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MASTER

CYCLIC PRESSURE TESTS OF LARGE SIZE PRESSURE VESSELS

M. M. Lemcoe

Contract No. AT(30-1)-2140
Project No. 773-2
Progress Report Number 6

15 April 1959

Department of Engineering Mechanics

SOUTHWEST RESEARCH INSTITUTE

SAN ANTONIO, TEXAS

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Prepared for

Reactor Development Division
U. S. Atomic Energy Commission

15 April 1959

APPROVED:

for Edward Wenk, Jr., Chairman
Department of Engineering
Mechanics

ABSTRACT

This investigation into the plastic fatigue strength of large size pressure vessels is a part of a general research program on plastic fatigue problems in pressure vessels which is being carried out at several laboratories. The vessels under study here are of 36 inch I.D. with 2" wall thickness and incorporate nozzles of several designs and sizes. While the overall program includes identical pairs of vessels fabricated from A-201, A-302, and T-1 steels, the work in progress concerns only the A-201 vessels.

Static stress analysis of one of the A-201 vessels has been performed with Stresscoat to identify regions of critical strain. This will be followed by a gage analysis to measure the critical strains resulting from internal pressure.

Fatigue testing will then be carried out on one vessel at a cyclic peak pressure selected to cause failure in approximately 20,000 cycles. The other vessel of the pair will be tested under a lower cyclic pressure selected to cause failure in approximately 100,000 cycles.

Strain concentration factors determined in the static stress analysis, initial cycling, and results of plastic fatigue tests will be correlated with results of related studies at l'Ecole Polytechnique, Lehigh University, and the University of Illinois.

This report covers the progress since the time of submission of the last Progress Report to 1 April 1959.

I. TEST VESSELS

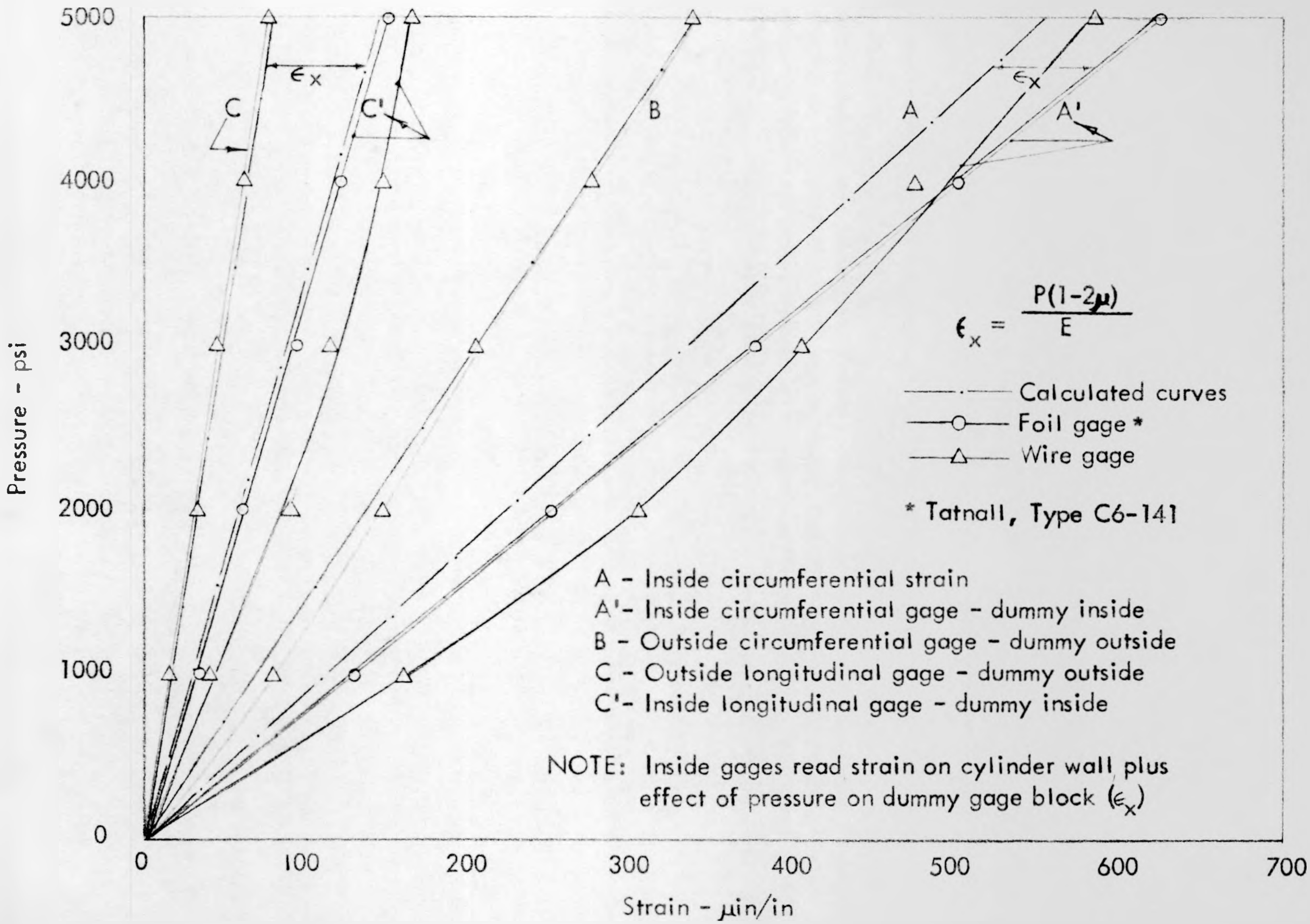
The two A-201 test vessels were received from Wyatt Metal and Boiler Works on March 10, 1959. "As fabricated" drawings are included as Appendix A. Cleaning up operations, wall thickness measurements, and location of reference points was begun immediately preliminary to preparation of the inside and outside surfaces for Stresscoat application. The Stresscoat analysis has been completed and the vessel is being prepared for the strain gage analysis.

II. INSTRUMENTATION

In order to detect the peak strains around the nozzle openings, a strain gage of short gage length was required - not longer than the fillet or corner radii, as the integrating effect of a longer gage would obscure the peak of a steep strain gradient. For purely economic reasons the A-8 wire "wrap-around" gage of 1/8" gage length was attractive, but because of their possible lack of stability under hydrostatic pressure a new type foil gage, along with the Type A-8 "wrap-around" gage, were evaluated in a pilot study wherein the gages were tested in a small cylinder under hydrostatic pressure. It was found that the A-8, while reliable and accurate for measurements on the outside of the vessel, was rather unstable under hydrostatic pressure and gave strain measurements at variance with the calculated strains in a small test cylinder. The foil gages of the same gage length installed side by side with the A-8 gages gave linear results indistinguishable from the calculated curves for strains on the interior surface of the test cylinder. The typical pressure-strain curves shown in Figure 1 were recorded during one of these tests. Zero drift did not exceed 10 microinches for any gage. It was decided that the accuracy and stability of the foil gages under pressure warranted their slight increase in cost for measuring strains inside the vessel, and of course, A-8 gages will be used on the exterior surface as originally planned.

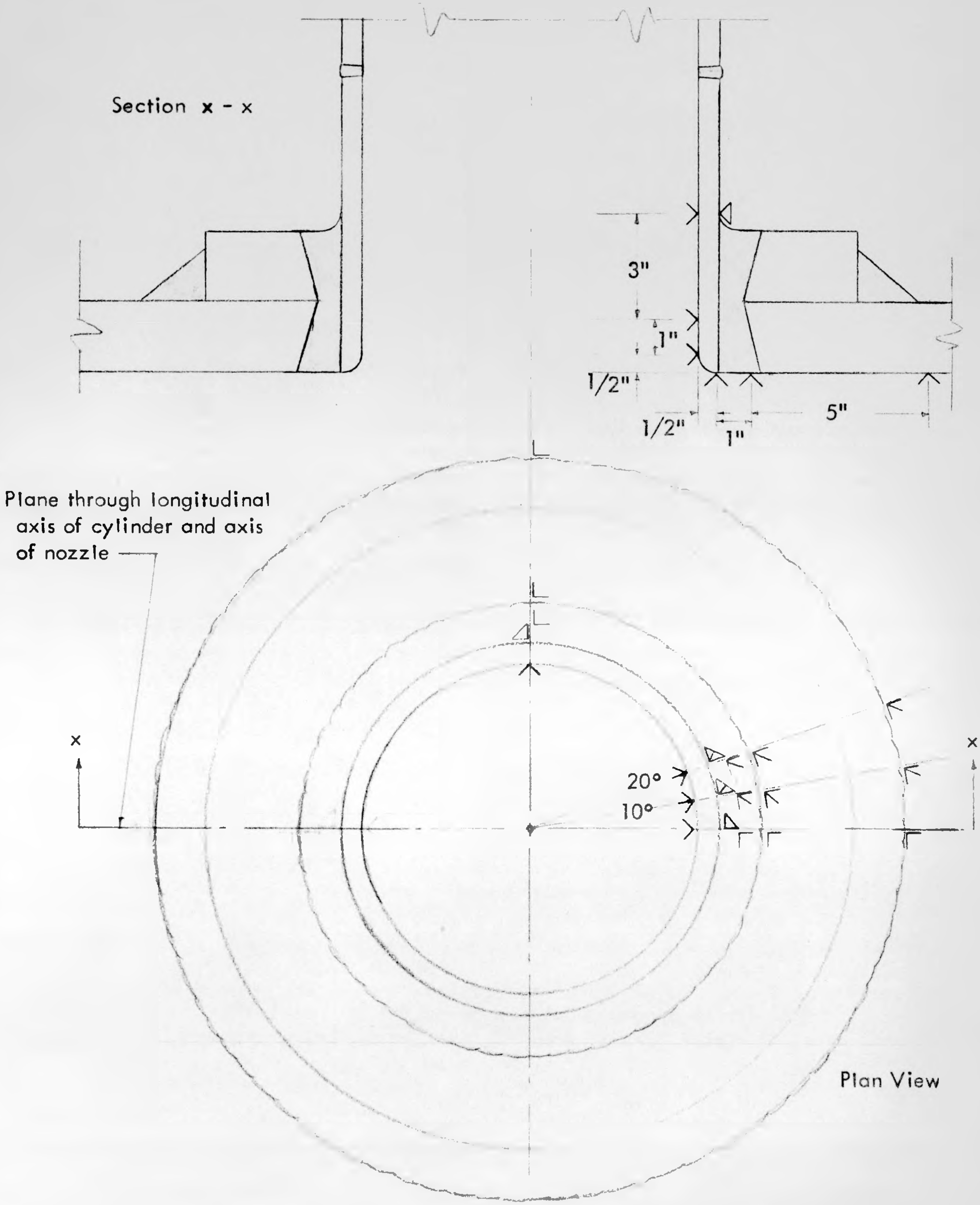
Strain gage locations for complete nozzle instrumentation, as detailed in Figures 2 through 10, were decided upon at a joint meeting of representatives of the Subcommittees on Plastic Fatigue Strength (Fabrication

Division) and Reinforced Openings (Design Division) of the Pressure Vessel Research Committee. Locations are based upon strain gage data accumulated from model studies at Pennsylvania State University. The Stresscoat analysis confirmed the proposed locations with only minor changes caused by interaction of discontinuities.



5000
4000
3000
2000
1000
0
Pressure - psi
0
100
200
300
400
500
600
700
Strain - μin/in
ϵ_x
C
C'
B
A
A'
$\epsilon_x = \frac{P(1-2\mu)}{E}$
Calculated curves
Foil gage *
Wire gage
* Tatnall, Type C6-141
A - Inside circumferential strain
A'- Inside circumferential gage - dummy inside
B - Outside circumferential gage - dummy outside
C - Outside longitudinal gage - dummy outside
C'- Inside longitudinal gage - dummy inside
NOTE: Inside gages read strain on cylinder wall plus effect of pressure on dummy gage block (ϵ_x)

FIGURE 1



Interior Rosettes
∟ (2-Gage) - 12
∠ (3-Gage) - 12

Exterior Rosettes
◺ (2-Gage) - 2
◺ (3-Gage) - 2

FIGURE 2

NOZZLE NO. 1

Scale: 3" = 1'

