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0. Summary

Corrosion data and operational information are presented for one slurry run at 300°C in which a specially pure thorium oxide was circulated for 312 hours at concentrations of from 440 to 1008 grams of thorium per kilogram of water. The concentration was increased from the lower to the higher level in four increments using a recently developed slurry addition device.

The developmental in-pile slurry loop made several runs on water to evaluate proposed systems for providing condensate for purge water to the 5 gpm pump.

Toroid results indicate that attack rates are dependent on circulation velocity and on ultimate particle size, but not on temperature of calcination of the oxide.

1.1 Loop Operation and Construction.

Two short-time tests, Runs CS-22W and CS-23 (1.1.a) were made in 100A pump loop CS during the quarter. Run CS-22W, a water run, was made to check performance after modification of the condensate system used to provide purge water for the cavity of the 100A pump. Run CS-23 was made using thorium oxide slurry in which the loop was charged to a concentration of 1200 g of thorium per kilogram of water. As in previous runs, a rapid drop in slurry concentration occurred early in Run CS-23. However, the concentration of the circulating slurry was gradually increased to 1000 g of thorium per kilogram of water during the run by employing a newly installed slurry addition system. Both tests were made at 300°C with the addition of gaseous oxygen to the system.

A schematic diagram of slurry loop CS with the modified condensate system and new slurry addition system is shown in Figure 1.1.1.

In Run CS-21, which was described previously (1.1.b), the purge water feed system used to flush the cavity and graphitar bearings of the 100A pump had been found to be unreliable for long-term operation. Gas binding which had occurred intermittently in the 1/4-in. tubing used for the passage of steam from the loop pressurizer to the condensate hold-up tank had prevented a continuous flow of purge water to the pump which had necessitated terminating the run after 30 hours operation because of excessive pump bearing wear. After Run CS-21 the 1/4-in. tubing was replaced by a 1-in. pipe connecting the pressurizer top with the condenser top, in order to permit a steam-gas thermal circulation circuit of suitable capacity to be established, and thus to prevent gas binding of the condenser. To provide an alternate method, a 1/4-in. vent tubing was connected to this 1-in. line, and a tap positioned at the throat of a venturi restrictor in the bypass mixing line. The pressure drop across the venturi throat was estimated to be sufficient to provide a positive flow of gas and steam through the condenser should it become gas bound during operation. The excess gas and steam would then return to the pressurizer via the by-pass line in which the venturi was installed.

Run CS-22W was made to check out the behavior of the modified condensate system and the general operation of the loop. During the fifty-four hour test at 300°C using water, condensation rates up to 10 liters/hr were obtained using the two coolers attached to the hold-up tank. A flow of 4 to 6 liters/hr purge water to the pump bearings was maintained without difficulty.

Although no gas binding occurred during the run, the system was operated for several hours with the valve to the venturi connection open. Readings from thermocouples attached to the 1/4-in. line indicated there was a steady flow of gas and steam to the venturi with continued satisfactory operation of the condensate system.

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Fig. 1.1.1. Slurry Pump Loop CS as of Run CS - 23

Before making Run CS-23, the slurry addition device shown in Fig. 1.1.1 was installed in the system. The slurry reservoir, of 2.3 liter capacity, was connected by 1/4-in. tubing to the loop main stream through an existing sample valve located at the suction side of the pump. Condensate used to flush the addition device enters at the top flanged closure through which the batch-wise additions of slurry are made. Appropriate valving was made to use a pulsafeeder for flushing the slurry from the reservoir if needed.

