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HEATING, VENTILATING, AND AIR CONDITIONING DEACTIVATION THERMAL ANALYSIS OF PUREX PLANT

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ABSTRACT

Thermal analysis was performed for the proposed Plutonium Uranium Extraction Plant exhaust system after deactivation. The purpose of the analysis was to determine if enough condensation will occur to plug or damage the filtration components. A heat transfer and fluid flow analysis was performed to evaluate the thermal characteristics of the underground duct system, the deep-bed glass fiber filter No. 2, and the high-efficiency particulate air filters in the fourth filter building. The analysis is based on extreme variations of air temperature, relative humidity, and dew point temperature using 15 years of Hanford Site weather data as a basis. The results will be used to evaluate the need for the electric heaters proposed for the canyon exhaust to prevent condensation.

Results of the analysis indicate that a condition may exist in the underground ductwork where the duct temperature can lead or lag changes in the ambient air temperature. This condition may contribute to condensation on the inside surfaces of the underground exhaust duct. A worst case conservative analysis was performed assuming that all of the water is removed from the moist air over the inside surface of the concrete duct area in the fully developed turbulent boundary layer while the moist air in the free stream will not condense. The total moisture accumulated in 24 hours is negligible. Water puddling would not be expected. The results of the analyses agree with plant operating experiences.

The filters were designed to resist high humidity and direct wetting, filter plugging caused by slight condensation in the upstream duct is not a concern.

I. INTRODUCTION

This paper documents the results of a thermal analysis that was performed for the proposed Plutonium Uranium Extraction (PUREX) Plant exhaust system after deactivation. The analysis was performed to determine if enough condensation will occur in the concrete duct to raise a concern and to plug or damage the filtration components. A thermal and fluid flow analysis was performed to evaluate the temperature characteristics of the underground duct system, the deep-bed glass fiber (DBGF) filter No. 2, and the high-efficiency particulate air (HEPA) filters in the fourth filter building (Figure 1). The analysis is based on the extreme variations of air temperature, relative humidity, and dew point temperature using 15 years of Hanford Site weather data as a basis. The results will be used to evaluate the need for the electric heaters being considered for the PUREX canyon exhaust to prevent condensation.

The pressure drop of moist air through the filter media because of the Joule-Thomson effect is addressed. Calculations that demonstrate the effect are presented.

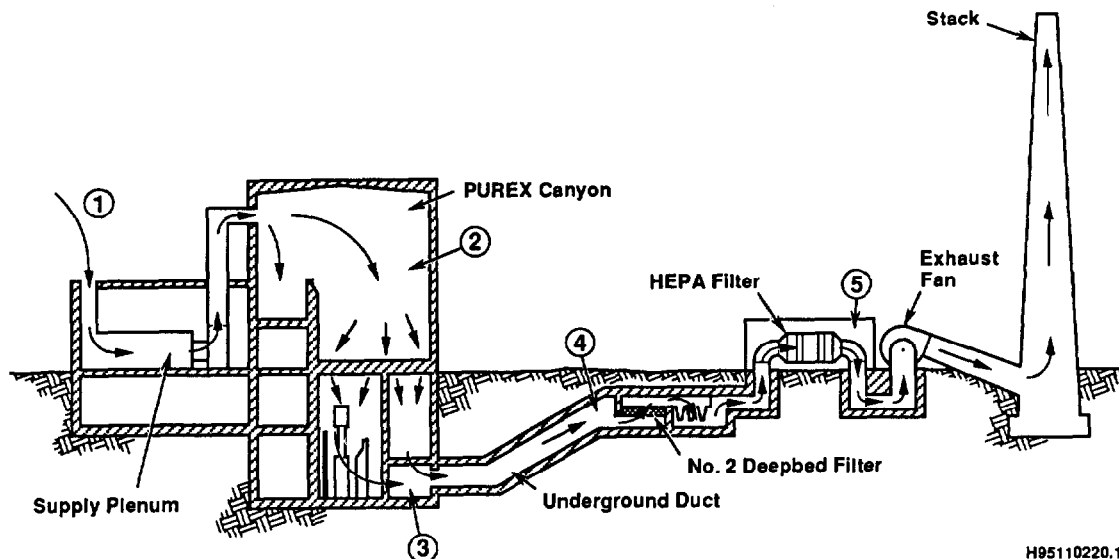


Figure 1. Operating System.

