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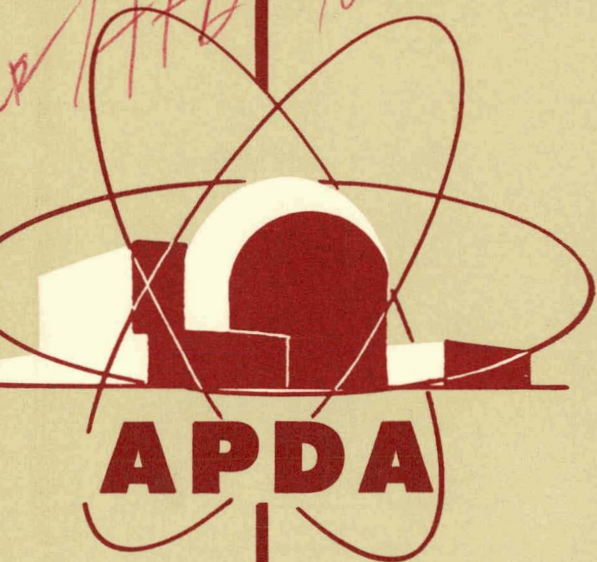
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**QUARTERLY TECHNICAL PROGRESS REPORT
ON
AEC-SPONSORED ACTIVITIES**

United States Atomic Energy Commission
Contract No. AT(11-1)-865

JANUARY-MARCH 1969

**ATOMIC POWER
DEVELOPMENT ASSOCIATES, INC.**

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Approved

E. C. Kovacic

**E. C. Kovacic
Senior Project Engineer, APDA**

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JANUARY-MARCH 1969

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ABSTRACT

This report is a summary of the technical progress made by Atomic Power Development Associates, Inc., in the period January through March 1969, under AEC Contract No. AT (11-1)-865. The individual projects are covered under the following headings:

Sodium-Water Reaction Test Program
Project Agreement No. 10

Sodium Technology Project
Project Agreement No. 11

Compilation of Fermi Experience
Project Agreement No. 15

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The preliminary results of Test No. 40, the first of a series of tests in Rig 10 to investigate the phenomenon of decreasing metal wastage with increasing leak rate, is reported. Instrumentation for acoustic data to be taken during this series of tests is described in detail and the test procedure given.

Also reported is the work on hot erosion studies.

<u>Sodium Technology Project - Project Agreement No. 11 - E. C. Kovacic and J. E. Meyers</u>	11.1
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Modification of the Rhometers was completed and calibration and evaluation initiated. Analysis of experimental data on the oxygen meter stability and sensitivity continued. A test program for evaluating the hydrogen detector was completed, and the side loop for the test program was under construction.

A small portion of the sodium film was removed from the centrifuge bowl for examination of the residue by BMI, and a new bowl was fabricated to replace the one sacrificed for the examination.

Also reported is the status of the hydrogen solubility studies and the sodium sampling procedures.

<u>Compilation of EFAPP Experience - Project Agreement No. 15 E. C. Kovacic</u>	15.1
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APDA-CFE-25 and APDA-CFE-26, compilation reports on current Fermi experience for the months of September and October, were published. APDA-CFE-28, the report for December, was in final preparation for publication, and the reports for January and February were in preparation.

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SODIUM-WATER REACTION TEST PROGRAM

PROJECT AGREEMENT NO. 10

SENIOR PROJECT ENGINEER: E. C. KOVACIC

PROJECT ENGINEER: H. V. CHAMBERLAIN

I. PREFACE

A. Background Information

Achievement of the LMFBR program objectives is highly dependent on the development of reliable system components. With regard to the current status of development, the steam generator is recognized to be the weakest link in the heat transport system. The question of what occurs in a steam generator during a sodium-water reaction and how to accommodate such a reaction in the design has been a problem since the inception of sodium- and NaK-cooled reactors. The damage resulting from a reaction may be caused by water leaks of two general categories: large leaks and small leaks. Until recently designers have been concerned with large leaks such as those resulting from the complete circumferential rupture of a water tube. However, in late 1962 a steam generator in the Enrico Fermi Atomic Power Plant (EFAPP) experienced a sodium-water reaction due to a tube failure produced by vibration. Subsequent examination of the unit indicated that a general corrosion had occurred in the area of the sodium-water reaction, producing wastage and failure of some of the adjacent tubes. It is not known at what stage in the propagation of the leaks the wastage occurred; that is, did the wastage occur as a result of the initiating leak, or did it occur as a result of the subsequent leaks? The question raised by this experience clearly indicate that a sodium-water reaction program should consider both small and large leaks. Subsequent to the EFAPP experience, the British conducted some tests in which they found that significant tube wastage rates can be incurred with small leaks.

B. Scope

This program is related entirely to the detection, behavior, and effects of sodium-water reactions resulting from leaks in sodium-heated generators. All of the activities of this program are within the scope of the Components Element (Vol. 3) of the LMFBR Program Plan (WASH-1103). However, some of the activities interface with the Instruments and Control

Element (Vol. 4) of the Program Plan. With regard to sodium-water reactions in steam generators, the emphasis in Program Element 3 is on developing information related to mechanisms producing wastage and to the effect of various system parameters and jet characteristics on material wastage; in Program Element 4, the emphasis is on evaluating and on demonstrating leak detection systems which, when used in conjunction with reactant isolation and reaction product relief system, would minimize damage to the steam generator and the secondary heat transport system.

The Program Plan states that the development of economical, reliable, and safe sodium-heated steam generators is a number 1 priority item in the LMFBR development program; and all activities in Program Element 3 that are related to steam generator development such as sodium-water reaction studies are assigned a number 1 priority rating. Thus, all of the activities conducted here are directed toward accomplishing number 1 priority tasks.

As part of the AEC program of steam generator development, a project was initiated at APDA for the purpose of investigating both small and large leaks. A series of tests is being run to

- Establish a means of estimating the extent of tube wastage during a small leak of water into sodium in a sodium-heated steam generator
- Determine the dominant parameters of tube wastage during a small water leak so that these parameters may be taken into account in the design of a unit
- Establish the feasibility of various candidate leak detection systems.

C. Relationship to Other Projects

This program is applicable to the development of sodium-heated steam generators and to the technology of sodium-water reactions in the LMFBR program. Data generated in the program will be used to prepare design criteria and design analysis procedures for steam generators from the standpoint of sodium-water reactions.

Information on the test program and the results to date are available in (1) the proceedings of the Sodium Components Development Program Information Meetings held on April 14, 1964, in Hollywood, California, and on June 17, 1965, in Chicago, Illinois; (2) APDA quarterly technical progress reports on AEC-sponsored activities; (3) a paper, "An Investigation of Tube Wastage Caused by Small Leaks of Water in Sodium-Heated Steam Generators," presented at the IAEA Symposium on Alkali Metals - Corrosion Studies and Systems Operation Experience, held at Vienna, Austria, November

28 to December 2, 1966; (4) paper titled "Leak Detection -- Sodium-Water Reactions" presented at The Symposium on Liquid Metal Instrumentation and Control, held in Idaho Falls, Idaho, March 1-2, 1967; (5) papers titled "Surface Temperature Measurements in Sodium-Water Reactions" and "Tube Wastage in Sodium-Water Reaction Tests" presented at the American Nuclear Society Winter Meeting held in Chicago, Illinois, November 5-9, 1967; (6) paper titled, "Sodium Heated Steam Generators," presented at the American Nuclear Society National Topical Meeting on Fast Reactor Systems, Materials, and Components held in Cincinnati, Ohio, April 2-4, 1968; (7) paper titled, "Wastage of Steam Generator Materials by Sodium-Water Reactions," presented at ANL International Conference on Sodium Technology and Large Fast Reactor Design, held at Argonne National Laboratory, November 7-9, 1968.

II. TECHNICAL PROGRESS

A. Rig 10 Tube Wastage (Task 20)

1. Testing (Job 03)

The scope of the FY-69 program is to conduct six tests at water injection rates larger than 0.01 lb/sec, approaching 1 lb/sec, (1) to clearly confirm the phenomenon of a decreasing wastage rate that was observed beyond the injection rate of 0.01 lb/sec¹ and (2) to determine the effect of gas versus water as the target coolant at the larger leak rates.

The test specification for the six tests to be conducted in Rig 10 in FY-69 was completed, and the tentative test conditions for these tests are presented in Table 1. The first test of the current test program, Test No. 40, was conducted successfully on March 28. A preliminary evaluation of the test data indicates that the actual conditions for this test closely approached those listed in the table. A summary of the actual test data and results will be reported in the next quarterly report.

The test itself ran quite smoothly; however, some problems were encountered during preparation for testing. These were primarily of a nature attributable to normal start-up difficulties for a facility which has been inactive for a long period of time (1 year). Difficulty was encountered in establishing sodium flow through the cold trap after the test rig was filled with sodium. Flow through the cold trap was established by selectively heating local areas. Following initiation of flow through the cold trap, 10 hours of cold-trapping was required to lower the plugging temperature of the sodium to less than 400 F so that the test could be conducted.

TABLE 10.1 - TENTATIVE TEST CONDITIONS FOR TESTS TO BE
CONDUCTED IN THE PERIOD MARCH THROUGH JUNE 1969

	Test Number					
	<u>40</u>	<u>41</u>	<u>42</u>	<u>43</u>	<u>44</u>	<u>45</u>
Leak Rate, lb/sec	0.01	0.1	0.5	1.0	0.1	1.0
Injection Nozzle to Target Tube Spacing, in.	←————— 1 —————→					
Target Tube Material	←————— 2-1/4 Cr-1 Mo —————→					
Quantity of Water Injected, lb	0.22	2.0	10	20	2.0	20
Estimated Duration of Injection, sec	22	20	20	20	20	20
Sodium and Injection Water Temperature, F	←————— 600 —————→					
Injection Water Pressure, psig	←————— 2650 —————→					
Fluid in Target Tube	←————— Stagnant Nitrogen —————→			←————— Circulating Water —————→		
Pressure of Fluid in Target Tube, psig	100	100	100	100	2650	2650
Sodium Flow, gpm	←————— 400 —————→					
Initial Sodium Cover Gas Pressure, psig	←————— 5 —————→					
Sodium Head Above Injection Point, ft	←————— 8.4 —————→					

10.4

2. Test Analysis (Job 04)

M. K. Deora
H. V. Chamberlain

The scope of this job is to perform additional detailed analyses of all Project 10 data to (1) provide a better understanding of the material wastage phenomenon, (2) determine the most meaningful correlation of the data, and (3) provide guidance for the experimental program to be conducted in FY-70.

Planning of work was completed and the first phase of the job, that of verifying the conclusions drawn with respect to the significance of leak rate, nozzle-to-target spacing, sodium velocity past the target tube, and duration of leak, was initiated.

3. Design, Procurement, Fabrication and Installation (Job 12)

Several modifications to Rig 10 are required to provide the rig with the capability of injecting water in quantities greater than 1.3 lb and at rates exceeding 0.10 lb/sec which are required in the current test program. A new water injection system has been designed with the capacity to inject the required quantity of water. The vessel is designed for a pressure of 3000 psig at 1050 F and a capacity of 25 lb of water at 600 F and 2650 psig. Fabrication of the vessel and sections of the piping for the injection system has been completed and installation at Rig 10 has begun.

Additional capacity is also required for the high-pressure nitrogen pressurization system in order to provide the proper injection pressure throughout the test for the increased leak rates which will be run during the current test program. A new five-bottle header including regulator for 6000 psi nitrogen has been ordered and will be delivered to the test facility and installed in April.

It is expected that significant wastage of tubes other than the target tube may occur at the high leak rates to be used in the current test program. In order to provide a uniform indication of this damage which can be compared to wastage occurring on the target tube, the stainless steel and 5 Cr-1 Mo tubes near the injection area in the row behind the 2-1/4 Cr-1 Mo target tube will be replaced with 2-1/4 Cr-1 Mo.

B. Rig 43 Tube Wastage (Task 21)

G. H. Reicks
J. A. Ford

All activity on this task was stopped and no other work is planned for the remainder of FY-69.

The scope of the acoustic detection program is to establish the feasibility of this technique for detecting small leaks of water or steam into sodium. Preliminary acoustic data obtained in Rig 10 tube wastage tests conducted during FY-68 did show that a detectable noise level above the background noise existed during the injection of the water into sodium. The scope of the FY-69 program is (1) perform a detailed analysis of the acoustic data obtained in Rig 10 during FY-68, and (2) obtain additional acoustic data from Rig 10 during the wastage tests that are to be conducted in FY-69.

