

DECLASSIFIED

FR-2236

REPORT NO. 0-23

DATE 17 February 1944

SUBJECT

Scale Model Test of High-Temperature

High-Pressure Steam Piping -

AV7 Class vessel

DECLASSIFIED by NRL Contract

Declassification Team

Date: 4 AUG 2016

Reviewer's name(s): A. THOMPSON

P. HANNA

Declassification authority: NAVY DECLASS
MANUAL, 11 DEC 2012, D3 SERIES

NAVAL RESEARCH LABORATORY

WASHINGTON 20, D. C.

DISTRIBUTION STATEMENT A APPLIES

Further distribution authorized by _____
UNLIMITED only.

DECLASSIFIED: By authority of
5000A January 1958
Entered by: E. Bliss Code 2027

DECLASSIFIED

DECLASSIFIED



17 February 1944

NRL Report No. 0-2236

FR-2236

NAVY DEPARTMENT

Report

on

Scale Model Test of High-Temperature
High-Pressure Steam Piping -
AV7 Glass Vessel

LIBRARY
NAVAL RESEARCH LABORATORY

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

Number of Pages: Text 10 Appendix 10 Plates 4

Authorization: BuShips letter AV7/S48-10(648-517-350).

Date of Tests: November 1, 1943 to January 15, 1944

Prepared by: Paul Symonds, Contract

Eugene Pardue, Assistant Physicist

Irwin Vigness, Physicist

Reviewed by: Ross Gunn, Superintendent
Mechanics & Electricity Division.

Approved by: A. H. Van Keuren, Rear Admiral, USN
Director

Distribution: BuShips (20)
NRL (10)

hlh

DECLASSIFIED

DECLASSIFIED

TABLE OF CONTENTS

<u>Subject</u>	<u>Page</u>
Abstract	
Introduction	1
A. Authorization	1
B. Statement of Problem.	1
C. Statement of Method	1
Description of Piping Under Consideration.	1
A. General Notes and Assumptions	1
B. Pipes a and b	2
C. Pipes c, d, e, f, g, and h.	2
Construction of Scale Model.	2
A. Selection Tubing for Tubular Model.	2
B. Models Constructed of Rods.	3
C. Scale Constants for Full-Scale Forces and Moments	3
D. Full-Scale Pipe Dimensions.	4
E. Construction of Pipes a and b	4
F. Construction of Pipes c, d, e, f, g, and h.	5
Results.	6
A. Tabulation of Data.	6
B. Discussion of Results	6
C. Errors.	6
Summary.	6
Bibliography	10

APPENDICES

Appendix I - Model Pipe Data

	<u>Plate</u>
Model Test Apparatus of Pipe a	1
Model Test Apparatus of Pipe b	2
Model Test Apparatus of Pipes c, d, e, f, g, and h	3
Diagramatic Arrangement of Piping in After Machinery Room and Parachute Packing Room With Test Results.	4

DECLASSIFIED

ABSTRACT

End reactions due to thermal expansion have been determined by means of model tests, for the main steam piping in the after machinery room of an AV7 class vessel. The values obtained are compared with those calculated by the Philadelphia Navy Yard.

DECLASSIFIED

Scale Model Test of High-Temperature
High-Pressure Steam Piping - AV7 Class Vessel

INTRODUCTION

A. Authorization.

1. This problem was authorized by the Bureau of Ships letter AV7/S48-10(648-517-350).

B. Statement of Problem.

2. End reactions of the steam piping of an AV7 Class Vessel were required. The reactions were determined for the main steam piping in the after machinery room and parachute packing room (pipes a, b, c, d, e, f, g, and h, see Plate IV). Cold pull up was neglected.

C. Statement of Method.

3. The end reactions were determined by the use of scale models. The method of scale models for the determination of end reactions in the case of three-dimensional piping systems having several branches has been described in previous reports^(1,2,3).

DESCRIPTION OF PIPING UNDER CONSIDERATION

A. General Notes and Assumptions

4. The similarity of the main steam piping in the forward machinery room and in the after machinery room is such that only scale model tests of the piping in the after machinery room were made. Stress calculations⁽⁴⁾ indicate the piping in forward machinery room is more flexible.

5. All connections to machinery and maneuvering valves are considered to have no rotations. Translations due to the thermal expansion of the machinery are taken into account. Pipe "d" is considered hinged at the inflection point as shown in Figure 1 of the Philadelphia Navy Yard calculations⁽⁴⁾. (See Plate III and IV)

6. The pipe coordinates x, y, and z are used consistently throughout; x being positive in the starboard direction; y positive in forward direction, and z positive upward. Nomenclature of the pipes and pipe-ends is the same as that used by the Philadelphia Navy Yard.

B. Pipes a and b.

7. Pipes a and b are considered rigidly anchored at the after maneuvering valve. At the turbines rotations are prohibited while the translations due to turbine expansions are permitted. The connection to the after maneuvering valve is used as the fixed reference point for determining the end motions of each pipe.

C. Pipes c, d, e, f, g, and h.

8. Pipes c, d, e, f, g, and h are considered to be a single complex piping system rigidly anchored at the connection of pipe "c" to the after maneuvering valve. At the connections to the boilers and turbo-generators there are no rotations, but translations of the pipe ends occur due to thermal expansion of the machinery. Pipe "d" is considered hinged at end O_d . The fixed reference point for this system is taken at the connection of pipe "c" to the after maneuvering valve. In setting up the scale model for tests, a more convenient set-up was possible if pipe ends O_e and O_f had motions only in the horizontal plane. Since the vertical motions of ends O_e and O_f are the same, the above condition could be obtained by subtracting the vertical motion of end O_e and O_f from the vertical motion of each pipe end, thus maintaining the correct relative motions.

