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I. PROJECT OBJECTIVES

MASTER

The objectives of this project are to:

- 1) Develop a computer program for calculating two-dimensional, transient, natural convection phenomena such as those arising from various sodium spill accidents in Liquid Metal Fast Breeder Reactor (LMFBR) heat transfer equipment vaults, head compartments, containment buildings, and secondary heat transfer systems
- 2) Develop experimental programs and conduct tests that will characterize the behavior of sodium, sodium oxide, fuel, fission product, and other aerosols as they might be generated by various postulated LMFBR accidents
- 3) Determine by analysis and experiment the generation and transport of these aerosols with respect to source (location, type, and configuration), release dispersal, agglomeration attenuation, and removal for the entire course of events associated with real and hypothetical accident conditions.
- 4) Determine the effects of an accident in an LMFBR involving fuel melting by contacting molten UO_2 (a fuel simulant) with stainless steel, sodium, concrete, and various sacrificial materials.

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II. MAJOR ACCOMPLISHMENTS DURING REPORT PERIOD

A. SUBTASK B - SODIUM JET DISPERSAL

Falling sodium drop burning tests were conducted at the Sodium Fires Test Facility. These tests investigated the ignition phenomena of sodium drops ranging in size from 0.2- to 0.9-cm initial diameter. The experimental data will be used to validate theoretical sodium drop burning models in SOMIX. A test report, N704TR130017, was prepared and issued.

B. SUBTASK F - PROPERTIES OF FUEL MIXTURES

The Arc-Melting Test Facility was successfully started up and demonstration melts and pours of stainless steel were made. A facility safety report, N704NSA90001, was prepared and issued.

III. MAJOR ACCOMPLISHMENTS DURING FISCAL YEAR
1976 AND 1976T

A. SUBTASK A - SOMIX CODE DEVELOPMENT

1. Description

SOMIX-1 is a computer program which was developed to study the transient convective motion of low-oxygen gas environments in cylindrical and rectangular enclosures, representing heat transfer vaults of LMFBR power plants. The gas is heated by a spray of hot sodium droplets generated by breaks in one of the large sodium pipes in the vault. The resulting high velocity liquid breaks up into a spray of drops. As the sodium drops fall, they react with the low oxygen environment (0 to 2 vol %) in the enclosure and are simultaneously heated by low-level combustion and cooled by convective heat transfer to the gas and by radiative heat transfer to the walls of the vault.

SOMIX-1 has now been incorporated into the Lawrence Berkeley Computing Facility and its interactive timeshare system. A preliminary Users' Manual⁽¹⁾ for the code has been completed and issued; and a paper⁽²⁾ describing the SOMIX Code and presenting results of spray fire analyses in large heat transfer equipment vaults was presented at the American Nuclear Society Winter Meeting.

2. Progress During Report Period

The SOMIX Code, modified to take into account the decrease in drop diameter due to burning, has been applied to the calculation of the burning of small drops. Calculated results for the burning of 0.07-cm-diameter drops in 5% oxygen showed that such small drops burn completely within a free fall distance of about 3 m. These results are similar to those obtained from the recent AI free-fall burning tests of 0.2-cm drops which burned to completion in an air atmosphere in a fall of less than 1 m. The complete disappearance of small drops by burning coupled with the experimental observation that large burning sodium drops (0.9-cm diameter) are unstable and quickly shed about 40% of their mass in the form of small satellite drops 0.2 cm in diameter, indicates that sodium spray fire calculations which assume constant drop diameters may have substantial error.

Previously, it has been assumed that large drops associated with guillotine pipe ruptures will always result in a lower burning rate than the smaller drops associated with partial pipe breaks. In view of the instability of large burning drops, which appears to start at a threshold diameter of about 0.73 cm, this is no longer obviously true. More needs to be known about the breakup characteristics of large burning drops, and the splattering characteristics of pipes, walls, and internal equipment items.

3. Next Report Period Activities

Test results of the falling sodium drop tests (Subtask B) will be used to validate the theoretical drop burning models in SOMIX.

B. SUBTASK B – SODIUM SPLASH DISPERSAL

1. Description of Drop Burning Tests

A series of sodium drop burning tests was conducted in a high bay cell of the Sodium Fires Test Facility. These tests provided experimental data on the burning rate of falling sodium drops which were released from a mono-size drop generator. This data will be used in the SOMIX computer program to estimate the effects of sodium fires in an LMFBR secondary heat transfer vault. The sodium drop generator produced drops ranging in size from 0.3- to

0.9-cm diameter at 555°C. It was located 14.7 m above the test cell floor, see Figure 1. The sodium drops produced by the generator were exposed to a normal air atmosphere where they ignited after falling a short distance.

