TRANSCO PRODUCTS INC.

Test Report No. ITR-93-02N

Measurements on the Sink Rate and Submersion Time for Fibrous Insulation

Test Performed By: Fluid Mechanics Laboratory,
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A CORPORATION OF THE TRANSCO GROUP

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report prepared by

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for

TRANSCO PRODUCTS, INC.

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Introduction

Should a loss of coolant accident (LOCA) occur in a nuclear power plant it is essential for the emergency core cooling system (ECCS) to operate efficiently. Debris generated during the accident by pipe breaks and jet impingement on lagging could potentially find its way to the sump screens covering the intake to the ECCS. If the debris accumulation is sufficient, then the flow rate through the ECCS may be reduced. It is possible that the thermal insulation on pipes and equipment in containment may be a principle source of the debris. Consequently there have been many experimental, theoretical and numerical investigations aimed at characterizing and understanding the behavior of fibrous insulation debris. Most of the investigations on fibrous insulation have been concerned with the amount of debris generated and the head loss that occurs if the debris collects on the sump screen.

One important area that has not received much attention is the rate that the insulation will sink in a pool of water to the containment floor. If the insulation is dislodged in containment after water has collected on the floor, then the time for the insulation to sink may become an important factor. This report discusses measurements designed to investigate the behavior of fibrous insulation that falls on the free surface of water and its rate of descent through water. The effects of insulation size and water temperature have been studied.

Experimental Set Up and Procedure

All experiments were conducted with ordinary neutral pH tap water placed in a large stainless steel tank (31 inch diameter and 36 inches depth). The water depth used during these tests varied from 18 inches to 24 inches. The water was heated with a 4 kW Thermo-coil immersion heater. The maximum temperature that could be reached was 91°C. Water temperature was measured with an Omega model 450 thermocouple placed in the center of the tank.

The test samples were cut from Thermal Wrap® insulation supplied by Transco Products, Inc. Four different sample sizes were cut from the as-fabricated 24"x24"x2" sheets. Sample sizes were 1/4x1/4x1/8, 1x1x1, 4x4x1 and 8x8x1. Additional tests were conducted on pillows with fiberglass covers with dimensions 12x12x2. In this report the samples are referred to by their largest dimension, i.e. 1/4, 1, 4, 8 and 12 inches, respectively. No attempt was made to simulate aging by heating the samples. After the samples were cut from the 2 inch thick sheet, they were torn in half to form two 1 inch thick samples. This left one side fluffy and the other side with a finished appearance. The water was heated to the desired test temperature before the sample was placed horizontally on the surface. It was allowed to sink under its own weight. Air was not manually pressed out of the insulation by preconditioning.

It was clear from preliminary tests that two separate phenomena were occurring, i.e., submersion of the sample and free-fall sinking to the bottom of the tank. In most cases the samples did not sink immediately, but floated on the surface while they absorbed water. Once the sample absorbed enough water to sink below the free surface, it began its free fall at a higher velocity toward the bottom. Therefore, two time measurements were recorded for each sample tested; namely, the time for complete submersion, t_{sub}, and the total time for the sample to reach the bottom of the tank, t_{tot}. The sink rate of the sample was defined as $(t_{tot}-t_{sub})/L$, where L was the distance to the bottom of the tank.

Even though the insulation samples were placed horizontally on the water surface, they did not always fall horizontally. Non-uniformities in the density of the insulation often caused the water to soak through one corner of the insulation first. This corner would sink, and the sample would rotate 90° to a vertical orientation. Occasionally air bubbles would be trapped inside the samples, which greatly reduced their sink rate. As a result, the variation in submersion time and sink rate was high from sample to sample.

