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RESULTS OF 105-DR EFFLUENT PIPING STRESS
MEASUREMENTS FROM IP-342-AG

by

J. P. HAWLEY

and

O. E. ADAMS, JR.

April 1, 1961

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RESULTS OF 105-DR EFFLUENT PIPING STRESS
MEASUREMENTS FROM IP-342-AG

INTRODUCTION

Development Test IP-342-AG was run on August 12, 1960, and August 25, 1960, for the purpose of measuring temperatures, pressures and strains throughout the 105-DR effluent systems. On October 24, 1960, additional strain readings were recorded prior to reactor shutdown, thus yielding strain data virtually free from strain gage drift.¹ Results of the tests were analyzed to determine if sustained operation at 93° C - 95° C bulk outlet temperature is practical, without increasing the danger of effluent system failure.

This document presents the results of stress measurements made during the test and their significance relevant to operation at 93 - 95° C bulk outlet temperature.

Strain measurements were made by R. L. Loundagin of Materials Development, Equipment Development Operation, and by Radiographics Testing Operation, Hanford Laboratories Operation.²

A sketch showing the strain gage locations (Figure 1) is included in Appendix "A".

CONCLUSIONS AND RECOMMENDATIONS

On the basis of the valid measurements made during Test IP-342-AG, certain conclusions can be drawn. Yielding of the riser walls and of the riser to crossover connection was detected, verifying previous calculations.

Many of the points which theoretically should be high stress locations were not measured accurately due to gage drift.

Fatigue may contribute to failure of the riser, riser to crossover line connection, and crossover line elbow. The far crossover line valve was observed oscillating at about .08 to 0.6 inch during operation at 50 percent power level.⁴ The cross-headers also vibrate but the amplitude is lower than at other areas which have been measured. With regard to obtaining strain readings on components within the downcomer, the scratch gage has the most to offer. No leads are utilized with this device, yet a target will show cyclic behavior of the strains. However, the strain indications must be magnified at least 500X. In addition, the gage must be installed within a waterproof container in order to prevent rusting of the gage target and each gage should be calibrated with a known load.

It is recommended that the stress measurement portion of IP-342-AG be repeated, allowing more time at split flow to determine if a stress reduction exists.

A study of gage drift phenomena (particularly in gages installed in a radiation zone) should be made by those groups directly involved in strain measurement.

The suitability of other types of gages, such as the unbonded gage, should be investigated.

Cascade tray #1 should be reinforced.

To minimize the possibility of an unexpected rupture of effluent piping in the downcomer room, it is recommended that those portions of the piping be inspected visually during each outage. This will help protect against a fatigue type failure, while system strengthening would be required to ensure no failure if boiling occurs.

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DISCUSSION

Observation of rear crossheader bowing, failure of effluent piping components, vibration measurements and preliminary strain measurements have indicated the over-stressing of certain components of the effluent system at some of the old reactors. On August 12, 1960, August 25, 1960, and October 24, 1960, strain gage readings were taken at DR reactor.

Strain Gages

In general, strain gages were placed on the effluent piping at or adjacent to points where the highest stresses in the system were predicted (see Figure 1). Temperature compensated variable resistance wire strain gages were used largely throughout the system.

This type of strain gage is extremely sensitive and will detect strains as small as 1 micro-inch per inch. Rosette gages, which measure strain in three fixed directions on the plane of attachment, were used in all locations where the direction of strain was not fixed by the geometry of the surface. The rosette gage allows analysis of the recorded strains to determine the direction and magnitude of the principal stresses at the point of attachment. The principal stresses, σ_1 and σ_2 , are the algebraic maximum and algebraic minimum normal stresses respectively, and they act on planes for which the shear stresses vanish. The principal stresses are always oriented perpendicular to each other. The computed angle of inclination of the principal stress from, for example, the pipe axis, is the direction of σ_1 . Thus, it is possible to get a complete, accurate picture of the stress at a point by the use of the variable resistance wire, rosette, strain gage.³

Other factors which made this type of strain gage seem desirable were ease of installation (compared to other types of gages), ease of remote reading, and rapid response to transient strains.

