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TITLE
REAR FACE HARDWARE REPLACEMENT
105-B, D, DR, F, AND H

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REAR FACE HARDWARE REPLACEMENT 105-B, D, DR, F, AND H

INTRODUCTION

Prior to the use of venturis on the front of the B, D, DR, F, and H Reactors, much of the pressure and velocity heads developed by the 190 process water pumps were used in overcoming built-in frictional losses in the system external to the process tubes. As Reactor Technology was gained, changes were continually taking place. Venturis replaced orifices installed during original construction. Hydraulically efficient front nozzles, front pigtails, front adaptors, and a second generation of front venturis were designed and installed as a part of Project CG-558. Process changes, such as eliminating upstream dummy charges, were also made to reduce the energy dissipation due to frictional losses. The pressure drop across the active section of a fuel charge was reduced by the internal flow passage in the I&E elements.

Little has been done to date, however, to reduce the pressure drops in the rear face fittings. This report is intended to review some of these still existent pressure restrictions and to discuss possible future courses of action.

SUMMARY AND CONCLUSIONS

The pressure drop in the rear face hardware on 100-B, D, DR, F, and H Reactor central tubes currently is 130 to 150 psi. Because of the high velocity and critical flow conditions in that hardware, the nozzles, nozzle-to-connector adaptors, and crossheader Parker fittings are being damaged by erosion and cavitation. Several nozzle adaptor failures have occurred, and the frequency of failures is expected to increase in the future. Replacement of the nozzles and adaptors is expected to be necessary within three years in order to prevent an excessive amount of outage time.

The existing nozzles and adaptors should be replaced with new nozzles and adaptors with the largest possible flow passages. This can be done with no extra cost. The benefits will be less pressure drop, erosion, and cavitation. In addition to less outage time for maintenance, either a two percent reactor flow increase or operation with one less process pump would be possible.

Laboratory flow tests also show that the coolant pressure drop can be reduced significantly by replacing the existing 5/8 inch connectors with 3/4 inch connectors, and by reaming the crossheader Parker fittings to 0.543 inch diameter. The benefits would be less outage time for maintenance plus either operation with one less process pump or up to a four percent reactor flow increase.

Nine crossheader Parker fittings reamed to 0.610 inch diameter have operated without failure for over three years on the 100-F Reactor. Since neither use of 3/4 inch connectors nor reaming the crossheader Parker fittings has been tested on large numbers of reactor tubes, such tests should be made before all tubes are converted.

Use of nozzles and adaptors with larger flow passages does not need testing because the 100-C and K Reactors have operated since startup with rear hardware with large flow

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passages. No adverse effects have been observed. Tube flow protection for modified cases has been investigated by Research and Engineering and no problems have been found.

RECOMMENDATIONS

1. The rear nozzles on the 100-B, D, DR, F, and H Reactors be replaced with either new nozzles with larger flow passages or the currently unused 100-K Reactor front face nozzles removed during the zirconium tube installation.

2. Reactor tests be made of 3/4 inch rear connectors and reaming the crossheader Parker fittings to 0.543 inch diameter on approximately 200 central tubes.

DISCUSSION

General

During original construction of the five smaller reactors, fittings with small flow openings were installed in the front and rear process water piping to each individual reactor process tube. This was originally felt to be required for reactor safety as a part of the protection against boiling. As additional technology was gained, this requirement was determined to be unnecessary and equipment changes were made to make the process cooling water flow streams hydraulically more efficient.

The following action was taken in a step-wise fashion:

1. Solid aluminum and other dummy pieces were replaced with tubular pieces in the downstream dummy charges. The entire upstream dummy charge was eliminated.

2. Front face orifices were changed to venturis except in the reactor fringe tubes.

3. Project CG-558 increased front face process water pressures and decreased pressure drop in the front face nozzles, pigtails, venturis, ends of the crossheaders, and the front face risers.