The burning characteristics of the falling sodium drops were determined by (1) observing and recording the elevation where ignition of a single drop first occurred and (2) measuring the mass of sodium consumed due to combustion as the drop fell 14.7 m. These measurements were made for various initial drop sizes, 0.3- to 0.9-cm diameter, all preheated to a temperature of 555°C. Additional burning characteristics were determined by releasing similar size drops which were preheated to temperatures ranging from 200 to 550°C. These later tests determined the preheat temperature required for the drop to ignite.

During the constant temperature drop tests, the initial drop size was determined by collecting drop samples directly at the generator nozzle and making weight measurements. The drops collected at the test cell floor were dissolved in water and analyzed for total sodium content. A still camera, positioned ~2 m below the sodium drop generator, provided photographic coverage of the initial drop burning. As the sodium drops were released into the unlighted test cell, the flame of a burning drop was recorded as a single streak. By panning the camera, all of the falling burning drops released during a test (constant size drops) could be recorded on a single photograph.

Figures 2, 3, and 4 are streak photographs of burning sodium drops where the initial drop sizes were 0.39-, 0.46-, and 0.73-cm diameter, respectively. An optical densitometer was used to scan each photographic negative to determine the elevations where first ignition and full burning occurred. Figure 5 shows the results of the densitometer data. The streak photographs indicate that the larger the initial drop size the farther the drop had to fall before ignition and full burning occurred; i. e., the 0.39-cm-diameter drops fell an average of 0.35 m before ignition, while the 0.73-cm-diameter drops fell 2.14 m before ignition.

Table 1 gives the initial and final masses of the sodium drops as well as the mass burned and fraction of mass burned. Each individual test consisted of at least 30 drops. Ten drops were collected close to the nozzle, 10 were allowed to fall, and then 10 again were collected at the nozzle.

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Figure 1. Schematic of Sodium Drop Generator Test Apparatus

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Figure 2. Streak Photograph of Sodium Drops Falling in Air
(0.392- and 0.718-cm Diameter; Scale: 1 cm = 14.8-cm
Falling Distance)

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Figure 3. Streak Photograph of Sodium Drops Falling in Air
(0.462-cm Diameter; Scale: 1 cm - 14.8-cm
Falling Distance)

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Figure 4. Streak Photograph of Sodium Drops Falling in Air
(0.731-cm Diameter; Scale: 1 cm = 14.8-cm
Falling Distance)

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Figure 5. Densitometer Data of Sodium Drop Flame Propagation for Tests 2, 4, and 8

TABLE 1
SUMMARY OF FALLING DROP TEST DATA[†]

Test No.	Initial Drop Mass (mg)	Final Drop Mass (mg)	Mass Burned (mg)	Fraction Burned
11 _s	3.88	0	3.88	1.00
10	13.35	5.7	7.6	0.57
9 _s	25.67	11.0	14.6	0.53
1	41.10	19.5	21.5	0.52
2	42.15	24.7	17.4	0.41
3	93.35	64.9	28.5	0.30
4	96.13	69.3	26.8	0.28
5	100.42	73.4	27.0	0.27
9 _l	157.54	118.0	39.5	0.25
8	159.03	132.5	26.5	0.17
6-7	166.74	136.0	30.7	0.18

[†]Air atmosphere; ~4000 ppm water vapor; initial drop test temperature = 550°C

The mass of the drops collected near the nozzle divided by the number of drops was considered to be the initial mass. The final mass was measured by dissolving the collected drops in water and measuring the sodium content by flame photometry. The mass shown is the total mass divided by the number of drops collected. Calculated diameters of the drops is given in Table 2, assuming that they are spherical and the density is 0.813 g/cm^3 , the density of sodium at the release temperature of 555°C. Actually, the falling burning drops will not necessarily be spherical, and the density would be somewhat less because of the increase in temperature. Figure 6 shows the air atmosphere fall distance required for ignition and full burning to occur as a function of drop size.

