RECEIVED BY DTIC MAY 24 1971

208
HEDL-TME 71-63

MASTER

A COMPARISON OF THE
FLUTED VALVE AND
ORIFICE PLATE
PLUGGING METERS

MAY 1971

HANFORD ENGINEERING DEVELOPMENT LABORATORY

UNITED STATES ATOMIC ENERGY COMMISSION

Operated by

CONTRACT AT(45-1)-2170

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED
GG

DISTRIBUTION OF THIS DOCUMENT IS LIMITED
No Automatic Distribution or Announcement
Refer all requests to *208/1000-P*

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

HANFORD ENGINEERING DEVELOPMENT LABORATORY

Richland, Washington
operated by

WADCO CORPORATION

A Subsidiary of Westinghouse Electric Corporation
for the

United States Atomic Energy Commission Under Contract No. AT(45-1)-2170

A COMPARISON OF THE
FLUTED VALVE AND
ORIFICE PLATE
PLUGGING METERS

G. E. Meadows

May 1971

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

HANFORD ENGINEERING DEVELOPMENT LABORATORY
UNITED STATES ATOMIC ENERGY COMMISSION

Operated by

CONTRACT AT(45-1)-2170

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED
GG

~~DISTRIBUTION OF THIS DOCUMENT IS LIMITED~~

~~No Automatic Distribution or Amendment~~

~~Refer all requests to~~

A COMPARISON OF THE FLUTED VALVE AND
ORIFICE PLATE PLUGGING METERS

ABSTRACT

The operating characteristics of two plugging meters have been studied. The meters located on the same sodium facility were subjected to four levels of sodium purity covering a concentration range of interest to operators of large sodium facilities. Two modes of meter operation were used: determination of plugging temperature obtained by starting with a bare restrictor and determination of saturation temperature obtained by operating the meters in the oscillating mode. The objective of the study was to supply comparative data required to select a "standard" plugging meter for the FFTF and FFTF support facilities. Selection of the orifice plate plugging meter was recommended for FFTF and FFTF Test Facilities. This selection was based primarily on superior performance of the orifice plate meter during determination of the saturation temperature when operated in the oscillating mode.

CONTENTS

	<u>Pages</u>
I. Introduction	1 - 3
II. Summary	3
III. Description of Equipment	3 - 5
IV. Experimental Results	5 - 15
V. Conclusions and Recommendations	15 - 18
VI. References	19
Appendix	

Figures

1. Plugging Meter Saturation Temperature During a Cold Trap Transient	9
2. Importance of Oscillating Plugging Meter	12
3. Example of Plugging Run	14

I. INTRODUCTION

A review of the in-line sodium impurity monitoring instruments for FFTF and related sodium facilities indicated the need for selection of a "standard" plugging meter design and application of the meter to FFTF and related test facilities at HEDL in order to insure a uniform approach for using a plugging meter.

A design review of plugging meters used in other installations narrowed the selection to two basic designs with significant published operating histories. The two designs are: the plugging meter developed at LASL which incorporates an orifice plate as the plugging restriction; and the EBR-II operations plugging meter which has a modified valve with a fluted stem as the plugging restriction. Due to insufficient data available for the meters in the impurity concentration range expected for the FFTF and the subjective nature of the available data, the need for comparative tests on one sodium system was indicated before final selection could be made.

A third design, an experimental meter used on the EBR-II secondary sodium system, which incorporates a filter as the plugging restriction, was included as a promising concept for evaluation. Due to scheduling and the highly developmental nature of the meter it was not included in this comparison study.

Plugging meters have been used extensively to measure the purity of sodium and NaK systems.^(1,9) The advantages of a plugging meter are the relative simplicity of design, installation and operation. The disadvantages are: the meter is not specific for any single impurity, and the data obtained from a plugging meter is sometimes difficult to interpret. The successful operation of a plugging meter as an impurity measuring device depends on the decreasing solubility of the impurity with decreasing temperature. Basically, plugging meter operation includes cooling the sodium, forcing the sodium to pass through a restriction which is at the

coldest point in the meter and reheating the sodium as it is returned to the system. As the impurities dissolved in the sodium are cooled below their respective saturation temperature, nucleation and precipitation of the impurity occur resulting in a flow decrease in the meter. The temperature of the sodium at the time of the first sustained flow loss is referred to as the plugging temperature. When the plugging restrictor is reheated, the loss of flow obtained on cooling will be regained as the impurity plug is redissolved. The temperature where the flow increase occurs is the unplugging temperature. When the plugging meter is used in the oscillating mode with a partial impurity plug in the plugging restrictor, the saturation temperature is obtained. The saturation temperature is that temperature where the impurities in solution are most nearly in equilibrium with the solid impurity plug in the plugging restrictor. When more than one impurity is present, which is the case when considering the ternary diagram for Na-O-H, the saturation temperature cannot be directly related to a specific impurity concentration. The saturation temperature as determined using the plugging meter in the oscillating mode defines the temperature where further cooling of the sodium will produce supersaturation. As the sodium becomes supersaturated, a probability of spontaneous precipitation of the impurities exists. The determination of plugging and unplugging temperatures has been shown to be effected by many operating variables; whereas, the determination of the saturation temperature is much less sensitive to operating parameters.⁽¹⁾

