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STUDY OF EXPANSION JOINTS AND GUIDES FOR
REAR CROSSHEADERS - B, D, F, DR, H & C REACTORS

By

P. H. Hutton
Reactor, Plant Engineering
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IRRADIATION PROCESSING DEPARTMENT

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REAR CROSSHEADERS - B, D, F, DR, H & C REACTORS

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STUDY OF EXPANSION JOINTS AND GUIDES FOR
REAR CROSSHEADERS - B, D, F, DR, H, & C REACTORS

INTRODUCTION

Measurements and calculations made by FEO and actual component failures have shown that two major causes of rear face piping problems at the subject reactors are crossheader vibration and high, thermally induced stress at the crossheader-riser joints. Documents HW-65269, "Existing Reactor Rear Face Piping Review", and HW-65569, "Vibration Studies, Reactor Rear Face Piping, 105-F, and H" discuss these conditions in detail. Briefly, measurements and calculations indicate: 1) Low frequency (2-6 cps) crossheader vibration as high as 0.9 inches double amplitude at H Reactor with maximum values less at the other reactors (0.3 to 0.5 inches double amplitude) resulting in cyclic stressing of the connectors and Parker fittings and 2) stress levels, induced by thermal expansion, in excess of the yield point at the crossheader-riser joints. The authenticity of these indications is supported by gross failure of stainless steel and slip joint rear connectors due to a combination of fatigue and stress corrosion, cracks in rear risers where the crossheaders join the risers and fatigue failure of rear crossheader Parker fittings.

PURPOSE

The purpose of this report is to describe the results of prototype tests of piping alterations designed to alleviate the above described conditions and to outline a program for full-scale implementation of these alterations.

SUMMARY AND CONCLUSIONS

Under authorization of Production Test PT-IP-356-AE; original and supplement one, prototype installations of rear crossheader expansion joints made up of standard Dresser couplings accompanied by a center anchor and spaced guide supports on the crossheader were made on No. 25 rear header at H Reactor on 3/10/61 and on No. 23-1/2 rear header at DR Reactor on 4/28/61. Results from these test installations show a reduction factor in low frequency vibration as high as two and a reduction factor in crossheader stress of approximately three. The expansion joints have functioned for 11 months at H Reactor and 9 months at DR Reactor with no indication of significant deterioration of the graphite impregnated asbestos gaskets used in the installation.

It is recommended that full scale installation of rear crossheader expansion joints made up of Dresser couplings together with crossheader guides and anchors be made at H Reactor on a lead reactor basis in FY-62 and that similar alterations be made at B, D, F, DR, and possibly C Reactors in FY-63. Budget action has been taken in accordance with the above recommendations.

The above recommended action is justified on the following bases:

1. Support of continuity of reactor operation by eliminating failure of rear connectors and risers from vibration and stress induced by thermal expansion and by preserving much of the remaining integrity of rear crossheader Parker fittings through reduced cyclic loading from vibration.

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2. Reduced operating costs through reduced rear face maintenance on the equipment mentioned in (1) above. It is estimated that the recommended work would eliminate one change of rear connectors in the next five years. Assuming 1800 connectors involved in each area @ \$15 per connector, this amounts to \$27,000/reactor. It is difficult to realistically evaluate reduced riser stress and Parker fitting stress in terms of dollars because the potential consequences of continuing these conditions covers such a wide range. This range goes all the way from relatively minor repair work on individual failures up to major work involving replacement of complete headers or risers.
3. Eliminate rear crossheader thermal expansion as a deterrent to any future plans for increased production through higher bulk outlet temperatures.

DISCUSSION

Analysis of study data shows that the problems of low frequency rear cross-header vibration and thermally induced stress at the crossheader riser joints are closely related. Indications are that because the expansion loops at each end of the crossheaders are inadequate to absorb thermal expansion of the crossheader under current operating conditions, excessive stress is established at the restrained ends of the crossheaders and the crossheaders also bow up off their support saddles for a sufficient length to make them susceptible to low frequency excitation. The resulting crossheader vibration induces a cyclic stress in both the connectors and the crossheader Parker fittings.