The only disadvantages which were apparent at the time of installation were that the gage had to be clamped in position until the adhesive took its initial set, and clamping difficulties often limited the point of installation to less desirable areas. At least one cycle of reactor operation was necessary to cure the adhesive.

In addition, it was discovered after the test, on September 9, 1960, that many of the gages had "drifted" or changed null settings during the test, indicating the possibility that the adhesive had not set sufficiently. Many of the gage readings recorded on August 12, 1960, and August 25, 1960, are not included because they demonstrated excessive drift (in excess of 125 micro-inches/inch) over a period of approximately a month. However, during the test on October 24, 1960, the error due to gage drift should have been greatly minimized, as readings were taken immediately before and after the reactor shutdown (approximately 2 to 3 hours test). Further study and analysis of the drift problem should be undertaken by the groups associated with strain measurement. The strains recorded by Radiographic Testing Operation were read with a set of Baldwin SR-4 static strain indicators. This situation was unfortunate since many of the strains, particularly those in the crossheaders, were of a transient nature. A recording instrument would have been preferred so that the frequency of strain variation could have been compared to crossheader vibration data which were taken simultaneously by P. Hutton of Reactor, Plant Engineering Operation.⁴

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Strength of Effluent Piping Materials

The 18-8 stainless steel used in the effluent piping has a yield point of 30,000 psi at 700° F and of 26,000 to 27,000 psi at 200° F.² This means that any measured stress of over 30,000 psi indicates in-elastic deformation of the piping at that point. Repeated deformation of this type may lead to formation of microcracks and fatigue failure of the component.

Failure of any component in the reactor effluent system will be defined henceforth, as yielding of the material at any point in that component. It is logical to assume that the load which caused yielding will be repeated and that eventually the system will rupture at that point.

The carbon steel used in the downcomer support members has a yield point of at least 33,000 psi. The portions of the downcomer which are wetted, but not submerged, during operation are corroded quite badly and this effect can shorten the useful life of the structure particularly under dynamic loading conditions.

Possible Failure Mechanism and Effects

Due to thermal expansion effects, the piping in the effluent system bends during startup and operation of the reactor. It is believed that failure would probably start as one or more microcracks which would probably form a macrocrack eventually. A noticeable leak would be produced at this time and visual detection would be possible. If this leak were located in the discharge area it would not be a serious problem; while, on the other hand, if the leak occurred in the downcomer room a problem would definitely exist which would require immediate attention.

A more serious aspect of the problem is the detection of a leak. In the event of a leak in that portion of the riser located in the downcomer room or crossover line the volume of water discharged could fill the downcomer room in a short time. The most extreme case would be that of complete rupture of the crossover line in the downcomer room.

For example:

Complete rupture of crossover line: 81,000 GPM flow

Volume of D.C. Room $\div 15.75 \times 18.75 \times 11 \div 3,248.4 \text{ ft}^3$

Volume of D.C. Room $\times \frac{\text{Gallons}}{\text{ft}^3} \div 3,248.4 (7.48) \div 24,298 \text{ Gallons}$

Minimum time to fill D.C. Room to door level $\div 18 \text{ seconds}$.

Since a complete rupture of this type is not probable, it is evident that more than 18 seconds will be available for detection of the leak. However, flow must be maintained to the reactor after the leak is detected so time must be allowed for switching flow to the other downcomer. At this time the flow diverting operation takes about 20 minutes to complete. Even if the reactor were scrambled and flow reduction accomplished immediately, it is possible that a large quantity of effluent could be spilled out onto the top of the reactor before diversion of flow could be completed.

Another interesting point is that even a slow leak may not be detected until the effluent begins spilling out of the downcomer room door. The downcomer door is only 8 feet above the center of the riser. Therefore, an increase in backpressure of

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only about 3 psi would be seen on the panallit gages. This is not enough to trip any of the gages. It is more likely, however, that the effluent vapors issuing from the downcomer room would set off the building radiation alarms before a slow leak could fill the downcomer room.

