

The Advanced Vitrification System Technologies

What It Is

The Advanced Vitrification System (AVS) is an in-canister vitrification process. Generally, the AVS is principally designed as a high-level waste (HLW) vitrification system. The AVS-II is generally designed as a low-level and hazardous waste vitrification system. Both AVS technologies are similar.

How It Works

In both AVS systems waste and frit mixtures are melted inside a final disposal canister, which has been modified to include the AVS internals. Virtually any disposal canister can be so modified to include AVS internals. When so modified, the disposal canister is referred to as a module. The melter and vitrified waste are disposed of together in the module, so there is no separate melter disposal decontamination, decommissioning, activity and cost.

Figure 1 shows a cutaway of a typical HLW canister modified with AVS internals. The AVS module internals include three components: a centimeter of insulation, two centimeters of crucible and a thin protective coating or half centimeter liner on the inside surface of the crucible usually made of alumina.

The crucible is made of graphite and serves as a heating element, which is heated inductively by a coil surrounding the exterior of the canister. Low frequency current in the coil preferentially heats the graphite crucible. The module internals reduce Hanford HLW canister volume by as much as 18%, but the combination of double waste loading obtainable with melt temperatures up to 1550 centigrade and higher product density combine to produce a canister holding about twice as much waste as with lower temperature melters.



Figure 1: Typical HLW AVS Configuration

The AVS uses a proprietary heating methodology that offers many benefits. It is called the Hot Hohlräum Melting (HHM) method. It permits waste to be added to the module in liquid or solid form and melted as it is added. In the HHM method, the walls of the crucible above the waste are heated to form a radiant hohlraum, which serves to heat small melt pool at the top of the canister. Active cooling of the lower part

of the module permits a rising molten pool of waste to be present over a solidified waste product. This ensures virtually no foaming during melting and a vitrified product as uniform as the waste feed.

AVS-II

The AVS-II offers a vitrification technology that reduces AVS processing costs while further reducing the number of disposal containers. Essentially, the AVS-II includes a drain valve at the bottom of the container, which allows the disposable melter to be continuously fed and used until the container internals erode to a predetermined level. Then, the AVS-II in-container melter is filled with melted waste, removed and disposed of like a standard disposal container. The drain valve at the bottom of the AVS-II in-container melter permits molten waste to pour into standard disposal containers, thus maximizing the disposal volume of each container. As with the AVS, the outer dimensions of the AVS-II in-container melter can be made to match almost any specified disposal container.



Figure 2: Typical AVS II Configuration

Enhanced Environmental Protection

The AVS has the potential for significantly enhancing waste containment, which derives from the high integrity containment within a sealed graphite/alumina crucible. Graphite is a crystalline form of carbon which is environmentally stable, potentially for millennia. When the waste is sealed in the graphite/alumina crucible, there is a potential to delay any mobilization and transport of radionuclides and hazardous metals for well in excess of existing environmental standards. And, the encapsulating graphite crucible provides no valuable mineral or mining attractant for future human intrusions. Also, but not as immediately apparent, is the environmental benefit derived from placing twice as much waste in a canister, which results in half the canister and waste product leaching surface area within the repository.

Cost

The added cost of the AVS internals is offset by avoiding the storage and disposal costs for up to half the number of disposal canisters, and eliminating melter disposal costs.

Modularity

The AVS is a modular technology and will function with a single melting station or any number of additional parallel stations to meet whatever processing rate and completion schedule required by the customer.

Reliability

An AVS facility thus has three inherent features contributing to reliability and robustness: 1) The high temperature materials in each module are exposed to molten glass only once for only a few hours; 2) One-time use of the AVS melter means that the AVS module widens the permissible waste feed chemistry envelope, with no concern for melt viscosity, electrical conductivity, crystallinity and noble metal settling; and 3) Failure of an AVS melter will, in most cases, halt only the processing of a single module, which could be quickly removed and replaced with the next module. As importantly, a single cell failure in the AVS facility would not prevent independent and parallel cell operation.

Subsystems

The AVS has ten major subsystems. These are shown in Figure 3.

The AVS off-gas subsystem makes use of proven technologies and is not expected to involve unique materials or manufacturing techniques. The AVS feed subsystem takes advantage of commercially available components suitably modified for application to the AVS. All other AVS subsystem components involve commercially available materials, manufactured components and systems. This ensures that the ancillary components are easy to acquire, with proven operating history.