The technique involved to oscillate the plugging meter for the determination of the saturation temperature is as follows: The sodium in the bare restrictor of the plugging meter is cooled below the impurity precipitation temperature where nucleation and precipitation of impurity and/impurities occur. The impurity plug in the restrictor is allowed to grow causing further flow blockage. When it has grown sufficiently to cause a 20% flow loss, heating is resumed.* Heating is then stopped and cooling is resumed at some point before

* The impurity plug to effect a 20% flow loss was arbitrarily chosen as the reference partial plug for the evaluation of the fluted valve and orifice plate plugging meters.

the partial impurity plug is completely dissolved. Alternate heating and cooling cycles are applied causing the flow and temperature to oscillate. At the arrests on the flow curve where the rate of change of flow is zero, the impurity and impurities forming the partial plug are dissolving and precipitating at equal rates. The temperature corresponding to this flow condition is the saturation temperature. The comparison of the capability of the two plugging meters to produce plugging, unplugging and saturation temperatures is the major effort of this study.

II. SUMMARY

The orifice and the valve plugging meters were compared for their ability to produce plugging, unplugging and saturation temperatures. Four impurity levels were studied, covering a concentration range over which the FFTF is expected to operate. Other important operating characteristics were also explored. The orifice plugging meter design is being recommended for selection as the "standard" plugging meter for the FFTF because of its overall capabilities and more desirable operating characteristics. Other recommendations are: the FFTF plugging meter should be operated in the oscillating mode to determine saturation temperature and the meter should be used with a standardized operating procedure.

III. DESCRIPTION OF EQUIPMENT

The two plugging meters evaluated in this study are part of the Small Components Evaluation Loop (SCEL) sample station.⁽²⁾ Sodium supply for the sample station was the SCEL,⁽³⁾ a forced convection sodium facility used for FFTF development studies. The sodium purity level was controlled by the SCEL cold trap system.

The basic difference between the valve meter and the orifice meter is in the geometry of the plugging restrictors. The plugging valve is a modified Nupro SS 8 U W liquid metal valve. The stem was modified by machining ten 0.040 by 0.040 inch slots in the sides of the stem before final assembly. The orifice plate in the orifice meter has four 0.052 inch holes as the plugging restrictor.

A valve mechanism activated by a solenoid operator is the design feature for restoring sodium flow through the orifice plate in the event the plate becomes completely plugged with impurity. The method for restoring flow in the valve meter is turning the valve handle as opening any bellows operated valve. The fluted valve and the orifice plate are located at the end of their respective regenerative heat exchanger in which the incoming sodium enters the meters through a center tube and loses heat to the sodium flowing up the outside annulus. The sodium is cooled by flowing air along the outside of the heat exchanger. The required temperature gradient along the heat exchanger is obtained by adjusting the sodium flow rate, air velocity and the power input to the heaters located on the outside of the heat exchanger. Thermowells with thermocouples monitor the sodium temperature and were used to record plugging meter temperatures. Orifice and valve temperatures and sodium flow rates for the meters were recorded on strip charts with two channel pen recorders. Switches incorporated in the flow channels of the recorder were used to turn the cooling blowers on and off at the appropriate time so the plugging meters would oscillate. The plugging meters are located in parallel flow paths across the sample station headers. Sodium flow rates for the meters are controlled with the isolation valves for each meter, the bypass valves in the header system, and the SCEL electromagnetic pump power.

A modified LASL vacuum distillation sampler,⁽⁴⁾ received as surplus from LASL, was incorporated into the sample station to initiate in-line vacuum distillation analyses and to verify the small impurity changes encountered during the plugging meter study. Operation of the laboratory model distillation sampler in the SCEL sample station represents a significant departure from the previous uses of the sampler. The normal placement and operation of the distillation sampler would be to locate the sampler so the sodium return line drains back to a free surface, i.e., gas phase of a surge tank or mixing tank. The surge tank for the SCEL is located ~ 12 feet above the floor level and spatial requirements for the sampler would not allow convenient placement of it at that level. The distillation sampler is located in a pod attached to the sample station at the building

floor level. Sodium flow to the distillation sampler is controlled by an isolation-throttle valve. The sodium is returned to a receiver tank which in turn feeds an electromagnetic pump used to inject the sodium into the SCEL sample station return header.

Oxygen results from the distillation sampler were used to verify the changes in impurity levels for the plugging meter studies. The distillation sampler takes a 5 millileter sodium sample in a nickel cup. After distillation the residues were analyzed for total sodium, and the oxygen values were computed assuming the residual sodium was present as Na_2O .

IV. EXPERIMENTAL RESULTS

After filling the SCEL sample station with sodium from the SCEL, a period of two weeks was taken to determine important operating characteristics for the sample station. The operating procedure for the vacuum distillation sampler was verified. The effects of sodium flow rate, cooling rate, upstream and downstream throttling on the operation of the plugging meters were studied briefly. Both plugging meters were found to be effected by all the variables studied. The effect of a higher sodium velocity resulted in a plugging temperature approaching the saturation temperature, and a lower velocity resulted in a depressed plugging temperature. The cooling rate was the most influential of the variables studied. The plugging process takes a finite time to occur and is very dependent on cooling rate. At faster cooling rates the determination for plugging temperature falls further below the saturation temperature. The unplugging temperature is also affected by the heating rate. Faster heating rates resulted in elevated unplugging temperatures. Throttling immediately upstream or downstream of the plugging meter affected the operation of the meters equally. The effect is a loss of sensitivity. Flow changes are not observed as quickly and readily. The greatest sensitivity is obtained when the throttling in series with the meters is held to a minimum. This situation is partially met by increasing the bypass flow between the inlet and outlet headers of the sample station and reducing the throttling through the plugging meters. The above mentioned effects on plugging meter operation have been observed and studied in more detail by other workers.^(2, 7) The

purpose for inclusion in this study was for optimizing the operating procedures for the two plugging meters to be evaluated. The following operating parameters were established for the comparison of the two meters. (Refer to the engineering flow diagram in the appendix for the location of the components shown in the list.)