The consequences of a large amount of effluent of high temperature and radioactivity spilling into the reactor building can readily be visualized and so will not be dealt with in detail here.

Discussion of Effluent System Components

As previously mentioned, many of the strain gage measurements taken on critical components during the test were invalidated by null point variation during the test.

The results of those measurements which did not show sizeable null point variation (less than 125 micro-inches/inch) are tabulated in appendix "B". A discussion of these stresses and their significance is presented in the following sections by component.

Rear Crossheaders: The crossheaders at all reactors have expansion loops at either end which were designed to absorb thermal expansion of the crossheaders. However, due to the increased reactor outlet temperatures, these expansion loops are no longer adequate.

The excessive thermal expansion which must be absorbed by the loops causes high stresses at the bends in the loop and in the crossheader to riser connections. It was observed that the center of crossheader #35 deflected one-quarter of an inch from reactor startup to full power operation.⁸

For reasons to be discussed in another section, the riser is more likely to fail than are the crossheaders.

Since the central zone tubes operate at higher temperatures than do the tubes at the top and bottom of the reactor, the central zone crossheaders have more thermal expansion. The result of this situation is that the riser is forced into a bowed shape. The crossheaders are also forced to bend and bow causing additional stresses in this portion of the system.

On the basis of measurements made during Test IP-342-AG, it can be stated that the crossheaders probably will not fail due to overstressing under the conditions tested. It should be noted that in some cases the highest stresses measured at the riser connections occurred during startup transient conditions at about 70 percent power and less than 70° C bulk outlet temperature. This is presumably because the crossheaders did not have adequate time to bow into their final position, relieving some of the stress in the crossheaders by distorting the riser.

Crossheader vibration frequency and amplitude were measured during the test by P. H. Hutton of Reactor, Plant Engineering Operation.

Rear Risers: The rear risers are manifolds which collect flow from all the crossheaders and deliver it to the crossover line. Strain measurements show that yielding of the far riser is occurring at the central zone crossheader connection. This is in agreement with previous calculations.⁶ Gage AS-4 (see Table I) indicates that the maximum principal stress attains a value of 38,500 psi at 75 percent power level.

Strain gages placed at the top of the far riser where it enters the downcomer room, AS 15 and AS 16, have indicated maximum principal stresses of 1500 to 8700 psi. These stresses indicate no problem as far as failure is concerned.

Far Riser to Crossover Connection

AS-10 gage (see Table III) located at the side of the crossover line to riser connection indicates that yielding is occurring at this location. The other strain readings, although fairly high, are less than one-half the maximum reading recorded for AS-10.

Crossover Line

The crossover line may be divided into three portions for purposes of discussion: (1) the center (concrete encased) section, (2) the near crossover line valve and elbow assembly and (3) the far crossover line valve and elbow assembly.

The three sections are isolated from each other, stresswise, by expansion bellows at both ends of the center section. The valve and elbow assemblies are isolated from the downcomers by flexible gas seals.

Although no rosette gages functioned completely on the crossover line, the individual gages BS-2A, BS-2B, BS-1A, and BS-1B (see Table II) gave rather high readings of 5800 to 8100 psi leading one to believe that if the third leg of each rosette has been functional, maximum principal stresses of about 15,000 to 20,000 psi might have been calculated.

The downcomer shutoff valve was observed to vibrate from 0.08 - 0.6 inches at about 0.8 cycle per second during the test.⁴ It would be desirable to measure the frequency and amplitude of stress in the crossover line adjacent to the valve. With this information, it will be possible to make fatigue failure calculations for that point.

It seems logical that the stresses in the crossover line and far downcomer would be reduced considerably if split flow were established as standard practice at all reactors with dual downcomers. This effect could not, however, be consistently noticed during the running of the split flow portion of the test. Possibly the test period was too short to observe steady state conditions. On the other hand, the only changes made during split flow were a reduction in flow and a very slight reduction in the pressure. Since it is apparent from the data that most stresses result from thermal expansion, it is possible that a reduction in flow and pressure resulting from split flow may produce no corresponding significant stress reduction in the crossover line. However, if slug flow occurs during high temperature operation (power excursion resulting in say, 5° C effluent temperature increase) split flow may offer several advantages including stress reduction in the elbows.

