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An overview of management requirements and applications based on practical experience

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FOREWORD

In 1990, the IAEA published the proceedings of a Technical Committee Meeting on Decontamination of Transport Casks and of Spent Fuel Storage Facilities. The report reviewed the state-of-the-art of technology and practice in this field, design of transportation and storage systems and equipment to facilitate decontamination.

Considering that since then many changes have been made in spent fuel storage, the Regular Advisory Group on Spent Fuel Management recommended in 1995 that a new report with the latest information on systems and equipment for preventing contamination and facilitating decontamination of spent fuel storage and transportation casks be prepared.

Since 1996, three consultancies, one Technical Committee meeting and one Advisory Group meeting were held to collect information and views, specify the contents and draft the publication. In addition, a number of experts have reviewed the final draft report.

This publication is a compilation of international experience with cask contamination problems and decontamination practices. The objective is to represent current knowledge and experience as well as developments, trends and potential for new applications in this field. Furthermore, the report may assist in new design or modification of existing casks, cask handling systems and decontamination equipment. The annexes contain figures of several cask types for illustration.

The IAEA wishes to express appreciation to all the experts for their contributions in the meetings and/or for their review of the draft reports. The IAEA officer responsible for this publication is M.J. Crijns of the Division of Nuclear Fuel Cycle and Waste Technology.

Note added in proof

In May 1998, it was widely reported that some transports of spent nuclear fuel in Europe had taken place for several years with a surface contamination which was locally higher than the international standard of 4 Bq/cm^2. Transports of spent nuclear fuel were halted in France, Germany and Switzerland and a joint working group of nuclear regulators from France, Germany, Switzerland and the United Kingdom was established. France resumed the transports after the introduction of improvements imposed by the nuclear regulatory body DSIN. At the end of 1998, the joint working group issued a report (Surface Contamination of Nuclear Spent Fuel Transports), in which the regulators conclude that this matter had no radiological consequences and that spent fuel can be transported in compliance with the regulation if the measures outlined in their report are implemented. Transports in France have been resumed in 1998 and it is expected that shipments in Germany and Switzerland will resume in 1999. The conclusions of the joint working group do not affect the contents of this TECDOC. The French and German annexes (Annexes III and IV) are amended with notes added in proof summarising developments to date, and the Czech and Swedish annexes (Annexes II and VII) report on similar experiences in the Czech Republic and Sweden.

CONTENTS

1. INTRODUCTION

A large increase in the number of casks required for transport and/or storage of spent nuclear fuel is forecast into the next century. The principal requirement will be for increased numbers of storage and dual purpose (transport/storage) casks for interim storage of spent fuel prior to reprocessing or permanent disposal. The increase in interim storage requirements is expected to include both on-site and off-site storage facilities. Dedicated transport casks will be needed to transfer fuel to off-site interim storage, reprocessing, and final disposal sites. The contamination of casks during fuel handling operations, and the potential for subsequent exposure and release, is an inevitable consequence of reactor operations and will continue to require careful management as it is a topic about which the public have direct concern.

Through contact with radioactive materials, spent fuel casks will become radioactively contaminated on both internal and external surfaces. Contamination on external surfaces of all casks transported over public facilities (e.g. roads, rail, and waterways) is a public radiation safety issue. Specific limits for contamination levels are set by national regulatory authorities based on international guidelines. Routine decontamination of transport cask external surfaces is required in order to ensure that these regulatory limits are met. Similar restrictions for external contamination may also be applicable to casks transferred internally at a nuclear site (i.e. not over public facilities) and those used for storage at a nuclear site. The frequency and degree of decontamination required will depend on the usage history of the cask and the governing national regulations for transportation of radioactive materials. External surfaces of dual purpose casks (when used principally for storage) and dedicated storage casks generally need to be decontaminated only once prior to movement.

Internal cask contamination is normally an occupational health and radiation safety issue. The acceptable levels are generally higher for internal surfaces than for the external surfaces and are governed by occupational radiation exposure limits set by national regulatory authorities and ALARA considerations. However, before final release of any decommissioned cask into the public domain, both the internal and external surfaces must be decontaminated to a very low limit, generally even lower than for routine transportation.

The majority of nuclear power reactors operating today discharge spent fuel into water pools (also known as "bays" or "ponds") where it is held in interim storage adjacent to the reactor. Over time, this water becomes contaminated mainly with activated corrosion products from the primary cooling system. Contamination of casks occurs during handling operations as a result of direct contact with the storage pool water and fuel elements. Surveys of world experience with decontamination of casks have shown that, although approaches may differ, there are common design features and operational procedures that can reduce the overall levels of contamination associated with these activities.

In broad terms, cask contamination management can be defined as having three components: minimisation, prevention and decontamination. For the purposes of this publication, minimisation is defined as a design-related issue, whereas prevention and decontamination address operational matters.

Ideally, minimisation of contamination can be accomplished through the introduction of new system facilities (such as dry-loading or canister-based systems) which eliminate as far as possible direct contact between the cask body and fuel assemblies. Even with current cask and facility design, however, some benefits can be gained by modifying existing equipment. In the main, this requires modifications to cask surfaces and features in order to improve the effectiveness of preventative measures and decontamination techniques.

Prevention of contamination relies on the adherence of operational procedures to best practice, such that the routine decontamination activities at each facility are optimised to meet the targets for throughput efficiency, generation of secondary waste and operator dose uptake. It is possible, but not necessarily commonplace, that an optimisation between minimisation and prevention may be reached such that the costs incurred achieve maximum benefit to the cask-handling cycle. However, this is a complex issue and one that is not addressed in detail here.

Irrespective of these philosophies, the nature of current practice in cask handling means that many casks will continue to require various degrees of routine decontamination throughout their operational lives, and at the end of this, it is likely that many will require some decontamination treatment as part of their decommissioning. It will never be realistic to expect that minimisation and preventative techniques alone can maintain contamination on casks within the levels required by international regulations. Even with the best attention to the design of modern facilities and operating practices, there will always be a requirement to call upon a range of decontamination techniques to ensure that all the requirements of the cask handling cycle can be met.

2. SOURCES OF ACTIVATION AND CONTAMINATION

In general, the origin of radioactive contamination of spent fuel casks arises from the use of fissile material in nuclear power plants (NPPs). Potential contaminants are the radionuclides arising from fuel itself and the fission products or other radionuclides generated by the nuclear reactor.

2.1. RELEASE AND DISTRIBUTION OF RADIOACTIVITY

The fuel and the fission products are contained in the fuel rods which are designed to remain leaktight under reactor operation and storage conditions. During reactor operation neutron activation of the fuel cladding material occurs. Further, the external surface of the fuel rods will, by adhesion, pick up a layer of activated corrosion products from the primary cooling system. This material is moved with the spent fuel elements into the pond and into the cask. Corresponding to the special conditions in the pond and in the cask, this crud can be dispersed from the fuel rods and become a loose (non-fixed) contamination in the pond or in the cask [1].

However, a small number of cladding failures do occur which allow radioactive material to spread into the surrounds of the fuel assembly. When a fuel failure (e.g. pinhole leak or major defect) is detected during the reactor operating cycle, it is usually removed from the reactor and returned to storage. The failed fuel assembly should be placed in a canister to prevent the spread of contamination to the water while allowing natural cooling to take place.

2.2. CASK CONTAMINATION

The internal surfaces of the cask are in contact with the pond water during loading. Additionally, the direct contact between contaminated fuel assemblies and interior cask structures can cause a significant transfer of contamination to the cask. In the case of a defective uncanistered fuel assembly loaded in a cask, a leakage of fuel, actinides, and volatile and non-volatile fission products into the cask cavity may occur. Depending on the temperature and chemistry of the cask atmosphere and the materials and surface finishes of the cask cavity, the released isotopes can form non-fixed (loose) contamination in the cask cavity and migrate into its surfaces where it can become fixed through several mechanisms depending on conditions in the cask cavity.

Unprotected external surfaces are exposed to the pond water and pick up contamination dispersed or dissolved in the pond water. The extent of contamination is dependent on the chemical or physical form and concentration of radioactive isotopes in the pond water and the contact time in the pond. Long contact times may lead to migration or diffusion of the contamination into the cask surface material. External surfaces may also become contaminated during dry loading operations if water is allowed to drip from the fuel assemblies and handling equipment onto the exterior surfaces.

2.3. NEUTRON ACTIVATION OF CASK STRUCTURE

Neutron radiation from spent fuel or high level radioactive waste (HLW) can cause activation of the cask structure and its components producing radioactive isotopes such as Co-60, Fe-55, Mn-54 and Ni-63. The neutron emitting isotopes, and the associated α-n-reactions, generate neutron fluxes which can lead to activation of the cask material. It appears that this effect is small, but may build up over time so that the cask structure becomes a source of residual radioactivity. This may be particularly noticeable in casks with long campaign histories and high neutron sources, e.g. for storage casks with vitrified high level radioactive waste.

For this reason, the maximum activation level which can be reached after the specified storage time should be assessed when planning the decommissioning of the cask. German experience indicates a typical period of 8–10 years after being emptied for this residual activity to decay to acceptable levels. As example, the activation of cast iron material of a canister by a neutron flux from HLW of 2.85×10^{10} n/s reaches a saturated level after about 20 years. These levels are 14.3, 1.5 and 0.5 Bq/g respectively for, Fe-55, Co-60 and Mn-54.

3. MINIMIZATION AND PREVENTION OF CASK CONTAMINATION

The majority of casks currently in use are manufactured from forged steel or cast iron. Design characteristics, handling and operational procedures, and continuing maintenance are important factors in minimising the contamination of spent fuel casks during loading and unloading operations.

3.1. CASK DESIGN

Certain features of spent fuel casks and handling facilities should be considered at the design stage to minimise cask contamination and make decontamination easier. Surface shape and complexity can be a factor in cask contamination and release. Cooling fins, valve housings, bolt holes, joints and welds can trap particulate contaminants and make subsequent decontamination difficult. The use of protective skirts, cover plates, plugs, and seals can help prevent contamination of these surfaces during underwater loading.

3.1.1. Internal cask surfaces

Internal surfaces are subject to contamination problems arising from loss of fuel integrity where the build-up of highly-active contaminants can give rise to occupational exposure risks. Internal components should be designed to minimise the adherence or trapping of particulate contaminants and "crud". Nickel plating, stainless steel liners, zinc aluminium coatings or zinc silicate painting of cask interior surfaces have been demonstrated to reduce corrosion and facilitate decontamination in France, Germany, Japan and the United Kingdom.

3.1.2. External casks surfaces

External surfaces of casks need to be kept smooth to ensure that contamination is not attracted. This can be achieved either by using a non-corrosive surface, such as stainless steel, or painting the surface with epoxy-based paints to provide a corrosion-resistant coating. The use of a epoxy/polyurethane coating systems has been shown to reduce the level of contaminants adsorbed from storage pools in the UK and Canada. Experiments in the USA with storage pool contamination of stainless steels has shown that smooth surfaces adsorb less contamination than rough ones and are more easily decontaminated. High quality machining, electro-polishing and shot-peening to remove superficial defects, can achieve satisfactory results. However, care should be taken to ensure that none of these hinder subsequent inspection.

The effectiveness of such protective measures may be limited by several factors including thermal cycling, mechanical stress, and environmental conditions encountered during transportation. These factors can cause fixed contamination to become mobile thereby increasing the level of loose contamination that exists without further exposure to a contaminated environment.

3.2. DESIGN OF FACILITIES AND SYSTEMS

The majority of nuclear facilities in the world use wet loading facilities for the transfer of spent fuel [2]. Contact between storage pool water and the cask is the main source of surface contamination for wet loaded casks. The use of separate pools for loading and storage operations can reduce the concentration of contaminants in direct contact with the cask. Modifications to facilities to permit the handling of larger capacity casks can reduce the number of transfer operations performed.

Facilities for dry handling of casks can be used in conjunction with both wet and dry storage. The latest reactors in France, and at Tihange 2 & 3 in Belgium, utilize a loading operation whereby the transport cask is docked beneath the storage pool and fuel transfers are made without immersing the cask in the pool water. Spent fuel is then transported to a dry unloading facility at the reprocessing plant where the spent fuel assemblies are removed from the cask individually by remote handling. With such a combination, the external surface of the cask never comes in contact with contaminated pool water. This combination is very "economical" in terms of low operator exposure and liquid waste minimisation at both power plants and reprocessing facilities. Remote operations experience with dry unloading facilities at La Hague, France, and RT-1 in the Russian Federation, has demonstrated lower levels of personnel exposure and reduced volumes of secondary wastes produced when compared to wet unloading operations.

Canisters can be used to isolate spent fuel elements from transport and storage casks as a means of reducing cask contamination. A canister system is currently in use for transportation and storage of fuels from ice-breaker vessel reactors in the Russian Federation. In the UK, a multi-element bottle (MEB) has been used to package and contain spent fuel elements within transport casks. In the United States of America a number of canister type systems are in use or have been proposed. The NUHOMS system utilizes a sealed canister combined with horizontal dry storage vault. Also, the Sierra Nuclear VSC-24 system uses a multi-element sealed basket (MSB) in combination with a ventilated concrete storage cask.

The USDOE has proposed the development of a multi-purpose canister (MPC) system that can be isolated from the pool environment during underwater loading by the use of an auxiliary transfer cask. The design calls for the spent fuel to be loaded and permanently sealed in the canister which is then transferred successively to transport and dry storage casks. The potential for cask contamination by direct contact with fuel elements is thereby significantly reduced. Unlike dedicated transport casks, multi-purpose casks may also undergo only a single pool loading, which itself has the potential for minimizing contamination.

3.3. OPERATIONS OF FACILITIES AND SYSTEMS

Control of pool water purity, chemistry, and temperature is essential for minimizing cask contamination. Most wet storage facilities use a combination of filters, skimmers, vacuum cleaners, and ion-exchangers to reduce the concentration of soluble and suspended contaminants in the storage pool. Monitoring of radiation fields and contamination levels in storage pools provide feedback on the fuel inventory and the effectiveness of the control of contamination [3].

Spent fuel assemblies should be rinsed prior to placement in the storage pool to remove crud accumulated during reactor operation. Identification and isolation of leaking or damaged fuel assemblies and rods can help to minimize the build-up of contaminants in the pool and reduce the cost of pool maintenance. Leaking or damaged fuel elements have been isolated in individual capsules to prevent contamination (experience exists in Germany and France).

Cask loading operations should be conducted to minimize the amount of time spent in contact with the pool water. Temporary barriers such as protective skirts (see Annex III) with demineralized water between the cask and the skirt, strippable coatings, "stretch-wrap" films, and chemical treatments can be applied to the cask exterior surface prior to submersion to reduce the adsorption of contaminants. The use of a water filled polyethylene "bag" to prevent contact of the external cask surface with pond water has been successful in the UK, Germany, and France.

Consideration should be given to washing the external surfaces of empty casks *prior* to submersion in the storage pool to eliminate accumulated dirt and grime which can adsorb radionuclides and contribute to "sweating", a phenomenon that causes the release of contamination from a cask surface over a period of time. Sweating, or “weeping”, is difficult to control by routine decontamination methods and is often seen in casks with poor surface finish which have been subjected to many immersions.

The addition of chemicals to wash water for the purpose of "blocking" adsorption sites on the surface of stainless steel casks has been proposed by the USDOE. Laboratory experiments have demonstrated some affect on reducing the adsorption of dissolved radionuclides. Operators at Ontario-Hydro (Canada) and Carolina Power & Light (USA) routinely wet down cask exteriors with demineralized water prior to submersion for loading. Experience has shown that this practice can reduce the level of contamination adsorbed on the cask surface. One possible explanation for this effect is that the clean water fills cracks and pores in the exterior surface, thereby preventing the entry of contaminated pool water. Rinsing and decontamination operations should commence immediately following re-emersion from the pool to prevent adsorption and diffusion of soluble species and settling of particulates into micro cracks. Difficulties in decontamination of spent fuel casks loaded at Vandellos I (Spain) occurred when the cask was allowed to dry prior to washing.

Regular maintenance of external cask surfaces is important to the long term reduction of cask contamination. Scuffing and abrasion of painted and machined surfaces should be repaired. Painted surfaces can be stripped and repainted as part of routine maintenance programmes. Dedicated facilities for the repair and maintenance of transport casks, such as those at Sellafield, UK, are essential for the maintenance of painted cask surfaces. Routinely the casks are pressure washed to effect decontamination, shot blasted to remove damaged paint and are repainted to renew specified standards of finish. This is done periodically to ensure that the surfaces exposed to contamination are retained in good condition to aid appearance as well as decontamination performance.

Inside the German pilot conditioning plant PKA, as well as in the French reprocessing plants at Marcoule and La Hague, there is a special decontamination and maintenance area for casks and baskets operation. Depending on the operating (thermal) requirements, casks should be covered during storage and transport to minimize accumulation of dirt and grime. Cask interiors should be decontaminated regularly to remove fuel rod crud and minimize re-contamination of the storage/transfer pools. Regular decontamination of handling equipment can help prevent cross-contamination.

4. DECONTAMINATION

This section describes the available decontamination techniques and the factors and criteria which influence the selection of a technique for a given application. Often a combination of several techniques is employed in order to economically achieve the acceptable level of decontamination in terms of time, dose and cost. Typical techniques and instrumentation for the measurement of contamination will also be described.

Transport casks are generally maintained on a regular basis. Typically, routine decontamination may be required during every cask handling cycle and is almost certainly prescribed as part of the periodic maintenance schedules. More aggressive decontamination techniques are performed less frequently in conjuction with the replacement of coating systems or intensive non-destructive examination (NDE) procedures. This work is usually performed in "purpose built" or "specially prepared" facilities which have good levels of containment and adequate means for handling the secondary waste arisings.

4.1. FACTORS INFLUENCING THE SELECTION OF DECONTAMINATION METHODS

The selection of decontamination methods depends on the following factors:

4.1.1. Type and level of contamination

Non-fixed (loose) contamination is easier to remove than fixed. By definition, fixed contamination is an integral part of the surface and requires special or more aggressive techniques for removal. In addition, the chemical form of the contamination (adherent particulate, chemically bonded to surface, etc.) will also influence the choice of technique. If the chemical form is not known, the general practice is to use the less aggressive techniques first, then utilise more aggressive techniques only if required. The scale of decontamination and the geometric complexity of the cask will greatly affect the personnel radiation exposure planning.

4.1.2. Regulatory requirements governing contamination levels

Contamination limits for packages and equipment (such as conveyances used in transport) are specified by international and national regulation standards. The current international transport standards which apply to casks and conveyances are: 4.0 Bq/cm^2 for non-fixed beta/gamma and low toxicity alpha emitters; and 0.4 Bq/cm^2 for other alpha emitters [4]. The requirements which apply to empty casks vary according the internal surface contamination; they can, on occasion, be consigned as “Excepted” packages, where the limits for external contamination are an order of magnitude lower than that for loaded casks. In addition, for conveyances, overall surface contamination (fixed and non-fixed) must be below 5 μSv/h.

Contamination limits for storage casks are governed by the licensing conditions in force at the particular site. However, it is unlikely that these limits will vary significantly from those applied for transport. These limits are based on acceptable levels of occupational radiation safety, the availability of facilities to deal with the secondary waste generated from the decontamination activities, and limits on contact dose rates on the external surfaces of casks. In addition, the ALARA principle applies when packages and equipment are decontaminated during routine cask handling operations.

If material from a decommissioned cask is to be reused or released to the public domain, the items must meet appropriate clearance levels prior to removing regulatory control. Both the internal and external surfaces must be decontaminated to a very low limit of surface contamination (i.e. 0.4 Bq/cm^2 for beta and gamma or 0.04 Bq/cm^2 for alpha emitters according to regulations in several countries). It may be necessary to store the cask for a period of time to allow neutron activation products to decay below the specific activity clearance level. The proposed international guidelines for clearance levels (interim report for comment) are published in Ref [5]. The principle of the guidelines is to apply a specific range of activity concentrations for particular groups of radionuclides depending on their toxicity to define the clearance levels. This requires a radionuclide identification analysis for the residual contamination. National experience indicates that competent authorities are approving requests on a case by case basis in most jurisdictions [5].

The use of flexible wrappings and engineered overpacks to contain loose surface contamination should be evaluated on a case-by-case basis in agreement with the licensing and/or competent authority(s). Attention will need to be given to the way in which such covers might affect the required dissipation of heat from the flask. Also, the need to decontaminate the overpack periodically and ensure that it is maintained essentially in a clean state, or dispose of the wrapping as a consumable item, will raise the issue of secondary waste.

4.1.3. Personnel radiation exposure

If a cask is highly contaminated and will result in large radiation doses to decontamination personnel (as defined by applicable national policies or regulations), a remotely operated technique is required for the initial decontamination to lower the radiation dose rates to a safe working level. The radiation dose is primarily a function of exposure time and working distance, so the selected technique should minimize the "hands on" working time. Most spent fuel transfer facilities are equipped with remotely operated decontamination (washdown) facilities and employ methods which reduce the worker exposure time to a minimum. Facilities for decommissioning casks utilizing aggressive techniques are not widely available, although there are facilities at Sellafield in the UK were they are practised.

The technique used and the type of radioactivity may have an influence on the type of personnel protection employed (e.g. ventilated suits, respirators, shielding). In any event, the technique should be chosen to keep the personnel doses ALARA.

4.1.4. Surface finish and features

The surface materials and finish of a cask can greatly influence the selection of a decontamination technique. The technique must be chemically compatible with the surface materials it comes in contact with, especially if the cask is to be re-used. While most of the techniques described in Section 4.3 are applicable to most surfaces, the operating parameters, such as application pressure and temperature, chemical concentrations, etc., may vary somewhat depending on the material and degree of surface removal desired. Certain techniques such as chemical cleaning and mechanical abrasion are more effective if they are repeated a number of times at less aggressive levels than a single application at a very aggressive level. In addition, the complexity of the surface (e.g. location and number of protrusions, cavities, surface discontinuities, surface finish requirements, etc.) may make some techniques easier to apply than others.

Certain techniques require specialized equipment not normally found in nuclear power plants. The purchase and installation of equipment and facilities for decontamination of casks can be a significant economic investment and may influence the choice of decontamination technique. Decontamination using specialized equipment requires specialized training for workers and is best supported by a dedicated crew.

4.2. CRITERIA FOR SELECTING DECONTAMINATION METHODS

The primary criteria in selecting decontamination methods are:

- the nature, level, location and accessibility of the contamination;
- the availability and accessibility of facilities, equipment and experienced personnel;
- the capabilities for handling secondary waste arisings;
- the allowable exposure limits for personnel.

In addition to these primary criteria, several secondary criteria exist, worthwhile mentioning:

- the cost effectiveness and efficiency of the decontamination method;
- the amount of secondary waste produced;
- the occurring conventional safety hazards.

Although not a technical limitation, the cost effectiveness and efficiency of the chosen decontamination technique(s) may influence the selection process. If decontamination is frequently performed on many casks, a dedicated "purpose built" facility may be economic to construct. The trend towards larger casks make this decision more significant since many existing facilities have limited craning capability. Less aggressive techniques (e.g., water washing, mild chemicals and hand brushing) will normally be used to avoid purchase of costly equipment wherever possible, although these techniques have their limitations.

Economics may also determine that contaminated components are replaced rather than refurbished. Standardization of cask component design will also assist in this process. The requirements for decommissioning life expired casks may determine that use of non-routine decontamination techniques and facilities can be justified.

Decontamination operations will always produce secondary wastes. The volume and form of these wastes may influence the choice of a technique. For example, if a liquid radioactive waste treatment system is not available at a facility, then use of a technique that produces large volumes of active liquid waste would not be appropriate. In addition, the technique should be chosen with a view to minimizing the overall amount of secondary waste which is generated. The majority of decontamination wastes are likely to be LLW.

Care should be taken when aggressive techniques (chemical, electrochemical, media blasting) are used, to ensure that the generation and processing of secondary wastes is properly controlled. Moreover, it is important to ensure that the use of aggressive techniques is not detrimental to the future operation, maintenance and inspection of the cask.

Conventional safety hazards must be recognized when selecting a decontamination technique. These may include lifting and moving of large, heavy objects (e.g. the cask or one of its components), chemical hazards from fumes and direct skin contact, airborne particulates and gases (both as a breathing hazard and an eye injury hazard), ergonomics (e.g. working in confined spaces or on elevated locations), sparks and hot metal flakes from grinding (hot work), high pressures from water jets and grit blasting, high temperatures from steam, etc.

4.3. DECONTAMINATION METHODS

The most effective methods of cask contamination control start with preventive measures such as minimising or avoiding direct contact with the contamination, preparing the cask prior to exposure to contamination, and decontaminating the cask immediately after exposure to contamination.

4.3.1. Water

The simplest decontamination technique is washing with water. This can range from low pressure flushing to remove loose contamination to high pressure water lancing, which can remove surface coatings as well as surface materials. The decontamination action of the water can be enhanced by the addition of chemicals, such as detergents, solvents or acids, to dissolve the contaminants, and/or by using higher temperature water or steam lancing. Further enhancement can be made by the application of scrubbing to physically wipe the surface. Water washing techniques can be adapted for either manual or remote application and are suitable for virtually all surface materials and configurations. The use of large volumes of water requires a low level radioactive liquid waste collection and treatment system to reduce or treat the volume of the contaminated liquids. This treatment system must also be capable of handling any chemicals which are added.

Remotely operated high pressure water lancing and rinsing facilities are very effective in removing contamination with minimal dose uptake to the worker. These facilities are most effective when they are customized for specific casks and provide a containment structure which address the radiological and conventional safety concerns.

A simple system is installed at Pickering (Canada) to wash the dry storage casks before immersion and after removal from the spent fuel pool. Internal decontamination of the Tritiated Heavy Water Transport Package (THWTP) (Canada) has been completed using low pressure water rinsing to remove contaminated sludge from the payload liners.

4.3.2. Mechanical

Mechanical techniques can be divided into two groups, those which decontaminate without damaging the surface (hand brushing, wiping, scrubbing) and more aggressive methods which remove the contamination and part of the substrate or coating system. Typically, both groups are very versatile and effective when integrated with chemical techniques. Since the techniques are so varied it is advantageous to utilize a centralized facility with all necessary handling equipment and support facilities for casks and other large contaminated equipment.

Aggressive methods are limited to areas of the cask where surface finish specifications are not critical (e.g. not applicable to seal face surfaces) or areas which allow the method to be used systematically over the whole unit (assumes the workpiece is free of tight corners and crevices). Surface contamination can be removed very effectively except in areas where accessibility is poor. Loose contamination and crud can be removed by a vacuum recovery system, fitted with a suitable high efficiency particulate airfilter (HEPA) to prevent the spread of airborne contamination. Waste volumes can be minimized through collection and recycling of the blast media using a vacuum recovery system or a contamination enclosure with automatic collection system.

Fixed surface contamination can be removed by abrasive blasting in either a wet or dry system. The media used may include sand, steel shot, glass beads, plastic pellets, corn husks, ground nut shells, dry ice (CO_2). Abrasive blasting equipment can be used in both open or closed loop systems, for both wet or dry applications using remote or manual equipment for simple to moderate surface geometries.

Sand and steel shot are the most abrasive and proven media available. They are capable of efficiently achieving the required surface profile for most coating systems, including epoxy based coating systems. Wet systems have the disadvantage of generating large volumes of liquid waste requiring filtering and processing while dry systems generate airborne dust and contamination requiring large capacity filtered recovery systems. The use of dry ice (solid CO_2 or pellets) as an abrasive has the advantage of producing very small quantities of secondary waste, leaving only the removed material as a residue after the dry ice particles evaporate.

Localized removal of fixed contamination and coating systems from areas which are inaccessible to abrasive blasting equipment can be achieved using hand held grinding or scabbing power tools. Wire brushing can be effective on very complex surfaces in small areas when coupled with the use of chemicals.

Aggressive mechanical decontamination methods are effective when considering decommissioning of casks. It is sometimes practical to remove all contaminated material and release the remainder of the cask into the public domain as inactive material.

4.3.3. Chemical

Chemical methods are often employed in conjunction with water washing, or mechanical methods but can also be used alone for soaking or scrubbing. Chemicals are employed as solvents to dissolve either the contaminant or the surface material to which the contaminant adheres. Examples include degreasing agents, detergents, organic acids (such as EDTA, citric, oxalic, etc.), mineral acids (phosphoric, nitric, etc.), paint removers and organic solvents. Foams and gels can be used to increase the contact time, especially on irregular or vertical surfaces [6]. Chemical techniques can be adapted for most surface materials and configurations, and can be adjusted in strength from weak action to destructively aggressive, depending on the degree of decontamination required.

Mild chemical techniques are used to remove contamination without attacking the base material, but require longer treatment times and achieve lower decontamination factors (DF). The effectiveness can be improved by increasing the treatment temperature in the range of 20–90°C. Aggressive techniques, using strong chemicals, can achieve higher DF with shorter treatment times but can attack the base materials being treated. They also create secondary wastes which are difficult to treat.

The chemical and its strength must be carefully chosen to match the type of contamination and the surface being decontaminated. The incorrect choice of chemical and its strength can have either very destructive acute effects (e.g. undesired excessive chemical dissolution of the base material which will preferentially attract contamination in the future) or long term detrimental effects on the cask materials (e.g. initiation of stress corrosion cracking).

Proper personnel protection must be practised when using chemical methods. All chemical methods should be immediately followed by a thorough water rinse. Chemical methods will remain a popular decontamination method in the future for small areas on internal and external surfaces.

4.3.4. Electrochemical

Electrochemical decontamination (a technique similar to electropolishing) involves placing the object to be decontaminated in an electrolyte bath and applying a direct electric current between any conducting surface of the object and anodes in the bath. This removes a layer of surface metal and oxides, thereby removing the contamination with it. By adjusting the potential and current density it is possible to remove the contamination selectively with minimal effect to the underlying surface. (Typically less than 25μm of the surface is removed.) This technique is limited by the size and weight of the object which can be fitted into the tank. However, it is particularly effective for removing contamination from regions where access is difficult, and can be used for very complex geometries that would be impossible to decontaminate by other methods. For decontaminating the inside of a cask, the cask itself can serve as the electrolyte tank.

Flat and relatively even surfaces are suitable shapes for using portable equipment, where the electrolyte is "sandwiched" between the flat hand-held pad applicator, and a small area of the surface to be decontaminated. The resulting solution, which contains the dissolved contamination and surface material, is then wiped from the surface using swabs.

Electrochemical decontamination action can be mild or very aggressive, depending on the operating parameters chosen (electrode potential, current density, temperature, electrolyte composition and strength, and contact/immersion time). It is essential that surfaces are free of grease, oil, rust and paint for this technique to work, and all treated surfaces will require rinsing with clean water afterwards.

Applications of these techniques must address conventional safety hazards such as control of gas generation, electric shock hazard, as well as disposal of the contaminated electrolyte solution, and control of the secondary waste arisings will be required. Volumes of liquid required for electrochemical decontamination are relatively low relative to chemical decontamination.

4.3.5. Ultrasonic

Ultrasonic cleaning techniques are commonly employed for smaller removable components of casks, such as baskets, nuts, bolts and studs. The technique can be used with very complex geometries but is limited by the physical size and weight of the part to fit in the washing tank and the corresponding transducer size. This type of cleaning technique is particularly suitable for stainless steel parts where the cost of decontamination and re-use is less than the replacement cost of the component and the preservation of surface finish is critical. The German PKA facility is equipped with a large tank for ultrasonic cleaning of baskets.

4.4. TECHNIQUES FOR MEASUREMENT OF CONTAMINATION

The measurement of contamination, especially very low residual contamination levels, requires sensitive instrumentation and a very low background. Different techniques are available to distinguish between non-fixed (or loose) and fixed contamination, as well as the type of radiation. It should be noted that it is not always possible to identify individual radionuclides in the contamination due to the very low levels, interference among the various radionuclides and the difficult measurement environment. Much of the characterization equipment is routinely available in nuclear power plants, fuel reprocessing plants and cask maintenance facilities. Highly sensitive alpha, beta and gamma spectroscopy equipment may only be available in specialized laboratories. However, such spectroscopic analyses are not generally required for routine decontamination purposes.

4.4.1. Gross contamination levels

Whilst the cask is unloaded, an initial survey is generally performed prior to decontamination using radiation field survey equipment. As the initial radiation fields before decontamination can be of the order of several μS/h (or higher), they are easily measured using standard beta-gamma survey equipment, either on a gross basis or as a gamma spectrum to identify the principal radionuclides. The initial survey can also be used to locate pockets of crud and hot particles which may have very significant radiation fields. Equipment is readily available which can measure down to environmental background levels with very fast response times (seconds or less) for most radionuclides.

4.4.2. Contamination records

A standard check sheet or "map" of the cask surfaces based on systematic gridlines is a practical method of managing contamination and the decontamination process. It provides a method to ensure that important locations are checked each time. Contamination measurements should be completed at various stages of a decontamination project. Detailed surveys of the complex geometries often found on external surfaces of casks can be a very labour intensive task and should be performed by appropriately trained personnel.

Contamination measurements are valuable if kept in a database format to provide historical data on the build-up of contamination on surfaces, the methods used and the decontaminability of the surfaces. Over time a surface which has been decontaminated with aggressive methods (chemical or mechanical) may degrade to a point where contamination is not readily removed and/or the surface is more readily contaminated. Degradation of critical surfaces will require repair or upgrade to reduce the contamination uptake and improve decontaminability.

4.4.3. Measurement of non-fixed contamination

Measurements of non-fixed contamination should be made in accordance with standards [7]. The presence of non-fixed contamination can be detected and initially measured by using paper or cotton swabs which may be moistened with a wetting or tacking agent to maximize pickup to wipe a portion of the surface area (usually 100–300 cm^2). For official measurement, a dry smear (paper wipe) of the surface should be taken with the measurement made in an area of low background radiation. Non-fixed contamination is generally measured before fixed contamination can be assessed and the action is often repeated several times until an acceptable non-fixed contamination level is found. Hence, decontamination and measurement are undertaken simultaneously. Normally, non-fixed contamination is measured after removal of visible debris and crud. Due to the low levels of radiation being measured, contamination meters are sensitive to interference from background radiation, so they should be suitably protected by location and/or shielding [8].

Typical measuring devices use the Geiger-Müller counter or solid state detectors and have counting response times on the order of seconds to minutes. Gas proportional instruments are more sensitive, especially for low energy betas and gammas. Sensitive laboratory style gamma spectrum equipment using long counting times (often days) is required if a detailed spectrum analysis is desired. Measurements are given in "becquerels per cm^2" over a standardized area; when they are expressed by operators in "counts per minute", they need to be translated into "becquerels per cm^2" to be compared to the allowable limits. Acceptable limits for non-fixed contamination are established by national regulations or facility policy. They are generally kept as low as possible, with many facilities having a zero limit on external surfaces. Measurements by the USDOE of the ratio of removable contamination to fixed contamination, as determined from swipes (swabs), showed that generally, the removable contamination was only 1%–2% of the total surface contamination after washing with demineralized water.

4.4.4. Measurement of fixed contamination

Fixed contamination is generally measured using a "frisker" passed over the surface of the object at a near-contact distance (~0.5–1 cm) in a regular pattern. The frisker probe is sensitive to all types of radiation down to very low levels. Measurements are typically expressed in counts per minute per 100 or 300 cm^2, becquerels per cm^2 or μSv/h. Acceptable limits for fixed contamination are established by national regulations or facility policy based on international standards regulations. Measurement of low level fixed surface contamination may be impeded by high background radiation (e.g. adjacent loaded casks). For example, even if the general background radiation at the work location is as low as 10 μSv/h, the frisker detector will be swamped and will not give a true reading of the "contamination". Gamma spectrum measurements are often difficult to perform, due to the extremely low levels of radiation.

4.4.5. Alpha surveys

Since the surface of the cask has come into contact with spent nuclear fuel, there is a strong possibility of transuranic or alpha emitting contamination. Many alpha emitting radionuclides can be detected by measuring their gamma signatures. Alpha assaying equipment may be used on loose contamination swab samples, but the chemical separations required to isolate particular species for detailed counting are generally not possible due to the small quantities found in typical contamination swabs. The acceptable limits for transuranic/alpha contamination are generally an order of magnitude lower than those for beta/gamma. Decontamination methods for alpha should include adequate protection of personnel to avoid worker internal dose uptake.

4.5. MANAGEMENT OF CONTAMINATION

Decontamination is a largely unavoidable aspect of cask operation and maintenance. To ensure that the costs incurred are controlled and budgeted, and that working practices are safe, operators should implement a formal management system for implementing inspection and decontamination activities. The system should address both short and long-term issues.

4.5.1. Quality programmes

Decontamination procedures should follow a prescribed quality programme in which plans and method statements are prepared to ensure that agreed working practices are followed and that adequate records of each decontamination operation for every individual cask are kept. These records provide important reference documentation for assessing, amongst other items (i) the progressive build-up of contamination on the cask's surfaces; (ii) the effectiveness of previous decontamination campaigns; (iii how proposed modifications may be affected by the cask's condition.