By means of the slurry addition device, the concentration of thorium oxide in the system can be increased without significantly changing liquid volume in the system in the following manner. The slurry addition tank is filled with the desired quantity of thorium oxide slurry while valved off from the loop. The top flange of the tank is closed and checked for leak tightness by means of the pulsafeeder. The 1/4-in. line from the top of the slurry tank to the loop condensate hold-up tank is opened. Then the 1/4-in. line from the bottom of the tank to the pump suction line is opened. The differential pressure between the condensate tank and pump suction forces slurry from the slurry tank into the loop, the slurry being replaced by clean water from the condensate system. Thus, the 2.3 liters of slurry in the addition tank are replaced by an equal volume of water from the loop. In the event of plugging of the 1/4-in. line from the slurry tank to the pump suction line, the pulsafeeder as shown in Figure 1.1.1 may be used to apply sufficient pressure to unplug this line. It can be seen in Figure 1.1.1 that the feed to the pulsafeeder may be taken from the loop condensate tank so that it is not necessary to add additional water to the loop during operation of the slurry addition system. A high pressure rotometer and regulating valve in the addition system is provided for measuring and adjusting the flow of condensate through the slurry tank within the limits of the condensing system, at the same time maintaining condensate flow to the pump bearings.

During run CS-23, four additions of thorium oxide slurry were made to the loop by means of the system described above. Operation of the system was very satisfactory as evidenced by the fact that essentially all thorium oxide charged to the slurry tank was transferred to the loop. In one case it was necessary to use the pulsafeeder to initiate the flow of slurry from the tank. In this case, the slurry charged to the tank had been allowed to stand and settle for several hours before opening the valves to the loop. In the other three additions and after the flow was started in the fourth case by means of the pulsafeeder, the pressure drop across the tank (estimated to be approximately 30 psi) was sufficient to maintain flow through the addition system. A flow of 20 to 40 cc/min through the slurry tank for one to two hours was sufficient to transfer all thorium oxide from the tank to the loop. After each addition the tank was valved off from the loop, opened, and examined. In one addition, a maximum of 6 grams of thorium oxide

Remained in the tank out of an original charge of 3500 grams. The other three additions were even more complete in the amount transferred. The slurry addition system described was designed after repeated unsatisfactory attempts had been made to use a one-gallon per hour 1500 psi Lapp pulsafeder unit to charge made-up thorium oxide slurry to a loop during operation.

For Run CS-23 the system was charged with 17.3 liters of slurry from batch LO-2 at a concentration of 1200 g thorium per kilogram of water. Thorium oxide used for the slurry charge was prepared at ORNL by calcining thorium oxalate at 800°C. Before charging to the loop, the slurry was wet screened through a 200 mesh (74 μ) screen.

The three sample barrels were loaded with pin type specimens and appropriate restrictors were used to give flows on water at room temperature of 6, 12, and 19 gpm. Flow through the by-pass line for the first 265 hours of operation was 31 gpm based on measurements on water at room temperature. The pressure drop was 40 psi. The restrictor in the by-pass line was changed after 265 hours operation to reduce the flow to 23 gpm, with a corresponding room temperature pressure drop of 60 psi (estimated for water).

During the 312-hr run, the loop was sampled periodically to follow changes in slurry concentration. After three and one-half hours operation at 300°C, the sampled concentration was 612 g of thorium per kilogram of water. Data from four subsequent samples taken during the following 140 hours showed a gradual downward trend in thorium content to 444 g per kilogram of water. During the next 80 hours, the concentration of slurry in the loop was increased to 900 g of thorium per kilogram of water with three separate charges of slurry to the system using the addition device.

Some irregularities in the pump power demand were noted as early in the run as hour 120. These fluctuations were observed after a sample withdrawal, and attributed to gassing in the pump. Gassing would include boiling or cavitation in the pump or gas entrainment in the pressurizer. Slurry volume at 300°C was 22.60 liters. The system volume to the top of the pressurizer heater was 23.1 liters, and to the by-pass inlet was 27.6 liters. Addition of 0.50 kilograms of water to the system gave some relief. Although the slurry volume was increased by various additions to 26.81 liters (at 300°C), irregularities in the pump power demand continued to be noted. Addition of oxygen gas to 350 psi overpressure also did not afford relief.

Fluctuations in the system pressure also were noted. As the fluctuations became somewhat more severe, and the above measures had not afforded relief, the system was shut down at hour 247 and cooled to room temperature to check for leaks.

