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REACTOR FUEL ELEMENTS
FUEL OUTFITTERS

AUTHOR

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INTERIM REPORT

REAR FACE PIPING STUDY AT ELEVATED
BULK OUTLET TEMPERATURE - KE REACTOR

By

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January 17, 1962

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INTERIM REPORT

REAR FACE PIPING STUDY AT ELEVATED BULK OUTLET TEMPERATURE - KE REACTOR

I. INTRODUCTION

The work described in this report was authorized under Development Test IP-419-E. The primary objective of this study was to establish the stress, hydraulic and vibration conditions which exist in KE Reactor rear face piping components under maximum presently authorized operating conditions and evaluate these conditions from the standpoint of continuity of reactor operation.

Test data were recorded at various levels of operation up to and including the maximum authorized bulk outlet temperature. The data recorded during this test were used to establish model conditions for Project CGI-883. With model conditions established, additional tests will be conducted to explore the possibility of operating the reactor in regions above the present limiting bulk outlet temperatures.

The test, as outlined in the development test document, has been conducted and the pressure, temperature, vibration, and stress data has been tabularly and graphically compiled. Indicated hydraulic conditions have been substantiated theoretically with reasonable accuracy.

A drawing indicating the instrumentation locations is provided in Appendix IV of this report.

II. PURPOSE

The purpose of this report is to document the raw test data, provide an evaluation of the test data relative to current operating conditions, and present a proposal of further studies evolving from this development test.

III. SUMMARY AND CONCLUSIONS

Overall structural capabilities of the KE rear face appears adequate at the current levels of reactor operation with the exception of the severe vibration occurring on the original style crossheader expansion joints. This problem has been previously recognized and work is being done by others to alleviate it. Current levels of operation are defined in this report as 184,000 gpm flow, 95 C bulk outlet temperature, and a 2 C temperature surge.

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The stress data accumulated from the approach section must be approached with some reservations due to the structural configuration of the monitored area. However, the design criterion, purchase specification, acceptance testing, current measurements, and associated calculations, provide adequate information to conclude that the approach section has sufficient strength to withstand the current operating conditions. The calculations included the possibility of complete downcomer blockage at current flows and consequent diversion of full flow through the overflow lines.

Under the initial concept of the downcomer hydraulic conditions (See Ref. HW-38795), the downcomer was to operate full and continuous from top to bottom. Test data indicate that the downcomer channels are not operating full. It appears that the entrance to the downcomer channels is more limiting to flow than the existing downcomer orifice plate. Hence, the effluent water appears to be in free-fall for about the first third of the downcomer. At 85 C, a hydraulic transition begins to appear. Evidence of this transition is consistent in several sets of data. During the transition, the static pressure of the continuously used water channels decreases, and additional channels are being utilized as evidenced by the increase in static pressure. This would indicate that an added flow restriction, such as two-phase flow, is occurring in the downcomer entrance elbow.

Vibration of the crossheader and the tube-to-crossheader connector appears to be quite nominal and should not present a problem. At the higher bulk outlet temperatures, the majority of the vibration experiences a decrease in intensity. Vibration indicated at the center of an expansion joint of original equipment design was intense, and is undoubtedly the mechanism which has brought about numerous failures in these joints. The reduction of vibration in the two-phase flow region has been noted in other test work and appears to be a general phenomena associated with transitional two-phase flow in all reactor piping systems. The average of the riser temperatures were slightly higher in magnitude than the bulk outlet temperature recorded in the control room. All of the four rear face temperature points were somewhat higher than the control room temperature, with the difference tending to increase as the reactor power level increased; this difference reaches a maximum of about 1-1/2 degrees. This difference may be significant to study further in relation to a better definition of power level, thus increasing the reactor production. Probable poor mixing of the water at the rear face data points and the scatter of data values makes it difficult to attach much significance to this indication.

IV. DISCUSSION

Instrument locations were selected to provide a maximum scope of data with a minimum number of points since installation of these points is costly in both outage time and manhours. In analysis of the collected data, substantial effort was devoted to arriving at a theoretical correlation of the measured values with quite reasonable success.

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Pressure

The pressure taps were installed to establish the hydraulic conditions, with emphasis on regions of potential two-phase flow. (See Appendix I for tabulation of pressure results and Appendix IV for the instrument locations). Where single pressure values are shown, they are average values because in nearly every case the indicated pressure fluctuated over a range as shown in the tabulations.

A pressure transducer was installed on the inside radius of the downcomer exit elbow contemplating the possibility of two-phase flow in this region; however, there was no such indication.

The areas of rather large pressure changes are of greatest interest due to the possibility of introducing boiling in the low pressure areas. The first area and probably most important is the static pressure drop across the inlet to channeled flow at the downcomer entrance. The pressure two inches inside of the channeled flow entrance is -4.7 psi at low, cold flows and increases to -1.5 psi at maximum, hot flow. The static pressure downstream tends to decrease as the temperature increases. The existence of this phenomena would indicate that a resistance is building up in this region. This is further substantiated by the fact that additional channels are being utilized as the bulk outlet temperature increases under constant flow conditions. Since the major portion of the change occurs at the higher temperatures, it is logical to assume that two-phase flow may be occurring in the downcomer entrance elbow.

A transition in the downcomer flow pattern begins at about 85 C in which a greater portion of the downcomer is being utilized. (See Appendix I, Figures 1, 2, and 3.) As shown in Figure 1, the pressure at the top and bottom of the downcomer entrance elbow (P-11 and P-13) reverse their relation to each other as the bulk temperature increases beyond 85 C. It appears that as the water temperature increases, saturation condition is reached in the curved portion of the water channel, and two-phase flow occurs, thus reducing the effective area and establishing a new limiting flow condition in each of the normally-used channels.

In reference to the foregoing discussion and considering the possibility of increased flow at the KE Reactor, one could speculate that the downcomer does not have the capacity to accommodate higher flows at the present maximum bulk outlet temperature without modification of the existing downcomer system either physically (such as a different orificing arrangement to increase pressures in the entrance elbow) and/or in-service conditions (such as pressurized operation). Model tests being conducted by Reactor Modification Design Operation, TEO, should more fully establish the validity of this statement.

