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FFTF VALVE EVALUATION

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FFTF VALVE EVALUATION

By

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ABSTRACT

The discussions contained in internal AI documents issued during GFY 1966 pertaining to the primary service rating of valves for the various FFTF service conditions are evaluated. A bibliography of documents representing an accumulation of liquid metal valve data and user experience is presented. Based on a tabulation of valves utilized in the several liquid metal systems shown in BNWL-CC-400, recommendations are made of valve concepts for the required service conditions. Reference to specific test or user data is noted to corroborate the recommendations.

I. SUMMARY EVALUATION, CONCLUSIONS, AND RECOMMENDATIONS

This report represents a review of work performed to date regarding FFTF valve evaluation and presents discussions relating to valve applications presently defined in BNWL-CC-400 as components in the Main Heat Removal Systems, Sodium Purification Systems, and Closed Loop Systems.

The recommendations noted in this report, which are of prime concern, are those associated with valve applications for combined high-pressure (215 psig) and high-temperature (1400°F) use as in the closed loop system. Pressure and temperature ratings associated with the FFTF Closed Loop System and with hot trap purification systems require that valves utilized in these areas be of 1500-lb primary service rating. Valves which conform with this pressure class have a relatively heavy wall thickness which will require special consideration regarding thermal stresses due to system transients and startup conditions. Operation of valves at the higher temperatures of these systems, 1400°F, represents a nominal advancement of liquid metal state-of-the-art technology regarding valves since the bulk of operating experience is at about 1000°F. Valves utilized in the Main Heat Removal System and in sodium purification systems (other than hot trap installations) are subject to a pressure and temperature within the allowables of 300-lb primary service rating. This operating range approximates that within which most state-of-the-art liquid metal valves have been operated.

Equipment and valves located in the primary side of the main heat removal, purification, and closed loop systems will be relatively inaccessible for maintenance or replacement and must therefore be highly reliable and capable of proper operation even when subject to system conditions other than nominal or ideal. Complicated mechanisms, highly stressed members, and components subject to relaxation and deformation after prolonged operation must be avoided. The quality control program associated with fabrication of the valves should adhere to strict standards of materials and weld-testing and proof-testing of the valves.

It is the conclusion of this report that the valve requirements for FFTF represent a nominal advancement in the state-of-the-art for application involving service temperatures in the order of 1400°F. When service conditions combine

this high temperature with a relatively high pressure, the resultant equipment requirements to meet these conditions are considered the most critical of the FFTF valve requirements.

As a means of establishing reliable valve concepts for FFTF while requiring a minimum of development effort, it is recommended that the system conditions involving both high temperature and high pressure be reviewed and, where possible, reduced to permit use of valves of a lower primary service rating.

The specific valve concepts recommended for FFTF development and test are basically identical to valves utilized in the Sodium Reactor Experiment (SRE), the Hallam Nuclear Power Facility (HNPF), and the Sodium Components Test Installation (SCTI) which have demonstrated satisfactory performance in similar service. Extrapolation of the designs to the higher pressure and temperature service is reasonable when verified by proof-testing with sodium at maximum FFTF service conditions.

Recommended valve concepts in size ranges according to Table 1 are as follows:

1) Blocking service (2 to 4 in.) – Gate valve with split or flexible wedge disc.

2) Throttling service (2 to 4 in.) – Angle pattern valve with "free standing" flexible seat (see Figure 1) and contoured valve plug. Butterfly valves are recommended where extremely low flow control is not required.

3) Antiflow reversal service (2 to 20 in.) – Swing check valve with knife-edge type hinge bearings.

4) Stem seals – Freeze seal type. System evaluation is required to determine whether an air-cooled or a liquid-cooled stem seal is the more appropriate for FFTF use. A backup stem seal device to prevent air in-leakage to the frozen seal is required on all freeze seals to minimize the formation of oxide. A bellows backup stem seal has been successfully used at SRE for valves nominally of 2-in. size and smaller. Development effort is recommended to improve on the packed type backup stem seals as utilized in HNPF and SCTI for the larger size valves.

