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ORGANIC MODERATED REACTOR
QUARTERLY PROGRESS REPORT
APRIL-JUNE, 1957

ATOMICS INTERNATIONAL
A DIVISION OF NORTH AMERICAN AVIATION, INC.

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APRIL-JUNE, 1957

BY:

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ABSTRACT

Work has been progressing on the development of components and systems for the Organic Moderated Reactor (OMR). Studies are under way for finding optimum parameters of fuel element design, flow rate, temperatures, and pressures in the primary system. Some tests have been performed on components of the control rod; several fuel element cladding techniques have been tried; and pressure drop measurements have been made on representative samples of possible fuel element configurations.

Equipment has been ordered and some has been received which will permit measurement of the physical properties of organics, measurement of gas solubilities, and determination of the components of irradiated organics. Corrosion samples have been sent to the OMRE for insertion when the reactor is loaded. The in-pile specimens are located in dummy fuel elements adjacent to the core; the out-of-pile specimens are located in the by-pass heater loop.

The project is generally on schedule, and results are bearing out previous expectations.

Previous Quarterly Progress Report: NAA-SR-1936 (January-March 1957).

I. PROGRESS

A. CORE DESIGN AND PLANT STUDIES (C. W. Wheelock)

1. Fuel Element Design

Preliminary studies of the heat transfer and pressure drop characteristics of several fuel element types have been investigated and compared for use in organic-moderated power reactors. This work is being prepared for distribution as a topical report NAA-SR-1998, to be issued.

The types of elements investigated included:

a) Parallel finned-plate type, single-pass, with flow parallel to the plates.

b) Spool type, single-pass, with flow perpendicular to the axis of small cylinders.

c) Parallel unfinned-plate type, single-pass, with flow parallel to the plates.

d) Parallel unfinned-plate type, three-pass, with flow parallel to the plates.

e) Baffle type, single-pass, with flow perpendicular to small rectangular plates.

The element types are listed above in the order of preference as determined by this study. The order is determined by comparing relative heat transfer, coolant pumping power, amount of cladding material required, and estimated cost of manufacture.

Performance characteristics are given in Table I and Table II. As a basis for comparison (excluding manufacturing costs), when considering a cell size of six inches, the element types with the best performance were as follows: Spool type for the element sizes between five and six inches, finned-plate type for the range between four and five inches, and unfinned-plate type for element sizes smaller than four inches.

Longitudinal variations of the fuel loading and flow rate were also studied and the results of these studies are given in Table III.

TABLE I

PERFORMANCE SUMMARY OF OMR FUEL ELEMENT TYPES

Fuel Element Type Characteristic	Performance in Most Favorable Size for the Particular Element				
	Excellent	Good	Fair	Poor	Prohibitive
Unfinned Plate, Single Pass					
Heat Transfer			x		
Pressure drop (pumping power)	x				
Cladding material fraction			x		
Manufacturability (preliminary estimate)	x				
Unfinned Plate, 3-Pass					
Heat Transfer		x			
Pressure drop (pumping power)			x		
Cladding material fraction			x		
Manufacturability (preliminary estimate)		x			
Finned Plate, Single Pass					
Heat Transfer	x				
Pressure drop (pumping power)	x				
Cladding material fraction			x		
Manufacturability (preliminary estimate)	x				
Baffle					
Heat Transfer	x				
Pressure drop (pumping power)					x
Cladding material fraction	x				
Manufacturability (preliminary estimate)		x			
Spool					
Heat Transfer	x				
Pressure drop (pumping power)			x		
Cladding material fraction	x				
Manufacturability (preliminary estimate)		x			

TABLE II-a

COMPARISON OF 1450 kw 6-INCH ELEMENTS

	Plate	3-Pass Plate	Finned Plate	Baffle	Spool
Number of Plates or Spools	39.9	21.5	18.9	85.3	2344 to 15.2/row
Thickness or Diameter (in.)	0.0398	0.063	0.024	0.1984	0.216
% Uranium of Plates or Spools					
0.005-in. Clad	74.9	84.3	16.7	95.0	90.8
0.015-in. Clad	24.6	53.1	-	84.9	74.1
% Stainless Steel of Cell	2.08	2.08	2.08	2.08	2.08
% Uranium of Cell					
0.005-in. Clad	18.8	18.05	4.18	25.8	22.8
0.015-in. Clad	6.18	11.21	-	23.1	18.6
% Cladding of Cell					
0.005-in. Clad	10.42	11.17	25.04	3.32	6.4
0.015-in. Clad	23.04	18.01	29.72	6.12	10.6
Pressure Drop (psi)	0.234	3.5	0.467	270	3.41
Pumping Power (kw)*	87.8	99.2	88.6	1025	98.8

TABLE II-b

COMPARISON OF 1450 kw 5-INCH ELEMENTS

	Plate	3-Pass Plate	Finned Plate	Baffle	Spool
Number of Plates or Spools	29.8	17.0	14.05	80.8	1510 to 11.2/row
Thickness or Diameter (in.)	0.0672	0.104	0.0828	0.375	0.302
% Uranium of Plates or Spools					
0.005-in. Clad	85.1	90.4	51.0	96.8	93.5
0.015-in. Clad	55.3	71.2	37.0	90.1	81.2
% Stainless Steel of Cell	1.735	1.735	1.735	1.735	1.735
% Uranium of Cell					
0.005-in. Clad	22.2	20.7	13.37	25.8	24.4
0.015-in. Clad	14.46	16.3	9.7	24.1	21.2
% Cladding of Cell					
0.005-in. Clad	7.36	8.86	16.19	3.72	5.2
0.015-in. Clad	15.1	13.26	19.86	5.47	8.4
Pressure Drop (psi)	0.752	12.0	1.76	620	11.7
Pumping Power (kw)*	89.6	128.7	93.1	2243	124

*For Reactor and Primary Loop assuming 25 psi drop through the primary loop and 75% efficiency.

TABLE II-c

COMPARISON OF 1450 kw 4.25-INCH ELEMENTS

	Plate	3-Pass Plate	Finned Plate
Number of Plates	19.8	11.9	9.5
Thickness (in.)	0.125	0.185	0.198
% Uranium of Plates			
0.005-in. Clad	92.1	94.7	73.3
0.015-in. Clad	76.1	83.8	65.5
% Stainless Steel of Cell	1.475	1.475	1.475
% Uranium of Cell			
0.005-in. Clad	24.7	22.8	19.5
0.015-in. Clad	20.4	20.2	17.4
% Cladding of Cell			
0.005-in. Clad	5.12	7.02	10.32
0.015-in. Clad	9.42	9.62	12.42
Pressure Drop (psi)	3.4	43.0	7.6
Pumping Power (kw)	98.8	237	113.5

TABLE II-d

COMPARISON OF 1450 kw 3.75-INCH ELEMENTS

	Plate	3-Pass Plate	Finned Plate
Number of Plates	10.8	-	5.7
Thickness (in.)	0.266	-	0.444
% Uranium of Plates			
0.005-in. Clad	96.3	-	86.2
0.015-in. Clad	88.7	-	82.2
% Stainless Steel of Cell	1.3	-	1.3
% Uranium of Cell			
0.005-in. Clad	26.4	-	23.6
0.015-in. Clad	24.4	-	22.6
% Cladding of Cell			
0.005-in. Clad	3.6	-	6.4
0.015-in. Clad	5.6	-	7.4
Pressure Drop (psi)	16.7	-	48.8
Pumping Power (kw)	145	-	257

TABLE III

EFFECT OF LONGITUDINAL VARIATION OF FLOW RATE

Stepwise Variation of Flow Rate

W_o = 20.9 lb/sec	$\Delta P / \Delta P_o$ = 0.753
W/W_o	X/L
0.500	0 to 0.255
0.667	0.255 to 0.329
0.833	0.329 to 0.415
1.000	0.415 to 1.00

Continuous Variation of Flow Rate

W_o = 20.9 lb/sec	$\Delta P / \Delta P_o$ = 0.66
W/W_o	X/L
0.023	0.000
0.163	0.100
0.298	0.167
0.547	0.278
0.782	0.389
0.942	0.500
1.000	0.625 to 1.00

X = distance from inlet end of element

L = length of element

W = flow rate at X

W_o = flow rate at outlet

ΔP = pressure drop for example ASE

ΔP = pressure drop for flow of W_o through entire element

Small increases in performance are attainable by varying the longitudinal distribution of fuel but the gain does not appear to be significant.

The pressure drop through an element can be reduced by introducing part of the coolant immediately upstream from regions of limiting temperature. This method of increasing performance appears to be practical when pressure drop through the core is significant as would be the case if the spool type design completely overshadowed the other types, and the optimum element size were less than about 4.75 inches.

It must be pointed out that this study is a comparative evaluation of several fuel element concepts. Two basic assumptions were made that will not apply to the actual selection, but which do apply to all of the element types; thus allowing a general comparison. These assumptions were: (1) the moderator is undamaged; and (2) the thermal neutron flux for any given cross section of a fuel element is constant.

The results of this study, together with applicable nuclear and manufacturing data, will be used to select the type of fuel element and its detailed design.

Detailed heat transfer studies of finned-plate and pin-type fuel elements are being continued. Flux distribution within the fuel elements and other factors contributing to hot channel factors are being considered in the establishment of a preliminary design for each element type.

2. Nuclear Calculations

A lattice code for the 704 computer has been completed and checked. This code is used to determine cell flux distributions and the constants required for two-group criticality calculations. Peak-to-average flux ratios have been calculated for various fuel element sizes (with a fixed cell size), and the results of these calculations are being used in the fuel element design work. Investigations of methods for determining flux distributions near the corners of the square fuel elements have been initiated.

A parameter survey with variables including U^{235} enrichment, fuel-to-moderator ratio, and temperature is now in progress. The effects of varying cladding fraction and the composition of the fuel element shell are also being studied for some values of the above mentioned variables. The 704 computer is being used to calculate the necessary constants and to solve for K_{eff} with the three-group WANDA code.

3. Fuel Handling Heat Transfer

Studies have been made to determine the air flow rates required to cool spent fuel elements in the fuel handling coffin. Figure 1 gives the results of this study. As shown by this figure, relatively high air flow rates and pressure drops are required to cool spent fuel elements to below the boiling point of water (a desired condition because the elements are to be transferred to a water-filled canal). Because air-flow cooling does not appear to be satisfactory for cooling the elements to such a low temperature, and other suggested methods also seem impractical, it is planned that the elements will not be cooled while in the coffin except when they must be held there for an extended period. When the latter cannot be avoided, the coffin will be filled with water.

4. Shielding Studies

Analyses are partially completed on the shielding requirements and the heating effects in the components external to the core. The objective of the studies is to establish the required combination of organic and iron which will give the least expensive, most workable thermal shield with the smallest practical tank diameter, yet not exceed reasonable temperatures and stresses in the shielding.

Calculations show that the heat fluxes at some surfaces of the thermal shield are too high for cooling of the thermal shield by natural convection; therefore, means of providing forced cooling are being studied.

A brief study has been completed which indicates that neutron leakage into the ground surrounding a subterranean reactor core should not exceed $10^8 n/cm^2$-sec under the worst probable ground water and soil conditions.

5. Reactor Control Studies

A general study of control approaches applicable to organic moderated reactors has been initiated. The objectives of this study include:

a) Summarizing information on poisons suitable for use in rod-type shim and control rods.

b) Evaluation of the practicability of organic-soluble poisons for shim and reserve safety control.

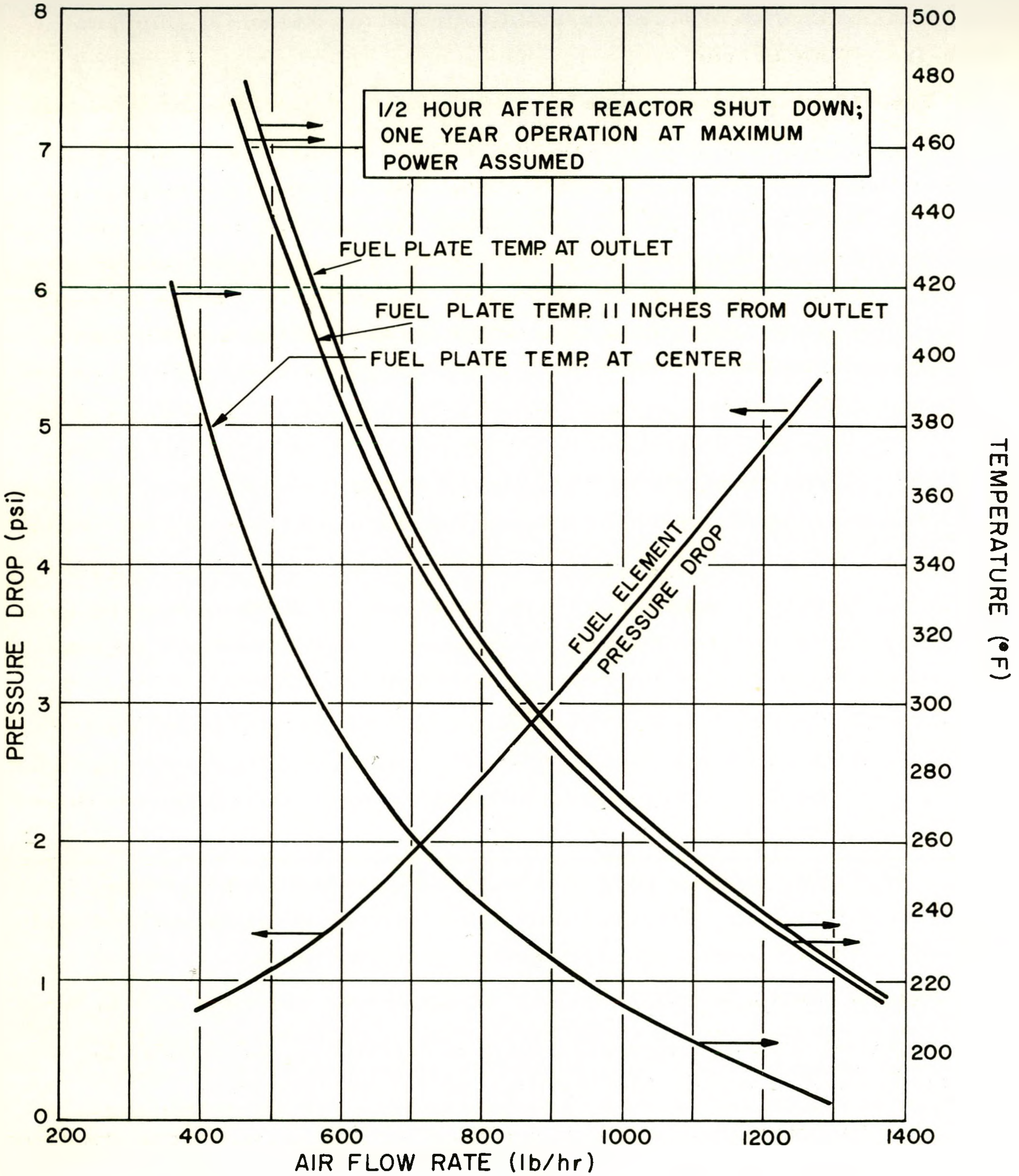


Fig. 1. Temperature and Pressure Drop for Air-Cooled OMR Fuel Elements

c) Evaluation of the practicability of reflector control for shim and safety.

Preliminary considerations of organic-soluble poisons have indicated that a practical material must have the following characteristics:

a) Effectiveness - Neutron absorbing atoms must be introduced in sufficient concentration to supplant the normal function of shim rods and to provide a back-up safety system. The absorber concentration estimated to accomplish the above is less than 10^{22} atoms of natural boron per liter of organic, or the equivalent in thermal neutron absorption cross section.

b) Stability - It should not break down excessively under irradiation or temperature and the decomposition products, if any, which may be formed should not be deposited in the primary coolant loop. Because water leaks may exist, the material should also be stable with water concentrations of perhaps 200 ppm.

c) Solubility - It should not have temperature or pressure dependent solubility characteristics which would allow it to precipitate from solution with sudden pressure or temperature changes.

d) Separability - A practical means must be available for extracting virtually all of the material from the organic. This processing might be accomplished in conjunction with the side-stream polymer removal system.

e) Negligible Radioactivity - The material added must not contain elements which will appreciably increase radioactivity in the primary loop.

Materials being considered include refractory type materials such as boron carbide or boron nitride (as a dispersion), volatile type materials like boron trifluoride, organic boron compounds such as triphenyl borate or decaborane ($B_{10}H_{14}$), complex compounds such as aminated boron hydride or triaminetriborane, and boric acids. Some of the metal borides may also be possibilities but the metals, in general, are undesirable because most of them have neutron cross-sections high enough to result in the production of gamma emitting isotopes.

6. Loop Circulation Studies

Investigations of the temperatures and circulation rates of coolant under natural convective circulation are in progress. These investigations have indicated the desirability of using a horizontal type boiler-superheater because of the increased length of the "hot leg" so afforded.

7. Steam Cycle Studies

The efficiency of various steam cycles adaptable for use with the 12,500-kw OMR plant have been investigated. The results of this study are given in Fig. 2. With the low temperatures available from the OMR, the best efficiencies appear to be obtained with little or no super heat. For maximum steam temperatures below about 600° F the saturated steam cycle appears to be most efficient. If higher steam temperatures are possible, some superheat may be advantageous.

8. Steam Generator Test

Discussions were held with a number of steam generator manufacturers, including Griscom-Russell, Babcock and Wilcox, Westinghouse, Foster Wheeler, Combustion Engineering, and C. F. Braun. All of the above suppliers felt that the construction of an organic-heated boiler and superheater would not be a difficult problem but that the performance (rating) might not be predictable because of the lack of data on the nature of organic fouling and the physical properties of the irradiated organic.

Further studies have been made on the installation of a steam generator on the OMRE. The conclusion is that the steam generator test can be connected to the OMRE loop and operated at steaming rates up to the equivalent of about 6.5 Mw with no changes required in the present OMRE core design or planned operating practices. The recommended unit rating under OMR design conditions is 4 Mw. It is felt that this test would yield valuable information on fouling or cold surfaces (organic side) and on the use of an organic heated superheater.

In addition to the heat transfer information obtainable from a steam generator test on the OMRE, much essential data could be obtained on power plant control. Methods of handling and the hazards associated with water leaks into the organic and organic leaks into the steam system could be studied. (This would include studies on feedwater treatment chemicals.) The installation would

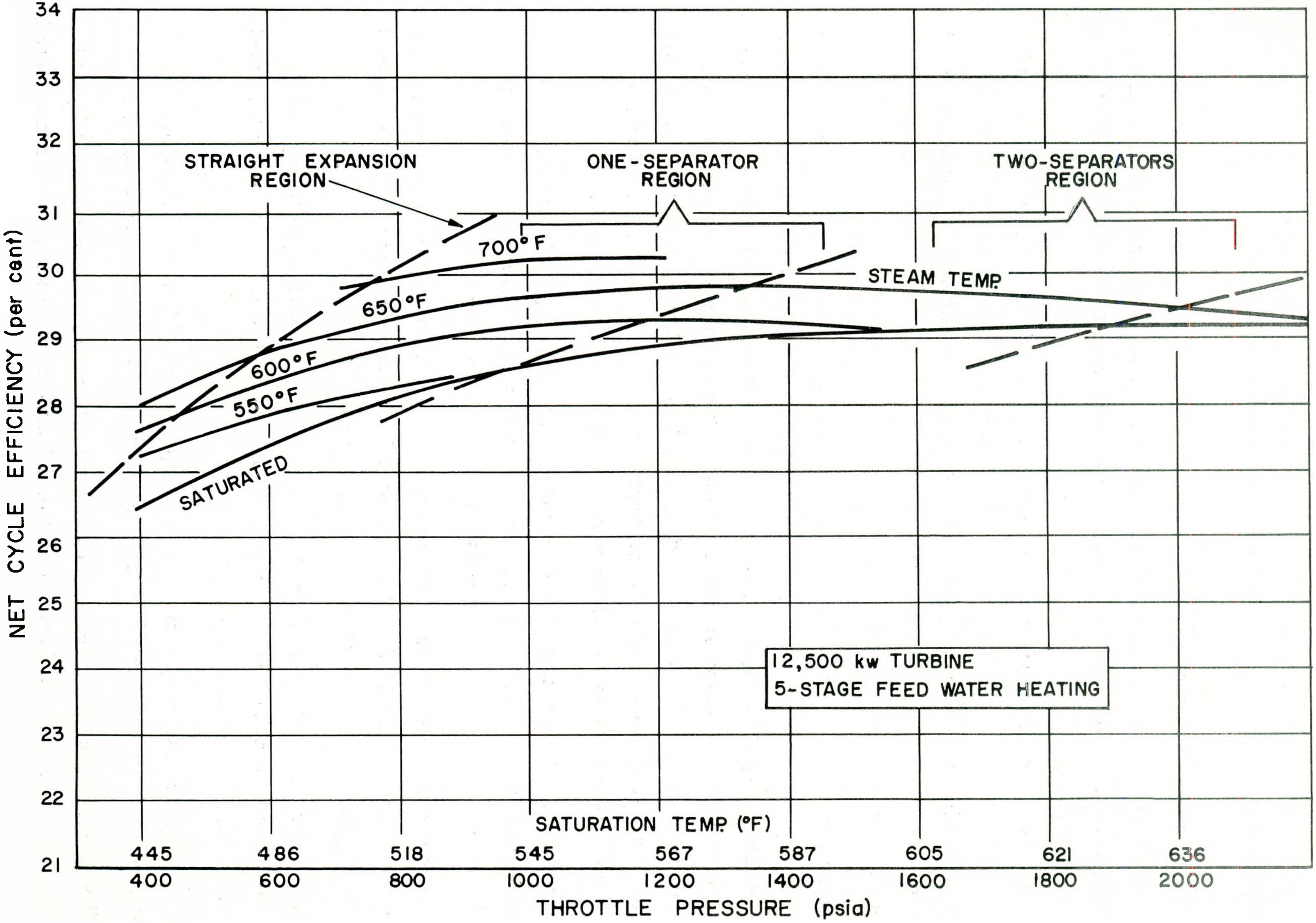


Fig. 2. Net Cycle Efficiency vs Steam Condition

also be valuable for training engineers and power plant operating crews, and for testing proposed methods of improving OMR power plants.