Whilst meeting the requirements of safety standards, assessments of the effectiveness of decontamination work can be an imprecise practice because certain information can be left unrecorded, or not recorded in sufficient detail, for operators, cask designers and system managers to review. To ensure that this does not happen, a strict management system should be implemented so that comprehensive records are maintained and subjected to regular audit. This practice is particularly valuable for managing the sweating phenomenon. Only by following such a scheme can adequate feedback be gained to help guide decisions about future activities.

4.5.2. Control of non-fixed contamination

One low-cost but effective technique that has proved useful in controlling levels of surface contamination without the need to undertake decontamination, is that of "fixation", which "seals" loose or semi-loose low-level contamination to the surface of the cask by applying a paint or varnish coating. This is used less these days because of advances in cask design and handling procedures, but was at one time widespread.

The use of this technique should be limited to single use packages because, although it may have short-term benefits, it can lead to long-term problems, for example in the promotion of "sweating" (a phenomenon that causes the gradual and unpredictable release of radioactivity from a cask surface over a period of time). This can lead to problems in shipping the cask as an "excepted" or "empty" packaging having contained radioactive materials. Also, it can give rise to uncertainties in quantifying the level of contamination held by the cask before it is sent for disposal, or otherwise treated in preparation for dismantling or decommissioning.

4.5.3. Preparations for shipment and receipt

In order to maintain consistency between the declaration of cask contamination on consignment documents and facility records at both the points of despatch and receipt, it is important that the procedures at these facilities are as identical as possible. Wherever possible, surveyors should use the same instruments (calibrated for the same isotopes) to eliminate discrepancies and misinterpretation.

Experience in the Russian Federation, where shipping distances average over 2000 km, has demonstrated that strict adherence to decontamination standards and procedures coupled with optimized designs of casks and railway wagons can avoid non-conformance incidents throughout the transport cycle.

4.6. THE GENERATION AND MANAGEMENT OF SECONDARY WASTE

Decontamination techniques, by their very nature, transfer contamination from the cask surfaces to a host material. This can be a solid substrate (such as a paper or cotton wipe or swab) or a liquid, commonly water. Hence the decontamination process is essentially one of transferring radioactivity from the cask surface to a carrier material to facilitate collection, treatment and disposal. This generates quantities of low-level (LLW) secondary waste which feed into the facility's radioactive waste streams. In only very exceptional circumstances is this waste likely to be higher than low-level.

In the case where water is the prime carrier, significant volumes of waste water are usually generated. It is typical for this to be filtered and recycled to minimise discharge activity levels. This can be achieved by using conventional filters, or ion exchange units to trap the contamination onto resins to facilitate ultimate disposal. The use of "flocs" to precipitate contaminated particles in the stream is also practised. Large scale facilities utilize an array of technologies including filtration, solidification, vacuum degassing, separation, reverse osmosis and ultra filtration to meet discharge criteria for active liquid waste streams [9].

Alternatively, either with or without pre-treatment, the waste water stream can be discharged directly to storage (delay) tanks where it can be chemically treated for discharging to the environment. The allowable discharge rates are strictly limited by regulations.

In the case where contamination is removed directly onto a solid substrate (for example either by wiping or by brushing and collection) or where it is trapped by a substrate from the aqueous medium (as in filtration), the resulting waste is segregated and placed into drums/bins where it enters the LLW stream for the facility. The waste can then be treated either as a combustible or non-combustible product.

The collection of radioactive particles onto soft, materials of low density means they can be easily compressed to maximise the total amount of waste that can be put into a drum. Furthermore, these drums can be super-compacted in order to minimise the volume (and hence cost) of disposal at the low-level waste site. Further information on the treatment of solid and liquid wastes is available in Refs[10, 11].

5. MODIFICATION OF CASKS

This section discusses the reasons why spent fuel casks may require modification, and gives examples of experience with existing designs used by IAEA Member States. It also proposes a methodology for controlling the modification process.

Most spent nuclear fuel casks do not undergo major design modification in their working life : it is more usual for them to have component upgrades to meet one or more of the various requirements given below. Generally speaking, these modifications involve transport casks rather than storage casks although, for reasons of economy and expediency, it is not unusual to find redundant transport casks used for certain storage purposes. This requirement can give rise to the cask being modified specifically for this purpose.

Any modification to a cask must be considered within the context of its licence or approval when such changes affect the design parameters identified in the safety analysis report (SAR) for the cask or storage facility.

Owing to the relatively high cost and timescale associated with designing, constructing and licensing a new cask, it can on occasions be more appropriate to modify an existing type to meet a new requirement rather than develop a new one. Casks are licensed to transport and/or store specific contents, although some designs accommodate a variety of fuel element types. Their usage is strictly controlled through formally-approved Operating and Handling Instructions, and their contents are prescribed in the SAR. Type B(U) and B(M) transport packages are designed to survive severe accident conditions. For these reasons, even a minor modification usually requires formal approval by a competent authority before it can be implemented.

The main reasons why a cask may require modification are:

- to accept different contents (or provide for a different contents configuration),
- to alter the method of operation,
- to meet safe working and regulatory requirements,
- to minimise contamination.

If a cask has been in regular service for transport or storage of spent fuel it will be necessary to reduce its contamination to acceptable levels before any modification work can be carried out.

5.1. MODIFICATIONS TO ACCEPT DIFFERENT CONTENTS

Transport casks may be designed and licensed to accommodate different types of fuel whereas storage casks are usually designed for one specific type and configuration. However, it is quite possible that either type may require modification to accommodate new authorized contents that were not envisaged at the initial design stage. Either way, the upgraded design specification must be approved formally by the competent authority.

Changes to accommodate new types of spent fuel arise for various reasons including higher initial enrichment; higher burnup; shorter cooling time; advanced fuel designs; transport of mixed oxide (MOX) and reprocessed uranium. Modification of a cask to take different contents usually focuses design effort upon criticality control, increased shielding, heat removal and fuel handling. These factors are usually interactive, and an analysis of the proposed configuration is inevitable in order to gain approval. Criticality analysis is the focus of the analysis in most cases. Substantial changes may lead to a prototype or model of the proposed cask having to be tested to prove compliance with the regulations.

Sometimes only the internal "basket" requires modification leaving the existing cask body unaffected. Only a modest reworking of the relevant parts of the SAR may then be required, thus shortening the time and cost for re-certification. Examples of where only the internal "basket" has been modified are found in the Russian Federation and in the UK. In the Russian Federation the TK-6 cask, which was designed for transporting WWER-440 fuel was fitted with a hermetic canister to carry assemblies for post-irradiation examination, whereas the TK-19 was supplied with a new basket for carrying UO_2 powder. In the UK the DN1113-L "Unifetch" cask, which was originally design to transport fuel irradiated from Dido & Pluto Materials Test Reactors was provided with a new basket so that it could carry fuel from the BR2 at Mol (Belgium) for reprocessing at Dounreay (UK).

Examples of where both the cask body and basket have both been modified are found in France, Germany and the Russian Federation. In France, new baskets for the TN12, TN13 & TN17 casks (which were licensed successively to transport PWR and BWR spent fuel) were redesigned, manufactured and fitted to carry defective assemblies. Otherwise, the design of the cask allowed to easily increase the thickness of neutron shielding to accept fuel of higher burnup. In Germany, the CASTOR 1C transport and storage cask, which was originally licensed to carry BWR fuel, was modified to provide interim storage for fuel from the Swiss DEORIT research reactor. In the Russian Federation, the TK-18 cask (which was designed to carry ice-breaker vessel reactor fuel) was modified to carry spent research reactor fuel by providing a new basket and a modified lid. It was also required to accommodate the wet loading system used on this duty.

5.2. MODIFICATIONS TO ALTER THE METHOD OF OPERATION

Modifications to alter the method of operation of the cask are undertaken either to allow the cask to operate in a more efficient way or at a different facility from that where it is currently in use. Again, the example of the CASTOR 1C used at DEORIT can be cited here where a transport cask was adapted for use as a storage cask.

In France, the TN12/1 design was modified to equip the casks for working in a dry unloading facility at La Hague which operates on a "double-containment" principle order to prevent operators coming into contact with the contaminated atmosphere in the cask cavity. This modification also allowed to fit protective plates on the upper surface of the cask before immersing the cask, in case of wet loading or unloading, and minimise its contamination.

Modifications to the associated plant can also be undertaken to aid cask handling. This does not always require major modification to the actual cask, as is the case with the fuel transfer system at the proposed Bruce Used Fuel Storage Facility in Canada. The proposed facility utilizes a transfer bay connected to the storage bay to load fuel in the dry storage container.

5.3. MODIFICATIONS TO MEET SAFE WORKING AND REGULATORY REQUIREMENTS

Modifications to maintain or improve standards of safe working are generally those which are introduced by an operator in order to conform to best practice over and above the basic standards required by the regulations. By virtue of their robust design many casks have a long operational life which means that their operating efficiency will be subjected to continuous review by several generations of engineers.

It is also important to recognize that the competent authority's interests cover all aspects of flask maintenance as well as operation, and hence modifications in this area are subject to similar assessment and approval. For example, it may be that during routine maintenance or inspection a component is found to be worn excessively, or damaged, and must be replaced. However, it may not be possible to substitute it with a component of identical specification as, for example, the specification may call for a material that is no longer available. Hence, a reasoned argument must be made to modify the SAR to allow the replacement component to be formally approved by the competent authority and accepted formally into the system.

The primary regulatory standards which govern the operation of spent nuclear fuel transport casks are contained in [4]. These are administered along with the safety system operated within a nuclear licensed site by the plant or utility operator (the licensee) under the authority of the country's government. In either case, ever-increasing requirements to minimize the effects of hazardous operations on the workforce and the general public can lead to modifications being introduced in order to justify continued operation.

Two of the most hazardous operations in cask handling are (i) loading & unloading the fuel, and (ii) undertaking high lifts between handling stations in the plant. Increasing safety standards over the years have obliged operators to introduce extra precautions here. These can take the form of modifications to the casks themselves, or occasionally a modification to the associated plant equipment, as is the case of a cask operated at Ignalina NPP in a shallow pond into which a shock absorber was placed to reduce impact damage if the cask were to fall in the case of a catastrophic failure.

At the Doel NPP in Belgium the route followed by the cask at the reactor site includes travelling some 25 m over hazardous parts of the facility (such as the spent fuel pool). With increasing standards of safety, additional provisions must be made to avoid any handling accidents. One solution was to equip the cask with an additional pair of trunnions and to use a special lifting beam incorporating appropriate attachments for these.

Modifications to a range of cask components have been undertaken over the years, for example in the UK where Magnox Mk2 cask lid seals have been upgraded to enhance leak-tightness capability and avoid over-pressurisation of the seal interspace if the cask is subjected to fire after an impact accident. Modifications have also been made on these casks to facilitate seal drying prior to testing before despatch. Also on this design, an outer lid seal which incorporated a coiled steel "spring" replaced an earlier type "O-section" (designed to meet the 1973 regulations), was fitted to ensure that the degree of containment met the 1985 standards.

To meet increasing regulatory requirements to minimize operator dose uptake, it is sometimes necessary to reduce (or preferably eliminate) radiation "shine paths" which can arise between the cask and the facility to which it is connected, such as a reactor top plate or a fuel storage pool. Although additional shielding may be introduced, it can also require a change in operating procedures to minimize exposure time for the workforce - for example, with the introduction of remote handling.

In France, the TN12/1 cask design was modified to comply with the additional shielding requirements of the Japanese competent authority — changes that were in fact introduced before manufacture of the fleet of casks was completed.

5.4. MODIFICATIONS TO MINIMIZE CONTAMINATION

5.4.1. General considerations

In modern cask design, contamination is taken into account as a primary factor (see Section 3.1). Other modification considerations for minimizing cask contamination are surface finish, coating technology and decommissioning.

5.4.2. Surface finish

Consideration should be given to providing a smooth surface finish in order to minimize retention of contaminated liquid, facilitate surface cleaning and reducing corrosion. Several techniques are available, such as surface passivation, anodization, polishing, painting, chemical or electrochemical plating, sand blasting, shot peening. However, care should be taken to ensure (i) that they are economic in application, (ii) they can be applied readily during routine operations, and (iii) that they do not cause secondary effects which are detrimental to the integrity and operability of the cask.

An example of cask surface finish modification to minimise contamination is illustrated by the experience at Oconee (USA), where a NUHOMS transfer cask used in repetitive wet loading operations was fitted with a new, highly polished, stainless steel skin to minimise adsorption from the spent fuel pool.

Experience with the TN1300 casks in Germany has shown that components which have simple geometries and smooth surfaces can be decontaminated to very low levels.

5.4.3. Coatings technology

Coatings technology has developed over the past few years as experience has been gained in the usage and decontamination of casks. Paints and other coatings are often simple to replace and "touch-up" on existing casks, without invalidating the licence and can usually be applied within the terms of the certification.

In Canada, lacquer-based coatings on NAC NLI-6502 cask were successfully replaced with a coating system comprising zinc-rich epoxy primer and two coats of gloss enamel to reduce the permeation of contamination into the surface, improve decontamination after wet unloading at Chalk River Laboratories, and reduce the contamination sweating problem.

5.4.4. Decommissioning considerations

Although modifications are made with the aim of minimizing contamination during cask operations, it is increasingly common practice to include decontamination considerations for the purposes of reducing decommissioning costs at the end of the casks' life. Nowadays it is expected that this will be an integral part of the original cask design, although there may be opportunities to apply these considerations retrospectively to existing casks, particularly if the life is to be extended for to cover new duties. Determination of the waste category into which the material will ultimately be placed (e.g. Free- release, LLW, ILW) may assist this process.

5.5. MANAGING THE CASK MODIFICATION PROCESS

5.5.1. The need for a managed process

The cask modification process is an integral part of the cask life-cycle. The methodology used for this must therefore meet the same rigorous standards of quality assurance and approval that govern the original design and licensing process. Use of a formal procedure, whereby the value of proposed modification(s) is assessed against the perceived benefits and associated costs and risks, is therefore essential.

The extent of modification work on spent fuel casks can vary considerably, although experience shows that most types undergo few major modifications during their lifetime. However, it is important that even for minor modifications the proposal, acceptance and implementation process is managed at each stage.

It should be noted that many procedural principles are also recommended for managing cask modifications. Given below is a brief summary of what a managed system would require.

5.5.2. The assessment process

The consequences of introducing a proposed modification should be assessed on a systematic basis to ensure that the proposed modification has been reviewed comprehensively and can be justified against the following criteria :

(i) technically feasibility;

(ii) regulatory acceptability;

(iii) efficient and safe operation and maintenance of the modified cask (including the effect on criticality);

(iv) efficient and safe operation of the facilities, where it will be used, and of the proposed transport system;

(v) effect on operator dose uptake;

(vi) effects of other proposed modifications being introduced;

(vii) costs and economic benefits.

5.5.3. The approval process

Once the proposed modification has been accepted in principle by the cask operators and design authority, it is necessary to obtain approval. It is good practice to consult with the competent authority, when considering modifications, to ensure that there are unlikely to be any significant issues which will prevent approval. In particular, the competent authority will be able to confirm at this stage that the classification of the proposed modification (i.e. the extent of its influence on safety considerations) is acceptable and properly identified.

The proposed modification should then be described and justified in a formal document which provides the basis of its approval by the competent authority. It can be submitted usually as an appendix or supplement to the SAR.

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Annexes I–IX

SUMMARY OF NATIONAL EXPERIENCES

Annex I
CANADA

I.1. DECONTAMINATION EXPERIENCE

I.1.1. Pickering Dry Storage Facility

Stage 1 of the Pickering Dry Storage Facility (DSF), located at the Pickering Nuclear generating station in Ontario (8 × 516 MW(e) CANDU), was commissioned in 1995. The facility building houses an operations area and a storage area with capacity for 185 dry storage containers (DSCs), each containing 384 bundles of used CANDU fuel. The DSC is a rectangular section container fabricated from an inner and outer 1.2 cm thick carbon steel shell, filled with reinforced high density concrete. The container measures approximately 2.4 m × 2.1 m × 3.5 m high, with an empty weight of 59 t, or 69 t when loaded. The internal and external surfaces of the container are painted with an epoxy paint for corrosion protection and to help decontamination of the external surface (see Figs I.1–I.5).

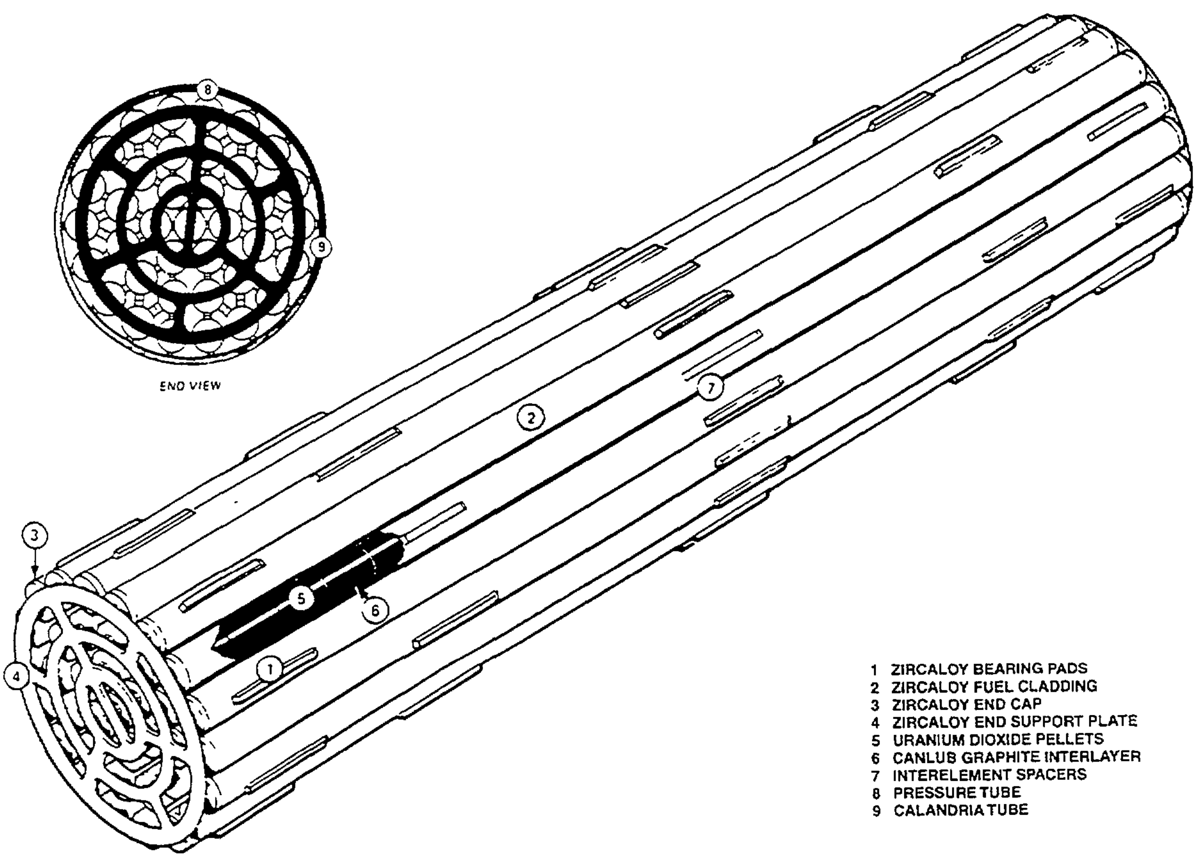


FIG. I.1. Candu fuel bundle.

The DSC is loaded in the station irradiated fuel bay (fuel storage pool) with minimum 10 years' cooled fuel. Prior to immersion in the bay, the DSC cavity is filled with demineralized water and the outer surface of the DSC is also wetted with demineralized water. This initial wetting minimizes the pickup of contamination from the fuel bay water. The fuel bay water is purified continuously with a filtration and IX (ion exchange) system to minimize water contamination.

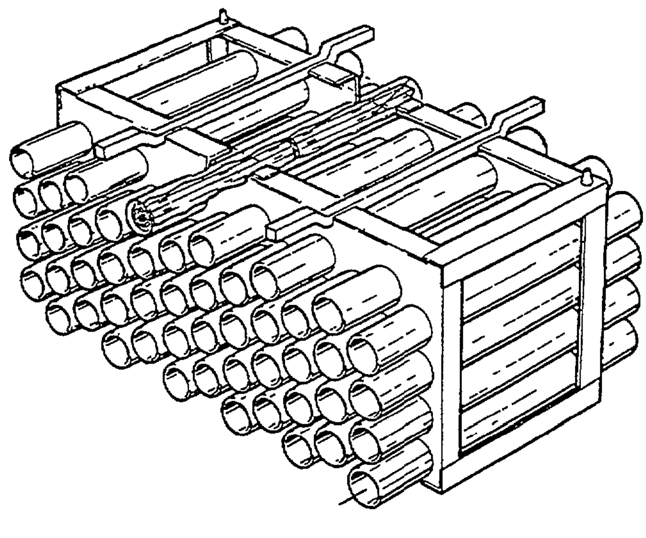


FIG I 2 Pickering/Darlington fuel storage module

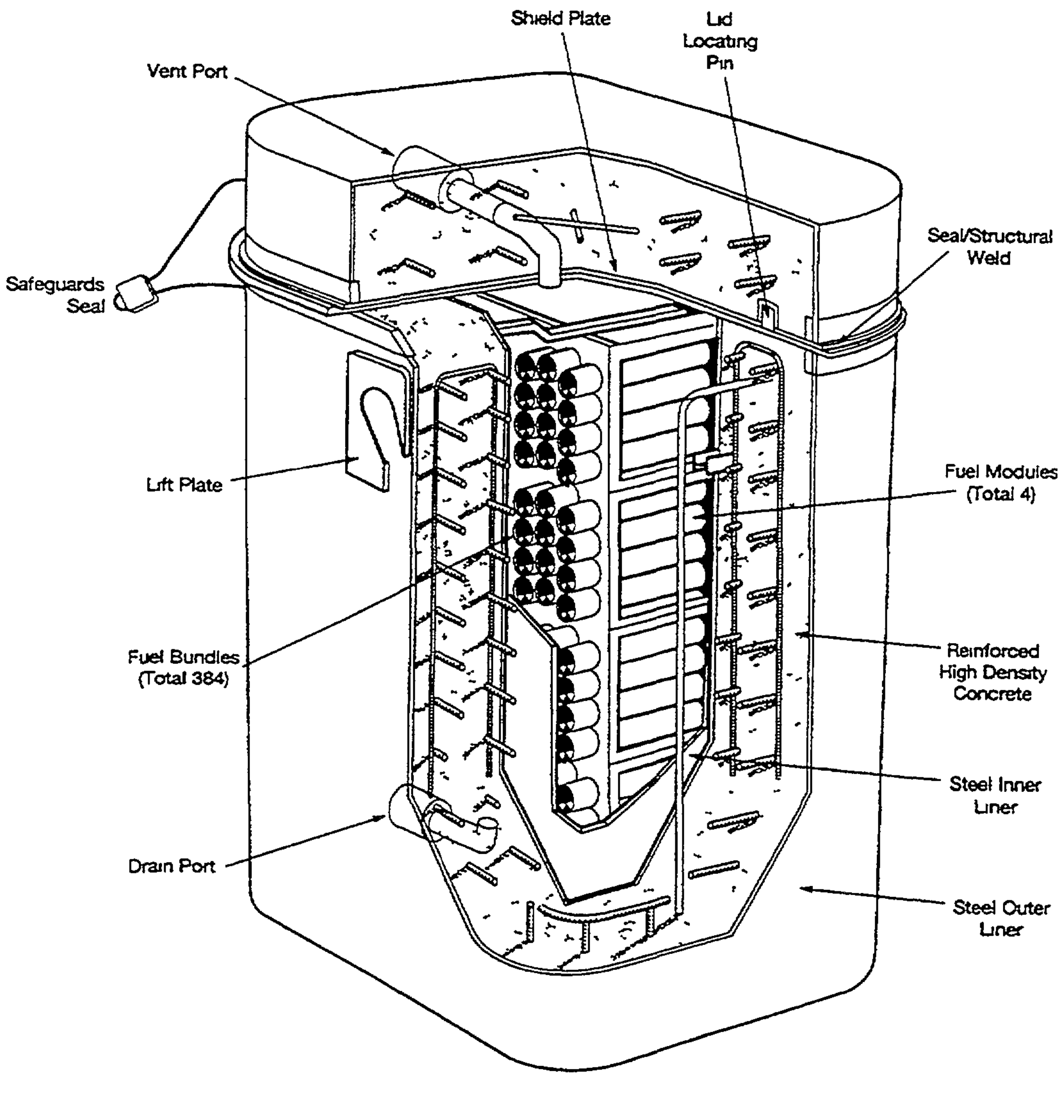


FIG I 3 Pickering dry storage container

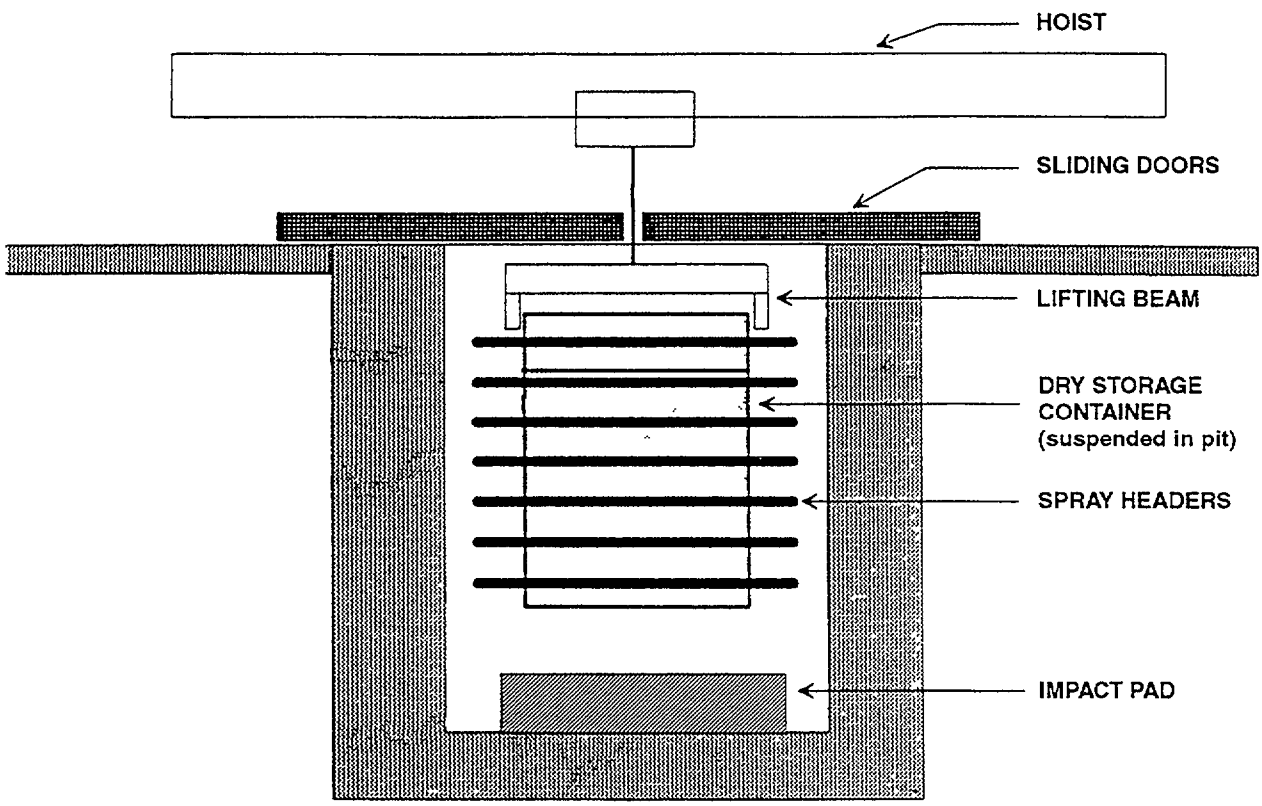


FIG. I.4. Pickering DSC decontamination pit.

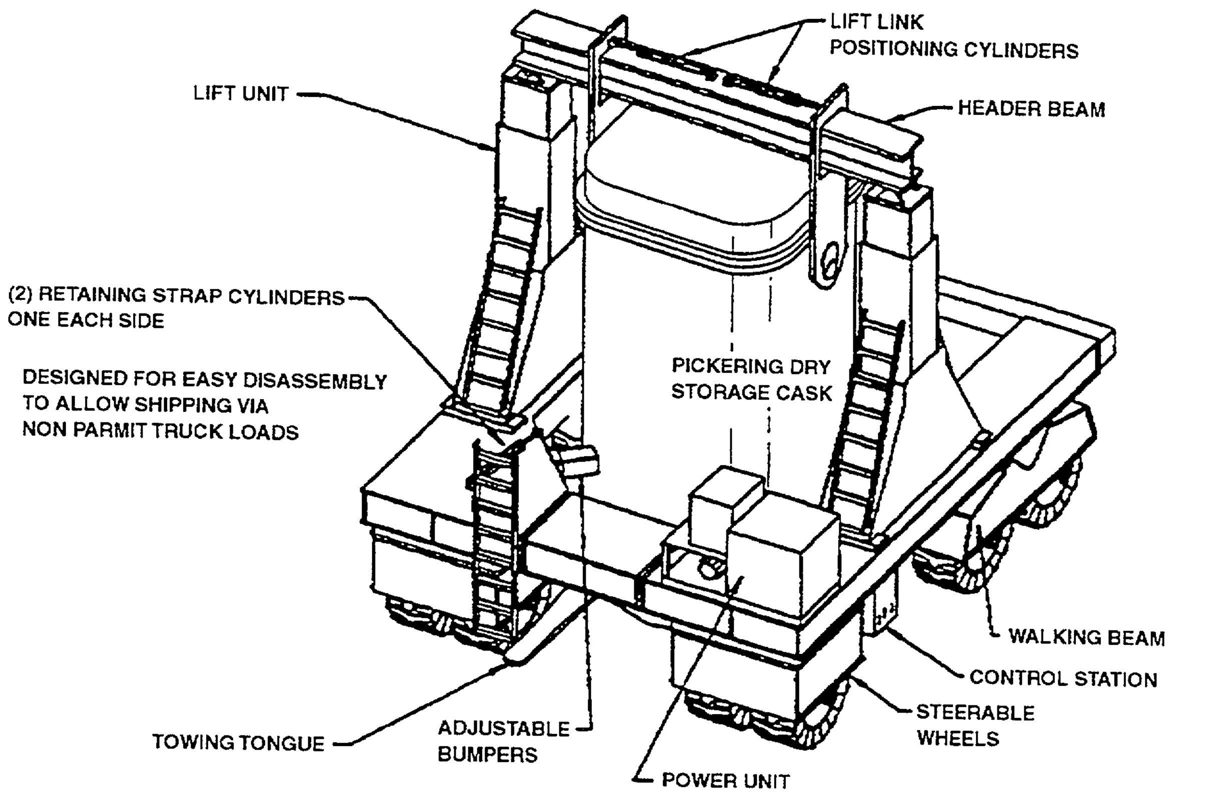


FIG. I.5. Pickering transporter (typical).

Once loaded, and the lid clamped in place, the container is washed with high pressure demineralized water as it is being lifted from the bay. It is then transferred to a decontamination pit adjacent to the fuel bay, where it is sprayed with demineralized water at 82°C for 10 to 15 minutes using a multiple nozzle spray header that fits around the container. After a 10 minute air dry, the container is lifted out and a manual surface contamination check is made. The station's acceptance criteria is less than 200 counts per minute (cpm) for surface contamination. The process can be repeated if the levels are found to be above 200 cpm above background. (Usually, the measured values are close to 0 after one decontamination cycle.)

After decontamination, the loaded DSC is transferred to the dry storage facility building, where the interior is vacuum dried, the lid is welded on and leak tested. A final contamination check is then done on the container (mostly around the weld area) prior to placing into storage. If contamination is found, the DSC is moved to the decontamination area of the DSF building, where it is manually decontaminated with wipes and water. After final decontamination, the surface around the weld area is repainted as required and the container is placed into storage. A total of 113 DSCs have been manufactured to date, with up to 87 more scheduled for 1998–1999. As of the end of June 1998, 64 containers have been filled and placed in storage.

I.1.2. Transport casks

The NAC/NLI 6502 cask was originally designed to ship LWR fuel (see Fig. I.6). It was retired in late 1997, but had been adapted for shipping irradiated core components, research reactor fuel and other high activity wastes. It has a cylindrical steel shell, approximately 0.85 m OD × 3.96 m long, square inner cavity 0.29 m × 0.29 m × 3.26 m, 0.61 m lead and depleted U shielding, with a weight of approximately 20.5 t. The removable lids at both ends allowed the cask to be loaded/unloaded from either end (horizontal or vertical). It is normally dry loaded at the nuclear stations (can be wet loaded), and dry unloaded at the BNPD waste operations site. However, shipments destined for the Chalk River Nuclear Labs (CRNL) are wet unloaded in the CRNL (NRX) fuel pool, which has no operating purification system. The radiation dose rate from contamination in the water is typically 300 μSv/h (30 mrem/h) at the surface. This resulted in significant contamination of the internal and external cask surfaces.

The outer shell is stainless steel, with a relatively rough "from the mill" rolled finish, coated with layers of lacquer to help "fix" contamination. Additional layers of lacquer were added to fix contamination as it built up. It was found that the lacquer attracted contamination, especially beta, into the subsurface, where it would "sweat" or leach out over time.

Prior to decontamination in early 1996, the external surface had up to 5000 cpm of loose contamination, 35 μSv/h (3.5 mrem/h) of gamma and 1000 μSv/h (100 mrem/h) of beta. No alpha contamination was detected. The external surfaces were then sandblasted to remove the lacquer build-up, and the contamination. External contamination levels were reduced to less than 1200 cpm, with no loose contamination after painting with zinc epoxy primer and 2 coats of high gloss white enamel.

Internal contamination levels were measured at up to 100 000 cpm, with 100 μSv/h (10 mrem/h) general gamma, and 8000 cpm of alpha. This cask will undergo further aggressive decontamination as part of the decommissioning phase.

In late 1997, the NAC/NLI 6502 was replaced by the Roadrunner (see Figs I.7–I.9). The Roadrunner was designed with additional ancillary equipment for dry unloading at CNRL, thus eliminating the sweating problem on cask surfaces.

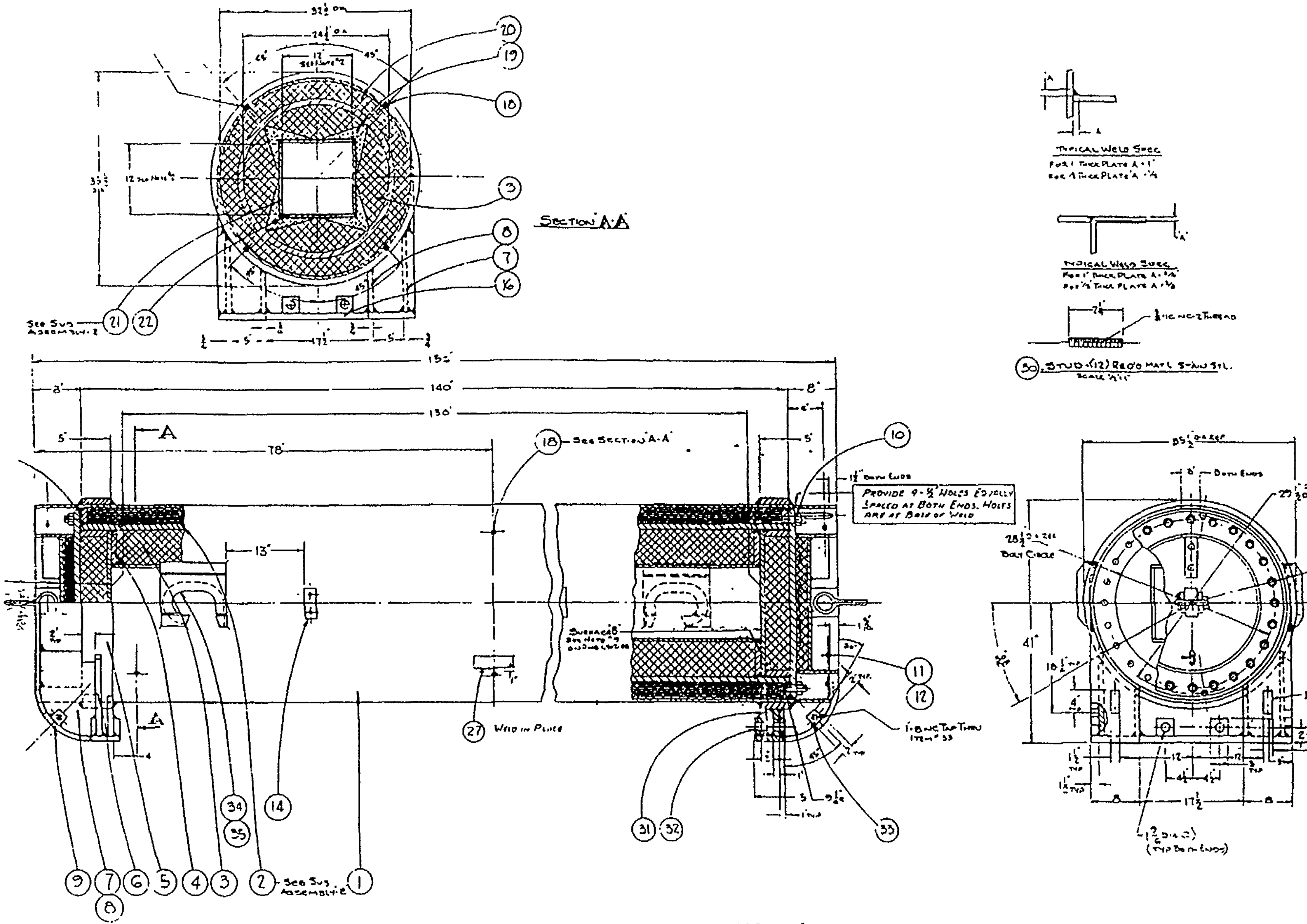


FIG. I.6. NAC/NLI-6502 cask.