5) Valve Operators — For power actuated valves located in radioactive areas, locate the drive units in accessible areas with accessible torque limiting devices and actuate valves through power transmission shafting which is relatively self-aligning and with a minimum of drive shaft offset relative to the valve. The design factor of safety of such devices should be double that of normally accepted practice. Valves located in nonradioactive areas should be provided with direct mounted operators of a type dictated by system conditions and requirements.

TABLE 1
VALVE TABULATION

	Heat Removal System			Purification and Storage System			Closed Loop System		
	Blocking	Control	Check	Blocking	Control	Check	Blocking	Control	Check
Maximum Pressure (psig)	175			175			75		
Maximum Temperature (°F)	1050			1050			1300		
Material	Type 304 SS			Type 304 SS			Type 304 SS		
Primary Service Rating	300-lb pressure series			300-lb pressure series			300-lb pressure series		
Size Range (in.)	2 through 4	2 and 3	20	2 through 4	2		2	2 and 4	2 and 6
Valve Operation	Manual motor (On-Off)	Manual motor (modulating)	Flow actuated	Manual	Manual		Manual motor (On-Off)	Manual motor (modulating)	Flow actuated
Maximum Pressure (psig)				175			215		
Maximum Temperature (°F)				1400			1400		
Material				Type 304 SS			Type 304 SS		
Primary Service Rating				1500-lb pressure series			1500-lb pressure series		
Size Range (in.)				2			2	2 and 4	2 and 6
Valve Operation				Manual			Manual motor (On-Off)	Manual motor (modulating)	Flow actuated

$$\beta = \sqrt[4]{\frac{3(1 - \nu^2)}{R^2 t^2}},$$

REF: "THEORY OF PLATES
AND SHELLS"
-S. TIMOSHENKO
SECOND ED. P. 468
-470

A VALUE OF $\beta L \geq 1.8$ EFFECTIVELY DAMPENS INDUCED STRESS BETWEEN THE POINT OF DISTURBANCE AND VALVE SEAT.

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Figure 1. "Free Standing" Valve Seat Configuration

II. OBJECTIVE

The objective of this report is to present data, discussions, and recommendations pertinent to the valve requirements for the FFTF liquid metal systems. The categories under which this information is presented are as follows:

1) Literature search — (a) Information primarily contained in internal office letters written by AI personnel during GFY 1966 and (b) bibliography of documents relating to liquid metal valve technology compiled from the Liquid Metals Information Center, "Valves, General," LMIC listing.

2) FFTF valve tabulation — List of valves utilized in the various liquid metal systems as shown in BNWL-CC-400.

3) Presentation of user experience relating to the AI-designed liquid metal systems at SRE, HNPF, and SCTI.

4) Evaluation of current studies applicable to the FFTF valves.

5) Recommendation of valve concepts — Specific recommendation of a valve concept and alternate, where applicable, for each valve category noted in item 2, above.

III. DISCUSSION

A. ACTIVITIES DURING GFY 1966

During GFY 1966, two documents were issued which define the initial phases of work associated with the FFTF Valve Evaluation. The first⁽¹⁾ outlines the effects upon the primary service rating of valves resulting from the use of higher allowable stress levels associated with the materials of construction. The second⁽²⁾ presents a tabulation of valves prepared from a detailed review of the BNWL-CC-400 sodium systems.

