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Superheater Hydraulic Model Test Plan

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ABSTRACT

The plan for conducting a hydraulic test on a full scale* model of the AI Steam Generator Module** design is presented herein. The model will incorporate all items necessary to simulate the hydraulic performance characteristics of the superheater but will utilize materials other than the 2-1/4 Cr - 1 Mo in its construction in order to minimize costs and expedite schedule. Testing will be performed in the Rockwell International Rocketdyne High Flow Test Facility which is capable of flowing up to 32,000 gpm of water at ambient temperatures. All necessary support instrumentation is also available at this facility. The Test Plan format is in accordance with the proposed Development Activity Description, Revision 1, being employed on the Demo Plant (see McCreary (WARD) letter LDC-73-38 to Nemzek (RRD), dated September 17, 1973).

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*except for length

**the AI superheater and evaporator modules are identical except for water orifices in the evaporator.

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REV	SUMMARY OF CHANGE	APPROVALS AND DATE
A	General Test Plan Revision to reflect change to 2:1	J. S. Lillie 4/12/74 OP Steele 4/12/74 Rel. Date 4/15/74BK

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FIGURES

1. DEVELOPMENT TEST NUMBER

No development task number or title (DAD) has been assigned.

2. DEVELOPMENT TITLE

See Item 1 above.

3. OBJECTIVES

The objective of this test effort is to generate experimental hydraulic flow and vibration test data which will be used to substantiate the superheater module hydraulics and heat transfer analysis and design, verify acceptably low vibration levels in the module components, assess leak detectability in the module end regions, and assess the influences of any near-term design modifications as may be dictated by the results of the small leak tests (e. g., lower end design changes) and/or systems analyses by GE (e. g., inclusion of an on-module relief device). Accordingly, hydraulic tests will be run on a full-scale*steam generator superheater model to

1) Determine the hydraulic entry length of shell side flow.
2) Confirm acceptably low vibration levels in the inlet/outlet cross-flow regions and in the tube bundle bend region.
3) Measure vibration response (frequency and amplitude) of tubes, tube bundle, and main shroud versus flow rates, with particular emphasis on the bend region.
4) Determine main section flow velocities, inlet region flow distribution, and mixing characteristics.
5) Determine mixing and mass transport characteristics in upper and lower end stagnant regions particularly with respect to leak detectability in these areas.

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*except for length

6) Ascertain the edge flow effects (streaming) between the tube bundle and the shroud.

7) Verify the pressure drop across individual tube support/ spacers and through the inlet and outlet shrouds at various flow rates.

8) Verify the anticipated low flow distribution in the shell-main shroud annulus.

9) Determine character of vent/bleed stream flow and its effect on end region flow distribution (for various rates of bleed flow) and leak detectability.

4. JUSTIFICATION

The main differences between the current prototype superheater module design and the AI-MSG are (1) the tube bundle diameter (due to the large number of tubes, viz, 757 - vs - 158) and (2) the longer radius "hockey stick" bend associated with the larger shell diameter, and (3) dual inlet and outlet nozzles on the superheater versus single nozzles on the MSG. These three items require hydraulic testing of a module mockup in order to

- determine the hydraulic entry length for the tube bundle so that the effective heat transfer length and inlet region radial ΔT can be verified
- confirm the effectiveness of the inlet and outlet flow distributors in maintaining acceptably low cross flow velocities to minimize tube vibration
- verify low levels of vibration in the region of the longer radius tube bundle bend

- assess leak detectability in the end regions by means of dye*/salt injection near the tubesheets with subsequent pickup by conductivity probes in the running vent line and/or main sodium outlet line. Visual evaluation of end region flow mixing/circulation will be available by sight ports near the tubesheets used to view and track the passage of dye or gas bubbles injected into these regions
- obtain edge bypass flow effects for the layer bundle.

Other important data to be obtained from the mockup test are:

1) Further verification of module flow-ΔP characteristics as currently predicted from MSG test data.
2) Further verification of acceptably low levels of tube vibration and, therefore, the effectiveness of the axial distribution of tube spacers as currently predicated on MSG test data.
3) Verification of acceptably low levels of vibration for the inlet, outlet and main shroud assemblies.
4) Influence of any lower end design modifications (if such changes are dictated as a result of the small leak test program) on leak detectability in that region.
5) Flow conditions in the region of on-module relief devices,** should GE system engineering dictate the need for addition of such devices to the modules. Particular attention would be directed to visual observation of possible flow eddies in the lower stagnant and rupture disc region which might lead to rupture disc erosion conditions.

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*gas injection/bubble tracking can also be used.

**on-module rupture discs are not currently employed; this is subject to change pending further discussions with GE.

For proper determination of hydraulic entry length, inlet/outlet cross flow conditions (inlet/outlet flow distributor effectiveness), and tube bundle bend region vibration characteristics, the use of a full (cross section) size mockup is required. Main tube bundle vibration/hydraulic characteristics are felt to be predictable on the basis of the MSG test results, and it is considered that some shortening of the main tube bundle in the main shroud region will not compromise the acquisition of data which provide confirmation of the hydraulic and vibrational characteristics of the SG modules, a key component in the LMFBR Demonstration Plant. An ancillary advantage associated with a full scale mockup, apart from hydraulic/vibration considerations, is the checkout of shroud/tube bundle/shell assembly operations and sequences.

5. DETAILED DESCRIPTION OF DEVELOPMENT PROGRAM

Testing of the superheater module hydraulic mockup will be performed at the Rocketdyne (Canoga) High Flow Test Facility which has the capability of flowing up to 32,000 gallons of water per minute. Water will be used to simulate sodium and will be of sufficient purity to permit acquisition of flow and mixing data using visual observation and/or resistive measurement techniques. There will be no fluid or gas flowing through the steam tubes during test.

A sequence of testing will be established (at a later date) consistent with attaining the test objectives and will be based on water flow simulations of the following key parameters which are also shown plotted in Figure 1 for the superheater module.

1) Kinetic head ($1/2\ \rho V^2$), which influences pressure loss;
2) Strouhal number (fD/V_x), which influences cross-flow induced tube vibration;
3) Burgreen parameter $[(\rho V_A^2 L^4/g_c EI)^{1/2}(\rho V^2/\mu\omega)]$, which influences parallel-flow induced tube vibration; and
4) Reynolds number ($D_H \rho V_A/\mu$), which influences frictional loss along the tube bundle and degree of turbulence.

where

f = driving frequency or vortex shedding frequency (cps)

D = tube diameter (ft); D_H = hydraulic diameter (ft)

V = velocity (ft/sec); V_x = crossflow; V_A = axial flow

ρ = fluid density (lb/ft^3)

L = unsupported tube length (in.)

g_c = gravitational constant ($\text{ft-lb F/sec}^2\text{-lb M}$)

E = modulus of elasticity (psi)

I = moment of inertia (in.^4)