II. SYSTEM BACKGROUND

The ventilation system for the deactivated PUREX plant will consist of a draw-through system as shown in Figure 1. One of 3 canyon exhaust fans with a capacity of 40,000 ft³/min (18.88 m³/sec) will maintain negative pressure on the canyon, which provides the motive force to bring outside air into the plant. The proposed design cascades ventilation air through various zones within the plant to the PUREX canyon where it exits through the air tunnel to the underground duct work. The exhaust air passes through the DBGF filter No. 2, the fourth filter building containing HEPA filters, and the main stack to the atmosphere.

III. OPERATING EXPERIENCES

Before 1982, air washers in the supply air inlet plenums were used throughout the year. Large quantities of moisture were added to the air stream providing a mechanism for condensation far greater than what will occur during the surveillance and maintenance period. Available operating history shows no record of filter plugging or large accumulations caused by water condensation. Drains in the underground filter plenums eliminated condensate water that may have formed, but no water was entrained into the air stream to plug the deep bed or HEPA Filters.

The east and west sample gallery hood exhaust system exhausts to underground HEPA filter housings. The cover blocks of the filter housings are exposed to the ambient temperature. During HEPA filter replacements in 1987 and 1992, no high water marks or water damage were observed on any of the filters or plenum walls.

On several occasions in 1992, contamination was found to be dripping from the exhaust duct of the sample gallery hood when the spray washers were turned on. The dripping was attributed to a chemical compound in the ductwork that had an affinity for water. Since 1992, the spray washers have been left off from early spring until late fall. This eliminated the contamination dripping from the duct work. It also provided a 3-year spring/summer operating history that duplicates the sample gallery exhaust (SGE) ventilation during deactivation. No dripping or wetting of the ductwork, piping, and walls has been detected or reported.

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During the winter, the sample gallery reheat coil supplies 70 °F (21.11 °C) air to the sample gallery. The walls, which maintain a temperature of 55 °F (12.78 °C), because of the earth's insulating effect, have shown no condensation or dripping. This provides the confidence necessary to predict that the sample gallery will not experience any condensation throughout the year.

IV. ANALYSIS PROCEDURES

The thermal and fluid flow characteristics were evaluated to determine the worst case variations at different locations along the flow path from the PUREX canyon to the 291-AE building (Figure 1). The basic mechanisms for condensation and frost formation were evaluated. The effects of heating and cooling in the underground portions of the ductwork were also described and evaluated. The temperature variations between the duct and exhaust air are investigated to determine if condensation and/or frost formation are likely under these conditions.

Condensation or Moisture Formation

Condensation Principle

Condensation or moisture formation may occur from the humid air under certain flow and thermal conditions. When moist air is exposed to a surface that is colder than the dew point temperature of the air, a trace of moisture film will appear on the surface (McQuiston and Parker 1988). This phase change is called condensation. The dew point (DP) temperature on the wall surface is the controlling factor for condensation to occur. The following conditions prevent condensation from forming:

- The unsaturated air temperature equals the duct surface temperature.
- The unsaturated air temperature is colder than the duct surface temperature.
- The air dew point temperature is colder than the duct surface temperature.

The thermodynamic process of atmospheric air flowing through the PUREX exhaust system is essentially a heating and cooling process without changing the humidity ratio; only sensible heat is added or removed. Therefore, the moist air that flows through the cold duct does not necessarily produce condensation.

Condensation Rate

Based on the Hanford Site weather data for 24 hours on December 11, 1994, the data indicated the dry-bulb temperature in the range of 30 to 33 °F, while the relative humidity was between 95 and 99 percent. The cumulative condensate was calculated based on persistent air temperature of 33 °F (0.56 °C) and relative humidity of 98 percent, for 24 hours, while the duct wall temperature (32 °F or 0 °C) was assumed to fall below the air dew point temperature of 32.5 °F (0.28 °C).

Because the condensation rate was calculated based on the variation of the humidity ratio, a worse $\Delta w = 0.000325$ lb of H₂O per lb of dry air was calculated for 24 hours.

The average specific volume of the air was determined at 12.5 ft³/lb (0.78 m³/kg), the mass flow rate was calculated as 3,200 lb/min (1,451.5 kg/min).

Because moist air condensation occurs only during contact with the cool wall surface, most of the free-stream air flows through the duct without producing

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condensation. The actual condensation occurs only for the moist air inside the laminar sublayer in a fully developed turbulent boundary layer. However, it is conservatively assumed that the moist air inside the fully developed turbulent boundary will be condensed.