1. Test Planning, Acoustic Detection (Job 12)

A plan was written for acquisition and analysis of acoustic data that will be obtained in conjunction with the Rig 10 wastage tests that are planned for the remainder of FY-1969. The plan includes a preliminary investigation of the significance of the location of the noise sensors relative to the leak location. Studies were made to determine the appropriate locations on the Rig 10 facility for mounting of acoustic transducers, and the following locations were specified: (1) one transducer on a waveguide inserted through the top flange of the reaction vessel and terminating in the pool of sodium located above the tube bundle, (2) two transducers on the side of the reaction vessel at the same elevation as the reaction zone, and (3) one transducer on the outlet valve from the reaction vessel (See Fig. 10.1).

2. Testing (Job 13)

Acoustic-transducer mountings designed and fabricated for Rig 10 are shown in Figure 10.2. The transducers are tightly coupled to the steel mounting rods using bolted clamps with a high temperature grease between the bottom of the transducer and the top of the rod. The steel mounting rod on the shell of the vessel is attached using a complete penetration weld, while the mounting rod on the outlet valve is welded to a plate that is fastened to the valve with a bolt. Three Edo 100-kHz transducers and one Endevco 30-kHz transducer were mounted in various positions of Rig 10, as shown on Fig. 10.2.

During wastage test No. 40 (see Table 10.1), the output of these transducers and their filtered outputs (15-kHz, high-pass) were taped on seven channels of the 100-kHz tape recorder. By the end of the report period, the output of the recordings had been inspected, using an oscilloscope and earphones.

3. Test Analysis (Job 14)

a. Description of Analysis Equipment

Analyses of the Rig 10 acoustic data recorded in the late FY-1968 tests (No. 30-39) were made to determine a characteristic spectrum of water leaks into sodium. The acoustic data for these tests had been recorded on an Ampex tape recorder, with a frequency range of 8 kHz at 3.75 ips and 10 kHz at 7.5 ips, using an Endevco accelerometer No. 2217E and General Radio preamplifier No. 1560. The pertinent conditions for these tests are given in Table 10.2. Each test recording includes the following sections: narrative description, pump and motor background noise, water injection into sodium noise, and backup gas flow noise.

A Federal Scientific No. VA-6 real-time, high-resolution spectrum analyzer; a Federal Scientific No. 129H statistical averager; an X-Y plotter; and a 100-kHz, 7-channel, 1-inch acoustic tape recorder were acquired for performing the analysis of the data. The existing 1/4-inch low-frequency acoustic tapes used during the Rig 10 tests were re-taped on the 1-inch tape recorder for ease of analysis. In most of the tests, various combinations of instrument control settings were tried on various segments of the tapes to arrive at an overall optimum setting.

The interconnections of the various instruments are shown on Fig. 10.3. The output of the Sangamo acoustic tape recorder feeds simultaneously to the analyzer and the earphones; the output of the analyzer feeds directly to the averager; and the output of the averager feeds simultaneously to the oscilloscope and the X-Y plotter. To record instantaneous spectrograms, a high-speed optical recorder (Visicorder), which required a buffer amplifier, was used.

b. System Geometry

Of importance in evaluating the results of the noise analysis is knowledge of the geometry in the reactor zone. Fig. 10.4 is a schematic of a cross section of the Rig 10 tube bundle showing the pertinent dimensions and relative location of the injection nozzle, the target tube, and one of the transducers. In addition to the noise generated by the injection of the water into the sodium are the background flow and mechanical noises. Fig. 10.5 is a schematic of the Rig 10 system showing the relative location of the reaction zone, the transducers, and the external mechanical noise source (the sodium pump). This pump is a single-stage, centrifugal-type NH-1-1A-Z401 made by Allis-Chalmers with 7 vanes and is driven by a 3600 rpm induction motor.

TABLE 10.2 - PHYSICAL DATA ON RIG 10 LEAK TESTS

	Test Number							
	<u>30</u>	<u>31</u>	<u>35</u>	<u>36</u>	<u>37</u>	<u>38</u>	<u>39</u>	<u>Low-Flow</u>
Sodium System								
Flowrate, gpm	400	400	400	400	400	400	400	400
Velocity past target tube, f./sec	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.1
Bulk Temperature, F	600	600	605	615	600	680	680	535
Injection Water System								
Water added, lb	1.3	0.065	0.96	0.96	0.197	0.20	0.49	Cont.
Temperature, F	600	608	605	615	600	680	680	535
Pressure, psig	2650	2650	2650	2650	2650	2900	2900	785
Orifice size, (nominal) in.	0.043	0.016	0.043	0.016	0.010	0.010	0.014	0.014
Injection point-to-target spacing, in.	1/4	1	1/4	1-9/32	1/4	1/4	1/4	1/4
Injection duration, sec	11	2.5	11	42.1	20.9	60*	74*	Cont.
Injection rate, lb/sec	0.118	0.026	0.087	0.0233	0.0094	0.0033	0.0066	0.00008
Recirculating Water System								
Pressure, psig	2650	100**	2650	10**	2650	2650**	2650**	None

* Tubes completely penetrated in 53 seconds. Tube wall was 0.120-in. thick.

** Test was run with stagnant nitrogen in the target tube instead of recirculating water.

c. Analytical Considerations

When the output of the frequency analyzer is directly viewed on the oscilloscope, consecutive traces are seen on the screen every 50 milliseconds. A look at these traces reveals that what seems to be steady-state to the ear (say, the background noise of pump and motor, etc.) is actually fluctuating haphazardly, and is very rapid and nonrepetitive both in amplitude and in frequency. This fact, which is due to the averaging time of the aural and visual senses, makes the visual real-time spectral analysis of the acoustic data almost impossible. To overcome this, the averager is used which adds many traces together, thus diluting the effect of random noise and amplifying the recurrent signal noise. The averager also has an input filter with variable time constants that can be used to smooth the incoming signal (in this case, amplitude versus frequency) without altering the frequency response of the entire system.

One other obstacle was the high amplitude of the low-frequency noise in comparison to the high-frequency noise. This was partially overcome by using the logarithmic output of the analyzer, which added an extra advantage to the capabilities of the averager - the averager became, in a sense, an autocorrelator of 2^n degrees. This is easily shown by the following simple algebraic relations.

If the normalization constant of averaging is $M = GN$, then the resultant of the averaging of N logarithmic consecutive spectrograms becomes

$$\begin{aligned} A &= \frac{1}{M} (\log S_1 + \log S_2 \dots + \log S_N) \\ &= \frac{1}{M} \left[\log (S_1 S_2 \dots S_N) \right] \\ &= \frac{1}{G} \log (S_1 S_2 \dots S_N)^{\frac{1}{N}} = \frac{1}{G} \log \sqrt[N]{S_1 S_2 \dots S_N} \end{aligned}$$

where

G = proportionality constant
 S = amplitude of the spectrogram

This last form indicated the multiplicative nature of the output. Particularly, if N is equal to 2, then

$$A = \frac{1}{G} \log \sqrt{S_1 S_2}$$

which represents multiplication of two spectrograms in the frequency domain, similar to autocorrelation where two time-domain functions are multiplied and then averaged. Another interpretation of the logarithmic averaging is

that it produces geometric mean rather than arithmetic mean, accentuating the recurrent signals. A representation of all the above points can be seen in Fig. 10.6b.

d. Results

Figures 10.7 and 10.8 show the results of the analysis of seven tests. Sixteen logarithmic traces are averaged, using a normalization constant of 1024, an input attenuation of ± 4 v, and a 500- μ sec time constant averager filter. The curves L—B represent the difference of the water-sodium leak noise and the background noise. The curves G—B represent the difference of backup gas flow noise and the background noise. The curves L—G represent the difference of water-sodium leak and backup gas flow noise.

The amplitudes of bell-shape peaks of sodium-water leak curves occurring around 2000 Hz are plotted versus the leak rate on log-log paper, as shown in Fig. 10.9. On the same graph, the amplitudes of bell-shape peaks occurring around 2000 Hz of backup gas flow are plotted for the corresponding tests. Although the orifice size for the water injection and backup gas are the same for each test, the leak rates (lb/sec) of the two are not the same. The results are two tightly fitted straight lines with a positive slope of approximately one-half, with the water-sodium leak line located above the backup gas line. The extreme left data point is the result of a low-pressure (785 psi) steam (gas phase) injection in 535 F sodium through a 14-mil orifice, yielding a leak rate of 0.00008 lb/sec. It is seen that this straight-line relationship for water-sodium leak noise holds true for leak rates covering of four orders of magnitude.

The analyzer, the averager, and the X-Y plotter were calibrated with an oscillator set at 2 kHz. The results of the calibration, a 16-trace averaging, 1024 normalization constant, ± 4 v attenuation and 500 μ sec input filter time constant, indicated that the inches I on the X-Y plotter as a function of the millivolts mv input of the analyzer can be expressed as:

$$mv = 2.5 (2)^{2I} = 2.5 e^{1.385I}$$

Approximating the straight-line relationship to be of a one-half positive slope, one can write

$$I = K \sqrt{L.R.}$$

where

L. R. = Leak rate in lb/sec
K = Proportionality constant

Taking $L.R. = 10^{-2}$ lb/sec, which corresponds to 1 inch in Fig. 10.9, K is found to be equal to 10.

Therefore: $I = 10 \sqrt{L.R.}$

hence, $mv = 2.5 e^{13.85 \sqrt{L.R.}}$

Since, in the linear range the acoustic noise pressure p is proportional to the electrical output of acoustic transducers, it is seen that the acoustic pressure is an exponential function of the leak rate, as written below:

$$p \propto e^{13.85 \sqrt{L.R.}}$$

Two backup gas flow noise data points from tests No. 38 and No. 39 do not fall on the gas flow noise line. This is due to the rupture of the target tubes prior to the termination of water injection. These target tubes are pressurized to 2650 psi by a separate nitrogen gas reservoir. The gas flow noise measured in these two tests is due to two leaks, one from the original capillary and the other from the rupture in the target tube.

e. Conclusions and Recommendations

1. Because of the haphazard variations of unaveraged spectra, no consistent spike or valley of frequency spectra could be detected to be associated with the sodium-water leaks.

2. After sufficient averaging and curve smoothing, a bell-shape pattern was observed in the sodium-water leak acoustic frequency spectrum.

3. The frequencies of the peak of the bell-shape curve of net acoustic pressure (the difference of the leak and the background noise) of various tests followed no conclusive pattern corresponding to the capillary diameters leak rate and/or target spacing.

4. The only generalization concluded was that in the audible range the frequencies of peaks remained in the neighborhood of 2 kHz (± 200 Hz). To gain more understanding of the leak noise, additional tests are needed to determine if the leak noise is due to boiling, to gargling, or to flow from a jet and if ultrasonic noise exists. Theoretical considerations indicate ultrasonic frequencies should be generated from the jet.

5. The backup gas flow noise had similar bell-shape peaks in the same frequency range, but with lower amplitudes.

6. When amplitudes of the net averaged logarithmic acoustic pressure peaks were plotted versus the leak rate on log-log graph paper, a tightly fitted straight line with a positive slope of one-half was produced.

7. A similar plot for the peak acoustic pressure of backup gas flow resulted in a straight line of similar slope, but with a lower amplitude.

8. Even the data from the very low leak rate test, conducted with steam at 785 psi in 535 F sodium through a 14-mil orifice and yielding a 0.00008 lb/sec leak rate did not fall too far from the sodium-water leak line, verifying the straight line relationship of the acoustic noise versus leak rate for almost 4 orders of magnitude of leak rates on the log-log paper.

9. To gain a better understanding of the net dynamics of the flow of water into sodium, a sodium-water-reaction-free simulation test should be conducted to visually observe the fluid dynamics of the leak and to compare its acoustic spectrum with that of sodium-water leak. This test can be done during the routine post-test flow check of the nozzle by placing the nozzle in a glass tank containing a colored fluid and injection room-temperature water at 2650 psi through the capillary.

10. The overall impact of the analysis done to date is that there exists at least one frequency band which is representative of leaks, and that the net logarithmic amplitude of the acoustic pressure in this band is proportional to the square root of the leak rate. Further tests should be conducted to determine the source of the noise, i. e., whether it is due to sodium-water reaction or due to water boiling or due to jet flow, and whether there exists an ultrasonic characteristic spectrum due to the leak.

