SHIPPING ENCAPSULATED CS-137 SOURCES AS SPECIAL AND NORMAL FORM

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ABSTRACT

In June 1988, a Cesium-137 irradiation source, located in a commercial irradiation facility water basin near Atlanta, Georgia, began to leak. Because of the failure of this source, the decision was made to transport it and all similar sources back to their place of manufacture at the Hanford Site in southeastern Washington State. As this shipping campaign progressed, many challenges were encountered, and the process of underwater loading, de-watering, and drying the transportation packages went through a significant evolution. The loading methods and drying standards that resulted may reflect a trend in underwater packaging requirements for this type of material.

BACKGROUND

In the 1960's and 1970's a large volume of high-level radioactive liquid containing Cesium-137 was produced as a byproduct of reprocessing defense-related nuclear materials. In an effort to reduce this volume of liquid a program was established at the Hanford Site, whereby reprocessed Cesium-137 in chloride form was encapsulated using double-walled stainless steel containers. These "capsules" were manufactured and stored in a water basin at the Waste Encapsulation and Storage Facility (WESF).

The capsule dimensions are 6.743 cm (2.655 in.) in diameter and 52.768 cm (20.775 in.) in length (Fig. 1). Capsule weight is typically about 9.07 kg. The average Cesium-137 loading was 42,500 Ci, generating an average of 200 W of heat per capsule. More than 1,500 of these capsules were produced between 1974 and 1983.

Early in the encapsulation program various tests were conducted to evaluate capsule performance for transportation and long term storage. Capsules were tested with nonradioactive cesium chloride and evaluated according to the requirements of Special Form Material in U.S. Energy Research and Development Administration (ERDA) Appendix 0509 and U.S. Nuclear Regulatory Commission (NRC) 49 CFR 173.469. This special form qualifies the capsule to be an integral part of the containment system for transportation.

In 1985, the NRC and U.S. Department of Energy (DOE) approved the leasing of these capsules as sources in commercial irradiation facilities. In 1986, 252 Cesium-137 capsules were delivered to a commercial irradiation facility located in Decatur, Georgia. The facility license specified that the source capsules would be transferred from a shielded shipping container underwater; stored underwater, when not being used for sterilization; and raised out of the pool into the air during product sterilization.

