FIFTEENTH ANNUAL NATIONAL ENERGY DIVISION CONFERENCE

QA IN THE DESIGN AND FABRICATION OF THE TMI-2 RAIL CASK[a]

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ABSTRACT

EG&G Idaho, Inc., acting on behalf of the U.S. Department of Energy, is responsible for transporting core debris from Three Mile Island-Unit 2 to the Idaho National Engineering Laboratory. Transportation of the debris is being accomplished using an NRC licensed container, called the NuPac 125-B. This paper describes the NuPac 125-B Rail Cask and the quality assurance (QA) requirements for that system. Also discussed are the QA roles of the various organizations involved in designing, building, inspecting and testing the NuPac 125-B. The paper presents QA/QC systems implemented during the design, procurement, and fabrication of the cask to assure compliance with all applicable technical codes, standards and regulations. It also goes beyond the "requirements" aspect and describes unique QA/QC measures employed to assure that the cask was built with minimum QA problems. Finally, the lessons learned from the NuPac 125-B project are discussed.

INTRODUCTION

The March 1979 accident at Unit 2 of the Three Mile Island Nuclear Power Station (TMI-2) damaged the core of the reactor. One of the major cleanup activities involves defueling the reactor vessel; this consists of removing the core debris from the reactor, packaging it into canisters, loading the canisters into a rail cask and transporting the debris to the Idaho National Engineering laboratory (INEL) for storage, examination, and preparation for final disposition. The NuPac 125-B Rail Cask was developed to provide a safe means of transporting the damaged core from TMI-2 to the INEL. Transportation of the debris is being accomplished using three Model 125-B Rail Casks which were designed and fabricated by Nuclear Packaging, Inc. (NuPac) of Federal Way, WA and certified for transporting the TMI-2 core debris by the U.S. Nuclear Regulatory Commission (NRC). Shipments began in July 1986, and through May 1988, 31 cask loads have been delivered to the INEL. To complete the shipping campaign will require approximately 21 more cask shipments.

This paper highlights some of the technical and QA challenges addressed in developing and licensing the NuPac 125-B Rail Cask. Topics to be discussed include a description of the NuPac 125-B Rail Cask and

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the QA requirements for the cask; the QA roles of the various organizations involved in designing, fabricating, inspecting, and testing the cask; and QA measures employed to assure compliance with applicable codes, standards and regulations. This paper also discusses QA/QC measures utilized to minimize QA problems. This was a significant factor in completing the project on schedule. Finally, the lessons learned from the NuPac 125-B project are discussed.

CASK DESCRIPTION

The NuPac 125-B Rail Cask (Figure 1) was developed after GPUN decided to dry load (in air) core debris at TMI. Design was based on federal regulations which require double containment of plutonium during transport. The cask is actually a vessel within a vessel (Figure 2).

The inner vessel is stainless steel. Each of its seven cavities accommodates a single canister, and the space surrounding the cavities is filled with a special neutron absorbing material called BISCO.[a] There are impact limiters (energy absorbers) at either end of each canister and radiation shield plugs at the top of each canister. The inner vessel lid provides a leak-tight seal.

The outer vessel is a stainless steel and lead composite vessel, i.e., the annulus between the two concentric stainless steel shells is filled with lead. Three sets of trunnions protrude from the outside of the shell. They are used to support the cask during transport and for cask handling operations. The outer vessel lid also provides a leak-tight seal.

Large foam-filled overpacks are attached to each end of the cask to protect the contents in case of a transportation accident. During transit, the cask rests horizontally in the transportation skid which is attached to a 165 ton, eight axle, flat bed railcar. The cask, including overpacks, is 23 feet long and 10 feet in diameter. Fully loaded, it weighs about 100 tons (including overpacks, contents, and transportation skid).

GENERAL CASK REQUIREMENTS

Radioactive materials must be transported in compliance with federal and state requirements. The federal regulations are issued by the Nuclear Regulatory Commission (NRC) and the Department of Transportation (DOT). The NRC certifies the design of shipping casks and DOT regulates the actual transportation of radioactive materials. This paper discusses only the NRC requirements; specifically Title 10, Part 71 of the Code of Federal Regulations (10 CFR 71), titled "Packaging and Transportation of Radioactive Material."

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a. BISCO is a tradename of Bisco Products Company.