CONSTRUCTION OF SCALE MODELA. Selection of tubing for tubular model

9. For a scale model constructed of tubing the scale factor, s , or ratio of axial dimensions of the model to those of the full scale pipe, is determined by (1)

$$s = \frac{L_m}{L_a} = \left(\frac{r_m}{r_a} \right)^2 \frac{t_a}{t_m}$$

where

L_m = axial dimension of model

L_a = corresponding axial dimension of prototype

r_a = mean radius of full-scale pipe

r_m = mean radius of model pipe

t_a = wall thickness of full-scale pipe

t_m = wall thickness of model pipe

This condition should be satisfied for each pipe size which contains a bend.

10. A second condition which must be satisfied when the piping system is composed of several pipe sizes is that the ratio of the moment of inertia of a pipe in a full-scale system to that of the corresponding pipe in the model system should be maintained constant for all the pipe sizes.

B. Models Constructed of Rod

11. In some cases, due to limitations in available sizes of tubing, it is found that the model constructed according to the above conditions is so rigid that the accuracy of measurements is uncertain. (It has been observed that the accuracy of the model force measurements decreases as the rigidity of the model is increased beyond certain limits.) In these cases it is considered better to use rods rather than tubes. The advantage of using rods is that then the scale factor, s , is independent of the diameter of the rod, and therefore a model constructed of rod can be made as flexible as desired. The disadvantage is that the measured end reactions are somewhat high, because of the lower flexibility of the rod bends as compared to the corresponding full-scale bends. The error due to this cause on the basis of calculations made in previous work (see Appendix I, reference (1)), is not believed to be more than about 15 percent.

C. Scale Factors for Full-Scale Forces and Moments

12. For models constructed of either tubing or rods, the full-scale forces are obtained by multiplying those measured on the model by the factor K , where

$$K = \frac{E_a}{E_m} \frac{I_a}{I_m} \cdot s^3 \frac{\Delta L_a}{\Delta L_m}$$

Here E_a = Young's modulus for full-scale piping at operating temperature
(24.8×10^6 lb/in² for AV7)

E_m = Young's Modulus for model (29.0×10^6 lbs/in²)

I_a = Moment of inertia of full-scale pipe

I_m = Moment of inertia of corresponding model pipe

s = scale factor, ratio of axial lengths of model to full-scale piping.

ΔL_a = End displacement of full-scale pipe.

ΔL_m = Displacement of corresponding end of model

The full-scale moments are obtained by multiplying the moments measured on the model by the factor K/s .

D. Full-Scale Pipe Dimensions

13. Dimensions of the full-scale piping are given in the following table.

Table I - Cross-sectional dimensions and moments of inertia of full-size piping

Pipe Size in.	O.D. in.	Wall Thick- ness. in.	I.D. in.	Moment of Inertia in. ⁴
2-1/2	2.875	.120	2.635	.9877
5	5.563	.230	5.103	13.724
5-1/2	6.125	.253	5.619	20.156
6	6.625	.273	6.079	27.529

E. Construction of Model Pipes a and b

14. Tubular models of pipes a and b constructed from available tubing were of such size and stiffness that the measurements of end reactions on these models was not considered reliable; therefore, rod models were used. Cross-sectional dimensions for the models are given in tables II and III.

Table II - Superheated branch from after maneuvering valve to astern turbine. Cross-sectional dimensions and moment of inertia to model.

Full-Scale Pipe Size in.	Pipe	Model Dimensions		
		O.D. in.	Moment of Inertia in. ⁴	Scale factor s
5	a	.375	9.7×10^{-4}	1/4

Table III - Superheated branch from after maneuvering valve to high-pressure turbine. Cross-sectional dimensions and moment of inertia of model.

Full-Scale Pipe Size in.	Pipe	Model Dimensions		
		O.D. in.	Moment of Inertia in. ⁴	Scale factor s
6	b	.375	0.75×10^{-4}	1/4

F. Construction of Pipes c, d, e, f, g, and h.

15. The model of pipes c, d, e, and f were constructed of tubes. Bends of long radius were represented by bends of proper radius in the model. In the case of the short radius bends, the tubing could not be bent to a sufficiently short radius to satisfy the scale requirement. Therefore, in these cases square corners (mitre bends) were used, these being considered the nearest approximation obtainable..

16. Pipes g and h were constructed of rod.

17. The junction at ends A_c, etc. were considered rigid in comparison to the attached piping. Thus, heavy solid stock was used in their construction.

18. The hinged end, O_d, was simulated by placing a self-aligning ball bearing at the pipe-end and fixing this by means of rigid connections, to the measuring head. (See Plate III)

19. Cross-sectional dimensions of the model are given in Table IV.

Table IV - Main steam piping in after machinery room and parachute packing room, from boilers to after maneuvering valve and turbo-generators. Cross-sectional dimensions and moments of inertia of model.

Full Scale Pipe Size in	Pipes	Model Dimensions					
		O.D. in.	Wall Thickness in.	I.D. in.	Moment of Inertia Cal. in ⁴	Moment of Inertia Used	Scale Factor s
2-1/2	g,h	.256			$.2095 \times 10^{-3}$	$.192 \times 10^{-3}$	1/7.52
5-1/2	d,e,f	.751	.0288	.694	4.276×10^{-3}	4.276×10^{-3}	1/7.52
6	c	.756	0.0362	.6836	5.84×10^{-3}	5.36×10^{-3}	1/7.52

RESULTSA. Tabulation of Data

20. End reactions for all heads measured are summarized in Table V, together with the corresponding values from the Philadelphia Navy Yard calculations (4). The coordinates of all values are those of the Naval Research Laboratory system.

B. Discussion of Results

21. The end reactions measured at the Naval Research Laboratory are in satisfactory agreement with those calculated by the Philadelphia Navy Yard for all pipes except pipe b. For this pipe the measured values are considerably higher than those calculated. The error in these moments due to use of a rod model has been referred to in paragraph 11, and the experimental accuracy of the measurements is discussed below in paragraph 23.

22. Checks of the measured results have been obtained by transferring the reactions to some common point for comparisons. Tables VI, VII, and VIII provide checks of the Naval Research Laboratory results.