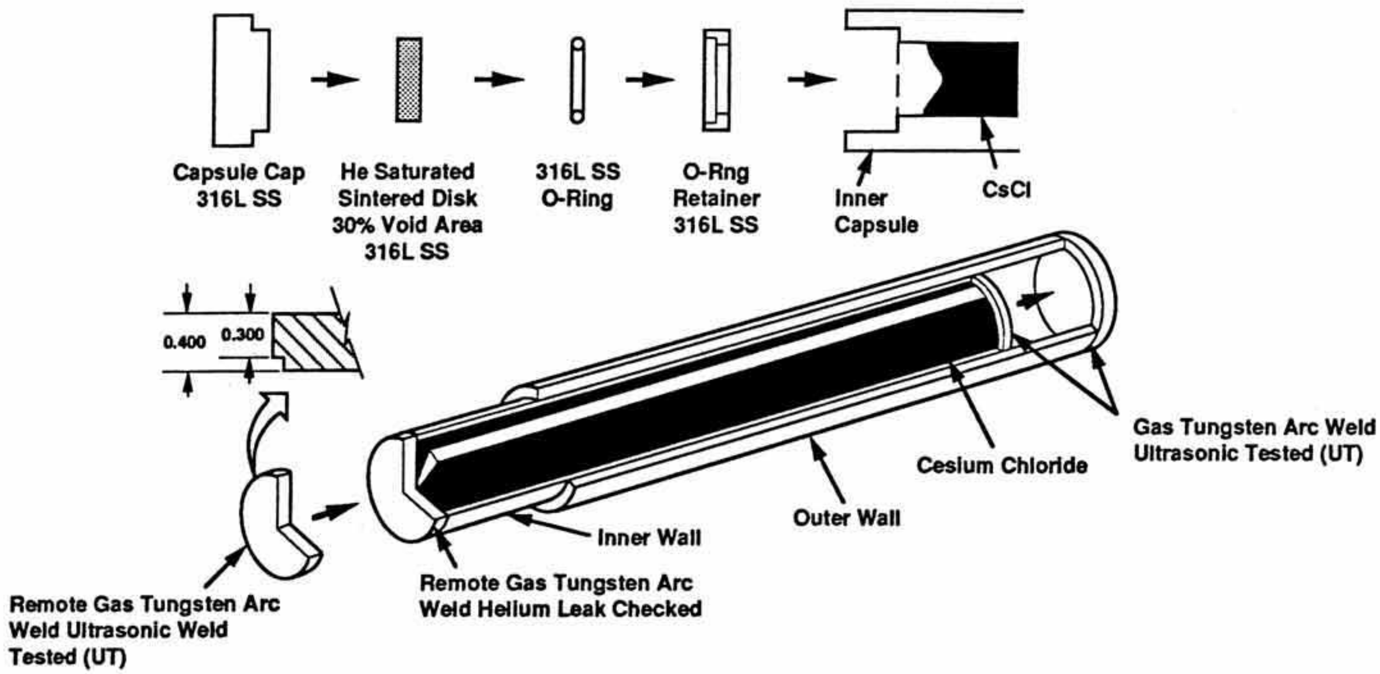
DECATUR INCIDENT

On June 6, 1988 workers at the Decatur facility detected higher than normal radiation levels at the surface of the storage pool. Sampling verified the presence of dissolved Cesium-137 in the pool water, indicating a leak in one of the capsules. During the next 6 mo, several methods were used in an attempt to identify the leaking capsule. The initial evaluation that was conducted used an underwater television camera, and identified certain capsules as "suspect" for various reasons. Further evaluation involved an ultrasonic probe to check for the presence of water leakage between the inner and outer cylinders. An underwater weighing procedure was initiated, but was considered unreliable and discontinued. Three capsules were also removed to a hot cell at Oak Ridge National Laboratories (ORNL) for nondestructive testing and further evaluation. Although three suspect capsules were shipped, none of them turned out to be the "leaker." In addition, analysis of the storage pool water indicated that the leak was continuing.

Since the leaking capsule had still not been identified, a special test device, the Pressure Cycle Leak Detector (PCLD), or "six pack sipper" was developed. The PCLD was designed to isolate up to six capsules at a time and allowed the surrounding water to be sampled for increased activity. Testing using the PCLD began in 1988 and on November 29, it was discovered that one capsule would not fit into the sipper due to a bulge located near one end. The capsule was isolated in a closed container. The next day the demineralizer system was able to significantly reduce the activity level of the pool water, indicating that this capsule was the leaker. Also another capsule was determined to have bulged, and both capsules were shipped to ORNL on December 20, 1988.

INITIAL SHIPMENTS

Shipping of the first five capsules to ORNL required the development of equipment and procedures. Because the suspect capsules were potentially breached, they were disqualified as meeting special form criteria and could not be shipped in their normal cask, the Model-1500. A review of certified Type B Radioactive Materials packages was conducted. The only suitable cask that could be used without a change to its NRC Certificate of Compliance (CoC) was the General Electric Model GE-600. Since a primary



Radio-active Material	Form	135 Cs Loading	Percent of Theoretical Density Based on Total Void Space of Capsule	Temperature: Air, Center Line	Temperature: Air, Surface	Temperature: Water, Center Line	Temperature: Water, Surface
Cesium Chloride	Melt-Cast	70 k Ci	65	450 °C	200 °C	327 °C	58 °C