Results - submersion time

Measurements of the time for samples of insulation to become saturated with water and sink below the surface are shown in Table 1. The data are plotted in Fig. 1 as t_{sub} (seconds) against the water temperature T(°C). The strong dependence on temperature and sample size can be seen in the log-log plot. The values of t_{sub} cover five decades in time for temperature ranging from 36°C to 91°C. As the temperature *increases* the submersion time *decreases* significantly. Regression analysis on the data showed the sink rate to vary like T^{-5}. At 36°C the 8 inch samples required several hours to submerge, while the same size sample only needed 6 seconds to submerge at 91°C.

In general, the small size samples submerge faster than the large samples. At 36°C the 1/4 inch samples submerged within 2 seconds exposure compared to 4 hours for the 8 inch samples. The pillows did not sink at temperatures below 56°C. The sample to sample variation in t_{sub} was very large. From the appearance of the insulation it seemed possible that non uniformity in the density of the insulation caused large variations in the rate of absorption of water, as well as trapping air inside. Therefore, the same size samples would have large differences in t_{sub}.

Table 1

Size\temp	91oC	81oC	78oC	71oC	63oC	56oC	45.5oC	36oC
0.25	0	0.5			1	33	2.8	1.5
1	0.7	3.3	1	2.1	8.1	7.2	12	5.3
4	6.1	7.6	7.5	45	129	186	113	300
8	6	53	14.1	324		270	1,630	14,400
12	48.9	51		67	148			

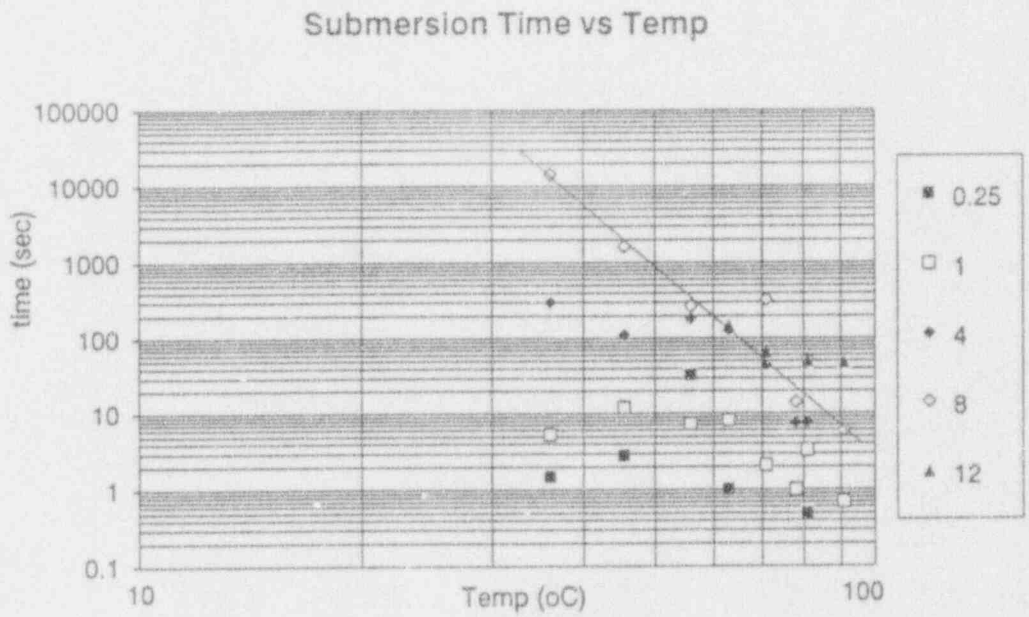

Figure 1 - Submersion time dependence on temperature.

The best-fit to the data obtained from multiple-regressions was found to be

$$\text{Submerge time (sec)} = 1.245\times10^{10}\,(\text{Size in.})^{1.745}(\text{Temp}^{o}\text{C})^{-5.035}$$

where Size is a characteristic length in inches and Temp is the water temperature in Celsius. The standard deviation between the data and regression formula was 60%.