Expansion joints in the crossheaders together with guides to maintain the crossheader in its proper lateral orientation appeared to offer a solution to both problems described above. Three types of expansion joints were considered. They were:

1. Hycar hose.
2. Two Dresser couplings with a spool piece between them.
3. An all-metallic, bellows type joint.

The Dresser coupling type joint is the one chosen for full-scale application. As shown on the attached Dwg. SK-1-5524, and in Figure 1, it consists of two Dresser couplings with a spool piece between them inserted in place of the bottom leg of the expansion "U" at each end of the crossheader. In this location it absorbs thermal expansion of the crossheader by utilizing the ability of Dresser couplings to accept up to about 4° angularity relative to the pipe.

The Hycar hose type joint has been abandoned because of difficulty in procuring satisfactory hose in the size needed. The first sample received was made up of the proper material but the fabrication was unacceptable. In a second sample received, the reverse conditions were true - fabrication acceptable, but improper material. At this point, the vendor indicated he could do no more for us. This type of procurement difficulty does little to recommend a piece of equipment for extensive use on a reactor.

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The all metallic, bellows type joint was eliminated because of cost. The bid price on suitable joints in quantity lots was \$390. each compared to a cost of about \$30 for each assembly of the Dresser coupling type joint. Functionally, this type of joint should be quite satisfactory. It would be used in the same location and manner as the Dresser coupling joint.

Dresser coupling expansion joints, an anchor bracket at the center of the crossheader and four guide brackets spaced along the length of the header were installed on a prototypic basis on No. 25 rear header at 105-H on March 10, 1961. A comparison of "before" and "after" data showed that where low frequency (2-6 cps) crossheader vibration averaged about 0.5 inches double amplitude with maximum values up to 0.9 inches "before", the values in the same frequency range averaged a fairly steady 0.18 inches "after" the installation. A similar comparison of strain gage data obtained from gages located on the inside radius of the first elbow out of the riser on No. 25 header showed a decrease in indicated stress from 76,000 psi "before" to 19,300 psi "after".

The prototype installation has operated satisfactorily for over 11 months with the exception of a leak at one coupling which was remedied by tightening the gasket follower.

Another prototype installation similar to that described above was made at 105-DR on No. 23-1/2 rear header on April 28, 1961. Unfortunately, the data available for evaluating the effect of this installation is not nearly so comprehensive as that available at 105-H. Since the original vibration condition was not as severe as that of "H". the indicated reduction was not as great. Where the low frequency (2-6 cps) vibration averaged about 0.31 inches double amplitude with maximum values up to 0.5 inches "before", it averaged about 0.17 inches "after". It is significant that the resultant vibration level is very similar to that attained at 105-H.

The indicated stress at the first elbow out from the riser on No. 23-1/2 header after installation of the expansion joints was 27,000 psi. Due to malfunction of instrumentation, no directly comparable stress data is available for the same location before modification of the crossheader. However, since cracks have occurred in the riser walls at DR adjacent to the crossheader-riser junction, it is reasonable to assume that stresses in excess of 35,000 psi (the nominal endurance limit for 18-8 stainless steel) existed in that region.

It should be noted that the installation under discussion did not nor was it expected to, alter the high frequency (1,000 to 6,000 cps) vibration evident on the crossheaders within the tube pattern. The high frequency vibration appears to be excited by the extreme turbulence and the cavitation in the water as it enters the crossheaders. This is a localized phenomena which one would not expect to alter by installing guide brackets on the crossheader because the amplitudes are very small - in the order of 0.0001 inches double amplitude or less. This condition can be expected to persist

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at present or higher operating levels until the flow path is enlarged to reduce flow velocity and increase static pressure in the connector and fittings.

Appendix 1 of this report describes the instrumentation used in obtaining the above data and also presents a condensed tabulation of the data.

In summary, the prototypic tests of rear crossheader expansion joints as accompanied by crossheader guide brackets show that a major reduction in both crossheader vibration and crossheader-riser stress can be expected from full scale installation of these modifications at 105-H. At 105-B, D, DR, and F, a major reduction in crossheader-riser stress and a lesser but still significant reduction in crossheader vibration can be expected. The resultant crossheader vibration level should be about the same at all reactors. The above results are significant because:

1. Reducing low frequency, high amplitude crossheader vibration will reduce the cyclic stress load which leads to fatigue failures in the rear connectors and crossheader Parker fittings.
2. Reducing stress at the crossheader-riser joint will alleviate the problem of potential riser failure at that point.
3. Providing a means for absorbing thermal expansion of the cross-headers removes this obstacle to operation at bulk outlet temperatures higher than those currently authorized.

Modification at 105-C have been included in budget provisions for this work on a conditional basis. Further study is needed to firmly establish the need for this work at 105-C. It is planned to conduct this study in the near future in order that a firm recommendation can be made by the end of FY-62.

