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Consumers Power Company

General Offices: 212 West Michigan Avenue, Jackson, Michigan 49201 • Area Code 517 788-0550

March 1, 1976

Director of Nuclear Reactor Regulation
US Nuclear Regulatory Commission
Washington, DC 20555

DOCKET 50-255, LICENCE DPR-20
PALISADES PLANT - TUBE BURST
AND LEAKAGE TEST REPORT

Our letter of January 30, 1976 proposed Technical Specifications changes relating to steam generator tube plugging criteria for the Palisades Plant. In that letter, we indicated that the Nuclear Steam Supply System Vendor was conducting a testing program and analysis relative to acceptable steam generator tube leakage. On February 26, 1976 we presented the results of the testing program and analysis to members of your staff. This letter transmits the report, "Tube Burst and Leakage Test (Palisades)", CENC-1256, which describes the testing program and analysis.

As discussed in the February 26, 1976 meeting, we have concluded that our January 30, 1976 Technical Specifications request with respect to allowable primary to secondary leakage should be amended. We expect to submit this amendment by March 15, 1976.

David A. Bixel

David A. Bixel
Assistant Nuclear Licensing Administrator

CC: JGKepper, USNRC

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50-255

Rec'd w/ltr 3-1-76

TUBE BURST AND LEAKAGE TEST (PALISADES) CENC-1256

J. K. Hayes
Lab Supervisor

February 1976

Components Engineering Test Laboratory
Chattanooga, Tennessee

CETL-2-76(R1)

2189

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ABSTRACT

This report documents the leak rate and burst tests performed on virgin, wasted, and wasted (with EDM cracks) tube speciments. All tube specimens were acquired from one steam generator tube of Inconel 600 material having a yield strength of 40,000 psi, a tensile strength of 91,000 psi and an elongation of 49% in two inches. The tube was nominally .750" O.D. X .048" average wall thickness.

A total of 27 tube specimens were prepared for test purposes. Selected tubes were machined to simulate uniform wastage (nominal 64% of tube wall removed) as shown on C-E Dwg. D-62676-003 which is located in this section of the report.

Approximately 1/2 of the tube specimens were prepared with cracks. The cracks were 1/4" in length machined parallel to the axis of the tubes. The cracks were machined using an Electric Discharge Machine (EDM). A 1/4" X .005" silver solder electrode was used. Since the electrode is always discharging as it progresses through the metal this provides a larger crack opening at the top than at the bottom. In some instances a variation in crack width also occurred. The crack width ranged from .007" to a maximum of .014" at the bottom of the crack. All crack measurements are documented in this report.

A brief discussion of the results of the various tests is provided below:

Burst Tests - Both simulated wasted and virgin tubes were ruptured under water pressure at room temperature conditions. Two of the wasted tubes were subjected to bending load such as to produce a maximum stress in the outer fiber equal to 35 ksi. The burst test results are provided in Table 1 of this section of the report.

Based on this data (2 tube samples of each type) it may be concluded that the average burst pressure is reduced approximately as follows compared to the virgin specimen for the various conditions:

Spec. Config. No.	Description	Ratio of Specimen Burst Pressure To Virgin Tube Burst Pressure
1	1/2" wasted all around (.017" MWT)	65%
2	5/16" wasted all around with bending load (.017" MWT)	68%
3	5/16" wasted all around (.017" MWT)	69%
4	1/2" long dished wastage, one side (.017" MWT)	63%

Based on the preceding, each condition produces approximately the same drop in burst pressure with the 1/2" long wasted condition being slightly more severe.

In inspecting the bursted test specimens the following types of failures were noted:

Spec. Config. No.	Type of Failure
1	Bulged in wasted region. Crack occurred transverse to tube axis for approximately 1/3 of circumference.
2,3	Tube failed by complete circumferential seperation at wastage region.
4	Bulging and rupture of tube in local region of wastage.
6 (Virgin Tube)	Bulging of entire tube occurred. O.D. of tube increased from .75" to .9". At failure tube split parallel to axis of tube.

Leak Tests - Both virgin and wasted tubes with EDM cracks (essentially 1/4" long) were leak tested with pressurized water under room temperature conditions. As noted earlier the width of the cracks in the various specimens varied to some extent at the bottom of the crack. Two to three specimens of each configuration were leak tested. Plots of the leak rate (GPM) versus pressure (psig) are contained in this report for each specimen.

Two different piping arrangements were used with an MTS servo controlled system and an oil to water intensifier. The maximum pumping rate with one arrangement was approximately 4 to 5 gpm and with the revised piping arrangement 14 gpm. This test phase was terminated when the maximum pressure was attained that could be achieved by the hydraulic system.

A summary data sheet showing the specimen number, crack width, leak rate at two pressures, maximum differential pressure imposed on the tube, and final appearance of specimen is shown in Table 2 of this section of the report.

Figure 1 contained in this section of the report provides a plot of average flow rate versus pressure for each test configuration. In reviewing this plot the following conclusions may be reached:

(A) At 1200 psig pressure differential the leak rate did not exceed 3 gpm for all test configurations.

(B) From the plots it may be concluded that local bulging of the tubes, resulting in greater increase in crack width opening, is starting to occur where the plots start deviating from a straight line.

However, it should be noted that this is not indicative of imminent tube failure as is apparent in the subsequent section.

Maximum Differential Pressure Test - Since the capacity of the hydraulic system could not exceed approximately 14 gpm it was considered desirable to utilize a system which could impose a higher differential pressure on the specimens containing EDM cracks. The piping arrangment shown on C-E Dwg. C-62676-004 was subsequently assembled. With this arrangement it was possible to pressurize both the I.D. and O.D. of the tube to the same pressure and then quickly vent the external pressure such as to achieve a high differential pressure. Sufficient volume existed on the primary side of the tube to allow flow through the crack for a very short interval.

It was decided to pressurize the specimens to a value not exceeding 5000 psig prior to the secondary side venting operation. Differential pressures of approximately 4600 to 4800 psig were subsequently measured using a differential pressure cell and a strip chart recorder. Measurements were made of the maximum crack opening at the end of the test and photographs were made. This test data is summarized in Table 2 in this section of the report and the photographs are included in the appendix.

In reviewing the information contained in Table 2 the following conclusions may be reached regarding the condition of the cracked tubes after being subjected to a pressure differential of 4600 to 4800 psig:

(A) Some bulging of the tubes occurred in the wasted region in the vicinity of the cracks.

(B) The cracks increased in width at the center but generally did not increase in length. When the crack did increase in length it did not exceed 1/16 inch at each end of crack. The crack openings varied as follows:

Config. No.	Type	Maximum Crack Width Opening
1	1/2" long wasted all around	.050" to .085" (Max. pressure 4700 psig)
2	5/16" long wasted all around	.025" to .027" (Bending load & pressure, maximum pressure of 4000 psig)
3	5/16" long wasted all around	.044" to .059" (Max. pressure of 4800 psig)
4	1/2" long dished wasted one side of tube	.032" (Max. pressure of 4900 psig)

(C) Based on (A) and (B) it may be concluded that with this type wastage and size cracks catastrophic failure of the tubes will not occur at pressure differentials up to 4800 psig under the conditions tested. The crack width openings will only increase to some extent resulting in increased flow rates.

Prepared by:

J. K. Hayes
Task Investigator
(Lab Supervisor)
Components Engineering
Test Laboratory

Accepted by:

F. P. Hill, Jr.
Manager
Analytical Engineering
Department

Approved by:

T. Halvorsen
Manager
Engineering Services

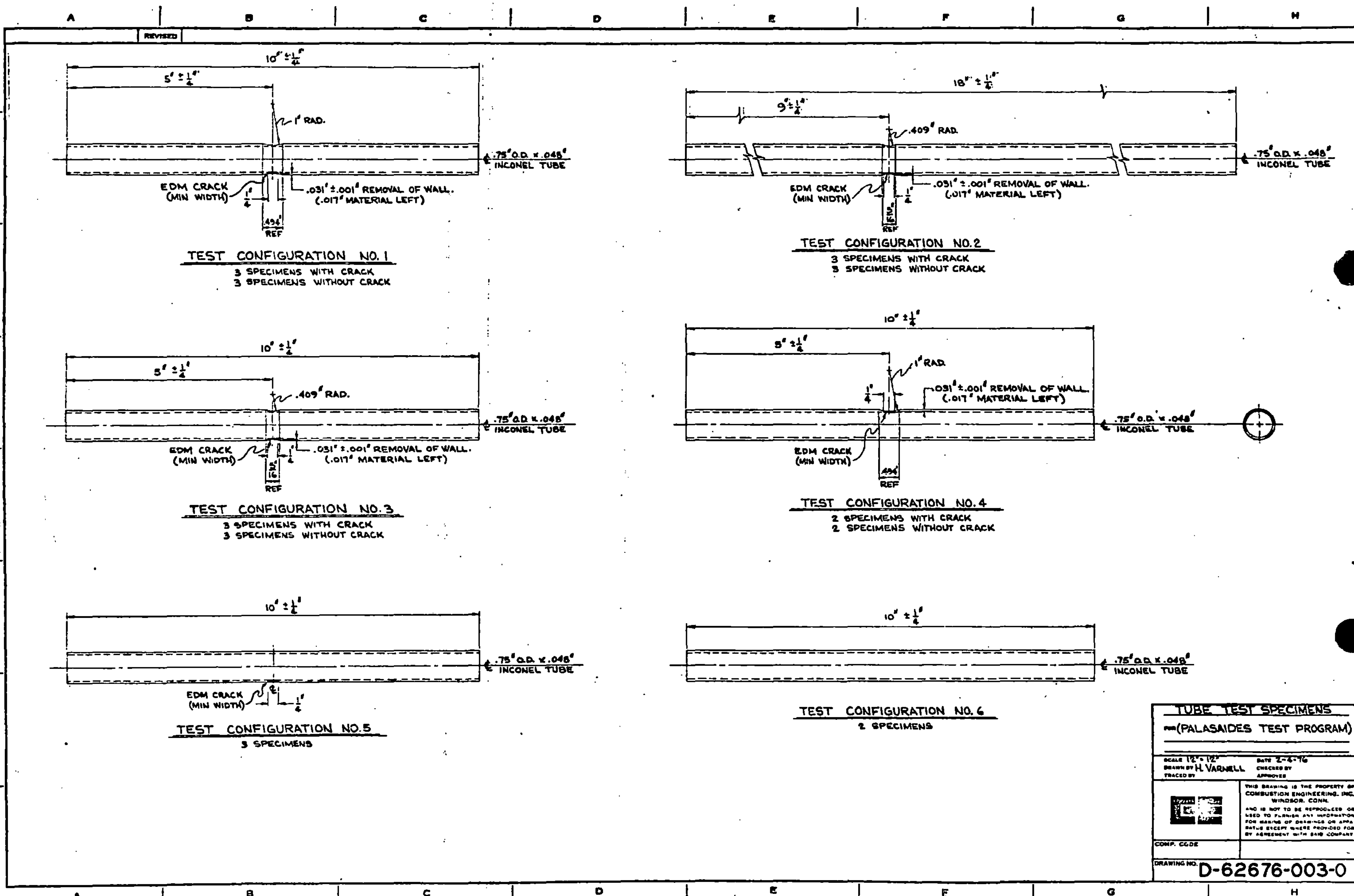
REVISED
10" ± 1/4"
5" ± 1/4"
1" RAD.
.75" O.D. x .048"
INCONEL TUBE
EDM CRACK
(MIN WIDTH)
.031" ± .001" REMOVAL OF WALL.
(.017" MATERIAL LEFT)
.494"
REF
TEST CONFIGURATION NO. 1
3 SPECIMENS WITH CRACK
3 SPECIMENS WITHOUT CRACK
18" ± 1/4"
9" ± 1/4"
.409" RAD.
TEST CONFIGURATION NO. 2
3 SPECIMENS WITH CRACK
3 SPECIMENS WITHOUT CRACK
.409" RAD.
TEST CONFIGURATION NO. 3
3 SPECIMENS WITH CRACK
3 SPECIMENS WITHOUT CRACK
TEST CONFIGURATION NO. 4
2 SPECIMENS WITH CRACK
2 SPECIMENS WITHOUT CRACK
TEST CONFIGURATION NO. 5
3 SPECIMENS
TEST CONFIGURATION NO. 6
2 SPECIMENS
TUBE TEST SPECIMENS
FOR (PALASAIDES TEST PROGRAM)
SCALE 12" = 12"
DATE 2-4-76
DRAWN BY H. VARNELL
CHECKED BY
TRACED BY
APPROVED
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Table 1

Tube Burst Tests

(Palisades)

Tube Size - .750"O.D. X .048"W.T., Material - Inconel 600

Specimen No.	Configuration No.	Brief Description of Specimen	Burst Pressure
1-1	1	1/2" long wastage all around	7400
3-1	1	1/2" long wastage all around	7450
*1-2	2	5/16" long wastage all around	*7700
*2-2	2	5/16" long wastage all around	*7900
4-3	3	5/16" long wastage all around	7800
5-3	3	5/16" long wastage all around	8000
3-4	4	1/2" long dished wastage one side	7000
4-4	4	1/2" long dished wastage one side	7500
1-6	6	Virgin Tube	11,900
2-6	6	Virgin Tube	11,100

Comments: *Bending load applied such as to produce bending stress equal to 35 ksi.

See C-E Drawing C-62676-006 for test apparatus.

Table 2. Summary Sheet for Specimens With EDM Cracks

Spec No.	Spec Config.	Description of Wastage	Crack Width at Bottom	Leak Rate Pressure	Leak Rate GPM	Max. Pressure Differential (PSIG)	Final Description of Specimen
4	1	1/2" long wastage all around	.007"	1400	1.8		
				2400	3.3	4700	Crack opened to .085"
							at the center.
5	1	1/2" long wastage all around	.008"	1400	2.6		
			to	2400	5.0	+3700	Crack opened to .050"
			.010"				at the center.
6	1	1/2" long wastage all around	.008"	1400	1.8		
			to	3560	7.2	4700	Crack opened to .072"
			.009"				at the center.
3	*2	5/16" long wastage all around	.007"	1400	2.0		
			to	2400	3.0		
			.012"	4000	6.6	4000	Crack opened to .027"
							at the center.
4	*2	5/16" long wastage all around	.012"	1400	3.2		
			to	2400	4.5		
			.013"	3950	8.3	3950	Crack opened to .025"
							at the center.

Comments: * These specimens tested with bending load such as to produce maximum stress equal to yield stress at outer fiber.

+ Solenoid valve failed. This was last specimen tested.

Table 2. Summary Sheet for Specimens With EDM Cracks

Spec No.	Spec Config.	Description of Wastage	Crack Width at Bottom	Leak Rate Pressure	Leak Rate GPM	Max. Pressure Differential (PSIG)	Final Description of Specimen
1	3	5/16" long wastage all around	.010"	1400	3.1		
			to	2400	4.8	4800	Crack opened to .044"
			.011"				at the center.
2	3	5/16" long wastage all around	.013"	1400	4.0		
			to	2400	5.5	4800	Crack opened to .054"
			.014"				at the center.
3	3	5/16" long wastage all around	.008"	1400	2.1		
			to	2260	4.1	+4100	Crack opened to .059"
			.009"				at the center.
1	4	5/16" long wastage all around	.007"	1400	2.0		
			to	2400	2.9		
			.008"	3500	4.5	4900	Crack opened to .032"
							at the center.
2	4	5/16" long wastage all around	.008"	1400	2.25		
				2400	3.0		
				3450	5.0	4900	Crack opened to .032"
							at the center.

Comments: + Shims placed in crack to increase pressure. Tube not tested in maximum differential pressure device.

Table 2. Summary Sheet for Specimens With EDM Cracks

Spec No.	Spec Config.	Description of Wastage	Crack Width at Bottom	Leak Rate Pressure	Leak Rate GPM	Max. Pressure Differential (PSIG)	Final Description of Specimen
1	5	Virgin	.007"	1400	2.7		
			to	3500	4.8	3500	
			.009"				
2	5	Virgin	.008"	1400	2.15	3500	
			to	3500	3.7		
			.009"				
3	5		.007"	1400	1.05		
			to	4400	3.5	5100	Very slight bulging in
			.009"				vicinity of crack. No
							apparent change in
							crack dimensions.