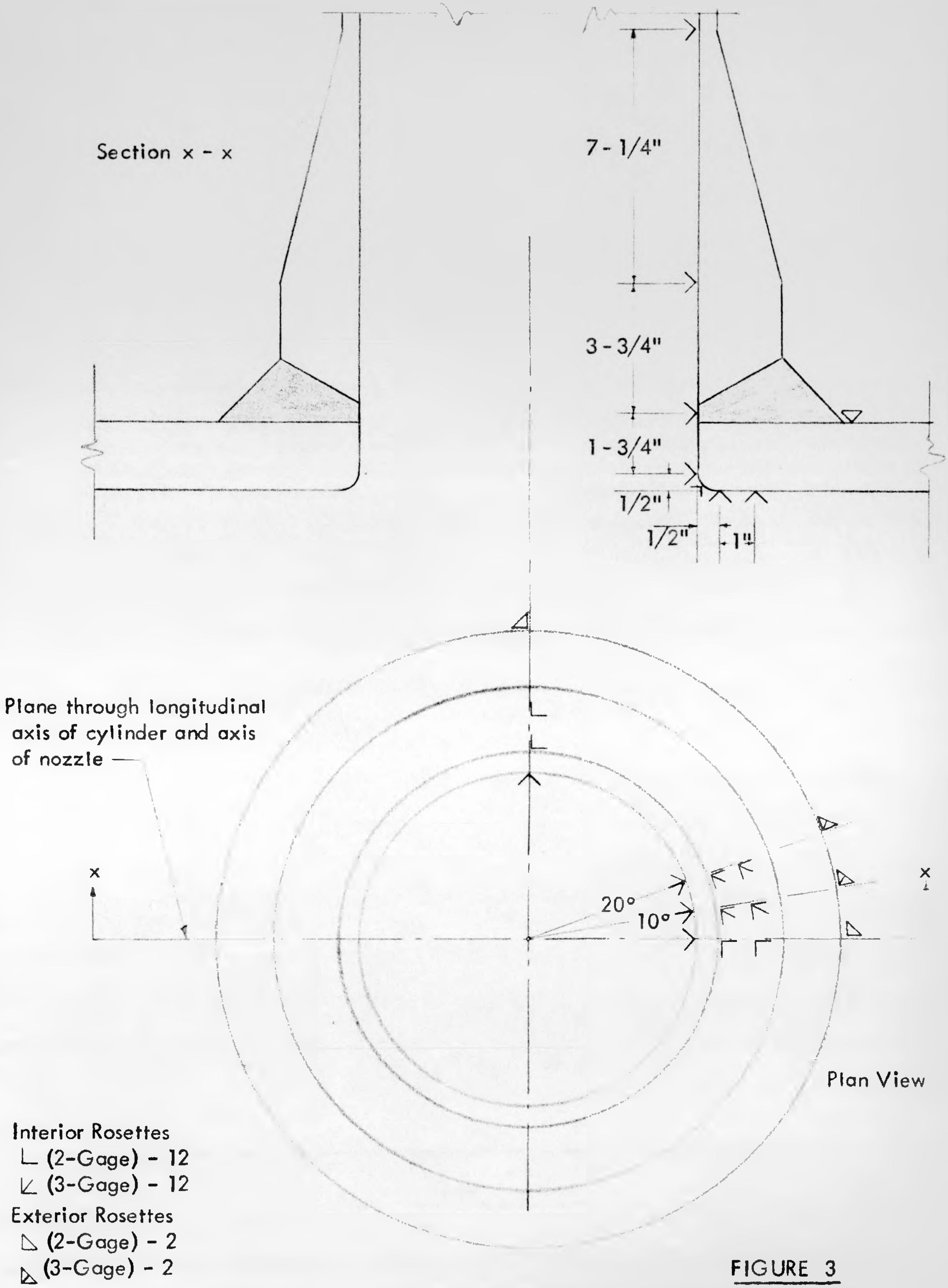


FIGURE 3

NOZZLE NO. 2

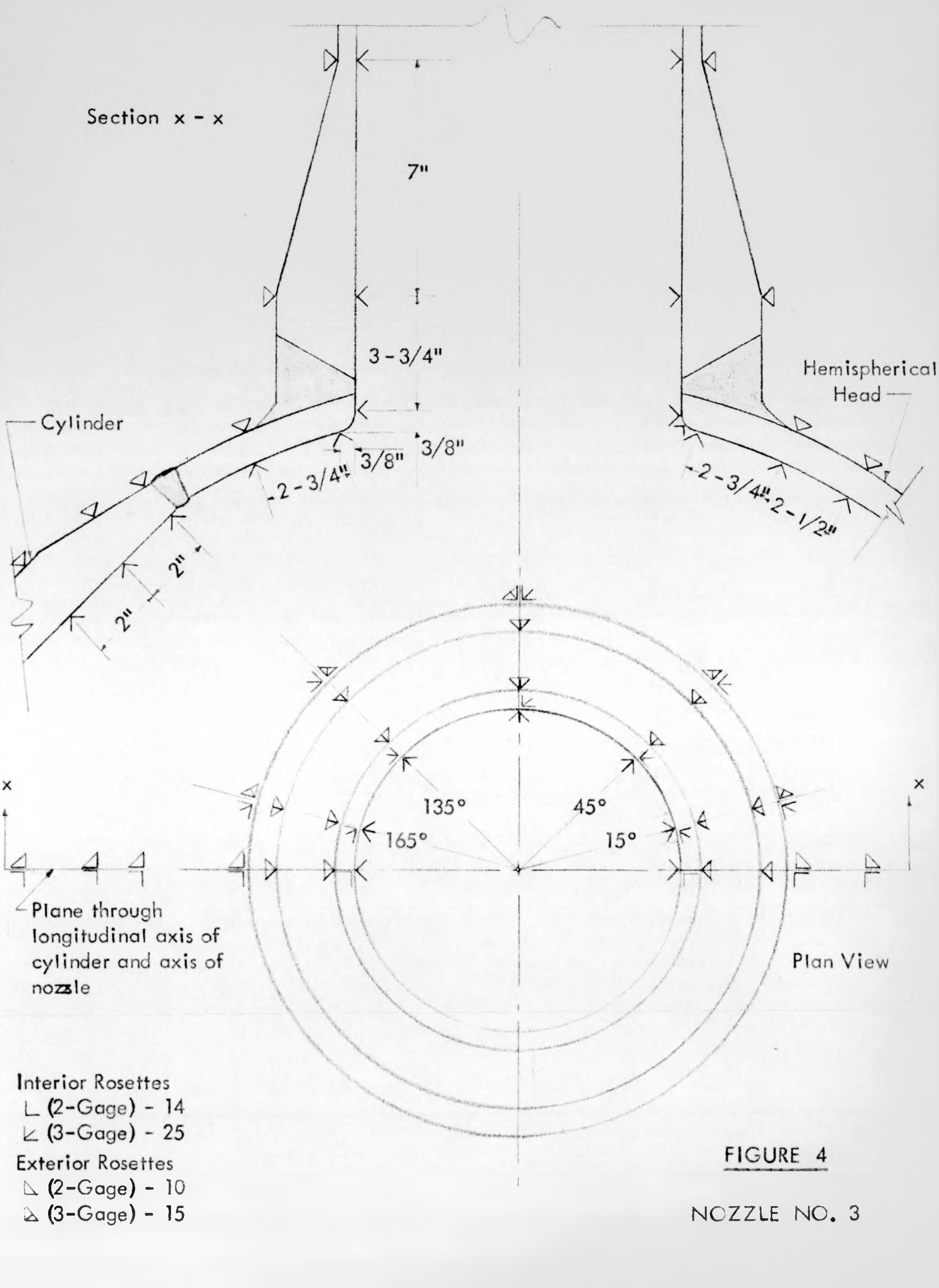


FIGURE 4

NOZZLE NO. 3

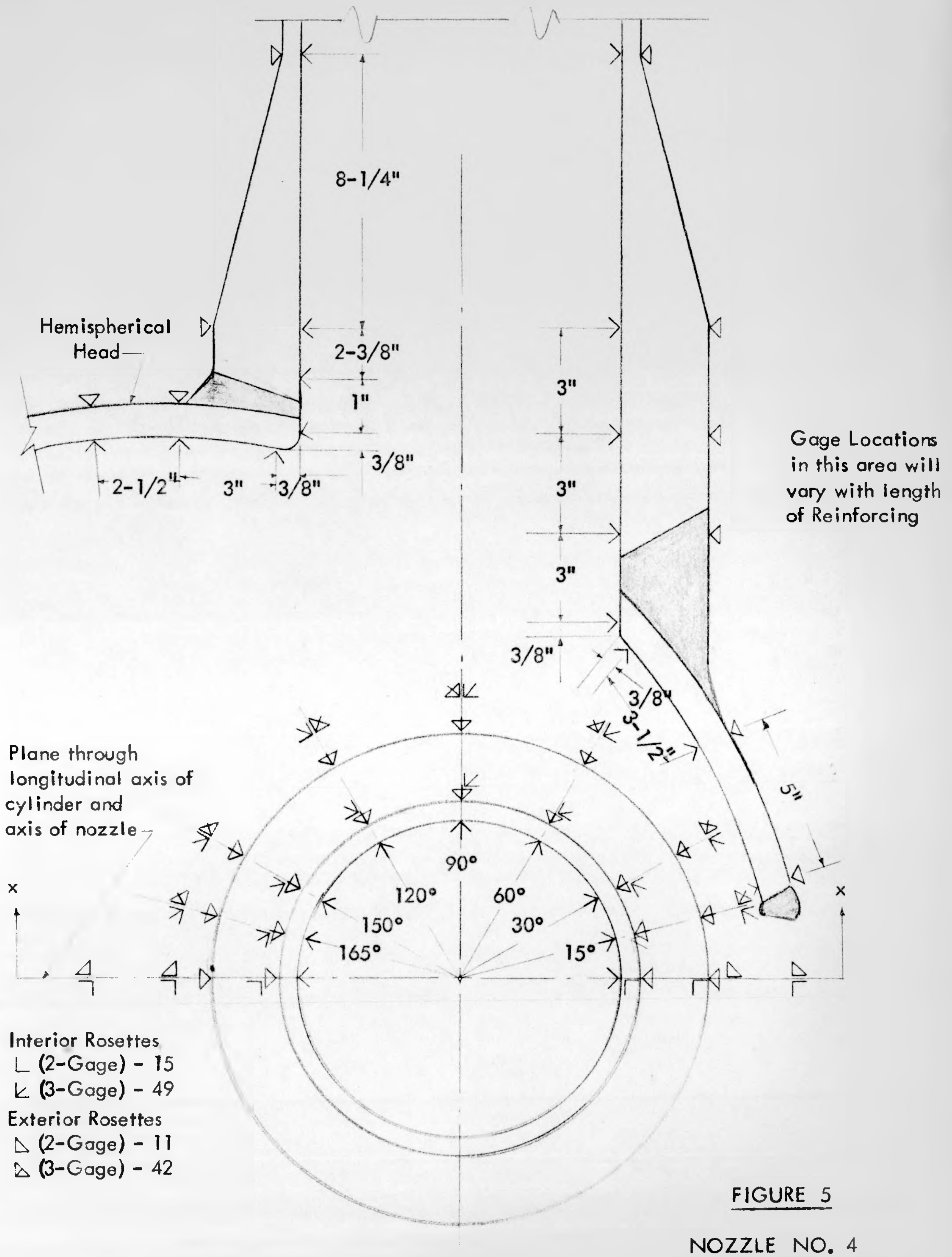
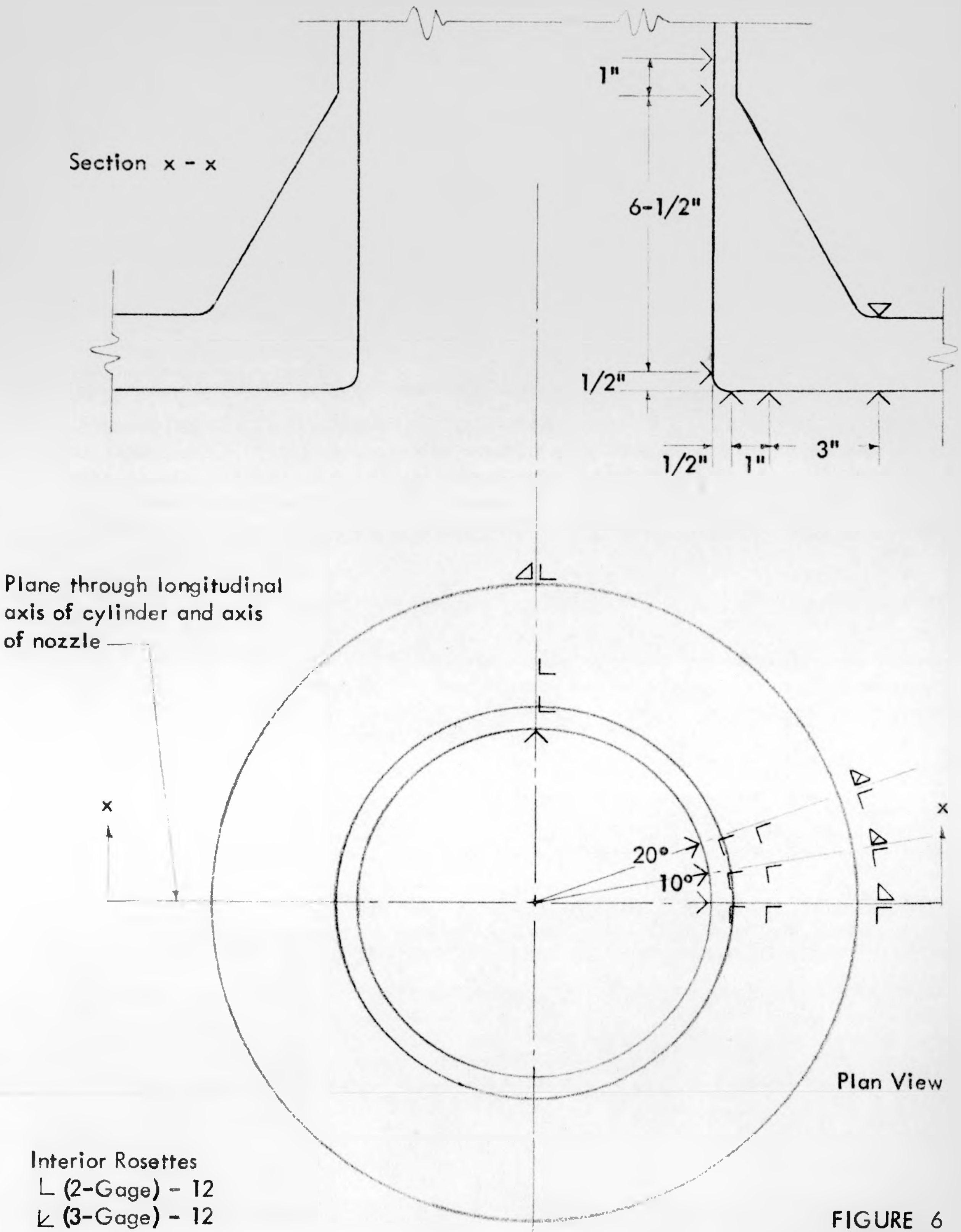


