

INTEGRATION OF LOW-LEVEL NUCLEAR WASTE STORAGE AND DISPOSAL REQUIREMENTS IN THE 1990'S

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ABSTRACT

Uncertainties in the availability of facilities for disposal of commercial low-level waste has led many utilities to develop contingency plans for on-site storage. The requirements for safe storage for extended periods are in many ways similar to that for waste disposal and other handling operations. Specifically, durable containment, ruggedness, shielding capability and flexibility in handling. Chem-Nuclear Systems, Inc. (CNSI) has developed a single container design that can be used for both storage and ultimate waste disposal. In many instances this container, known as the Multi-Use Container (MUC) can also be used for waste processing operations and transportation, thus integrating the entire spectrum of waste container needs.

The MUC container is a composite vessel consisting of a concrete external shell and an inner polyethylene vessel. The concrete used is a tested, highly durable formulation with a corrosion resistant fiber additive developed in France by SOGEFIBRE. CNSI has supplied polyethylene vessels for storage and disposal in U.S. for over 10 years. The integrated material systems offers many technical and cost advantages to counteract problem trends in the 90's. This paper presents details on the design and operation of the MUC. Information on applications and certification as a high integrity container for disposal is also presented.

INTRODUCTION

Chem-Nuclear Systems, Inc. (CNSI) has developed a proprietary concrete/polyethylene container for use in storage, process, transport and disposal of waste. This single container design will integrate all of the most common waste disposal functions. Its development was focused on minimizing the effect of uncertainties in the national programs for the disposal of low-level radioactive waste. A major concern is the possibility that the unavailability of existing disposal sites and the protracted start-up of new sites will require long-term waste storage at the generator's site.

Chem-Nuclear Systems, Inc. has been directly involved as developer and operating contractor of three new LLW disposal facilities in Illinois, North Carolina and Pennsylvania. Each of these disposal facilities will require placement of the waste container into a concrete overpack prior to final disposal. CNSI, as the operator of the Barnwell burial facility, has also placed polyethylene vessels in concrete overpacks. Several years ago, we recognized that a specialized concrete container could be developed which combined interim storage at the generator's site as well as the final disposal container functions. Additional functions could be added such as the use as a processing vessel and for transport of certain wastes. CNSI, in 1991, embarked on the design of a family of concrete vessels which we called the Multi-Use Container (MUC). After considerable design, evaluation and testing, a license application, as a Topical report, containing proprietary technical data was submitted to the Nuclear Regulatory Commission (NRC) in 1992. The objective of obtaining approval of the MUC as a High Integrity Container will provide federal certification of the structural strength and long-term durability of the container as well as suitability for low level waste disposal.

The MUC design consists of a heavy walled concrete shell. It is fabricated using a special proprietary formulation of fiber reinforced concrete which has been developed by the French company, SOGEFIBRE. This concrete formulation has been extensively tested by the French government, and has been validated for use as a burial container for low level waste due to its projected lifetime of from 300 to 500 years or more.

The concrete vessel also provides structural integrity under burial conditions and radiation shielding during handling. The inner polyethylene liner provides an additional level of protection. Polyethylene vessels have been used in the U.S. for waste processing, transport and disposal by CNSI and others for more than 10 years. It has considerable chemical resistance, reasonable structural strength, and it can be sealed to provide a virtually leak-tight, impermeable barrier.

The paper will discuss the various technical details of the MUC design and its adaptation for use at nuclear power plants. Our objective is to have available, an NRC-approved disposal container in 1993.

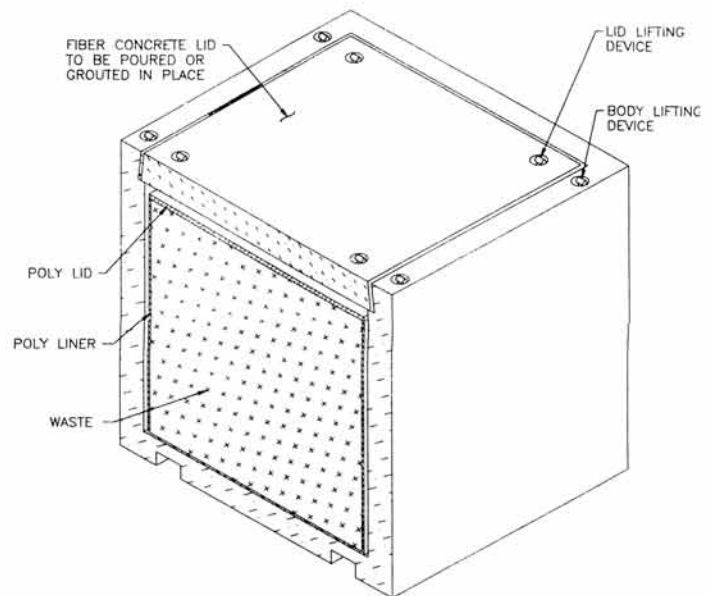


Fig. 1. Disposal configuration.