For the fully developed boundary layer, the Reynolds number is calculated based on boundary layer length of 50 ft (15.24 m) at 3,787,698. The boundary layer thickness, δ , was calculated at 11 in. (27.94 cm). The total volume for condensation is 3,200 ft³ (90.6 m³). The total condensation rate for all the air moisture in 24 hours is 608 lb (275.8 kg).

The total surface area that this amount of condensate will cover in 24 hours is 1,600 ft² (148.6 m²). Therefore, the condensate rate over unit duct surface area is 0.016 lb of H₂O/hr-ft² (0.078 kg of H₂O/hr-m²) or a total of the moisture at 0.38 lb H₂O/ft² (1.85 kg H₂O/m²) per day on the duct wall surface.

The remaining non-condensed moist air outside the boundary layer will flow through the duct. The condensate on the wall surface causes no concern because the accumulated quantity is small; dripping or puddling is not expected.

If the Amercoat on the concrete has deteriorated or the concrete interior is not in a saturated state, the sorption characteristics, capillary suction, and moisture transfer capabilities of the concrete may be able to absorb a small amount of moisture (Jonasson 1985).

For the concrete surface in the air duct, this rate of condensation cannot produce dropwise condensation. The moisture will be spread over the concrete surface with a thin layer of film with no dripping or puddling.

As a result of the assumed condensation, the humidity ratio or moisture contents in the flowing air will be reduced when the air flows through the DBGF filter No. 2.

Fog and Frost Formation

Fog is a disperse system consisting of liquid drops suspended in a gas. The conversion of vapor to fog is a discontinuous process occurring under critical conditions when vapor reaches the supersaturation state (Amelin 1967). The air flow in this study has not experienced any isentropic expansion into the wet region in the enthalpy/entropy diagram (Obert 1960) and the supersaturation condition has never been attained. Thus, fog formation inside the air duct is not possible.

If the fog or gaseous suspensions are flowing from the environment into the plant with the moist air, the warming effect inside the building and air duct will evaporate the moist fog. The fog can be sustained only if a source within the plant continuously supplies the moisture and the temperature in the duct is much colder than the outside air. As the moist air flows through a complicated and winding path inside the plant, the moist drops may impact a surface and deposit along the pathway. Because the fog conditions at the Hanford Site lasted only few hours, a limited amount of moisture was deposited in the air duct.

Frost forms when the moist air is exposed to a surface that is colder than the dew point temperature of the air, which must be far below 32 °F (0 °C). Under this condition, the moisture content of the air passes directly from the gaseous state to the solid state forming a porous layer of frost on the cooled surface. The rates of increase of the frost thickness require a continuous cooler temperature and high-humidity environment. Otherwise, the frost begins to melt and evaporates into the air stream. When the air/frost interface temperature temporarily warms back to 32 °F

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(0 °C), even in a high-humidity environment, the frost layer will occasionally undergo cycles of melting and refreezing (Trammell 1968). Considering the high affinity the air has for moisture, the frost melts and is evaporated by the dry air.

Air and Duct Temperature

The worst temperature variations contained in the Hanford Site weather data for the past 15 years were reviewed. The two wettest years, and the two coldest years, and the 1994 winter data were used as the basis for performing the heat transfer analyses. Heat transfer calculations and numerical examples for the conditions described are presented in the following paragraphs.

Transient Heat Conduction

Based on the weather data for the coldest and wettest years at the Hanford Site, transient heat conduction calculations were performed to determine the worse environmental temperature conditions and the depth the freezing layer penetrates into the soil resulting from the worst weather scenario (Schneider 1955).

Two examples are used to demonstrate the depth the frozen layer penetrates into the underground soil under extreme weather conditions.

Example 1: On a cold winter day, after a sudden change in weather conditions, the surface temperature of the plant environment drops to 18 °F (-7.8 °C). These cold conditions continue for 14 days. The temperature of the ground before the weather change is assumed to be 35 °F (1.7 °C). After this period, the temperature is calculated at different distances from the surface (Schneider 1955):

$x = 4 \text{ ft (1.220 m)}, T = 32.1^{\circ}\text{F (0.08 }^{\circ}\text{C)}.$

$x = 5 \text{ ft (1.524 m)}, T = 33.6^{\circ}\text{F (0.89 }^{\circ}\text{C)}.$

$x = 6 \text{ ft (1.829 m)}, T = 34.3^{\circ}\text{F (1.28 }^{\circ}\text{C)}.$

Example 2: During the winter, a sudden cold wave reduces the ambient air temperature to 0 °F (-17.8 °C). If the earth was at a uniform temperature of 40 °F (4.4 °C) before the onset of the cold wave, the freezing temperature penetrations were calculated to different depth after various hours,