4. A decreased pressure drop across the fuel column resulted from the change from solid to internal and externally cooled fuel elements.

5. Venturi sizes were increased to accommodate still more flow.

6. The number of central flow tubes was increased.

Each of these changes increased flow which therefore increased the pressure drop across the last remaining portion of the system that has not been hydraulically modified. This portion of the system, the rear face hardware and piping, therefore has a large pressure drop and is dissipating a large amount of energy (over five horsepower per tube).

The effects of this energy dissipation are seen today as erosion, cavitation, and large pressure drops across the rear face fittings (see references 1 and 2 and pictures in Appendix). This, coupled with the high temperature corrosion effects on the rear aluminum nozzles and damage done during rework of the nozzles, has already caused several reactor outages.

Future Action

Future action can be taken along several lines:

1. The present condition can be allowed to worsen and gradually cause increased costs and lost production through equipment breakdowns.

2. The present nozzles and fittings can be replaced with fittings of the same design realizing that it will again start to deteriorate fairly rapidly.

3. The present assemblies can be modified to decrease the energy dissipation and therefore the metal removal taking place.

4. The front face K nozzles that are presently being removed as a part of the zirconium tube program can be modified and utilized on the rear faces of some of the older reactors to also decrease energy dissipation.

5. New assemblies can be purchased which have a hydraulically efficient design.

To do item 2 above would be unwise since, if work is to be done, then a more hydraulically efficient assembly should be installed. This can be done at no extra cost if new nozzles and fittings are purchased.

To do item 3 above is estimated to cost more than item 4 without as many benefits to be gained as item 4.

To do item 4 or 5 would solve the maintenance problem and still provide the largest flow or pressure drop benefits at lower costs. It is therefore reasoned that we should do either item 4 or 5 above. Item 1 is a breakdown maintenance approach while item 4 and 5 are productive maintenance approaches.

History has shown that it is better to move into a maintenance job and do it early enough to avoid double reactor outage costs that are normally associated with breakdown maintenance.

Since, however, if item 4 is chosen, there will only be enough K Area nozzles available to do two reactors, it is important to do this work at the most desirable reactor locations. It is also important that the reactor which is improved should not then have production curtailed without reaping the benefits to be gained.

If item 5 is chosen, or a combination of items 4 and 5, the modifications could be made to all five smaller reactors.

Detailed Changes and Flow Advantages

The advantages of the changes that should be made were first calculated. Then supporting tests were run in the 189-D flow mockup since the rear face Parker fitting is known to operate in two-phase flow region which is difficult to calculate. The summary test results are shown on page 5. Supporting data will be published by the Thermal Hydraulics Operation, HLO, at a later date.

Type Nozzle	Header Fitting Size	Nozzle Fitting Size	I.D. of Pigtail	ΔP from EOAS to Crossheader at 45 gpm H	B,D,F,DR	Approx. % Flow Increase*	Remarks
Current	.469	.469	.543	149	119	Base	Current Standard Fittings
Current	.543	.543	.543	112	92	2	Constant Flow Path Size
K Front	.469	.543	.543	112	85	2	Size Changes are Venturi Shaped
K Front	.469	.690	.690	91	59	3 - 4	
K Front	.543	.543	.543	82	66	4	Constant Flow Path Size
K Front	.543	.690	.690	64	43	6	Size Changes are Venturi Shaped

* If water is available from Water Plants

The fittings for converting a K front nozzle for use at B, D, DR, F, and H for 2, 4, and 5 above are shown on SK-1-14258. Also, the rear spiral inconel pigtail must be cut in length or rebent, the K nozzle barrel reamed to 1.690 inch, and the lug ring repositioned. In B, D, DR, or F, the nozzle must be drilled and tapped for the thermocouple fitting. With these modification costs for the K nozzle, the cost of new nozzles for the rear of B, D, and F must also be investigated and carefully evaluated.