SYSTEM DESCRIPTION

The key system component is the overpack vessel shown in Fig. 1. The overpack consists of a large, rectangular external concrete shell with an inner polyethylene vessel. The composite vessels are configured with different accessories to accommodate, processing, storage, transport and disposal functions. These configurations are illustrated in Figs. 2(A) - 2(D).

The vessel materials provide different functional capabilities which serve in a complementary manner. The concrete shell provides a durable structural envelope. The concrete structure is designed to withstand the loading effects associated with burial up to 55 feet deep, or a 3 tier high stacking. The basic concrete formulation and additives/admixtures have been designed and tested to provide great durability even under adverse operating conditions (e.g., high freeze-thaw cycling, continuous exposure to acid solutions emanating from local soil conditions, etc.). The polyethylene shell provides a sealed vessel which is impermeable to liquids, and highly chemically resistant. The polyethylene shell provides operational flexibility in that it may be independently used as a storage/processing vessel at the generator's site, and shipped with a metal radwaste cask to the disposal site. Alternatively, the concrete shell provides radiation shielding for processing and storing the waste at a generator's site.

Disposal Option

The MUC configuration for disposal is shown in Fig. 2(A). This configuration consists of the following components:

- External Shell - The vessel can be configured in a variety of sizes from a nominal 5 foot cube (with an volume value of 60 cubic feet) to a vessel 8 foot square

by 10 foot high (nominal internal volume of 275 cubic feet). The nominal wall thickness is 5-1/2 inches thick when used for disposal within a concrete module. When the MUC is used for landfill burial, or extra radiation shielding is needed, the vessel concrete wall thickness may be increased to as much as 10-12 inches.

The shell has handling provisions for vertical hoisting using the four sling lifting connections in the upper corners. Notches in the vessel bottom are provided for forklift handling.

- Polyethylene Vessel - The internal polyethylene vessel may be rectangular or cylindrical in shape, and will fill most of the available empty volume formed by the concrete vessel cavity. The wall thickness is a minimum of 3/8 inch, which provides considerable margin against failure, even including possible pin-hole failures in the plastic. It has sufficient strength to permit independent handling of the polyethylene vessel. The vessel may be filled through either a processing port or through a full diametral opening. Following loading, either lid can be remotely closed and sealed using a thermal resistance element embedded in the plastic. Optional enhancements include:
 - Gas Vent - Used for release of gaseous products emanating from decomposition of organic wastes.
 - Sample Tube - Used to verify that liquids have been removed from the waste form.