Radio-active Material	Capsule: Inner, Material	Inner, Wall Thickness	Inner, Outside Diameter	Inner, Total Length	Inner, Total Cap Thickness	Outer, Material	Outer, Wall Thickness	Outer, Outside Diameter	Outer, Total Length	Outer, Total Cap Thickness
Cesium Chloride	316L Stainless Steel (UT)	0.095 (UT)	2.250	19.375	0.400	316L Stainless Steel (UT)	0.109 (UT)	2.625	20.425	0.400

Note: All dimensions are in Inches

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Fig. 1. Detail of waste encapsulation and storage facility Cesium-137 source capsule.

requirement was to isolate and remove the leaking capsule as quickly as possible, the time required for preparation and approval of a CoC revision was considered to be unacceptable. With the Model GE-600 cask (Fig. 2a), a special "capsule overpack" would be required to comply with the CoC, but special form qualification of the capsules was not needed.

An overpack was designed to fit inside the Model GE-600 cask. Because of the CoC decay heat limit of 600 W, the cask was limited to transporting 2 capsules at a time. The CoC for the Model GE-600 cask also required the package contents to be dry, therefore the overpack was designed to be blown dry with nitrogen. This requirement was complicated by the fact that operations involving the canisters at the Decatur facility were all conducted underwater at a depth of 4.572 m (15 ft) to 7.315 m (24 ft).

The capsules were lifted using tong type manipulators and loaded into the overpack underwater. Next, the overpack lid was lowered into place, and the 16 lid bolts were torqued using a long extension tool. Dry nitrogen was blown from a cylinder located above the pool, down through a 0.635 cm (1/4 in.) flexible plastic hose, into the overpack. The water in the overpack was displaced through another flexible hose to a dry "condensate trap" also located underwater. This condensate trap was used to contain the water and any radioactive CsCl that may have leaked from the capsule. A nitrogen purge was continued for 3 h to remove any residual water from the overpack.

The first shipment (one capsule) was made on August 17, 1988. Upon arrival, it was discovered that the overpack contained several milliliters of water. Two measures were taken to eliminate this from occurring in future shipments. First, the overpack was redesigned with an improved valve system. Second, the loading procedure was revised to require pulling a vacuum on the overpack to further ensure dryness. This vacuum drying required that the overpack be evacuated to 4 mm Hg less than the vapor pressure of water at pool water temperature and held for 15 min. The overpack was then isolated from the vacuum pump and considered to be dry if pressure rose less than 4 mm Hg in 5 min. This new design and procedure proved to be more successful in eliminating the water.

SEGREGATION AND DISPOSITION OF REMAINING CAPSULES

Because the mechanism for the capsule failure was unknown, and potential for additional failures, it was determined that all the remaining capsules would be returned to their place of manufacture, the WESF at the Hanford Site. Because there was only one Model GE-600 cask in existence, limited to transporting 2 capsules per shipment, and due to the difficulty of loading the cask/overpack package, it was necessary to use a different method to ship the remaining capsules to ensure transportation within a reasonable time period.

All of the capsules were originally transported to Decatur as "special form" in a Model-1500 shipping cask (Fig. 2b). This cask held four capsules in a specially designed basket. The leaser of the capsules had manufactured nine of these casks and therefore the transportation was able to proceed rapidly. Capsules that still qualified as "special form" could be returned to the Hanford Site using this method. However, potentially faulty capsules required using the Model GE-600 cask for return shipment.

Based on examination of the two bulged sources, it was suspected that the failure of the capsules involved swelling of the cesium salt. This information led to development of the following three basic inspections to check the integrity of the remaining source capsules.

1. Visual Inspection--using an underwater television camera, to check for unusual surface conditions.
2. "Clunk" Test--grasping a single capsule with a manipulator, lowering it quickly toward the pool bottom, and then stopping the motion. If the inner capsule is free to slide inside the outer capsule, there is an audible "clunk" noise. Absence of this "clunk" indicates that there may be swelling of the inner capsule.
3. "Ring Gauge" Test--passing the capsule through a 6.985 cm diameter circular gage. If the capsule does not slide through, swelling is indicated.