10 CFR 71 requires that each package (container and contents) design be certified by the NRC. Radioactive materials are categorized according to criteria specified in 10 CFR 71, and container requirements are based on the contents (category) to be shipped. In the case of the NuPac 125-B shipping container, the most stringent packaging requirements were applied (Type B, Fissile Class III).

Cask design was licensed by the NRC in accordance with a DOE programmatic decision. The license application, called a Safety Analysis Report for Packaging (SARP), was submitted to the NRC. The SARP (Figure 3) is a comprehensive technical document containing engineering drawings and cask/payload descriptions; structural, thermal, containment, shielding, and criticality evaluations; operating procedures; acceptance test and maintenance procedures; and a description of the applicant's Quality Assurance Program. Requirements and guidelines for preparing a SARP are specified in 10 CFR 71 and Regulatory Guide 7.9[1], respectively. After NRC review and approval of the SARP; the Certificate of Compliance (license) is issued. For certification by the NRC, a cask design must be shown by test or analysis to withstand a series of accident conditions that simulate the most severe credible accidents. The impact, fire and water-immersion tests are considered in sequence to determine their cumulative effects on the cask.

All codes and standards which apply to design, procurement, fabrication, inspection, and testing of a cask are identified in the SARP. The shipping container industry uses nationally recognized codes and standards for fabrication of casks; however, there is no "cookbook" (such as the Section III of the ASME Boiler and Pressure Code in the case of NSSS Components) which has been adopted by industry for designing and fabricating casks. Regulatory Guide 7.6[2] provides nonmandatory guidance regarding cask design criteria. In the absence of any codes or standards for a special process such as lead pour, information which describes the process is included in the SARP.

The QA program requirements ensure that the approved cask design is correctly translated into specifications, drawings, procedures and instructions for fabrication; and that special processes such as welding, heat treating, NDE and testing are conducted by qualified personnel using qualified procedures. All activities related to the design, procurement, fabrication, inspection, test, and use of the cask are required to be conducted under a quality assurance program (QAP) which complies with 10 CFR 71 Subpart H. The QAP must be described in the SARP and address 18 quality criteria. The NRC has also issued Regulatory Guide 7.10[3] which provides additional guidance regarding QA Program requirements. This Regulatory Guide is not a substitute for regulations and compliance is not mandatory; however it does communicate QA methods that the NRC staff considers acceptable to comply with the requirements of 10 CFR 71.

PROJECT INTRODUCTION

Obtaining an NRC license for a new cask design is a long and involved process. Preparation of the SARP and obtaining NRC approval normally takes about two to three years. After design approval and issue of the cask license, cask fabrication, inspection, and acceptance testing takes about another two years.

The TMI-2 defueling schedule demanded a cask development schedule one-third as long as normally required. The NuPac 125-B cask was designed, licensed, fabricated, and accepted in less than 24 months. This accomplishment was made possibly by (a) a team approach to the project, (b) conservative design assumptions, (c) the decision to perform drop tests of the cask and canisters in order to validate analytical calculations, and (d) assuming programmatic risks and fabricating the casks in parallel with the certification process.

Quality Assurance played a significant role in the success of this project. Due to the schedule restraints, QA measures beyond the "book" were utilized to minimize QA problems and associated schedule delays during design and fabrication of the cask. The remainder of this paper discusses items that made this project a success.

QA PROGRAM

Since NuPac (on behalf of the DOE) applied for the cask license, NuPac's QA Program was subject to NRC approval. NRC's approval was based on a desk survey of NuPac's Quality Manual. Therefore, EG&G performed an on-site audit of NuPac's QA system to verify implementation of their NRC approved QA manual, prior to placing the design and build contract with NuPac.

Both NuPac and EG&G placed major emphasis on control of purchased items.[4] Numerous subcontractors were involved in design and fabrication of the cask, such as material suppliers, fabricators, inspection and test service organizations, and other special process services (lead pour, BISCO pour). NuPac was responsible to ensure that each subcontractors' QA program complied with the applicable requirements of 10 CFR 71 Subpart H.

NuPac performed a thorough evaluation of each potential vendors' QA capabilities (equipment and personnel) and QA Program, and performed audits of the suppliers QA procedures prior to placing them on the "Approved Suppliers List." Actual compliance was verified via preaward quality audits, in process audits, and source inspections.

EG&G also performed in-process QA audits and inspections at NuPac and their major subcontractors throughout all phases of the project.