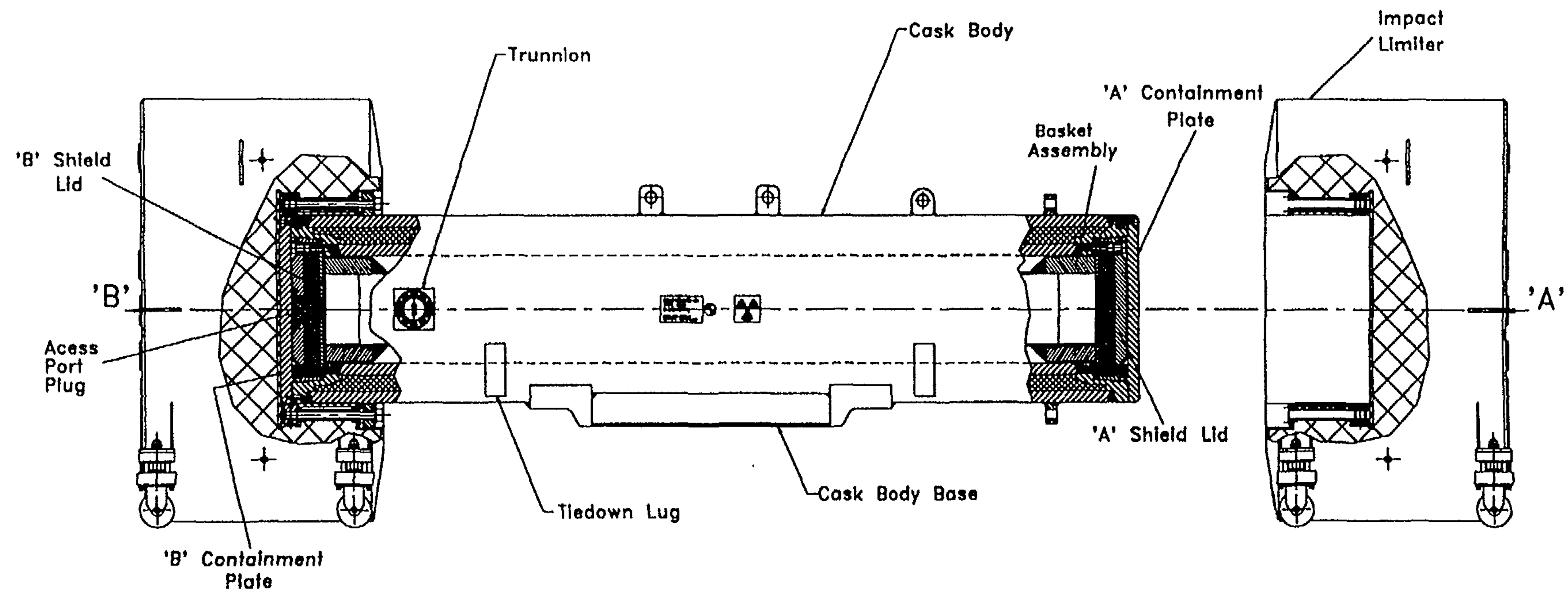


FIG. I.7. Roadrunner transportation package — general arrangement.

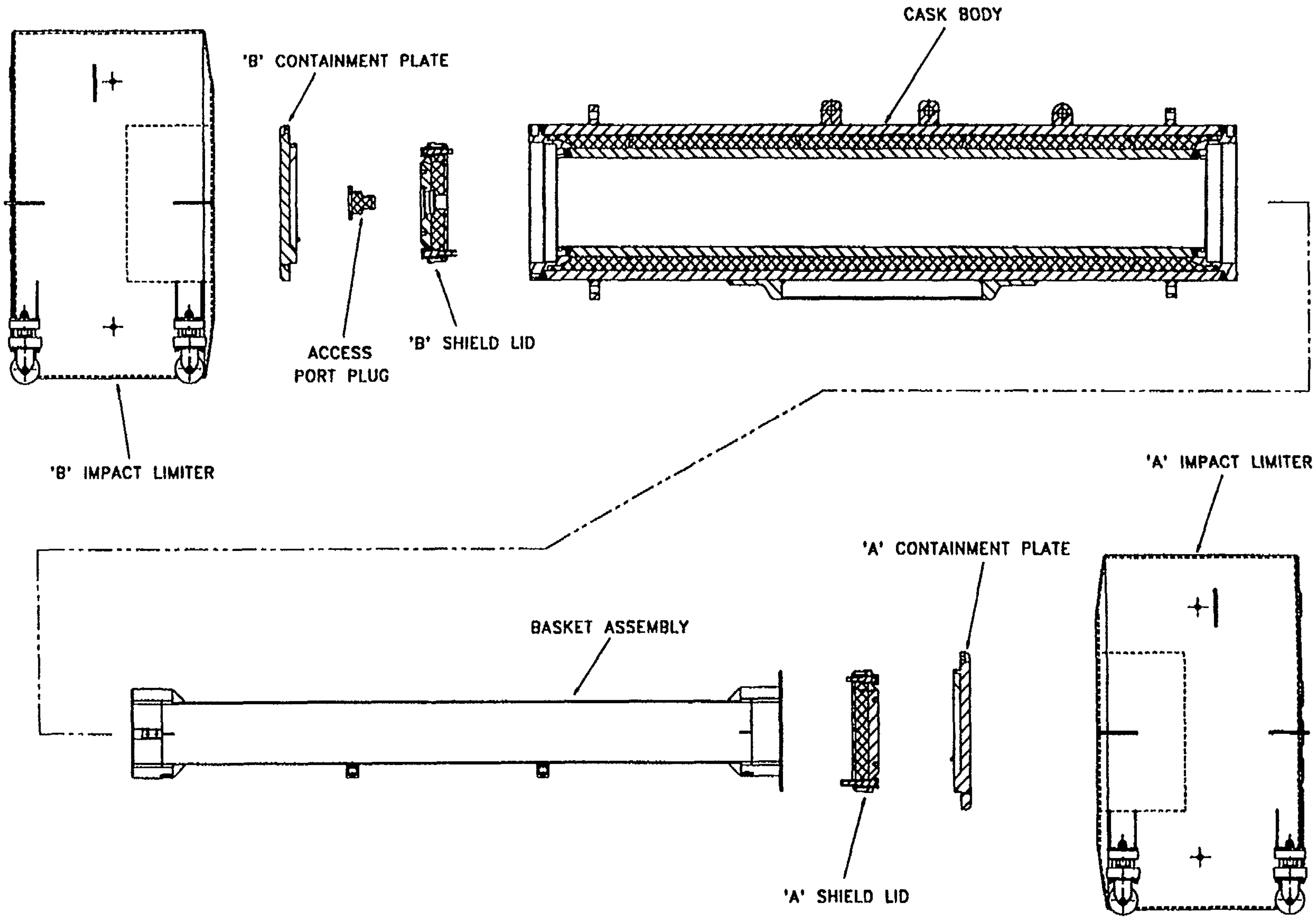


FIG. I.8. Roadrunner transportation package — components parts.

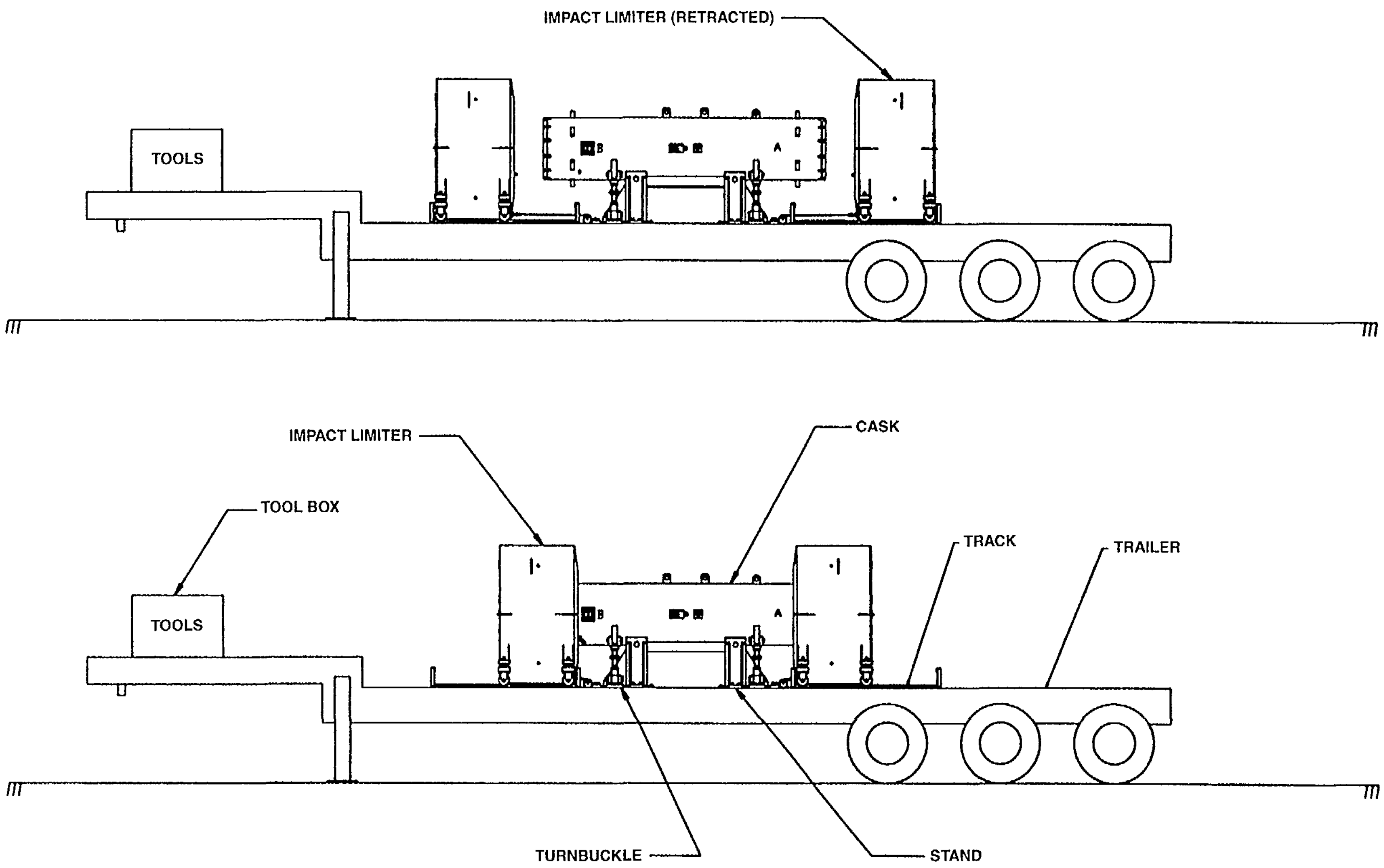


FIG. I.9. Roadrunner transportation package — trailer tiedown arrangement.

The NOD-F1 2 bundle cask is used to ship irradiated CANDU fuel, up to two bundles at a time, primarily from the nuclear generating stations to research facilities for post irradiation examination (see Fig. I.10). The NOD-F1 is a rectangular, laminated steel container approximately 0.92 m × 0.92 m × 1.85 m long, with a horizontal cavity (0.15 m × 0.15 m × 1.02 m long) that contains a basket arrangement for the fuel bundles. The gross package weight is approx. 12 t. It is generally wet loaded at the nuclear station and dry unloaded at the Atomic Energy of Canada Ltd (AECL) research facility.

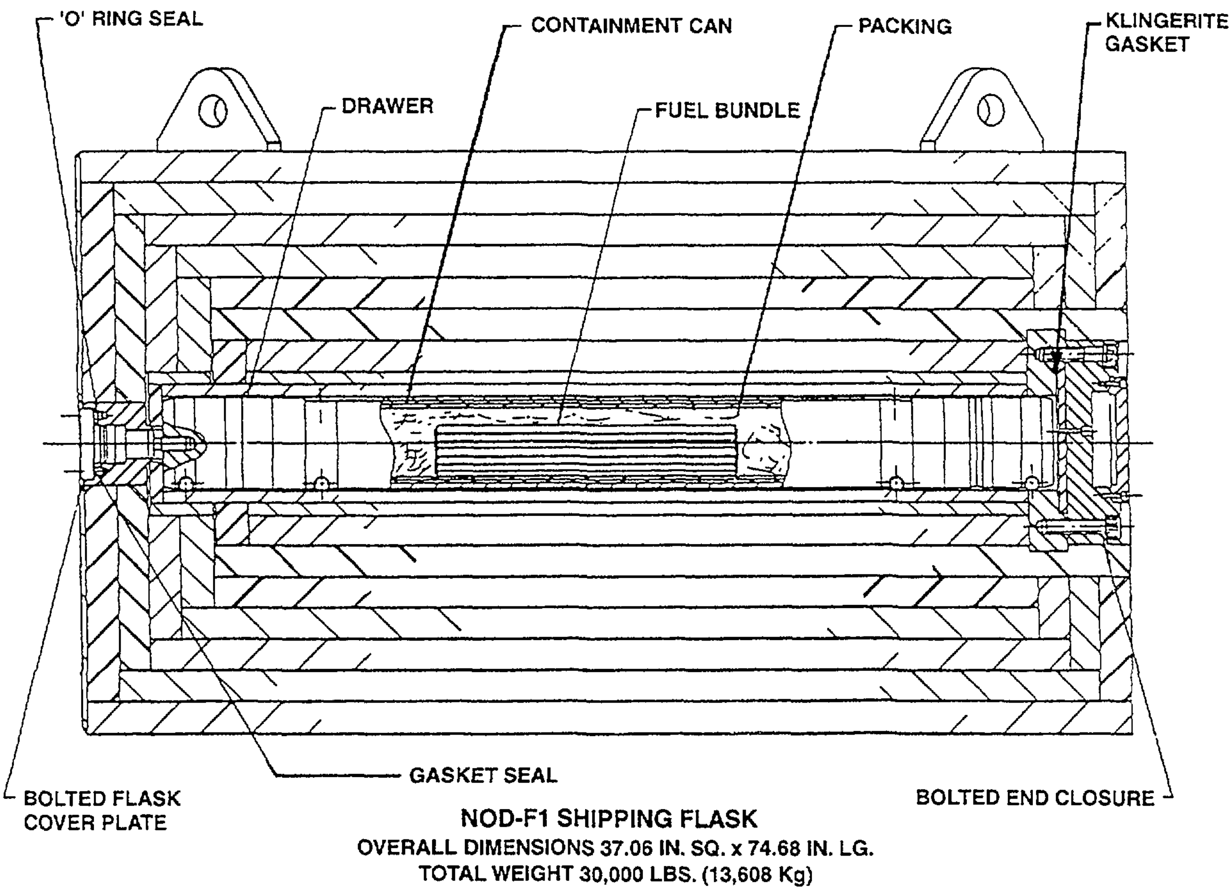


FIG. I.10. NOD-F1 flask.

In 1995 the external contamination had reached about 50 000 cpm and a decision was made to decontaminate and repaint. The old external coating had been in place for about 3 years. It was removed by sandblasting, which also removed all of the external contamination. No sweating or leaching of surface contamination was observed on the bare metal. A new three part external coating system, similar to that used on our current generation of casks, was then applied: epoxy zinc primer, epoxy mastic build coat and high gloss polyurethane top coat. The fixed internal contamination of the cavity was in the order of 100 000 cpm. This was removed by wet brush scrubbing. Removable internals were decontaminated by soak and scrub methods. This brought the average levels down to about 2000 cpm, with a few hot spots of up to 12 000 cpm.

I.1.3. Storage casks

In 1987, a full scale demonstration programme for dry storage of used fuel was initiated at Pickering. The purpose of the programme was to assess the actual performance of the full sized containers under real operating conditions. Among the critical parameters monitored were: radiation fields, temperatures, leak rates, surface contamination and release of gaseous fission products into the cavity Two full size containers, termed concrete integrated containers (CICs), were constructed (see Fig. I 11). The first was loaded with 4 modules (384 bundles) of 10 year cooled fuel in October 1988. It was unloaded in November 1992. The second was loaded with 4 modules of six year cooled fuel in September 1989 and unloaded in November 1994 Both CICs were wet loaded and unloaded in the Pickering fuel bay. Once emptied, the CICs were transported to the Bruce Nuclear Power Development (BNPD) Radioactive Waste Operations Site (Ontario Hydro's centralized low and intermediate level waste processing and storage facility) for decontamination and further testing.

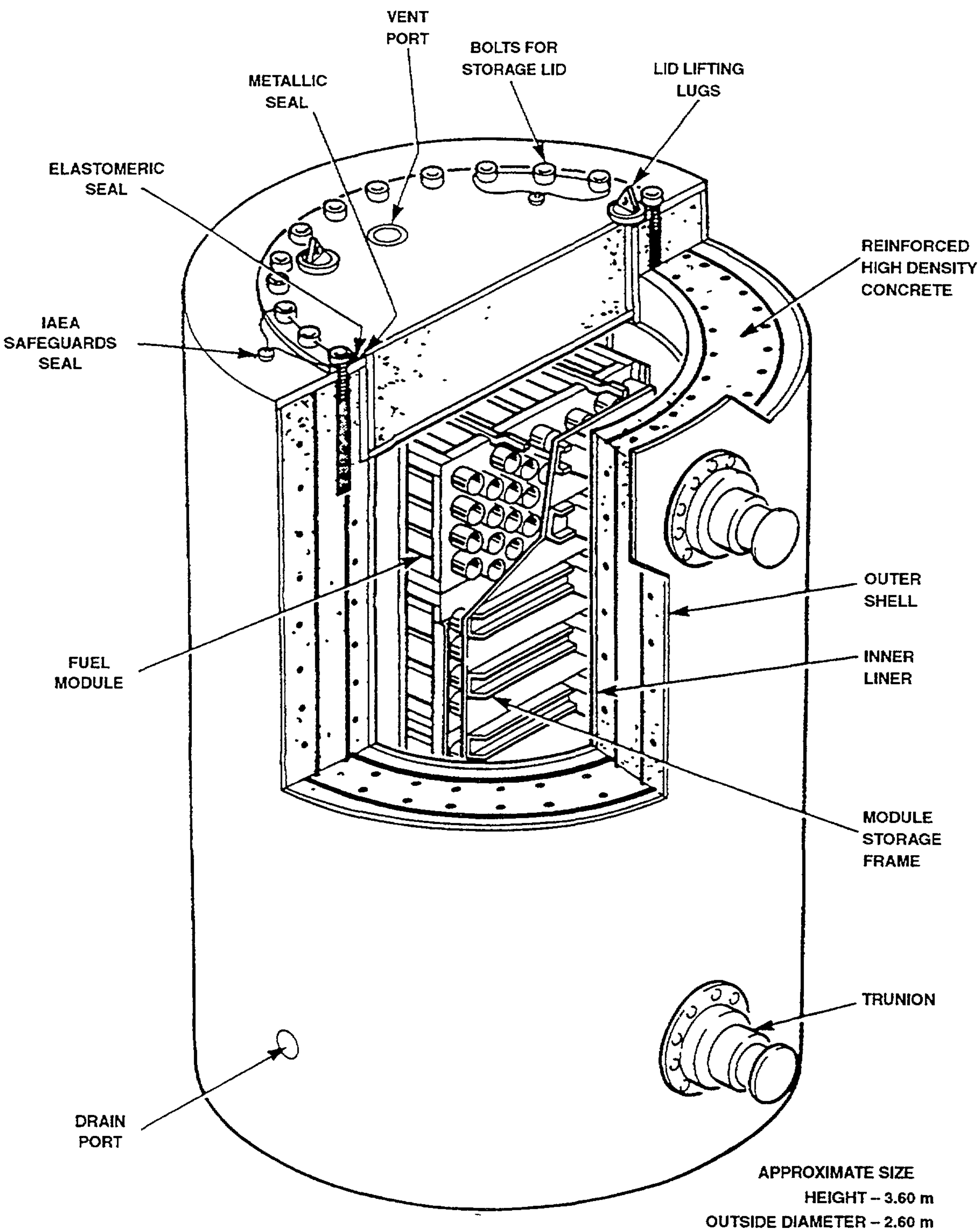


FIG. I.11 Concrete integrated container.

When they arrived at the BNPD site, the CICs had a general contact dose rate of approximately 25 μSv/h (2.5 mrem/h), which was composed of mostly Cs-137, and internal surface contamination levels on the order of 100 000 cpm. Because they were intended to be used for further testing in a non-radioactive environment, an attempt was made to decontaminate the CICs to a level as low as possible. In addition, the test provided an opportunity to evaluate decontamination techniques that would be required for eventual decommissioning and disposal of all dry storage containers.

CIC number 2 was chosen as the better candidate for the test, since it was similar in physical construction to the current generation of dry storage containers (painted, double steel shell). Following an initial decontamination using manual vacuuming and wipe down to remove the bulk of the loose particulate, the internal spacers and other structures were removed by manual torch cutting and grinding. During the initial phases of this operation, the staff wore protective clothing and air supplied masks. Following a second vacuuming and wipe down step, the internal contamination levels were reduced by a factor of about 2.

The second phase of the decontamination involved sandblasting. The CIC was turned over on to its side, and a plastic tent was erected around it to provide a confinement area. (In addition, all work was done inside various buildings). Both the inside and outside surfaces were sandblasted to bare metal, rolling the container as required to make sure all surfaces were reached. After sandblasting was complete, residual contamination was less than 2000 cpm. (Due to high background radiation from other equipment in the area, the detection limit for contamination was 2000 cpm.) The major problem encountered during the sandblasting was the severely limited vision, especially inside the CIC. This made maintaining a standard distance and concentrating on specific areas difficult. During the sand blasting, a conventional blast nozzle was used. Vision could have been improved by using a vacuum recovery type of blasting system. Used sand was collected in 210 L drums for storage as LLW.

After removal to a low background radiation area, the general surfaces were found to be clean (no detected contamination), but a few "hot spots" were found, with levels of 500 to 1000 cpm, mostly in areas such as in the threads of bolt holes and cap screws. While these levels were not considered to be significant enough to delay the planned tests using the CIC, further localized decontamination will be attempted in the future, using chemical or physical methods. (If the cask were to be disposed of today, one would drill out the bolt holes to remove all the contaminated material.)

The CIC lid was decontaminated with high pressure water spray (10 000 psi, 70 MPa). This proved more difficult than expected due to limited manoeuvrability of the lid with the existing hoisting equipment at the facility. Despite this, the lid was decontaminated to less than 200 cpm, in all but a few spots, which ranged up to 400 cpm.

After decontamination, the inside and outside surfaces were repainted with epoxy paint to the same specification used for the current containers. No consideration has been made for free release of these casks They remain at the Bruce Radioactive Waste Operations Site # 2 (RWOS 2).

I.2. MODIFICATION EXPERIENCE

In 1995, a CIC container, which had previously stored Pickering fuel in a demonstration project, was decontaminated (as described above) and the internals (fuel module guides) removed in order to modify the casks for a programme of thermal testing. The decontamination and modification work was completed in early 1996, and the thermal testing has indicated improved heat loading capability from earlier design calculations.

One of the major difficulties was the restricted movement for personnel working inside the container, due to the severely confined space, combined with the need for plastic suits and breathing air to protect against airborne contamination inhalation. This hampered the use of cutting torches and grinders for removal of components. As the internals were removed, the working space became somewhat less confined. Another of the difficulties encountered was the removal of seized cap screws. After several unsuccessful attempts, they were finally removed by a process called 'electrical discharge machining' (EDM). This process uses an electrical arc to melt and remove the material. The holes were then re-threaded to the original size. This was a very time consuming process. Manipulation of the large, heavy container (59 t) was also a problem, often involving two mobile cranes, especially when tilting or rotation of the container was required. Use of a large capacity bridge crane would greatly simplify this.

I.3. DESIGN FEATURES OF THE BRUCE USED FUEL DRY STORAGE PROJECT TO MINIMIZE CONTAMINATION

The Bruce Used Fuel Dry Storage Project (BUFDSP) is similar to the Pickering Facility, with a slightly modified loading system. Fuel bundles are stored in trays (see Fig. I.12) at the two Bruce stations and will be transferred to modules prior to loading into the Pickering DSC. The proposed Bruce system will utilize a separate loading bay attached to the large secondary storage bay fitted with impact pads and built-in automatic washdown equipment (see Fig. I.13). The loaded containers transferred across the Bruce site to a central storage facility similar to Pickering (see Fig. I.14). The casks will be stored in an access controlled outdoor yard adjacent to the Radioactive Waste Operations Site # 2 (RWOS 2) at Bruce, with a capacity of. approximately 3000 containers. The storage yard will be built in stages, with expansion as required. (The RWOS 2 is Ontario Hydro's centralized processing and storage facility for low- and intermediate level radioactive wastes.)

A wet loading system is currently being designed for the Bruce Dry Storage Facility. The system will be installed in the fuel bay at each of the Bruce A (4 × 770 MW(e)) and Bruce B (4 × 860 MW(e)) stations. The purpose of the wet load system was to eliminate a potential risk of dropping a DSC in the station's elevated irradiated fuel bay. Because the fuel bay was never designed to withstand such a drop, massive damage, including potential loss of bay water, was considered possible under this accident scenario. Even with the use of impact pads in the bay, it was considered to be impractical to reinforce the bay floor to the degree required, due to the location of some auxiliary equipment in rooms directly below the fuel bay. In addition, physically lifting a dry storage container into the bay would have required a fairly costly upgrade to the fuel handling crane.

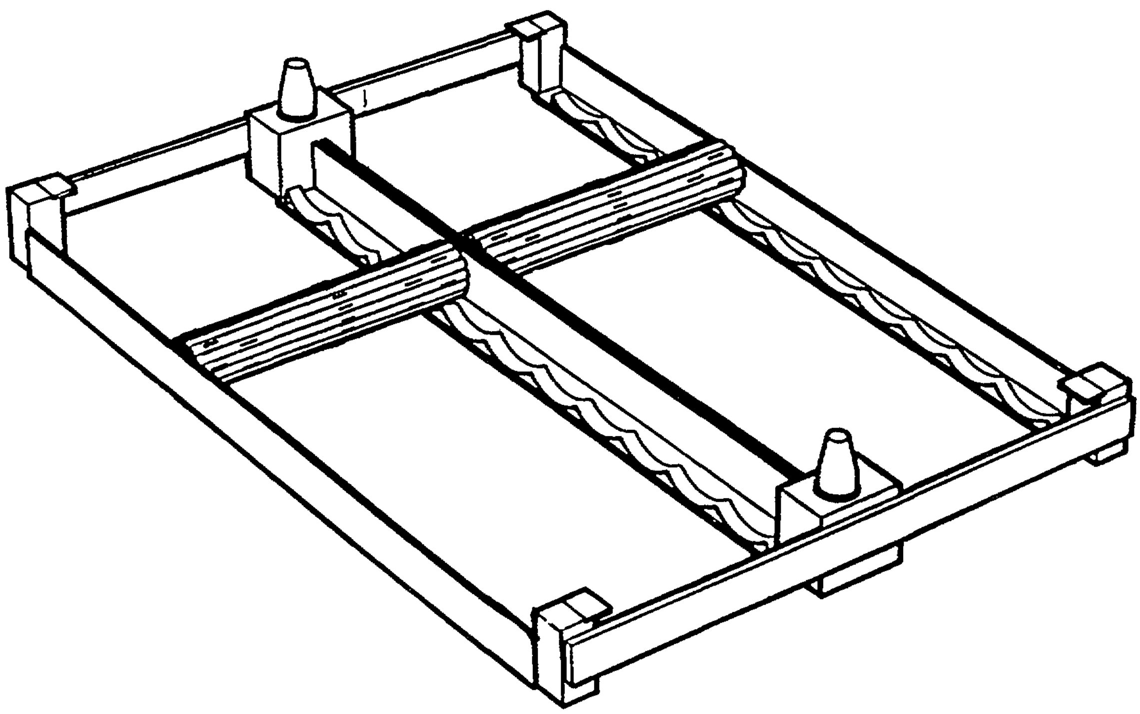


FIG. I.12. Bruce fuel storage tray.

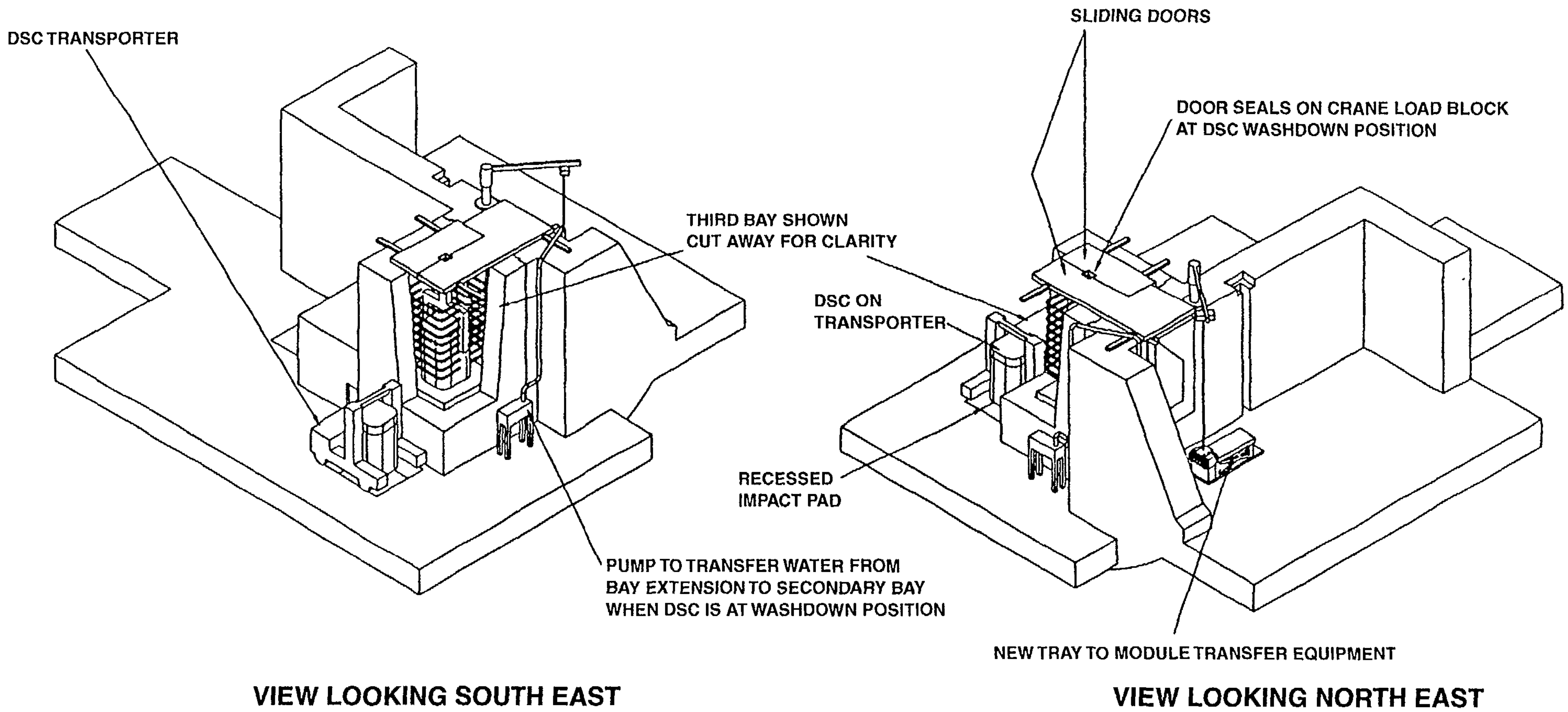
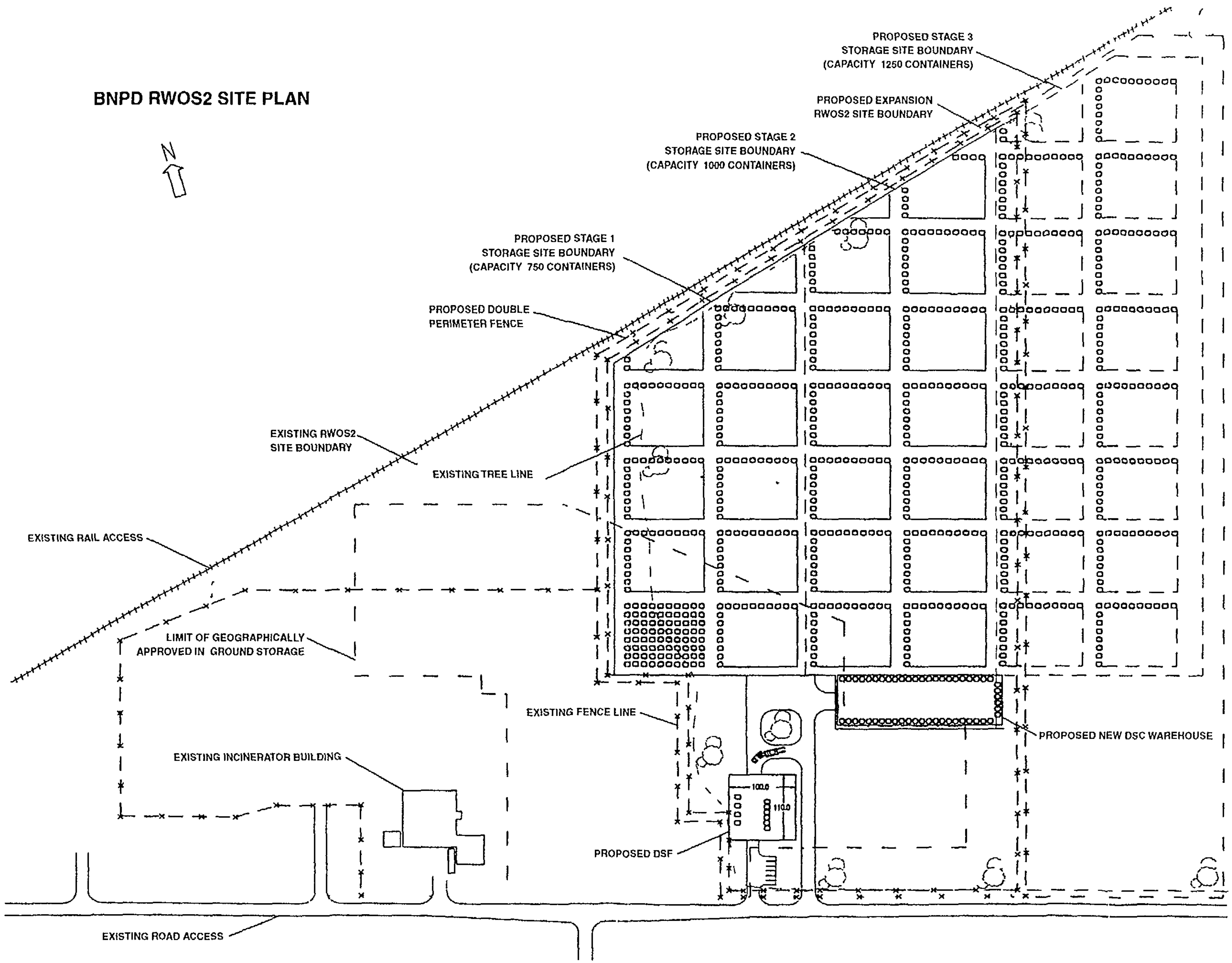


FIG. I 13. Bruce wet loading facility.



RWOS2 SITE PLAN SHOWING NEW DSF, WAREHOUSE AND STORAGE AREAS

FIG I 14 Bruce dry storage facility

Dry loading concepts were investigated initially along with a larger DSC utilizing the existing trays as carriers (baskets). This concept was recently re-evaluated against other options based on criteria critical to the system; e.g. safety, cost and schedule, impact on station operations and facilities, co-location of facilities required for the dry storage system, operations staff involvement in the process, increased standardisation, use of known technology, operability , maintainability, and licensability. The assessment indicated the wet loading concept utilizing a loading bay was slightly favoured over other wet loading concepts and the dry transfer concept primarily based on safe working requirements and further supported in areas of standardization, co-location and maintainability. Final performance specifications are now being prepared for the favoured concept for completion in late 1998. The BUFDSP is currently scheduled for turnover to Ontario Hydro operations in August 2002.