Comments: ______________________________

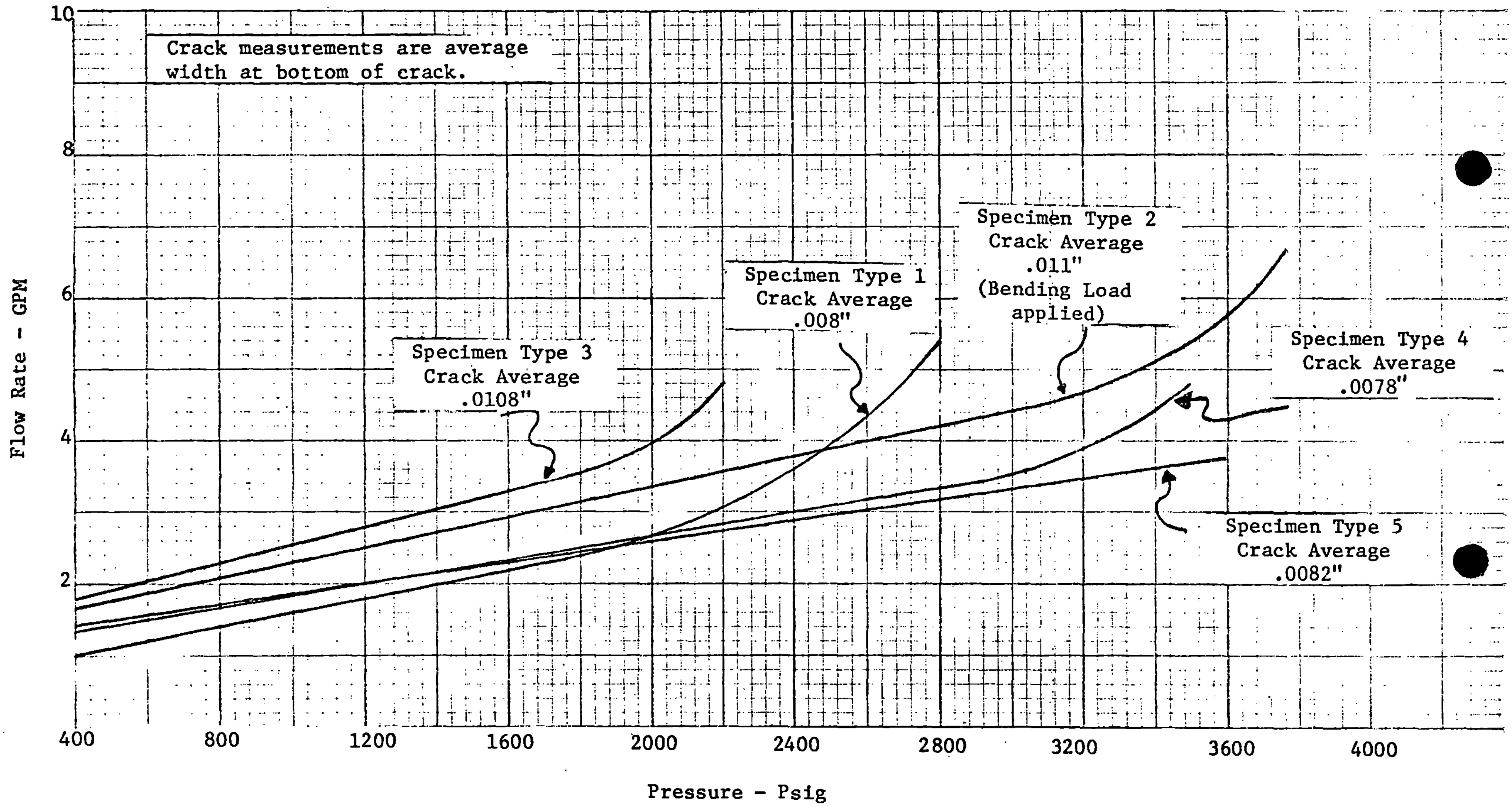
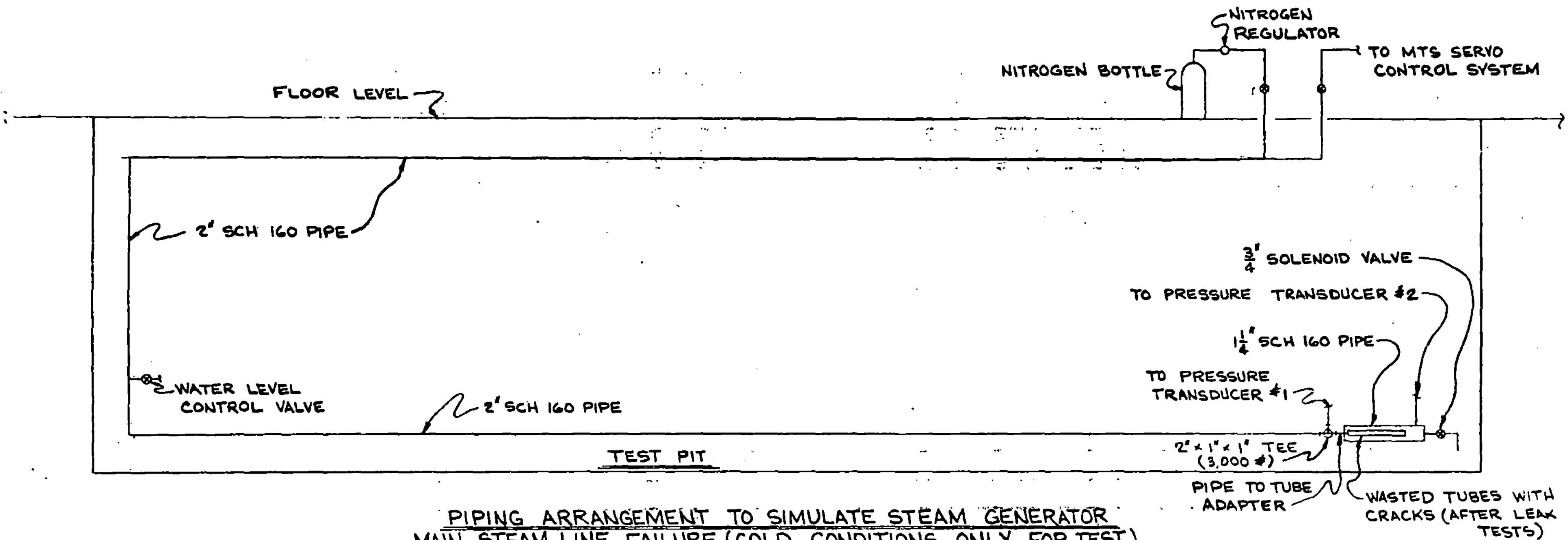


Figure 1. Average Flow Rate Vs. Pressure (Test Configurations 1 through 5)



PIPING ARRANGEMENT TO SIMULATE STEAM GENERATOR MAIN STEAM LINE FAILURE (COLD CONDITIONS ONLY FOR TEST)

PIPING SCHEMATIC

FOR PALASAIDES TEST PROGRAM

SCALE ~
DRAWN BY H. VARNELL
TRACED BY
DATE 2-5-76
CHECKED BY
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DRAWING NO. C-62676-004-0

CONTENTS

1.0 PURPOSE

The general problem is that of tube degradation and the allowable pressures for particular degradations. The type degradations to be investigated are:

(A) Uniform wastage - Nominal tube size .750" O.D. X .048" wall thickness. Wastage shall be such as to reduce wall thickness to .017 inches.

(B) Longitudinal through wall cracks superposed upon the wastage.

2.0 OBJECTIVES

The objectives of the tests are as follows:

(A) Determine burst pressures at room temperature for tubes with no degradation and with simulated wastage degradation alone.

(B) Determine leak rates vs. pressure for tubes with no wastage degradation and through-the-wall cracks; and for tubes with wastage and cracks.

(C) With tubes containing simulated wastage and cracks impose maximum differential pressure feasible (approximately 5,000 psi) and identify physical changes in the tube at the crack location.

3.0 DESCRIPTION OF TEST SPECIMENS

All tubular test specimens were cut from one steam generator tube to ensure there would be no variation in material properties. The mill test report for this tubing is contained in Appendix E.

The fabrication drawing used for preparing the test specimens is provided in Appendix A. Six seperate specimen configurations are identified with the desired simulated wastage shown for each specimen. The quantity of specimens with and without EDM cracks are also shown. Throughout the test report the specimens are identified by two numbers. The first number is the specimen number in a particular test configuration. The second number identifies the test configuration. The test plan for the specimens is provided in Table 1A of Appendix B.

The "as built" dimensions of the specimens are shown in Table 3 located in Appendix B. The machined dimensions of the EDM (Electric Discharge Machine) cracks are also provided in Table 4 in Appendix B.

The cracks were machined with an Electric Discharge Machine (EDM) using a .005" silver solder electrode. Since the electrode is always discharging as it progresses through the metal this provides a larger crack opening at this top than at the bottom. In some instances a variation in crack width also occurred. The crack width ranged from .007" to a maximum of .014" at the bottom of the crack as shown in Table 4.

4.0 DISCUSSION OF TEST RESULTS

Burst Tests - Both simulated wasted and virgin tubes were ruptured under water pressure at room temperature conditions. Two of the wasted tubes were subjected to bending load such as to produce a maximum stress in the outer fiber equal to 35 ksi. The burst test results are provided in Table 1 of Appendix B.

Based on this data (average of two specimens) it may be concluded that the average burst pressure is reduced approximately as follows compared to the virgin specimen for the various conditions:

Spec. Config. No.	Description	Ratio of Specimen Burst Pressure To Virgin Tube Burst Pressure
1	1/2" wasted all around (.017" MWT)	65%
2	5/16" wasted all around with bending load (.017" MWT)	68%
3	5/16" wasted all around (.017" MWT)	69%
4	1/2" long dished wastage, one side (.017" MWT)	63%

Based on the preceding, each condition produces approximately the same drop in burst pressure with the 1/2" long wasted condition being slightly more severe.

In inspecting the bursted test specimens the following types of failures were noted:

Spec. Config. No.	Type of Failure
1	Bulged in wasted region. Crack occurred transverse to tube axis for approximately 1/2 of circumference.
2,3	Tube failed by complete seperation at wastage region.
4	Bulging and rupture of tube in local region of wastage.
6 (Virgin Spec.)	Bulging of entire tube occurred. O.D. of tube increased from .75" to .9". At failure tube split parallel to axis of tube.

Photographs of the following specimens after the burst test are contained in Appendix D:

Photo No.	Spec. No.	Description
1,2	1-1	1/2" wasted all around
3	3-1	5/16" wasted all around
18	*1-2	5/16" wasted all around
20	4-3	5/16" wasted all around
31,32	3-4	1/2" dished wastage, one side
33,34	4-4	1/2" dished wastage, one side
40,41	1-6	Virgin tube
42,43	2-6	Virgin tube

* Burst Test with bending

Leak Rate Tests - Both virgin and wasted tubes with EDM cracks (essentially 1/4" long) were leak tested with pressurized water under room temperature conditions. As noted earlier the width of the cracks in the various specimens varied to some extent at the bottom of the crack. See Table 4 in Appendix B for detail dimensions. Two to three specimens of each configuration were leak tested. Plots of the leak rate (GPM) versus pressure (psig) are contained in this report for each specimen. These plots are identified as Figures 1 through 6 and are contained in Appendix C. Figure 1 is a plot of the average flow rate versus pressure. Tabular data of all leak rate tests is shown in Table 5 in Appendix B.

The leak rate data for the 1/2" long wasted (all around) tubes is shown in Figure 2. It appears that crack widening is starting to occur at 2400 psig since one of the curves starts to deviate from a straight line.

In Figure 3 it can be readily seen that the bending load (crack on neutral axis) did slightly increase the leak rate for the 5/16" wasted (all around) specimens. A good comparison between crack on the neutral axis and compressive side was not feasible since the crack width varied between the two specimens. Crack widening of the tubing apparently occurred at around 3200 psig.

In Figure 4 the leak rates for the 5/16" wasted (all around) tubes vary as would be expected in that the specimen with the largest crack width had the largest leak rate. Apparently, crack widening of this tubing started occurring around 2000 psig.

In Figure 5 crack widening of the 1/4" long dished (one side only) samples started to occur at around 2800 psig.

In Figure 6 it is apparent that no appreciable changes in the crack width occurred in the virgin tubes up to a pressure of 3600 psig.

Two different piping arrangements were used with an MTS servo controlled system and an oil to water intensifier. The maximum pumping rate with the first arrangement was approximately 4 to 5 gpm and with the revised piping arrangement 14 gpm. This test phase was terminated when the maximum pressure was attained that could be achieved by the hydraulic system.

A summary data sheet showing the specimen number, crack width, leak rate at two pressure, maximum differential pressure imposed on the tube, and final appearance of specimen is shown in Table 2 in Appendix B.

Figure 1 contained in Appendix C provides a plot of average flow rate versus pressure for each test configuration. In reviewing this plot the following conclusions may be reached:

(A) At 1200 psig pressure differential the leak rate did not exceed 3 gpm for all test configurations.

(B) From the plots it may be concluded that local crack widening resulting in greater increase in crack opening, is starting to occur where the plots start deviating from a straight line. However, it should be noted that this is not indicative of imminent tube failure as is apparent in the subsequent section.

Maximum Differential Pressure Test - Since the capacity of the hydraulic system could not exceed approximately 14 gpm it was considered desirable to utilize a system which could impose a higher differential pressure on the specimens containing EDM cracks. The test arrangement discussed in Section 5.0 was utilized. With this arrangement it was possible to pressurize both the I.D. and O.D. of the tube to the same pressure and then quickly vent the external pressure such as to achieve a high differential pressure. Sufficient volume existed on the primary side of the tube to allow flow through the crack for a very short interval.

It was decided to pressurize the specimens to a value not exceeding 5000 psig prior to the secondary side venting operation. Differential pressures of approximately 4600 to 4800 psig were subsequently measured using a differential pressure cell and a strip chart recorder. Measurements were made of the maximum crack opening at the end of the test and photographs were made. This test data is summarized in Table 2 of Appendix B. Photographs of the test specimens are included in Appendix D.

In reviewing the information contained in Table 2 the following conclusions may be reached regarding the condition of the cracked tubes after being subjected to a pressure differential of 3700 to 4900 psig:

(A) Some local puckering of the tubes occurred in the wasted region in the vicinity of the cracks in range of 3700 to 4900 psig for 1/2" long wasted (all around) tubes.

(B) Local puckering was barely visible for the 5/16" long wasted tubes up to 4000 psig. More identifiable puckering was evident after pressurization from 4000 to 5000 psig. However, this puckering was less than for the 1/2" long wasted (all around) tubes.

(C) The cracks increased in width at the center but generally did not increase in length. When the crack did increase in length it did not exceed 1/16 inch at each end of crack. The crack openings varied as follows:

Config. No.	Type	Maximum Crack Width Opening
1	1/2" long wasted all around	.050" to .085" (Max. pressure 4700 psig)
2	5/16" long wasted all around	.025" to .027" (Bending load & pressure, maximum pressure of 4000 psig)
3	5/16" long wasted all around	.044" to .054" (Max. pressure of 4800 psig)
4	1/2" long dished wasted one side of tube	.032" (Max. pressure of 4900 psig)

(D) Based on (A), (B), and (C) above it may be concluded that with this type wastage and size cracks catastrophic failure of the tubes will not occur at pressure differentials up to 4800 psig under the conditions tested. The crack opening (width) will only increase to some extent resulting in increased flow rates.

5.0 DESCRIPTION OF TEST FACILITY

(A) Burst and Leak Rate Test Equipment

Equipment for burst and leak rate test consisted of an MTS closed loop hydraulic servo control system with a hydraulic power supply of 35 gpm at 3000 psi as shown on C-E Dwg. C-62676-005 shown in Appendix A. A pressure transducer near the test specimen links the MTS system controls to the desired pressure at the test specimen. An oil to water intensifier is used to provide water at elevated pressures for testing of the specimens. The intensifier was used in two different arrangements, one provided higher pressures, required for burst testing, the other arrangement provided a greater flow rate (but lower maximum pressure) used for testing of specimens requiring the higher flow rates. The intensifier was filled with city water for each test. Water flow was limited to approximately 3 gpm for the high pressure arrangement and approximately 14 gpm for the high flow rate arrangement.

For the leak rate tests a pipe to tube adapter and an outer pipe over the tube was used to contain and collect the water as shown on C-E Dwg. C-62676-005. After the desired pressure was achieved for each leak rate test the water was collected for a specific time interval (stop watch used) and then the water weighed and the flow rate calculated, tabulated in Table 5 in Appendix B and plotted.

For the leak rate tests in which bending was employed the test arrangement shown on C-E Dwg. C-62676-006 was utilized. A copy of the drawing is contained in Appendix A. The leaking water was trapped in a plastic tee with o-ring seals in the vicinity of the crack. The water leaking out of the branch of the tee was then collected and weighed as discussed previously. Prior to the leak rate test each wasted specimen was loaded to produce a maximum bending stress at the outer fiber of the wasted section of 35 ksi.