Other observations made during the constant temperature test series indicate that sodium drops at 555°C which were greater than ~0.73-cm diameter became unstable during free fall. Results of a test which produced

TABLE 2
SODIUM DROP BURNING CHARACTERISTICS

Test Number	Calculated Initial Drop Diam, D_I (cm)	Fall Distance to Drop Ignition (m)	Fall Distance to Full Burning (m)	Flame Diameter at Full Burning (cm)	Temperature at Full Burning Drop ($^{\circ}\text{C}$)
11 _s	0.209	0.101	0.200	*	*
10	0.315	0.355	*	*	*
9 _s	0.392	0.355	*	*	*
1	0.459	0.502	*	*	*
2	0.462	0.502	0.987	0.94	*
3	0.603	0.788	1.426	0.94	*
4	0.609	1.234	2.237	1.72	*
5	0.617	0.929	2.268	1.53	*
9 _l	0.718	1.264	*	2.1	*
8	0.720	1.938	3.419	1.8	1035
6-7	0.731	2.143	3.499	1.8	1123
11 _l	*	2.153	*		

* = Measurement not recorded

s = Denotes small drop of small/large drop combination

l = Denotes large drop of small/large drop combination

0.93-cm-diameter drops showed that the drops fragmented after falling 10 to 20 cm. The smaller fragments ignited either during formation or immediately after formation. Drops in this size range (~ 0.2 -cm diameter) were observed to burn to completion after falling ~ 1 m. Figure 7 shows the streaks produced by burning of the smaller and larger drops.

The second phase of the sodium drop experiments was conducted to determine the effect of initial sodium temperature on burning initiation as the drops fell 14.7 m in the test cell. In air containing 3800 to 4000 ppm water vapor, preheat temperatures of 540°C were required before ignition of drops of 0.8-cm diameter occurred. All other drops, 0.3 to 0.72-cm diameter, ignited at preheat

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Figure 6. Fall Distance for Ignition and Full Burning vs Drop Diameter

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Figure 7. Streak Photo of Small and Large Burning Sodium Drops
(Scale: 1 cm = 14.4-cm Falling Distance)

temperatures around 425° C. Drops preheated to temperatures less than those noted did not ignite after falling 14.7 m. Additional tests will be conducted with air containing 10,000 to 14,000 ppm water vapor to determine the effect of water vapor content on sodium drop ignition.

C. SUBTASK C - AEROSOL LEAKAGE

1. Description

The reactor system and containment of an LMFBR can be expected to be very effective in preventing the spread of radioactivity following an accident. However, with current leak rate measurement technology, a steel reactor containment building is usually assumed to have 0.1 vol % leakage/day, since this is close to the limit of leak detection sensitivity. This much gas leakage can be accommodated by flow through a single, short length hole having an equivalent diameter of ~ 1 mm. The purpose of these experiments is to measure aerosol leakage through such holes that may be present in containment structures. As plugging occurs, the aerosol and gas leakage is much less than would otherwise be expected.

All experiments to date have been conducted in a 0.44 m^3 vessel. The aerosol concentration and humidity are controlled by injecting Na_2O_x aerosol and air into the vessel as required.

Examples of the sampling methods are given in Reference 2.

2. Test Results

Given a certain pressure differential or flow rate, there is generally an aerosol concentration above which plugging occurs and below which no plugging occurs.

Tests were performed to determine (1) the plugging time and strength of the plugs formed in capillaries when exposed to a sodium oxide aerosol, and (2) the mass of respirable-size particles which penetrate the capillary. In addition, the formation of an entrance plug was documented photographically.

During the plug strength test, the aerosol was allowed to flow through the capillary to form the plug. After formation of the plug, the pressure differential across the capillary was raised until gas flow was again observed

through the capillary or 0.68 atm was reached. The results shown in Table 3 generally indicate that for this set of conditions, the plugs formed at the greater vessel pressure can withstand a greater pressure differential as compared to those plugs formed at the lower vessel pressures.

Size measurements were made of aerosols emerging from a capillary exposed to identical conditions as Capillary 11. The results show that 65% of the mass emerging from the capillary was greater than $10.1 \mu\text{m}$. The size of the aerosol in the vessel was $\sim 3.5 \mu\text{m}$ (AED_{50}).^{*}

The data presented in Table 4 indicate that for low humidities and low aerosol concentrations (best conditions for not plugging the capillary), $\sim 60\%$ or more of the mass which emerged from the capillary was $\geq 7 \mu\text{m}$ (AED_{50}). In addition, the analysis of the sodium content on the final filter shows that only 27% of the entering aerosol penetrated the capillary. Therefore, for the above conditions, passage through the capillary reduced the respirable aerosol to $\sim 11\% = (27\% \times 40\%)$ of the mass of the entering aerosols.

