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A COMPARISON OF THE
STACKED FOIL FILTER
AND THE
ORIFICE PLATE
PLUGGING TEMPERATURE INDICATORS

HANFORD ENGINEERING DEVELOPMENT LABORATORY

UNITED STATES ATOMIC ENERGY COMMISSION

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PLUGGING TEMPERATURE INDICATORS

By

G. E. Meadows
Sodium Technology

September 10, 1971

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A COMPARISON OF THE STACKED FOIL FILTER
AND THE ORIFICE PLATE PLUGGING TEMPERATURE INDICATORS

ABSTRACT

The operating characteristics of two plugging temperature indicators have been studied. The plugging temperature indicators located on the same sodium facility were subjected to four levels of sodium purity and to four operating temperatures. Two modes of plugging temperature indicator operation were used: determination of the plugging temperature obtained by starting with a bare restrictor and determination of the saturation temperature obtained by operating the indicators in the oscillating mode. The purpose of the study was to evaluate the filter plugging temperature indicator design as a possible supplemental or replacement plugging temperature indicator for the orifice plate plugging temperature indicator design which had been previously selected as the "standard" design for the FFTF and FFTF support facilities. Testing of the two indicators did not indicate any advantages of the filter plugging temperature indicator over the orifice plate plugging temperature indicator.

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I. INTRODUCTION

Three plugging temperature indicator designs were selected as potential designs for the standard plugging temperature indicator for the FFTF and FFTF test facilities. The basic difference between the three designs is the geometry of the plugging restrictions. The three designs are the fluted valve plugging temperature indicator, the orifice plate plugging temperature indicator, and an indicator using a filter as the plugging restrictor. Due to insufficient data and the subjective nature of the available data, the need for comparative tests on one sodium system was indicated before a selection could be made. Previously a comparison of the fluted valve and orifice plate plugging temperature indicators was completed and the orifice plate plugging temperature indicator was recommended as the standard design for the FFTF plugging temperature indicator. The filter plugging temperature indicator was not included in the first comparison due to scheduling and the highly developmental nature of the indicator.

Plugging temperature indicator determinations are difficult and time consuming below a saturation temperature of 300°F.⁽¹⁾ (Operation of a well cold trapped sodium system will produce saturation temperatures below 300°F.) A plugging temperature indicator incorporating a filter as the plugging restriction offered great promise of increased sensitivity for impurity detection and measurement. The filter gives an extended and suitable surface for nucleation of impurities. Presumably any crystallites of impurities - larger than the pore size of the filter - formed in the sodium would be caught in the filter, whereas similar crystallites would flow on through the fluted valve or orifice plate plugging temperature indicators without indication of plugging.

II. SUMMARY

The filter plugging temperature indicator and the orifice plate plugging temperature indicators were compared for their ability to produce plugging, unplugging and saturation temperatures. Four impurity levels and four indicator inlet temperatures were studied covering temperatures

and impurity concentrations of expected importance to FFTF operation. Testing of the two indicators has not indicated any advantages of the filter plugging temperature indicator over the orifice plate plugging temperature indicator. The orifice plate plugging temperature indicator remains the recommended standard plugging temperature indicator for FFTF because of its overall capabilities and more desirable operating characteristics.

III. DESCRIPTION OF EQUIPMENT

The two plugging temperature indicators evaluated in this study are part of the Small Components Evaluation Loop (SCEL) sample station.^(2,3) Sodium supply for the sample station was the SCEL,⁽⁴⁾ a forced convection sodium facility used for FFTF development studies. The sodium purity level was controlled by the SCEL cold trap systems.

A sketch of the filter plugging temperature indicator is shown in Figure 1. The filter assembly for the plugging temperature indicator was purchased from Vacco Corporation. The filter consists of a series of stacked discs. The dimensions of the filter are 2-7/8 inches long by .990 O.D. The pore size of the filter is 60 microns. Sodium enters the plugging temperature indicator and flows down the outer annulus. The sodium flow separates at the filter end of the plugging temperature indicator; one flow path is through the filter and the other flow return is through the other annulus which serves as a bypass flow. The sodium flow rates are controlled with the two outlet valves. The bypass flow rate and the filter flow rate are recorded on two strip chart recorders. The temperature of the filter is recorded on the same strip chart recorder as the filter flow rate. As plugging occurs in the filter of the plugging temperature indicator, the sodium flow in the bypass increases resulting in a relatively constant sodium flow for the plugging temperature indicator during all phases of operation. The bypass sodium flow serves as the method for quickly re-establishing flow through the filter in the event of complete plugging of the filter. The plug in the filter dissolves into the bypass sodium

Figure 1. Sketch of Stacked Filter Plugging Temperature Indicator

flow when the cooling is terminated. During this study all flow through the plugging temperature indicator could be stopped only by cooling the sodium below the freezing point or with the plugging temperature indicator isolation valves.