In addition to the capsules that were suspect resulting from these inspections, there was another group of capsules that, based on evaluation of their manufacturing history and other factors, were no longer able to be considered special form.

Following the inspections and evaluations of manufacturing history, the remaining capsules were divided into three groups.

1. Normal Form (11 capsules)--capsules that failed one or more of the tests to be shipped in the Model GE-600 cask with the overpack.
2. Special Form (161 capsules)--capsules that passed the tests and had adequate certification to qualify as special form to be shipped as special form in the Model-1500 cask.
3. Non-Special Form (75 capsules)--capsules that for various reasons had inadequate documentation to be shipped in the Model-1500 cask with added packaging to ensure containment.

NORMAL FORM

The normal form shipments were completed using the previously described procedure from May to September 1989.

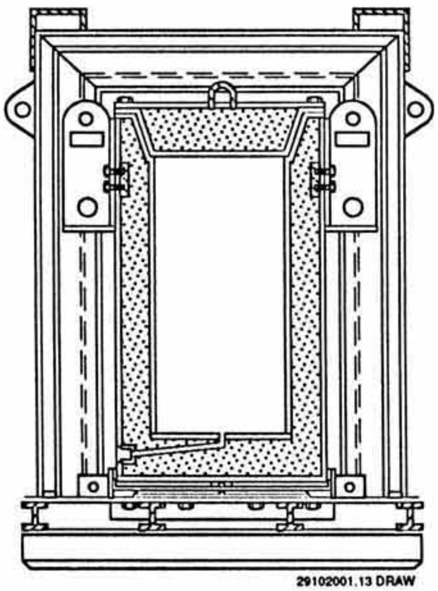

Fig. 2a. Model GE-600 shielded container (cask).

SPECIAL FORM SHIPMENTS

Loading for special form capsule shipments was relatively easy. The capsules were lifted using tong type manipulators, and loaded into a special four capsule rack in the Model-1500 cask. Next, the cask lid was lowered into place. The cask was lifted above the surface of the pool and lid bolts were installed. The cask was allowed to drain and then blown down with dry air for 15 min. Several successful shipments were made using this procedure.

In August 1989, during special form shipping, water was discovered in one of the Model-1500 casks when it arrived at the Hanford Site. Since the loading procedure included blowing down the cask to ensure its internal dryness, the mechanism for this influx of water was not immediately apparent. The most probable cause was a leak from the internal void areas of the cask into the center cavity. Several cask integrity tests, described below were conducted to definitively establish the source of the water.

1. Bubble Test--the bottom of the cask is filled with water, and a vacuum is pulled on the cask. The cask bottom is observed for generation of bubbles.
2. Pressure Test--the cask cavity is filled with water and pressurized, any decrease in water level indicates a leak.