All burst tests were performed with the specimens in the test pit as shown on C-E Dwgs. C-62676-005 and C-62676-006. The wasted specimens were loaded in the same manner in the test pit for the burst tests.

(B) Maximum Pressure Differential Test

As noted earlier the hydraulic system had limited capacity. It was therefore decided that to achieve the desired high pressure differential that the piping system shown on C-E Dwg. C-62676-004 should be assembled. With the arrangement it was possible to fill the primary and secondary side of the tubing with water and maintain an air reservoir of approximately the same volume over the water on the primary side. To achieve the desired pressure the 2" pipe was first pressurized with nitrogen to 2500 psig and then the MTS system used to raise the pressure to 5000 psig. A differential pressure transducer was piped to connections 1 and 2 shown on C-E Dwg. C-62676-004.A Heise gage was used to monitor the total pressure. A strip chart recorder was also used to record the differential pressure reading versus time.

When the desired test pressure was reached (generally 5000 psig) the strip chart recorder was activated at 125 mm/minute and the solenoid valve energized. This very quickly vented the secondary pressure resulting in a pressure differential of 4600 to 4800 psig (per strip chart). The pressure differential then dropped in a few seconds as the reserve water flowed through the leak. This system worked very satisfactorily.

6.0 CONCLUSIONS

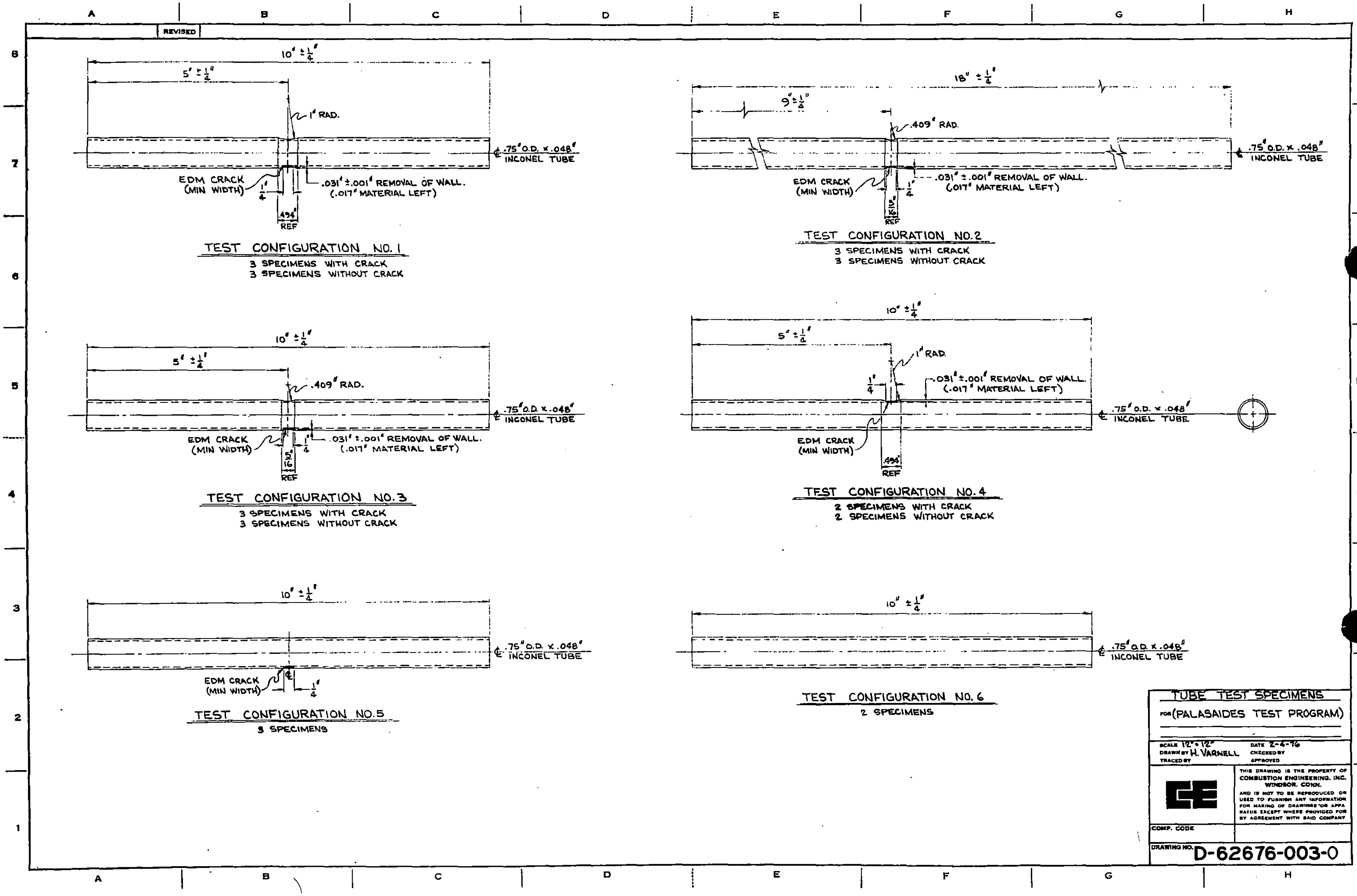
The burst pressure of tubes with no through wall cracks and with 64% through wall wastage (remaining wall thickness = .017") is approximately 63% to 69% of that for a virgin tube, the smallest burst pressure measured at room temperature being 7000 psi. This would correspond to a burst pressure of approximately 6150 psi at 600°F. This represents a margin against bursting of 6150/1380 = 4.46 for the specified operating conditions. The reinforcing influence of the unwasted portions of the tube accounts for the difference from the 4140 psi calculated burst pressure for the 64% wasted tube.

The tubes with 1/4 inch long machined through wall cracks at the 64% wasted locations exhibited leak rates between 2 and 3.5 gallons per minute at 1380 psi, with the leak rates increasing to between 3 and 5.5 gallons per minute at 2500 psi. The "bulge" pressure of these tubes was determined to be in the range 4600 psi to 4800 psi at which time the cracks had not propogated in the longitudinal direction but had widened considerably. This indicates that the tubes with through wall cracks will leak considerably beyond the leak detection levels at 1380 psi differential pressure, and that the leak rates at 2500 psi differential pressure will increase to only approximately twice those at 1380 psi. The margin to the bulge pressure is up to approximately 4700 psi. At 600°F the bulge pressure could be expected to be approximately 4100 psi.

Thus the leakage rates above the leak detection levels at operating pressures with a bulge pressure of more than 4000 psi indicate the leaks through cracks to be detected during operation with a margin against bulging and gross leakage up to in excess of 4000 psi.

APPENDIX A

Drawings of Test Specimens
And Test Apparatus



REVISED
10" ± 1/4"
5" ± 1/4"
1" RAD.
.75" O.D. × .048" INCONEL TUBE
EDM CRACK (MIN WIDTH)
1/4"
.031" ± .001" REMOVAL OF WALL. (.017" MATERIAL LEFT)
.494" REF
TEST CONFIGURATION NO. 1
3 SPECIMENS WITH CRACK
3 SPECIMENS WITHOUT CRACK
18" ± 1/4"
9" ± 1/4"
.409" RAD.
.75" O.D. × .048" INCONEL TUBE
EDM CRACK (MIN WIDTH)
.031" ± .001" REMOVAL OF WALL. (.017" MATERIAL LEFT)
1/4
5/16 REF
TEST CONFIGURATION NO. 2
3 SPECIMENS WITH CRACK
3 SPECIMENS WITHOUT CRACK
10" ± 1/4"
5" ± 1/4"
.409" RAD.
.75" O.D. × .048" INCONEL TUBE
EDM CRACK (MIN WIDTH)
.031" ± .001" REMOVAL OF WALL. (.017" MATERIAL LEFT)
1/4
5/16 REF
TEST CONFIGURATION NO. 3
3 SPECIMENS WITH CRACK
3 SPECIMENS WITHOUT CRACK
10" ± 1/4"
5" ± 1/4"
1" RAD.
1/4"
.031" ± .001" REMOVAL OF WALL. (.017" MATERIAL LEFT)
.75" O.D. × .048" INCONEL TUBE
EDM CRACK (MIN WIDTH)
.494 REF
TEST CONFIGURATION NO. 4
2 SPECIMENS WITH CRACK
2 SPECIMENS WITHOUT CRACK
10" ± 1/4"
.75" O.D. × .048" INCONEL TUBE
EDM CRACK (MIN WIDTH)
1/4
TEST CONFIGURATION NO. 5
3 SPECIMENS
10" ± 1/4"
.75" O.D. × .048" INCONEL TUBE
TEST CONFIGURATION NO. 6
2 SPECIMENS
TUBE TEST SPECIMENS
FOR (PALASAIDES TEST PROGRAM)
SCALE 12" = 12"
DATE 2-4-76
DRAWN BY H. VARNELL
CHECKED BY
TRACED BY
APPROVED
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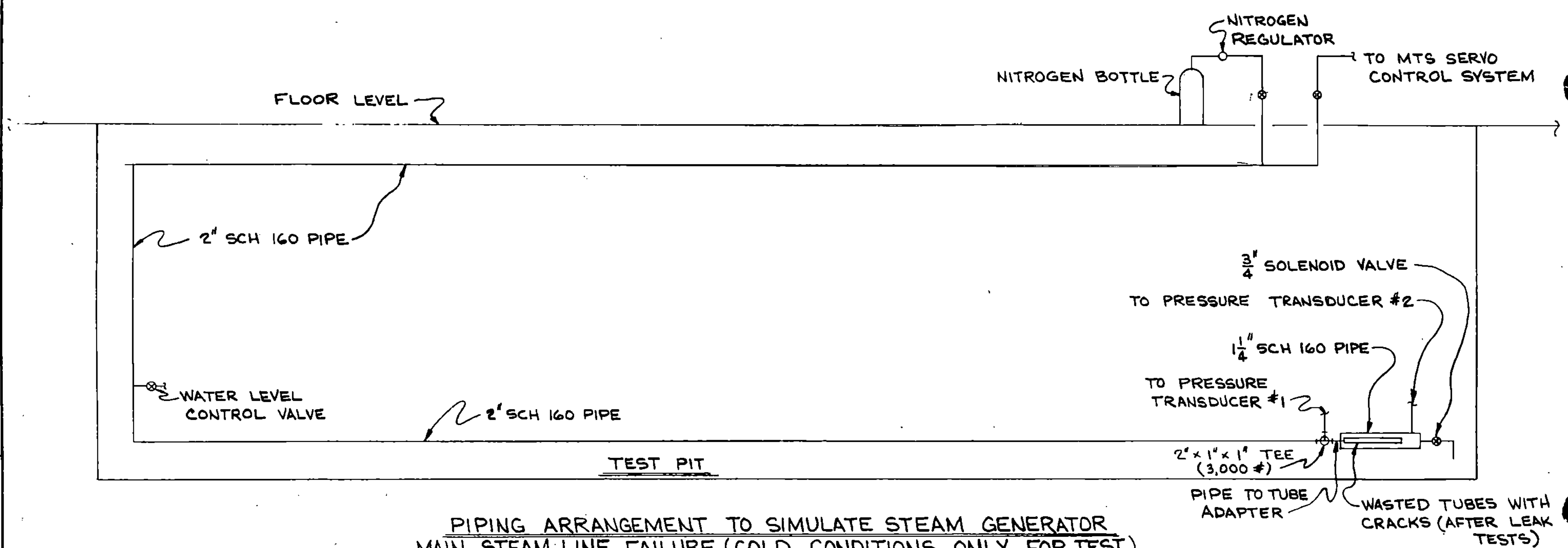

PIPING ARRANGEMENT TO SIMULATE STEAM GENERATOR
MAIN STEAM LINE FAILURE (COLD CONDITIONS ONLY FOR TEST)

PIPING SCHEMATIC
FOR PALASAIDES TEST PROGRAM

SCALE ~
DRAWN BY H. VARNELL
TRACED BY
DATE 2-5-76
CHECKED BY
APPROVED

COMP. CODE

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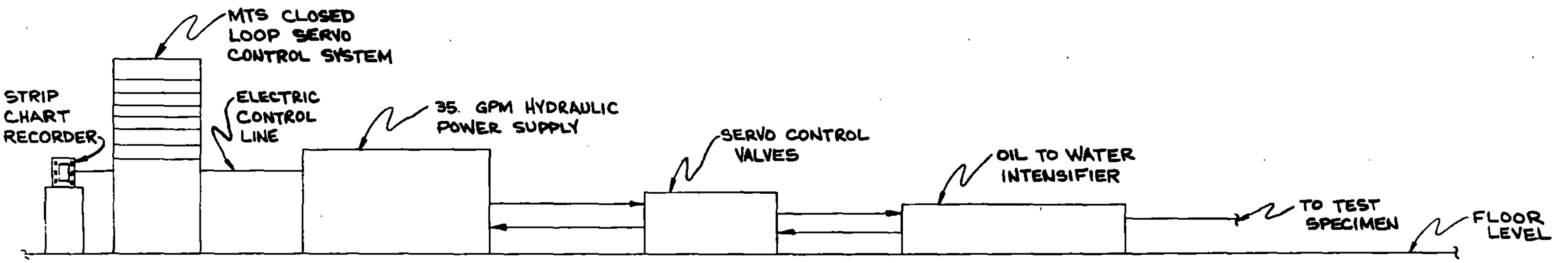
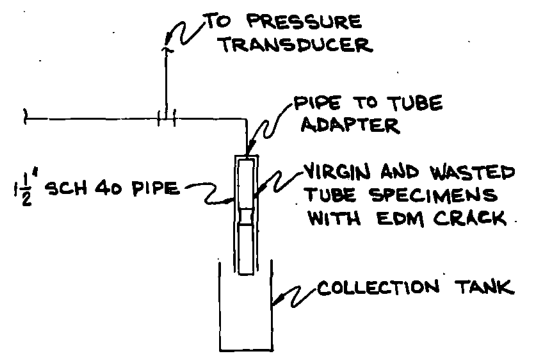
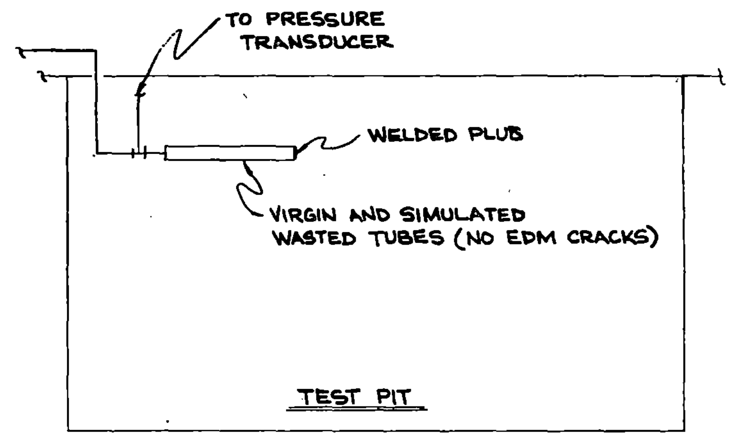
REVISED



TEST ARRANGEMENT FOR LEAK AND BURST TESTS OF TUBE SPECIMENS (PALASAIDES)