Far Downcomer

The strain gage installed on expansion joint CS-3, (see Table II) was the only strain gage in this general area that gave reliable results. The peak stress determined is 16,940 psi indicating that failure (static) should not occur.

The points in the downcomer which give cause for concern are the support beams for cascade trays one, seven and eight (numbered from the top) Tray one is the most likely to fail due to the impact of effluent spilling into the downcomer. Trays

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seven and eight are below the water level in the downcomer and are buffeted by extreme turbulence.

The tray support beams were weakened somewhat by modifications made after project CG-558 to allow additional flows. Calculations based on pressure data only indicate an allowable bulk outlet temperature of over 99° C at present flows. However, thermal effects cannot be neglected.

The results of a failed tray support beam, are not difficult to visualize. The tray could be torn completely loose to eventually plug the effluent line or could hang from one or more supports. If it were merely bent out of the way, it is probable that the additional 12 feet of acceleration of the entering effluent stream would tear out all trays directly below the first tray to fail. Eventually, plugging of the downcomer would result.

Installation of an additional reinforcement beam under the center of the tray would be inexpensive insurance against such a messy incident as previously described.

Calculations show that the walls, bottom and containment well of the downcomer are structurally strong enough to withstand pressures more severe than those encountered during normal operation.

The reason no valid stress measurements were obtained in the downcomer was that temperature sensitive leads were attached to the gages on this component. It is impossible to establish the temperature distribution along the lead wire so that compensation can be made. Many difficulties were encountered in attaching the gages to the corroded downcomer trays and walls. Only a few of the rosette legs attached gave readings which may be valid if lead wire error could be corrected.

If readings are to be taken on these gages in the future, it will be possible to install identical lead wire in parallel to that attached to the gages. In this way, the lead wires can be made self-compensating. However, the simple scratch gage seems to offer the most satisfactory solution provided it is contained in a waterproof box. This instrument will indicate the maximum strains on the structure to which it is attached.

J. P. Hawley /ceah

J. P. Hawley
Reactor Engineering Unit
Research and Engineering Section
Irradiation Processing Department

O.E. Adams, Jr.

O. E. Adams, Jr.
Reactor Engineering Unit
Research and Engineering Section
Irradiation Processing Department

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TABLE I - ROSETTE GAGE READINGS**DECLASSIFIED**Rosette No. AS-1Test IP-342-1A Date 8-12 & 8-25-1960Gage Location: AS-1 On Rear Side of 1½ Crossheader at Far Riser Connection

Phase No.	Flow (+ 1000 GPM)	Power (MW)	B.O.T.* (°C)	Principal Stresses (psi)		θ^{**}
				σ_1	σ_2	
1	28.0	0	23.5	-1,215	-3,265	50°↓
2	40.7	0	23.5	-1,470	-3,990	30°↑
3	58.3	0	22.5	-1,050	-2,730	40°↓
4	79.2	0	22.2	-1,070	-3,270	50°↑
5	77.8	97.5	26.0	7,150	-1,550	54°↓
6	81.0	819.0	60.0	620	-3,980	150°↑
				1,640	-1,360	220°↓
7	81.9	1177.0	74.5	1,790	-2,210	140°↓
8	81.2	1660.0	93.5	1,780	-4,160	70°↓
9	81.3	1660.0	94.9	410	-3,490	780°↓

Rosette No. AS-2Test IP-342-1A Date 8-12 & 8-25-1960Gage Location: AS-2 On Side of Far Riser behind 1½ Crossheader Connection

Phase No.	Flow (+ 1000 GPM)	Power (MW)	B.O.T.* (°C)	Principal Stresses (psi)		θ^{**}
				σ_1	σ_2	
1	28.0	0	23.5	- 200	-1,480	540°↓
2	40.7	0	23.5	- 200	-1,480	540°↓
3	58.3	0	22.5	- 155	- 525	200°↓
4	79.2	0	22.0	- 70	- 210	300°↓
5	77.8	97.5	26.0	- 510	- 750	140°↓
6	81.0	819.0	60.0	232	- 512	500°↓
7	81.9	1177.0	74.5	965	- 545	530°↓
8	81.2	1660.0	93.5	-2,310	-5,110	580°↓
9	81.3	1660.0	94.9	-2,480	-5,080	560°↓

* B.O.T. indicates Bulk Outlet Temperature.