FIGURE 5

NOZZLE NO. 4



Interior Rosettes
∟ (2-Gage) - 12
∟ (3-Gage) - 12

Exterior Rosettes
△ (2-Gage) - 2
△ (3-Gage) - 2

FIGURE 6

NOZZLE NO. 6

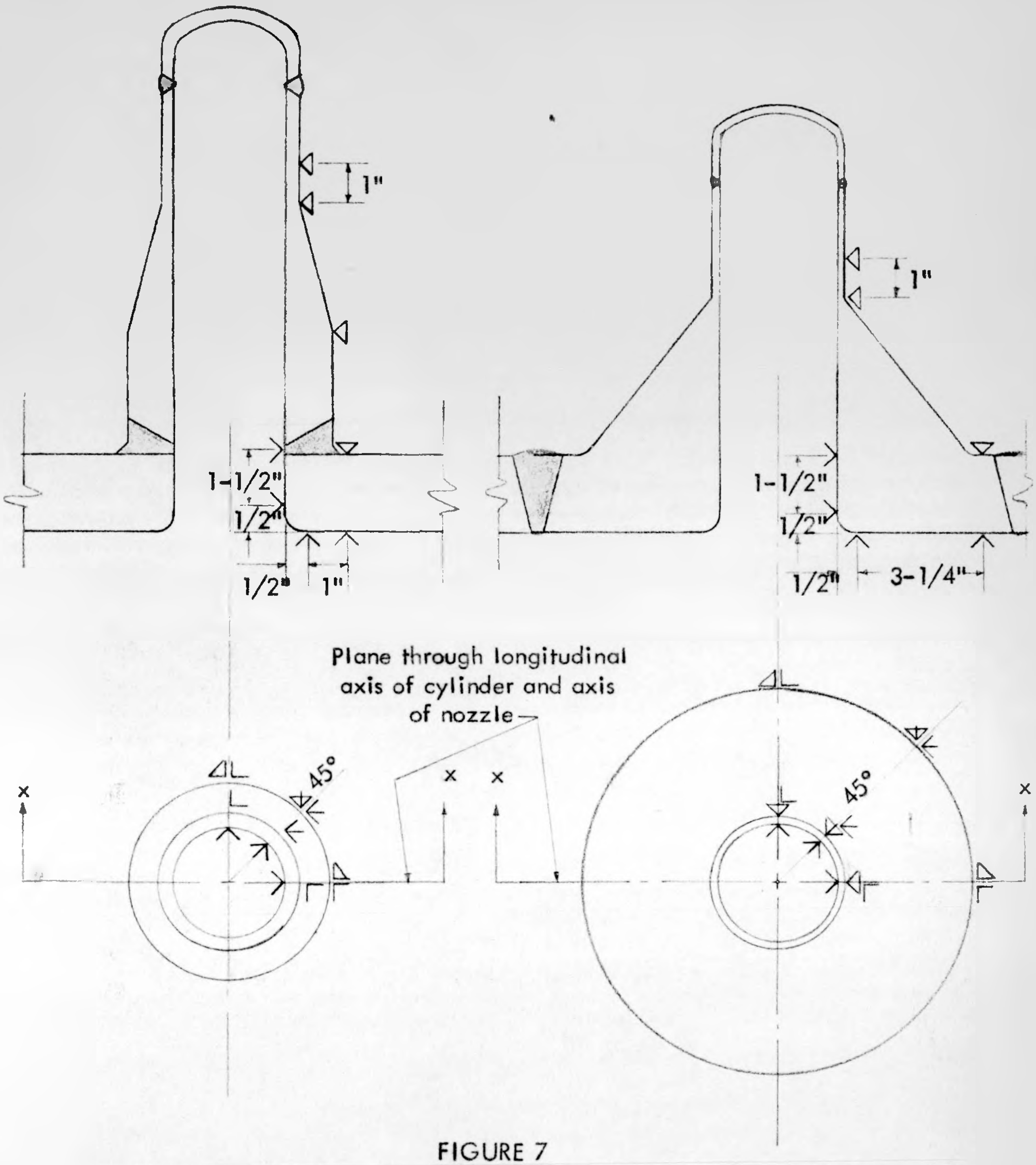
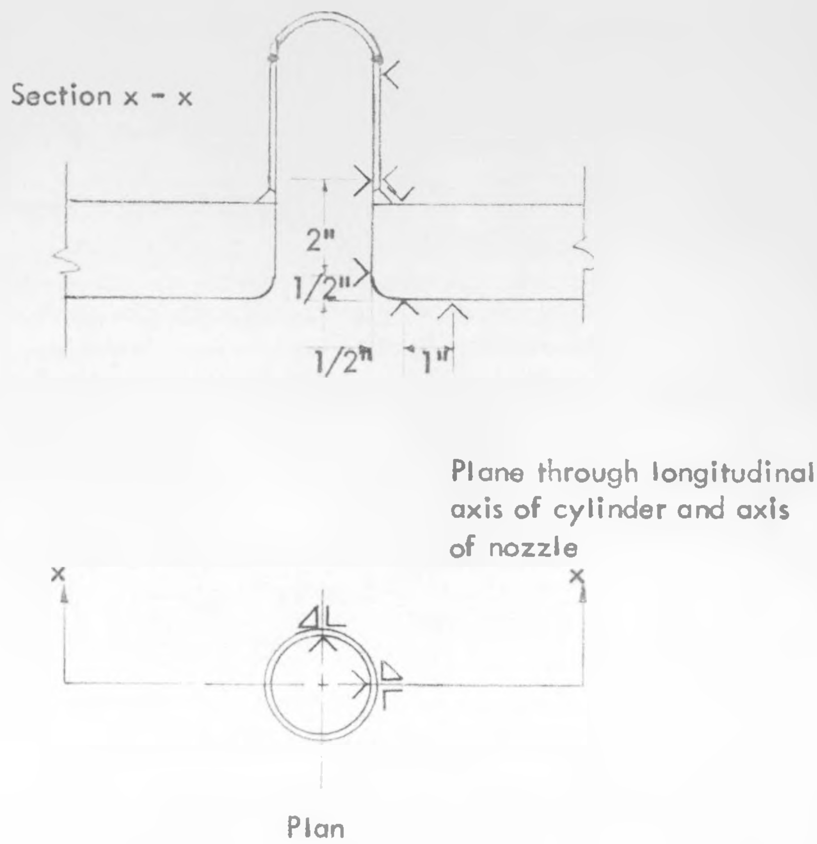


FIGURE 7

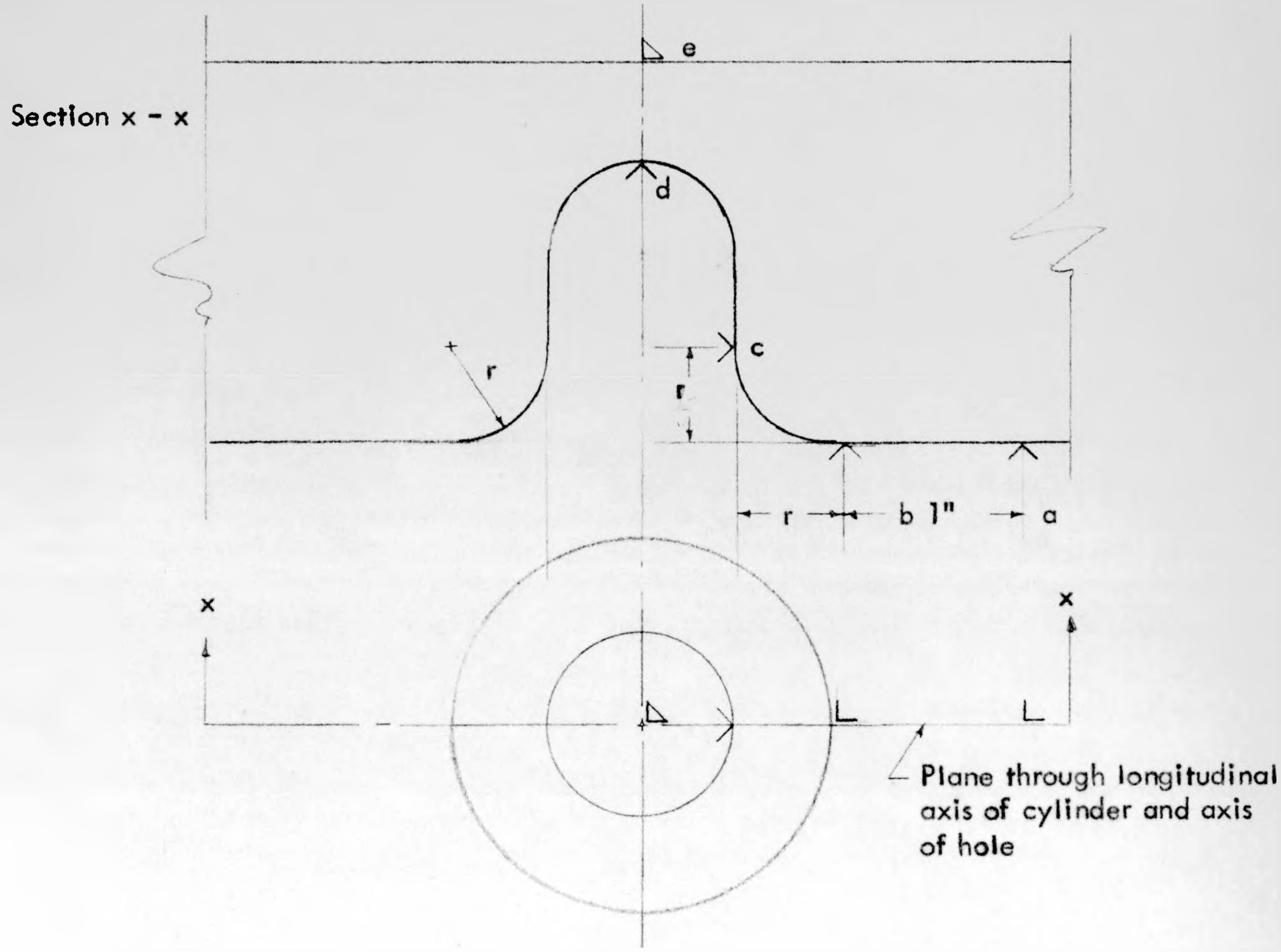
NOZZLE NO. 8		NOZZLE NO. 9
	Interior Rosettes	
8	∟ (2-Gage)	8
4	(3-Gage)	4
	Exterior Rosettes	
8	(2-Gage)	6
4	(3-Gage)	3



∟ Interior Rosettes 8
◺ Exterior Rosettes 6

FIGURE 8

NOZZLE NO. 11



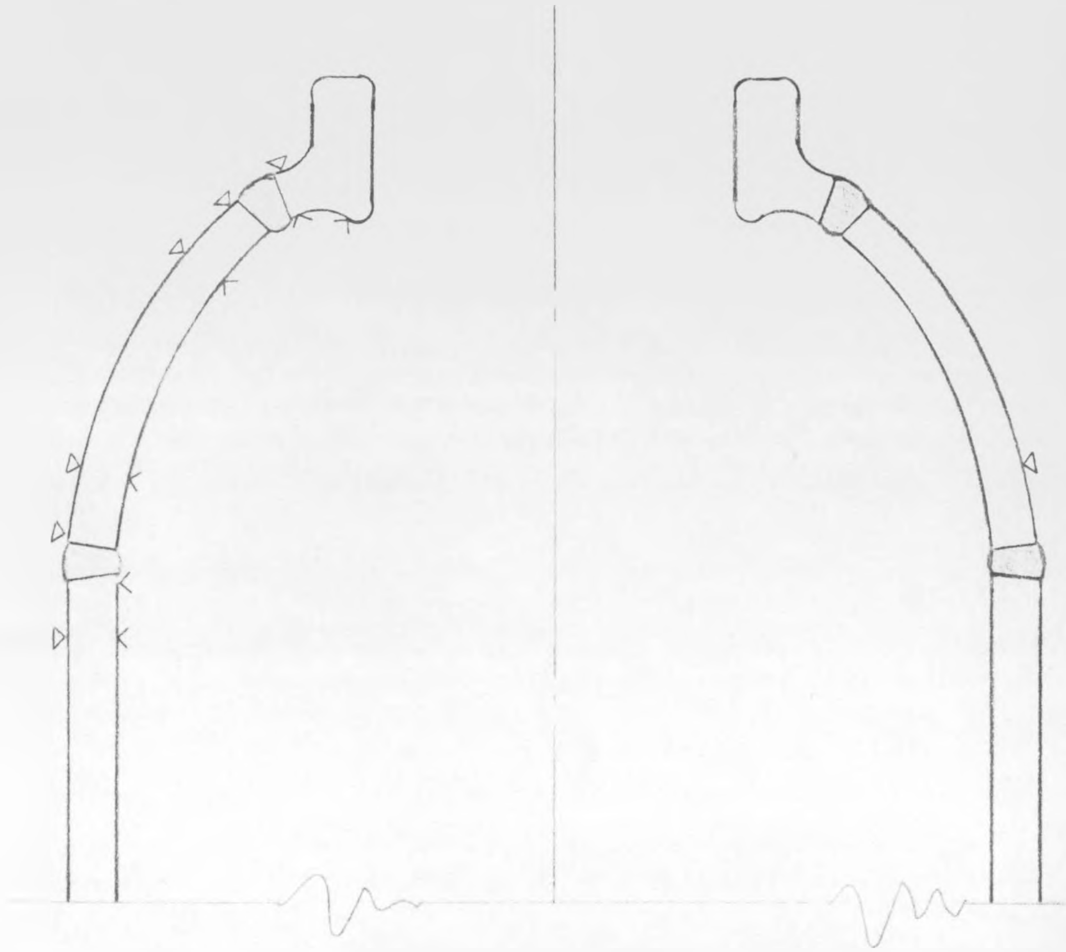
TYPICAL HOLE

Schedule

No.	Dia.	r	a	b	c	d	e
11	1/4"	1/8"	1	1			1
12 and 16	1/2"	1/4"	1	1			1
13 and 17	1"	1/2"	1	1	1		1
14 and 18	2"	1/2"	1	1	1	1	1

Total Interior - 20
Total Exterior - 7

FIGURE 9



Section of plane through
longitudinal axis of cylinder

▷ Exterior - 7
∟ Interior - 6

HEMISPHERICAL HEAD WITH MAN HOLE

Scale 1-1/2" = 1 foot

FIGURE 10

III. STRESSCOAT ANALYSIS

In determining location, direction, and approximate magnitude of strains with Stresscoat, the usual technique is to apply a coating of the correct sensitivity for the temperature and humidity conditions prevailing during the test, and then to load the test article by increments, noting the appearance and growth of crack patterns at each increment. This procedure is quite satisfactory for determining locations of strain concentration on the exterior of the pressure vessel. However, the effect of hydrostatic pressure on the brittle coatings requires a different approach in order to obtain the desired information for the interior surface. As a result, separate Stresscoat tests were performed for inside and outside of the vessel.

In carrying out the Stresscoat analysis for the interior of the vessel, it was originally proposed to use air or nitrogen gas as the pressurizing medium. However, no practical method was found for controlling the temperature of the gas, without special heat exchanger equipment.