ARRANGEMENT FOR LEAK TESTS



ARRANGEMENT FOR BURST TESTS

LEAK AND BURST TEST SCHEMATIC
FOR PALASAIDES TEST PROGRAM

SCALE ~
DRAWN BY H. VARNELL
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DATE 2-5-76
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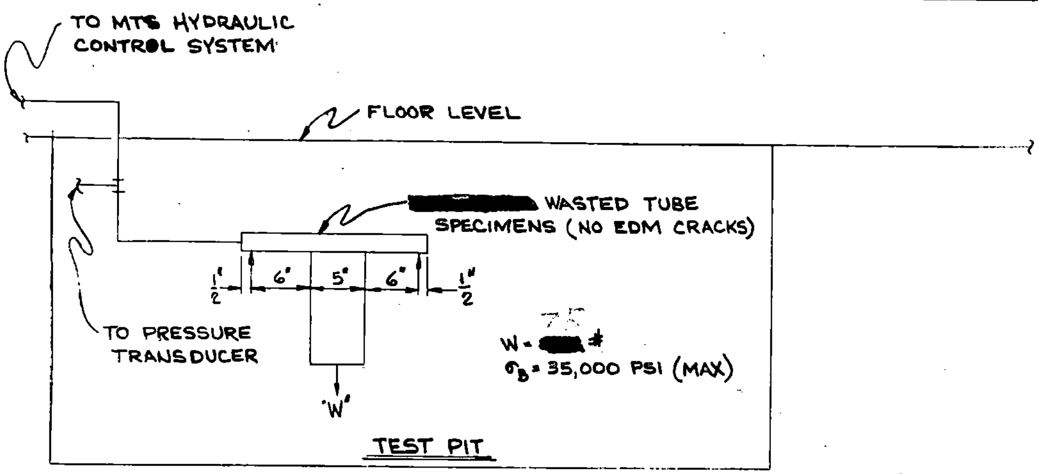
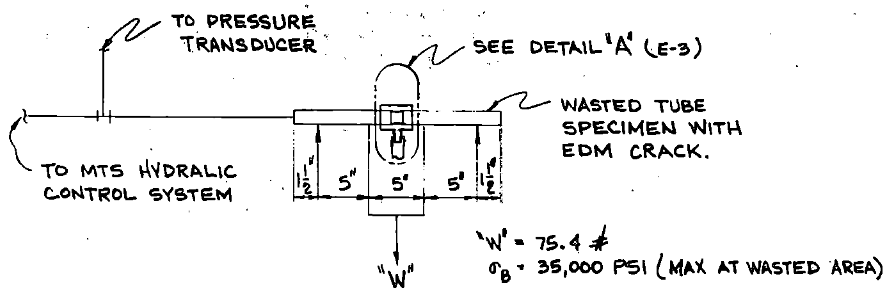
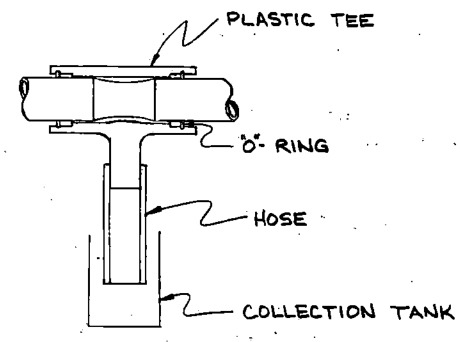
DRAWING NO. C-62676-005-0



ARRANGEMENT FOR BURST TEST



ARRANGEMENT FOR LEAK TESTS



DETAIL "A" (C-4)

SCHEMATIC OF TEST ARRANGEMENT FOR BENDING SPECIMENS
FOR PALASAIDES TEST PROGRAM

SCALE ~	DATE 2-5-76
DRAWN BY H. VARNELL	CHECKED BY
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DRAWING NO. C-6267[illegible]06-0

REVISED

APPENDIX B

Tables of "As Built" Dimension of
Specimens, Crack, and Test Data

TABLE 1A

TEST PLAN FOR SPECIMENS

Spec. No.	Test Config.	Description	Crack Req'd	Leak Test	Diff. Press. Test	Burst Test
1-1	1	1/2" long wasted	No	No	No	Yes
2-1	1	all around	Reserve			
3-1	1	(10" long)	No	No	No	Yes
4-1	1		Yes	Yes	Yes	No
5-1	1		Yes	Yes	Yes	No
6-1	1		Reserve			
1-2	2	5/16" long wasted	No	No	No	*Yes
2-2	2	all around	No	No	No	*Yes
3-2	2	(18" long)	Yes	Yes	No	No
4-2	2		Yes	Yes	No	No
5-2	2		Reserve			
6-2	2		Reserve			
1-3	3	5/16" long wasted	Yes	Yes	Yes	No
2-3	3	all around	Yes	Yes	Yes	No
3-3	3	(10" long)	Yes	Yes	Yes	No
4-3	3		No	No	No	Yes
5-3	3		No	No	No	Yes
6-3	3		Reserve			
1-4	4	1/2" dished	Yes	Yes	Yes	No
2-4	4	one side, only	Yes	Yes	Yes	No
3-4	4	(10" long)	No	No	No	Yes
4-4	4		No	No	No	Yes
1-5	5	Virgin	Yes	Yes	No	No
2-5	5	Tube	Yes	Yes	No	No
3-5	5		Yes	Yes	Yes	No
1-6	6	Virgin	No	No	No	Yes
2-6	6	Tube	No	No	No	Yes

27 specimens (TOTAL)

Table 1
Tube Burst Tests
(Palisades)

Tube Size - .750"O.D. X .048"W.T., Material - Inconel 600

Specimen No.	Configuration No.	Brief Description of Specimen	Burst Pressure
1-1	1	1/2" long wastage all around	7400
3-1	1	1/2" long wastage all around	7450
*1-2	2	5/16" long wastage all around	*7700
*2-2	2	5/16" long wastage all around	*7900
4-3	3	5/16" long wastage all around	7800
5-3	3	5/16" long wastage all around	8000
3-4	4	1/2" long dished wastage one side	7000
4-4	4	1/2" long dished wastage one side	7500
1-6	6	Virgin Tube	11,900
2-6	6	Virgin Tube	11,100

Comments: *Bending load applied such as to produce bending stress equal to 35 ksi.

See C-E Drawing C-62676-006 for test apparatus.

Table 2. Summary Sheet for Specimens With EDM Cracks

Spec No.	Spec Config.	Description of Wastage	Crack Width at Bottom	Leak Rate Pressure	Leak Rate GPM	Max. Pressure Differential (PSIG)	Final Description of Specimen
4	1	1/2" long wastage all around	.007"	1400	1.8		
				2400	3.3	4700	Crack opened to .085"
							at the center.
5	1	1/2" long wastage all around	.008"	1400	2.6		
			to	2400	5.0	+3700	Crack opened to .050"
			.010"				at the center.
6	1	1/2" long wastage all around	.008"	1400	1.8		
			to	3560	7.2	4700	Crack opened to .072"
			.009"				at the center.
3	*2	5/16" long wastage all around	.007"	1400	2.0		
			to	2400	3.0		
			.012"	4000	6.6	4000	Crack opened to .027"
							at the center.
4	*2	5/16" long wastage all around	.012"	1400	3.2		
			to	2400	4.5		
			.013"	3950	8.3	3950	Crack opened to .025"
							at the center.

Comments: * These specimens tested with bending load such as to produce maximum stress equal to yield stress at outer fiber.

\+ Solenoid valve failed. This was last specimen tested.

Table 2. Summary Sheet for Specimens With EDM Cracks

Spec No.	Spec Config.	Description of Wastage	Crack Width at Bottom	Leak Rate Pressure	Leak Rate GPM	Max. Pressure Differential (PSIG)	Final Description of Specimen
1	3	5/16" long wastage all around	.010"	1400	3.1		
			to	2400	4.8	4800	Crack opened to .044"
			.011"				at the center.
2	3	5/16" long wastage all around	.013"	1400	4.0		
			to	2400	5.5	4800	Crack opened to .054"
			.014"				at the center.
3	3	5/16" long wastage all around	.008"	1400	2.1		
			to	2260	4.1	+4100	Crack opened to .059"
			.009"				at the center.
1	4	5/16" long wastage all around	.007"	1400	2.0		
			to	2400	2.9		
			.008"	3500	4.5	4900	Crack opened to .032"
							at the center.
2	4	5/16" long wastage all around	.008"	1400	2.25		
				2400	3.0		
				3450	5.0	4900	Crack opened to .032"
							at the center.

Comments: + Shims placed in crack to increase pressure. Tube not tested in maximum differential pressure device.

Table 2. Summary Sheet for Specimens With EDM Cracks

Spec No.	Spec Config.	Description of Wastage	Crack Width at Bottom	Leak Rate Pressure	Leak Rate GPM	Max. Pressure Differential (PSIG)	Final Description of Specimen
1	5	Virgin	.007"	1400	2.7		
			to	3500	4.8	3500	
			.009"				
2	5	Virgin	.008"	1400	2.15	3500	
			to	3500	3.7		
			.009"				
3	5		.007"	1400	1.05		
			to	4400	3.5	5100	Very slight bulging in vicinity of crack. No apparent change in crack dimensions.
			.009"				

Comments:

Table 3. "As Machined" Dimensions of Specimen*

Specimen No.	Configuration No.	Length of Wastage	Nom. Tube O.D.	Tube Wall Thickness (Nom.)	Wasted Area Min. O.D.	Wasted Area Min. Wall Thickness
5-3	3	.305	.748	.0465-.049	.688	.0165
3-4	4	.506 long .323 wide	.748	.047-.049	.715	.014
4-3	3	.314	.748	.0465-.049	.686	.0155
5-2	2	.315	.748	.048	.686	.017
6-2	2	.305	.748	.048	.687	.0175
6-1	1	.465	.748	.047-.049	.687	.0165
6-3	3	.315	.748	.047-.049	.686	.016
4-4	4	.495 long .300 wide	.748	.046-.049	.718	.016
1-2	2	.325	.748	.046-.048	.687	.0155
2-2	2	.295	.748	.047-.048	.688	.017
6-1	1	.475	.748	.047-.049	.689	.0175

Comments: *All measurements are in inches. All specimens were checked after machining.

Table 4. "As Machined" Dimensions of Cracks

Specimen No.	Configuration No.	Length of Crack	Crack Opening (inches)					
			Top			Bottom		
			Left	Center	Right	Left	Center	Right
4-1	1	.259	.009	.009	.009	.007	.007	.007
5-1	1	.244	.012	.013	.013	.009	.008	.010
6-1	1	.250	.012	.012	.012	.009	.009	.008
3-2	2	.232	.013	.020	.015	.007	.012	.010
4-2	2	.255	.014	.014	.019	.012	.013	.013
1-3	3	.253	.014	.013	.013	.011	.011	.010
2-3	3	.265	.015	.015	.015	.014	.014	.013
3-3	3	.260	.013	.011	.009	.009	.009	.008
1-4	4	.240	.010	.010	.012	.008	.007	.007
2-4	4	.251	.015	.013	.013	.008	.008	.008
1-5	5	.274	.019	.012	.013	.009	.007	.007
2-5	5	.253	.016	.015	.015	.009	.008	.008
3-5	5	.250	.015	.015	.015	.007	.008	.009

Comments:

Sheet No. 1

Table 5
Tube Burst and Leakage Tests
(Palisades)

Specimen No.	Brief Description of Specimen	Leak Rate Pressure (Psig)	Leak Rate GPM	Crack Opening	Bulge Pressure	Tube Failure Pressure
4-1	1/2" long wasted all around	500	.43			
		1000	1.3			
		1500	1.8			
		1800	1.9			
		2000	2.7			
		2400	3.4			
		2600	4.2			
		2800	5.4			
		2900	7.2			
		4700	---	**.085"		
5-1	1/2" long wasted all around	500	1.5			
		1000	2.2			
		1500	2.7			
		1800	3.2			
		2000	3.6			
		2200	3.9			
		2400	4.6			
		2600	5.8			
		2800	7.5			
		*3700	---	**.050"		

Comments: * Last specimen tested. Solenoid valve malfunctioned. Higher pressure could not be achieved.

** Measured at center of crack.

Sheet No. 2

Table 5

Tube Burst and Leakage Tests

(Palisades)

Specimen No.	Brief Description of Specimen	Leak Rate Pressure (Psig)	Leak Rate GPM	Crack Opening	Bulge Pressure	Tube Failure Pressure
6-1	1/2" long wastage all around	200	0.5			
		400	0.8			
		600	1.1			
		800	1.3			
		1000	1.5			
		1200	1.7			
		1400	1.8			
		1600	2.0			
		1800	2.2			
		2000	2.3			
		2200	2.6			
		2400	2.7			
		2600	3.0			
		2800	3.3			
		3000	4.0			
		3200	4.9			
		3400	6.0			
		3560	7.2			
		3900	---	*.044"		
		4700	---	*.072"		

Comments: * Measured at center of crack. This test performed in apparatus shown on C-E Dwg. C-62676-004.

Table 5
Tube Burst and Leakage Tests
(Palisades)

Specimen No.	Brief Description of Specimen	Leak Rate Pressure (Psig)	Leak Rate GPM	Crack Opening	Bulge Pressure	Tube Failure Pressure
3-2	5/16" long wastage all around	400	0.7	No load		
		800	1.0			
		1200	1.2			
		800	1.6			
		1200	1.9			
		1400	2.0			
		1600	2.2			
		1900	2.4			
		2100	2.6			
		2300	2.7			
		2500	3.0			
		2700	3.1			
		2900	3.3	No visual growth of crack		
		3300	3.8			
		3500	4.0			
		3800	5.8			
		4000	6.6	*.027"		
4-2	5/16" long wastage all around	800	2.5			
		1200	2.9			
		1600	3.5			

Comments: * Measured at center of crack.

Table 5
Tube Burst and Leakage Tests
(Palisades)

Specimen No.	Brief Description of Specimen	Leak Rate Pressure (Psig)	Leak Rate GPM	Crack Opening	Bulge Pressure	Tube Failure Pressure
		2000	4.2			
		2400	4.5			
		3200	5.6			
		3600	7.2			
		3950	8.3	*.025		
1-3	5/16" long all around wastage	700	2.1			
		1200	2.8			
		1600	3.3			
		2000	3.6			
		2400	4.8			
		4800	---	**.044		
2-3	5/16" long all around wastage	1200	3.6			
		1600	4.4			
		2000	4.9			
		2400	5.5			
		2800	---			
		In trying to pressurize to 2800 psig flow rate required was greater than hydraulic system capability.				

Comments: * Measured at center of crack.

** Measured at center of crack. Test apparatus shown on C-E Dwg. C-62676-004 used for this test.

Table 5
Tube Burst and Leakage Tests
(Palisades)

Specimen No.	Brief Description of Specimen	Leak Rate Pressure (Psig)	Leak Rate GPM	Crack Opening	Bulge Pressure	Tube Failure Pressure
		4800	---	*.054"		
3-3	5/16" long all around wastage	1240	1.9			
		1600	2.25			
		2000	2.4			
		2450	4.1			
		2260	4.1			
		**4100	---			
		+4400	---			
1-4		800	1.1			
		1200	1.8			
		1650	2.3			
		2000	2.5			
		2400	2.9			
		2800	3.3			
		3000	3.4			
		3200	3.9			
		++3500	4.5			
		4900	---	+++.032"		

Comments: * Measurement at center of specimen. Specimen tested in apparatus shown on C-E Dwg. C-62676-004 used for this test.

** .010" installed in crack in attempt to increase pressure. (Shims)

+ .030" installed in crack in attempt to increase pressure. (Shims)

++ No visual enlargement of crack.

+++ Measurement at center of crack. Specimen tested in apparatus on C-E Dwg. C-62676-004.

Table 5

Tube Burst and Leakage Tests

(Palisades)

Specimen No.	Brief Description of Specimen	Leak Rate Pressure (Psig)	Leak Rate GPM	Crack Opening	Bulge Pressure	Tube Failure Pressure
2-4		1175	2.1			
		1600	2.4			
		2000	2.7			
		2400	3.0			
		2800	3.5			
		3200	4.1			
		*3450	5.0			
		4900	---	**.032"		
1-5		1200	2.4			
		1600	2.9			
		2000	3.6			
		2300	5.3			
		2400	3.7			
		2800	4.0			
		3200	4.3			
		3400	4.3			
		3500	4.8			
2-5		1200	2.0			
		1600	2.3			

Comments: * No visual enlargement of crack.

** Measurement at center of crack. Specimen tested in apparatus shown on C-E Dwg. C-62676-004.

Table 5
Tube Burst and Leakage Tests
(Palisades)

Specimen No.	Brief Description of Specimen	Leak Rate Pressure (Psig)	Leak Rate GPM	Crack Opening	Bulge Pressure	Tube Failure Pressure
		2000	2.6			
		2400	2.9			
		2800	3.2			
		3200	3.5			
		*3500	3.7			
3-5		1200	1.5			
		1600	1.8			
		2000	2.0			
		2400	2.3			
		2800	2.5			
		3200	2.6			
		3600	2.9			
		4000	3.1			
		4400	3.5			
		**5100		Only slight bulging noted in general vicinity of crack. Crack does not appear to have increased in width.		

Comments: * No enlargement of crack visually detectable.