After a 40-hr shutdown the run was continued. During start-up and the following 18-hr period at 300°C, operating conditions were

controlled to minimize the possibility of boiling by using oxygen overpressure of approximately 300 psi at 300°C and keeping the temperature of the pressurizer about 10°C above the loop main stream temperature. No fluctuations in pressure occurred. The sampled concentration at 300°C was 904 g of thorium per kilogram of water. However, irregularities in the pump power demand continued.

The system was shut down at hour 264 and cooled to room temperature. Flow to the pressurizer was reduced from 32 gpm by changing flow restrictors in the bypass mixing line. The loop was then heated to 300°C without incident. Slurry was readily resuspended. At hour 288, a fourth addition of slurry was made which increased the concentration of thorium in the circulating stream to 1089 grams per kilogram of water. Increasing pump noise began to be noted at hour 294. Operation was continued for an additional 18 hours, at which time the run was terminated because of excessive pump noise. Total circulation time at shutdown was 312.6 hours.

After the run was terminated, the bulk of the slurry was drained from the system and the pressurizer was inspected for evidence of caking. No accumulations were found. After one 20-minute water rinse, at room temperature, the system was disassembled for inspection. No obstructions were found in the main loop piping, pump, or in the three pin holders. However, in all three sample barrels (1.1.c), there remained a plug of solids which partially blocked the annulus between the barrel wall and pin holders. Openings through the plugs appeared to be the result of channeling during the course of the run. Two barrels were 40 to 60 percent blocked by a heavy slurry paste, while in the third barrel about 10 to 15 per cent of the opening was filled. By analysis the average density of these solids was 2.7.

Pump components suffered extensive wear. Titanium seal rings were badly worn. The front graphitar bearing bore had increased 0.0485 inches in diameter, the back bearing 0.0005 inches. The front face of the titanium impeller was pitted at the welded junctions and along the periphery, and the front hub was severely abraded. The impeller lost 29 grams during this run.

In general, the loop exhibited a very satisfactory smoothness of operation during this run. This was attributed to the steady production of condensate at high rates. This permitted free use of the slurry addition system, and consequent adjustment of loop inventory at will. The apparent disappearance during the early part of the run of substantial amounts of the charged thorium oxide, corresponding to about 700 grams of thorium per kilogram of water, did not affect the validity of the run as a corrosion test, but is not a satisfactory operational characteristic. Such a disappearance has happened in this loop on nearly all previous runs and may be associated to a considerable

extent with various "dead spaces" in the loop in which the oxide could pack.

A second slurry corrosion test facility, 100A pump loop BS (1.1.d), is currently being assembled. A schematic drawing of the system is shown in Fig. 1.1.2. Originally, the system was planned as a duplicate of loop CS. However, based on experience in the present system, several design changes have been made to gain more flexibility in both operation and corrosion testing. By the incorporation of a titanium pump head for corrosion resistance, a condensate feed system pulsafeder to be used in the event of loss of pressure drop between the pressurizer and the back of the pump, and slurry addition system to adjust the thorium oxide concentration, many operational difficulties which were experienced in loop CS are expected to be eliminated in loop BS. Less slurry disappearance is to be expected.

To afford more flexibility in corrosion testing, the system can be operated using either the straight-through type double sample barrel shown in Fig. 1.1.2, similar to the solution corrosion sample units, or the vertical multiple barrel arrangement which is used in loop CS. In the former arrangement a third corrosion specimen holder can be placed in the line connected to the suction side of the pump. Alternately, a fourth holder may be used in the section containing the loop heater. By placing the corrosion specimen holders in series rather than parallel, as is done in loop CS, the bulk flow through each holder is identical. Thus, the relative velocity through each holder can be adjusted by changes in the cross sectional areas of the flow channels of the specimen holders. The present rheology of thorium oxide slurries results in possible uncertainties in the relative bulk flow rates of these through parallel lines using the pressure drop measurements determined with water as a means of determining flow rates. The effect of relative velocities on corrosion and/or erosion may thus be more precisely evaluated.