Results - Sink Rate

The data for the sink rate at different tempeartures is shown in Fig. 2. Each line represents a different size sample ranging from 1/4 inch to 12 inches. The sink rates range from 0.91 in./s to 10.24 in./s. For a given sample size it can be seen that the sink rate is very weakly dependent on the water temperature. The slight increase in the sink rate with increasing temperature may be associated with the change in water viscosity. However, the scatter in the data is too large to draw a definite conclusion. The large scatter in the 8 inch and 12 inch samples is believed to be caused by trapped air. The sink rate has a stronger dependence on sample size.

The sink rate data for different sample sizes are shown in Fig. 3. Each line represents a different temperature. The data show a nearly linear increase with sample size. Linear regression gives a best-fit relation of

$$\text{Sink Rate (in/s)} = 0.45 \times \text{Size (in.)} + 1.22$$

for the data in Fig. 3.

Table 2

Size\Temp	91oC	81oC	78oC	63oC	58oC	45.5oC	36oC
1/4x1/4	1.10	1.54	1.10	1.46	1.06	0.91	1.10
1x1	2.56	2.32	2.24	2.52	2.28	1.93	1.30
4x4	3.23	3.46	3.07	3.66	2.91	2.56	2.76
8x8	2.01	2.91	5.12		2.09	5.12	
pillow	6.06	10.24	6.69	7.87			