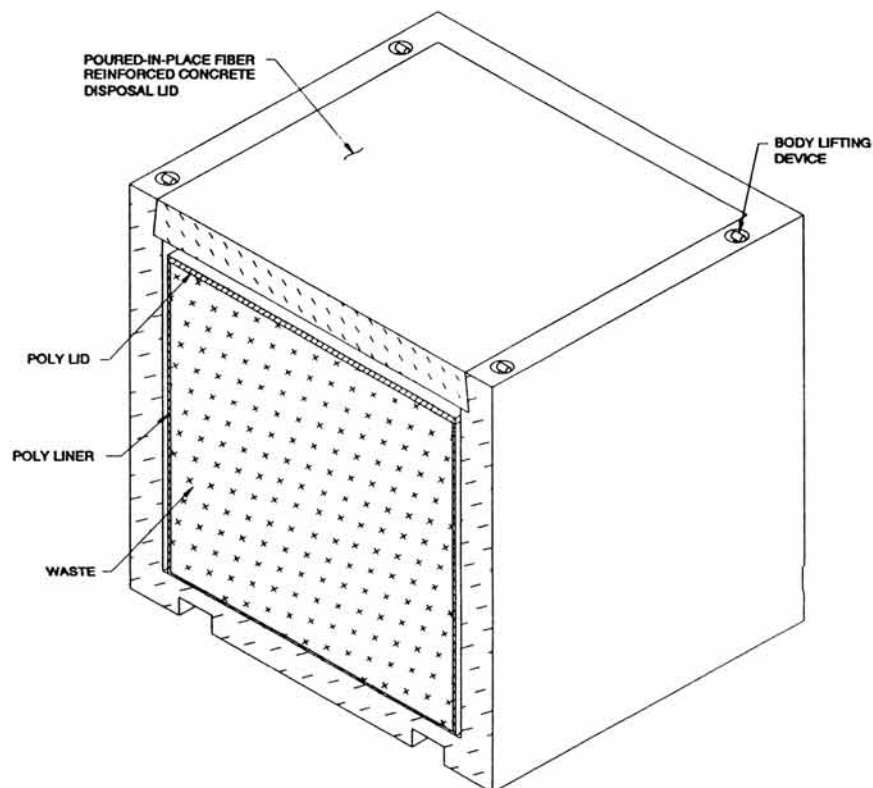
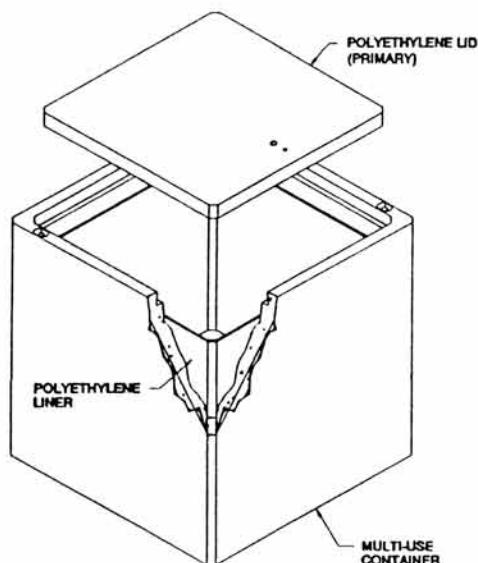
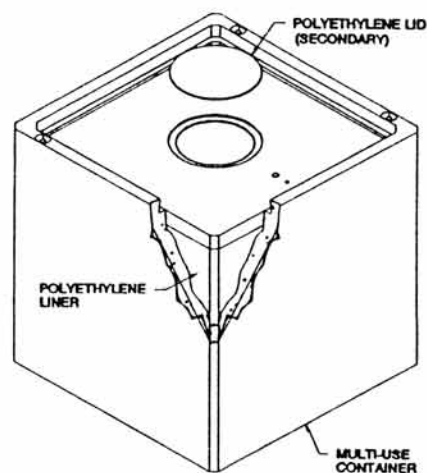


Fig. 2a. Disposal Configuration.

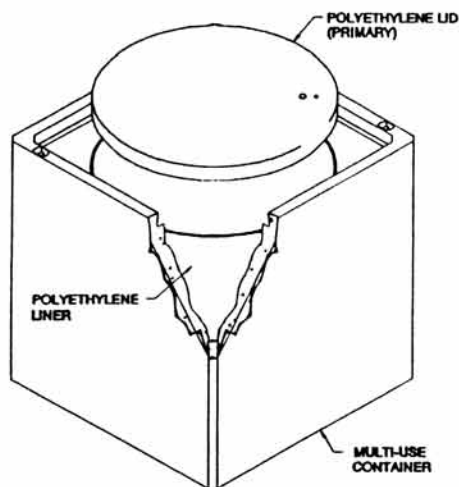
HIC WITH RECTANGULAR POLYETHYLENE INNER CONTAINER/PRIMARY LID



HIC WITH RECTANGULAR POLYETHYLENE INNER CONTAINER/SECONDARY LID



HIC WITH CYLINDRICAL POLYETHYLENE INNER CONTAINER/PRIMARY LID



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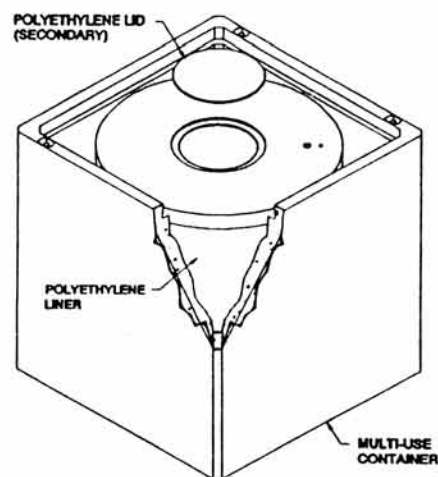


Fig. 2B. Processing configuration.

- Shielding - Steel rings may be placed within the vessel to enhance gamma shielding.

