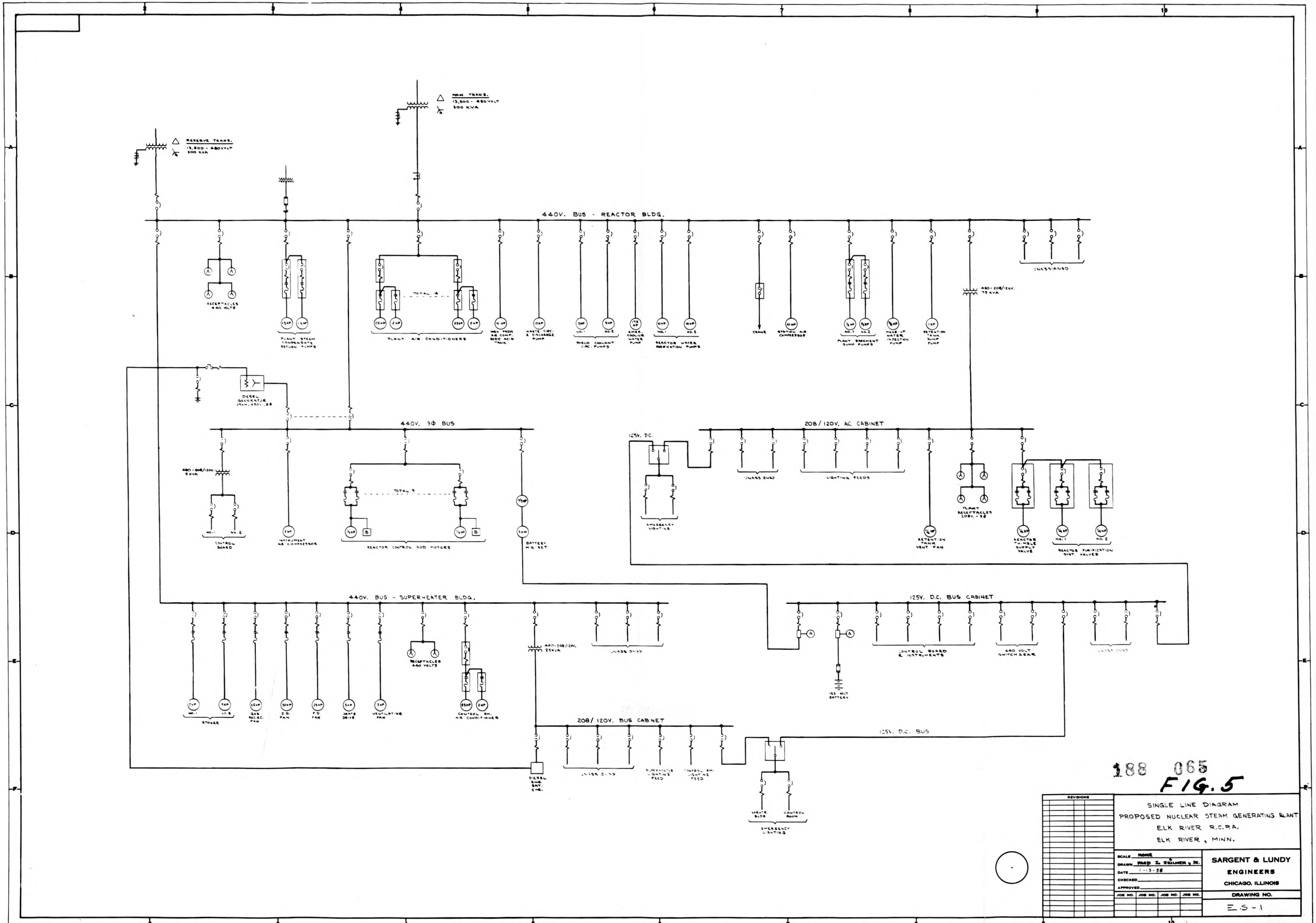

SUPERHEATER BUILDING
SWITCHGEAR & MOTOR CONTROL CENTER
REACTOR CONTAINMENT VESSEL
EXISTING WALL TO BE REMOVED
REACTOR PLANT CONTROL PANEL
℄ SUPERHEATER
℄ F.D. FAN
EXISTING WALL
℄ BUNKER
PLAN "A-A"
ELEV. 882'-0"
BATTERY
BATTERY CHARGER
NUCLEAR INSTRUMENT PANEL
SUMP
FLOOR ELEV. 869'-6"
TURBINE RM. BASEMENT FLOOR ELEV. 864'-0"
PLAN "B-B"
ELEV. 864'-0"
ROOF ELEV. 939'-0
COAL BUNKER (EXISTING)
SEPARATELY FIRED SUPERHEATER
℄ I.D. FAN
UNINSULATED METAL PANEL SIDING
GRADE ELEV. 902'-0"
STOKER
℄ RECIRC. FAN
℄ F.D. FAN
ELEV. 892'-4
REACTOR PLANT CONTROL PANEL
SWITCHGEAR & MOTOR CONTROL CENTER
NUCLEAR INST. PANEL
GRADE ELEV. 895'-0"
BASEMENT FLOOR ELEV. 867'-0"
SECTION "C-C"
EXISTING STEAM POWER PLANT BUILDING
NORMAL & RESERVE AUXILIARY TRANS.
SUPERHEATER BUILDING
REACTOR CONTAINMENT VESSEL
CONTROL ROOM
PLOT PLAN OF PRESENT BUILDING & PROPOSED SUPERHEATER & REACTOR BUILDING
NORTH
188 064
REVISIONS
GEN. ARRANGEMENT- SUPERHEATER PLANT
PROPOSED NUCLEAR STEAM GENERATING PLANT
ELK RIVER RCPA
ELK RIVER, MINNESOTA
SCALE 1/8" = 1'-0"
DRAWN R FELTZ
CHECKED 1-13-58
ENGINEER
APPROVED
JOB NO.
JOB NO.
JOB NO.
JOB NO.
SARGENT & LUNDY ENGINEERS
CHICAGO 3, ILLINOIS
DRAWING NO.
NS-2

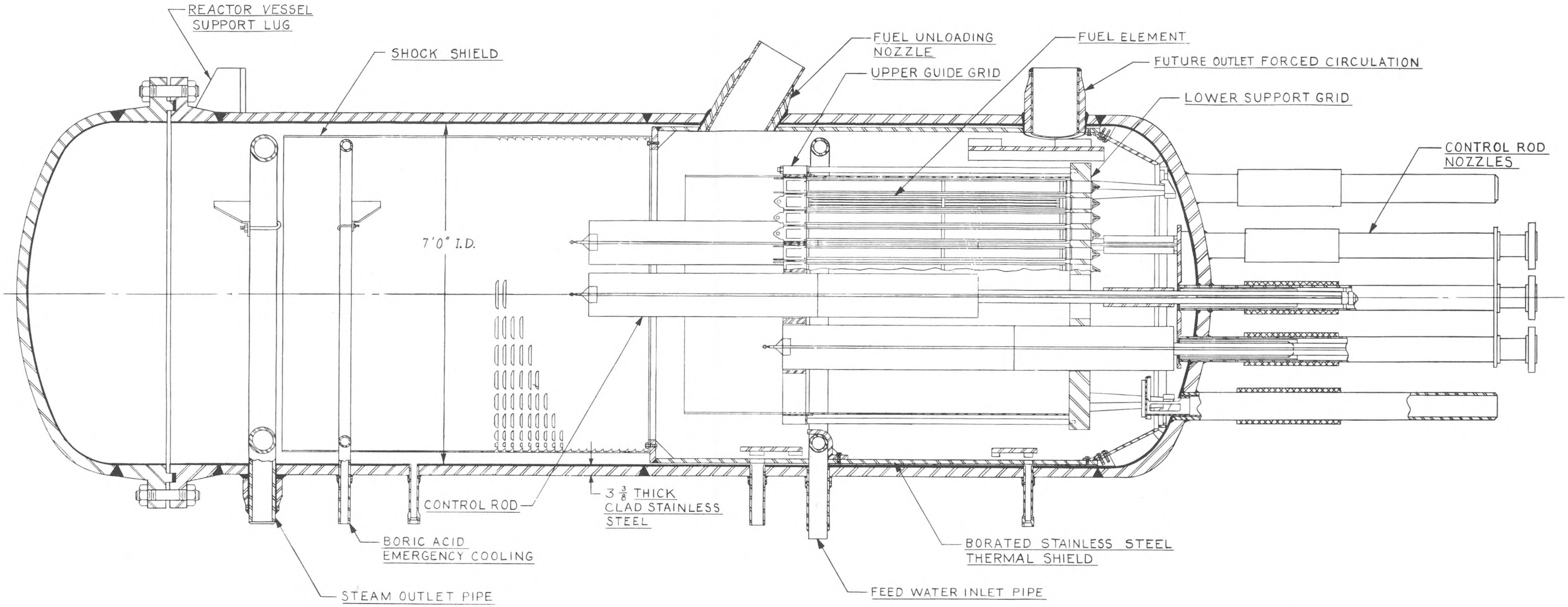
FIG. 4



MAIN TRANS.
13,800 - 480 VOLT
300 KVA
RESERVE TRANS.
13,800 - 480 VOLT
300 KVA
440V. BUS - REACTOR BLDG.
RECEPTACLES
440 VOLTS
PLANT STEAM CONDENSATE RETURN PUMPS
TOTAL 4
PLANT AIR CONDITIONERS
SHIELD COOLANT CIRC. PUMPS
REACTOR WATER PURIFICATION PUMPS
CRANE
STATION AIR COMPRESSOR
PLANT BASEMENT SUMP PUMPS
MAKE-UP WATER INJECTION PUMP
RETENTION TANK SUMP PUMP
UNASSIGNED
480-208/120V.
75 KVA
DIESEL GENERATOR
440V. 3Φ BUS
480-208/120V.
3 KVA
CONTROL BOARD
INSTRUMENT AIR COMPRESSOR
TOTAL 3
REACTOR CONTROL ROD MOTORS
BATTERY M.G. SET
208/120V. AC. CABINET
125V. D.C.
EMERGENCY LIGHTING
UNASSIGNED
LIGHTING FEEDS
RETENTION TANK VENT FAN
PLANT RECEPTACLES
208V. - 3Φ
REACTOR THIMBLE SUPPLY VALVE
REACTOR PURIFICATION SYST. VALVES
440V. BUS - SUPER-HEATER BLDG.
STOKER
I.D. FAN
F.D. FAN
GRATE DRIVE
VENTILATING FAN
RECEPTACLES
440 VOLTS
CONTROL RM. AIR CONDITIONER
480-208/120V.
25KVA
UNASSIGNED
125V. D.C. BUS CABINET
CONTROL BOARD & INSTRUMENTS
440 VOLT SWITCHGEAR
UNASSIGNED
125 VOLT BATTERY
208/120V. BUS CABINET
125V. D.C. BUS
DIESEL ENG. BAT. CHG.
UNASSIGNED
EMERGENCY LIGHTING
REVISIONS
SINGLE LINE DIAGRAM
PROPOSED NUCLEAR STEAM GENERATING PLANT
ELK RIVER R.C.P.A.
ELK RIVER, MINN.
SCALE NONE
DATE 1-13-58
CHECKED
APPROVED
SARGENT & LUNDY
ENGINEERS
CHICAGO, ILLINOIS
DRAWING NO.
E-S-1

188 065

FIG. 5



NOTE - REACTOR VESSEL DESIGNED FOR 1200 PSI AT 650° F.

188 066

SYM.	DESCRIPTION	DATE	BY	CK.
REVISIONS				

MATERIAL —

UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS IN INCHES
SURFACE ROUGHNESS ____
BREAK SHARP EDGES ____ R. MAX.
FILLETS ____ R. MAX.
TOLERANCES:
FRACTIONAL ± —
DECIMAL ± —
ANGLE ± —

NEXT ASSEMBLY | NO. REQD.

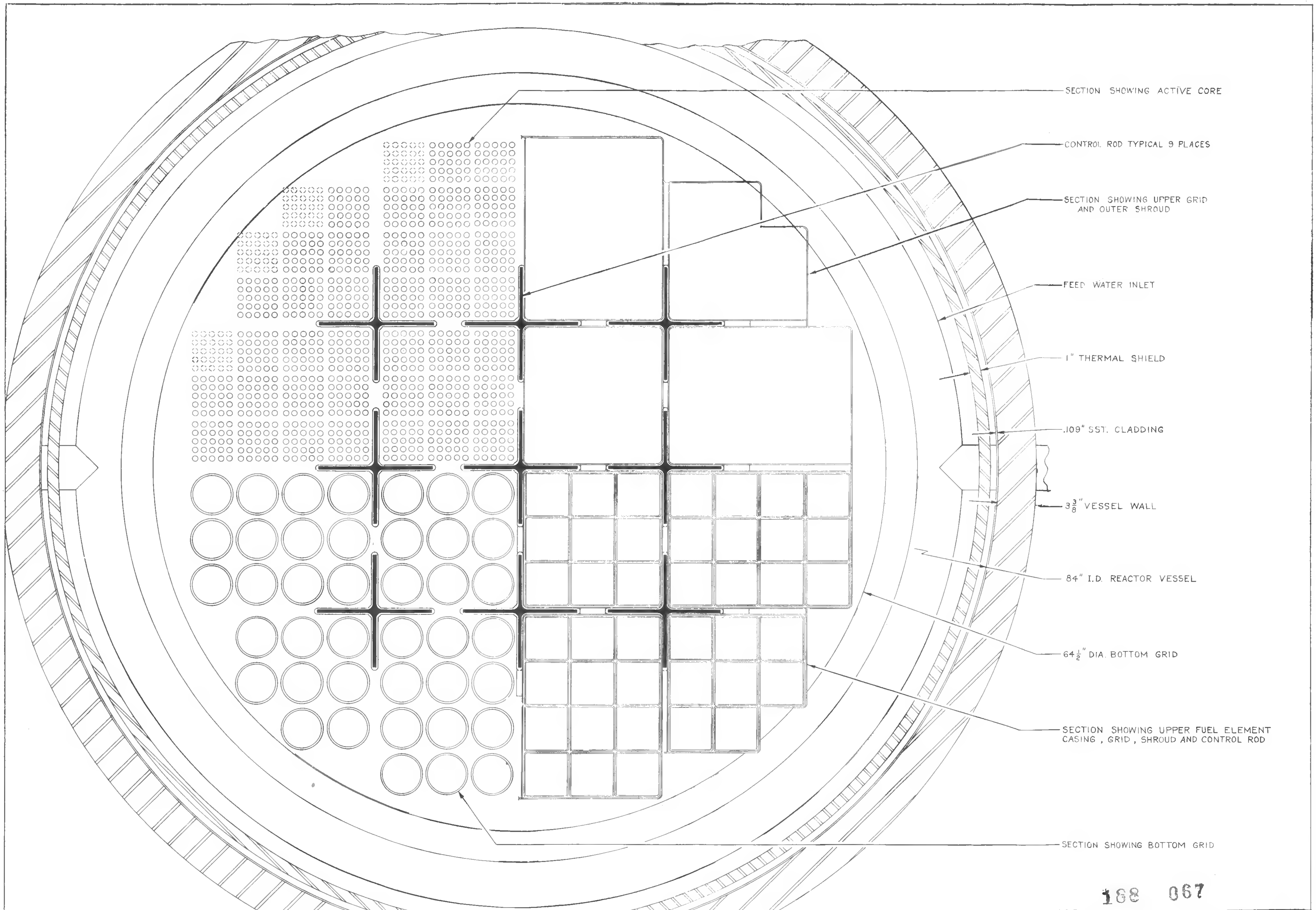
NUCLEAR PRODUCTS-ERCO
DIVISION OF ACF INDUSTRIES INCORPORATED
REACTOR ENGINEERING

