A Remote Absorption Process for Disposal of Evaporate and Reverse Osmosis Concentrates - 8200

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ABSTRACT

Many commercial nuclear plants and DOE facilities generate secondary waste streams consisting of evaporator bottoms and reverse osmosis (RO) concentrate. Since liquids are not permitted in disposal facilities, these waste streams must be converted to dry solids, either by evaporation to dried solids or by solidification to liquid-free solids.

Evaporation of the liquid wastes reduces their volume, but requires costly energy and capital equipment. In some cases, concentration of the contaminants during drying can cause the waste to exceed Class A waste for nuclear utilities or exceed DOE transuranic limits. This means that disposal costs will be increased, or that, when the Barnwell, SC disposal site closes to waste outside of the Atlantic Compact in July 2008, the waste will be precluded from disposal for the foreseeable future).

Solidification with cement agents requires less energy and equipment than drying, but results in a volume increase of 50-100%. The doubling or tripling of waste weight, along with the increased volume, sharply increases shipping and disposal costs.

Confronted with these unattractive alternatives, Diversified Technologies Services (DTS), in conjunction with selected nuclear utilities and D&D operations at Rocky Flats, undertook an exploratory effort to convert this liquid wastewater to a solid without using cement. This would avoid the bulking effect of cement, and permit the waste to be disposed of the Energy Solutions facility in Utah as well as some DOE facilities.

To address the need for an attractive alternative to drying and cement solidification, a test program was developed using a polymer absorbent media to convert the concentrate streams to a liquid-free waste form that meets the waste acceptance criteria of the pertinent burial sites. Two approaches for mixing the polymer with the liquid were tested: mechanical mixing and insitu incorporation. As part of this test program, a process control program (PCP) was developed that is 100% scalable from a concentrate test sample as small as 50 grams to full-scale processing of 100 cubic foot containers or larger.

INTRODUCTION

Industry Waste Streams

The waste stream of greatest interest is the secondary waste generated by evaporator operations (evaporator bottoms) or RO processes (concentrates) at commercial nuclear and DOE facilities. These secondary liquid wastes must be further processed to an acceptable waste form, either by drying to dried solids or by solidifying to a liquid-free mass. This processing can be accomplished at the plant site or at an off-site vendor facility.

While the use of evaporators has diminished over the last several years for liquid radwaste (LRW) processing, the resulting decrease in secondary waste evaporator bottoms has been more than offset by the increased use of RO, as facilities strive to meet increasingly stringent effluent and recycle goals. Similarly, as ion exchange is replaced by RO, larger volumes of concentrates are generated, requiring additional treatment before disposal. Most of the nuclear plants now being planned will use membrane systems to process their LRW streams, so the need for an efficient means of processing these concentrates will only grow.

Current Approaches

To process the secondary waste concentrates from RO or evaporators, a plant traditionally chooses between evaporating the concentrates to dry solids and converting the liquid to another solid form for burial.

Evaporation reduces volume, but has several drawbacks. Drying equipment tends to be large and expensive to buy and operate, and to have attendant radiation control issues. Organics in the waste stream may inhibit evaporation because of low vapor pressure of the liquid constituents, and scaling problems often occur during the drying process. Depending on the dryer design and operation, a highly dispersible powder may be generated that must be further treated to prevent contamination spread. Finally, in some cases when key isotopes are near the Class A or TRU limits, the concentrating effect of drying can up-class the waste, creating transportation and disposal concerns.

If solidification of the concentrate with cement agent is selected, the equipment investment and energy requirements are less than those for drying. However, cement solidification results in a volume increase of 50-100%. The doubling or tripling of waste weight, along with the higher volume, sharply increases shipping and disposal costs.

Currently, the most common approach is to process these concentrates by evaporating/drying them on site or shipping them to an off-site processor. A few generators still rely on cement solidification, but its drawbacks have sharply curtailed use in recent years.

Barnwell Site Closing

With the closing of the Barnwell site scheduled for July 2008, all but Atlantic Compact members will be prohibited from accessing the site, and there will be no disposal pathway for greater than Class A waste. Accordingly, avoiding generation of >Class A waste during the drying process is particularly important, as such waste will have to be stored on site indefinitely, at significant cost.

BACKGROUND

Superabsorbent History

The use of superabsorbents such as polyacrylates for immobilizing liquids dates back to the patents of 1960’s in the area of personal care products. These were finally commercialized in about 1980. Over the last 25 years, the use and applications of superabsorbents have greatly expanded. Today, with enhanced controls over cross-linking and selective exchange capacity of the superabsorbents, new applications are being pursued.