- SCEL flow rate 15 GPM
- SCEL bulk sodium temperature $580 \pm 10^\circ\text{F}$
- Sample Station

	<u>Flowmeter</u>	<u>GPM</u>
Total Flow	1	1.25
Bypass 1	7	0.6
Bypass 2	8	0.6
Valve meter	2	0.08
Orifice meter	3	0.11
Distillation sampler	4	0.2
Sampler E.M. pump	9	0.2
- Cooling rate $< 5^\circ\text{F/minute}$
Cooling rate determined from that portion of the cooling curve after the temperature is below the saturation temperature.
- A 20% flow loss was chosen as the partial plug used for oscillating the meters.
- Heating rate was not controlled for the study.
- Throttling

Valve meter inlet	10%
outlet	0
Orifice meter inlet	20%
outlet	0

Table 1 is a compilation of 70 plugging runs showing the response of the plugging meters to four levels of impurities obtained by operating the SCEL cold trap at 350 , 325 , 300 and 260°F. Five sodium samples were taken at each impurity level for distillation and analyses of the residues for sodium.

Continuous plugging runs were made of impurity transients. The plugging meters were placed in the oscillating mode with the partial plug formed at a steady-state cold trap temperature. The oscillations were continued during the concentration change and the re-equilibration at the new cold trap temperature. A flow arrest occurs approximately every 15 minutes and a saturation temperature

TABLE 1
COMPILATION OF PLUGGING METER DATA

Cold Trap Temp. °F (a)	Distillation Analyses PPM O (b)	Calculated PPM O (c)	Plugging Meter	No. of Runs	Plugging Temp. °F (d)	No. of Runs	Unplugging Temp. °F (d)	No. of Runs	Saturation Temp. °F (d)
350 ± 5	7.6 ± 1.2	6.8	Valve	16	260 ± 20	16	360 ± 25	10	325 ± 5
			Orifice	17	270 ± 20	17	355 ± 30	12	326 ± 10
325 ± 5	4.8 ± .7	4.2	Valve	8	236 ± 5	8	335 ± 15	3	295 ± 10
			Orifice	6	245 ± 14	6	344 ± 9	6	300 ± 5
300 ± 5	3.8 ± .4	2.7	Valve	6	222 ± 8	6	297 ± 30	6(f)	278 ± 16
			Orifice	8	224 ± 10	8	316 ± 16	6	280 ± 15
260 ± 5	2.1 ± .1	1.3	Valve	5	(e)	5	(e)	5	(e)
			Orifice	4	215 ± 3	4	300 ± 10	3 (g) (h)	240 ± 10

(a) Cold trap temperature as measured and limits of control.

(b) Median value of 5 distillation analyses at each temperature with average deviation.

(c) Calculated from the expression $\text{Log } S (\text{WPPM O}) = 6.239 - \frac{4405}{T(R^\circ)}$ using the corresponding cold trap temperature (6).

(d) Median value with average deviation.

(e) No observed plug other than plugging obtained when sodium in the meter reached the freezing point.

(f) Valve meter unstable, meter failed to oscillate on 70% of the plugging runs at 300°F.

(g) Obtained by using a partial plug developed at 300°F.

(h) Approximately 8 hours are required to obtain a 20% plug at this purity level.

can be obtained for each flow arrest thus giving continuous information for the transient. Figure 1 gives a plot of saturation temperature vs. time for a cold trap temperature transient from 325° to 300°F. Both of the plugging meters demonstrated the capability for following the impurity change from 350° to 325°F. Continuous plugging runs with the valve meter could not be made of the transients at other impurity levels. Difficulty in keeping the valve meter oscillating for long periods of time was encountered. The orifice meter was used to follow the three impurity transients incurred during the plugging meter evaluation.

Multi-flow breaks were obtained at all cold trap temperatures. The complex breaks were most apparent when dissolving off a partial plug after completion of a plugging run. Multi-flow breaks are characterized by changes in the rate of sodium flow when the impurity plug is dissolving or depositing at a constant heating rate or a constant cooling rate. Multi-flow breaks are thought to be evidence for changes in the composition of the impurity plug. Not knowing the composition of the impurity plug causing the flow changes makes translation of a plugging temperature or a saturation temperature into a concentration of the impurity in the sodium difficult, if not impossible. The formation of a typical impurity plug that caused the flow losses during this study are as follows: the initial formation of a plug having a relatively slow deposition rate; followed by the formation of a plug with a more rapid deposition rate. The abundance of the impurities forming both of the plugs was found to change with cold trap temperature. In general after a transient in cold trap temperature, the portion of the plug causing the rapid flow response was in equilibrium with the new cold trap temperature within 4 hours. That part of the plug with the slow formation would take 12 hours or more to approach equilibrium. The difference in equilibration rates indicates the cold trap has a greater efficiency for removal of the impurity that forms that part of plug causing the rapid flow response in the plugging meters. The SCEAL cold trap is a relatively old cold trap and at times has been subjected to high impurity loads. Chemical analyses of the sodium from the SCEAL indicated the sodium was saturated with oxygen and hydrogen at all the cold trap temperatures studied.