TITLE BOILING WATER POWER REACTOR
REACTOR ARRANGEMENT
REACTOR VESSEL

DR. CARLE	DATE 11-25-57	APP.	DATE —
CK. [illegible]	12-12-57	APP. J.J. DICKSON	12-12-57
APP.	— —	CUSTOMER APP.	— —
SCALE - —	DO NOT SCALE DWG.	SHEET	OF

DWG. NO. B8D-003 FIG. 6a

REV.

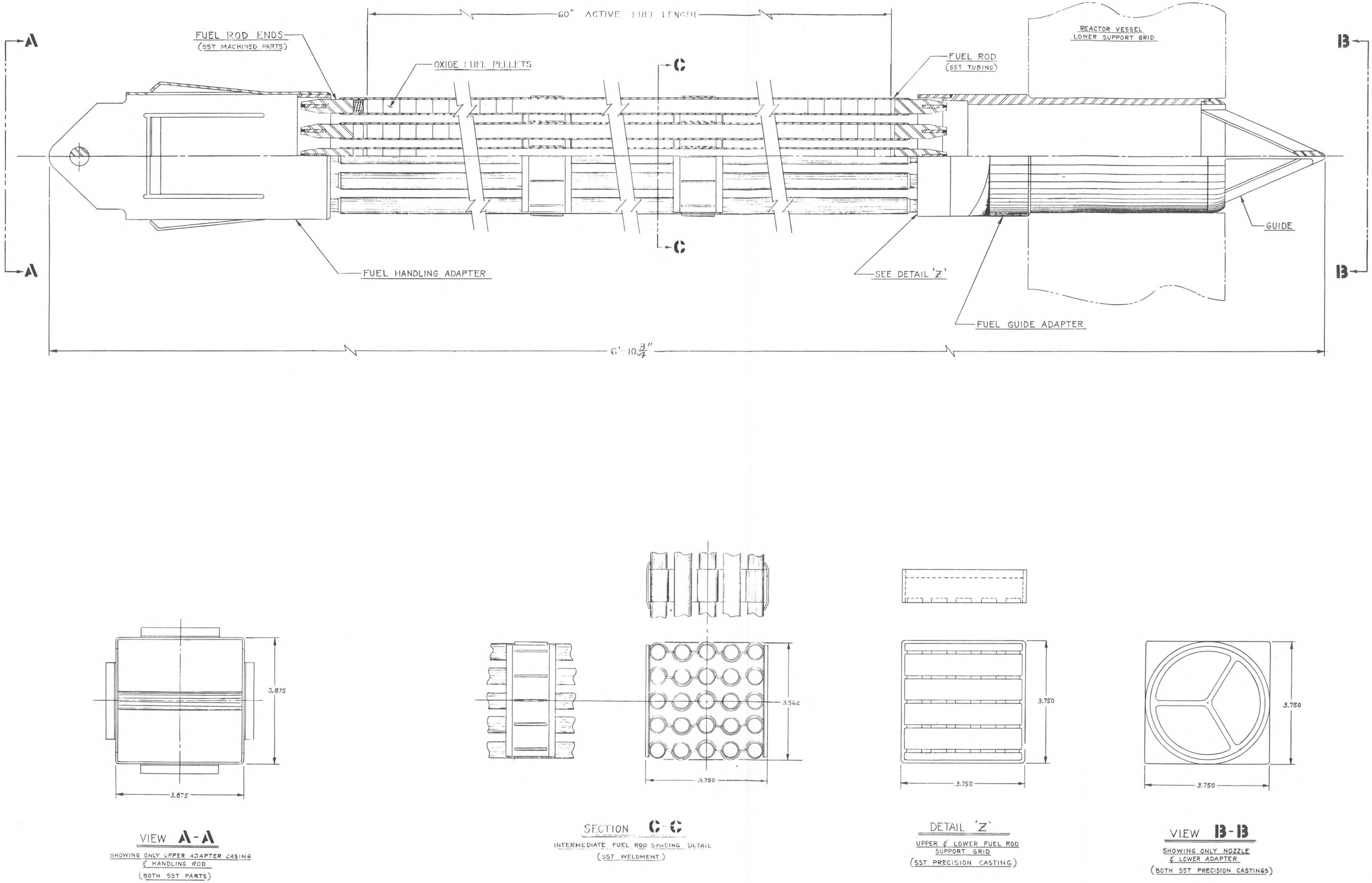


188 067

BOILING WATER POWER REACTOR
HORIZONTAL SECTIONS

CARLE
J.J. DICKSON 12 12 56
NONE
B8 004

FIG. 6



188 068

SYM.	DESCRIPTION	DATE	BY	CK.
REVISIONS				

MATERIAL: -

UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS IN INCHES
SURFACE ROUGHNESS -
BREAK SHARP EDGES - R. MAX.
FILLETS - R. MAX.
TOLERANCES
FRACTIONAL ± -
DECIMAL ± -
ANGLE ± -

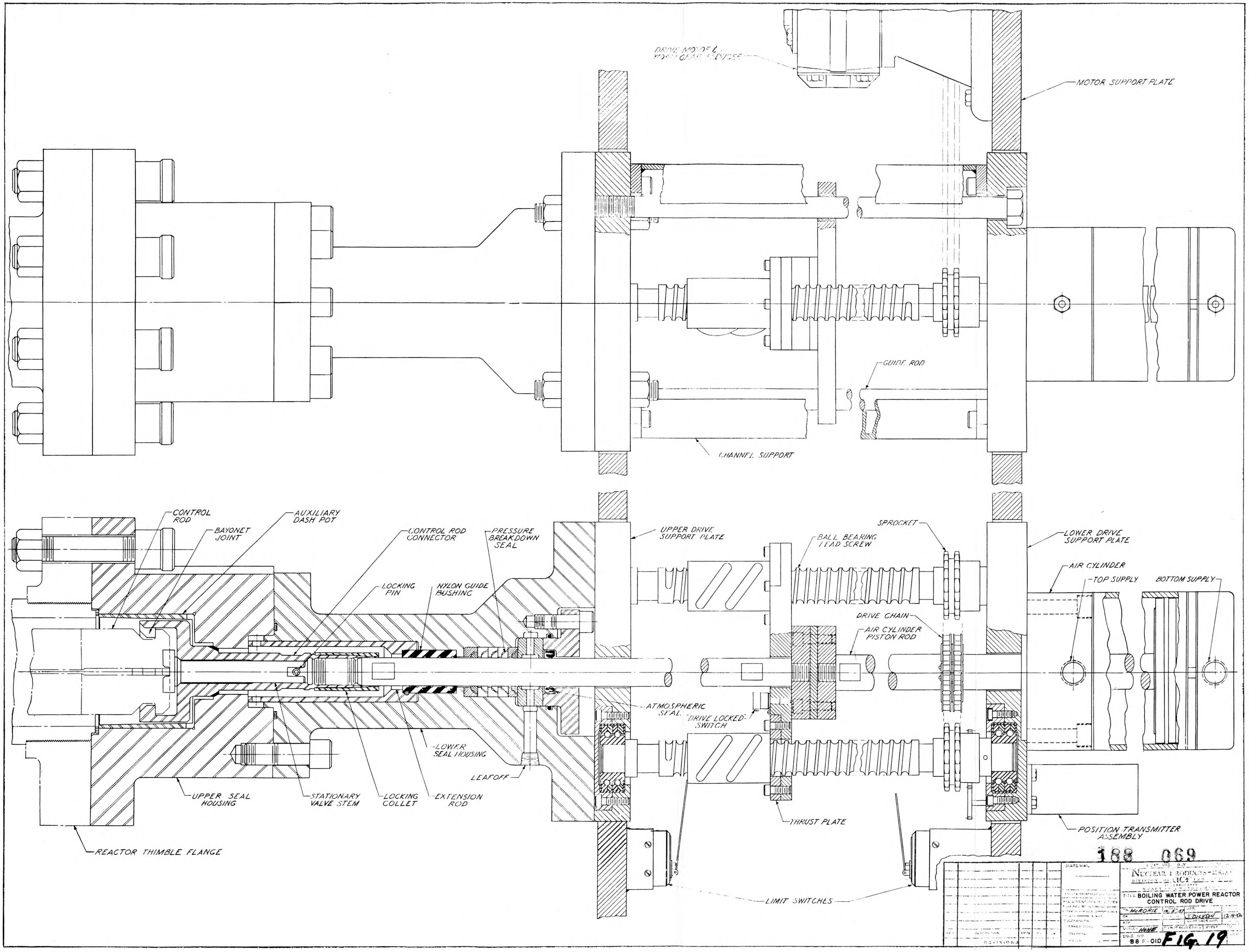
NEXT ASSEMBLY | NO. REQD.

NUCLEAR PRODUCTS-ERCO
DIVISION OF ACF INDUSTRIES INCORPORATED
REACTOR ENGINEERING

TITLE BOILING WATER POWER REACTOR FUEL ELEMENT ASSEMBLY

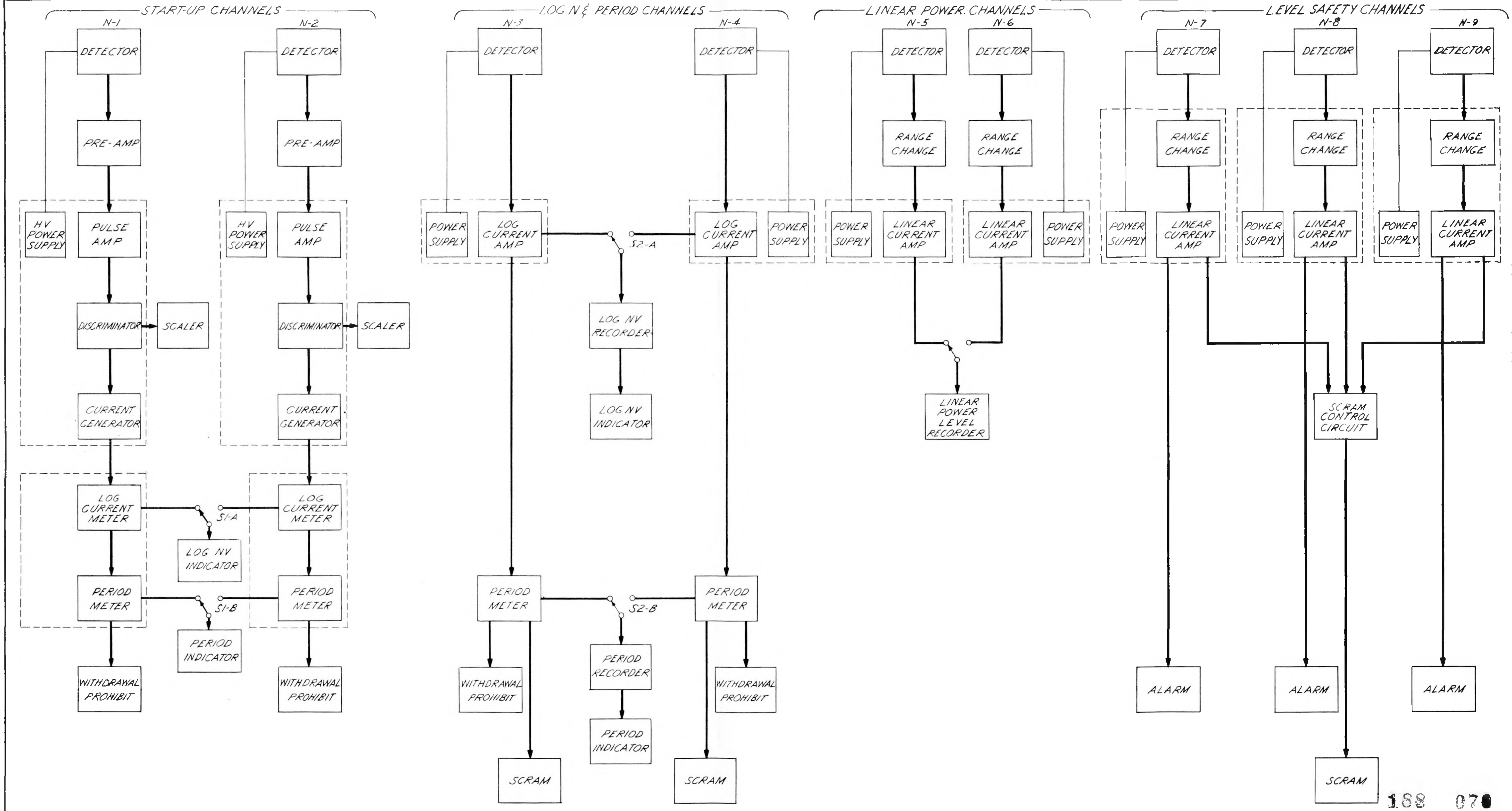
DR. CARLE	DATE 12-3-57	APP.	DATE - -
CK. [illegible]	12-12-57	APP. J.J. DICKSON	12-12-57
APP.	- -	CUSTOMER APP.	- -
SCALE - NONE	DO NOT SCALE DWG.	SHEET	OF

DWG. NO. B8 E-001 FIG. 8 REV.