Reference 1 defines means whereby the primary service rating of FFTF valves could be reduced. In the closed loop primary systems, as an example, the pressure and temperature rating is 215 psig at 1400°F. Using the original stress levels, these service conditions require a valve of primary service rating of 1500-lb series if the valve is constructed of the same material (type 304 stainless steel) as is specified for the remainder of the system. The wall thickness of valves of this pressure rating are approximately 3/4 in. for a 2-in. valve and 1-1/2 in. for a 6-in. valve. Relative wall thicknesses of this magnitude may introduce thermal stress problems if system thermal transients are not adequately controlled. In order to reduce the primary service rating of the valves, and consequently the body wall thickness, the referenced internal letter (IL) defines the increased allowable stress levels associated with the use of type 304 H stainless steel as compared with type 304. Alternate stainless steels are similarly compared. The primary difference in the materials is the carbon content which ranges from 0.04 to 0.10% for the type 304 H steel and is 0.08% maximum for the type 304 steel. By limiting the carbon range for the 304 H material to 0.04 - 0.065, as an example, the higher strength is gained without increasing the potential of intergranular corrosion at weld joints due to a higher carbon content. The remaining constituents are identical for both designations. The use of type 304 H material to obtain the higher allowable stress levels in materials normally used for valve body construction is, however, presently limited to forgings which would be applicable in the small-size range (2 to 4 in.) and is not applicable to cast materials. For this reason, the primary service ratings noted subsequently in the valve tabulation do not reflect the higher allowable stress levels.

The closed loop flow diagram [BNWL-CC-400, Figure 3.11 (d)] lists an alternate operating temperature of 1000°F which is associated with a higher flowrate. This lower operating temperature would permit the use of 300-lb primary service rating valves.

The use of socket weld end connections, discussed in Reference 1 as a means of reducing the primary service ratings of the valves, is not recommended due to the built-in crack potential associated with this type of joint.

Reference 2, "Tabulation of Valve Requirements for Sodium Service - FFTF," defines the limitations and assumptions made in compiling the valve tabulation presented in this discussion (Table 1). The pressure class of the valves noted in the tabulation assumes the maximum pressure and temperature associated with a given loop as shown in BNWL-CC-400, and all valves within the loop are rated equally to this service. This results in a conservative rating for valves located in the cold leg of the loop when at normal operation but protects against possible isothermal conditions in the event of equipment failure. The pressure class ratings listed in Reference 2 assume the use of the higher allowable stress levels associated with the type 304-H stainless steel, whereas pressure class ratings subsequently listed in this report do not.

B. ACTIVITIES INITIATED DURING GFY 1967

A literature search was initiated during GFY 1967 as a means of accumulating data and user experience regarding valves for liquid metal service. A list of documents was compiled, based on direct relevance to the subject, from a list consisting of 159 computer-produced printouts for documents containing information on valves as prepared by the Liquid Metals Information Center. The selected documents are identified in a bibliography (Appendix I).

C. LIQUID METAL VALVE APPLICATIONS FOR FFTF

The valve tabulation shown in Table 1 is listed by the intended service; i.e., blocking valves, control valves, and check valves within the various systems. Primary service ratings of the valves, based on the system operating conditions and material of construction, are as noted.

In the majority of cases, the maximum pressure and temperature of sodium purification and storage systems is assumed to be equal to the Main Heat Removal System from which these systems are supplied (175 psig at 1050°F). Valve applications in the vicinity of the carbon hot trap and its heater are subject to a maximum of 1400°F, and the maximum pressure and temperature of these applications is therefore assumed to be 175 psig at 1400°F. Valve body material is type 304 stainless steel for both service conditions.

D. DISCUSSION OF EXPERIENCE

Valve installations in the liquid sodium systems of the SRE, HNPF, and SCTI are representative of the valve concepts required for FFTF applications. Operating experience with this equipment has developed high confidence in certain valve concepts and has indicated areas where design and development effort is required to improve present designs. The following discussion, relative to this experience, is divided into the several service categories of blocking, flow control, antiflow reversal, stem seals, and valve operators.

1. Blocking Service

For blocking valve (isolation service) application in the FFTF size range, gate valves with flexible wedge discs and globe valves with the "free standing" valve seat configuration (Figure 1) have demonstrated good shutoff capability at varying sodium pressure and temperature. The shutoff capability of the valves is achieved by the use of flexible valve discs and a flexible valve seat which compensates for thermal distortion, a major factor in sodium valve seat leakage.