Prior to final disposal, the free internal volume between the polyethylene and concrete container is completely filled by pumping a cementitious grout. This grout, when cured, serves to totally encapsulate the waste as a monolithic waste structure.

Processing Option

The MUC configuration used for waste processing is shown as Fig. 2(B). Waste processing (e.g. - resin dewatering or waste solidification) occurs within the polyethylene vessel. This vessel would typically be surrounded by the concrete

vessel which provides shielding. Following the processing operations, the polyethylene top will be closed by heat sealing. This renders the inner container leak-tight. In certain cases the weight of the filled vessel may exceed the facility radwaste crane capacity. In these situations the waste can be processed in a bare polyethylene container thereby reducing the overall weight. The polyethylene container can be mated with the concrete container at a different location provided specified handling precautions are taken.

On-site Storage

The composite concrete/polyethylene MUC can be utilized as a shielded container for extended on-site storage.

Polyethylene containers have been previously evaluated and shown to be suitable for safe storage of radwaste for extended periods of time (1). A concrete closure lid, fabricated from concrete, would be placed into the flanged recess of the concrete container (See Fig. 2C). The proven durability of the MUC vessel ensures long-term safe storage of the waste material.

Off-site Transport

Off-site shipment, using the MUC system, has both economic advantages and provides some measure of operational simplicity. There are two options for use of the MUC system for off-site transport. With waste quantities requiring ship-

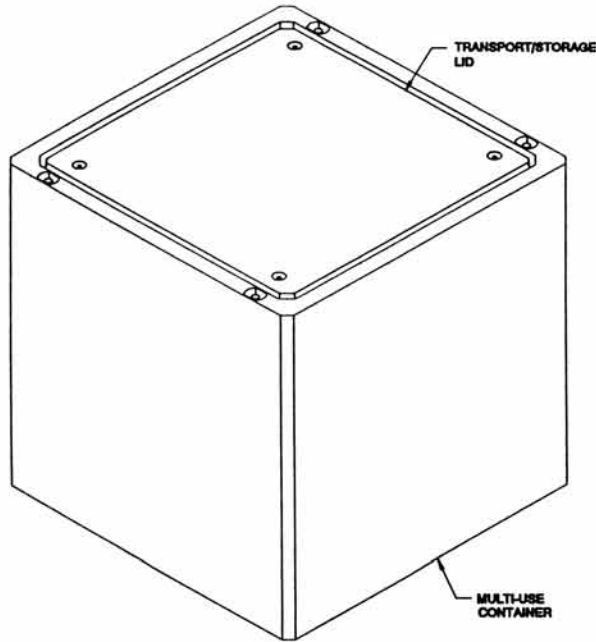


Fig. 2C. MUC storage configuration.

ment in an approved Type B package, the polyethylene inner liner must be separately shipped in an NRC-certified, metal radwaste cask. The polyethylene container and concrete vessel will then be mated at the disposal site. All other waste can be shipped in the MUC vessel in the configuration shown in Fig. 2D). This shipping configuration consists of a removable device with tie-downs and shock absorbers. It envelops the container during transport. Also, included in this shipping device is the concrete storage lid which closes the vessel cavity. The MUC system has been evaluated and tested to verify conformance to Titles 49 and 10 of the Code of Federal Regulations. This evaluation showed acceptability as Type A packaging (Specification 7A container) in accordance with U.S. Department of Transportation regulations. Successful full-scale drop testing of the vessel was performed to verify the container integrity under worst case accident scenarios.

SPECIAL SYSTEM FEATURES

The MUC system has been designed for the known waste disposal needs for all nuclear generator and disposal sites. To provide this versatility, the design can be modified as follows:

- Sizes - Container sizes with internal volume of 40 to over 200 cubic feet.
- Shielding - Extra radiation protection is available by increasing the concrete wall thickness or adding steel rings internally.
- Disposal - The containers contain adequate structural reinforcement to accommodate disposal in above-grade modules or burial at an engineered landfill to a depth of up to 55 ft.

