Advanced Transport System for Dangerous Materials Based on New 20-Foot Container with Computable Load Behavior

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INTRODUCTION

The newly developed F.H. Timpert freight-securing system is a reusable, elastic system consisting of support trays serving to secure drums with dangerous goods in a 20-foot ISO box container during road and rail transport. The geometry and material of the support trays can be varied within broad limits so that the system can be adapted to the various levels of demand in the transport regulations for dangerous goods corresponding to the classification of the dangerous goods. In the following, this is shown in detail on the basis of restraining devices for steel drums used for the transport of lowlevel radioactive wastes.

To date, steel drums with dangerous freight have often been anchored by tension straps to secure the load in the container. The tension straps were applied around several steel drums and attached at the bottom to the anchoring points in the container. Securing the load in this way often proved to be disadvantageous in practice, since steel drums do not have any special anchoring facilities, such as eyelet attachments, shackles, or clips, for reliable restraining with tension straps. Due to the inevitable vibrations and movements of the steel drums in the container during transport, the tension straps may slip and thus fail to fulfill their task of securing the load.

The F.H.TIMPERT freight-securing system avoids this disadvantage, since an interchangeable tray system takes up the forces emanating from the drums and transfers them to the container walls or container roof and floor. Wedges between the individual trays ensure that the system automatically adjusts itself.

The system can be described mathematically. It can thus be precalculated and designed for different load cases, e.g., collisions at various speeds or drops from different heights. Expensive and time-consuming tests to demonstrate the safety of different load variants can be dispensed with.

The container, interchangeable tray system, and drums form one package, which fulfills the requirements for the transport and storage of radioactive substances. Not only is the tray system of significance, but also the jointless interior design of the container and the paint finish. This paint finish is radiation- and corrosion-resistant, provides good protection against mechanical damage and can be easily decontaminated.

CONTAINER

The container is a 20-foot ISO piece goods all-steel container designed according to DIN ISO 668: CC (Klassifikation, Masse, Gesamtgewichte) and closed on all sides. The manufacturer's model code is M-CB 49. It has a double-wing door at one end. The door wings each have a rubber seal all the way around, and in the closed state they are secured by latches and bolts. The container floor is shaped like a trough. The inner surfaces of the walls and their transition of the floor are jointless. The container is coated on the inside and outside with a paint finish whose surface is easily decontaminated pursuant to DIN 25415 Part I. Inside, the container is equipped with anchoring points to secure the load. The permissible total weight is 26 tons, and the payload is 22 tons.

FREIGHT-SECURING SYSTEM, PAYLOAD

The F.H.TIMPERT freight-securing system is a dynamic system whose main elements are the support trays. These shaped pieces serve as elastic top and bottom shock absorbers, which in this example comprise the top and bottom sections of the drums. They are contiguous to each other and the container walls, to which they transfer the forces.

The support trays of the first level are placed on the ground of the container. The support trays of the second and third level have grooves at the side to accommodate the restraining and tensioning devices. The restraining elements are bars anchored to the side walls of the container to effect load transfer. The tensioning elements are wedges which slide into the wedge-shaped grooves because of their weight and thus continuously ensure passive tightening of the entire formation.

The drums are attached to the container roof by passive restraining devices consisting of masses and springs that lock the trays into place and which adjust themselves as the container is shaken by vibrations.

The geometry, mass, and physical properties, such as spring and damping behavior, of the materials are known. The formation consisting of the drums and restraining devices represents a system of coupled oscillators, whose essential properties can be described mathematically and may thus be precalculated. The mathematical modeling of such a system for the collision was undertaken by Kausel, et al. (1995). The advantage of this freight-securing system is its calculability. Different configurations can be designed computationally, thus enabling their reliability to be predicted. Expensive and time-consuming collision and drop tests, which have to be performed for systems not determinable mathematically in order to demonstrate transport safety, could be dispensed with.

Standard configurations with the F.H.TIMPERT freight-securing system are:

- 48 x 200-l drums in two layers with a maximum drum weight of 437.5 kg;
- 42 x 200-l drums in two layers with a maximum drum weight of 500 kg;
- 24 x 200-l drums in one layer with a maximum drum weight of 875 kg;

- 42 x 280-l drums in two layers with a maximum drum weight of 500 kg;
- 21 x 280-l drums in one layer with a maximum drum weight of 1,000 kg.