Valve concepts which have demonstrated unsatisfactory shutoff capability in mechanical valves are the plug valve (plug cock configuration) and globe valves, which employ a relatively rigid seat geometry. Thermal distortion, of the relatively massive valve plug and valve body, is the major contributing cause of seat leakage in the plug valves. Although no direct correlation of seat leakage vs thermal cycles is apparent from data obtained from testing of small globe valves,⁽³⁾ the marked difference in the shutoff capability of these valves, as compared with globe valves fitted with a flexible (free standing) seat, is most likely due to the seat geometry.

2. Flow Control Service

Operating experience at SRE regarding an angle-pattern globe-type throttling valve has demonstrated satisfactory performance of the concept for sodium service. The valve is used for moderator coolant flow control service and is in the nominal size range of the FFTF flow control valves. The valve is fitted with a liquid-cooled stem-freeze seal and is manually operated. If required for tight shutoff service, this valve concept would be modified to incorporate the "free standing" seat geometry. Butterfly valves of nominal 10-in. size have been successfully used in the SCTI for flow control service. The valves utilize an air-cooled stem freeze seal and are actuated by a direct mounted positioning-type pneumatic operator. The throttling characteristic of the valves in the low flow range (below 15° open) appears to differ from the supplier's data indicating a higher throttling rangeability than is published.

Comparing the butterfly valve concept with the angle-pattern globe-type valve, consideration should be given to the extremely low flow control and potentially tight shutoff capabilities of the angle valve as compared with the relatively low pressure drop of the butterfly valve at full flow conditions. System operational requirements will dictate selection of the appropriate valve concept.

3. Antiflow Reversal Service

During operation of the SRE, a condition of disc sticking at full open position was noted in a conventional "pin-in-sleeve" type hinge structure of a swing-check valve following system contamination with high-oxide content sodium.

The knife-edge-type hinge structure utilized in the HNPF swing-check valves is a design which was incorporated to prevent this malfunction caused by the accumulation of sodium oxides at the hinge.

The knife-edge hinge has free communication with the flowing sodium to minimize the oxide buildup at this critical area. A nominal formation of oxides at the hinge has no effect on the freedom of disc movement. Test results associated with this valve are shown in Reference 4. Performance of the valve during operation at HNPF was completely satisfactory. The design is considered to be adaptable to the FFTF size range of 2 to 20 in.

4. Stem Seals

In general, bellows stem seals, for primary containment of the molten sodium, have been found to be unsatisfactory. The design, analysis, manufacture, and operation of the bellows require great care in all of the areas noted in order to achieve a successful application in molten sodium service. Operating experience at SRE and HNPF has resulted in replacement of many bellows seal valves with freeze stem seal valves in order to eliminate equipment failures due to bellows rupture.

Stem freeze seals for axial and rotary valve actuation have performed satisfactorily in valves installed in the various liquid-metal systems. Some operational difficulties have been experienced with the freeze seals due to the buildup of sodium oxide surrounding the valve stem, which in turn increases the force necessary to operate the valve. It is in this area that development effort is required. As an example, a bellows backup to the stem freeze seal was incorporated on small valves (2-in. and smaller) at the SRE. The bellows prevented air in-leakage to the freeze seal. The valves have been operated for several years without increase in the required actuating force.⁽⁵⁾

Where this bellows backup arrangement has not been employed due to a large valve stroke or similar requirement, a technique of melt and "blow down" (with inert gas) of the existing frozen section, followed by recasting a new stem seal, has been used. The frequency of performing this "blow down" is dependent on frequency of valve operation and ambient conditions. This practice, however, can be objectionable in a reactor system if a sizable gas bubble is introduced into the pipeline.

Valves which are actuated by rotating the valve stem, such as butterfly valve, are significantly less affected by the formation of oxides at the stem seal. The "pumping action" associated with axial stem movement is considered to be contributing to oxide buildup.

