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SUBJECT: Testing of Dump Valve Trim in the Valve Test Loop and the
Performance of Dump Valves in the HRT

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SUMMARY

The Homogeneous Reactor Test requires an emergency or dump valve for rapidly releasing the contents of the high-pressure systems to the low-pressure systems. In order to determine the most suitable trim material for this service, a loop was constructed and used to test a variety of materials under simulated reactor dump conditions. As a result of the tests both 347 and 17-4 PH stainless steels were recommended and used in the HRT dump valves. The HRT core dump valve has not been replaced since the beginning of critical operations. The blanket dump valve has been replaced twice since criticality; once apparently as a result of mechanical binding and once following a dump.

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INTRODUCTION

The Homogeneous Reactor Test requires an emergency valve for rapidly releasing the contents of each the core and blanket high-pressure system to its low-pressure system. This emergency release or dump is accomplished through the core and blanket dump valves. These valves are required to provide absolute shut-off against 2000 psi for long periods of time and, when called upon, to release approximately 500 liters of core solution through a 1/2 in. ($C_v^* = 4$) valve and 1700 liters of blanket material through a 1 in. ($C_v = 10$) valve (Fig. 1) from 2000 psi and 285°C to the low-pressure system initially near atmospheric conditions. They also serve as drain valves for normal shutdown at which time they are opened when system pressure is reduced to 500 to 700 psi and during rinsing operations when they may be opened and closed many times with little pressure differential. This report describes the testing of dump valve trim in the Valve Test Loop and the performance of dump valves in the HRT to date.

TEST PROCEDURE

The valve test loop schematically illustrated in Fig. 2 was designed to test HRT dump valve trim by releasing approximately 60 liters of fuel solution at 2000 psi and 300°C through a test valve on a 15 to 20 minute automatic cycle. Starting with the test valve closed, the continuously running feed pump injects 0.75 to 1.0 gpm, varying inversely with pressure, of oxygenated fuel solution into the high pressure system consisting of one-inch pipe heater legs and a 15 gallon sphere. The system pressure, shown in the pressure trace of Fig. 3, is the vapor pressure of the steadily heated liquid plus some small oxygen partial pressure, until the system approaches solid-filled, at which time the pressure rises rapidly. At a preset pressure the test valve is automatically opened releasing the contents of the high-pressure system into the dump tank. When a preset low-pressure of 25 psi is reached the test valve is automatically closed and the cycle repeated. The dump tank vapor is condensed and the oxygen vented off. The feed pump supply is cooled to prevent flashing on the suction stroke.

The loop was put into operation in November 1955 by REED Instrumentation and Controls Section¹ and was transferred to REED Engineering Development Section in November 1957. Twelve sets of trim were tested at a dump pressure of 2000 psi and temperature of 300°C; however, loop operation was so unreliable that the conditions were reduced to a range of 1200 to 1500 psi and 250°C to 275°C.

Two valves were fabricated for testing trims. They were fitted with weighed and photographed test trim, leak tested, and alternately installed in the test loop. The usual test run was four hundred cycles; however, some valves failed after only a few cycles and a few valves were given a life test extending to thousands of cycles. At the end of the test the valve was again leak tested and the trim weighed and photographed.

The test loop has required frequent maintenance as a result of the rigorous and frequent pressure and temperature cycling with attendant flashing and boiling of fuel solution in the piping. The high corrosion rate resulting from the flashing and boiling caused short pipe life and the rapid scale buildup with attendant loss of heat transfer efficiency caused

*For a fluid of specific gravity = 1 in turbulent flow $C_v = Q \text{ in gpm} / \sqrt{\Delta P \text{ in psi}}$.

short heater life. The feed pump suction line plugged once from corrosion products and had to be replaced. It was possible, however, to test 48 sets of trim.

RESULTS

Detailed trim test results through October 18, 1957, are reported in references 1 and 2. Metallurgical examinations of test trims are reported in references 3 and 4. A recapitulation of all trim tested is given in Table I.

DISCUSSION

A representative sampling of the metals, cermets, and ceramics which were considered possibly suitable for dump valve trim as a result of static corrosion tests were fabricated into trim and tested.

The very soft and very hard materials in general suffered mechanical failure in the form of deformation or cracking. A novel design for using a soft material, in this case gold, by confining it in a circular groove in the plug and mating it with circular tongue on the seat showed considerable promise. However, one set of trim was damaged from misalignment and one seat was damaged by a foreign particle. This design may be particularly vulnerable to foreign particles because of the recess in the plug.

The pyrophoricity of titanium may not constitute a valid objection to the use of that material since the test valve is located at a high-point, which could permit the valve to open in an atmosphere of high pressure oxygen. However, of the two that did not burn, only one was satisfactory.

Several alloys failed from corrosion.

The best performances were obtained from the 347 and 17-4 PH stainless steels, which were both recommended as suitable for HRT use. The performance of these trims in the HRT is tabulated in Table II.

The original core dump valve served throughout the pre-critical testing and was replaced when the reactor was readied for critical operation. The replacement valve has been in service since. The dump valve is now also asked to act as a safety relief valve. The core valve is loaded to relieve at 2700 psi system pressure with an air loading of 20.9 psig in lieu of the design loading of 50 psig. Although the present core valve (K72) leaks 2 to 4 lb/min with the 20.9 psig loading, no leakage can be detected at the design loading of 50 psig.

