GPU Service

GPU Service Corporation
260 Cherry Hill Road
Parsippany New Jersey 07054
201 263-4900

November 17, 1979

Mr. J. T. Collins
USNRC
Three Mile Island Site
P.O. Box 311
Middletown, PA 17507

Dear Mr. Collins:

As you requested, attached is a summary of our technical evaluation of winterization requirements for the Temporary Solid Waste Staging Facility, wherein we concluded that it is not necessary to provide an external heat source for the liners to protect against potentially adverse effects of freezing. As we discussed on November 2, 1979, this conclusion was based on our analysis of conditions inside the cell, which showed that even under very severe weather conditions, insulation provided by surrounding soil will naturally maintain interior cell temperatures above freezing, combined with information provided by the resin suppliers which shows that freezing, if it were to occur, would not be hazardous to resins or liners. In addition we pointed out the significant complexity involved in providing an external heating system which would be reliable and maintainable for an extended period within loaded cells.

Subsequent to the meeting on November 2, 1979, you requested that we confirm that measures will be taken to ensure that there is essentially no air exchange between cell interior and ambient, for loaded cells. This condition will be prevented by caulking, as presently required by approved procedures.

Details of our analysis are attached for your information

Based on our agreement on this matter, we have discontinued engineering work on the cell heating system.

Please advise if you have any questions on the above.

Very truly yours,

J. C. DeVine, Jr.

Approved: R. F. Wilson

JCD:GMS:gp

7912040 104

P

cc: R. C. Arnold
J. C. DeVine, Jr.
G. M. Staudt
R. J. McGoey
J. Pearson

I. PURPOSE AND SUMMARY

This report summarizes the discussions held with Mr. J. T. Collins, NRC, on November 2, 1979., It describes the heat transfer aspects of the temporary staging facility for the winter month, and effects of temperature on the resins and liners.

Information in this report was initially developed in the course of defining design requirements for winterization of the temporary staging facility.

As the information was compiled it was noted that even under extended conditions of extreme cold (0°F) outside, the temperature inside the cells should be above 32°F due to the insulation provided by the earth work around the cells. Furthermore, it was learned that there should be no detrimental effects on resins which undergo freeze-thaw cycles and that because there is substantial free volume within the liners (approximately 44% due to both free/board and free space within and amoung resin beads), the liners should not be stressed or damaged in any way by freeze-thaw cycles

II. CALCULATION OF TEMPERATURE IN THE TEMPORARY STAGING FACILITY

Heat transfer calculations were done to determine the temperature in the temporary staging facility cells during winter conditions. A steady state heat balance around a cell was used to calculate the temperature in the cell. An iterative calculation was used as the temperature of the air in the cell was necessary for calculation of the film coefficients used in the heat balance. The steps of this method are given on page 2 of the attached calculations (Attachment 1). The steps are as follows: 1) Assume the temperature of the air in the cell and also the inside temperature of the concrete plug(these temperatures will be used in estimating the heat transfer coefficients and heat losses), 2) Calculate the film coefficient for the bottom of the concrete plug and also the total heat transfer coefficient through the plug, 3) Calculate the total heat loss through the concrete plug, 4) Calculate a new inner temperature of the plug based on values calculated in steps 2 and 3, 5) Calculate a new film coefficient for the plug based on the new inner plug temperature calculated in step 4, 6) Calculate the film coefficients of the other areas of heat transfer in the cell, 7) Do a heat balance to determine the temperature of the air in the cell; if this temperature is the same as the initial assumption in step 1 then calculation is complete; if temperature is different then use the latest values calculated in steps 4 and 7 for the assumed temperature in step 1.