C. Errors

23. The force measuring heads have been calibrated using a special test set-up, to determine the magnitude of the error expected from measurements taken of any one of the six reaction forces. The root mean square value of this error varied between 1 and 2.5 percent for the four measuring heads. A conservative value of 3 percent for any reaction force was chosen to determine the probable errors in a set of forces and moments. Using this value the estimated errors for reactions of pipe b are given in Table VII. The estimated error is larger than the discrepancy between the values compared in the tables, for almost all cases. It should be noted that large discrepancies between the measured and the transferred moments may occur, despite the relatively small errors in the force and moment measurements.

SUMMARY

24. Reaction forces and moments caused by thermal expansion have been determined for the main steam piping in the after machinery room of an AV7 class vessel. These have been determined by measurements on suitable model systems. The values of reactions obtained are in reasonable agreement with those calculated by the Philadelphia Navy Yard, with the exception of the superheated branch from the after maneuvering valve to the high pressure turbine, for which the measured reactions were considerably larger than the calculated values. A discussion of these discrepancies is given in the text.

Table V - Summary of Results for all pipes measured and corresponding calculated values. Forces are in pounds; moments in inch-pounds.

Position on Piping	End Reactions																
	Reaction Forces						Reaction Moments										
	F _x		F _y		F _z		F _R		M _x		M _y		M _z		M _R		
NRL	PNY	NRL	PNY	NRL	PNY	NRL	PNY	NRL	PNY	NRL	PNY	NRL	PNY	NRL	PNY	NRL	PNY
Oa	+1188	+963	+ 51	- 32	+ 523	+ 429	1300	1064	-12830	+6730	+29490	+23370	+23250	+21960	39700	32900	
Aa	-1332	-963	- 58	+ 32	-567	-429	1445	1064	+25330	+20330	-12660	-12210	-52582	-50800	59750	56100	
O _b	+1954	+943	+1019	+1127	+1245	+781	2540	1664	-38150	-63540	+76800	+27820	+32200	+38430	101100	79300	
Ab	-1900	-943	-692	-1127	-1125	-781	2315	1664	+63250	+40460	-14600	-19620	-77500	-22400	101300	50100	
O _c	+695	+950	+264	+357	-500	-597	896	1173	+4510	+6900	+22980	+38700	+12180	+33400	26400	51600	
O _d	- 38	- 32	-167	-166	+2.3	0	171	169	-112	0	108	0	-262	0	--	--	
O _e	-240	-262	-283	-443	+307	+415	481	661	+10800	+24180	+14480	+21950	+16420	+30390	24400	44600	
O _f	-115	-155	+123	+190	+103	+161	186	293	-2880	-8610	-16180	-24075	-12360	-22667	20700	34150	
O _g	-177	-177	+176	+157	+10	+13	250	237	-2010	-2156	-1030	-1272	-8420	-9831	8720	10100	
O _h	-153	-123	-108	-94	+ 5	+ 3	187	155	+1330	+1080	-1150	-1240	+ 420	+2240	1810	2770	

DECLASSIFIED

Table VI - Check of results for pipe a. Forces are in pounds; moments in inch-pounds.

Reaction	End O _a		End A _a	
	Measured	Transferred from end A _a	Measured	Transferred from end O _a
F _x	+ 1,188	+ 1,332	- 1,332	- 1,188
F _y	+ 51	+ 58	- 58	- 51
F _z	+ 523	+ 567	- 567	- 523
Resultant	1,300	1,445	1,445	1,300
M _x	-12,830	-11,900	+25,330	+25,360
M _y	+29,490	+30,120	-12,660	-14,850
M _z	+23,250	+19,170	-52,580	-53,130
Resultant	39,700	37,600	59,750	60,700

Table VII - Check of results for pipe b. Forces are in pounds; moments are in inch-pounds.

Reaction	End O _b				End A _b			
	Measured	Probable Error	Trans. From end A _a	Probable Error	Measured	Probable Error	Trans. From end O _b	Probable Error
F _x	+ 1,954	132	+ 1,900	106	- 1,900	106	- 1,954	132
F _y	+ 1,019	32	+ 692	74	- 692	74	- 1,019	32
F _z	+ 1,246	137	+ 1,125	58	- 1,125	58	- 1,246	137
Resultant	2,540		2,315		2,315		2,540	
M _x	-58,150	1,630	-55,300	4,230	+63,250	783	+52,600	5,810
M _y	+76,800	2,640	+80,500	6,070	-14,600	2,114	-12,600	7,570
M _z	+32,200	1,440	+23,500	4,480	-77,500	1,900	-75,600	5,580
Resultant	101,100		100,400		101,300		91,800	

DECLASSIFIED

Table VIII - Check of forces for pipes c, d, e, f, g, and h.
Forces are in pounds.

Sign of force	Direction		
	x	y	z
+	695	563	427
-	723	558	500

DECLASSIFIED

Bibliography

1. Scale Model tests for High Pressure High-Temperature Steam Piping, First Partial Report, NRL Report No. O-1684.
2. Scale Model tests for High-Pressure High-Temperature Steam Piping, Second Partial Report. NRL Report No. O-1749.
3. Scale Model tests for High-Pressure High-Temperature Steam Piping, Third Partial Report. NRL Report No. O-1829.
4. Stress Analysis, Main Steam Piping. AV7-SK-S48-58, Navy Yard, Philadelphia, Pa., dated 8 September 1942.

APPENDIX I

MODEL TEST DATA

A. Coordinates

1. Coordinate systems used are as follows⁽³⁾:

- (x,y,z) = pipe coordinates; x = starboard, y = forward, z = up.
- (x_r, y_r, z_r) = reference coordinates; arbitrary fixed axes with positive z always up.
- (x', y', z') = measuring head coordinates.