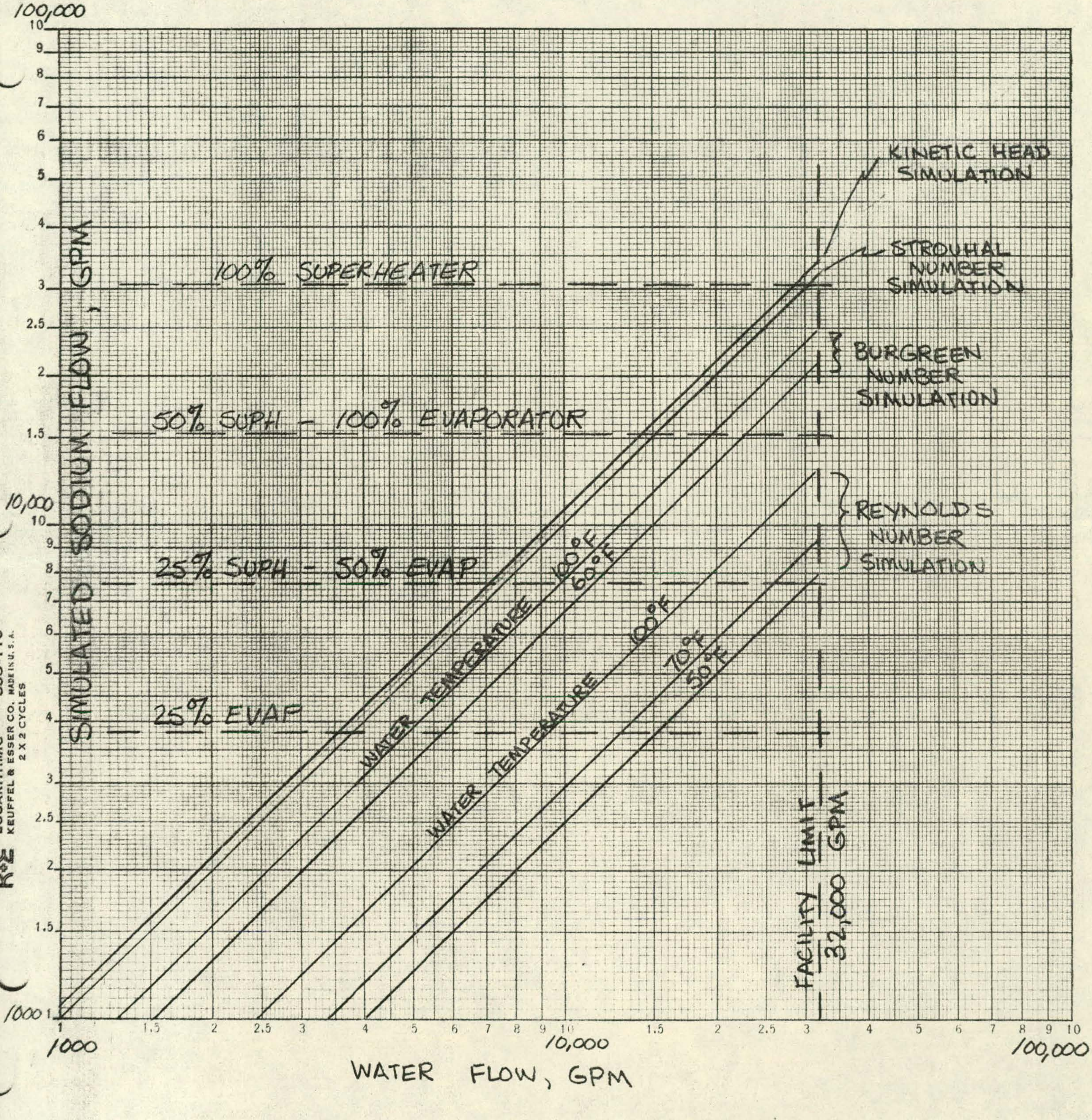
μ = dynamic viscosity (lb-F/ft-sec)

ω = angular natural frequency (rps) ($= 2\pi f_N$)

f_N = natural vibration frequency (cps)

FIGURE 1

WATER FLOW SIMULATION OF KEY HYDRAULIC PARAMETERS IN THE SUPERHEATER AND EVAPORATOR MODULES

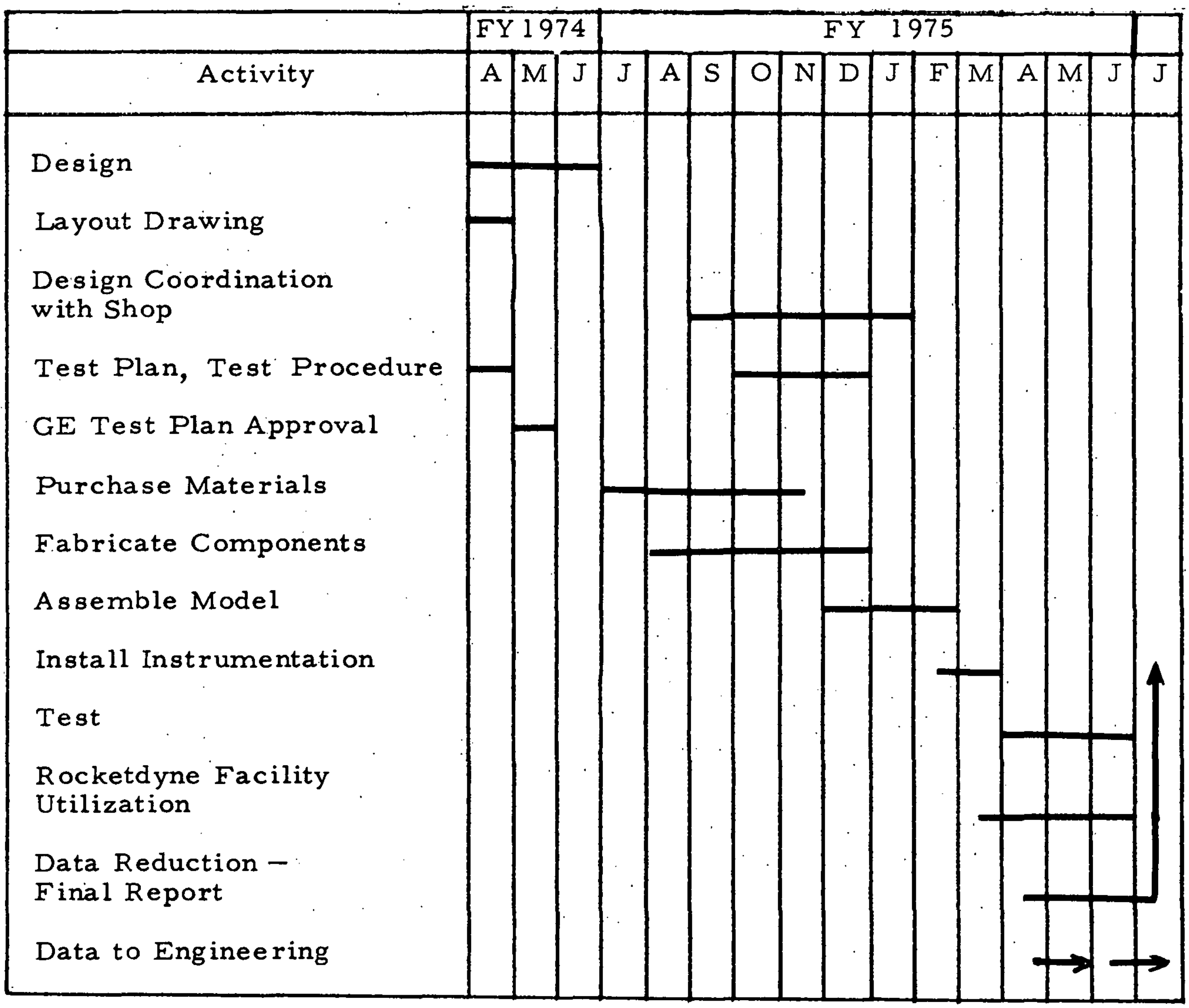


mG 4/10/74

The dimensionless numbers (Reynolds, Strouhal, Burgreen, etc.), which are used in simulating sodium flow conditions using water are independent of each other, per se. It will not be possible, however, to provide complete dynamic similarity among all of the dimensionless numbers simultaneously under a given set of water-flow conditions. This is apparent from Figure 1 and is a situation generally encountered in hydraulic testing with other than the actual end item in its actual service environment. These effects, however, are analytically separable by water testing over a range of flowrates at constant temperature and/or constant flowrate at variable temperature. The range of dimensionless variables which can be employed by using the variable flowrate-constant temperature technique is, from Figure 1, significantly greater than the range which can be investigated in the existing test rig using a constant flowrate-variable temperature approach. For analytical interpolation/extrapolation of test results, therefore, the first approach (i.e., variable flowrate-constant temperature) is preferred to the second approach. The second approach, however, will be held as a possible confirmatory technique should test results indicate the need for its use.

The hydraulic model utilized for these tests will be designed to specifically allow for the investigation of the following general parameters: (1) velocity profiles and flow characteristics with emphasis on the inlet/outlet shroud regions, (2) pressure drop across various elements, (3) extent of flow and mixing in the "stagnant" end sections with emphasis on leak detectability therein, (4) vortexing, and (5) vibration response of various components. Measurement of the above characteristics will be made at various flow rates up to 32,000 gallons per minute. A discussion of the techniques which will be used to measure these parameters appears in Section 7.