Pilot tests were then conducted using water as the pressurizing medium. The problem of accommodating changes in temperature due to the rapid gas expansion was thus avoided, since the temperature of the water was found to be quite uniform without the use of auxiliary heat exchanger equipment. Coatings were then selected on the basis of the measured water temperature and 100% relative humidity. The results were sufficiently encouraging to warrant the use of water for the interior Stresscoat study of the PVRC vessel. It should be noted that the water has a softening or desensitizing effect on the threshold sensitivity of the coating. However, this is offset by an increase in coating sensitivity due to the pressure. This increase in sensitivity is sufficient to cause indiscriminate cracking, or "crazing" of the coating under pressure at load levels below the strain threshold of the exterior coating. Another problem with this technique is the time required to pressurize a vessel of this size. Each increment of loading entails filling the vessel, applying a certain amount of pressure, and then emptying and drying the interior surface in order to inspect for crack patterns. The length of time for which the coating can be exposed to water without damage limits the test to one filling and application of load. To obtain the necessary information in one test, coatings of varying sensitivities are applied to symmetrical sections of the vessel. For example, a typical nozzle can be divided into four symmetrical quadrants. Each quadrant is sprayed with a different coating, with strain sensitivities ranging from one which will crack under relatively small strains to one with a strain threshold so high as to crack only in areas of high strain concentration. Quantitative data is available to compute the effect of pressure upon the strain threshold of the coatings, which, in combination with data from tests of calibration bars, can be used to determine the magnitude of strain required to crack each coating. Thus in one test, data can be obtained equivalent to that resulting from four load increments on a single coating.

Preliminary tests were made on a smaller vessel to determine the proper coatings to bracket the range of strains expected in the large vessel. With the completion of pressure tests to check out equipment and determine the time interval necessary to fill and pressurize the vessel, Stresscoat application was begun. These lengthy preliminaries were necessary to obtain background information, since the actual application, drying, and loading must be carried out without interruption under carefully controlled conditions. The actual Stresscoat tests of the pressure vessel are summarized in the following tabulations.

Test Run No. 1

Internal Pressure:	1,000 psig
Temperature:	71°F
Pressurizing Medium:	Tap water
Time to Pressure:	7 minutes

Coating	Theoretical* Threshold Strain MII	Actual Threshold Strain MII	(Theoretical)* Corrected for Creep. MII	(Theoretical)* Corrected Hydrostatic Pressure MII	Pr/tE Corr. Thres. Strain
1206	800	900	1220	457	1.5
1204	1000	1100	1520	570	1.9
1202	1200	1300	1800	675	2.2
1200	1400	1600	----	---	2.4

* Principles of Stresscoat, Magnaflux Corporation, 1955, Chart No. 1, Chart No. 2, and p. 55.

Inspection of the coating showed no cracks in the 1200 or 1202 coating, cracks limited to the short radii at the intersection of nozzles and shell in the 1204, and a combination of crazing and cracking at the intersection of nozzles and shell in the 1206. No patterns were found in locations other than these. The highest strains seemed to be at the nozzle intersections with the hemispherical head.

Test Run No. 2

Internal Pressure:	1,200 psig and 1,440 psig*
Temperature:	73°F
Pressurizing Medium:	Tap water
Time to pressure:	7 minutes to 1,200 psig; 8 minutes to 1,440 psig

Coating Number	Theoretical** Threshold Strain Mil	Actual Threshold Strain Mil	(Theoretical)** Corrected for Creep Mil	(Theoretical)** Corrected for Hydrostatic Pressure Mil	Theo. Max. Membrane Strain Mil
1204	1100	1300			
	at 1200 psig		1810	452	360
	at 1440 psig		1830	183	433

* Stresscoat begins to craze indiscriminately at 1500 psig which establishes upper limit for internal testing.

** Principles of Stresscoat, Magnaflux Corporation, 1955, Chart No. 1, Chart No. 2, and p. 55.

Inspection of the coating after the 1200 psig loading showed only five well developed sets of crack patterns:

(1) An area on the shell extending for about one inch from the intersection of nozzle Number 9* with the shell.

(2) A star shaped pattern at the bottom of hole Number 18 and well defined patterns on the shell radiating from the intersection of nozzle Number 18 with the shell and extending for about 2 inches from this intersection.

(3) An area on the shell extending about one inch from the intersection of nozzle Number 3 with the shell.

(4) An area on the shell and inside the nozzle extending about one inch from the intersection of nozzle Number 4 with the shell.

(5) The arcs at the intersection of nozzles and shell.

Inspection of the coating after the 1440 psig loading showed only the extension of these cracks together with the development of a lobe of cracks from the hillside nozzle Number 4 midway between the line between nozzles 3 and 4 and the junction of the head and shell.

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* Refer to Drawings in Appendix A for nozzle locations and geometries.

Figures 11 and 12 are photographs of two of the most highly stressed areas of the interior surface of the vessel. Figure 11 was taken at the junction between the radial nozzle and hemispherical head at approximately 45 degrees to the line between the two nozzles on the head. The black grease pencil line nearest the nozzle marks the extent of the cracks in the brittle coating at 1200 psig (about 1 inch from junction of internal surfaces). These lines were radial from the nozzle. The outmost grease pencil line marks the average extent of the cracks in the brittle coating at 1440 psig, at which pressure the "mud cracking" appeared on the highly stressed area while areas farther away from the discontinuity were free of cracks. This "mud cracking" appears to be the result of nearly equal principal tensile strains in the biaxial field.

Figure 12 shows similar behavior at a two inch blind hole with the 1200 and 1440 psig lines.

FIGURE 11. INTERIOR SURFACE STRESSCOAT PATTERNS AT RADIAL NOZZLE

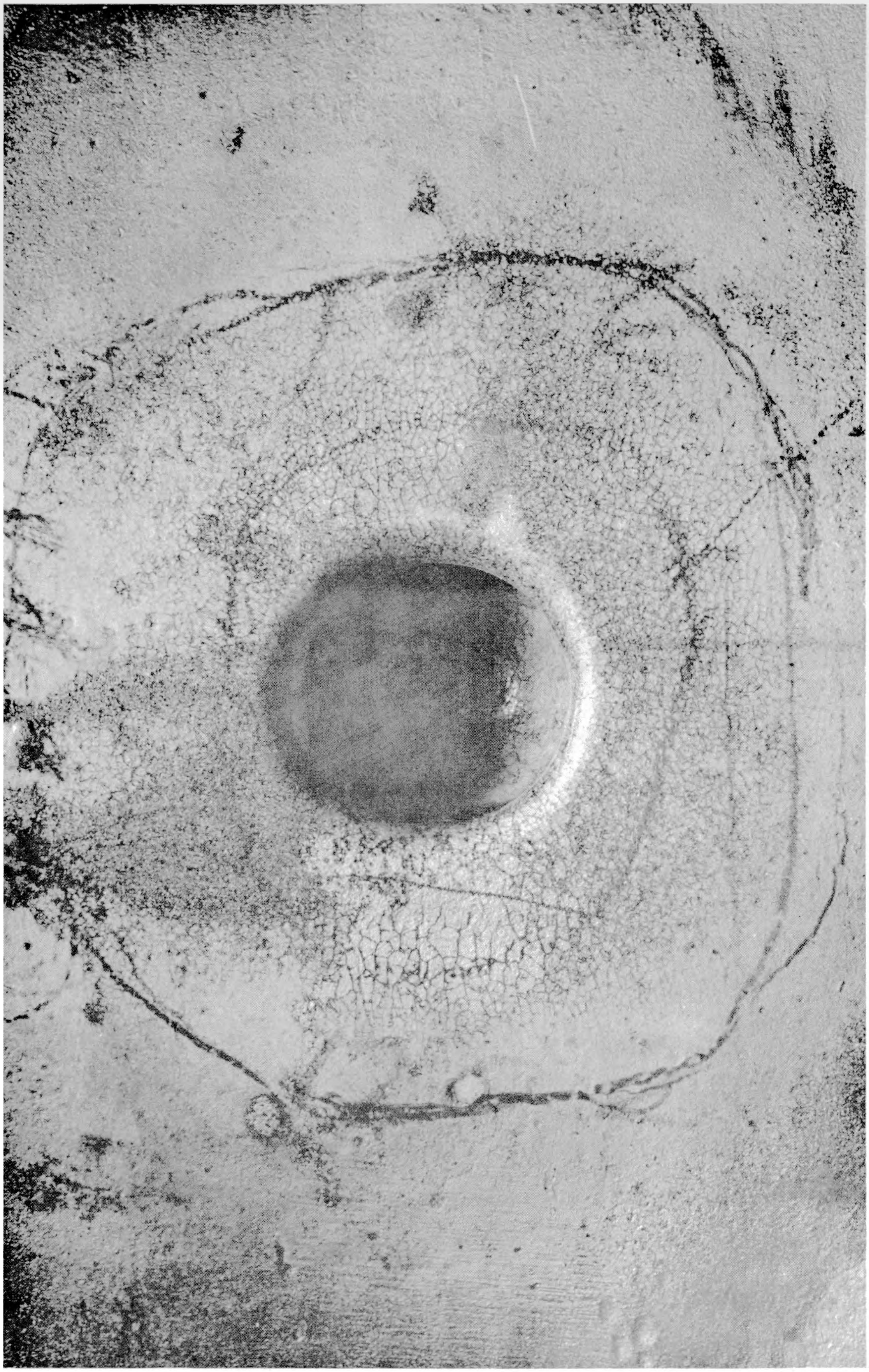


FIGURE 12. INTERIOR SURFACE STRESSCOAT PATTERNS AT BLIND HOLE

Test Run No. 3

Internal Pressure:	2,000 psig
Temperature:	73°F
Humidity:	55% R. H.
Time to Pressure:	10 minutes

Coating Number	Theoretical Threshold Strain * Mil	Actual Threshold Strain Mil	(Theoretical) Corrected for Creep* Mil	(Theoretical) Sensitized with Dye Etchant* Mil	pr/tE / Corr. Thres. Strain
1206	600	650	900	600	1.0

No visible cracks developed in the brittle coating at maximum Stresscoat pressure (2000 psig) and so the dye etchant sensitization technique was used. The cracks developed by this technique indicated that the greatest strains on the exterior surface occurred on the hillside nozzle Number 4, the pipe nozzle Number N-11, on the shell adjacent to nozzle Number 1, and on the nozzle-shell fillets.

* Principles of Stresscoat, Magnaflux Corporation, 1955, Chart No. 1, Chart No. 2, and Chart No. 5.

Figure 13 is a photograph showing the cracks in the brittle coating around the pad of Nozzle No. 1. "Mud cracking" developed in this area also, and the major crack lines are outlined with grease pencil. The Stresscoat on the nozzle and pad showed but a few widely spaced cracks in the brittle coating with no "mud cracking."

FIGURE 13. EXTERIOR SURFACE STRESSCOAT PATTERNS AT NOZZLE NO. 1

Discussion of Stresscoat Tests

The test conditions were unfavorable for obtaining excellent Stresscoat results. These conditions were:

(1) The low strains caused by permissible test pressures. The upper limits of test pressures were 1500 psig for internal surface Stresscoat (which is the hydrostatic pressure at which Stresscoat begins to craze indiscriminately) and 2200 psig for external surface Stresscoat (which was the proof pressure which could not be exceeded because of the desire to study strain redistribution after cycling).

(2) The crazing threshold of Stresscoat which establishes the lower limit of coating sensitivity available. Stresscoat more sensitive than 600 MII threshold strain is apt to craze indiscriminately. This situation was aggravated by the springtime weather changes which occurred during the test period. Although the temperature of the laboratory is controlled and was maintained within reasonable limits, the humidity was uncontrolled and fluctuated unpredictably over a range of from below 20% R.H. to above 80% R.H. during the 48 hour periods required for applying the coating and testing.

(3) The vessel could not be brought to load as rapidly as desired.

The vessel was tested in the laboratory and not in the cycling well and it was necessary to use a Sprague pump instead of the high speed cycling pump to build up pressure. This would not have been a serious handicap except for the previously mentioned low strain levels which result from the permissible pressure limits and the high threshold strain levels of the Stresscoat.

The result of using Stresscoat at the limit of its applicability was the loss of ability to measure strains quantitatively (as is obvious from the variance between theoretical threshold strains and estimated strains). The primary objective of the tests was, however, attained. This objective was to determine if strain gage locations chosen by reference to previous work would measure the actual maximum strains in this vessel. The location and direction of maximum strains indicated by cracks in the brittle coating conformed to the predicted locations with the possible exception of the interior surface area bounded by the juncture of hemispherical head and shell and the line between the nozzles on the hemispherical head. The interaction of discontinuity strains in this area seems to increase the tensile strains adjacent to the hillside nozzle in a location which had not been foreseen. In addition, the strains on the interior surface adjacent to the two inch blind holes seem to be greater than had been expected.

It is recommended that the proposed strain gage locations be used and that additional gages be mounted in the two areas where discrepancy was found between the Stresscoat tests and the locations chosen by reference to previous work.

IV. SCHEDULED WORK

With the completion of the Stresscoat tests, strain gages will be installed at critical points to obtain quantitative data on strain magnitudes. Details will appear in the next progress report.

