MOBILE LIQUID VR SYSTEM - A COST EFFECTIVE ALTERNATIVE

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ABSTRACT

The need for cost effective alternatives to treat large volumes of liquid radwaste has never been more evident. As part of a continuing effort to introduce such alternatives, HPD, Inc., and Chem-Nuclear Systems, Inc., have integrated two proven state-of-the-art technologies to offer a mobile liquid volume reduction system that satisfies nuclear industry requirements, with respect to liquid radwaste handling.

This system optimizes proven technology by employing a crystallizer unit to concentrate the waste liquids to 50 weight percent solids, thereby reducing the volume to be solidified by factors of 40, while using only 20 percent of the energy required by conventional evaporative systems. In addition, the system employs a field proven cement solidification process which has been accepted in a Topical Report by the US NRC and which offers the highest waste to container volume ratios for stable waste forms in the industry. This volume reduction-solidification system is able to reduce over 7000 gallons of liquid waste per day to less than 30 cubic feet of 10CFR61 certified stable solidified waste for ultimate disposal or on-site storage. This document describes the GEODE^{sm} System; its applicability; economics; volume reduction; scope of responsibility and experience. Major benefits include higher VR factors; assurance of continual regulatory compliance; and no capital investment.

APPLICABILITY

Just as Eberhard Faber invented the pencil with eraser: the combining of two proven useful entities into a single, more efficient operation; similarly the GEODE^{sm} System is the ultimate combining of volume reduction and solidification into one integrated service.

This mobile radwaste system can be transported to a specific facility in two self-contained trailers, which can be made operational in 48-72 hours. These two trailers are set up adjacent to each other and controlled from one central control room. Upon completion of the VR/solidification task, the GEODE^{sm} System is available for transport to the next facility or to interim storage. The flexibility is further enhanced by the field proven ability of both technologies to process a wide range of liquid wastes.

The GEODE^{sm} System employs an HPD mobile MVR crystallizer (MCU) along with a CNSI mobile cement solidification unit (MSU). The approach optimizes available technology, employing the extensively proven HPD evaporation/crystallization technology. Over 70 systems have been purchased for installation world-wide. In addition the CNSI solidification technology is the only one to be successfully employed in the processing of the four major chemical cleaning solutions used in the nuclear power plants in the last two years: CAN-DECON; NS-1; LOMI; and AP/CITROX.

CNSI's cement solidification process has been reviewed and accepted in a Topical Report by the US NRC. In addition over 17 waste forms solidified with CNSI's proprietary cement media have been tested and qualified to the requirements of 10CFR61 and associated regulatory requirements. The highest waste to container ratio in the industry is offered, with up to 80 percent efficiency for stable waste forms.

In developing this integrated mobile system, a prime consideration was process operating costs. In particular volume reduction energy costs. With HPD's extensive experience and development work with Mechanical Vapor Recompression (MVR), a highly reliable inexpensive source of evaporative energy is available to complete the GEODE^{sm} System. Thus MVR not only eliminates the need for steam supply but requires about 1/5th the cost of conventional energy input.

Another benefit is the full service availability, with over 15 years of service to the nuclear utilities, GEODE^{sm} System offers complete project capability, including waste removal from plant storage and delivery to a disposal facility. This also provides all equipment and controls so that a minimum of support items such as utilities and health physics coverage is required.

The GEODE^{sm} Advantage:

- optimum liquid waste volume reduction; 50% solids
- optimum solidification waste to container efficiencies
- minimum energy requirements; only 20% of normal
- minimum plant support
- no expensive auxiliary steam required
- no tech-spec change; only 10CFR50.59 review required
- equipment flexibility; modular or all-weather, self contained
- minimum move-in and set-up time; 48-72 hours
- fully qualified operators; maximum process efficiency
- a service; no plant maintenance support required
- NRC accepted solidification Topical Report
- meets 10CFR61 & BTP; over 17 stable waste forms qualified

Fig. 1. Advantages of a Mobile Volume Reduction/ Solidification Service.

The System offers the utility, the ability to plan and program its liquid waste processing program on an annual basis, while having the flexibility to handle unforeseen upsets.

PROCESS DESCRIPTION

The processing of waste liquids in the GEODE^{sm} System is performed in two distinct, but intergrated process steps. The first process step is volume reduction of the waste solution in the Mobile MVR Crystallizer Unit (MCU). The second process step is immobilization and stabilization of the concentrated waste solution in disposable liners by the Mobile Cement Solidification Unit (MSU).