The photographs in Figure 8 present the entrance plugging sequence when conditions are proper for this type of plugging. These capillaries were exposed to concentrations ranging from 4 to $16 \mu\text{g}/\text{cm}^3$, humidities of 3000 to 3400 ppm, and pressure differentials of 0.068 to 0.2 atm.

D. SUBTASK D - HIGH TEMPERATURE-CONCENTRATION AEROSOL TESTS

1. Introduction

The purpose of the high temperature-concentration aerosol (HTCA) tests is to characterize the formation and evolution of aerosols following a Hypothetical Core Disruptive Accident (HCDA) and subsequent bubble rise to the cover gas space. To generate the aerosols, a sodium-oxygen "blow torch" has been constructed which produces a very concentrated aerosol in a tank. It has been found that agglomeration and fall-out in the first few seconds following formation greatly diminishes the concentration and increases the mean size of the aerosol. Thus, even in the presence of a sizeable gas leak from the cover gas space to the reactor containment, escaping aerosols will be strongly attenuated.

^{*}AED = Aerodynamic Equivalent Diameter

TABLE 3
DATA FOR TESTS 39 TO 41

Capillary Number*	Aerosol Concentration (g/cm ³)	Vessel		Flow Through Capillary (liter)	Time to Plug (min)	ΔP to Unplug (atm)
		Pressure (atm)	Humidity (ppm)			
1	~20 to 5	1.07	1,100	11		Did not plug†
2	~5	1.07	~1,100	7	3	
3	6 to 10	1.07	3,500	~2	0.6	0.6
4	6 to 10	1.07	~3,000	22.5	4-6	>0.6
5	2.6 to 3.5	1.07	~2,500	~5	3-4.5	0.54
6	9.4	1.14	~2,500	1.4	1-5	0.68
7	9 to 13	1.34	~2,100	2.0	<0.25	Did not unplug at 0.68 ΔP
8	9 to 13	1.34	1,350	117.0	117.0	Did not plug
9	24	1.07	6,000	1.35	0.15	~0.4
10	18	1.07	~5,000	1.8	0.5	0.17
11	27	1.14	~4,000	3.0	0.35	0.64

*Capillary 1, 0.29-cm diameter by 13 cm; Capillaries 2-11, 0.127-cm diameter by 5 cm

†Capillary 1 flow reduced from 19.5 liter/min to 0.28 liter/min

TABLE 4
DATA FOR TEST 42

Leak Path	Initial Flow (liter/min)	Aerosol in Vessel		Humidity (ppm)	Aerosol Emerging Mass $\geq 7\mu\text{m}$ (%)	Vessel ΔP (atm)	Volume-to Plug (liter)	Remarks
		Concentration ($\mu\text{g}/\text{cm}^3$)	Size AED ₅₀ (μm)					
Capillary 1*	5.5	5	2	3800	68	1.08	—	Did not plug
Capillary 2*	5.5	5	2.5	<3800	64	1.068	—	Did not plug
Capillary 3*	14	~ 3.5	3.5	~ 3000	59§	1.34	—	Did not plug
Crack 1	7	22	3.1	<3000	17	1.068	0.72	
Crack 2	7	14	2.5	<2500	35	1.068	1.6	
Crack 3†	18.5	~ 13	4.0	3800	50	1.34	3.0	
Crack 4	25	~ 13	4.0	3800	—	1.34	<0.6	Plugged in 0.1 min

*Capillary sizes = 0.129-cm diameter by 5 cm

†Flow rate reduced to 7% in 0.3 min

§Filter mounted at exit of capillary; analysis of collected mass indicated capillary filtration efficiencies of 63% at a flow rate of 3 liter/min, and 87% at a rate of 0.122 liter/min

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Figure 8. Entrance Plugging Sequence