Crossheader Fitting Reaming

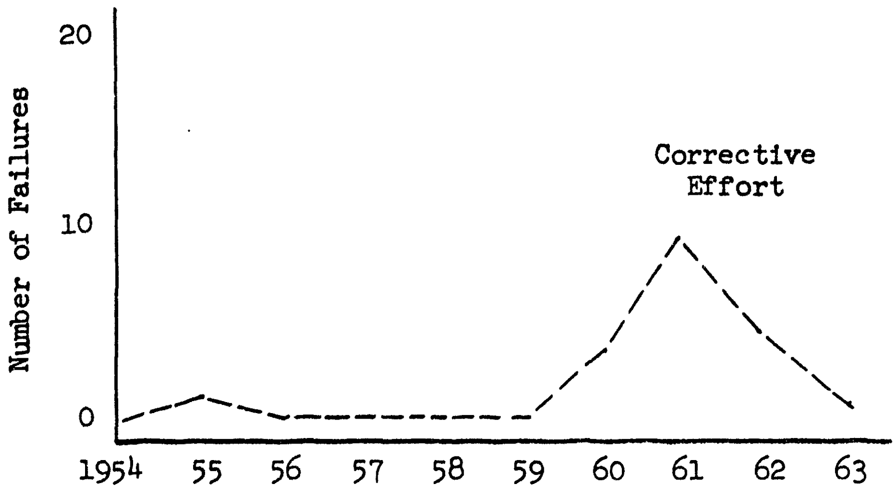
In the past, there has been much published on crossheader fitting reaming.(3) The reaming of the present .469 inch I.D. fittings on the rear crossheaders to .543 inch I.D. may bring opposition from the standpoint of reduction of strength. This is acknowledged, but this reduction in strength is approximately eight percent in bending and twelve percent in shear. It should be recognized, however, that this reaming minimizes pressure drop, eliminates two-phase flow, and therefore should minimize cavitation, stress, and resultant metal disappearance that is known to be occurring on some of the fittings and crossheaders today.(2) This may require additional study and testing, but the small reduction in strength for the known immediate flow gain and stress improvement and the probable long-range maintenance improvement appear to be worth the risk involved, especially if approached on a logical systematic schedule. Reaming studies previously had considered reaming up to .650 inches which would have appreciably reduced the fitting strength. It can be seen from the above figures that it is unnecessary to ream to this value to make major gains and therefore the additional risk is felt to be unjustified, especially since larger diameter connectors are presently unavailable.

During 1960, nine rear crossheader Parker fittings on the 100-F Reactor were reamed to 0.610 inch diameter. To date, these fittings have operated for over three years with no failures. Although this is a small sample, the good performance to date is an indication that reaming will not cause large numbers of failures. If the fittings were reamed to 0.543 instead of 0.610, the probability of failure should be much less. A test of reaming large numbers of crossheader Parker fittings to 0.543 inch diameter now appears appropriate for developing tools and techniques and for assuring that a significant increase in failure rate does not occur. The test should be made on approximately 200 central tubes. This number was selected because it is the number of central tubes on five tube rows and because it is large enough that a significant failure rate (one percent) would be observed within a reasonable period of time (less than one year). If less than this number were tested, the time required to observe a significant failure rate probably would be prohibitively long. It should be stated, however, that engineering opinion (which has not been substantiated by test) is that a significant increase in fitting failures is not expected even if full reactor reaming is effected for other management or scheduling reasons.

Rear Crossheader Fitting Failures

Starting in 1960, crossheader fitting failures started to occur both by stress corrosion and by fatigue. Actually, there was one earlier known failure in 1955. These fitting failures occurred on B, D, F, and H Reactors. None are known to have occurred on DR Reactor. A concerted effort was made early in 1961 to reduce stress levels and stop the water leaks by replacing "J" type pigtails and failed spiral stainless steel pigtails with spiral Inconel components. Although the reduction in number of fitting failures cannot be proved to be directly attributed to this effort, this reduction certainly appears to be more than just a coincidence (see plot below). Therefore, if the cause for the earlier fitting failures has been removed, crossheader fitting reaming still appears to be acceptable. The strength of these fittings is reduced by about eight percent when reaming to 0.543 inch diameter. If this small reduction in strength causes failure because of past deterioration, it would be beneficial if it could be found on a planned program rather than to wait for breakdown failures.