CASK DESIGN

The "team approach" to QA started at the beginning, i.e., the establishment of design requirements. Extreme care was exercised to assure that all requirements were recognized and addressed. Design requirements were based not only on regulatory requirements, but also on input from the ultimate uses of the cask and organizations responsible for interfacing equipment and facilities. Informal and formal design reviews were conducted throughout the design process to assure all parties that the design was progressing satisfactorily. Members of the "design team" included NuPac and their subcontractors, four DOE national laboratories, EG&G Idaho, and GPUN and their subcontractors.

A high degree of conservatism was incorporated into the cask design to allow for quick and simplified demonstration of design adequacy to the NRC. Redundant design techniques were employed in all areas of uncertainty. Also, design qualification testing was used to validate analyses and arrive at design decisions more quickly. Drop testing of the 1/4 scale model cask was a prime example of this situation. It should be noted that either testing or analysis are acceptable as stand-alone methods for demonstrating a cask's ability to meet NRC requirements; however, performing 1/4 scale model testing validated cask structural analyses and removed performance uncertainties. This had the net effect of expediting the approval process.

Also, canister design qualification tests were performed. Full-scale canister drop tests validated the structural analyses and verified the structural adequacy of the canister internals which provide criticality control.

The end product of the design phase was the SARP. This three volume technical document was accepted and the Certificate of Compliance issued by the NRC in April 1986.

CASK FABRICATION

EG&G Idaho contracted with NuPac to build two Model 125-B casks. The first unit was completed in December 1985 and the second in January 1986. Since the NRC Certificate of Compliance for the cask design was not issued until April 1986, it was essential that technical and quality planning took into consideration the programmatic risks of proceeding with fabrication prior to design approval. From a QA standpoint, this situation dictated detailed fabrication, inspection and test planning, redundant technical reviews of planning documents, and almost constant on-site technical and quality monitoring of work.

The "team approach" to the project was also quite evident during cask fabrication. NuPac provided essentially full-time engineering on-site coverage at their major subcontractors in order to minimize the time required for technical reviews, provide assistance as necessary and minimize delays in resolving technical problems. NuPac also provided constant on-site quality inspection coverage during "peak" times. In addition, EG&G Idaho provided a resident engineer at NuPac to monitor job progress, review technical documents, and identify problems requiring resolutions. This resident engineer also performed some quality overview activities as specified in planning prepared by the EG&G cognizant Quality Engineer.

Quality Objectives

The primary objectives of the QA program were to (1) assure that working documents were consistent with SARP requirements, (2) avoid quality problems during fabrication of the casks, and (3) verify that the casks were built in strict compliance with the planning documents. The methods employed to achieve these objectives are explained in more detail below.

Objective 1 - Working Documents Consistent with SARP

In general terms, working documents are any engineering/technical documents which convey instructions to the workers who actual fabricate, inspect, or test the hardware. These documents are not normally included in the SARP; however, they are as important as the SARP because they are used to actually build the cask. Both EG&G and NuPac placed emphasis on detailed technical reviews of all working documents such as shop drawings, shop travellers, weld and NDE procedures, inspection and test procedures, and other special process procedures.

NuPac prepared fabrication drawings and specifications. They also reviewed and approved vendors drawings, shop travellers, and special process, inspection, and test procedures. EG&G also reviewed these same documents. This attention to detail paid big dividends because numerous mistakes and oversights were identified and corrected before they resulted in hardware deficiencies.

Objective 2 - Avoid Quality Problems or Build it Right the First Time

Quality problems can be minimized by careful fabrication and quality planning. The NuPac 125-B planning was prepared with two specific goals in mind; plan to avoid problems and/or to detect problems early. Achievement of these goals can best be illustrated with specific examples.

Plan to Avoid Quality Problems. The first step in avoiding quality problems is to anticipate problems and plan to avoid them. In the case of the NuPac 125-B fabrication, several potential problem areas were identified as having both a high probability of occurrence and a high consequence. Two areas which received much attention were (a) special processes and (b) weld distortion/shrinkage. Both of these areas were crucial to achieving the cask performance requirements listed below:

Cask Performance	Method of Compliance
Radiation Shielding	Lead shielding installed in OCV
Criticality Control	Neutron moderator material (BISCO) installed in ICV
Containment	Both ICV and OCV shown to be leak-tight by testing

Special processes consisted of welding, NDE, lead pour, BISCO pour and foam filling of overpacks. All special process procedures were reviewed and approved by NuPac and EG&G Idaho. Welding and NDE were performed in accordance with nationally recognized codes and standards which assured that both the procedures and personnel were qualified.