Several assumptions were used in order to perform this calculation: 1) Outside air at a constant 0°F (ie outside air temperature for entire winter 0°F). This is an ultra-conservative assumption as when 0°F is compared to the average temperature history for the years 1946 to 1979(Fed. Safety Analysis Report Vol. 1, 2, 3-14) it can be seen that for no long periods of time was the temperature at 0°F or below. 2) The frost line was 3 feet deep. This is conservative, the area's frost line is typically 18"-24". 3) The earth surrounding the cell would exhibit a straight line temperature profile. 4) Down to a level of 8 feet the ground temperature is dependent on the air temperature above the ground and at 8 foot and below the ground is at a constant temperature of 50°F. The assumption was taken from Couriers Air Conditioning Design Book, 1965, pgs. 1-81.

Based on the above assumptions the average temperature to a depth of 3 feet is 16°F which covers 66 square feet of the cell's surface area and the average temperature from 3 feet to 8 feet is 41°F which covers 110 square feet of the cell's surface area. A final assumption is that there is no air exchange between the air in the cell and the outside air. This is necessary for an accurate heat balance. Provisions for a water tight seal which would also insure an air tight seal are required in the operating procedure for the staging facility. (Transfer of radioactive resin liners from Epicor I to temporary on-site staging facility and from temporary staging facility to shipping cask, # 2104-4.13, step 4.21, pg. 5.) This step of the procedure requires that the sealing surface be caulked prior to setting the cap on the cell.

Under the conditions mentioned above the temperature in the cell was determined to be 32.7°F. A copy of the calculations is attached (Attachment 2). This temperature is a conservative estimate since assumptions used represent a most extreme case.

III. RESIN LINER INTEGRITY

Following usage in the Epicor I or Epicor II Radwaste System, carbon steel liners containing resin beads are dewatered. For a typical 4' x 4' liner used in Epicor II, there is approximately 16 Ft^3 of water chemically bound in the matrix of hydration of the resin beads following dewatering. When freezing occurs, this expands to approximately 16.3 Ft^3. A typical dewatered liner contains 4 Ft^3 of void space between the top of the resin and the top of the liner, and 19 Ft^3 of void space within the resin itself. This provides a total volume of 23 Ft^3 for the 0.3 Ft^3 volumetric expansion of water to take place. With this understanding, it is apparent that sufficient room within the liner exists for the expansion of water so that the liner should not be subjected to expansion forces, and therefore, its integrity not jeopardized.

Experimental tests were conducted in support of verifying the effects of freezing a spent resin liner. At first conditions similar to an Epicor II dewatered liner were established and the container frozen. This test showed no detrimental effects. Conditions were then worsened to represent an extremely conservative situation:

1. 100% of Line Volume Filled with Resin
2. Resin Only 75% Dewatered
3. Glass Container
4. Container Fully Frozen

This test also showed no detrimental effects which supports the fact that water will expand into voids existing within resin beads and the liner volume and will not overstress the container itself.

IV. RESIN BEAD INTEGRITY

The last aspect of evaluating the effects of freezing resin containers deals with the resin beads themselves. Realizing the purpose of resins is to immobilize and retain radionuclides, it is of primary importance to understand what happens to resin beads during freezing and during freeze-thaw cycles.

Radionuclides are predominatly held by an electro-chemical bond to resin bead. Mechanical or physical disruption to resin has little to no effect on this bond. Therefore, as the chemically bound water in resin expands a bead will swell and if it is a physically weak bead it may crack. Cracking results in resin fines, however, it does not cause a chemical breakdown and therefore radionuclides will not be released. In a typical Epicor Resin Bead, 7.0% of the beads will expand and crack during a freezing condition. That is, the elastic strength of 7.0% of the resin beads will be overcome resulting in stress releiving with a bead by cracking. Freeze-thaw cycling has negligable effect since a resin bead is extremely elastic and does not undergo fatigue failure as metallic materials do. Therefore, it is expected that 7% of the resins will crack and create fines during a lifetime of resin freeze-thawing. The production of fines will have negligable effect on future solidification of resins since the solidification process and possible sluicing operation can be performed equally well with resin beads as will resin fines.

V. CONCLUSION

It is not expected that Epicor I and II liners will be exposed to freezing conditions even if they are stored in TMI Staging Facilities. The heat produced by radionuclide decay will also assist in maintaining resin container temperatures above freezing. However, should the containers freeze there will be no detrimental effect on the retention of radionuclides by the resin itself or detrimental affects on the liners.