A sketch of the orifice plate plugging temperature indicator is shown in Figure 2. The orifice plate in the orifice plugging temperature indicator has four 0.052 inch holes as the plugging restrictor. A valve mechanism activated by a solenoid operator is the design feature for restoring flow through the orifice plate in the event the plate becomes completely plugged with impurity. The orifice plate is located at the end of a regenerative heat exchanger and the sodium enters the plugging temperature indicator through a center tube and loses heat to the sodium flowing up the outside annulus. A thermowell with a thermocouple monitors the temperature of the orifice plate. The plugging temperature indicator flow rate and orifice plate temperature is recorded on a strip chart with a dual pen recorder. 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 temperature indicators would oscillate. The plugging temperature indicators are located in parallel flow paths across the sample station headers. (See engineering flow diagram in appendix section.) Sodium flow rates for the plugging temperature indicators are controlled with the throttle valves for each meter, the bypass valves in the header systems, and the SCEL electromagnetic pump power.

IV. EXPERIMENTAL RESULTS

After filling the plugging temperature indicator portion of the SCEL sample station with sodium from the SCEL, a period of two weeks was taken to determine important operating characteristics of the filter plugging temperature indicator and the operating procedure for the filter plugging temperature indicator was verified. The effects of sodium flow rate, cooling rate, and throttling in series with the plugging temperature indicator were studied, briefly. All of the variables studied affected

Figure 2. Sketch of Orifice Plate Plugging Temperature Indicator

the plugging temperature indicator results. Results from the filter plugging temperature indicator were observed to be especially dependent on the sodium flow rate through the filter. Throttling in series with the plugging temperature indicators significantly reduced the sensitivity of the plugging temperature indicators. The above mentioned effects on plugging temperature indicator operation have been observed and studied in detail by other workers.^(5,6) The purpose for inclusion in this study was for optimizing the operating procedures for the two plugging temperature indicators being evaluated. The following operating parameters were established for the comparison of the two plugging temperature indicators. (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 425° — 1050°F
- SCEL cold trap flow rate 1.0 GPM
- Sample Station

	<u>Flowmeter</u>	<u>GPM</u>
Total Flow	1	1.25
Bypass 1	7	0.6
Bypass 2	8	0.6
Filter Plugging Temperature Indicator		
filter flow	10	0.2
internal bypass	11	0.1
Orifice Plugging Temperature Indicator	3	0.11
- Cooling rate <5°F/minute
Cooling rate determined from that portion of the cooling curve after the plugging restriction temperature is below the saturation temperature.
- A 20% flow loss was chosen as the partial plug used for oscillating the plugging temperature indicators.
- Heating rate was not controlled for the study.
- Throttling in series with the plugging temperature indicators

Filter plugging temperature indicator inlet	0
outlet	20%
Orifice plugging temperature indicator inlet	20%
outlet	0

Table 1 is a compilation of 142 plugging runs showing the response of the plugging temperature indicators to four levels of impurities by operating the SCEL cold trap at 300°, 325°, 350° and 400°F. At a cold trap temperature of 325°F bulk sodium temperatures of 425°, 600, 850, and 1050°F were studied.

A plugging run consists of the determination for the plugging temperature, the unplugging temperature and 5 cycles in the oscillating mode, which produces a series of determinations for the saturation temperature. A saturation temperature for each plugging run is obtained as an average value for the 5 cycles. The technique used to produce a plugging run is as follows: The flowing sodium in the bare restrictor of the plugging temperature indicator is cooled below the impurity precipitation temperature where nucleation and precipitation of the impurity and /impurities occur. The temperature at the first sustained loss of flow is recorded as the plugging temperature. The impurity plug in the restrictor is allowed to grow causing further flow blockage. When the impurity plug 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 partial impurity plug is completely dissolved. Alternate heating and cooling cycles are applied causing the flow and temperature to oscillate. At the arrest 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 unplugging temperature is obtained from the first heating cycle of the oscillations, and is the temperature corresponding to the flow increase as the partial plug starts to dissolve into the flowing sodium.