Lead pour of the OCV and BISCO pour of the ICV were recognized as especially "risky" special processes because recovery from quality problems would be difficult, time consuming and expensive. Also, unlike welding and NDE, these processes were not covered by national codes or standards. Therefore, they were subjected to preproduction qualification tests and detailed step-by-step production procedures, including numerous in-process quality checks.

Weld distortion and shrinkage cannot be eliminated but it can be controlled by fixturing and the welding process itself. Engineering planning associated with the complex ICV SST weldment received the most attention. Numerous weldment mockups (including the 1/4 in. scale model cask) were utilized to quantify weld shrinkage, and preweld fabrication dimensions on the production units were adjusted accordingly. In addition, numerous in-process inspections were performed during production welding to verify both the quality of partially completed welds and the dimensions of the weldment itself.

Plan to Detect Problems Early. The second step in avoiding quality problems is to detect problems early. The earlier problems can be identified, the easier they can be fixed. Even with the best planning, one cannot hope to anticipate and avoid all quality problems. Also, in-process inspections and tests can be used to verify whether or not the plans to avoid anticipated problems are working. In addition to in-process inspections of the ICV weldment previously discussed, some other examples of early detection of problems were:

- Informational NDE of starting material (e.g., ultrasonic testing of forgings and radiography of castings).
- Informational NDE of high stress areas prior to load test.
- In-process pressure tests and leak tests (accessibility for repairs is a major consideration).

- o Timely review of procedure and personnel qualification/certification records.

- o Measurement of the OCV annulus prior to lead pour.

- o Functional test of components.

The Cask Integrated Test was an excellent illustration of the benefits of a functional test. In this month-long test, the cask and the seven pieces of cask handling and loading equipment shown in Figure 4 were brought together, fit up and operated as they would be at TMI. This "dry run" identified over 100 action items (physical equipment inferences, operating problems, and procedure deficiencies) that were corrected prior to delivery of the equipment to TMI. It also identified about 25 minor design refinements to improve the ease and efficiency of the cask loading operations. Correction of the problems at TMI would have been much more costly and time consuming. This test also proved a valuable training exercise for the operations crew.

Objective 3 - Verify Casks Built Per Plans

The inspections discussed in the previous sections are only a sample of the overall inspection program. The overall program can be summarized as follows:

a. Each NuPac subcontractor implemented their own inspection program.

b. NuPac reviewed vendor inspection and fabrication planning for technical adequacy, mistakes and oversights.

c. NuPac prepared a project quality plan which identified all inspections and tests required for each component and assembly. This document was reviewed and approved by EG&G Idaho.

d. NuPac performed inspections at the vendor's facilities to detailed instructions prepared by the NuPac cognizant QE. There were 90 detailed inspection instructions.

e. EG&G also performed inspections at the vendors' facilities to detailed instructions. There were 25 detailed inspection instructions. EG&G also reviewed the majority of NuPac's inspection records and some of the vendors' inspection records.

LESSONS LEARNED

The experience gained on the NuPac 125-B project should find widespread interest and applicability to other radioactive material shipping campaigns. The approach to QA, and especially, the lessons learned, will benefit anyone involved in the licensing of transport packages. A good QA "checklist" for future projects would include:

- o Design input--Be sure to obtain input from all parties that will be involved in the transport campaign. Prepare design requirements documents and obtain formal reviews.

- o Design conservatism--Take the conservative approach. Make full use of design qualification tests (e.g., drop tests, special processes). Remember, the number one priority is to positively demonstrate the integrity of the cask design to the regulators.

- o Working documents--Be sure that they contain detailed instructions which can be easily understood by the operator, machinist, etc. Thoroughly review them for technical adequacy and consistency with the design (SARP).

- o Minimize quality problems--Plan to avoid problems and plan to detect problems early. This involves doing more inspection and testing than required by regulations; however, it will be cost effective.

- o Special processes--They are critical to a quality fabrication job. Qualify all processes and use full-scale mockup tests. Special processes not covered by national codes or standards are especially "risky." The quality problems experienced on the NuPac 125-B project were in this area.