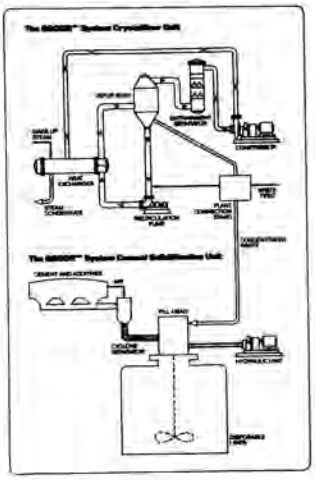

Fig. 2. GEODE^{sm} Process Flow Diagram

Volume Reduction

The crystallizer process is capable of concentrating, at a net capacity of 5 gpm, various waste streams to more than 50 weight percent total solids, while assuring:

A decontamination factor from feed to distillate of up to 10^4 for non-volatile radioactive species, and

less than 1.0 ppm total solids in the distillate.

The crystallizer has operated on the following solutions:

- o cleaning solutions,
- o chemical decontamination solutions,
- o neutralized borated waste,
- o chemical waste,
- o floor drain waste,
- o regenerative waste,
- o laundry drain waste.

The crystallizer process operates at concentrations of 50 percent solids or higher which reduces waste concentrate volume and, significantly reduces scale formation, due to:

- o the presences of solids in the slurry which offer a high surface area for deposition and entrapment of scale-forming material thereby preventing deposition of these materials on heater and vapor body surfaces.
- o the temperature rise of the liquid flowing through the heat exchanger is controlled to minimize the influence of heat-sensitive scale forming materials.

The volume reduction process step starts with the introduction of the preconditioned waste feed stream into the crystallizer concentrate recirculation pipe at the suction of the recirculation pump. Concentrate is recirculated from the vapor body crystallization chamber, through a double-pass, shell-and-tube heat exchanger and back to the vapor body. In the vapor body, the temperature of the process liquor is reduced by flashing. The flash vapor exits the vapor body and passes through an external entrainment separator and on to the compressor, where, the pressure of the vapors are increased by a factor of two, then desuperheated and finally condensed on the shell side of the heat exchanger.

The vapor body serves two functions. The lower portion of the vapor body provides retention volume (and time) for the recirculating liquor (concentrate). This time is necessary to assure separation of vapors from the concentrate and for crystal formation. The upper portion of the vapor body provides a disengagement area where the entrained concentrate, under the forces fo gravity, is separated from the vapor.

The entrainment separator produces a high quality vapor by mechanically separating the remaining entrained solids to 1 ppm. The separator vessel is separate from the vapor body in order to provide more efficient, flexible operation and easier maintenance than can be provided by an integral separator. The separator consists of a mesh pad and trays with a pad washing system. The separator agglomerates water particles, dissolved solids, and suspended solids and drops them to the bottom of the separator where they are returned to the vapor body for reprocessing.

After the clean vapors leave the separator, they go to a motor-driven mechanical compressor which compresses the vapors to the condensing pressure of the unit's heater. The heat added during compression raises the vapor temperature to above saturation and are desuperheated prior to discharging into the heat exchanger where they condense and give up their sensible heat to the recirculating concentrate liquor.

The waste solution concentration is allowed to build-up in the crystallizer until the desired concentration is obtained and a sufficient volume for transfer has been produced. The concentrate is then rapidly transferred to the MSU; the transfer lines flushed with feed, and concentration continued.

The process has been designed to take careful consideration of the problems associated with transfer of the concentrated waste, to subsequent processing. This transfer is particularly important since the slurry concentrate is at 50 percent total solids or higher.

Mechanical Vapor Recompression

The concept of mechanical vapor recompression is that heat generated can be recovered. For application to radwaste volume reduction with low boiling point rise, the vapors of evaporation, captive with their available latent heat, are compressed to approximately double the saturation vapor pressure. The compression of the vapors by the single stage compressor adds energy to the vapors in the form of discharge pressure and superheat. This higher pressure, superheated vapor is then desuperheated to approximately the saturation point (discharge pressure value) thus recovering the superheat of the vapor as sensible heat. Therefore the total "steam" heat available to the heater from the vapors is equal to: Heat of vaporization of the initial evaporation, plus the heat of compression, plus the superheat of compression (recovered by desuperheating). This total heat input is given up as heat of condensation at the heater.