DRIVE MOTOR & WORM GEAR ASSEMBLY
MOTOR SUPPORT PLATE
GUIDE ROD
CHANNEL SUPPORT
CONTROL ROD
BAYONET JOINT
AUXILIARY DASH POT
CONTROL ROD CONNECTOR
PRESSURE BREAKDOWN SEAL
UPPER DRIVE SUPPORT PLATE
BALL BEARING LEAD SCREW
SPROCKET
LOWER DRIVE SUPPORT PLATE
AIR CYLINDER
TOP SUPPLY
BOTTOM SUPPLY
LOCKING PIN
NYLON GUIDE BUSHING
DRIVE CHAIN
AIR CYLINDER PISTON ROD
ATMOSPHERIC SEAL
"DRIVE LOCKED" SWITCH
LOWER SEAL HOUSING
LEAKOFF
UPPER SEAL HOUSING
STATIONARY VALVE STEM
LOCKING COLLET
EXTENSION ROD
THRUST PLATE
POSITION TRANSMITTER ASSEMBLY
REACTOR THIMBLE FLANGE
LIMIT SWITCHES
188 069
MATERIAL
REVISIONS
NUCLEAR PRODUCTS
BOILING WATER POWER REACTOR CONTROL ROD DRIVE
McRORIE 12-5-57
J. DICKSON 12-19-56
SCALE NONE
DWG. NO. B8 F-010

FIG. 19



188 070

SYM.	DESCRIPTION	DATE	BY	CK.
	REVISIONS			

MATERIAL

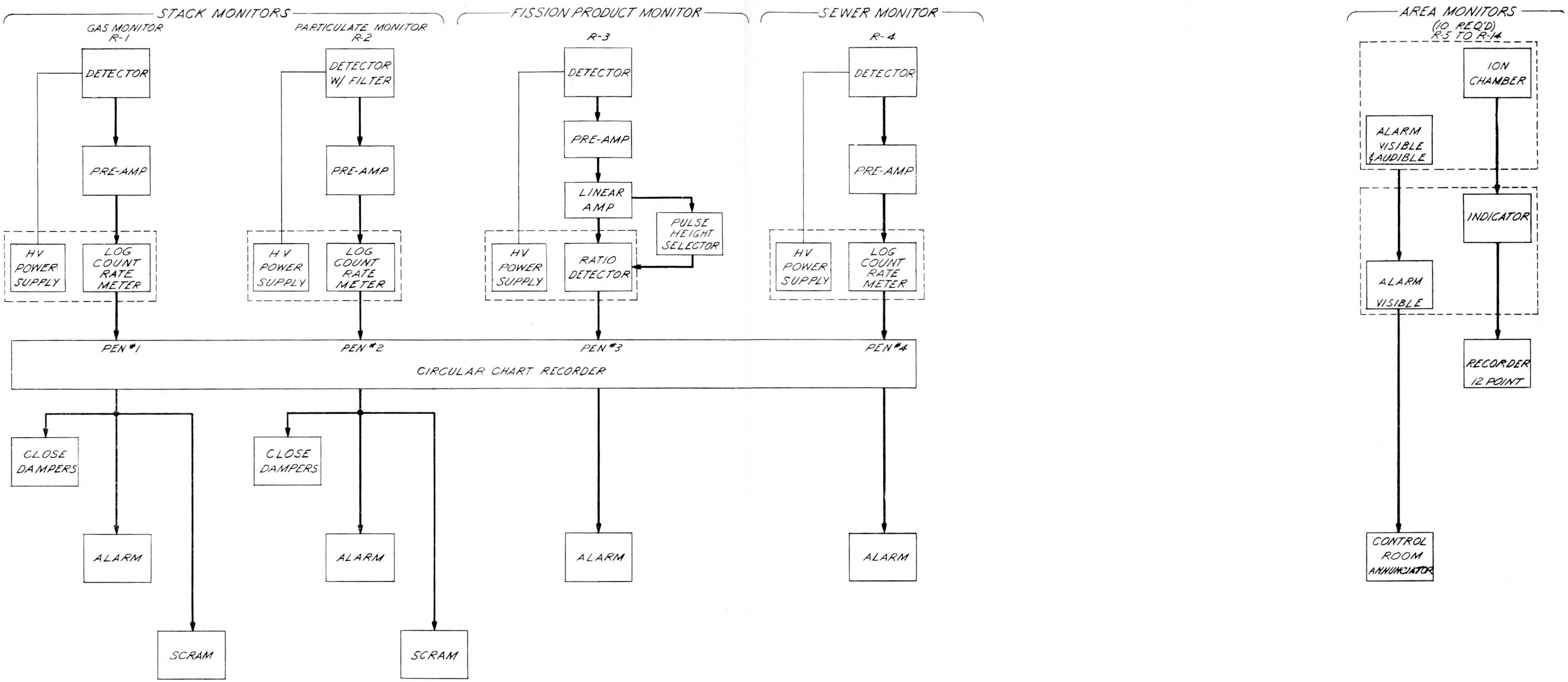
UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS IN INCHES
SURFACE ROUGHNESS
BREAK SHARP EDGES — R. MAX.
FILLETS — R. MAX.
TOLERANCES:
FRACTIONAL ±
DECIMAL ±
ANGLE ±

NEXT ASSEMBLY | NO. REQD.

NUCLEAR PRODUCTS-ERCO
DIVISION OF ACF INDUSTRIES INCORPORATED
REACTOR ENGINEERING

TITLE BOILING WATER POWER REACTOR NUCLEAR FLUX INSTRUMENTATION

DR. McRORIE DATE 12-30-57 APP.
CK. 12-31-57 APP.
APP. CUSTOMER APP.
SCALE - NONE | DO NOT SCALE DWG. | SHEET 1 OF 1
DWG. NO. B8-D-011 **FIG. 20** REV.



188 071

SYM.	DESCRIPTION	DATE	BY	CK.

REVISIONS

MATERIAL

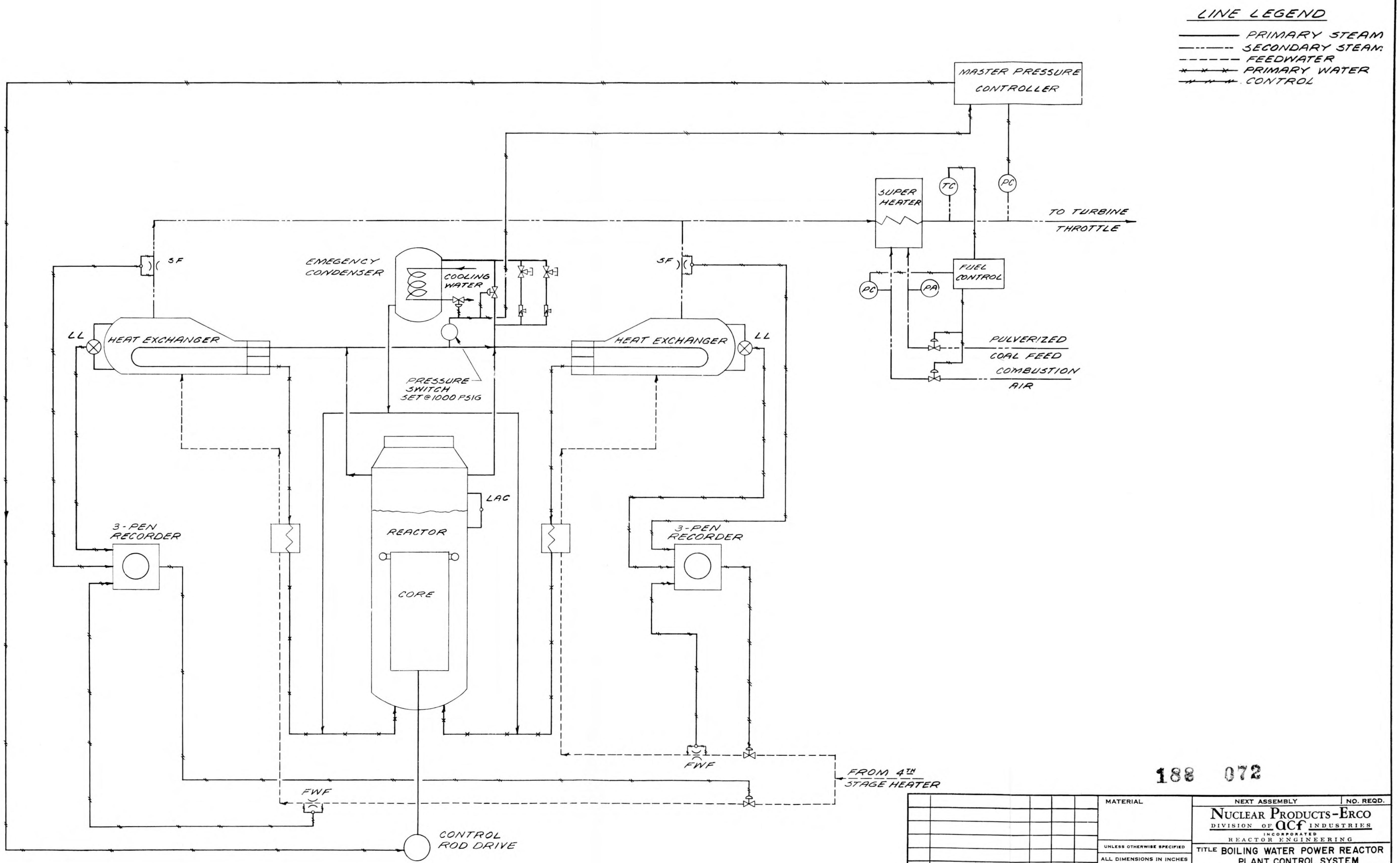
UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS IN INCHES
SURFACE ROUGHNESS
BREAK SHARP EDGES R. MAX.
FILLETS R. MAX.
TOLERANCES:
FRACTIONAL ±
DECIMAL ±
ANGLE ±

NEXT ASSEMBLY | NO. REQD.

NUCLEAR PRODUCTS-ERCO
DIVISION OF ACF INDUSTRIES INCORPORATED
REACTOR ENGINEERING

TITLE BOILING WATER POWER REACTOR RADIATION MONITORING INSTRUMENTATION

DR. McRORIE DATE 12-27-57 APP.
CK. [illegible] 12-29-57 APP.
APP. — — CUSTOMER APP. — —
SCALE NONE | DO NOT SCALE DWG. | SHEET 1 OF 1
DWG. NO. 88-D-012 FIG. 21 | REV.



188 072

SYM.	DESCRIPTION	DATE	BY	CK.
	REVISIONS			

MATERIAL

UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS IN INCHES
SURFACE ROUGHNESS ____
BREAK SHARP EDGES ____ R. MAX.
FILLETS ____ R. MAX.
TOLERANCES:
FRACTIONAL ±
DECIMAL ±
ANGLE ±

NEXT ASSEMBLY | NO. REQD.

NUCLEAR PRODUCTS-ERCO
DIVISION OF ACF INDUSTRIES INCORPORATED
REACTOR ENGINEERING

TITLE BOILING WATER POWER REACTOR PLANT CONTROL SYSTEM

DR. T. BRYANT	DATE 1-23-58	APP.	DATE
CK. [signature]	1-23-58	APP. J. DICKSON	— —
APP.	— —	CUSTOMER APP.	— —
SCALE - NONE	DO NOT SCALE DWG.	SHEET 1	OF 1

DWG. NO. B8D-014 FIG. 22 | REV.

VI

QUALIFICATIONS

1. INTRODUCTION

ACF Industries, Incorporated will act as prime contractor for the proposed Elk River Nuclear Reactor Project, and assume full responsibility for the completion of work as described earlier in this proposal. ACF is qualified to undertake such an endeavor by virtue of its past accomplishments in the nuclear energy field, its trained nuclear engineering and management personnel, and its direct activity and association with the boiling water reactor concept as a proprietary design product.

In order to supplement these qualifications and present both the Rural Cooperative Power Association and the Atomic Energy Commission with the full breadth of experience available on the projects of this type, ACF has chosen to engage as its prime subcontractors Sargent & Lundy Engineers of Chicago, Illinois, as Architectural Engineers for this project, and the Maxon Construction Company, Incorporated, of Dayton, Ohio, as the general contractors. Both of these firms are well known for their previous accomplishments in the Atomic Energy field and specifically for the direct contribution by Sargent & Lundy to the development of Boiling Water Reactors for the Argonne National Laboratory.

Contained in this section are the qualifications of these two companies, as well as ACF Industries, Incorporated. In accordance with the bid invitation, not only the key personnel and facilities of each of these firms are indicated, but also a brief summary of the more important projects in which each has taken part. Additional information describing in more detail the overall activities of ACF Industries, Incorporated and its two subcontractors is available for inspection by the AEC or RCPA.