I.4. DESIGN FEATURES TO MINIMIZE CONTAMINATION

The two module irradiated fuel cask (IFC) is constructed in the shape of a rectangular box and is designed to contain two stacked fuel modules with a total of 192 fuel bundles for road transport (see Fig. I.15). The body is constructed of a single forged block of type 304 L stainless steel, with the cavity machined out of the interior. The external dimensions, not including impact limiter, are 1.8 m (high) × 1.6 m × 1.9 m, with an empty weight of 28 t. The loaded weight with fuel and impact limiter is 35 t. The cask is licensed for a maximum 1.5 kW heat load, which corresponds to minimum 10 year cooled CANDU fuel.

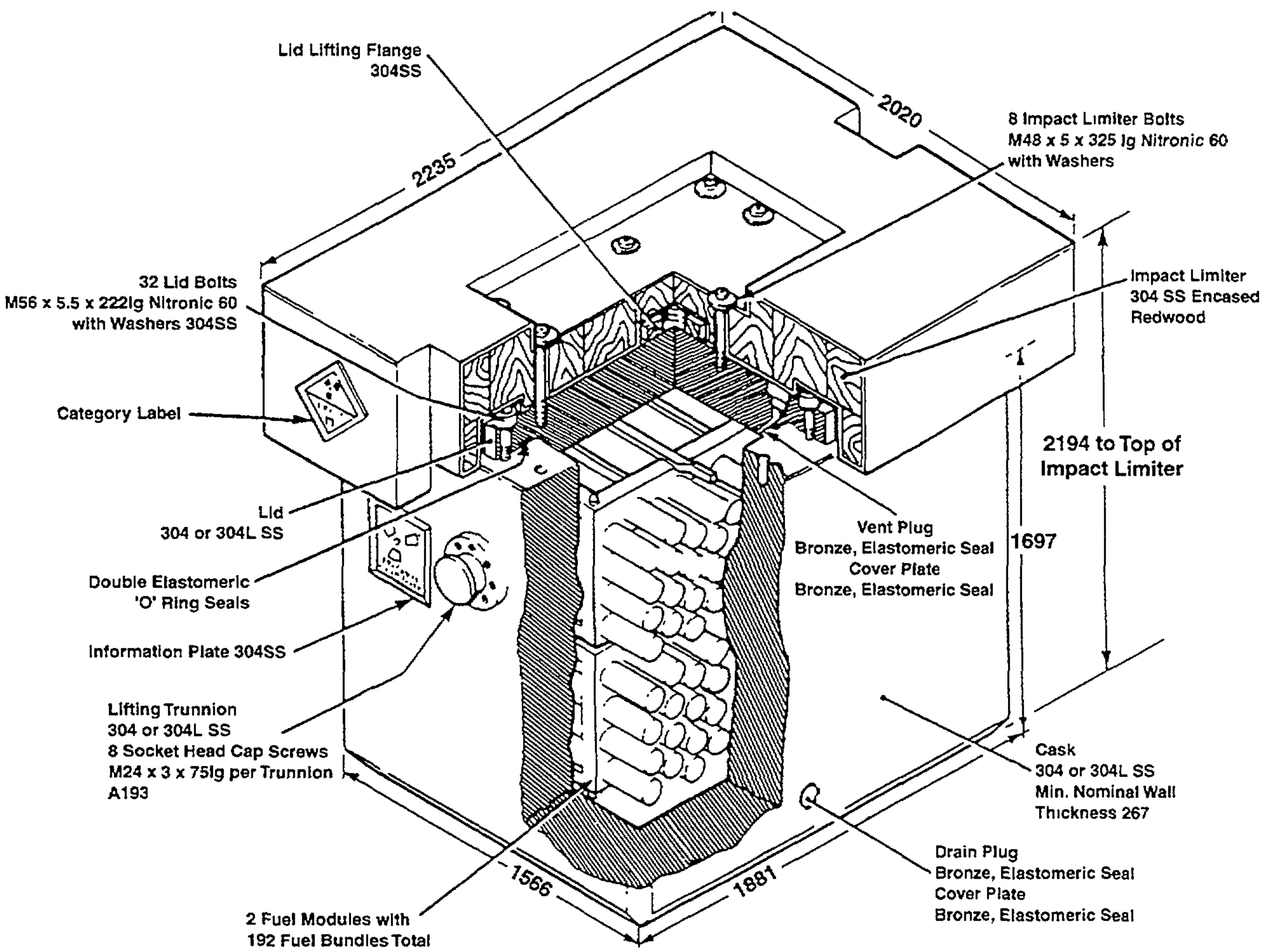


FIG. I.15. Two module stainless steel irradiated fuel cask.

The walls are approximately 0.27 m thick, which provides sufficient shielding to limit radiation fields to 190 μSv/h (19 mrem/h) at contact with the walls, and 79 μSv/h (7.9 mrem/h) at one metre for 10 year cooled fuel. (Maximum allowable under Canadian regulations are 2000 μSv/h (200 mrem/h) at contact and 100 μSv/h (10 mrem/h) at 1 metre.)

The single piece steel lid is sealed with two Viton O-rings and is fastened by 32 bolts. Two lifting trunnions are provided on the inside of the cask body for cask handling. Drain, vent, and leak test ports are also provided. Vent and drain plugs are also sealed with two Viton O-rings each.

The internal and external surfaces of the cask are polished to a 0.8 Fm finish to minimize the pickup of contamination and to facilitate decontamination when required.

The IFC is designed primarily for wet loading/unloading, but can also be loaded/unloaded dry. To date, it has not been used, but is planned to be put in service in the near future and modified with a new basket to transport one or two bundles of CANDU fuel for post irradiation examination at AECL research facilities. For wet loading, the operating procedure calls for the cask to be filled with demineralized water, and the external surfaces wetted, prior to immersion in the bay. Based on experience with the Pickering dry storage containers, it is expected this precaution will further reduce the pickup of contamination from the bay water.

I.5. SUMMARY

Ontario Hydro experience has shown that:

- Conventional sandblasting and repainting is an effective means to decontaminate aged, painted cask surfaces, even ones which have been repeatedly submersed in very contaminated water, or which have contained fuel for several years.
- Water sprays or blasting is effective for decontamination of recent lightly contaminated surfaces.
- Scrub and soak methods are good for decontaminating relatively small parts that can be removed from casks.
- More aggressive techniques, involving base metal removal, are required for "complete" decontamination prior to decommissioning.
- Prevention of contamination through control of water bay purity is important for minimization of decontamination requirements.
- Design features, such as dry loading and polished surfaces can minimize the need for decontamination by preventing it from occurring.

Annex II

CZECH REPUBLIC

II.1. INTERIM SPENT NUCLEAR FUEL STORAGE FACILITY (ISNFSF) PROJECT

It was originally intended that spent nuclear (SNF) fuel should be managed by the Soviet Union. This situation changed when a resolution of the Russian Parliament prohibited acceptance of any spent fuel from foreign countries. As a result of this, 141 t U of SNF from Dukovany was transported into the wet storage facility at Jaslovské Bohunice in Slovakia until 1992, when the Czech and Slovak Republics were formed.

Following political changes, economic evaluation and assessment of new conditions, ČEZ, a.s. has adopted the spent fuel management concept based on long-term storage for 40–60 years (i.e. a "wait and see" strategy). The Czech SNF production is expected to be:

NPP	**SNF** in t U
Dukovany 40 years operation :	1940
Temelín 30 years operation[a] :	1348

[a] expected also to be 40 years

II.1.1. Site selection

In order to maintain the operation of Dukovany NPP, ČEZ, a.s. had to carry out the following tasks:

- compaction of storage racks in the reactor pools in the Dukovany NPP;
- implementation of an interim spent fuel storage facility at Dukovany site;
- return of SNF from Dukovany NPPs, which was temporarily stored at Jaslovské Bohunice in Slovakia.

II.1.1.1. Initial status

The trade-off between the urgent need for a storage facility and public resistance in the Dukovany region (stipulated in the government decree of 1992) resulted in limiting the storage capacity at Dukovany to 600 t U, which could be reached as early as 2005. Subsequently ČEZ, a.s. started a site selection procedure for a central ISNFSF (CISNFSF) which would handle all SNF production from both Czech NPPs. Originally 10 potential sites were considered, but the list was progressively reduced to two options in 1996/97. These were:

Favourite	Underground site	Skalka
Stand-by	Surface site	Batelov

II.1.1.2. Current status

Once it was realized that the 600 t U storage limit at Dukovany was insufficient to meet the national requirements, the Ministry of Trade and Industry requested a study of five possible alternative sites for the spent fuel storage facility. This resulted in the following, in order of preference:

Alternatives	Ranking
Separate storage at Dukovany and Temelín NPPs	1.
Centralised storage at Temelín	2.
Centralised storage at Dukovany	3.
Centralised underground storage at Skalka	4.
Centralised surface storage at Batelov	5.

Safety, technology, ecological and economical issues were taken into account. Both local government and the public in the relevant regions were invited to comment. Based on this information, Government cancelled the Dukovany 600 t U storage limit in March 1997, and ČEZ, a.s. has modified its priorities as follows:

Favourite site :	Dukovany NPP and Temelín NPPs
Stand-by site :	Skalka

II.1.2. Technology selection

In 1995 ČEZ, a.s. invited 17 reputable suppliers of dry storage technology to propose preliminary bids. Among 9 proposals received, ČEZ, a.s. selected the dual purpose casks technology as the way forward. By January 1996 the short list of potential companies for both underground and surface storage consisted of:

Company	Country	Cask type
Nukem	Germany	CASTOR
Škoda	Czech Rep.	ŠKODA
Transnucléaire	France	TN
Voest Alpine/NAC	Austria/USA	NAC

In 1997 the preliminary bids were extended by ČEZ, a.s. through a request for additional information in order to prepare a preliminary safety analysis report and site permit documentation for the Dukovany and Skalka sites. ČEZ, a.s. intends to invite the short-listed companies for a final bid as soon as the site permit is obtained.

ČEZ, a.s. preference is to construct a "universal" storage hall where handling can be accommodated so that any type B(U) or type S cask can handled. Purchase would be open to competitive tender to reduce costs and benefit from the latest technologies and design improvements.

II.2. DECONTAMINATION

The matter of cask decontamination at the reactor building where the cask is in the contact with the pool's water is being considered.

II.2.1. Present experience at Dukovany

After loading and lifting above the water surface, the cask is decontaminated in the over-hung position. An autonomous spray system supplies the demineralized water of variable temperature and pressure into the tube equipped with a system of nozzles.

In spite of the horizontal outer-fin features on the CASTOR 440/84 body, the operators of Dukovany have good experience with this procedure because the manufacturer paid attention to smoothing the external cask surface with suitable coatings and quality of coating mixtures. At the moment (06/98), there are 27 CASTORs placed in the existing storage facility.

II.2.2. Operation of prepared storage facility

The possibility of the cask's external surfaces becoming contaminated is very low. However, careful attention is required to ensure that quality assurance (QA) requirements when undertaking decontamination and measurements of radioactivity in the reactor hall. No secondary liquid waste is likely to be produced in the storage facility during its operation, but a small volume of solid LLW is anticipated in exceptional circumstances.

Spent fuel is never unloaded from the casks in the storage facility, and the primary lid remains closed even if a leak occurs. In this situation, renewal of the secondary lid sealing system *in situ* would be the first option. As a back-up, an additional "third lid" sealing arrangement could be introduced, or the cask taken to the fuel pond and opened for repair of the primary seal.

As a standby option, consideration is being given to installing a "hot cell to allow decontamination or seal repair to be done when localised radiation levels on the cask are. The hot cell will also be required when the reactor pools are decommissioned.

II.3. MODIFICATIONS MADE TO CASKS

II.3.1. New fuel

ČEZ, a.s. will use "second generation" nuclear fuel with higher initial enrichment and higher possible burnup in its NPPs. The following table compares present and new fuel parameters:

	Max. enrichment [%]	**Max. burnup [GW•d/tU]**	**Min. cooling time in the pools**
Present WWER 440	3.6	43.5	5 years
New WWER 440	4.3	55	7 years
New WWER 1000	5.0	60	12 years

Regardless of who will manage the work for CISNFSF, the licensing procedure will be administered by the Czech Authority. To date, casks of the short-listed companies have been designed and licensed for lower values of the spent fuel parameters than ČEZ, a.s. requires, so the new cask design must accommodate the dual purpose requirements. The domestic company, ŠKODA, is developing its own technology for commercial use, meeting B(U) standards. The cask consists of two packages - a bolted flask with a welded canister inside.

II.3.2. Cask capacity optimisation

The aim of this particular modification is to achieve the maximum loading capacity for the cask within the limits allowed by criticality, heat removal, shielding, handling and transport compatibility. It was determined that optimisation should concentrate on the basket design, no special modification to the permanent hermetic sealing arrangements was required.

Criticality control of the fuel basket has to comply with the additional conservative requirements of ČEZ, a.s.:

- fresh fuel, application of burnup credit as an alternative only;
- cooling *by pure water with no dissolved neutron absorber.*

The fuel basket pitch was consequently determined with respect to the limited concentration of neutron absorber, which was, with one exception, a fixed component of the fuel basket. ČEZ, a.s. is also considering advanced designs of baskets for improved criticality control that follow an approach similar to that of the reactivity control systems in reactors.

II.3.3. Regulations

In 1997 Czech nuclear legislation made progressed significantly towards European standards, when the "Nuclear Law", along with relevant regulations, was approved. The "Decree on radioactive waste package type licensing" stipulates mandatory requirements for securing approval for transporting type B(U) and storage (type S) package[1] in Czech Republic. Furthermore, an applicant for type S approval must be a separate design authority and not the storage facility operator. Thus ČEZ, a.s. will require cask suppliers to obtain B(U) and S certificates independently.

II.4. CONCLUSIONS

(1) With respect to the Czech Interim Spent Nuclear Fuel Storage Facility project, the advantage of using the existing design of CASTOR 440/84 cask cannot be utilised because modifications are required to accommodate the parameters of the new fuel.

(2) Cask capacity optimization, which involved establishing fuel parameters on subcriticality, heat removal and shielding, for these modifications was determined by ČEZ a.s.

(3) Cask handling limitations may impose further constraints on cask capacity.

(4) The Czech Regulatory Body (the State Office for Nuclear Safety), will decide which modifications will be acceptable, particularly with respect to control of criticality.

(5) ČEZ, a.s. will support the introduction of the latest cask modifications and improvements for the unified storage facility by encouraging competition between cask suppliers.

[1] "S" type package is a Czech specification for storage purpose only. The container must not be subject to tests as are type B packages, but only proof on mechanical resistance against designed handling needs to be submitted.

II.5. RESULTS OF CASK CONTAMINATION AT ISNFSF AT DUKOVANY

Initiated by the international public discussions concerning problems with cask surface contamination in some European countries, a thorough operator inspection of the loaded casks surface contamination was carried out in July 1998. The NPP staff used for these inspections more measurement points than for the routine inspections and the SÚJB inspectors examined selected casks. The maximum discovered non-fixed contamination on the CASTOR-440/84 cask surface averaged over 300 cm^2 has been within the limits and did not exceed 4 Bq/cm^2 for beta and gamma emitters and low toxicity alpha emitters, or 0.4 Bq/cm^2 for all other alpha emitters.

Annex III

FRANCE

III.1. INTRODUCTION

Current French policy is to reprocess spent fuel, which demands the transport of irradiated fuel from the nuclear power stations to the reprocessing plants. The French experience concerning decontamination of transport casks loaded with spent fuel in view of their transport is described in this Annex.

III.2. CASKS DESIGN AND OPERATING METHODS

There are mainly two types of fuel assemblies which are used in France : 12 foot long assemblies are used in the 900 MW(e) series of nuclear reactors and 14 foot long assemblies are used in the 1300 and 1450 MW(e) series. TN 12 casks are used to carry twelve fuel assemblies from the 900 MW(e) reactors (see Fig. III.1). TN 13 casks are used to carry twelve spent fuel assemblies, from the 1300 and 1450 MW(e) stations. The TN 12 and TN 13 casks are identical, except the length. For the loading of the fuel assemblies, the cask is either immersed in the spent fuel storage pond (for the 900 MW(e) and some of the 1300 MW(e) reactors), or docked under the bottom of the spent fuel pond and connected to it by a valved system for loading.

The potential risks of contamination were examined at the design stage of the casks. They have been designed to minimise contamination and also to ease decontamination. For this purpose, the finned area (which is necessary to dissipate the heat power of the assemblies which were cooled for a short time) is designed to be equipped with a metallic skirt. During operations, the skirt has to be filled with clean water, in order to prevent the contamination of the fins through contact with the contaminating

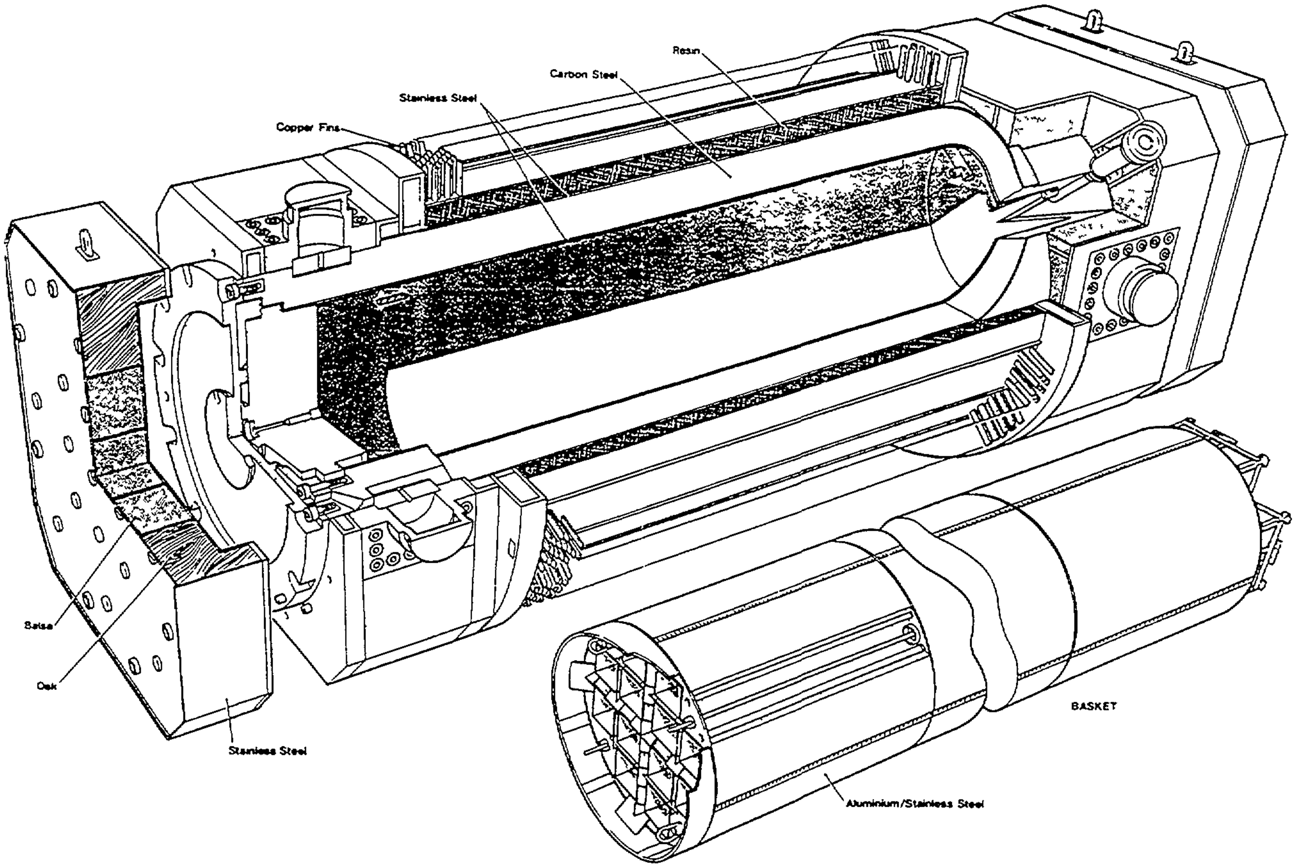


FIG. III.1. Cross-section of TN 12.

water of the spent fuel storage pond (Fig III.2). All the other surfaces are free from protruding features - which makes it easy to protect against contamination by using films or protective plates, for instance, and easier to decontaminate - and are made of, or cladded with, stainless steel - which makes them easy to decontaminate.

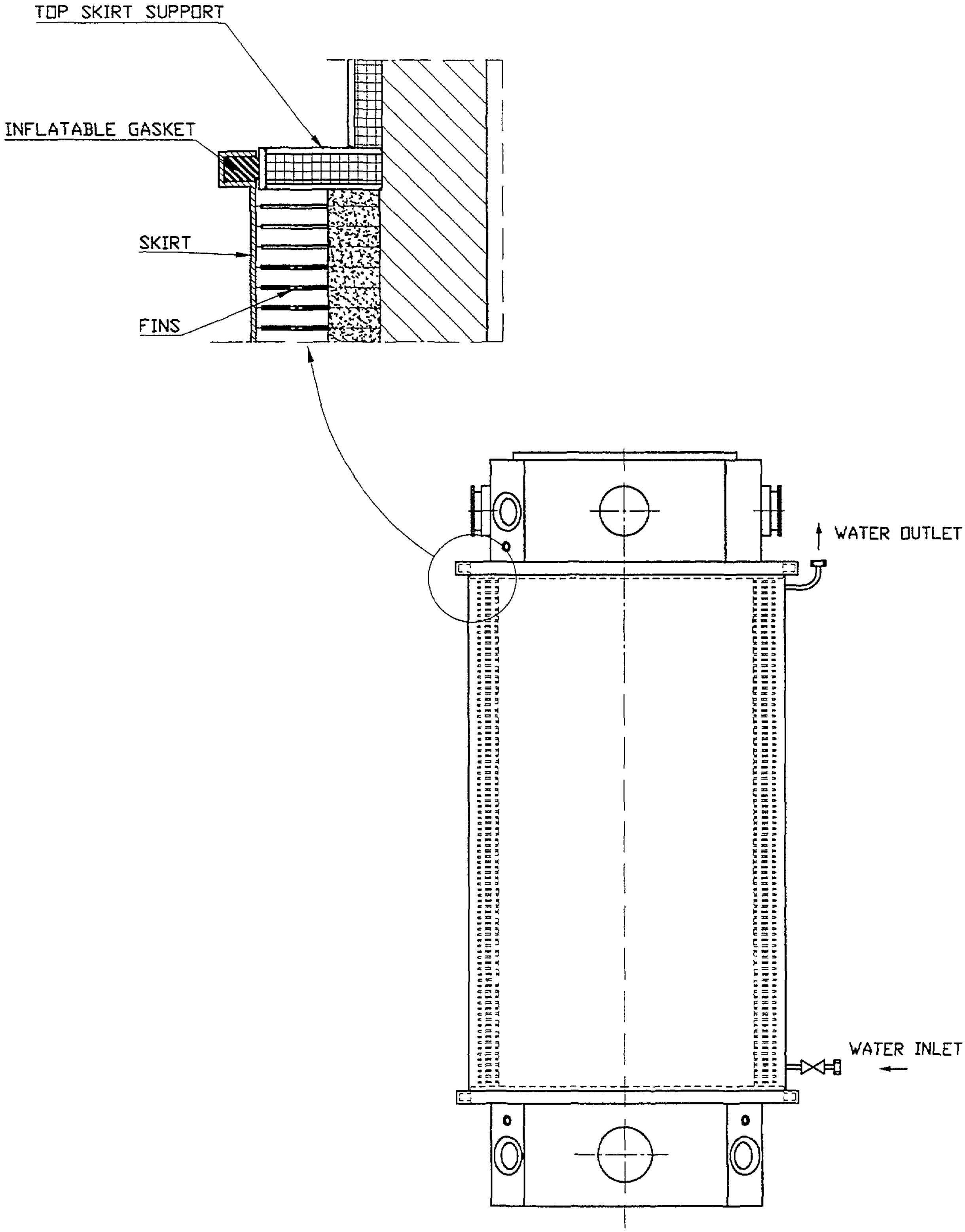


FIG. III.2 Protective skirt

III.3 PREVENTION OF CONTAMINATION

The two families of nuclear plants in France are those where the cask is:

- immersed in the spent fuel pond prior to loading the fuel assemblies,
- docked under the bottom of the spent fuel pond and connected to it by a valved system for loading.

The latter type have a low risk of contamination due to minimum contact with the pond water Absence of contamination can be achieved by special care when disconnecting the tools which equip the cask during operations, in order to prevent leakage of contaminated water (which fills the cask) onto the external surfaces Discussion will therefore concentrate on the first generations of plants, for which the cask is immersed in the pond for the loading of the fuel assemblies. To minimise the contamination of the casks during the loading operations the following is considered:

(1) The activity of the spent fuel pond water is maintained at a value around 15 MBq/t.

(2) The activity of the working environment (fuel storage building (FSB), handling equipment, protective equipment, connecting tools, etc.) is surveyed and minimised.

(3) The contamination of the external surfaces of the cask is avoided or minimised by using :
protective skirt, or
strippable paint, or
adhesive films.

(4) These operational aspects of these techniques are summarised in the following Table III.1. The effectiveness of the methods depends greatly of the quality of implementation. In general, adhesive films give the best results for minimising contamination.

(5) The duration of the immersion of the cask in the pond is kept at a value as low as possible.

(6) Special care is taken when disconnecting the tools or removing the equipment which equip the cask during the operations, in order to prevent drip of the contaminated water (which fills the cask) onto the external surfaces of the cask or transfer of contamination from the equipment to the cask.

TABLE III.1. SUMMARY OF OPERATIONAL ASPECTS OF DECONTAMINATION TECHNIQUES

Method	Protective skirt	Adhesive films	Strippable paint
Location	Preparation pit of the FSB	Rail wagon and FSB	Preparation pit of the FSB
Application time	3 hours x 3 men	Rail wagon 4 hours x 2 men FSB 8 hours x 2 men	3 hours x 3 men
Removal time	1 hours × 3 men 1 hours × 3 men (decontamination)	Rail wagon 1 hours x 2 men FSB : 6 hours x 2 men	6 to 8 hours for the peeling and the decontamination
Difficulties	- locking of the skirt - turn of the skirt by the lifting beams		- volume of the drying machines - inflatable gaskets zone
Precautions	- protection from sharp corners - use of procedures - typical water volume	- use of procedures - cleaning and removal of grease - pre-cut of films	- skin temperature # 80°C - natural drying 24 to 48h
Total dose uptake (collective)	0 5 mSv (skirt) 1 mSv (decontamination)	1.5 mSv	0.5 mSv
Typical waste arising	4 x 100 l-bags (non-compacted)	3 x 100 l-bags + 1 dust-bin bag (non-compacted)	1x 100 l-bag (non-compacted)

III.4. DECONTAMINATION OF THE CASKS

General decontamination of the cask is first carried out by conventional means (e.g. pressure wash with water). The surfaces are then cleaned by wiping with phosphoric acid and rinsed - for instance with alcohol, where the use is acceptable. The surfaces are then surveyed by health physics surveyors to assess the level of remaining contamination.

III.5. MEASUREMENT OF THE CONTAMINATION

Because the background level of radiation can be significant where the measurements are performed, to avoid wrong interpretation of the results, the measurements are, as far as necessary performed using a shielding around the probes.

III.5.1. Measurement on casks

The regulatory acceptance levels for loose contamination on a cask used for the transport of spent fuel are 4 Bq/cm^2, for beta and gamma emitters and low toxicity alpha emitters, and 0.4 Bq/cm^2 for all other alpha emitters. An initial general survey is performed by wiping all the potentially contaminated surfaces, using a pre-moistened tissue. Swabs are then taken using a "blue filter" paper at several many places in order to confirm and assure that the activity on all external surfaces of the cask are within the regulatory limits.

The typical area of a wipe is 300 cm^2. Measurement is made with a "low energy beta" probe (sensitivity better than 4 Bq/cm^2), following an assessment of the spectrum of the contamination to show the adequacy of such a probe in checking that the regulatory criteria is met for all energies of beta and gamma emitters. If the swabs show there is contamination outside the threshold limit, the measurements are repeated with an alpha probe, which has a sensitivity better than 0.4 Bq/cm^2.

III.5.2. Measurement on rail wagons and/or road trailers

The regulatory acceptance levels for loose contamination on a conveyance used for the transport of spent fuel are 4 Bq/cm^2, for beta and gamma emitters and low toxicity alpha emitters, and 0.4 Bq/cm^2 for all other alpha emitters. For fixed contamination, it is 5 μSv/h.

When there is no radiation sources other than the potential contamination of the conveyance, the loose and the fixed contamination are measured directly with a proportional counter (e.g. CV28) over the whole area of the platform and the sides. The alarm thresholds are commonly set at a value ten times lower than the regulatory limit for loose contamination. If the alarm is triggered additional measurements are made for:

- loose contamination: additional swabs are taken in the suspected areas of high contamination,
- fixed contamination: a radiation probe is used over the suspected areas of high contamination.

III.6. CONCLUSION

Good results in decontaminating casks below the regulatory threshold are more readily achieved if there is a high level of management, training, experience and practice for the personnel. This is of particular importance in places where there are only a small number of operations, such as the power reactors where a flask is decontaminated only four times per year. In the meantime, systematic checking and decontamination of the working area, as well as of the working equipment, are necessary.

III.7. NOTE ADDED IN PROOF

In May 1998, it was reported in the media that some transports of spent nuclear fuel in Europe had taken place for several years with a surface contamination which was locally higher than the international standards of 4 Bq/cm^2 on arrival at the Valognes terminal near La Hague, although a review of the transport documentation showed that the casks had been indicated clean when leaving the NPPS. This caused a suspension of the spent fuel transports in France, Germany and Switzerland.

It was rapidly confirmed, that this abnormal situation had no radiological consequences and that communication was not done in the past at the appropriate level. The investigations which were led concluded that the main reasons for this situation was a lack of radiological cleanliness in the facilities, as well as a lack of rigor in the implementation of the decontamination and measurement procedures.

Transports in France resumed two months later, following the recognition of the origin of the problem, the implementation of corrective provisions and the establishment of a formal information and reporting system.

Annex IV

GERMANY

IV.1. INTRODUCTION

The interim storage of spent nuclear fuel is carried out today and probably in the future as well predominantly in transport and storage casks, with a noble gas atmosphere. At the end of the interim storage period, the casks must be decontaminated and decommissioned. The cask interior and the basket may become contaminated during wet loading in the pool, during the drying process and during transport by splitting off of crud particles from the fuel surface. During the storage of defective fuel, additional heavy contamination by fission products and possibly by fuel particles can be expected.

In order to make the decontamination of the inner cask and decommissioning process for the cask body and basket as simple and favourable as possible at the end of the service period, the cask body and components have to be designed in a suitable way for decontamination and decommissioning. Consequently, the inner surface of the cask cavity should be as smooth as possible or alternatively it should be possible to remove the inner surface of the cask easily. The basket should be designed in a simple way without a complicated structure, because such a structure cannot be decontaminated. This means that the basket should be composed of components which can be decontaminated separately and easily after removal.

It is particularly important that hot-cells with sufficient transport and crane capacity for the decontamination and decommissioning processes are available.

IV.2. TECHNICAL DESCRIPTION OF THE CASK TN 1300

The cask TN 1300 was designed for the transport and interim storage of irradiated fuel from light water reactors of the 1300 MW class (see Fig. IV.1). The cask meets the requirements of international transport regulations for packages of the type B(U) category. Furthermore, the cask has all the necessary characteristics for use as a storage cask. The transport licence for the cask of the type TN 1300 was issued on 29/06/1983 by the German competent authority Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig.

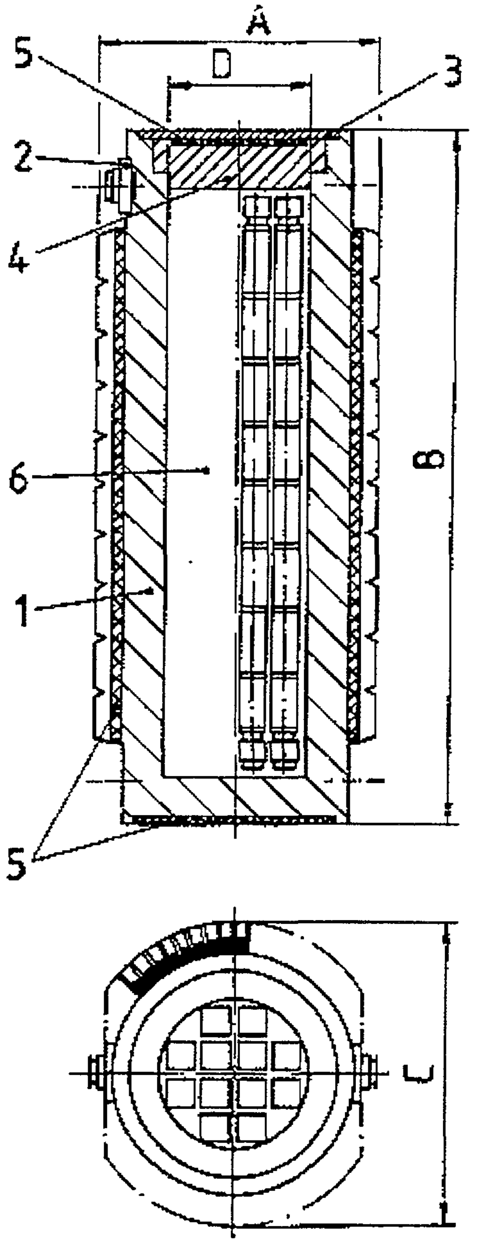
IV.2.1. Description of the cask components

The cask consists basically of the following components:

- a cask body made of nodular cast iron (GGG 40.3) casted in one piece;
- inner liner made of stainless steel, serving as protection against corrosion;
- shielding lid made of forged steel X 5 CrNi 13 4, held by 36 screws to the cask body;
- neutron radiation shielding made of an artificial resin mixture, fixed between the cooling fins at the cask body;
- lid shock absorber held by 4 screws to the cask body;
- bottom shock absorber held by 4 screws to the cask body;
- internals in the cask include the basket, the basket centering and the gas filling and drain systems.

The cask body is a thick-walled hollow cylinder. The cylindrical part, the bottom and the fins are casted in one piece using the material nodular cast iron (GGG 40.3). 60 rows of fins are located on the periphery of the cask, with each row consisting of 10 part fins.

The cavity of the cask has a liner made of stainless steel in order to protect the inner surface against corrosion. The wall thickness of the inner liner is 8 mm (minimum) and at the bottom end it increases to 50 mm. At the lid end it is welded with a flange ring. In order to compensate for thermal expansion, there is an expansion gap of 8 mm at a minimum between the inner liner and the cask bottom. The inner stainless steel liner is made of a sheet, a bottom plate and the flange ring. After installation into the cask interior, these parts are welded together leaktight. The flange ring is sealed radially to the basic cask body by a metal gasket, thus avoiding penetration of water.



Key
1 cask body
2 lifting trunnion
3 secondary lid
4 primary lid
5 moderator
6 FE shaft

main dimensions (mm)	TN-1300
A	Φ2425
B	5967
C	2425
D	Φ1220
weight (kg)	
transport weight (loaded)	121,000
max. weight (handling)	115,500
no. FE's and weight	12peace 10,000

FIG. IV.1. Cross-section of TN-1300.

The cask interior is hermetically closed by a shielding lid, forged from stainless steel. The functions of the shielding lid are the shielding and the sealing of the cask interior. The shielding lid is linked to the cask body by 36 high-strength screws closing the cask interior. The shielding lid contains two orifices, one intended for gas-filling and one for draining the cask after wet loading. They are located at the top of the lid, each with a valve and in addition both can be closed leak-tight by a cover lid. The steel closure lid is located above the shielding lid, consisting of stainless steel. The closure lid was designed in view of use as a storage cask. According to the requirements of storage, it forms the second barrier. The closure lid is fixed to the cask body by 36 high-strength screws.

For the purpose of handling and fixing on the transport vehicle, the cask has four hollow trunnions made of forged stainless steel. One pair of trunnions is fixed at each end of the cask body (bottom and lid), by 16 high-strength screws.

The neutron shielding in the finned zone consists of a fireproof artificial resin mixture. The shielding is located in the space between the fins. It is sealed by welding a leak-tight cover plate together leak-tight with the fins and the cask body. The neutron radiation shielding at the lid and bottom ends is ensured by polyethylene discs. The neutron shielding at the bottom is sealed by a cover plate, welded together leak-tight with the cask body.

Shock absorbers are fixed at the ends of the cask. They enclose the ends of the cask completely, protecting them from accidental damage. The inner cask surface is protected against corrosion by the inner lining, made of stainless steel. The outer cask surface has a decontaminable protection paint. The cask interior holds the basket, depending on the cask type, in a different way. The tube for draining is an integrated component of the basket structure. The basket consists of the following components:

- basket elements
- connecting components(i.e. radial and/or axial tie rods)
- bottom piece
- head piece
- handling elements.

After the wet loading or unloading of the cask, water is suctioned out of the cask cavity. The drain system projects into the cask interior. The guiding mechanism for it is located in the basket and connects the system directly with the bore hole intended for draining while the shielding lid is installed.