B. FUEL ELEMENT DEVELOPMENT (M. H. Binstock)

Several methods for fabrication of the fuel element core and cladding have been investigated, including the metallurgical bonding of the cladding to the core. Injection casting of aluminum around a core was investigated and has been developed to the point where it appears to be feasible. Both Vycor and steel molds were tried, but steel gave the better result. A split steel mold is being designed for further experiments of this type. Die casting as a method of cladding is also being investigated. Harvill Corporation is building a die for experimental die casting, but no results are yet available.

The production of uranium alloy cores by casting has also been tried. Both injection casting and static casting appear to be satisfactory approaches. Melts have been made using alloying additions of molybdenum and of zirconium resulting in good dispersion of the alloy in the uranium. The vacuum melting equipment is being modified and a centrifugal casting machine is being installed to extend the effort on the development of casting techniques. The casting of flat plate core alloys will be investigated after some equipment modification.

A literature search was conducted to determine the expected interaction between aluminum and nickel, and between nickel and uranium in contact at 800° F and higher. The results of this search are as follows:

1) The solid state bonding of aluminum to nickel is likely to result in having most of the 0.5 mil of nickel combined with aluminum in the form of $NiAl_3$ and Ni_2Al_3 as intermetallic compounds.

2) Service temperatures of 850° F for 100 hours would probably cause complete combination of 0.5 mil of nickel with aluminum though initially there may be no interaction layer.

3) The mechanical properties of the high nickel (14 to 34 w/o aluminum) aluminides are reported to be excellent, possessing some ductility.

4) The mechanical properties of the high aluminum phases of $NiAl_3$ and Ni_2Al_3, such as are formed in the diffusion processes, were not listed in the reports covered.

5) Previous experience with intermetallic compounds indicates a decrease in thermal conductivity from that of the constituents. The per cent decrease in this case is not known.

6) Extrapolation of the reaction layer thickness vs time curves for nickel-uranium couples indicates that intermetallic compounds would form a band approximately 0.2 mils thick in 10 days.

7) Some interaction between Ni-Al compounds and U-Ni compounds might be expected depending on whether or not a zone of uncombined nickel remains between them. It appears that such interaction would occur early in the life of an element clad in this manner when in service at around 800° F.

8) The effects of irradiation on diffusion rates and intermetallic compound formation have not been included because no such data were available for the systems being considered.

C. COMPONENT HANDLING AND MAINTENANCE TECHNIQUES (J. A. Leppard, H. Nadler)

The design of the fuel handling test structure was completed and the drawings were released. A contract for the construction of this structure was awarded and construction has begun. It is scheduled to be completed by September 13.

The design of the fuel handling cask carriage has also been completed, and bids have been requested. One of the problems in the design of this carriage was the requirement for the reproducible accuracy of placement over the core tank grid area. Vee guide rail and snubber rail positioners were both considered for this purpose but were discarded in favor of cam rollers. The cam rollers are mounted on the bridge and bear on both sides of a master rail. The cask carriage is a standard bridge crane structure. Both electric motor drives and handwheel operation (similar to the EBWR) are being considered for the bridge and trolley.

Several different design studies have been made on the fuel handling cask to determine the most practicable one. The cask design which is to be detailed incorporates a long rigid guide rod supporting the fuel retrieving tool. This rod is raised and lowered by a double chain mechanism which remains external to the cask and core tank. There are two concentric bearing liners for the cask, the inner of which may be removed when it is required to handle a control element. Two different guide rods are used: a long one for fuel and a short one for control rods. Several different schemes have been proposed for accomplishing a vapor-tight seal at the bottom of the cask, but the one to be used has not been selected. Two different latches have been detailed and are being made in the shops.

D. DEVELOPMENT OF CONTROL AND SAFETY SYSTEM COMPONENTS

(J. D. Howell)

1. Magnetic Jack Drive

Design changes have been made to reduce the diameter of the magnetic jack parts to a maximum OD of 6.25 inches. A mock-up assembly was made of the lifting section of the jack, using these dimensions. A power supply for the magnetic jack was assembled. Lift coils were wound using anodized aluminum wire, high temperature cement, and anodized aluminum coil forms. Lift capacity vs length of step were checked at room temperature.

A design was released to the shop for a furnace and test assembly for determining the lifting ability vs step length and life expectancy of the coil at expected operating temperatures and under thermal cycling conditions. Provision has been made in the assembly to determine the effect of side thrust and friction on the lifting ability. The temperature rise of the coil when energized and cooled by air in free convection was checked. An autoclave is being designed for lifetime tests of coils in a high temperature organic bath.

A survey was made to select a material for the magnetic parts of component and prototype magnetic jack tests. A grade of silicon steel (2.5 per cent silicon) was selected and ordered. This material possesses better magnetic properties than carbon steel or the magnetic stainless steels, e.g., greater ease of magnetization and higher saturation density.

2. Snubbing Devices

Calculations have been made for the design of ring-spring snubbers for several promising materials. Haynes Alloy No. 25, Inconel X, and 17-4-PH stainless steel were selected for high strength, high hot hardness, and resistance to galling. Orders have been placed for these materials. A miniature ring spring of Haynes Alloy No. 25 has been machined in the shop to demonstrate the characteristics of the device. A fixture is being assembled for determining the spring rate with a hydraulic press. High temperature tests are planned using high temperature lubricants produced by the Electro-Film Company, dry lubricants such as MoS_2, etc.

Analog computer curves have been obtained which predict the expected performance of the eddy current snubber. This device produces a retarding force on the rod as a permanent magnet assembly falls through a copper sleeve. Analog results indicate that a considerable portion of the kinetic energy of the rod may be dissipated in this way.

A set of permanent magnets for use in the full scale snubber tests was received. Magnetic flux measurements proved these magnets to be defective. Replacement parts were ordered. The magnet assembly was redesigned to reduce its weight. The thickness of the copper sleeve was made optimum for maximum retarding force. Fabrication of the full scale snubber test assembly and furnace parts are approximately 75 per cent complete in the shop.

A version of the eddy current snubber is being investigated in which the copper cylinder falls with the rod through a set of electromagnets. Use of such a device would require that the ring spring be designed to be capable of absorbing the full energy of the falling rod, in case of failure of the eddy current brake due to loss of power.

3. Position Indicator

Two types of position indicators have been investigated, namely, (1) potentiometers, and (2) inductance coils. Use of potentiometers in this application would require considerable development work due to difficulty of manufacture, the requirement of rubbing parts, etc. Therefore, effort on this type has been restricted to inquiries for bids from vendors on samples of developmental high-temperature potentiometers.

An inductance coil which senses the motion of the end of the magnetic jack rod bundle is being tested. In these tests the coil has been connected as one leg of an impedance bridge where bridge unbalance indicates rod position. Tests in a furnace at temperatures up to 300° F have shown temperature drift due to changes in resistivity of the coil wire. Use of wire with a lower temperature coefficient of resistivity and methods of temperature compensation are being investigated.

Shim rod position indicator accuracy requirements have been examined critically from the standpoint of: (1) requirements for anticipated nuclear experiments on the reactor, e.g., temperature coefficient, etc., and (2) probable accuracy of measurements of other variables, such as average coolant temperature, etc. As a result of this examination, a rod indicator tolerance of ± 1/4 in. was found to be satisfactory.

4. Materials Tests

Materials tests are being made to aid in selection of materials for rubbing parts of the magnetic jack, and to provide information for design of the ring-spring snubber. A test fixture utilizing a modified drill press and furnace has been built and operated. This test fixture will allow determination of coefficients of friction and galling characteristics of bearing combinations at expected temperatures. Samples of materials which will be used in the magnetic jack and snubber have been ordered.

E. REACTOR STRUCTURE AND PRIMARY LOOP STUDIES (J. Jacobson)

1. System Pressurization

A tentative decision to use mechanical pressurization in preference to inert gas or boiling vapor was made. The mechanical method offers the opportunity of removing water from solution by degasification of the solution at low pressures. The water may enter the system through small leaks in the steam generating system. Figure 3 is a schematic of the test loop being set up to determine the effects of dissolved water, steam, and inert gas in the coolant. The variables to be studied will be: (1) water concentration, (2) system operating pressure, (3) system operating temperature, (4) degasifier pressure, (5) condenser operation, and (6) degasification rate.

Figure 4 indicates the effects of various sized water leaks and degasification flow rates on the water concentration in the primary loop. Calculations indicate

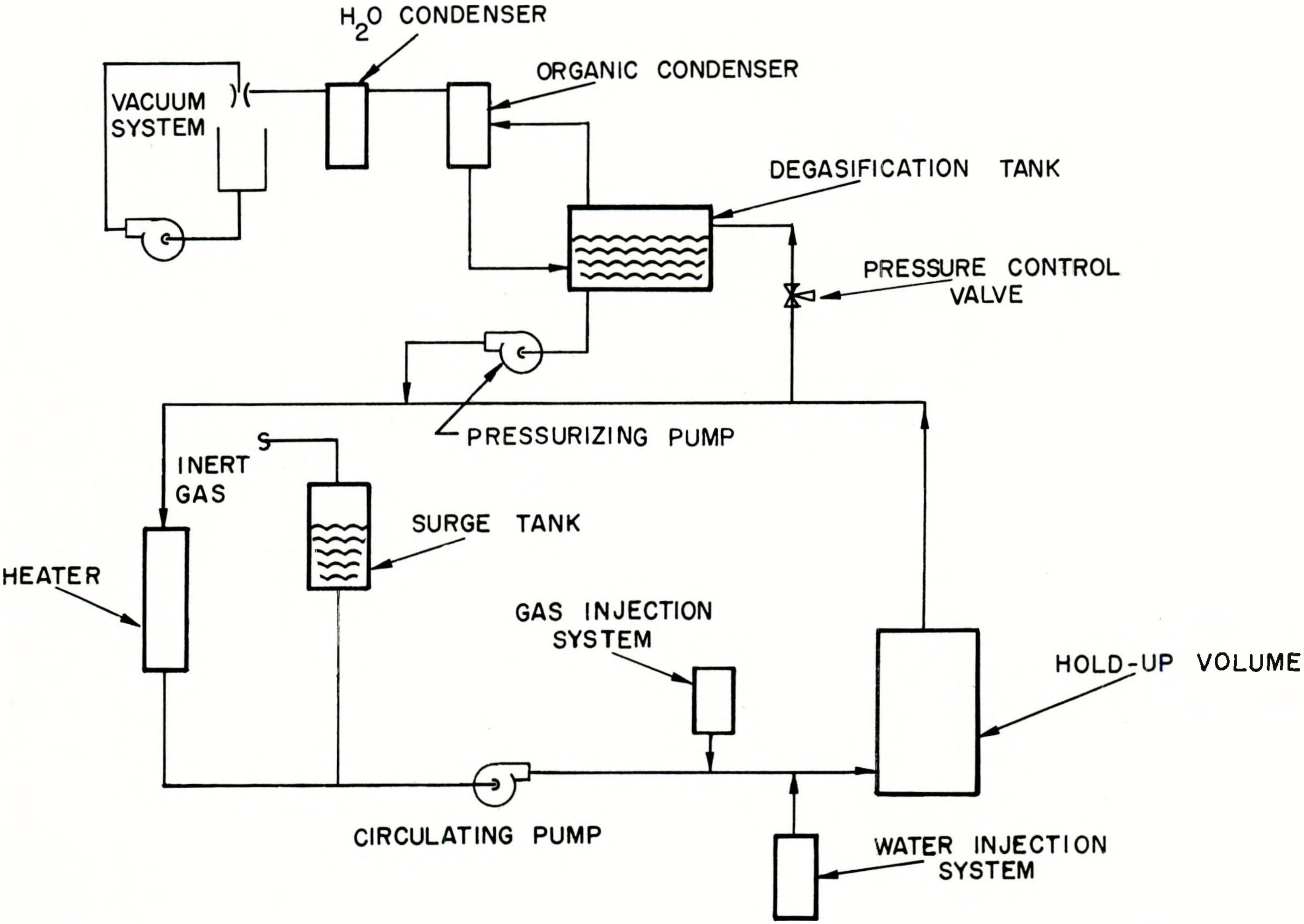


Fig. 3. OMR Primary Loop Test Schematic

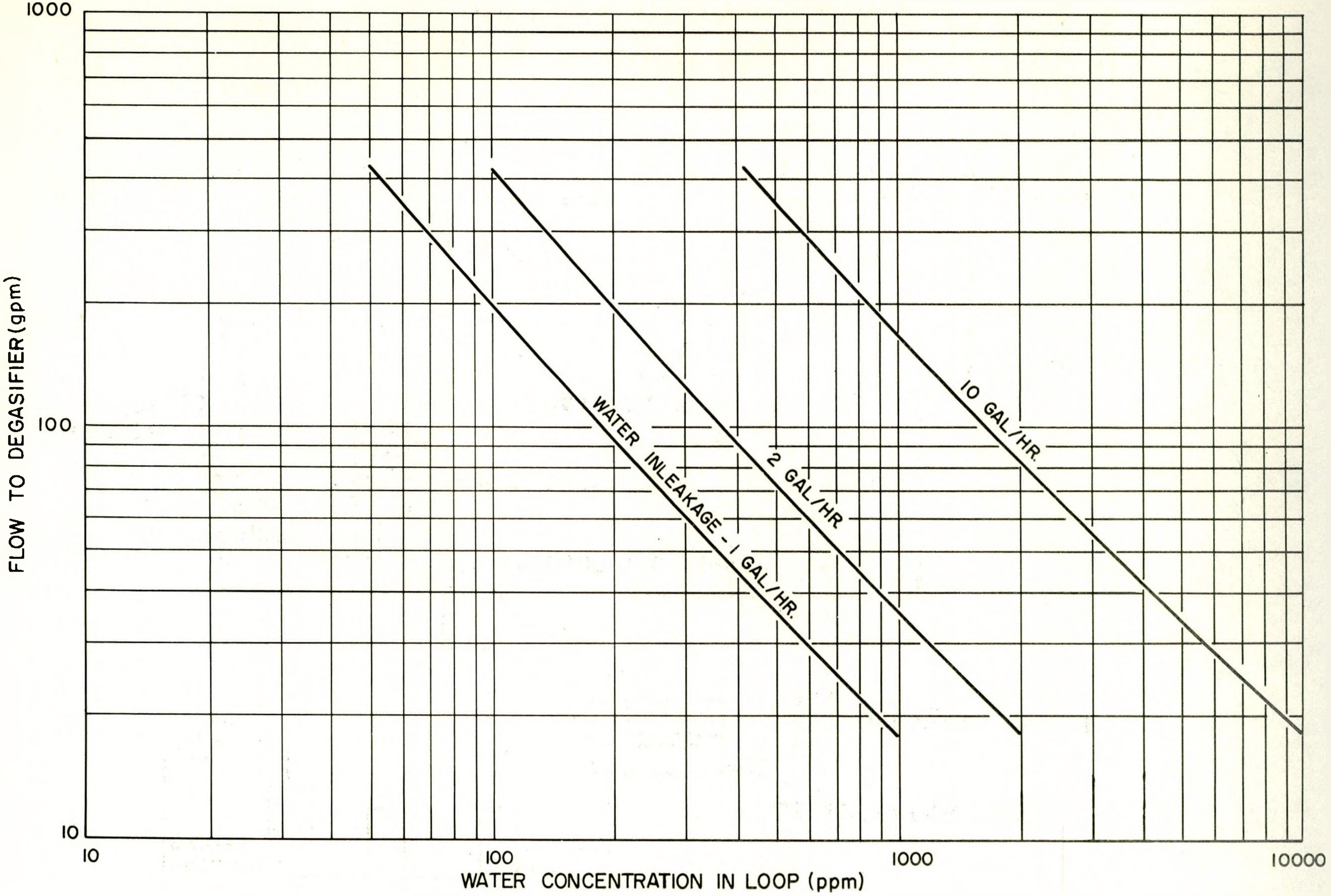


Fig. 4. Effects of Water Leaks and Degasification Flow Rates on Water Concentration in Primary Loop

that if the degasifier loop flow rate is high enough to remove water, the loop will have sufficient capacity to remove dissolved gas resulting from decomposition of coolant.

2. Coolant Makeup System

The economic analyses for the available methods of providing makeup coolant was completed. The analyses indicated that the use of a heated tank car to provide makeup coolant was preferable to the use of bags or drums containing flaked solid coolant.

In addition to the economic advantage, the tank car method requires less handling of the coolant, thereby reducing the problem of contamination. This is a very important factor since the coolant activity is influenced to a great extent by impurities.

3. Polymer Concentration in Primary Loop

A study was initiated to determine the effects of polymer concentration in the main loop. Previous experimental studies have shown that as the polymer concentration increases, the heat transfer coefficient of the coolant decreases. This decrease necessitates a higher pumping rate through a fuel element of a given design to give the same power output. This increased pumping rate will result in higher inlet temperatures, require larger pipe and equipment sizes, and necessitate increased coolant inventory.

It is possible to keep the polymer concentration in the system to a low value by increasing the purification rate. A deterrent to this approach is the possibility of higher rates of coolant damage as a result of low polymer concentration in the coolant. Capsule experiments have indicated that the rate of coolant damage decreases with increasing polymer concentration. However, the difficulties involved in estimating total energy absorption make the values obtained for decomposition rate difficult to interpret. Also, there is some evidence to indicate that decomposition rate is strongly influenced by temperature, and that a particular threshold temperature is required before the decomposition rate varies to any significant extent.