** θ is angle between σ_1 and Pipe Axis, except when noted.

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TABLE I (Continued)

Rosette No. AS-4Test IP-342-1AGage Location: AS-4 Side of Far Riser in front of 23½ Crossheader Connection

Phase No.	Flow (+ 1000 GPM)	Power (MW)	B.O.T. (°C)	Principal Stresses (psi)		θ
				σ_1	σ_2	
1	28.0	0	23.5	- 210	-1,190	200°
2	40.7	0	23.5	630	490	600°
3	58.3	0	22.5	2,000	1,360	850°
4	79.2	0	22.0	7,840	3,780	900°
5	77.8	97.5	26.0	8,150	3,750	870°
6	81.0	819.0	60.0	28,440	18,040	890°
7	81.9	1177.0	74.5	38,500	27,500	900°
8	81.2	1660.0	93.5	30,780	20,180	820°
9	81.3	1660.0	94.9	31,680	20,680	810°

Rosette No. AS-5Test IP-342-1A Date 8-12 & 8-25-1960Gage Location: AS-5 Rear Side of 23½ Crossheader at Connection to Far Riser

Phase No.	Flow (+ 1000 GPM)	Power (MW)	B.O.T. (°C)	Principal Stresses (psi)		θ
				σ_1	σ_2	
1	28.0	0	23.5	-2,100	-2,100	0
2	40.7	0	23.5	-5,150	-7,870	40°
3	58.3	0	22.5	-6,790	-9,030	220°
4	79.2	0	22.2	-6,530	-8,730	190°
5	77.8	97.5	26.0	-6,700	-8,700	210°
6	81.0	819.0	60.0	-4,940	-8,640	100°
7	81.9	1177.0	74.5	-6,700	-8,700	210°
8	81.2	1660.0	93.5	-11,000	-11,900	630°
9	81.3	1660.0	94.9	-14,830	-16,030	530°

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TABLE II - SINGLE STRAIN GAGESRosette No. AS-3Test: IP-342-1A Date: 8-12 & 8-25-1960Gage Location: On Front Side of 23½ Crossheader at Far Riser ConnectionGage Leg A

<u>Phase No.</u>	<u>Flow (+ 1000 GPM)</u>	<u>Power (MW)</u>	<u>B.O.T.* (°C)</u>	<u>ε (Strain)</u>	<u>σ (Apparent Tensile Stress, psi)</u>
1	28.0	0	23.5	+ 5	140
2	40.7	0	23.5	+17	476
3	58.3	0	22.5	19	532
4	79.2	0	22.0	27	756
5	77.8	97.5	26.0	7	196
6	81.0	819.0	60.0	-308	-8,624
7	81.9	1177.0	74.5	-568	-15,904
8	81.2	1660.0	93.5	-363	-10,164
9	81.3	1660.0	94.9	-390	-10,920

Rosette No. AS-6Test: IP-342-1A Date: 8-12 & 8-25-1960Gage Location: Side of Far Riser behind 23½ Crossheader ConnectionGage Leg AOrientation: Parallel to Pipe Axis

<u>Phase No.</u>	<u>Flow (+ 1000 GPM)</u>	<u>Power (MW)</u>	<u>B.O.T.* (°C)</u>	<u>ε (Strain)</u>	<u>σ (Apparent Tensile Stress, psi)</u>
1	28.0	0	23.5	5	140
2	40.7	0	23.5	25	700
3	58.3	0	22.5	35	980
4	79.2	0	22.0	65	1,820
5	77.8	97.5	26.0	57	1,596
6	81.0	819.0	60.0	75	2,100
7	81.9	1177.0	74.5	135	3,780
8	(Far) 81.2	1660.0	93.5	445	12,460
8A**	(Split) 81.2	1660.0	93.5	395	11,060
9	(Far) 81.3	1660.0	94.9	450	12,600
9A**	(Split) 81.3	1660.0	93.5	385	10,780

* B.O.T indicates Bulk Outlet Temperature.