IV.3. CAUSE OF CONTAMINATION AND REASON FOR DECOMMISSIONING

The cask TN 1300 was built and later tested in an extensive thermal test programmes in 1981 with electrical heaters. On the basis of this test programmes, the cask received a transport licence in 1983 from the German licensing authority PTB. In 1984 a hot handling and measurement programmes was carried out with PWR fuel elements of the Biblis-type. The cask was loaded in the Biblis reactor pool, closed with the primary lid and dried according the drying procedure suitable for long term storage (see Fig. IV.2). After this procedure, an 8 day measurement programmes was performed to measure the fuel pin temperature of the hottest fuel element as well as dose rates at the cask surface, and contents of H_2, tritium, H_20, and noble gases such as Kr-85. At the end of this measurement programmes, the cask was reloaded under wet conditions (see Fig. IV.3). Later the cask was used for several transports of spent fuel elements between the Biblis reactor units A and B.

In the meantime, there were some indications from the licensing authorities that the storage licence would not be issued in the next several years for this type of cask. This was mainly due to the new inner liner concept and the impossibility of periodic inspections of the inner liner during the storage period. Thus, DWK (Deutsche Gesellschaft fur Wiederaufbereitung von Kernbrennstoffen) decided to decommission this cask. The assumption was that the cask would not have much activity because it had only been loaded with intact fuel elements for testing and transport. This meant that only crud could be contained within the cask.

IV.4. PROCESS OF DECONTAMINATION AND DECOMMISSIONING IN THE WASTE PROCESSING FACILITY OF THE KARLSRUHE RESEARCH CENTRE

DWK requested several offers within Europe for decontamination and decommissioning of the TN 1300 cask. DWK chose the best and the most economical offer from the research centre of Karlsruhe. The offer based on the following tasks:

(a) Decontamination and decommissioning of the cask
- removal of the neutron moderator material
- removal of the basket
- inside deco of the cask
- cutting of the liner
- scrapping and compacting of the basket and liner
- conditioning of the compacted material in 200 L drums
- conditioning of the neutron absorber material

(b) Transport of the decontaminated cask body

(c) Cutting and melting of the cask body including the refund for the iron material

(d) DWK-project-management.

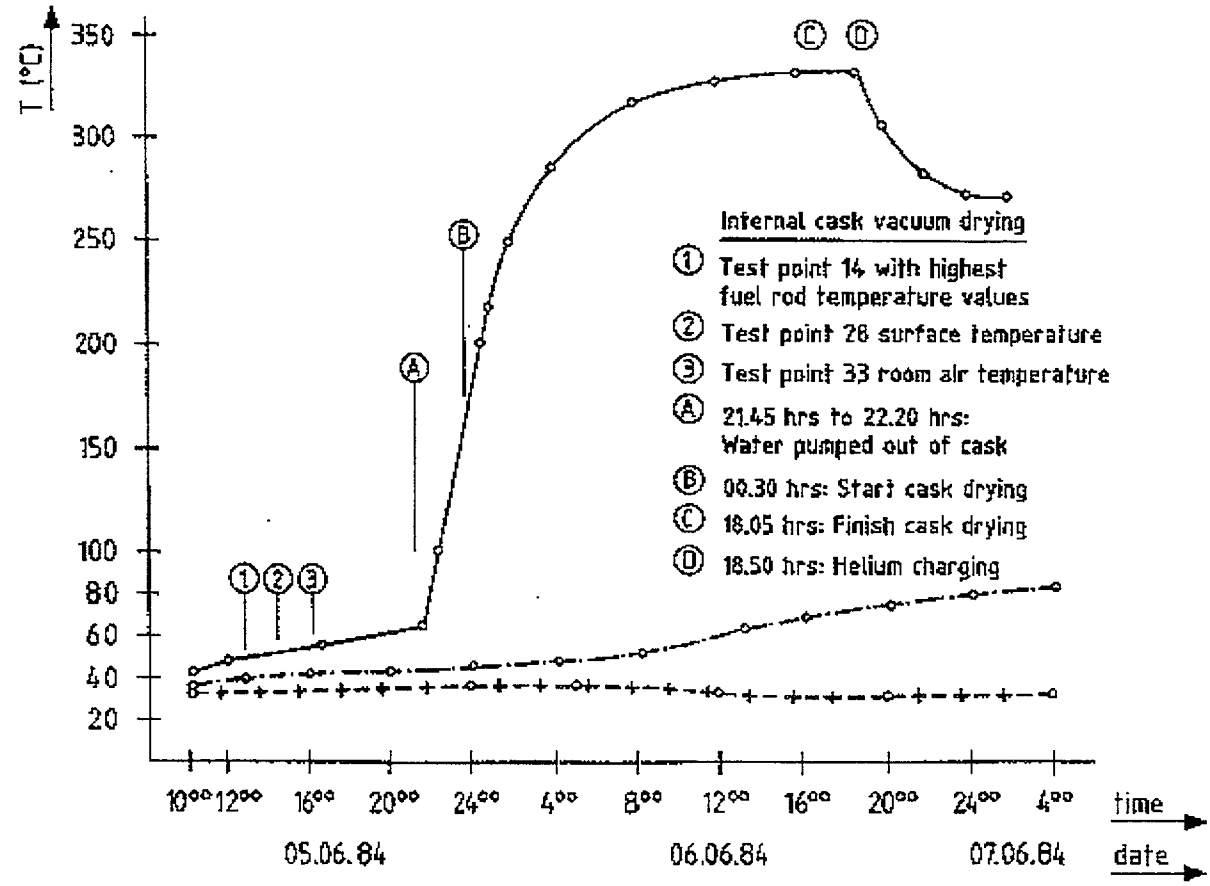


FIG. IV.2. Temperature development during vacuum drying TN-1300.

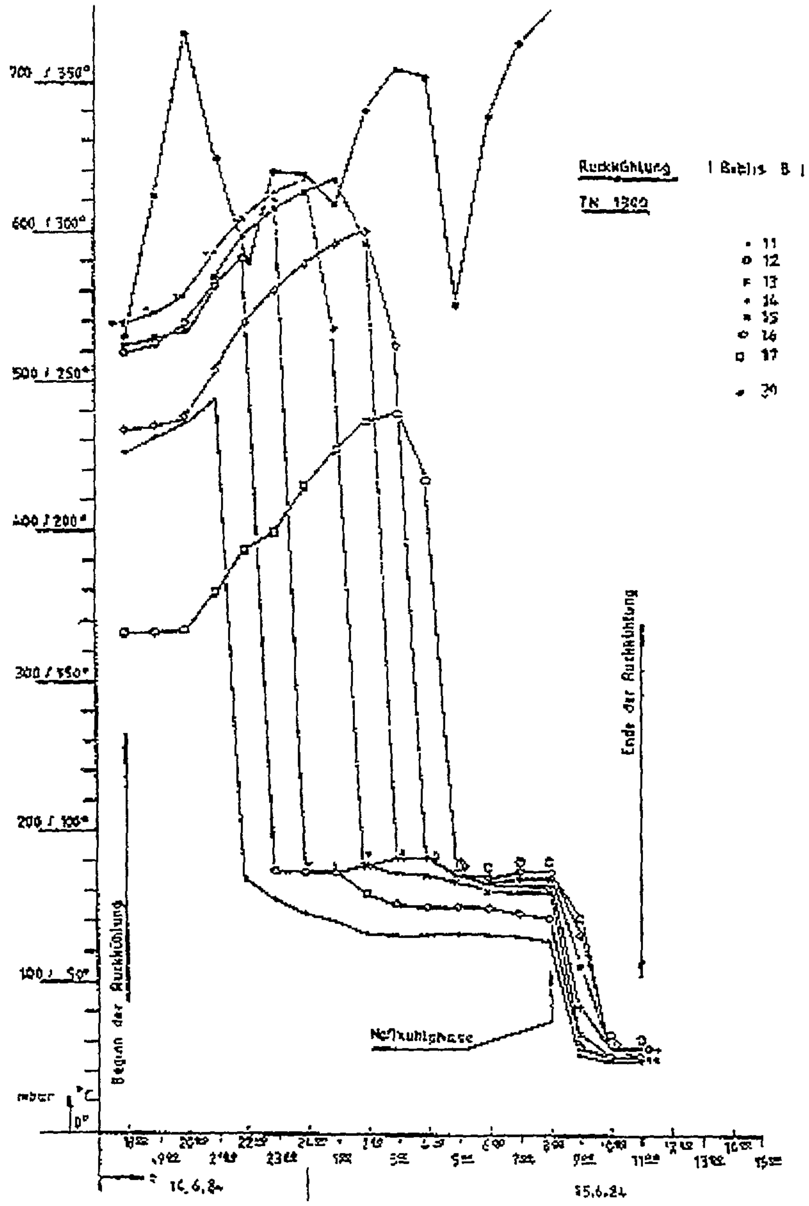


FIG. IV 3 Temperature profile during reloading of TN-1300

The decontamination work was performed during the last quarter of 1990. The total cost was DM 715 000 (cost basis 1990). The following steps were performed during decontamination and decommissioning process:

(a) Removal of the neutron moderator material and the cover plates.

- It was expected that this material was not contaminated, but it was declared to be special, not conventional, waste. This means, a special disposal method was needed.

(b) The cask was connected in horizontal position in a hot-cell area and the primary lid was removed.

- Measurements inside the cask cavity showed a dose rate of 4 mSv/h.
- The primary lid showed a dose rate of 3 mSv/h at the inner surface. After wet decontamination-procedure, the dose rate was reduced to 0.15 mSv/h.

(c) Removal and stripping of the Al-basket

- The basket showed a mean dose rate of 4 mSv/h. Part of the bottom part of the basket showed a dose rate of 20 mSv/h.

- Several deco procedures could not remove these ,"hot" spots.
- For these reasons, it was decided to scrap and compact the entire basket.

(d) The cask cavity after the basket removal showed a mean value of 4 mSv/h. Wiping test specimens on the surface of the liner showed values of 0.1 mSv/h.

- The liner was cut into several segments inside the cask cavity with a special milling tool developed for this process.
- Each segment was decontaminated to a lower level inside the hot-cell area and then scrapped and compacted.
- The decontamination process of the liner segments created a rather high level of contamination on the plastic cover inside the hot-cell area.
- Maximum values of 80 mSv/h were measured on the surface of these plastic sheets.
- Consequently this contaminated plastic material had to be packed for disposal in a specially shielded drum.
- The decontamination and decommissioning process of the TN 1300 cask created sixteen 200 L drums filled with intermediate level waste and 100 t of decontaminated steel and cast iron.
- The 16 drums were collected in a waste container of the Type. Ill which fulfils the preliminary acceptance criteria for the German final disposal mine Konrad.
- The dimensions of this container are 2.0 x 1.7 x 1.7 m, with a total weight of 7310 kg.
- This container is now stored in an interim waste storage facility at Karlsruhe.
- For each drum, a very precise documentation was collected in a special internal report. The contaminated steel and cast iron was melted in a foundry and used for new casks.

IV.5. TIME AND ESTIMATED COST OF THE DECONTAMINATION AND DECOMMISSIONING PROCESS

At the end of the decommissioning process, the total costs were calculated to an amount of DM 960 000 (cost basis 1990). These costs do not include the final disposal costs of the 16 waste drums, since no one is able to calculate these figures at this time. The duration of the decommissioning process was approximately3 months.

IV.6. CONCLUSION

Decommissioning of a used transport and storage cask, including the basket, is feasible in a hot-cell with a reasonable transport and crane capacity and tools for remote handling ability. Decontamination of the specific Al-basket was not feasible. The decommissioning costs were very high and rose in this case to 50% of the cask production costs. In the case of spent fuel contamination of the cask due to cladding failure of fuel rods, a higher level of contamination can be expected.

IV.7. NOTE ADDED IN PROOF[2]

Over the last two decades a steadily increasing number of casks has been transported to the reprocessing plants every year. Through an official message of the French Environmental Minister at

[2] Excerpt from "Practical experience in spent fuel management for German Nuclear power plants" by Lürmannn et al., presented at the International Symposium on Storage of Spent Fuel from Power Reactors held in Vienna from 9 to 13 November 1998.

the end of April 1998, it became known, that a number of transport casks were found to have local surface contamination above the regulatory value of 4 Bq/cm^2 on arrival at the Valognes terminal near La Hague, although a review of the transport documentation showed, that the casks had been clean when leaving the NPPs in Germany. This caused a suspension of the spent fuel transports in France, Germany and Switzerland.

In the run-up to the federal elections, this contamination phenomenon became a major political issue. All spent fuel transports from German NPPs have been halted, and it is expected that they will be resumed as soon as the requirements of the Federal Ministry for the Environment, the so-called 10 points-plan, have been fulfilled. In this context, the utilities have proposed to take the following measures:

(1) Optimization of the technical measures to prevent contamination and extension of the radiation protection measurements;

(2) Establishment of an information and reporting system;

(3) Improvement of the organisational structure within the utilities;

(4) Restructuring of the transport organisation.

Annex V

RUSSIAN FEDERATION

V.1. INTRODUCTION

The Russian Federation uses a closed fuel cycle for the majority of its nuclear programmes, i.e. nuclear fuel, after irradiation in reactors, is reprocessed to extract the recoverable uranium and plutonium. Recovered uranium is used in thermal reactors and plutonium in fast reactors (Fig. V.1).

WWER-440, WWER-1000 and RBMK-1000 thermal neutron reactors and BN-350, and BN-600 fast neutron reactors are in service. Economic estimates show that it is unreasonable to reprocess spent fuel (SF) from RBMK reactors, as its original enrichment is only 1.8–2.4 %. The centralized storage and final disposal of RBMK reactor spent fuel, as well as of non-reprocessable fuel from ice-breaker and some research reactors are being studied in The Russian Federation. Storage of non-reprocessable fuel is currently in cooling pools with plans to move the fuel to a centralized storage facility or recoverable disposal facility.

Spent fuel from WWER-440, BN-350, BN-600 reactors as well as from research reactors has been transported the reprocessing plant RT-1, near Chelybinsk since 1977. The plant has a capacity of 400 tons of Uranium per year and can adequately satisfy the current and future requirements for reprocessing the spent fuel from all of the above reactors. Fuel from WWER-1000 reactors will be reprocessed at the plant RT-2, near Krasnoyarsk which is now under construction. The plant will have a capacity of 1500 tons of Uranium per year. Transport of all spent fuel to the reprocessing and centralized storage facilities in the Russian Federation is by rail.

Some types of casks and canisters for SF transportation are shown in Figs. V.2–V.6.

V.2. CONTAMINATION MANAGEMENT OF RUSSIAN CASKS

The Russian casks contamination management based on:

- Prevention of cask contamination,
- Decontamination immediately after spent fuel loading/unloading,
- The design of the cask.

V.3. CONTAMINATION PREVENTION

Protection of transport packages from contamination is achieved by the following methods:

- use of a dry loading/unloading technique, where the surface of the package is not in contact with the contaminated water of the cooling pool;
- use of protective equipment in “wet” loading, where protective skirt is put on the cask before its immersion into cooling pools.

V.4. LOADING AT NPP

Dry loading of SF is used at the Beloyarsk NPP, BN-600 reactor. The railway wagon is positioned in the transport corridor in the loading area. The transportation cover is removed, the primary lids are removed and placed in the transfer area.

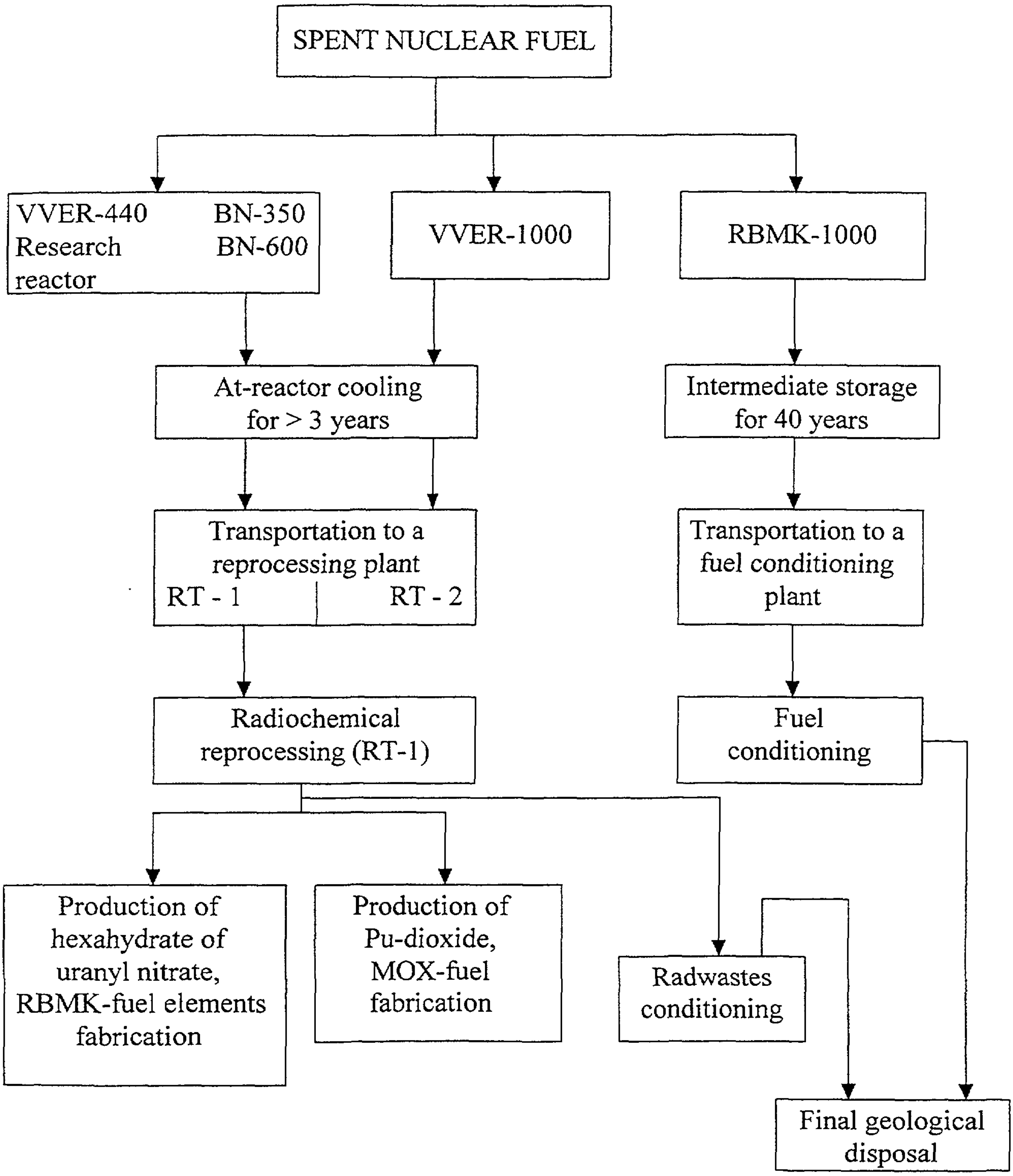


FIG. V.1. Spent fuel management concept.

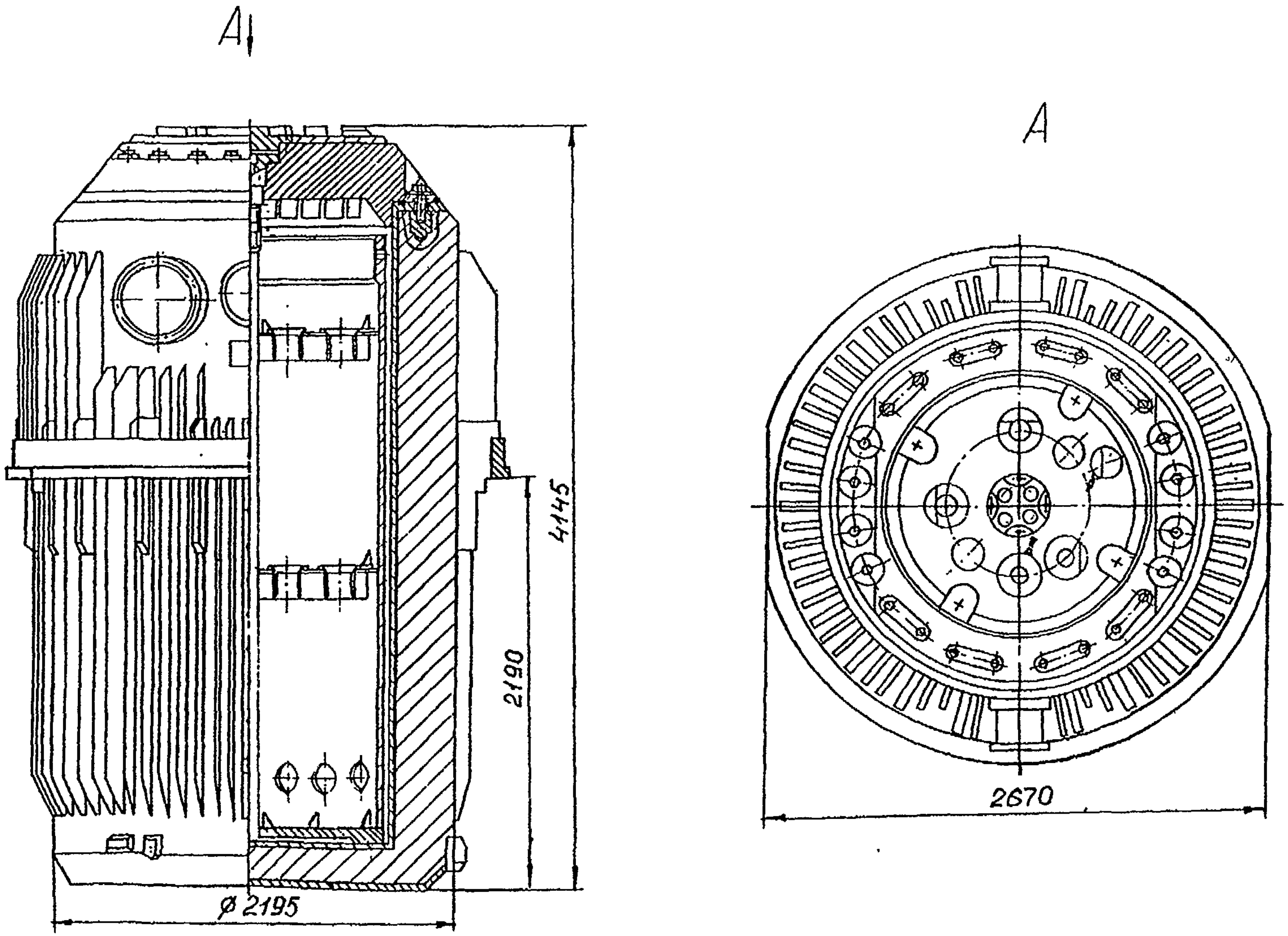
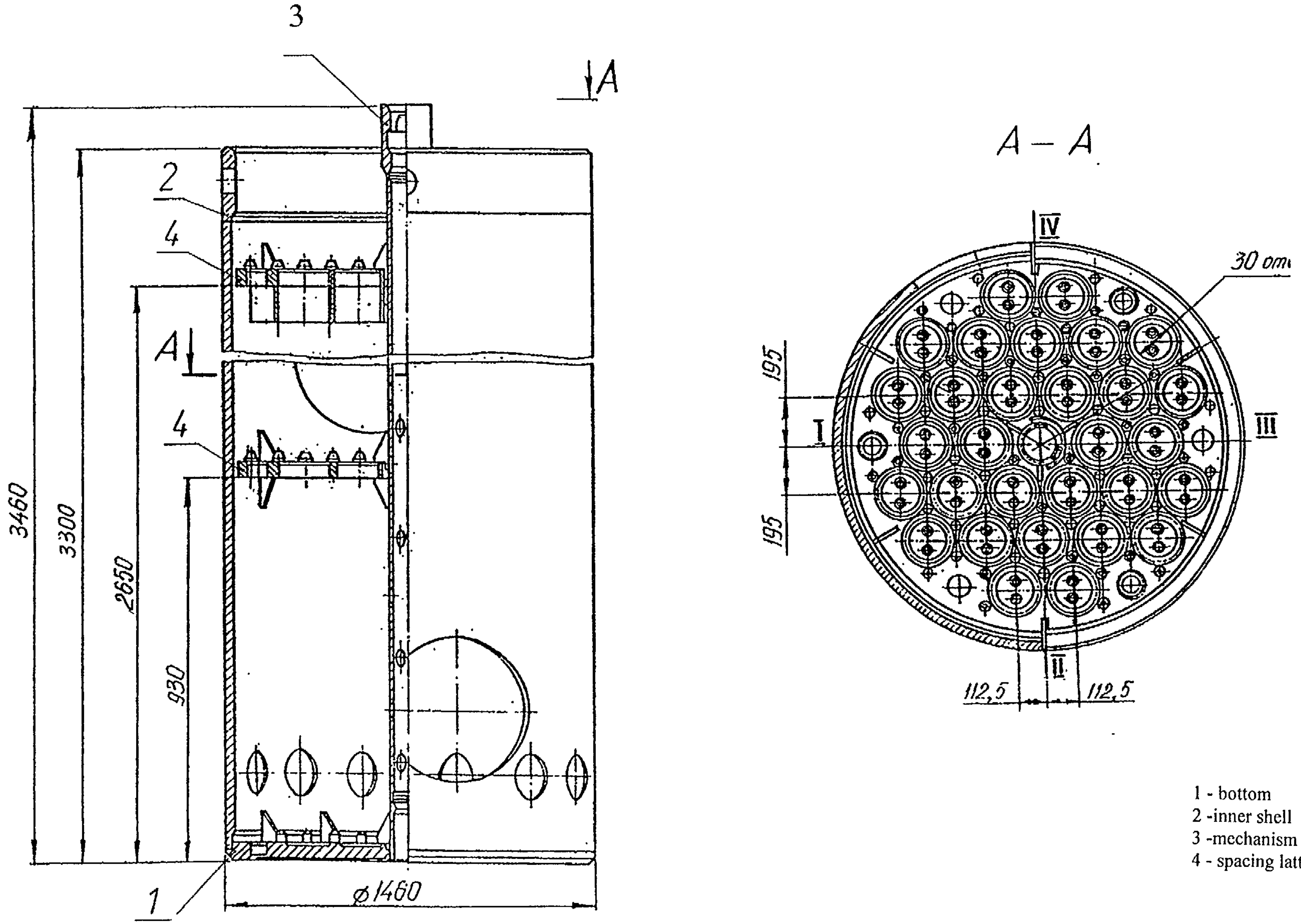


FIG. V 2 Transport packaging TK-6 for spent fuel of WWER-1000.



1 - bottom
2 -inner shell
3 -mechanism for gripping
4 - spacing lattices

FIG. V.3. Basket 13 for TK-6.

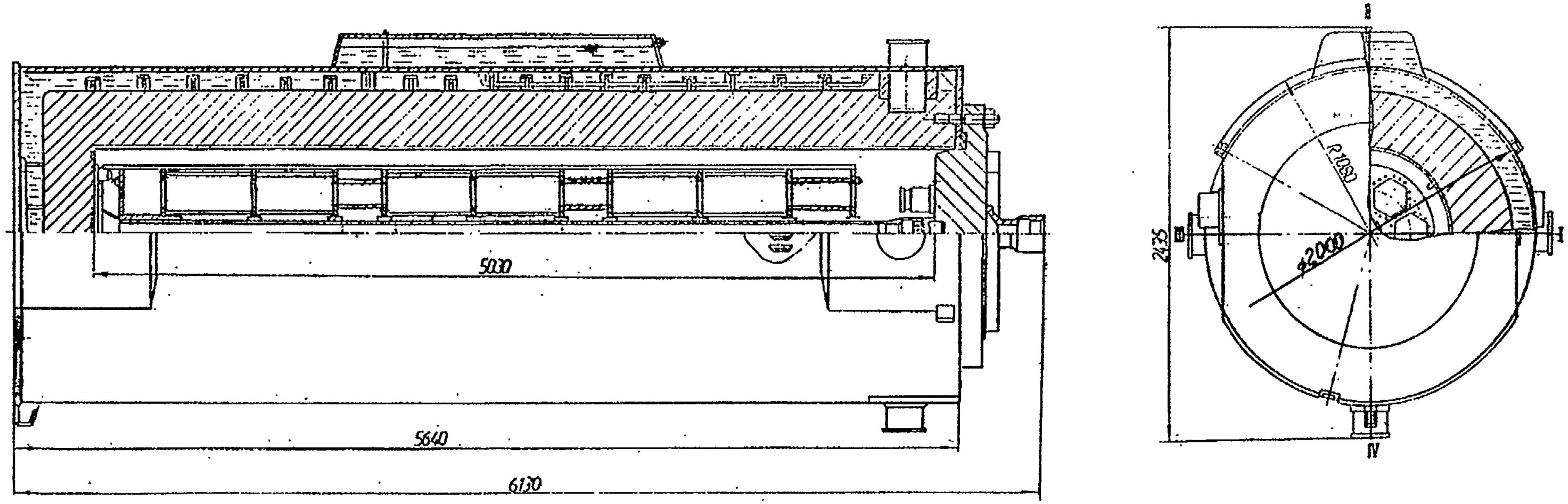


FIG. V.4. Transport packaging TK-10B for spent fuel of WWER-1000.

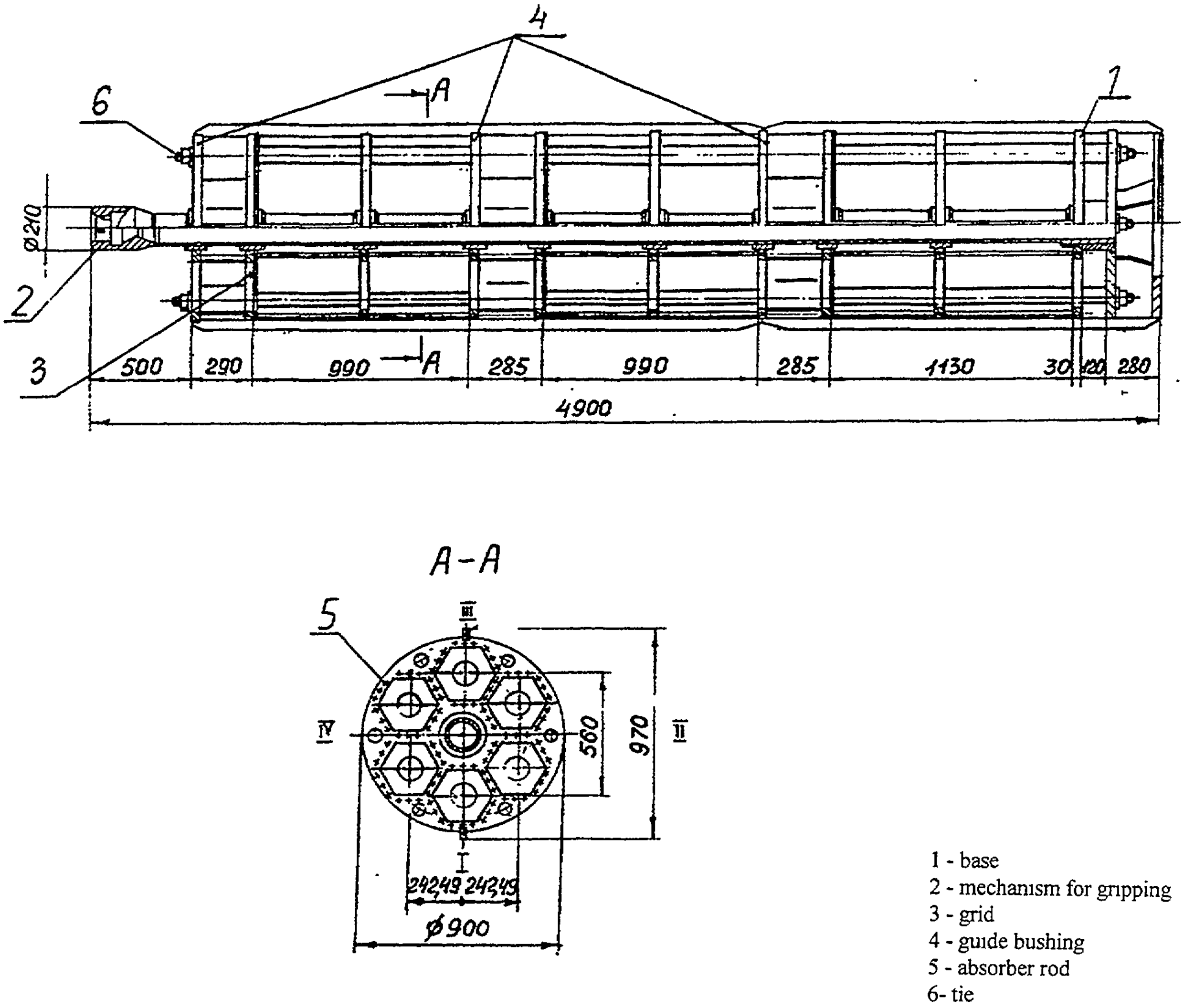


FIG. V.5. Basket 30 for TK-10-B.

A shielded removable protective skirt is placed over the top of the opened cask. The secondary lid is removed and placed in the transfer area. The basket of SF is loaded in the cask. The secondary lid is replaced and the protective skirt is removed. After the loading operations are completed, the exposed cask surfaces are first decontaminated using water and mild chemicals followed by localized electropolishing as required.

A wet loading technique to prevent cask contamination has been developed in the Russian Federation for use at the Ignalina NPP in Lithuania (see Fig. V.7). The cask loading is carried out underwater in the loading pool adjacent to the main storage pool. The cask is placed inside the lower part of the protection shell in the empty loading pool with an overhead crane. The upper part of the protection shell is placed on the cask and is fastened to the lower part. The protection shell is filled with pure water to act a barrier to the pool water. The loading pool is then filled with demineralized water.

After the loaded spent fuel basket is lowered into the cask and the lid replaced, water is removed from the loading pool and then the protection shell. The exposed surfaces of the lid and the cask neck not protected by the protective shell are washed with demineralized water. The upper part of protection shell is then removed, the cask is withdrawn from the empty loading pool and put on the operational platform. The leak tightness of the water filled cask and its contamination levels are checked. If necessary, the contaminated external surfaces of the cask are manually decontaminated. The loaded cask is then replaced and secured on the rail wagon.

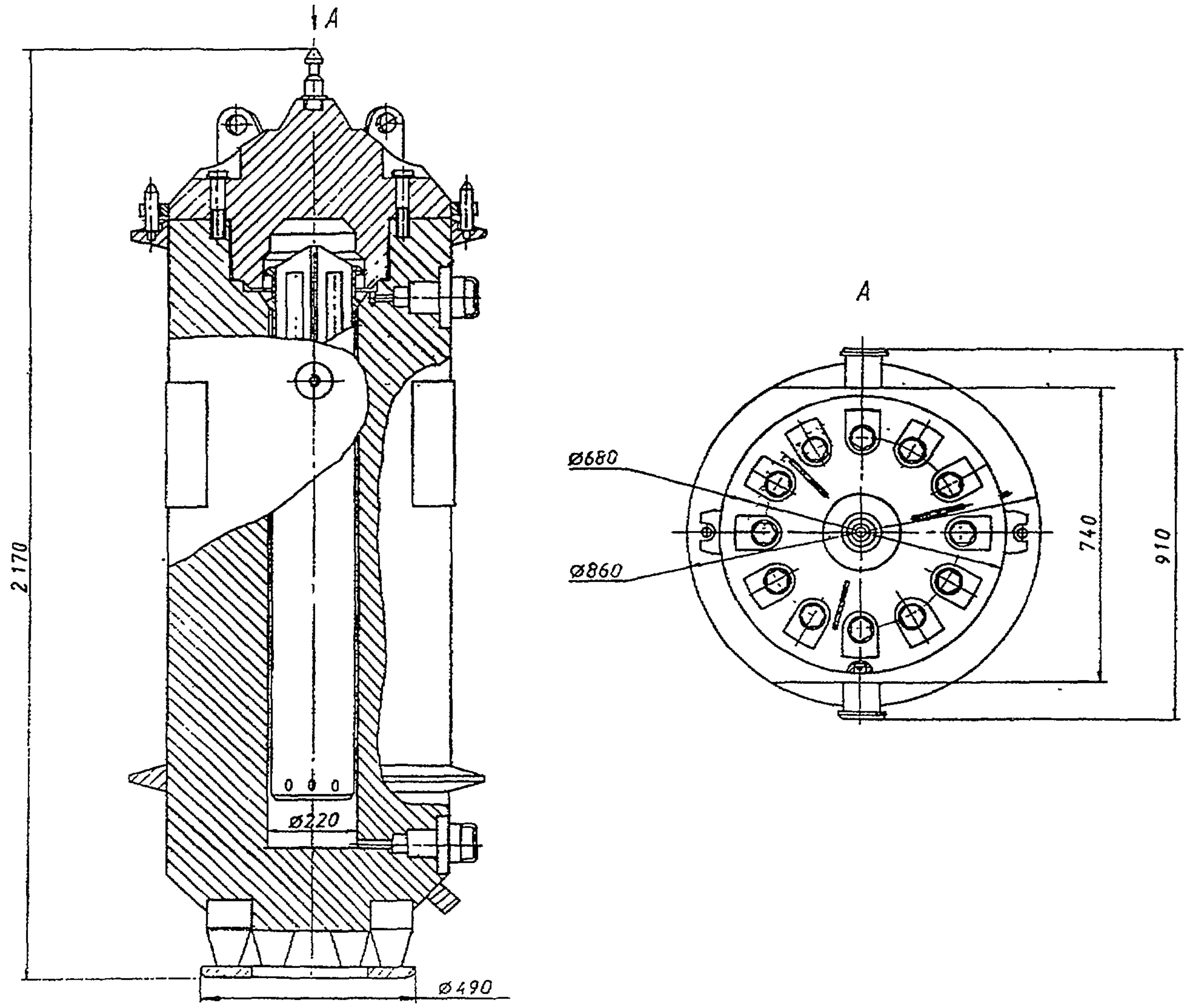


FIG. V.6. Transport packaging TK-19 for spent fuel of research reactors.