4. Background Noise Measurement (Job 17)

A comparison of amplitudes of the sound level obtained from Fermi steam generator background noise and the Rig 10 leak test noise indicated approximately the same order of magnitude in both. There will be no further work during FY-69 on measuring the background boiling water and mechanical noise spectra in the EBR-II, Sodium Components Test Installation (SCTI), and Enrico Fermi facilities. This activity is being deferred until FY-70.

5. Leak Detection Criteria (Job 20)

The scope of this job is to establish a basis for evaluating methods of detecting sodium-water reactions in sodium-heated generators. The need is for early detection of leaks to prevent damage to the unit. Included in this effort are (1) definition of leak detection criteria for the LMFBR program, (2) description of a reference LMFBR secondary sodium coolant system, (3) determination of the behavior of the reaction products

throughout the coolant system, (4) assessment of candidate leak detection systems, and (5) recommendations for a leak detection system for an LMFBR plant.

Work was initiated in FY-68 on establishing the criteria, describing a reference secondary system, and a preliminary evaluation of the candidate leak detection systems. The original draft of this internal report was revised in FY-69 to include more up-to-date information; the revised draft has been completed and will again be issued for internal review. The analysis indicates that for leaks in many locations and under some operating conditions for a large pot-type steam generator in a three-loop 1000-Mwe plant using Croloy 2-1/4 tubing, propagation of a water leak to another tube will occur before the leak can be detected and the steam generator dumped.

This analysis is based on the current capabilities of existing detection instrumentation, which does not include acoustic detection. The major factor which contributes to the inability of the leak detection system to prevent propagation is the transport time of the impurities from the leak site to the detector. Also contributing to the problem is the large dilution of the impurities resulting from a reaction due to the sodium inventory in the system. Although acoustic detection has shown promise for detecting small leaks, more work is necessary to establish the lower limit of leak that can be detected in a real system before the usefulness of this method can be established.

D. Sodium-Water Reaction Data Correlation (Task 28)

1. Topical Report (Job 12)

H. V. Chamberlain

The scope of this job was to make a review of the literature pertaining to reactions of water with sodium, with particular emphasis on the factors influencing wastage of materials in such reactions. The main objective of the review was to determine if sufficient experimental data exist to develop a correlation of the various factors which affect materials wastage rates. A draft of the topical report covering this review was submitted to the AEC for review and comments in FY-68. Work in FY-69 will consist of incorporating the comments of the AEC and issuing the topical report.

During this report period the comments were received from the AEC and work was initiated on incorporating these comments.

E. Hot Erosion Studies (Task 60)

J. A. Ford
G. H. Reicks

The scope of this task was to establish the relative contribution of erosion and corrosion to the wastage process by injecting water, sodium,

and sodium hydroxide against targets made of the materials of interest to the LMFBR program. Construction of test equipment and initial operation was completed in FY-68. Several operating problems including failure of the injection tube were encountered during this initial operation period.

In FY-69 the scope of the work is (1) to make an evaluation of the design and performance of the hot erosion test equipment, including analysis of the failed injection tube, and (2) to make recommendations for corrective action.

1. Design Evaluation of Hot Erosion
Test Equipment (Job 12)

The failed U leg from the hot erosion test apparatus has been examined metallurgically by Southern Research Institute to determine the cause of failure. From the evidence shown by the specimens examined, SRI concluded that

- the pipe was probably pressurized at least once while the center section of the heated length was at a high temperature
- the failure was essentially ductile in nature
- the crack which penetrated the entire wall thickness initiated at an internal fusion line of the weld (in the seam-welded pipe)
- the principal cause for the crack initiation and propagation at this site was due to the rather severe restraint on plastic flow in that region produced by the notch formed by the localized decrease in wall thickness at that fusion line
- no evidence was found to indicate that the material, per se, was at fault, but it does appear that notches produced by decreased wall thickness at weld fusion lines are undesirable for such service as that to which the pipe was subjected.

APDA is currently reviewing the SRI analysis.

Review of the test data is in progress and the report summarizing the design evaluation and recommended solutions has been initiated.

III. NEXT REPORT PERIOD ACTIVITIES

A. Rig 10 Tube Wastage (Task 20)

1. Testing (Job 03)

The results for Test No. 40 conducted in Rig 10 in March will be presented, Tests 41 through 45 will be completed, and preliminary test results published.

2. Test Analysis (Job 04)

Detailed analysis of existing wastage data will continued.

3. Design, Procurement, Fabrication and Installation (Job 12)

Installation of the new water injection system and high pressure gas header will be completed. Modifications to the row of tubes behind the target tube will be completed.

B. Leak Detection (Task 22)

1. Test Planning, Acoustic Detection (Job 12)

No activity is scheduled.

2. Testing (Job 13)

Repositioning of the present transducers to determine effect of transducer location on output signal during the sodium-water reaction in different areas of the reaction vessel and system will be carried out. Acoustic (tape) and visual (photographs) recordings of the post-test flow checks of the nozzles will be taken to correlate the fluid dynamics of the jet with its acoustic characteristics.

3. Test Analysis (Job 14)

The new acoustic recordings taken at 100-kHz from the post-leak flow check of the nozzles and from tests No. 40 and up will be analyzed to correlate leak fluid dynamics to its high-frequency acoustic characteristics and to determine if there is any ultrasonic noise associated with the leak.

4. Background Noise Measurement (Job 17)

No activity is scheduled.

5. Leak Detection Criteria (Job 20)

Internal review of the leak detection criteria will be completed and a final draft of this task will be issued.

C. Sodium-Water Reaction Data Correlation (Task 28)

APDA-227, the topical report titled "Evaluation of Materials Wastage Due to Reactions of Water in Sodium," will be issued.

D. Hot Erosion Studies (Task 60)

1. Design Evaluation of Hot Erosion
Test Equipment

The report summarizing the design evaluation of the hot erosion test equipment will be completed.

REFERENCES

1. "Quarterly Technical Progress Report on AEC-sponsored Activities - January to March 1968," APDA-224, 1968.