5. Valve Operators

Actuation of remotely located valves has been successfully accomplished in both the SRE and the HNPF systems. At the SRE, flexible shafting for manual

operation of valves has been utilized. No remote power actuator valves are employed. Manual and power actuation of remotely located valves are performed at HNPF utilizing solid shafting; gear boxes are employed for change of direction. Remote actuation of valves in FFTF is considered to be similar to that used at HNPF. Experience has shown that the actuator devices and the connecting mechanical shafting must be designed to conservative proportions. The design safety factor used in sizing the shafting should be double that of conventional practice, and the starting torque of rotating drive units nominally 50% above maximum anticipated requirements. A device, which is readily accessible, must be provided to limit the input torque to the actuating shafts to a safe level. The length of shafting and the number of changes of direction employed between the valve proper and the actuating device must be minimized, particularly if the shaft represents its own valve position feedback signal.

Direct mounted actuators such as pneumatic cylinders and gear-electric drive units have been successfully used, but are limited to valve installations in the nonradioactive area where conventional seals, lubricants, etc., can be employed.

6. General

The report, "Conceptual Design of Large Sodium Valves" (ACNP-65575), prepared and issued by Allis-Chalmers in March 1966 is a comprehensive discussion of user experience (including some AI experience as previously noted) relating to liquid-metal valves. Although the objective of the report is aimed at developing large sodium valves, many of the discussions are based on experience with small valves which represent the majority of valve applications utilized in the FFTF systems. The conclusions and recommendations of the report are intended to provide direction for the development of large valves for high-temperature sodium service. Areas where the recommendations of the Allis-Chalmers report differ from that which would be dictated by AI experience are as follows:

- 1) The use of springs in a high-temperature liquid-metal environment is not recommended by AI due to unpredictable relaxation rates.
- 2) Successful development of a "freeze seat" of a simple butterfly valve is considered by AI to be questionable due to the relatively small area at the

seat where the freeze could occur, as compared with the pipeline size from which heat is supplied. More complex arrangements may make it feasible.

3) Based on SCTI operating experience, AI would recommend that the butterfly valve concept be considered for flow control service.

E. FFTF VALVE APPLICATIONS

The following series of comments are related to valve applications as shown on the several P&I diagrams of BNWL-CC-400, which define the Main Heat Removal, Purification, and Closed Loop Systems:

1) The pressure and temperature ratings associated with the closed loop system and valve applications at hot trap installations require the use of 1500-lb primary service rating valves. As previously noted, the wall thickness of such valves is relatively heavy. It is recommended that where possible the system conditions be modified to permit the use of valves in the 300-lb (preferred) to 600-lb (maximum) primary service rating class. The American Standards Rating Tables (ASA B16.5) present the pressure-temperature limits of the various classes.

2) The Primary Loop Check Valves are specified to be designed for removal of internal assemblies from fixed sumps with access from above through removable floor plugs. To be fully effective as a technique of valve maintenance, this design feature must be combined with a capability of remote handling with a shielded cask. A possible variation on this concept is to install the valve in the sump of the main circulating pump, so that valve maintenance is combined with pump maintenance.

3) Valves which are infrequently used often are subject to malfunction due to inadvertent operation while the valve is filled with frozen sodium due to failure to maintain live heaters in operation. The total number of valves should be minimized and maintenance procedures established to ensure that sodium within the valve is maintained in a molten state.

F. CONCLUSIONS AND RECOMMENDATIONS

1. General

The most serious consideration associated with the valves for the several FFTF systems is the high pressure and temperature requirements of the

Primary Closed Loop System. Although some equipment has been operated at this 1400°F temperature range, extensive operating experience is limited to a nominal 1000°F. For this reason, it is recommended that a comprehensive testing and development program be initiated to achieve a satisfactory valve concept for these service conditions. The primary areas of test investigation are thermal shock resistance of the relatively massive valve body (1500-lb primary service rating), valve seat distortion due to thermal shock, and self-welding of valve seats.