V.5. DRY LOADING ICE BREAKER REACTOR FUEL AT MYRMANSK

Minimisation of contamination of the TK-18 cask used for transportation of spent fuel from ice-breaker reactors is accomplished using a new design of cask and system facilities. The loading facilities avoid direct contact of the spent fuel with the cask body, by utilizing canisters and a shielded transport container. This dry loading system minimizes the contamination of the external and internal cask surfaces.

The spent fuel assemblies are stored in multi cavity canisters in the storage pool. The railway wagon is first positioned in the loading area. The TK-18 cask is removed from the rail wagon and transferred to the reception area using the overhead crane. The cask lid is unbolted and removed. The cask is loaded using a special purpose shielded transfer flask and a guide device.

After placing the seven type "Ch-T" canisters loaded with spent fuel into the cask, the transfer flask and the guide device are removed and the lids replaced. Operators control the quantity of water in the TK-18 container during the loading operation using siphon tubes to avoid criticality problems. The leak-tightness and contamination levels of the loaded cask are checked prior to loading the TK-18 on the railway wagon. Decontamination is completed prior to loading the cask on the railway wagon (Figs V.8–V.15).

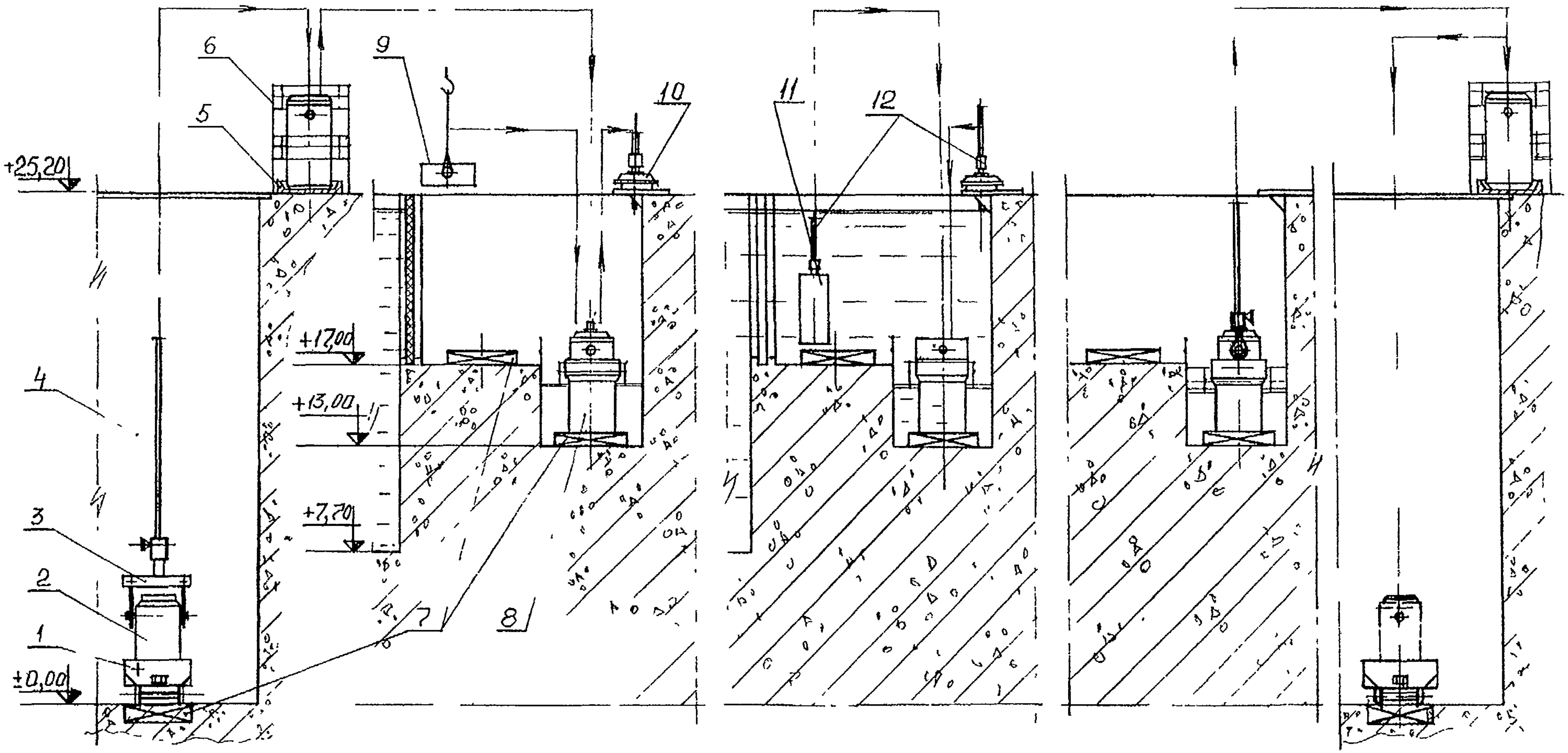


FIG V 7 Diagram of management of spent fuel at Ignalina NPP; Use of skirt and shock absorber

1 - transporter
2 - cask
3 - traverse
4 - clean transport area
5 - troughs
6 - operatıng platform
7 - shock-absorber
8 - bottom part of case
9 - upper part of case
10 - cover of cask
11 - basket
12 0 yoke

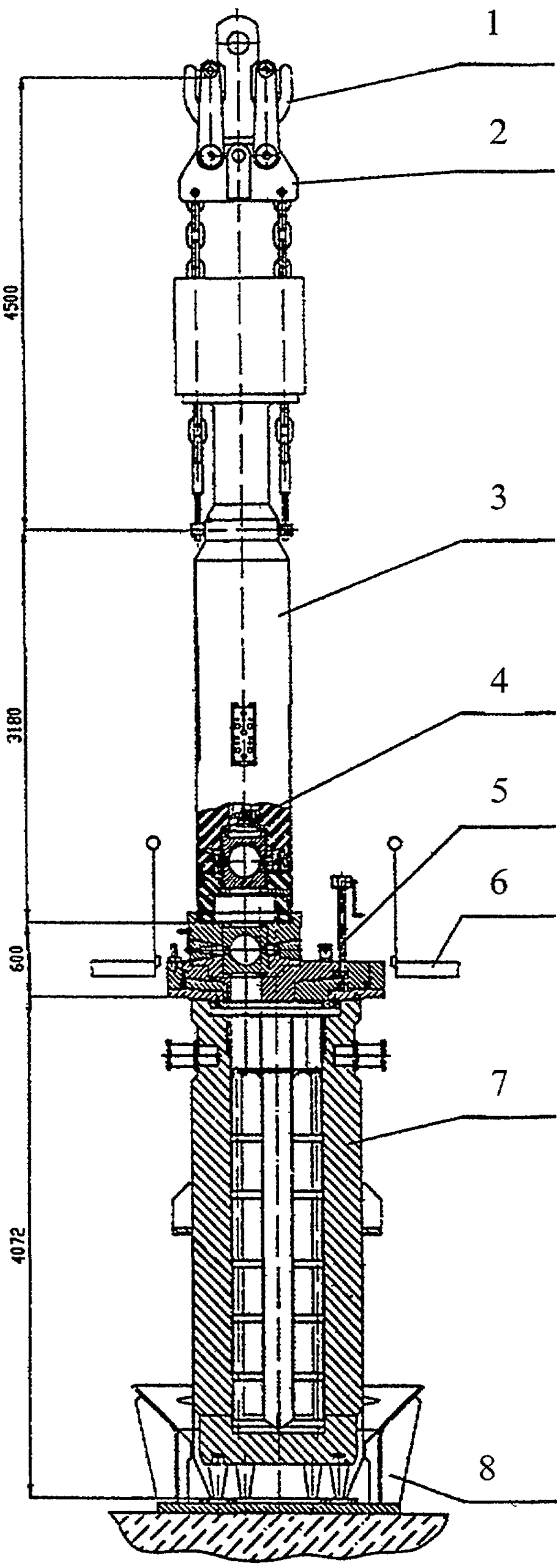


FIG. V.8. Scheme of TL-18 shipping loading cask

1 - crane hook
2 - yoke
3 - KP 400 transfer container
4 - "ChT" type canister
5 - guide device
6 - working platform
7 - TK-18 shipping cask
8 - support tray

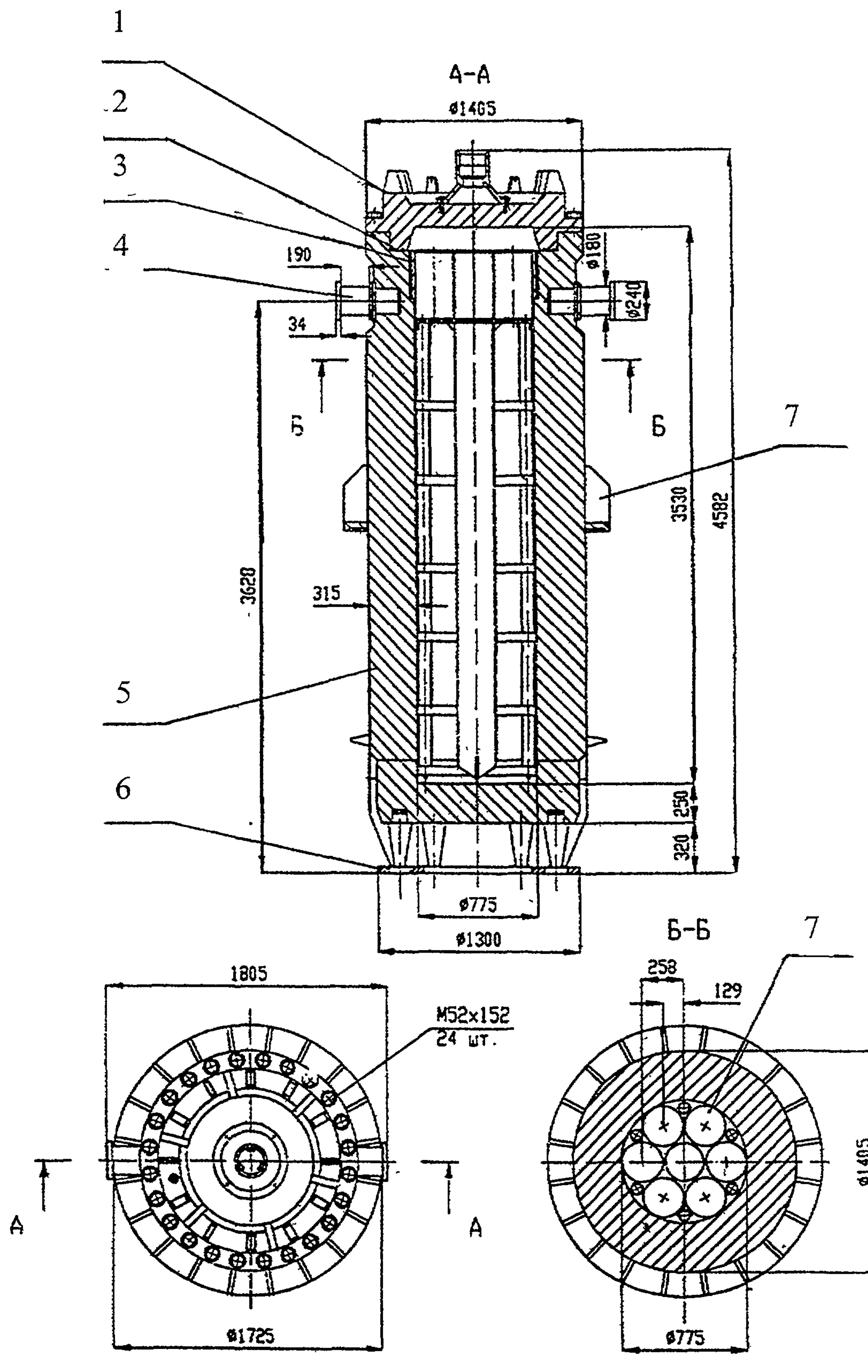


FIG V.9. TK-18 Cask for Shipment of "ChT" canisters with SFAs of the Atomic Fleet.

1 - lid	3 - removable part	5 - body	7 - support flange
2 - seals	4 - trunnion	6 - support ring	8 - place of "ChT" canister location

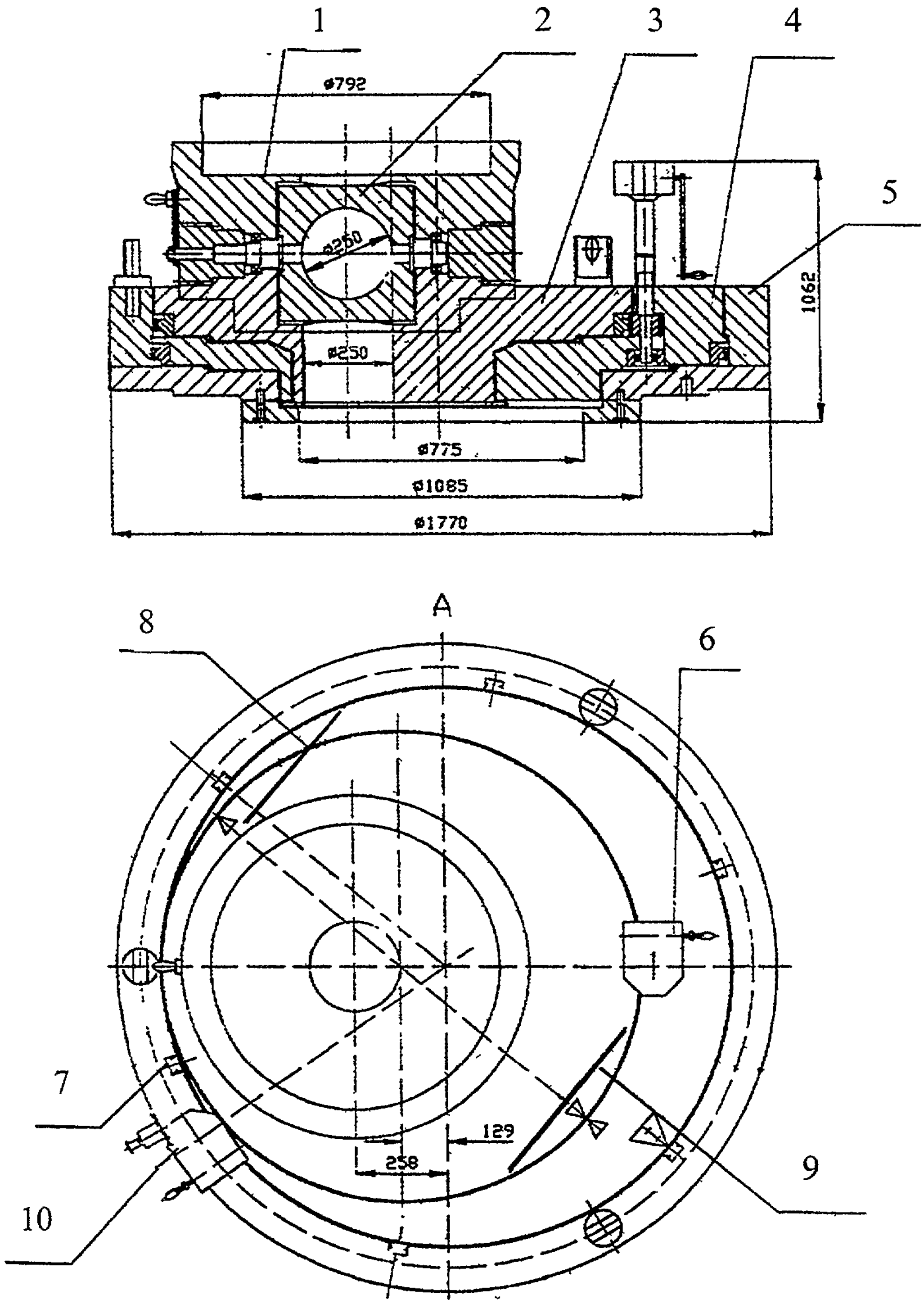


FIG V 10 Guide device

1 - mating unit
2 - gate
3 - rotating plug (inner)
4 - rotating plug (outer)rotation plug
5 - body

6 - manual drive of the rotation outer plug
7 - cell 1, 2, 3, 4, 5, 6, 7, 8
8 - central
9 - radial
10 - manual drive for inner 4 - 4

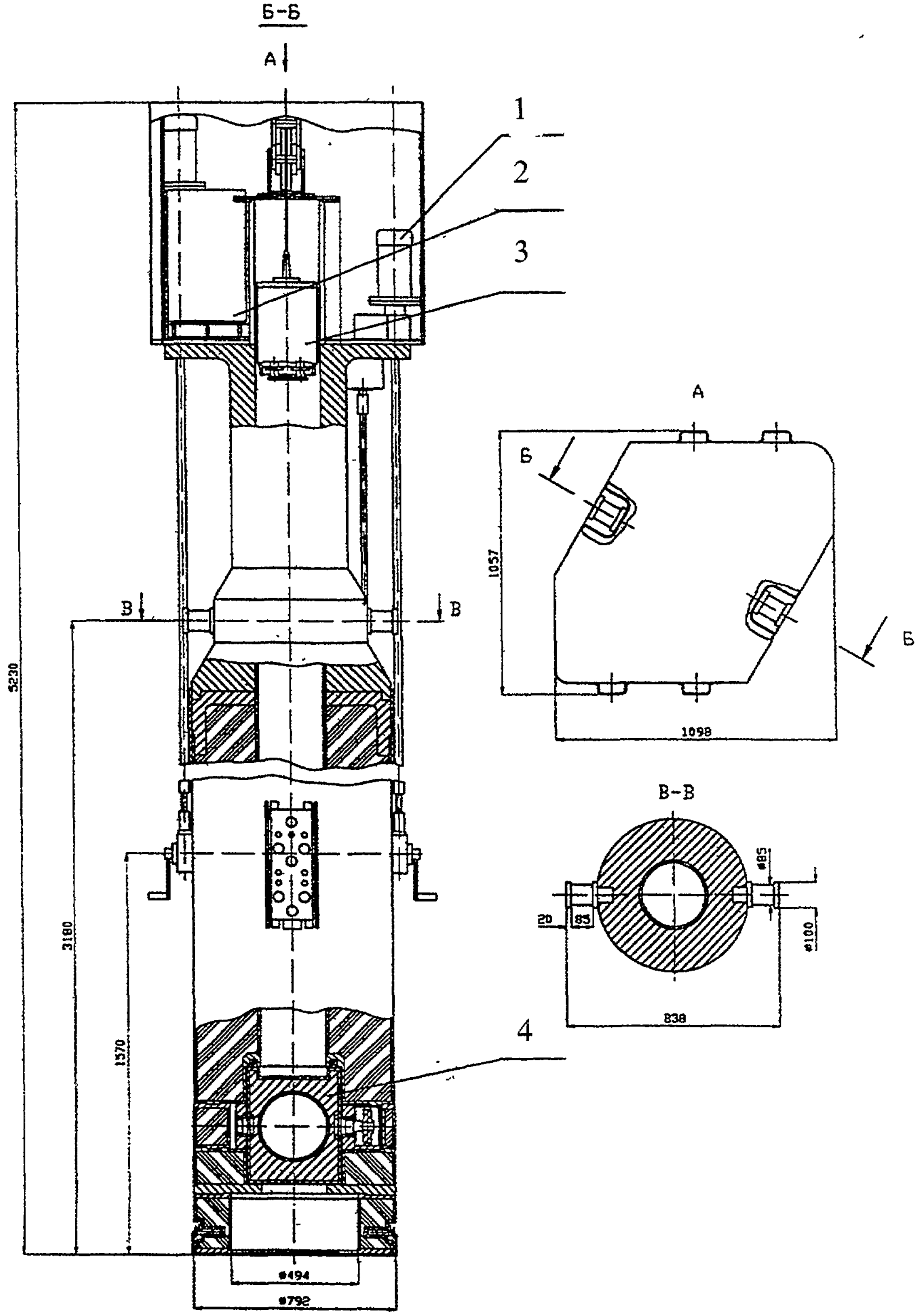


FIG. V.11. KP-400 transfer container.

1 - gate drive
2 - lifting grip drive
3 - controlled grip
4 - gate

Note the manual grips are notionally aligned with the drawing flatness

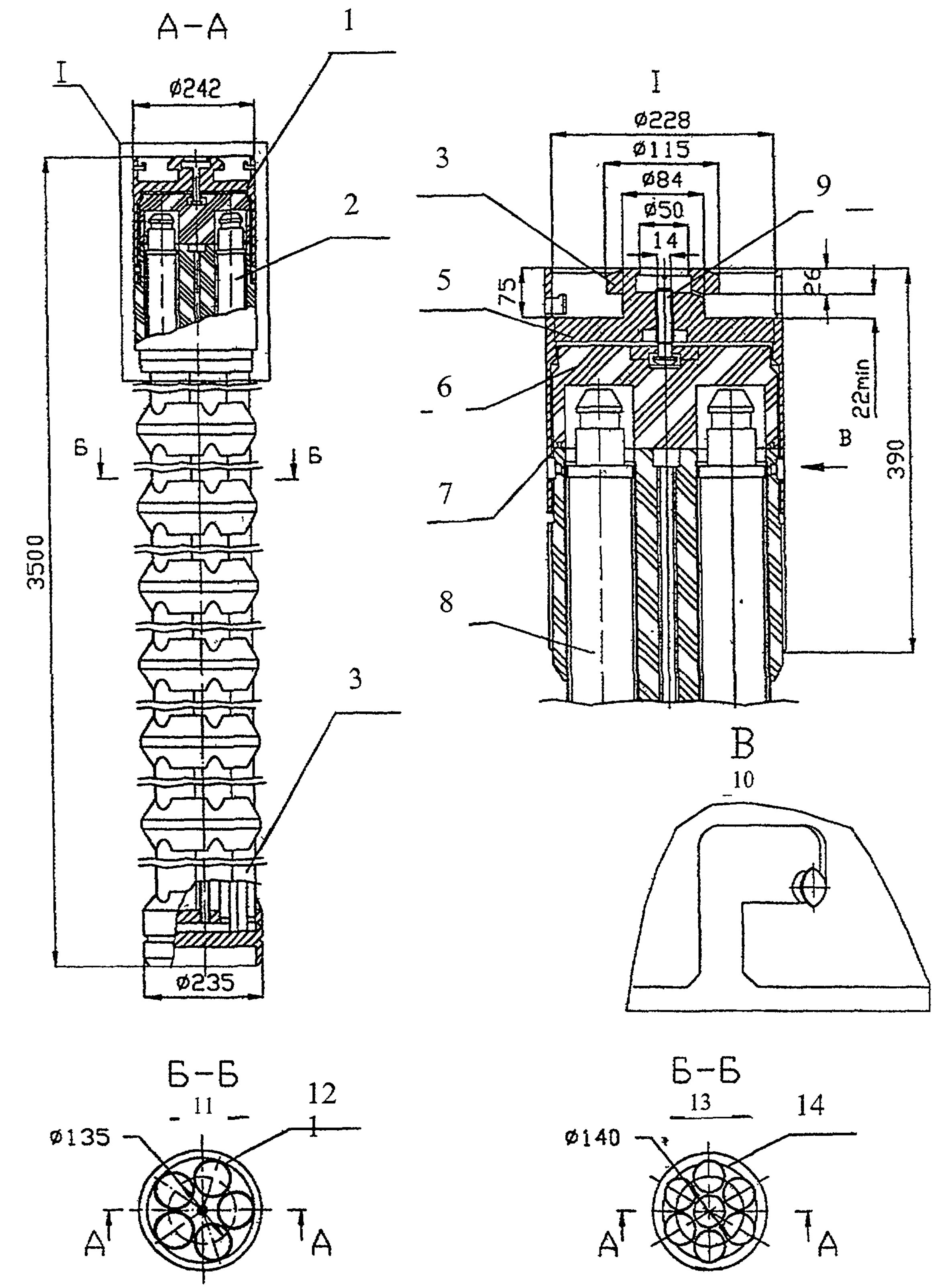


FIG V.12 "ChT" type canister for icebreaker SFA.

1 - plug with cap and clamp	4 - grip	7 - seal	10 - 3 places	13 - type 2
2 - SFA	5 - plug	8 - SFA	11 - type 1	14 - tube Ø65x3
3 - tube part with spacing grid	6 - lid	9 - clamp	12 - tube Ø70x3	

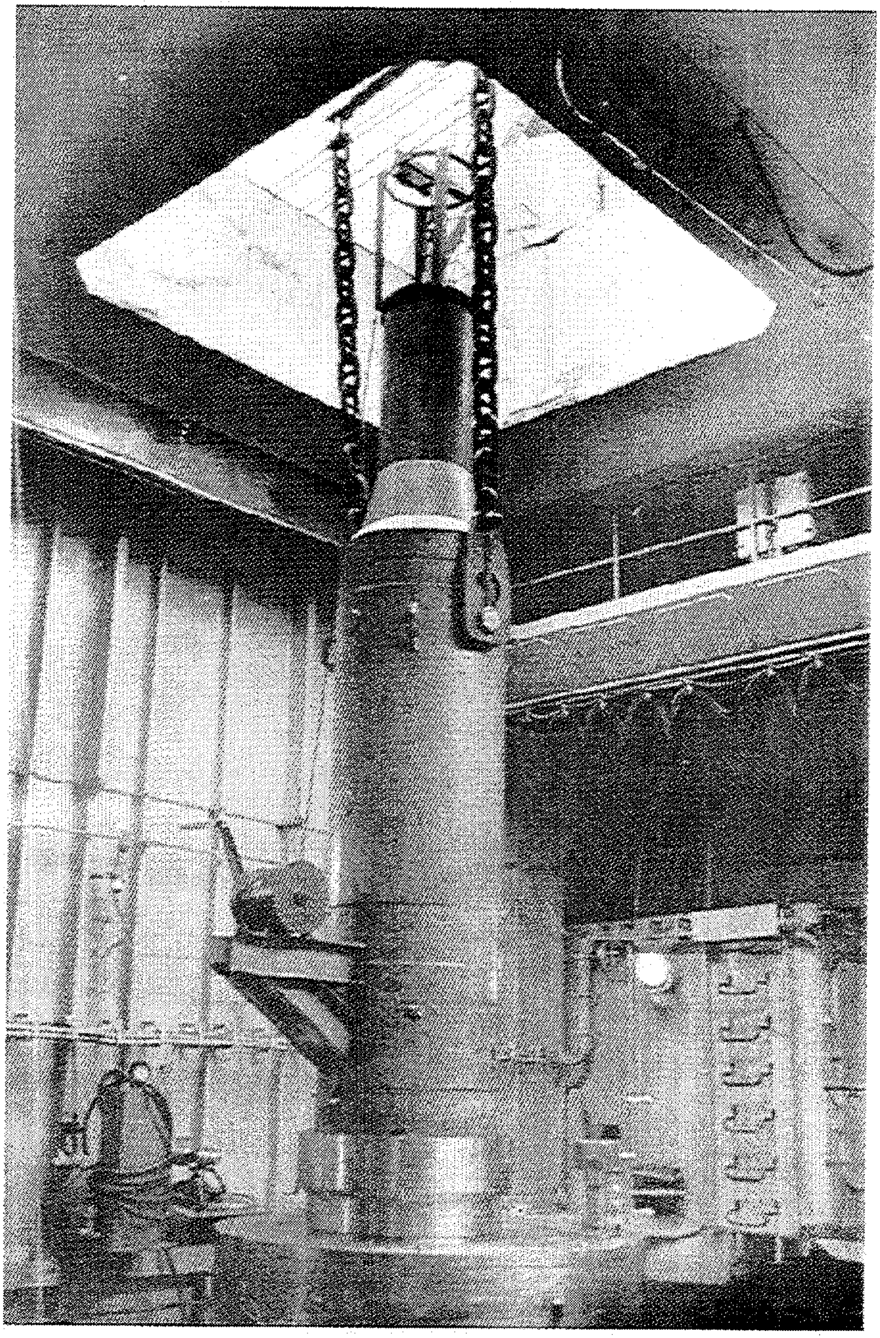


FIG. V.13. Transport container and guide device.

V.6. DRY UNLOADING AT RT-1

All transfer operations at RT-1 are carried out remotely (Fig. V.16). The railway wagon is positioned in the transport corridor of the unloading area. The doors on the wagon roof are opened, the TK-6 transport cask depressurized (through the special ventilation system), the cask lid is unbolted and lid bolts removed.

Unloading operations are remotely controlled from the control room while the TK-6 cask stays on the railway wagon in a vertical orientation. The unloading process is monitored by TV cameras. A 15 t crane removes the cask lid, removes the loaded spent fuel baskets from the cask and places them on the 15 t inclined elevator for transfer to the receiving pool. At the receiving pool, a 15 t crane removes the basket (with fuel assemblies) from the elevator and places them in the storage area of the receiving pool. The empty cask and railway wagon are transferred to the decontamination area where it is decontaminated, if necessary.

V.7. WET UNLOADING AT RT-2

The transportation of WWER-1000 spent fuel to the RT-2 plant utilizes the TK-10 and TK-13 casks. These casks have smooth external surfaces of stainless steel which are more easily decontaminated than those with ribbed external surfaces.

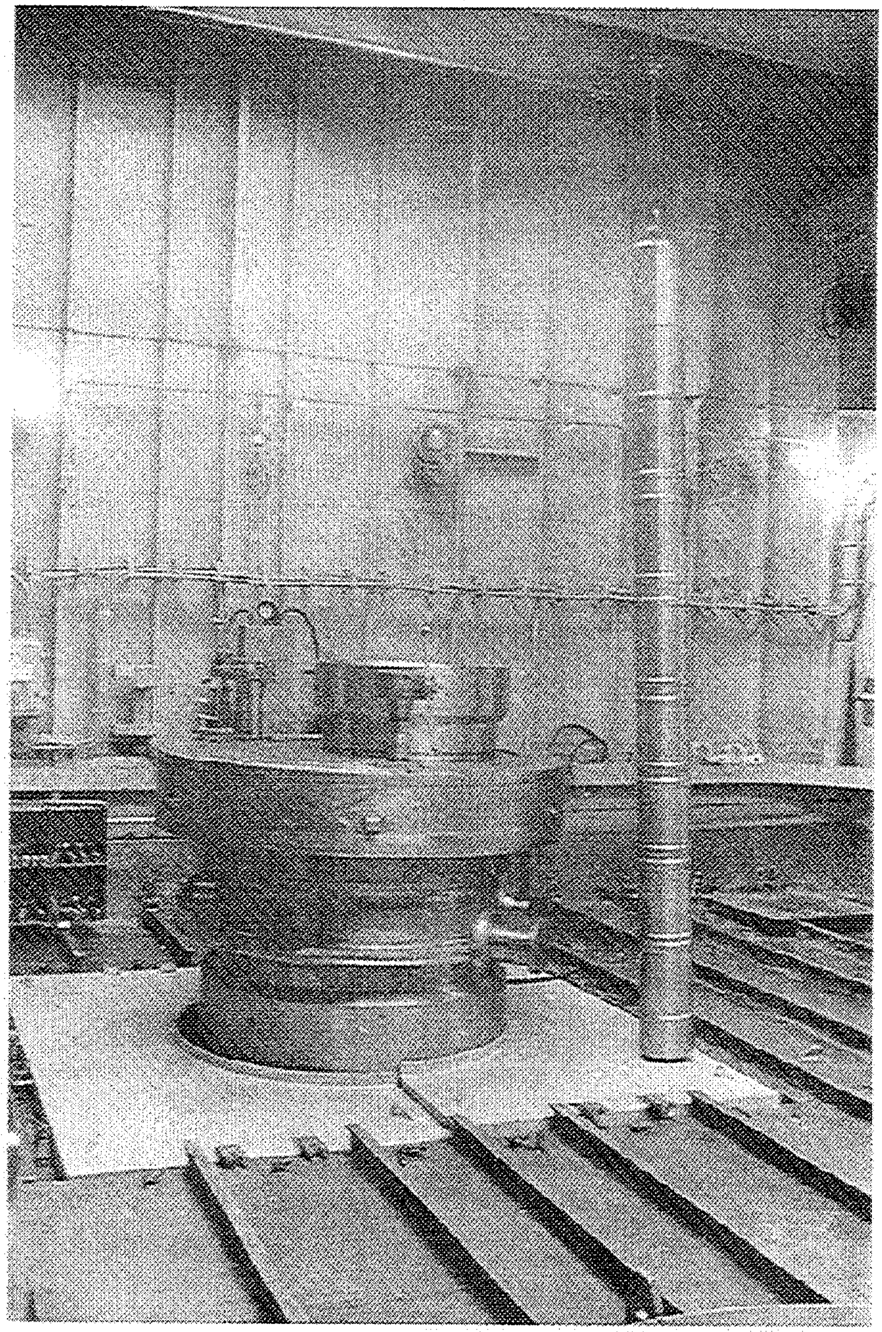


FIG. V.14. Guide device and mockup for canister.

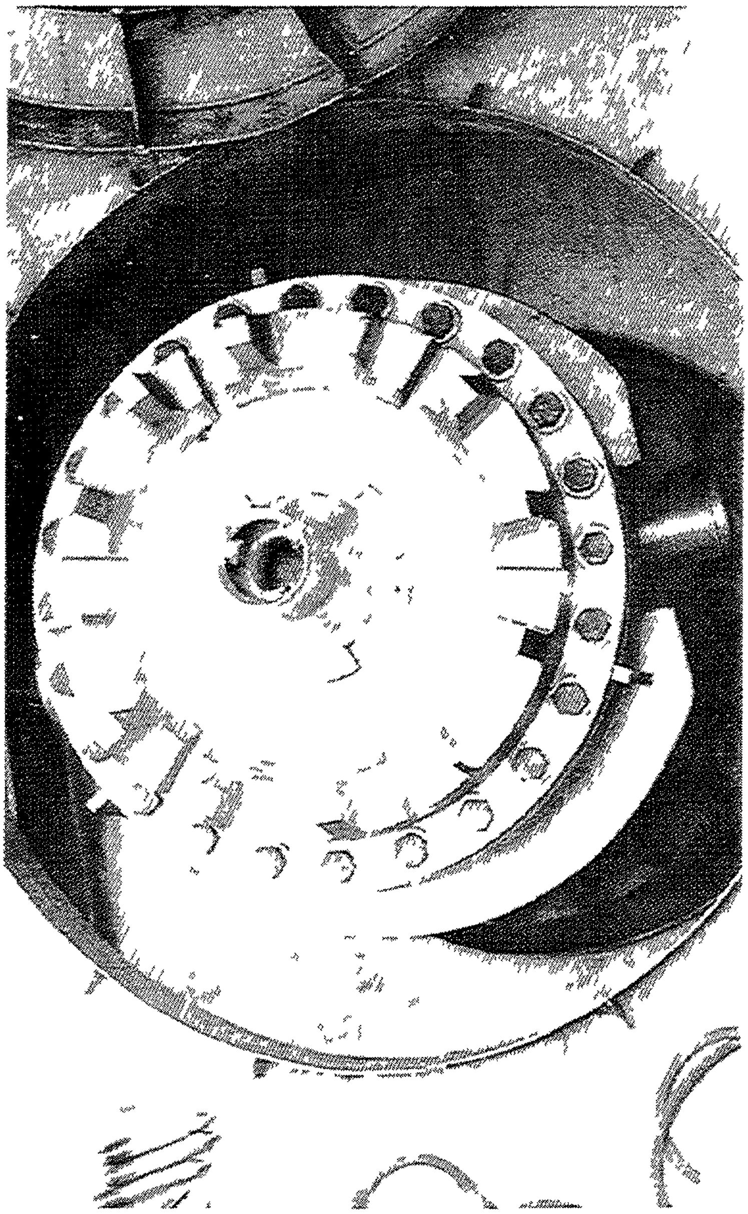


FIG V 15 Lid of TK-18

The cask is removed from the rail wagon in the transfer corridor and transferred to the reception area using the transport hall crane (160/32 t capacity) The temperature inside the water filled cask is lowered by controlled water circulation through the cask cavity prior to removal of the lid bolts The transport basket loaded with spent fuel is removed from the cask in the unloading pool The spent fuel assemblies are loaded into storage baskets and the empty transport basket is readied to be replaced in the cask cavity After the unloading operations are completed, the cask surfaces and the transport basket are washed with decontamination solutions and then checked for traces of contamination

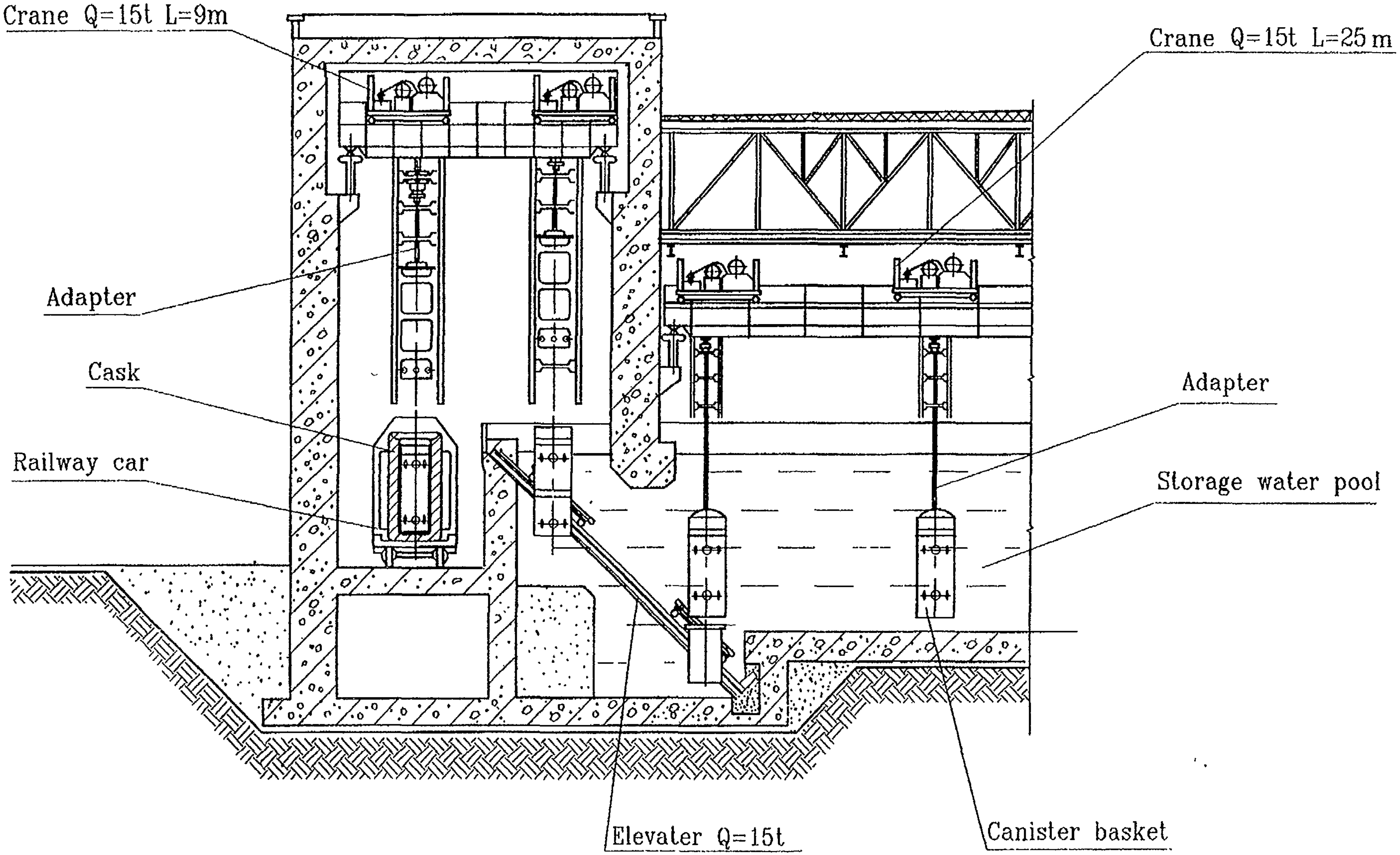


FIG. V.16. Spent fuel reception and storage PT-1.