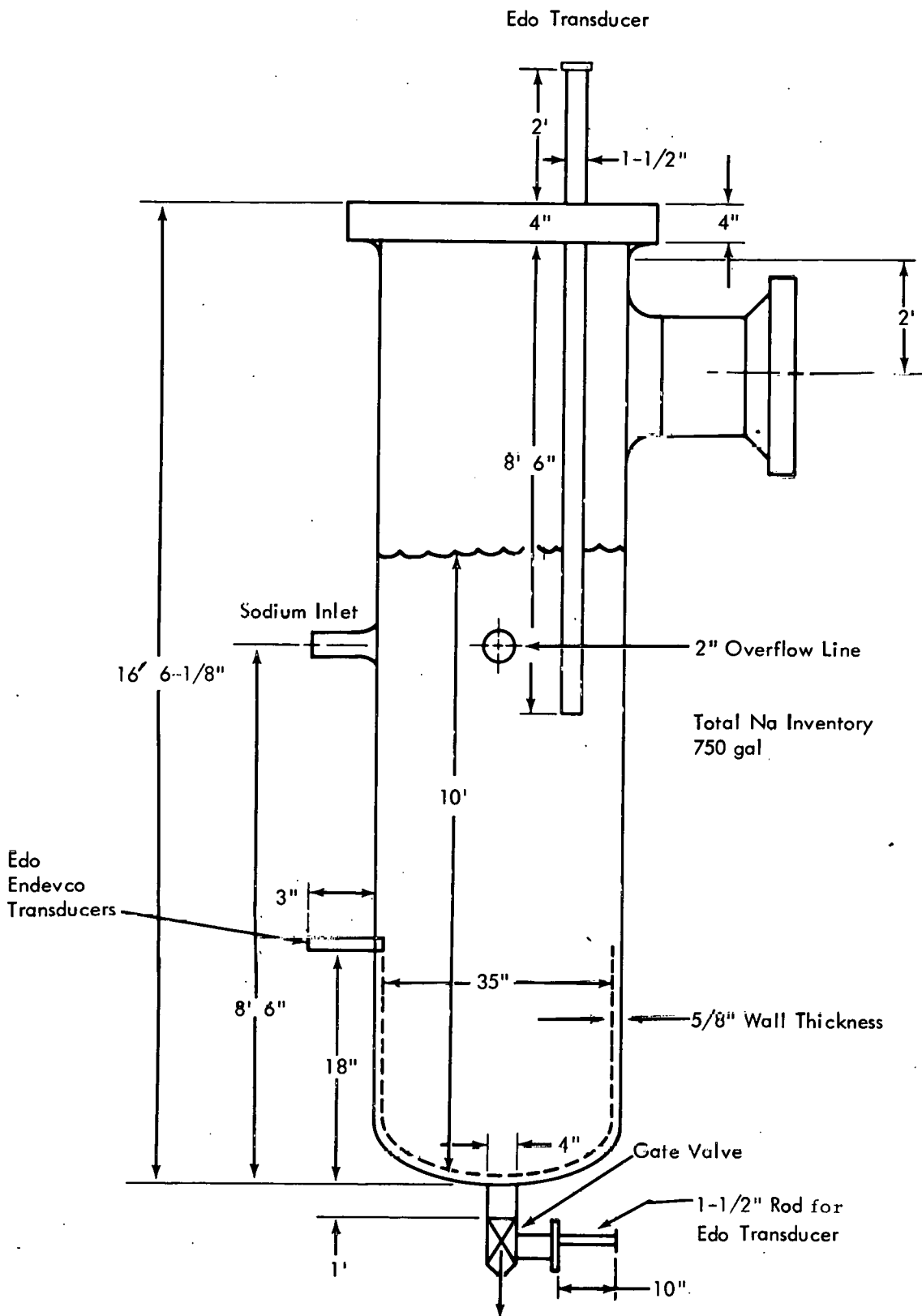


FIG. 10.1 LOCATION OF TRANSDUCERS ON RIG 10 REACTION VESSEL

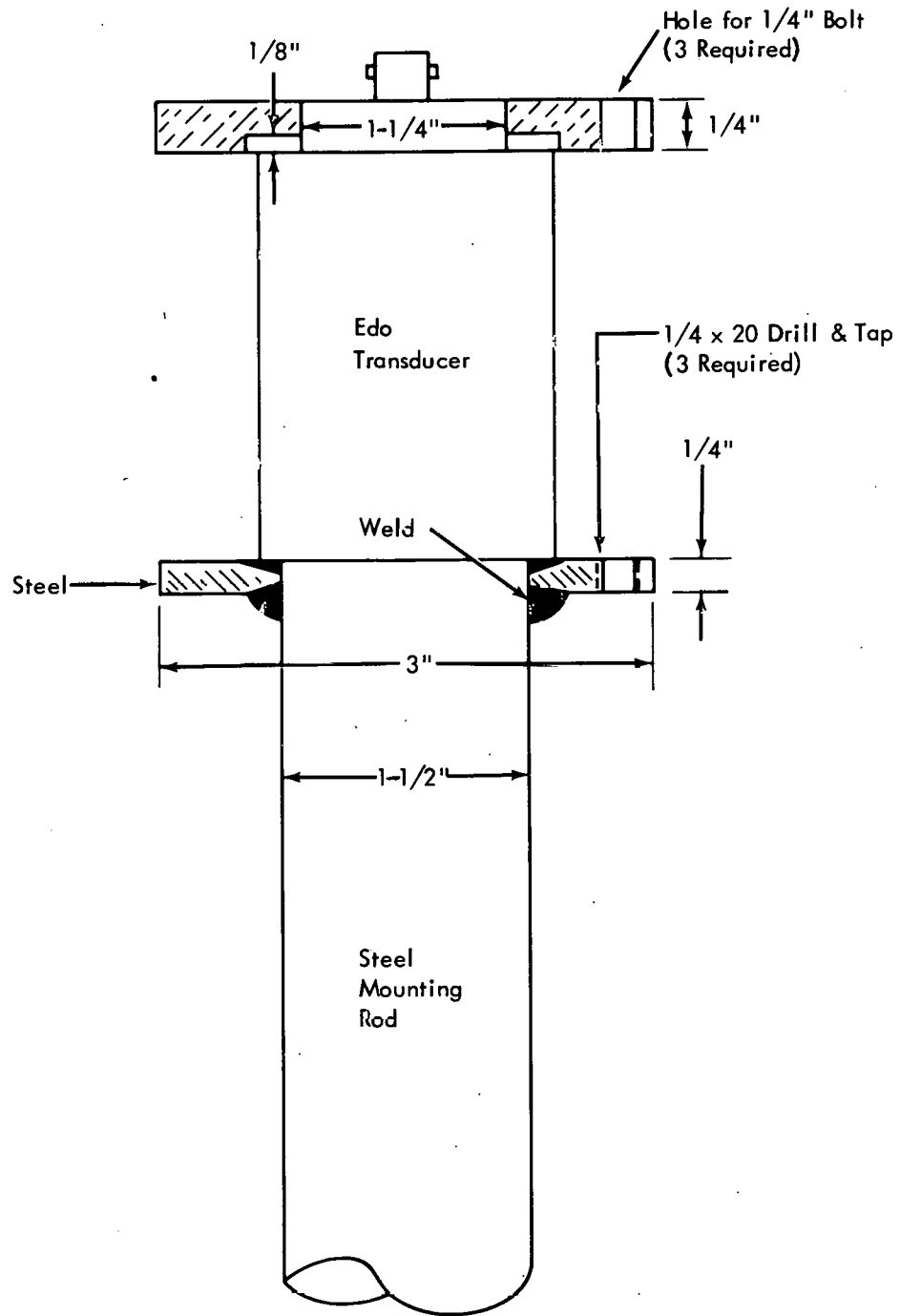


FIG. 10.2 MOUNTING FIXTURE FOR EDO ACOUSTIC TRANSDUCERS

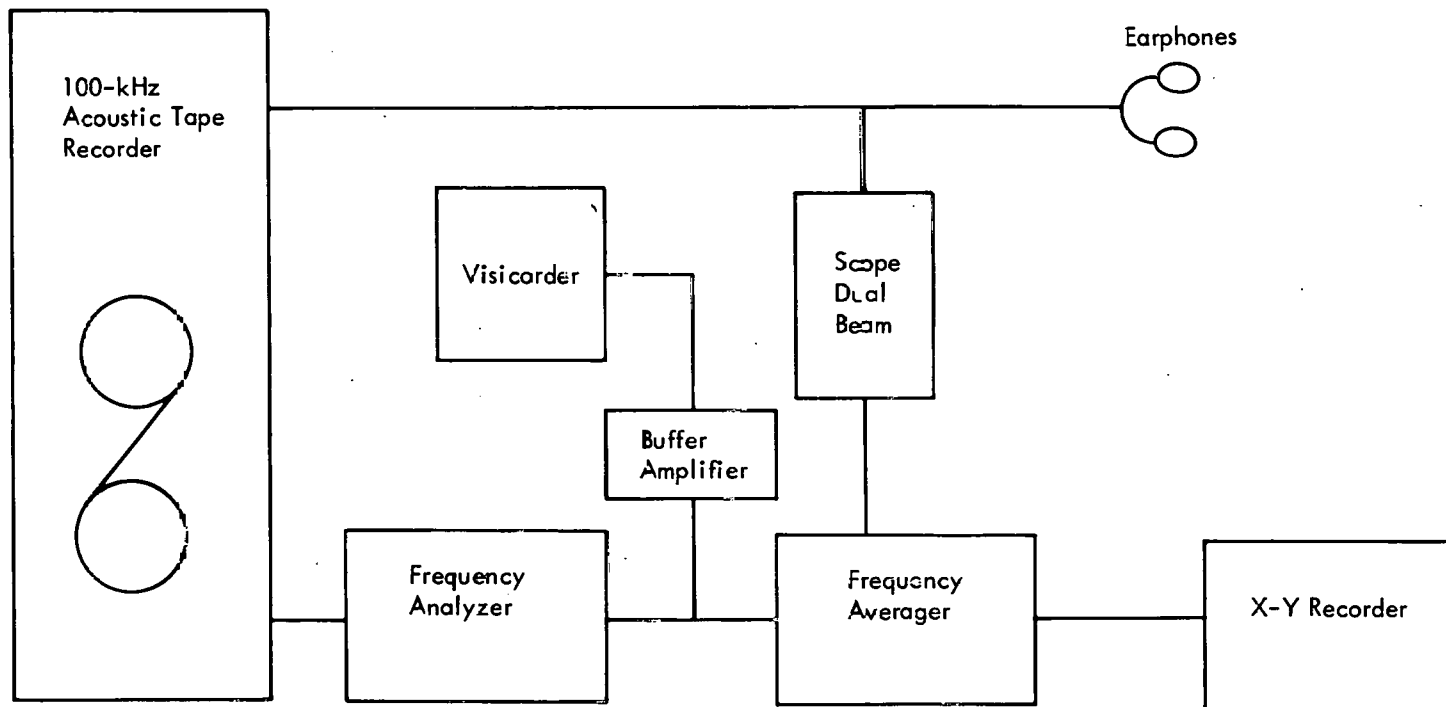


FIG. 10.3 BLOCK DIAGRAM OF DATA ANALYSIS INSTRUMENTATION

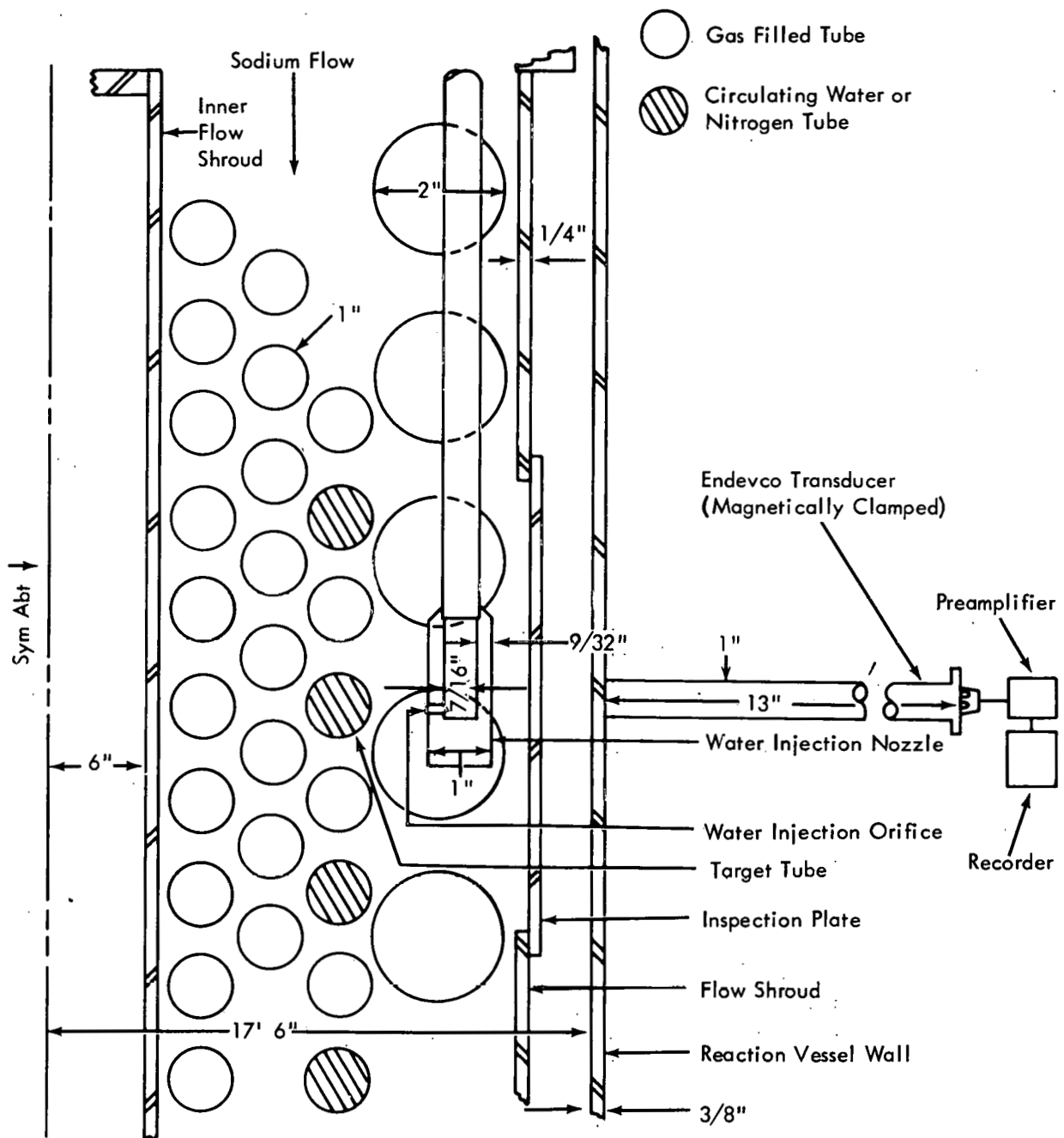


FIG. 10.4. RELATIVE LOCATION OF THE NOZZLE AND TARGET TUBES IN RIG 10

