APR 22 1966

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LIVERMORE

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SUMMARY OF PLUGGING METER DESIGN AND OPERATING DATA*

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*Work performed under AEC Contract AT(30-1)-2789

The use of plugging meters to determine oxide content in liquid metal test loops at Pratt & Whitney Aircraft-CANEL has been limited and the only experience has been with NaK. Two designs of such instruments are included in this report along with the available operating data. Both plugging meters performed satisfactorily and no attempt is made to make a choice between the two, although a wider range of data was obtained with the meter designated as Plugging Indicator No. 2.

Plugging Indicator No. 1 was an integral part of a Liquid Metal Oxide Control and Indicating System, MSA Research Corporation (MSAR 60-180), supplied to Pratt & Whitney Aircraft-CANEL for the startup procedure of the 8.4 megawatt Non-Nuclear System Test (NNST). Descriptive information follows:

MSAR Plugging Plate Instrument
Plugging Indicator No. 1

MSA Research Corporation

Reference: SK-2-231

Type: Fixed orifice plate

Orifice size - 18 - 0.047 inch dia. holes in 1/8 inch x 1 inch plate fixed to 1.050 inch OD inlet tube.
Cooling rates - Approximately 50°F/min.

Configuration Fig 1

Body - 1 1/2 inch Sch. 160 3 x 6 inch long with reducers at each end and fitted with thermowell and drain.
Nozzles - Inlet 1 inch Sch. 80 concentric
Outlet - 1 inch Sch. 80 eccentric
Drain - 1/4 inch Sch. 40 5 x 6 inch long
Thermowell - 3/8 inch x 120 inch wall with 0.068 inch wall tip.

Flow rate: 1/2 to 1 gpm nominal

Oxide range measured - 20-35 ppm
Temperature limits of operation - 250 to 1600F

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Results are shown in Fig 3 and Table I. Plugging temperature values measured by the plugging indicator were converted to equivalent oxygen concentration through the use of solubility data for oxygen in eutectic NaK as shown by Rodgers, et al. (Ref. 1).

During startup of the Non-Nuclear Systems Test, the type 316 stainless steel secondary system contained approximately 300 gallons of eutectic NaK. The oxide control station was used only during test startup to insure a low value of oxide in the NaK before connecting to the Cb-1 Zr alloy heat exchanger. During the period when plugging runs were made, samples of the NaK were taken at approximate loop temperatures through a bypass sample line. These samples analyzed by an inert gas-amalgamation method. Data in Table I show that only low plugging plate temperatures were encountered. Although the plugging meter operated satisfactorily at low temperatures, it is not possible to give unqualified approval of this plugging meter design over a large oxygen concentration range because test conditions did not permit its evaluation at high oxygen concentrations.

Plugging Indicator No. 2 was a modified ORNL plugging plate instrument as part of the oxide control station used in a Test Loop X-87⁴ at Pratt & Whitney Aircraft-CANEL. This loop was adapted to evaluate plugging indications, sampling techniques and chemical analysis for oxygen and is reported in CANEL TIM-718, "Evaluation of a Sampling Technique and a Plugging Plate Instrument for Determination of Oxygen in NaK." From this work a proposed modification of the plugging plate instrument resulted which unfortunately was never tested, Fig 2. Descriptive information of the test instrument follows:

Modified ORNL Plugging Plate Instrument
Plugging Indicator No. 2

Type: Fixed orifice plate

Orifice size - One 0.05 inch hole in center and four 0.031 inch holes equally spaced on a concentric circle in 1/16 inch x 0.675 inch diameter plate.

Cooling rates - approximately 50° F/min.

Configuration - Fig 2 - Body - 2 inch Sch. 40 stainless steel pipe by 12 inch long. Two inch x one inch reducer at end near plugging plate.

Outlet - 3/8 inch Sch. 40 stainless steel pipe.

Indicating thermocouple attached to body adjacent to plugging plate. Flush valve adjacent to plugging plate.

Flow rate - approximately 1/2 gpm

Oxide range measured - 30-300 ppm O₂

Temperature limit - In operation, it was not possible to control the cold trap temperature with a loop temperature above 1300F because of lack of cooling capacity for the cold trap.

The test loop contained approximately 30 gallons of NaK (Na 56, K 44). Initially it was hoped to attain various oxide levels in the NaK by raising the temperature of the cold trap and equilibrating at temperature. It was found, however, that this would not give the desired levels of oxygen in the NaK and actual additions of Na_2O_2 were made to raise the plugging temperature. Results are shown in Fig 4 and Table II. Plugging temperature values measured by plugging indicator were converted to equivalent oxygen concentration through the use of solubility data for oxygen in NaK (Na 56, K 44) as shown by Rodgers, et al. (Ref. 1). During the period of test over 100 plugging runs were made and approximately 24 samples taken of the NaK at loop temperature. The samples were isolated from the loop in a flow through bypass line and analyzed by an inert gas amalgamation method.

The general agreement between the plugging temperature oxygen values and the values obtained by chemical analysis combined with the response of both of these methods to the addition of oxide to this test system indicate that the plugging meter is capable of detecting changes in oxygen concentration over the range of approximately 40 ppm to 150 ppm.

References:

1. Rodgers, S. J. and Mausteller, J. W., "Solubility of Sodium Monoxide in NaK," Mine Safety Appliance Company Technical Report 47, March 15, 1956.

