IMPROVED HEAT TRANSFER FROM RADIOACTIVE WASTE CANISTERS

The radioactive nuclide content that can be tolerated in a canister full of solid waste can be increased by lowering the thermal resistance of the average path for heat flowing to the surroundings from the waste. The value of increasing the contents must then be weighed against the total cost of the improvement, in terms of additional cost of the container and plant operating costs.

The types of canister design modifications studied have been compared with simple cylindrical canisters that contain only nonmetallic wastes. These modifications include (a) annular canisters, (b) internally-finned canisters, (c) canisters with multiple internal cooling ports, (d) intimately-mixed metal-waste composites and (e) alternate layers of metal and heat-generating ceramic wastes. The limiting temperature is assumed to be the maximum waste temperature, and the volumetric heat generation rate is allowed to vary as the allowable total power varies. Parametric correlations for the improved internal heat transfer were developed for each of these systems.

The principal effects of annular canisters are to shorten the path length for conduction through the solid and provide a second path for heat to flow to the surroundings. With internally-finned canisters, the improved heat transfer is gained by providing a high-conductivity path from the more centrally located waste to the outer wall. The increased capacity

is a function of the number of fins, fin thickness, fin thermal conductivity and the depth of penetration of the fins from the wall toward the canister axis. Correlations were made in terms of a fin conductance parameter. Containers with multiple internal cooling ports are basically annuli with additional cooling tubes arranged parallel to the container axis throughout the volume of the waste. The improvement in heat transfer for this system is a function of the number, location and diameter of the internal ports, and the temperature of the coolant in the internal ports. Mixing of wastes with metal particles or waste cladding hulls improves the thermal conditions in simple cylindrical containers without changing the geometry or the container cost. The thermal conductivity of the ceramic-metal composite is a function of the thermal conductivities of ceramic and metal, the volume fraction of metal, whether the metal or ceramic is the dispersed phase, and the shape of the dispersed phase particles. The effective thermal conductivity of the container contents can also be improved by filling with alternating layers of metal and ceramic. The fixed parallel orientation of the layers improves the overall thermal conductivity over that for random composite orientation, but thick layers tend to reduce the effect of the metal on the central portion of the waste layer.

Cost comparisons between cylindrical canisters, annular canisters, and internally-finned canisters for both stainless steel and carbon steel structural materials were based on estimates from architect engineers and from vendors. The costs expressed in terms of dollars per unit volume of waste were reduced to empirical equations involving the same variables as the heat transfer. Comparison of the two correlations, with due regard to the higher costs of nonstandard pipe sizes, resulted in correlations of the canister cost in dollars per watt of waste for each type of canister. The cost advantage of annular canisters over simple cylinders passed through a maximum as the size increased. Similar behavior is observed as a function of the number of internal fins, but at a much larger number of fins than is currently considered practicable. Neither cost advantage was greater than a factor of two over simple cylinders, and the resultant increase in operating costs for filling, shipping and container integrity would tend to make their use marginally desirable.