Column 7, time to start plug, of Table 1, is the elapsed time from the beginning of cooling until the first sustained flow loss is observed (the plugging temperature). Column 8, time to oscillate, is the elapsed time from the beginning of the plugging process (plugging temperature) to the point of oscillation -- collection of enough impurity in the plugging restriction of the plugging temperature indicator to cause a 20% flow loss. Recording of the two time intervals as shown in Table 1 can be used as additional data

TABLE 1
COMPILATION OF PLUGGING TEMPERATURE INDICATOR DATA

Number of Puns	Pulk Sodium Temp. °F	¹ Cold Trap Temp. °F	² Plugging Temp. °F	² Unplugging Temp. °F	² Saturation Temp. °F	³ Time to Start Plug	⁴ Time to Oscillate	⁶ Meter
12	425	325	237 ± 7	325 ± 10	292 ± 6	45 ± 20	54 ± 18	0
9	425	325	235 ± 9	308 ± 20	283 ± 18	52 ± 33	56 ± 26	F
7	600	325	255 ± 15	325 ± 8	317 ± 7	24 ± 6	22 ± 4	0
15	600	325	232 ± 13	310 ± 10	287 ± 13	47 ± 17	58 ± 20	F
10	850	300	241 ± 11	300 ± 10	279 ± 10	36 ± 6	71 ± 8	0
3	850	300	233 ± 10	275 ± 15	262 ± 8	67 ± 25	97 ± 15	F
6	850	325	244 ± 11	338 ± 12	295 ± 9	41 ± 8	52 ± 6	0
13	850	325	231 ± 10	343 ± 30	319 ± 14	37 ± 20	39 ± 25	F
20	850	350	251 ± 10	351 ± 10	327 ± 7	30 ± 5	38 ± 7	0
7	850	350	234 ± 10	317 ± 12	302 ± 5	45 ± 10	40 ± 13	F
8	850	400	278 ± 7	419 ± 11	379 ± 10	19 ± 5	9 ± 4	0
9	850	400	278 ± 10	396 ± 10	368 ± 15	29 ± 8	18 ± 10	F
10	1050	325	238 ± 9	293 ± 13	281 ± 15	35 ± 5	28 ± 6	0
13	1050	325	(5)	295 ± 10	311 ± 15	(5)	(5)	F

(1) Average cold trap temperature; the deviation from control point was ± 10°F.

(2) Average and standard deviation.

(3) Time from start of cooling until plugging temperature is attained.

(4) Time from plugging temperature to 20% flow loss, the point of oscillation.

(5) Flow drift obscured plugging temperature determination, time to start plug and time to oscillate.

(6) 0 Orifice plate plugging temperature indicator

F Filter plugging temperature indicator

to indicate the quality of the sodium. As the impurity level in the sodium becomes less the more difficult it becomes to initiate the plugging process, giving a longer time interval to start the plug and the greater the time interval to transport enough impurities to cause a 20% flow loss.

A nonconformity exists 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 in the cold trap to saturate the system at that temperature. An average negative bias of 25°F is apparent (Table 1) for the saturation temperatures determined by the plugging temperature indicators. The bias is consistent with the -22°F bias obtained during a similar comparison of the fluted valve and orifice plate plugging temperature indicators.⁽¹⁾ The bias is not thought to be inherent in the plugging temperature indicator determinations, but most probably arises from an inaccurate measurement of the equilibrium cold trap temperatures. 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.

All flow losses encountered during the evaluation of the two plugging temperature indicators were reversible when normal operating conditions were restored. No long term flow rate decays were observed which indicates insoluble impurities of sufficient size to cause fouling of the plugging temperature indicators were not being transported through the plugging temperature indicator plumbing.

The filter plugging temperature indicator was observed to have some undesirable operating characteristics. In general the flow losses incurred by the filter plugging temperature indicator during a plugging run has been linear with time; while plugging of the orifice plate is exponential with time. The linear flow loss being a more subtle change requires a greater

flow change before a particular event can be distinguished. The HEDL filter plugging temperature indicator has a flow drift as the plugging temperature indicator is cooled down from system temperature and is not attributed to impurities plugging the filter. The flow drift was observed at all temperatures tested. At an inlet temperature of 1050°F the flow drift obscured the plugging temperature determination. The flow drift may be associated with the relatively large ΔT across the filter plugging temperature indicator economizer (85°F at 1050°F) during a plugging run.