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With current flow (184,000 gpm) and 95 C bulk temperature, however, it appears that about 1-1/2 rows of the downcomer channels are still unused. Contemplating a possible temperature surge of 2 C, an extrapolation of the attached curves (Appendix I), would indicate that one additional row of channels would be utilized to accommodate the total flow. From this evaluation, it can be concluded that the capacity of the downcomer is adequate for the conditions described above with at least a 20 temperature surge. This analysis, of course, assumes that the slope of the curves established for 95 C continues essentially constant to 97 C.

The second area exhibiting a large static pressure drop is across the orifice plate in the lower extremity of the downcomer. The static pressure loss across the orifice is in the neighborhood of 20 psig. At 93.6 C, the vapor pressure is -1.81 psig. The average recorded vena contracta pressure (P-15)* below the orifice plate of 1.5 psig is close to the vapor pressure, and transient pressure pulsations as low as -2.5 appear. Consequently, the vena contracta area is susceptible to the two-phase flow condition, and brief intervals of two-phase flow may be occurring.

Vibration

Vibration data were collected from a tube-to-crossheader connector, the crossheader (2 places outside of the tube pattern) and the center pipe of an original design-type expansion joint (See Appendix IV). The crossheaders were not monitored within the tube pattern because of the physical impossibility of attaching a pickup without removing a nozzle. In that section, however, the crossheaders are supported in a manner which could be expected to prevent significant vibration. The reader is cautioned against taking the numbers too literally.

Due to the effects of long leads, instrument error, and human error in interpretation, the frequency may be altered by an estimated ± 5 per cent and the magnitude by ± 20 per cent. The following is an outline of the vibration conditions.

A. Crossheaders

1. There is a definite vibration made at about 10 cps indicated in the crossheader between the expansion joint and the tube

* The location of this pressure tap may not be located exactly at the vena contracta; however, the Handbook of Hydraulics by King, p. 43, indicates that the vena contracta is about one-half the diameter of the opening from the orifice plate, and corresponds readily with the subject condition.

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pattern. Since this does not match the natural frequency of that section of pipe, it can be reasonably concluded that this vibration is probably induced by the vibration of the expansion joint which is discussed below. Although the indicated amplitude is sizeable (± 0.3 inches), this should not introduce significant bending stress in the pipe and it does not appear to be transmitted in any great degree to the rear face connectors as described below. This does not appear to be a significant condition; however, it is felt that further vibration study should be made to better define the typical conditions and to investigate the effect of the new design expansion joints in this condition as well as the response of the new joints themselves.

2. The majority of the vibrations tend to decrease in magnitude at the bulk outlet temperatures above 90 C (See Appendix II, Figure #1). This is of particular significance because it supports model tests which indicate that a hydro life system may actually operate in a more stable condition with significant two-phase flow than it does just below this point.

B. Tube-to-Crossheader Connector

1. Low frequency vibration (2 to 10 cps) yielded a maximum indicated amplitude of ± 0.075 inches.
2. High frequency vibration (3600-4600 cps) possessed a maximum amplitude of 0.0000041 inches.
3. The acceleration at this location was out of service before the high temperature tests were conducted. However, the measurements which were recorded and briefly described above do not appear to be significant.

C. Expansion Joint

1. Low frequency vibration (3-5 cps) showed a maximum indicated amplitude of ± 0.43 . This amplitude decreased somewhat as the bulk outlet temperature decreased. This is undoubtedly a major contributor to the recent failures which have occurred in the original design type of expansion joints.
2. A maximum amplitude of 0.42 inches was recorded at the medium frequencies (85-200 cps).
3. A maximum amplitude of ± 0.0000007 occurred at the higher frequencies (3600-4100 cps). At these higher frequencies, the amplitude tended to decrease as the bulk temperature increased.

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Stress

Selection of the strain-gage locations was based on preliminary study of rear face piping for potential weak points. Assuming that the approach section would not be completely full during normal operation at the present reactor conditions, the upper sections of the approach section would be loaded only by a reflected loading, and not under a pressurized condition; thus, the side panels on the approach section were considered the weakest section of the assembly. Past experience in other areas regarding the riser stress condition prompted a measurement on the riser wall near the crossheader junction. Riser stresses were low in magnitude (See Appendix III); however, in view of the severe vibration occurring on the expansion joint, a closer look should be taken to better assess the stress conditions in the riser wall. Additional work will be accomplished, and a subsequent document issued.

The approach section strain recordings were also low and showed a compressive stress; however, the geometry of the system would indicate the higher stresses could be existing on the water-side fibers. With a given deflection on the approach section panel, and a compressive stress on the outside fibers (as measured) a tensile stress would necessarily occur on the water-side fibers of the panel as shown in Figure 1.

FIGURE 1

Since the position of the neutral axis cannot be established, the magnitude of this tensile stress cannot be readily determined directly from the strain measurements obtained. Calculations indicate that a pressurization of 10 psi after the approach section has been filled with water would exert a 36,000 psi maximum stress on the largest approach-section panel. This would be considered the maximum conditions which may be applied to the approach section as it now exists. This assumes the welds meet the requirements specified in the purchase specification. A recent inspection of the approach section weld revealed that the welds are in good condition. (See Ref.)

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The approach-section purchase specification indicates that a 50 psi hydrostatic test would be conducted upon completing the construction. These tests were conducted; however, records were not established, and it is doubtful that the approach section was hydrostatically tested to this pressure.

In view of the specifications, calculations, and measurements, the downcomer approach section appears to be fully satisfactory under present operating conditions, even assuming complete blockage of the downcomer where the total flow would be diverted through the overflow lines, and does not require additional supporting structure. When considering higher flows and complete blockage of the downcomer thus utilizing the overflow lines, modest reinforcement is recommended in two areas - namely, the approach-section panels as discussed above and the ends of the half-cylinder top of the approach section.

Temperature

Temperature differentials occurring between the far and near risers steadily increased with a corresponding increase in power level. However, a marked change occurs at about the 3300 MW power level, and the two temperatures converge to essentially the same values as the power level increases (see Appendix I, Figure 4).