Industry Uses

Polyacrylates are commonly used as absorbents in such products as diapers and feminine hygiene products. Expansion of their use outside the area of personal care has been somewhat slower, but is building momentum because of the versatility and reliability of these substances. Absorbents have found a place in agriculture as soil enhancers and also as a medium for controlled delivery of fertilizers and pesticides. The construction industry has found uses for superabsorbents as additives in the prevention of water intrusion. The medical/biological field has begun examining them as delivery systems for special types of cells to enhance rebuilding of bones and organs. In robotics, gels are used in robotic fingers to gently adjust gripping forces by applying an electrical field to the gel to make it swell or shrink. More recently, superabsorbents are being used in the waste industries to solidify sewage sludge, pond sludge and river dredgings, making them easier to handle.

Limitations

Superabsorbents have had some use in the nuclear industry, for absorption or prevention of incidental accumulated water in packaging. A drawback to this application was the need for intimate contact between the liquid and absorbent, which usually required mixing. Unless the absorbent is properly mixed and distributed, the rapidly occurring gelation leaves areas with either insufficient absorbent to absorb the available liquids, or with excess (wasted) absorbent. Improper mixing and distribution could potentially leave pockets of water in the container that would make the material unacceptable at the burial facility.

PROCESS DESCRIPTION

Development of New Application Technology

To address the need for improved application of superabsorbents, an extensive test program was undertaken to develop automated yet simple methods for applying superabsorbents to liquid concentrates such as those generated by RO and evaporator operations. These streams present special problems due to increased radiation activity and often-elevated temperatures. Both of these challenges lend themselves to remote and automated mixing.

Though alpha contamination found in some DOE wastes does not pose an external radiation hazard, the potential for airborne contamination dictates use of bulky personal protective gear. The presence of hazardous materials such as beryllium, polonium and americium creates additional hazards that dictate remote operations. Remote operations reduce the contact handling of these wastes, thus providing greater personnel protection and efficiency.

Testing revealed two basic methods for obtaining the proper mixing to assure distribution of the polymer throughout the waste while minimizing the quantity required to yield a high-quality, repeatable product suitable for transportation and burial. One method involves the controlled dispensing and mixing of the superabsorbent during filling of the container. The second method involves injection the waste into a container already containing the superabsorbent, in such a way as to cause the container to fill evenly, with the absorbent distributing itself as the container fills. This pressurized injection has the benefit of exposing virtually no liquid to the atmosphere, thus avoiding potential airborne contamination.

Mixing

While mixing can be accomplished with large heavy-duty mixers much like those used for concrete solidification, such equipment is expensive to procure and cumbersome to mobilize and operate. Testing found that much simpler mixing techniques, requiring more modestly priced and more easily mobilized/demobilized equipment, could effect proper commingling of the liquid and absorbent components.

The optimum mixing configuration uses the turbulence of the liquid concentrate being added to the disposal container to effect the necessary mixing. The polymer is metered into the waste stream as it enters the waste container. The metering can be done by screw feeders, loss-in-weight controlled apparatus or even by simple valves set to deliver a known quantity of polymer per unit time. The flow rate of the wastewater feed can be matched to the polymer flow rate. The matched polymer/waste addition mechanism supports a flow ranging from 5- 50 gpm.

The metered application of the superabsorbent can be in an open or closed trough, or into a solid stream of water. A fan type trough was determined to provide best cross-sectional distribution of polymer into the passing liquid stream. The shape of the chute is controlled to provide even distribution of the liquid/polymer mixture in the disposal container.

Distribution in the waste container can be controlled through three mechanisms: nozzle/trough movement, container movement, and feed flow rate.

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Fig. 1 Absorption of concentrates at San Onofre Nuclear Generating Station (SONGS)

Since the liquid/polymer mixture is only semi-liquid as the absorbent starts the uptake of liquid, the nozzle or trough can be pivoted from side to side and to greater or lesser angles to fill the entire container. The pivot point of the trough is also the entry point for the polymer, so movement of the trough does not affect polymer addition to the passing liquid. Stops on the nozzle or trough prevent the waste mixture from being delivered outside the waste container.

An alternate approach is to a have fixed nozzle or trough trajectory, and move the waste container to distribute the waste throughout. This may be more practical when large roll-offs or inter-modals are used. Vibration and/or tilting the container may also be effective in some applications.

The faster the feed flow, the less time there is for mixing and gelation to occur. With high flow rates, the material entering the container will flow better, since gelation has not yet markedly increased the viscosity of the mixture. Thus, when high-rate delivery systems are available, physical distribution across different regions of the container may not be necessary. This is the simplest approach. If very high temperatures or very high absorbent concentrations are encountered, distribution of the mixture will likely be necessary because of the rapid gelation and increased viscosity.

Fig. 2 SONGS absorbed waste

Insitu Incorporation

An alternative to physical mixing may be useful for applications where mobilization of superabsorbent dispensing equipment and mixing are not applicable or economical. The insitu method requires no mixing equipment outside the disposal container: only a simple control manifold is needed o control liquid flow rates. The insitu process also provides control of airborne activity, as the waste liquid is introduced under the preloaded superabsorbent.