The general recommendations relating to the FFTF valves are intended to be consistent with the remainder of the fluid-containing system. Materials of construction of the valve body are to be the cast or forged or wrought equal to that used in the piping system. End connections are to be full penetration butt-weld joints. Quality control aspects of the valves shall conform with the Nuclear Code for Class A vessels. The pressure-temperature rating of the valves for the respective service conditions shall conform with the requirements of ASA B16.5.

Regarding materials selection, exception is taken of the specification per BNWL-CC-400 of type 302 SS for the primary cooling system piping. It has been our experience that austenitic stainless steels with high carbon content (0.20% maximum in the case of 302 SS) are difficult to weld and tend to be susceptible to intergranular corrosion following welding or high temperature service. It is our recommendation that type 304 SS with a carbon content of 0.04 to 0.08% be utilized in the primary cooling system piping.

The use of Stellite hard-facing alloys on all valve seats, guides, and internal wearing parts is recommended. These materials have demonstrated non-self-welding properties in a liquid metal environment⁽⁶⁾ and provide a wear resistant surface at valve seats to maintain tight shutoff capability.

The valve concepts recommended in this report are for specific FFTF applications as shown in BNWL-CC-400. In most cases the valve concepts have been previously employed in systems at lower pressure or temperature than is presently defined for the FFTF. Verification should be accomplished through a program involving (1) hardware design, (2) analysis of the design at dynamic system conditions, and (3) component testing using molten sodium as the test medium.

Consideration should also be given to the incorporation of valves in locations not presently designated in BNWL-CC-400. As an example, the use of isolation valves in the main primary system lines may improve the overall plant availability as compared with that associated with the present design. The valves would be used to isolate a given loop for maintenance or repair while the remaining loop(s) continue to operate. Radioactive decay in the "down" loop would be accomplished simultaneously with continued (at reduced output) plant operation. Maintenance or repair of the accessible loop (following radioactive decay) would then be accomplished with the entire plant shut down.

2. Stem Seals

Due to the relative inaccessibility of valves located in the main heat removal system, the primary purification systems, and the primary closed loop system, it is recommended that freeze-type stem seals be utilized rather than bellows-type stem seals. Operating experience at SRE, SCTI, and HNPF installations has resulted in replacement of many bellows seal valves with freeze stem seal valves in order to eliminate equipment failures due to bellows rupture. The bellows is a relatively fragile part of the valve as compared with a freeze seal and is subject to damage by vibration and by inadvertent operation while the valve interior contains solidified sodium.

Operation of the freeze seal valves requires higher stem forces than is associated with an equivalent bellows seal valve. This stem force will usually increase over an extended period of time unless design conditions are established to prevent it. The increased force required is due to an accumulation of oxides in the freeze zone resulting from in-leakage of air through the backup stem packing at the outboard end of the seal and by the "cold trapping" effect of oxides from the flowing sodium stream at the inboard end. The cold trapping effect appears to be of significantly lesser effect than the air in-leakage effect. A valve modification at the SRE utilizes a stem freeze seal as the primary seal device with a bellows acting as a stem seal to prevent in-leakage of air. Under normal operation, sodium does not come in contact with the bellows. This modification has been applied to valves of nominal 2-in. pipe size with a valve stem travel of nominally 1 in. The equipment has operated for several years without

increase in the required actuator force.⁽⁵⁾ In large valves which require a long stem travel, such applications may not be directly applicable and a research and development effort regarding alternate methods of preventing gas in-leakage and freeze stem sodium oxidation is required.

3. Check Valves

The specific concept recommended for the 20-in. check valve incorporated in the Main Heat Removal System is a swing check valve installed in a horizontal run of pipe and basically identical to that installed in HNPF. This recommendation assumes that the requirements of accomplishing removal of the valve internal through an access plug will be deleted. This valve concept in the smaller size range is also recommended for antiflow reversal service as required for the Closed Loop Systems. Maintenance requirements for the check valves are considered to be infrequent since the unit is totally enclosed and is flow actuated. The valve is not intended to provide tight shutoff.