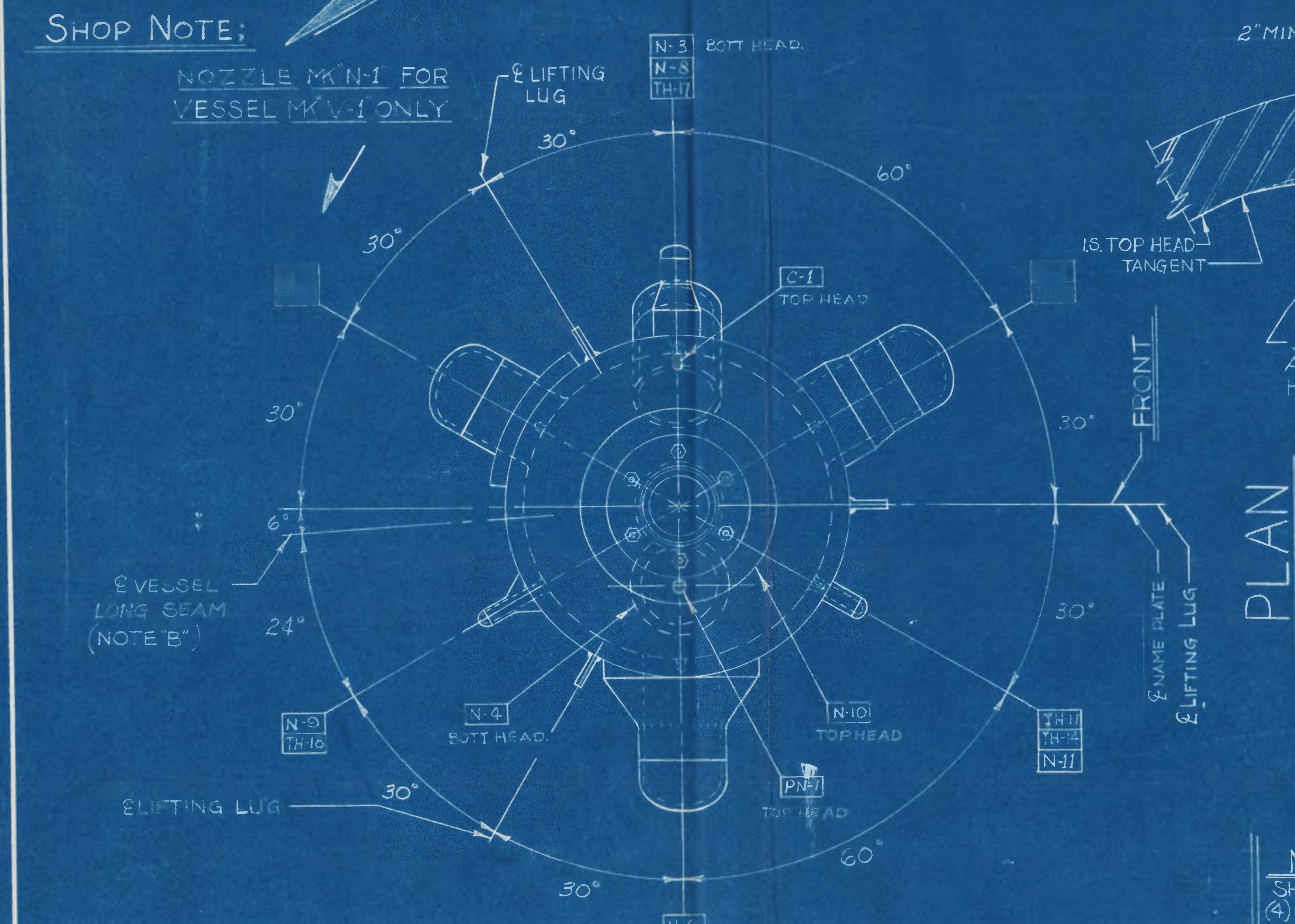
V. FISCAL INFORMATION

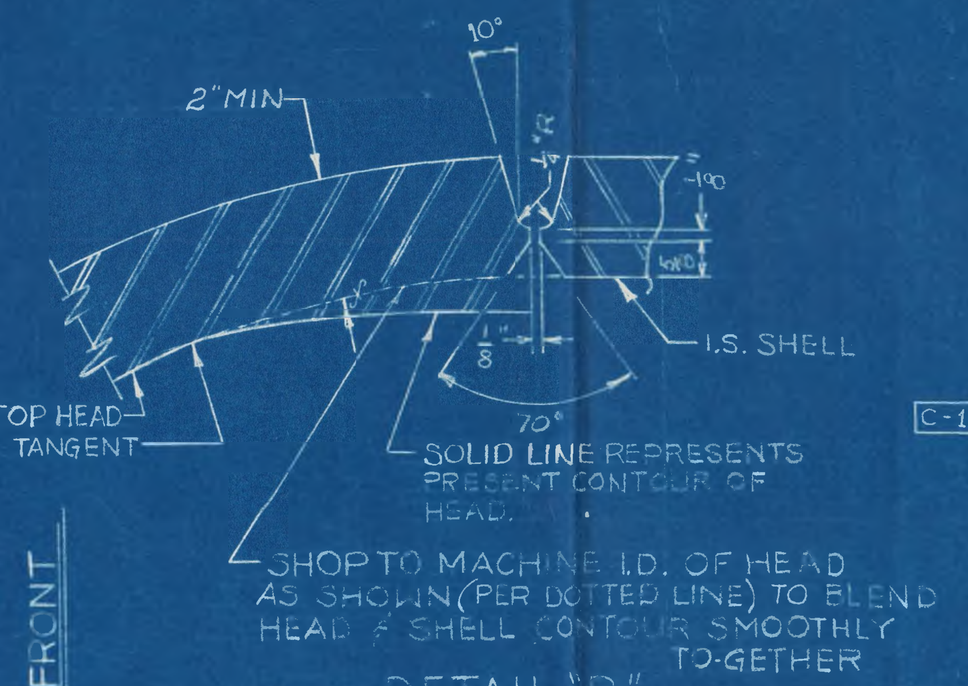
Project expenditures to March 14, 1959 total approximately $20,321.59, leaving a balance of $4,888.41.

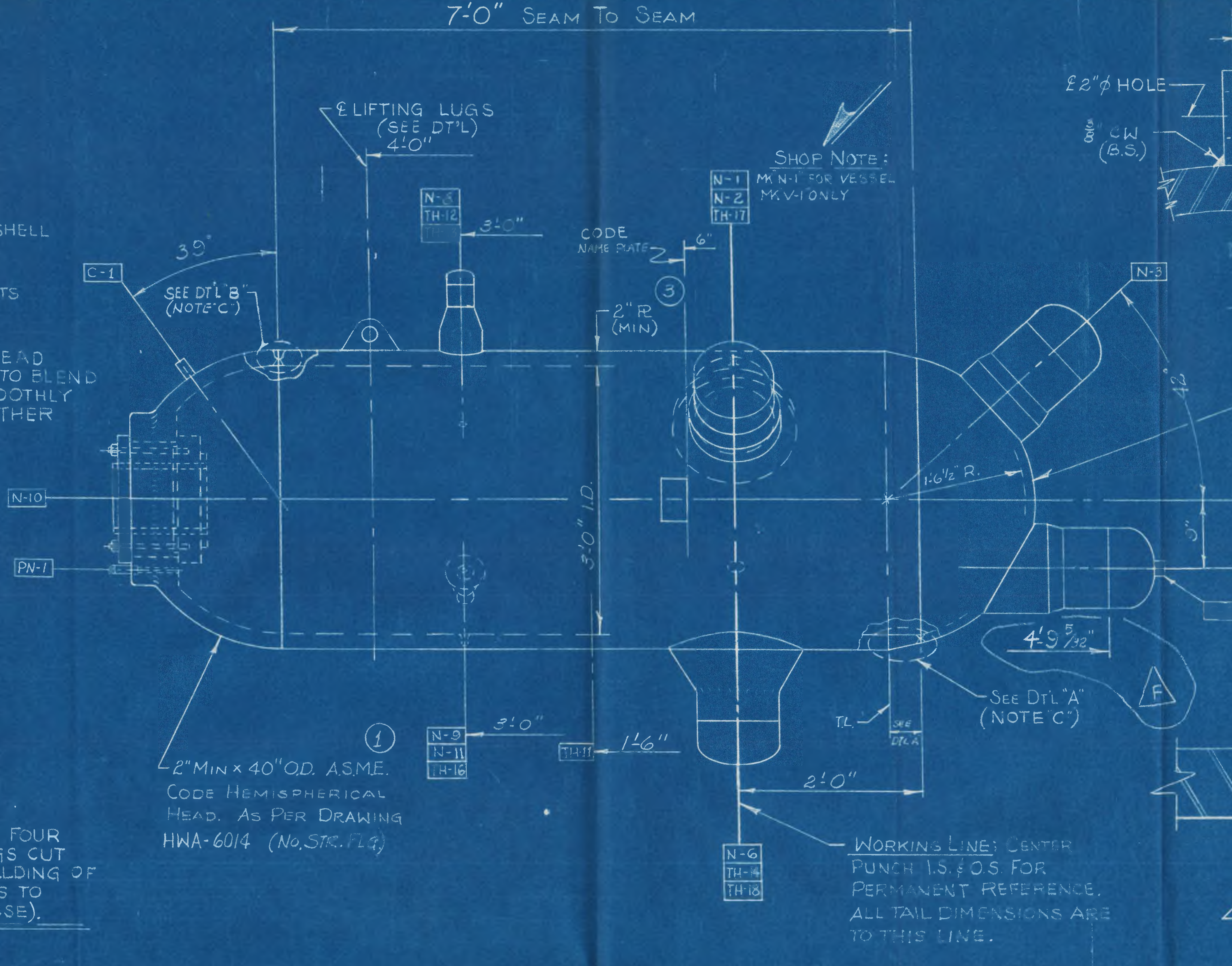
APPENDIX A

SHOP NOTE:

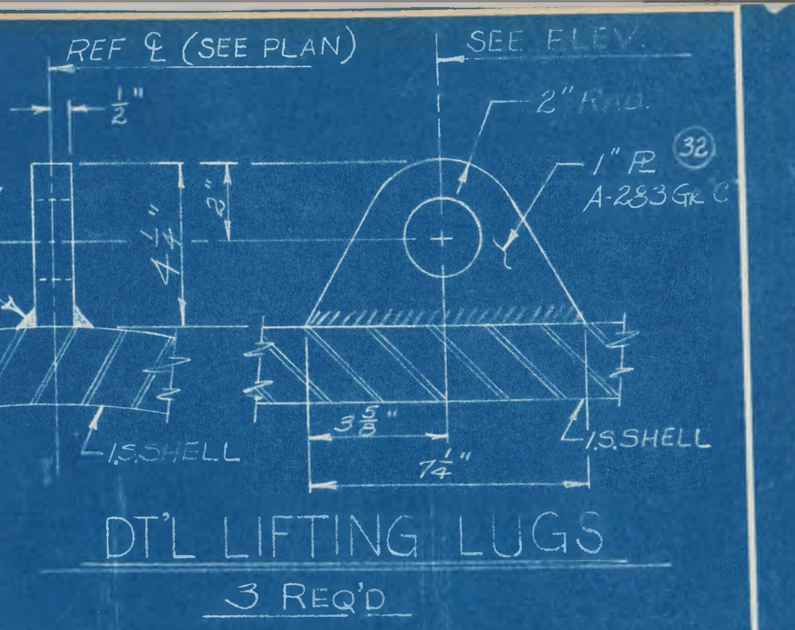
NOZZLE MK N-1 FOR VESSEL MK V-1 ONLY

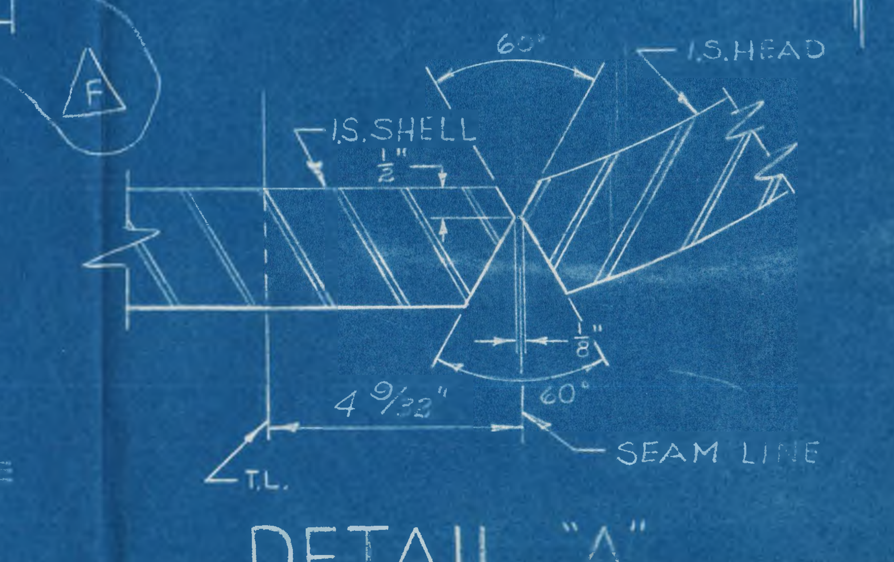






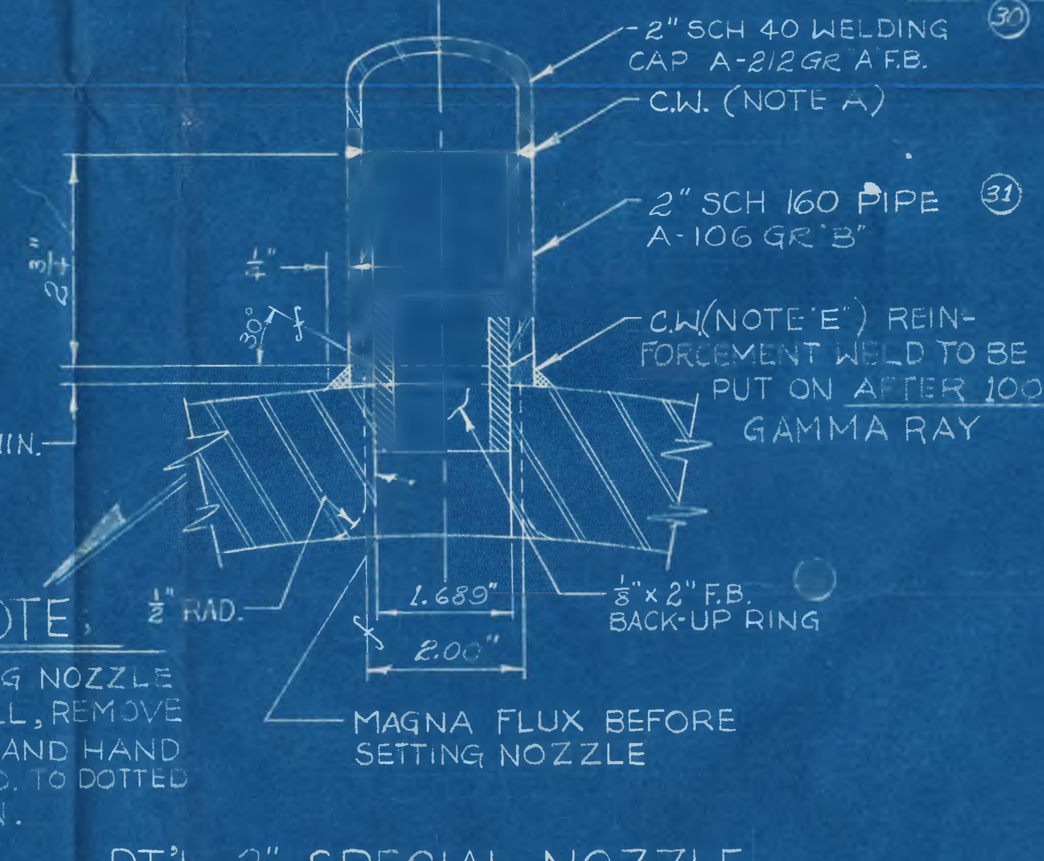
NOTE:
SHOP TO MEASURE THICKNESS AT FOUR (4) POINTS AROUND ALL OPENINGS CUT IN HEADS & SHELL PRIOR TO WELDING OF NOZZLES. FURNISH READINGS TO DRAFTING ROOM. (FOR CUSTOMER USE).