2. Test Results

During this report period, five HTCA tests were conducted. These tests were designated 9, 10, 11, 12, and 13 in the test series. Considerable in-vessel and ex-vessel instrumentation have been added along with system modifications during this testing period. The automatic aerosol fallout sampling device, linear voltage differential transformer (LVDT) scale, was used during Tests 9 through 11 but functioned successfully only on Test 10. Between Tests 9 and 10 a new floor fallout and wall plateout sampling device was installed. This sampling device is manually operated to expose 6.5 cm^2 of clean surface area at two positions on the vessel wall and at one position on the floor per increment of movement. Ex-vessel instrumentation developed for the test series included fixed volume aerosol concentration samplers which are attached to the test vessel at three locations. These samplers are actuated during the 0- to 0.25-min period after completion of the spray. The sodium injection system was modified to reduce the down-time experienced between tests. Modifications included adding a pneumatically operated valve on the sodium reservoir and reorienting the outlet of the reservoir to a vertical downward outlet. This modification removes the U-tube transfer line previously used. To reduce the injection time, two spray nozzles are connected to the sodium reservoir outlet. Preliminary tests with water indicate that 250 g of sodium can be ejected in a 2.5-s spray period. Figure 9 is a schematic of the current HTCA test apparatus configuration.

Tests 9, 10, and 11 yielded some useful information, although the intense 1000°C gas temperature within the flame region was very detrimental to the in-vessel instrumentation. During Test 10, the automatic LVDT fallout sensor functioned properly and indicated that 90% of the aerosol fallout occurred within a 30-s period. Test 11 showed similar results for wall plateout. Analysis of the incremental wall plateout collector showed that 90% of the plateout occurred within 12-s and 94% within 24-s.

Tests 12 and 13 were conducted to define the initial conditions of the HTCA test series. During each test, $\sim 30 \text{ g}$ of 540°C sodium were released into the

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Figure 9. Schematic of HTCA Test Apparatus

test apparatus. The atmosphere was inerted to 0 vol % O_2 on Test 12 to determine the size of the droplets produced during a spray. Test 13 was conducted in a 21 vol % O_2 atmosphere to determine the initial size of the Na_2O_x aerosols. Sodium drops collected on the floor of the test apparatus were microscopically examined to determine the size distribution. Results show that the drops produced from the spray nozzle ranged from 0.9- to 3.5- μm diameter, with the average being 2.6 μm , see Figure 10. Impactor data show the initial size range to be 0.5 to 1.0 μm AED₅₀. A second impactor sample, taken 30-s after the spray, showed the airborne particles to be of 1.6 μm AED₅₀. During Test 13, where the atmosphere was 21 vol % O_2 , impactor samples were taken at the completion of the spray and 30-s after the spray. The first sample showed the aerosols to be of 1.1 μm AED₅₀ and the second to be 3.9 μm AED₅₀. It was noted that 79% of the mass collected on the first sample was >7 μm . A fallout chamber was connected to the test apparatus and a sample collected during the spray. Figure 11 distinctly shows the 1- μm primary particle and also a large 400- μm agglomerate. This large aerosol particle is very branched in composition and can be seen to be comprised of the primary 1.1- μm particles.

These tests showed that the size distribution of the sodium oxide aerosols produced during the sodium spray fire was independent of the original sodium drop size. The large particles observed during the burning period were formed by agglomeration.

Future tests conducted in the HTCA series will continue to characterize the aerosol behavior during the early spray period.

E. SUBTASK E - AEROSOL SOURCE TERM FROM VAPORIZED FUEL

1. Introduction

In a transient overpower (TOP) accident in an LMFBR, a neutron flux pulse of short duration (~ 1 ms) can deliver several kilojoules per gram of energy density to the fuel and vaporize it. The condensate aerosol may be a uranium or plutonium oxide or sodium uranate/plutonate. Atomics International is simulating the TOP by vaporizing wires of appropriate materials with equivalent energy, fast electric pulses in order to measure the effects of varying

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Figure 10. HTCA Initial Sodium Spray Drop Size

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Figure 11. HTCA Initial Na_2O_x Aerosol Size

cover gas density and chemistry, injected energy density, and sample properties on the particle size distribution.

2. Test Results

The effort to quantify the effect of cover gas density on the aerosol's mean particle size was continued this quarter. Several uranium wires were vaporized in a 1-atm Kr - 2% O₂ cover gas at specific energies of 2-5 kJ/g and the aerosols collected in an impactor. Figure 12 shows the resultant data. When the aerodynamic equivalent (cut-off) diameter of a given stage is plotted on probability paper as a function of percent of particles larger than that size, the result should be a straight line if the size distribution is log-normal. Distributions observed for the U (Kr) case were approximately log-normal with mean particle sizes falling above those derived for the U (Ar) and U (Xe) cases (Figure 13). This was expected since the density of krypton is intermediate between argon and xenon at constant pressure which should lead to an intermediate diffusion rate for UO₂ aerosol particles in krypton.