The major failure mode associated with check valves for sodium service is considered to be disc sticking due to an accumulation of oxides at the hinge. This condition leads to "water hammer" when the disc eventually closes at a time when a substantial reverse flow velocity has developed. This failure must be preceded by a prolonged high oxide level in the sodium and could therefore be prevented by proper operation of the Purification System. The knife-edge-type hinge is specifically designed to accommodate a nominal accumulation of oxides. An alternate consideration would be the incorporation of a "manual override" to accomplish disc movement resulting in clearing of the accumulation by mechanical means. Test results⁽⁴⁾ relating to the performance of this valve at conditions approaching that of FFTF indicate that reliable performance can be expected at a variety of system conditions. Operating experience at HNPF corroborates component test results which form the basis for this recommendation. The lift-check concept was discarded primarily due to its inherently high pressure drop (approximately 4 to 6 times higher than the swing-check). Swing-check valves which utilize "pin-in" sleeve-type journals were similarly discarded because of the potential to hold the disc open due to oxide accumulation or misalignment of parts. This "holdup" could prevent the disc from closing during decay of flow in the normal direction; subsequent flow reversal would then result in rapid disc closure with a resultant water hammer.

4. Blocking Valves

The valve concept recommended for blocking service is the flexible wedge or split wedge disc gate valve. This basic valve design in the 300- to 1500-lb primary service rating and in the size range of 2 to 4 in. is considered well suited for blocking service in FFTF. Developmental or proof-testing of valves in the 1500-lb class is considered necessary, however, to obtain use experience at the high temperature level. Selection of this valve concept is based on the satisfactory performance of the primary blocking valves installed in HNPF. Test results of the prototype of these valves⁽⁷⁾ disclosed good shutoff capability following thermal and pressure cycling of the valve. These tests pertain to 12-in. valves of 300-lb primary service rating. Extrapolation of the design to the smaller sizes and higher pressure class is considered reasonable.

5. Throttling Valves

For FFTF valve applications which involve a throttling service, particularly when combined with a requirement for blocking service, the recommended valve concept is an angle pattern valve designed with a "free standing," flexible seat arrangement and contoured valve plug to achieve the required throttling characteristic. This seating arrangement was used in a bellows seal valve in HNPF; testing of the valve is described in Reference 3. The valve seat consists of a relatively thin cylinder which can flex to conform with the conical valve disc which forms the closure member. Proportions of the cylinder are such that the seating surface is relatively unaffected by forces and moments applied to the valve by the adjacent piping. Figure 1 illustrates the required configuration. In applications where extremely low flow control or tight shutoff are not required, the use of butterfly control valves is recommended. In this regard, verification of the supplier's throttling characteristics data by means of a hydraulic flow test is recommended.

6. Valve Operators

Conventional, direct-mounted valve operators have been used successfully in providing power actuation for sodium service valves which are installed in a nonradioactive environment. Materials normally used in the construction of these operators prevents their extended use in a high radiation field. To avoid

a major redesign of a valve operator (such as an electric motor-gear box-type drive) in order to eliminate these materials, it is recommended that the valve operators be installed in a nonradioactive area, and drive shafting installed through sleeves in the biological shielding for actuation of the valves. These extension shafts should be as short and direct-routed as is practical. These criteria also apply to extension shafting, whether solid or flexible, utilized for remote manual actuation of valves.

The drives for valves to be used in radioactive service should use a design factor of safety double that of the normal mechanical engineering practice. In addition, these drives should utilize torque limiting devices in readily accessible areas.