Crossheader Fitting Failures[4]



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Economics of Hardware Replacement

The estimated costs of replacing the rear hardware and reaming the crossheader Parker fittings are as follows for one reactor:

Table 2
Rear Hardware Modification Costs

Item	Cost: Apiece	Cost: Per Reactor
New nozzles	$20	$40,000
Nozzle adaptors	2	4,000
Tooling		5,000
Connectors	15	30,000
Labor		28,000
Outage time		6 Days

These costs were deliberately estimated on the high side to assure that the economic analysis is conservative. If the 100-K front face nozzles are used, the cost per nozzle should be less than $20. Similarly, it is questionable that the labor cost is an additional cost since existing plant forces would be used.

Although the replacement of the nozzles and adaptors is justified solely on a basis of reduced future maintenance outage time and cost, the economics also can be calculated on the basis of justifying the expenditures for materials and tools by the increased production or by reduced pumping costs. The labor cost is expected to occur regardless of whether or not the hardware is modified. These economics are as follows:

Table 3
Economics of Rear Hardware Modification Per Reactor

Hardware Modification	Maintenance Material and Tool Cost (5)	Percent Production Increase	MWD Production Increase in First Three Years (1,2,4)	Out-of-Pocket Material Cost Per MWD Production Gain (3) or Cost Savings
1. New nozzles	$44,000	2.2	29,000	$1.92
2. New nozzles + reaming crossheader Parker fittings	49,000	4.2	66,000	1.14
3. New nozzles, 3/4" connectors, and reaming crossheader Parker fittings	79,000	5.5	90,000	1.28
4. Items 1 and 2[(6)]	49,000	0.0	0.0	Cost savings of at least $34,000 per year for operating with one less pump

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Basis: (1) Six days production loss during installation.

(2) 100-H Reactor hydraulics.

(3) Includes $0.40 per MWD for Power chemical costs.

(4) Constant reactor TOE.

(5) Does not include labor costs.

(6) A production loss of 11,600 MWD for installation is assumed to be reclaimed by improved maintenance outage time.

These economics show that the additional production obtained during the first three years after the rear hardware modification will repay the production loss during modification and then will increase total production by 29,000 to 90,000 MWD during that period at a material cost of one to two dollars per MWD. This low incremental cost compares very favorably to the current average IPD conversion cost of approximately $8.00 per MWD. It also shows it to be justified on cost savings of $34,000 per reactor per year cost of electricity for operating one less pump.

Selection of Alternate

The selection of the plan to follow is still a little difficult to determine totally at this time, but the following statements can be supported.

The replacement of nozzles in the B, D, F, DR, and H Reactors is justified on a programmed maintenance basis. The reaming of crossheader fittings to .543 is justified on both economics and long-range maintenance. The replacement of the existing 5/8 inch O.D. Inconel pigtails (.543 I.D.) with 3/4 inch O.D. pigtails (.690 I.D.) is justified if additional production is desired.