6. SCHEDULE



	FY 1974			FY 1975											
Activity	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
Design	━	━	━													
Layout Drawing	━															
Design Coordination with Shop						━	━	━	━	━						
Test Plan, Test Procedure	━						━	━	━							
GE Test Plan Approval		━														
Purchase Materials				━	━	━	━	━								
Fabricate Components					━	━	━	━	━							
Assemble Model									━	━	━					
Install Instrumentation											━	━				↑
Test													━	━	━	↑
Rocketdyne Facility Utilization												━	━	━	━	↑
Data Reduction — Final Report													━	━	━	↑
Data to Engineering														→		→

7. PARAMETERS TO BE MEASURED

The following parameters are to be measured or determined:

1) Main section hydraulic entrance length
2) Flow distribution in the inlet flow distributor (shroud)
3) Mixing and fluid circulation in the "stagnant" hockey stick and lower tube sheet regions including vent/bleed flow and outlet flow characteristics to demonstrate ability to detect leaks in the tube sheet regions
4) Flow distribution and mixing in the main bundle cross section and bundle edge flow effects
5) Pressure drops across tube spacers, along the tube bundle, and across the inlet to outlet nozzles.
6) Velocity flow profiles in the main section and in the shell-shroud annulus
7) Vibration response of individual tubes (with emphasis on the bend region) and shrouds.

The <u>velocity flow profiles</u> in areas of concern will be measured using pitot tubes*, conductivity probes, or a combination of both. With the conductivity probe technique, a quantity of Na_2SO_4 solution is suddenly introduced to the flow stream and the average velocity through the module is obtained by measuring the velocity of the solution as it moves with the flow. The movement of solution is measured by detecting a change in electrical conductivity of the water-Na_2SO_4 solution as it passes a given station which has a number of representative steam tubes fitted with flush mounted electrodes. Figure 2 shows the locations (suggested but not limited to) which will be instrumented with pitot tubes or conductivity probes to obtain hydraulic entry length data and bundle to shroud bypass flow data.

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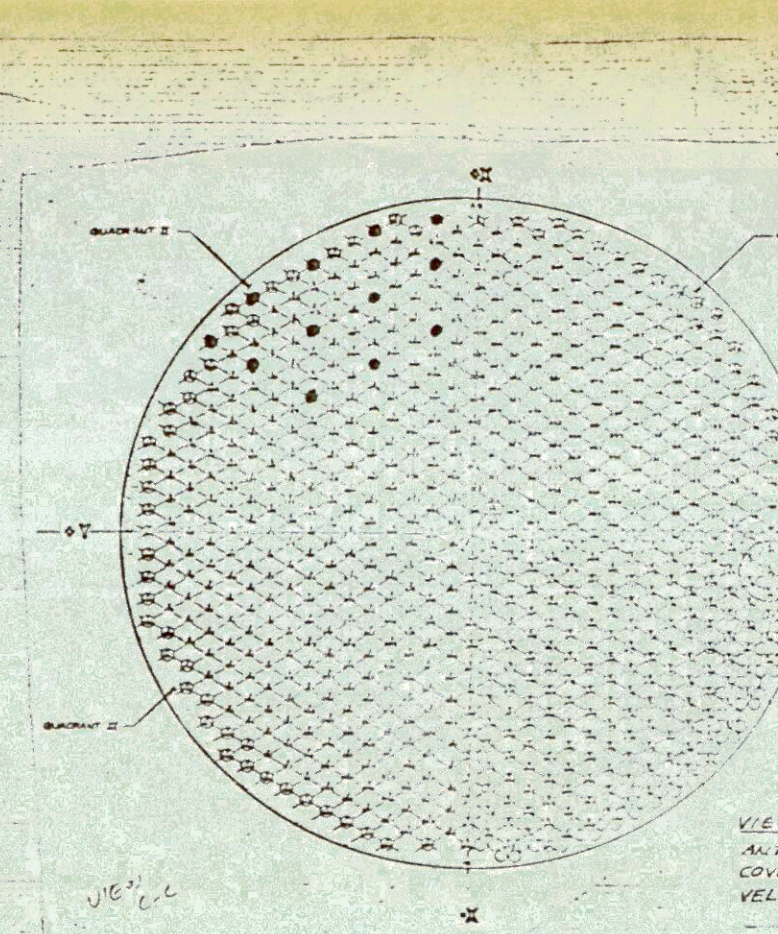
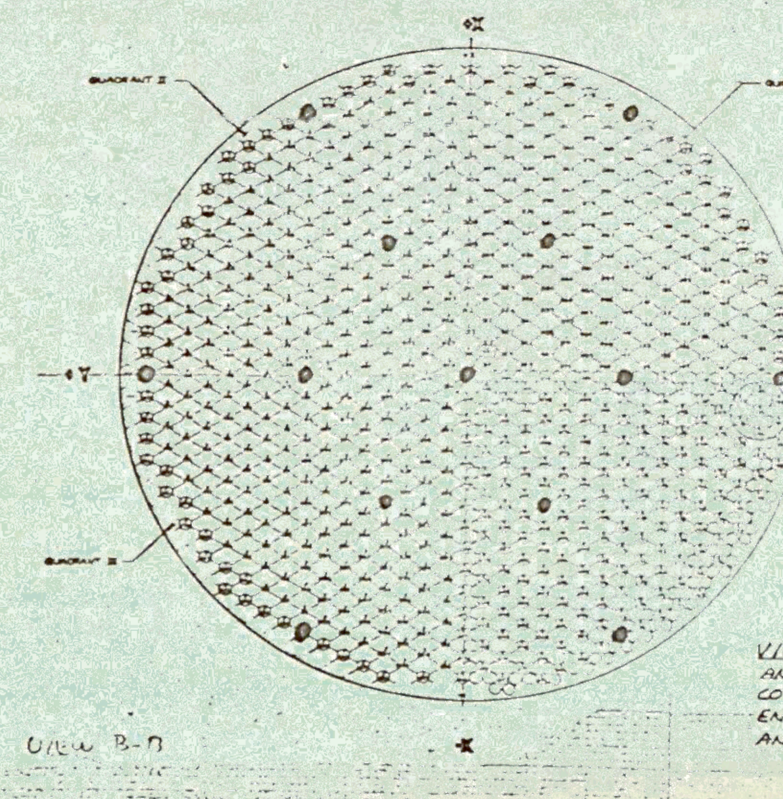
*pitot tubes are the favored first-line approach; the salt injection technique is being held as a backup approach.