Since the integrity of the rear crossheader Parker fittings is somewhat questionable at this point, it would be well to consider means to allow removing any heavy fixtures such as the zone temperature wye fittings which are currently attached to the Parker fittings. Even though the proposed work will reduce the level of low frequency crossheader vibration, these relatively heavy fixtures will still exert an undesirable concentrated bending load on the Parker fittings. To date, about 90 per cent of the known Parker fitting failures have occurred on zone temperature tubes or on tubes equipped with "J" connectors which required the heavy brass adapter on the Parker fitting.

COSTS

A current cost estimate for accomplishing the recommended alterations at 105-H by Maintenance Job Authorization is \$24,000. The cost for 105-DR should be similar. The costs for this work at 105-B, D, and F would probably be about \$30,000 each and about \$40,000 for 105-C because these reactors have more crossheaders.

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A rough estimate of outage time required is 8 to 9 days each at 105-B, D, F, and C and 5 to 7 days at 105-H, and DR if the work is done by itself. The time chargeable to this work can be drastically reduced by doing the work in conjunction with other reactor work and/or doing it piece-meal. Generally, the work is compatible with both of these considerations.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the splendid general cooperation and support received from others in the accomplishment of this work. The efforts of "H" Reactor Operation and DR Reactor Operation personnel and J. H. Hoage and W. W. Porter, Equipment Application Engineering Operation, FEC warrant particular mention in this regard.

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Hand-drawn diagram of a 3D structure with nodes 5, 6, 7, 8, and 9. Node 5 is central, with 6 to its right, 7 below it, and 9 to its left. Node 8 is above 9. Lines connect 5-6, 5-7, 5-9, and 9-8. Labels include "MATL: C. STL." near nodes 6 and 7, and "TYP." near nodes 9 and 5.

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FIGURE 1
Prototypic Dresser Coupling Expansion Joint
No. 25 Rear Crossheader, Near Side 105-H

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APPENDIX I

DESCRIPTION OF INSTRUMENTATION AND
TABULATION OF DATA

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STUDY OF EXPANSION JOINTS AND GUIDES FOR REAR CROSSHEADERS - B, D, F, DR, H, & C REACTORS

APPENDIX I

INSTRUMENTATION

Measurement of vibration and strain in reactor rear face components during operation requires a rather specialized approach. The fact that personnel can not enter the discharge area during reactor operation necessitates a system which records the information remotely. The environment-humidity in the order of 100 per cent; temperatures ranging from 85°C to 120°C depending on location and intermittent exposure to hot water from leaks - requires that instrumentation components located on the rear face be of a very high quality and rugged make-up. In the case of vibration, the wide range of frequencies present requires transducers capable of sensing from 1 cps. to about 7,000 cps. without adjustment.

The instrumentation used in making vibration measurements consisted of the following:

Endevco or Gulton crystal accelerometer were attached ungrounded to the component to be monitored. Microdot "Mini-Noise" coaxial signal lead wires 75 to 100 feet long connected the accelerometers to Gulton cathode followers located outside the discharge area. The output from the cathode followers went to Minneapolis-Honeywell linear/integrate amplifiers and they in turn fed to a Minneapolis-Honeywell "Viscorder" oscillograph. Each accelerometer was calibrated with the complete measuring system using an electrodynamic shaker table to simulate conditions before it was installed on the reactor. Considering the effects of long signal leads, instrument error, human error in interpreting oscillograph charts, etc., it is estimated that the overall accuracy of a specific piece of data is about + 5 per cent on frequency and + 20 per cent on magnitude. The accuracy of the average of several similar data measurements, however, should be substantially better. In an effort to improve accuracy, each accelerometer output was monitored on at least two different channels of the read-out system which gave a comparative check on everything but the accelerometers and lead wires. As a further step, in many cases several measurements were taken at a specific point over a period of time using different accelerometers and lead wires with similar reactor operating conditions prevailing. The vibration data tabulated below represents averages arrived at by these types of comparisons. In most cases, reproducibility of data was suprisingly good.

The instrumentation used in making strain measurements consisted of the following:

Baldwin ABR-4 strain gage rosettes were attached with Epicast 546 adhesive to the component to be monitored. Beldon shielded, six conductor cable was used. The strain gages were read out on a Baldwin SR-4 strain indicator. Radiographic Testing Operation, HLO performed all strain measurements related to this study.