FIGURE 1. Plugging Meter Saturation Temperature During a Cold Trap Transient

Table 2 is a compilation of the elapsed time from the start of the plugging process (plugging temperature) to the point of oscillation - collection of enough impurity in the plugging restriction of the meter to cause a 20% flow loss. The time table offers a comparison of the transfer rates for the impurity or impurities forming the plug.

TABLE 2

TIME TO FORM A PARTIAL PLUG

<u>Cold Trap Temperature °F</u>	<u>Valve Meter T minutes</u>	<u>Orifice Meter T minutes</u>
350	15 ± 4	18 ± 3
325	59 ± 5	49 ± 5
300	132 ± 30	120 ± 20
260	(1) _____	> 600
(1) Unable to collect enough plug (20% flow loss) to oscillate meter at this temperature.		

The observed time for transport of enough impurity to cause a 20% flow loss is similar for the two meters. The similarity is coincidental and was caused by the difference in throttling in series with the meters. The valve and orifice meter are located between the inlet and outlet headers of the SCEL sample station. In order to operate the two meters simultaneously and at the desired flow rate, the throttling in series with the meters has to be different. The throttling in series with the valve meter added a 10% restriction on the flow through the valve meter plumbing. The throttling in series with the orifice meter added a 20% restriction on the flow through the orifice meter plumbing. The throttling valves are effectively second restrictions in series with the plugging meters, and the pressure drops in the plugging meter plumbing is divided between the plugging restrictor and the throttling valve. The orifice meter with the greater percent throttling in series with the orifice plate required a larger plug fraction to be transferred before a given flow change was detected. Had the throttling in series with

the meters been equal, the time to collect a 20% plug would not have been similar. This factor created a positive sensitivity bias for the valve meter during this evaluation.

Figure 2 is a bar graph showing a comparison of the cold trap temperatures, plugging temperatures and saturation temperatures for this study. The saturation temperatures were obtained by using the plugging meters in the oscillating mode. Plugging temperatures are significantly lower than the actual temperature at which precipitation can occur. The plugging process takes a finite time to occur, and the operation of a plugging meter for the determination of the plugging temperature allows significant undercooling before nucleation and precipitation occurs. When the operation of a sodium system is considered, the time interval and cooling rate are not fixed as in the case of the plugging meter determination; therefore, significant under cooling need not be required before precipitation of the impurity begins. As the system operating temperature drops below the impurity saturation temperature, the sodium becomes supersaturated and the probability of spontaneous precipitation of the impurity exists. Further penetration into the supersaturated region will cause precipitation of the impurity to be inevitable. The exact temperature where spontaneous precipitation will occur is dependent on many of the systems operating parameters.⁽¹⁰⁾ Herein lies the importance of using the plugging meter in the oscillating mode to determine the temperature more accurately where precipitation of the impurities can occur.

To evaluate the effectiveness of the respective clearing mechanisms, both of the plugging meters were purposely plugged with impurities to the point of undetected flow. When the fluted valve was opened after being plugged with impurity, considerable resistance was encountered; however, sodium flow was resumed and bare valve flow was reached in 15 minutes. The fluted valve was given one cycle only because repeated cycling under these conditions would probably result in permanent damage to the valve. It was found the solenoid operator that lifts the internal bypass mechanism for the orifice meter was very effective in clearing the meter from a zero flow condition. Bare orifice flow was restored in 19 ± 2 minutes.

COLD TRAP TEMPERATURE

[REDACTED]

PLUGGING TEMPERATURE

[REDACTED]

SATURATION TEMPERATURE

[REDACTED]

FIGURE 2. Importance of Oscillating Plugging Meter

Normal operation of the plugging meters did not require periodic opening of the clearing mechanism. Recovery from partial impurity plugs, complete impurity plugs and plugs caused by sodium freezing in the restrictors of the meters was accomplished by reheating the meters above the required unplugging temperature. All flow losses encountered during the evaluation were reversible indicating insoluble impurities of sufficient size to cause fouling of the meters were not being transported through the plugging meter plumbing.

A short evaluation was conducted to study the effects of a higher sodium inlet temperature on the operation of the plugging meters. The SCEL cold trap was maintained at 325°F and the bulk sodium temperature transient was begun. Trace heater outage in the sample station headers resulted in a large temperature drop across the sample station. The maximum plugging meter inlet temperature achieved was 850°F. Future plugging meter studies will include inlet temperatures up to 1200°F to study the effects of high temperature sodium on the operation of plugging meters.