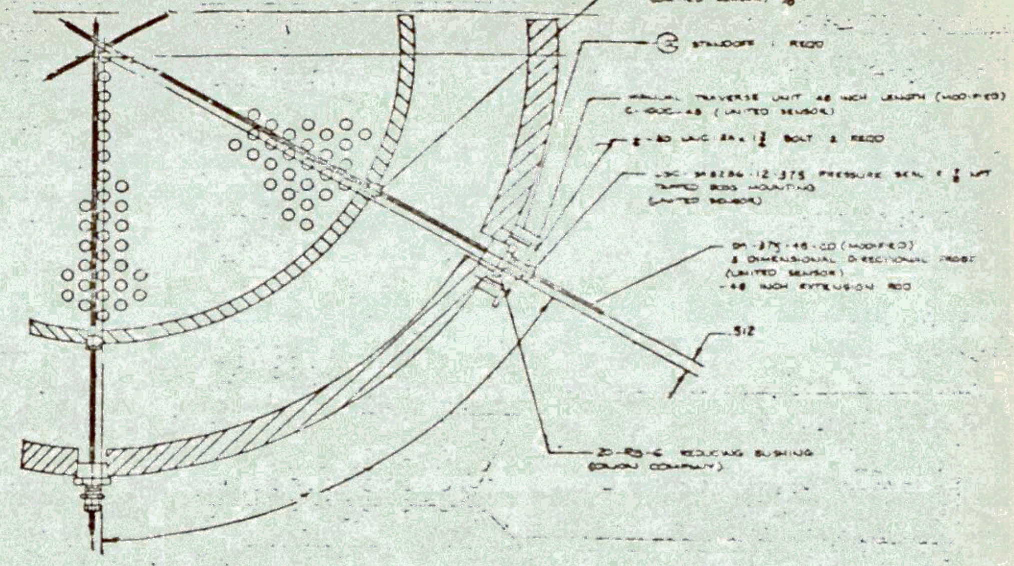


VIEW C-C
ANTICIPATED CONDUCTIVITY PROBE
COVERAGE IN MAIN BODY FOR FLOW
VELOCITIES AND BUNDLE BYPASS FLOW

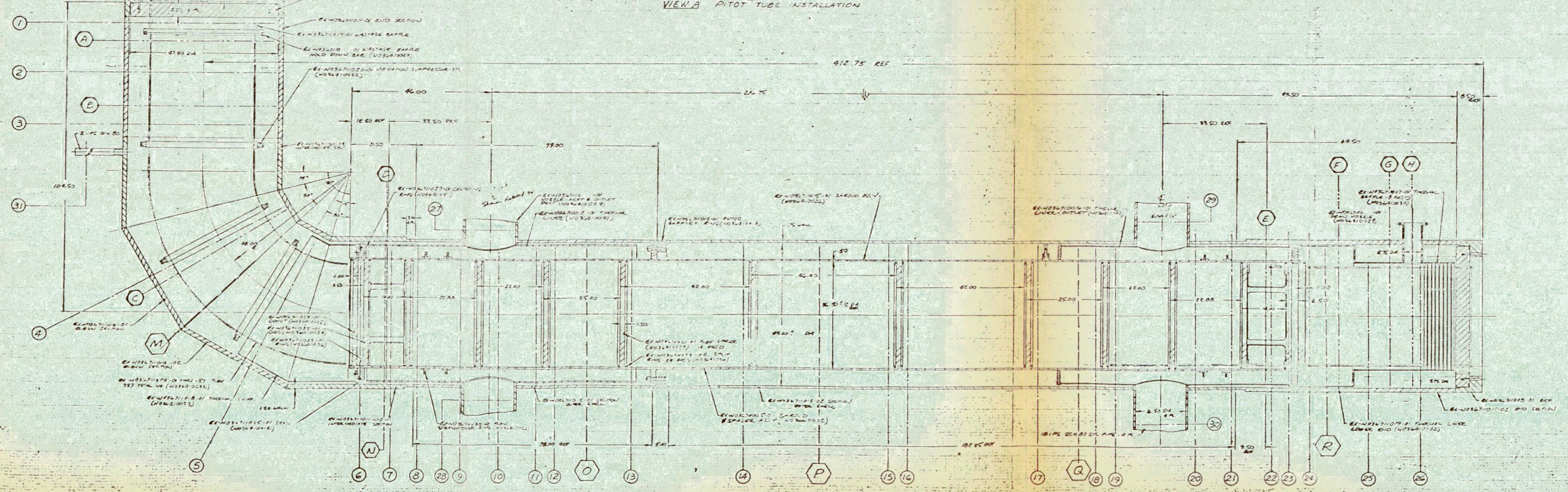


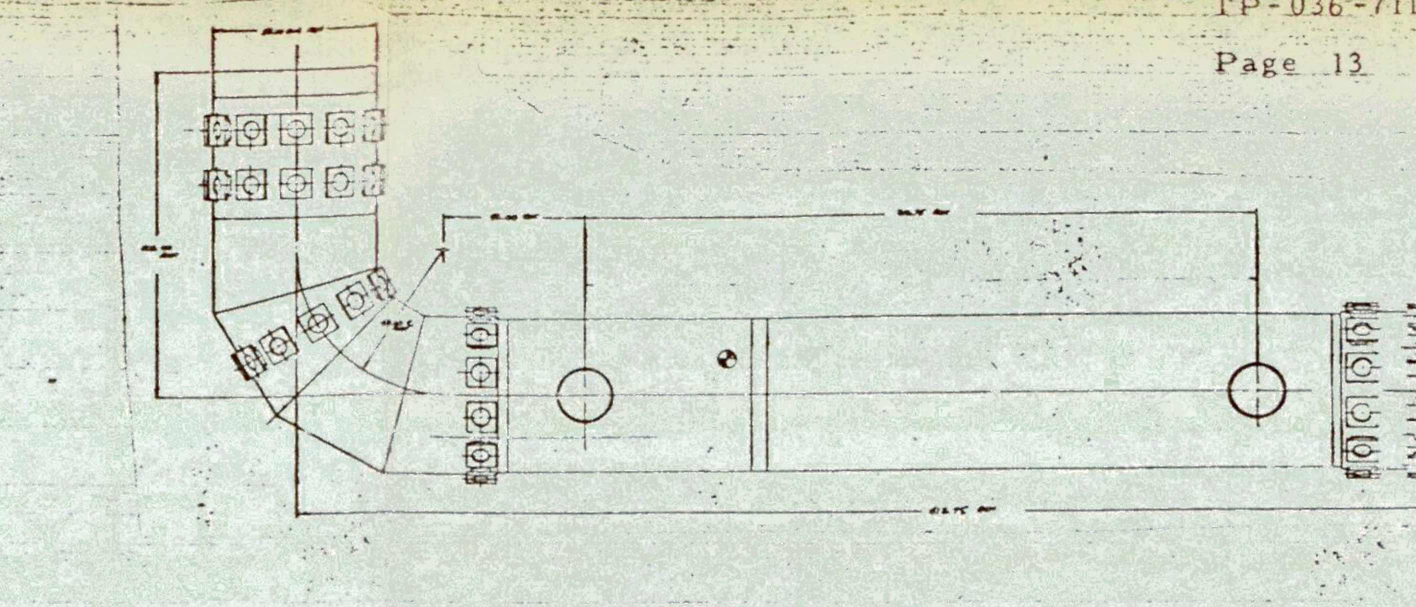
View B-B

VIEW B-B
ANTICIPATED CONDUCTIVITY PROBE
COVERAGE IN MAIN BODY AND STAGNANT
ENDS FOR FLOW VELOCITY, FLOW DISTRIBUTION,
AND MIXING



VIEW A PITOT TUBE INSTALLATION





VIEW D WINDOW LOCATION

INSTRUMENTATION TYPE	LOCATION	TYPE OF DATA	EXTENT OF COVERAGE
PITOT TUBE	STATIONS 1 THROUGH 30	FLOW VELOCITIES, PRESSURE DROP, FLOW DIRECTION	COMPLETE CROSS SECTION SURVEY OF TUBE BUNDLE AND SHROUD - SHELL ANNULUS IN TWO PLANES 60° APART, SEE VIEW A
CONDUCTIVITY PROBE	STATIONS 1-5, 7, 9, 12-15, 17, 24-26, 29-31	FLOW VELOCITIES, FLOW DISTRIBUTION, MIXING	CROSS SECTIONAL COVERAGE AS REQUIRED TO OBTAIN DESIRED TEST INFORMATION. SEE VIEW B-B AND C-C FOR TYPICAL PROBE ARRANGEMENTS
VIEW WINDOW (VISUAL AND/OR MOVIES)	STATIONS A THROUGH H	MIXING, FLOW DIRECTION, VORTEXING	TUBE SHEETS, INLET AND OUTLET WINDOWS, STAGNANT REGIONS, SEE VIEW D
DYE/SALT/AIR INJECTOR	STATIONS 1-5, 7, 16, 24-26	MIXING, FLOW DIRECTION, LEAK DETECTABILITY, VORTEXING, FLOW VELOCITIES	STAGNANT END REGIONS IN CONJUNCTION WITH VIEW WINDOWS AND CONDUCTIVITY PROBES FOR MIXING, FLOW DIRECTION, VORTEXING, AND LEAK DETECTABILITY. MAIN BODY FOR VELOCITY INFORMATION (SALT INJECTION)
ACCELEROMETER (OR STRAIN GAGE)	STATIONS M THROUGH Q	VIBRATION RESPONSE IN AMPLITUDE (g) AND FREQUENCY (Hz)	ON OR IN TUBES (ESPECIALLY ELBOW REGION), SHROUD (MID SPAN AND INLET/OUTLET ENDS), THERMAL LINERS, SHELL

Figure 2

INSTRUMENTATION DRAWING
MSG HYDRAULIC FLOW TEST

The flow distribution characteristics will be determined concurrent with the flow velocity measurements. Pitot tube readings and movement of Na_2O_4 solution through or across the superheater mockup will be measured to ascertain the flow characteristics associated with the flow distributor, shroud, and tube support structures. Flow which occurs in the "stagnant" hockey stick and/or lower tube sheet regions will be determined by pitot tubes, the conductivity technique and/or by introducing dye or gas bubbles and visually observing flow through view ports located at the appropriate locations. Evidence of mixing in stagnant ends may also be found at the vent/outlet nozzles by measuring the variation in electrical conductivity of the water over the face of the outlet lines (from Na_2SO_4) solution released in the end sections), from observing the flow of dye injected in the tube sheet face region, and from observing flow patterns via pitot tube readings.