GM Staudt

G. M. Staudt

J. C. DeVine, Jr.

GS/kd

Attachment

TMI-II-R-2160

CALC.NO.

GPU SERVICE

SHEET NO. 1 OF 9

DATE November 8, 1979

SUBJECT Temperature in Temporary Staging Facility

COMP. BY DATE

CHK'D BY DATE

Calculations Attached

SUBJECT: TEMPERATURE IN TEMPORARY STAGING FACILITY

PROBLEM STATEMENT

It is necessary to determine the temperature inside the cells of the temporary waste staging facility during winter conditions.

SUMMARY OF RESULTS

A steady state heat balance (iterative method) was used to determine the temperature in the cells. After 4 iterations the temperature in the cell was determined to be 32.7°F.

CONCLUSION

These calculations are provided as supporting information for determining wether a heating system for the temporary staging facility is necessary. The temperature in the cells should remain just above freezing during extreme conditions. This along with the properties of the resin materials to be stored in the cells indicate that a heating system should not be needed.

REFERENCES

1. Cariers Air Conditoning Design Book, 1965, pg. 1-81.
2. Unit Operations, McCabe & Smith, 1976, Appendix.
3. Principals of Heat Transfer, Kreith, 1976, Table H-3.
4. Chemical Engineer's Handbook, Perry, 1973, pg. 10-11, 10-12.
5. Figure1: General Cell Layout.

ASSUMPTIONS AND BASIC DATA

Assumptions:

1. Outside air at 0°F.
2. Frost line at 3'.
3. Straight line temprofile in earth.
4. Temperature at a depth of 8' is 50°F. Temperature constant at 50°F below 8'. (1)
   This gives an average temperature of 16°F from 0 to 3 feet deep, which covers 66 square feet of surface area of the cell. The average temperature from 3 feet to 8 feet is 41°F, which covers 110 ft^2 of surface area.
5. No air exchange from the outside of the cell to the inside of the cell.
6. No film coefficient was used on the outside of the plug. (This would tend to make our results more conservative as an outside film coefficient would be one more resistance to heat flow.)

BASIC DATA

Properties of Air at 32°F (2)
Density = ρ = .0808 16/$ft.^3$
Viscosity = μ = .040/ 16/hr.ft.
Thermal coefficient of expansion = β = .002
Thermal conductivity = k = .014 BTU/hr.ft.°F
Heat capacity = Cp = .25 BTU/16°F
Acelleration due to gravity = g = 4.18 x 10^8 ft/hr^2

$$\frac{g\,\beta\,\rho^2}{\mu^2} = 3.16 \times 10^6 / {}^\circ F \text{ ft.}^3 \qquad (3)$$

SUBJECT Temperature in Temporary Staging Facility

COMP. BY DATE ______

CHK'D BY DATE ______

Correlation of Film Coefficients (4)

$N_{Gr} = L^3 \Delta T \frac{g \beta \rho^2}{\mu^2}$ $\quad N_{Pr} = \frac{C_p \mu}{k}$

$h = (K/L)\, a\, (N_{Gr} N_{Pr})^m$

$a = .13$, $m = 1/3$ } vertical Surface → L is height

$a = .14$, $m = 1/3$ } Horizontal Surface → L is diameter

Calculation of h through concrete $= h_p = h_{plug}$

$k_{conc} = .8$ BTU/ft hr °F

$h_p = \frac{k_{conc}}{thick} = \frac{.8 \text{ BTU/ft hr °F}}{3 \text{ ft}} = .2667$ BTU/hr ft² °F

Steps for iterative method heat balance

1.) Estimate inside air temperature, T_A, and inner temperature of concrete plug, T_p'.

2.) Calculate the inside film coefficient of the plug, h_{fp}, and the total resistance through plug, $h_{trp} = \frac{1}{1/h_{fp} + 1/h_p}$

3.) Calculate heat flow through plug, q_p.