Table I

OCS Plugging Runs and L.M. Samples

<u>Hours</u>	<u>Date</u>	<u>Run No.</u>	<u>Plugging Temp.</u>	<u>Avg. Loop Temp.</u>	<u>O₂, ppm</u>	<u>Chem. Anal. O₂, ppm</u>
3	3/5/63	1	110F	265F	20	
3 1/2	"	2	80F	265F	20	
4 1/2	"	3	120F	310F	20	
4 1/2	"	4	60F	315F	20	
7	"	5	80F	350F	20	
8 1/2	"	6	80F	400F	20	
9 1/2	"	7	80F	400F	20	
10	IM Sample #1	(O ₂ = 20 ppm)				20
11 1/2	IM Sample #2	(O ₂ = 30 ppm)				30
14	"	8	175F	410F	20	
14 3/4	"	9	110F	410F	20	
15 1/4	"	10	135F	410F	20	
17	"	11	N.G.	500F		
19	"	12	250F	595F	25	
19	"	IM Sample #3	(O ₂ = 26 ppm)			26
20	"	13	210F	600F	20	
21 1/2	"	14	245F	598F	25	
21 1/2	"	IM Sample #4	(O ₂ = 20 ppm)			20
24 1/2	3/6/63	15	240F	640F	24	
25	"	16	242F	683F	24	
25 1/2	"	17	240F	700F	24	
26	"	18	242F	715F	24	
26 1/2	"	19	238F	765F	24	
27	"	20	242F	780F	24	
27 1/2	"	21	238F	780F	24	
28	"	22	242F	800F	24	
28 1/2	"	23	230F	805F	23	
29	"	24	230F	800F	23	
31 1/2	"	25	110F	800F	20	
32 1/2	"	26	125F	810F	20	
33 1/2	"	27	120F	770F	20	
34 1/2	"	28	180F	870F	20	
35 1/2	"	29	85F	910F	20	
36 1/2	"	30	110F	940F	20	
37 1/2	"	31	290F	950F	30	
38 1/2	"	32	327F	985F	34	
38 1/2	"	IM Sample #5	(O ₂ = 30 ppm)			30
39 1/2	"	33	247F	980F	25	
40	"	34	292F	980F	30	
41 1/2	"	35	312F	995F	32	
42 1/2	"	36	300F	998F	31	
43 1/2	"	37	320F	997F	33	
44	"	38	227F	1000F	23	

Table I
(cont'd.)

<u>Hours</u>	<u>Date</u>	<u>Run No.</u>	<u>Plugging Temp.</u>	<u>Avg. Loop Temp.</u>	<u>O₂, ppm</u>	<u>Chem. Anal. O₂, ppm</u>
45	3/6/63	39	290F	1000F	30	
47 1/2	3/7/63	41	262F	1000F	28	
48 1/2	"	42	245F	1000F	25	
49 1/2	"	43	242F	1000F	24	
52	"	44	223F	800F	22	
	"	Dumped Loop & Raised Level				
57 1/2	"	45	228F	800F	23	
58 1/2	"	46	223F	800F	22	
61 1/2	3/8/63	47	240F	800F	24	
62	"	48	222F	800F	22	
63 1/2	"	49	215F	800F	21	
64	"	50	209F	800F	20	
65	"	51	209F	800F	20	
67	"	52	-	800F		21

Table II

Chemical Analysis vs. Plugging Plate Temperatures

<u>Sample No.</u>	<u>Date Sampled</u>	<u>Date Analyzed</u>	<u>ppm O₂</u>	<u>Plugging Run No.</u>	<u>Plugging Plate</u>	<u>Loop NaK</u>	<u>Cold Trap</u>	<u>Total O₂ Added</u>	<u>Remarks</u>
1	4/17/62	4/17	84,46,64	2	355	740	400		
2	"	5/25	28,16,19	3	350	750	400		
3	4/18	4/18	160,132,164	12	375	850	550		Dry box contaminated
4	4/19	4/19	58,92	13	375	835	550		
5	"	4/23	68,86,67	15	375	845	550		
	4/23	O ₂ addition - 196 ppm (46 gr. Na ₂ O ₂)						196	
6	4/24	4/25	67,54,125	23	530	925	700		
7	"	5/24	97,79,50	25	530	925	700		
	4/25	O ₂ addition - 392 ppm (92 gr. Na ₂ O ₂)						588	
8	4/25	4/26	320,261,165	38	665	927	800		Poor sampling technique
9	"	5/1	222,218,191	38	665	927	800		"
10	4/26	4/27	134,150,142	47	595	920	725		
11	"	5/23	148,145	50	600	930	705		
12	4/27	4/30	33,49,23	55	450	840	550		
13	"	5/22	41,45,66	55	450	850	550		
	5/22	O ₂ addition - 294 ppm (69 gr. Na ₂ O ₂)						980	
		Ave.							
14	5/2	5/3	199,184,210	198	66	695	900	850	Subsequent samples taken with best technique. Sampler not filled.
15	"	5/14	168,126	147	67	690	925	850	
16	5/3	5/7	121,123	122	72	600	885	700	
17	"	5/15	112,119,103	111	74	610	920	700	
18	"	5/8	103,100,84	95	79	495	900	607	Loop oxide not at equilibrium
19	"	5/10	61,68,67	65	80	495	905	610	
20	5/4	5/9	76,80,100	85	92	425	820	450	
21	"	5/11	58,43,57	52	95	415	795	455	
22	5/9	5/16	<10 <10	106	205	1200	300		
23	5/10	5/17	<10 <10	108	235	1200	305		
24	5/11	5/18	<10 <10	111	245	1200	325		

FIG 1

CONFIGURATION OF MSAR OXIDE INDICATING SECTION

FIG 2

PRESENT PLUGGING PLATE INSTRUMENT

PROPOSED MODIFICATION OF PLUGGING PLATE INSTRUMENT

CORRELATION OF PLUGGING TEMPERATURE WITH OPERATION OF NON-NUCLEAR SYSTEM TEST

FIG 4

CORRELATION OF PLUGGING TEMPERATURE WITH OXYGEN CONCENTRATION DETERMINED CHEMICALLY