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Figure 12. Uranium Oxide Particle Size Distribution in Krypton Gas

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Figure 13. Uranium Oxide Geometric Mean Particle Size vs Specific Energy

In addition, the problems previously encountered with molybdenum aerosols were reexamined. Molybdenum or tungsten aerosols are interesting as preliminaries to direct UO_2 vaporization because of their comparable melting points. Thus, the effect of sample melting point on the particle size distribution might be examined without the difficulty of having to preheat the (UO_2) sample to increase its conductivity before vaporization. Molybdenum ribbons were vaporized in Ar - 2% O_2 , Kr - 2% O_2 , and Ar - Kr - 2% O_2 mixtures at a specific energy of ~ 2.2 kJ/g. The resultant data are shown in Figure 14.

An absorption cryopump has been added to the gas flow system of the exploding wire apparatus in order to conserve expensive heavy rare gases. This has allowed storage of xenon or krypton gas in the system for up to several weeks. In addition, the electrical discharge system is now being modified to allow for clamping and preheat of UO_2 wire samples which have been obtained from Argonne National Laboratory.

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Figure 14. Molybdenum Oxide Geometric Mean Particle Size vs Relative Gas Density

F. SUBTASK F - PROPERTIES OF HIGH TEMPERATURE FUEL MIXTURES

1. Introduction

A facility for arc melting and pouring large quantities (10 to 100 kg) of UO_2 or stainless steel has been constructed. The UO_2 will be used as a simulant for fuel which might melt during a reactor accident. It is desirable to study the consequences of such an accident by interacting molten UO_2 with stainless steel, sodium, concrete, or sacrificial material. The arc melter is capable of melting and pouring the equivalent of a single fuel element.

The several uses of the molten UO_2 are to: (1) study the production, agglomeration, and dispersal of fuel aerosol; (2) test the interaction of molten UO_2 and sodium, particularly in regard to any reaction-producing overpressure; (3) determine the rate of melt-through of the reactor vessel, underlying concrete, and/or sacrificial material used to retard melt-through; and (4) study post-accident heat removal and containment rupture problems in general.

2. Facility Description

At present, the arc furnace, vacuum system, and cooling system have been installed. A 1-MW substation has been constructed to supply the furnace.

A former reactor building has been decontaminated and refurbished in order to house the arc melter. Of the building's two levels, the upper level is used for power supplies, laboratories, and office space; the lower level is subterranean and contains the arc melter.

The melting crucible is double-walled copper with cooling water flowing between the walls directed toward the bottom and tangentially on the sides. During operation, some UO_2 remains frozen in a skull next to the copper, while the remainder is melted in the center by the high current arc. About 100 kg of UO_2 can be contained, of which 70 kg can be melted.

The electric arc passes from a stinger electrode to the UO_2 surface and then through the UO_2 to the copper hearth. The stinger is a 10-cm-diameter, hollow, water-cooled copper rod with a graphite tip. Its vertical position is automatically controlled by a servomotor so that the arc voltage drop is 40 V.

To start the arc, it is necessary to contact a metallic electrode embedded in the UO_2 , since cold UO_2 is an insulator.

Pouring the melt is accomplished by quickly withdrawing the stinger and tilting the crucible by means of motor drive. The melt can either be poured within the tank or through a large valve in the bottom of the tank.

The power supply for the melter consists of eight heavy-duty welder supplies with outputs connected in parallel. Four of the supplies have a capacity of 1500 A and four are 1000 A, to make a total of 10,000 A. During operation, the supplies operating at full power are switched off or on as needed. Skull arc melting is accomplished by strongly heating the surface of the substance to be melted while cooling the crucible. More heat must be supplied by the arc than escapes to the crucible walls or radiates from the surface. It is difficult to calculate the heat balance because of unknown heat conductivity of the melt. The degree of stirring within the melt will greatly affect the heat conductivity. Nevertheless, estimates have been made which show that the power supply has adequate capacity for melting 70 kg of UO_2 .