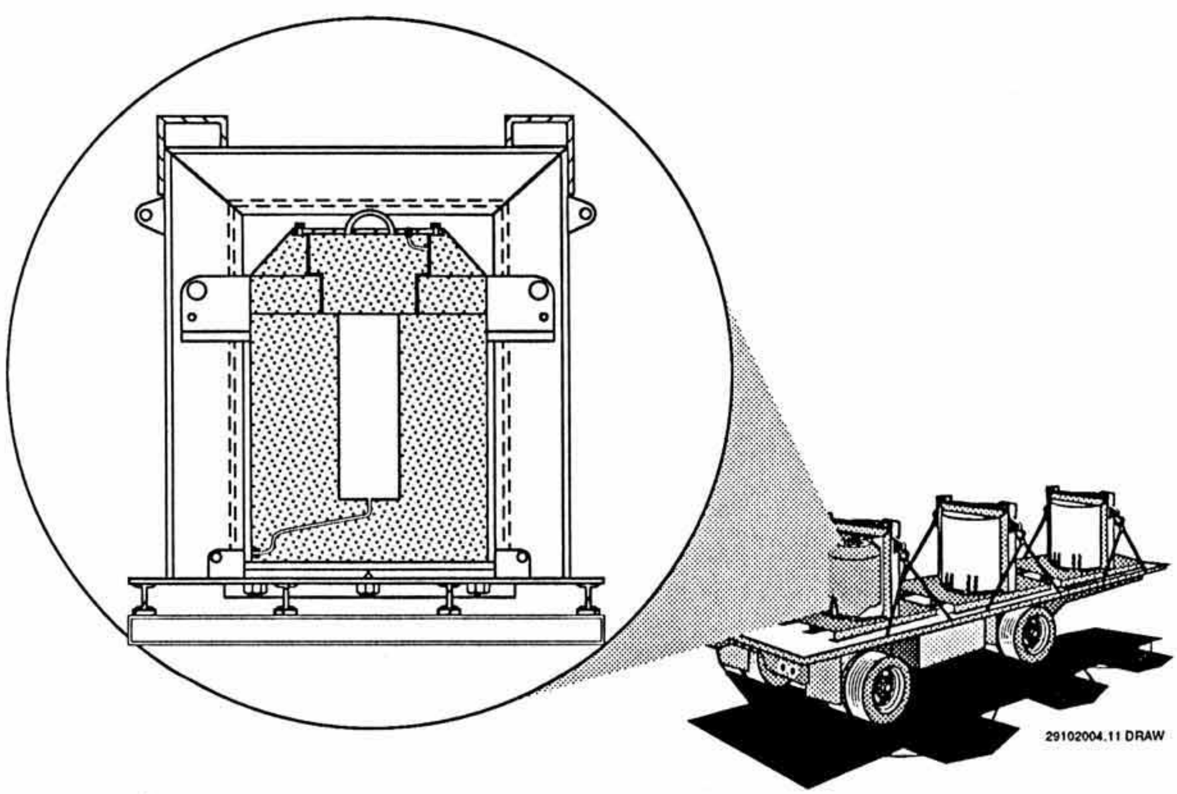

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Fig. 2b. Model-1500 shielded container (cask).

3. Chalk Test--cask cavity welds are dusted with chalk, and a vacuum is pulled on the cask. Wetting of the chalk indicates a leak.

These tests demonstrated that several casks had internal leakage. The problem was eventually isolated to a leak between the drain line and the internal portions of the cask (Fig. 2b). The situation was corrected by welding a new drain line internal to the original drain line. No further incidents were encountered and the last special form source was shipped in April 1990. In addition, these tests were incorporated into the CoC for the cask to be performed before every third shipment.

NON-SPECIAL FORM SHIPMENTS

Shipment of the non-special form capsules required the design of a new special form canister to be shipped internal to the Model 1500 cask. This canister was designed to hold up to three Cesium-137 capsules. Because the canister does not contain integral shielding, it was designed to be loaded, drained, dried, and sealed underwater before being loaded into the Model-1500 cask. Also it was designed to meet more stringent containment criteria.

To facilitate sealing the canister underwater, remote operating valves were designed into the lid of the canister using O-rings as seals (Fig. 3a). The inlet and outlet ports of the valves were machined into the canister lid with a small tube welded to the top of the valve. A quick release tubing connector was used to mate the plastic tubes to the welded drain tubes. The welded tubes were recessed into the top of the canister so they would survive the required 9.144-m (30-ft) drop test of the canister assembly. The lid was sealed to the canister with a silicon rubber O-ring having a 30-d operating life (limited due to the high radiation field exposure during shipment). Three closure nuts with rubber gaskets locked the lid to the canister. The lid had an additional seal in the middle of the interior surface area that sealed to a dip tube used to drain water from the canister during the dewatering process.