** Effluent flow was split to both downcomers. The amount of flow to each downcomer could not be determined.

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TABLE II (Continued)

AS-6, Gage Leg B Gage Location: Side of Far Riser Behind 23 $\frac{1}{2}$ Crossheader Connection
 Orientation: 60° from Pipe Axis

Phase No.	Flow ($\pm$ 1000 GPM)	Power (MW)	B.O.T.* (°C)	ϵ (Strain)	σ (Apparent Tensile Stress, psi)
1	28.0	0	23.5	-10	-280
2	40.7	0	23.5	55	1,540
3	58.3	0	22.5	135	3,780
4	79.2	0	22.0	235	6,580
5	77.8	97.5	26.0	215	6,020
6	81.0	819.0	60.0	225	6,300
7	81.9	1177.0	74.5	265	7,420
8	81.2	1660.0	93.5	595	16,660
8A**	81.2 (Split)	1660.0	93.5	545	15,260
9	81.3	1660.0	94.9	580	16,240
9A**	81.3 (Split)	1660.0	93.5	535	14,980

Rosette No. AS-7Test: IP-342-1ADate: 8-12 & 8-25-1960Gage Location: On Rear Side of 45 $\frac{1}{2}$ Crossheader at Far Riser ConnectionGage Leg A Orientation: Parallel to Pipe Axis

Phase No.	Flow ($\pm$ 1000 GPM)	Power (MW)	B.O.T.* (°C)	Strain ϵ (μ in/in)	Apparent Tensile Stress σ (psi)
1	28.0	0	23.5	0	0
2	40.7	0	23.5	0	0
3	58.3	0	22.5	0	0
4	79.2	0	22.0	0	0
5	77.8	97.5	26.0	- 5	-140
6	81.0	819.0	60.0	15	420
7	81.9	1177.0	74.5	40	1,120
8	81.2	1660.0	93.5	385	10,780
9	81.3	1660.0	94.9	340	9,520

* B.O.T. indicates Bulk Outlet Temperature

** Effluent flow was split to both downcomers. The amount of flow to each downcomer could not be determined.

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TABLE II (Continued)

AS-7, Gage Leg B Location: On Rear Side of 45¹/₂ Crossheader at Far Riser Connection
 Orientation: Parallel to Pipe Axis

<u>Phase No.</u>	<u>Flow (+ 1000 GPM)</u>	<u>Power (MW)</u>	<u>B.O.T.* (°C)</u>	<u>Strain ε (Min/in)</u>	<u>Apparent Tensile Stress, σ (psi)</u>
1	28.0	0	23.5	-2	-56
2	40.7	0	23.5	3	84
3	58.3	0	22.5	3	84
4	79.2	0	22.0	3	84
5	77.8	97.5	26.0	-2	-56
6	81.0	819.0	60.0	3	84
7	81.9	1177.0	74.5	23	644
8 (Far)	81.2	1660.0	93.5	378	10,584
9 (Far)	81.3	1660.0	94.9	347	9,716

Rosette No. AS-8

Test: IP-342-1A

Date: 8-12 & 8-25-1960

Gage Location: Side of Far Riser behind 45¹/₂ Crossheader Connection

Gage Leg A Orientation: Parallel to Pipe Axis

<u>Phase No.</u>	<u>Flow (+ 1000 GPM)</u>	<u>Power (MW)</u>	<u>B.O.T.* (°C)</u>	<u>Strain ε (Min/in)</u>	<u>Apparent Tensile Stress, σ (psi)</u>
1	All Same as AS-10A			3	84
2				23	644
3				28	784
4				28	784
5				8	224
6				-102	-2,856
7				-112	-3,136
8 (Far)				-42	-1,176
8A** (Split)				93.5	-896
9 (Far)				93.5	-1,456
9A** (Split)				94.9	-1,176
				93.5	-1,176