Figures 5 through 8 compare the capital and yearly operating costs of various polymer concentrations. Figure 5 indicates the operating cost when the

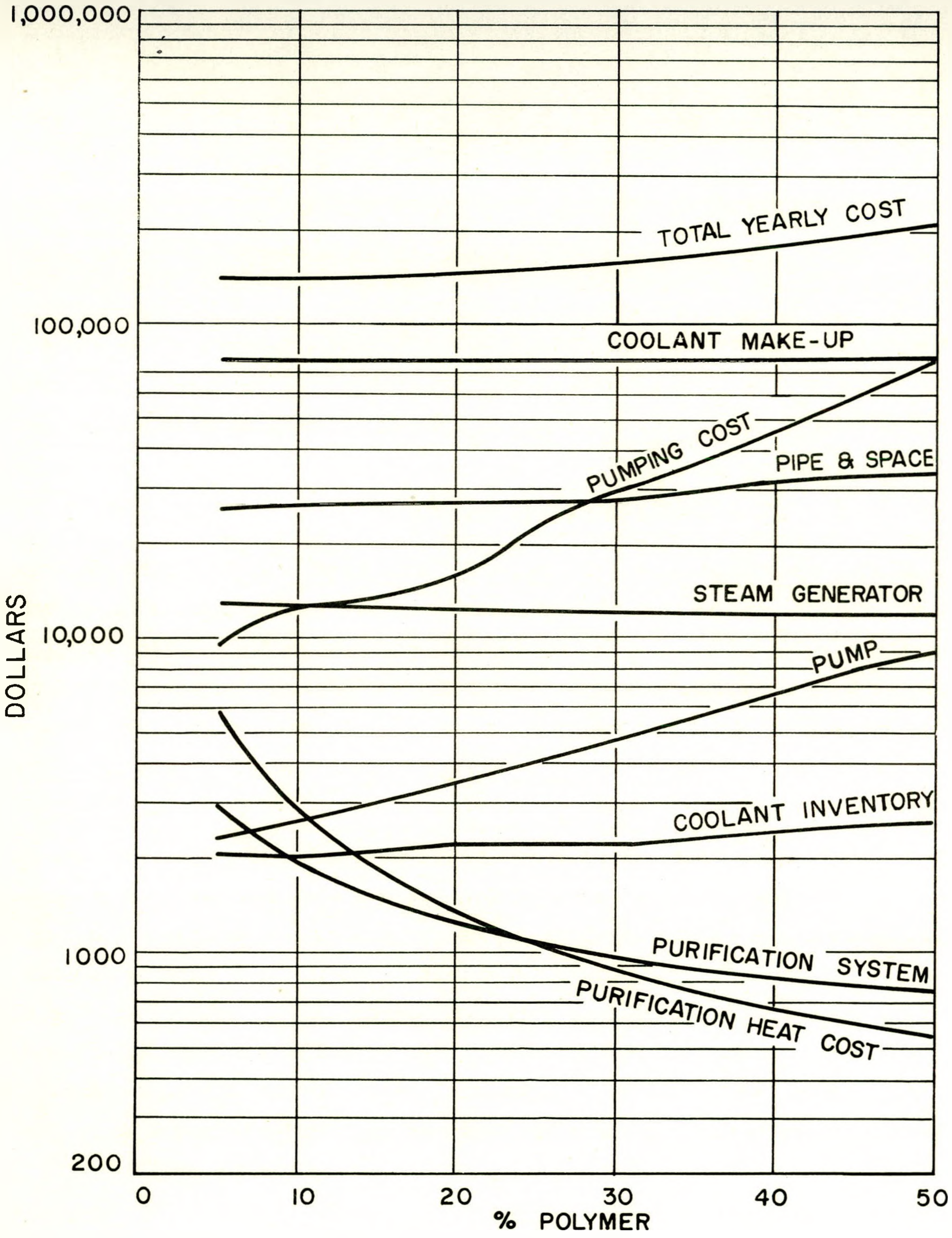


Fig. 5. Yearly Operating Costs (h_o = 1000; ΔG_p = 0)

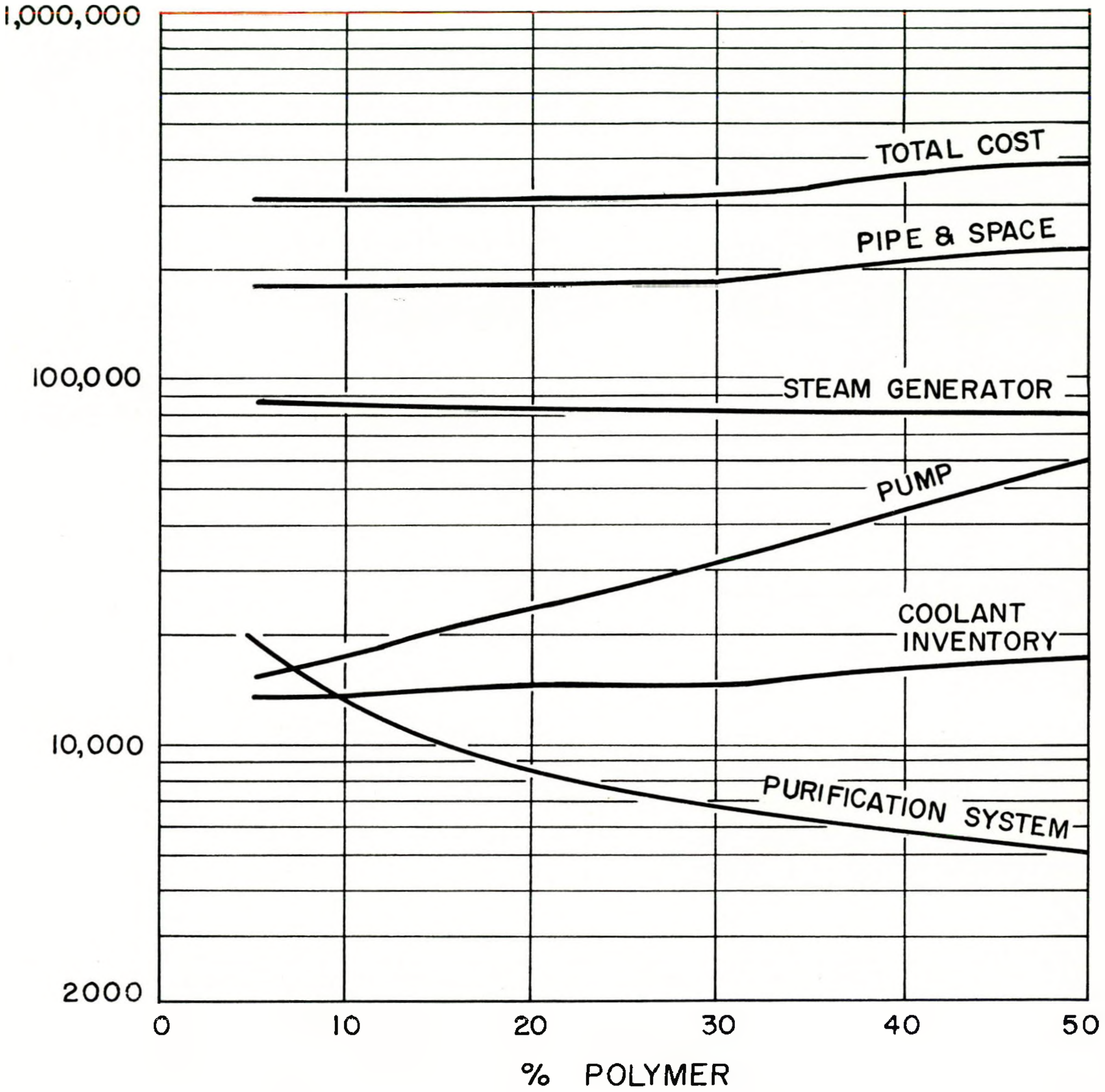


Fig. 6. Capital Investment (h_o = 1000; ΔG_p = 0)

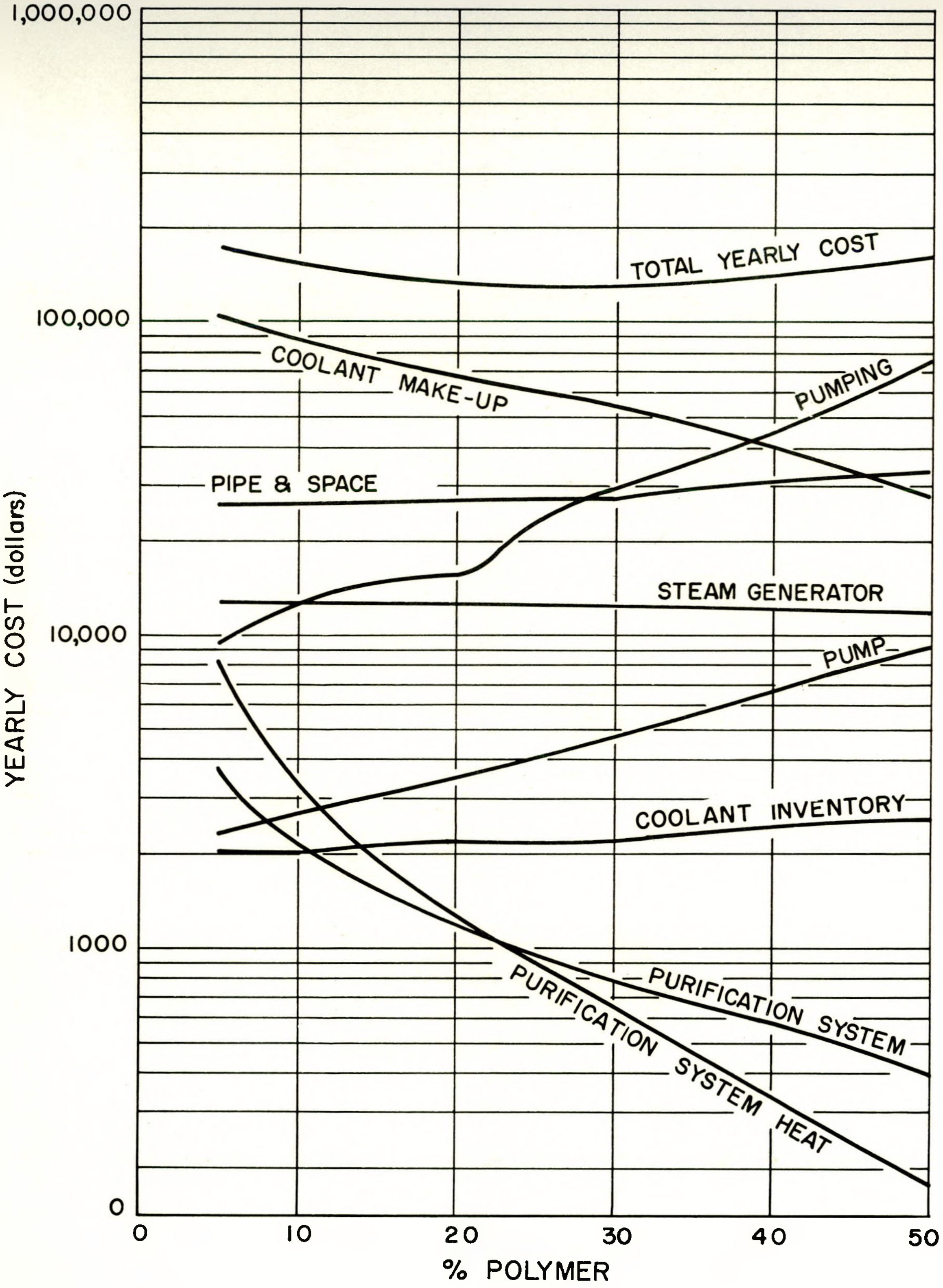


Fig. 7. Yearly Operating Costs (h_o = 1000; ΔG_p decreases)

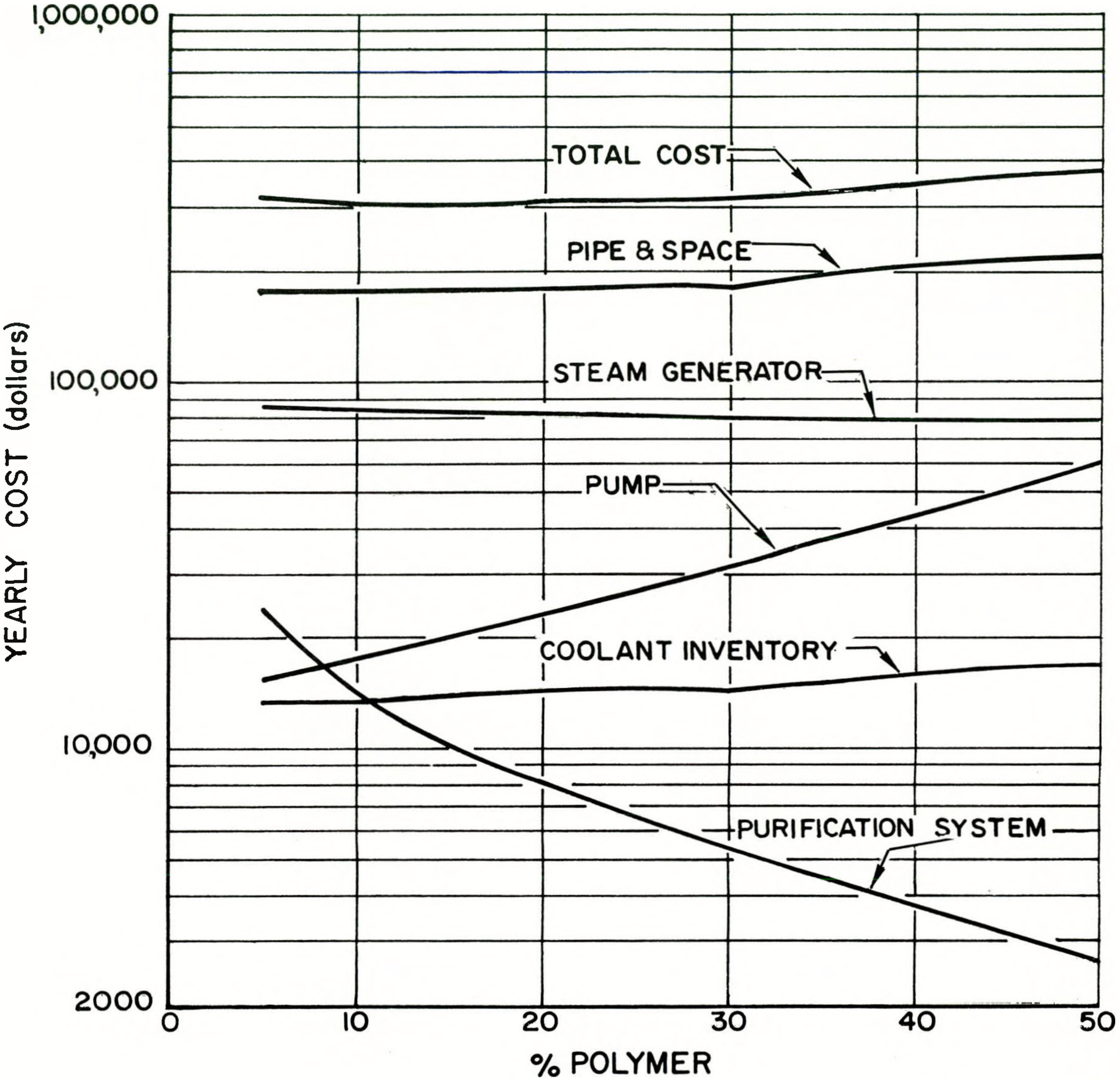


Fig. 8. Capital Investment (h_o = 1000; ΔG_p decreases)

heat transfer coefficient is initially 1000 at 0 per cent polymer, and the decomposition rate is constant. Figure 6 indicates the capital costs associated with this system. Figure 7 shows the variation of operating cost when the decomposition rate decreases with increasing polymer concentration. Figure 8 indicates the capital costs associated with this system.

4. Reactor Head

Drawings were completed for a one-half scale model of the reactor head. Tests will be run to determine the stresses resulting from the rectangular opening required for the fuel handling equipment.

5. Piping

A literature search was undertaken to determine the stresses involved in bellows when used in the piping system to compensate for temperature expansion. Inquiries have been sent to bellows manufacturers to determine the stresses in their units when subjected to design loads and pressures that may be found in the OMR.

A preliminary study on valves for OMR service was completed. Included were globe, gate, check, relief, and sample valves. The results of this survey are being evaluated to determine the types of valves requiring testing and development.

6. Cladding Failure

A design study has been completed that compares the various methods available for determining which fuel element has experienced a cladding failure. Methods investigated were gamma-ray monitoring, spectrographic fission product gamma-ray monitoring, fission gas monitoring, and delayed neutron detection. It was concluded that delayed neutron monitoring would give the most reliable indication of a cladding failure. Calculations indicate that a one square-centimeter cladding failure will cause a delayed neutron density in the organic from the affected fuel channel of 35 disintegrations per cm^3 per second, ten seconds after recoil of fission fragments into the coolant.

7. Relief System

Equipment is being purchased to test the operation of pressure relief valves. The equipment consists of a steam generator, an organic tank, knock-out drum, scrubber, and relief valves. Tests simulating a boiler tube leak will be conducted under various operating conditions. The action of the relief valves and efficiency of the scrubbing system will be determined. Information obtained from the tests will be used in designing the relief system.

F. DYNAMICS OF OMR POWER PLANTS (W. W. Scott)

1. Steady State Performance of OMR Power Plant

Results are now being obtained from the digital analysis of steady state power plant performance. The analysis is based upon a mass and energy balance of the heat transfer system, utilizing the effectiveness concept. Figure 9 is a schematic of the power plant model employed. Figure 10 shows the results of the first run in which superheater pressure was held constant at 440 psia while the load was varied from minimum to 110 per cent of rated (full load = 171×10^6 Btu/hr). The feedwater temperature is a function of steam flow and varies in accordance with the 5th stage extraction point of the turbine.

Many more runs will be performed for a parametric study of coolant flow rate, steam pressure, feedwater temperature, superheat temperature, hot leg temperature, and cold leg temperature. The results of these runs will be compared and an optimum control program deduced. This optimum program will fall between two conflicting criteria: a constant average reactor temperature (desirable for reactor control) and constant steam pressure, (desirable for turbine performance). Also, the results of this analysis will provide check points for the boiler transient study.

The analysis is based upon the following assumptions:

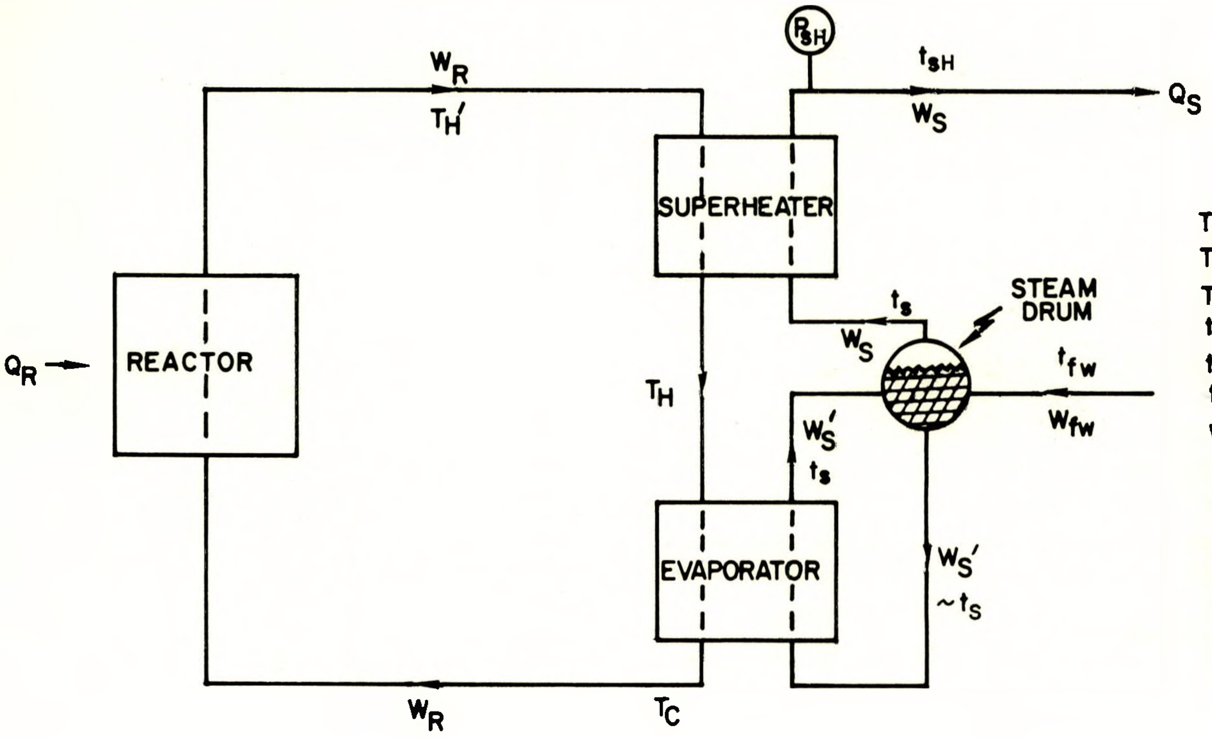
a) The superheater is a counterflow type.

b) The superheater heat transfer coefficient varies directly as the square root of steam flow.

c) The full load superheater heat transfer coefficient is 150 Btu/hr-ft^2-°F.

d) The evaporator overall heat transfer coefficient is constant at 625 Btu/hr-ft^2-°F.

e) The enthalpy of superheated steam is a function of temperature only.