The maximum drum weight depends on the weight of the freight-securing system, in which the permissible payload of 22,000 kg per container may not be exceeded.

LOAD TESTS

The load tests necessary for granting the qualification certificate for the design as a package pattern type IP-2, IP-3, and type A for the transport of radioactive substances by the German Federal Institute for Material Research and Testing (BAM) were successfully performed on a container fully loaded with 48 200-l drums.

For these tests, the support trays and restraining devices were made of pasteboard.

The following tests were performed:

- Tests pursuant to DIN-ISO 1496 Part I with the following supplementary tests:
  - front and door wall load: 51,000 kg
  - side wall load: 33,000 kg
  - anchoring point tensile test with 1.5-fold rated load.
- Collision tests with delayed impacts at the advancing lower corner fittings of the container with lowpass filtering of 16 Hz
  - up to 40 m/s^2 towards the rear door and
  - up to 32 m/s^2 towards the front wall
- Free-fall tests, primarily from 0.3 m approximately along the principal diagonal onto the roof edge of the container door side and secondarily on the roof surface.

On the basis of the positive test results, BAM certified that the package type

- fulfilled the requirements specified in Exception 49 of the Exception Regulation for Dangerous Goods for the scope of the German Ordinance on the Transport of Dangerous Goods on the Rhine (ADNR), the Dangerous Goods Ordinance for Inland Waterways (GGV BinSch), the Dangerous Goods Ordinance for Rail Transport (GGVE), and Dangerous Goods Ordinance for Roads (GGVS) for the transportation of substances with low specific activity and of surface-contaminated objects; and
- corresponds to the requirements made on Type A packages for the transportation of solid radioactive substances laid down in the Regulations for the Safe Transport of Radioactive Material, 1985 Edition (as amended in 1990) of the International Atomic Energy Agency in Article 524.

The following data were recorded for the collision tests:

- collision velocity v [km/h]
- longitudinal acceleration velocity [m/s^2] at the advancing restraining fittings of the container to evaluate container strength
- longitudinal acceleration velocity [m/s^2] of the bottom, central, and top layers of drums in rows 1, 3, 6, and 8 to evaluate the vibration behavior of the drums inside the container.

The loaded container was placed on a flat car with a net weight of 20.5 tons. A ramcar with a weight of 80 tons ran down a shunting slope against the free, breakless flat car standing on the track. Changes in the direction of load (rear door or end wall in the direction of collision) were effected by rotating the flat car. Before beginning the tests and after changing the direction of load, a setting blow was first executed in order to exhaust the axial play between the holding pins and the restraining fittings in the direction of collision.

Table 1 shows the results of the collision tests with the rear door in the direction of collision.

Table 1: Results of the Collision Test (Rear Door in the Direction of the Collision)

Test No.	v [km/h]	Acceleration at the anchoring points [m/s^2]
1	5,0	setting blow
2	7,0	20
3	9,0	26
4	9,5	29
5	10,0	31
9	5,1	setting blow
10	11,4	40

After test no. 5, damage to the support trays was found upon opening the rear door. No obvious damage to the drums and container was established. No permanent deformations occurred at the container door and in the roof region. Tightness of the rear door was maintained. On the basis of the container stability, which was sufficient for the evaluation criteria, a further test with an accelaration of 4 g (test no. 10) was carried out at the client's initiative (CORROBESCH Vertriebsgesellschaft mbH), after the variants with the end wall in the direction of collision.

The interior of the container was not inspected after test no. 10. However, no external damage was apparent.

Three tests were performed with the end wall in the direction of collision and the results are shown in Table 2.

Table 2: Results of the Collision Tests (End Wall in the Direction of the Collision)

Test No.	v [km/h]	Acceleration at the anchoring points [m/s^2]
6	5,0	setting blow
7	9,9	30
8	11,0	32

After test no. 9, the interior of the container was not examined. No external damage to the container was detected. The support trays and passive restraining devices display damage, whereas the drums and container remain undamaged.

The free-fall test was performed on a crash plate consisting of a concrete mat of 18.0 m × 15.4 m with a thickness of 1.5 m (approximately 800 tons total weight), which was overlain by a steel plate 35 mm in thickness. The container was hung in such a way that it was dropped from 0.3 m on to its upper corner on the doorside and then pivoted about this point and slammed onto its roof.