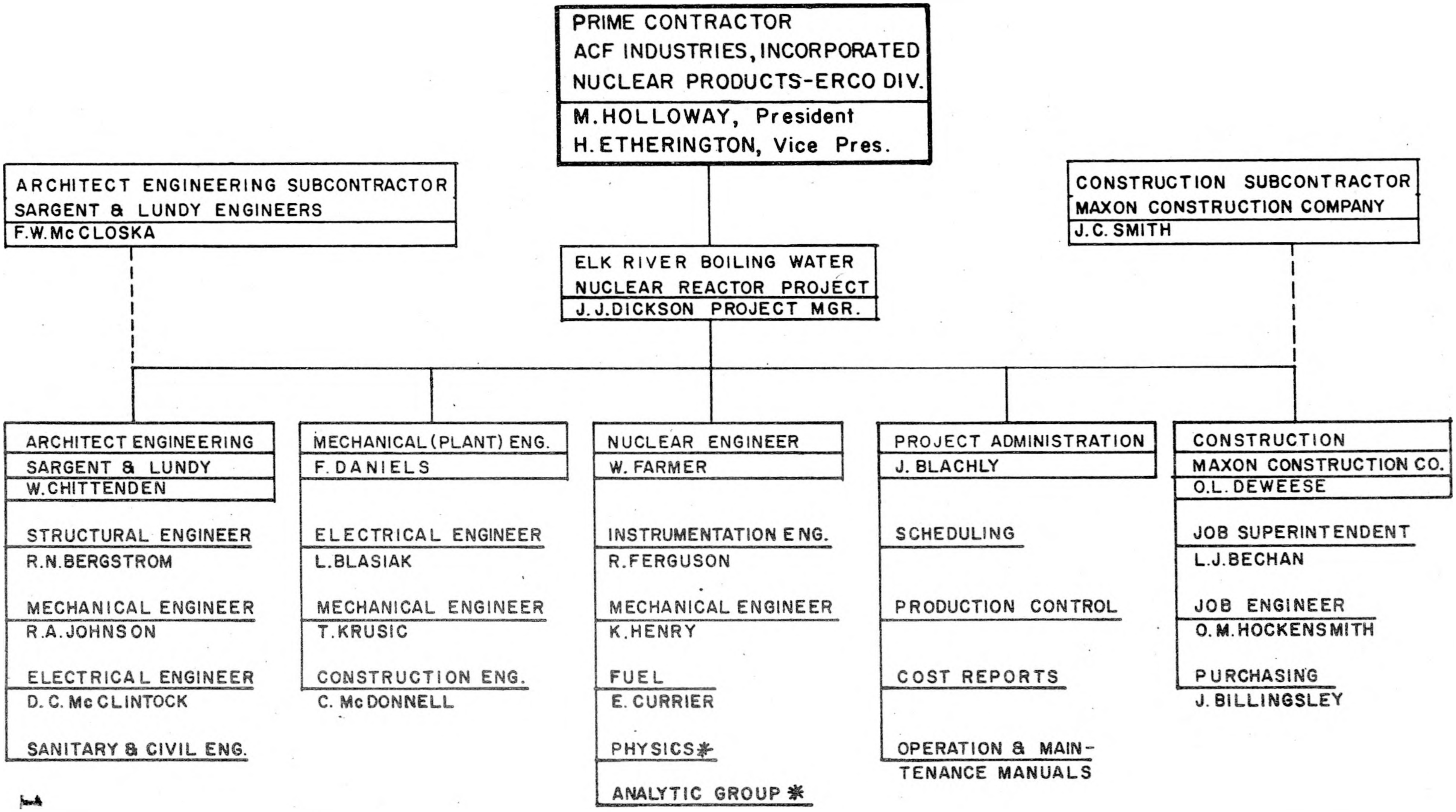
It should be noted that ACF has, in the past, worked on actual projects with both of these companies and established well organized relations with them. It is expected that the headquarters for all operations concerned with the Elk River Project would be in Washington, D. C. at the ACF Engineering headquarters. This central location will result in a minimum of liaison by the Rural Cooperative Power Association and the Atomic Energy Commission with the prime contractor and all of the subcontractors.

It is felt that the assembly of a working team such as this will insure the prompt execution of the proposed project. Each company has fully contributed to the preparation of this proposal and each company stands ready to provide not only key personnel as shown in the organization chart but also the complete resources of their entire organizations.

2. PROPOSED ORGANIZATION AND KEY PERSONNEL

On the following page is shown the proposed organization for the Elk River Nuclear Power Reactor Project. This organization is represented by a simplified chart showing the general division of duties and indicating some of the key personnel who are expected to contribute to the operation of the project. The resumes of experience for these people shown on the chart and for other management and supporting personnel are included in later portions of this section.

Inasmuch as this group will be part of the ACF Reactor Engineering Offices and be reporting directly to the divisional Vice President, the services of other specialized groups already functioning on other reactor projects will be made available to the Elk River Project. The skills and services of the many specialist departments and groups employed by Maxon and Sargent & Lundy will also be available in similar manner although not specifically shown on the chart. Thus, while the proposed organization will function as an independent and separate group, it will draw on the resources and skills of established and experienced management and engineering groups.



* WORK TO BE CARRIED OUT BY REGULAR ACF ENGINEERING SPECIALISTS GROUPS.

PROPOSED ORGANIZATION FOR ELK RIVER NUCLEAR POWER REACTOR PROJECT. FIGURE 23

3. ACF INDUSTRIES, INCORPORATED

A. Background

Nuclear Products-Erco, a Division of ACF Industries, Incorporated, one of ACF's seven operating divisions, offers a long and distinguished record in the nuclear energy field, both as a designer and builder of commercial reactors and as a prime contractor for the United States Government.

This Division carries on its operations at five main locations: two production plants in Buffalo, New York; its Erco Manufacturing Plant in Riverdale, Maryland; its Reactor Engineering Headquarters in Washington, D. C.; and the Albuquerque facility which is owned by the United States Government and operated by ACF.

The Washington Engineering Office is the design center for ACF's commercial reactor operations. The staff of the Engineering Headquarters consists of over 315 employees, of which over 175 are trained and experienced reactor specialists. The staff represents hundreds of manyears of direct experience in design, development, erection, operation and maintenance of nuclear reactors and associated facilities. This experience has been received not only in the commercial reactor field but in Government atomic energy laboratories such as Argonne National Laboratory, Oak Ridge National Laboratory, Los Alamos National Laboratory and the Materials Testing Reactor Center.

ACF is able to supplement its nuclear activities by its 20 other manufacturing plants which are engaged in the design and manufacture of electrical instruments and control systems, pressure vessels, storage tanks, high pressure valve fittings, small precision equipment, massive heavy equipment and highly complex products for aircraft and ordnance. The constant interchange and flow of technical information among its 20 plants is an essential factor in the continual development of new ideas and improvement of product that ACF is noted for. The combination of highly trained, skilled and experienced personnel, plus its diversified manufacturing facilities, qualifies ACF to undertake a nuclear project such as the one proposed for Elk River.

Contained on the following pages is information concerning the personnel who will be directly assigned to this project and those who will generally support it. Also shown on the following pages are brief descriptions of the projects in which ACF is currently engaged. In this connection, these projects are distinguished by the fact that they represent some of the largest and most important reactors being built both in the United States and in Europe.

In addition to the specific projects listed, ACF has been conducting, for the past 18 months, a design program on the boiling water power reactor concept financed entirely by ACF company funds. The objective of this program was to develop an optimum design for a nuclear power plant which could be built and operated on a sound economical and technical basis. Much of the results and effort of this program have been incorporated into this proposal and the experience gained during this program will contribute heavily towards completion of the proposed plant. Special efforts were also made by ACF in preparing the proposal; as evidenced by the manufacture of a special dummy fuel element in order to completely analyze the fuel manufacturing and cost problems prior to inclusion in the proposal.

SUMMARY OF DESIGN AND CONSTRUCTION COSTS

FOR ACF NUCLEAR REACTOR PROJECTS

Client	Project	Construction Cost	Design Cost	Type Contract
Mass. Inst. of Tech.	Heavy Water Reactor	$ 1,300,000	$ 500,000	FP
Comitato Nazaionale per le Ricerche Nucleari	Heavy Water Reactor	1,300,000 *	375,000	FP
Argonne National Laboratory	Heavy Water Reactor Cost Prospective	No const. wk. incl. in cont.	15,000	CPFF
Reactor Centrum Nederland	Light Water Reactor	1,600,000 *	500,000	FP
Atomic Energy Company of Sweden	Light Water Reactor	1,600,000 *	700,000	FP
Nuclear Eng. Test Facility	Light Water Reactor	2,300,000	700,000	FP
Case Inst. of Tech.	Light Water Reactor	No const. wk. incl. in cont.	73,000	CPFF
A.E.C.	Gas Cooled Power Reactor	Not yet established	500,000	CPFF

* Approximate figures only.

C. Current and Past Nuclear Projects

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

The Massachusetts Institute of Technology has selected ACF Industries, Incorporated to engineer and construct the MIT research reactor and associated facilities. A heavy water cooled and moderated reactor, selected primarily because of its inherent safety features, will operate at a power level of 1000 KW, producing 10^{13} n/cm^2/sec flux at any of a variety of experimental ports. Experimental facilities include 13 fixed ports, 1 through port, and 4 instrument ports, as well as 6 vertical thimbles in the graphite region and sample thimbles for the core. Also included is a thermal column and medical therapy facility with a water and boron filled shutter arrangement. A thermal neutron flux of 10^{10} n/cm^2/sec with a fast neutron background held to 10^7 n/cm^2/sec and gamma background of 100 r/hr is expected in this area. Other facilities in the basement are a gamma irradiation room using stored spent fuel elements, chemistry hot labs, reactor control room and equipment for servicing the reactor building. It is expected that this reactor will achieve criticality sometime early in 1958.

ITALIAN NATIONAL COMMITTEE ON NUCLEAR RESEARCH

The Comitato Nazionale per le Ricerche Nucleari of Rome, Italy is building a research center in northern Italy. For this center, ACF Industries, Incorporated is providing a heavy water cooled and moderated 5000 KW research reactor. The reactor will use 20% enriched fuel and will feature a graphite reflector. The heavy water cooling system consists of two 2.5 MW loops in parallel, allowing continuous half power operation while servicing one of the loops. Experimental facilities include 13 fixed ports, 3 through ports, 10 instrument ports, 5 vertical thimbles and 4 pneumatic rabbits. Also, a thermal column and two isotope production facilities will be provided. In addition to the design and fabrication of this reactor, ACF will provide technical supervision for the construction, installation, pre-operational testing, and start-up of the reactor.

ARGONNE NATIONAL LABORATORY

ACF has completed a general scoping report on a new research reactor for the Argonne National Laboratory. Designated as the CP-5 Prime, this reactor is a heterogeneous fully enriched heavy water machine, designed to operate at 10,000 KW. Featured in the scoping study are detailed specifications on the reactor, its experimental facilities, its cooling systems and auxiliary systems, as well as general specifications for the supporting buildings, laboratories and their utilities. ACF feels distinguished to have been selected to perform work on what is probably the most advanced heavy water research reactor yet proposed.

REACTOR CENTRUM NEDERLAND

Reactor Centrum Nederland, the Netherlands' Institute for the development of atomic energy for peaceful purposes, has selected ACF Industries, Incorporated to design and build a materials testing and research reactor for their use. This will be a light water cooled and moderated, high flux reactor to operate at 20,000 KW. The reactor vessel is immersed in a light water pool with concrete shielding walls pierced with ten experimental beam tubes, a large facility hole, and four rabbit tubes. Two adjacent storage pools are separated by aluminum gates from the main pool. An 82 foot diameter gastight steel shell with airtight access ports for personnel and equipment contains the reactor and pools. An adjacent building will contain assembly area, storage rooms, work shops, control consoles, instrument rooms and office space.

ATOMIC ENERGY COMPANY OF SWEDEN

ACF Industries, Incorporated is presently designing a 30,000 KW light water cooled and moderated research and test reactor for the Atomic Energy Company of Sweden. This reactor is capable of producing thermal flux in excess of 2×10^{14} n/cm^2/sec. One of the unique features of this reactor is the arrangement of the experimental facilities which will include provisions for a channel through the center of the fuel section and four channels in each of the fuel section corners. A flat side on the pressure vessel enables a through 7" x 24" column to be located adjacent to the core. Additional experimental facilities include 8 beam tubes, 2 pneumatic and 2 hydraulic rabbits, and a dry gamma irradiation facility. ACF will supply the reactor, supervise the construction and installation, and conduct reactor start-up operations.

NUCLEAR ENGINEERING TEST FACILITY - U. S. AIR FORCE

A 10,000 KW light water cooled and moderated nuclear reactor is being designed and fabricated by ACF Industries, Incorporated for the U. S. Air Force at Wright-Patterson Air Force Base, Ohio. This reactor is part of a facility being built by the Maxon Construction Company under contract to the U. S. Army Corps of Engineers. This reactor includes irradiation cells equipped with facilities for simulating high altitude conditions to determine behavior of nuclear aircraft equipment while under irradiation and in flight. These cells are loaded by a small remotely operated rail car. Additional radiation space is available within the reactor vessel directly over the core. Also included is a bulk shielding facility, fuel element storage and gamma irradiation well, thermal column, and a number of beam tubes. ACF will design and fabricate the reactor and associated equipment and supervise start-up, operational tests and operator training.

CASE INSTITUTE OF TECHNOLOGY

ACF Industries, Incorporated has been selected by the Case Institute of Technology to provide the preliminary design and scoping for a high flux engineering and test reactor and associated nuclear facilities for the proposed Case Industrial Nuclear Center. ACF will participate in the project under subcontract to the Austin Company, a nationally known engineering and building firm. The reactor to be designed by ACF will operate at a power level of 15,000 to 20,000 KW with a flux of approximately 2×10^{14} n/cm^2/sec. To be included in the project are gamma irradiation facilities, with laboratories and caves, radiochemistry laboratories, and other appurtenances to complement the irradiation facilities in the reactor.

GAS COOLED POWER REACTOR PROJECT

ACF Industries, Incorporated has been selected as subcontractor to Kaiser Engineers to perform the nuclear portion of the Gas Cooled Power Reactor Project. This project requires the preliminary design and engineering services of a complete nuclear power reactor system. This reactor will be a partially enriched uranium, gas cooled, graphite moderated reactor capable of furnishing approximately 40,000 KW net electrical capacity. The initial studies will not only show the design characteristics but also estimates for both capital and operating costs. In addition to performing the actual engineering, design, and physics work on the nuclear portion of this plant, ACF will assist in the preparation of defense and safeguard reports and selection of design characteristics of optimized reactors with respect to power costs and most economical size.