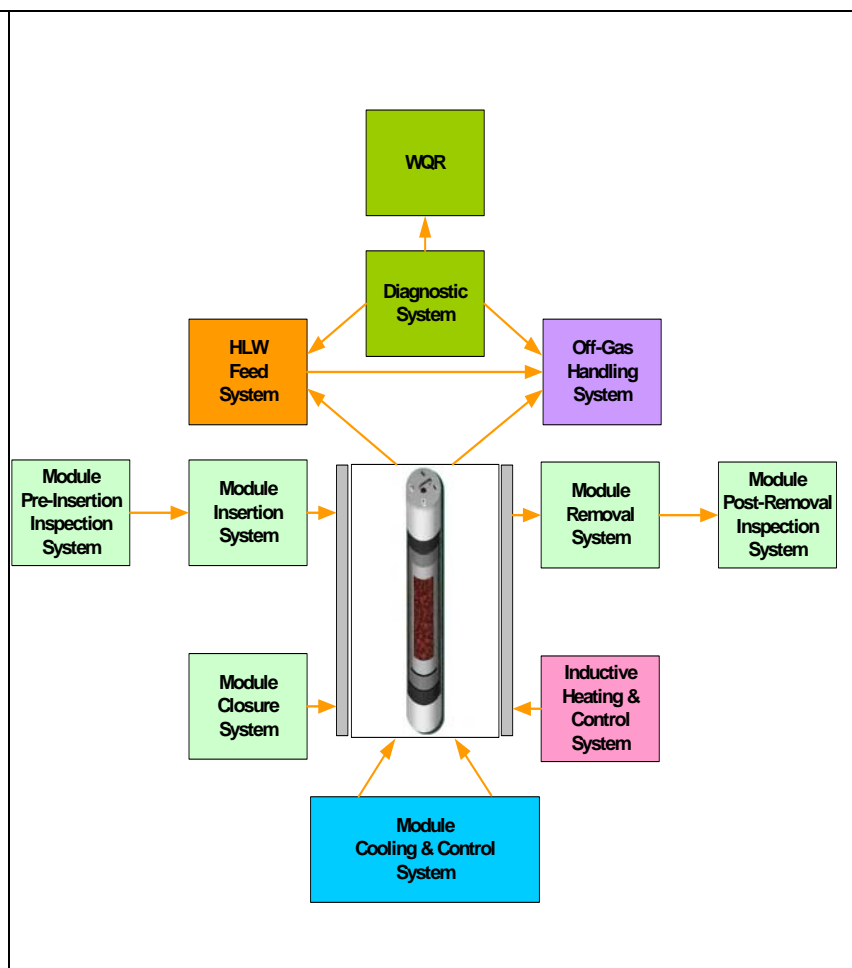


Figure 3: AVS Subsystems

Discussion of Attributes

RIC-AVS is an in-canister vitrification process in which the waste is melted in its final disposal container, eliminating the need to pour the waste from a permanent melter into each canister for disposal. The canister, or module, can be manufactured in a variety of container sizes. The largest application proposed has a susceptor of about 6 feet in diameter. The tallest application proposed has been the height of the Hanford baseline canister, which has external dimensions of 4.5 meters tall and 61 cm. outside diameter.

The AVS canister is typically a stainless-steel outer container of the kind manufactured to hold vitrified wastes using other melting technologies. For the AVS, the stainless steel outer container could be replaced by other materials such as high-strength carbon fibers similar to the materials used in aircraft wings, golf club shafts, and tennis racquets.

Immediately inside the stainless-steel container there is a layer of graphite fiber insulation, and inside that is a dense graphite container. Finally, the graphite is lined with a ceramic shell or coating intended to limit contact between the graphite susceptor and the molten material being vitrified, even though testing has shown that direct contact between test waste simulant and the graphite crucible for the required melting period did not breach the graphite crucible.

A bath gas above the molten material and the gas in the insulating container is typically an inert gas to further minimize chemical interactions between the canister internals and the waste. RIC's baseline vitrification system design uses argon as a bath gas during filling and melting

The energy for vitrification of the waste material is supplied by an external water-cooled induction coil, which transfers energy to the graphite susceptor, which in turn heats the waste primarily by radiation from above the waste. If the canister is heated in the baseline design configuration using a stainless steel canister as the outer shell, the graphite is preferentially heated by knowledgeable selection of the coil frequency.

Both the stainless steel shell and the graphite container are nevertheless heated and the outer steel shell is cooled to maintain it a near ambient temperature. The steel canister is cooled by convection to a cascading water curtain in a surrounding jacket or by an air flow in a surrounding shroud. Unlike other melter induction systems, the melt is not required to serve as a conductor to create heat for the melting process. This feature increases the variety of wastes that can be vitrified because the conductivity of the waste is not a concern.