Pitot tubes strategically located in the system will be used to determine the pressure drop over the entire system (inlet to outlet), across selected tube supports and at appropriate locations along the length of the module in the passages between the shroud and shell. Figure 2 shows the currently anticipated location for these sensors.

A measure of the vibration (amplitude and frequency) occurring in the steam tubes during hydraulic flow tests will be made by use of small sensors placed at various locations inside or on certain tubes. Vibration response of the shrouds will be measured by sensors placed on the outside of the shrouds at appropriate locations.

Vortex action in the elbow section and in the end regions will be visually determined through windows installed at those locations. Motion picture and still photography coverage will be obtained when appropriate.

8. INSTRUMENTATION ACCURACY AND RESPONSE

Instrumentation employed in this test will be required to measure and record four types of test data: fluid flow rates, pressure, resistivity changes, and vibration response. All of the instrumentation are standard state of the art gear commonly in use in modern test laboratories.

Flow Measurements

Facility flow to the test model is monitored by AC electromagnetic flowmeters. The meter employed on the facility's 20-in. header has a range from 2500 to 32,000 gpm with a calibrated accuracy of ±0.5%. If and when flow rates less than 2500 gpm are required, meters with 500 to 17,000 gpm capacity are incorporated into the system.

Pressure

Steady-state pressure conditions are monitored and read in the Rocketdyne facility on calibrated pressure gages. The accuracy of each gage is 0.25% of full scale. Gages of various ranges are available to accurately read the pressures in the test model for all anticipated flow conditions.

The use of Pitot tubes introduces the following probable primary probe errors:

total pressure:	less than 0.1%
static pressure:	1%
yaw angle:	0.2
pitch angle	2°

Diaphragm type pressure transducers used with the Pitot tubes at high scale are good to about 1% and at low scale about 2%.

When the Pitot tubes and pressure transducers are integrated with signal conditioning and recording equipment, an overall system accuracy of ±5% at medium to high pressures and ±10% at low pressures can be attained.

Resistivity

The conductivity probe instrumentation which will be used to make flow velocity and flow distribution (mixing) measurements simply detects a change in the water's resistivity when a charge of salt solution (Na_2SO_4) is injected into the flow stream. No attempt is made to measure concentration changes (dilution effect) because the costs of developing a system to perform this function in such a large volume open water facility would be prohibitive.

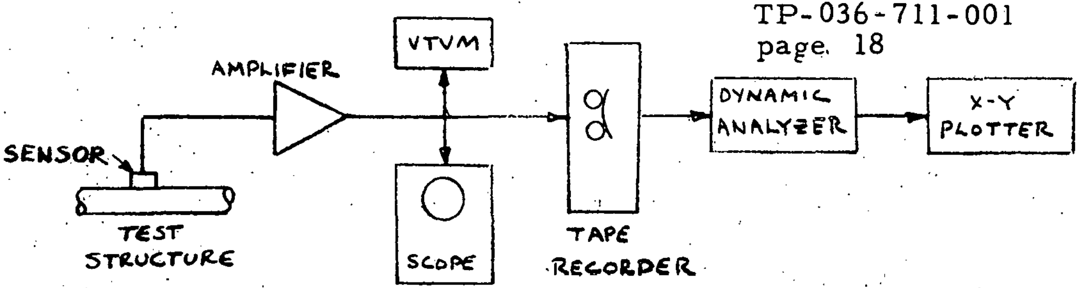
Test signals (resistance changes) which are generated by electrodes flush mounted on certain steam tubes are suitably amplified and then recorded on direct write osciollograph recorders. Manual interpretation and reduction of these data are performed, since only the detection of resistance change and the elapsed time of this detection between conductivity probes is determined by this test technique. The accuracy of the system consists of the response time of the electronic components, ±5%, and the errors inherent with the manual interpretation of data. This manual interpretation of data concerns the visual detection of the onset of an oscillograph trace displacement and the relation of this incident in time to some other point in time. The error in determining this time interval is minimized in practice by using a sufficiently fast recorder paper speed to "spread out" the trace to reduce detection uncertainties. Errors in determining the time of flight measurements are assumed to not exceed ±10%.

Vibration

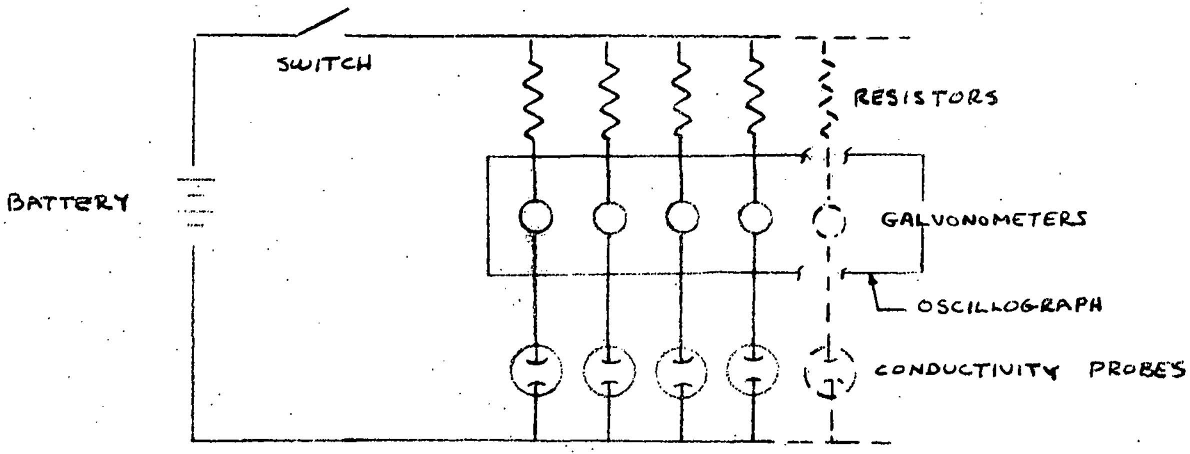
Instrumentation employed for obtaining the vibration response of the hydraulic model structure will be the same assembly of gear in use by Rocketdyne to measure vibration characteristics of critical rocket engines and space components. The integrated instrumentation package when calibrated as a unit is calculated to be accurate within ±5%. Analysis of data will be performed by Rocketdyne's Analog Data Analysis Center and presented as (1) direct playback of acceleration response on brush recorders (±3% maximum error), (2) a record of displacement, via double integration of the acceleration record (±3% maximum error), and (3) Spectral Density Plots vs Frequency (±5% error in amplitude, ±2% in frequency).

Instruments and Calibration

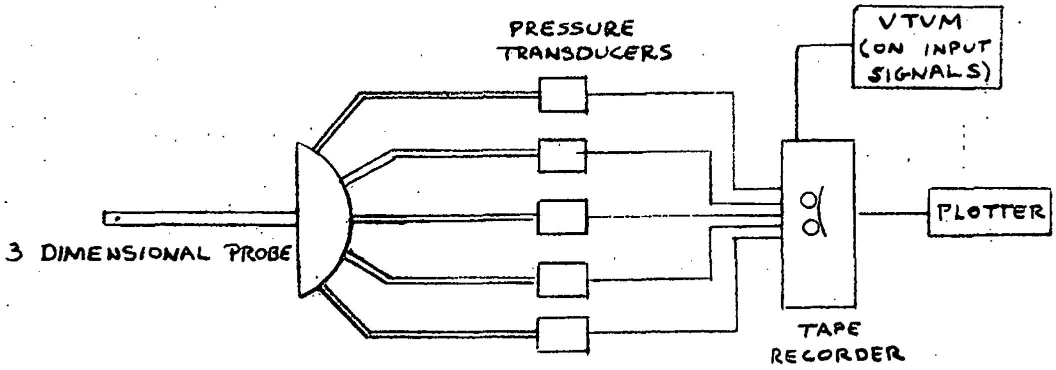
The following list itemizes the type of equipment which will be required to support this test program. An assembly of the noted instruments is shown on Figure 3.