* B.O.T. indicates Bulk Outlet Temperature

** Effluent flow was split to both downcomers. The amount of flow to each downcomer could not be determined.

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AS-8, Gage Leg C Location: Side of Far Riser to Crossover Connection

Phase No.	Orientation: 60° from Pipe Axis		B.O.T.* (°C)	Strain ε (μin/in)	Apparent Tensile Stress, σ (psi)
	Flow (+ 1000 GPM)	Power (MW)			
1	All same as AS-8, Gage Leg A			-10	-280
2				-5	-140
3				10	280
4				15	420
5				40	1,120
6				180	5,040
7				260	7,280
8 (Far)			93.5	310	8,680
8A** (Split)			93.5	260	7,280
9 (Far)			94.9	305	8,540
9A** (Split)			93.5	265	7,420

Rosette No. AS-10

Test: IP-342-1A Date: 8-12 & 8-25-1960

Gage Location: Side of Crossover Line to Riser Connection at Crossover Line.

Gage Leg A Orientation: Parallel to Pipe Axis

<u>Phase No.</u>	<u>Flow (+ 1000 GPM)</u>	<u>Power (MW)</u>	<u>B.O.T.* (°C)</u>	<u>Strain ε (in/in)</u>	<u>Apparent Tensile Stress, σ (psi)</u>
1	28.0	0	23.5	3	84
2	40.7	0	23.5	3	84
3	58.3	0	22.5	-7	-196
4	79.2	0	22.0	-17	-476
5	77.8	97.5	26.0	-9	-252
6	81.0	819	60.0	148	4,144
7	81.9	1177	74.5	198	5,544
8	81.2	1660	93.5	198	5,544
8A** (Split)	81.2	1660	93.5	108	3,024
9	81.3	1660	94.9	128	3,584
9A** (Split)	81.3	1660	93.5	88	2,464

* B.O.T. indicates Bulk Outlet Temperature

** Effluent flow was split to both downcomers. The amount of flow to each downcomer could not be determined.

LOCATION: APPROACH ELBOW (ON INNER BEND)

Rosette No. BS-2

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Gage Leg A Orientation: 60° from Pipe Axis

Phase No.	Flow (+ 1000 GPM)	Power (MW)	B.O.T. (°C)	Strain ε (in/in)	Apparent Tensile Stress, σ (psi)
1	28.0	0	23.5	5	140
2	40.7	0	23.5	35	980
3	58.3	0	22.5	40	1,120
4	79.2	0	22.2	-40	-1,120
5	77.8	97.5	26.0	-20	-560
6	81.0	819	60.0	-25	-700
7	81.9	1177	74.5	-25	-700
8 (Far)	81.2	1660	93.5	135	3,780
9 (Far)	81.3	1660	94.9	235	6,580

BS-2, Gage Leg B Orientation: Parallel to Pipe Axis

Phase No.	Flow (+ 1000 GPM)	Power (MW)	B.O.T. (°C)	Strain ε (in/in)	Apparent Tensile Stress, σ (psi)
1	28.0	0	23.5	20	560
2	40.7	0	23.5	10	280
3	58.3	0	22.5	10	280
4	79.2	0	22.2	10	280
5	77.8	97.5	26.0	-2	-56
6	81.0	819	60.0	38	1,064
7	81.9	1177	74.5	40	1,120
8 (Far)	81.2	1660	93.5	208	5,824
9 (Far)	81.3	1660	94.9	205	5,740

Rosette No. CS-3

Test: IP-342-1A

Date: 8-12 & 8-25-1960

Gage Location: On Downcomer Elbow Vapor Seal. On Circumference of Seal.