Fig. 1.1.2. 100 A Slurry Pump Loop BS as Constructed

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- 1.1.a S. A. Reed, E. L. Compere, S. R. Buxton, and H. C. Savage, HRP Dynamic Corrosion Studies: Summary of Run CS-23, ORNL-CF-56-7-1.
- 1.1.b E.L. Compere, H. C. Savage, et al., Dynamic Slurry Corrosion Studies -- Quarter Ending January 31, 1956, ORNL-CF-56-1-168.
- 1.1.c E. G. Bohlmann, HRP Quarterly Progress Report, October 31, 1954, ORNL-1813, p. 63-65 and Fig. 3.1.
- 1.1.d H. C. Savage and F. J. Walter, HRP Quarterly Progress Report, July 31, 1955, ORNL 1943, p. 69-70.

1.2 Loop Corrosion Results.

Corrosion rates of pin-type specimens exposed in Run CS-23 are presented in Table 1.2.1. Gold specimens showed excellent resistance to attack: 0.05 mpy at 10 fps, 0.07 mpy at 21 fps, 0.34 mpy at 31 fps. However, their surfaces were badly deformed. Average attack on titanium and the titanium alloys closely paralleled those of type 347 stainless steel and was somewhat higher than results obtained at similar conditions in previous tests.

The loop attack rate during Run CS-23, based on the total iron, chromium, and nickel observed in samples, and on the slurry volume, was 2.1 mpy. The attack rate on the loop appeared to be highest just after a slurry addition, and to diminish as circulation continued until the next addition was made.

Additional attack data from weight losses of the type 100A titanium restrictors are given in Table 1.2.2. Two of these restrictors, presented in Figs. 1.2.1 and 1.2.2, show the extent of localized attack. A photograph of the front hub of the type 75A titanium impeller is shown in Fig. 1.2.3.

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TABLE 1.2.1

CORROSION RATE OF PIN TYPE SPECIMENS, RUN CS-23

ThO ₂ Slurry Concentration (°C) (gTh/kg H ₂ O)	Temp. (°C)	Time (hrs)	Additions	Flow Rate (fps ± 10%)	Pin Material	No. Pins	Conversion Rate (mpy)		
							Min.	Average	Max.
444 - 1008 Avg. 774	300	312.6	267-5874 ppm O ₂ (avg 2700 ppm) ²	10	309 SCb SS	1		3	
					316 SS	1		4	
					347 SS	1		3	
					17-7 PH	1		4	
					Mild Steel ^a	1		14	
					Gold	1		0.1	
					Monel	1		8	
					Platinum	1		0.4	
					Rhodium ^b	1		4	
					Ti (6% Al, 4% V)	1		4	
					Ti RC-55	1		3	
					Ti RC-70	1		3	
					Ti 75A	1		7	
					Zircaloy-2	1		1	
				21	309 SCb SS	1		3	
					316 SS	1		4	
					322 W SS ^c	1		3	
					347 SS	2	4	5	7
					430 SS	1		8	
					Gold	1		0.1	
					Inconel X	1		13	
					Platinum	1		0.6	
					Tantalum	1		0.7	
					Ti (6% Al, 4% V)	1		4	
					Ti RC-70	1		4	
					Ti 75A	1		4	
					Zircaloy-2	1		1	
				31	309 SCb	1		8	
					347 SS	2	10	11	11
					17-7 PH SS	1		12	

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TABLE 1.2.1 (cont.)

Gold	1	0.3
Monel	1	19
Nickel	1	7
Platinum	1	2
Rhodium ^b	1	8
Ti (4% Al, 4% Mn)	1	10
Ti RC-55	1	10
Ti RC-70	1	13
Ti 75A	1	10
Zircaloy-2	1	4

- (a) Grade B fire box quality, ASME Type SA-212
- (b) 1 mil plate on Type 347 SS
- (c) Annealed

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TABLE 1.2.2

ATTACK ON TYPE 100A TITANIUM RESTRICTORS USED IN RUN CS-23

Position and Diameter of Restrictor ¹	Flow Through Orifice (gpm)	Velocity Through Orifice (fps)	Weight Loss (mg)	Exposure Time (hours)	Corrosion Rate (mpy)
In No. 2 sample barrel (0.276")	12	63	28.9	312.6	100
In No. 3 sample barrel (0.195") ²	6	65	76.6	312.6	380
In No. 4 sample barrel (-.337") ³	19	73	54.9	312.6	160
In bypass mixing line (0.400")	23	58	8.1	46.0	130
In bypass mixing line (0.460")	31	61	82.1	266.6	200
In return line (0.750")	67 ⁴ , 59 ⁵	49 ⁴ , 43 ⁵	62.4	312.6	81