OTHER PROJECTS

In addition to the projects listed above, ACF has also been selected by the Atomic Energy Commission to prepare a book manuscript describing the various techniques of irradiation testing. This book will be prepared and edited by the Nuclear Engineering staff of ACF and turned over to AEC for publication.

The Air Force Cambridge Research Center has selected ACF to perform a series of studies concerning the selection of a reactor type most suitable for their specific requirements. As part of their responsibility, ACF will analyze the needs and objectives of the Research Center and suggest a reactor type best suited for their requirements.

D. <u>Personnel</u>

Many of the present members of the Nuclear Products-Erco Division of ACF Industries, Incorporated previously held responsible positions in projects of significant importance in the field of nuclear energy. The following list indicates some of the more important projects:

CP-5	Heavy water nuclear research reactor, designed and built at Argonne National Laboratory.
LITR	Low Intensity Training Reactor, the MTR prototype designed and built at Oak Ridge National Laboratory
MTR	Materials Testing Reactor, the AEC 40 MW test facility at the National Reactor Testing Station
ETR	Engineering Test Reactor, the AEC 175 MW test facility now under construction at the National Reactor Testing Station.
RMF	Reactivity Measurement Facility, a zero-plus power critical assembly at the National Reactor Testing Station
BORAX I and BORAX II	Boiling Reactor transient experiments conducted in specially designed reactors at the National Reactor Testing Station
STR	Submarine Thermal Reactor, the Nautilus prototype test reactor at the National Reactor Testing Station
EBR II Working Model Experiment	Mechanical test of components for EBR II in a tank containing 5000 gal. sodium at a temperature of 750F
SIR	Submarine Intermediate Reactor Program, the sodium cooled reactor power unit for the submarine "Seawolf". Designed and built at Knolls Atomic Power Laboratory
EBWR	Experimental Boiling Water Reactor at Argonne National Laboratory
SPERT-1	Special Power Excursion Reactor Test, NRTS, Idaho Falls, Idaho

SRE	Sodium Reactor Experiment, Santa Susanna, California

From the diverse projects listed, there has been acquired a comprehensive and well-rounded experience in research, development, design, manufacture, operation and maintenance of nuclear reactors. This accumulation of reactor technology is being directed toward the design and construction of commercial reactors available to private industry.

The personnel listed under Part (1) are members of the ACF engineering group who have been designated for work on the Elk River Project and will be directly responsible for its completion. These men are not presently assigned to any long range projects and will be made available for work on the proposed Elk River design. Each has participated to some extent in the preparation of this proposal and consequently is familiar with design proposed herein.

The personnel listed under Part (2) are members of ACF management who will be directly concerned with the Elk River project and devote part of their time towards overall supervision and general policy considerations involving this work.

(1) Technical Personnel

(a) Project

JAMES J. DICKSON — Assistant Manager of Engineering

Mr. Dickson received his B.S. degree in Mechanical Engineering from Purdue University.

As Assistant Manager of Engineering at ACF, his responsibilities include design and construction of power and research reactors.

Mr. Dickson has a total of 17 years professional experience, 7 of which have been devoted to design and development of nuclear reactors. With the Argonne National Laboratory, Mr. Dickson was the head of the design group in the liquid metals section of the Reactor Engineering Division immediately before joining the ACF staff in Washington. In this position he was responsible for the design of fuel elements, reactor controls, process piping, instrumentation and reactor facilities for the EBR II fast breeder power reactor. In addition to his work with sodium cooled reactors, Mr. Dickson also played an important part in the design, construction and operation of the CP-5 and BORAX II reactors of the Argonne National Laboratory.

While at Argonne, Mr. Dickson designed facilities for testing fuel elements and material samples in the CP-5. He assisted in the design of the coffins used for fuel loading of the CP-5 and the design of facilities for the handling of radiation sources. Mr. Dickson conducted examination of test samples of EBR II fuel irradiated in the CP-5. He conducted danger coefficient tests in the CP-2 for closure brazing of fuel elements.

It is to be noted that Mr. Dickson participated in the final experiments on BORAX I. Upon completion of BORAX I tests it was planned to install a new core, vessel and modify the piping system for BORAX II. This modification was Mr. Dickson's responsibility. Due to extensive damage to the test facility Argonne decided to build a new facility. Mr. Dickson was responsible for the design and construction of the new test facility.

Mr. Dickson participated in the startup and operation of BORAX II. He has gained considerable basic knowledge in design and operation of boiling water power reactors. Mr. Dickson has directed two projects which involved an architect-engineer and general contractor, - Massachusetts Institute of Technology Reactor and BORAX II.

Mr. Dickson is the project manager designate for the proposed Elk River Boiling Water Reactor Project.

FRANK B. DANIELS — Assistant Manager of Research and Development

Mr. Daniels received his B.S. degree in Mechanical Engineering from Bucknell University. He is a licensed Professional Engineer in the States of New York and Wisconsin.

Mr. Daniels is Assistant Manager of the Research and Development Section and is in charge of the design of complete power reactor systems.

His professional engineering experience totals over 34 years. Most of this experience has been acquired in the fields of thermodynamics and engineering of land based and maritime power plants, steam turbine work and more recently in the application of nuclear reactors for propulsion and power generation.

Immediately prior to joining the ACF staff in Washington, Mr. Daniels directed the development of several designs for submarine power plants using gas cooled reactors as engineer-in-charge of the Atomic Power Department of Allis-Chalmers Manufacturing Company. During this time he took part in nuclear power development studies and also engineering applications of gas turbine and associated power plant equipment. Earlier Mr. Daniels assisted in the design of an experimental nuclear power plant (EBWR) for the Argonne National Laboratory. He also directed the control rod study program for the Atomic Power Development Associates power reactor program.

WILLIAM S. FARMER — Nuclear Engineer

Mr. Farmer received his B.S. from Tufts University and his M.S. from the University of Tennessee. He has also completed the necessary credits for his Ph.D.

Mr. Farmer has 14 years total professional experience, 12 of which have been in the nuclear energy field. In his current position with ACF, he is a nuclear engineer in responsible charge of the analytical design for power and research reactors.

In 1943, Mr. Farmer was the technical supervisor on initial start-up and operation of the thermal diffusion plant for uranium-235 separation. He later worked on nuclear engineering problems on the MTR and the heavy water version of the MTR, which preceded the final light water design. He had responsible supervision of a reactor evaluation group which set up and developed an IBM machine code for multigroup reactor calculations, cross-section and neutron gamma heating calculations. He was jointly responsible for development of information for reactor hazards reports on aircraft power reactors and critical experiments. Thereafter, he was the engineer in responsible charge of the development and design program of aircraft nuclear reactor systems at the Pratt and Whitney nuclear project. He was also responsible jointly for the direction of subcontracts covering fuel elements development, corrosion loop testing, multigroup physics calculations on the NYU univac, and the development of numerical and analog techniques of solving heat flow problems and in-pile testing of fuel elements immediately before joining the ACF staff in Washington.

JOSEPH H. BLACHLY — Nuclear Engineer

Mr. Blachly received his B.S. degree in Mechanical Engineering from the University of Missouri and also holds a B.S. degree in Electrical Engineering.

Mr. Blachly's present position is Project Director of the 30,000 KW light water cooled and moderated reactor which ACF is designing and constructing for the Atomic Energy Company of Sweden.

Mr. Blachly has had 7 years professional experience. Prior to joining ACF, he was successively Quality Control Engineer, Chief of Engineering Branch, and Chief of Operations Branch of the U. S. Atomic Energy Commission's Kansas City (Missouri) Field office. As Chief of Operations Branch, he was responsible for contractor's production and inspection programs, including planning, directing and coordinating the programs, testing and methods studies, establishing quality control standards, and technical review of drawings and specifications. He also directed engineering evaluation programs and directed fire protection and plant safety programs.

THOMAS P. KRUZIC — Chemical Engineer

Mr. Kruzic received his B.S. degree in Chemical Engineering at the University of Illinois and has taken graduate work in related courses at the University of Chicago and Columbia University.

At ACF, he is a member of the Reactor Engineering Group responsible for the design and construction of research and power reactors.

Mr. Kruzic has had over 24 years professional experience. Prior to joining ACF, he was employed as a Chemical Engineer by the U. S. Army, City of Richmond, Virginia and the Allied Chemical and Dye Corporation. Before accepting these engineering assignments, he worked as a Chemist-Bacteriologist for the Borden Milk Company and was an instructor at the Stibel Institute of Technology.

While employed as a Chemical Engineer by the City of Richmond and the Allied Chemical and Dye Corporation, he conducted plant capacity, efficiency expansion and design studies on high pressure-temperature gas and steam generating plants. He also assisted in the design, construction and operation of gas production and purification plants. In addition, he served as an advisory Engineer for coal gasification plants producing ammonia, fertilizer, chlorine, nitric acid and methanol.

EDWIN L. CURRIER, JR. — Project Engineer

Mr. Currier received his B.S. degree in Chemistry from Creighton University and B.S. in Chemical Engineering from Newark College of Engineering.

In his present position as Fuel Element Group Leader he is responsible for the design, cost estimation, specifications and fabrication of complete fuel systems for research and power reactors, as well as material recommendations, radiation damage and special reactor materials.

Mr. Currier has had 15 years experience, 7 years of which have been in the nuclear field. As Associate Chemical Engineer at Argonne National Laboratory, he was engaged in fuel element design and development. In addition, he was in responsible charge of the refabrication of the ZPR-1 Core and designed the Sodium Test Loop for the development of PBR and EBR II.

Mr. Currier conducted the irradiation tests for experimental development of the EBR II fuel elements. He also performed danger co-efficient cross-section tests on ZrO_2 core fabrication for the STR-Mark I. He participated in the fabrication of fuel element test samples irradiated at NRX Chalk River for the STR-Mark I.

(b) Supporting Personnel

AVERY M. GAGE — Nuclear Engineer

Mr. Gage received his B.S. degree in Physics from Iowa State College and M.S. degree in Reactor Engineering from the University of Southern California.

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With ACF Mr. Gage is a member of the Reactor Engineering staff.

Mr. Gage has had 11 years professional experience, all in the nuclear field. Prior to joining ACF, he was employed at the Los Alamos Scientific Laboratory. As a member of the Reactor Engineering group, he participated in the design of the Los Alamos Fast Reactor on instrumentation of pressure, temperature and flow of water and mercury systems, development of DC electromagnetic pump for mercury, heat transfer calculations and preparation of reactor reports.

While at Los Alamos, he was also a military liaison section leader, doing liaison work with the Air Force Special Weapons Program, Sandia Corporation, Kirtland Air Force Base and the U.S.A.E.C. His duties included preparation of technical manuals, training, field engineering on storage and maintenance and weapons preparation for tests at Eniwetok and Nevada.

Immediately prior to leaving Los Alamos, he was engaged in work on the Omega West Reactor, assisting in construction supervision, fluid flow calculations, shielding calculations, fabrication and procurement of reactor components, and is the author of "Design of the Shield for OWR."

THOMAS R. CUEROU — Senior Project Engineer

Mr. Cuerou received his Bachelor of Mechanical Engineering degree from New York University and has completed Reactor Engineering courses in Columbia University Graduate School. He has also completed special courses in reactor technology at Knolls Atomic Power Laboratory.

Mr. Cuerou is a member of the Research and Development Department of the Nuclear Products - Erco Division.

His professional experience totals over 11 years of which 6 years have been in the nuclear energy field. His main endeavor has been in the utilization of nuclear power in electrical generation. For one and one half years, Mr. Cuerou was a resident consultant at Knolls Atomic Power Laboratory and supervised the development and design of controls and instrumentation for the SIR project.

Mr. Cuerou participated with representatives of four electric utility companies in the Northwest Nuclear Power Study Group located at Hanford, Washington, evaluating proposals for a large scale nuclear electric station.

With Ebasco Services, Inc., Mr. Cuerou was nuclear project engineer for three 10000 EKW nuclear power plants to be located in Latin America. In this capacity, he was responsible for the entire project.

including site selection, engineering design, liaison with reactor manufacturer, dealing with U. S. and foreign government agencies and cost control. He completed detailed site surveys in Cuba and Brazil and presented the data before the U.S.A.E.C. Hazard Evaluation Group.

Prior to his nuclear assignments, Mr. Cuerou was job engineer on five large steam electric stations totaling 450,000 KW in capacity. He was responsible for the design and engineering of the plant, including general arrangement and process diagrams; participated in the construction of three large electric stations and was responsible for the piping systems and controls. He was in charge of the starting and testing procedures of a new 66,000 KW steam electric station.

LESTER L. KINTNER   Nuclear Engineer

Mr. Kintner received his B.S. and M.S. degrees in Mechanical Engineering from the University of Illinois and the Illinois Institute of Technology respectively.

Mr. Kintner's present position is that of Group Leader-Heat Transfer Analysis, for ACF reactor projects presently under design and construction.

He has a total of 7 years experience, all of which has been in the nuclear field. Immediately before joining ACF, Mr. Kintner worked on the fuel element design and analysis and heat transfer problems associated with the Fast Breeder Reactor for Atomic Power Development Associates. Prior to this assignment, he participated in the design and analysis of STR, the conceptual design of EBR II, and the evaluation of thermal performance of other reactors at Argonne National Laboratory for 5 years.

FRANK W. KLEIMOLA   Nuclear Engineer

Mr. Kleimola holds a B.S. degree in Mechanical Engineering from Michigan College of Mining and Technology, Houghton, Michigan, and is a registered Professional Engineer in the State of Illinois.

At ACF, he is a member of the Reactor Engineer Group responsible for the design and construction of research and power reactors.