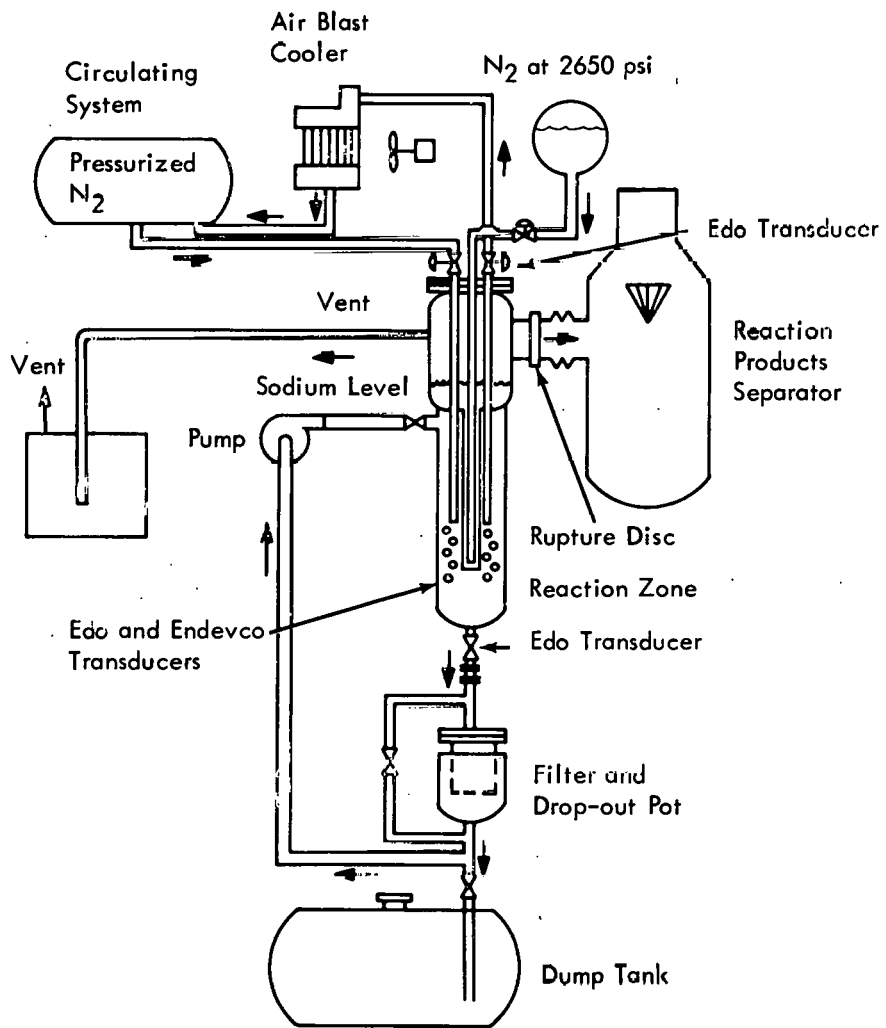
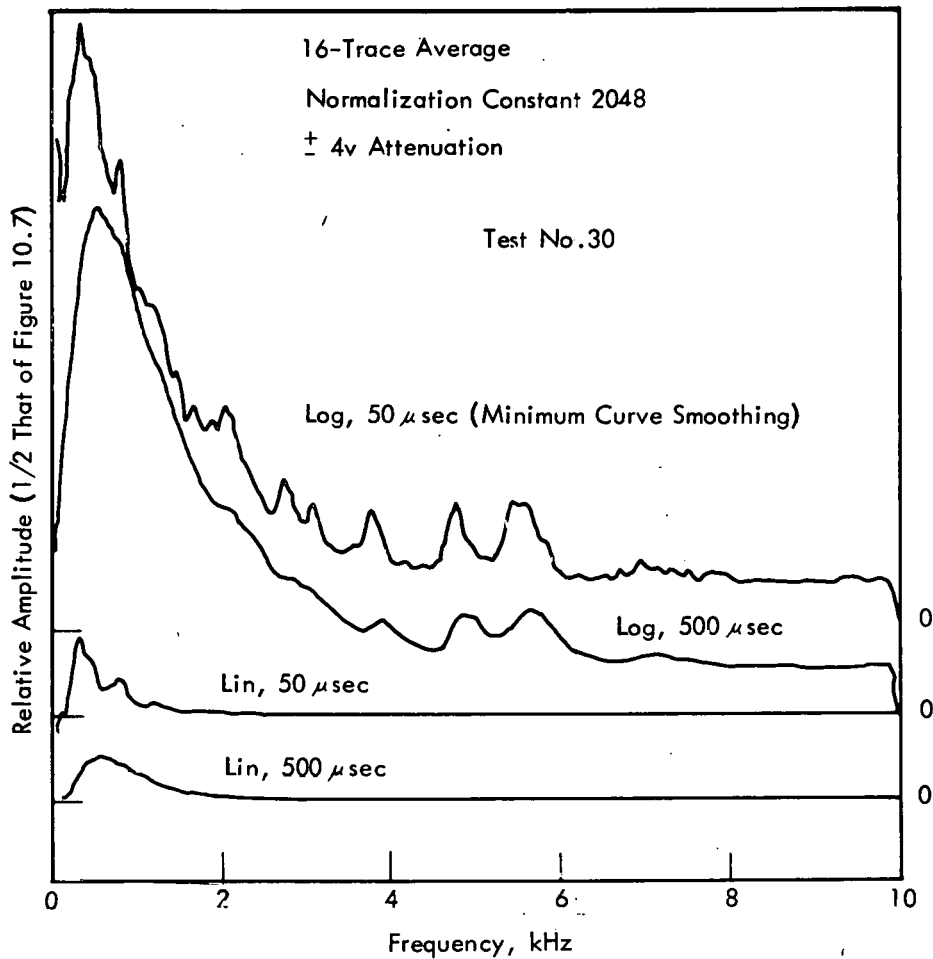
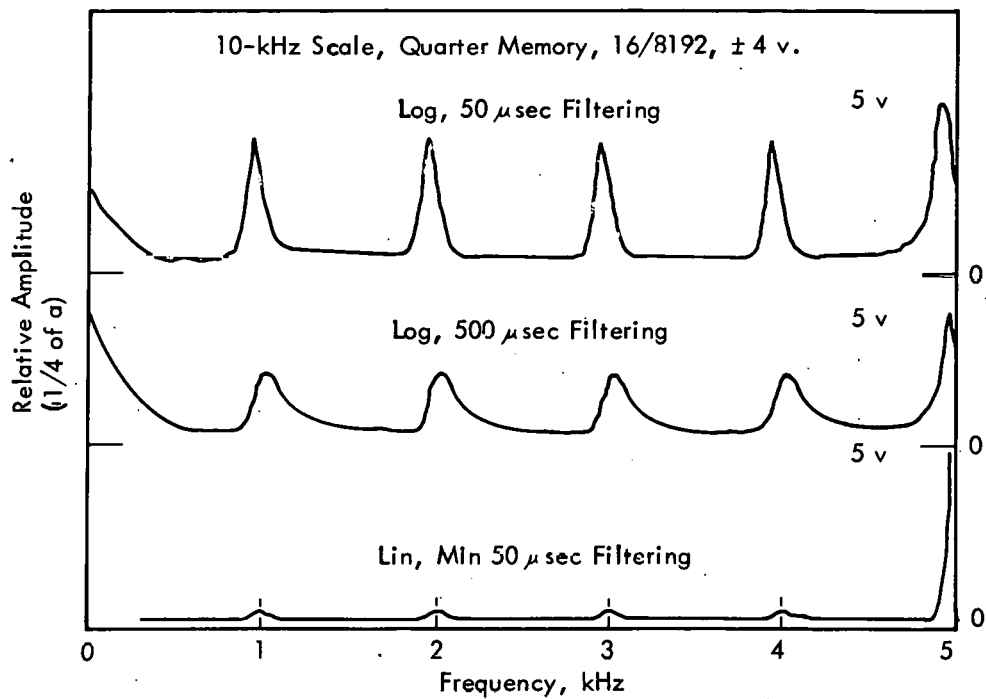


FIG. 10.5 SCHEMATIC DIAGRAM OF SODIUM-WATER REACTION TEST RIG 10

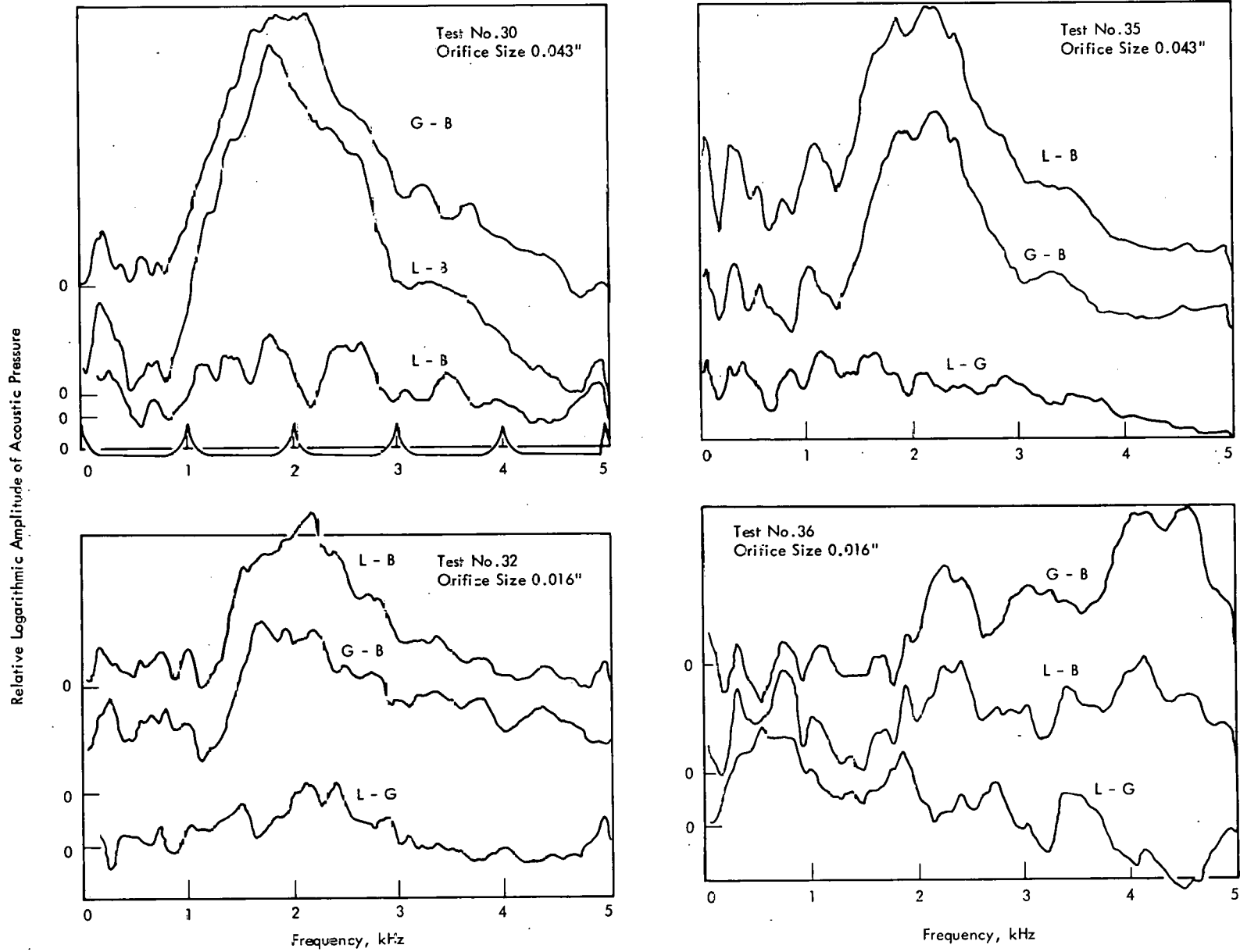


(a) Typical Background Noise from Rig 10



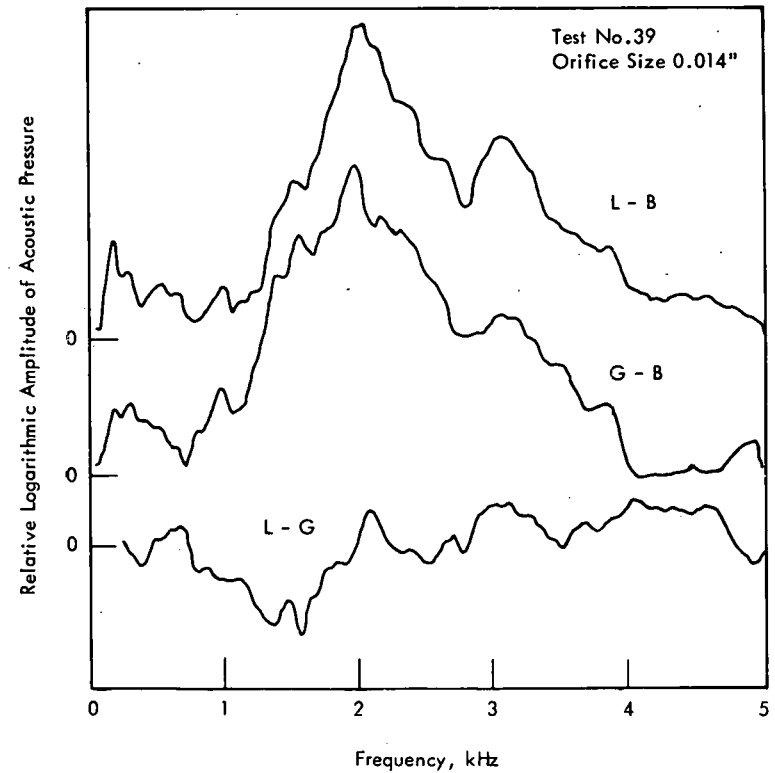
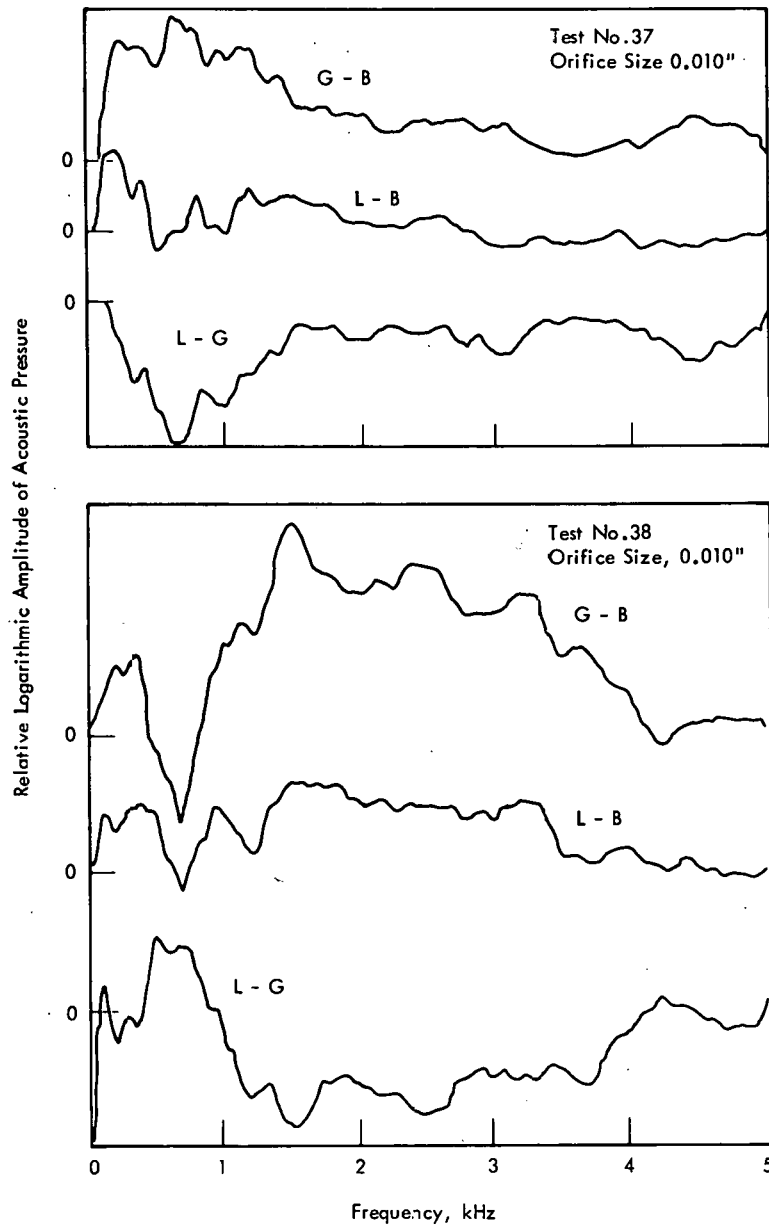
(b) 1 kHz Resolution Markers