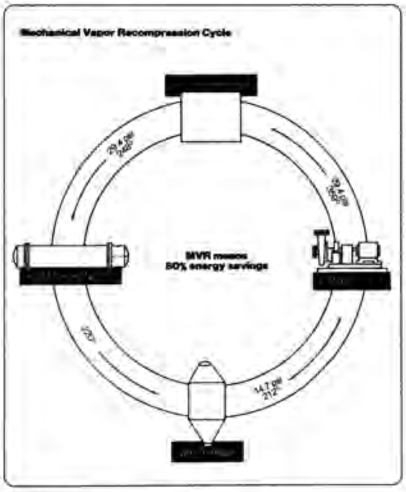

Fig. 3. MVR Energy Cycle.

Actual economics are such that only the incremental heat load between that required at the heater and that available in the evaporation vapors need be provided by the machanical compressor. Whereas the coventional steam heated source supplies 100 percent of the heat energy, plus a vapor condenser with cooling water is required. For example, a 5 gpm feed to 50 percent solids at atmospheric operation requires approximately 1.8 million BTU/hr or 1950 lbs/hr of steam. Where, mechanical vapor recompression requires about 95BHP. Using a $6/1000 steam and 3.5¢/kwh yields a 5.0 cost factor.

Solidification

The Mobile Cement Solidification Unit will mix the concentrated solution from the MCU with dry portland cement and CNSI's propietary additives as determined during simulated waste solution testing, qualification and certification which will also develop the Process Control Program (PCP).

Waste will be processed by the MSU in a semi-continuous batch mode at a rate which will be a function of several individual process functions including: The rate of waste concentrate production from the MCU; the rate of waste formulation verification using the PCP; the rate of waste pretreatment; and the rate of waste solidification.

The waste concentrate produced from the MCU will be transferred directly into a disposable liner equipped to adjust the waste concentrate chemistry, mix the waste concentrate, and sample the waste concentrate for PCP verification. When sufficient quantity of waste concentrate has been received in the disposable liner, input from the MCU is held and the contents of the liner thoroughly mixed. A sample will be taken and the PCP will be used to verify solidification. Upon verification the waste will be solidified, the liner moved to a holding place for shipment and a new liner moved into place.

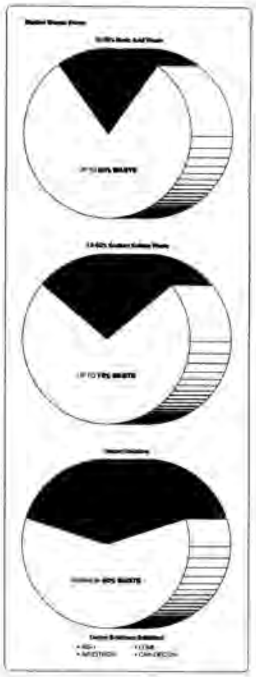

Fig. 4. Cement Solidification: Cement to Waste Ratio for Various Waste Forms.

EQUIPMENT DESCRIPTION

Mobile MVR Crystallizer Unit

The design is based upon a forced circulation crystallizer with heat exchanger tube boiling suppression. The major components of this system (see Fig.5) are a vapor body, heat exchanger, recirculation pump, entrainment separator and motor-driven mechanical vapor compressor. Specific attention is given to design details which will ensure safe and stable operation as well as ease of operation and decontamination.

The vapor body is constructed of a high alloy material for severe conditions without susceptibility to pitting or chloride-induced stress corrosion cracking. Special vapor body design features include: Wash nozzles to clean surfaces above liquid level; polished internal surfaces to mitigate scale formation on the crystallizer walls; very low vapor velocities and proper disengagement height to minimize carry-over; and properly designed re-entry nozzle to minimize erosion of vapor body wall opposite to re-entry. The construction of the separate entrainment separator protects the mesh pad from crud build-up and provides ease of maintenance.

The heat exchanger has 2" diameter high alloy tubes with a #4 sanitary finish on the internal surfaces which offers significant ease of decontamination as well as much higher heat transfer coefficients than typical tubes. The tubesheets are solid high alloy. Along with a solid high alloy tubesheet, the rolled tube offers a second barrier to heat exchanger leakage.