V.8. STORAGE OF RBMK SPENT FUEL

A centralized dry storage facility for the spent fuel from RBMK reactors is now being designed. Some examples are shown in Figs V.17–V.19. Transport containers and dry unloading systems are being developed to minimize the transfer of contamination.

V.9. MODIFICATION OF CASKS

Russian transport casks have been modified to accommodate different types of fuel. Examples include:

– the adaptation of the TK-6 cask to transport fuel assemblies in a special canister (shown in figure 20) inside the existing basket for post irradiation examination. TK -6 is used without any major modification.

– the TK-19 cask was upgraded with a new basket and canister for carrying UO_2 and PuO_2 powder. This modification required a licence change and is identified as type TK-42 (see Fig. V.21).

V.10. PERMISSIBLE LEVELS OF RADIOACTIVE CONTAMINATION FOR THE TRANSPORT CASK AND VEHICLE

According to the current Russian regulations, the contamination present on the internal surfaces of car body, wagon, ship deck area for packages and the surfaces of packages, on the accessible surface averaged over 300 cm^2 shall not exceed:

– 3.7 Bq/cm^2 in beta-emitters;
– 0.37 Bq/cm^2 in alpha-emitters.

Non-fixed radioactive contamination on the external surfaces of the transport vehicles is not permitted. These standards are maintained by preventing or minimising exposure to contamination, decontaminating immediately after exposure and designing decontaminability into the cask, railway wagon and the loading/unloading equipment and facilities. These requirements specify that all surfaces shall be highly finished or have a high quality paint coating which is resistant to atmospheric and decontaminating solutions attack.

The surface contamination check is performed in areas of mandatory control and in areas of periodic control. The mandatory control areas include the accessible surfaces as follows:

– cask lid;
– cask sides and exposed top surfaces;
– protruding structural components;
– areas near drain ports and penetrations for instrumentation;
– wagon side walls in the region of vent ports;
– wagon steps;
– wagon floor around the cask;
– wagon handrails.

The periodic control areas include:

– wagon roof (internal and external);

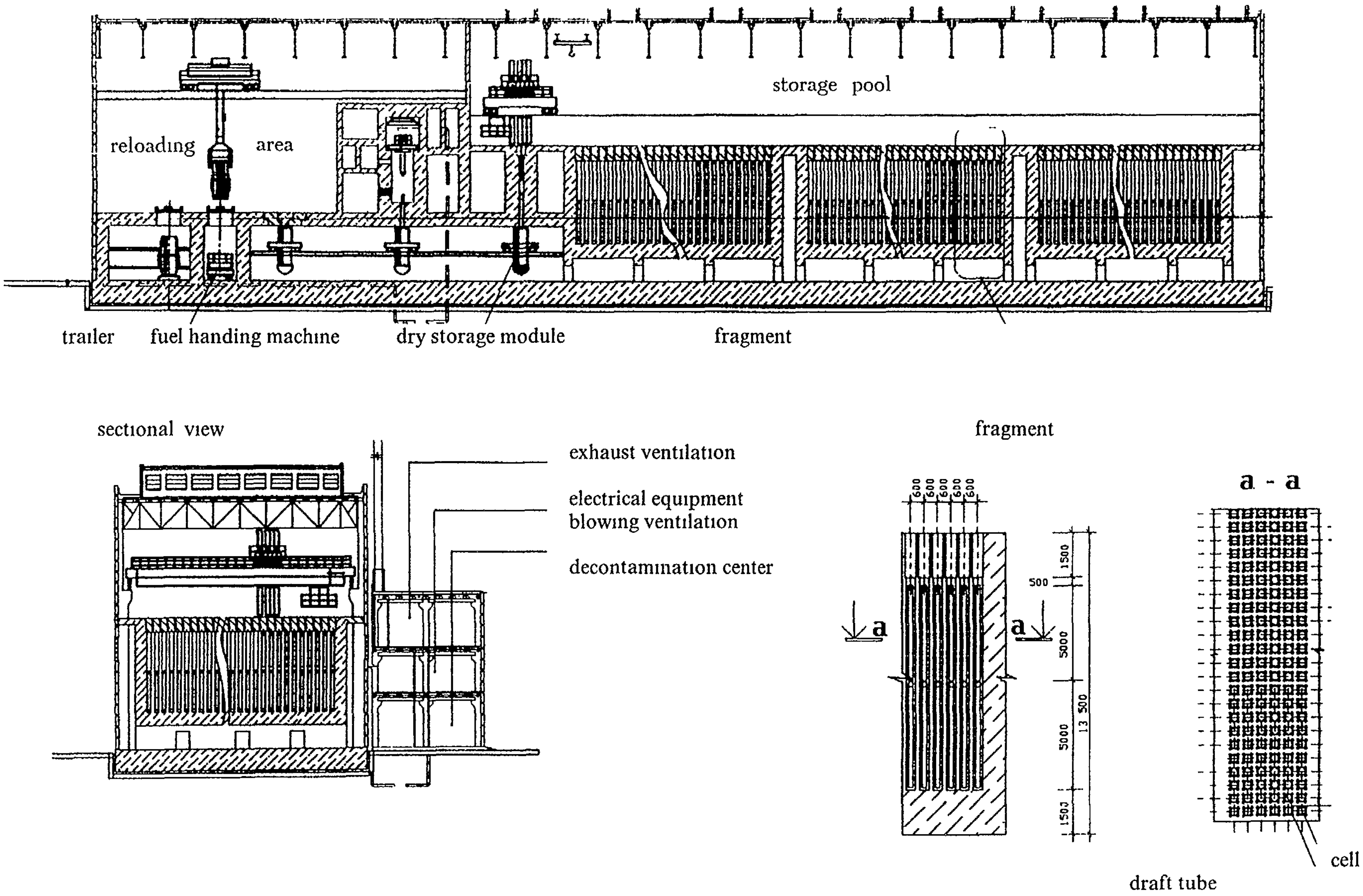


FIG V 17 Long term dry storage facility for spent nuclear fuel for RBMKs

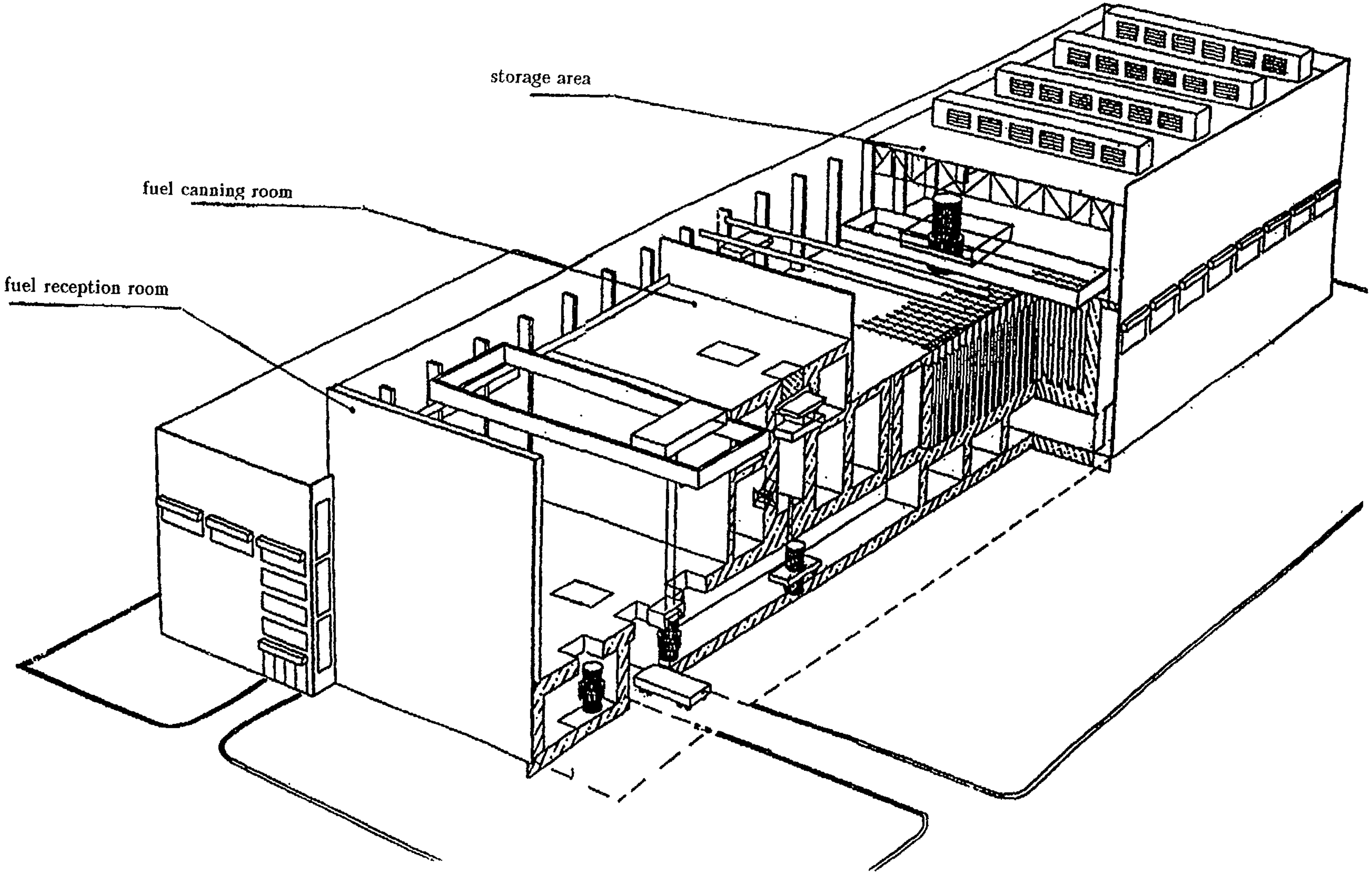


FIG. V.18. Long term dry storage facility in ferroconcrete block.

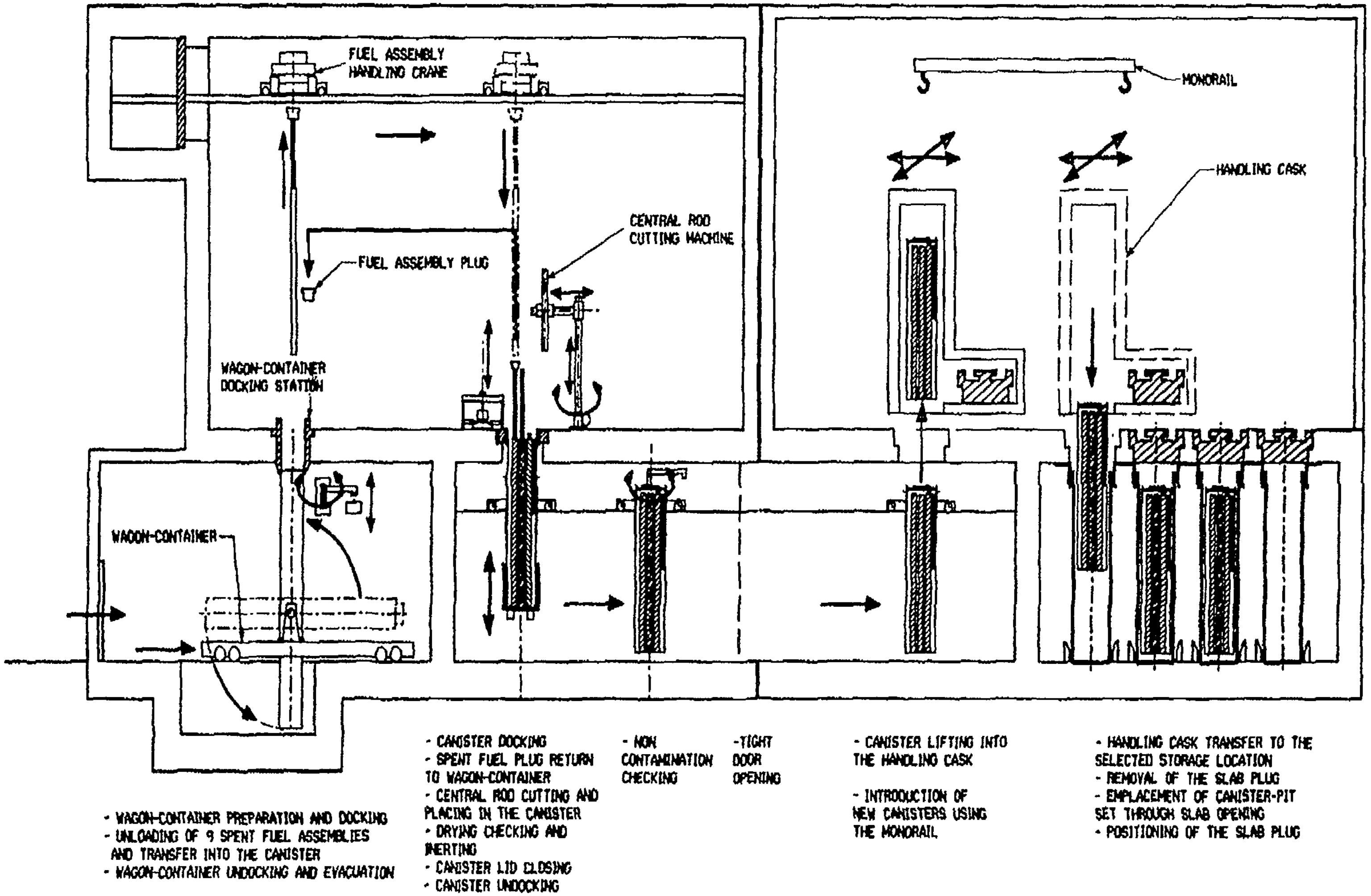
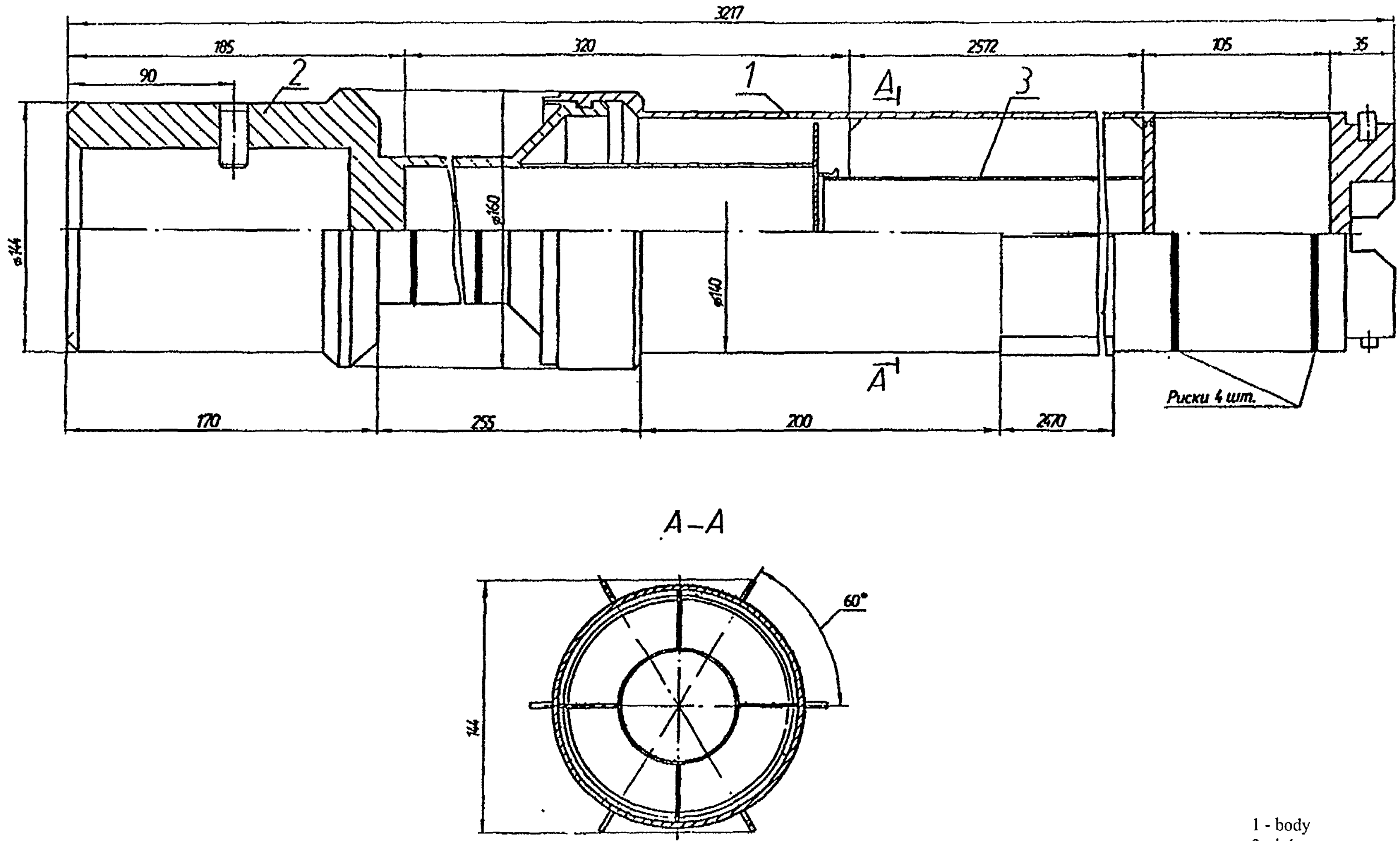


FIG. V.19. Dry storage facility of CASCADE type — joint design SNG/MO AEP for RBMKs.



1 - body
2 - lid
3 - center tube

FIG V 20 Can 24/Canister 24

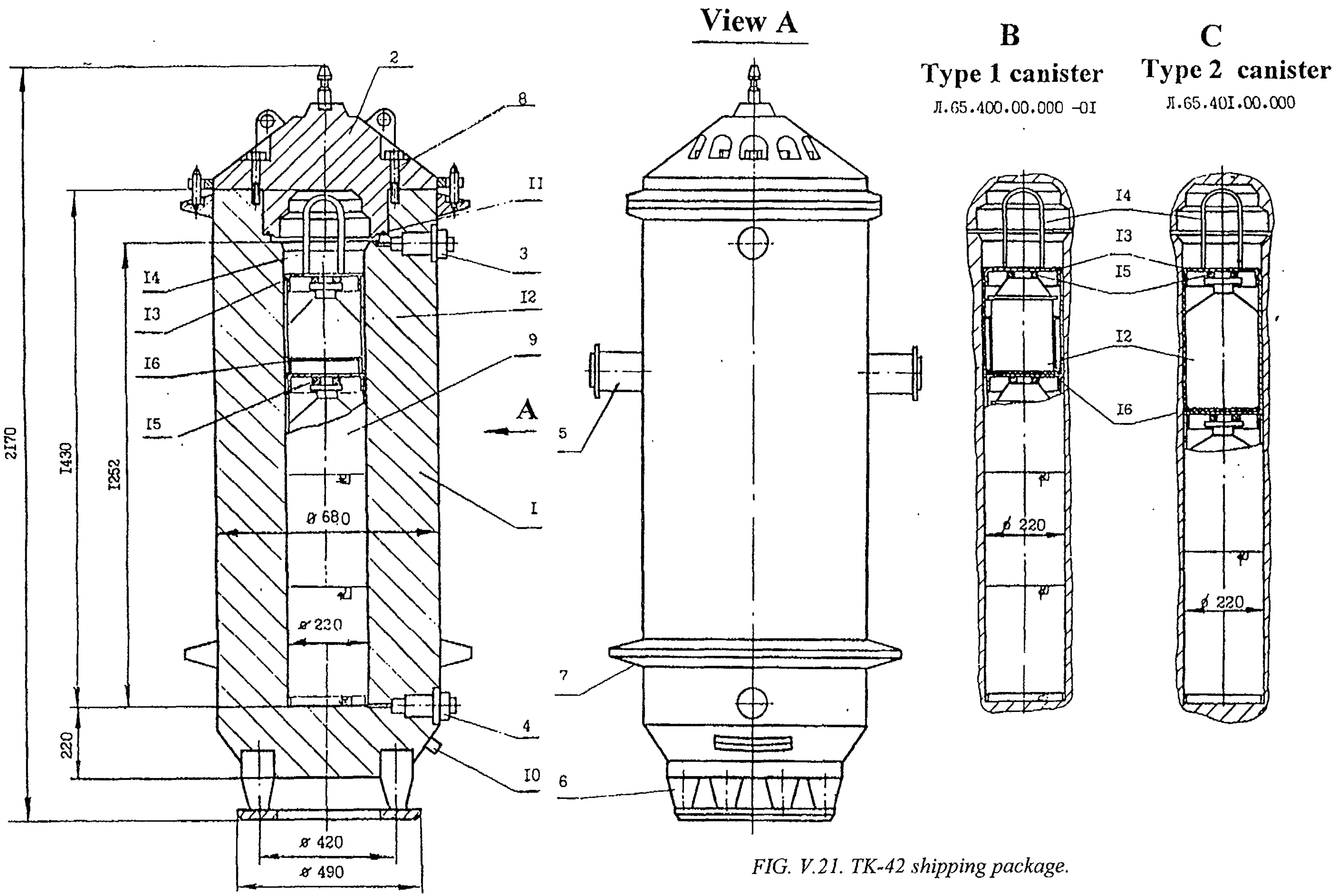


FIG. V.21. TK-42 shipping package.

1 - body	5 - trunnion	9 - type 1 canister	13 - canister lid
2 - lid	6 - shock absorbers	10 - rib	14 - clamp
3 - lock device	7 - shock abosorbing ring	11 - resin seal	15 - support of microporous resin
4 - lock device	8 - lid fastening bolts	12 - inner container	16 - insert

- vertical part of the external and internal side wall of the wagon;
- wagon floor (non-mandatory areas);
- cask external surface in areas of paint coating damage;
- cask bottom.

Checks for surface contamination in the periodic control areas are carried out once in each transport cycle after unloading the spent fuel at the reprocessing or centralized storage facility (consignee plant) both before and after decontamination.

Non-fixed contamination measurement is carried out using a sample smear. It is recommended to look for contaminated surface points in the periodic control area using a survey or contamination meter with beta-monitor before smear sampling. Smear sampling is performed on a 300 cm^2 surface using a gauze tampon 5 × 4 cm^2, 1–1.5 cm thick. For smear activity, monitoring standard contamination instruments are used.

Contamination of the cask, when it is loaded with spent fuel is prevented through protection of its surface from radioactive contamination with polyethylene film and by barriers put in place to isolate the cask and railway wagon from contamination.

V.11. DECONTAMINATION

Decontamination is carried out by washing the cask with the conventional agents and solutions adopted by the reactor sites (consignor) and the reprocessing/storage sites (consignee). In most cases this involves special purpose remotely operated solution sprinklers for casks and utilizing steam cleaning and chemical baths for the baskets.

Annex VI

SPAIN

VI.1. INTRODUCTION

The Spanish experience with spent fuel transportation casks is limited considering that only Vandellós I Nuclear Power Plant, nowadays under decommission, has regularly sent its spent fuel for reprocessing from the beginning of its operation.

Vandellós I NPP is a French graphite-gas plant type. The fuel element consists of an uranium metallic tube filled with graphite and clad in a magnesium sheath containing 0.5% zirconium with a length of 570.9 mm. The fuel has been renovated during operation. After unloading from the reactor, the fuel elements are placed in cooling pools where they remain for more than 150 days.

Due to the type of sheath and the type of material from which they are made -natural uranium-, these fuel elements are quite vulnerable when submerged in water, even though the pool water is kept at a pH in order of 12 to diminish the magnesium solubility product. In spite of this, the specifications do not permit the fuel to be under water for more than 2 years, and this period is divided between the time that the fuel is cooling off in the Plant and the time it is waiting in the reprocessing plant in Marcoule (France).

VI.2. TRANSPORT CASKS

The packages for transporting the fuel were classified B(U) and two basic cuboid design (COGEMA) IU 09 and IU 17 were used. Another special cask IU 04, cylindrical-shaped, was used for transportation of damaged spent fuel. Both casks IU 09 and IU 17 were lead casks lined with unpainted stainless steel with the four vertical sides covered with vertical fins for cooling. The IU 09 cask cover is fixed with 4 bolts and the IU 17, of a more recent generation, is closed by 30 bolts.

Both types of casks are used to transport the spent fuel by rail in a dry condition using specially designed rail wagons which incorporate a cover for enclosing the cask during transport. The casks were wet loaded in the pool of the Nuclear Power Plant and dry unloaded in the unloading cell of the UP1 reprocessing plant at Marcoule.

VI.3. CASK MANAGEMENT

The reception of any empty cask and the shipping of the casks with spent fuel for reprocessing were controlled by radiation protection specialists that checked the fixed and non-fixed contamination and the gamma and neutron radiation according to the procedures in force.

These inspections concern the irradiation of the load and the irradiation and contamination on the cask and rail wagons. The points to be checked compulsory were indicated in the "Transport Documentation of Radioactive Material" publication.

The maximum permissible non-fixed external surface contamination was checked according to the applicable transport regulation requiremets. The seals, plugs and bolts were checked in routine procedure at each loading or unloading operation and the detected defective elements were replaced.

The risk of contamination is associated with the presence of fission products contained in the fuel and activation products fixed outside the fuel. The procedures concerning acceptance of spent fuel to be transported in the IU 09 and IU 17 casks state that fuel integrity should be demonstrated before leaving the reactor pool. Transportation of damaged spent fuel, previously encapsulated, is done in a special IU 04 casks.

VI.4. DECONTAMINATION EXPERIENCE

Experience shows that the internal contamination of transport casks mainly comprises activation products. External contamination of the casks comes from the products in suspension or in solution in the reactor pool during the loading process. The management of decontamination of the casks can be analysed in two complementary approaches: prevention of contamination and decontamination.

Control of pool water conditions was essential for limiting the spread of cask contamination. The cask loading immersion time in the pool should be minimised if necessary by changing operational procedures.

External decontamination was done during the lifting of loaded cask from the pool, while the cask was still hanging by the crane, by flushing it with hot demineralized water under pressure (30 bar). The washing of external surface should commence immediately following re-emersion from the pool to prevent fixation of the contamination, some difficulties were found when the cask was allowed to dry. After radiological monitoring, if needed, complementary decontamination is done manually wiping the cask surface with a normal detergent powder dissolved in ordinary water.

The maintenance of the casks was made in the receiving facility at Marcoule. Each year a basic maintenance was performed, including check of the contamination. Every 4 years the casks undergo an intensive external decontamination and every 8 years a main maintenance is undertaken, including internal decontamination.

VI.5. LESSONS LEARNED

Prevention of contamination in the external surface of the casks is obtained by:

- Keeping the level of contamination of load pool as low as possible:
  - Procedures for acceptance of the spent fuels -canning of leaky fuel elements;
  - Efficient water clean-up system of the pool.
- Keeping the residence time of cask inside the pool to a minimum:
  - Providing easy handling and loading arrangements;
  - Providing adequate underwater illumination and visibility.

The efficiency of the decontamination procedure should be increased:

- If elimination of the contamination is done as soon as it is detected:
  - After removal from the pool, casks must be decontaminated without delay.

Annex VII

SWEDEN

VII.1. CONTAMINATED TRANSPORT CASKS IN SWEDEN

During summer 1998, problems with contaminated transport casks were discovered and debated in Europe. In Sweden, SKB made an investigation of all transports performed since the start of the regular domestic sea transports in 1985 and up to 1998 from the nuclear power plants to CLAB, the intermediate storage facility for spent fuel, and published a detailed report.

The report indicates that 952 casks (type TN 17/2) were shipped in 702 shipments with the purpose built ship M/S Sigyn. The casks were loaded under wet conditions, but transported in a dry environment. The report shows that none of the casks had left the power plants with contamination above the 4 Bq/cm^2 limit. There are 21 sampling points taken at the top and bottom end of the cask. However, at the reception controls of CLAB, 2% of the 21 896 samples had shown contamination above the limit. The distribution of the measured values is shown in Table VII.1 and the maximum value was 531 Bq/cm^2. Fig. VII.1 shows the distribution of the samples exceeding the limit. One of the main causes of the contamination at the reception controls is believed to be the sweating or weeping phenomena.

TABLE VII.1. DISTRIBUTION OF MEASURED CONTAMINATION

Range in Bq/cm^2	# of Samples
<4	21 434
4–40	441
40–100	18
>100	3
Total	21 896

In August 1998, a meeting with all power plants took place in order to discuss actions to be taken to improve the situation. It was decided to investigate:

- Suitable decontamination detergents;
- Decontamination procedures;
- Sampling procedures and techniques before and after transport;
- Information and education of staff.

The Swedish Radiation Protection Institute issued the following procedures for reporting:

- Surface contamination above the limits of the transport regulations and discovered at the arrival of the cask at the CLAB facility should immediately be reported to the power plant, which delivered the cask. The power plant should investigate possible reasons for the contamination to prevent exceeding the limits in the future;
- Values above 20 Bq/cm^{2}should be reported to the authorities within 5 days;

A yearly report including all measurements above 4 Bq/cm^2 should be sent to the authorities. A follow up of the measurements of transports performed during 1998 showed that two measurements above 20 Bq/cm^2 had been found. During this period 83 casks had been transported to CLAB. From 1750 samples, 21 samples showed values between 4-20 Bq/cm^2. Although the situation has been improved in Sweden, SKB will continue to follow up the development of this matter both in Sweden and abroad.

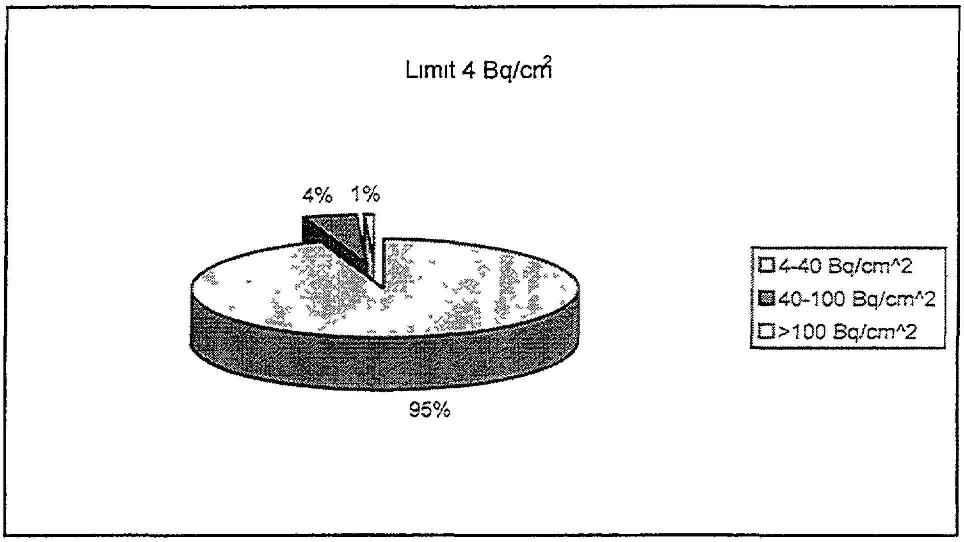


FIG. VII.1. Distribution in percentage of samples exceeded the 4 Bq/cm^2 limit

Annex VIII

UNITED KINGDOM

VIII.1. MODIFICATIONS TO ACCEPT DIFFERENT CONTENTS

Experience with modifications which have not re-engineered the cask body

Following the closure of Dido and Pluto research reactors in 1990, the two "UNIFETCH -L" (DN 1113) MTR fuel flasks, which were used to ship spent fuel from Harwell to Dounreay, were taken out of service. Some time later they were re-commissioned and prepared for the transport of several hundred elements from the Belgian MOL BR2 reactor to Dounreay for reprocessing (see Fig VIII.1). To carry this fuel a new basket was designed and two manufactured to meet the requirements for carrying fuel with a slightly higher U-235 mass content than the existing certificate permitted.

This work involved a reassessment of the thermal loading and a reworking of the criticality calculations. Following this, the B(M)F certificate was re-issued. The new basket was made from a nickel-plated carbon steel casting with holes drilled through to accommodate the fuel elements. This is a completely different fabrication from the earlier design, which was of a plate-type construction that produced a close-fitting square-matrix type of multiple channel cavity to suit the rectangular cross-section of the earlier types of fuel element.

Another design of basket will be introduced in order to transport fuel elements from the Jason training reactor at the Royal Naval College (Greenwich, London) to Dounreay for reprocessing.