4.) Calculate new inner temperature of plug, T_p'.

5.) Calculate the new inner film coefficient of the plug, h_{fp}.

6.) Calculate film coefficients for: 1.) lower walls $= h_{flw}$, 2.) base $= h_{fb}$, 3.) upper walls $= h_{fuw}$

GPU SERVICE

CALC. NO.

SHEET NO. 5 OF 9

DATE Nov. 3 1979

SUBJECT Temperature in Temporary Staging Facility

COMP. BY DATE

CHK'D BY DATE

7.) Do a heat balance to determine the temperature of the air inside cells, T_A.

8.) If T_A, calculated in step 7 is same as that estimated in step 1 then calculation is complete; if T_A calculated in step 7 is not equal to that estimated in step 1 the use latest values for T_p and T_A calculated in steps 4 and 7 respectively.

Begin Initial Iteration

Step 1: $T_A = 40\,°F$ $\quad T_p = 23.5\,°F$

Step 2: $h_{cp} = \left(\frac{.014}{7}\right)(.14)\left[(7^3)(16.5)(3.16\times10^6)(.716)\right]^{.33} = .655$

$$h_{ttp} = \frac{1}{1/.655 + 1/.2667} = .1895 \text{ BTU/hr-ft}^2\,°F$$

Step 3: $q_p = (h_{ttp})(\Delta T)(A)$

$= (.1895)(40)(38.5$

$= 291.85 \text{ BTU/hr}$

Step 4: $q_p = (h_p)(\Delta T_p)(A)$

$291.85 = (.2667)(T_p - 0)(38.5$

$T_p = 28.42\,°F$

SUBJECT Temperature in Temporary Staging Facility

COMP. BY DATE ______

CHK'D BY DATE ______

Step 5: $h_{fp} = .582$

Step 6: $h_{flw} = \left(\frac{.014}{5}\right)(.13)\left[(5^3)(1)(3.16\times10^6)(.716)\right]^{.33}$

$h_{flw} = .2389$

$h_{fb} = \left(\frac{.014}{7}\right)(.14)\left[(7^3)(10)(3.16\times10^6)(.716)\right]^{.33}$

$h_{fb} = .55435$

$h_{fuw} = \left(\frac{.014}{3}\right)(.13)\left[(3^3)(24)(3.16\times10^6)(.716)\right]^{.35}$

$h_{fuw} = .689$

Step 7: $\dot{q}_{\text{in lower wall}} + \dot{q}_{\text{in base}} = q_{\text{out upper wall}} + q_{\text{out plug}}$

$(h_{flw})(A_{lw})(\Delta T_{lw}) + (h_{fb})(A_b)(\Delta T_b) = (h_{fuw})(A_{uw})(\Delta T_{uw}) + (h_{fp})(\Delta T_p)(A_p)$

$(.2389)(110)(41 - T_A) + (.55435)(38.5)(50 - T_A) = (.689)(16)(T_A - 16) + (.582)(38.5)(T_A - 28.42)$

$T_A = 30.27°F\ (\neq 40°F$

Step 8: Next Iteration

Step 1: $T_A = 30.27°F \quad T_p = 28.42°F$

Step 2: $h_{fp} = .316 \quad h_{Hp} = .1446$

Step 3: $q_p = 168.56$

GPU SERVICE

CALC. NO.

SHEET NO. 7 OF 9

DATE Nov. 8, 1979

SUBJECT Temperature to Temporary Staging Facility

COMP. BY DATE

CHK'D BY DATE

Step 4: $T_p = 16.4$

Step 5: $h_{fp} = .6179$

Step 6: $h_{flw} = .5269$

$h_{fL} = .695288$

$h_{fuw} = .5795$

Step 7: $T_A = 32.14°F \; (\neq 30.27°F)$

Step 8: Next Iteration

Step 1: $T_A = 32.14\,°F \quad T_p = 16.4°F$

Step 2: $h_{fp} = .6448 \quad h'_{rrp} = .1719$

Step 3: $q_p = 212.78$

Step 4: $T_p = 20.7\,°F$

Step 5: $h_{fp} = .58$

Step 6: $h_{flw} = .4944$

$h_{fL} = .672589$

$h_{fuw} = .6038$

GPU SERVICE

CALC. NO. ______

SHEET NO. 8 OF 9

DATE Nov. 8, 1979

SUBJECT Temperature in Temporary Storage Facility

COMP. BY DATE ______

CHK'D BY DATE ______

Step 7: 32.469 °F ($\approx$ 32.14)