Comparison between the average riser temperature and the control room temperature indicates a steadily increasing differential as the power level increases. (See Appendix I, Figure 5.) The significance of this should be evaluated with some reservation since the riser temperatures were recorded close to the riser wall, and relatively little, if any, water mixing will occur.

The temperature (Appendix II, P-2) recorded just upstream of the orifice is also slightly higher than the control room temperature. (See Appendix I, Figure 6.) As before, the water flowing between the water entrance to the riser and the entrance to the channeled flow cannot be considered fully-mixed.

V. ADDITIONAL STUDIES PLANNED

Through Model testing at Washington State University, it is planned to investigate the feasibility of operating the subject system at still higher bulk outlet temperature after design conditions for Project-883 have been established.

Vibration measurements on the crossheaders with the newly-designed expansion joints will be performed to determine whether or not the

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modified design of the center section has effectively reduced the vibration to a reasonable level.

VI. ACKNOWLEDGEMENTS

The writer wishes to acknowledge the fine cooperation of the KE Reactor Operation personnel during the conducting of this test. Also, appreciation is expressed for the able assistance of W. E. Love, Consulting Engineer, of the NPR Project Operation.

VII. REFERENCES

Note: Although few specific references are mentioned in the test, the following were used as reference material.

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APPENDIX I

PRESSURE TEMPERATURE TABULATIONS
AND GRAPHS

REAR FACE PIPING STUDY AT ELEVATED BULK OUTLET TEMPERATURE
KE REACTOR

GENERAL	POINT NO.	MAX. ⁽¹⁾ PRESS. (psig)	MIN. ⁽¹⁾ PRESS. (psig)	AVE. ⁽¹⁾ PRESS. (psig)	CYCLIC CONDITION ⁽¹⁾ AND DOUBLE AMPLITUDE	POINT NO.	TEMPERATURE ⁽²⁾ RECORDINGS TAKEN DURING TEST (°C)
TEST DATE: 9-1-61 TOTAL FLOW: 175,000 gal/min. POWER LEVEL: 3 MW BULK OUTLET TEMP: 21°C TORP: 360 TIME: 3:25 p.m.	P-1	Out of Service				T-1	20.42
	P-2	2.5	1.3	1.7	0.8 cps 0.5 to 1.2 psig 34 cps 0.2 to 1.0 psig	T-2	21.79
	P-3	17.9	13.7	16.4	175 cps 0.6 to 4.2 psig	T-3	20.56
	P-4	Out of Service				T-4	20.06
	P-5	10.0	8.9	9.5	55 cps 0.2 to 0.7 psig		
	P-7	4.0	2.3	3.2	0.5 cps 1.5 to 1.9 psig 40 cps 0.3 to 1.7 psig		
	P-8	4.0	4.4	4.6	120 cps 0.2 to 0.3 psig		
	P-9	5.2	4.3	4.6	9 cps 0.3 to 0.5 psig		
	* P-10	Negl. Variation		-0.1	Negligible Variation		
	P-11	-2.0	-7.0	-4.5	27 cps 1.0 to 3.0 psig		
	P-13	-1.4	-3.2	-2.3	31 cps 0.2 to 1.4 psig		
	P-14	5.7	4.6	5.2	3.8 cps 0.5 to 1.0 psig 41 cps 0.3 to 0.4 psig		
	P-15	-2.3	-6.2	-4.3	26 cps 1.5 to 3.5 psig		
	P-16	8.6	7.8	8.2	0.6 cps 0.5 to 1.0 psig 6 cps 0.2 to 0.3 psig		

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2) Unless otherwise noted, accuracy of $\pm 1\%$ is assumed.

* Sensing element port may have been plugged; pressure will be checked.

(1) Unless otherwise noted, accuracy of $\pm 10\%$ is assumed.

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REAR FACE PIPING STUDY AT ELEVATED BULK OUTLET TEMPERATURE
KE REACTOR

GENERAL	POINT NO.	MAX. ⁽¹⁾ PRESS. (psig)	MIN. ⁽¹⁾ PRESS. (psig)	AVE. ⁽¹⁾ PRESS. (psig)	CYCLIC CONDITION ⁽¹⁾ AND DOUBLE AMPLITUDE	POINT NO.	TEMPERATURE ⁽²⁾ RECORDINGS TAKEN DURING TEST (°C)
TEST DATE: 9-1-61 TOTAL FLOW: 175,000 gal/min. POWER LEVEL: 750 MW BULK OUTLET TEMP: 36.0°C TORP: 364 psig TIME: 7:40 p.m.	P-1	Out of	Service			T-1	35.27
	P-2	2.3	1.0	1.7	23 cps 0.6 to 1.3 psig	T-2	37.71
	P-3	18.0	15.0	16.5	No Reading	T-3	36.48
	P-4	Out of	Service			T-4	36.95
	P-5	10.4	9.2	9.6	19 cps 0.2 to 0.6 psig		
	P-7	5.0	3.0	4.0	6 cps 1.0 to 1.6 psig 48 cps 0.5 to 1.4 psig		
	P-8	6.0	4.8	5.4	19 cps 0.4 to 0.7 psig		
	P-9	5.4	4.8	5.1	10 cps 0.2 to 0.6 psig		
	* P-10	Neg. Variation		0.0	Negligible Variation		
	P-11	-2.0	-6.0	-4.0	18 cps 0.8 to 3 psig		
	P-13	-1.6	-3.8	-2.5	19 cps 0.8 to 2.2 psig		
	P-14	5.7	4.7	5.2	5 cps 0.4 to 0.7 psig		
	P-15	-3.8	-6.8	-4.8	12 cps 2.0 to 3.0 psig		
	P-16	8.3	7.2	7.8	4 cps 0.1 to 0.2 psig		

(1) Unless otherwise noted, accuracy of $\pm 10\%$ is assumed.
 (2) Unless otherwise noted, accuracy of $\pm 1\%$ is assumed.
 * Sensing element port may have been plugged; pressure will be checked.