BLOCK DIAGRAM - VIBRATION INSTRUMENTATION



BLOCK DIAGRAM - CONDUCTIVITY PROBE INSTRUMENTATION



BLOCK DIAGRAM - PITOT TUBE INSTRUMENTATION

FIGURE 3
TEST INSTRUMENTATION

1) Accelerometers — Endevco Model 2222A, Unholtz Dickie 2E5, Endevco N2284M13, or equivalent
2) Accelerometer Amplifiers — Endevco or Unholtz Dickie (compatible with Item 1)
3) Tape recorder — CEC-3300, 14 channel or equivalent
4) Vacuum tube voltmeter — Ballentine, N-120 or equivalent
5) Oscilloscope — HP 122 AR or equivalent
6) X-Y plotter — EI 320 or Moseley 135
7) Brush recorders
8) Oscillograph (direct write)(3) — CEC or Minneapolis Honeywell 36 channel
9) Manometers — any quality instrument with suitable sensitivity
10) Conductivity probes — fabricated by AI.
11) Pitot tubes — United Sensor and Control, three dimensional, Model DA-375-50-CD
12) Pressure transducers, Endevco, Models 8504A and 8503A or equivalent and/or suitable differential pressure transducers
13) Signal Conditioners/amplifiers/recorders — appropriate instruments compatible with type of pressure transducers selected.

All instrumentation and test equipment employed for this test will be properly maintained and calibrated according to procedures and standards specified and approved by Rockwell International. Every reasonable attempt shall be made to utilize gear which shall remain in calibration throughout the duration of test. All instrumentation should be traceable to the National Bureau of Standards, or in the absence of National Standards, to other generally recognized standards.

9. PARAMETER LIMITS

The parameter limits on boundary conditions such as temperature, pressure, and flow, which will be specified for the Rocketdyne High Flow Test Facility, will appear in the Test Procedure which is yet to be written. These requirements, or restrictions, will be tabulated for each test condition required and will be based on flow simulation required (see Section 5). A deviation from these requirements, however, will not endanger the model, its instrumentation, or the test facility; the only repercussion would be the necessity to rerun the test in question.

The Rocketdyne High Flow Test Facility flow rates will be those flow rates as determined by the final AI model design. The only facility "shut-down limits" to be exercised in this program will be those imposed by this AI model or by those facility safety limitations or precautions already in force by the operators of the hydraulic loop.

10. DESCRIPTION OF THE TEST ARTICLE

The hydraulic test model utilized for these tests will be a full-scale model, except for length, of the superheater module (Figure 4) incorporating all important internal elements (baffles, tube supports, shrouds, flow distributors, etc.) necessary for proper hydraulic simulation. A full length model is not a prerequisite to obtaining the required hydraulic performance data. However, the model will be of sufficient length to (1) allow determination of the tube bundle entry length and (2) establish stabilized or steady state flow in the main section of the model before encountering the outlet flow distributor. The mockup will be constructed entirely of ordinary carbon steel.

A preliminary layout of the outer shell is shown in Figure 2. The layout notes the inclusion of view ports. At each selected station, sufficient 6-in. diameter "windows" will be installed around the circumference to enable the visual observation (through the use of dye or gas bubbles) of flow and/or vortexing action. Also shown on the layout are the tentative main body locations which will be instrumented with conductivity probes to measure bundle to shroud bypass flow characteristics. The anticipated locations of pressure probes to measure pressures, flow velocities, and flow direction are noted. Steam tube and shell locations yet to be defined will be selected for vibration response instrumentation; however, tube vibration studies will be primarily concerned with the elbow section where the vibration of the long curved sections will be of interest.

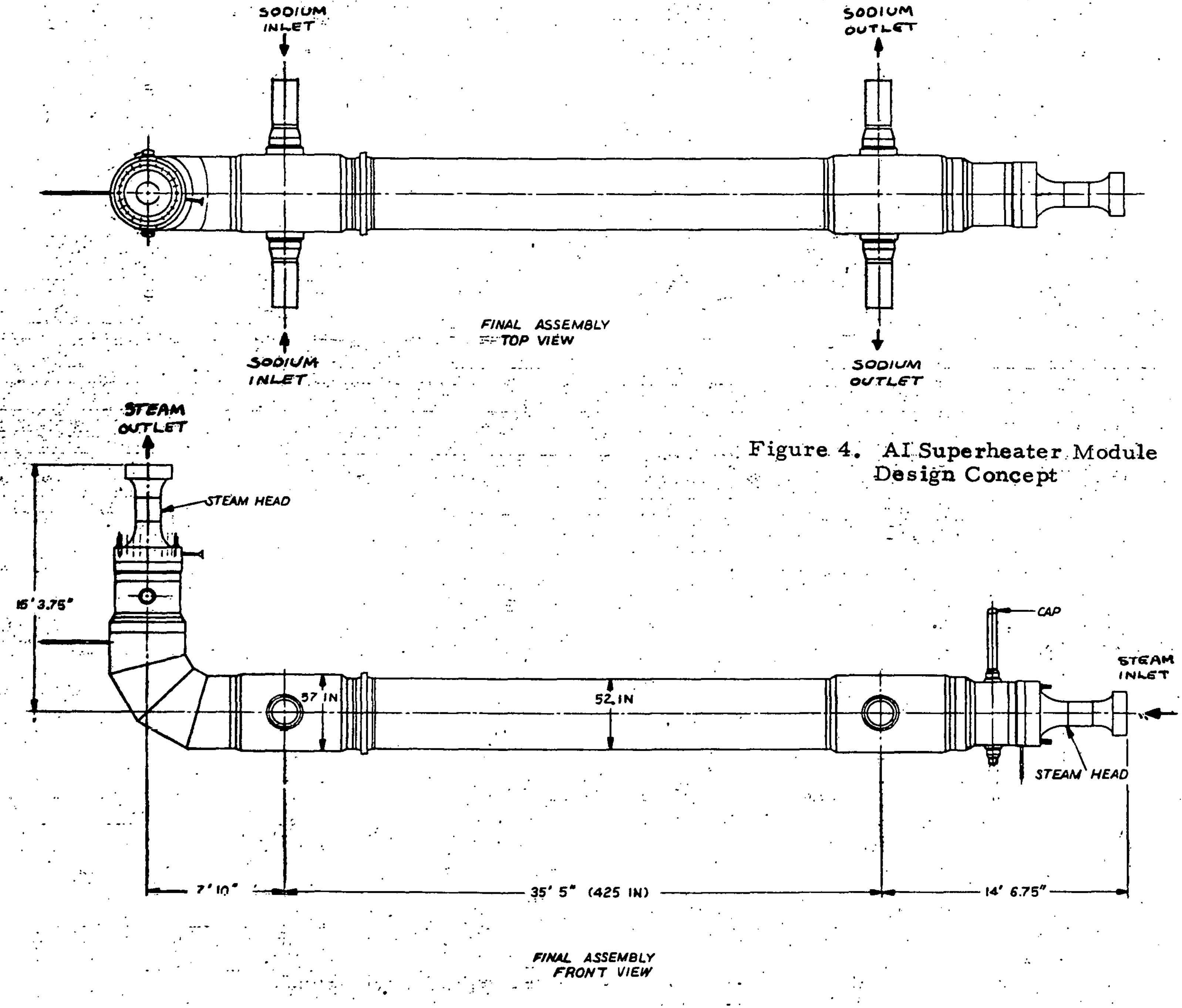


Figure 4. AI Superheater Module Design Concept

The size and weight of the hydraulic model will require a special support fixture such as the one shown in Figure 5. (The possibility of modifying this existing strongback for use in this program will be investigated.) Handling of the model and transport of the unit from the point of test will be handled by equipment and movers specialized for this type of work.

At the test site, installation and hook-up of the hydraulic model into the test facility will be performed by trained Rocketdyne personnel. Upon completion of the installation and subsequent low flow checkout, a test program will be conducted following a detailed Test Procedure yet to be written.