Canister operations are remotely performed under 4.572 m (15 ft) to 7.315 m (24 ft) of water using remote handling tools. All dewatering and vacuum drying equipment is located outside the pool water area. Prior to loading, each capsule is inspected using the "clunk" and "ring gauge" tests. *If the capsule* fails, it is not loaded.

Three capsules are loaded into the canister using tong type manipulators. The canister lid is lowered into place with the three closure nuts resting in place, and the 0.635-cm (1/4-in.) plastic vent and drain tubes connected to the canister using quick release connectors. The closure nuts are torqued and the canister is pressurized with nitrogen through the vent line, forcing the water out through the drain line. This line empties into a bottle with a calibration mark to ensure that the proper amount of water has been removed. The canister is vacuumed using the same method as the Model GE-600 overpack (Fig. 3b).

The vent and drain valves are torqued shut, the quick release connectors are removed from the vent and drain tubes using remote manipulators, and the canister is observed for bubbles. If none are observed, the canister is loaded into the cask, the lid is put in place, and the cask is removed from the pool. Last, the cask is drained and blown down with three cycles of 5 min. nitrogen purges followed by 25-min. wait periods.

CONTINUING CHALLENGES

In May 1990, during unloading at the WESF, water was discovered in the first Model-1500 cask containing a "non-special form" shipment. Testing was conducted to evaluate if the blowdown of the cask was sufficient to ensure removal of all the water. It was determined that the geometry of the recessed valves and vented drain tubes prevented removal of about 20 mL of water.

Two alternatives were evaluated for drying this residual water from the casks; (1) evaporation of the water due to heat generated by the capsules, and (2) vacuum drying of the entire cask. Following correspondence with the NRC, the decision was reached that the preferred method would be vacuum drying. The procedure that was developed includes a 15 min. nitrogen purge of the cask, followed by a 20-min. wait period, and an evacuation of the cask to 1 Torr vacuum. Testing of this procedure showed that evacuation to this low level ensured removal of the water.

In June 1990 shipping resumed, but further challenges were encountered. In this instance, something prevented loaded casks from draining properly. Investigation revealed that in some cases the flat bottom of the canister fitted tightly against the cask drain line (possibly due to the recently installed inner drain line) and restricted the proper operation of the drain. This was solved by placing stainless steel mesh under each canister to lift it slightly above the drain allowing free flow of the water.

Vacuum drying of the canisters and casks was difficult because of the potential contamination to the vacuum pump oil with Cesium-137 from the pool water. The pump oil had to be changed frequently due to the amount of water that was removed by the vacuum. Several attempts were made to improve this situation (i.e., installation of a liquid nitrogen cold trap in the vacuum line, and attempted use of an oil free vacuum pump). These attempts were unsuccessful. The best results were obtained by continually running the vacuum pump 24 h/d to keep the oil as hot as possible to reduce water contamination.

On August 15 1990, during unloading at the WESF, operators noted that when the closure nuts were untorqued on one canister, a small amount of steam escaped.

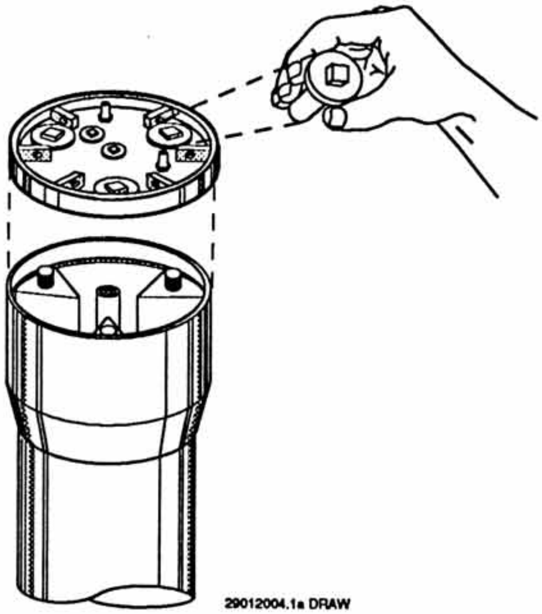

Fig. 3a. New special form canister.