Step 8: This is close but let's go once more

Step 1: $T_A = 32.469$ °F $T_P = 20.7$ °F

Step 2: $h_{fp} = .58529$ $h_{Hp} = .1831$

Step 3: $q_p = 228.88$

Step 4: $T_P = 22.2$ °F

Step 5: $h_{fp} = .5592$

Step 6: $h_{flw} = .4632$

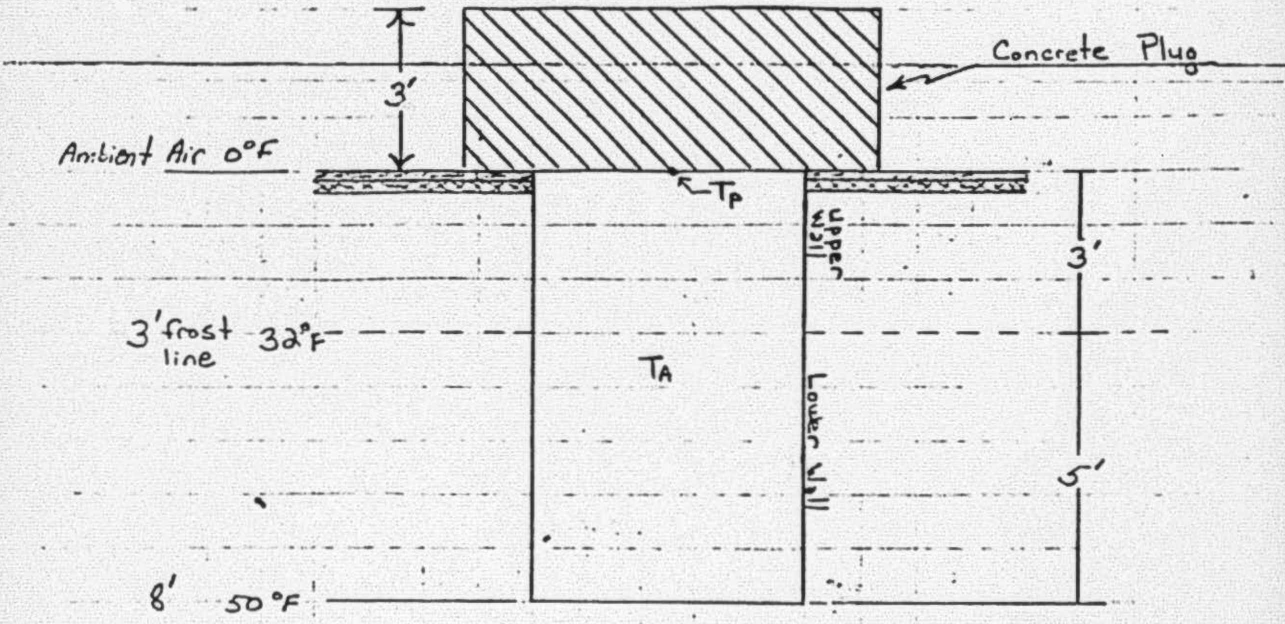
$h_{fb} = .66843$

$h_{cuw} = .6078$

Step 7: $T_A = 32.7$ °F ($\approx$ 32.5 °F)

Step 8: This is close enough $\Rightarrow$ Temperature in cell

is $T_A = 32.7$ °F



T_P = Temperature on inside of plug
T_A = Temperature of inside Air

Figure 1: General Cell Layout