** Specimen tested in device shown on C-E Dwg. C-62676-004.

APPENDIX C

Plots of Test Data

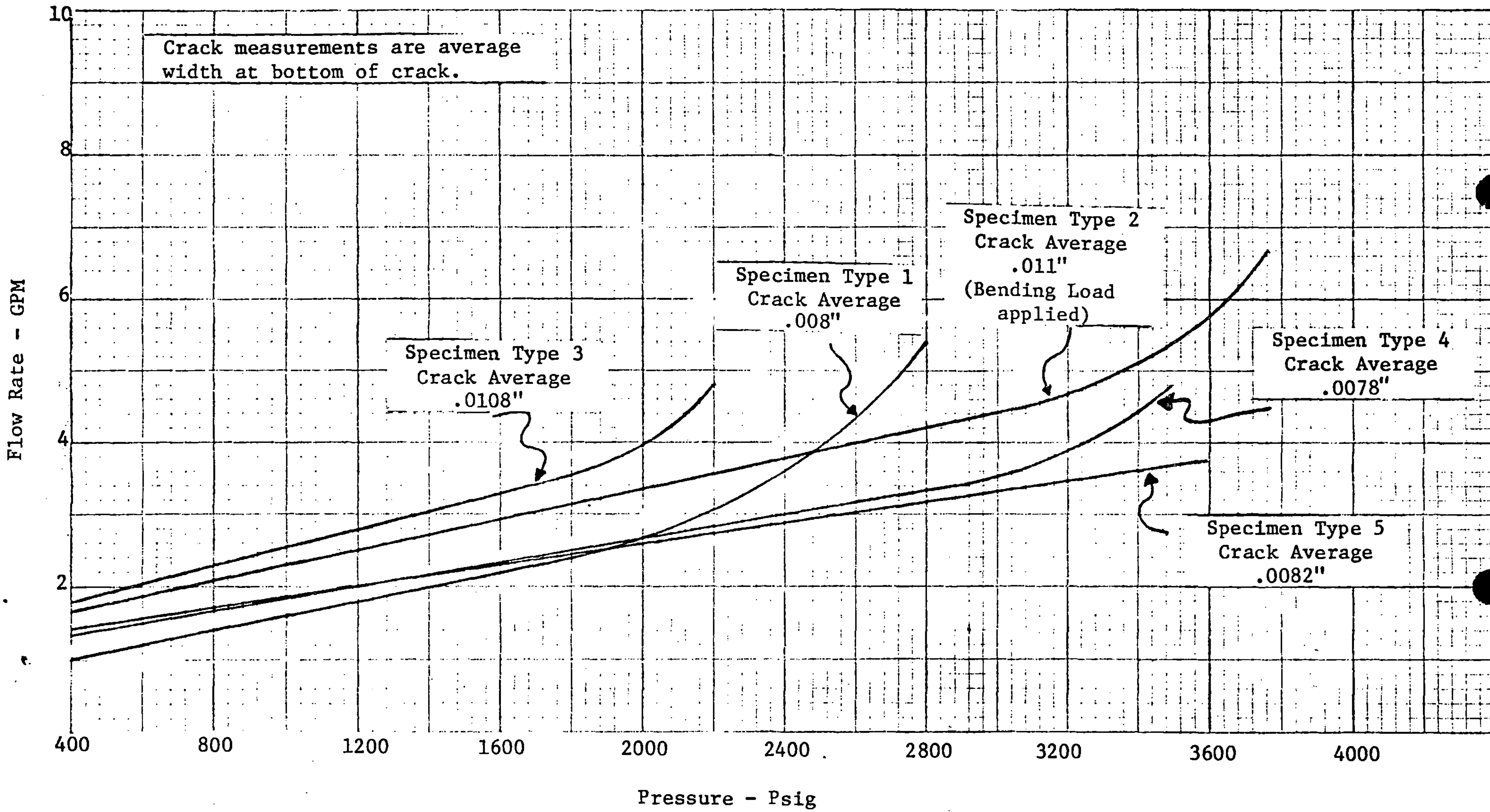


Figure 1. Average Flow Rate Vs. Pressure (Test Configurations 1 through 5)

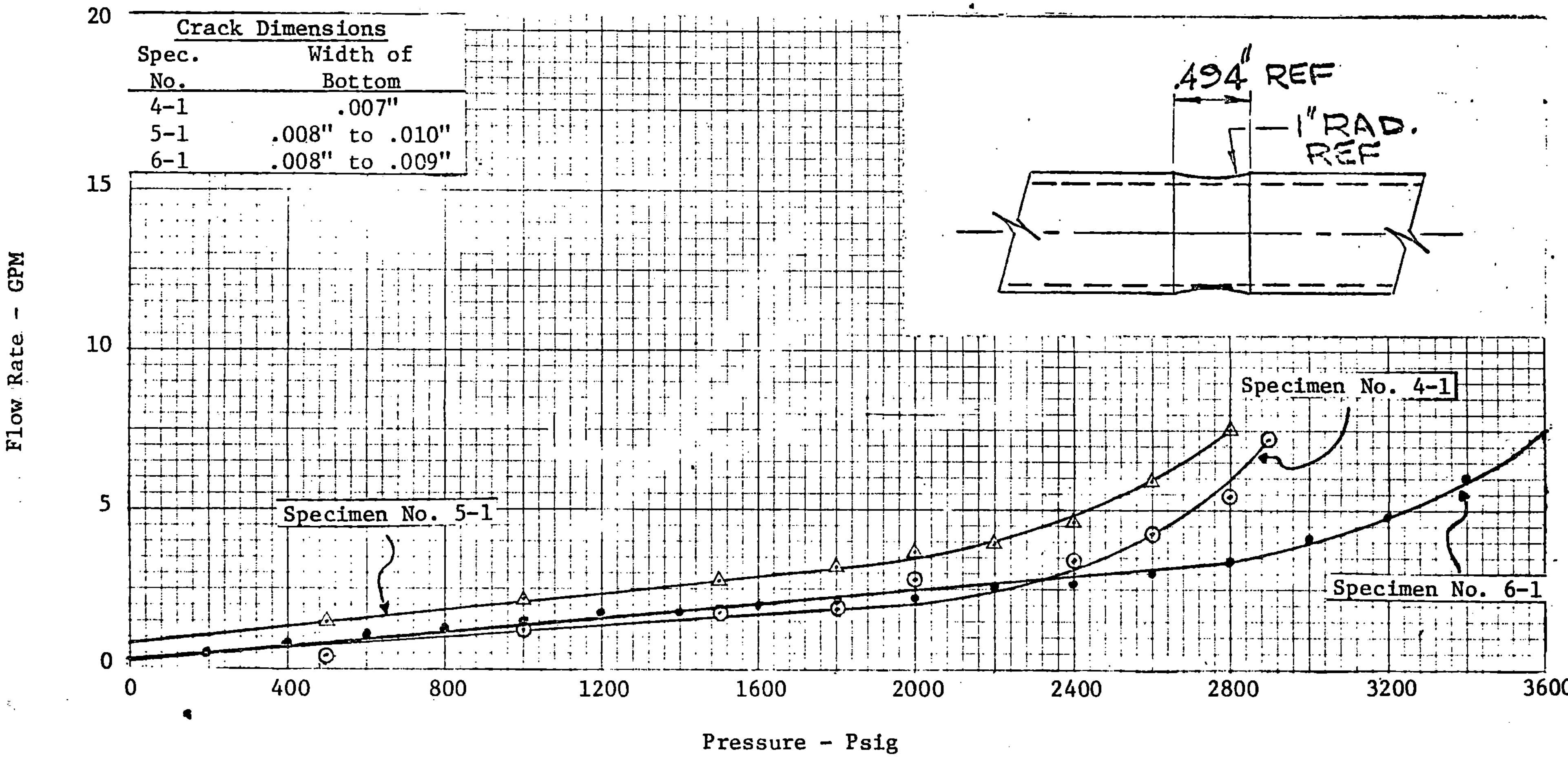


Figure 2. Flow Rate Versus Pressure, Test Configuration No. 1

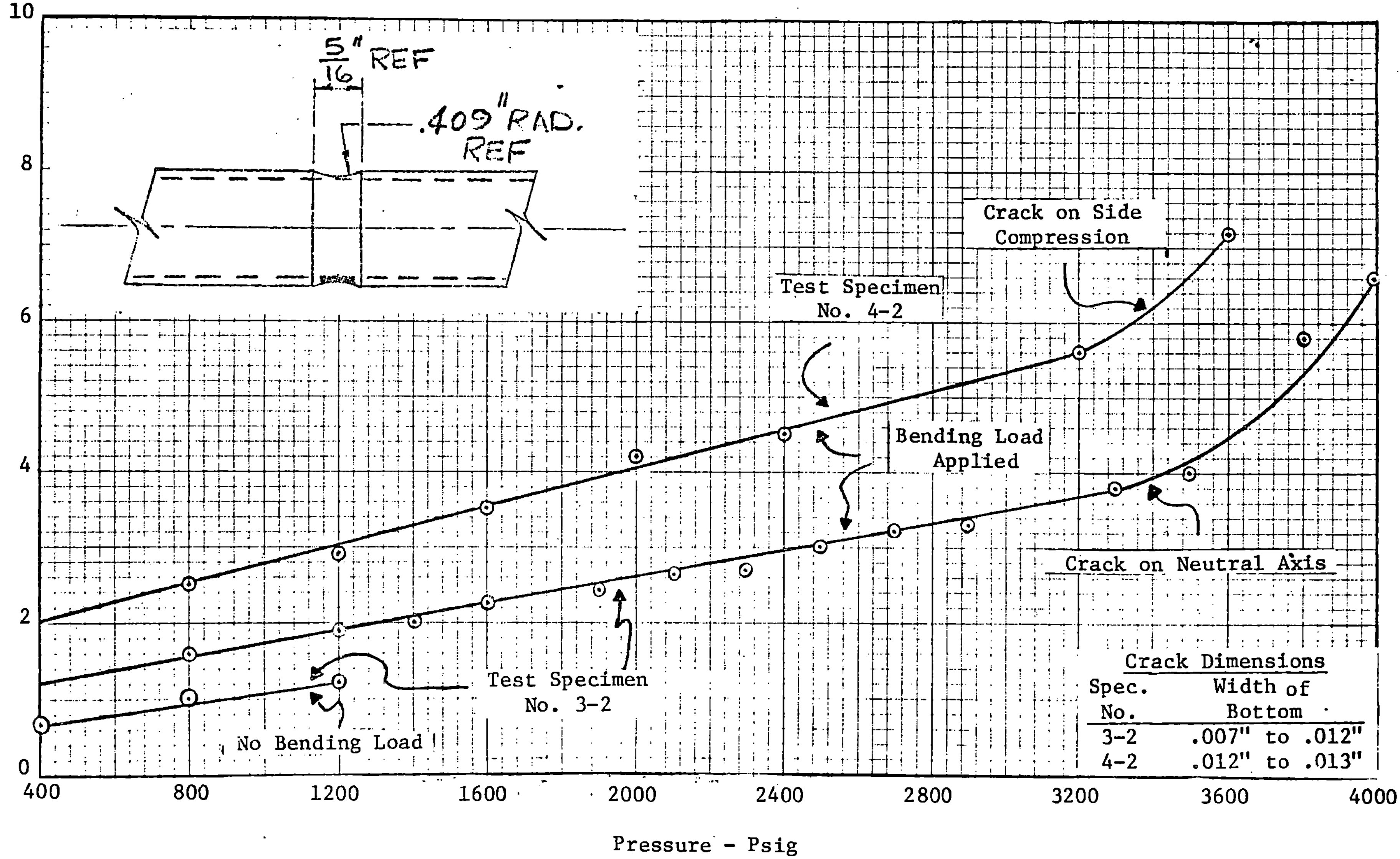
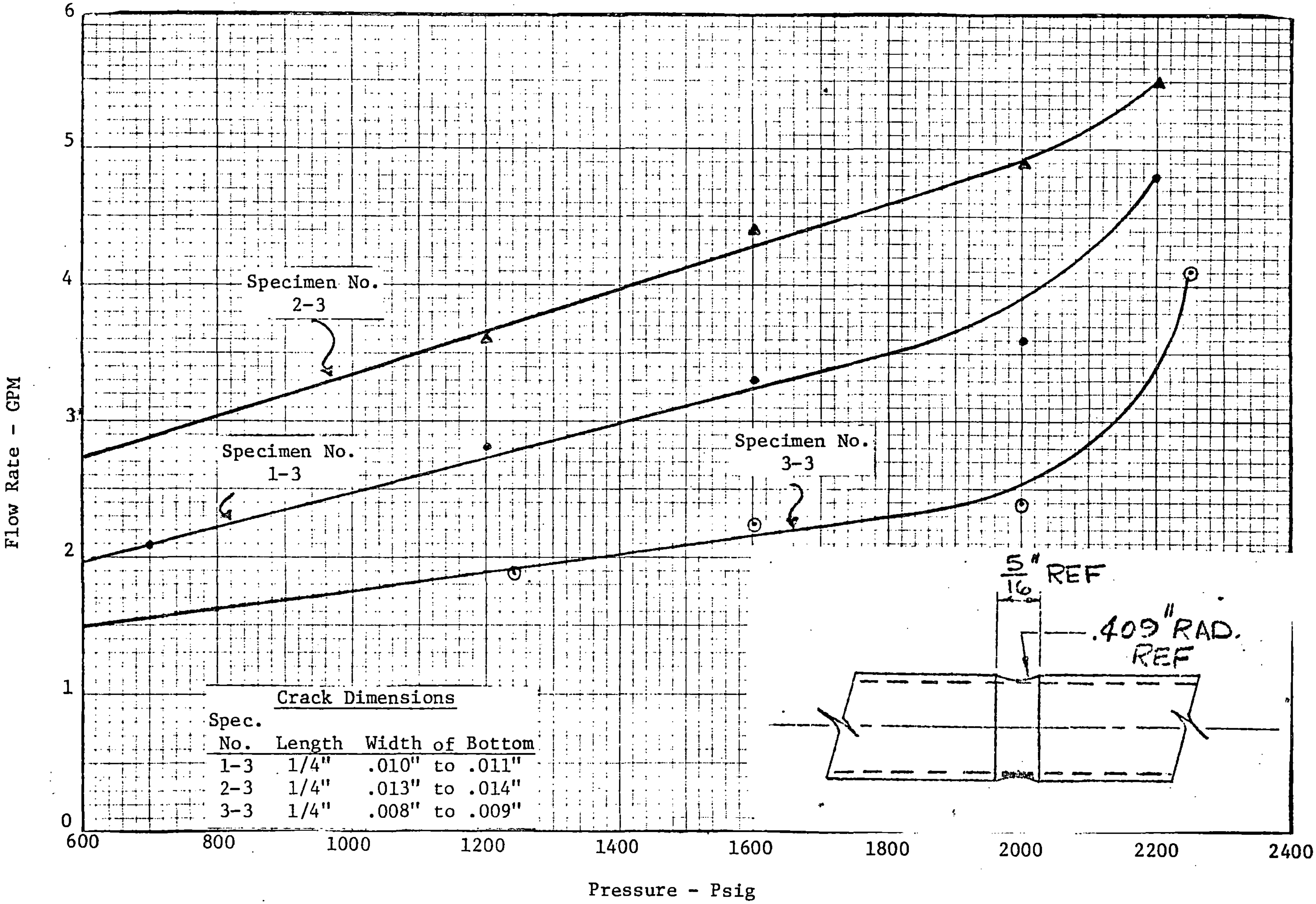


Figure 3. Flow Rate Versus Pressure, Test Configuration No. 2



Crack Dimensions

Spec. No.	Length	Width of Bottom
1-3	1/4"	.010" to .011"
2-3	1/4"	.013" to .014"
3-3	1/4"	.008" to .009"