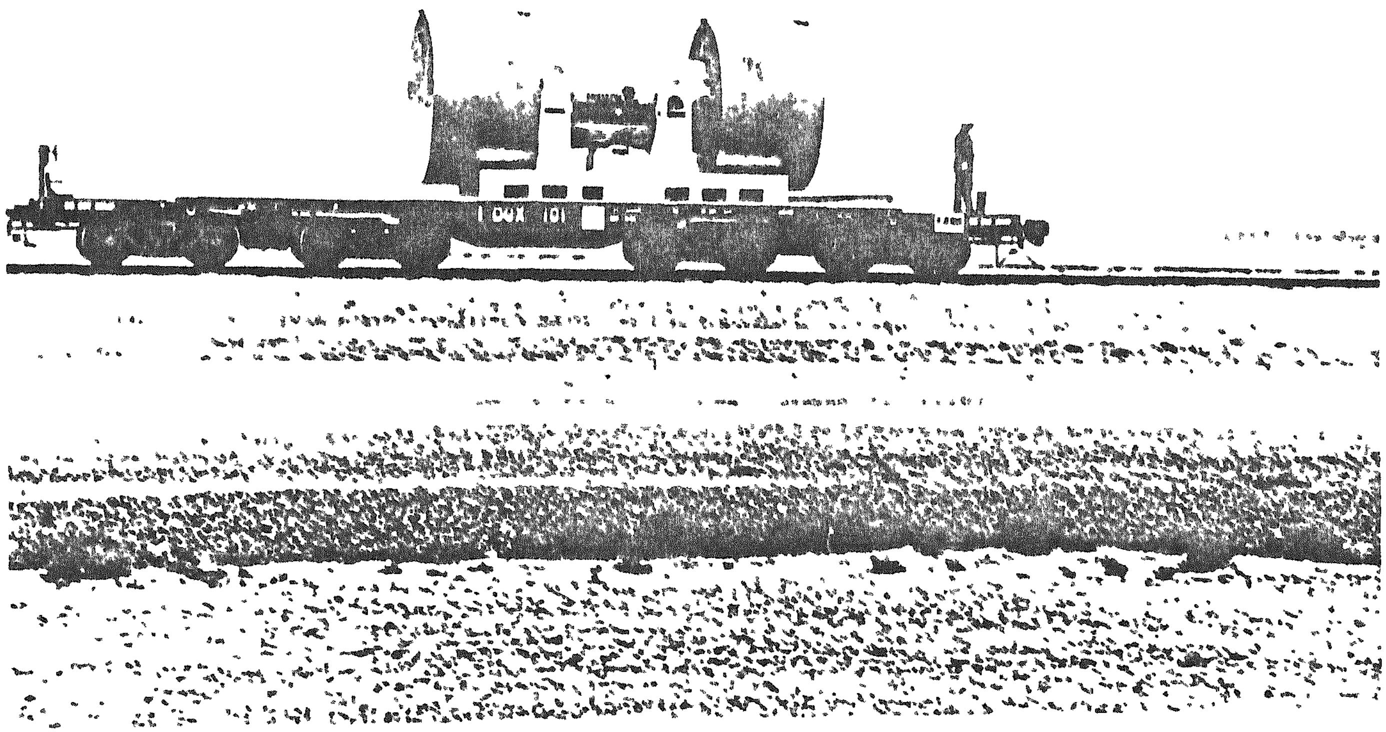
REFERENCES

1. Regulatory Guide 7.9, "Standard Format and Content of Part 71 Applications for Approval of Packaging of Radioactive Material," published by the NRC.

2. Regulatory Guide 7.6, "Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels," published by the NRC Office of Standards Development.

3. Regulatory Guide 7.10, "Establishing Quality Assurance Programs for Packaging Used in the Transport of radioactive Material," published by the NRC Office of Nuclear Regulatory Research.

4. 10 CFR 71.113, "Control of purchased material, equipment, and services," Title 10, Part 71, of the Code of Federal Regulations.