(1) Restrictor thickness, 1/8 inch

(2) Shown in Figure 3

(3) Shown in Figure 4

(4) Using 0.460" restrictor in bypass line

(5) Using 0.400" restrictor in bypass line

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Plate 1512
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Fig. 1.2.1. Titanium Flow Restrictor After Run CS-23
(I.D. 0.195 in.) Corrosion Lab. Plate 1512: 1.7 X

Plate 1513
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Fig. 1.2.2. Titanium Flow Restrictor After Run CS-23
(I.D. 0.337 in.) Corrosion Lab. Plate 1513, 1.7 X.

Fig. 1.2.3. Front Hub of Titanium Pump Impeller
After Run CS-23. Corrosion Lab. Plate 1504-3, 1.6 X

1.3 In-Pile Slurry Loop Development.

During the previous quarter the experimental in-pile slurry loop made six short-term water runs to evaluate a succession of additional modifications made to the pressurizer section and the condensate system. A basic operational requirement of an in-pile slurry loop includes a condensate system capable of providing purge water feed to the pump bearings with a gas overpressure in the vapor space of the pressurizer. The modifications made to the loop were to insure the return of the non-condensable gas used in pressurization from the condenser to the pressurizer, thereby preventing the condenser from bas binding. Gas bound condenser operation permits an undesirable carryover of gas with the purge water to the rear of the pump, or, if severe, causes the purge water flow to stop completely. Figure 1.3.1 is a sketch of the loop following the latest modifications.

The present design offers two separate methods of operation for preventing an excess accumulation of non-condensables in the condenser, and each must be evaluated. In one the gas and vapor are introduced into the top of the vertical condenser through the 3/8-in. pipe connected to the pressurizer cap. During this time the valve in the 1/4-in. tubing line between the 3/8-in. pipe and the venturi in the pressurizer side inlet line is closed. The water vapor is condensed in the section of the condenser served by the cooling coils, and the non-condensable gas is cooled. The cold gas flows from the condenser to the pressurizer through the condenser side outlet line. Also, any quantity of water condensed in excess of the required purge water flow to the pump drains back to the pressurizer through this line. In the pressurizer the cool gas is heated again, mixes with water vapor, rises, and completes a thermal cycle.

The other method of venting the condenser is through the 1/4-in. tubing connected between the overhead 3/8-in. pipe serving the condenser and the throat of the venturi installed in the slurry side inlet line to the pressurizer. When this method of operation is used, gas and water vapor flow toward the condenser through both the side inlet line and the overhead line. Location of the 1/4-in. tubing vent connection in the 3/8-in. overhead line permits the top of the pressurizer as well as the condenser to be vented, thus preventing any stagnant accumulation of gas under the pressurizer cap well above the slurry liquid level in the pressurizer.

Additional work planned during the present quarter includes development of a slurry addition system which will enable slurry to be charged to the loop during operation, thereby permitting any desired adjustment of either loop concentration and/or loop inventory after sampling. Also, the use of aluminum oxide as a pump bearing material must be evaluated in slurry operation and the advantages of increasing the 5 gpm pump frequency to facilitate circulating concentrated slurries (1000 g of thorium per kilogram of water) must be investigated.

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Fig. 1.3.1. Thorium Oxide Slurry Experimental In-pile Development Loop

2. TOROIDS.

2.1 Toroid Corrosion Studies.

Data from toroid runs have been presented (2.1.a) to show that the attack rates on type 347 stainless steel, titanium 75A and Zircaloy-2 by circulating, aqueous thorium oxide slurries were independent of the calcination temperature of the oxide up to 1600°C for relative flow velocities up to 26 fps. Although much higher attack rates were found in several instances, the large majority of the data showed that the attack rates on type 347 stainless steel were in the range of 0.5 to 12 mpy for circulating slurries of 1000 grams of thorium per kilogram of water at 26 fps, 250°C and with approximately 100 psi oxygen pressure at room temperature. Comparable rates for titanium 75A were 0.3 to 13 mpy and for Zircaloy-2, 0.1 to 2.4 mpy. Unsized, ORNL-produced Batch D-17 thorium oxide was used at maximum calcination temperatures from 650 to 1600°C.