A typical plugging run is shown in Figure 3. At point A, the blower motor was activated and cooling was started. The bare orifice flow rate was 0.110 GPM at point A. The orifice plate was cooled to 250°F (plugging temperature) where at point B, the first sustained loss of flow occurred. The cooling was maintained while the impurity plug continued to grow. When the flow dropped to 0.094 GPM, the first switch in the flow channel was activated. The blower remained on until a flow rate of 0.088 GPM was attained where the second switch turned the cooling off, automatically. The momentum of the plugging cycle continued until the flow reached 0.080 GPM where the plugging arrest reached a minimum. At point C the orifice plate began to unplug, with the corresponding temperature being the unplugging temperature. As the orifice plate continued to unplug, the flow increased to 0.094 GPM where switch number one activated the blower motor. The momentum of the unplugging cycle continued to 0.103 GPM where the unplugging arrest reached a maximum. Alternate heating and cooling cycles were repeated, producing a series of temperature and flow oscillations. With points E on the flow curve at equilibrium the impurity

plug dissolved and precipitated at equal rates. The corresponding temperature at point D on the temperature curve is the saturation temperature. The oscillations continued to point F where the plugging run was terminated. With a change in rate of unplugging indicated at G, the bare orifice flow was resumed at H.

The compound switches in the flow channel of the recorder forces the flow to oscillate through a relatively wide flow pattern. By use of this technique, the orifice meter was left in the oscillating mode up to 36 hours on a partially coated orifice. It was found that a single switch or contact in the flow channel of the recorders was not sufficient to keep the meters in oscillation for extended periods. The magnitude and the period of the flow and temperature oscillations were found to change with the length of time the meters were oscillating on a given partial plug. In general, the amplitude of the oscillation became less, and the period of the oscillation became longer. The situation finally reached was an imperceptible rate of flow change--a somewhat unpredictable and difficult event to analyze. Perhaps the condition could be interpreted as the approach to equilibrium. Another plausible explanation would be the influence of multi-impurities that other workers have described.^(2,5) Use of a single switch in the flow channel allows the period of oscillation to be determined by the kinetics of the impurity forming the partial plug; the observed change described was a gradual change in the dominant impurity forming the plug.

V. CONCLUSIONS AND RECOMMENDATIONS

The orifice and valve plugging meters were compared for their ability to produce plugging, unplugging and saturation temperatures. Other operating characteristics were also explored.

The orifice meter design is being recommended for selection as the standard plugging meter for the FFTF because of its overall capabilities and more desirable operating characteristics. Plugging meter determinations below a saturation temperature of 300°F are difficult and time consuming (Tables 1 and 2) and the stability of a plugging meter becomes an important

and necessary feature when making determinations in this range. Throughout the plugging meter evaluation study the valve meter lacked the control (stability) needed. This is caused in part by the relatively large thermal lag for the valve meter. (Thermal lag.....the sensitivity of the meter to temperature changes.) The affect of the lag became apparent during the 325°F cold trap run; contributed heavily at 300°F and rendered the meter essentially useless at the 260°F cold trap temperature. One explanation for the greater thermal lag is the relatively large mass of the fluted valve. The location of the plugging restrictors is another important factor for consideration. The orifice plate is located within a heat exchanger protected by a buffer of liquid sodium. The fluted valve is located directly in the cooling air.

An irreversible flow loss resulting from collection of insoluble impurities in the restrictor of a plugging meter is a potential problem with all plugging meters. The valve meter has the advantage of having a larger flow opening. The flow passage for the fluted valve is 1/8 inch when the valve is in the wide open position. The maximum flow path for the orifice meter is 0.052 inch of the orifice diameter. Addition of a high capacity low pressure drop filter upstream of the plugging is one technique used to protect the restrictor of the plugging meter from insoluble impurities.⁽⁹⁾ There is evidence that insoluble impurities (particulates) of sufficient diameter to cause flow blockage in a plugging meter do not exist in low oxygen sodium contained in austenitic steel systems.⁽⁸⁾ For the FFTF application, insoluble impurities capable of plugging the 0.052 inch orifices of the orifice plugging meter would be an intolerable situation for operation of the reactor.

The solenoid used for lifting the internal bypass mechanism for the orifice meter is undoubtedly the least reliable part of the meter. To assure reliability for long term use in high temperature and radioactive sodium service, the solenoid should be fabricated from materials equal to the quality of the coils of an electromagnetic pump.

It is recommended that the plugging meters for the FFTF include determinations for the saturation temperature by operating the meters in the oscillating mode. It should be recognized that the determinations for plugging and unplugging temperature are particularly sensitive to meter operating variables. A standardized operating procedure should be followed to insure reproducibility.

The results obtained by oscillating a plugging meter are not completely free of complications. Changes of the temperature and flow oscillations can occur during a continuous plugging run and are not necessarily associated with actual impurity changes. Such changes require a finite time to occur and are usually characterized by a change in the period of oscillation. Forcing the meter to oscillate using a compound switch with a definite dead time (described under the experimental section) for activating the blower will reduce this problem to a minimum. Periodically taking the meter out of oscillation, dissolving off the partial plug, and reforming a new partial plug for oscillation are other techniques to assure consistent results.

Continuous plugging runs made during cold trap transients enabled the operator to detect changes in saturation temperature of 25°F. The reproducibility for determination of the saturation temperatures at steady state operating conditions was $\pm 10^\circ\text{F}$.