WELDING NOTES

NOTE "A" - WYATT SPEC HW 1-1
NOTE "B" - WYATT SPEC HW 1A
NOTE "C" - WYATT SPEC HW 1B
NOTE "D" - WYATT SPEC HW SF-1
NOTE "E" - CUST SPEC PAGE 3, PAR VII

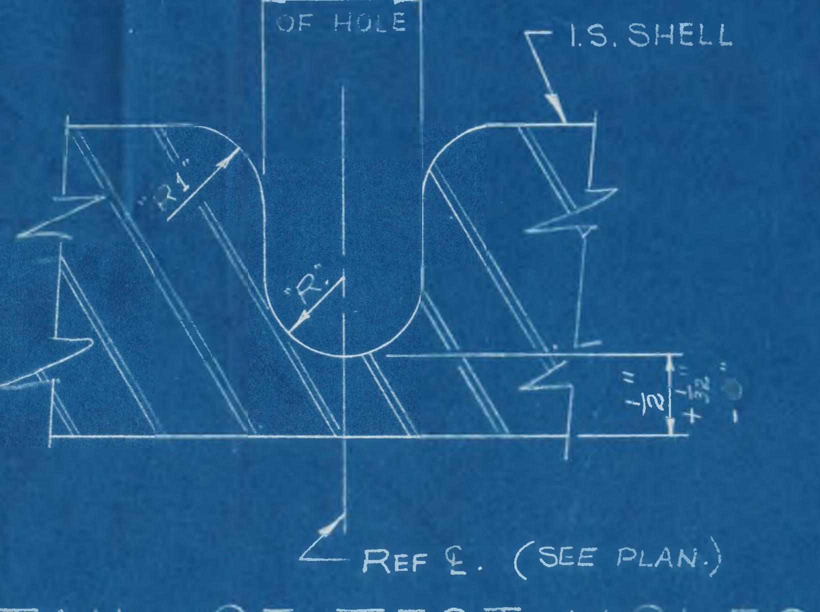


CONVERSION TABLE	
DEGREES	DISTANCE MEASURED ON O.S. CIRCUMFERENCE OF SHELL
6°	2 1/8"
24°	8 3/8"
30°	1[illegible] 1/2"
60°	1'-8 15/16"
90°	2'-7 7/16"

SHOP NOTE:
AFTER WELDING NOZZLE MK "N-11" TO SHELL, REMOVE BACK-UP STRIP, AND HAND REAM NOZZLE I.D. TO DOTTED LINE AS SHOWN.

DT'L 2" SPECIAL NOZZLE
ONE REQ'D MK N-11

SHOP NOTE:
FOR DIMENSIONS "D", "R" & "R-1" SEE SCHEDULE OF TEST HOLES.



DETAIL OF TEST HOLES
TOTAL OF (7) REQ'D (SEE SCHEDULE)

MATERIAL NOTE

UNLESS OTHERWISE NOTED ALL MATERIAL ON THIS DRAWING ONLY TO BE AS FOLLOWS:

SHELL A-201 GR "B" F.B.
HEADS A-201 GR "B" F.B.
VESSEL SUPPORTS
FORGED FLANGES
PLATE FLANGES
PIPE NECKS
PLATE NECKS
REINFORCING PADS
STRUCTURAL SHAPES AISI A-107 GR 1020

GENERAL NOTES CON'T

ALL OPENINGS IN THE SHELL OR HEADS MAY BE FLAME CUT PROVIDED THEY ARE CUT UNDERSIZE AND GROUND TO SOUND METAL AND CRACK FREE BEFORE WELDING. **

ALL CUT EDGES WHICH WILL NOT BE INVOLVED IN SUBSEQUENT WELDING SHOULD ALSO BE GROUND TO REMOVE SURFACE CHECKS AND CRACKS. **

INTERIOR EDGES OF OPENINGS ARE TO BE GROUND TO PRESCRIBED RADII USING TEMPLATES OR GAGES TO ASSURE ACCURACY. THIS ALSO APPLIES TO THE CONTOURING OF FILLET WELDS AT VARIOUS OPENINGS.

ALL HEADS ARE TO BE VIDIGAGED UPON RECEIPT FROM THE MILL USING A COORDINATE SYSTEM, ALL READINGS ARE TO BE RECORDED AND FURNISHED TO THE CUSTOMER FOR FUTURE REFERENCE PARTICULARLY THE HEAD THICKNESS AT THE AREAS OF THE OPENINGS AND THE GIRTH SEAM ATTACHMENT WELDS.

NOZZLE MARK "N-8" IS TO BE BORED UNDERSIZE BY A FEW THOUSANDTHS PRIOR TO WELDING AND THEN HAND REAMED TO SIZE.

** SOUNDNESS TO BE DETERMINED BY MAGNETIC PARTICLE INSPECTION PER REF 1.

THE TAPER AS SHOWN IN DETAIL "A" SHALL BE GROUND SMOOTH AFTER BURNING AND INSPECTED FOR SURFACE CRACKS. ALL CRACKS ARE TO BE REMOVED. **

* ALL WELDS EXCEPT THE ATTACHMENT WELDS OF NOZZLES MK "N-1", AND NOZZLE CLOSURE ATTACHMENT WELDS TO BE X-RAYED EXAMINED. RADIOGRAPHIC INSPECTION IS REQUIRED ON THE THROUGH WELD ATTACHING THE NOZZLE TO THE VESSEL PRIOR TO THE DISPOSITION OF THE REINFORCING FILLET.

REF #1:
ALL WELDS TO BE MAGNETIC PARTICLE INSPECTED PER CUSTOMERS "SPEC'S FOR PVRC TEST VESSELS," DATED MAY 20, 1958. ✡

ALL SHELL SEAMS ARE TO BE GROUND FLUSH I.S. & O.S. USING CARE NOT TO OVER-GRIND AT ANY POINT.

ROUNDNESS OF SHELL SHOULD BE BETTER THAN CODE IF POSSIBLE, OR IN ANY EVENT, EQUAL. SPECIAL CARE SHOULD BE TAKEN TO MAINTAIN ROUNDNESS IN THE AREAS OF ALL OPENINGS.

THE HEADS SHALL BE MACHINED INSIDE IF NECESSARY TO ELIMINATE SHARP CHANGES FROM SHELL THICKNESS TO HEAD THICKNESS. MACHINING TO A UNIFORM THICKNESS IS PREFERABLE TO A STANDARD 1 TO 4 TAPER.

✡ UNLESS OTHERWISE NOTED, ALL MAT'L & FABRICATION SHALL CONFORM TO SPECS IN REF 1

TABLE "A"		
[illegible]	H.S.B. Nº	MFG. SERIAL Nº
[illegible]	15806	H-2079-58-1
[illegible]	15807	H-2079-58-2

GENERAL NOTES

CONSTRUCTION: ASME CODE 1956 EDITION & SPECIFICATIONS FOR PVRC TEST VESSEL
APPLY SYMBOL PER PAR. NO SYMBOL APPLIED.
DESIGN PRESSURE 1475 P.S.I. DESIGN TEMPERATURE 650 °F CORR. ALL. NONE
STRESS RELIEVE YES RADIOGRAPH YES * JOINT EFF. SHELL 95 % HEAD 100 %
SHELL AND HEAD THICKNESSES HAVE BEEN DETERMINED USING A TENSILE STRENGTH OF 60,000 P.S.I.
HYDROSTATIC TEST BASED ON
INITIAL TEST NONE P.S.I. HAMMER TEST NONE P.S.I. FINAL TEST 2,212 P.S.I.
INSPECTION BY HARTFORD S. B. I. AND I. CO. & CUSTOMER
HSB SEE TABLE "A"
MFG. SERIAL NO. SEE TABLE "A"
PROTECT ALL MACHINE SURFACES & THREADED CONNECTIONS WITH RUST PREVENTIVE IMMEDIATELY AFTER MACHINING. INSTALL WOOD OR STEEL PROTECTORS OF FITTINGS IMMEDIATELY AFTER TESTING.
VESSEL TO BE DRAINED AND CLEANED BEFORE SHIPPING.
ALL NOZZLE AND MANHOLE BOLTS TO STRADDLE CENTER-LINE UNLESS NOTED.
VESSEL TO BE WELDED BY SUBMERGED ARC PROCESS AT FABRICATORS OPTION.
PAINT IN 6" HIGH LETTERS ON HORIZONTAL CENTER-LINE
AS LOADED THE FOLLOWING ON BOTH SIDES OF VESSEL: P.O. Nº 009-SW
PAINT: NO

(40) SHOP TO APPLY ONE COAT OF UN-DILUTED WATER SOLUBLE CUTTING OIL I.S. & O.S. OF VESSEL.
(39) SHOP TO SANDBLAST I.S. & O.S. OF VESSEL. SHOP TO PROTECT MACHINED SURFACES DURING SANDBLASTING.

REFERENCE DRAWINGS:
DT'L SPECIAL NOZZLES — HWE-27889
DT'L SPECIAL NOZZLES — HWD-8509
(F) LOCATION OF VIDIGAGE READINGS — HWD-8841

MARK Nº	Nº REQ'D	SIZE OR "D" =	"R" =	"R1" =
TH-18	ONE	2"	1"	1/2"
TH-17		1"	1/2"	1/2"
TH-16		1/2"	1/4"	1/4"
TH-14		2"	1"	1/2"
TH-13		1"	1/2"	1/2"
TH-12		1/2"	1/4"	1/4"
TH-11	ONE	1/4"	1/8"	1/8"

SCHEDULE OF TEST HOLES

MARK	NO. REQ'D	SIZE	SERIES	TYPE	REMARKS
PN-1	ONE	1/2"	X HVY	PIPE NIPPLE	
C-3	ONE	1½"	3000#	COUPLING	
C-1	ONE	1"	3000#	COUPLING	
N-11	ONE	2"	SPECIAL	NOZZLE	
N-10		15"			
N-9		3"			
N-8		3"			
N-6		10"			
N-4		10"			
N-3		10"			
N-2		10"			
N-1	ONE	10"	SPECIAL	NOZZLE	FOR VESSEL MK V-1 ONLY

SCHEDULE OF OPENINGS

TWO VESSELS REQ'D. S/O 2079

CUST. REF. DWGS. SOUTHWEST RESEARCH INSTITUTE DWG Nº 6601-1-REV. Nº 6 DTD 11-6-58

SHIPPING WEIGHT 9,500 EA. #

SHIPPING CLEARANCE

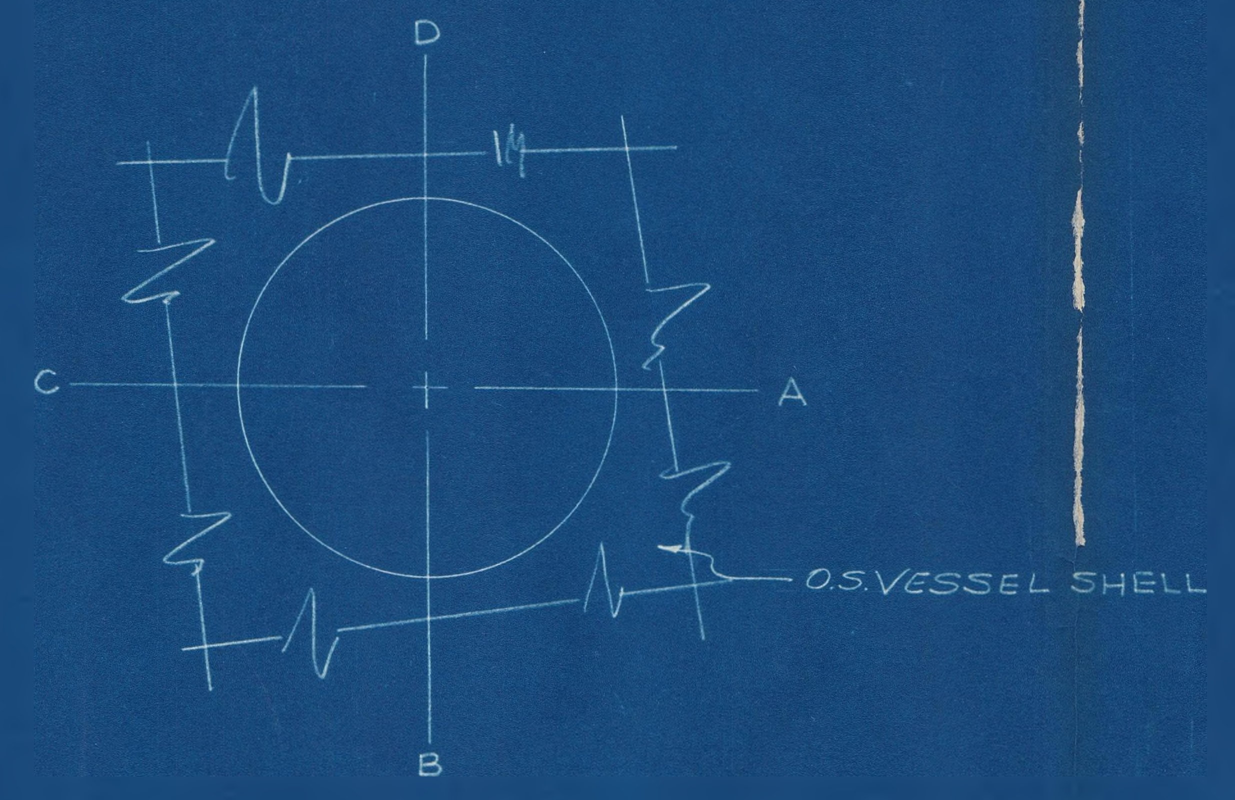
NO.	REVISION	DATE	BY	CKD
	REV PROJECTION OF "N-4"	3/24/59		AJP
	REV PROTECTIVE COATING OF VESSEL	2/27/59	P.S.	AJP
	REV SANDBLAST FROM I.S. TO I.S. & O.S.	2/5/59	P.S.	AJP
C	ADDED SANDBLASTING NOTE; REV. ORIENTATION OF LIFTING LUGS		P.S.	AJP
B	REV DT'L "A" & "B", ADDED NOZZLE "N-11", REVISED ELEVATION OF "TH-11" ADDED LIFTING LUGS & REVISED GENERAL NOTES.	12/12/58	P.S.	AJP
A	REVISED PER CUSTOMER APPROVAL		P.S.	AJP