V. CONCLUSION AND RECOMMENDATIONS

Data obtained with the filter plugging temperature indicator has not shown the plugging temperature indicator has extended or added capabilities for impurity detection. The time intervals for initiating the plug (Table 1) for the filter plugging temperature indicator are equal to or greater than the time interval for the orifice plate plugging temperature indicator at comparable impurity conditions. Ease of nucleation and precipitation of the impurities in the plugging restrictor of a plugging temperature indicator is the key to extending plugging temperature indicator determination into the impurity levels attained in a well cold trapped sodium system. The flow drift incurred in the operation of the filter plugging temperature indicator is troublesome and will obscure the plugging temperature determination at the higher inlet temperatures.

The orifice plate plugging temperature indicator design remains the recommended design for the standard plugging temperature indicator for the FFTF and FFTF support facilities because of its overall capabilities and more desirable operating characteristics.

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APPENDIX

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

Orifice Plugging Indicator
Assembly and Details (H-3-29797 Sheet - 2)

Stacked Foil Filter Plugging Meter
Assembly and Details (H 3-32183 Sheet - 2)

QTY	PART NO	DESCRIPTION	MATL OR CAT #
1	1	ASSEMBLY	
1	2	HEATER	
1	3	TUBE	
1	4	PROBE	
1	5	CAP	
1	6	HEX NUT #4-40UNC 2B	SST
1	7	BODY	
1	8	CAP	SWABELOW #400 C 3/16
1	9	CAP 1/16 DIA X 1/8 THK	304 SST
1	10	ADAPTER	
1	11	BLOWER	DAYTON MODEL 2C610
7	12	HEX HD SCR 1/4 20UNC 2A X 3/4 LG	SST
7	13	HEX NUT 1/4 20UNC 2B	SST
7	14	LOCKWASHER 1/4	SST
1	15	THERMOCOUPLE 1/16 DIA SHEATH	FURNISHED

FOR GENERAL NOTES SEE SH #1

APPROVED FOR CONFORMANCE	DATE	U S ATOMIC ENERGY COMMISSION
BY: J. R. ALEXANDER	5/17/70	RICHLAND OPERATIONS OFFICE
FOR: J. R. ALEXANDER	5/17/70	PACIFIC NORTHWEST LABORATORY
OPERATED BY BATTTELLE MEMORIAL INSTITUTE		
ORIFICE PLUGGING INDICATOR ASSEMBLY & DETS		
CHECKED	REVISIONS	BLD NO 335
BY: J. R. ALEXANDER	5/17/70	REV NO 4800
SCALE: NONE	DATE: 5/17/70	DWG NO H-3-29797
CHECKED BY: J. R. ALEXANDER	DATE: 5/17/70	REV: 2
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97. 1/16 DIA (1 WALL ONLY)	5/17/70	97
98. 1/16 DIA (1 WALL ONLY)	5/17/70	98
99. 1/16 DIA (1 WALL ONLY)	5/17/70	99
100. 1/16 DIA (1 WALL ONLY)	5/17/70	100

2 BODY
MATL 304 SST AND NOTE

3 SHROUD
MATL 304 L SST

SECTION 'Y-Y'

DETAIL A

1 ASSEMBLY

SECTION Z-Z

13 DAMPER
MATL 16 GA (.063) 304 L SST (A D NOTED)

QTY	DESCRIPTION	MATL CAT OR SH
1	ASSEMBLY	
1	BODY	
1	SHROUD	
2	HEATER 5/8 DIA 72 HEATED LENGTH	ALLOY 1 1/2 SH FAB 13 012-10F
1	THERMOCOUPLE, 1/8 DIA SHEATH	
4	HEX HD SCR 1/4 20UNC 2A x 1 1/2 LG	SST
8	HEX NUT 1/4 20UNC 2B	SST
8	LOCKWASHER 1/4	SST
4	HEX HD SCR 1/4 20UNC 2A x 5/8 LG	SST
AR	INSULATION	CERFORM
1	BLOWER	TYPE 1 M 1 1/2 1/10
AR	FOIL .050 THK	304 SST
1	DAMPER	SST
1	WING NUT #10 24UNC 2B	SST
1	MACH SCR, #10 24UNC 2A x 1/2 LG RD HD	SST

FOR GENERAL NOTES SEE SH #1

REV	DESCRIPTION	DATE	BY	CHKD	APPD
1	IN LINE INST PIPING LAYOUT				
2	FILTER PLUGGING HEAT RATE				
3	REVISIONS				
4	COMMENTARY				
5	STATUS				

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