Several nonconformities exist in the data obtained during this study. The saturation temperature by definition will be equal to the equilibrium cold trap temperature when there is sufficient impurity to saturate the system at that temperature. A negative bias of $22 \pm 3^\circ\text{F}$ is indicated for the saturation temperatures determined by the plugging meters. The temperature profile for the crystallizer tank of the SCEL cold trap system is not known. A colder zone in the tank may exist where actual equilibrium is established resulting in a lower saturation temperature than indicated by the thermocouple recording the cold trap temperature. The oxygen values reported for this evaluation are higher than expected for the four cold trap temperatures studied. The experimental oxygen values have a +0.8 ppm O bias when compared to the oxygen numbers obtained from the recommended expression for

the solubility of oxygen in sodium.⁽⁶⁾ The oxygen determinations indicate the as-measured cold trap temperatures were close to equilibrium conditions. It should be remembered, however, that neither the plugging meter nor the distillation sampler are specific for the determination of oxygen in sodium.

ACKNOWLEDGMENTS

The author wishes to express appreciation for the assistance from the following departments within the WADCO Corporation:

- Sodium Systems Engineering, for design and engineering;
- Sodium Systems Chemistry, for analytical chemistry support;
- Sodium Systems Development, for technical assistance; and
- Sodium Engineering Operations, for operations of the SCEL and the SCEL sample station.

REFERENCES

1. C. C. McPheeters and J. C. Biery. "The Dynamic Characteristics of a Plugging Indicator for Sodium," Nuclear Applications, Vol. 6, June 1967, pp 573-581.
2. Sodium Technology Quarterly Report, April, May & June 1970, BNW-1200-4. Battelle-Northwest, Richland, Washington, 1970.
3. R. L. Knecht. "A Liquid Sodium Test Facility for Engineering Evaluation of the Fuel Re-Use Concept," HW-84088, General Electric Co., September 1964.
4. V. J. Rutkauskas. "Integral Full Flow Vacuum Distillation Sampler for Use in a High Temperature Radioactive Sodium Environment," LA-DC-9666. Los Alamos, May 1969.
5. J. C. Biery. Private Communication, Los Alamos Scientific Laboratory, June 1970.
6. W. H. Yunker. "Standard FFTF Values for the Physical and Thermophysical Properties of Sodium," WHAN-D-3, WADCO Corporation, Richland, July 1970.
7. P. Vilinskas, E. C. Filewiaz and J. R. Humphreys. "Selected Data and Discussion of the Plugging Indicator for Sodium Loops," ANL-7658, Argonne National Laboratory, June 1970.
8. J. E. Draley and John R. Weeks. Corrosion by Liquid Metals, Plenum Press, New York London, 1970.
9. J. P. Delisle. "Automatic Measurement of the Plugging Temperature of Sodium and of NaK," Liquid Metal Colloquium of the European Society of Atomic Energy Aix-en-Provence, Cadaruche, France, Sept 30 & Oct 1-2, 1963.
10. B. R. Grundy and R. Swinhol. "Plugging Meter Behavior in Liquid Sodium Systems," TRG Report 1634, March 11, 1968.

APPENDIX

Engineering Flow Diagram of the S.C.E.L. Header/Sampling System (H-3-29934)

Valve Plugging Indicator

Assembly and Details (H-3-29929 Sheet - 2 & 3)

Orifice Plugging Indicator

Assembly and Details (H-3-29797 Sheet - 2)

Plugging Meter Valve (H-3-29926)

QTY	PART NO.	DESCRIPTION	MATL, CAT OR SH #
1	1	ASSEMBLY	
1	2	TUBE	SH #3
1	3	FINTUBE	SH #3
1	4	COVER	SH #3
1	5	COVER	
1	6	THERMOWELL	
1	7	BLOWER	DAYTON MODEL 2C610
4	8	HEX HD SCR, $\frac{1}{4}$ -20UNC-2A x $\frac{3}{4}$ LG	SST
4	9	HEX NUT, $\frac{1}{4}$ -20UNC-2B	SST
4	10	LOCKWASHER $\frac{1}{4}$	SST
1	11	HEATER, .045 DIA x 36 LG	AERO-RESEARCH #1804-B36-10F
1	12	HEATER, .125 DIA x 72 LG	AERO-RESEARCH #1813-B72-10F

⑤ COVER
MATL: 16 GA (.0598) 304 L-SST

⑥ THERMOWELL
MATL: 304 SST

① ASSEMBLY

FOR GENERAL NOTES SEE SH #1

APPROVED FOR CONFORMANCE BY: J.E. MADON DATE: 5/10/70		U. S. ATOMIC ENERGY COMMISSION RICHLAND OPERATIONS OFFICE PACIFIC NORTHWEST LABORATORY OPERATED BY BATTTELLE MEMORIAL INSTITUTE	
DRAWN: J. ALEXANDER SCALE: NONE		VALVE PLUGGING INDICATOR ASSEMBLY & DETS.	
CHECKED: J. ALEXANDER DATE: 5/11/70		335	
REVISIONS DATE: 7/17/70 CHECK PRT ISSUE NO: 2		2303	
REFERENCE DRAWINGS DRAWING STATUS		H-3-29929 2 3

FOR MATL LIST SEE SH#2
FOR GENERAL NOTES SEE SH#1

APPRO. FOR CONFORMANCE WITH DESIGN CRITERIA BY: J. RALEXANDER DATE: 5/12/70		U. S. ATOMIC ENERGY COMMISSION RICHLAND OPERATIONS OFFICE PACIFIC NORTHWEST LABORATORY OPERATED BY BATTTELLE MEMORIAL INSTITUTE	
CHECKED BY: J. RALEXANDER DATE: 5/12/70		VALVE PLUGGING INDICATOR DETAILS	
CLASSIFIED BY: J. RALEXANDER DATE: 5/12/70		335	
H-3-29929		2303	