FIG. 10.6 COMPARISON OF VARIOUS MODES OF OPERATION



Normalization Constant 1024, ± 4 v, 500 μ sec, 0 db Input, 0 db Output See Legend on Fig. 10.8

FIG. 10.7 SIXTEEN-TRACE LOGARITHMIC SMOOTHED AVERAGES — TESTS NO. 30, 32, 35, AND 36



Normalization Constant 1024, ± 4 v, 500 μ sec,
0 db Input, 0 db Output

L-B = Difference in Na - H₂O Leak Noise
And Background Noise

L-G = Difference in Na - H₂O Leak Noise And
Backup Gas Flow Noise

G-B = Difference in Backup Gas Flow Noise
And Background Noise

FIG. 10.8 SIXTEEN-TRACE LOGARITHMIC SMOOTHED AVERAGES — TESTS NO. 37, 38, AND 39

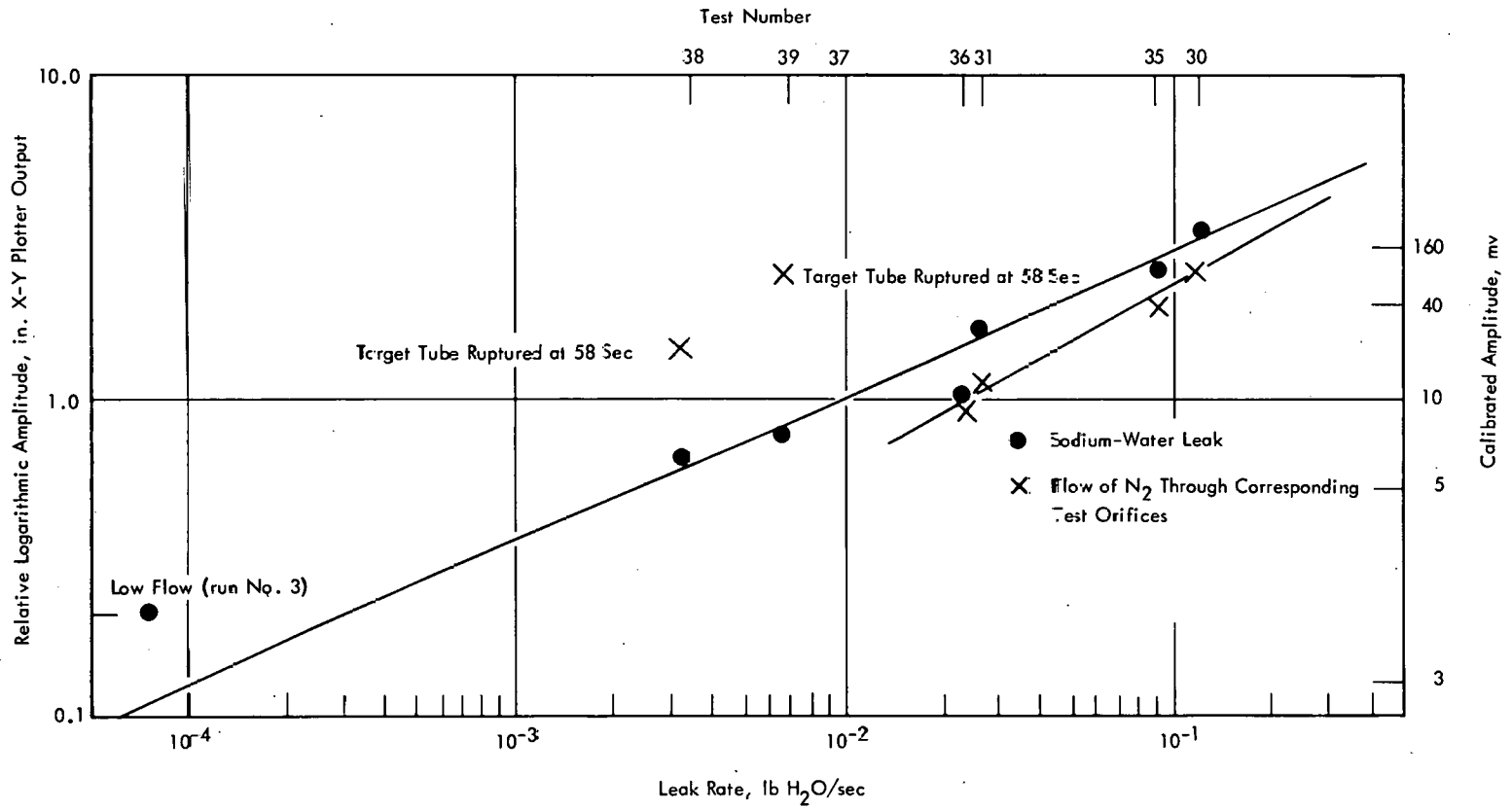


FIG. 10.9 AMPLITUDE OF NOISE VERSUS LEAK RATE AROUND 2 KHZ

SODIUM TECHNOLOGY PROJECT

PROJECT AGREEMENT NO. 11

SENIOR PROJECT ENGINEER: E. C. KOVACIC

PROJECT ENGINEER: J. E. MEYERS

I. PREFACE

A. Scope

The present scope of the sodium technology project encompasses the following elements:

1. Impurity monitoring devices, including the development and evaluation of the Rhometer, oxygen meter, hydrogen meter, and plugging meter.
2. Sodium purification processes, including the evaluation and/or development of cold trapping, hot trapping, centrifuging, movable bed gettering, and thermal decomposition.
3. Sodium sampling and analysis, including the reliability of through-flow samplers, oxygen analysis, and hydrogen analysis.
4. Physical and chemical behavior of sodium and impurities, including the investigation of the solubility of hydrogen and sodium carbonate in sodium, the equilibrium distribution of hydrogen between sodium and the cover gas, and interaction of hydrogen and oxygen in sodium.

B. Relationship to Other Projects

This project is oriented entirely to the Commission's research and development program on the LMFBR.

II. TECHNICAL PROGRESS

A. Impurity Monitoring Devices

1. Rhometer (Task 20)

The objective of this task is to develop and test an automatic temperature compensator and resistivity meter system capable of operating in the range of 400 to 1000 F with sufficient sensitivity and stability to detect a change in sodium resistivity equivalent to 1 ppm of oxygen.

a. Loop Evaluation, Prototypes (Job 06)

J. E. Knight
C. C. Scott

Because the resistance temperature detectors (RTDs) on order had not been received, the prototype Rhometer was operated isothermally in the sodium technology loop at 600 F without temperature compensation in January by substituting a fixed resistance for the RTD. The system operated satisfactorily during this period.

In February, three new RTDs were satisfactorily tested for resistance to grounds and for specific resistance at 100 C and then installed in thermowells in the sodium technology loop. The test procedure for calibrating the Rhometer system over the temperature range of 400 F to 900 F was written and approved. Late in the reporting period the loop was re-filled with sodium, after which Rhometer calibration and evaluation were started.

2. Oxygen Meter (Task 27)

a. Electrometer Evaluation (Job 03)

C. C. Scott

The test on the solid-state electrometer was inactive for most of the reporting period due to (1) scheduled tests requiring loop sodium temperatures greater than 600 F, during which time the oxygen meter employing the solid-state electrometer was deactivated, and (2) dumping of loop sodium to accommodate installation of the Rhometer RTD thermowells. However, during the time the solid-state electrometer was in service, the zero drift was within the manufacturer's specification of ± 1 mv per day.

b. Behavior in High-Temperature
Loop Sodium (Job 05)

A. J. Friedland
N. N. Mueller

This job includes the determination of (1) oxygen meter base-line stability and (2) oxygen meter sensitivity to an oxygen concentration change when operating in high-temperature (900 F) loop sodium.

The analysis of the experimental data has not been completed. It is expected that this work will be completed and reported in detail in the next quarterly report.

3. Hydrogen Detector (Task 21)

a. Test Program Plan (Job 05)

J. A. Ford
J. H. Coleman

The scope of this job is to formulate a detailed program for the installation of the APDA hydrogen detector system in the sodium technology loop and plan the test program.

An initial test program plan has been completed wherein three perturbations will be effected and their influence on the hydrogen detector will be noted. These perturbations are (1) hydrogen concentration, (2) oxygen concentration, and (3) sodium flow rate.

b. Evaluate Loop Hydrogen Stability (Job 06)

N. N. Mueller

The scope of this job is to establish the hydrogen stability of the technology loop as an initial step in the evaluation program for the hydrogen detector. Testing is being conducted in the 600 F to 900 F temperature range and in the 1.5 ppm to 3 ppm hydrogen concentration range.

Chemical analyses of some of the loop sodium samples taken for this evaluation have indicated a higher than expected level in total hydrogen content of the loop sodium. Additional chemical analyses of samples tubes taken as spares are in progress. This work will be completed and reported in detail in the next quarterly report.

c. Final Design and Installation (Job 08)

J. H. Coleman

The scope of this job is the final design and installation of the hydrogen detector into the sodium technology loop.

The final design of the hydrogen detector loop has been completed and installation is approximately 60 per cent complete. All the materials and equipment are on hand. Construction is expected to be completed and the hydrogen detector loop filled with sodium by the end of May.

The test loop and gas flow system are shown schematically in Figures 11.1 and 11.2; photographs of the detector coil and the injection removal coil are shown in Figures 11.3 and 11.4.

4. Plugging Meter (Task 23)

a. Behavior at High Loop Temperatures (Job 06) N. N. Mueller

In a previous operation of the APDA sodium technology loop at 900 F, high plugging temperatures were obtained which were neither anticipated nor explainable on the basis of measured chemistry results. The scope of this job is to collect more data on this phenomenon and to determine what effects conventional cleanup devices such as the cold trap and hot trap have on reducing and stabilizing the plugging temperature.

For the same reasons as indicated in Section II. A. 3. b, completion of this job has been delayed pending analysis of some spare sample tubes. This work will be completed and reported in detail in the next quarterly report.

B. Sodium Purification Processes

1. Centrifuging (Task 12)

a. Topical Report (Job 15)

J. Matte

A topical report is being prepared on the design, construction, and initial testing of the sodium centrifuge.

The first draft was completed during the quarter and re-writing of several sections was begun. Nearly all of the artwork for figures was procured.

b. Examination of Bowl Surface
for Impurities (Job 16)

A. A. Shoudy
W. E. McHugh

A two-inch section, measuring from the inlet, was removed from the centrifuge bowl to facilitate examination of the impurities collected therein. After removal of the bulk sodium in this section by coring, a sample of the 10-mil sodium film remaining was analyzed for carbon. The smallest sample taken contained more carbon than APDA's present microanalytical methods could handle. Thus no accurate carbon values can be reported.

Vacuum distillation of a small portion of the sodium film removed from the bowl wall yielded a black residue. Qualitative analysis

of the residue for metallics yielded: iron, 1.05 w/o; nickel, 0.53 w/o; and chromium, 0.18 w/o.

The remaining sodium in the two-inch section of the bowl was removed by vacuum distillation. A more extensive examination of the residue on this section of the bowl will be made at Battelle Memorial Institute (BMI) early in April.

e. Test Preparation, Run No. 2 (Job 18)

J. Matte
J. Wooton

This job covers execution of all preparations and modifications necessary to properly prepare the centrifuge and its related equipment for the next run, a 100-hour mechanical performance evaluation. These include changes to reduce drippage from the bowl housing, procurement of replacement or spare parts, preparation of the test specification, and a brief dry run at the beginning of the 100-hour test.

The two drive spindles which had been slightly scored in the seal region during earlier operations were repaired. The spindle seal subassembly was dimensionally checked by a seal consultant and modified to eliminate the scoring of the drive spindle. A new bowl was fabricated and balanced to replace the one sacrificed for analysis of results of the first sodium run. Revisions were specified to the gas inlets intended to reduce the drippage of sodium from the housing into the glove box to the bowl housing. The test specification was issued for the 100-hour run scheduled for the month of June.