Figure 4. Flow Rate Versus Pressure, Test Configuration No. 3

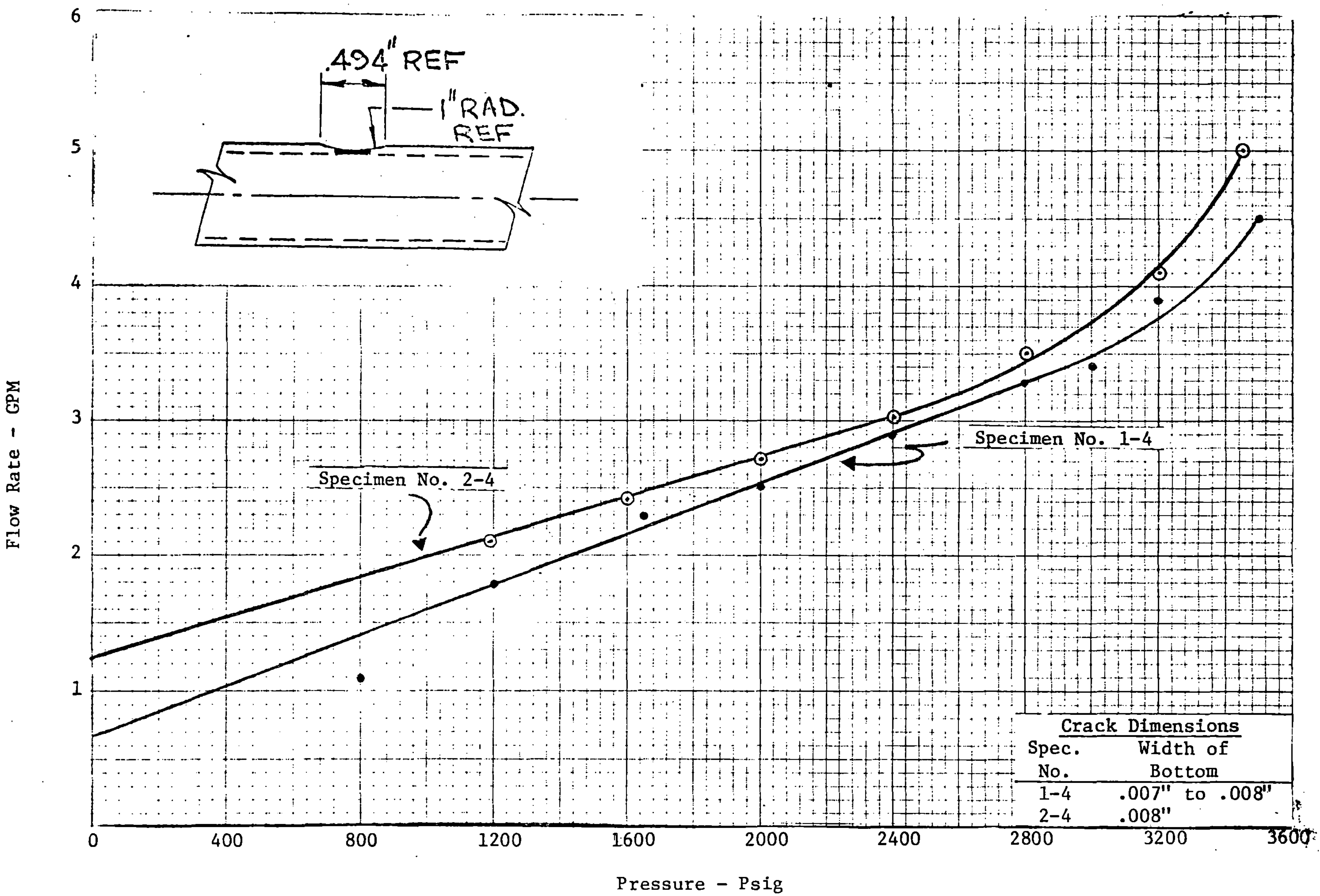


Figure 5. Flow Rate Versus Pressure, Test Configuration No. 4

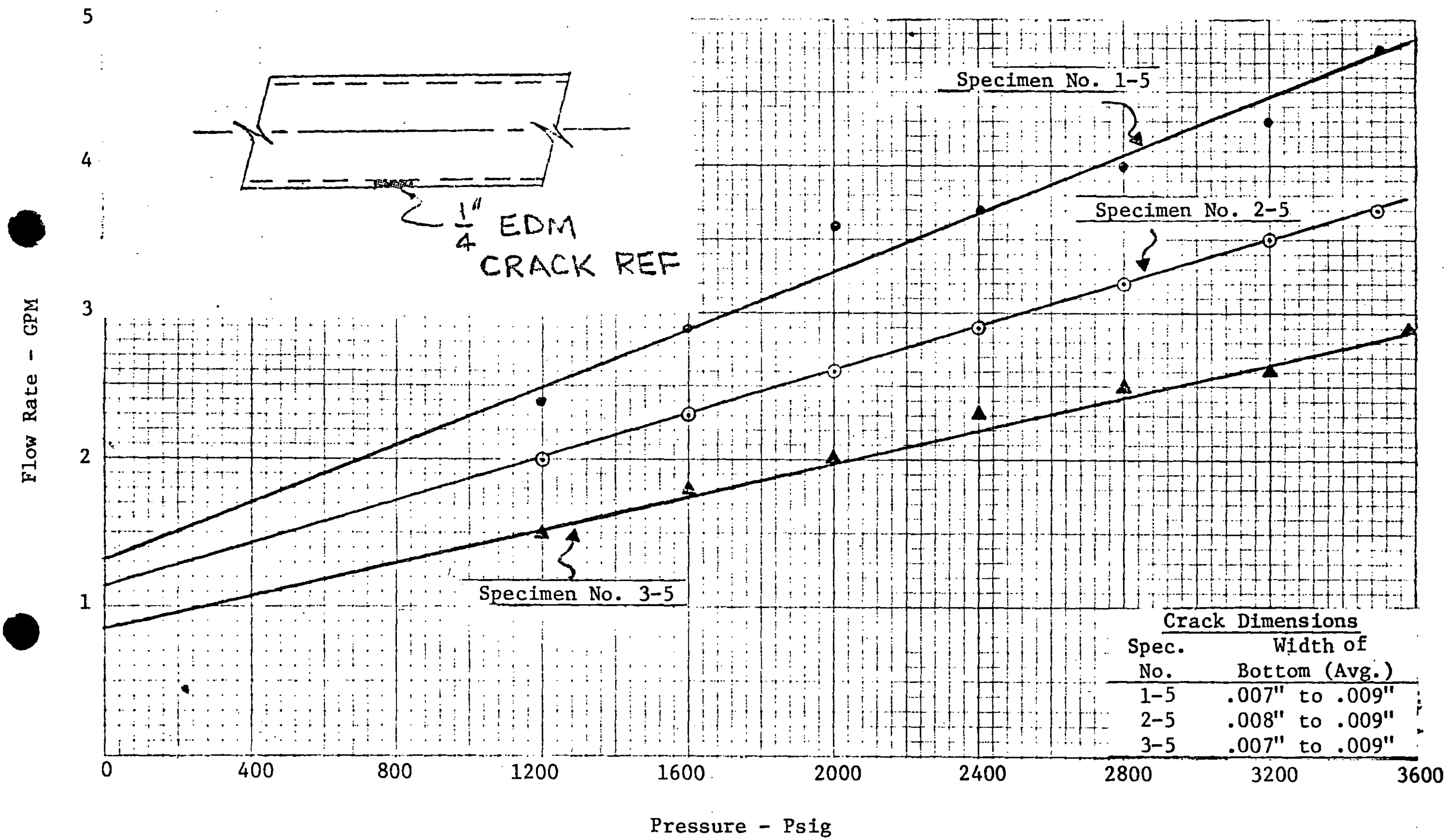


Figure 6. Flow Rate Versus Pressure, Test Configuration No. 5

APPENDIX D

Photographs of Specimens

List of Photographs

Photo No.	Spec. No.	Description of Phase of Test Shown
1,2	1-1	After Burst Test
3	3-1	After Burst Test
6,7	4-1	After Leak Test
8,9	5-1	After Leak Test
16,17	6-1	After Maximum Differential Pressure
18	1-2	After Burst Test (with bending)
19	3-2	After Leak Test (with bending)
20	4-3	After Burst Test
21,22	1-3	After Leak Test
23,24	2-3	After Leak Test
25,26	1-3	After Maximum Differential Pressure
27,28	2-3	After Maximum Differential Pressure
29,30	3-3	After Maximum Differential Pressure
31,32	3-4	After Burst Test
33,34	4-4	After Burst Test
35,36	1-4	After Maximum Differential Pressure
37,38	2-4	After Maximum Differential Pressure
39	1-5	After Maximum Differential Pressure
40,41	1-6	After Burst Test
42,43	2-6	After Burst Test

Test Configuration 1
After Burst Test

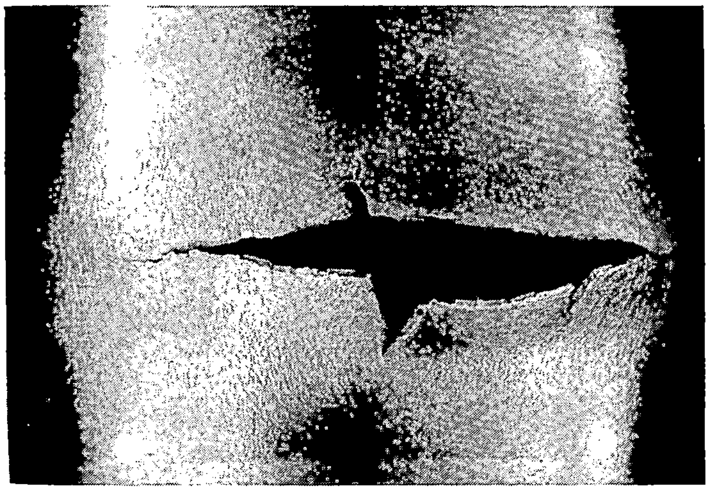


Photo 1

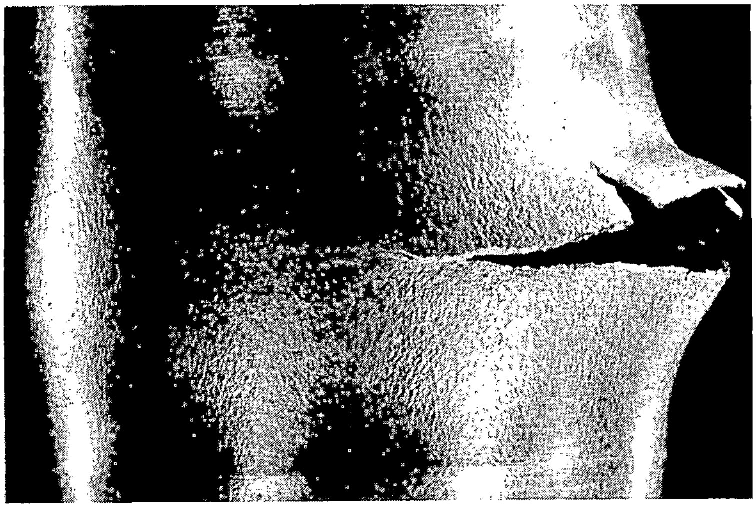


Photo 2

Specimen 1-1

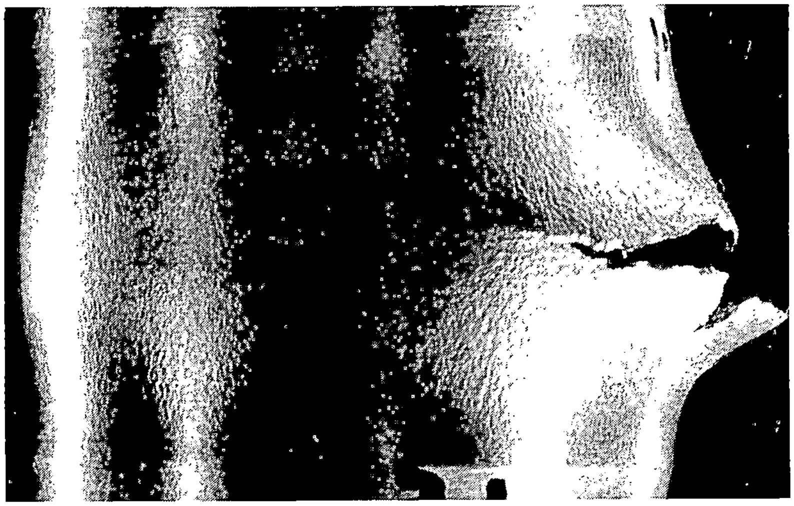


Photo 3

Specimen 3-1

Test Configuration 1 (Cont.)
After Leak Test

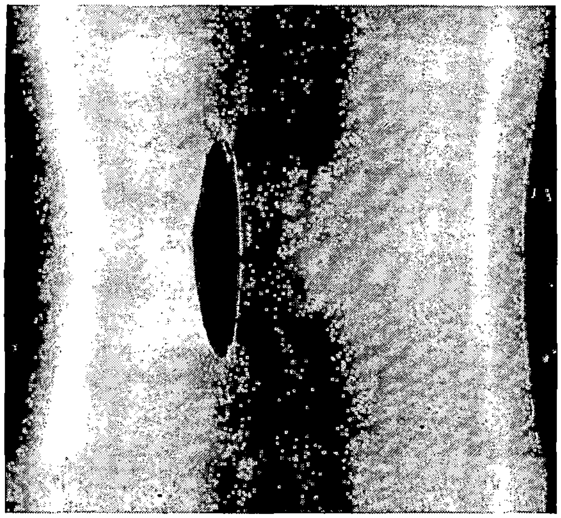


Photo 6

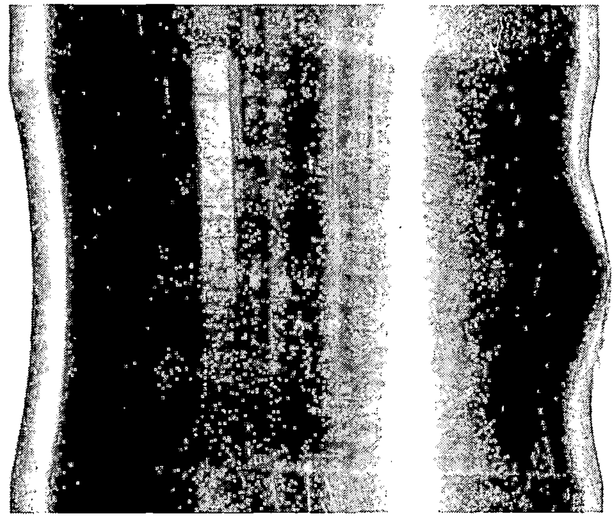


Photo 7

Specimen 4-1

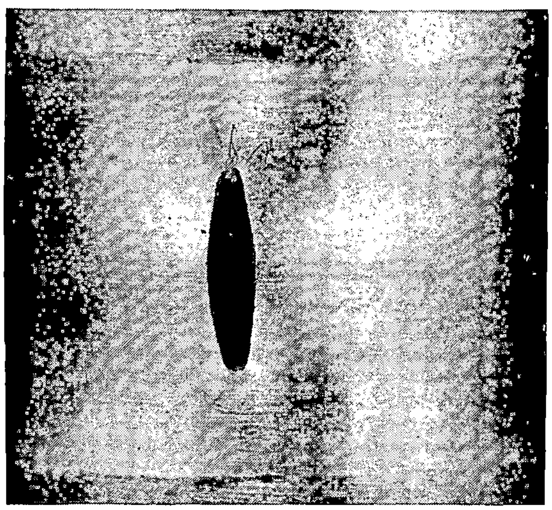


Photo 8

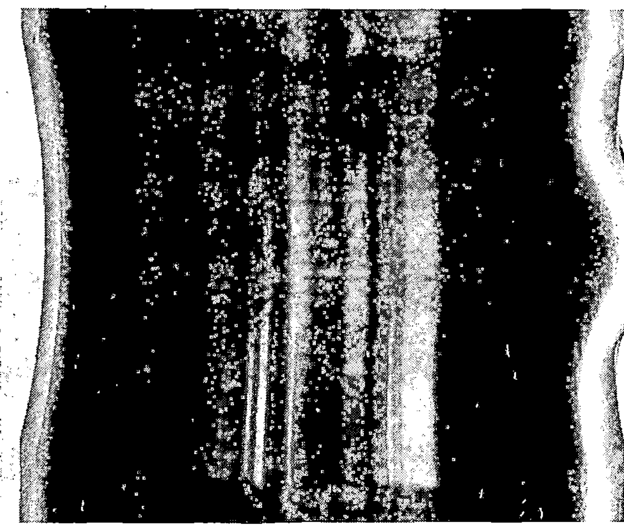


Photo 9

Specimen 5-1

Test Configuration 1 (Cont.)
After Maximum Differential Pressure

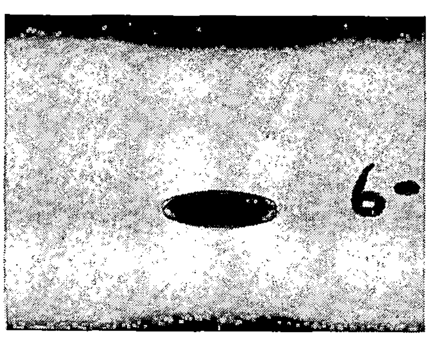


Photo 16

Photo 17

Specimen 6-1

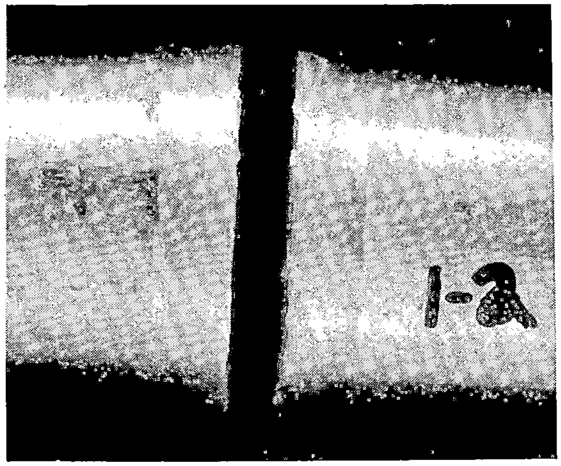


Photo 18

Specimen 1-2
(After Burst Test)

