COMPLEX METHOD OF FISSILE MATERIAL PACKAGES SAFETY SUBSTANTIATION

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INTRODUCTION

Nuclear fissile materials (NFM) transport safety in Russia is assured by the state regulation system on the basis of the Law of Russian Federation "About utilisation of atomic energy", which came into force in 1995.

The main regulatory document, regulating NFM shipment safety in Russian Federation is "Basic regulations for safety and physical protection of nuclear materials transportation" (OPBZ-83). These regulations cover NFM shipments by rail, by road and by sea, shipment by air is regulated by "Provisions for NFM transport by air" (PVP-93).

OPBZ-83 determine requirements to packages, shipment safety confirmation procedures, shipment order, requirements for physical protection assurance, an order of actions in emergency situations. The regulations are developed on the basis of IAEA Regulations-73 for safe shipment of radioactive substances with IAEA draft Regulations-85 being taken into account. Receipt order of the approval for transport is determined by "Temporary provisions for the order of issue of certificates-approvals"(PVSR-92). Certificates-approvals are issued by a RF Competent Authority - the Ministry for Atomic Energy of Russian Federation (Minatom RF). Materials examination confirming shipment safety and transport technology development are carried out by basic organisations of the Competent Authority. The basic organisation for NFM transport is All-Russian Project and Research Institute of Complex Energy Technology (VNIPIET). Transport safety supervision is carried out by the federal Supervision of nuclear and radiation safety of Russia (Gosatomnadzor).

Concrete conditions of shipment are determined by the Federal Regulations for dangerous goods shipments, which are in force for all modes of transport. By air transport "Technical instructions for safe shipment of dangerous goods by air" ICAO are taken as federal regulations.

In 1996-1997, the working group of all organisations and state authorities concerned has developed new "Regulations for the safe transport of radioactive materials (PBTRM-97). These regulations conform entirely to international regulations, concerning safety of radioactive materials shipment, including IAEA Regulations-96. At present PBTRM-97 are submitted for approval. They are anticipated to be put in force in 1998. As soon as, they will be in force, regulations of shipment of dangerous goods by all modes of transport will be brought into accordance with them.

OBJECTIVES

Radioactive materials, being transported between industrial objects can be conventionally divided into three basic kinds:

- nuclear fissile materials (NFM), including concentrates, different components of uranium, powders, pellets, metal granules and other semifinished articles;
- fresh nuclear fuel including fuel rods, fuel assemblies, cassettes, and other articles, intended for irradiation in reactors;
- spent nuclear fuel.

For shipment of aforesaid kinds of radioactive materials transport packagings (packages) of different design are used.

According to Russian and International regulations, shipment safety and conformity to the regulations requirements should be confirmed by following procedures:

- by testing of prototypes or actual specimens with contents, completely simulating actual contents of packagings;
- reference to previous satisfactory demonstration of a sufficiently similar nature;
- by testing of models, all scale factors and assumptions being taken into account;
- by calculations provided that the procedure is generally accepted.

Transport packagings, intended for spent fuel shipment, are thick-walled steel containers of diameter to 2,5 m, height (length) to 12 m, mass more than 100 t, produced in small batches. For packagings of this type reliable procedures of strength and heat transfer calculation are available. Therefore, because of high cost of the packagings and for lack of an appropriate rig base in Russia, their full-scale tests are not performed, while principal tests of models are carried out to confirm calculation procedures.

As for the two other sub-types of packagings (for shipping of NFM and fresh fuel), they are thin-walled welded constructions of mass about 10 t, including components of light alloys and non-metal materials, valves, tightness check devices and other units.

The constructions strength calculation procedures available under dynamic loading give as a rule reduced strength characteristics, leading in designing to unjustified increase of bearing unite thickness and mass some parts and so on. Therefore, in practice, for packagings of this type full-scale testing is the main way of safety substantiation.

TEST RIGS

Packaging tests are carried out at specially created rig bases. Such bases are at some enterprises - "Machine-Building plant" in Electrostal, "Novosibirsk Chemiconcentrates Plant", VNIITF, PO "Majak", VNIPIET. Some enterprises have sites and equipment adopted for individual tests.

The rig base of VNIPIET in Sosnovy Bor was put into operation in 1990. Practically all tests, to foresee by regulations, are performed at the rig base.

The rig base includes:

- Impact test rig;
- Fire test rig;
- Static test rig;
- Tightness test rig.

Rig construction is developed in accordance with requirements of Regulations OPBZ-83 and IAEA-85.

Impact test rig is intended for testing of articles under conditions of free drop onto rigid base. Impact rig construction is a framework on four columns arranged at the concrete base.

A target for specimens drop is a concrete base of 8,0x6,0x6,5 m, mass about 1000 t with a steel plate of thickness 100 mm on it. The rig is completed with a pin, being arranged in any point of the target, a rod for penetration test and a plate of mass 500 kg for dropping onto specimens.

Maximum height of the rig electric hoist hook lift is 15 m, maximum mass of the load, being lifted is 10 t.

For remote load dropping on the target a tripping device with electric release complete with the rig equipment is provided for. The rig equipment includes: instruments for recording and measuring acceleration, deformation and stresses, a speed camera and a video.

Fire rig is intended for articles testing in open flame of liquid fuel (petrol, kerosene). The fire rig construction is a right-angled pallet, placed on the concrete base. The pallet is divided into sections for restriction of burning area.

In its central part two pairs of supports, intended for setting up an article being tested, are provided for. The rig is equipped with a wind protection enclosure a smoke decrease system, a system for supports and metalwork cooling and a system of forced air feed into the burning zone.