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DATA

H-Reactor:

The vibration data presented below consists of two parts. Part "A" represents measurements obtained from specific points on crossheaders No's 25 and 33 prior to any crossheader modification work. Part "B" represents measurements obtained from these same points after crossheader No. 25 only had been modified by installation of Dresser coupling expansion joints, an anchor bracket at the center of the header and four guide brackets spaced along the length of the header. On both headers, the vibration was measured in a vertical plane between Columns 92 and 93.

PART "A"

DATE	FREQUENCY CPS	ACCELERATION "G" PEAK	VELOCITY IN/SEC-PEAK	DISPLACEMENT IN.-PEAK TO PEAK
<u>Header No. 25; Header Flow - 3925 gpm; Operating Level-Approx. 1500 MW</u>				
10-5-59	4	0.2 - 0.75	2.9 - 11.6	0.2 - 0.9
	625	3.7 - 7.4	0.4 - 0.8	0.0002 - 0.0004
	3300	5.3 - 25.6	0.1 - 0.5	0.00001 - 0.00005
10-22-59	4-5	0.06 - 0.3	0.9 - 4.5	0.065 - 0.3
	4500-5000	10.0 - 45.0	0.2 - 0.65	0.00001 - 0.00005
11-10-59	3-5	0.07 - 0.2	0.8 - 4.45	0.055 - 0.6
	1260	4.5 - 9.0	0.2 - 0.5	0.00006 - 0.00013
	6300	6.0 - 18.0	0.06 - 0.2	0.000003 - 0.000009
<u>Header No. 25; Header Flow - 3930 gpm; Operating Level - 1550 MW</u>				
12-14-59	5	0.035 - 0.3	0.4 - 3.6	0.03 - 0.23
	3300	5.0 - 30.0	0.1 - 0.6	0.000009 - 0.00005
	6400	5.7 - 20.0	0.055 - 0.2	0.000003 - 0.00001
<u>Header No. 33; Header Flow - $\approx$ 3900 gpm; Operating Level - 850 MW</u>				
11-30-59	3-4	0.06 - 0.2	1.14 - 3.4	0.10 - 0.30
<u>Header No. 33; Header Flow - 3986 gpm; Operating Level - 1300 MW</u>				
12-1-59	4	0.06 - 0.5	1.0 - 8.0	0.08 - 0.65
	650	3.2 - 13.0	0.3 - 1.3	0.0002 - 0.00065
	3360	6.9 - 53.0	0.15 - 1.05	0.000015 - 0.0001

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DATE	FREQUENCY CPS	ACCELERATION "G" PEAK	VELOCITY IN/SEC-PEAK	DISPLACEMENT IN.-PEAK TO PEAK
<u>Header No. 33; Header Flow - 3990 gpm; Operating Level - 1550 MW</u>				
12-14-59	4-5	0.07 - 0.5	1.0 - 7.0	0.07 - 0.55
	700	5.0 - 21.0	0.5 - 2.0	0.0002 - 0.0009
	3350	5.6 - 53.3	0.1 - 1.0	0.00001 - 0.0001

PART "B"

<u>Header No. 25; Header Flow - 4064 gpm; Operating Level - 1820 MW</u>				
3-13-61	2-4	0.01 - 0.1	0.3 - 2.0	0.03 - 0.2
	3200	2.5 - 55.0	0.05 - 1.2	0.000005 - 0.0001
	4500	3.5 - 40.0	0.05 - 0.6	0.000004 - 0.00005
<u>Header No. 33; Header Flow - 4129 gpm; Operating Level - 1820 MW</u>				
3-13-61	2-4	0.04 - 0.2	0.8 - 3.1	0.08 - 0.35
	3300	3.5 - 28.0	0.07 - 0.55	0.000007 - 0.00005
	4650	3.0 - 35.0	0.04 - 0.5	0.000003 - 0.00004
<u>Header No. 25; Header Flow - 4055 gpm; Operating Level - 1930 MW</u>				
3-24-61	3-5	0.03 - 0.13	0.45 - 2.0	0.035 - 0.17
	3300	4.9 - 49.0	0.1 - 1.0	0.00001 - 0.0001
	4600	3.7 - 39.0	0.05 - 0.6	0.000004 - 0.00004
<u>Header No. 33; Header Flow - 4135 gpm; Operating Level - 1930 MW</u>				
3-24-61	2-4	0.09 - 0.25	1.9 - 5.0	0.2 - 0.5
	4600	6.5 - 40.0	0.1 - 0.6	0.000007 - 0.00004

The following stress information was derived from the response of a rosette strain gage located on the inside radius of the first elbow out from the near riser on No. 25 rear crossheader at H Reactor.