The container was equipped with a total of 14 acceleration sensors. The acceleration signatures display values of up to approximately 140 g.

Inspection of the container after the drop revealed the following:

- No damage occurred which would permit any escape of the radioactive contents or would result in reduced shielding.

- Control measurements of the upper door corner fittings at the corner pillar, the longitudinal roof bar, and at the side wall in the direction of the diagonals did not indicate any measurable linear deformations.

- The front corner pillar directly above the corner fittings displayed a compression, which may in part be attributable to the fact that the other corner fitting did not crash onto the steel plate during the drop test.

ANTI-CORROSION FINISH

The containers are coated with the special anti-corrosion finish CORROBESCH-DF-Nuklear. This spray coating is smooth, glossy, and tight to water vapor diffusion. Its base component consists of tar epoxide polyurethane and inert additives as well as color components. The second component is cycloaliphatic amine.

The container's good radiation and corrosion resistance as well as ease of decontamination was experimentally demonstrated according to the relevant DIN and ISO regulations (Kunze and Geiser, 1994). Anti-corrosion finishes were tested in the colors black, yellow, blue, red, and white.

After exposing the test pieces to radiation of 10^7 Gy, discolorations of various intensities resulted (greatest discoloration of the white finish, least of the black finish) as well as very slight decreases in gloss. Other changes were not detected.

In order to evaluate possible changes after the action of chemicals and decontamination solutions, ethanol, 20 % phosphoric acid as well as sodium hydroxide solution, materials testing mixture A 20/NP II, and two decontamination detergents frequently used in practice were applied to the test pieces, which had been irradiated with various energy doses.

- After an exposure time of five minutes, both unexposed surfaces and also those exposed to a radiation dose of up to 10^7 Gy displayed only insignificant changes, irrespective of coloring agent.

- After an exposure time of 24 hours, all surfaces displayed very slight changes after the action of materials testing mixture A 20/NP II and the two water-diluted decontamination detergent solutions.

- After an exposure time of 24 hours to ethanol, phosphoric acid and sodium hydroxide solution the color change increased with rising radiation exposure of the surface and the hardness of the finish temporarily decreased (the white finish had the poorest values).

Other changes such as blisters, fissures, or swelling due to the action of the above-mentioned solutions were not detected on any of the specimens irradiated with up to 10^7 Gy.

All anti-corrosion finshes, whether black, yellow, blue, red, or white, are easy to decontaminate before irradiation.

The following results were obtained after irradiation:

- with 3×10^5 Gy = very easy to decontaminate,
- with 3×10^6 Gy = easy to very easy to decontaminate,
- with 6.8×10^6 Gy = easy to decontaminate, and
- with 10^7 Gy = moderately easy to easy to decontaminate.

CERTIFICATION

To date, the following certification has been granted for the container or for the package:

By Germanischer Lloyd

- CSC license,

- certification of the successful free-fall test in accordance with the requirements of the Regulations for Safe Transport of Radioactive Material, 1985 Edition (as amended in 1990) of the IAEA in Article 524 (622).

By Bundesanstalt für Materialprüfung (BAM)

- license as an IP-2, IP-3, and type A package

Deutsche Bahn AG

- certification pursuant to UIC 592-1

Main Customs Office Bremerhaven

- license for the transportation of goods in bond.

CONCLUSIONS

The ISO piece goods container M-CB 49 coated with CORROBESCH-DF-Nuklear with the F.H.TIMPERT freight-securing system represents an advanced system particulary suitable for the storage and transport of radioactive substances.

It offers economic benefits due to the fact that:

- the computational demonstration of the safety of the box-container system can replace expensive tests,

- the container shows a very favorable ratio between payload and net weight, and

- the anti-corrosion finish of organic base material displays, contrary to expectation, a high radiation resistance so that it can be used instead of electrodeposited coatings.

REFERENCES

Kausel, E., Flessner, H.C., Timpert, F.H.: *New Box-Container System for Waste Drums: Dynamic Tests and Qualification,* WM '95 Conference, Tucson, February 26, March 2, 1995.

Kunze, S., Geiser, H.: *Beschichtungen für Behälter radioaktiver Abfälle,* Atomwirtschaft, Vol. XXXIX, No. 5, May 1994.