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REAR FACE PIPING STUDY AT ELEVATED BULK OUTLET TEMPERATURE
KE REACTOR

GENERAL	POINT NO.	MAX. ⁽¹⁾ PRESS. (psig)	MIN. ⁽¹⁾ PRESS. (psig)	AVE. ⁽¹⁾ PRESS. (psig)	CYCLIC CONDITION ⁽¹⁾ AND DOUBLE AMPLITUDE	POINT NO.	TEMPERATURE ⁽²⁾ RECORDINGS TAKEN DURING TEST (°C)
TEST DATE: 9-1-61	P-1	Out of Service					
TOTAL FLOW: 176,000 gpm	P-2	3.9	1.5	2.4	29 cps 0.3 to 1.2 psig	T-1	39.06
POWER LEVEL: 1010 MW	P-3	18.7	14.3	16.5	98 cps 2.0 to 3.8 psig	T-2	43.83
BULK OUTLET TEMP: 42.0°C	P-4	Out of Service					
TORP: 375 psig	P-5	10.2	8.7	9.5	20-1/2 cps 0.1 to 0.8 psig	T-3	42.68
TIME: 8:35 p.m.	P-7	5.2	2.5	3.9	1 cps 1.0 to 2.1 psig		
					38 cps 0.4 to 1.4 psig	T-4	43.22
	P-8	6.1	4.8	5.5	27 cps 0.3 to 0.8 psig		
	P-9	5.1	4.0	4.5	8-1/2 cps 0.3 to 0.7 psig		
	P-10	Neg. Variation		+0.05	Negligible Variation		
	P-11	-1.0	-7.0	-4.0	20 cps constant 0.1 psig		
	P-13	0.0	-3.8	-1.9	26 cps 0.3 to 2.3 psig		
	P-14	6.0	4.3	5.3	49 cps 0.2 to 0.6 psig		
	P-15	-1.0	-7.0	-4.0	19 cps 2.0 to 5.5 psig		
	P-16	7.8	6.6	7.2	8 cps 0.2 to 0.4 psig		
(1) Unless otherwise noted, accuracy of $\pm 10\%$ is assumed. (2) Unless otherwise noted, accuracy of $\pm 1^\circ$ is assumed. * Sensing element port may have been plugged; pressure will be checked.							

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REAR FACE PIPING STUDY AT ELEVATED BULK OUTLET TEMPERATURE
KE REACTOR

GENERAL	POINT NO.	MAX. ⁽¹⁾ PRESS. (psig)	MIN. ⁽¹⁾ PRESS. (psig)	AVE. ⁽¹⁾ PRESS. (psig)	CYCLIC CONDITION ⁽¹⁾ AND DOUBLE AMPLITUDE	POINT NO.	TEMPERATURE ⁽²⁾ RECORDINGS TAKEN DURING TEST (°C)
TEST DATE: 9-2-61 TOTAL FLOW: 184,000 gpm POWER LEVEL: 3140 MW BULK OUTLET TEMP: 82.4°C TORP: 390 psig TIME: 12:10 p.m.	P-1	Out of	Service			T-1	79.73
	P-2	3.0	0.7	1.9	19 cps 0.1 to 1.7 psig	T-2	87.10
	P-3	18.0	15.2	16.6	11 cps 0.5 to 2.0 psig	T-3	86.12
	P-4	Out of	Service			T-4	87.40
	P-5	Out of	Service				
	P-7	5.2	2.3	3.8	31 cps 0.3 to 2.6 psig		
	P-8	6.5	2.9	4.7	59 cps 0.5 to 3.1 psig		
	P-9	6.7	4.9	5.8	7 cps 0.4 to 1.0 psig		
	* P-10	Neg. Variation		+0.1	Negligible Variation		
	P-11	0.0	-6.0	-3.0	18 cps 1.0 to 3.0 psig		
	P-13	0.0	-3.75	-1.9	13 cps 0.5 to 3.5 psig		
	P-14	6.0	4.5	5.3	2-3/4 cps 0.6 to 1.3 psig 58 cps 0.1 to 0.8 psig		
	P-15	-5.5	-7.1	-6.3	17 cps 0.3 to 1.5 psig		
	P-16	9.4	8.1	8.8	29 cps 0.1 to 0.5 psig		
(1) Unless otherwise noted, accuracy of $\pm 10\%$ is assumed. (2) Unless otherwise noted, accuracy of $\pm 1\%$ is assumed. * Sensing element port may have been plugged; pressure will be checked.							

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REAR FACE PIPING STUDY AT ELEVATED BULK OUTLET TEMPERATURE
KE REACTOR

GENERAL	POINT NO..	MAX. ⁽¹⁾ PRESS. (psig)	MIN. ⁽¹⁾ PRESS. (psig)	AVE. ⁽¹⁾ PRESS. (psig)	CYCLIC CONDITION ⁽¹⁾ AND DOUBLE AMPLITUDE	POINT NO.	TEMPERATURE ⁽²⁾ RECORDINGS TAKEN DURING TEST (°C)
TEST DATE: 9-6-61 TOTAL FLOW: 184,000 gpm POWER LEVEL: 3300 MW BULK OUTLET TEMP: 86.2°C TORP: 389 psig TIME: 9:30 a.m.	P-1	Out of Service					
	P-2	2.5	0.7	1.6	19 cps 0.2 to 1.5 psig	T-1	87.40
	P-3	18.0	14.8	16.4	6 cps 0.5 to 2.0 psig		
	P-4	Out of Service				T-2	87.19
	P-5	11.2	9.2	10.2	21 cps 0.5 to 1.9 psig		
	P-7	5.3	2.4	3.9	32 cps 0.3 to 1.5 psig	T-3	85.86
	P-8	8.3	5.0	6.7	55 cps 0.3 to 3.3 psig Slight Modulation	T-4	86.33
	P-9	6.1	4.3	5.2	8 cps 0.5 to 1.6 psig		
	*P-10	Neg. Variation		+0.04	Negligible Variation		
	P-11	-0.5	-6.0	-2.5	19 cps 1.0 to 3.0 psig		
	P-13	2.0	-4.5	-2.0	7 cps 0.7 to 5.5 psig		
	P-14	5.6	4.3	4.9	31 cps 0.2 to 0.7 psig		
	P-15	-5.2	-6.3	-5.8	16 cps 0.2 to 1.0 psig		
	P-16	9.2	8.2	8.7	26 cps 0.1 to 0.4 psig		

(1) Unless otherwise noted, accuracy of $\pm 10\%$ is assumed.
 (2) Unless otherwise noted, accuracy of $\pm 1\%$ is assumed.
 * Sensing element port may have been plugged; pressure will be checked.