The recirculation pump is of a Cast Alloy 20 construction. Specific design features include the use of a special packing gland beside the double mechanical seal. Additional unique features of HPD recirculation pumps are low operating speed for long life; and spring mounted base to eliminate expansion joints in recirculation piping, as well as vibrational fatigue.

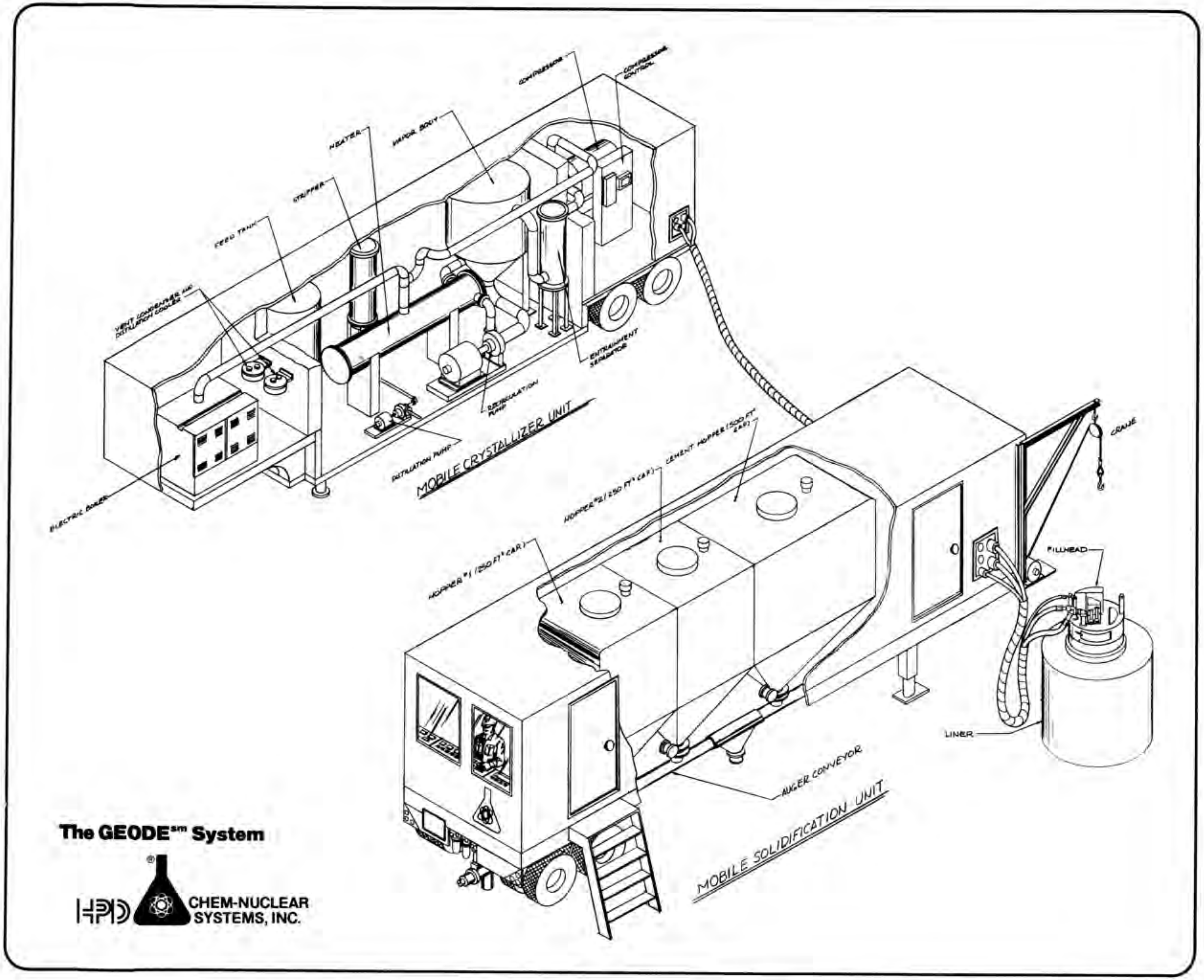

Fig. 5. GEODE^{sm} Service: Isometric View

Mechanical vapor recompression (MVR) is provided by a Turbonetics single stage centrifugal compressor driven by a electrical motor which develops a 2.0 compression ratio. Centrifugal compression provides pulsation-free, vibration-free operation that ensures longer equipment life. Another advantage of this type of compression is that wear and tear on the impeller does not result in lowering of efficiency during the life of the unit. Also, it is possible to turn down the capacity of the compressor in such a way that there will also be power savings.