11. TEST FACILITY

The Rocketdyne High Flow Facility (Figure 6) which will be used for this test is designed for water flow testing of component hardware at flows up to 32,000 gpm. This facility has 9000 ft^2 of floor space. Four 2000-hp synchronous electric motor driven pumps take suction from a 200,000 gallon reservoir (of water maintained at swimming-pool type cleanliness*) located beneath the facility. The output of the pumps is fed to supply headers with the largest diameter header, 20 in., being used to supply flow from the combination of all four pumps.

Test installations are made between the supply and discharge header systems with the latter emptying into the return channels which are covered with gratings. The plumbing is assembled using Victaulic couplings and other couplings of a similar design but much larger in size. A stock of piping and fittings in various sizes and lengths is maintained for assembly, erector-set style. When special pipe sizes or special fixtures are required, they are fabricated for the facility.

To support the facility plumbing against large hydraulic shock forces which develop when conducting component flow transient studies, a massive pile system was installed. This support system consists of

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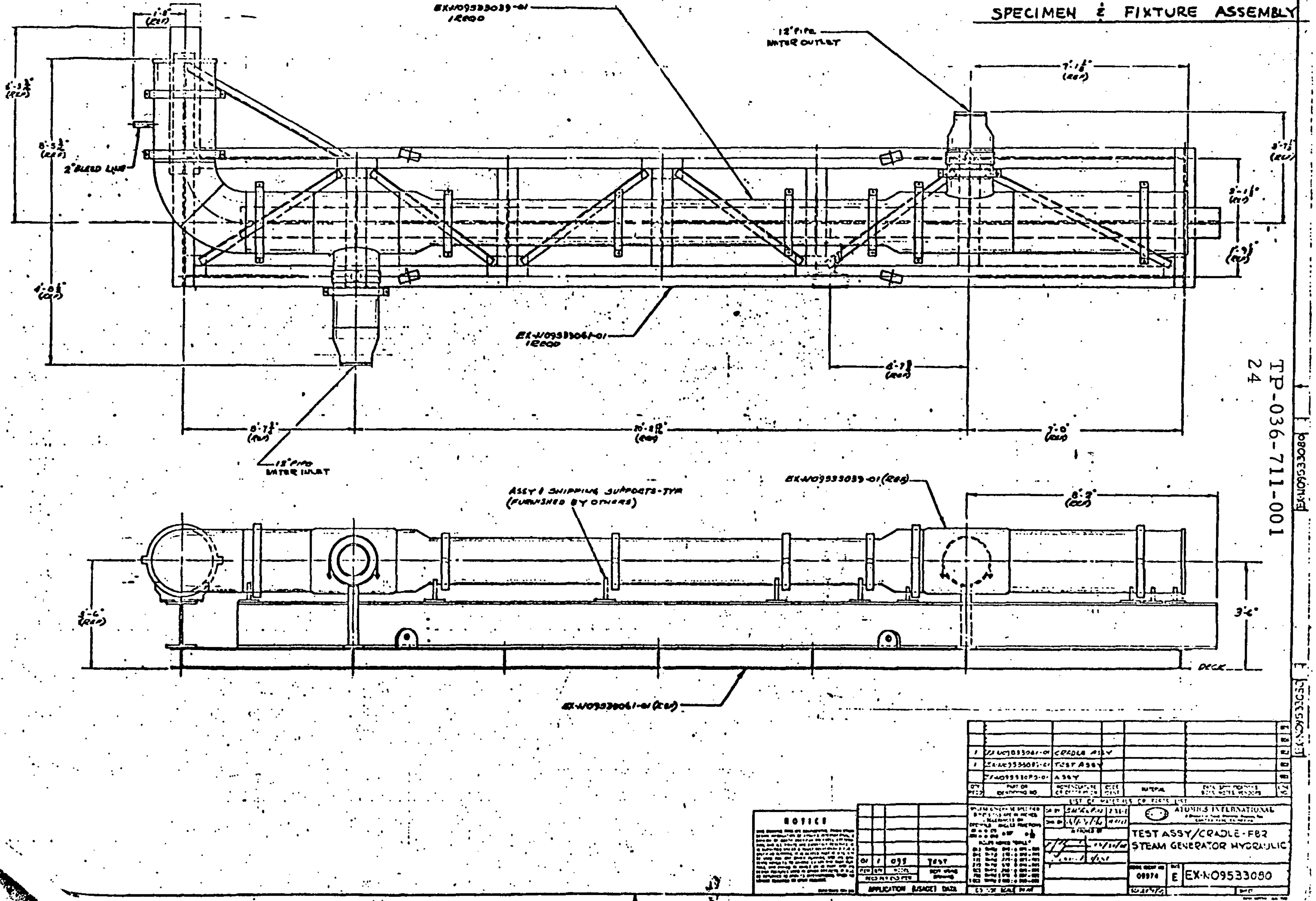
*This degree of purity was found to be completely suitable for the conductivity probe technique, which measures a change in water resistivity when a small quantity of Na_2SO_4 solution is introduced. (AI MSG hydraulic test program)

FIGURE 5

SPECIMEN & FIXTURE ASSEMBLY



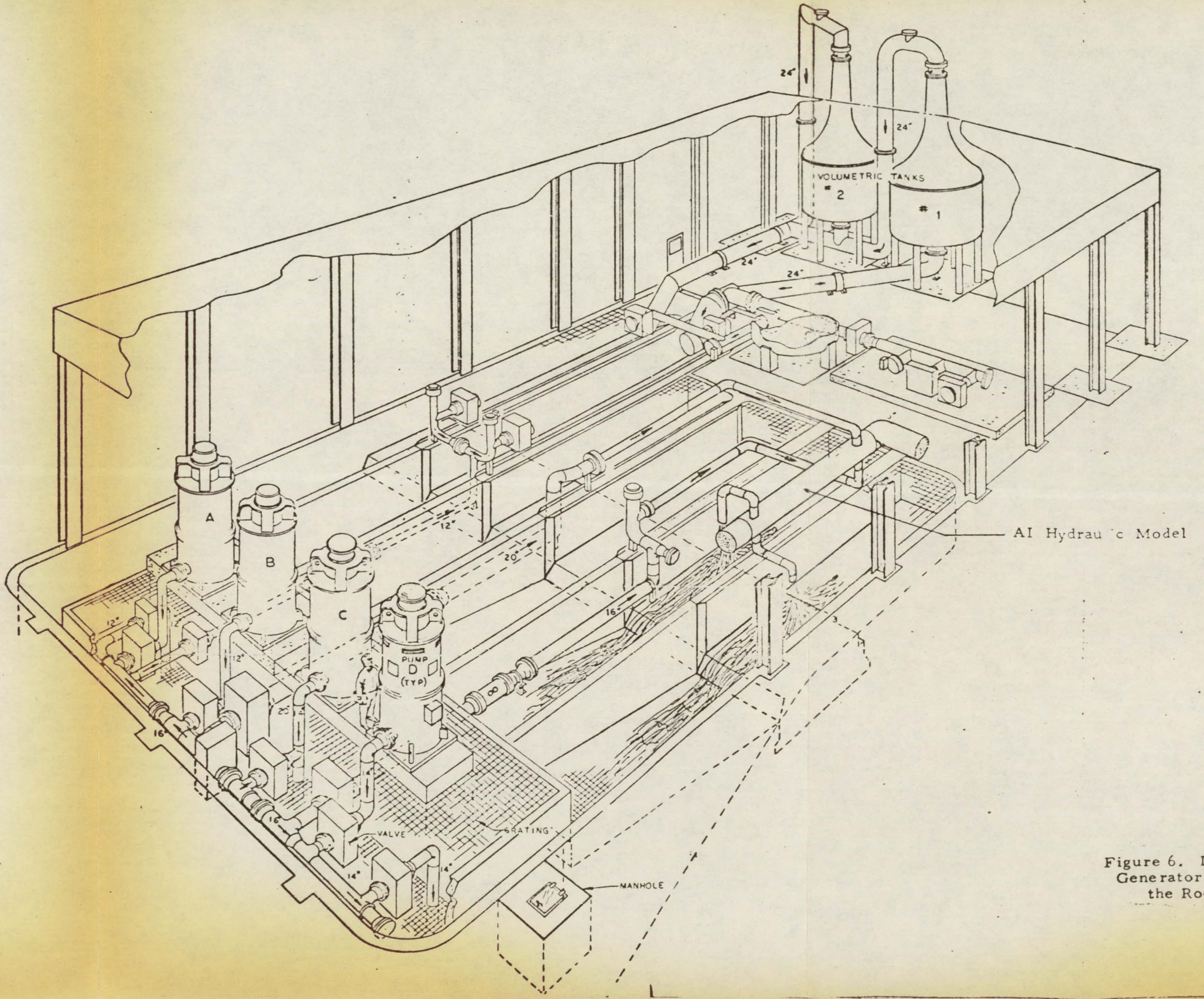


Figure 6. Installation of the Steam Generator Evaporator Model in the Rocketdyne High Flow Test Facility

14-in. wide-flange beams driven to a depth of 60 ft and capped with a 50- by 12- by 6-ft concrete and steel mass. Pile design parameters were based upon a sudden fluid stop in 100 milliseconds from 12,000 gpm. For the attachment of fixtures, 10-in. wide-flange beams are embedded in the top of the channel dividing walls and are also tied to the pile system.