During the past quarter the particle size distribution was determined for as many of these slurries as were still available. The neutron activation analysis method of determining the particle size distribution by gravitational sedimentation in 0.001 M $\text{Na}_4\text{P}_2\text{O}_7$, was employed (2.1.b).

In addition to the tests previously described, several other toroid runs were completed and will be included in the discussion since the data for them is also pertinent. These runs were all carried out in type 347 stainless steel toroids, at a slurry concentration of 1000 grams of thorium per kilogram of water at 250°C, and with approximately 100 psi oxygen pressure at temperature. The results include only those data for unsized thorium oxide of known maximum calcination temperature and whose ultimate particle size has been determined after circulation. Properties of the oxides are shown in Table 2.1.1.

Table 2.1.1 shows that the three oxides used in these tests are not very different in their properties except for the higher sulfate content of the D-47X material. As noted in the table the average particle size of the oxide has been reduced from the original diameter of about 2.5 μ to about 0.7 μ after about 200 hours circulation for the LO-1 oxide and D-17 oxide calcined from 650 to 1600°C. This reduction is about the same as that demonstrated to occur by circulation in loops (2.1.c). The D-47X oxide was degraded even more, about 83 weight per cent of the oxide being less than 0.7 μ in diameter.

Three runs had been especially designed to study the effect of velocity and maximum calcination temperature of the oxide on the attack rate of type 347 stainless steel, titanium 75A and Zircaloy-2. The results from these runs are shown in Table 2.1.2. The two lower velocity runs showed the independence of the attack rates on the calcination temperature of the oxide and that the oxide itself was degraded during circulation, a smaller ultimate size being obtained as the maximum

TABLE 2.1.1

PROPERTIES OF SOME THORIUM OXIDES^a

Batch Number	D-17	D-47X	LO-1
Maximum Calcination Temp., °C	650 - 1600	800	800
Thorium, % ^b	86.2	86.7	86.3
Iron, ppm	30	40	20
Chromium, ppm	10	10	5
Nickel, ppm	10	8	5
Aluminum, ppm	--	60	40
Sulfate, ppm	160	1300	160
Chloride, ppm	30	40	20
Avg. Part. Diam., μ			
Before circulation	2.5 ^d	2.6 ^e	2.3
After circulation ^c	0.8 ^d	(0.1) ^e	0.7

All oxides were produced by thermal decomposition of thorium oxalate.

- a. Approximate averages of several analyses.
- b. After drying at 110 to 150°C. Theoretical 87.9%.
- c. After circulation as aqueous slurry of 100 grams of thorium per kilogram of water at 26 fps relative velocity and 250°C in toroids with 100 psi oxygen pressure for about 200 hours.
- d. Exclusive of several very much larger values discussed in text.
- e. Extrapolated value from size distribution curve.

TABLE 2.1.2

EFFECT OF VELOCITY AND MAXIMUM CALCINATION TEMPERATURE
OF THE THORIUM OXIDE ON THE ATTACK RATE OF TYPE 347
STAINLESS STEEL, TITANIUM, and ZIRCALOY-2

1000 g thorium per kilogram of water
250°C
90 psi oxygen (250°C)
D-17 Thorium Oxide