The blanket dump valve has been replaced three times because of leakage. On the first two occasions, it is suspected that improper mounting and stem galling caused the trouble. On the third occasion, the valve had served 3239 hours, had been found not leaking just prior to the dump, and after flushing and loading to 74 psig (design load is 50 psig and maximum is 80 psig) did not leak after the dump. It did

TABLE I

Dump Valve Material Test

<u>Plug Material</u>	<u>Seat Material</u>	<u>Quantity Tested</u>	<u>Results of Post-Run Examination</u>
Type 347 stainless steel	347	9	Six had extremely small leak rates after 400 cycles. Two leaked 20 and 140 cc/min H ₂ O at 2000 psi respectively, after 1476 and 709 cycles respectively. One was scored by a foreign particle and leaked 50 cc/min after 224 cycles.
17-4 PH stainless steel hardened to R.C. 35-40	347	7	Six had extremely small leak rates after 400 cycles each. One leaked 10 cc/min after 5918 cycles.
Stellite No. 6	347	4	Two had very small leak rates after 400 cycles. Two were removed before completion of 400 cycles for excessive leakage.
Tungsten carbide flame plated on 347	347	3	Two were satisfactory after 420 and 990 cycles. One leaked 100 cc/min of N ₂ at 2000 psi after 424 cycles.
Gold ring recessed into a 347 plug	347	5	Three were satisfactory after 400 cycles. One leaked excessively from misalignment damage. One was leaktight after 2000 cycles but leaked 85 cc/min H ₂ O at 2000 psi after 4000 cycles. Mechanical damage to the seat by a foreign particle was evident.
Various platinum alloys capped over 347	347	6	One was satisfactory. The remainder leaked excessively due to deformation.
Titanium alloys	Matching	4	One was satisfactory. One leaked 500 cc/min H ₂ O at 2000 psi. Two burned in test.
Aluminum oxide flame plated on 347	347	1	Aluminum oxide plate cracked after 46 cycles.
Kennametal No. 501 and No. 96	347	2	Failed from fracture after 3 and 60 cycles.
Zircaloy No. 2	347	3	All unsatisfactory due to galling or deformation of the plug.
Type AM 355 stainless steel	347	2	Spectacularly large holes corroded in plugs in 25 cycles. Material was possibly sensitized by heat treatment.
Tantalum	347	2	Gross leakage due to plug deformation after a few cycles.

TABLE II

HRT Dump Valve Experience
as of July 18, 1959Core Dump Valve Position No. 152 $C_v = 4$

Identification	Plug Material	Date Instal. In Reactor	Removed	Service	Remarks
K 67	347	Oct. 1956	Aug. 1957	Water and depleted fuel	Served throughout the pre-critical testing, including test dumps, was replaced by K 72 during pre-critical overhaul and rebuilt as spare.
K 72	347	Oct. 1957	In service	Fuel. 5435 hrs 5381 MW hrs 45 thermal cycles	Has experienced at least 10 drains, numerous flushes, and numerous openings and closings for loading determinations, etc. is now suspected of leaking > 2 > 4 lb/min, with less than half design air loading (20.9 psig vs 50 psig).
Blanket Dump Valve Position No. 252 $C_v = 10$					
K 71	347	2/13/56	?	Water	Apparently replaced by K 73; reason unknown.
K 73	347	?	1/31/57	Water	Trouble with the mechanical leakage. Rebuilt.
K 71	347	1/31/57	4/25/57	Water	Removed for excessive leakage. Improper support caused misalignment. Rebuilt with 17-4 PH trim.
K 71	17-4 PH	Oct. 1957	5/26/58	Water and fuel 7 drains 1176 hrs. 400 MW hrs 33 thermal cycles. Many flushes.	Reported leaking. Fig. 4 is of plug and bellows after decontamination. The stem was galled at the bellows joint. No record of leakage measurements before decontamination.
K 73	17-4 PH	5/26/58	2/17/59	Fuel. 3239 hrs 4444 MW hrs 4 drains 8 thermal cycles- 1 dump.	This valve was removed after the only full scale reactor dump from 1450 psi - 260°C. It served for many drains and flushes; was tested numerous times to act as a relief valve at 2310 psig and air loading was set at 36.9 psig instead of designed 50 psig. It was leak tested in place 5 times including one 6 days prior to the dump and found not leaking. It was leak tight after the dump with an air loading of 74 psig.
K 71	347	2/17/59	In service	Fuel. 1020 hrs 537 MW hrs 4 thermal cycles	No indication of leakage.

leak at the required relief valve loading of 36.9 psig and was replaced.

The second valve failure was examined after decontamination, Fig. 4, however, it is suspected that the decontaminating acids altered the appearance of the plug. The third failure has not been examined and so the condition of the only valve to have made HRT dump is not known.

CONCLUSIONS AND RECOMMENDATIONS

It has been concluded that either type 347 or 17-4 PH stainless steels are suitable for dump valve trim on both the basis of tests and service.

It is recommended that a strong effort be made to examine valve K 73 in its present condition to determine the effect of the dump and cause of leakage.

It is recommended that in future AHR designs the dump valve be asked to serve only as a dump valve and that the functions of relief valve, drain valve, and flush valve be placed elsewhere.

It is recommended that the Valve Test Loop operation be discontinued.

REFERENCES

1. A. M. Billings, "Valve Test Loop Operation, Nov. 23, 1955 through Oct. 18, 1957," ORNL-CF-57-12-57, Dec. 12, 1957.
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3. F. W. Cooke, "Examination of Zircaloy-2 Poppets from the Dump Valve Test Loop," HRP-MET-6, March 20, 1958.
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Fig. 1. Blanket Dump Valve. (The test valve is similar but with a replaceable seat.)

Fig. 2. Valve Test Loop Flowsheet.

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Fig. 3. Pressure Cycles of High Pressure System of Valve Test Loop.

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Fig. 4. 17-4 PH Plug from Valve K 71. (After removal from HRT and decontamination).

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