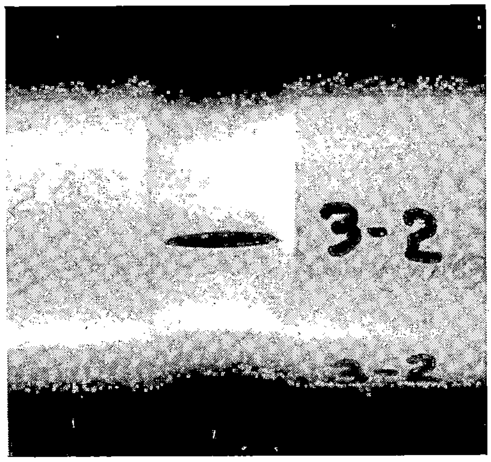


Photo 19

Specimen 3-2
(After Leak Test)

Test Configuration 3

After Burst Test

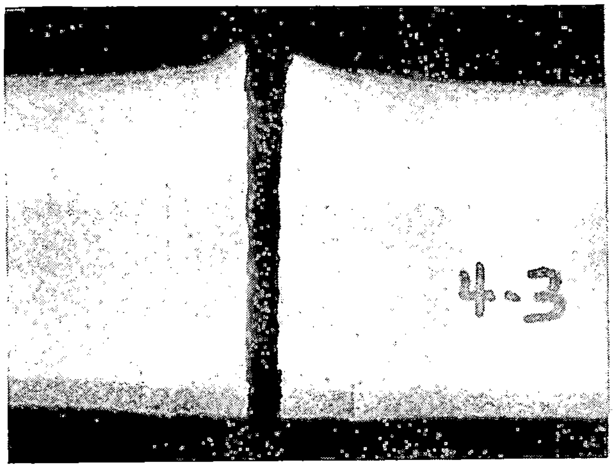


Photo 20

Specimen 4-3

After Leak Test

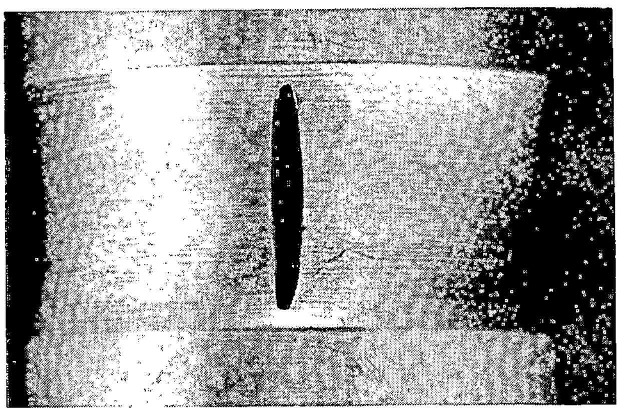


Photo 21

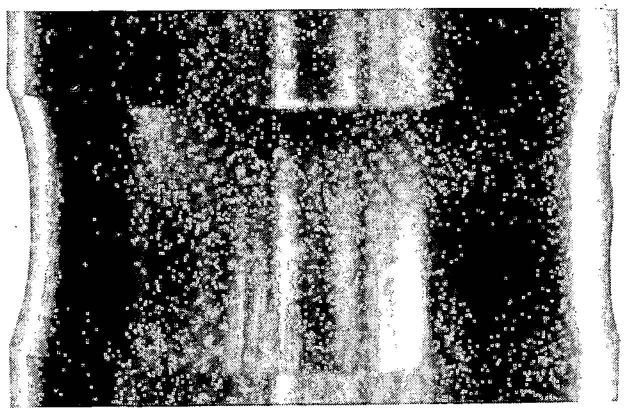


Photo 22

Specimen 1-3

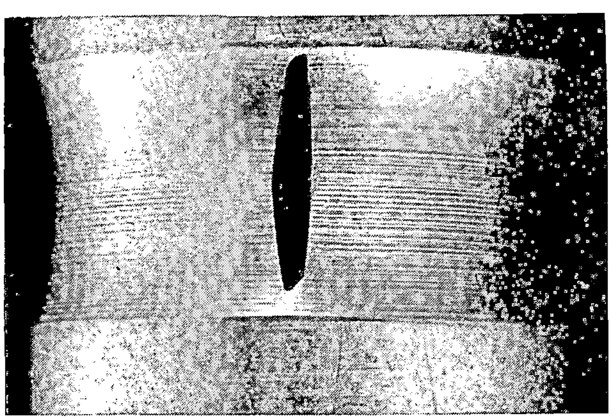


Photo 23

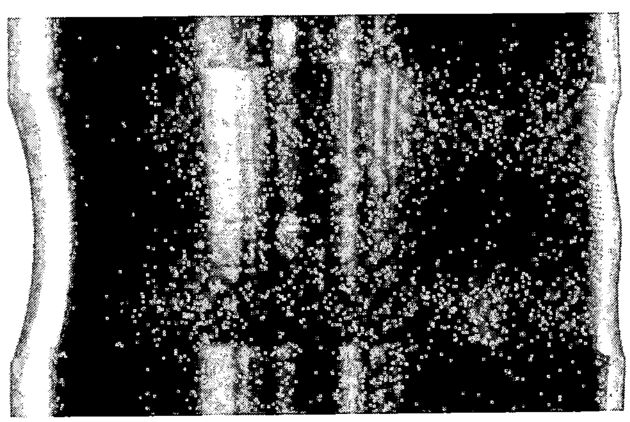


Photo 24

Specimen 2-3

Test Configuration 3 (Cont.)
After Maximum Differential Pressure

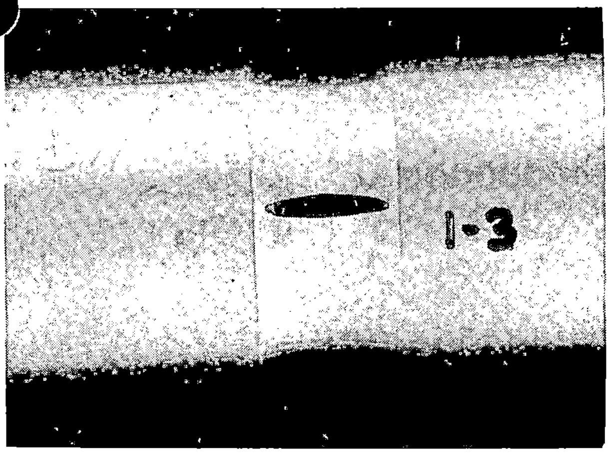


Photo 25

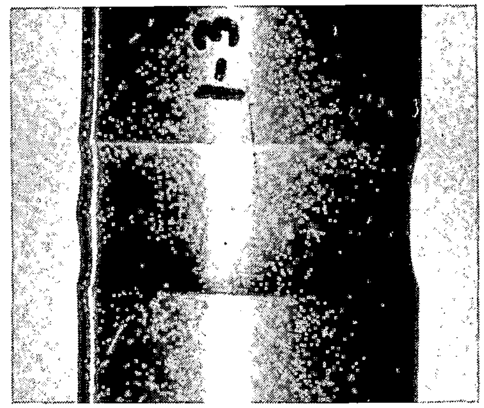


Photo 26

Specimen 1-3

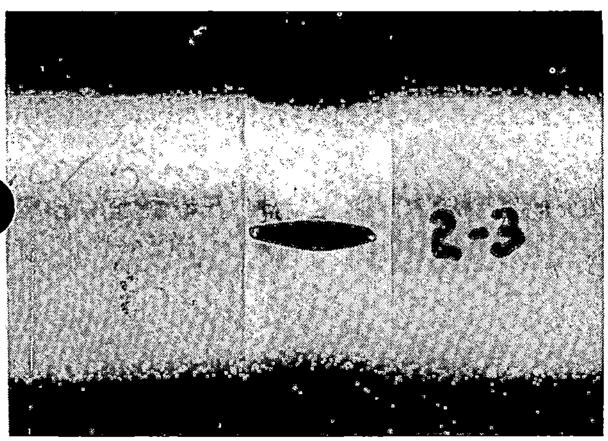


Photo 27

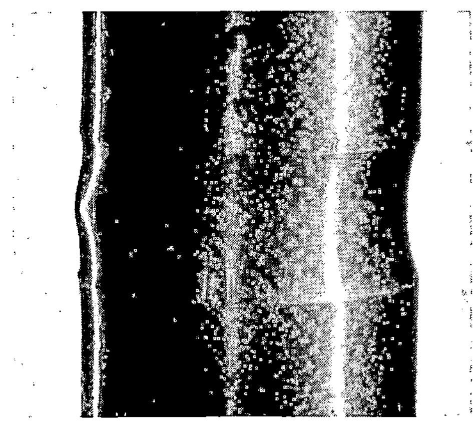


Photo 28

Specimen 2-3

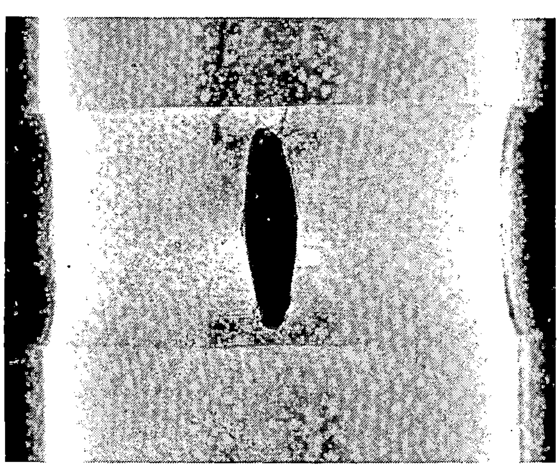


Photo 29

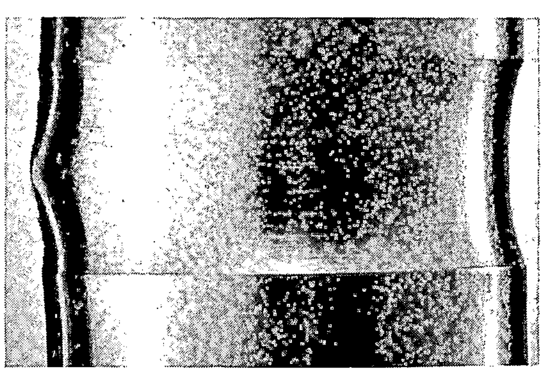


Photo 30

Specimen 3-3

Test Configuration 4
After Burst Test

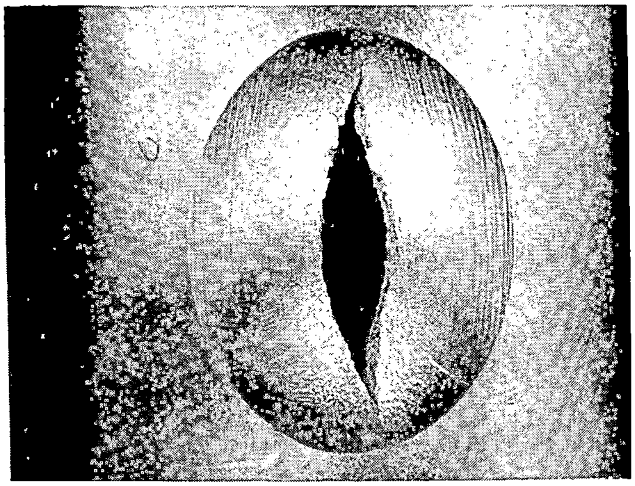


Photo 31

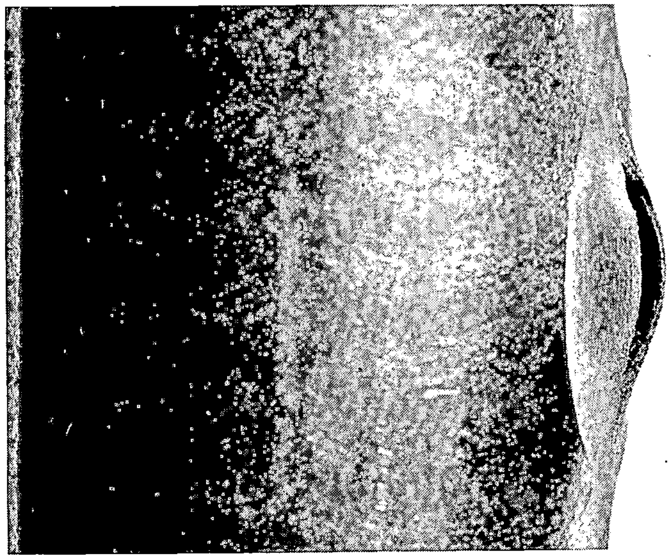


Photo 32

Specimen 3-4

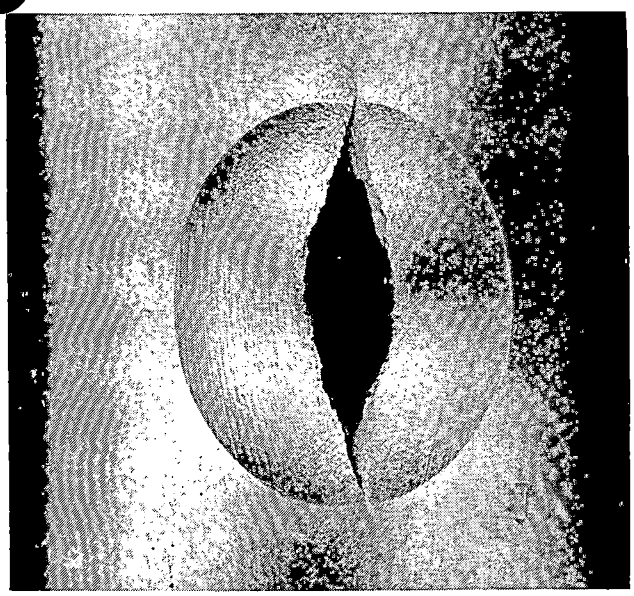


Photo 33

Photo 34

Specimen 4-4

Test Configuration 4 (Cont.)
After Maximum Differential Pressure

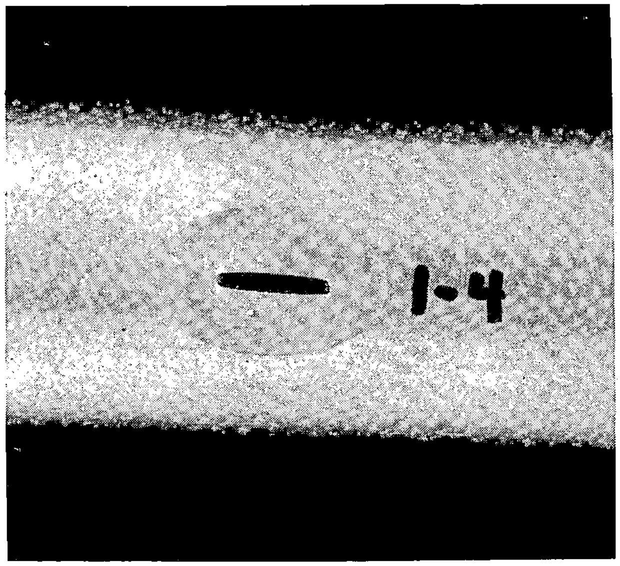


Photo 35

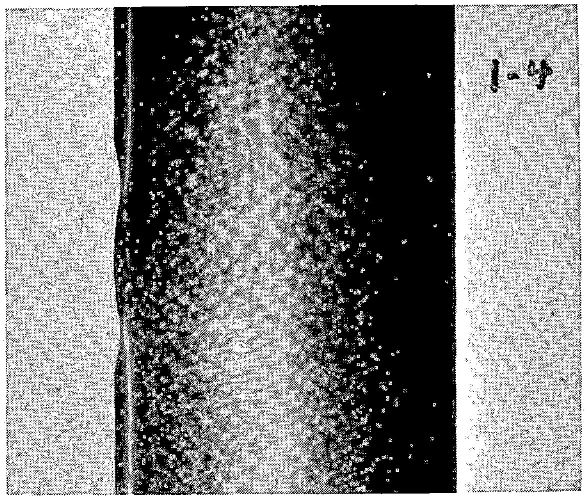


Photo 36

Specimen 1-4

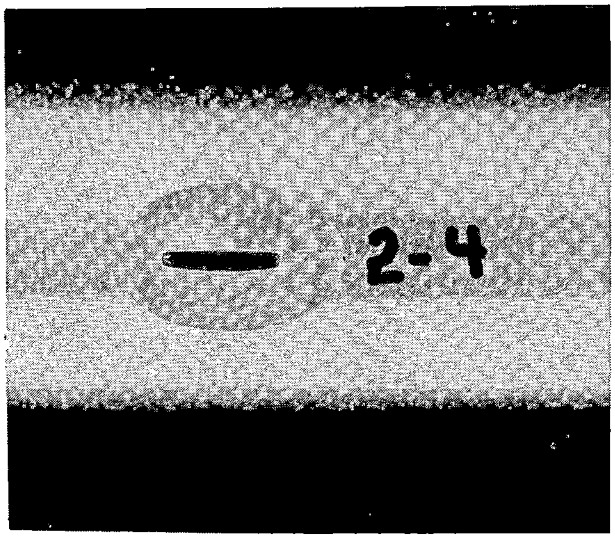


Photo 37

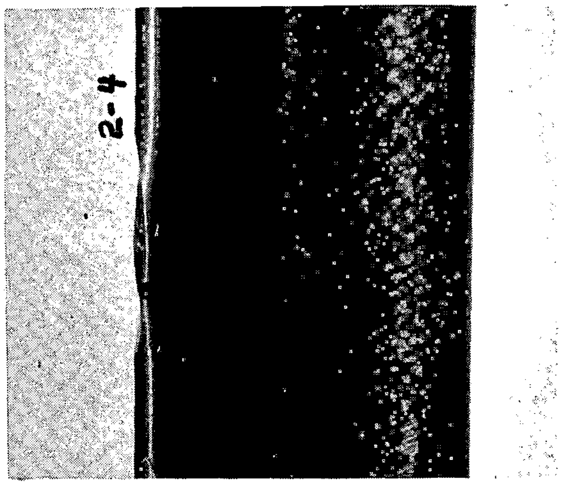


Photo 38

Specimen 2-4

Test Configuration 5
After Maximum Differential Pressure

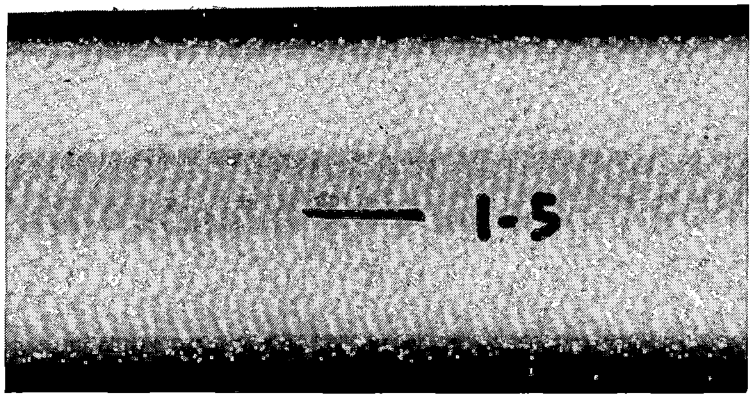
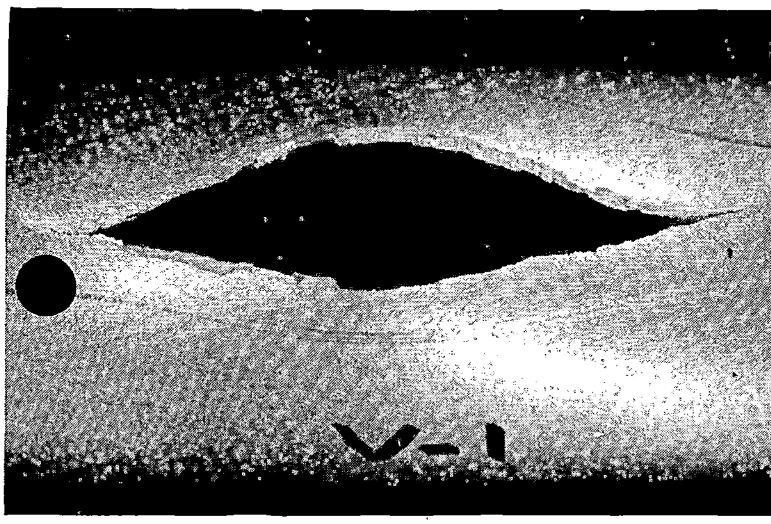


Photo 39

Specimen 1-5

Test Configuration 6
After Burst Test



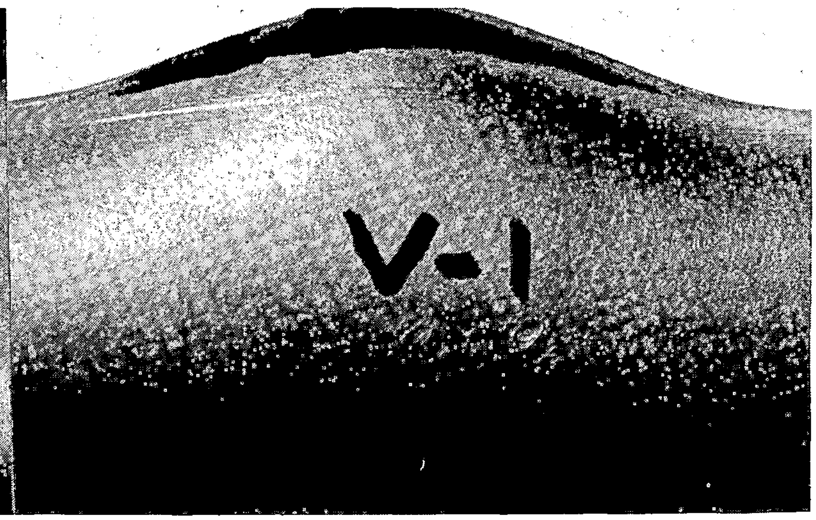
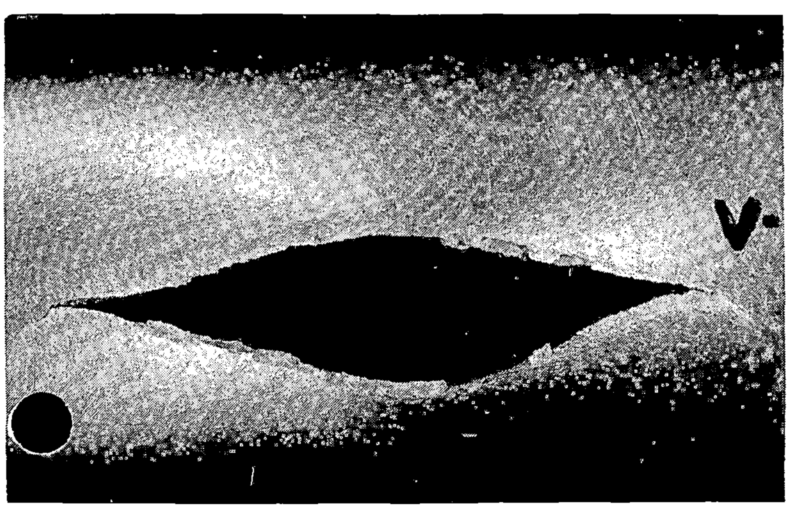


Photo 40

Photo 41

Specimen 1-6



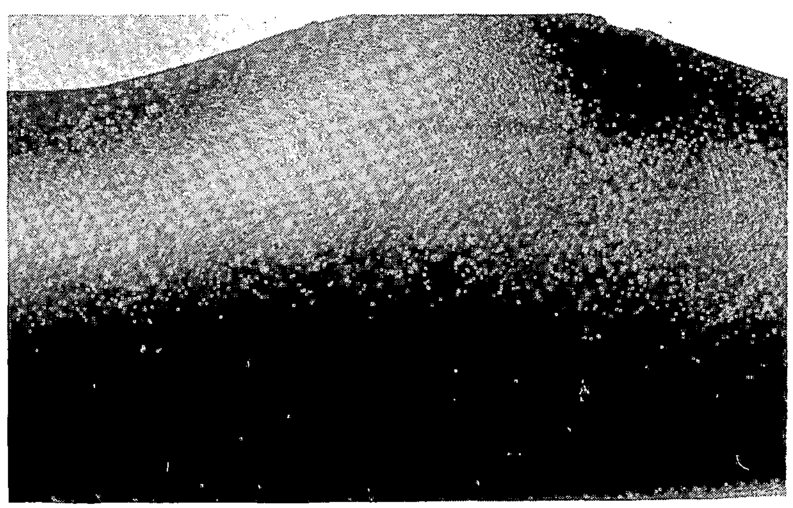


Photo 42

Photo 43

Specimen 2-6

APPENDIX E

Mill Test Report for Tubing

CYCLOPS CORPORATION
Sawhill Tubular Division
Sharon, Pa.
CERTIFICATE OF TESTS

Date 11/5/75

Southern California Edison
San Onofre III
Unit No. 2

u omer	Combustion Engineering, Inc.	Sawhill S.O.	60002
ity	Chattanooga, Tennessee	Size	.750" O.D. x .048" Ave. Wall
.O.	44-80079	Material	Seamless Ni-Cr-Fe Alloy Tubing
ontract	72270		
ob No.	A-98098	Specification	ASME SB-163-71 As Modified By C.E. Purchase Spec P43B2(h) And P.O. 44-80079 And Supplements

M.O.	Lot	Heat	.750" O.D. Tube Check Analyses For Carbon
0000-92	L-16-M	NX6824	.03

CHEMICAL ANALYSIS

at Number NX6824	C	Mn	P	S	Si	Cr	Ni	Cu	Ti	Fe	Al	Co	B	Mg
Ladle Analysis	.03	.34	.009	.003	.16	15.35	74.13	.30	.28	9.18	.17	.05	.005	-
Hollow Check A ysis	-	.40	.009	.004	.15	15.60	73.63	.33	.34	9.00	.16	.05	.002	.010

MECHANICAL PROPERTIES

M.O.	Lot	Yield Strength	Tensile Strength	Elongation in 2"	Rockwell B *
0000-92	L-16-M	40,000 psi	91,000 psi	49%	75-75

M	Lot	I.G.A.		Grain Size *		Microstructure * (Photomicrographs Submitted)	
		Long.	Tran.	Long.	Tran.	Long.	Tran.
0000-92	L-16-M	.001 max.	.001 max.	5-6	5-6	Complete	Complete

M.O.	Lot	Surface Roughness
0000-92	L-16-M	26 - 42 AA

* Information Only

ll tubes were flare tested on each end in accordance with SB-163.
ll tubes were eddy current tested in accordance with Sawhill Procedure STP-21B, July 1, 1974.
ll tubes were ultrasonic tested in two circumferential directions in accordance with Sawhill Procedure STP-22D, July 1, 1974.
ll tubes were ultrasonically tested for wall thickness in accordance with Sawhill Procedure STP-24A, July 1, 1974.
ny reconditioning was performed, when necessary, in accordance with Sawhill Procedure STP-23B, July 1, 1974.
ll tubes were bent in accordance with Sawhill Bending Procedure, October 10, 1974.
ll tubes were hydrostatically tested in the bent condition at 3150 psi for 10 seconds minimum.
ll tubes were tested for alloy identity.

Refer to lot number, mill order and heat number on attached packing list.

he above material has been inspected and conforms to the applicable specifications to the best f o knowledge and belief.

wor d subscribed to before me
h. 5th day of November, 1975

Ethel Tranick

ETHEL TRANICK, Notary Public
Wheatland, Mercer County, Pennsylvania

CYCLOPS CORPORATION
Sawhill Tubular Division

Frank X. Clark
Authorized Signature

APPENDIX F

Engineering Request for Test Program

Interoffice Correspondence

POWER SYSTEMS

Mr. J. K. Hayes

cc: Mr. P. Anderson
Mr. W. Heilker

Tube Burst and Leakage Test (Palisades)

Analytical Engineering

AMG-76-015
January 29, 1976

This is to fulfill the requirements of Section 3.5.1 of the Design Quality Assurance Procedures for establishing test requirements for a test or development program.

3.5.1.5

(1) Description of Design Problem -

The general problem is that of tube degradation and the allowable pressures for particular degradations. The type degradations to be investigated are:

a. Uniform "Wastage" - Remaining wall thickness = .017"

b. Longitudinal through wall cracks superposed upon the wastage.

(2) Detailed Objectives of Test -