C. Physical and Chemical Behavior of Sodium Impurities

1. Hydrogen Solubility (Task 31)

a. Planning, Design, and Construction
of Test Apparatus (Job 02)

A. A. Gordus*
E. F. Hill
S. A. Meacham

The scope of this job is to design and construct the apparatus required to achieve the following objectives:

- Determine the equilibrium pressure of hydrogen in sodium between the concentrations of 0.1 ppm and 1.0 ppm at two temperature levels in the range of 240 to 1000 F

* University of Michigan

- Determine the effect of oxygen on hydrogen equilibrium in sodium at two oxygen concentrations.

Calibration of the system has continued at a low level of effort. It is expected that the calibration will be completed early next quarter and all of the planned solubility studies completed before the end of the quarter.

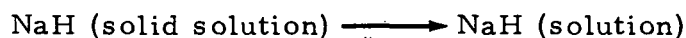
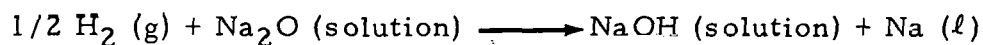
b. Data Analysis (Job 05)

A. A. Gordus*
E. F. Hill
S. A. Meacham

The scope of this work includes a reduction of the experimental data to obtain (1) equilibrium isotherms; (2) saturation pressures, temperatures, and hydrogen content; and (3) other thermodynamic data such as heat of solution, heat of reaction, etc.

The internal consistency of the present data is exceptionally good. As a result, any small deviations from Sievert's Law can be examined and correlated with other factors such as the amount of "dissolved" oxygen.

Evaluation of the experimental data is nearly completed. Values are being obtained for ΔH for reactions given in the following equations:



These values will be presented in a topical report scheduled for publication in FY-1970.

* University of Michigan

2. Cover Gas Impurities (Task 33)

a. Hydrogen Gettering in Gas
Sample Lines (Job 02)

J. H. Coleman
J. A. Ford

The specific objectives of this job are to determine the quantity and composition of deposits collected in the cover gas sampling lines and estimate the error in the cover gas analysis.

After 4 to 5 months of operation at loop temperatures ranging from 600 to 900 F, the sample line was removed and stored in the chemistry laboratory glove box for examination.

A replacement sample line was fabricated and will be installed. The same basic design has been employed with one addition: That addition, a T-section and a valve to allow the addition of calibrated span gas into the sample line, is illustrated on Figure 11.5 by the dotted lines. Any difference between the hydrogen content of the span gas as it passes through the sample line and the analysis of the gas as determined by the chromatograph will be a measure of the error involved in this method of sampling.

b. Compilation of Chromatograph
Experience (Job 03)

J. H. Coleman
J. A. Ford

The objectives of this job are to compile the data from the chromatograph for FY-69 and evaluate it in terms of loop operation and loop chemistry. Specific data may be chosen from earlier periods for comparative purposes.

Nothing to report this period.

D. Sodium Sampling and Analysis

1. Sampling Reliability (Task 70)

a. Hydrogen Sampling (Job 05)

A. J. Friedland
N. N. Mueller

The objective of this test program is to establish the precision of a combined sampling and analysis procedure when sampling 900 F cold-trapped sodium for hydrogen.

The testing phase of this program is complete.

No work was scheduled during this quarter, pending supporting chemical analysis of the sodium samples.

b. Flush Time and Atmospheric Purity Study (Job 06)

A. J. Friedland
N. N. Mueller

To provide information to assist in establishing sodium sampling procedures, the following specific studies are being undertaken:

- Determine the minimum flush time required for sample tubes when sampling 900 F cold trap sodium.
- Demonstrate whether end-crimping of sample tubes isolated at 900 F is an effective means of eliminating the necessity for a high-purity environment when sampling for oxygen.
- Determine the temperature profile during cooling for sample tubes isolated at 900 F.

The testing program is complete. Analysis of the data is being deferred pending availability of sodium chemical analyses, which are expected in April.

c. Topical Report - Oxygen (Job 03)

M. K. Deora
A. J. Friedland

This report is to be a documentation and evaluation of the results obtained from three previously completed sampling reliability tests for oxygen at the 11, 45, and 76 ppm level (APDA-193, -195, and -228). The test results of the round robin test for pinched tubes are also to be incorporated to compare the segregation effect and random site-to-site variation within a sample tube.

The preliminary statistical analysis for the raw data and an outline of the final topical report have been completed. The work towards the write-up of the report is in progress, and it is expected that the draft will be ready for review early next quarter.

2. ASTM Round Robin on Oxygen in Sodium (Task 73)

E. F. Hill
S. A. Meacham

The objectives of this task are

- To prepare samples of sodium containing known quantities of oxygen as specified by the ASTM subcommittee
- To distribute these samples to five participating laboratories

- To collect and evaluate the results obtained by the five laboratories
- To report the results and the committee's conclusions.

The first two objectives were completed in FY-68.

a. Reduction of Data and Report (Job 05)

E. F. Hill

The scope of this job is defined as the reduction, evaluation, and reporting of the data submitted by the five participating laboratories.

During this report period, the final draft of the topical report was prepared and sent to the committee members for comments. These comments have been received and will be incorporated into the final report. A final draft will be sent to the AEC-RDT office for approval before final distribution.

E. Loop Operations

1. Supporting Chemistry Services (Task 51)

a. Uranium Gettering Technique (Job 04)

E. F. Hill
S. A. Meacham

The objectives of this program are

- To briefly review the most pertinent technical literature on the gettering technique for oxygen in sodium.
- To evaluate the proposed Brookhaven technique for oxygen in sodium using uranium as a getter metal in APDA's sodium technology loop.

Ten uranium specimens were procured from BNL. A test program utilizing these uranium specimens has been finalized and the initial evaluation is scheduled early in the next quarter.

III. NEXT REPORT PERIOD ACTIVITIES

A. Impurity Monitoring Devices

1. Rhometer (Task 20)

Calibration and evaluation of the prototype automatic-temperature-compensated Rhometer in the sodium technology loop (Job 06) will be continued.

2. Oxygen Meter (Task 27)

The study of the behavior of the oxygen meter in high temperature loop sodium (Job 05) will be completed.

3. Hydrogen Detector (Task 21)

Jobs 05, 06, and 08 under this task will be completed early in the next quarter and testing of the hydrogen detector in the loop will begin.

4. Plugging Meter (Task 23)

Work on the technical evaluation of test data (Job 06) will be completed.

B. Sodium Purification Processes

1. Centrifuging (Task 12)

The first draft of the topical report (Job 15) will be completed and issued for approval.

Qualitative analysis of the centrifuge bowl residue (Job 16) will be completed.

All preparations necessary to prepare the centrifuge and its related equipment for run No. 2 (Job 18) are scheduled for completion in June.

C. Physical and Chemical Behavior of Sodium Impurities

1. Hydrogen Solubility (Task 31)

The hydrogen solubility test apparatus will be calibrated and the hydrogen absorption studies completed (Job 02). Thermodynamic interpretation of hydrogen solubility test data (Job 05) will continue.

2. Cover Gas Impurities (Task 33)

The original sample line will be examined for sodium and for hydrogen and the new sample line will be installed (Job 02).

Compilation of gas chromatograph experience and evaluation of the data (Job 03) will continue.

D. Sampling and Analysis

1. Sampling Reliability (Task 70)

Work on the technical evaluation of the test data (Jobs 05 and 06) will be completed and reported during the next quarter.

The first draft of the topical report on oxygen sampling and reliability (Job 03) will be completed early in the quarter.

2. ASTM Round Robin on Oxygen in Sodium (Task 73)

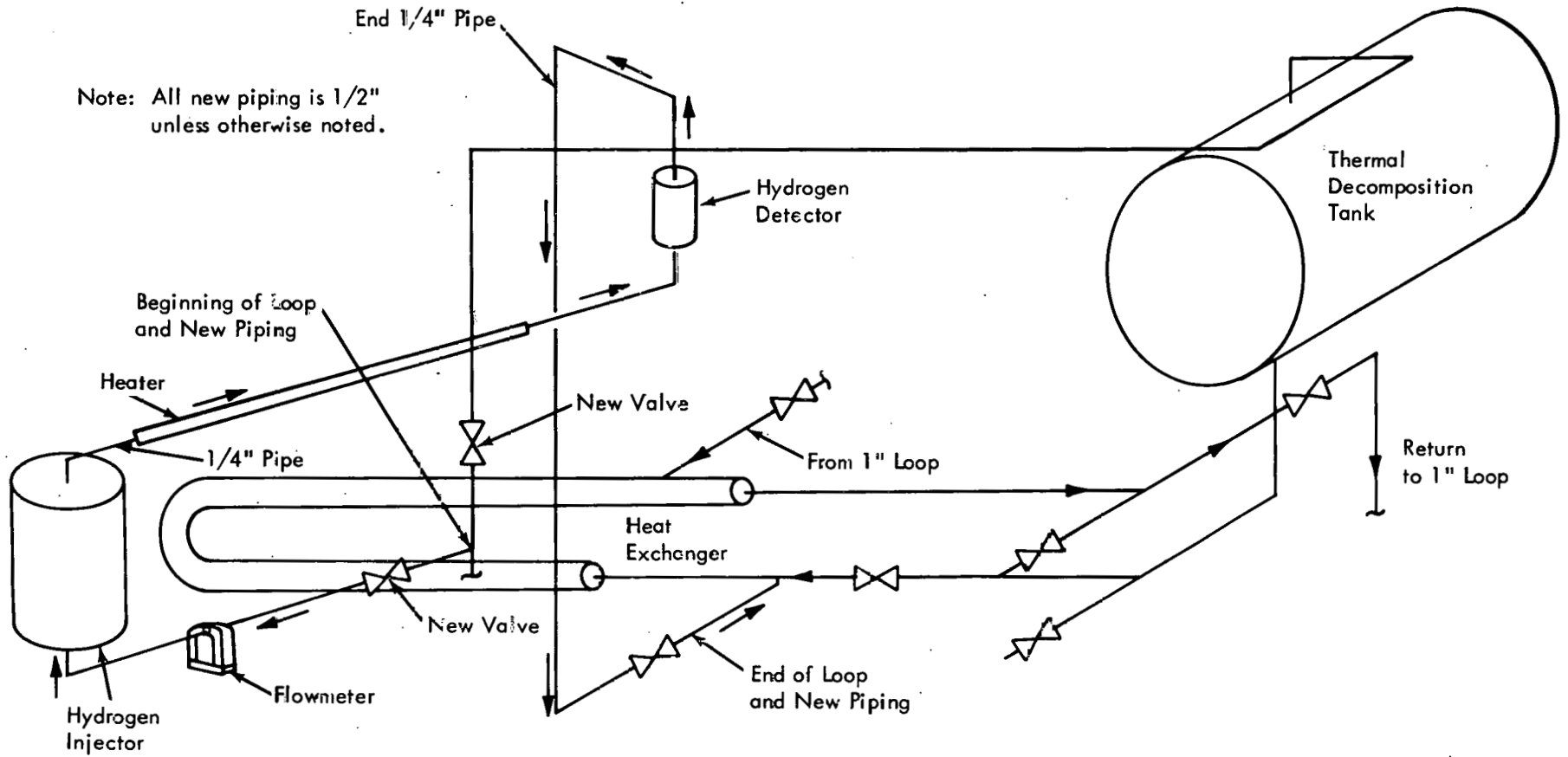
Compilation of the comments of committee members on the final draft of the topical report on this work will be completed and submitted to the AEC for approval.

E. Loop Operations

1. Supporting Chemistry Services (Task 04)

Evaluation of the uranium gettering technique (Job 04) in the sodium technology loop will be completed.