DATE RECORDED	REACTOR CONDITIONS			STRAIN-Microinches/Inch			MAXIMUM STRESS PSI
	FLOW-GPM	POWER-MW	TEMP.-°C	A	B	C	
12-5-60	86,794	1830	92.4	-1380	-1730	-1870	76,000
4-10-61	86,376	1800	88.2	-400	-430	-480	19,300

DR REACTOR:

Vibration data at DR Reactor was taken on No. 23-1/2 rear header only.

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DATE	FREQUENCY CPS	ACCELERATION "G"-PEAK	VELOCITY IN/SEC-PEAK	DISPLACEMENT IN.-PEAK TO PEAK
<u>Before Modification; Bulk Temp. - 93.5°C; Total Flow - 81,200 gpm; Level-1660 MW</u>				
8-25-60	3-4	0.02 - 0.13	0.31 - 2.46	0.03 - 0.25
	1500	3.0 - 9.0	0.15 - 0.42	0.00003 - 0.0001
	5000	6.25 - 30.0	0.08 - 0.4	0.000005 - 0.000025
	3-4	0.02 - 0.15	0.36 - 2.9	0.03 - 0.28
	1000	1.2 - 5.5	0.08 - 0.34	0.000025 - 0.0001
	6700	4.1 - 34.0	0.04 - 0.32	0.000002 - 0.000015
	3-4	0.02 - 0.16	0.4 - 2.8	0.04 - 0.27
	4400	1.25 - 29.4	0.02 - 0.4	0.000001 - 0.00003
	3	0.02 - 0.12	0.36 - 2.55	0.04 - 0.28
	8	0.05 - 0.25	0.36 - 1.8	0.01 - 0.07
	5600	3.6 - 33.0	0.04 - 0.4	0.0000025 - 0.00002
	6500	2.7 - 43.6	0.03 - 0.4	0.0000014 - 0.00002
	2-4	0.02 - 0.11	0.57 - 3.43	0.09 - 0.54
	6000	1.8 - 45.6	0.02 - 0.5	0.000001 - 0.000027
	3	0.02 - 0.1	0.46 - 2.16	0.05 - 0.23
	4900	1.1 - 16.0	0.02 - 0.22	0.000001 - 0.000015
	6100	1.5 - 31.25	0.02 - 0.33	0.0000008 - 0.00002
<u>After Modification; Bulk Temp. - 91.3°C; Total Flow - 87,500 gpm; Level-1825 MW</u>				
5-1-61	3	0.04 - 0.08	0.8 - 1.7	0.08 - 0.18
	100	0.3 - 0.55	0.2 - 0.3	0.0006 - 0.001
	3600	0.75 - 9.5	0.013 - 0.17	0.000001 - 0.00002
	4500	1.1 - 14.6	0.02 - 0.2	0.000001 - 0.000015
	3	0.04 - 0.13	0.9 - 2.86	0.09 - 0.3
	100	0.28 - 0.58	0.2 - 0.38	0.0005 - 0.0013
	3750	1.0 - 10.0	0.02 - 0.18	0.000002 - 0.00002
	4560	1.0 - 9.4	0.015 - 0.15	0.000001 - 0.00001
	4	0.03 - 0.06	0.5 - 1.0	0.04 - 0.07
	55	0.3 - 0.6	0.35 - 0.7	0.002 - 0.004
	135	0.55 - 0.95	0.27 - 0.46	0.0006 - 0.001
	3600	1.8 - 10.5	0.03 - 0.27	0.000003 - 0.00002
	4050	2.3 - 16.2	0.04 - 0.8	0.000003 - 0.00005

Stress levels were arrived at with information gained from a strain gage rosette installed on the inside radius of the first elbow out from the far riser on No. 23-1/2 rear crossheader at DR Reactor. Due to malfunction of equipment, no directly comparable "Before Modification" data are available.

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DATE RECORDED	REACTOR CONDITIONS			STRAIN-Microinches/Inch			MAXIMUM STRESS - PSI
	FLOW-GPM	POWER-MW	TEMP.-°C	A	B	C	
5-10-61	87,600	1860	91.7	-50	-970	85	27,200

DATE

FILMED

7/21/94

END