B. Pipe a

1. Point O_a

End motions:

$$\Delta x_r = .418''$$

$$\Delta y_r = .1397''$$

$$\Delta z_r = .3727''$$

Coordinates of pipe end:

$$x' = 0; y' = 0; z' = + 2.65''.$$

Scale constants:

$$K = 244.5 \quad K/s = 978$$

Measuring head reactions;

$$R_{x'} = + 11.32 \#$$

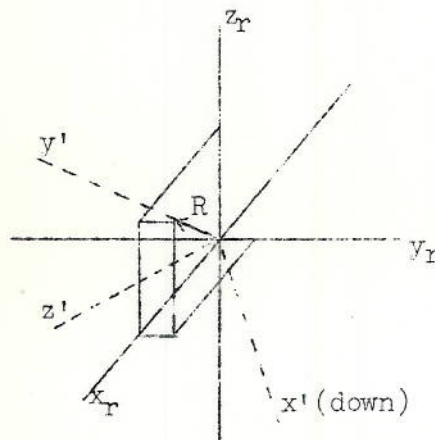
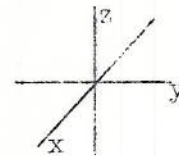
$$R_{y'} = + 11.59$$

$$R_{z'} = + 1.330$$

$$R_{x'y'} = - 6.55$$

$$R_{y'z'} = - 6.63$$

$$R_{z'x'} = + 3.37$$



2. Point A_a

End motions:

$$\Delta x_r = 0$$

$$\Delta x_r = 0$$

$$\Delta z_r = 0$$

Coordinates of pipe-end:

$$x' = 0; y' = 0; z' = + 2.65''$$

Scale constants:

$$K = 244.5 \quad K/s = 978$$

Measuring head reactions:

$$R_x' = - 21.68 \#$$

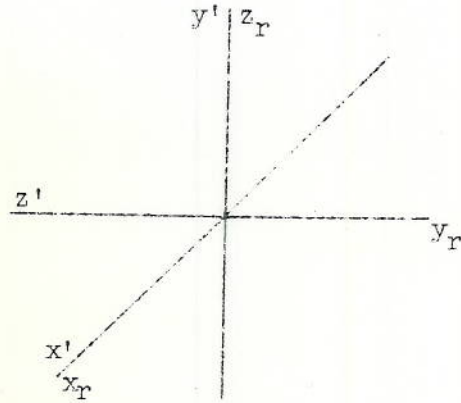
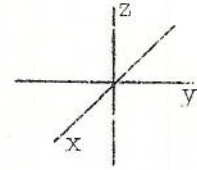
$$R_y' = - 8.73$$

$$R_z' = + .24$$

$$R_{x'y'} = + 2.59$$

$$R_{y'z'} = + 6.41$$

$$R_{z'x'} = - 13.64$$



C. Pipe b

1. Point O_b

End motions:

$$\Delta x_r = .387''$$

$$\Delta y_r = .1125''$$

$$\Delta z_r = .4745''$$

Coordinates of pipe-end:

$$x' = 0; \quad y' = 0; \quad z' = + 2.65''$$

Scale constants:

$$K = 528.5 \quad K/s = 2114$$

Measuring head reactions:

$$R_{x'} = + 5.86 \#$$

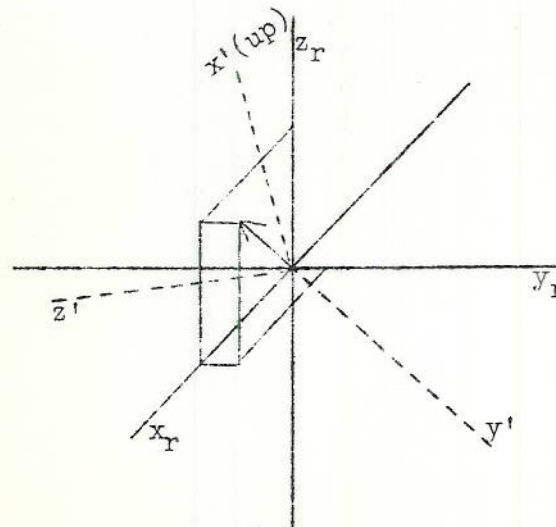
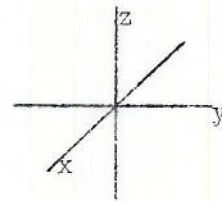
$$R_{y'} = - 11.32 \#$$

$$R_{z'} = - .821$$

$$R_{x'y'} = - 8.52$$

$$R_{y'z'} = + 6.81$$

$$R_{z'x'} = - 1.06$$



DECLASSIFIED

2. Point A_b

End motions:

$$\Delta x_R = 0$$

$$\Delta y_R = 0$$

$$\Delta z_R = 0$$

Coordinates of pipe-end:

$$x' = 0; \quad y' = 0; \quad z' = + 2.65''$$

Scale constants:

$$K = 528.5 \quad K/s = 2114$$

Measuring head reactions:

$$R_{x'}' = + .630 \#$$

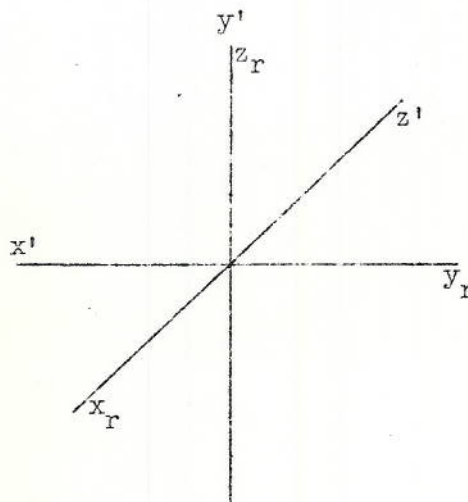
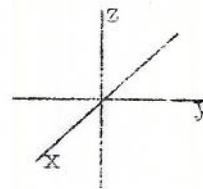
$$R_{y'}' = - 4.64$$

$$R_{z'}' = + 3.60$$

$$R_{x'y'}' = - 5.99$$

$$R_{y'z'}' = + 2.51$$

$$R_{z'x'}' = - 6.67$$



DECLASSIFIED

DECLASSIFIED

D. Pipes c, d, e, f, g and h

1. Point O_c

End motions:

$$\Delta x_r = 0$$

$$\Delta y_r = 0$$

$$\Delta z_r = - .8565''$$

Coordinates of pipe-end:

$$x' = - 1.0''; \quad y' = + 1.875''; \quad z' = + 2.625''$$

Scale constants:

$$K = 13.7 \quad K/s = 103$$

Measuring head reactions:

$$R_{x'} = + 54.55 \#$$

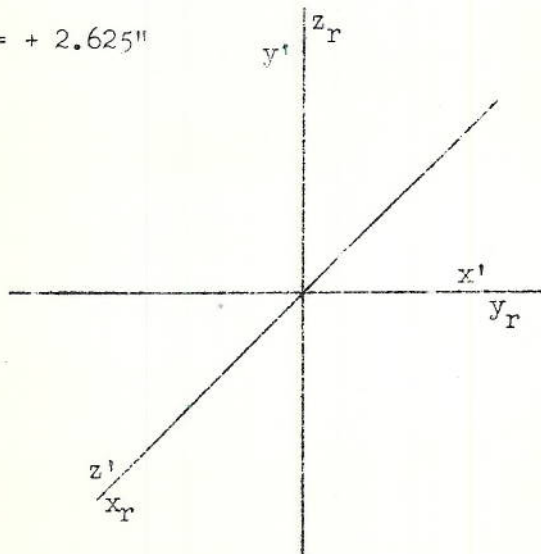
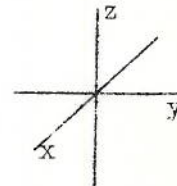
$$R_{y'} = - 119.46$$

$$R_{z'} = + 50.46$$

$$R_{x'y'} = + 8.80$$

$$R_{y'z'} = + 82.91$$

$$R_{z'x'} = + 44.0$$



DECLASSIFIED

DECLASSIFIED

2. Point O_d

End motions:

$$\Delta x_r = -0.4586''$$

$$\Delta y_r = -3.211''$$

$$\Delta z_r = -0.8565''$$

Coordinates of pipe-end:

$$x' = 2.055''; \quad y' = .542''; \quad z' = +2.62$$

Scale constants:

$$K = 13.7 \quad K/s = 103$$

Measuring head reactions:

$$R_{x'} = +9.72 \#$$

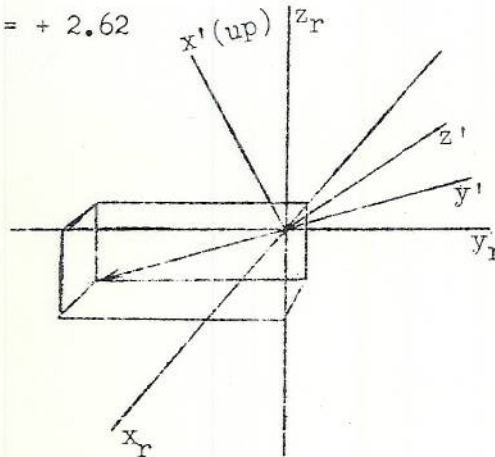
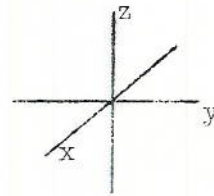
$$R_{y'} = -17.72$$

$$R_{z'} = +1.00$$

$$R_{x'y'} = -5.05$$

$$R_{y'z'} = +5.86$$

$$R_{z'x'} = +1.36$$



DECLASSIFIED

3. Point O_e

End motions:

$$\Delta x_r = - .9363''$$

$$\Delta y_r = - .4844''$$

$$\Delta z_r = .0$$

Coordinates of pipe-end:

$$x' = 0; \quad y' = 0; \quad z' = + 2.65''$$

Scale constants:

$$K = 13.7 \quad K/s = 103$$

Measuring head reactions:

$$R_{x'} = + 15.54 \#$$

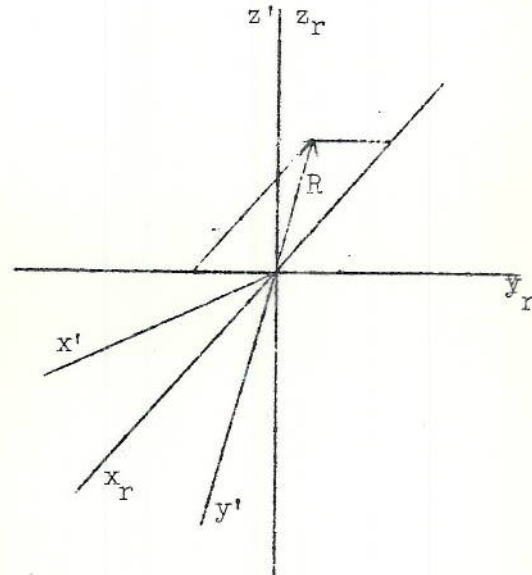
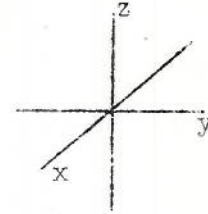
$$R_{y'} = - 22.9$$

$$R_{z'} = + 22.35$$

$$R_{x'y'} = + 31.9$$

$$R_{y'z'} = - 2.07$$

$$R_{z'x'} = + 37.1$$



DECLASSIFIED

4. Point O_f

End motions:

$$\Delta x_r = - .4768''$$

$$\Delta y_r = + .939''$$

$$\Delta z_r = .0$$

Coordinates of pipe-end:

$$x' = 0; \quad y' = 0; \quad z' = + 2.65''$$

Scale constants:

$$K = 13.7 \quad K/s = 103$$

Measuring head reactions:

$$R_{x'} = + 6.73 \#$$

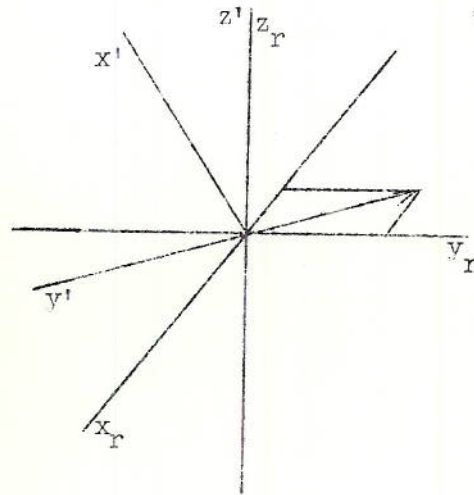
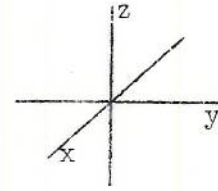
$$R_{y'} = - 36.3$$

$$R_{z'} = + 7.5$$

$$R_{x'y'} = + 24.0$$

$$R_{y'z'} = + 25.5$$

$$R_{z'x'} = + 27.27$$



DECLASSIFIED

DECLASSIFIED

5. Point O_g

End motions:

$$\Delta x_r = -1.670''$$

$$\Delta y_r = +.7711$$

$$\Delta z_r = -.5271$$

Coordinates of pipe-end:

$$x' = 0; \quad y' = 0; \quad z' = 2.65''.$$

Scale constants:

$$K = 13.7 \quad K/s = 103$$

Measuring head reactions:

$$R_{x'}' = +11.93 \text{ #}$$

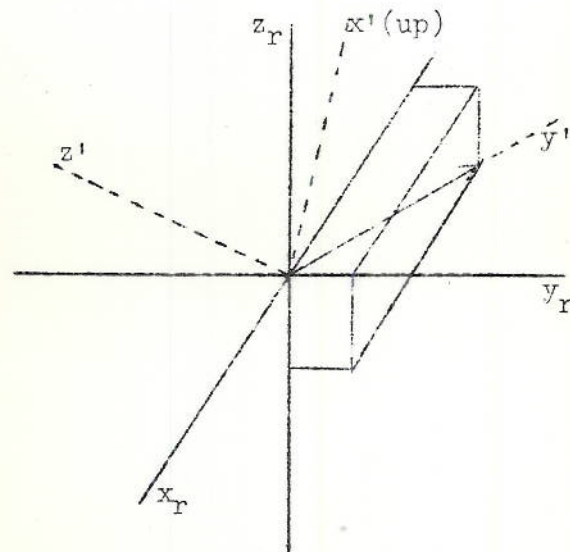
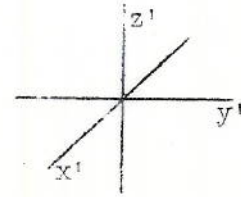
$$R_{y'}' = +40.1$$

$$R_{z'}' = -6.27$$

$$R_{x'y'}' = +3.45$$

$$R_{y'z'}' = -23.8$$

$$R_{z'x'}' = +9.97$$



DECLASSIFIED

DECLASSIFIED

6. Point O_h

End motions:

$$\Delta x = -1.524$$

$$\Delta y = -0.3168$$

$$\Delta z = -0.5271$$

Coordinates of pipe-ends:

$$x' = 0; \quad y' = 0; \quad z' = +2.65''$$

Scale constants:

$$K = 13.7 \quad K/s = 103$$

Measuring head reactions:

$$R_{x'}' = +11.5 \#$$

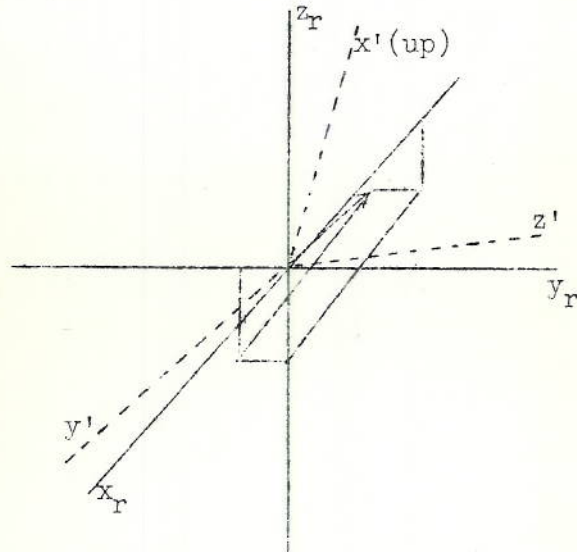
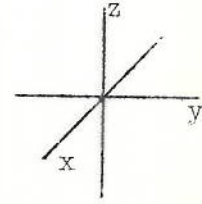
$$R_{y'}' = -18.0$$