Relative Velocity fps	Duration of Run hrs	Max. Calc. Temp. °C	Avg. Part. Diam., μ		Attack Rate, mpy		
			Before Run	After Run	347SS	Ti	Zr-2
3.2 ——— 9.8 ———	432 } 34 }	650	2.4	1.2	0.2, 0.3	0.2	--
		800	2.6	1.5	0.4, 0.5	0.7	+
		1200	3.0	2.2	0.2, 0.3	0.3	+
		1600	2.3	Leak	---	---	--
15.4	342	650	2.4	0.8	2, 3	0.9	--
		800	2.6	1.0	2, 2	3	2
		1200	3.0	1.3	2, 2	2	0.1
		1600	2.3	2.1	2, 2	0.8	0.5
26.3	213	650	2.4	0.6	3, 3	2	--
		800	2.6	2.1	24, 27	9	2
		1200	3.0	4.1	36, 40	11	3
		1600	2.3	Leak	---	---	--

calcination temperature decreased. The higher velocity appeared to degrade the particles to a greater extent than the lower velocity. However, the run at 26 fps showed anomolous results: much higher attack rates of type 347 stainless steel, and to a lesser extent, of titanium for the 800 and 1200°C were observed. Considerably less oxide degradation was found than was expected on the basis of previous tests. As a matter of fact, an apparent larger particle size was obtained for the 1200°C oxide.

These results suggested the comparison shown in Table 2.1.3 which summarizes pertinent data for those oxides for which abnormally large attack rates of type 347 stainless steel had been observed. This table includes all anomolous runs so far encountered: the two from Table 2.1.2 and also those reported in the last progress report (Table 2.2.3, Reference 2.1.a).

Inspection of Table 2.1.3 invites the comparison of attack rate of type 347 stainless steel with the average particle diameter determined after circulation by the gravitational sedimentation method in 0.001 M $\text{Na}_4\text{P}_2\text{O}_7$. This comparison is shown in Figure 2.1.1. The line is dotted because there is still the possibility of an intercorrelation of effects; that is, in those cases where abnormally high attack rates on stainless steel were experienced, the slurry picked up large amounts of corrosion products (up to about 4% Fe) which conceivably could interfere in the particle size determination and lead to erroneously high particle sizes. In those tests in which high attack rates were observed, the slurry was either black or gray-black and in two of the four cases definitely magnetic. These observations strongly suggest the presence of magnetite, which in turn suggests a depletion of oxygen. Calculations based on the amount of iron chemically determined to be in the slurry and the known amount of oxygen added as hydrogen peroxide support this conclusion. Previous results (2.1.d) have indicated that under the conditions of these tests oxygen is beneficial in obtaining low attack rates on stainless steel (2.1.e). Similar conclusion has recently been drawn on the basis of loop tests.

The presence of magnetite in the oxide and the integrity of the particle size measurements in the presence of large amounts of corrosion products are being investigated further.

TABLE 2.1.3

SUMMARY OF TOROID RUNS SHOWING HIGH ATTACK RATES OF TYPE 347 STAINLESS STEEL BY CIRCULATING THORIUM OXIDE SLURRIES.

1000 g of thorium per kilogram of water
 250°C
 90 psi oxygen (250°C)
 D-17 Thorium Oxide

Run	Duration of Run (hrs)	Max. Calcn. Temp. °C	Avg. Part. Diam., μ ^a		Attack Rate, mpy		
			Before Run	After Run	347SS	Ti	Zr-2
83H ^b	213	800	2.6	2.1	24, 27	9	2
63J	241	800	2.6	0.6	8, 8	7	2
69P	200	800	2.6	0.5	6, 6	8	2
59J ^c	208	1000	2.5	3.0	29, 32	10	2
63K ^c	241	1000	2.5	3.2	36, 37	13	2
66J	216	1000	2.5	1.1	3, 3	1	1
83G ^b	213	1200	3.0	4.1	36, 40	11	3
66K	216	1200	3.0	1.2	4, 4	2	0
68J	195	1200	3.0	0.8	5, 5	2	1

- a. The estimated maximum deviation is about $\pm 0.5\mu$. The average value is reported.
- b. From Table 2.1.2 this section.
- c. From Table 2.2.3 in Reference 2.1.a.

Fig. 2.1.1. Effect of Average Particle Diameter of Thorium Oxide After Circulation as Aqueous Slurry on the Attack Rate of Type 347 Stainless Steel

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- 2.1.e D. G. Thomas, HRP Quarterly Progress Report, Jan. 31, 1956, ORNL-2057, p. 76.