The following additional system features are important:

- Experience - The concrete/polyethylene vessel system combines construction and operational experience of both France and the U.S. The French national waste disposal program has employed concrete overpacks since the mid 70's and over 100,000

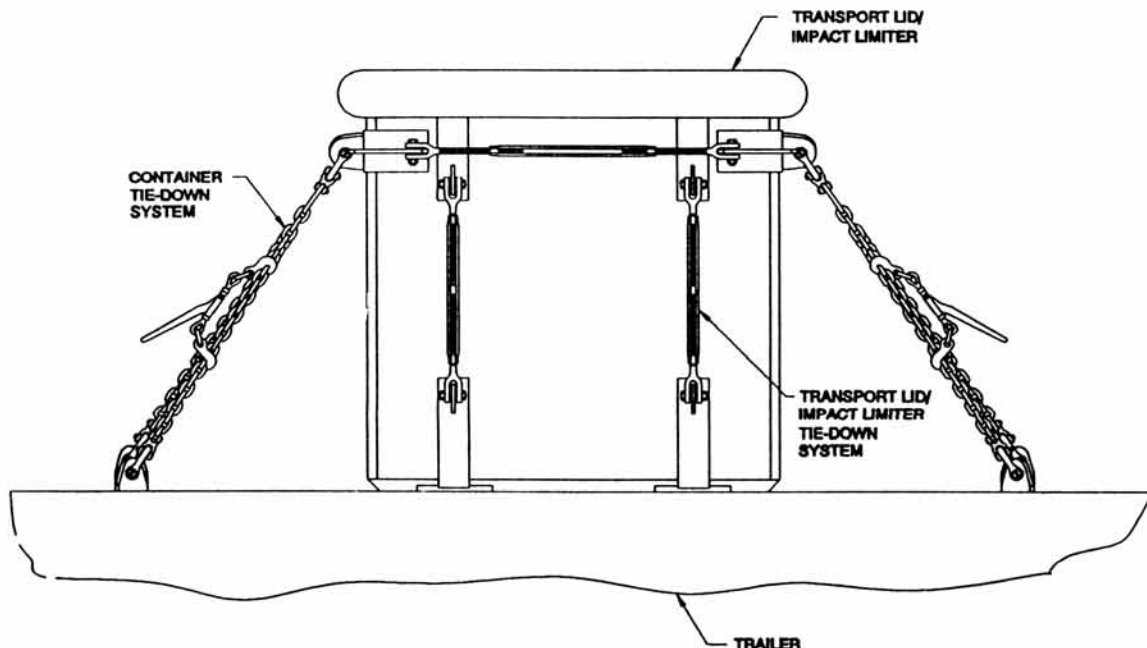


Fig. 2D. MUC transport configuration.

have been used to date. The concrete formulation has been part of a multi-million dollar, eight year test program. This program has resulted in French government certification of the material durability under disposal conditions.

In the U.S. there has been over 10 years experience with polyethylene disposal containers. During this time, over 10,000 containers have been buried. In 1988, the polyethylene containers were mated with reinforced steel concrete overpacks for burial at Barnwell. Over 1,200 containers have been buried in that configuration for Class B, C wastes.

- **Durability** - A performance objective of the MUC system has been to eliminate any known factor that could lead to failure of the MUC, even over multi-hundred year periods. The design makes provision for great structural strength and resistance to any chemicals or physical condition that could lead to deterioration. Factory production with a stringent quality program will greatly minimize the possibility of poor manufacture.

Testing programs of this specific concrete formulation have shown that a mean container lifetime of at least 500 years is attainable. This projected lifetime is as a direct result of the previously mentioned multi-year testing program by a French national agency. A significant outcome of this program has been the replacement of steel reinforcement bar with fiber reinforcement known as Fibraflex. The reinforcing fibers have an amorphous structure. The amorphous structure along with the presence of chromium yields a highly corrosion resistant fiber (over 2,000 times more corrosion resistant than stainless steel). The fibers enhance the concrete structural properties, thereby minimizing the potential for micro-cracking, and are highly durable.

The sealed polyethylene inner containers also provide a high measure of durability and protection against long-term material release. The polyethylene is highly corrosion and erosion resistant, and virtually impermeable to liquids. When sealed, the vessel is leak-tight. The concrete structure surrounding the polyethylene isolates this plastic material from structural loadings and other external factors which might otherwise cause deterioration.

- **Quality** - The MUC system was designed to be fabricated in a factory-production environment. This leads to both cost improvements and consistency in the quality of production. In a factory environment where standardized production methods are practiced, in-process inspections, consistent raw material quality, etc. will lead to containers with an extremely low probability of failure.
- **Cost** - A key MUC system attribute is the cost-effectiveness to the waste generator. The multi-use provision permits the vessel cost to be shared between multiple applications. At present new LLW compact sites will require durable concrete overpacks for disposal. In addition, many generators are presently purchasing concrete vessels for interim on-site storage. These two functions can be totally performed by

the MUC vessel. Use of the MUC for direct waste processing needs and transport requirements is also a significant advantage. The use of the MUC vessel also obviates the necessity of a costly radwaste storage building.