$$R_{z'}' = -5.46$$

$$R_{x'y'}'' = -2.7$$

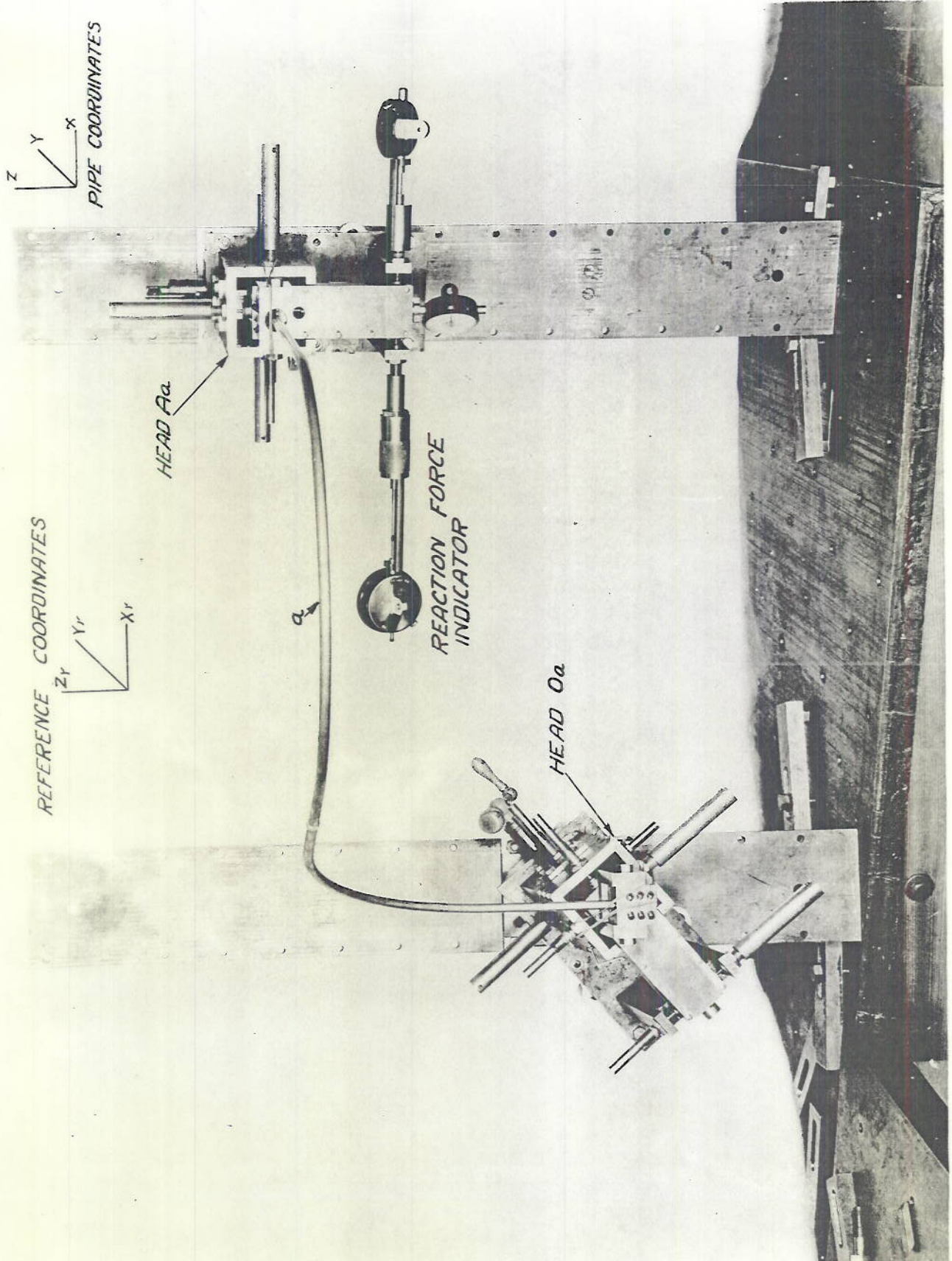
$$R_{y'z'}'' = +6.15$$

$$R_{z'x'}'' = +4.43$$



DECLASSIFIED

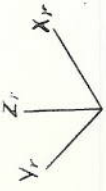
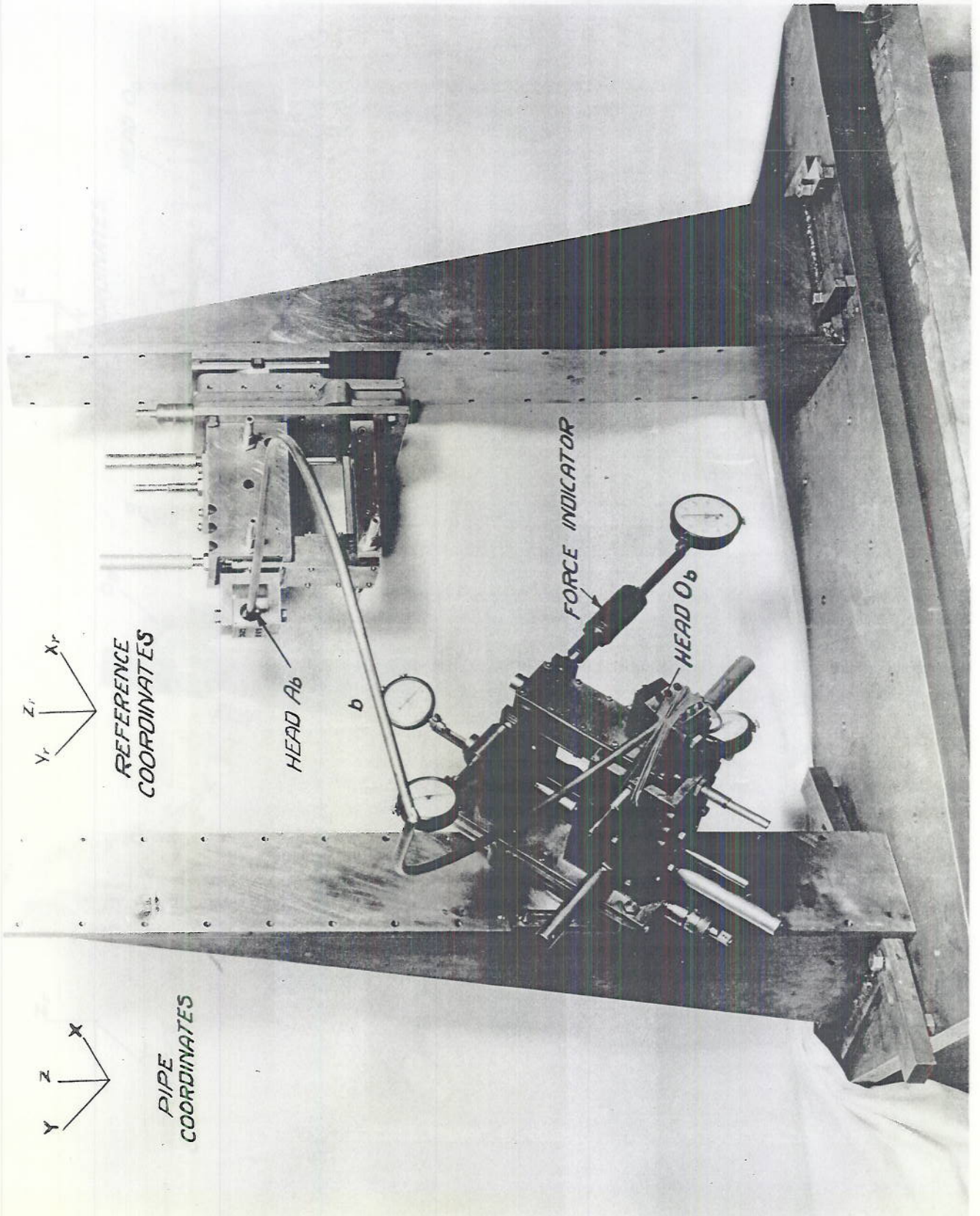
DECLASSIFIED