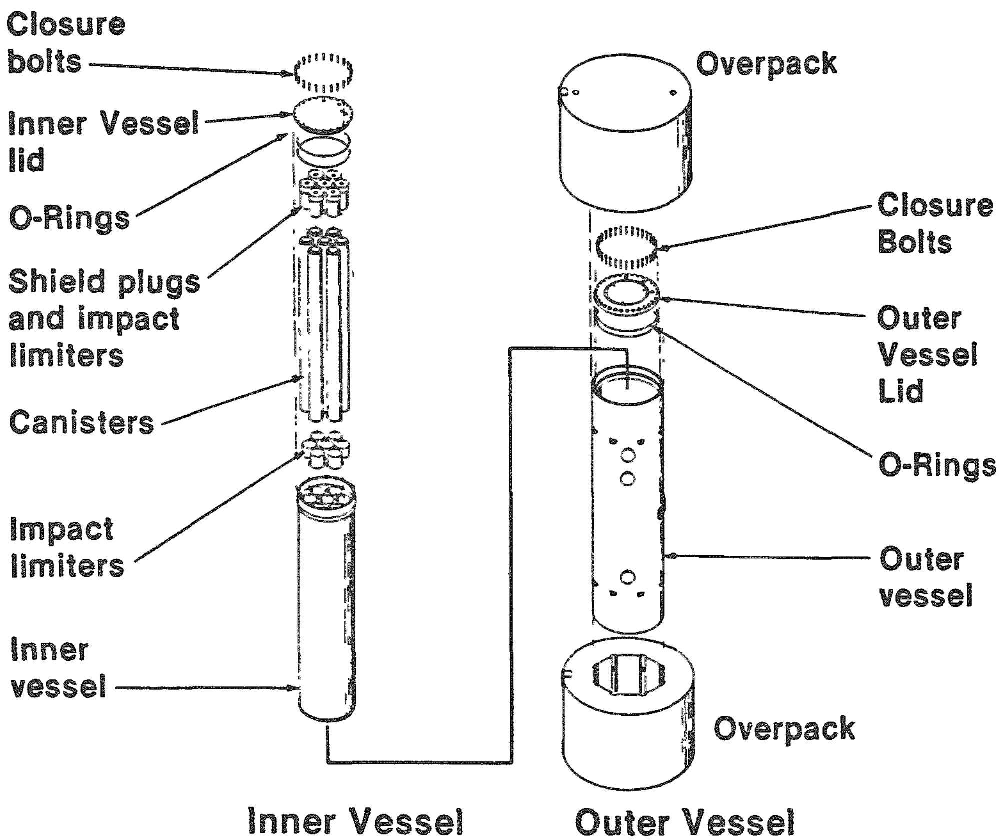
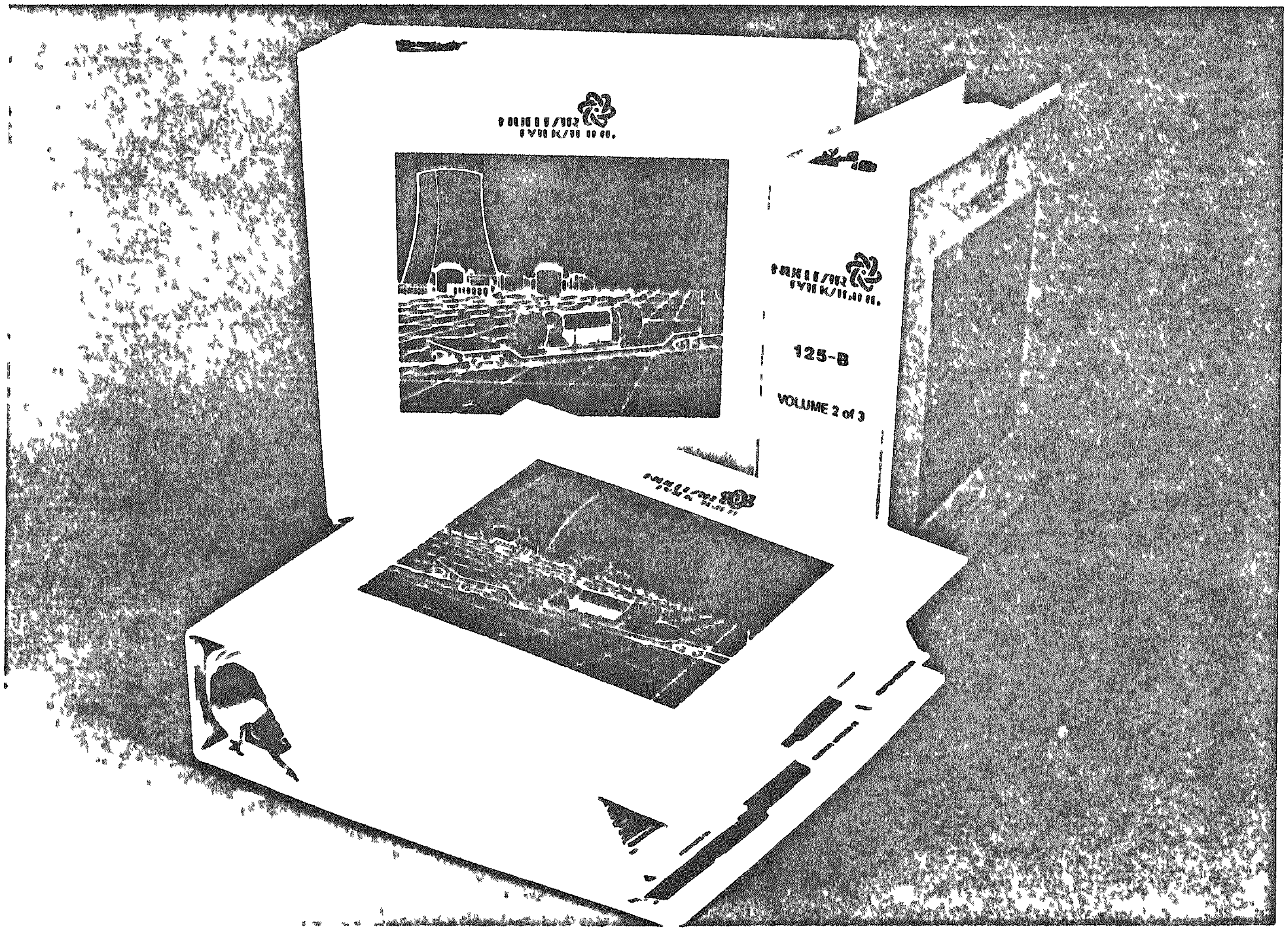