The compressor casing, diffuser and shroud are constructed of 316 SS materials. The impeller is 17-4 pH SS material and the gear housing of cast iron. The majority of the lubrication oil system is constructed of carbon steel materials. The single Helical gears is constructed of high alloy steel.

Mobile Cement Solidification Unit

The MSU is a unit which has been proven in the field and will meet the demands of the job. The MSU is an all weather, self-contained 45 foot trailer(see Fig. 5) with all equipment, controls and chemicals contained within the trailer necessary to perform volume reduction and solidification of waste. The major components of the MSU are a control cabin, chemical bulk storage hopper section with transfer equipment and plant connection stand area with fillhead storage provisions. The MSU meets all design considerations of CNSI's U.S. NRC accepted Topical Report.

Chemicals are transferred to the process fillhead from the bulk storage hoppers, by an auger transfer system. The transfer system is designed to collect all chemical dust which is filtered out and vented to the atmosphere. The quantity of chemcals transferred through the fillhead to the disposal liner is verified by means of a load cell mounted on the trailer frame.

A fillhead with extension skirt is provided to permit remote introduction of solidification materials and waste concentrate into the disposal liner and remote in-container mixing of these materials to provide a completely homogeneous mixture.

The stainless steel fillhead is capable of being hoist mounted to provide vertical movement and also removal for storage. A series of spray nozzles are located beneath the extension skirt enabling remote decontamination with water. The advantage of the extension skirt design is that waste filling is lowered onto a 55-gallon drum sized fill port on the disposal liner and is sealed by a rubber gasket. The fillhead is then secured by quick disconnect chain binders.

Mixing of the waste and binder is accomplished using a disposable in-container mixing blade assembly coupled to a hydraulic drive on the fillhead. Coupling of the mixer shaft to the drive is by means of a square drive shaft inserted into the hollow mixer blade shaft. The hydraulic power supply is remotely located to allow ease of maintenance.

The transfer of required utilities to the GEODE^{sm} System is accomplished through the plant connection stand. At this one mainfold, the waste feed, flush water, compressed air, and ventilation connection to the plant's piping systems are made. Instruments for the measuring of the flow and pressure of these streams are provided on the plant connection stand and transmitted to the control panel for use in operating the system.

The main control panel provides a total display of the GEODE^{sm} System operation. All of the critical system components are indicated. This includes the major valve positions, pump performance, heat transfer data, compressor status, and critical operating pressures and temperatures. In general, the system is instrumented to provide safe, reliable operation that is easy to control and maintain.

Functional automatic controls are provided in which the operator actuates controls sequentially. The control system has been designed to simplify the operator's job and also to preclude the possibility of making an error. A manual control mode is also provided to individually operate any item of equipment for test purposes or special operation.

The control panel provides a complete display of the system to clearly show the operating condition (including valve positions) of the entire system. A closed circuit TV monitor for the fillhead is mounted on the control panel to provide a operator with a visual indication of the solidification process.

All equipment provided is designed to fail in the safe position, should a loss of air or electrical power occur.

The GEODE^{sm} System is designed in accordance with the ALARA principal with equipment arranged and shielding provided to minimize operational and maintenance personnel exposure. The equipment is arranged with easiest access to those active pieces with highest probability of requiring maintenance, thereby reducing maintenance time. In addition, those pieces that will contain the most concentrated liquids and therefore expect to have the highest source term are designed and provided with shielding. Although it is CNSI's personnel that are responsible for operation and maintenance of the system, minimizing its overall exposure contribution to the facilities personnel is very important.

RESPONSIBILITIES

The GEODE^{sm} System provides:

- a system designed and constructed to Guide 1.143.
- a maintenance of the system's equipment.
- solidification chemicals and disposable liners.
- qualified technician(s) to operate the system.
- Process Control Program (PCP) and system operating procedures.
- documents to support plant safety evaluations.
- solidifications qualification testing and certifications.
- transport of the waste to ultimate disposal (optional).

The customer provides:

- adequate work space for:
  - operation of the GEODE^{sm} System.
  - storage of solidification chemicals and disposable liners.
  - operator business and personal hygiene space.
- operator(s) and equipment for the movement of GEODE^{sm} equipment and supplies.
- protective clothing and adequate radiation monitoring equipment.
- Health Physics coverage to conduct operations in compliance with ALARA.