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REAR FACE PIPING STUDY AT ELEVATED BULK OUTLET TEMPERATURE
KE REACTOR

GENERAL	POINT NO.	MAX. ⁽¹⁾	MIN. ⁽¹⁾	AVE. ⁽¹⁾	CYCLIC CONDITION ⁽¹⁾ AND DOUBLE AMPLITUDE	POINT TEMPERATURE ⁽²⁾	
		PRESS. (psig)	PRESS. (psig)	PRESS. (psig)		NO. RECORDINGS TAKEN DURING TEST (°C)	
TEST DATE: 9-6-61 TOTAL FLOW: 184,000 gpm POWER LEVEL: 3400 MW BULK OUTLET TEMP: 90°C TORP: 389 psig TIME: 11:15 p.m.	P-1	Out of Service				T-1	90.92
	P-2	2.4	1.1	1.8	19 cps 0.1 to 1.2 psig	T-2	91.63
	P-3	17.0	13.9	15.5	4 cps 0.8 to 2.8 psig		
	P-4	Out of Service				T-3	90.40
	P-5	12.8	7.8	10.3	48 cps 1.0 to 4.0 psig		
	P-7	5.4	2.7	4.1	1-3/8 cps 1.2 to 2.5 psig	T-4	89.99
					33 cps 0.2 to 1.4 psig		
	P-8	10.2	4.4	7.3	75 cps 0.4 to 2.0 psig		
	P-9	4.9	3.9	4.5	8-1/2 cps 0.4 to 0.7 psig		
	* P-10	Neg. Variation		+0.1	Negligible Variation		
	P-11	-1.0	-3.0	-2.0	19 cps 0.3 to 1.5 psig		
	P-13	0.0	-4.0	-2.0	14 cps 0.1 to 0.6 psig		
	P-14	5.9	4.7	5.3	2 cps 0.4 to 0.8 psig		
					38-3/4 cps 0.1 to 0.3 psig		
	P-15	-3.8	-4.3	-4.2	20-1/2 cps 0.2 to 0.4 psig		
	P-16	9.0	7.7	8.4	2-1/4 cps 0.2 to 0.7 psig		
					25 cps 0.1 to 0.3 psig		

(1) Unless otherwise noted, accuracy of $\pm 10\%$ is assumed.(2) Unless otherwise noted, accuracy of $\pm 1\%$ is assumed.

* Sensing element port may have been plugged; pressure will be checked.

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REAR FACE PIPING STUDY AT ELEVATED BULK OUTLET TEMPERATURE
KE REACTOR

GENERAL	POINT NO.	MAX. ⁽¹⁾ PRESS. (psig)	MIN. ⁽¹⁾ PRESS. (psig)	AVE. ⁽¹⁾ PRESS. (psig)	CYCLIC CONDITION ⁽¹⁾ AND DOUBLE AMPLITUDE	POINT NO.	TEMPERATURE ⁽²⁾ RECORDINGS TAKEN DURING TEST (°C)
TEST DATE: 9-8-61 TOTAL FLOW: 184,000 gpm POWER LEVEL: 3650 MW BULK OUTLET TEMP: 93.6°C TORP: 389 psig TIME: 10:40 a.m.	P-1	Out of Service				T-1	93.94
	P-2	3.0	1.0	2.0	18 cps 0.1 to 1.4 psig	T-2	95.73
	P-3	17.2	12.5	14.9	3 cps 1.8 to 3.1 psig		
	P-4	Out of Service					
	P-5	12.6	9.5	11.5	51 cps 0.4 to 2.4 psig	T-3	94.57
	P-7	4.2	1.5	3.0	32 cps 0.4 to 1.6 psig		
	P-8	18.0	10.0	14.0	1-1/3 cps 2.5 to 10 psig	T-4	94.62
	P-9	7.3	4.6	5.9	10 cps 0.5 to 1 psig		
	* P-10	Neg. Variation		+0.05	Negligible Variation		
	P-11	-0.5	-3.0	-1.8	26 cps 0.5 to 2 psig		
	P-13	-2.8	-3.3	-3.1	16 cps 0.05 to 0.3 psig		
	P-14	5.8	4.8	5.3	48 cps 0.1 to 0.5 psig		
	P-15	-0.7	-2.3	-1.5	16 cps 0.2 to 0.8 psig		
	P-16	9.3	8.7	9.0	21 cps 0.1 to 0.5 psig		
(1) Unless otherwise noted, accuracy of + 10% is assumed. (2) Unless otherwise noted, accuracy of 1% is assumed. * Sensing element port may have been plugged; pressure will be checked.							

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REAR FACE PIPING STUDY AT ELEVATED BULK OUTLET TEMPERATURE
KE REACTOR