Mr. Kleimola has had over 8 years experience in nuclear engineering. Prior to joining ACF, he was at Argonne National Laboratory. He participated in the design, erection, and operation of in-reactor water loops installed in X-10, a Hanford production reactor and MTR. Fuel element, structural material, water decomposition and corrosion tests were performed in these loops operating at 1500 psig and 600F. Mr. Kleimola participated in the preparation and interpretation of test results. He was responsible for in-reactor gas loop tests of fuel elements and structural materials in the BNL and CP-5 reactors. He also participated in Naval reactor design studies, BORAX I and EBWR.

Before joining the Argonne staff, Mr. Kleimola was a member of the Pile Technology Division at Hanford where he participated in maintenance problems, fuel slug development and graphite growth-studies.

EVAN F. WILSON — Nuclear Engineer

Mr. Wilson received his B.S. degree in Metallurgical Engineering from the Massachusetts Institute of Technology. He has also done graduate work at the University of Maine and Carnegie Institute of Technology. He is a licensed Professional Engineer in the District of Columbia.

With ACF, he serves as the Materials Engineer for the Research and Development Group.

His professional experience totals 35 years, 8 of which have been directly related to the nuclear energy field.

Immediately before joining the ACF staff, Mr. Wilson held a classified position in the Central Intelligence Agency (CIA).

For 5 years, Mr. Wilson was Assistant Manager, Raw Materials Operations, U. S. Atomic Energy Commission. He directed a program of development for economic processing of domestic and foreign material for nuclear energy applications.

Before joining the AEC staff, Mr. Wilson held the positions of Chief Metallurgist and Executive Assistant to the Vice President at Babcock and Wilcox Company. He directed research and development of materials and standards for shop practices, contributed to technology of welding high temperature materials and was consultant on engineering problems for structures of unusual service requirements.

Mr. Wilson is a member of the American Institute of Mining and Metals Engineering and the American Society for Metals.

KENNETH J. HENRY — Nuclear Engineer

Mr. Henry received his B.S.M.E. degree from the University of Buffalo.

At ACF he is serving as the Design Coordinator for the MIT Reactor project. Mr. Henry has a total of over 10 years of professional engineering experience.

Prior to his association with ACF, Mr. Henry was responsible for the design and manufacture of special automatic manufacturing machines for use by Fisher Price, Inc. of Buffalo. He was also associated with the Chaffee Design and Manufacturing Company of Buffalo in the same capacity.

LEON J. BLASIAK — Electrical Engineer

Mr. Blasiak received his B.S.E.E. degree from Purdue University and is a member of the American Institute of Electrical Engineers.

Mr. Blasiak is presently engaged in the design of the control and instrumentation systems for various reactors.

He was Project Electrical Engineer on the MIT Reactor project. In this capacity he was responsible for design of the controls and instrumentation; and represented coordination with electrical contractor.

Prior to his association with ACF, he spent 6 years with the Niagara Mohawk Power Company in their Relay Department, making power system studies and assisted in the application of power system protection devices.

ROBERT L. FERGUSON — Nuclear Engineer

Mr. Ferguson received his B.S. degree in Electrical Engineering from the Illinois Institute of Technology.

His present position is Group Leader-Instrumentation, in charge of design and coordination of Instrument and Control Systems for nuclear reactors.

He has a total of 6 years experience, all in the nuclear field. Prior to joining ACF, Mr. Ferguson was Associate Electronic Engineer at Argonne National Laboratory. He was associated with the detail design and construction of neutron and gamma sensitive ionization chambers, logarithmic amplifiers, radiation monitors, counting circuitry and various special control circuits for the BORAX Experiments and CP-5 reactors. He was also responsible for the detail design and construction of the instrumentation and control circuitry for the Argonne 8.8 meter curved crystal spectrometer.

(2) Management

DR. MARSHALL G. HOLLOWAY Division President

Dr. Holloway holds B.S. and M.S. degrees from the University of Florida as well as a Ph.D. from Cornell University. He has a total of 21 years professional experience, 15 years of which were in the nuclear energy field.

At ACF Industries, Incorporated, Dr. Holloway is President of the Nuclear Products-Erco Division. His responsibilities include the direction of operations at Albuquerque, New Mexico; Buffalo, New York; Riverdale, Maryland; and Washington, D. C.

Immediately prior to joining ACF, Dr. Holloway was a Director of the Massachusetts Institute of Technology Lincoln Laboratory. Dr. Holloway participated in three series of nuclear weapons tests in the Pacific: Operations "Crossroads" in 1946, Operation "Ivy" in 1952, and Operation "Castle" in 1954. He was in charge of the scientific phases of the first test at Bikini Atoll. In 1951, he was given special assignments relating to the development of thermonuclear weapons at the Los Alamos Laboratory.

Since 1943, Dr. Holloway has played a major part in the development of both atomic and hydrogen weapons. He took part in the historic detonation near Alamogordo, New Mexico, in July 1945, while working on the components of the first atomic bomb. He has also participated in the design and construction of the first homogeneous reactor known as the "Water Boiler".

In 1953, Dr. Holloway was one of three senior members of the Los Alamos Scientific Laboratory staff who received "citations of appreciation", the Defense Department's highest civilian award for his participation in the AEC's Marshall Islands tests the year before.

HAROLD ETHERINGTON Vice President

Mr. Etherington received his engineering degree from the University of London, England, and is a licensed Professional Engineer in the State of Wisconsin.

Mr. Etherington is Vice President of the Nuclear Products-Erco Division and is responsible for the technical operations of the commercial nuclear facilities of this Division.

He has a total of 36 years of professional experience, 11 of which have been in the nuclear field. He was a member of the Power Pile Division at Oak Ridge National Laboratory, the first group set up for the development of atomic power. He joined the Power Pile Division in 1946 and became Division Director in 1948.

He subsequently joined Argonne National Laboratory in Chicago as Director of the Naval Reactor Division which was responsible for the basic nuclear engineering design of the reactor for the submarine "Nautilus". In 1952 he became Director of the Reactor Engineering Division formed by the consolidation of the two reactor divisions at Argonne. He held this position until he accepted an appointment to the staff of ACF Industries, Incorporated.

JAMES C. STOWERS   Assistant to the President

Mr. Stowers received a B.S. in Mechanical Engineering at the University of Wisconsin in 1928. He has a total of 30 years professional experience, 15 of which have been in the field of nuclear energy.

With ACF Industries, Incorporated, Mr. Stowers is Assistant to the President of the Nuclear Products-Erco Division. His responsibilities include the overall coordination of technical administrative duties of the Division.

Before being named Assistant to the President, Mr. Stowers was Works Manager of the ACF plant at Buffalo. Prior to this time, Mr. Stowers was the Area Manager of the Kansas City Project for the AEC which was established in 1949. In 1943, he joined the Manhattan Engineering District, the World War II agency which developed the atomic bomb. As New York Area Engineer he coordinated design, engineering and construction and procured equipment for the nation's first gaseous diffusion process plant for the separation of uranium at Oak Ridge, Tennessee. His background also includes employment with the Public Service Company of Colorado, 6 years active duty with the Infantry Reserve and 6 years active duty with the Corps of Engineers in Washington and New York.

Mr. Stowers was awarded the Legion of Merit and Meritorious Service Commendation medals by the Army for his work with the Manhattan District. In November, 1956 he received an Outstanding Service Award from the U. S. Atomic Energy Commission for his contributions to the atomic weapons and industrial production programs.

RALPH CARLISLE SMITH — Assistant to the President

Mr. Smith holds a degree in chemical engineering from Rensseleer Polytechnic Institute and has completed graduate work in chemistry at Rutgers University. He received his Doctor of Jurisprudence Degree from George Washington University in 1939 and a Master's Degree in Government from the University of New Mexico in 1955. He is a registered professional engineer in New Mexico and a member of the bar of the United States Supreme Court.

At ACF Mr. Smith's position is Assistant to the President of the Nuclear Products-Erco Division. His responsibilities include the general coordination of technical and administrative work concerned with the various division's departments.

Mr. Smith has 26 years of total professional experience, 14 of those years were with the Los Alamos Scientific Laboratory as Assistant Director and a division leader of the Laboratory. Prior to his joining Los Alamos, Mr. Smith served with the U. S. Army Chemical Warfare Service and the Manhattan District, Corps of Engineers, being discharged as a Lieutenant Colonel. He also has been associated with E. I. DuPont de Nemours and Company and has served as a U. S. Patent Attorney for other industrial corporations.

Mr. Smith has participated in all U. S. nuclear tests in New Mexico, Nevada, and in the Pacific, and is said to have witnessed more detonations than any other person. He holds several patents in the field of chemistry and has served as co-editor of the Atomic Energy Commission's "Effects of Atomic Weapons", and the National Nuclear Energy Series, which was published by the McGraw-Hill Book publishing company.

GEORGE A. ANDERSON — Manager, Reactor Engineering

Mr. Anderson is a graduate of the University of Minnesota and holds a degree of Bachelor of Science in Mechanical Engineering. He has a total of 17 years professional experience, 13 of which were directly related to the nuclear energy field, specifically in the design and construction of nuclear reactors.

His position with the Nuclear Products-Erco Division of ACF Industries, Incorporated, is Manager of Reactor Engineering. In this capacity Mr. Anderson is responsible for the complete design of both light and heavy water research reactors and their associated facilities.

Before joining the ACF staff in Washington, Mr. Anderson was associated with Argonne National Laboratory, Chicago, Illinois for over 8 years. As Project Engineer for the Naval Reactor Division he was responsible for the development of the in-pile loop method of utilizing existing reactors to test reactor materials and system performance at operating conditions. He has installed such loops in reactors at Oak Ridge National Laboratory, Hanford Works, and at Chalk River facilities. Mr. Anderson was closely associated with the CP-5 heavy water research reactor at Argonne and supervised not only the detail design of this reactor, but also the construction and fabrication. As a Project Engineer at ANL, he was in charge of the design of the reactor and building for the boiling water experimental reactor project which has recently begun operation.

Prior to joining Argonne, Mr. Anderson spent 7 years at Oak Ridge National Laboratory as a member of the Power Pile Division.

R. M. JONES Manager of Marketing & Planning

Mr. Jones received his B.S. in Mechanical Engineering from Rice Institute and is a licensed Professional Engineer in the State of Texas.

Mr. Jones is Manager of Marketing & Planning for the Nuclear Products-Erco Division. He also serves as technical consultant on reactor projects currently in progress and under consideration for future work.

He has a total of 17 years professional experience, 13 of which have been in the atomic energy field, specifically related to nuclear engineering and reactor design, erection and operation. He was in responsible charge of mechanical design of the original LITR and MTR at Oak Ridge National Laboratory. He later directed ETR conceptual design and served as general consultant to principals of ETR project, and was in charge of MTR engineering, experimental project engineering, MTR shops and MTR maintenance personnel at the National Reactor Testing Station, Arco, Idaho.

Mr. Jones was a member of the MTR approval (L.C.) Committee for reviewing all proposed irradiation tests on MTR. He was responsible for the approval of irradiation test procedures capsule design, and proposed scheduling and handling for all tests conducted in the MTR.

Before joining the ACF staff, Mr. Jones was the Manager of Engineering for the Phillips Petroleum Company at Arco, Idaho.

HENRY C. NICKEL Counsel

Mr. Nickel received his Bachelor of Science and his Juris Doctors Degree at Northwestern University. He also completed a course in Reactor Engineering at the Argonne National Laboratory. He is admitted to the practice of law in the State of Illinois and the District of Columbia.

Mr. Nickel has specialized in the handling of business, legal and administrative problems related to Atomic Energy since 1948. He was formerly Senior Attorney at Argonne National Laboratory where he represented Argonne in contract negotiations and handled the legal and business administration of such contracts. He assisted in the developing of standard procedures and policies related to contractual arrangements between the AEC and its prime contractors.

Mr. Nickel was former Vice-Chairman of the Illinois Atomic Power Investigating Commission; former Chairman of the Chicago Bar Association's Committee on Atomic Energy Law; member of the Committee on Legal Problems and Committee on Financial Practices of the Atomic Industrial Forum. He is also a member of the American Bar Association's Mineral Law Section's Special Committee on Atomic Energy.

Mr. Nickel served from October 1941 to November 1945 in the U. S. Marine Corps. He participated in the Bougainville, Guam, and Iwo Jima operations as a Weapons Company Commander. He was retired from the Marine Corps with the permanent rank of Major.

WILLIAM M. HAWKINS, JR. Manager of Research & Development

Mr. Hawkins received his A.B. and M.S.E. at Harvard University and M.M.E. from the Chrysler Institute of Engineering. He is a licensed Professional Engineer in the State of Ohio.

Mr. Hawkins is Manager of Research & Development of the Nuclear Products-Erco Division and is in responsible charge of analytical development, heat transfer, stress analysis, and experimental activities for reactor projects and related fields.

Mr. Hawkins has had over 23 years of professional experience and has been with ACF Industries, Incorporated since 1948. As assistant to the Director of Research and Development, he reorganized and directed the laboratory and development program at the ACF Detroit Valve Division. Then as Director of General Laboratories, he reorganized and directed the General Laboratories at the Berwick Plant. In 1951 he became Chief Engineer and then Manager of Test and Development of the Albuquerque, New Mexico plant. This work involved laboratory development work and field operations direction at the Nevada Proving Grounds and Pacific Proving Grounds of the U. S. Atomic Energy Commission. Before joining the staff in Washington, Mr. Hawkins was the Chief Engineer of the Special Products Department (NP-ED) of ACF in New York.

KARL M. MAYER — Director of Economic Research

Dr. Mayer received his B.S. degree in chemical engineering from Worcester Polytechnic Institute, his M.S. degree in statistics from the University of Tennessee and his Ph.D. degree in economics from New York University.

At ACF, Dr. Mayer is Director of Economic Research and undertakes techno-economic studies in the atomic energy and power fields.

After leaving college he worked as an engineer for the Naval Ordnance Laboratory on rocket and missile research programs. He joined the staff of the AEC about 10 years ago and worked at both the New York Operations office as an engineer and the AEC headquarters in Washington as an economist.