T_H' = REACTOR OUTLET TEMPERATURE
T_H = S.H. OUTLET ORGANIC TEMP.
T_C = REACTOR INLET TEMPERATURE
t_{sH} = SUPERHEATER STEAM TEMP.
t_s = SATURATED STEAM TEMP.
t_{fw} = FREEDWATER TEMPERATURE
W_R = ORGANIC FLOW RATE
W_S = STEAM FLOW RATE
W_S' = STEAM-WATER FLOW RATE
W_{fw} = FEEDWATER FLOW RATE
Q_R = REACTOR POWER
Q_S = STEAM POWER
P_{SH} = SUPERHEATER PRESSURE

Fig. 9. OMR Steady-State Boiler Analysis Flow Diagram

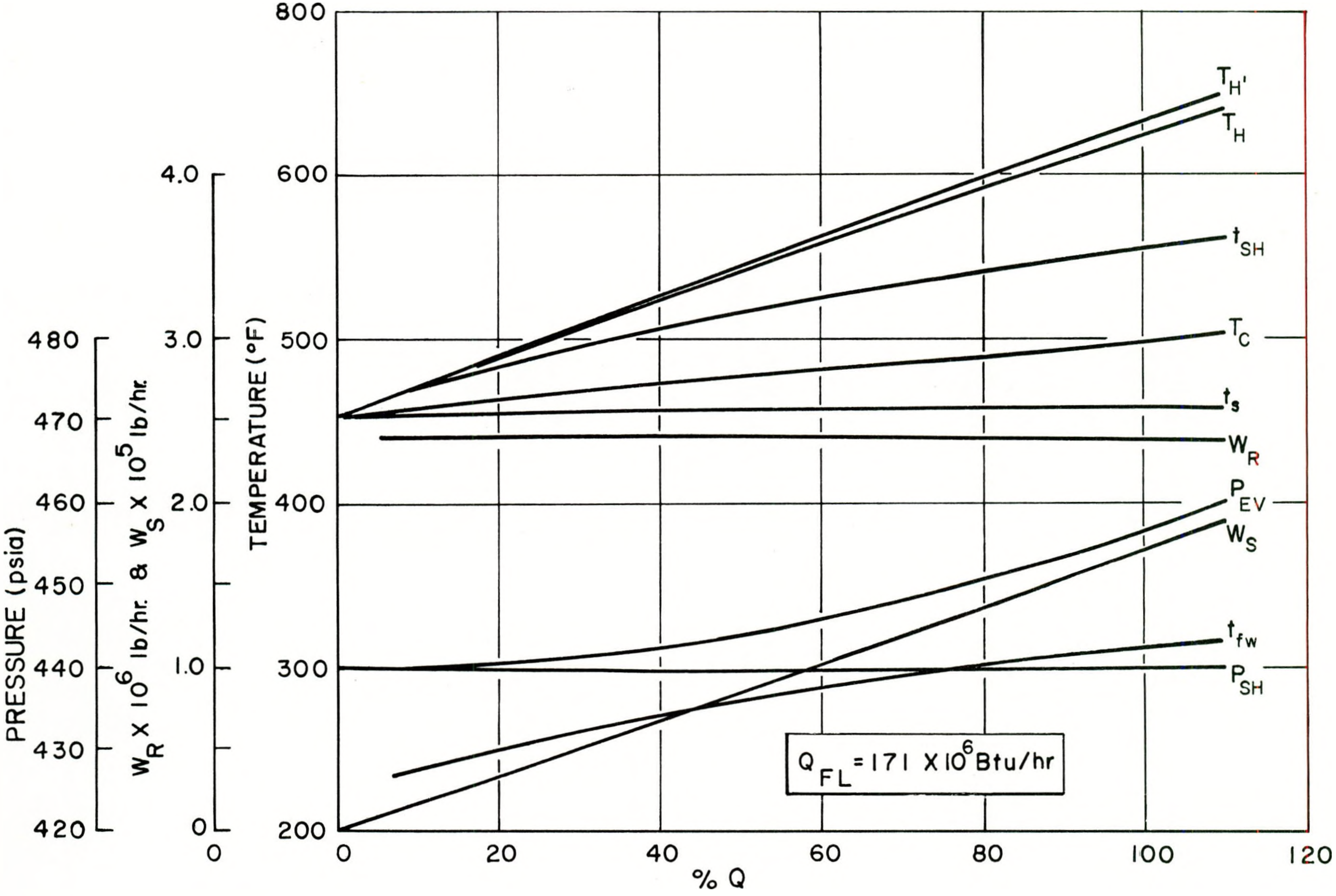


Fig. 10. OMR Parameters vs Per Cent Q

f) The full load superheater pressure drop is 15 psi.

g) The superheater pressure drop varies as the square of steam flow.

h) The feedwater temperature is either 250° F or is varied in accordance with the 5th stage extraction point of the turbine.

i) The enthalpy of the feedwater is a function of temperature only.

j) Organic coolant specific heat is constant at 0.527 Btu/lb-° F.

k) Full load is 171×10^6 Btu/hr.

2. Boiler Transient Performance

Several methods of predicting boiler transient performance are under consideration; none of which appear satisfactory. One method is not rigorous, another is rigorous but not readily adapted to digital or analogue techniques, and still another is restricted in application to steam generators of a certain configuration. Information on a fourth method, developed by the Holly Carburetor Company, Van Dyke, Michigan, is now being obtained.

Transient data from the OMR Steam Generator Test and results from the steady state plant performance analysis will be relied upon for checking the boiler transient analysis.

3. OMR Steam Generator Test

The controls on the OMRE were reviewed to determine the feasibility of controlling the reactor inlet coolant temperature with the air-blast heat exchanger utilizing the existing controller. The following conclusions were drawn:

a) If possible, the OMRE air-blast heat exchanger should be used for control of cold leg temperature during steam generator tests.

b) Air-blast heat exchanger performance data should be obtained from the OMRE site as it becomes available.

c) An analysis of the air-blast heat exchanger must be performed to determine its capabilities.

d) A minimum power of 1 megawatt must be dissipated in the air-blast heat exchanger for good regulation.

e) Transient boiler tests should be performed to permit evaluation of boiler transient analysis.

An eight lump electric analogue representation of the air-blast heat exchanger has been developed. The representation includes an idealized three-action controller, adjustable louvers, adjustable ambient air temperature, automatic control of air velocity, and adjustable organic temperature and mass flow rate.

Two basic connections of steam generator-air blast heat exchanger are being studied: (1) the steam generator in parallel with the air-blast exchanger, and (2) the steam generator with a by-pass loop in series with the air-blast heat exchanger (see Fig. 11).

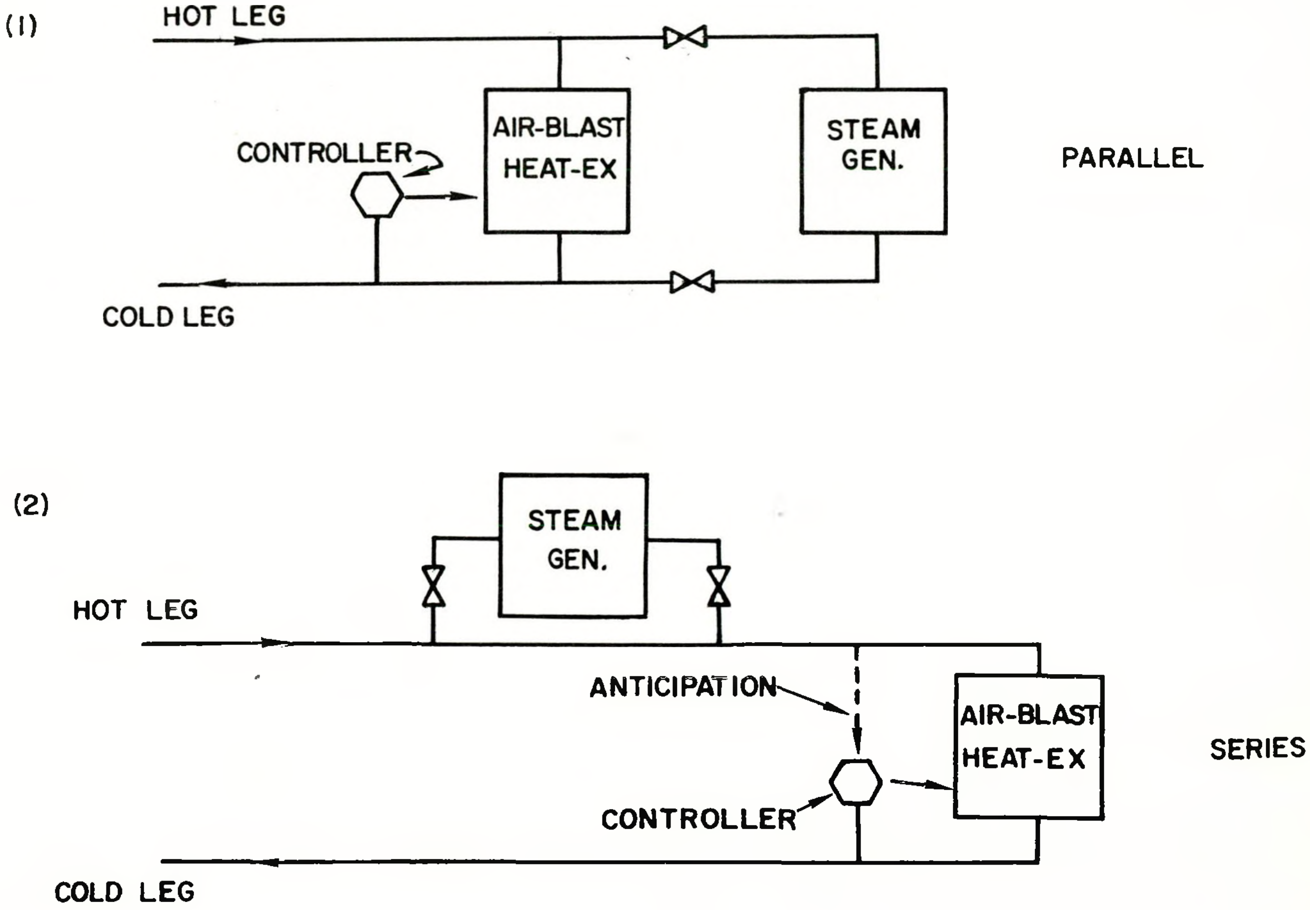


Fig. 11. Two Basic Connections of Steam Generator to OMRE Cooling System

A qualitative comparison indicates that the series arrangement provides the best control of cold leg temperature in response to fast changes in steam generator load as any changes will be attenuated by the air-blast heat exchanger before appearing in the cold leg. Also, anticipation control is more readily contrived. The parallel arrangement has the advantage of being less affected by changes in air velocity and air temperature as only a fraction of the organic flows through the air-blast heat exchanger. A comparison of the two control schemes will be made on the analogue model. Air temperature, organic hot leg temperature, air velocity, and accidents such as step changes in load will be studied. Step and ramp changes in steam generator load, corresponding to maximum permissible reactor inlet coolant temperature disturbances, will be determined.

Analysis of an accident wherein a rupture occurs in the steam generator and steam leaks into the organic has been started. Areas of consideration include:

a) Temperature transients in the coolant loop.

b) Pressure transients in the coolant loop.

c) Reactivity transients due to presence of steam in the moderator.

d) Requirements for additional safety circuits.

4. Stability Analysis of OMR Power Plant

A preliminary block diagram, utilizing servomechanism techniques, has been developed. Included in the diagram are reactor thermal characteristics, transport delays, boiler thermal characteristics, reactor kinetics, metal temperature coefficient of reactivity, moderator temperature coefficient of reactivity, and coolant flow rate.

Approximate values and ranges of values of pertinent core parameters are being obtained.

Parametric studies will be made of:

a) Core heat transfer area.

b) Heat transfer coefficient between fuel and coolant.

c) Metal temperature coefficient of reactivity.

d) Moderator temperature coefficient of reactivity.

e) Transport delays.

f) Coolant flow rate.

g) Mixing volumes.

Results of the stability study will predict:

a) Relative stability of reactor and power plant without external rod controls.

b) Optimum (from a control point of view) values of parameters listed above.

c) Need of an automatic regulating rod.

If an automatic regulating rod is needed, the same block diagram will be utilized for a subsequent stability study of the reactor complex with external controls.

5. Mixing in the Upper Plenum

The table below summarizes the maximum controllable upper plenum inlet coolant temperature steps when assuming a rod rate of 33×10^{-5} $\delta k/sec$, a negative temperature coefficient of reactivity of 15×10^{-5} $\delta k/°F$, an upper plenum volume of 625 ft^3, and a coolant flow rate of 11.4 ft^3/sec. Maximum temperature steps (ΔT_{max}) are indicated as a function of fraction of rated flow (F), and fraction of upper plenum volume (V) in which 100 per cent mixing occurs. Also indicated is the time interval (τ) during which the maximum rod reactivity rate of 33×10^{-5} $\delta k/sec$ is necessary to counteract the reactivity change produced by the inlet coolant temperature step.

Analysis of Table IV plus results of stability and accident studies will determine an optimum mixing volume.

G. HYDRAULICS TEST (C. R. Davidson)

Pressure drop measurements and friction factor calculations for the OMR cylinder-type fuel element were completed. In addition to the work during the previous quarter on the cylinder-type fuel elements having center-to-center spacings of 0.600 and 0.437 inches, elements having spacings of 0.393 and 0.326 inches were studied. Pressure drops for all of the element configurations as a

TABLE IV

MAXIMUM CONTROLLABLE UPPER PLENUM INLET COOLANT TEMPERATURE STEPS

Fraction of Upper Plenum Volume	Fraction of Rated Flow							
	1/4 F		1/2 F		3/4 F		F	
	ΔT_{max} °F	τ (sec)	ΔT_{max} °F	τ (sec)	ΔT_{max} °F	τ (sec)	ΔT_{max} °F	τ (sec)
1/4 V	100	20	51	10	34	6.8	25	5
1/2 V	200	40	100	20	68	14	51	10
3/4 V	340	70	180	35	110	23	88	18
V	410	80	200	40	140	27	100	20

This table can be extrapolated by noting:

1) $\Delta T_{max} \propto$ Rod Rate
2) $\tau = f(F, V)$

function of water flow rates are shown in Fig. 12. Friction factors based on these pressure drops as defined by

$$4f = \frac{2g_c \Delta P}{N \rho V^2_{max}} \qquad \text{...(1)}$$

are shown in Fig. 13 for the four cylinder-type element configurations. The length term in the Reynolds Number (Fig. 13) is the hydraulic equivalent diameter (four times the minimum flow area divided by the wetted perimeter). Some pertinent dimensions of the various cylinder-type configurations are tabulated below.

TABLE V

PERTINENT DIMENSIONS FOR CYLINDER-TYPE FUEL ELEMENTS

Center-to-Center Spacing (in.)	Cylinder Length (in.)	Cylinder Diameter (in.)	Transverse Pitch-to-Diameter Ratio	Longitudinal Pitch-to-Diameter Ratio	Equivalent Diameter (ft)
0.326	3.906*	0.300	1.087	0.941	0.005
0.393	3.875	0.300	1.310	1.135	0.015
0.437	3.875	0.300	1.457	1.262	0.023
0.600	3.875	0.300	2.000	1.732	0.053

*No cover plate in this model, also no heads on the cylinders.

In all cases, the cylinders were spaced in an equilateral triangular array having twenty transverse rows in the direction of flow. Figure 14 is a photograph of the element having 0.326-inch spacing and shows minor differences from the previously tested configurations necessitated by this close spacing.

A proposed finned-plate fuel element was fabricated and two configurations were tested for pressure drop. This element consisted in the first case of six finned aluminum plates having 60 longitudinal triangular fins. Fin height was 0.100 inches, with a base width of 0.075 inches. The plates were separated by