GENERAL	POINT NO.	MAX. ⁽¹⁾ PRESS. (psig)	MIN. ⁽¹⁾ PRESS. (psig)	AVE. ⁽¹⁾ PRESS. (psig)	CYCLIC CONDITION ⁽¹⁾ AND DOUBLE AMPLITUDE	POINT NO.	TEMPERATURE ⁽²⁾ RECORDINGS TAKEN DURING TEST (°C)
TEST DATE: 9-11-61 TOTAL FLOW: 184,000 gpm POWER LEVEL: 3670 MW BULK OUTLET TEMP: 94.4°C TORP: 189 psig TIME: 10:00 a.m.	P-1	Out of	Service			T-1	95.83
	P-2	2.9	0.7	2.1	36 cps 0.1 to 1.0 psig	T-2	95.92
	P-3	18.0	10.8	14.4	2 cps 2.0 to 6.5 psig 450 cps 0.2 to 1.1 psig (Extensive Modulation)	T-3	94.97
	P-4	Out of	Service			T-4	95.79
	P-5	12.2	9.0	10.5	28 cps 0.3 to 2.0 psig		
	P-7	5.0	2.2	3.6	31 cps 0.2 to 1.6 psig		
	P-8	18.4	10.0	14.0	1-3/4 cps 3.4 to 6.6 psig 420 cps 0.4 to 6.6 psig (Extensive Modulation)		
	P-9	10.0	4.8	7.0	1-1/2 cps 1.5 to 2.8 psig		
	*P-10	Neg. Variation		+0.02	Negligible Variation		
	P-11	-0.5	-2.5	-1.4	26 cps 0.5 to 1.5 psig		
	P-13	-2.4	-3.0	-2.7	19 cps 0.05 to 0.3 psig		
	P-14	5.9	4.7	5.6	41 cps 0.2 to 0.6 psig		
	P-15	-0.4	-2.1	-1.3	15 cps 0.3 to 0.8 psig		
	P-16	9.0	7.8	8.6	15 cps 0.1 to 0.7 psig		

(1) Unless otherwise noted, accuracy of + 10% is assumed.

(2) Unless otherwise noted, accuracy of + 1% is assumed.

* Sensing element port may have been plugged; pressure will be checked.

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REAR FACE PIPING STUDY AT ELEVATED BULK OUTLET TEMPERATURE
KE REACTOR

GENERAL	POINT NO.	MAX. ⁽¹⁾ PRESS. (psig)	MIN. ⁽¹⁾ PRESS. (psig)	AVE. ⁽¹⁾ PRESS. (psig)	CYCLIC CONDITION ⁽¹⁾ AND DOUBLE AMPLITUDE	POINT NO.	TEMPERATURE ⁽²⁾ RECORDINGS TAKEN DURING TEST (°C)
TEST DATE: 9-8-61 TOTAL FLOW: 184,000 gpm POWER LEVE: 3670 MW BULK OUTLET TEMP: 94.6°C TORP: 389 psig TIME: 5:45 p.m.	P-1	Out of Service				T-1	95.48
	P-2	3.0	1.2	2.1	22 cps 0.2 to 1.3 psig	T-2	96.36
	P-3	17.0	11.5	14.3	High Noise Level 2-3/4 cps 2.0 to 5.0 psig 500 cps 0.2 to 1.8 psig	T-3	95.16
	P-4	Out of Service				T-4	95.35
	P-5	11.7	9.3	10.5	37 cps 0.4 to 2.1 psig		
	P-7	5.0	2.5	3.7	1 cps 1.0 to 2.0 psig 26 cps 0.5 to 1.5 psig		
	P-8	16.0	10.8	14.0	2 cps 1.8 to 4.0 psig 600 cps 0.3 to 2.0 psig		
	P-9	10.5	6.5	8.5	12 cps 0.8 to 2.5 psig 180 cps 1.5 psig (Constant)		
	* P-10	Neg. Variation		+0.1	Negligible Variation		
	P-11	-0.05	-2.5	-1.3	31 cps 0.5 to 1.5 psig		
	P-13	-2.6	-2.9	-2.8	18 cps 0.1 to 0.3 psig		
	P-14	6.3	5.3	5.8	3/4 cps 0.3 to 0.9 psig 38 cps 0.1 to 0.4 psig		
	P-15	-0.3	-1.7	-1.0	17 cps 0.1 to 0.7 psig		
	P-16	9.7	8.2	8.9	19 cps 0.1 to 0.7 psig		

(1) Unless otherwise noted, accuracy of $\pm 10\%$ is assumed.(2) Unless otherwise noted, accuracy of $\pm 1\%$ is assumed.

* Sensing element port may have been plugged; pressure will be checked.

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REAR FACE RIFLING STUDY

KE REACTION

MECHANISM TEST NO. 12-51

DATE RECEIVED: JAN 1961

BY FRANK W-12-51

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FIGURE #3

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FIGURE 1 DECLASSIFIED

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7-1-1966
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DATE RECEIVED: 30 JUL 1968
D.H. FRIEDMAN 10-19-68

GENERAL INVESTIGATION

RESEARCH

PROJECT SYMBOL

FIGURE 1

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WATER COOLING PIPELINE STUDY

REPERCUSSION

DEVELOPMENT TEST RESULTS

DATE RECALCULATED 9-61

WATER FLOWING 10-10-61

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APPENDIX II

VIBRATION TABULATIONS AND GRAPHS

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INTERIM REPORT

PIPING STUDY AT ELEVATED BULK OUTLET TEMPERATURE KE REACTOR

REACTOR: 105-KE

FLOW: 170,000 gpm

POWER LEVEL: 0 MW

BULK OUTLET TEMP: 21°C

TORP: 360 psig

BY: D. H. Frieling
P. H. Hutton

DATE RECORDED: 9-1-61

POINT	FREQUENCY (cps)	ACCELERATION MAXIMUM (G) PEAK	VELOCITY MAXIMUM (IN/SEC.) PEAK	AMPLITUDE PEAK TO PEAK (inches)
V-1	10	0.05 -0.19	0.30 -1.5	0.01 -0.049
	220	0.22 -1.0	0.092 -0.3	0.00023 -0.00044
	3600	0.77 -2.3	0.015 -0.045	0.000003 -0.0000039
	4400	0.65 -2.4	0.0095 -0.04	0.0000007 -0.000003
	5300	0.50 -1.67	0.006 -0.019	0.00000038 -0.0000012
V-2	11	0.085-0.30	0.46 -1.6	0.013 -0.04
	40	0.38 -1.2	0.55 -1.8	0.0039 -0.014
	660	3.8 -10	0.38 -1.0	0.00019 -0.0005
	4950	0.057-0.52	0.00068-0.0051	0.000000011-0.00000034
V-3	12	0.05 -0.13	0.24 -1.15	0.007 -0.03
	85	0.091-0.78	0.067 -0.54	0.00026 -0.0019
	5200	0.06 -0.82	0.0032 -0.032	0.00000005 -0.00000055
	6300	0.44 -1.32	0.0045 -0.12	0.00000023 -0.00000065
V-4	3-3-/2	0.16 -0.5	2.7 -8.3	0.22 -0.80
	85	0.21 -1.6	0.15 -1.2	0.00060 -0.0048
	3600	0.098-0.69	0.0018 -0.014	0.00000017 -0.0000013