WYATT METAL & BOILER WORKS INC.
DALLAS, TEXAS • HOUSTON, TEXAS

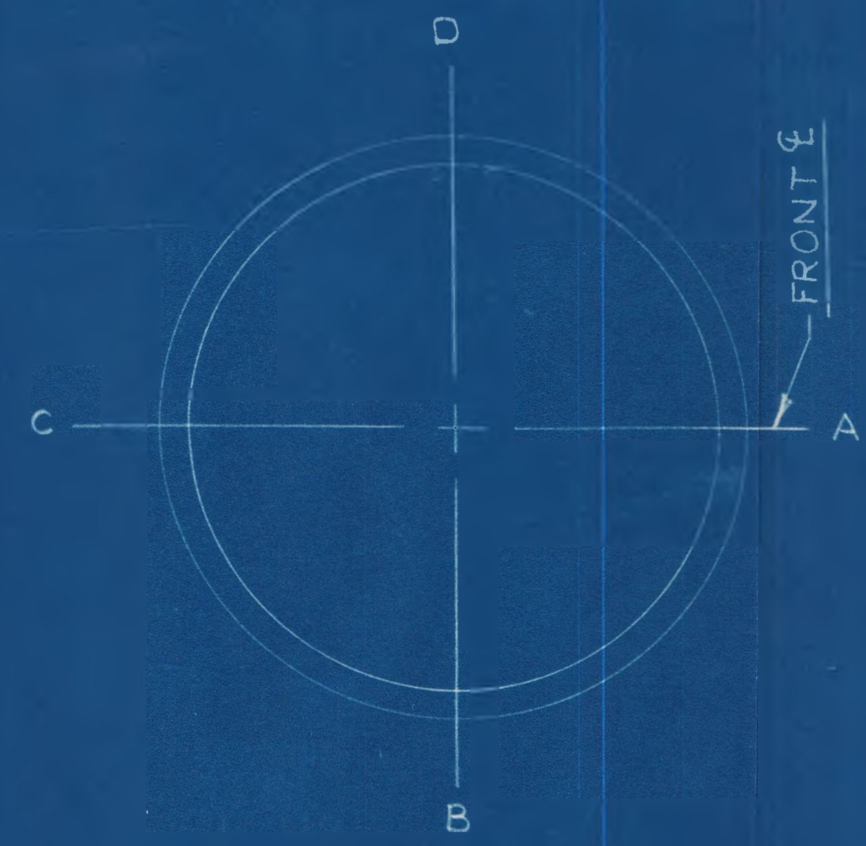
3'-0" I.D. × 7'-0" SEAM TO SEAM
PLASTIC FATIGUE TEST VESSEL
ELEVATION & GENERAL NOTES

CUST. SOUTHWEST RESEARCH INSTITUTE
P. O. NO. 009-SW JOB NO.
DRAWN SAYERS DATE 8-13-58
CHECKED AJP
APPROVED
No. HWE-27888

10" SCH 80 WELDING CAP A-212 GR A F.B.
C.W. (NOTE "A")
10 3/4" O.D.
ROUGH MACHINE FORGING x 14 1/2" O.D. x 9.564" I.D. x 15" LG. A-105 GR I, WITH 0.30% MAX. CARBON. (SHOP TO MACHINE AS SHOWN).
C.W. (NOTE "E") REINFORCEMENT WELD TO BE PUT ON AFTER 100% GAMMA RAY
I.S. SHELL
1/2" R.
1/2" MIN
MAGNA FLUX BEFORE SETTING NOZZLE.
1/4" x 2" F.B. BACK-UP STRIP REMOVE AFTER WELDING, BACK CHIP, RE-WELD AND GRIND FLUSH WITH I.D. OF NOZZLE.
DT'L 10" SPECIAL NOZZLE
ONE REQ'D MK "N-2"
SEE ELEVATION.
10 3/4" O.D.
10" SCH 80 WELDING CAP A-212 GR. A F.B.
C.W. (NOTE "A")
ROUGH MACHINE FORGING x 14 1/2" O.D. x 9.564" I.D. x 16 1/2" LG. A 105 GR I. WITH 0.30% MAX. CARBON (SHOP TO MACHINE AS SHOWN)
1/4" x 2" F.B. BACK-UP STRIP REMOVE AFTER WELDING, BACK CHIP, RE-WELD AND GRIND FLUSH WITH I.D. OF NOZZLE.
MAGNA FLUX AFTER SETTING NOZZLE.
I.S. BOTT. HEAD
C.W. (NOTE "E") REINFORCEMENT WELD TO BE PUT ON AFTER 100% GAMMA RAY
DT'L 10" SPECIAL NOZZLE
ONE REQ'D MK "N-3"
10" SCH 80 WELDING CAP A-212 GR. A F.B.
10" SCH 80 PIPE
C.W. (NOTE "A")
℄ T.T.H.
C.W. (NOTE "A")
3/4" PL x 18 3/8" O.D. PAD.
1 5/8" C.W. (NOTE "A")
C.W. (NOTE "A")
1/2" R.
I.S. SHELL
DT'L 10" SPECIAL NOZZLE
ONE REQ'D MK "N-1"
SHOP NOTE:
NOZZLE MK "N-1" FOR VESSEL MK "V-1" ONLY.
3" SCH 80 WELDING CAP A-212 GR A F.B.
C.W. (NOTE "A")
3 1/2" O.D.
ROUGH MACHINE FORGING x 5 3/4" O.D. x 2 3/4" I.D. x 9 1/4" LG A-105 GR I. WITH 0.30% MAX. CARBON (SHOP TO MACHINE AS SHOWN)
C.W. (NOTE "E") REINFORCEMENT WELD TO BE PUT ON AFTER 100% GAMMA RAY
1/4" MIN.
1/2" R.
I.S. SHELL
2.900
1/4" x 2" F.B. BACK-UP RING.
MAGNA FLUX BEFORE SETTING NOZZLE.
SHOP NOTE:
AFTER WELDING NOZZLE MK "N-8" TO SHELL, REMOVE BACK-UP STRIP, AND HAND REAM NOZZLE I.D. TO DOTTED LINE AS SHOWN.
DT'L 3" SPECIAL NOZZLE
ONE REQ'D MK "N-8"
VESSEL ℄
C.W. (NOTE "A")
3/8" C.W. (NOTE "A")
SEE ELEVATION
1/4" PL x 7 1/4" LG BACK-UP STRIP. REMOVE AFTER WELDING, BACK CHIP, RE WELD AND GRIND FLUSH WITH I.D. OF NOZZLE. A-283 GR C
MAGNA FLUX BEFORE SETTING NOZZLE
I.S. BOTT. HEAD.
1 1/2"-3000 # F.S. HALF COUPLING
HOLE IN CAP
10" SCH 80 WELDING CAP. A-212 GR. A F.B.
ROUGH MACHINE FORGING x 14 1/2" O.D. x 9.564" I.D. x 22 5/8" LG. A-105 GR I. WITH 0.30% MAX CARBON. (SHOP TO MACHINE AS SHOWN).
1/2" MIN.
C.W. (NOTE "E") REINFORCEMENT WELD TO BE PUT ON AFTER 100% GAMMA RAY
7 1/2"
8 1/4"
6 5/8"
1'-10 3/8"
SEE ELEVATION.
DT'L 10" SPECIAL NOZZLE MK "N-4"
W/ 1 1/2"-3000 # COUPLING MK "C-3"
ONE ASSEMBLY REQ'D
10" SCH 80 WELDING CAP A-212 GR A F.B.
C.W. (NOTE "A")
10" SCH 80 INSERT TYPE NOZZLE AS PER TAYLOR FORGE & PIPE WORKS DRAWING № S-80586 A-105 GR I.
C.W. (NOTE "A") 100% X-RAY
I.S. NOZZLE
I.S. SHELL
DT'L 10" SPECIAL NOZZLE
ONE REQ'D MK "N-6"
REFERENCE DRAWING
ELEVATION & GENERAL NOTES ---- H.W.E.-27888
MATERIAL NOTE
UNLESS OTHERWISE NOTED ALL MATERIAL ON THIS DRAWING ONLY TO BE AS FOLLOWS:
PLATE
FORGED FLANGES
PLATE FLANGES
PIPE NECKS A-106 GR "B"
PLATE NECKS
REINFORCING PADS A-201 GR "B"
STRUCTURAL SHAPES AISI A-107 GR 1020
WELDING NOTES:
NOTE "A" - WYATT SPEC № HW 1.1
NOTE "E" - CUST. SPEC PAGE 3 PAR VII
TWO VESSELS REQ'D.
S/O 2079
WYATT METAL & BOILER WORKS INC.
DALLAS, TEXAS • HOUSTON, TEXAS
3'-0" I.D. x 7'-0" SEAM TO SEAM
PLASTIC FATIGUE TEST VESSEL
DETAIL SPECIAL NOZZLES
CUSTOMER SOUTHWEST RESEARCH INSTITUTE
C REV. DIM. & NOZZLE "N-3"
B ADDED 1/8" INCR. FOR NOZZLE MK "N-6"
A REV. PER CUSTOMER APP.
NO. REVISION DATE BY CHK.
DRAWN P.E. SAYERS JR.
CHECKED
APPROVED
DATE
No. HWE-27889



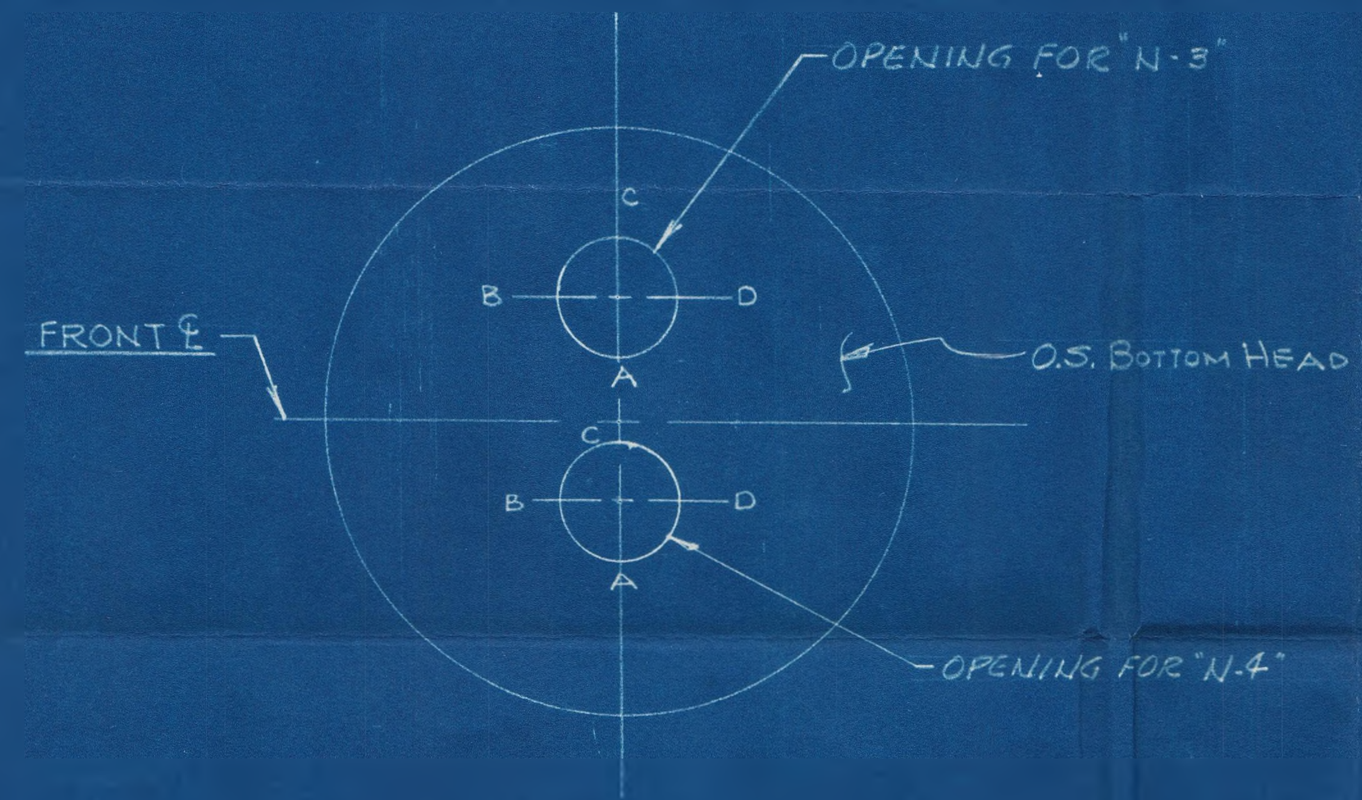
VIEW OF NOZZLE OPENINGS
LOOKING TOWARD VESSEL



END OF VESSEL SHELL @
TOP HEAD

VIDIGAGE READINGS (In Inches & Decimal Of Inches)								
DESCRIPTION	VESSEL MK"V-1"				VESSEL MK"V-2"			
	A	B	C	D	A	B	C	D
END OF VESSEL SHELL @ TOP HEAD	2.019	2.028	2.00	2.024	2.012	2.023	2.032	2.023
NOZZLE MK"N-1"	2.033	2.022	2.043	2.024	—	—	—	—
NOZZLE MK"N-2"	2.033	2.032	2.034	2.034	2.037	2.034	2.038	2.035
NOZZLE MK"N-3"	1.365	1.327	1.266	1.309	1.323	1.258	1.477	1.310
NOZZLE MK"N-4"	1.429	1.265	1.333	1.266	1.270	1.305	1.361	1.321
NOZZLE MK"N-6"	2.048	2.040	2.037	2.052	2.034	2.044	2.022	2.027
NOZZLE MK"N-8"	2.034	2.056	2.045	2.052	2.039	2.033	2.025	2.031
NOZZLE MK"N-9"	2.038	2.033	2.037	2.028	2.037	2.044	2.047	2.047
NOZZLE MK"N-10"	2.000	1.9375	1.9687	2.000	1.9375	1.9375	1.9375	1.9375
NOZZLE MK"N-11"	—	—	—	—	—	—	—	—

All Readings Are Taken Clockwise As Shown With A(4) Four Point Coordinate System Marked A, B, C & D.
Pad @ Nozzle "N-1" Has (3) Three Readings @ 120° Each: 2.026", 2.050" & 2.037"