Figure 2. Disassembled view of NuPac 125-B cask.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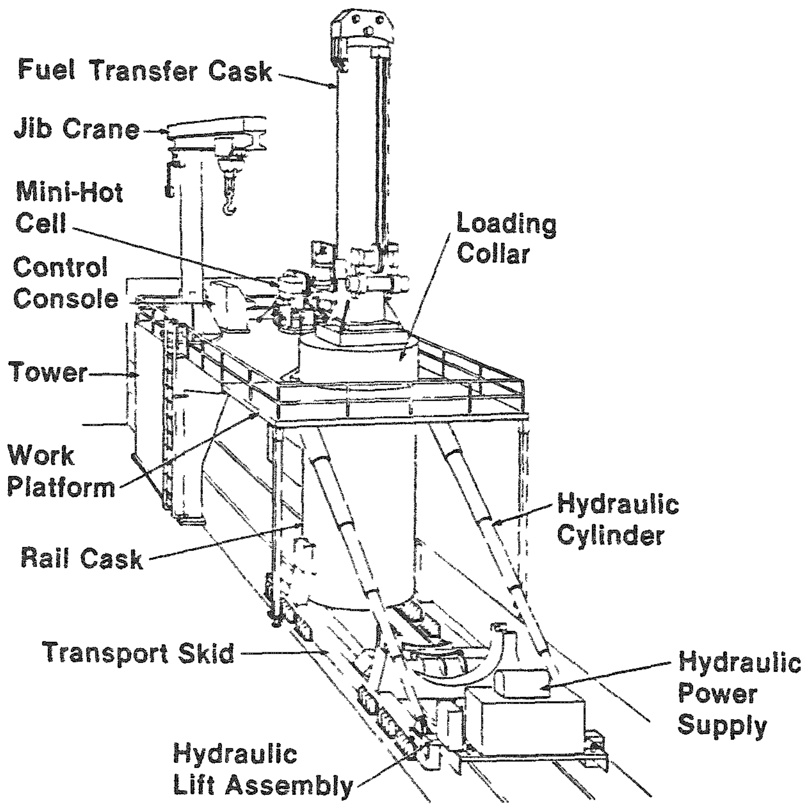

Figure 4. Schematic of the NuPac 125-B rail cask being loaded with a core debris canister at TMI-2, using the shielded fuel transfer cask.

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