The objectives of the tests are:

a. Determine burst pressures at room temperature for tubes with no degradation, with wastage degradation alone, and with wastage and crack degradation at the same location.

b. Determine leak rates vs. pressure for tubes with no wastage degradation and through wall cracks; and for tubes with wastage and cracks degradation.

(3) Description of Proposed Test Models -

There are six (6) styles or types of specimens (see attached drawing).

a. 6 specimens - Wastage simulation all around for a length of 1/2" - the minimum wall thickness being .017". 3 specimens to be with 1/4" longitudinal cracks at the location of wastage - 3 specimens without cracks.

b. 6 specimens - Same as Type a except that the wastage length is 5/16" instead of 1/2".

c. 4 specimens - Local simulated wastage (machined flat-dished on one side only) for 1/2" length - minimum wall thickness .017". 2 specimens with simulated wastage and 1/4" longitudinal through wall crack - 2 specimens with simulated wastage only.

d. 3 specimens with no simulated wastage and 1/4" longitudinal cracks.

e. 2 specimens with no wastage and no cracks - virgin tubes.

All specimens for Types a, b, c, d and e approximately 10" long.

f. 6 specimens like Type b except the tube length approximately 18". (These are to be loaded in bending and internal pressure.)

(4) Acceptance Criteria -

Accurately determine and report required data listed in Items (5) through (9) below.

(5) Discussion of Tests to be Performed -

a. All specimens for Types a through e shall be loaded with internal pressure (pressurized water) only.

1. Determine bursting pressure for those specimens without cracks (for Types a through e).

2. Determine leakage rate for those specimens with cracks (for specimens a through e).

The leakage rates should be determined as a function of pressure - 1200 psi, 1600 psi, 2000 psi, 2400 psi, 2800 psi .... as high as can be determined. The failure mode will probably be local bulging with a widening of the crack and subsequent greatly increased leakage. The failure mode is to be qualitatively determined by observation and a final burst pressure is to be determined.

b. Specimens of Type f

These are to be loaded with internal pressure plus bending (4 point bending). The bending should be of such magnitude to cause a bending stress of approximately S_y (yield stress) in the tube. The loads will be larger for the unwasted tubes than for the wasted tubes since the moment of inertia of the wasted tube is smaller. The specimens without cracks are to be burst with internal pressure while the bending stress is present.

The leakage rate of the specimens with cracks shall be determined as a function of pressure while the bending stress is present. One specimen should have the crack on the compression side, one on the tensile side and one on the neutral axis.

(6) Instrumentation and Readout Equipment -

That necessary to document pressures and leak rates.

(7) Test Data - A

Specimens should be identified as to material, mil test properties, type degradation (wastage and cracks).

a. Pressure vs leak rates should be obtained for the cracked specimens to as high pressure as reasonably feasible, then obtain burst pressure. Plots of pressure vs leak rates should be made. The specimen should be identified on the plot sheet.

b. Burst pressure should be obtained for uncracked specimens.

(8) Qualification Standards

(Not applicable.)

(9) Test Report -

A test report should be produced. The results should be close to the beginning of the report.

a. Specimens should be completely described (the size and type of degradation, physical properties, size of crack, etc.). Photographs of specimens if possible.

b. Plots of leak rate and burst pressure for the cracked specimens should be given.

c. Burst pressures for uncracked specimens should be given.

d. A comparison of the following should be made:

1. Burst pressure of virgin tube (uncracked) (unwasted).

2. Burst pressure of 1/2" long flat wasted tube (uncracked).

3. Burst pressure of 5/16" long all around wasted tube (uncracked).

4. Burst pressure of 1/2" long all around wasted tube (uncracked).

5. Burst pressure of 5/16" long all around wasted tube (uncracked) with bending stress present.

6. Burst pressure of unwasted tube with cracks with leak rates at varying pressures given.

7. Burst pressure of 1/2" long flat wasted tube with cracks with leak rates at varying pressures given.

8. Burst pressure of 5/16" long all around wasted tube with cracks with leak rates given at varying pressures.

9. Burst pressure of 1/2" long all around wasted tube with cracks with leak rates given at varying pressures.

10. Burst pressure of 5/16" long all around wasted tube with cracks with bending stress present with leak rates at varying pressures given.

A table is the preferred way to give these data. An example of the table is shown on attached sheet.

F. Hill

FH/lh
Attach.