6 hours, $x = 0.9 \times 2\sqrt{1.8 \times 6} = 5.9 \text{ in (14.98 cm)}.$

12 hours, $x = 0.9 \times 2\sqrt{1.8 \times 12} = 8.4 \text{ in (21.34 cm)}.$

24 hours, $x = 0.9 \times 2\sqrt{1.8 \times 24} = 11.8 \text{ in (29.97 cm)}.$

This indicates that the frozen layer penetrates less than 1 ft (0.3048 m) in 24 hours.

Flowing Air Temperature

The winter atmospheric air flows from the PUREX canyon building and enters the inclined air duct system. The wall surface temperature of the air duct was assumed to be 55 °F (12.8 °C) at 30 ft (9.144 m) below grade and cooled to near the environment temperature at the upper section close to the grade level. Heat transfer calculations were performed to determine the temperature increase of the flowing air at the turbulent boundary layer because of the warmer wall.

This section calculates the moist air temperature change caused by the effect of the warm concrete duct wall. The underground concrete duct cross-section area varies from the lower portion of 11 ft x 5 ft-9 in. (3.35 m x 1.75 m) to the upper portion of 8 ft

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x 8 ft (2.44 m x 2.44 m). The upper section is near the grade level, so its temperature is closer to the environmental temperature.

Consider a 40,000-ft³/min (1,132 m³/min) flow rate, the flow velocity through an 11 ft x 5 ft-9 in. (3.35 m x 1.75 m) duct is 10.54 ft/sec (3.21 m/sec). The equivalent hydraulic diameter is 90.6 in. (2.3 m). The Reynolds number is 578,529, which falls within the turbulent flow region. Assume that the Prandtl number is 0.7 for air. The heat transfer coefficient was calculated at 0.0196 Btu/hr-in²-°F (16.02 W/m²-K) using the correlation (Lancet 1959) $Nu = 0.042 (Re)^{0.8} (Pr)^{1/3}$.

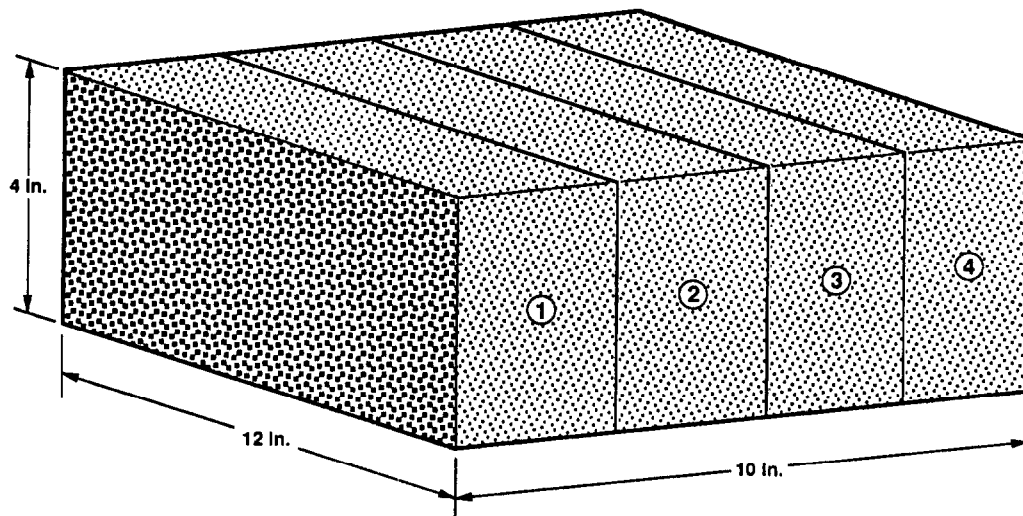
Assuming that the moist air at 32 °F (0 °C) flows through the concrete duct section at 55 °F (12.8 °C), the heat balance equation may be applied to calculate the flowing-air temperature at 34.4 °F (1.33 °C). This demonstrates that the air temperature in the boundary layer will be warmed up to 34.4 °F (1.33 °C), while the air temperature outside of the thin boundary layer remains at 32 °F (0 °C).