3. Startup Tests

The purpose of these tests is to develop the technique of melting and pouring large quantities of UO_2 . Stainless steel was melted initially as it melts at a lower temperature and is needed as a crucible liner. Such parameters as arc voltage, arc current, furnace pressure, electrode materials, etc., must be established. The sequence of startup tests is outlined in the following paragraphs.

In the first test, stainless steel was melted and then poured into an in-vessel receiver, a tray lined with sand. Two of the power supplies were used to provide about 2500 A current. One difficulty experienced was the occasional arcing to the copper crucible rather than the melt. This caused boiling or outgassing of the cooling water which was cooling the region of the crucible in contact with the arc. The cooling water bumped and surged rather than flowing steadily. A partial solution to this problem was to increase cooling water flow rate and to minimize the magnetic effects of the current leads. While arcing to the crucible has been mostly eliminated, it is planned to direct a flow of argon gas around the periphery of the vessel to completely prevent arcing to the crucible.

In a second test, a small amount of UO_2 (60 g) was placed in the crucible on top of stainless steel. The UO_2 was strongly heated and then melted by the arc. Figure 15 is a photomicrograph of a small piece of UO_2 residue left on top of the stainless steel after melting. This demonstrates that actual melting has taken place because the granular structure associated with sintered UO_2 is not present.

In a third test, stainless steel was melted and poured onto a slab of concrete. The primary purpose of this test was to develop pouring techniques rather than provide much useful data in connection with past accident heat removal (PAHR) by concrete. A photograph of the slightly spalled region of concrete under the molten stainless steel is shown in Figure 16. Temperature rise of the concrete about 2.5 cm under the surface was only 35°C . For PAHR tests it will be necessary to maintain the stainless steel molten after the pour in order to adequately characterize concrete resistance to molten stainless steel attack.

In a fourth test, a bottom liner of stainless steel was cast within the crucible. This liner will be used in subsequent tests with UO_2 where it will provide a thermal barrier between the copper crucible and the UO_2 skull. UO_2 must be heated several hundred degrees before it will conduct electricity appreciably. It is desired to keep the UO_2 at the crucible bottom at least 1500 K. This will sinter the initial charge of powder UO_2 into a skull liner at the bottom of the crucible. Along the cylindrical side of the crucible, the UO_2 will also sinter except where it contacts the cold wall of copper. This is a desirable condition because the cold powder UO_2 will form an insulation layer along the wall and prevent both appreciable heat and electrical current from flowing into the side wall of the crucible.

4. Conclusions and Planned Activities

First, experiments with the arc melter have demonstrated the ability to melt stainless steel and UO_2 . Tests at full power will take place as soon as some further electrical connections are made. To adequately test PAHR mechanisms, it will be necessary to pour large quantities of materials and to maintain the material molten for some time after contact. Methods of doing so are under review and will be developed in the next report period.

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Figure 15. Photomicrograph of
Arc Melted UO_2 (100X)

Figure 16. Photograph of Results of
Pouring Molten Stainless Steel Onto
Concrete

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IV. NEXT REPORT PERIOD ACTIVITIES

A. SUBTASK A - SOMIX

Analysis of the experimental data on the falling drop burning tests will be completed and compared with the drop burning model. The burning model will be incorporated into SOMIX-I before the code is submitted to the Argonne Code Center, along with a User's Manual.

B. SUBTASK B - SODIUM JET DISPERSAL

Additional falling drop tests will be conducted to determine the effects of humidity on the ignition of sodium drops and the effect of burning on the terminal velocity of a drop.

C. SUBTASK C - AEROSOL LEAKAGE

Aerosol leakage tests will be initiated through simulated reactor head plug cracks.

D. SUBTASK D - HIGH TEMPERATURE-CONCENTRATION AEROSOL

Characterization of high temperature-concentration aerosols will continue.

E. SUBTASK E - AEROSOL SOURCE TERM

Analysis of the aerosol source term experiments will be completed and a test report issued.

F. SUBTASK F - PROPERTIES OF FUEL MIXTURES

Tests, melting various quantities of UO_2 and pouring the melt onto concrete, will be conducted in the arc-melting test apparatus.

G. SUBTASK L - ANALYTICAL ASSESSMENTS

Analytical examination of bubble reactivity is expected to make substantial progress.

H. SUBTASK M - AEROSOL RELEASE

Laboratory experiments will be conducted to verify and calibrate selected aerosol samplers which will be used on the aerosol release tests. A test plan for the test series will be prepared and issued.

REFERENCES

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