Testing is remotely controlled from the facility's control and instrumentation room which contains a graphic panel, a control console, and a calibration console. After a component has been mounted and connected to the supply header, the proper valving and pump combinations are selected on the graphic panel. The panel controls all valves, closures, and pump combinations at the facility in addition to displaying their position schematically. The four pumps A, B, C, and D can be used individually or may be combined to obtain flowrates up to 32,000 gpm.

The calibration console contains all the auxiliary controls. The controls included are flowmeter recorders, orifice indicators, and calibration controls. Recording instrumentation available includes one 36- and one 18-channel CEC recording system, each complete with amplifiers, balancing circuits, and calibrating circuits. Three d-c amplifiers, two position-potentiometers with power supply, and a balancing unit are also available. Fourteen channels of tape recording for strain gages, accelerometers, and photocon instrumentation are connected to the Laboratory's recording center.

Situated in primary locations in the test area are four instrumentation junction boxes, each containing 20 outlets of stainless-steel tubing which feed back to a patch panel located in the control console. Each box also contains 28 electrical instrumentation plugs which feed back to a patch panel in the recording console. When employing instrumentation during a test, the line goes from the tested item to the junction box, then to the patch panel, and finally to the appropriate recording device.

The facility's flow measurement is made with Fischer and Porter magnetic flowmeters backed up with orifice plates should the meters fail or a quick accuracy check be required. Each supply header has a meter. The 12- and 16-in. meters each range from 500 to 17,000 gpm, and the 20-in. meter ranges from 2500 to 32,000 gpm. These instruments have a calibrated accuracy of ±0.5%. The instruments are calibrated with one or the other of the two primary calibration standards.

12. SAFETY

There are no hazards associated with the hydraulic and/or vibration test programs providing test personnel follow and practice good workmanship and sensible test techniques.

13. DATA

Test data will consist of conductivity data (described in Section 7) and recorded on oscillograph recorders, vibration data from accelerometers and/or strain gages recorded on magnetic tape, pressure data recorded on magnetic tape or direct with recorders, flow which will be visually monitored during test and recorded on magnetic tape and/or oscillograph recorders when appropriate, and vortexing fluid circulation phenomena which will be observed visually through special windows and recorded on film when appropriate.

14. DATA REDUCTION AND ANALYSES

Test data presentation will be in tabular or graphic form and will consist of flow profiles, pressure drops, mixing characteristics diagrams, descriptions or photos of vortexing action, and tube and shell vibration response. All test data resulting from conductivity probe measurements will be taken from oscillograph records and manually reduced and summarized on various graphs or charts. Pitot tube pressure data and vibration data recorded on magnetic tape will be subjected to detailed analysis on existing specialized electronic equipment.

A complete chronological record of all test events will be kept in a laboratory notebook. This record will (1) accurately note all test events and test environments, (2) list pertinent test facilities and/or test equipment utilized, (3) detail test deviations, (4) define the pre- and post-test calibration methods utilized for the equipment and instrumentation, (5) tabulate all data which is manually read and recorded, (6) identify all supplemental test records (such as recorder charts, X-Y plots, magnetic tape, etc.), and (7) report any and all anomalies that occur. Photographs of the test set up and test events will complete the data package.

Upon completion of all data reduction and release of a final test report, Laboratory Notebooks will be returned to the AI Library for permanent storage (5-yr minimum). All raw data records, magnetic tape, etc., will be stored for future reference by Department 716-66 for a period of 5 yr or as specified by the Project Manager.

15. INTERIM AND FINAL REPORTS

Program activities will be reported in the monthly progress reports issued by AI. No interim reports or data presentations for this test are contemplated because of the relatively short duration of actual hydraulic testing (about two months). A final formal test report, which will give a detailed accounting of the test program and a comprehensive presentation of the reduced data, is expected to be released about two months after conclusion of testing. However, because of the urgency of generating test data in support of the design effort, test findings will be made available to Engineering concurrent with the conduct of the test and reduction of test data.

16. QUALITY ASSURANCE

Quality Assurance engineering surveillance will be maintained throughout the design, procurement, and fabrication phase of the effort. Q/A signoff on all design drawings and design review reports shall be required. The Q/A effort is funded under the Production Operations effort.(1)

Inspection will be required during fabrication of the test specimens in order to verify the shop's compliance with drawing requirements on certain critical test components.

The testing phase of the program will be continuously monitored by Q/A to assure compliance with test requirements, adequate data recordings and instrumentation calibration.

17. REFERENCES

1. WPL-036-100-001, "AI Reference LMFBR SG Development GFY 1974 Work Plan" September 6, 1973 (to be revised)
2. PP-036-810-001, "AI Reference Steam Generator, Contract AT (04-3)-824, Task 14 – Program Plan," September 17, 1973 (to be revised)
3. GE-AI-PA61-K 0.0-0707, "GE Review of Superheater Hydraulic Model Test Plan TP-036-711-001," December 19, 1973
4. 74AT-525, "AI Responses to GE Comments on Superheater Hydraulic Model Test Plan," January 25, 1974
5. Agreements and Commitments, GE/AI Meeting on AI LMFBR Prototype Steam Generator, March 18, 1974
6. GE-ANL-893-A6.4-0858, "ANL Recommendations – AI Hydraulic Model Test," March 20, 1974

APPENDIX A
ALTERNATE APPROACHES

As previously noted, the hydraulic model will be a full size (cross section), sublength unit. The foreshortening occurs entirely in the "active" length with the "stagnant" end regions being to exact scale with respect to the prototype SG. Alternatives to this approach which have been considered are

1) reduced cross section size
2) partial cross section size
3) vertical-vs-horizontal test orientation

The reduced cross section approach (i.e., a fewer number of tubes with associated reduction in cross sectional size of the model) was rejected because of the influence such reduction could have on the data obtained for 1) the inlet length required for full flow development and 2) leak detectability studies.

The partial cross section approach (i.e., a 180° section rather than a full 360° section) was rejected on the same bases as item 1 above.

Vertical orientation of the model during testing was rejected in favor of the horizontal attitude due to the trade-off of facility modification costs required to provide for vertical testing-versus-the incremental data to be obtained, specifically

- test data from the AI-MSG hydraulic model have indicated that the horizontal test attitude has no discernable effect on shell side diametral flow distribution for flowrates as low as 1% of full flow

- leak detectability data from the hockey stick region will be unaffected by the model attitude inasmuch as the hockey stick region is horizontal in the actual plant installation (it will be necessary to relocate the running vent line on the hydraulic model 90° from its actual prototype position to place the vent at the high point of the hockey stick section of the hydraulic model)
- vertical orientation of the model could be of benefit to leak detectability studies in the lower "stagnant" end if gas bubble injection in the lower tubesheet region was the sole approach for the leak detectability studies. Using dye/salt injection methods for the lower end leak detectability studies could overcome some of the influence of a horizontal attitude since these methods do not rely so heavily on bouyancy effects for transport to the outlet nozzle. Furthermore, thermal convection effects, which will exist in the actual SG prototype, and as such will influence to some extent the lower end leak detectability, cannot be simulated in the isothermal hydraulic model water flow tests. These considerations, coupled with an estimated 180K facility modification cost associated with changeover to a vertical test orientation, have led to selection of the horizontal test attitude in favor of the vertical orientation.