Duct Wall Temperature

Another calculation shows the cooling effect on the wall surface if cool air is flowing continuously through the duct. The convective cooling from the wall requires temperature gradient in the concrete wall to initiate the conduction heat flow. Hand calculations appeared to be fairly involved. A transient heat transfer analysis using a simplified finite-element model (ANSYS 1993) was performed to determine the temperature distributions throughout a concrete section.

The warm wall surface of the underground duct may be cooled if air at 32 °F flows through continuously. However, at a great distance from the surface, the duct surrounding remains at 55 °F (12.8 °C).

The finite-element mesh denoting the node and element numbering is shown in Figure 2. The three-dimensional thermal solid elements (solid70) have eight nodes with a single degree of freedom, temperature, at each node was used. Convective boundary condition, with heat transfer coefficient of 0.0196 Btu/in²-hr-°F (16.02 W/m²-K), was applied at the inside wall surface. Concrete material properties were used.



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Figure 2. ANSYS Finite-Element Model.

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A small initial temperature gradient was applied to start the transient solution. Results indicate that the temperature distribution throughout the section of the wall reached a steady-state temperature of approximately 42 °F (5.56 °C) after 4 hours.

Filter System Condensation

This section describes possible condensation and moisture effects on the filter systems.

Prefilter (Deep Bed Filter No. 2)

If condensation were assumed to have occurred at the cold wall surfaces in the upper portion of the inclined air duct system, the moisture content of the air would be reduced and further effect of condensation on the deep bed filter would be decreased because the air entering the filter is dryer.

Generally, sufficient moisture in droplet form is hazardous to a filter system. However, the filters are designed to resist moisture as long as plugging does not occur. Filtration is achieved by various mechanisms depending on the particle size and flow velocity (Davies 1973). The penetration mechanism is controlled by either molecular diffusion, interception, Brownian motion, or inertial impacting depending on the air flow velocity.

In good-quality filters with low resistance and high efficiency against submicron particles, the air flow obeys Darcy's law, which is usually considered to be valid for creeping flow with low Reynolds number. The low-Reynolds-number flow is dominated by viscous force. The viscous effect between the air particles and the filter fibers may keep the filter surface temperature from decreasing below the air temperature. As a result, the filter surface temperature is generally close to the air flow temperature.

High-Efficiency Particulate Air Filter

If condensation occurs in the underground duct work, the air flowing through the HEPA filters in the 291-AE building will be dryer.

Before the air reaches the HEPA filters, it has to flow through the concrete duct that has a wall surface temperature close to that of the inlet plenum wall located at the entrance to the HEPA filter. The temperature of the plenum wall should be the same as or colder than that of the HEPA filter. If the plenum wall temperature is at or colder than the dew point of the flowing air, condensation will occur at the plenum.

Condensation will not take place in the filters whether or not condensation occurs at the plenum. The air will simply flow through the filters. The HEPA filter media is treated with a water-resistant binder and will tolerate both high humidity and direct wetting (Flanders 1988). Several tests (First and Leith 1976) indicated that no degradation in filtering ability occurs after exposure to a steam-droplet atmosphere.

Joule-Thomson Effects

The Joule-Thomson experiment (Jones and Hawkins 1960, Kestin 1979) may resemble the moist air flowing through filter media and produce condensation. The basic condition for the Joule-Thomson effect to cause cooling is that the initial temperature of the gas must be below the maximum inversion air temperature, which is 628 °F (331 °C). The temperature of the flowing air is below the maximum inversion temperature.

If air is compressed to a pressure of 200 atm (2,940 psi or 20,265 KPa) and a temperature of 126 °F (52 °C), after throttling to a pressure of 1 atm (14.7 psi or

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101.325 KPa), it will be cooled to 73 °F (23 °C). For a small pressure drop of few inches or centimeters, such as flow through porous media, the temperature drop and the air cooling effect of the Joule-Thomson phenomenon are negligible.

Frost Formation on HEPA Filters

The possible frost conditions in the HEPA filter building are evaluated under the assumed frozen temperature in the environment. Two conditions may subject a cool surface to frost formation: when the surface has been exposed to nocturnal radiation and when a surface that has cooled below 32 °F (0 °C) contacts the moist air with a dew-point temperature higher than the surface temperature.

The first condition is unlikely to occur because the HEPA filters are housed in a building and not exposed to nocturnal radiation. Therefore, the cooling will not be present inside the building.