His main interest during the last 6 years has centered on the economic aspects of nuclear power production. He has worked on nuclear power problems with executives of such organizations as The Florida Power and Light Company, the Georgia Power Company, the Alabama Power and Light Company, the Tennessee Valley Authority and the U. S. Corps of Engineers.

Dr. Mayer was a member of the official United States Delegation to Geneva in 1955 where he presented a paper entitled "The Economic Potential of Nuclear Energy". One of his more recent publications in the field is "Nuclear Power and the World Market" published in 1957 by the National Industrial Conference Board, New York, N. Y. as Studies in Business Policy, No. 83.

RAYMOND W. DURANTE Asst. to Mgr. Marketing & Planning

Mr. Durante holds ME and MSIE degrees from the Stevens Institute of Technology. He has also completed special courses in reactor technology at the Knolls Atomic Power Laboratory.

Mr. Durante has 8 years professional experience, 7 of which have been directly in the nuclear energy field.

He was project engineer on the Savannah River project for 2-1/2 years where his major endeavor was in the design of remote automatic machinery used to disassemble irradiated fuel slugs and the design and construction of complete hot cells and remote handling equipment.

For 1-1/2 years Mr. Durante was resident consultant at the Knolls Atomic Power Laboratory, Schenectady, New York. Here, he supervised the design of apparatus for testing components of the SAR and SIR projects, under environmental conditions. He was a member of the advanced design group and helped to establish the core design for the pressurized water reactor to be used in SAR.

After leaving KAPL, Mr. Durante was project supervisor, responsible for the design and construction of special refueling equipment, transporting casks, and handling mechanisms for the submarine "Seawolf". He also directed the conceptual design of the handling mechanisms for the Westinghouse test reactor.

For the past 3 years, Mr. Durante has supervised the preparation of proposals for complete power and research reactor facilities as well as nuclear components and engineering services. His duties included the analysis of customer requirements, assembly and coordination of technical material, and establishment of the cost estimates.

Mr. Durante's position at ACF is assistant to the manager of Marketing and Planning.

H. C. TELLOCK Manager of Administration

Mr. Tellock studied Mechanical Automotive Engineering at the University of Chicago and Armour and has done graduate work in Administration at Penn State and New York University.

Mr. Tellock has had 20 years experience in Engineering, Reactor Engineering and Administration. Prior to joining ACF, Mr. Tellock was Assistant Director of the Reactor Engineering Division at Argonne National Laboratory.

For 13 years, before joining Argonne, Mr. Tellock had extensive experience in the aircraft, automotive and armament industries in inspection, maintenance, production management, tool design and administrative engineering.

DR. EDWIN F. FRICKE — Physicist

Dr. Fricke holds six degrees from three universities, including his Ph.D. in Physics from the University of California.

He is Senior Physicist with the reactor physics group, responsible for core design and analysis.

He has a total of 21 years experience in the field of nuclear physics, 7 of which have been in nuclear reactor technology. He was associated with the Argonne National Laboratory for over 6 years. He was a staff engineer on the Mark 1 reactor and Chief Nuclear Physicist on the Organic Cooled and Moderated project. In the capacity of Senior Scientist he served as Argonne's representative on the Mark I Safety Committee. All drawings and specifications for the Westinghouse Mark I reactor were reviewed and approved by Dr. Fricke before release for construction.

Prior to joining Argonne National Laboratory, he participated in the design and construction of the K-25 plant at Oak Ridge, Tennessee. He also instructed courses in theoretical microwaves, electromagnetics and ultra-high frequencies at Fournier Institute of Technology. From 1953 to the present time he has been a reviewer on standing committee for American Standards Association, and a reviewer for Chemical Kinetics, American Chemical Society.

WILLIAM F. BANKS — Project Manager, Gas Cooled Reactor Project

Mr. Banks received his B.S. degree in Physics from Texas A & M and his M.S. degree in Nuclear Engineering from U.C.L.A.

Formerly with Atomics International, he was Project Engineer in charge of the evaluation and design of a Calder Hall type of nuclear plant for the Atomic Energy Commission. He participated in the nuclear and thermal core design and plant performance studies on the Sodium Graphite Reactor, and holds a patent on a method of steam pressure control in liquid metal steam generators.

As President of William F. Banks, Inc., Mr. Banks was formerly responsible for Army and Air Force construction projects in the southwest.

<u>GEORGE C. HOVORKA</u> — Asst. Mgr., Gas Cooled Reactor Project

Mr. Hovorka is a graduate of Wayne Institute and holds a degree in civil engineering. He is also a licensed professional engineer for the state of Michigan. His professional experience includes a total of 16 years, 13 of which were directly related to nuclear reactor technology and associated nuclear work.

As a specialist member of the reactor hazards evaluation staff of the U. S. Atomic Energy Commission, Mr. Hovorka was instrumental in establishing preliminary standards, guides and codes presently utilized by the Commission in the evaluation of all power reactor proposals requiring the licensing by the United States Government. He assisted in the hazard evaluation and site location as well as analysis of the engineering features of the first three power reactors proposed in the United States.

For 5 years Mr. Hovorka served as Chief of the Engineering Division, Savannah River Operations Office during the design, construction, testing and operation of the five production reactors, chemical separation facilities, fuel fabrication plant and heavy water production facilities.

As liaison engineer with the University of Chicago for 2 years, Mr. Hovorka was responsible for developing technical data and scientific requirements for use at Argonne National Laboratory for the design and construction of chemical engineering laboratory facilities, prototype reactors, waste disposal plant and related facilities. Mr. Hovorka spent 5 years at the Oak Ridge National Laboratory where his assignments included design work on the materials testing reactor, operation of pilot plants, chemical separation facilities, design of hot laboratory facilities, as well as coordination of preliminary design for a proposed research center at Oak Ridge.

Mr. Hovorka's present position with the Nuclear Products-Erco Division of ACF Industries, Incorporated, is Project Engineer responsible for the design, construction and installation of a complete research reactor facility. Mr. Hovorka is a member of the American Nuclear Society and the American Society of Chemical Engineers.

4. SARGENT AND LUNDY ENGINEERS

A. Background

Sargent and Lundy is a firm of consulting engineers with 65 years experience designing for the electric power industry and industrial firms using large amounts of electric power and process steam. The firm is a partnership with all partners actively and solely engaged in the operation of the business. The engineering, drafting and field staffs are directed by men who have been associated with the firm most of their professional lives. The firm has a total of 700 employees, of which 550 are engineers, designers and draftsmen. To date, Sargent & Lundy have engineered approximately 17,600,000 kilowatts of generating capacity for plants located in all parts of the world. Five and a half million kilowatts of this is represented by units which have been placed in service since 1952, ranging from 2,000 kilowatts to 330,000 kilowatts. These projects alone amounted to construction costs of more than $700,000,000. In addition to work carried out on conventional power generating stations, Sargent & Lundy has been one of the most active architectural-engineering firms in the nuclear energy industry. Listed in the following pages are some of the more important nuclear projects with which this company is associated. In each of the plants listed on the attached pages, Sargent & Lundy has carried through the complete design of the plant, including its auxiliary facilities, developing the flow diagrams and general arrangements. Also shown on the attached pages is a list of experienced personnel that will be assigned to this project. Sargent & Lundy is fortunate to have all of the people assigned to the Elk River Project as experienced nuclear engineers and people who have had close contact with AEC work.

B. Current and Past Nuclear Projects

The following is a list of projects with which Sargent & Lundy Engineers have been associated.

(1) Experimental Boiling Water Reactor

Sargent & Lundy engineering staff worked closely with the Argonne National Laboratory in a development of the basic plans for the experimental boiling water reactor facility. This work included the preparation of design studies for the entire plant; preparation of detailed cost estimates for the project; the preparation of specifications for commercially available equipment and the development of construction drawings and specifications. Argonne National Laboratory developed and supplied the basic nuclear information required to enable Sargent & Lundy to prepare these specifications for nuclear and steam plant equipment which could be purchased commercially. The design proposed herein for Elk River has as its basis the experimental boiling water reactor project.

(2) Borax III

Sargent & Lundy designed the installation facilities for the turbine generator and secured this piece of equipment for the Borax III project. In addition, Sargent & Lundy was responsible for the coordination of the turbine and generator controls with the reactor controls.

(3) Wright-Patterson Research Reactor

Under a subcontract with ACF Industries, Incorporated, the Sargent & Lundy Company is responsible for the design and detail of the piping systems based on flow diagrams for the cooling system of this reactor supplied by ACF

(4) Belgian Pressurized Water Reactor

For this project, Sargent & Lundy Engineers are designing the containment vessel, preparing the necessary drawings and specifications to enable fabrication of the containment facility plates to be done in Belgium at local manufacturing plants.

(5) The Brookhaven Gas Cooled Reactor

Sargent & Lundy, on a contract basis, originally with the Manhattan District and later with the Atomic Energy Commission, furnished the services of one of their employees to form a team of three individuals who developed the design of this reactor from information and requirements furnished by the scientific personnel of Brookhaven. This team handled the development of the control rods and drives as well as the control instrumentation and electrical requirements for the over-all facility.

(6) Atomic Power Engineering Group

Sargent & Lundy is the sponsor of a group of fourteen of the firm's middle-west public utility clients known as the Atomic Power Engineering Group. The firm maintains a staff of nuclear engineers to keep this group informed of nuclear developments here and abroad, both from an engineering and economic point of view. Regular discussion meetings on the various types of reactors available, and the status of their development, are held. Another of the activities of the group has been the preparation of conceptual designs of proposed reactor plants. The experience and background knowledge gained through such an association is of invaluable use to the nuclear engineering efforts of Sargent & Lundy.

(7) Special Consultant and Study Contracts

Under contract with Argonne National Laboratory, Sargent & Lundy recently completed a detailed study to evaluate the cost of containment for boiling water reactors. In performing this study, investigation was made into the economic and technical problems of containment construction as well as the reactor hazards problems. A recently completed review of the engineering design of the TREAT facility to be constructed at the National Reactor Testing Station was completed by Sargent & Lundy. In addition, this firm is presently retained to provide special consulting services under a contract with Oak Ridge Operations Office and with Argonne National Laboratory. These contracts have been in effect since 1955 and 1949, respectively.

C. Personnel

The following personnel represent a few of the key individuals currently on the staff of Sargent & Lundy, who will be assigned to any work involved with the Elk River Boiling Water Reactor Project.

FRED W. McCLOSKA — Partner-Nuclear Activities

Mr. McCloska received his B.S. degree in Electrical Engineering from Armour Institute of Technology and has taken graduate courses at Northwestern University. Mr. McCloska is a licensed Professional Engineer in the states of Illinois, Indiana, Tennessee, Kentucky and Ohio.

As Partner-Nuclear Activities, Mr. McCloska is engaged in the over-all supervision of the nuclear activities of Sargent & Lundy.

Mr. McCloska has over 25 years of professional experience. From 1930 to 1942 he was an Electrical Engineer for the Chicago District Electric Generating Corporation. From 1942 to date, he has been with Sargent & Lundy. During this association with his present firm, he has been responsible for the electrical design for many major steam-electric generating stations and substations. He was responsible for over-all coordination of the design of the EBWR installation, the turbine installation for the Borax III project, a study of containment vessel design problems for the Argonne National Laboratory, a recently completed cost and feasibility study of an aqueous homogeneous reactor power plant, and a review of the Transient Test Reactor Facility design.

He was the sponsoring partner for the development and expansion of the power facilities for the gaseous diffusion plants at Oak Ridge, Paducah and Portsmouth. He was a member of the Commonwealth Edison Company's Nuclear Study Group.

While on loan to the Brookhaven Reactor project, he was directly responsible for the control, instrumentation and electrical design. This work involved development and detail design of the control rods and nuclear instrumentation, most of which was done in conjunction with the Radiation Laboratories of the Massachusetts Institute of Technology.

He is currently engaged in overall supervision of the nuclear activities of the firm, the Atomic Power Engineering Group, the Belgium reactor containment vessel, and the Wright-Patterson research reactor piping requirements.

WILLIAM A. CHITTENDEN — Nuclear Engineer, Atomic Power Engineering

Mr. Chittenden received his B.S. degree in Engineering from the University of Illinois and has completed graduate studies in nuclear engineering at Northwestern University. He is a licensed Professional Engineer in the state of Illinois.

Mr. Chittenden has six years experience on the Sargent & Lundy staff and has worked on the mechanical design of several steam power plants. His work includes the study and selection of plant cycles, the sizing of equipment, preparation of equipment specifications, the evaluation of bids, and the coordination of mechanical design work.

Mr. Chittenden became a member of the Atomic Power Engineering Group at its inception in 1955 and is now the group leader. This group is composed of seven nuclear engineers. He was in responsible charge of a cost study of containment features for boiling water reactors for the Argonne National Laboratory, a feasibility and cost study of an aqueous homogeneous reactor power plant for the Oak Ridge National Laboratory, the design of the Belgian Reactor containment vessel, and the process equipment for the AF-NETR at Wright-Patterson Air Force Base. He has also made exhaustive evaluation studies of nuclear power producing reactors.

Before accepting his present position, Mr. Chittenden worked as a mechanical engineer on power plant design and in plant maintenance engineering.

Mr. Chittenden is the Project Engineer designate for the proposed Elk River Boiling Water Reactor Project.

RICHARD N. BERGSTROM — Associate

Mr. Bergstrom received his B.S. and M.S. in Civil Engineering from the Illinois Institute of Technology. He is a licensed Structural Engineer in the state of Illinois and a licensed Professional Engineer in the states of Illinois, Tennessee and Ohio.

Mr. Bergstrom has been a Structural Engineer on the staff of Sargent & Lundy since 1946 and has been an associate of the firm since 1956.

As a Structural Project Engineer, Mr. Bergstrom is responsible for the design and coordination of all phases of the structural design of some of Sargent & Lundy's largest projects. He has specialized in the field of soil mechanics, with experience over a wide topographical range. His work has included the design of foundations, superstructures, material handling facilities such as roads and docks, and the architectural aspects of plant design. His assignments have included the power facilities for the AEC gaseous diffusion plants at Oak Ridge, Paducah, and Portsmouth. He also was in responsible charge of the civil and structural engineering aspects of the Experimental Boiling Water Reactor at Argonne National Laboratory and the turbine installation for the Borax III project. Currently, he is in charge of the structural design of the containment vessel for the Belgian reactor.