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INTERIM REPORT

PIPING STUDY AT ELEVATED BULK OUTLET TEMPERATURE
KE REACTOR

REACTOR: 105-KE

FLOW: 184,000 gpm

BY: D. H. Frieling

P. H. Hutton

POWER LEVEL: 3140 MW

BULK OUTLET TEMP: 32.4°C

DATE RECORDED: 9-2-61

TORP: 390 psig

POINT	FREQUENCY (cps)	ACCELERATION MAXIMUM (G) PEAK	VELOCITY MAXIMUM (IN/SEC.) PEAK	AMPLITUDE PEAK TO PEAK inches
V-1	Out of Service.			
V-2	11	0.09 - 0.43	0.55 - 2.8	0.017 - 0.081
	67	0.15 - 0.49	0.17 - 0.69	0.00081 - 0.0031
	3875	1.5 - 21	0.025 - 0.35	0.000002 - 0.000017
	4450	0.070 - 5.0	0.0010 - 0.71	0.000000069 - 0.0000050
	5700	1.79 - 7.16	0.019 - 0.082	0.000006 - 0.000046
V-3	2	0.03 - 0.095	0.056 - 3.06	0.15 - 0.48
	11	0.031 - 0.18	0.19 - 1.2	0.0062 - 0.035
	83	0.0095 - 0.37	0.0089 - 0.27	0.000037 - 0.00085
	3800	0.18 - 2.6	0.0044 - 0.056	0.0000052 - 0.0000061
	5450	0.264 - 1.50	0.0030 - 0.015	0.00000018 - 0.0000085
V-4	5	0.11 - 0.34	1.7 - 12.8	0.11 - 0.72
	95	0.16 - 0.68	0.093 - 0.49	0.00029 - 0.0017
	4100	0.064 - 0.64	0.0011 - 0.011	0.00000084 - 0.0000084

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INTERIM REPORT

PIPING STUDY AT ELEVATED BULK OUTLET TEMPERATURE KE REACTOR

REACTOR: 105-KE

FLOW: 175,000 gpm

POWER LEVEL: 750 MW

BULK OUTLET TEMP: 360°C

TORP: 364

BY: D. H. Frieeling
P. H. Hutton

DATE RECORDED: 9-1-61

POINT	FREQUENCY (cps)	ACCELERATION MAXIMUM (G) PEAK	VELOCITY MAXIMUM (IN/SEC.) PEAK	AMPLITUDE PEAK TO PEAK (inches)
V-1	2-1/2	0.032-0.11	0.02-0.1	0.12-0.38
	8	0.07-0.31	0.61-3.4	0.023-0.063
	170	0.14-1.3	1.180-11.8	0.00011-0.00001
	3200	0.22-1.1	1.1000-0.014	0.0000011-0.0000071
V-2	2-1/2 to 3-3/4	0.000-0.001	0.00-1.14	0.005-0.17
	10-1/2	0.055-0.15	0.04-1.1	0.001-0.011
	46	0.13-0.50	0.07-1.49	0.0012-0.0042
	3600	0.18-1.8	0.0000-0.00	0.00000072-0.000002
	5350	0.18-4.1	0.0100-0.057	0.00000013-0.0000031
V-3	11-12	0.05-0.18	1.05	1.00-0.000
	73	0.01-1.8	1.04-1.1	0.0000-1.1000
	3150	0.41-1.1	0.002-0.1	0.00000073-0.000001
	4600	0.05-0.07	1.00-0.000	0.00000043-0.0000006
V-4	4-1/2	0.01-1.0	0.80-11.1	0.73-0.73
	100	0.00-1.07	0.11-0.4	1.0000-0.0011
	3600	0.115-1.12	0.000-0.000	0.00000001-0.0000018

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INTERIM REPORT

PIPING STUDY AT ELEVATED BULK OUTLET TEMPERATURE KE REACTOR

REACTOR: 105-KE

FLOW: 175,000 gpm

POWER LEVEL: 1010 MW

BULK OUTLET TEMP: 42°C.

TORP: 375

By: D. H. Fiedling
P. H. Hatten

DATE RECORDED: 5-2-61

POINT	FREQUENCY (cps)	ACCELERATION MAXIMUM (g) PEAK	TIME IN N.A. LOG. CORREL. TEST	AMPLITUDE PEAK TO PEAK (mm)
V-1	4-6	0.03 - 0.10	0.61 - 1.4	0.00000000 - 0.00000000
	250	0.40 - 0.5	0.12 - 0.35	0.00000000 - 0.00000000
	4500	0.40 - 0.5	0.0000 - 0.0	0.00000000 - 0.00000000
V-2	11	0.05 - 0.1	1.0 - 1.5	0.00000000 - 0.00000000
	50	0.10 - 0.2	0.0 - 0.1	0.00000000 - 0.00000000
	3500	0.10 - 0.2	1.0 - 1.5	0.00000000 - 0.00000000
	6200	0.10 - 0.2	1.0 - 1.5	0.00000000 - 0.00000000
V-3	11	0.04 - 0.1	0.14 - 0.3	0.00000000 - 0.00000000
	25	0.05 - 0.1	1.0 - 1.5	0.00000000 - 0.00000000
	5900	0.10 - 0.2	1.0 - 1.5	0.00000000 - 0.00000000
V-4	5-6	0.10 - 0.1	1.7 - 11.1	1.15 - 0.85
	38	0.10 - 0.1	0.10 - 0.8	0.00000000 - 0.00000000
	4050	0.09 - 0.05	0.10 - 0.2	0.00000000 - 0.00000000