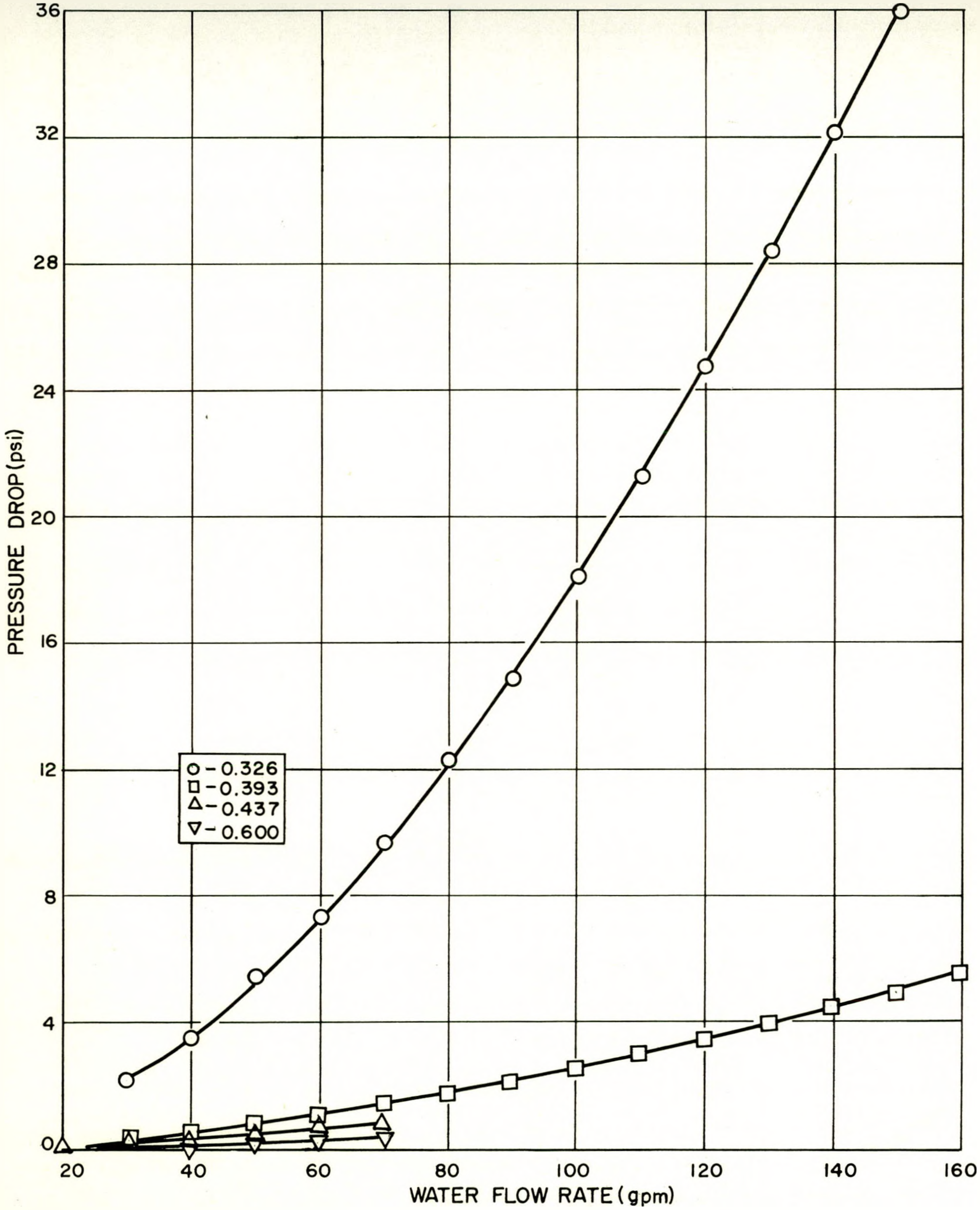


Fig. 12. Pressure Drop vs Flow Rate for Various Cylinder Spacings

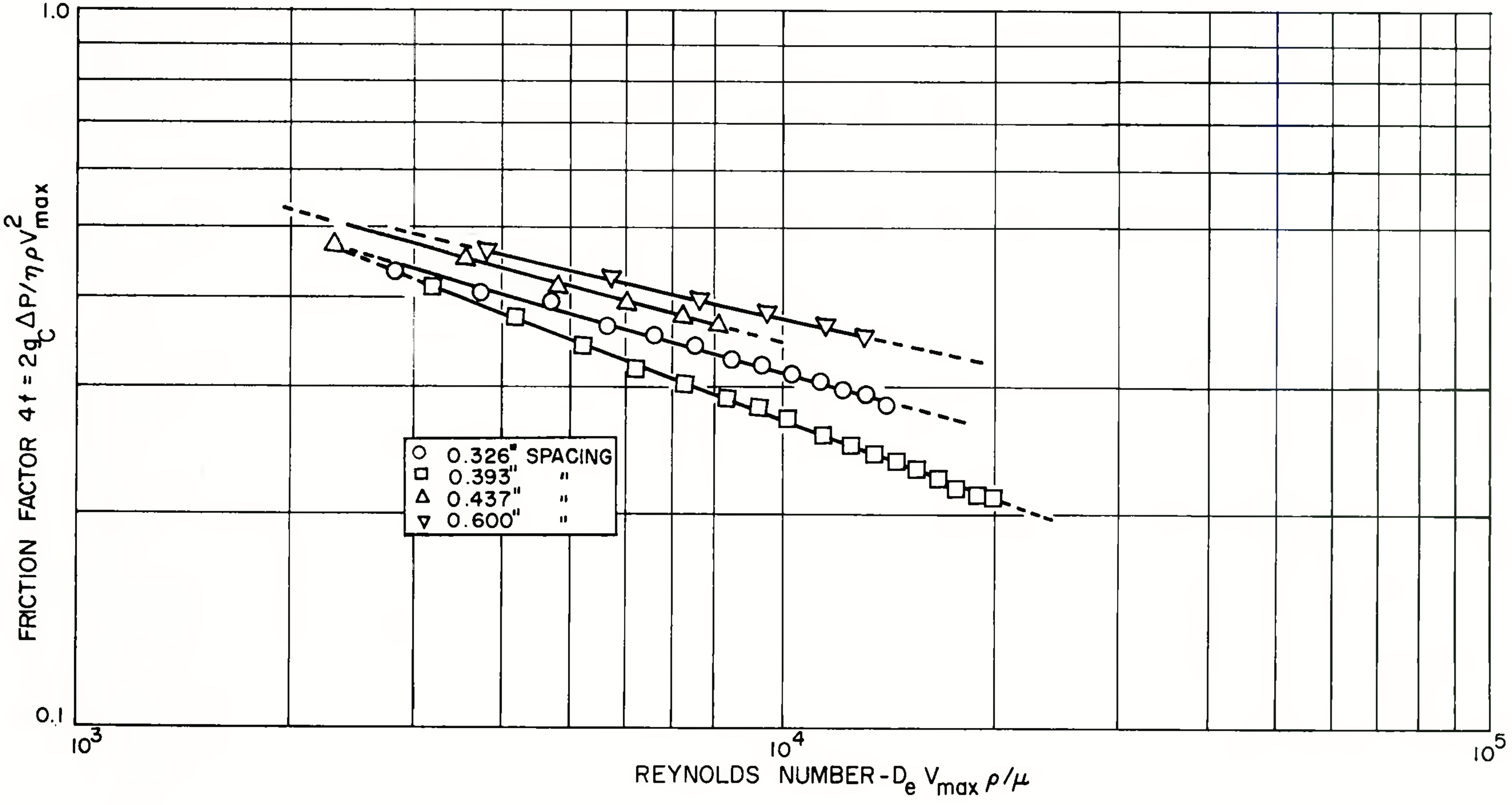


Fig. 13. Experimental Friction Factors vs Reynolds Number

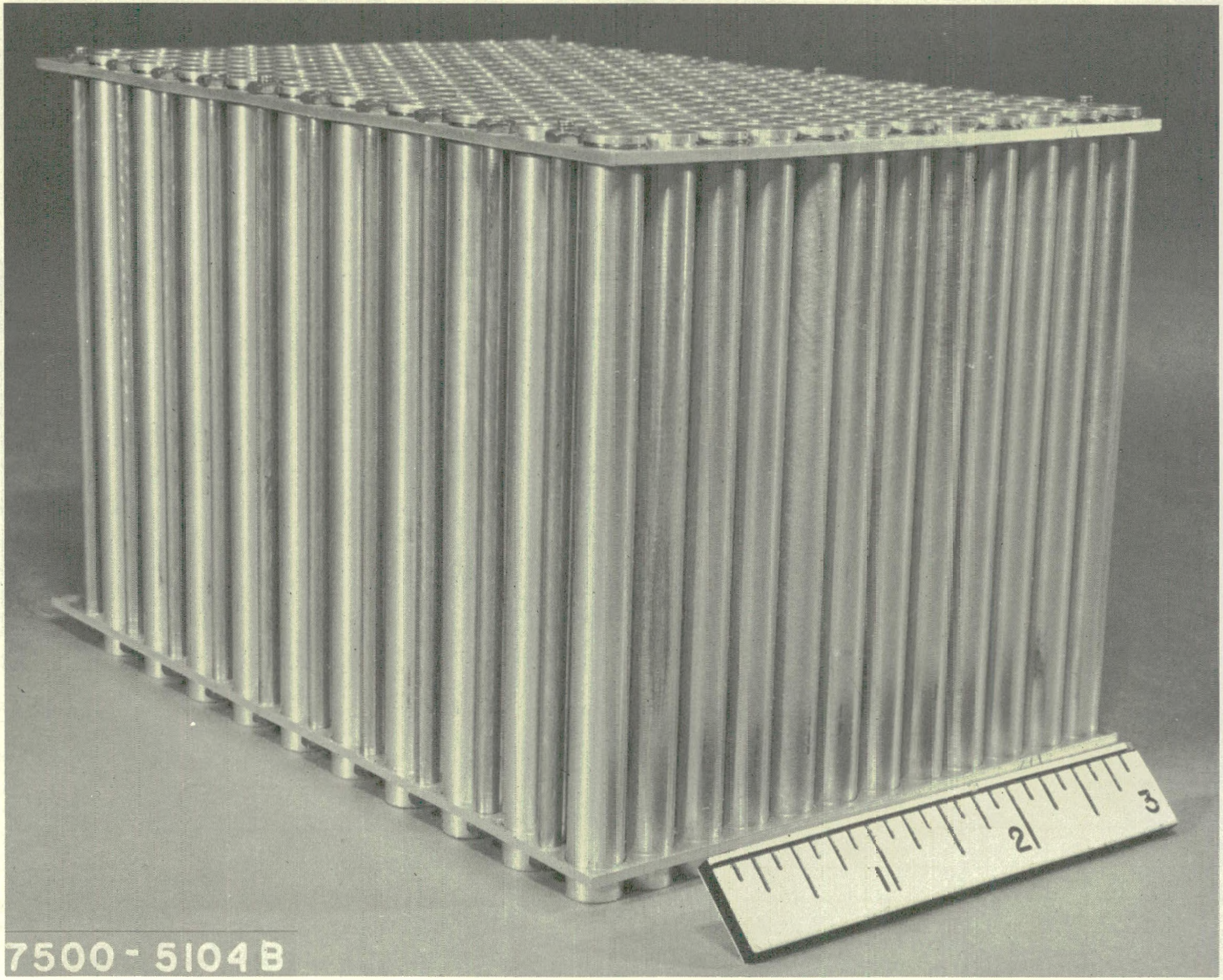


Fig. 14. Cylinder-Type Element Having 0.326-Inch Spacing

0.105-inch high spacer bars on each plate and the orientation of the fins was such that the fins would mesh if there were no spacers (Fig. 15). Each plate was 3.875-inches wide, 0.646-inches high and 10-inches long. A similar element consisting of five plates instead of six, with additional 0.130-inch spacers between the plates and 0.060-inch spacers between plate and test section wall, was also tested. The results are shown in Fig. 16.

The following symbols have been used in this report:

$4f$ = Friction factor of the fuel element section - dimensionless

g_c = Gravitational constant - 32.2 ft/sec^2

N = Number of transverse rows of cylinders in the longitudinal direction - dimensionless

ΔP = Pressure drop across the fuel element only - lb/ft^2

V_{max} = Water velocity in the minimum flow area - ft/sec

ρ = Water density* - lbs/ft^3

H. FLUX DISTRIBUTION MEASUREMENTS IN OMR CORES (W. W. Brown, V. A. Swanson)

The reactivity and heat generation characteristics of a reactor core depend on, among other things, the distribution of the thermal neutrons within the core. In cores of the type proposed for organic moderated reactors, the distributions are difficult to calculate and the calculations are subject to large uncertainties. The purpose of this study is to determine the distributions by direct measurement in a flexible mock-up of a portion of an OMR core. Both spacing of the fuel in the elements and the spacing of the elements will be varied so that the dependence of the neutron distributions on these parameters can be determined empirically.

As presently designed, the mock-up core elements contain 1.9 per cent enriched uranium as fuel in the form of flat plates 54 x 5 x 0.1 inches in dimensions. The plates are clad in 20-mil-thick aluminum and held in a box of 30-mil aluminum as shown in Fig. 17. The grooved aluminum plates at the top and bottom of the

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*All tests were conducted at room temperature, isothermally.

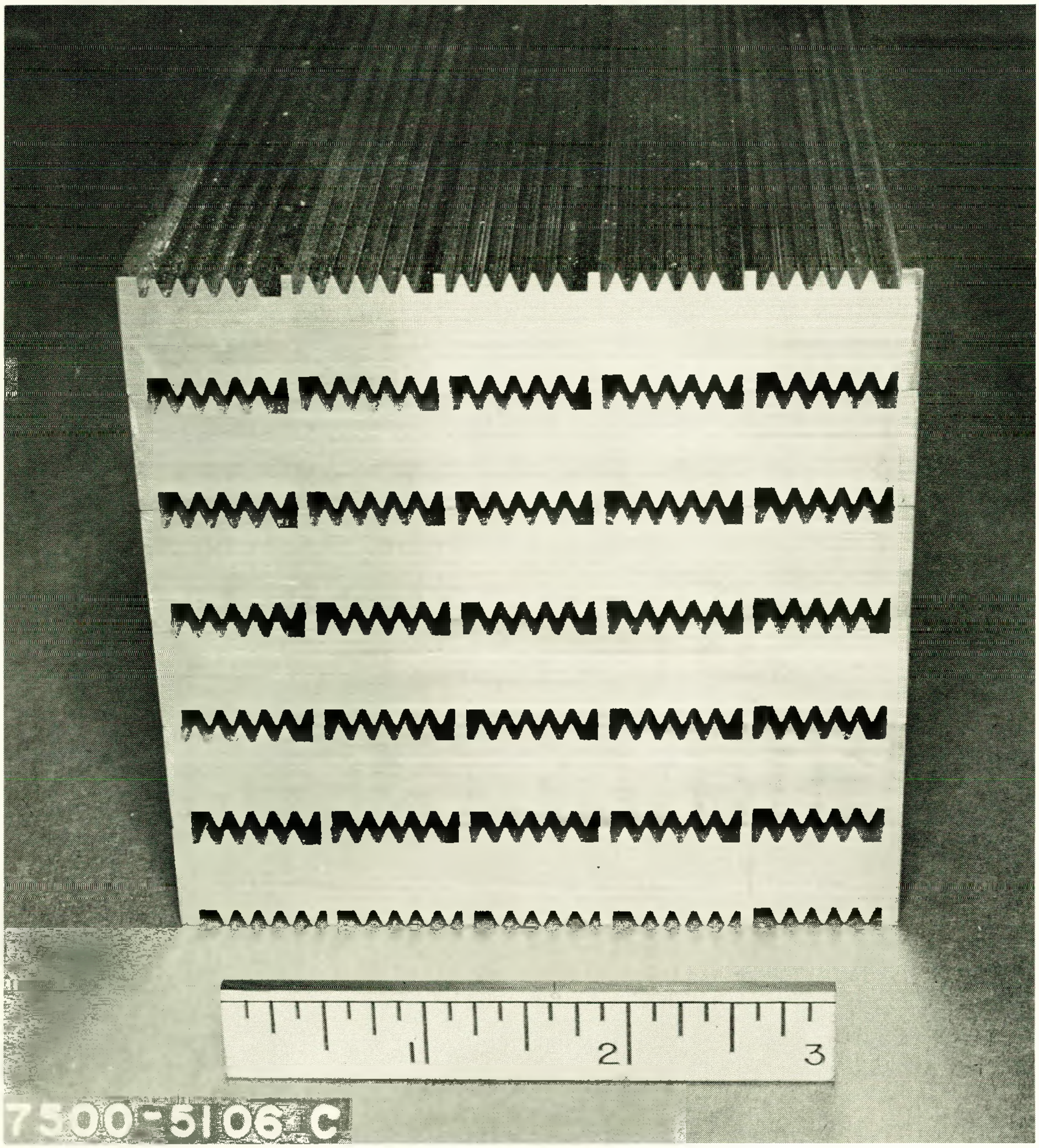


Fig. 15. Finned-Plate Fuel Element Mock-Up

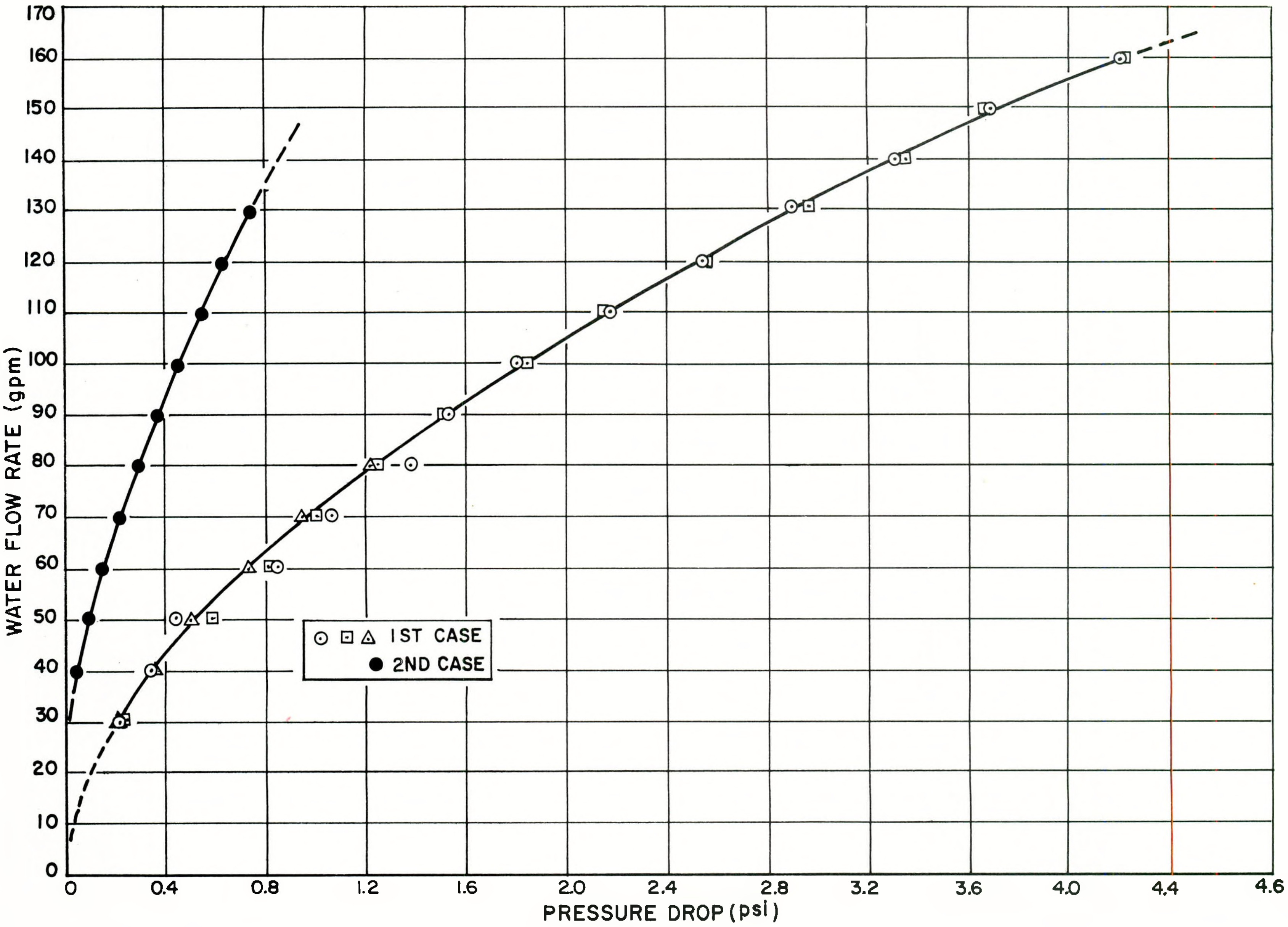


Fig. 16. Pressure Drop vs Flow Rate for OMR Finned-Plate Fuel Element Section

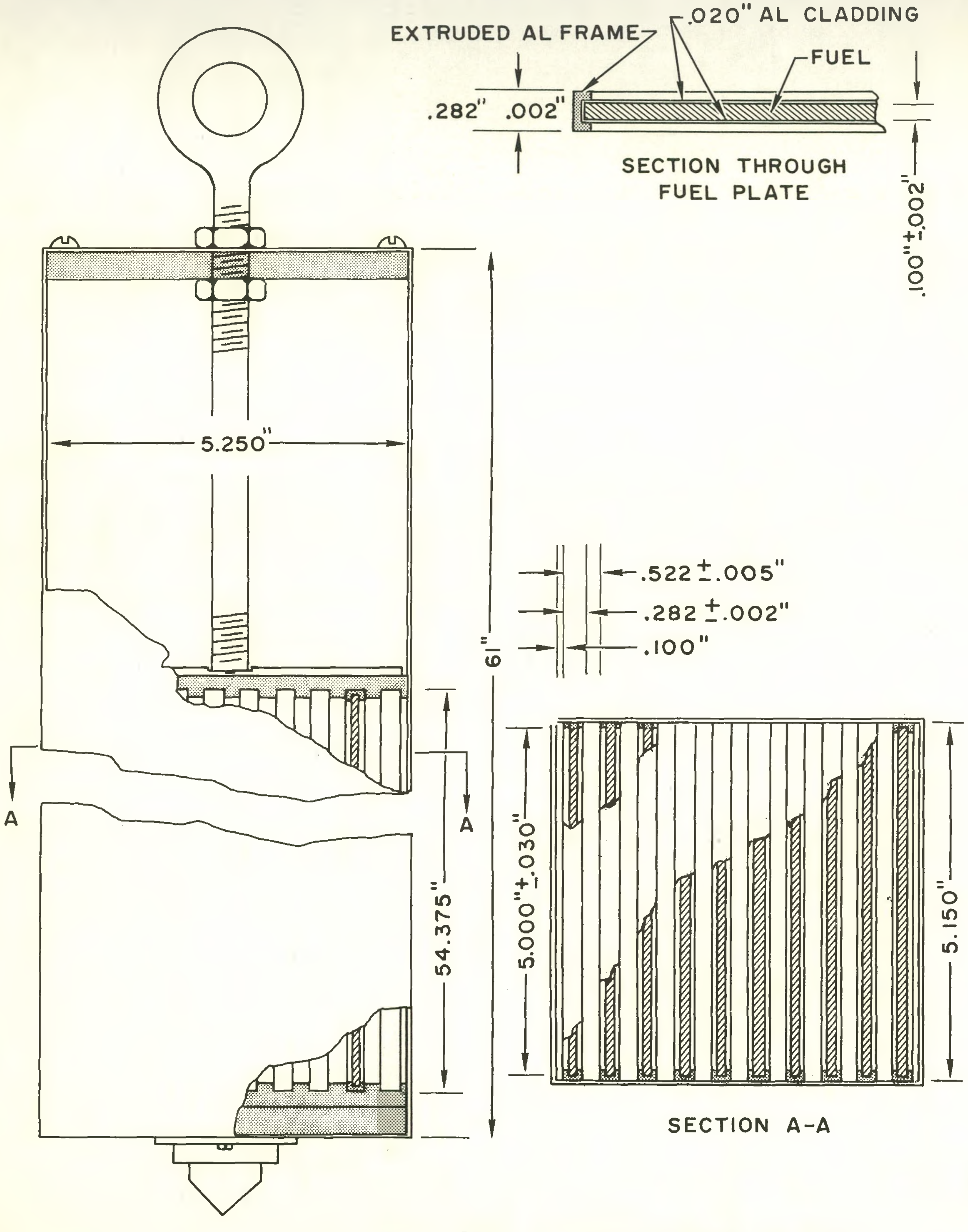


Fig. 17. Fuel Element, 10 Plates

element are removable. Three sets of the grooved plates are to be made so that 10, 12, or 14 fuel plates can be held at uniform spacing within an element. At these spacings the distances between the centers of the fuel plates are 0.522, 0.428, and 0.368 inches respectively.

The elements are to be mounted in a cylindrical aluminum tank four feet in diameter and six feet high. Four pairs of grid plates will hold the elements at top and bottom in the tank in four different square lattice configurations, one of which is shown in Fig. 18. The center-to-center spacings between rows of elements in these four configurations are 5.375, 6, 6.5, and 7.25 inches. By thus varying plate spacing and element spacing, the moderator-to-fuel volume ratio can be varied from 2.5 to 6.

A removable cladding of 0.025-inch steel is to surround each element. For at least one configuration, measurements with and without this cladding in place will be made in order to determine its effect on the neutron distribution.

Santowax-OM (a mixture of ortho and meta terphenyls) will be used as the moderator. The mixture is such that the moderator is liquid at room temperature. Provision is made for pumping the moderator to or from a storage vessel so that lattice changes can be made with the core tank empty.

The experiment will be performed with the core tank situated on top of the thermal column of a water boiler reactor (AE-6) which will serve as the neutron source. From activation analyses of foils irradiated within an assembly, the neutron distribution in it can be obtained. Parts for holding the foils in each assembly are being designed.

The fuel material is at present on order, the elements and supporting grids have been designed and the moderator, core tank, and storage tank are on hand.

I. CRITICAL EXPERIMENTS (G. B. Zwetzig)

1. Critical Experiment Facility

Figure 19 presents the general features of the planned critical experiment facility. The basic design as shown in the figure and as described in the previous quarterly report was not significantly changed during this period.