Evaluating of the canister design drawings indicated that the most likely steam source was water trapped between the closure nuts and their holes in the canister lid. Actual testing of the canisters with nonradioactive capsules confirmed this evaluation. Further evaluation determined that this water could not enter the payload area of the canister or the cask cavity, and was therefore of limited concern.

Following resolution of the steam incident, no other major challenges were encountered, and the last of the remaining sources were removed from the Decatur facility on November 19, 1990.

CONCLUSIONS

This paper has discussed the difficulties that were encountered in shipping Cesium-137 capsules and the solutions that were implemented. The lessons that were learned can be applied to other situations involving underwater loading of radioactive materials, and the dryness criteria that resulted perhaps represents a trend in packaging requirements.

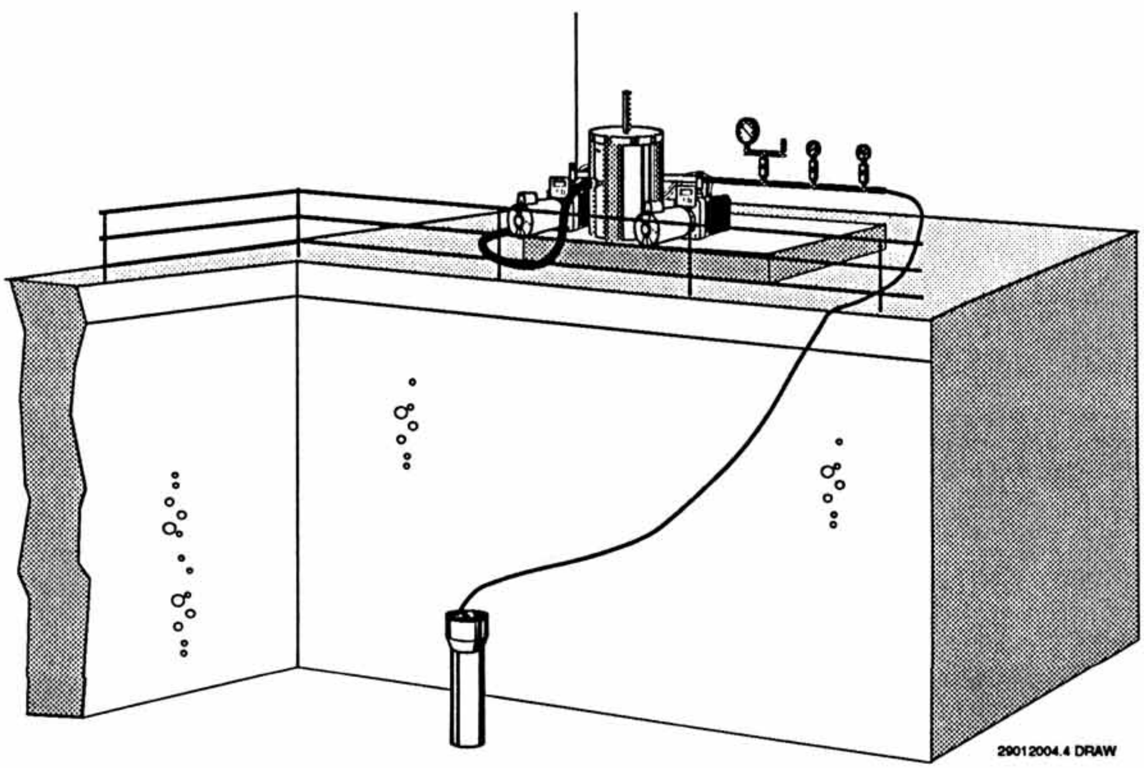

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Fig. 3b. Dry vacuuming of new special form canister.