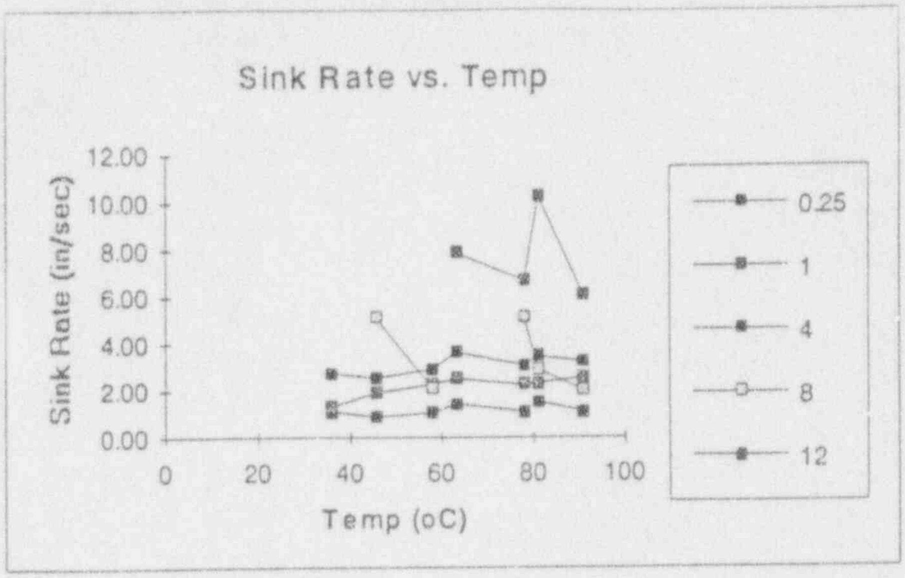

Figure 2 - Sink rate dependence on temperature

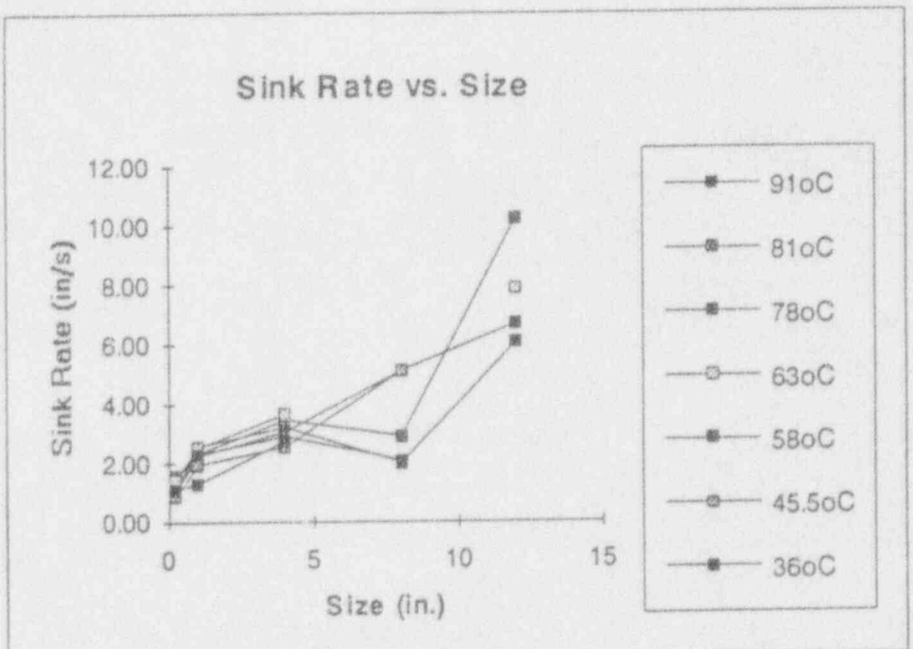

Figure 3 - Sink rate dependence on sample size.

Conclusions

The experiments have shown that two separate phenomena occur when fibrous insulation falls into a pool of water and sinks to the bottom. First is the submersion process that occurs while the sample floats on the water surface. This process is extremely sensitive to the water temperature. The submersion time decreases with increasing water temperature. The size of the debris is also important, since larger samples require more time to submerge than small samples.

The second phenomenon is the free fall sinking to the bottom of containment. This process is very weakly dependent on temperature. More important is the debris size. Larger debris sinks faster than small size samples.

TRANSCO PRODUCTS INC.

Test Report No. ITR-92-03N

Experimental Measurements on the Characteristics of Flow Transport, Pressure Drop, and Jet Impact on Thermal Insulation, NRC Guide 1.82

Test Performed By: Fluid Mechanics Laboratory,
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EXECUTIVE SUMMARY

TRANSCO PRODUCTS INC. commissioned Dr. Dave Williams, Professor of Mechanical Engineering, Fluid Mechanics Laboratory at the Illinois Institute of Technology (IIT) to perform test associated with USNRC Reg. Guide 1.82 on two samples of insulation. The insulation supplied was only identified as Series A and B. Series A insulation is the insulation that TRANSCO PRODUCTS INC. utilizes in the construction of Thermal-Wrap® blanket insulation. Series B insulation was a comparative product not currently in use by TRANSCO.

The results as reported indicate that the Series A insulation performed more effectively than the Series B insulation. The data that specifically applies to TRANSCO's insulation is shown in tables 1, 3, 5 and in figures 2, 3, and 4. The data in Table 1 shows the test results on transport for Series A insulation, which includes sample size, transport speed, flip-up speed, and additional comments. Table 3 data is results on head loss tests for preconditioned Series A insulation, indicating flow speed, sample size, nominal thickness, and associated head loss. The table also includes a column for series A insulation which was not preconditioned for the test. Using data from these tests a regression analysis was performed to obtain the best fit equation to the results. Table 5 shows a summary of regression equations for different debris conditions of Series A insulation. The equation for unconditioned shreds shown below is used to evaluate the expected head loss in the sump analysis.

$$\Delta H = 1285\ T^{-0.54}\ e^{1.32}\ v^{2.08}$$

where:

$\Delta H \equiv$ Head Loss in feet of water
$T \equiv$ Water Temperature in °C
$e \equiv$ Insulation bed thickness in feet
(Volume of insulation divided by the screen area)
$v \equiv$ Approach flow velocity in feet per second

The data on the thickness and the flow rate for Series A can be seen in Figures 2, 3, and 4. In all cases shown, the insulation was preconditioned. Figure 8 shows the sensitivity of the head loss to the water temperature, which is consistent with published data for the decrease (like $T^{-.549}$) in viscosity of water.