Phase No.	Flow (+ 1000 GPM)	Power (MW)	B.O.T. (°C)	Strain ε (in/in)	Apparent Tensile Stress, σ (psi)
1	28.0	0	23.5	5	140
				-5	-140
2	40.7	0	23.5	-5	-140
				5	140
3	58.3	0	22.5	5	140
				30	840
4	79.2	0	22.0	10	280
				-15	-420
5	77.8	97.5	26.0	0	0
				5	140

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CS-3 Continued

<u>Phase No.</u>	<u>Flow (+ 1000 GPM)</u>	<u>Power (MW)</u>	<u>B.O.T. (°C)</u>	<u>Strain ε (μin/in)</u>	<u>Apparent Tensile Stress, σ (psi)</u>
6	81.0	819	60.0	235	6,580
				315	8,820
7	81.9	1177	74.5	455	12,740
				510	14,280
8	81.2	1660	93.5	585	16,380
9	81.3	1660	94.9	605	16,940

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TABLE III

STRAIN READINGS AT ELEVATED BULK OUTLET TEMPERATURE CONDITIONS

Test Run on 10/24/60

Readings Taken Before and After Reactor Shutdown

	Reactor Operating Conditions		
	Flow (+ 1000 GPM)	Power (MW)	B.O.T. °C
Before Shutdown	84.4	1695	94.2
After Shutdown (Taken as Null Point)	28.8	0	25.7

Gage	Principal Stresses		θ*
	σ_1 (psi)	σ_2 (psi)	
AS-5 Rear Side of 23½ Cross-header connection to Far Riser	5,246	-10,454	67° ↗
AS-6 Side of Far Riser behind 23½ crossheader connection	10,780	140	86.5° ↗
AS-8 Side of Far Riser behind 45½ crossheader connection	14,190	790	87° ↓
AS-10 Side of crossover line to Riser connection (on crossover line)	36,700	17,000	77° ↗
AS-11 Top of Riser - Crossover Line at Riser Connection	13,900	-3,600	67° ↓
AS-12 Top of Riser - Crossover Line at Crossover Line Connection	-13,800	-24,200	63° ↓
AS-15 Rear of Far Riser at floor of Downcomer Room	1,550	-18,800	41.2° ↓
AS-16 Side of Far Riser at floor of Downcomer Room	8,740	-340	62° ↓

Gages AS-2, AS-4, BS-1, BS-2 and CS-3 gave readings that appear too high. These gages suggest stresses well above a yield strength of 33,000 psi and the readings must be incorrect.

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BS1-A

UNDERSIDE OF EFFLUENT LINE, UPSTREAM OF APPROACH ELBOW

Leg A Parallel to Flow

<u>Phase No.</u>	<u>Flow (+ 1000 GPM)</u>	<u>Power (MW)</u>	<u>B.O.T. °C</u>	<u>* ε Strain (in/in)</u>	<u>σ Apparent Stress, psi</u>
1	28.0	0	23.5	+5	+140
2	40.7	0	23.5	-20	-560
3	58.3	0	22.5	+10	+280
4	79.2	0	22.0	-30	-840
5	77.8	97.5	26.0	-10	-280
6	81.0	819	60.0	+130	+3,640
7	81.9	1177	74.5	+180	+5,030
8	81.2	1660	93.5	+260	+7,280
8A (Split)	81.2	1660	93.5	-	-
9	81.3	1660	94.9	+290	+8,100
9A (Split)	81.3	1660	93.5	+290	+8,100

BS1-B

<u>Phase No.</u>	<u>Flow (+ 1000 GPM)</u>	<u>Power (MW)</u>	<u>B.O.T. °C</u>	<u>* ε Strain (in/in)</u>	<u>σ Apparent Stress, psi</u>
1	28.0	0	23.5	-19	-531
2	40.7	0	23.5	-19	-531
3	58.3	0	22.5	+5	+140
4	79.2	0	22.0	-15	-420
5	77.8	97.5	26.0	+5	+140
6	81.0	819	60.0	+140	+3,820
7	81.9	1177	74.5	+245	+6,870
8	81.2	1660	93.5	+330	+9,220
8A (Split)	81.2	1660	93.5	-	-
9	81.3	1660	94.9	+310	+8,680
9A (Split)	81.3	1660	93.5	+305	+8,520

DATE

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6/15/94

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