The second condition becomes possible when a surface cools to a subzero temperature that is below the dew point of the moist air. If the wall surface temperature of the HEPA filter building is cooled down well below the freezing point, the concrete duct and inlet plenum surface temperature will be near or at the freezing point temperature. Under this condition, the water vapor leaving the air and attaching to the surface may pass directly from gaseous to solid state forming a porous layer of frost.

Tests (Brian et al. 1970) indicate that continuous frost formation requires a subzero temperature and high specific humidity. After the frost formation, frost growth requires a sustained cooling mechanism, a continuous temperature decrease of the cooled surface, and an increase of the specific humidity of the air stream. In the absence of this persistent cooling phenomenon, frost buildup is not possible (Trammell 1968). If at any time the surface temperature reaches 32 °F (0 °C), melting will occur (Jones and Parker 1975). Based on temperature fluctuations from the Hanford weather data, frost may have formed on cold surfaces as a transient condition.

If condensation has already occurred as the cold air flows through the concrete duct or inlet plenum, the same amount of air that flows into the HEPA filters would have reduced the moisture content or humidity ratio. With a reduced humidity ratio because moisture is lost in the duct, the effect on the filters is not a concern.

V. RESULTS AND DISCUSSIONS

The results of a transient heat conduction analysis show that the depth of frozen soil, resulting from a subfreezing surface temperature of 18 °F (-7.78 °C) penetrates 6 ft (1.83 m) below grade after 14 days. These results agree with the publications from the U.S. Weather Bureau map that show the average and maximum depths of frost penetration as 12 and 36 in. (30.48 and 91.44 cm), respectively, in southeastern Washington State (Strock 1965). This indicates that only a small upper section of the air duct perimeter near the grade level may temporarily come close to the freezing temperature under the possible worst environmental condition.

An extreme weather condition that may never occur at the Hanford Site also was analyzed. A plant environmental surface temperature of -27 °F (-32.8 °C) lasting for 60 days was assumed. Results indicate that the frozen layer may penetrate into the soil to a depth of 7 ft (2.134 m).

The earth has been shown to maintain a constant temperature of 55 °F (12.78 °C) throughout the year at the lower section of the air duct. Cool moist air at 32 °F (0 °C) flowing through the 55 °F (12.78 °C) air duct can warm up only 2 °F (1.11 °C)

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near the boundary layer, while a large quantity of air at the free stream remains at 32 °F (0 °C). A continuous flow of cold air at 32 °F (0 °C) may lower the wall temperature to 42 °F (5.56 °C) when reaching a steady-state condition in 4 hours. The 42 °F (5.56 °C) temperature is above the dew point of the air.

If the air flows at a velocity of 10.54 ft/sec (3.213 m/sec), the time for air to travel from the duct entrance to deep bed filter no. 2 takes approximately 25 seconds. The duct wall temperature cannot be cooled much lower than the steady-state temperature. Condensation in the lower section of the air duct during the winter is not possible.

A condition may exist in the underground ductwork where the duct temperature can lead or lag the changes in the ambient air temperature because of the thermal storage characteristics of the underground duct. This condition may contribute to condensation on the inside surfaces of the underground exhaust duct.

The coldest and wettest weather data for the past 15 years have shown that only short periods in the early spring and winter of 1994 could contribute to some slight condensation that is barely enough to dampen the duct wall surfaces.

However, the condensation rate was conservatively calculated based on the worst recorded data during the 1994 winter. The dry-bulb temperature occurred between 30 to 33 °F (-1.1 to 0.56 °C), while the relative humidity was between 95 and 99 percent for 24 hours, assuming that the moist air flowing through the boundary layer in the concrete duct is condensed during the 24 hours. Results indicated that only 0.38 lb (0.172 kg) of moisture may be accumulated on 1 ft² (0.093 m²) in 24 hours. A large amount of flowing air in the free stream does not condense.

This small amount of moisture may be evaporated under the condition of temperature variations without producing significant wetting. From the plant operating histories, no significant condensation has been observed, even when the water spray system was in operation.

If condensation occurs on the concrete duct-wall surfaces, the humidity ratio for the air downstream is reduced. As a result, the filter housing temperature is above the dew point temperature of the air; therefore, condensation does not take place. The potential for condensation on the HEPA filter housing surfaces will be less of a concern.

The pressure drop through the filter system is not sufficient to cause any temperature drop and condensation. In addition, the filters are designed to resist high humidity and direct wetting (Burchsted 1978, Flanders 1988), so a small amount of moisture would be of no concern.