Injection of the waste under the absorbent bed eliminates spraying and splashing, and provides uniform distribution of the polymer/waste mixture in the container.

The manifold system uses a waste distribution system (similar to a dewatering system in a liner) to distribute the wastewater within the superabsorbent. Distribution nozzles distribute the flow of wastewater evenly across the superabsorbent. As the absorbent contacts the wastewater, it expands and moves away from the nozzles, and fresh absorbent is exposed.

Fig. 3 Distribution manifold in disposal bag

The size and shape of the container determine the quantity of superabsorbent required above and below the manifold. The spacing and directional orientation of the nozzles are also adjusted during design to minimize the polymer usage through proper distribution of the liquid.

A floating manifold can be used when the depth of the waste container is significant. This manifold is permitted to float in the expanding gel, with the unreacted granular material staying above the manifold. As the manifold reaches the surface, the filling operation is completed with little or no liquid actually being exposed to the atmosphere.

While the manifold system is more sensitive to delivery conditions than the mixing process, when flow rate, pressure, viscosity, and temperature are controlled, effective penetration and mixing of the polymer with the wastewater will be affected. When these feed conditions are controlled within process limits, the manifold system is a reliable and low cost method of producing a quality waste product suitable for storage, transport and burial.

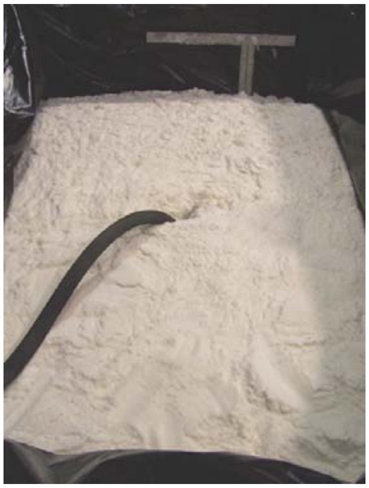

Fig. 4. Bag filled after insitu absorption

Process Control Program

A PCP was developed as part of the test program that permits bench-scale tests to be linearly scaled to full-scale operations. Under the PCP, a 50-100 mls waste sample can be tested to obtain the formulation required for application to full-scale treatment of containers holding hundreds or thousands of gallons. This PCP testing ensures the compatibility of the waste/polymer mixture and the effectiveness of the determined formulation in advance of full-scale operations. The process formulation can be further adjusted to provide additional conservatism for a greater safety factor above the minimum required to meet burial site acceptance criteria.

The scalability of the PCP test is essential to the success of the process. Although additional polymer can always be added and mixed with an unsatisfactory product to correct a poor solidification, such corrective actions are labor- and dose-intensive. Instead, the scalable PCP formulation determines the optimum formulation to ensure satisfactory full-scale processing.

The polymer to waste loading is typically in the range of 2-6 wt%. The volume increase, which is primarily due to air entrainment, typically ranges from 1-5%. The efficiency of the polymer drops slightly as the specific gravity of the dissolved ionic species increases. For instance a 1.2 sp.gr. solution may require 3-4 wt% polymer, while a 1.01 sp.gr. solution requires 1-2% wt%. Usually, higher concentrations of polymer are utilized only when the client requires a greater safety margin than that needed to meet burial requirements.

EXPERIENCE

A number of successful absorbent processing campaigns have been conducted using superabsorbent to immobilize liquids and wet sludges into a liquid-free waste form that is acceptable for burial at commercial and government disposal facilities. The following is a sampling of these projects.

Rocky Flats

In 2003 and 2004, more than a ton of superabsorbents were used to process RO concentrates at the Rocky Flats DOE Facility in the support of hydrolasing D&D of Buildings 771/774. More than 1.6M gallons of water were recycled during this project, and approximately 10,000 gallons of RO concentrate were produced, solidified using superabsorbent, and shipped to Energy Solutions for disposal in B-25 type boxes.

San Onofre Nuclear Generating Station

In 2006, in approximately 15 hours of operation, 10,000 gallons of concentrates from the SONGS Unit #1 decommissioning project were solidified in 23 B-25 boxes. A box of waste was solidified, packaged and surveyed every 30-40 minutes. All of the equipment, with the exception of the trough, delivery valve and flow meter, were returned uncontaminated. (These items could have been reused, or dropped into the last container for disposal without impacting the disposal volume). The boxes containing the solidified waste were then dumped into intermodal containers full of steel debris. By combining these waste streams, SONGS was able to bury this waste at no additional burial cost/volume. The absorbed liquid filled the void spaces between the steel members, leaving the burial volume unchanged.

SUMMARY

The absorption process offers utilities a viable and less costly alternative to on-site drying or solidification of concentrates. The absorption process can be completed by site personnel or by a vendor as a turnkey service. The process is suitable for multiple types of waste, including RO and evaporator concentrates, sludges, and other difficult to process waters and wet solids.