BY-DATE	FOR	BY-DATE	FOR	REV	BY	DATE	DESCRIPTION
5/12/70	J. RALEXANDER	5/12/70	J. RALEXANDER	1	J. RALEXANDER	5/12/70	PLUGGING INDICATOR VALVE
REFERENCE DRAWINGS							
NEXT USED ON							
DRAWING STATUS

① ASSEMBLY

② HEATER
MATL: 304 SST (AND NOTED)

③ TUBE
MAY: 304 SST

33.37
④ PROBE
MATL: 304 SST (AND NOTED)

FOR GENERAL NOTES SEE SH#1

APPROVE THE PERFORMANCE		DATE		U. S. ATOMIC ENERGY COMMISSION	
WRITE BRIEF COMMENTARY				RICHLAND OPERATIONS OFFICE	
BY <u>GE MORGAN</u>				PACIFIC NORTHWEST LABORATORY	
				OPERATED BY BATTTELLE MEMORIAL INSTITUTE	
APPROVED BY <u>J. R. Alexander</u>		4/23/70		ORIFICE PLUGGING INDICATOR ASSEMBLY & DETS.	
APPROVED BY <u>D. V. BENNET</u>		5/1/70			
DATE APPROVED		5-4-70			
CHECKED					
BY <u>J. R. ALEXANDER</u>		5/1/70			
SCALE <u>NONE</u>					
CLASSIFICATION BY <u>John</u>		DATE <u>4/26</u>		BLDG. NO. <u>335</u>	
CLASSIFICATION				W-600 NO. <u>4800</u>	
<u>NONE</u>				DWG. NO. <u>H-3-29797</u>	
				SHEET <u>2</u>

DETAIL 'A'

① VALVE
MODIFY VALVE,
NUPPO # SS-BUW-SW-T2
AS NOTED

- GENERAL NOTES
(UNLESS OTHERWISE SPECIFIED)
1. TOLERANCES: FRACTIONAL $\pm \frac{1}{64}$, DECIMAL $\pm .005$, ANGULAR $\pm 0^\circ 30'$
 2. ALL MACHINED SURFACES $\sqrt{63}$ SURFACE TEXTURE SHALL BE IN ACCORDANCE WITH, ASA B46.1 (LATEST REV)
 3. BREAK ALL SHARP EDGES AND REMOVE ALL BURRS
 4. ALL MATL SHALL BE AS SPECIFIED OR APPROVED EQUAL QUALITY

H-3-29926		O VALVE PLUGGING INDICATOR		DATE 5-6-70		BY J.R. ALEXANDER		SCALE NONE		U. S. ATOMIC ENERGY COMMISSION RICHLAND OPERATIONS OFFICE PACIFIC NORTHWEST LABORATORY OPERATED BY BATTTELLE MEMORIAL INSTITUTE	
DRAWING TITLE OR INDEX NO		DRAWING NO		DATE		BY		SCALE		U. S. ATOMIC ENERGY COMMISSION RICHLAND OPERATIONS OFFICE PACIFIC NORTHWEST LABORATORY OPERATED BY BATTTELLE MEMORIAL INSTITUTE	
REFERENCE DRAWINGS		COMMENT PRT ISSUE NO		DATE		BY		SCALE		U. S. ATOMIC ENERGY COMMISSION RICHLAND OPERATIONS OFFICE PACIFIC NORTHWEST LABORATORY OPERATED BY BATTTELLE MEMORIAL INSTITUTE	
NEXT USED ON		DRAWING STATUS		DATE		BY		SCALE		U. S. ATOMIC ENERGY COMMISSION RICHLAND OPERATIONS OFFICE PACIFIC NORTHWEST LABORATORY OPERATED BY BATTTELLE MEMORIAL INSTITUTE	

PLUGGING
METER VALVE

335 2303
H-3-29926 111

OPERATING PROCEDURE FOR THE ORIFICE PLATE PLUGGING METEROperating Conditions

Sodium Flow Rate (Bare orifice flow)	0.5 mV (0.11 gpm)
Blower Damper	90% Closed
Blower Speed Control	70 V
Economizer Heater	95 V (120 W)
Recorder Auto-switch	
Upper limit	0.40 mV
Lower limit	0.35 mV

Operating conditions were established for a plugging meter sodium inlet temperature of 600°F. For higher inlet temperatures an increase in the cooling air flow rate will be required. The air flow rate is adjusted with the blower damper and/blower speed control. Several trial and error plugging runs may be required after making an air flow rate adjustment to establish a cooling curve with a cooling rate of 2 to 5°F/minute at the time the plugging temperature is observed.

Procedure

1. Turn the economizer heater switch (SP0-4) to the manual position.
2. Turn the blower control switch to the manual operate position.
3. Cool the sodium until a sustained flow loss is observed (FM-3). Do not cool below 215°F. This completes the determination of the plugging temperature using the bare orifice mode. To terminate the plugging run at this point; return the blower switch to the off position and set the economizer heater controller in the automatic position. The plugging meter will return to the bare orifice flow and system operating temperature. If the determination of the saturation temperature is desired continue to Step 4.