ACKNOWLEDGEMENT

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APPENDIX

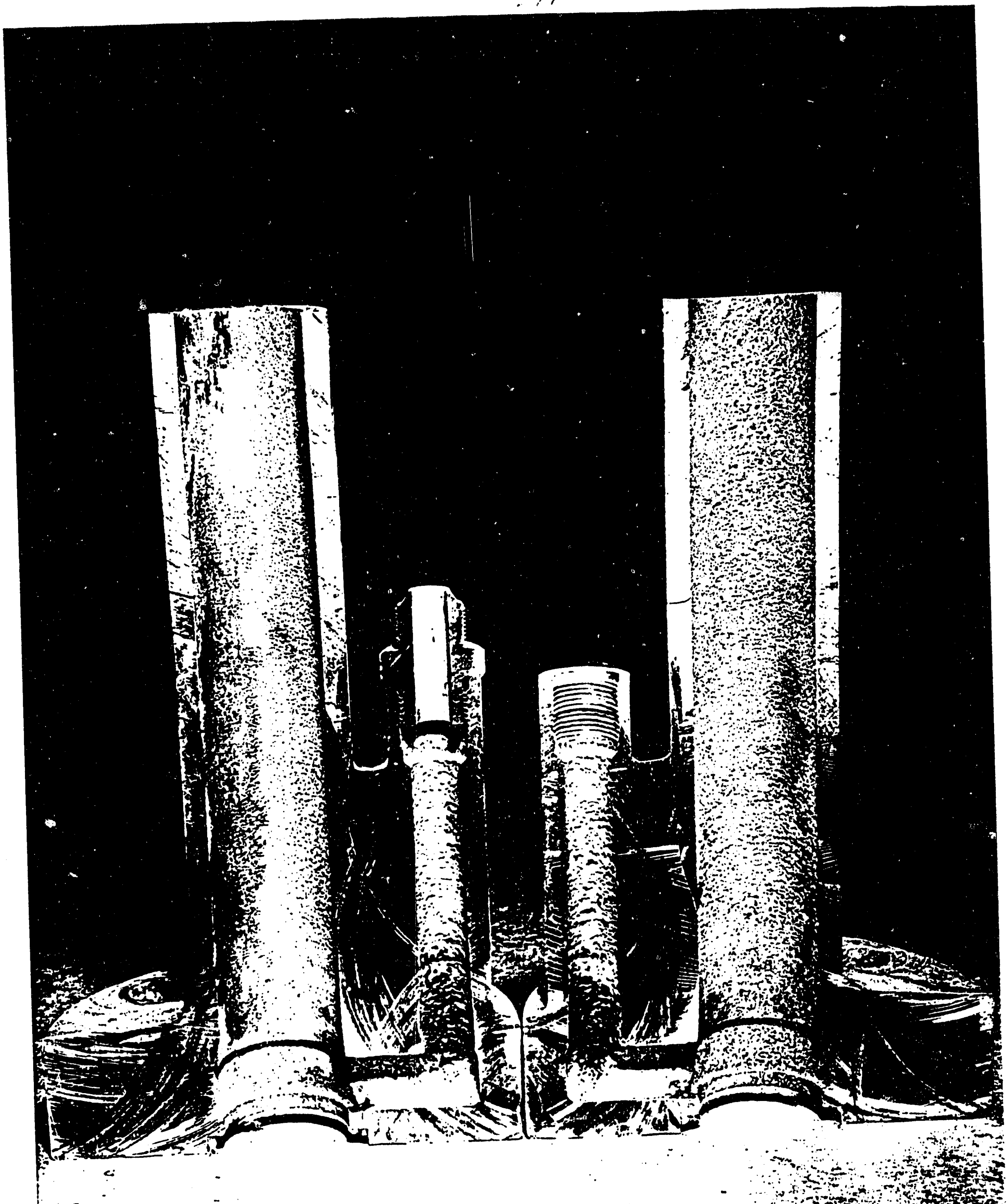
REFERENCES:

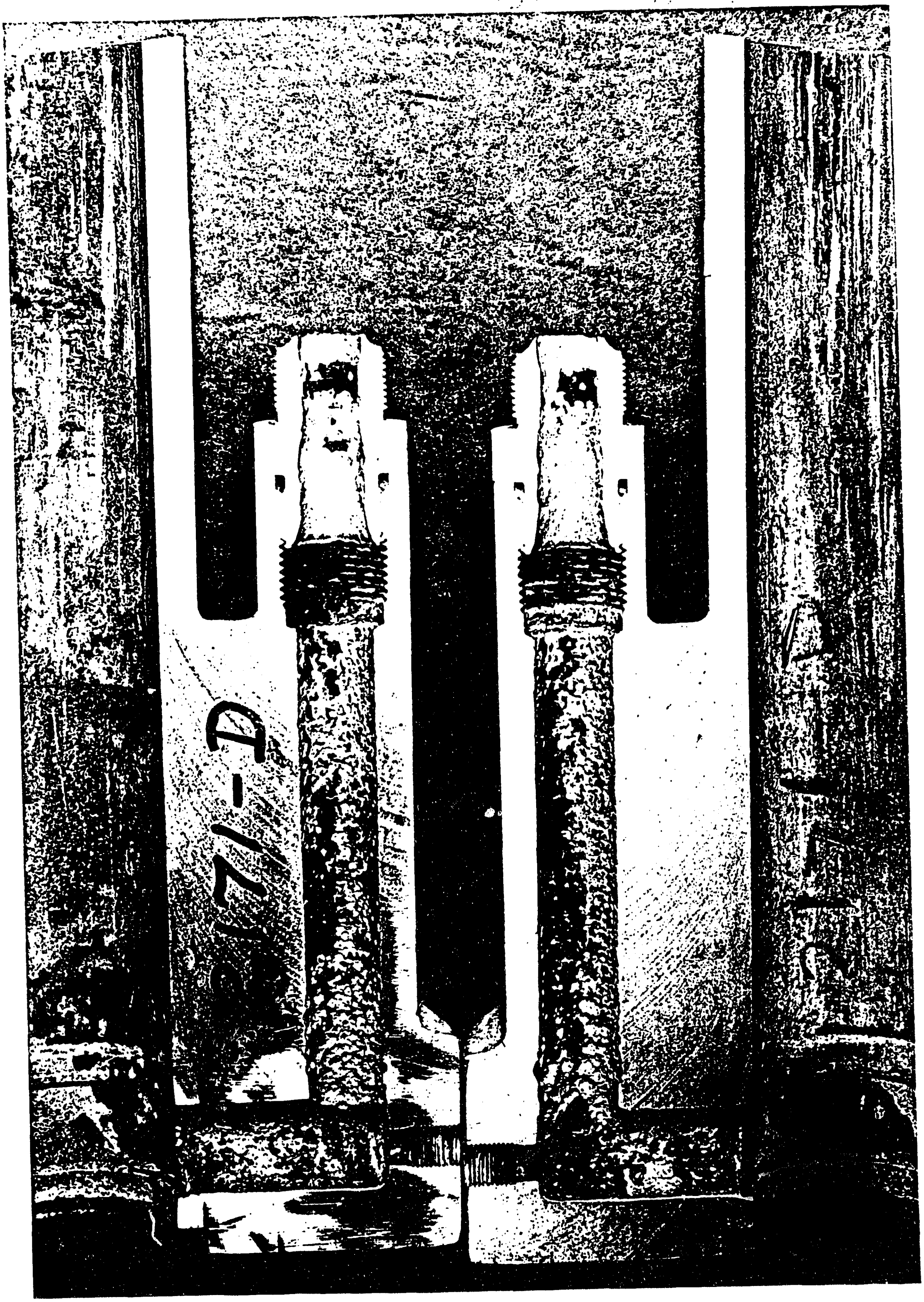
1. HW-76604, "Interim Report Outlet Nozzle Thread Failures, B, D, F, DR, and H", dated March 1, 1963, by R. M. DuPerre.

2. HW-63873, "Rear Crossheader Fitting Inspection, B, D, and F Reactors", dated February 10, 1960, by F. J. Kempf.

3. HW-63756 - 1, 2, 3, 4, "Flow Tests of Enlarged Outlet Fittings for B, D, and F Reactors", by E. D. Waters.

4. Information collected by C. R. Barker.





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