Frost formation on the HEPA filters is not possible because frost forms only on much colder surfaces, such as the duct wall or inlet plenum, before the cold air flows into the filters. No enduring mechanisms, such as continuous cooling and a high-humidity environment, exist to build up such effects on the HEPA filters.

VI. CONCLUSION

Condensation heat transfer and fluid flow analyses were completed to evaluate the effects of condensate in the underground duct and filters in the PUREX plant. The results of the analysis indicate that the ductwork upstream of the DBGF filters bed No. 2 is the most likely place for condensation to form.

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A worst case conservative analysis was performed assuming that all of the water is removed from the moist air over the inside surface of the concrete duct area in the fully developed turbulent boundary layer while the moist air in the free stream will not condense. The total moisture accumulated in 24 hours is $0.38 \text{ lb H}_2\text{O/ft}^2$ ($1.85 \text{ kg H}_2\text{O/m}^2$), which is barely enough to dampen the concrete wall surfaces. Water dripping and puddling is not expected.

Turbulent heat transfer analysis has shown that 32°F (0°C) air flowing through the duct will be warmed to 34.4°F (1.33°C) inside the thin laminar sublayer, while the air in the free stream remains at 32°F (0°C). Further analysis has indicated that the surface of the duct wall may be cooled to 42°F (5.56°C) after reaching a steady state condition in 4 hours.

Based on an air flow velocity through the concrete duct at 10.54 ft/sec (3.213 m/s), the air has a resident time of approximately 25 seconds traveling from the underground duct entrance to the DBGF No. 2 filter. Therefore, the lead/lag temperature characteristics of the underground duct are of short duration allowing the duct to follow changes in air temperature rather closely. This reduces the condition for possible condensation. On the other hand, condensation occurring in the ductwork upstream of the DBGF No. 2 filter will provide dryer air in the downstream duct and filters.

If no condensation occurs before the deep bed filters, the same moist air flows through the concrete duct, the HEPA filter building, and the exhaust system without further condensation. The pressure drop through the filter system is not sufficient to cause any temperature drop that will initiate condensation. However, the filters were designed to resist high humidity and direct wetting (Burchsted 1978, Flanders 1988), filter plugging caused by condensation is not a concern. Tests (First and Leith 1976) indicated no degradation in filtering ability after exposure to a steam-droplet atmosphere. The results of the analyses also agree with the operating experiences. Therefore, it is concluded that no electrical heating system is required for the PUREX canyon exhaust to prevent condensation.

VII. REFERENCES

- Amelin, A. G., 1967, *Theory of Fog Formation*, 2nd ed., Israel Program for Scientific Translation Ltd., Jerusalem, Israel.
- ANSYS, 1993, "Engineering Analysis Computer Program," Version 5.0A, Swanson Analysis Systems, Inc., Houston, Pennsylvania.
- Brian, P. L. T., and R. C. Reid and Y. T. Shah, 1970, *Frost Deposition on Cold Surfaces*, Ind. Eng. Chem. Fundamental, Vol. 9, No. 3, pp. 375-380.
- Burchsted, C. A. and J. E. Kahn and A. B. Fuller, 1978, *Nuclear Air Cleaning Book*, ERDA 76-21, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- Davies, C. N., 1973, *Air Filtration*, Academic Press, New York, New York.
- First, M. W. and D. Leith, 1976, *Entrainment Separator Performance*, Paper No. 101, Proceedings of the 14th ERDA Air Cleaning Conference, pp. 694-710.
- Flanders, 1988, *Nuclear Grade HEPA Filters*, Bulletin No. 812E, Flanders Filters Inc., Washington, North Carolina.

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Jonasson, J. E., 1985, *Moisture Fixation and Moisture Transfer in concrete*, Paper No. H5/11, 8th International Conference on Structural Mechanics in Reactor Technology, August 19-23, 1985, Brussels, Belgium.

Jones, J. B., and G. A. Hawkins, 1960, *Engineering Thermodynamics*, John Wiley & sons, Inc., New York, New York.

Jones, B. W. and J. D. Parker, 1975, *Frost Formation With Varying Environmental Parameters*, J. of Heat Transfer, May, 1975, pp. 255-259.

Kays, W. M. and M. E. Crawford, 1993, *Convective Heat and Mass Transfer*, 3rd ed., McGraw Hill Book Company, New York, New York.

Kestin, J., 1979, *A Course in Thermodynamics*, Revised Edition, Volume One, Hemisphere Publishing Corporation, New York, New York.