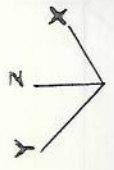
DECLASSIFIED

PLATE I

DECLASSIFIED



REFERENCE
COORDINATES



PIPE
COORDINATES

DECLASSIFIED

PLATE 2

DECLASSIFIED

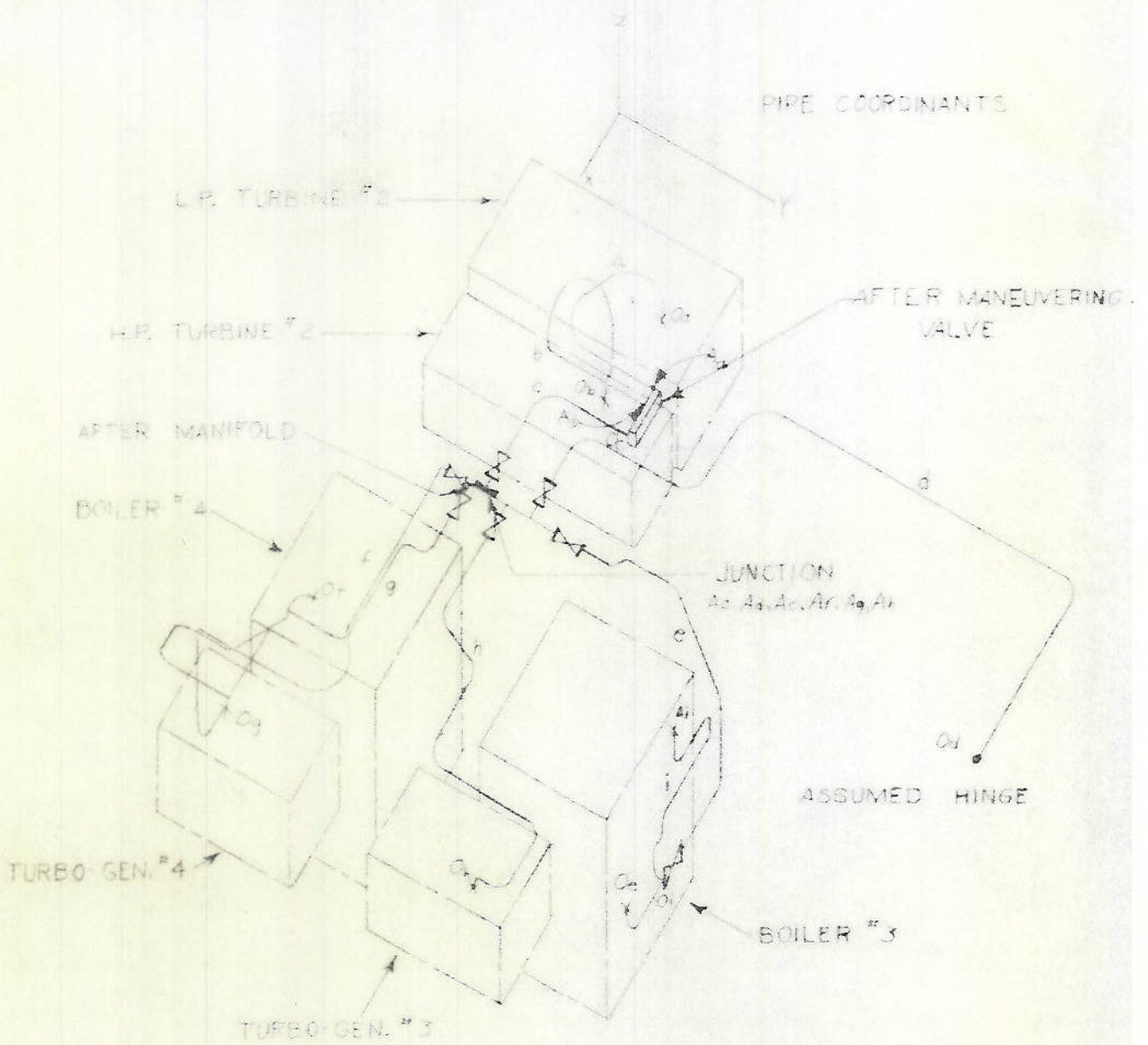
SUMMARY OF MEASURED MOMENTS AND FORCES AT PIPE END.

Forces are in pounds; moments in inch pounds.

Position on Piping	Forces			Moments		
	F _x	F _y	F _z	M _x	M _y	M _z
O _a	+ 1,188	+ 51	+ 523	- 12,830	+ 29,490	+ 23,250
A _a	- 1,332	- 58	- 567	+ 25,330	- 12,660	- 52,580
O _b	+ 1,954	+ 1,019	+ 1,246	- 58,150	+ 76,800	+ 32,200
A _b	- 1,900	- 692	- 1,125	+ 63,250	- 14,600	- 77,500
O _c	+ 695	+ 264	- 500	+ 4,510	+ 22,980	+ 12,180
O _d	- 38	- 167	+ 2.3	- 112	+ 108	- 262
O _e	- 240	- 283	+ 307	+ 10,800	+ 14,480	+ 16,420
O _f	- 115	+ 123	+ 103	- 2,880	- 16,180	+ 12,360
O _g	- 177	+ 176	+ 10	- 2,010	- 1,030	- 8,420
O _h	- 153	- 108	+ 5	+ 1,330	- 1,150	+ 2,240

DECLASSIFIED

DECLASSIFIED



MAIN STEAM PIPING IN AFTER MACHINERY ROOM AND PARACHUTE PACKING ROOM

DECLASSIFIED