The MUC system does not use any costly materials to meet the required performance needs. Concrete and polyethylene are experienced, cost-effective materials with well known manufacturing techniques. Hence, the projected production cost is reasonable.

- **Logistics and Handling** - The integrated MUC system provides considerable operational flexibility, since the same equipment can be used for many purposes. There is no need to have an inventory of special purpose equipment. There is also less concern with contaminated disposal of special equipment after the equipment is no longer needed.

However, the MUC system design provides intrinsic flexibility for a variety of applications. Specifically, extra shielding can be added; handling by both cranes and forklift is possible; and the polyethylene inner container may be decoupled from the concrete vessels when space and weight concerns are limiting.

MUC DEVELOPMENT PROGRESS

The need for integrating various disposal system functions in a single, highly durable, containment system has long been recognized by CNSI. A program to develop the MUC system was started in mid-1991. Since that date considerable progress has been made in development of a system for widespread U.S. application. The following program accomplishments are critical to its eventual usage:

- **US/French Design Integration** - The concrete shell is based on the French disposal overpack. Full-scale, factory production has been underway in France for several years. Over 20,000 concrete vessels have been produced using the SOGEFIBRE technology. This concrete technology has been certified by the French national nuclear waste program as meeting, and even exceeding their long-term durability requirements necessary for safe waste disposal. The polyethylene vessel technology was required for U.S. application, since certain waste forms that are approved in this country are not practiced in France. In addition, the polyethylene vessel provides an extra, high durability container. Construction of prototypes combining both the concrete and polyethylene vessels was completed in mid '92 and various operational tests were successfully performed.
- **DOT/SPEC 7A Testing** - Testing of the MUC container to DOT standards, provides verifiable assurance of the ruggedness of the system under worst case handling conditions. It also permits highway transport of the MUC vessel for Type A quantities of radioactive material. A testing program of the MUC vessel showing conformance to both DOT and international transport standards was performed in 1992. The limiting test was a 4-foot drop of a loaded MUC vessel onto an unyielding surface over a number of drop configurations. The drop tests were successful. Test results showed that there was no release of

contents following the drop. In fact, there was no material damage to the inner polyethylene vessel and the concrete vessel, though evidencing local cracking, did not lose its basic configuration.

- **High Integrity Container (HIC) Certification** - A topical report application was prepared by CNSI for the MUC and submitted to the U.S. Nuclear Regulatory Commission (NRC) in July 1992. The license application was developed to obtain NRC approval as a HIC disposal container. Several progress meetings have been held with the NRC and we are targeting approval in 1993.
- **Facility Application Studies** - Several nuclear plants were targeted for application studies. On-site surveys and discussions were held with plant operations personnel. The objective of these studies was to verify the compatibility of the MUC vessel with plant operations. CNSI records of all of the waste shipments were also examined for a two-year period to statistically evaluate such parameters as weight/size capability, radiation shielding requirements, etc. The applicability studies verified that the MUC could be successfully used, without significant variation from the basic design configuration at these nuclear plants. Surveys of other plants generally show the same level of applicability.
- **Production Capability** - The MUC system requires a factory environment for efficient, high quality, low cost production. The concrete formulation requires that certain material controls, production tests, and inspections be performed. CNSI has had discussions with suitable fabricators and has developed a plan for volume production in the U.S. Decisions on the date

for full-scale production will be made in the near future.

CONCLUSIONS

The results of CNSI's experience and marketing studies has shown that a disposal system employing waste containers with multiple uses has considerable advantage. Of particular importance is the need for a system to "bridge" the possible gap in availability of low-level waste disposal sites in the mid 1990's. The MUC system provides confidence to the cognizant waste supervisor that the waste package will provide both safe on-site storage and will be suitable for eventual waste disposal. It also provides to the nation, an extremely durable waste container. Under expected disposal conditions the waste container should provide leak-tight containment of the radioactive materials for many hundreds of years. This confidence is amplified by the review and certification by governmental agencies, the high quality and durability of the materials, and the proposed method of manufacture.

In summation, the difficulties in ensuring that allocation for low-level waste disposal are available mandate that contingency plans be made. Clearly any plan should focus on a standardized and straight-forward system design. The MUC system has been designed to provide both simplicity and flexibility to the waste generator. We feel that an integrating approach such as this is needed for the problems expected in the 90's.

REFERENCES

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