Lancet, R. T., 1959, *The Effect of Surface Roughness on the Convection Heat-Transfer Coefficient for Fully Developed Turbulent Flow in Ducts With Uniform Heat Flux*, J. of Heat Transfer, May, 1959, pp. 168-174.

McQuiston, F. C. and J. D. Parker, 1988, *Heating, Ventilating, and Air Conditioning, Analysis and Design*, 3rd ed., John Wiley & Sons, Inc.

Obert, E. F., 1960, *Concepts of Thermodynamics*, McGraw Hill Book Company, New York, New York.

Schneider, P. J., 1955, *Conduction Heat Transfer*, Addison-Wesley Publishing Company, Inc., Reading, Massachusetts.

Strock, C and R. L. Koral, 1965, *Handbook of Air Conditioning Heating and Ventilating*, 2nd ed., Industrial Press Inc., New York, New York.

Trammell, G. J., and D. C. Little and E. M. Killgore, 1968, *A Study of Frost Formed on A Flat Plate Held at Sub-Zero Temperatures*, ASHRAE Journal, July 1968, pp. 42-47.

The Trane Company, 1977, *Trane Air Conditioning Manual*, 53rd Printing, The Trane Company, La Crosse, Wisconsin.

DISCUSSION

FRETTHOLD: Are you planning on changing out all of your filters prior to going into this condition, so you start with new filters?

GREGONIS: No, we are not. We test our HEPA filters annually and we have recently replaced up to five banks. Because the system for our filter building was built for 120,000 CFM we have ten banks. Five will be available on-line and five will be off-line. If we have a problem we will just valve in another bank and then replace them during that time.

FRETTHOLD: You are running your filters at your 40,000 CMF instead of 120,000?

GREGONIS: That is correct.

FRETTHOLD: You plan to down rate the filter by going to twice the number of filters?

GREGONIS: That is the plan. This system has been online since '83. Based on its' history has been pretty reliable. Have not had a major problem. So the thought is that it will continue.

FRETTHOLD: Where will supply air come from? It is not supplied with a fan, is it just drawn in through the supply?

GREGONIS: It is drawn through the system by the negative pressure in the canyon, basically it is infiltration. We will have prescribed paths for the air to enter.

BERGMAN: I was looking through your references and I did not see any reference to the excellent work done by Dr. Wilhelm and his group at KfK about moisture accumulation on filters. If I recall right, just a little bit of particle deposition will literally suck the moisture out of the air, even when it is below saturation and when you have a powerful enough fan it will suck the innards out of the filter. That is one thing. A second item is that we were shown at a prior conference that even when you leave a HEPA filter sit in storage, it loses all its water repellency after about ten years. In that case, the image of the filter is not that of a water repellant substance, but a sponge that will literally soak up the water. My question is, have you considered any of these facts from previous literature reports?

GREGONIS: We have a extensive list of research on that. There was a paper presented by Dr. First that showed a case where they were testing a droplet retrainier, I believe, and that paper pretty much showed that water was not a problem. In addition, we go through a deep bed before we go through the HEPA filter. So the dust loading on the HEPA filters is basically nil.

BERGMAN: All studies before the KfK studies during the mid-80's had been done with brand new filters. Again I point out, it does not take a lot of dust, just a little bit of dust immediately changes the characteristics from a brand new filter to an aged filter. And again, the image is a sponge even though you have a very clean environment, the fact that you lose the organic water repellency characteristic transforms the filter into a sponge. And so I would recommend you to refer to some of the pioneering work in Germany, and include that in your references because by not doing so, you may have a little surprise.

GREGONIS: Just a comment based on our operating experience. They used to run the spray washers

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year-round and the mechanism for condensation was that the filter housings are out in the ambient temperature. I have been in almost all the filter housings, and been involved in filter changes. We did not see any degradation or ruptures. Therefore, in our deactivation state, where we are not putting any water in, but are just taking ambient air and running it through the plant and out again, I feel we have a pretty good basis for utilizing these filters. However we will study the matter you presented.

ENGELMANN: Whether there can be condensation on the filter depends almost entirely upon the absolute humidity of the air and the filter temperature. A simple and adequate approach is to estimate or measure the absolute humidity within the building and that of the makeup air to calculate what is presented to the filter. A simple solution (if there is a problem) is to add more makeup air which at Hanford, has low humidity. Heating of the air did not merit consideration as a solution, unless there are expected to be major activities with much evaporation within the building.