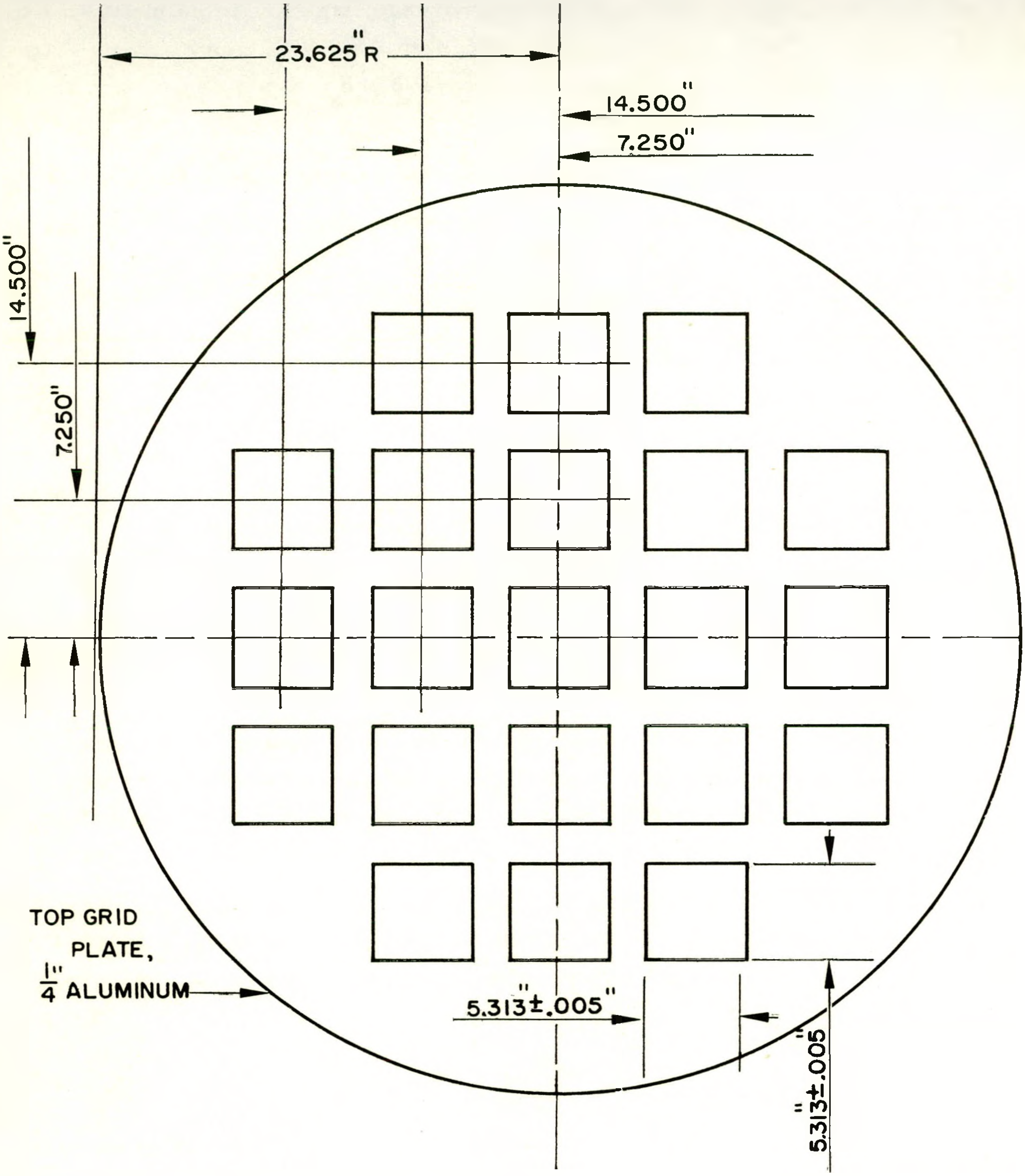


Fig. 18. Lattice Configuration, 7-1/4-Inch Spacing

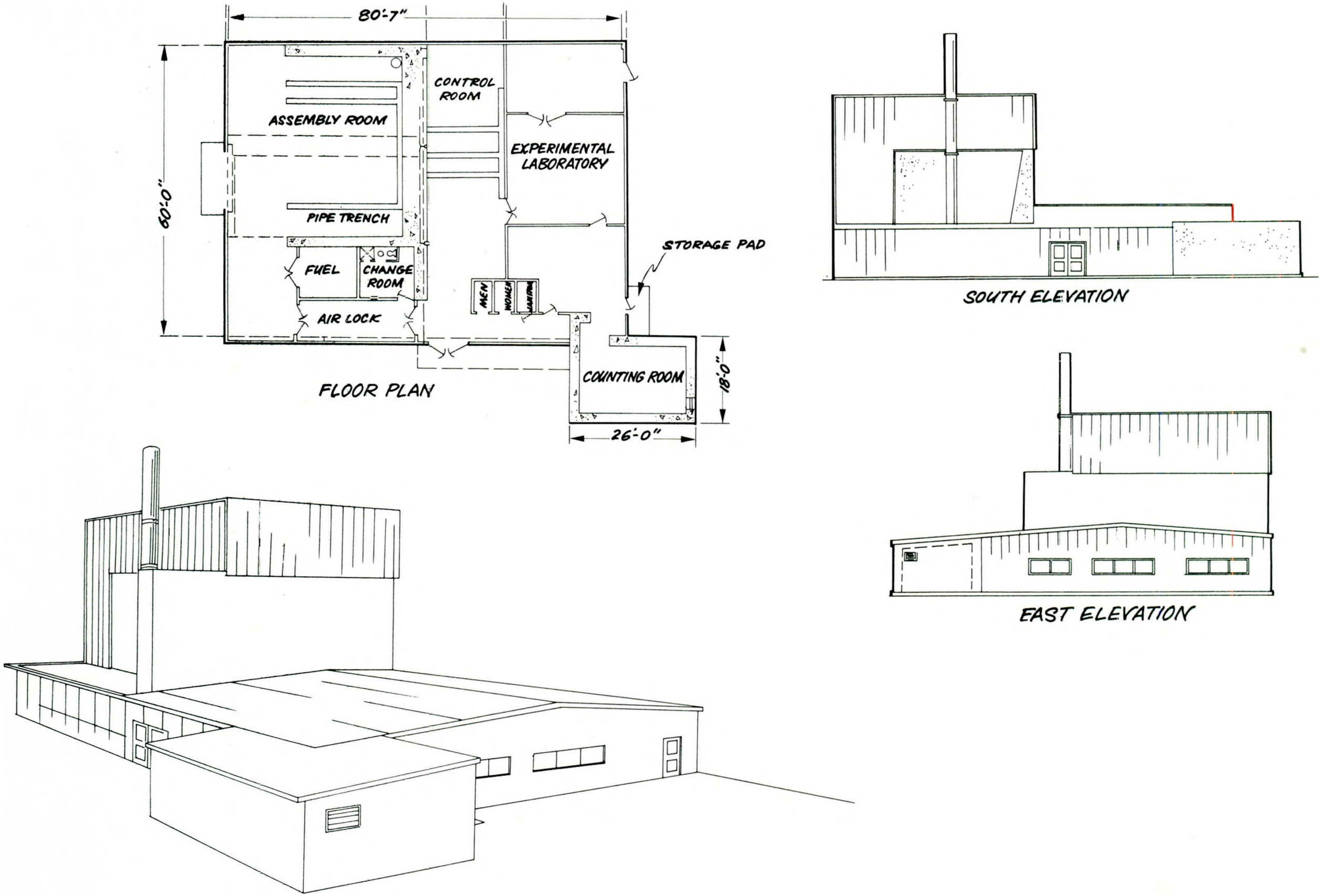


Fig. 19. Critical Experiment Facility

2. Critical Experiment

a. Experimental Apparatus

During this quarter the design of the basic apparatus was approximately 90 per cent completed. Figure 20 is the Process and Instrumentation Diagram of the proposed system. Basically, the system is as described in the previous report. The following decisions were made concerning the design:

1) Heating - The core vessel will be heated by immersion heaters. The balance of the system will be heated by 60-cycle induction heating.

2) Gas Blanket - A gas other than air will be used to blanket the organic surface. Gases tentatively considered are CO_2 or N_2. The reason for using a gas blanket is to reduce the explosion hazard associated with hot organic exposed to the air. This feature will also allow safe operation at temperatures up to 600° F.

3) Dump Valve - The butterfly valve originally selected for use in the dump line has been replaced by a DeZurik lever-operated wedge plug valve. This substitution was made because of the problem of finding a suitable gasket material to provide a good degree of leak-tightness in the butterfly valve. The DeZurik valve will provide a metal-to-metal seat, thereby eliminating gasket problems. Due to its wedge-type action, this valve is expected to provide a good degree of leak-tightness.

   Because the valve will constitute a part of the scram system, it is planned to add weights to the valve lever so that it will open automatically under the force of gravity. The valve will be held in the closed position by means of an electromagnet.

4) Bottom Grid Plates - Bottom grid plates will be fabricated of two-inch steel. Three lattice spacings will be investigated so that three plates will be required. All three plates will be kept stacked in the core vessel with the desired lattice plate on top. This will give a bottom grid plate thickness of six inches which corresponds to the planned thickness to be used in the actual reactor.

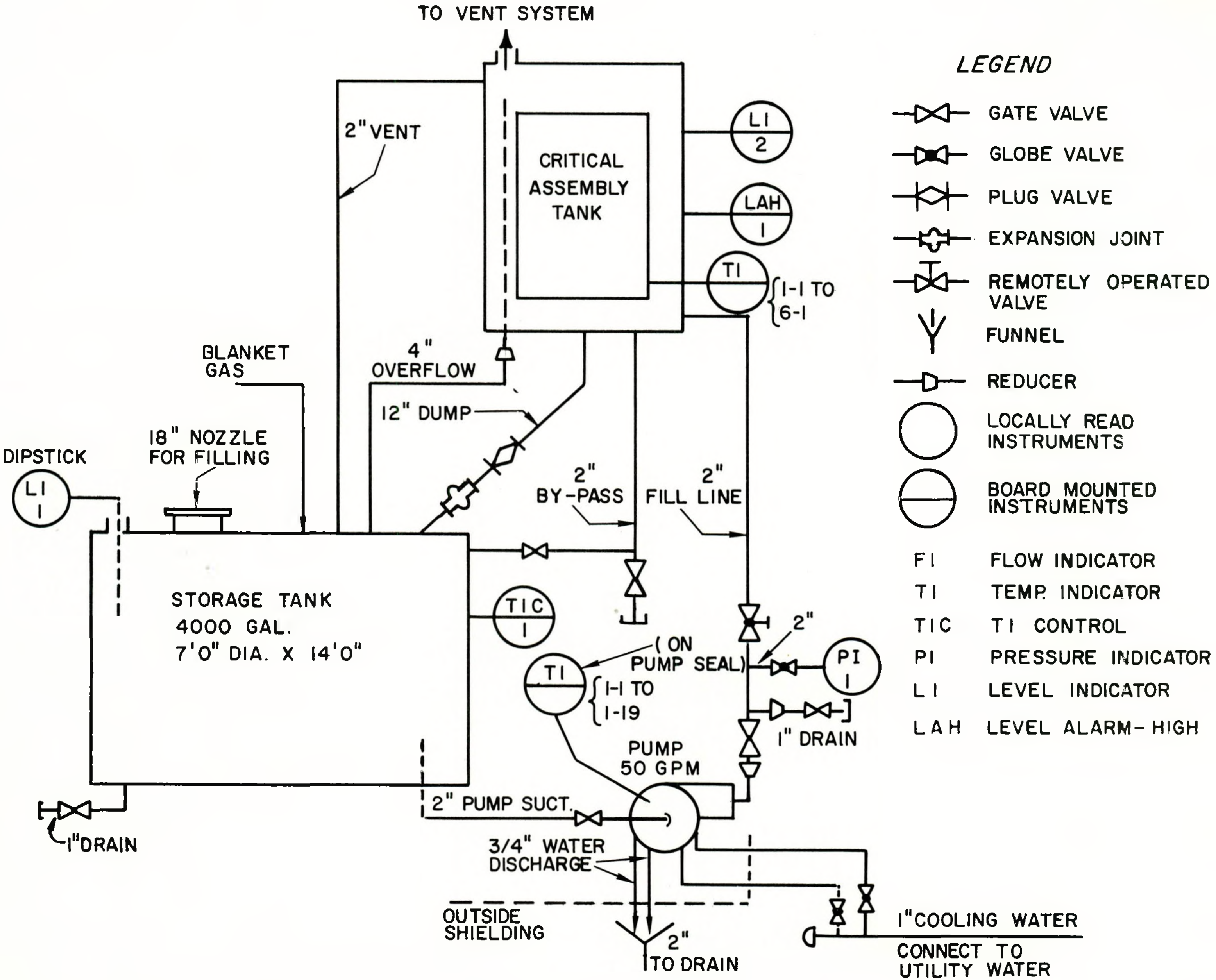


Fig. 20. OMR Critical Experiment P & I Diagram

5) Thermal Shield - Design and procurement of a steel thermal shield will be postponed until after the assembly has become critical and the permissible excess fuel loading has been made. This will allow the thermal shield to be sized so as to provide the designed spacing between the outer fuel elements and the thermal shield.

6) Core Vessel - Three stirrers will be utilized to maintain a uniform temperature throughout the core. The stirrers will be located in the bottom plenum below the bottom grid plate. In addition several nozzles will be provided in the sides of the tank.

b. Nuclear Instrumentation

Most of the basic nuclear instrumentation equipment was ordered and delivered during the past quarter. The nuclear instrumentation plan, together with the interlock and scram systems, has been subjected to study and review and is currently being finalized.

c. Fuel Elements

Fuel for the critical assembly was ordered. Delivery is expected during the next quarter. The fuel will be in the form of uranium plates 54 x 5 x 0.100 inches, with an enrichment of 1.9 per cent. Sixty plates of the same size of natural uranium are in the process of being ordered. By substituting these plates for some of the 1.9 per cent enrichment plates in the critical assembly, it is planned to estimate the effect of variations in enrichment.

Several possible fuel element box designs have been considered during this period. The final design, however, has not yet been selected. An attempt is being made to coordinate the design requirements of the critical experiment with those of the OMR flux distribution experiment (Subaccount 4810). It is expected that a final design will be selected very early in the next quarter.

Investigations of the oxidation properties of uranium immersed in 350° F Santowax-R in a vessel open to the atmosphere were concluded. Initial indications of severe oxidation were confirmed. Four specimens (3/4-in. diam.

by 1/8-in. thick; weight about 22 gm) were exposed for one week and showed an average weight gain of 8 mg. The thin, loosely adherent, black coating was identified as uranium dioxide. Because of this loosely adherent coating, no weight changes were made on the specimens exposed for one and two month periods. Preparations are underway for performing similar measurements using a CO_2 or N_2 blanket gas.

A number of methods for physically protecting the uranium against oxidation have been investigated. Varying degrees of success have been achieved; however, no system investigated to date is ideal. On the limited basis of one sample, the simplest and most effective measure seems to be tightly wrapping the uranium in a sheet of silicone adhesive-backed aluminum foil. Using this method there appears to be definite organic penetration of the cladding; however, the extent of oxidation appears to be significantly reduced. It is believed that the experiments using a blanket gas will lead to a major reduction in the seriousness of this problem.

d. Control and Safety Rod Drive

Construction of a prototype combination control and safety rod drive was undertaken. The design is similar to that used at the Argonne Critical Experiment Facility. In this design the control rod is fastened to a cable which is wound over a grooved drum. Power is furnished by a gear motor. Scram release is provided by a magnetic clutch on the drive shaft. Position indication will be provided to an estimated duplication and differential accuracy of 0.01 inch. Position indication is provided by a pair of selsyns: one for coarse indication and one for fine indication. Snubbing is provided by a rotary hydraulic shock absorber. At the close of this period, construction of the unit was about 75 per cent complete.

J. COMPOSITION OF REACTOR COOLANT (R. H. J. Gercke)

A chromatograph to operate as high as 400° C is needed in our work, but such a unit is not yet available commercially. One has been designed in a joint effort with Loe Engineering. It has been built and received. Initial testing showed that the temperature controller did not meet specifications but it was replaced and the unit now performs satisfactorily.

Commercially available infrared spectrometers were investigated and a Beckman IR-4 instrument was purchased. The instrument has been received and is now being set up in the laboratory by the vendor.

Elution chromatography equipment was ordered and received.

A method was developed for the determination of molecular weight of polyphenyl materials. Equipment for this purpose has been received and is being set up and adjusted.

A method for simultaneous determination of the three terphenyl isomers was developed using the infrared spectrometer.

Two courses were attended, one at MIT and the other at Beckman Instruments, to learn the techniques of infrared spectroscopy.

Various methods of preliminary separation of the complex mass of decomposition products in the decomposed coolant were discussed. A separation technique depending upon solubility in a variety of solvents is currently being tried.

K. PHYSICAL PROPERTIES AND GAS SOLUBILITY OF THE COOLANT

(R. H. J. Gercke)

An experimental method was designed for determining equilibrium gas solubility as a function of temperature and pressure for organic coolants. Equipment was chosen and purchased and all components have been received.(Fig. 21). All shop work has been completed and the equipment has been assembled in the laboratory. The gas-liquid contacting unit and the glass gas handling system have been volume calibrated and leak checked. Experimental determinations are ready to begin.

Reactor problems related to transient gas solubility effects were analyzed and an experimental apparatus designed. The equipment was chosen and ordered. (Fig. 22). Almost all items have been received. Assembly of this equipment is 70 per cent completed.

A method was developed and the apparatus assembled for the determination of carbon and hydrogen content of irradiated organic coolants. A number of samples of irradiated diphenyl, Santowax-R, Santowax-OM, and isopropyl diphenyl were tested.

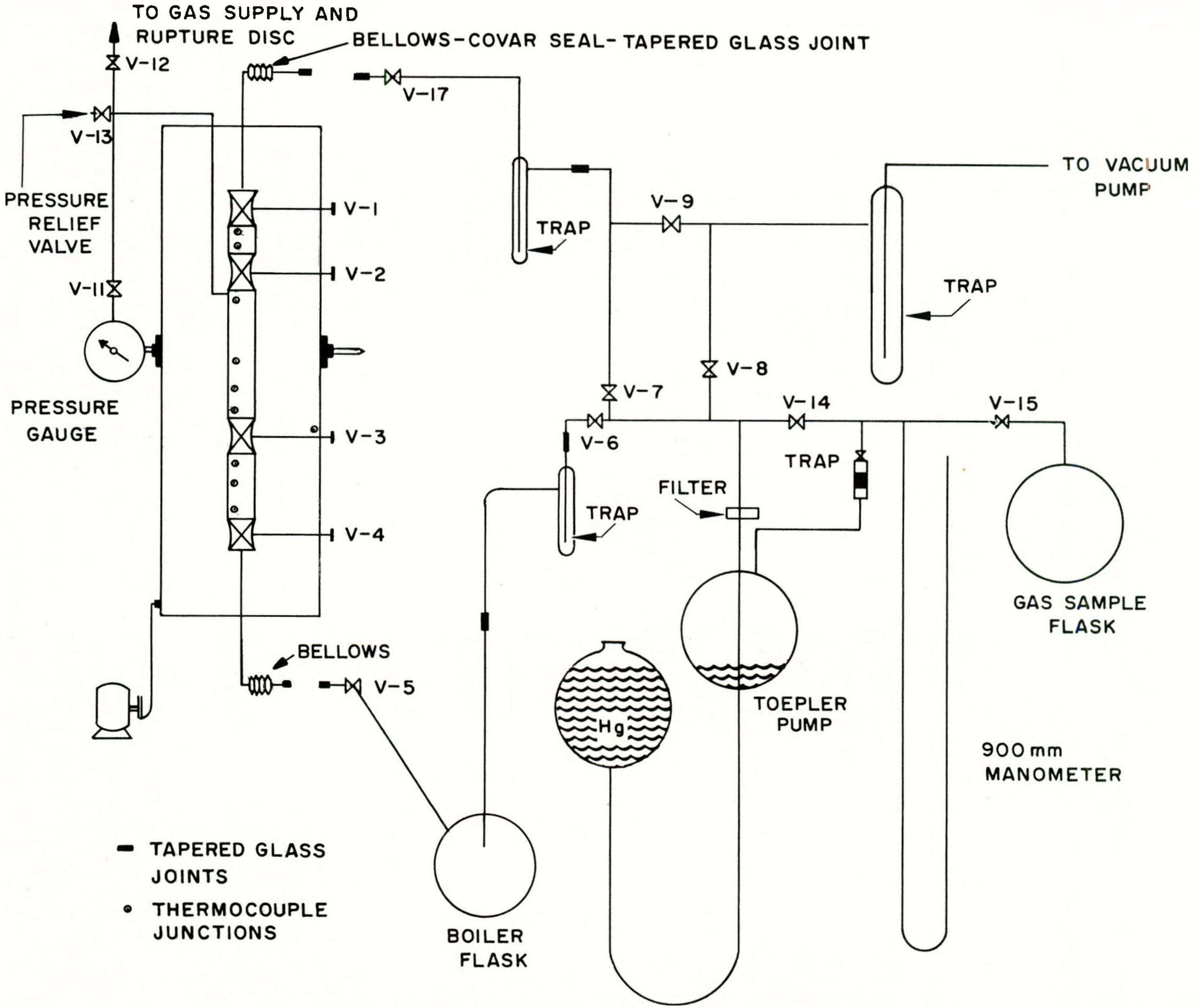


Fig. 21. Equipment Schematic for Equilibrium Gas Solubility

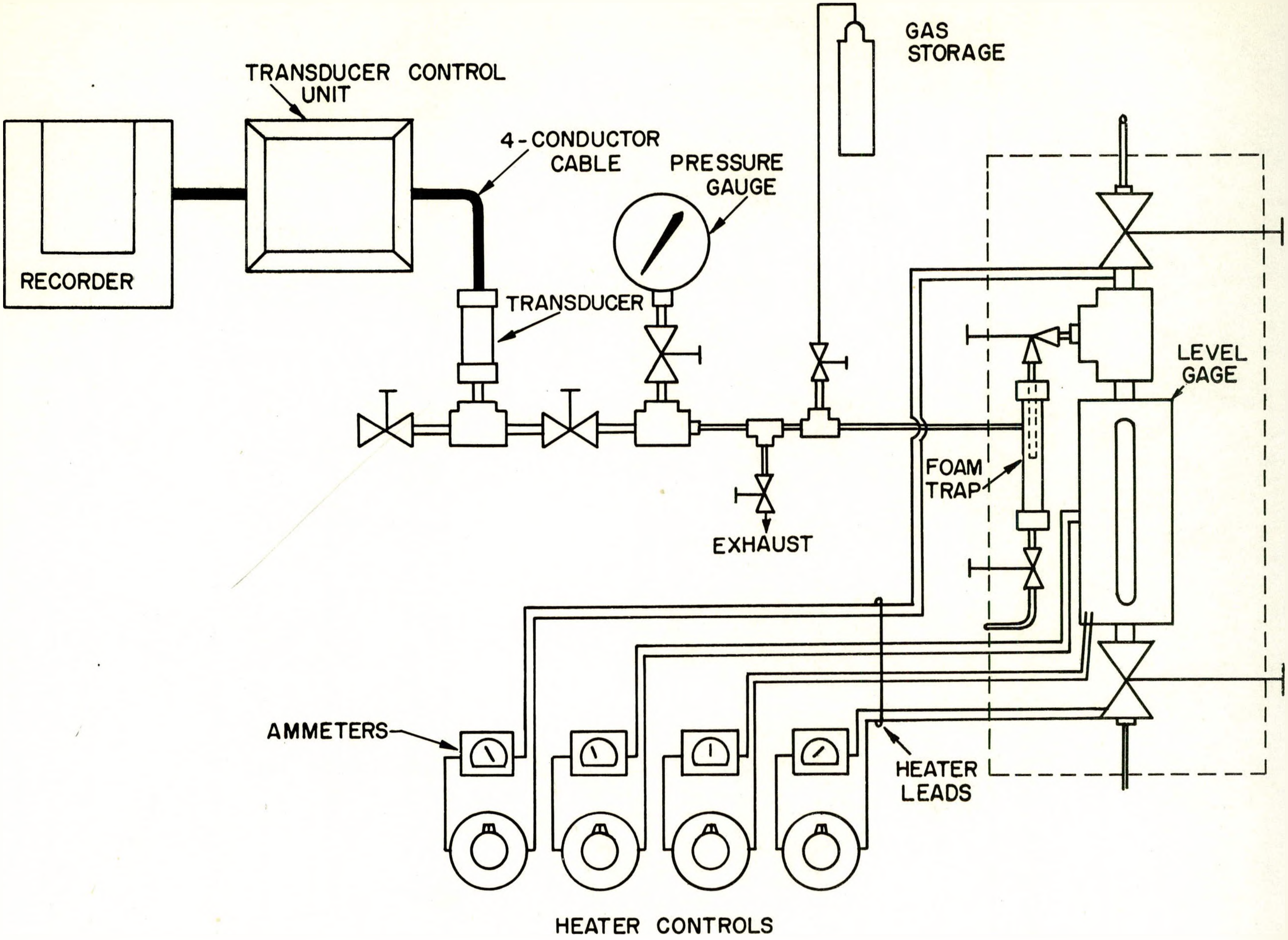


Fig. 22. Equipment Schematic for Transient Gas Solubility

The following table summarizes the maximum variation in the hydrogen density for the four materials studied. The hydrogen density increases with decomposition because the increase in fluid density more than counterbalances the loss of hydrogen.