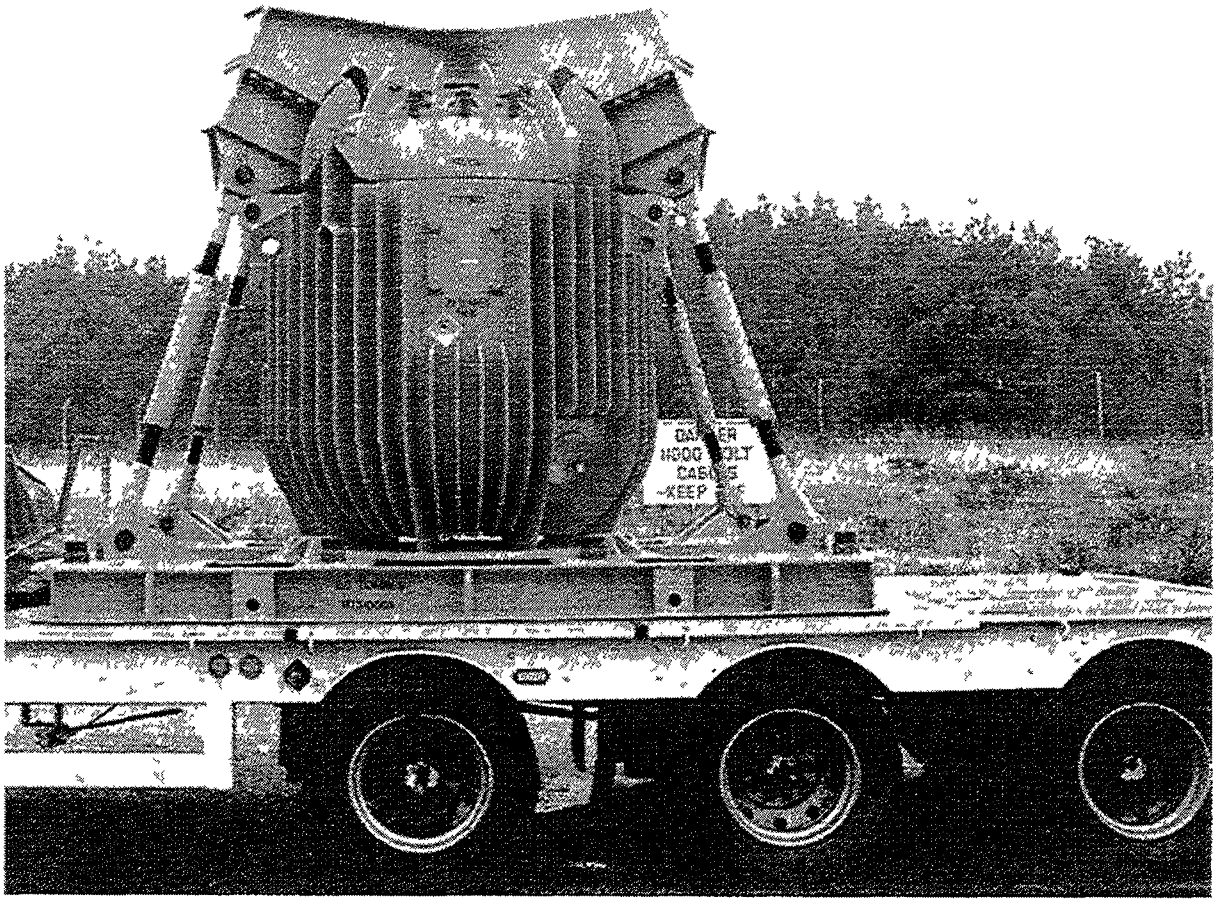


FIG. VIII.1. Transport packaging DN 1113 (Unifetch)

VIII.2. MODIFICATIONS TO MAINTAIN OR IMPROVE SAFE WORKING AND TO MEET REGULATORY REQUIREMENTS

In the early 1990s, the Magnox fuel flasks (see Fig. VIII.2) had their lid inner seal modified to ensure that, in the case of an accident which resulted in fire, any water trapped within the seal interspace could escape into the flask cavity to prevent over-pressurisation of the outer seal. The modification called for the progressive introduction of a fusible-plug type of inner seal on the whole fleet over an eighteen month period. The casks were fitted with a "spring" type outer seal similar to that developed for the other variants to ensure that the required standard of containment was maintained. This replaced a plain circular cross-section outer seal (designed to meet the IAEA's 1973 standards) which could not meet the more onerous conditions required by the 1985/90 regulations. These were fitted with slotted retention pillars to allow the seals' interspace to be dried prior to leak testing before despatch.

More recent modifications to these casks were carried out to enable seal drying to be performed. This involved the replacement of the solid seal retention bollards by slotted pillars to aid the drying process. Subsequently, a modified lid valve was fitted with an "L" section seal which had a slightly deeper section fitted in order to increase initial compression to improve seal performance. Also, the replacement specification called for the seal to be made from a specific formulation of Viton material with defined chemical and physical properties to allow better control of material properties.

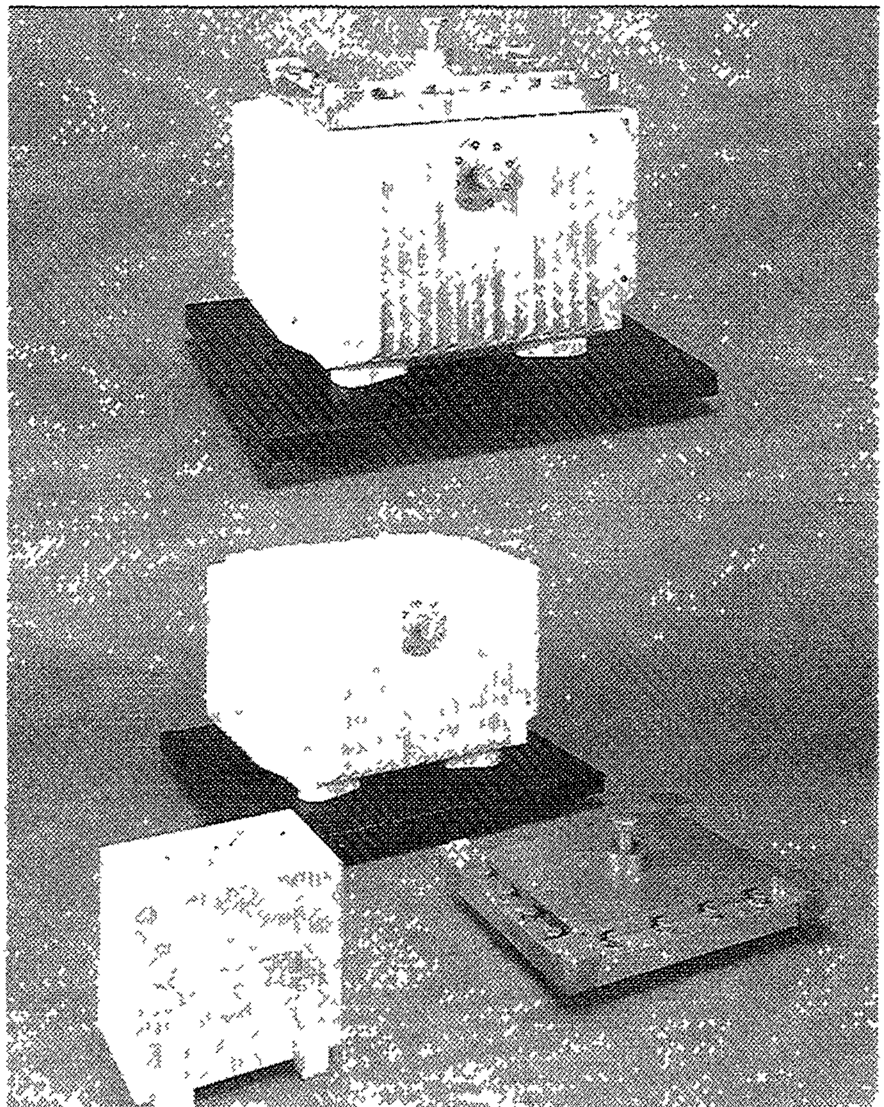


FIG. VIII.2. M2 Magnox flask

During the 1980's at Harwell, certain fuel-handling casks which supported the operation of Dido & Pluto Material Test Reactors were modified to improve the shielding provided at the door and other areas of the body, for example, where the fuel-handling cable entered the body . This work reflected the need to reduce radiation levels encountered by personnel working in the facility. These casks were progressively taken out of service in the mid-1990's when the defuelling and interim decommissioning programme for these reactors was completed.

VIII.3. EXPERIENCE IN THE UNITED KINGDOM

BNFL currently operates a fleet of 85 Excellox and 18 Magnox flasks. These are fabricated in ferritic steel and painted. Fig. VIII.3 shows the unloading of an Excellox Flask. The flasks are subjected to periodic maintenance which requires that every six years they are decontaminated, the surface is cleaned to bare metal and then repainted. The flasks are flushed repeatedly to remove loose contamination and the internal surfaces are cleaned by water jetting. At this stage, the average radioactivity over the whole flask will have been reduced to below 10 MBq, which is below the "free-release" target for disposal in the public domain. Pressure washing has proved to be an effective decontamination technique for reducing levels of contamination prior to grit blasting, where environmental considerations limit the release of airborne particulates from this process. Grit-blasting reduces the contamination to a level well below the free-release target before repainting is done.

It has on occasions been necessary to release flask components off-site for modification and repair so that (commercial machine shops in uncontrolled environments) can be utilised. This has been achieved by carrying out a detailed health physics survey of the total surface of the flask to ensure that there is no part of it that has unacceptable levels of radioactivity. Items which have been subjected to this process included a 7 ton flask lid in which the sealing grooves were damaged during handling, and a flask body which was sent for modification.

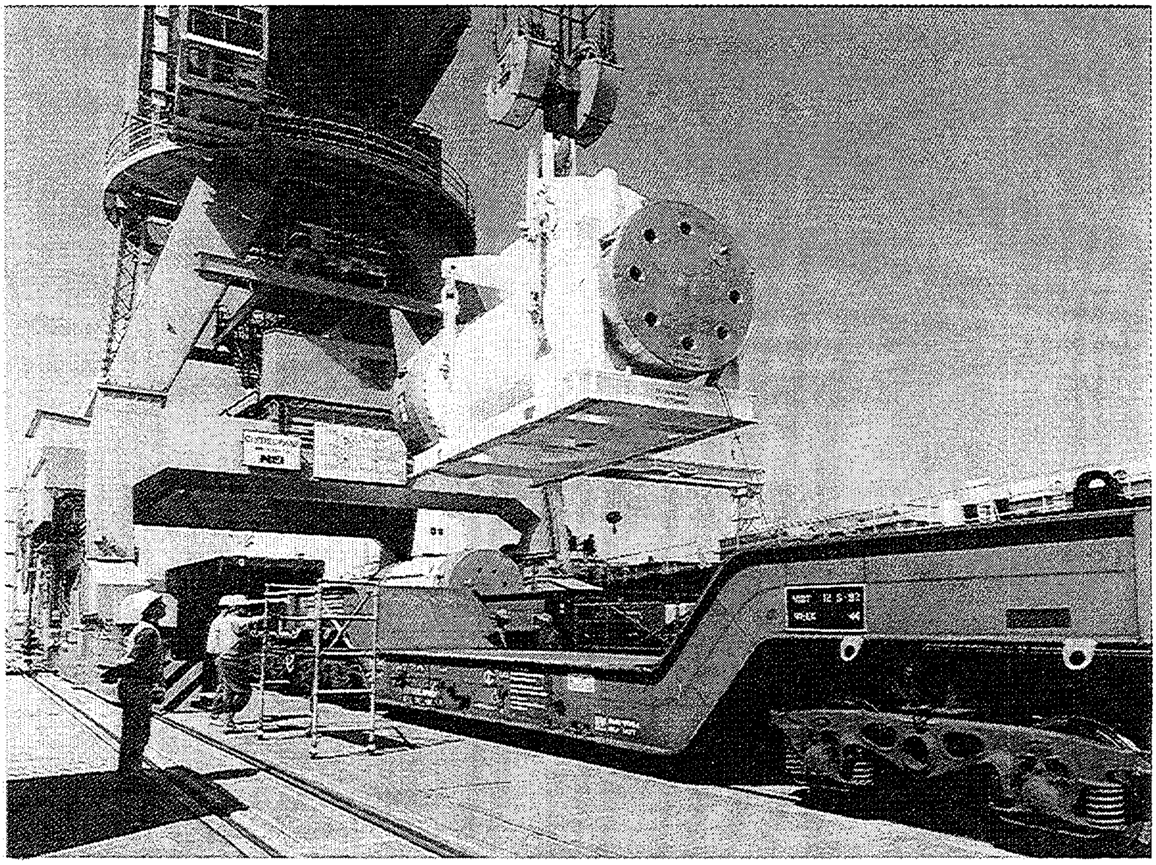


FIG. VIII.3. Unloading an Excellox flask.

Annex IX

UNITED STATES OF AMERICA

IX.1. INTRODUCTION

A combination of laboratory research and nuclear utility experience has shown that spent fuel pool contamination of stainless steel casks can be managed effectively by controlling those factors which appear to have the greatest effect on the cask decontamination process, including:

- spent fuel pool chemistry (contaminant level);
- contact time (submerged in the pool);
- time interval between removal from the pool and start of decontamination;
- surface finish of the stainless steel cask..

IX.2. LABORATORY RESEARCH EFFORTS

An EPRI sponsored test programmes was conducted by Transnuclear Inc. and Virginia Electric Power Co. (VEPCO) to evaluate the effects of surface finish and various cleaning agents on decontamination of stainless steels used in the manufacture of transport and storage casks [IX.1]. Stainless steel coupons with a range of surface finishes were immersed in the VEPCO spent fuel storage pool for varying periods of time. Other coupons had strippable coatings applied. All coupons were rinsed with water immediately after removal from the pool. Some of the coupons were subsequently decontaminated with various household and industrial cleaners. Residual smearable and fixed contamination was then measured to establish the effectiveness of all combinations of finishes and cleaners.

The results of these tests showed that polished steel surfaces retained less fixed contamination than factory finishes (hot-rolled, annealed, etc.). The results also showed that detergents were more effective in removing contamination when combined with water washes and wiping, then just water washing alone. Solvent based strippable coatings also were effective at minimizing contamination levels.

A USDOE sponsored programmes was conducted at Sandia National Laboratories to investigate the mechanisms responsible for cask "sweating" or "weeping" [IX.2]. These terms are used to describe the appearance of removable contamination on a cask which has previously been decontaminated.

This study was conducted in co-operation with the University of Missouri, Columbia, and the Callaway nuclear power plant. Stainless steel rings with different surface finishes were contaminated by suspending them in the Callaway spent fuel pool for varying periods of time. Some of the rings were pre-treated with a chemical treatment (phosphate buffer solution) to saturate or, "block" adsorption sites with the phosphate ion. A key component of the investigation was the theory that chemical ion-exchange mechanisms were responsible for the initial adsorption of dissolved radionuclides and for the conversion of fixed to removable contamination. All test rings were decontaminated using a variety of procedures ranging in aggressiveness from water washing to electrochemical removal.

The results of this study were in concurrence with the EPRI study which showed that polished surfaces adsorb less contamination. The results also indicate that contamination levels can be reduced by blocking the adsorption sites on the highly oxidized surface of stainless steels with non-radioactive ions prior to submersion in a spent fuel pool. Measurements of removable (determined from swipes) and "fixed" contamination on the test rings showed that the removable contamination accounted for only 1-2% of the total contamination remaining after washing. These results indicate that the adsorption of dissolved radionuclides by the cask surface, while submerged in the spent fuel pool, is a primary mechanism for cask surface contamination.

IX.3. INDUSTRY EXPERIENCE

Duke Power Company — Oconee

Duke Power Co. has a licence to store spent fuel at the Oconee site in a NUHOMS-24P horizontal modular dry storage system. The NUHOMS-24P system consists of a sealed dry storage canister (DSC) and a ventilated, reinforced concrete horizontal storage module (HSM). The DSCs are loaded in the spent fuel pool and transferred to the HSMs by utilizing a transfer system which includes a transfer cask, lifting yoke, hydraulic ram, transporter, and positioning system. The transfer system interfaces with the spent fuel pool cask handling crane for loading [IX.3].

The NUHOMS-24P transfer cask at the Oconee site was the first such cask manufactured and was designed to accommodate the limited crane capacity at Oconee. The original exterior stainless steel "skin" was damaged in shipment from the manufacturer. A new stainless steel shell was welded on over the damaged skin at the Oconee site prior to commencement of transfer operations. The new skin was polished to a mirror finish with mechanical grinders and finished with hand polishing using Scotch-Brite(TM) pads. The cask has since been used for over 40 transfers without incident and is routinely decontaminated to less than 1000 disintegrations per minute (dpm, equal to 16 Bq/cm^2) average fixed surface contamination between transfers. The surface was re-polished twice within this period of use to maintain efficiency of decontamination. The decontamination procedure used is typical of many plants in the USA and consists of high pressure water washing with detergent and wiping.

Carolina Power and Light (CP&L)

CP&L uses two IF-300 rail casks to transport spent fuel between reactor sites at Robinson, Brunswick, and Harris stations (see Fig. IX.1). The GE IF-300 can be constructed of either 303 or 304L stainless steel. The cask surfaces have been maintained in the manufactured "as received" condition without refinishing or polishing. The time that the cask is in the pool is kept to a minimum to minimize the absorption of pool water into the cask exterior metal pores. Loading operations are typically conducted in 4 to 8 hours. The time in the pool for unloading is longer, typically 12 to 14 hours, due to the unloading pool being located further away from the fuel storage racks. The loading and decontamination sequence is as follows:

(1) casks surfaces are washed down with de-mineralized water and kept wet until submerged in the pool;

(2) the loading time is kept to a minimum (typically <1 hour);

(3) the cask is rinsed immediately on removal from the pool with de-mineralized water.

After draining and sealing, the cask is moved to the decontamination area where it is decontaminated using a combination of:

(1) spot decontamination as necessary;

(2) high pressure water (2000 lb.);

(3) commercial cleaners including: Formula 409™ household cleaner; Tri-Sodium Phosphate, and Blaze-Off™ Emulsifier Degreaser Cleaner;

(4) high pressure steam;

(5) brushing and scouring;

(6) demineralized water rinse.

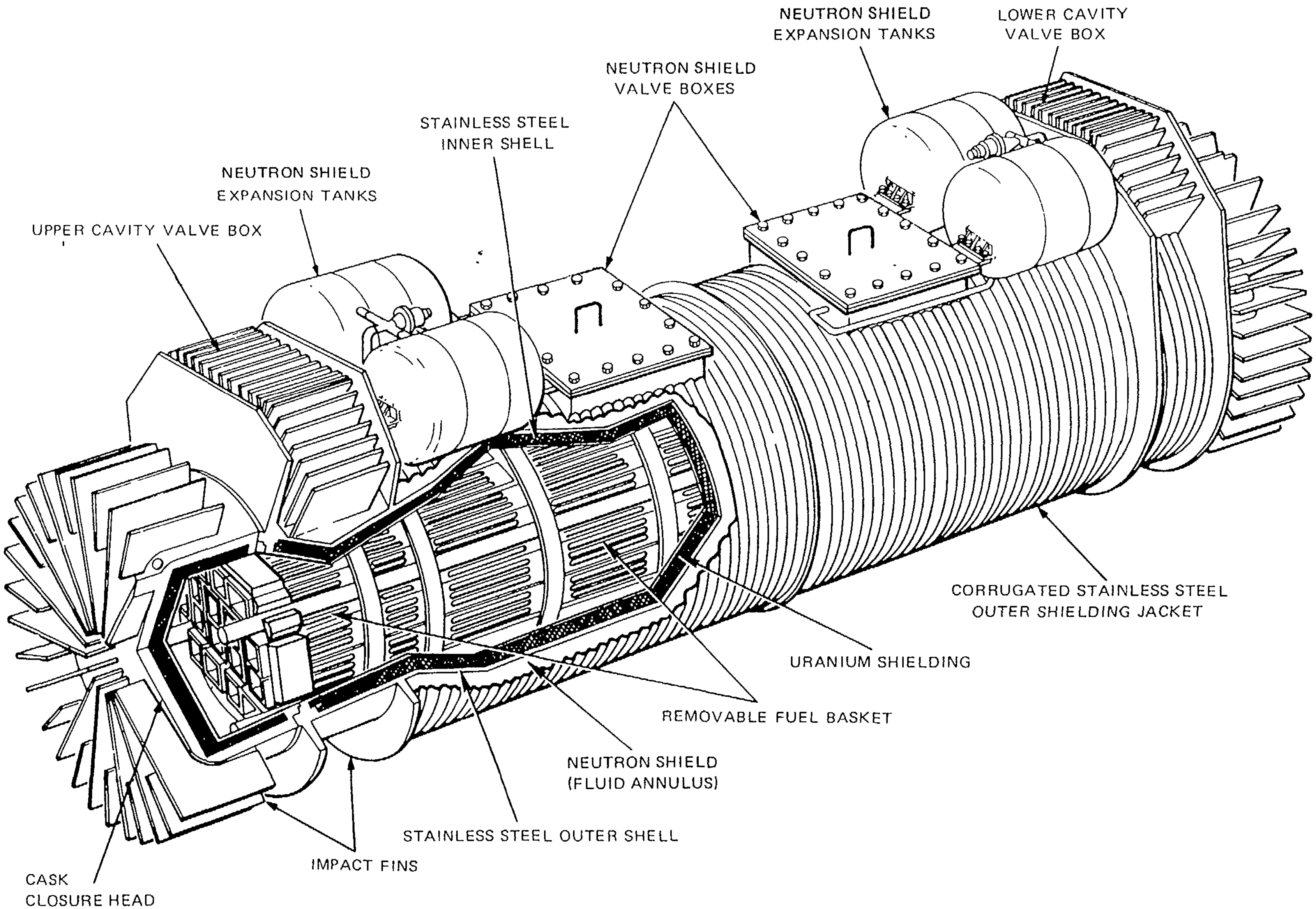


FIG. IX.1. IF-300 irradiated fuel shipping cask.

Fixed surface contamination levels of <200–300 dpm (3–5 Bq/cm^2) are typically reached within a 4–5 hour decontamination operation. Casks are stored outdoors in between transports and are monitored daily for contamination levels. Some incidences of weeping have been observed.

IX.4. CONCLUSIONS

Experience with decontamination of stainless steel casks has shown that an effective decontamination programmes can be achieved with standard industry procedures combined with good storage pool and cask maintenance practices. Polished steel surfaces have been demonstrated to retain less contamination than factory finishes and are less prone to weeping. One recommendation, if practical, would be to wash down the transport cask exterior surfaces before loading operations, preferably with a phosphate containing detergent, followed by a demineralized water rinse. This step has the dual benefit of:

(1) removing road dirt and grime which attract contamination in the pool and thereafter become a source of removable contamination;

(2) blocking ion adsorption sites on the stainless steel surface.

REFERENCES TO ANNEX IX

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ABBREVIATIONS

ALARA	As low as reasonable achievable
AR	At reactor
BNPD	Bruce Nuclear Power Development (Canada)
BWR	Boiling water reactor
CIC	Concrete integrated container
DF	Decontamination factor
DN	Design number; prefix used by UK competent authority followed by a four-figure number to designate the unique "design number" for a cask
DSC	Dry storage container
DSF	Dry storage facility
EDTA	Ethylene diamine tetra acetic acid (CAS: 60-00-4)
HEPA	High efficiency particulate air filter
HLW	High level waste
HM	Heavy metal
IFC	Integrated fuel cask
ISFSF	Interim spent fuel storage facility
ILW	Intermediate level waste
LLW	Low level waste
MEB	Multi- element bottle
MOX	Mixed oxide fuel
MPC	Multi-purpose canister
MSB	Multi-element sealed basket
MTR	Material test reactor
NDE	Non-destructive examination
NUHOMS	Nutech horizontal modular storage system
PWR	Pressurised water reactor
RBMK	Reaktor Bolshoy Moschnosti Kipyaschiy, Russian type of water cooled, graphite moderated reactor
SAR	Safety analysis report
SCO	Surface contaminated object
tHM	ton heavy metal
THWTP	Tritiated heavy water transportation package
TK	Transport Kask, Russian transport cask
USDOE	United States Department of Energy
WWER	Wodo Wodyanoi Energetichecki Reactor, Russian type PWR

CONVERSION FACTORS

Activity in becquerel (Bq) or curie (Ci) (also in dpm, disintegrations per minute)

$1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq}$

$1 \text{ Bq} = 2.7 \times 10^{-11} \text{ Ci}$

$10^3 \text{ dpm} = 17 \text{ Bq}$ (APPROX.)

Specific activity in Bq/cm^2 or Ci/cm^2

$1 \text{ Ci/cm}^2 = 3.7 \times 10^{10} \text{ Bq/cm}^2$

$1 \text{ Bq/cm}^2 = 2.7 \times 10^{-11} \text{ Ci/cm}^2$

Dose equivalent in sievert (Sv) or rem

$1 \text{ rem} = 1.0 \times 10^{-2} \text{ Sv}$

$1 \text{ Sv} = 100 \text{ rem}$

Dose rate in sievert per hour (Sv/h)

$1 \text{ Sv/h} = 100 \text{ rem/h}$

$1 \text{ μSv/h} = 10^{-4} \text{ rem/h}$

PACKAGE TYPES

(see Ref. [2])

A	Type A package
B(M)	Type B(M) package
B(U)	Type B(U) package
C	Type C package
*F	Package * for fissile material
IP	Industrial package

GLOSSARY

actinide. Actinides are elements with an atomic number between 89 and 103, inclusive. All are radioactive and most are formed by neutron capture in thorium, uranium or plutonium.

adhesive film. A protective film which is adhered through heating to the cask.

aggressive decontamination techniques. Techniques such as acid cleaning, electrochemical, and abrasive mechanical treatment.

air-cooling. Heat removal with air by either natural or forced convection, applied in dry storage.

basket. (a) An open **container** used to hold **spent fuel** during **handling**, **transport** and **storage** operations.
(b) A structure used in **casks** which facilitates structural support, criticality control and heat transfer from spent fuel.

bay. (a) Specially equipped area in spent fuel management facilities for receiving, loading and maintaining of **containers**.
(b) See **pool**, also basin, pond.

burnup. A measure of consumption of fissile content of reactor **fuel**, expressed as either the percentage of **fuel** atoms that have undergone fission or the amount of energy released per unit mass of **fuel** in the reactor. Units normally used for the latter are megawatt-days per ton of uranium (MWd/tU) or **heavy metal** (MWd/t HM).

canister (can). A **container** used to isolate **fuel**.

cask. A massive **container** (various) used in the **transport**, **storage** and eventual **disposal** of **spent fuel** and other radioactive material. It provides together with the basket, criticality control, **shielding**, mechanical, chemical, and radiological protection and dissipates heat from the **fuel**. Casks can be single, dual, or multi-purpose.

cask lid (closure). A removable cover for closing and sealing a **cask**.

cladding, fuel. An external layer of material (for example Zircaloy, stainless steel, magnesium alloys) directly surrounding **fuel** that seals and protects it from environment and protects the environment from radioactive material produced during irradiation. For HTR fuel particles, protective layers are known as coatings.

cladding defect. Through-wall penetration in **fuel cladding** caused by a manufacturing fault or by in-reactor service and/or post-irradiation **handling** and **storage**. It may lead to the release of radioactive material.

confinement. The isolation of radioactive material in such a way that it is not dispersed into the environment in an unacceptable manner.

container. A general term for a receptacle designed to hold **spent fuel** to facilitate movement and **storage** or for eventual **disposal**.

containment. (a) Retention of radioactive material such that it is prevented from dispersing into the environment or so that it is only released at acceptable rates.
(b) A structure or system used to provide such retention of radioactive material

cooling. The removal of heat in nuclear fuel, by a suitable medium (liquid or gaseous). In spent fuel management systems, usually the removal of the **decay heat** of the **spent fuel**.

cooling system. A system which removes the heat generated by **spent fuel**. The system can consist of a wet or dry process and uses natural (passive) or forced (active) means.

cooling time, fuel. The time **spent fuel** has cooled since discharged from the reactor core.

crud. Particulate deposits on **fuel assembly** surfaces, which arise from species circulating in the reactor coolant. Neutron activation or **fission products** cause the crud to become radioactive.

decay. The reduction in radioactivity of **radioactive isotopes** with the passage of time.

damaged fuel. See **failed fuel**.

decommissioning. Action taken at the end of the useful life of a nuclear facility and/or equipment in retiring it from service with adequate regard for the health and safety of workers, public and protection of the environment. The ultimate goal of decommissioning is unrestricted release or use of the **site**.

decontamination. Removal or reduction of contamination by physical and/or chemical processes usually to achieve a specified level of activity.

decontamination factor. The ratio of radioactive contamination levels before and after **decontamination**, which is a quantitative criterion of decontamination effectiveness.

defective fuel. See **failed fuel** and **damaged fuel**.

disposal. Emplacement of **spent fuel** or **waste** in an approved, specified facility, e.g. a **repository**, without intention of retrieval.

dry loading/unloading. Handling of **spent fuel** in a dry environment (air or inert gas).

dry storage. Storage of **spent fuel** and related components in a gas environment such as air or inert gas. Dry **storage facilities** include **casks, silos** and **vaults**.

dual purpose cask. A **cask** licensed for both **transport** and **storage** of **spent fuel**.

failed fuel. Fuel with a **cladding** defect or structural damage which may require special measures in subsequent **handling, transport** and **storage**.

fertile material. Nuclides which can be converted to fissile nuclides through neutron capture (e.g. thorium-232, uranium-238, plutonium-242).

filler (cover) gas, container. (a) Gas used to fill **ullage space** in wet transport and storage **containers**. (b) Gas used in dry **canisters, casks** or **cells**.

fissile material. Material consisting of **fissile nuclides**.

fissile nuclides. Nuclides which are fissionable by neutrons of any energy (e.g. uranium-233, uranium-235, plutonium-239, plutonium-241).

fission product. Any radionuclide or stable nuclide resulting from nuclear fission including both primary fission fragments and their **radioactive decay** products.

fixed contamination. Contamination other than **non-fixed** contamination, which cannot be easily removed from the surface of a cask.

frisker. A surface scanning radiation detection instrument.

fuel assembly. A geometrical array of **fuel rods**, **pins**, plates, etc., held together by structural components such as **end fittings**. Also called a **fuel bundle, fuel cluster** and **fuel element**.

fuel failure. See **failed fuel**.

fuel, nuclear. (a) **Fissile** and **fertile material** used in a nuclear reactor for the purpose of generating energy.
(b) See **fuel assembly**.

fuel rod. A basic component of **fuel** fabricated for service in a reactor, comprising **fissile** and/or **fertile material** (oxide or metal) in a **pellet** form sealed in a metal tube (see **fuel element**, **cladding** and **fuel assembly**); also called **fuel pin** and fuel subassembly.

handling. Movement of a component (e.g. **spent fuel assembly**, waste, cask) to allow transport, storage, reprocessing and disposal operations.

hot-cell. A facility to handle, process, and/or examine radioactive materials and which provides **containment**, radiological **shielding**, remote **handling** and viewing.

interim (extended, intermediate, long term) storage. Storage of **spent fuel**, which takes place after a limited storage period at the reactor pool, until it is retrieved for further processing. Additional **storage** may be involved. The total **storage period** ends when the **spent fuel** is reprocessed or placed in a geologic **repository**.

irradiated fuel. Fuel that has been exposed to neutron radiation in a nuclear reactor.

isotope. Nuclides having the same atomic number (i.e. the same number of protons in the nucleus) but different mass.

licence. The **authorization** issued to the applicant by the **regulatory authority** to perform specified activities related to **spent fuel management** activities (e.g. operation of a facility, **transport** of **spent fuel**).

licensee. The holder of a **licence**.

licensing. The process of granting a **licence**.

liner. A protective layer or covering, which is normally corrosion resistant and capable of being decontaminated, to prevent migration of material to and from a component of the facility (e.g. caisson, **cask, storage pool**).

loose contamination. Identical to non-fixed contamination.

modular design. A concept that allows sequential addition of similar structures or components to increase storage, treatment and handling capacity as the need arises.

monitoring. (a) A systematic activity to evaluate specified parameters, e.g. temperatures, impurity or radiation levels, etc.

(b) A remote visual check of handling operations. The purpose is to ensure safe operation of the facility.

multi-purpose canister (MPC). A canister-based system used in combination with various **overpacks** for the **storage**, **transport** and **disposal** of **spent fuel**. The intent of the system is to seal the **canister** after initial loading and never reopen it. The design must be acceptable for **storage**, **transport**, and **disposal**.

neutron absorber. Solid or liquid material that absorbs neutrons and may reduce reactivity, prevents criticality, and provides some neutron **shielding**. Also called poison.

neutron shield. Shielding using material specially selected to attenuate neutrons.

non-fixed contamination. Contamination that can be removed from a cask surface by wiping or washing during routine transport conditions

on-site transport. Transport of **spent fuel** within the boundaries of a licensed facility (**transfer**).

package. The **packaging** with its radioactive contents as presented for **transport**.

packaging. The assembly of components necessary to enclose the radioactive contents completely. It may consist of a box, drum, **container** or similar receptacles.

penetration. An opening or conduit through a wall of **container** or **containment**.

plug. A component to seal a penetration or openings in a facility or **cask**. The plug may also provide **shielding**.

pool. A water-filled facility designed and operated for storing, cooling, maintaining and **shielding spent fuel** assemblies or rods. Also basin, bay, pond.

primary cooling system. A system which removes the heat generated in the reactor core due to the fissions occurring there.

primary lid. The lid to seal the primary enclosure of a **canister** or **cask**.

protective skirt. (a) Covering placed around a **cask** to avoid or limit contamination arising from pool water with the intention of avoiding a difficult **decontamination** on finned surfaces.

(b) Metallic band attached to a **spent fuel pool** wall at its water level to facilitate **decontamination** of the pool wall.

quality assurance. Planned and documented systematic programme of controls necessary to provide adequate confidence that an item, process, or service will satisfy given requirements for quality.

radioactive isotopes. Unstable isotopes which undergo spontaneous change, i.e. radioactive disintegration or radioactive decay, at defined rates.

radioactive contents. The **spent fuel** and any contaminated solids, liquids or gases within its **container**.

radioactive waste. See **waste, radioactive**.

regulatory authority. A national authority or a system of authorities designated by a Member State, assisted by technical and other advisory bodies, and having the statutory authority for conducting the licensing process, for issuing licences and thereby for regulating **spent fuel management**. The regulatory authority will consider the siting, design, construction, commissioning, operation and decommissioning or specified aspects thereof.

safety system. A system both to assure safe operation in normal circumstances and limit the consequences of abnormal occurrences and accident conditions.

secondary lid. The lid which may be used variously to provide additional **shielding**, monitoring interspace, structural physical protection, and additional corrosion resistance.

shielding. A selected material interposed between a source of radiation and personnel or equipment in order to attenuate radiation.

shipment. See **transport**.

shot peening. A process consisting of shooting miniature iron balls on a surface, in order to harden it or to prevent further crack growth by introducing compressive stresses into the material.

site. The area containing a nuclear facility, defined by a boundary and under effective control of the operating organization.

site, licensed. A controlled area defined by the site **licence** on which specified nuclear activities are permitted.

spent fuel. Irradiated fuel not intended for further use in a reactor without **refabrication** or **reprocessing**.

spent fuel management. All activities, administrative and operational, that, following **discharge**, are involved in the **handling**, treatment, **conditioning**, **transport**, **storage** and **reprocessing** of **spent fuel**, recycling of **fissile** and/or **fertile materials** and its final **disposal**.

storage. The process of emplacement and retention of **spent fuel** in a safe and retrievable manner. This implies an facility affording adequate environmental and physical protection. **Shielding**, **containment** of radionuclides, criticality control, and **decay heat** dissipation must be provided.

storage facility/system. An facility used for the **storage** of spent **fuel unit**s and related components (see **spent fuel storage**).

storage module. A defined unit for storing multiple **fuel elements** and to which similar units may be added sequentially (e.g. **cask**, **vault** or **silo**).

storage period (time). The length of time **irradiated fuel** resides in a **storage facility**.

storage pool. A specially designed **spent fuel pool** for **interim storage** and associated operations

storage rack, fuel. A structure in a wet or dry **storage facility** that holds **spent fuel assemblies** or storage **container** in a configuration to control criticality, provide heat removal, facilitate **fuel handling**, and to prevent seismic damage.

sweating. See **weeping**.

transfer. See **on-site transport**.

transport. Movement of **spent fuel** from one licensed facility to another in the public domain using **transport packages** under prescribed conditions and regulations, in respect of which there are international guidelines.

transport cask (packaging). A heavy protective **container** used in the **transport** of **spent fuel**, and which dissipates heat, and provides **shielding** and **containment**, and prevents criticality. Transport cask could be wet and dry.

transport package. The packaging with its radioactive contents as presented for transport. Package performance standards are given in IAEA Safety Series No. ST-1, Regulations for the Safe Transport of Radioactive Material.

trans-shipment. A US term for **transport** of **spent fuel** between **storage facilities** at two reactor sites.

ullage. Excess space in a liquid filled **package**.

waste, high level (HLW). (a) The radioactive liquid containing most of the **fission products** and **actinides** originally presented in **spent fuel** and forming the residue from the first solvent extraction cycle in **reprocessing** and some of the associated waste streams.
(b) Solidified high level waste from (1) above and **spent fuel** when it is declared a waste.
(c) Any other waste with a radioactivity level comparable to (a) or (b).

waste, low-level (LLW) and intermediate-level (ILW). Radioactive wastes in which the concentration of or quantity of radionuclides is above clearance levels established by the **regulatory authority**, but with a radionuclide content and thermal power below those of **high level waste**.

waste package. The product of conditioning that includes the waste form and any **container** and internal **barriers** (e.g. absorbing materials and **liner**), as prepared in accordance with requirements for handling, transport, storage and/or disposal.

weeping. Weeping or **sweating** is a phenomenon that causes the gradual release of radioactivity from a cask surface over a period of time (these terms are used to describe the appearance of non-fixed or loose contamination on a cask which has previously been decontaminated).

wet loading/unloading. Handling of **fuel assemblies** or **elements** into/from transport **containers** under water.

wet storage. Storage of **spent fuel** in submerged in water, also called pool storage.

wet storage systems. Spent fuel storage pools and their auxiliary components.

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