Heating of the melt is accomplished by a high radiation flux from above the melt surface in a process known as the "Hot Hohlräum Melting (HHM) method. The radiative flux comes from inductive heating of a segment of the walls of the graphite susceptor above the melt surface, for a Hanford canister this segment would typically be about 3 feet or less in height. Thus, the short segment of graphite susceptor

walls that is heated rises as the module fills. This is accomplished either by physically raising the induction coil, or by switching on and off various sections of the induction coil stacked one above the other.

One of the more interesting and significant process advantages of the HHM is the elimination of foaming, a highly deleterious and carefully controlled characteristic of melting wastes in traditional melters. While traditional melters require testing and difficult waste pretreatments to address this phenomena, the AVS heating methodology virtually eliminates concern over foaming. No sugars or other chemical additions to the waste need be made for the AVS. Thus, eliminating testing and waste pretreatments to control foaming.

The absence of electrodes in contact with the molten waste permits processing wastes with little regard for controlling waste chemistry to achieve conductivity. Since no pouring of molten waste into a canister is required because the melting occurs in-can, there need be no process control of melt viscosity, no concern over melter burnout due to shorted electrodes from melt crystallinity, no concern for pour spout clogging and no concern about incidental contamination from pouring spills.

Elimination of the need for process controls for these traditional melter failure modes enables the AVS to vitrify at much higher temperatures, typically 400 degrees centigrade higher than a joule heated melter. This, in turn, means that more waste can be dissolved in the glass, which means higher waste loadings per canister. Higher waste loadings have immediate cost and schedule benefits manifested by reducing the total volume of vitrified product requiring disposal.

An important inherent feature of radiative heating in the AVS is that the molten materials are optically opaque, i.e., heat transfer within the melt by radiation is very low, because of strong absorption of infrared radiation by iron in the glass. Thus, the transfer of radiative energy at the surface means that the highest temperature is literally at the surface of the melt in the canister. A high surface temperature delivers a very efficient melting rate per unit of surface measure. A foam free and high temperature molten bed enables a much faster rate of feed dissolution than traditional melters that operate with a much cooler foamy “cold cap”.

A fast dissolution rate, high temperature radiative melting, and lack of foaming are particular melter advantages for Hanford type wastes. Hanford wastes have a high melting point and tend to rapidly evolve oxygen bubbles.

For traditional melters, Hanford waste is expected to be diluted prior to melting, which means that the volume of waste will be increased to permit melting. As importantly, dilution of the Hanford wastes by pretreatment additives is complex because additives to control one factor often have adverse consequences on other essential waste melting characteristics.

No matter how much characterization testing has or will be done of the tank wastes at Hanford, the actual physical limitations governing the sampling process, translates to large uncertainties in the actual chemistry of the waste prior to vitrification. For traditional melting technology, this uncertainty adds an unknowable level of risk to the safe operation of the vitrification process. It almost certainly will require dilution of the wastes in excess of what is planned, meaning more waste volume should be anticipated. For this situation, a melting technology, like the AVS, that is largely process insensitive to waste chemistry is the ideal vitrification technology.

The AVS in-can melting process also offers advantages in product homogeneity, product predictability and enhanced containment of volatile hazardous elements. The AVS does not rely on heating the melt through convection, stirring or bubbling for homogenization. Rather, the AVS homogenizes the waste prior to introduction to the melter. Homogenizing prior to melting allows for more reliable pumping for slurries into the canister and for better control over waste chemistry. Because only a small top segment of the waste is actually molten within the canister, there is no opportunity for the molten waste to segregate beyond the molten segment. This adds to product homogeneity, which, in turn, enhances the predictability of vitrified product performance.

Containment of volatile hazardous elements, like cesium, is an advantage for the AVS. The lack of natural convection in the molten segment of the waste reduces exposure of volatile elements to the surface as is typical for high convection and stirred melters. Because volatile elements are held below the melt surface, volatilization is reduced, especially in comparison to conventional melters, which employ convection, stirring and bubbling to achieve homogeneity of the melt. The surface exposure (area exposed times time exposed, per unit waste oxides vitrified) is more than 5 times lower for RIC-AVS than for conventional melters, leading to a lower total volatilization rate. The enhanced and advanced joule melters are expected to provide no answer to volatilization because they rely on convection, stirring and bubbling. It is a simple physical fact that the volatilization rate of alkalis, such as cesium, is about 2000 times higher at 1350 °C than at 950 °C, based on a rough estimate of the melt surface temperature next to the cold cap in these melters.