11.12



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FIG. 11.1 LAYOUT OF HYDROGEN DETECTOR TEST LOOP

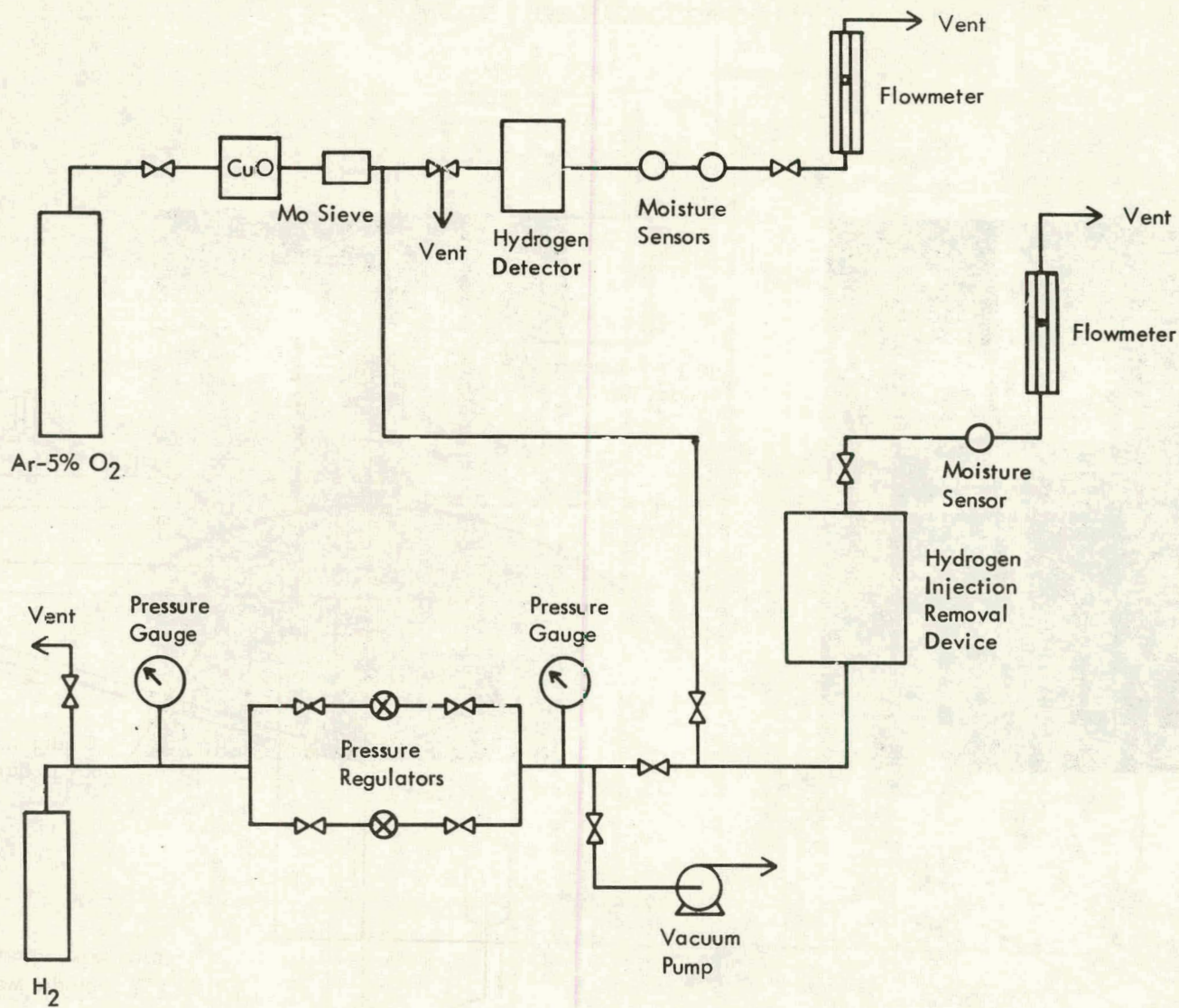


FIG. 11.2 SCHEMATIC OF THE GAS FLOW SYSTEM FOR HYDROGEN DETECTOR LOOP

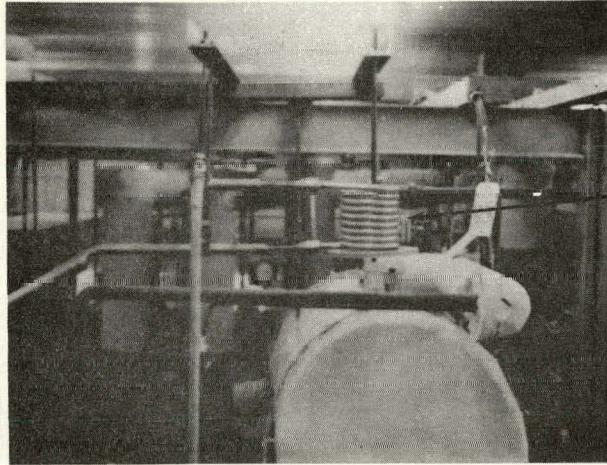
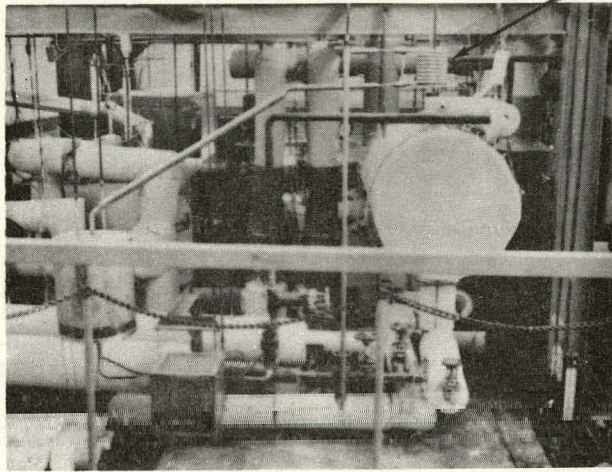


FIG. 11.3 TWO VIEWS OF HYDROGEN DETECTOR INSTALLATION

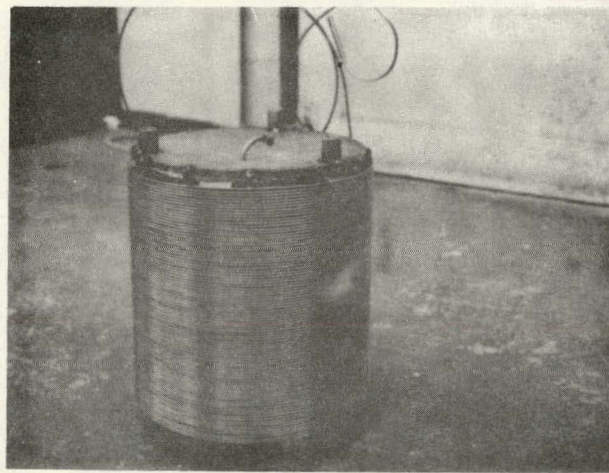
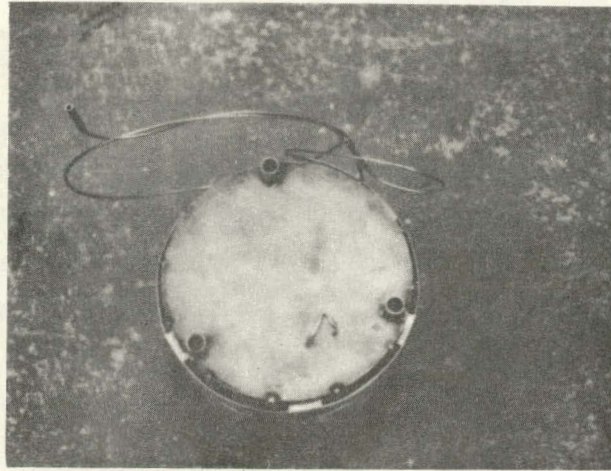
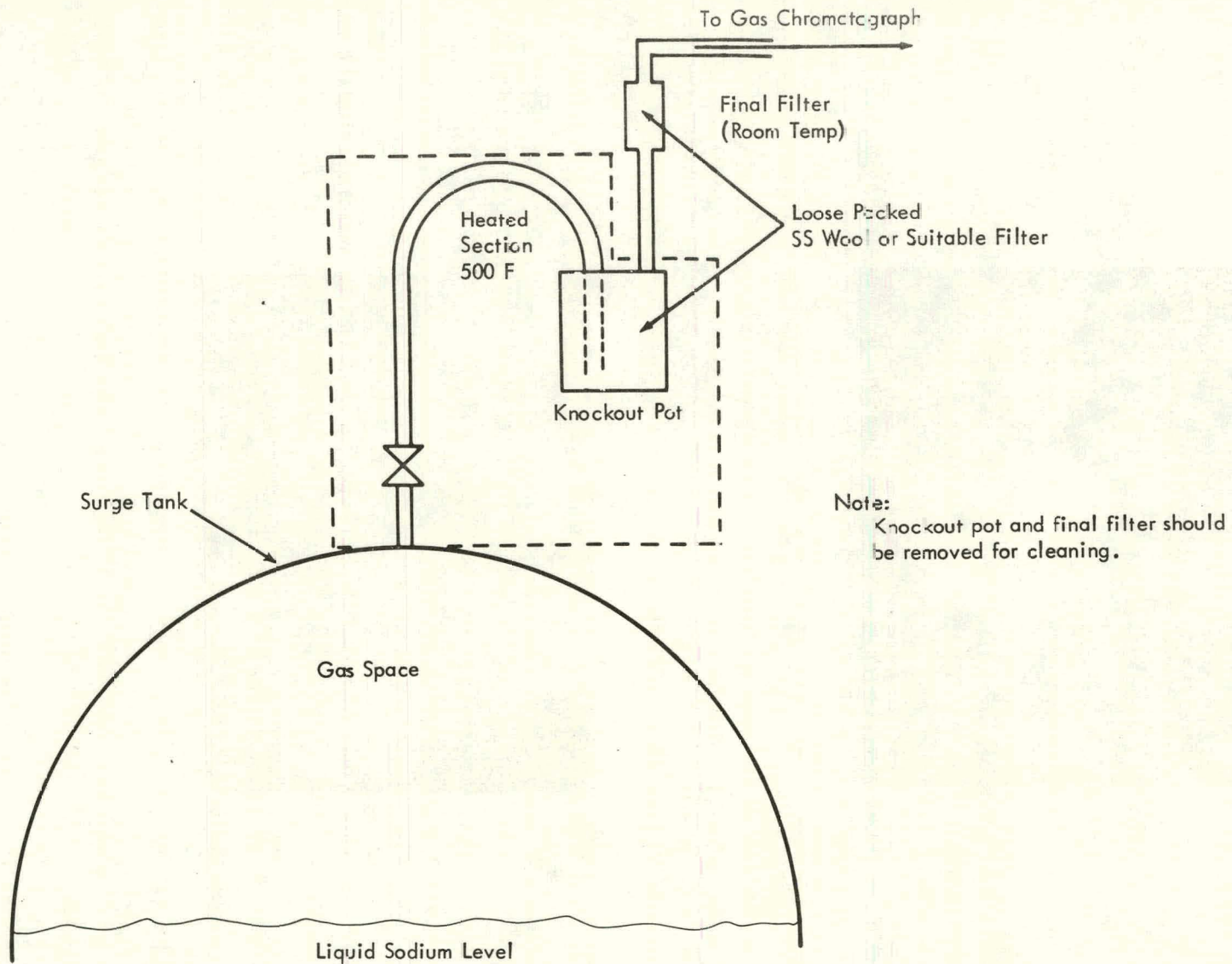


FIG. 11.4 TWO VIEWS OF HYDROGEN DETECTOR REMOVAL COIL



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FIG 11.5 ARRANGEMENT OF THE GAS SAMPLE LINE FOR THE SODIUM TECHNOLOGY LOOP

COMPILATION OF FERMI EXPERIENCE

PROJECT AGREEMENT NO. 15

PROJECT ENGINEER: E. C. Kovacic

I. PREFACE

A. Scope

The purpose of the project is to make available to the fast reactor development program the experience that has been gained from the Enrico Fermi Atomic Power Plant project. The scope of effort covers the compilation of noteworthy experience into reports suitable for general use, starting with the evolution of the design and progressing through the fabrication, construction, testing, and operation of the Fermi plant. Important components and systems will be treated in individual reports which will include sufficient descriptive and background material to make each a reporting entity.

B. Relationship to Other Projects

This project is related generally to the Commission's program of the development of fast reactor technology.

II. TECHNICAL PROGRESS

The progress and status for the reports that had not been formally published prior to the current quarter are as follows:

A. Compilation of Current EFAPP
Experience (Task 19)

R. A. Costello

The reports for the months of September and October, APDA-CFE-25 and APDA-CFE-26, respectively, were issued. Reports for the months of November, December, January, and February are in various stages of preparation.

EFAPP Primary Sodium System
Pumps, APDA-309 (Task 20)

T. P. Ross

The second draft of this report is complete and in the editing process.

III. NEXT REPORT PERIOD ACTIVITIES

A. Compilation of Current EFAPP Experience

Reports for the months November through March will be issued and reports for April and May will be initiated.

B. EFAPP Primary Sodium System Pumps

Preparation of this report will be completed and the draft will be transmitted to the Commission for approval prior to publication.

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