Mr. Bergstrom is the Structural Project Engineer designate for the proposed Elk River Boiling Water Reactor Project.

RICHARD A. JOHNSON — Mechanical Engineer

Mr. Johnson received his B.A. degree in Physics from Millikan University and his B.S. in Mechanical Engineering from the University of Illinois. He also completed graduate studies in Physics at the University of Minnesota and in Nuclear Engineering at Northwestern University.

Mr. Johnson is a Mechanical Engineer with ten years experience on the Sargent & Lundy staff and has worked on a wide variety of mechanical problems involved in power plant design. His work includes the study and selection of plant cycles, the sizing of equipment, preparation of equipment specifications, the evaluation of bids, and the coordination of the mechanical design work. His assignments have included work on the power facilities for the AEC gaseous diffusion plants at Oak Ridge, Paducah and Portsmouth. He was in responsible charge of the mechanical design phase of the Experimental Boiling Water Reactor at Argonne National Laboratory and the turbine installation for the Borax III project.

Before accepting his present position, Mr. Johnson worked as a draftsman, engineer, and university instructor of mathematics and physics.

Mr. Johnson is the Mechanical Project Engineer designate for the proposed Elk River Boiling Water Reactor Project.

DAVID C. McCLINTOCK Electrical Engineer

Mr. McClintock received his B.S. and M.S. degrees in Electrical Engineer from Northwestern University.

Mr. McClintock is at present an Electrical Engineer with ten years experience on the Sargent & Lundy staff and is engaged in the design of electrical systems for power plants. His work includes the study and selection of plant electrical systems, sizing of equipment, preparation of equipment specifications, the evaluation of bids, and the coordination of electrical design work. His assignments have included the engineering of the electrical phases of the power facilities for the AEC gaseous diffusion plant at Oak Ridge. He was in responsible charge of the electrical design phase of the Experimental Boiling Water Reactor at Argonne National Laboratory and the turbine installation for the Borax III project.

He has spent nine months in the Atomic Power Engineering Group investigating the electrical engineering problems involved in the application of nuclear energy to electric power generation and has recently completed a review of the design of the Transient Test Facility.

Mr. McClintock is the Electrical Project Engineer designate for the proposed Elk River Boiling Water Reactor Project.

EDWIN H. HYKAN Nuclear Engineer, Atomic Power Engineering Group

Mr. Hykan received his B.S. degree in Chemical Engineering from the University of Illinois. He has had 10 years professional engineering experience.

As a member of the Atomic Power Engineering Group he is engaged in various studies in the field of waste disposal and water purifications systems.

Prior to joining the Sargent & Lundy staff, Mr. Hykan was a Group Leader in the Chemical Plants Division in Chicago; there he was engaged in the preparation of design drawings, specifications and contracts for mechanical equipment and instrumentation for chemical plants. He also worked as a Senior Engineer in the Design Section of the United States Rubber Company, Joliet, Illinois, engaged in designing and modifying new and existing chemical processing installations involving process piping, instrumentation and economic evaluations.

From 1948 to 1953, Mr. Hykan was a Chemical Project Engineer on the staff of Argonne National Laboratory. There he had 3-1/2 years experience with design, installation and operational responsibility for radioactive waste incinerator, stainless steel evaporators, chemical feed material make-up area and automatic flow control systems. He spent 1-1/2 years as shift supervisor in chemical separation pilot plant and has heavy experience in nitric acid-organic systems. He is a co-author of "Basic Report - Argonne Radioactive Waste Incinerator", Argonne National Laboratory, 1953.

HAROLD J. SLAGTER — Engineer

Mr. Slagter was awarded his B.S. degree in Mechanical Engineering from Northwestern University and has also taken a course in Industrial Engineering.

Mr. Slagter has over 10 years of professional experience; the bulk of this experience has been in the power plant field.

As an Engineer on the Sargent & Lundy staff, Mr. Slagter has been engaged in expediting and scheduling of major power plant equipment and coordinating shipment to conform with field erection schedules. He is charged with the preparation of monthly report to clients, including the AEC, on engineering progress. His work has included inspection of equipment and materials at the place of manufacture or fabrication.

DECKER F. GODFREY — Field Engineer

Mr. Godfrey has held his present position of Field Engineer with Sargent & Lundy for over 10 years. He has a total of more than 20 years of experience in the construction field.

Before World War II, Mr. Godfrey worked on a number of construction assignments in the United States and in overseas areas. From 1943 to 1946 he was a Field Engineer engaged in supervising and checking field installations at Oak Ridge, Tennessee. During the last 10 years, he has been responsible for the supervision of construction and erection of electric generating plants in various areas of the United States. His assignments have included the power facilities of the AEC gaseous diffusion plants at Oak Ridge, Paducah and Portsmouth, as well as large public utility plants.

DANIEL J. J. PIRHOFER

Control & Instrument Engineer
Atomic Power Engineering Group

Mr. Pirhofer received his B.S. degree in Electrical Engineering from the Illinois Institute of Technology.

At the present time, Mr. Pirhofer is a Control and Instrument Engineer in the Atomic Power Engineering Group of Sargent & Lundy. He has had a total of 12 years of engineering experience.

After graduation from college, Mr. Pirhofer worked as a Development Engineer for the Perfex Corporation, engaged in the development, design, and testing of temperature controls and related equipment.

Before joining Sargent & Lundy, Mr. Pirhofer was an Application Engineer concerned with problems of instrumentation and control involved in electric power distribution apparatus.

Mr. Pirhofer's work at Sargent & Lundy includes studies of the problems involved, analysis of requirements, investigation of available equipment and the design and application of instrumentation and control systems for atomic generating plants.

5. THE MAXON CONSTRUCTION COMPANY

A. Background

The Maxon Construction Company is one of the foremost construction companies in the United States. Their background includes an impressive list of projects amounting to approximately $1 billion. In addition to standard construction work, Maxon has also compiled an impressive record of accomplishments in the nuclear energy field.

This company was the recipient of the first contract awarded by the Atomic Energy Commission in 1946 and since then they have had 11 years of continuous physical construction operations on nuclear projects amounting to over $450,000,000 of completed contract value in nuclear construction.

Some of the technical personnel on the Maxon Engineering staff have been trained in the construction phases of nuclear reactors under programs sponsored by the Atomic Energy Commission, and they total 33,000,000 manhours of work that have been completed in nuclear construction of Maxon contracts.

Shown on the following pages are brief descriptions of the projects in which Maxon has been engaged. From these descriptions it can be seen that this company can contribute the specialist background, plus complete general construction experience, which is necessary in the undertaking of nuclear energy projects.

B. Current and Past Nuclear Projects

(1) Mound Laboratory

This project was a complete laboratory for experimentation with atomic energy and ionizing radiation. Construction operations began in Miamisburg, Ohio, in November of 1946, and were completed in October 1948, Total cost of this project was $21,000,000 and peak employment reached 2,000. Since 1948, this laboratory has been expanded and modified. The Maxon Construction Company has completed over $900,000 of additional construction on a competitive bid, fixed price basis.

(2) Scioto Laboratory

This project was basically similar to the Mound Laboratory, though smaller in scope. Construction started in Marion, Ohio, in April 1948, this was completed in July 1949. The total cost was $6,000,000 with a peak employment of 600 people. This project was carried out at the same time as the Mound Laboratory project by splitting the construction organization without delay or interruption to either project.

(3) Oak Ridge Gaseous Diffusion Plants

Maxon Construction Company completed for the Atomic Energy Commission in Oak Ridge, Tennessee, the following projects:

K-29, K-31 and K-33 gaseous diffusion plants for separation of U-235

UF-6 feed material processing plant

Gaseous Diffusion Barrier Fabrication Plant

Design and construction of Gaseous Diffusion Test Loop Facility

Gaseous Diffusion Process Cascade Pilot Plant

Modification of Product Purification and Withdrawal Facilities - K-25 Plant

Uranium Control Sampling Facilities - K-25 Plant

Modification of Contamination Facility

The initial budgeted cost of $400,000,000 for the above projects was underrun by millions of dollars and the facilities placed "on stream" months ahead of scheduled target dates. The physical size and complexity of these installations required not only solving of new problems but the development of new approaches to many construction procedures.

(4) The Maxon Construction Company constructed the building for the Oak Ridge School of Reactor Technology. They completed the installation of the Fissionable Materials Process Equipment and the construction of an Alloy Development Plant for the Y-12 area. Work carried out in this area still remains on a classified basis.

(5) Feed Materials Production Center for the Atomic Energy Commission, Fernald, Ohio. Maxon constructed an addition to the plant for the production of natural uranium reactor fuel elements. Work was started in January 1955 and completed in December 1956. The over-all program expenditure for this work was approximately $11,000,000, with employment peaking at 1000 persons.

(6) Maxon Construction Company has been selected as the prime contractor for the first complete Reactor Facility to be built under a single fixed price contract. The contract for the construction of a 10,000 kilowatt reactor, and its supporting facilities, was awarded to Maxon on the basis of its low bid of $7,500,000. Work is currently in progress on this facility with an anticipated completion in October 1958. ACF Industries, Incorporated, is working with Maxon as the prime subcontractor on the nuclear portion of this project.

C. Personnel

O. L. DEWEESE — Project Manager

Mr. Deweese received his degree in Civil Engineering from Evansville College, Indiana.

He has had over 30 years professional experience, all of which has been in the construction business.

Mr. Deweese has been with Maxon Construction Company for over 17 years as Chief Field Engineer, Chief Engineer, General Superintendent, Project Manager and Branch Manager. As Chief Field Engineer and Chief Engineer, he supervised construction of a Powder Storage Depot, and was General Superintendent on construction of the U. S. Naval Ammunition Depot at Crane, Indiana. He was Project Manager on the construction of Dayton Power & Light Company's 360,000 KW steam electric generating plant built by Maxon. Mr. Deweese was responsible for supervising the planning, scheduling, estimating, cost control, materials control, field engineering and engineering coordination for the $264 million Combined Alloy Development Project and K-33 Gaseous Diffusion Expansion Programs for the U. S. Atomic Energy Commission, Oak Ridge, Tennessee.

Before joining Maxon, Mr. Deweese had 13 years experience in the construction of steam-electric generating plants, as well as semi-hydraulic type, earth fill dam, hydroelectric generating plant and substations. He also supervised a surveying and mapping project, including contour survey, for the corporation limits of the City of Evansville, Indiana.

Mr. Deweese's present position is Branch Manager for Maxon's Oak Ridge, Tennessee, office, responsible for client contacts, site investigations and cost estimating for all Maxon bidding activity in the South.

LEO JAMES BECHAN — *Job Superintendent*

Mr. Bechan is a Civil Engineer with over 23 years' experience.

He has been with Maxon Construction Company for over 14 years as Engineer, Chief Field Engineer, Assistant General Superintendent and Project Manager. As Chief Field Engineer for Maxon at Oak Ridge, Tennessee, Mr. Bechan was responsible for all building layout, roads, railroads, temporary site and gas line installation and supervision of equipment setting and piping layouts for the construction of the combined K-29 and K-31 projects for the U. S. Atomic Energy Commission, comprising a labor force of 5,000 persons for this $140 million project. As Assistant General Superintendent he was responsible for coordination and scheduling of all work on the K-33 Building at Oak Ridge, and worked on the $264 million Combined Alloy Program with a working force of 8,300 men.

Before joining Maxon, Mr. Bechan had over 10 years' experience in power and irrigation projects, roads, bridges and drainage structures. He was in charge of all layout of an 87-building hospital project, including underground roads and power. He was also engineer in charge of layout of a Canadian Air Base's runways, setting all lines and grades for runway construction.

Most recently, Mr. Bechan was Project Manager in complete charge of construction of the $1,200,000 Universal Atlas Cement Company Plant, Independence, Kansas, built by Maxon Construction Company.

JOHN BILLINGSLEY — *Office Manager & Purchasing Agent*

Mr. Billingsley is a graduate of Lockyears Business College, Indiana. He has had over 16 years' experience, most of which has been in the construction business.

Mr. Billingsley has been with Maxon Construction Company for 13 years as Office Manager of various Maxon offices. He was responsible for purchasing and receipt of all materials, payroll for the Flood Wall Project, U. S. Army Engineers. He was also in complete charge of payroll, purchasing, receipts, and accounting for the Dayton Power & Light Plant. During construction of the Kraft Paper Mill built by Maxon for Rome Kraft Company, Mr. Billingsley was in complete charge of all payroll, general purchasing and accounting for the project.

Most recently, Mr. Billingsley has been in complete charge of all payroll, purchasing and accounting for construction of the $1,200,000 addition to the Universal Atlas Cement Company Plant.

O. M. HOCKENSMITH — Field Engineer

Mr. Hockensmith received his B.S. degree in Civil Engineering from the University of Kentucky and has done post graduate work in Organic Chemistry & Sanitary Engineering.

He has had four years experience, all of which has been in the construction business. Mr. Hockensmith has been with Maxon Construction Company since 1955. He was Junior Engineer on the construction of a $1,200,000 addition to a cement plant for Southwestern Portland Cement Company, Fairborn, Ohio. He has also been Field Engineer on the construction of a $2,100,000 manufacturing plant for Moraine Products Division of General Motors and a $1,300,000 paper box plant for Hinde & Dauch Paper Company. His duties for these projects included engineering layout, liaison with the Architect-Engineer and coordination of work of the subcontractors.

Most recently, Mr. Hockensmith has been Field Engineer on construction of the $7,700,000 Nuclear Engineering Test Facility for the U.S. Air Force at Wright-Patterson Air Force Base. His duties included engineering layout, liaison with the Architect-Engineer and coordination of the work of sub-contractors. In the absence of the Job Superintendent, Mr. Hockensmith acts for him.