Average flame temperature in tests is 850-900 °C. The fire rig is equipped with instruments for temperature measuring in 50 points of the article and in 6 points of flame.

Static test rig is intended for articles testing by static loading by mass 5-fold of the article mass. The rig is a site and a set loads, being set upon the article by crane.

Tightness cheek rig is intended for articles check by a helium probe. The rig is mounted in laboratory-wagon and equipped by the helium leak detector PTI-10 and a set of necessary fixtures.

TESTING TECHNOLOGY

At different enterprises almost all the packaging designs are tested according to the programs worked out by VNIPIET and agreed with RF Gosatomnadzor.

The most rigid tests for the packages simulate the emergency situations during transport: free drop from a 9 m height, drop onto a pin and getting into the fire. In accordance with the current regulations the free drop tests should be performed with the package in a position to get the maximum damage under a subsequent thermal test. To determine such positions the following provisions shall be made.

In developing the program and tests procedures, the package design is analysed from the viewpoint of it components strength in different directions of dynamic load, with consideration for the package contents behaviour under the impact conditions. Checking calculations are performed for possible deformations of the package dropped in different positions onto a rigid base and a pin, and the most vulnerable positions of the package are determined. Account is also taken of the testing experience available with other package designs close enough to those considered.

As a rule, two or three specimens are tested, one or two of these are subject to preliminary testes and one - to final (assessment) tests. In the test the specimens are filled with mass - and - sized simulators of the contents (sand, iron pellets, metal rods, etc). Tests of the packages for fresh fuel, conducted on the territory of the enterprises - fuel manufacturers, are performed with actual fuel.

In the preliminary tests the first specimen is tested in a sequence of positions as stipulated in the program, to determine the greatest damages, if such vulnerable positions are numerous and cannot be tried on one specimen, because of its getting completely distructed, another specimen is used. After each drop the specimen is visually inspected, its tightness is checked (if envisaged in the program), the lid is opened, and the package inner parts and contents state is examined. To restore the specimen, the parts damaged may be repaired and replaced. After the preliminary tests, the commission determines the specimen drop position susceptible of the maximum damage.

Then, an individual specimen is put to the whole complex of tests simulating the normal transport conditions (drop from a height of 0,3-1,2 m, impact with a rod, static compression, water sprinkling) and emergency situations (drop from a 9 m height, a 1 m drop onto a pin, fire test). It should be taken into account, that the regulations allow to perform each normal operation test on different specimens; so the approach adopted in our practice is more strict than that stipulated by the regulations.

It should be also noted, that the Russian rules OPBZ, include the temperature range from - 50 °C to + 38 °C for the packaging operation; therefore, during the tests it is necessary to confirm the package structural strength at low temperatures. The transport packagings for nuclear fissile materials are generally made of austenitic stainless steels or cold-resistant carbon steels, so the results of mechanical damage tests performed at the normal temperature will be valid for the whole operating temperature range.

However, the fresh fuel packagings designed in previous years are made, for the most part, of steel 20 or st.3 which are not cold resistant.

To confirm the package structural strength at low temperatures, tests by 9 m drop and those by 1 m drop onto a pin are performed on a specimen cooled to - 50 °C.

For these tests to be conducted, a chamber to cool packages of up to 10 m long (package TK-C6 for RBMK fresh fuel) was constructed at Machine-Building Plant, the manufacturer of a greater part of the fresh fuel packagings

By now, practically all types of the fresh fuel packages, which are made of carbon steels or have attaching parts of these steels, have been tested at - 50 °C.

After the mechanical test completed, a damaged package is subject to thermal tests. The OPBZ rules stipulate that the thermal test should be conducted, at the specimen temperature, equal to the maximum operating temperature i.e. + 38 °C. This is not so in practice, and the tests are carried out at the temperature of - 10 °C to + 25 °C, i.e. the package components temperature measured during the tests is some tens of degrees less than that really possible.

For packages with nuclear fissile materials and fresh fuel, many of which either involve the parts of non-metallic and fusible materials or have limitations on the greatest possible temperature of the product transported, this discrepancy between the measured and real temperatures is impermissible. To ensure the test representativeness, from the results of temperature measurements, taken of different points outside and inside the package, checking calculations of the package temperature fields are carried out, with the initial temperature of + 38 °C taken into consideration, for further assessments of the package compliance with the regulatory requirements to be based upon.

Moreover, the preliminary calculations of criticality and radiation safety in the package design, i.e. prior to the tests, are performed with due regard for the package postulated damages; so, in case of difference between the actual damages caused by testing and those assumed in calculations, additional calculations of criticality and radiation safety are made.

Having completed the tests and checking calculations, VNIPIET carries out the expertise of all the available materials justifying the package compliance with the regulatory requirements.

From the expertise results, either the conclusion is drawn that the package meets the requirements of the regulations, or recommendations are provided for the package design to be modified.

SUMMARY

Within 1990-1996 VNIPIET has executed tests more than 50 types of packages. Based on the experience that and other enterprises testing the transport packaging for nuclear fissile materials and fresh fuel, the principal conclusions may be drawn, as follows:

- the test experience accumulated and material base available enable the tests to be conducted in accordance with the general requirements of the Russian OPBZ rules and IAEA Regulations;
- from the test results, the safety of the package fleet used for transportation of nuclear fissile materials and fresh fuel is well grounded;
- the VNIPIET method, which combines testing with corrective calculations is the most optimal for small-mass packages considering reliability of the results obtained, labour intensity and cost of works.

SESSION 13.3

Waste and Back-End