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INTERIM REPORT

PIPING STUDY AT ELEVATED BULK OUTLET TEMPERATURE KE REACTOR

REACTOR: 105-KE

FLOW: 184,000 gpm

BY: O. H. Frieling
P. H. Hutton

POWER LEVE: 3650 MW

BULK OUTLET TEMP: 93.6°C

DATE RECORDED: 9-8-61

TORP: 389 psig

POINT	FREQUENCY (cps)	ACCELERATION MAXIMUM (G) PEAK	VELOCITY MAXIMUM (IN/SEC.) PEAK	AMPLITUDE PEAK TO PEAK (Inches)
V-1	Out of Service.			
V-2	10	0.34 - 0.46	0.33 - 0.47	0.0035 - 0.13
	63	0.13 - 0.61	0.13 - 0.61	0.00084 - 0.0032
	3800	1.3 - 7.6	0.13 - 0.14	0.000011 - 0.0000188
	5500	1.4 - 8.7	0.13 - 0.13	0.00000030 - 0.0000054
V-3	4	0.063 - 0.41	0.33 - 0.33	0.13 - 0.56
	155	0.13 - 0.61	0.13 - 0.18	0.00013 - 0.00014
	2300	0.39 - 1.1	0.13 - 0.057	0.000017 - 0.0000071
	4800	0.13 - 0.61	0.13 - 0.017	0.0000015 - 0.0000003
V-4	5	0.33 - 0.47	0.33 - 0.33	0.13 - 0.78
	180	0.13 - 0.61	0.06 - 0.13	0.00012 - 0.00014
	4000	0.017 - 0.13	0.0001 - 0.0001	0.0000000041 - 0.000000026

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INTERIM REPORT

PIPING STUDY AT ELEVATED BULK OUTLET TEMPERATURE KE REACTOR

REACTOR: 105-KE

FLOW: 184,000 gpm

BY: D. H. Frieeling
P. H. Hutton

POWER LEVEL: 3670 MW

BULK OUTLET TEMP: 94.6°C

DATE RECORDED: 9-8-61

TORP: 389 psig

POINT	FREQUENCY (cps)	ACCELERATION MAXIMUM (G) PEAK	VELOCITY MAXIMUM (IN/SEC.) PEAK	AMPLITUDE PEAK TO PEAK (inches)
V-1	Out of Service			
V-2	5	0.18 - 0.85	2.21 - 11.0	0.14 - 0.62
	11	0.035 - 0.22	0.58 - 1.4	0.017 - 0.041
	77	0.25 - 0.75	0.128 - 0.4	0.00072 - 0.0027
	4950	0.56 - 14	0.013 - 0.20	0.00000068 - 0.0000013
V-3	5-6	0.044 - 0.72	0.48 - 11.5	0.035 - 0.75
	128	0.79 - 41	0.40 - 2.1	0.00097 - 0.0051
	2000	0.12 - 1.5	0.0040 - 0.050	0.00000067 - 0.0000075
	4970	0.13 - 1.36	0.0018 - 0.011	0.00000013 - 0.00000035
V-4	5	0.091 - 0.59	2.03 - 10.8	0.073 - 0.65
	175	0.082 - 1.3	0.032 - 0.50	0.000058 - 0.0021
	3370	0.025 - 0.30	0.00052 - 0.0032	0.000000051 - 0.00000031

VIBRATIONAL VELOCITY DISTRIBUTION
KE REACTOR - REAR FACE PIPE
DEVELOPMENT TEST NO. 1A90-E

DATA ACCUMULATED
ON FRANKLIN 10-04

VELOCITY
[in/sec - peak]

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FIGURE #1

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APPENDIX III

STRESS TABULATION

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INTERIM REPORT

PIPING STUDY AT ELEVATED BULK OUTLET TEMPERATURE KE REACTOR

STRESS TABULATION

REACTOR: KE

RECORDING DATES: 9-1-61 through
9-8-61

BY: D. H. Frieling
P. H. Hutton

BULK OUTLET TEMPERATURE	S-1(1)	S-2(1)	SR-1(1)			
	COMPRESSIVE (psi)	COMPRESSIVE (psi)	MAX. COMPRESSIVE (psi)	MIN. COMP. (2)	ANGLE(θ) X-AXIS TO MAX. STRESS	MIN. PURE SHEAR (psi)
21	770	0	0	0	---	0
36	1400	1960	966	684	83	140
42	1260	1260	1320	717	86	300
82.4	1960	2800	3040	1570	82	735
86.2	2450	2520	2440	1760	83	340
90	2240	3080	3100	1380	80	865
93.6	2660	3550	3210	1270	84	970
94.6	2660	3500	3070	1130	83	970
94.4	2520	3360	3160	1590	83	785

NOTE: (1) Assume an accuracy of $\pm 10\%$.

(2) Minimum stress will be located at 90°
from the position of the maximum stress.

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APPENDIX IV

STRAIN, VIBRATION, TEMPERATURE
AND PRESSURE-SENSING LOCATIONS ON THE
REAR FACE PIPING - 105-KE REACTOR
SK-1-22984

24-72366

7.39

DECLASSIFIED

SECT A-A

SECT B-B

SECT C-C

DESCRIPTION		REV	APP	FOR	DATE
REVISIONS		BY	BY		
CLASSIFICATION		CLASSIFIED BY			
NONE		R.H. Dornenill			
DATE		10-7-60			
DWS NO		SK-1-22984		REV NO	
		1		0	
SCALE: NONE		APPROVALS			
DRAWN BY: S.H. Dornenill		BY	FOR	DATE	
CHECKED BY: S.H. Dornenill		DATE	6/20/61	6/20/61	
ISSUED					
DWS ENGINEERING UNIT: H-200					
HIST					
PROJECT					
U. S. ATOMIC ENERGY COMMISSION					
HANFORD ATOMIC PRODUCTS OPERATION					
GENERAL ELECTRIC					
DEVELOPMENT TEST					
STRAIN, VIBRATION, TEMPERATURE, AND PRESSURE SENSING LOCATIONS ON THE REAR FACE PIPING					
DWS NO		1025 AF		REV NO	
		6004			
NEXT USED ON		SK-1-22984		REV NO	
				1/1	

**DATE
FILMED**

7 / 1 / 94

END