REFERENCES

1. IL, G. D. Duncan to R. E. Aronstein, 7-1-66, "Valve Selection for High Temperature Liquid Metals - FFTF" (File 731-131-8.0-7681-30115).
2. IL, G. D. Duncan to R. E. Aronstein, 7-1-66, "Tabulation of Valve Requirements for Sodium Service - FFTF" (File 731-131-8.0-7681-30115).
3. NAA-SR-5275, "Thermal Cycling and Leakage Tests of 2-Inch Valves for Sodium Service," Atomics International (pp 7, 15, 21, and 22).
4. NAA-TDR-4934, "14-Inch Swing Check Valve Test," Atomics International (pp 1-3).
5. Personal communication, R. Haines, Dept. 736, Systems Test Group, Atomics International.
6. TID-5277, "Liquid Metals Handbook" (p 317).
7. NAA-SR-4947, "Thermal Cycling and Leakage Tests of 12-Inch Valves for Sodium Service," Atomics International (pp 17-19).

APPENDIX – BIBLIOGRAPHY

1. Patent-UK-843.317, "Improvements in, or relating to, Fluid Flow Valve Mechanisms," Westinghouse Electric Corp., Pittsburg, Pa., The Patent Office, London
2. NAA-SR-Memo-4754, "Technical Description of a Sodium Component Test Installation," Atomics International
3. ORNL 2348, "Components of the Fused-salt and Sodium Circuits of the Aircraft Reactor Experiment," OakRidge National Lab.
4. NAA-SR-4863, "Valve Stem Freeze Seal for High Temperature Sodium," Atomics International
5. Pergamon-478-61, "An Appraisal of the Enrico Fermi Reactor," Pergamon Press, Inc., Division of Macmillan Co.
6. NAA-SR-10743, "Hallam Nuclear Power Facility Reactor Operations," Atomics International
7. NAA-SR-4411, "A Description of SGR Test Installations," Atomics International
8. NAA-SR-5241, "A Combination Strainer and Blocking Valve for Liquid Metal Systems," Atomics International
9. NAA-SR-9777, "Hallam Nuclear Power Facility – Pre-Operational Tests," Atomics International, Vols 1 and 4
10. ACND-65579, "Conceptual Design of Large Sodium Valves," Allis-Chalmers Mfg. Co.
11. NUCL-19-65-61, "Trends in Sodium Equipment," Nucleonics
12. NAA-SR-Memo-3296, "Throttling and Blocking Tests for 2-Inch Valve," Atomics International
13. NAA-SR-7534, "Flow Controller Evaluation for Sodium Service," Atomics International
14. NAA-SR-Memo-3961, "Thermal Cycling and Leakage Tests of 12-inch Sodium Valves," Atomics International
15. NAA-SR-5463, "The Selection, Design, Modification and Analysis of Sodium Valves for HNPF," Atomics International
16. NAA-SR-4947, "Thermal Cycling and Leakage Tests of 12-inch Valves for Sodium Service," Atomics International

17. CONF-BNES-66-5B + 4, "United States Sodium Components Program," Atomic Energy Commission
18. CONF-BNES-66-5B + 5, "Engineering Development for Sodium Systems," United Kingdom Atomic Energy Authority
19. ORNL-TR-854, "Technology of Liquid Metals," OakRidge National Lab
20. NAA-SR-8401, "Hallam Nuclear Power Facility – Reactor Operations," Atomics International
21. PWAC-401 Pt. II, "Final Report, LCRE Valve Development," Pratt & Whitney Aircraft Div.
22. SAN-8002, "SRE Systems and Components Experience," Atomic Energy Commission, p 78
23. NAA-SR-4050, "A Siphon Break as a Blocking Valve," Atomics International
24. NAA-SR-Memo-2920, "A Study of Various Types of Freeze Type Liquid Metal Valves," Atomics International
25. NAA-SR-5275, "Thermal Cycling and Leakage Tests of 2-inch Valves for Sodium Service," Atomics International
26. MSA Memo Report 107, "Two-inch Stop Valve Tests with Sodium," Mine Safety Appliances Co.
27. LAMS-2531, "Quarterly Status Report on Lampre Program, Calif. University, Los Alamos Scientific Lab.
28. NAA-SR-Memo-6374, "Torque Tube Seal – OIC Flow Controller," Atomics International
29. TID-15913, "12-inch Sodium Flow Controller," Westinghouse Electric Corp.