VIEW OF NOZZLE OPENINGS
LOOKING TOWARD VESSEL

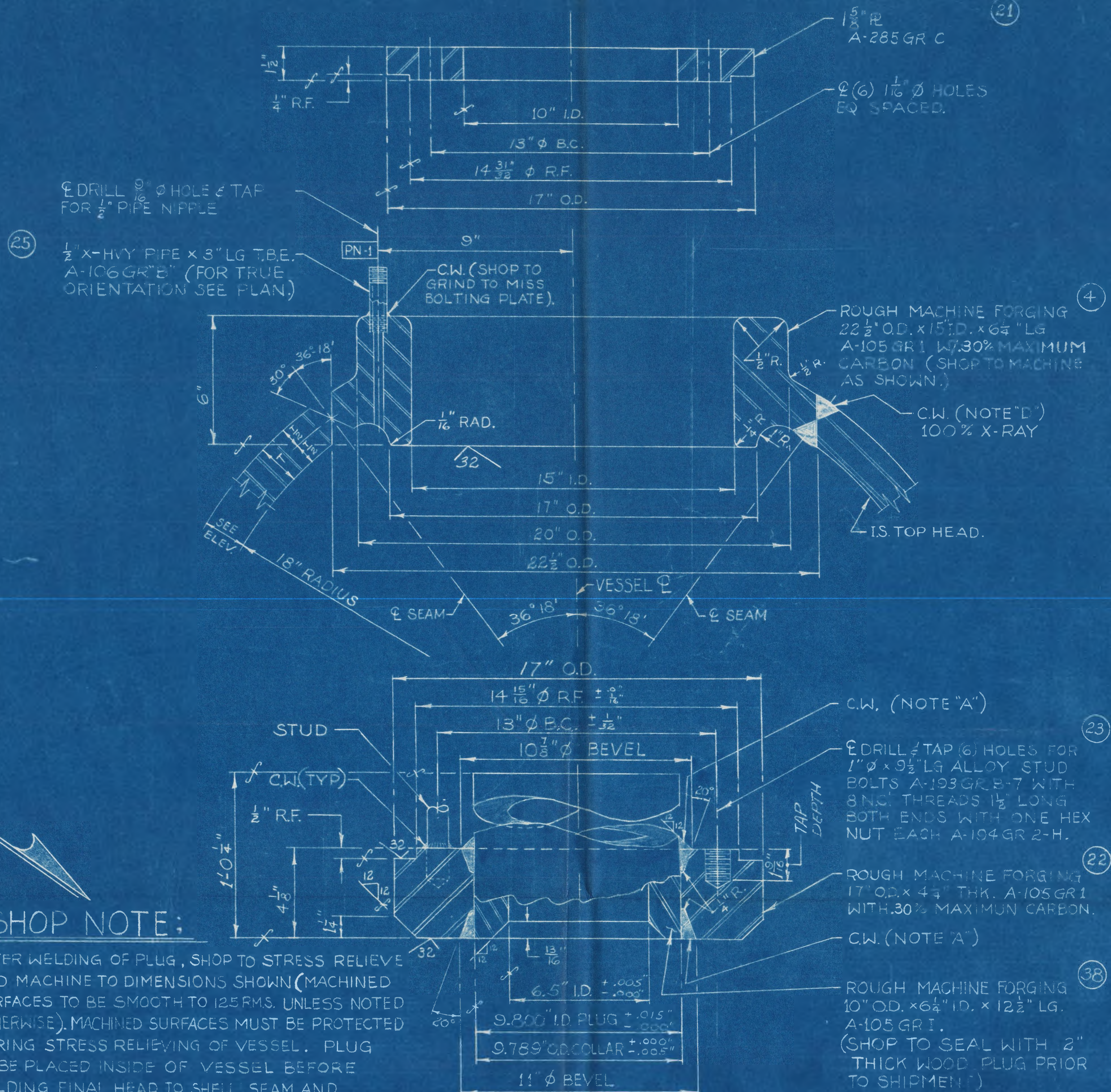
REFERENCE DRAWING:
ELEVATION & GENERAL NOTES - - - - - - - HWE-27888

TWO VESSELS REQ'D.	S/O 2079
	WYATT METAL & BOILER WORKS INC. DALLAS, TEXAS • HOUSTON, TEXAS
	3'-0" I.D. × 7'-0" Seam To Seam PLASTIC FATIGUE TEST VESSEL LOCATION OF VIDIGAGE READINGS
	CUSTOMER SOUTHWEST RESEARCH INSTITUTE
NO. | REVISION | DATE | BY | CHK.	DRAWN SAYERS DATE 3/25/58 CHECKED AJP APPROVED No. HWD-8841

MATERIAL NOTE

UNLESS OTHERWISE NOTED ALL MATERIAL ON THIS DRAWING ONLY TO BE AS FOLLOWS:

PLATE..........
FORGED FLANGES..........
PLATE FLANGES..........
PIPE NECKS..........
PLATE NECKS..........
REINFORCING PADS..........
STRUCTURAL SHAPES..........



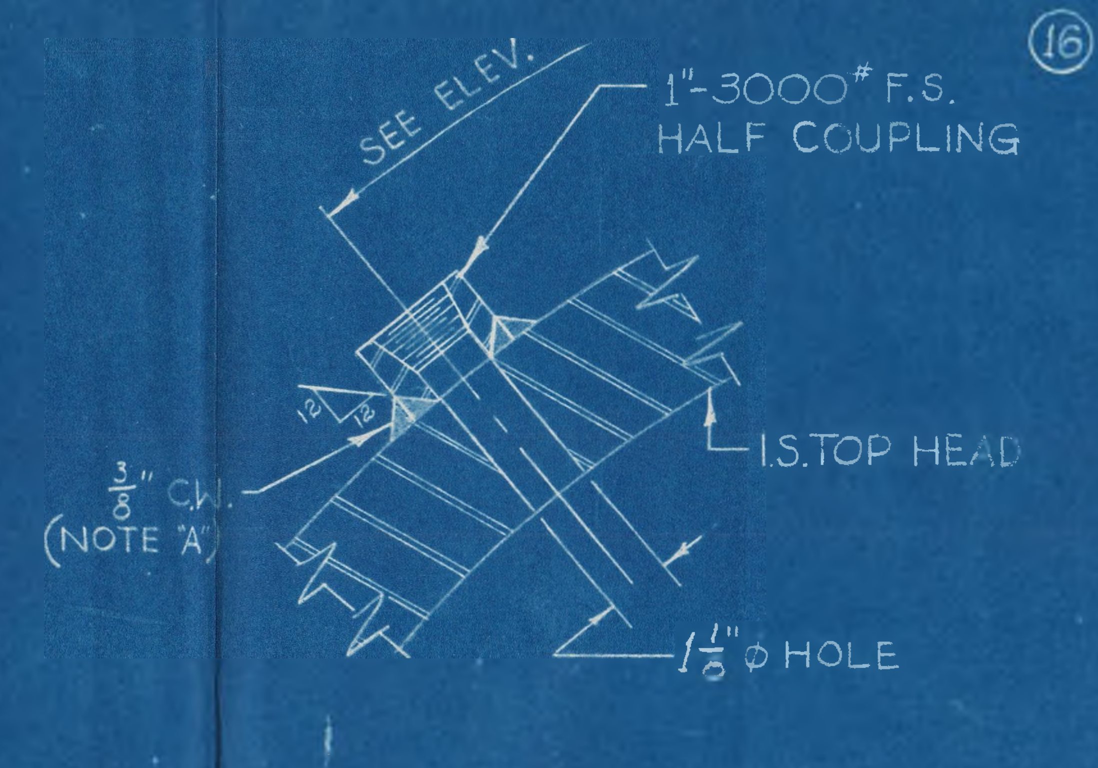
SHOP NOTE:

AFTER WELDING OF PLUG, SHOP TO STRESS RELIEVE AND MACHINE TO DIMENSIONS SHOWN (MACHINED SURFACES TO BE SMOOTH TO 125 RMS. UNLESS NOTED OTHERWISE). MACHINED SURFACES MUST BE PROTECTED DURING STRESS RELIEVING OF VESSEL. PLUG TO BE PLACED INSIDE OF VESSEL BEFORE WELDING FINAL HEAD TO SHELL SEAM AND SUPPORTED INSIDE VESSEL TO PREVENT WARPAGE DURING VESSEL STRESS RELIEVE.

DT'L 15" SPECIAL NOZZLE "N-10"

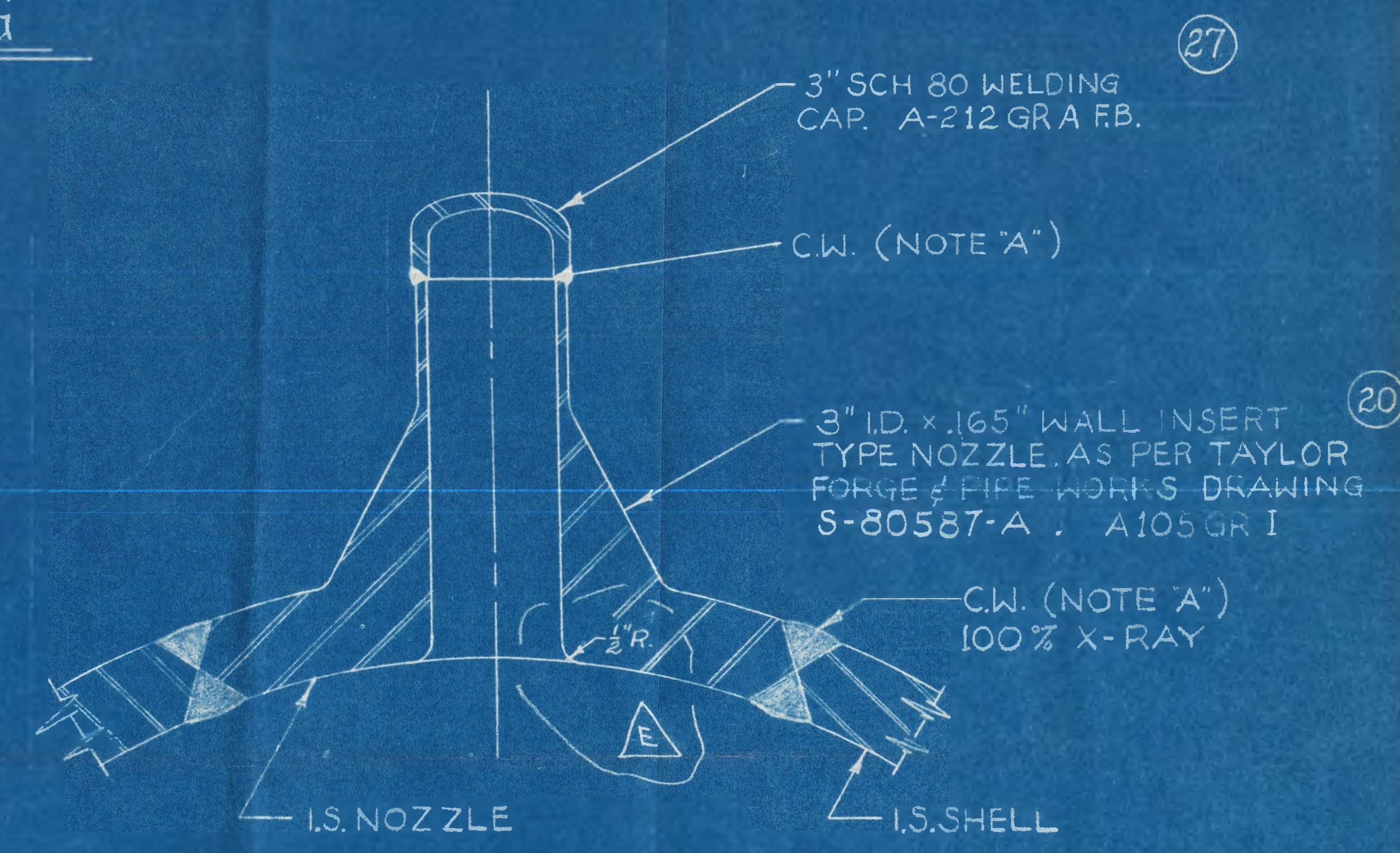
W/ PLUG & PIPE NIPPLE MK "PN-1"

ONE ASSEMBLY REQ'D



DT'L 1"-3000# COUPLING

ONE REQ'D MK "C-1"



DT'L 3" SPECIAL NOZZLE

ONE REQ'D MK "N-9"

REFERENCE DRAWING:

ELEVATION & GENERAL NOTES -------- H.W.E. 27888

WELDING NOTES:

NOTE "A" - WYATT SPEC HW 1.1

NOTE "D" - WYATT SPEC HWSR 1

MATERIAL NOTE

UNLESS OTHERWISE NOTED ALL MATERIAL ON THIS DRAWING ONLY TO BE AS FOLLOWS:

PLATE..........

FORGED FLANGES..........

PLATE FLANGES..........

PIPE NECKS..........

PLATE NECKS..........

REINFORCING PADS..........

STRUCTURAL SHAPES..........

AS NOTED

TWO VESSELS **REQ'D.**

NO.	REVISION	DATE	BY	CHK.
E	ADDED 1/2" I.S.C.R. FOR NOZZLE MK "N-9"	2/19/59	P.S.	AJP
D	REVISED DIA OF HOLE THRU SHELL @ COUPLING MK "C-1"	2/9/59	P.S.	AJP
C	ADDED FINISH MK ON BOTTOM SIDE OF ITEM #4 REVISED DTL OF PLUG @ NOZZLE N-10, ALSO CHANGED SHOP NOTE	1/16/59	P.S.	AJP
B	REVISED I.D. BOLTING RING AT "N-10" DELETED LIFTING EYES FOR PLUG AT NOZZ N-10 & ADDED COLLAR	12/15/58	P.S.	AJP
A	REVISED PER CUSTOMER APPROVAL	12/1/58	P.S.	AJP

S/O 2079

WYATT METAL & BOILER WORKS INC.
DALLAS, TEXAS • HOUSTON, TEXAS

3'-0" I.D. × 7'-0" SEAM TO SEAM

PLASTIC FATIGUE TEST VESSEL

DETAIL SPECIAL NOZZLES

CUSTOMER SOUTHWEST RESEARCH INSTITUTE.

DRAWN P.E. SAYERS JR. **DATE** 9/4/5

CHECKED AJP

APPROVED No. HWD-8509