4. Allow the plugging meter to plug until a flow rate of 0.4 mV is achieved.
5. Turn the blower control switch to the automatic operate position. The auto-switches in the flow channel of the orifice meter recorder will control the blower motor producing a series of flow and temperature oscillations. Leave the meter in the oscillating mode until 10 cycles have been completed.
6. To terminate the plugging run return the blower switch to the off position and set the economizer heater controller in the automatic position. The partial impurity plug will be dissolved off and the flow and temperature will return to the bare orifice flow and the system operating temperature.

See example of a typical plugging run for analyses of the plugging meter chart.

DISTRIBUTION

OFFSITE

<u>No. of Copies</u>		<u>No. of Copies</u>	
28	<u>AEC Div. of Reactor Dev. and Tec.</u> Director, RDT Asst. Dir. for Nuclear Safety Analysis & Evaluation Br, RDT:NS Asst. Dir. for Plant Engr., RDT Facilities Br, RDT:PE Components Br, RDT:PE Instrument & Control Br, RDT:PE Liquid Metal Systems Br, RDT:PE Asst. Dir. for Program Anal., RDT Asst. Dir. for Project Mgmt., RDT Liquid Metals Projects Br, RDT:PM FFTF Project Manager, RDT:PM (3) Asst. Dir. for Reactor Engrg., RDT Control Mechanisms Br, RDT:RE Core Design Br, RDT:RE (2) Fuel Engineering Br, RDT:RE (2) Fuel Handling Br, RDT:RE Reactor Vessels Br, RDT:RE Coolant Chemistry Br, RDT:RT Fuel Recycle Br, RDT:RT Fuels & Materials Br, RDT:RT Reactor Physics Br, RDT:RT Special Technology Br, RDT:RT Asst. Dir. for Engrg. Standards:RDT LMFBR Project Manager, RDT:PM	1	<u>AEC Idaho Operations Office</u> Nuclear Technology Division CW Bills, Director
		1	<u>Aerojet General Corporation</u> SG Harbison
		7	<u>Argonne National Laboratory</u> RA Jaross LMFBR Program Office (3) A Travelli ANL (Idaho Falls) DW Cissel WH Olsen
		1	<u>Atomic Power Development Assoc.</u> Document Librarian
		6	<u>Atomics International</u> Dr. HW Alter, Mgr. FFTF Program Office (5) FBR Project Definition Phase WT Morgan
		1	<u>Babcock & Wilcox Co.</u> Atomic Energy Division SH Esleeck
3	<u>AEC Div. of Reactor Licensing</u> PA Morris	1	<u>Combustion Engineering</u> 1000 MWe Follow-on Study WP Staker, Project Manager
2	<u>AEC Div. of Reactor Standards</u> EG Case	1	<u>Combustion Engineering</u> Mrs. Nell Holder, Librarian
1	<u>AEC San Francisco Operations Office</u> Director, Reactor Division	4	<u>General Electric Co.</u> Advanced Products Operation LF Fidrych
5	<u>AEC Site Representatives</u> Argonne National Laboratory - ID Argonne National Laboratory - AR Atomics International General Electric Company Westinghouse Electric Corporation	2	<u>Gulf General Atomic Inc.</u> General Atomic Division RH Simon, Mgr. Proj. Dept. GCFR Program
1	<u>Atomics International</u> Westinghouse Field Manager JS Theilacker	1	<u>Idaho Nuclear Corporation</u> JA Buckham
10	<u>Bechtel Corporation</u> Project Admin., FFTF JJ Teachnor	3	<u>Liquid Metal Engineering Center</u> KH Davis RW Dickinson DV Hammond
2	<u>SEFOR Facility</u> Breeder Reactor Division P. O. Box 847 Fayetteville, Arkansas 72701 QL Baird	2	<u>Liquid Metal Information Center</u> AE Miller
16	<u>Westinghouse Electric Corporation</u> Advanced Reactor Division DC Spencer, Mgr., FFTF RJ Cregan, Mgr, LMFBR	2	<u>Oak Ridge National Laboratory</u> WO Harms P Partiarca
1	<u>AEC Chicago Patent Group</u> GH Lee	1	<u>United Nuclear Corporation</u> Research and Engrg. Center Library RF DeAngelis
2	<u>AEC Div. of Tech. Info. Ext.</u>		<u>ONSITE-HANFORD</u>
		1	<u>AEC Chicago Patent Group (Richland)</u> RM Poteat

No. of
Copies

1 AEC Richland Operations Office
JM Shively

3 Battelle-Northwest
Technical Library

1 Bechtel Corporation (Richland)
WA Smith

2 RDT Asst. Dir. for Pacific Northwest
Programs

2 Vitro-Hanford Engineering Services
JM Frame

52 WADCO Corporation

GB Barton
DW Bennett
RR Borisch
WF Brehm
WH Caplinger
VF Fitzpatrick
TJ Kabele
VP Kelly
R Kolowith
DH Lester
CE Linderoth
HP Maffei
HM McCall
JJ McCown
GE Meadows (15)
TJ Owen
VJ Rutkauskas
FA Scott
DW Shannon
WR Wykoff
KL Young
WH Yunker
Document Control (15)
Technical Publications