TABLE VI

HYDROGEN DENSITY AT 600° F

Material	High Boiler Residue*	
	0% (atoms/cm^3)	35% (atoms/cm^3)
Isopropyl diphenyl	3.75×10^{22}	3.82×10^{22}
Diphenyl	3.08×10^{22}	3.24×10^{22}
Santowax-R	3.23×10^{22}	3.30×10^{22}
Santowax-OM	3.15×10^{22}	3.28×10^{22}

*Decomposition product of lower volatility than the terphenyls.

L. CORROSION STUDIES (H. E. Kline)

A suitable location was found in the OMRE circulating by-pass loop for the insertion of a section of pipe containing corrosion and mechanical test specimens (Fig. 23, 24, 25, and 26). The specific location is between the cunno filter and valve in line 109 of the OMRE P & I diagram. This is a 2-in. pipe section which will have a volume flow rate of approximately 20 gpm.

A pipe spool section (see Fig. 27) was fabricated to OMRE specifications, specimens were installed, and the unit shipped from AI to the OMRE site where it will be placed in the by-pass section during or before the week of July 7.

Two dummy fuel elements were also loaded with corrosion and mechanical test specimens and shipped to the OMRE site during the month of May. These will be inserted along with the first core loading. Tables VII and VIII list the type, location, and number of specimens in each dummy element. Figures 28 and 29 are photographs of the actual specimens taken prior to loading.

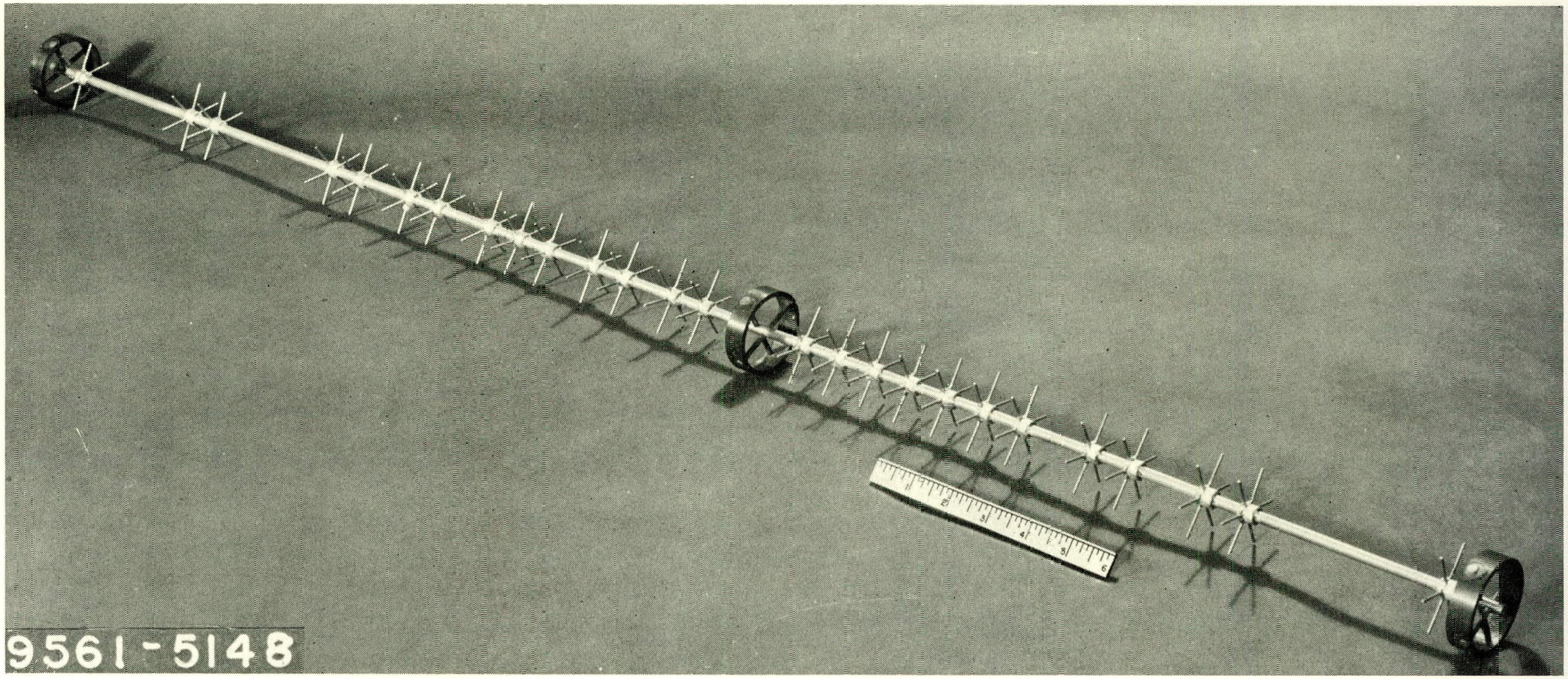


Fig. 23. Specimen Holder

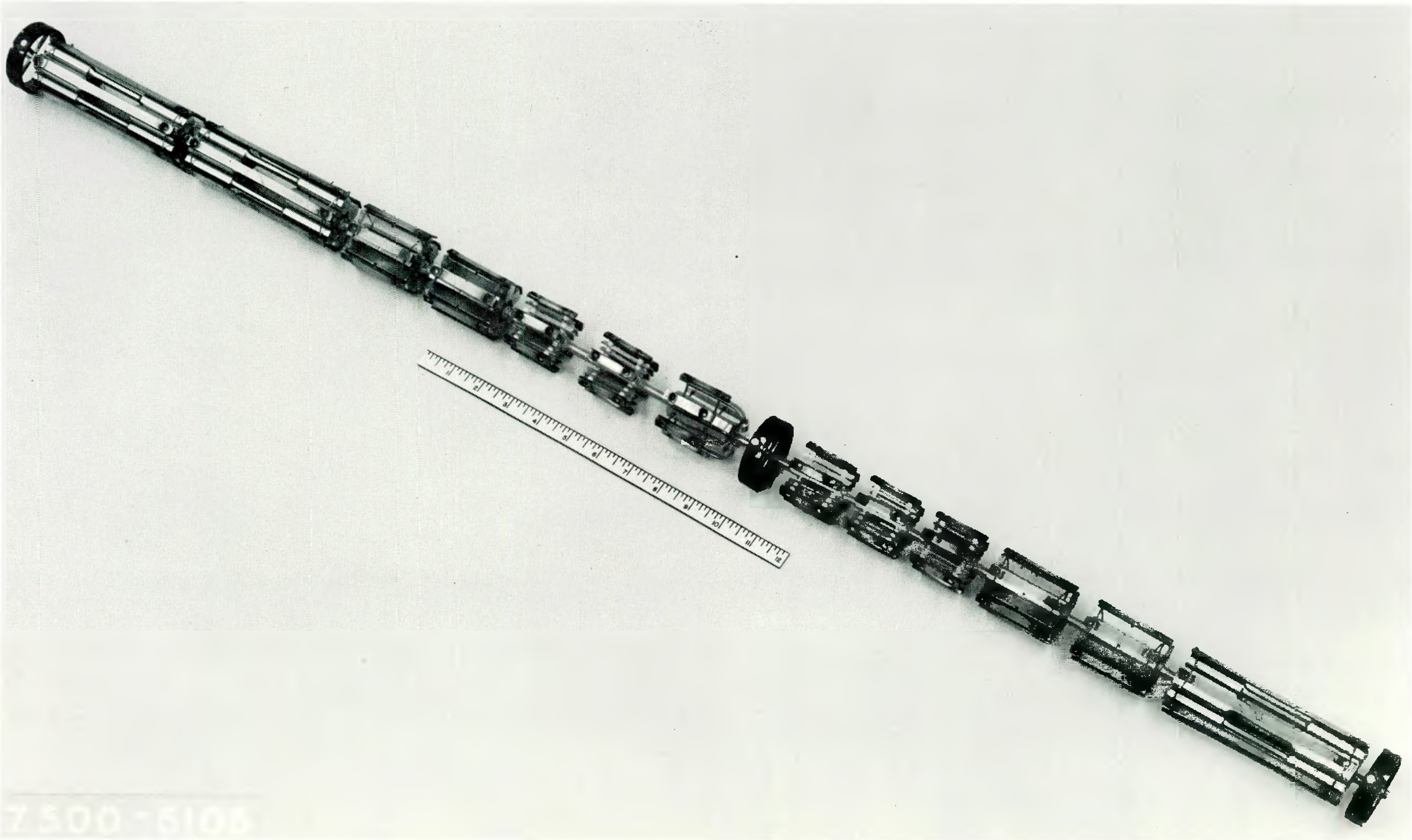


Fig. 24. Specimen Holder With Specimens in Place

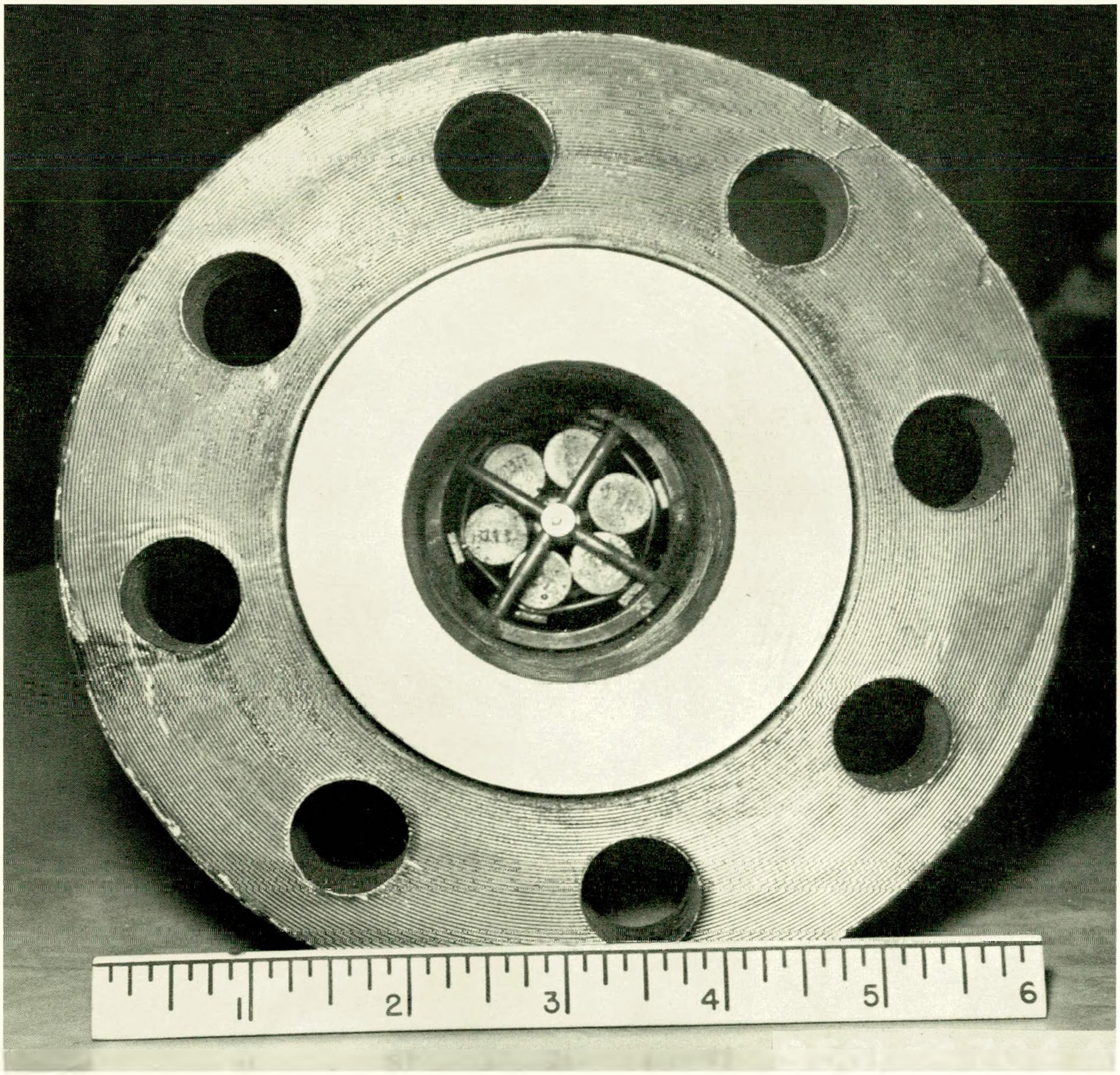
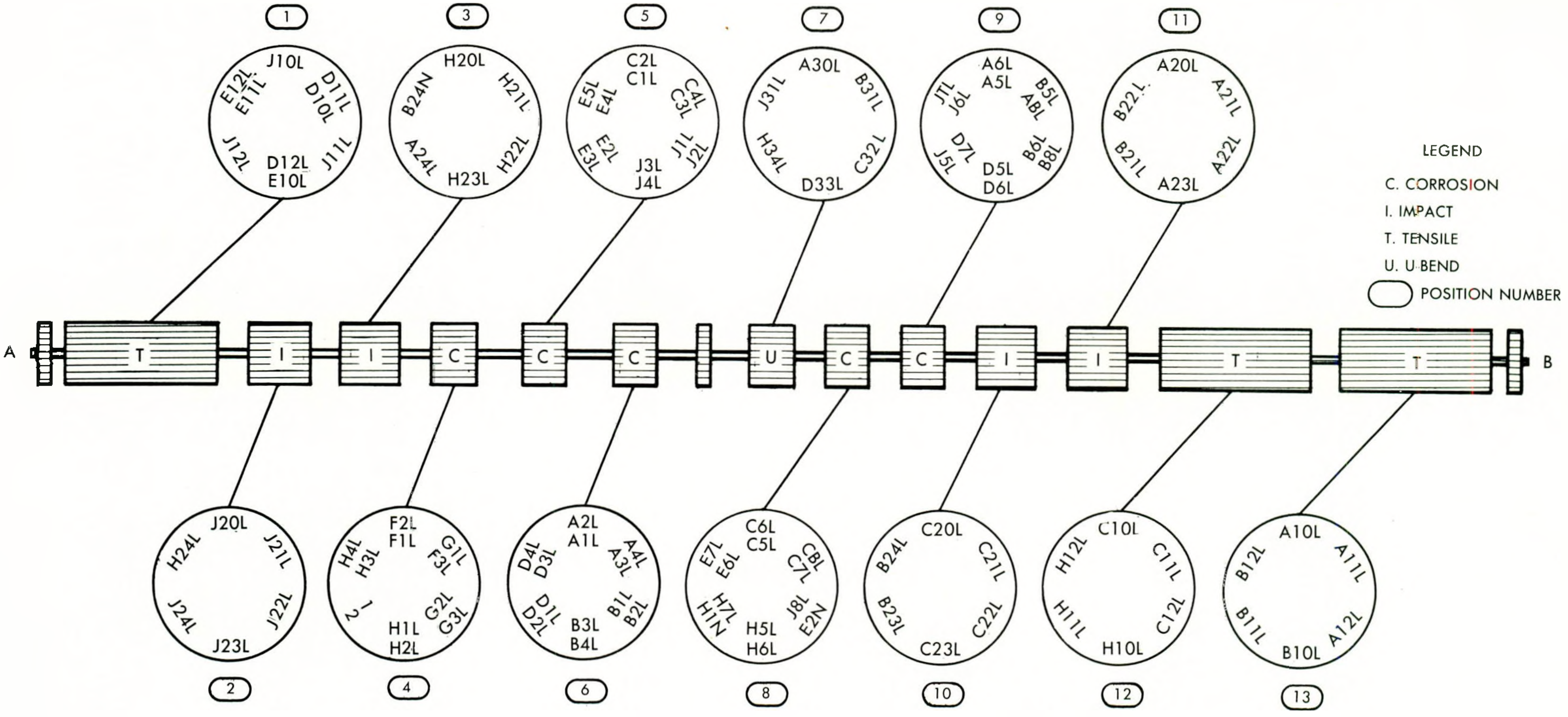


Fig. 25. End View of Specimens in Pipe Spool



KEY TO SPECIMEN IDENTIFICATION

PREFIX:

A. CARBON STEEL
B. TP-304 STAINLESS STEEL—ANNEALED
C. TP-304 STAINLESS STEEL—SENSITIZED
D. 1100 ALUMINUM (2S)
E. MAGNESIUM—PURE
F. MAGNESIUM—ANODIZED—LIGHT
G. MAGNESIUM—ANODIZED—HEAVY
H. TP 410 STAINLESS STEEL
J. 4130—ALLOY STEEL

IDENTIFICATION NO.:

1 THRU 8—CORROSION
10 THRU 13—TENSILE
20 THRU 26—IMPACT
30 THRU 34—U-BEND

SUFFIX:

L. INDICATES OUT-OF-PILE SPECIMENS IN OMRE
N. CONTROL

EXAMPLE:

A	10	L
C STL	TENSILE SPECIMEN	OMRE BY-PASS

Fig. 26. Key to Specimen Identification

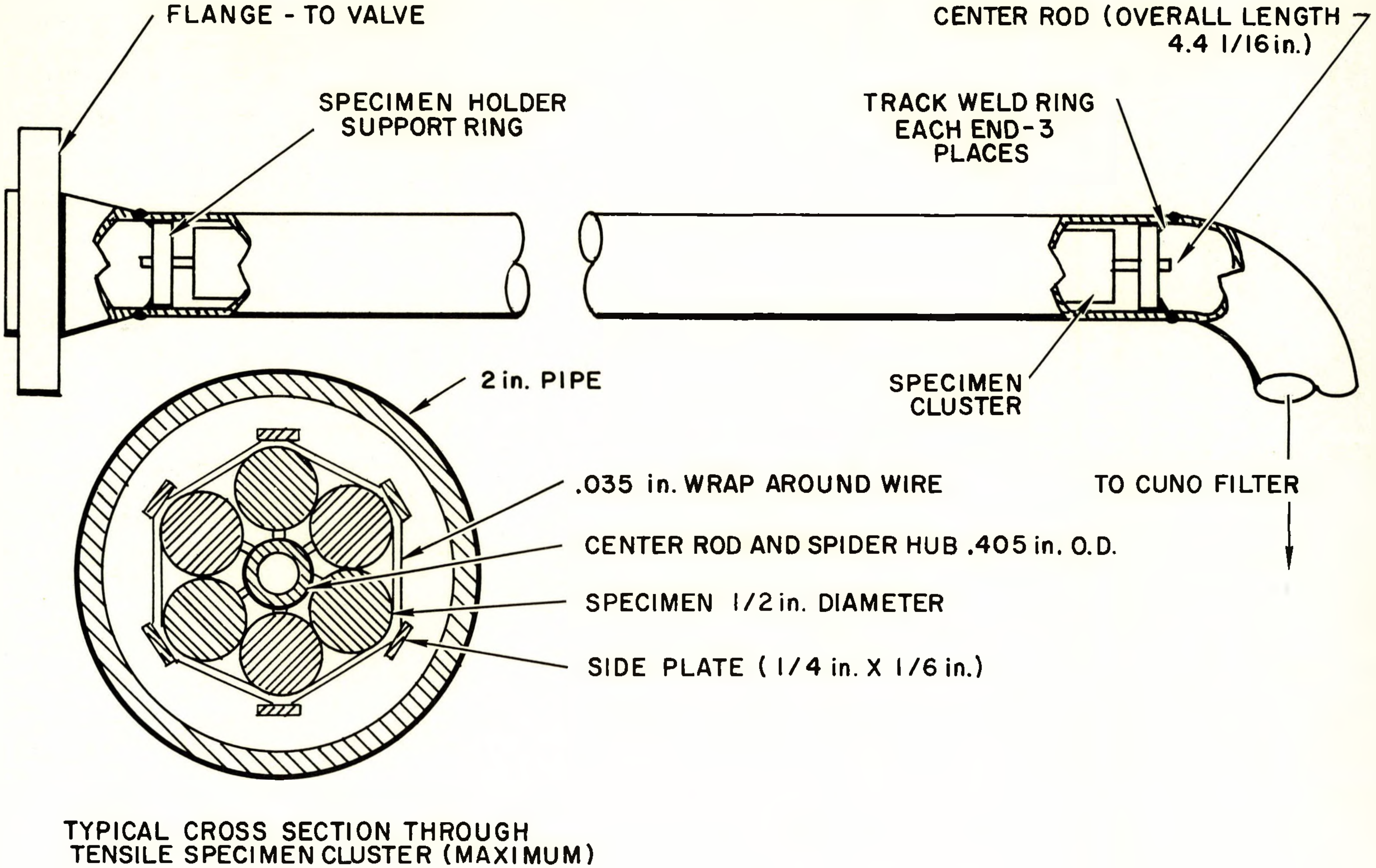


Fig. 27. Specimen Location in OMRE By-Pass Line

TABLE VII

DUMMY ELEMENT NO. 1

Position No.	Specimen Type	No. of Specimens	Material
1	Corrosion	12	Carbon Steel, Type-304-SS, Aluminum, Magnesium, Type-410-SS, 4130 Alloy Steel
2	U-Bend	6	Aluminum, 4130 Alloy Steel
3	Impact	6	Type-304-SS
4	Tensile-Round	6	Type-304-SS
5	Impact	6	Type-304-SS, Type-410-SS
6	Tensile-Round	6	Type-410-SS, Carbon Steel, Type-304-SS, 4130 Alloy Steel
7	U-Bend	6	Type-304-SS
8	U-Bend	6	Carbon Steel, Type-410-SS

TABLE VIII

DUMMY ELEMENT NO. 2

Position No.	Specimen Type	No. of Specimens	Material
1	Corrosion	12	Magnesium, Type-410-SS 4130 Alloy Steel
2	Corrosion	12	Aluminum, Type-304-SS
3	Corrosion	12	Magnesium, Carbon Steel, Type-410-SS
4	Corrosion	12	Type-304-SS, Carbon Steel, Aluminum 4130 Alloy Steel
5	Impact	6	Carbon Steel, Type-304-SS
6	Tensile-Round	6	Carbon Steel, 4130 Alloy Steel
7	Impact	6	4130 Alloy Steel, Type-410-SS
8	Tensile-Sheet	9	Aluminum, Magnesium
9	U-Bend	6	Carbon Steel, Type-304-SS, Aluminum, Type-410-SS, 4130 Alloy Steel

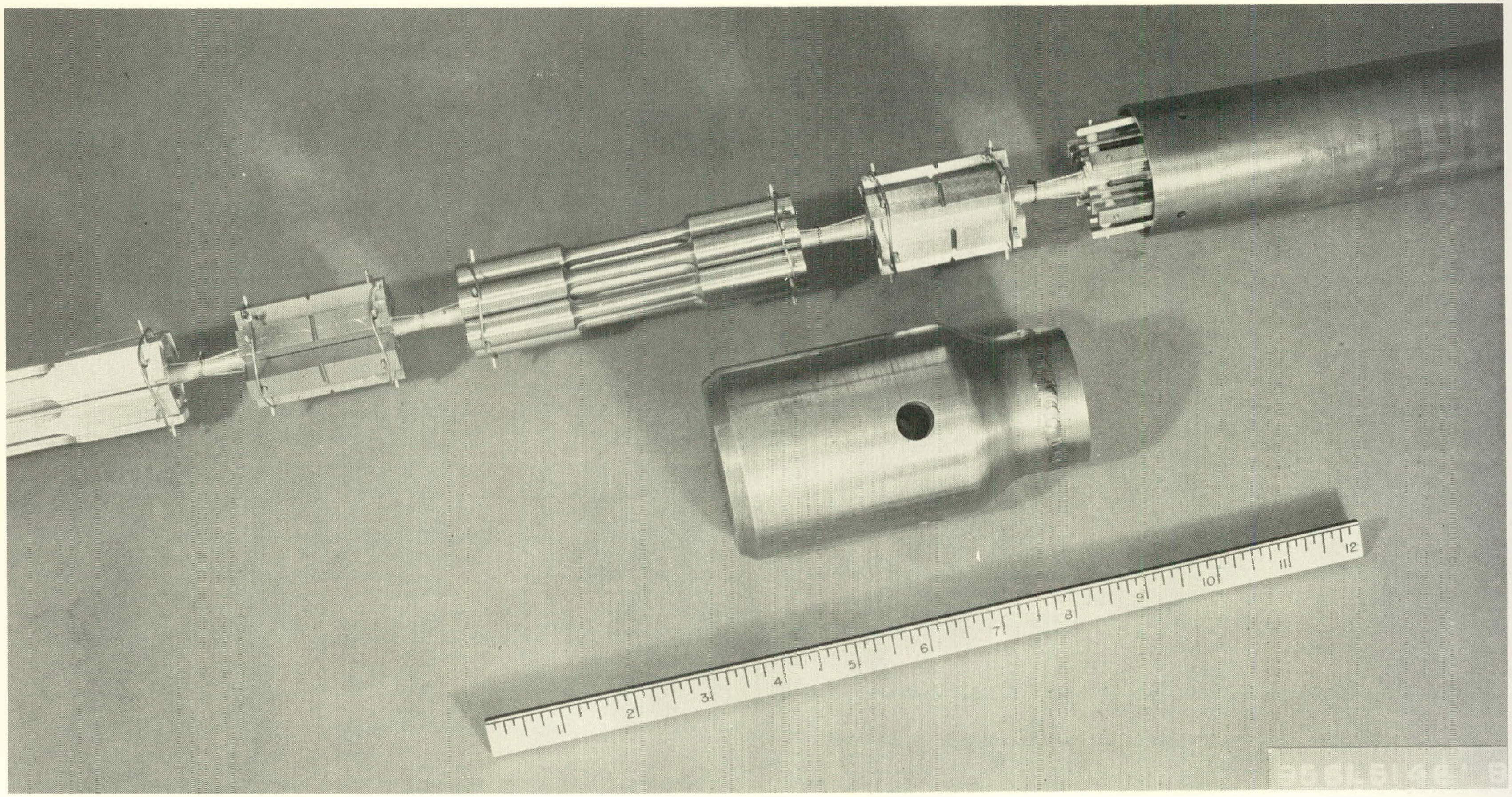


Fig. 28. Specimen Being Loaded into OMRE Dummy Fuel Element

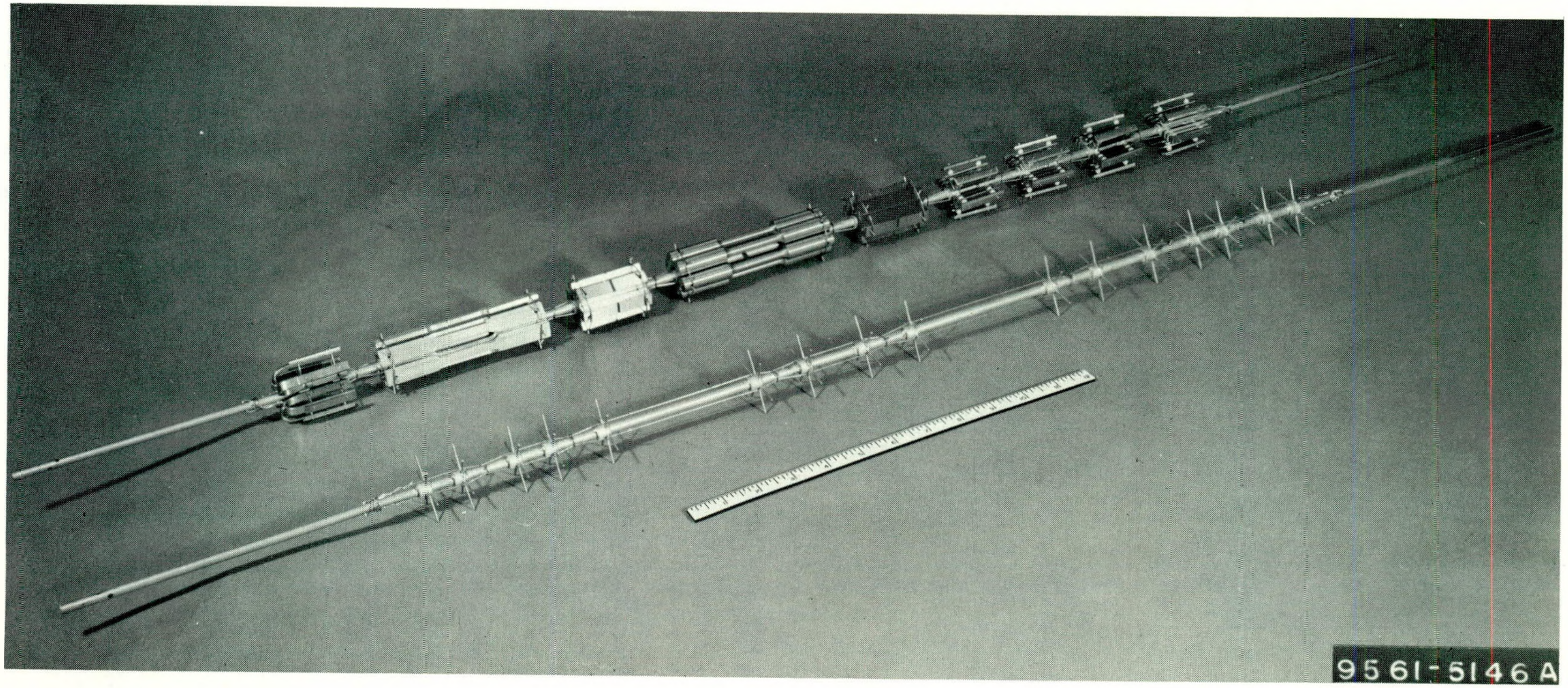


Fig. 29. Dummy Fuel Element Specimen Holder and Specimens

During the month of June, a request was entered for the construction of a cask and cradle which will be used for the removal and shipment of the dummy elements after they have undergone their exposure times in the reactor.

A request for quotes on two five-gallon capacity autoclaves has been released to Erb and Gray and to American Instrument Company. These autoclaves will be used in the study of the effects of blanket gases on the corrosivity of organics.

Specimen holders are presently being fabricated for insertion of corrosion coupons in an experimental organic loop which will be operated at Atomics International. The primary purpose of this loop is to study the effects of water in organics.

M. WASTE GAS TREATMENT (R. J. Edwards)

The development program for the Waste Gas Treatment System can be considered as having three distinct operational phases. The accumulation of the information required to establish the flow scheme constitutes the first phase which is outlined below. The second phase involves the testing of process components having a new design or application in the WGTS, in order to verify or test the practicability of the flow scheme which is chosen. Experimental work during this phase will include bench-scale testing of process components as well as experimental studies of OMRE components and operations. This phase will provide the specifications for the pilot plant design. It is planned to design a full scale WGTS pilot plant having the components arranged in the same configuration as they will be in the OMR plant. The third and final phase will allow the operation of the pilot plant in order to check out the design and make whatever modifications are required. A final design specification and operating procedure will be formulated thereafter. It is anticipated that the latter phase may not be finished until the beginning of the OMR construction. However, the OMR construction schedule is not likely to be affected by the design modifications required by this phase of the WGTS development program.

The maximum permissible concentrations of radioisotopes allowed in air and water have been established by the AEC. Compliance with AEC requirements may be met during normal reactor operation by dilution of the waste gases in a stack with exhaust air from the plant ventilation system. However, a system

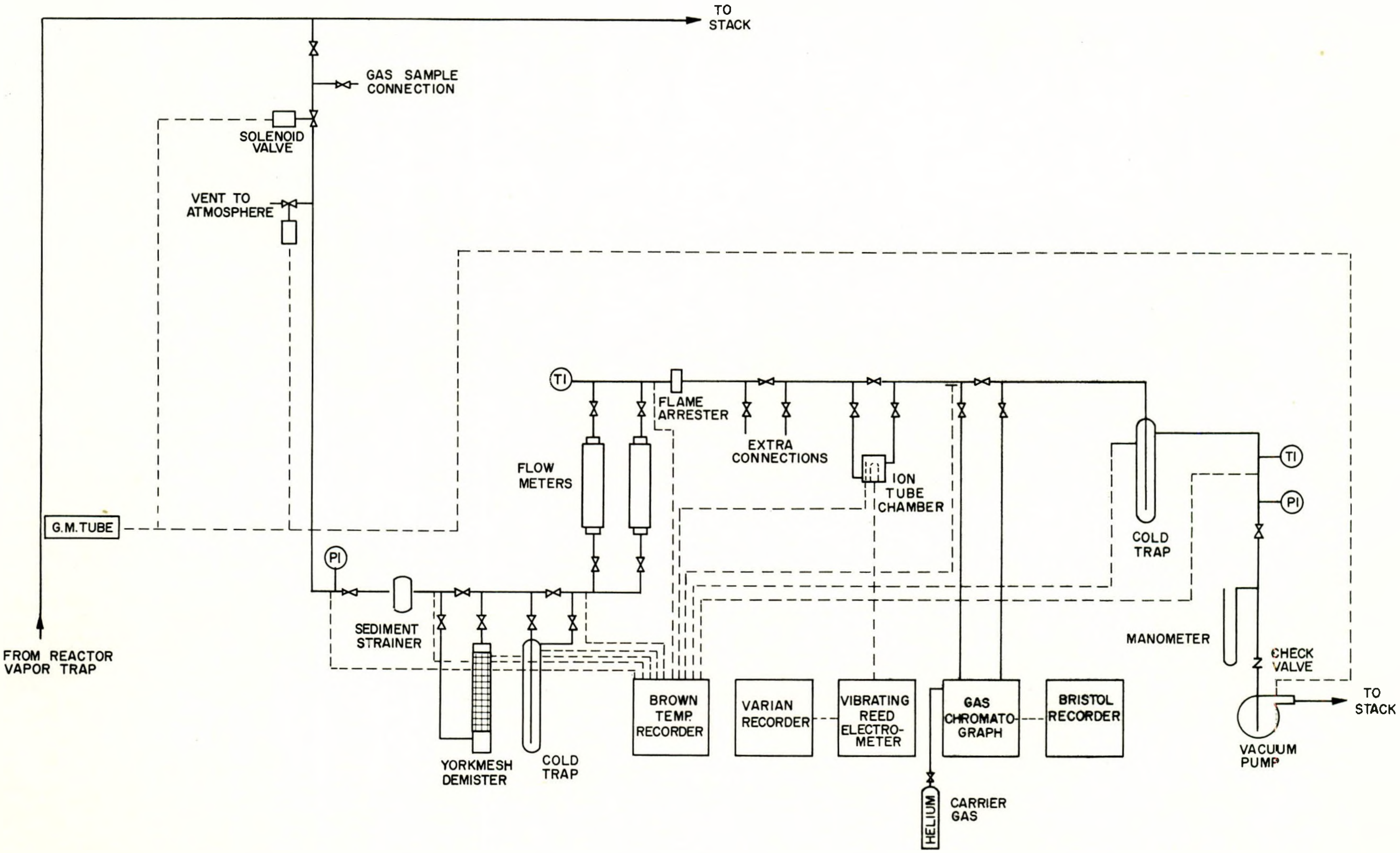


Fig. 30. Flow Diagram for Waste Gas Analyzer Console

must be designed to handle fission gases released following a fuel element failure. Calculations indicate that the OMR will release coolant vapors to the atmosphere at a rate of 0.12 pounds per hour. Since this rate is only to the maximum allowable release rate for such contaminants as prescribed by the Los Angeles Air Pollution Control District, a vapor removal system may be required to comply with regulations in force at a particular reactor site.

The OMRE is expected to provide information helpful to the design of the WGTS, including radiolytic gas generation rate, gas composition, and the amount of radioactivity associated with the waste gas. Now being planned is the assembly of gas analysis instrumentation in the form of a portable console for temporary installation at the OMRE. The flow diagram for this console is shown in Fig. 30. The console unit will include a chromatograph for gas analysis and a vibrating reed electrometer - ion chamber system for radioactivity monitoring. Most of the components have been received and assembly will start in early July. Assembly, testing, and any modifications found necessary should be completed in time for installation at the OMRE by October 1, 1957.

N. DEVELOPMENT OF OPTIMUM COOLANTS (J. G. Burr)

1. General

Duplicate two-gram samples of purified, degassed, anhydrous acetone and isopropanol have been irradiated in the cobalt-60 source. Those gases noncondensable in liquid nitrogen (methane, carbon monoxide, and hydrogen) have been collected and submitted for mass spectrometer analysis. This gas fraction is formed from acetone with a G value of 3.52 (source intensity: 1.60×10^{18} ev/ml H_2O-min) and from isopropanol with a G of 4.62. Measurement of the source intensity with the ceric sulfate dosimeter has begun.

An order for a Consolidated Electrodynamics Modified 21-620 Mass Spectrometer has been placed. Delivery is expected in December. A Perkin-Elmer Vapor Fractometer has been received and installed.

2. Biphenyl-d_{10} and D_2SO_4

A method with an appropriate apparatus has been designed and tested for preparing D_2SO_4 by sweeping SO_3 with helium into D_2O. In a trial run, 91.1 weight-per cent H_2SO_4 (65.3 mol per cent; total volume about 400 ml) was prepared with an 82.6 per cent recovery of SO_3. Using this procedure, 67 ml of D_2O has been converted to about 150 ml of D_2SO_4. Measurement of the acid and deuterium content of this material will soon be made. Following an unsuccessful attempt to measure deuterium content by means of the infrared pattern of benzene-d, prepared by the interaction of the heavy water or acid sample with a solution of phenyl magnesium bromide in di-butyl ether, it has been decided to analyze our materials for deuterium content by combusting them to water. Deuterium content of the water so obtained will be measured either with the falling drop technique (rate of fall of a drop of the sample in fluorotoluene maintained at 27.2° C) or by converting the water to hydrogen and analyzing the hydrogen in a mass spectrometer.

3. Biphenyl-4,4'-d_2

Preparation of the di-Grignard compound from 4,4' dibromobiphenyl by several procedures was unsuccessfully attempted. None gave an efficient conversion into the organometallic compound. Two preparations of the analogous biphenyl dilithium have been accomplished. Decomposition of the second of these, followed by fractionation of the product, has given 800 mg of slightly impure diphenyl whose infrared spectrum contains a strong peak at the C-D stretching wavelength of 4.4 microns. Purification and mass spectrometry of this sample is in process, and the preparation and decomposition of the dilithium compound will be explored at lower temperatures to minimize secondary reactions.

4. Biphenyl-2,2',4,4',6,6'-d_6

Irradiation of this material will give information quite analogous to irradiation of biphenyl-3,3',5,5'-d_4. Aniline has been converted by the Sandmeyer reaction into bromobenzene in 60 per cent yield of biphenyl. An Ullman-type coupling of the phenyl magnesium bromide (catalyzed by cobaltous chloride) was found to give a 50 per cent yield of biphenyl. Thus, the synthesis of biphenyl via bromobenzene from aniline has been accomplished with an overall yield of 35 to 40 per cent. The exchange of aniline hydrobromide with D_2O to give aniline-2,4,6-d_3 is in progress. The material has been carried through five equilibrations; the introduction of deuterium has been followed by the growth of intensity of the 4.4 micron C-D stretching peak in the infrared spectrum. One more equilibration is required to finish this preparation, followed by conversion of the aniline to bromobenzene and thence to the desired biphenyl.