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NEW PACKAGING AND TRANSPORT REGULATIONS FOR IP-2/IP-3 ISO FREIGHT CONTAINERS ARE IN FORCE IN CANADA SINCE JUNE 1, 2000

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ABSTRACT

Since June 1, 2000 the new Packaging and Transport of Nuclear Substances Regulations are in force in Canada. The Canadian Regulations adopt already elements which are in the new IAEA Safety Standards Series ST-1 (1996 Edition) regarding the qualification of ISO freight containers as industrial packages Type 2 and Type 3 (IP-2,3).

The new Canadian transport regulation require the consideration of dynamic loads for routine respectively normal transport conditions in the package design for IP-2,3 ISO freight container. Safety Technology Management (STM) has met this challenge to fulfill the dynamic impact requirements in performing full scale drop tests with 20 ft and 40 ft ISO freight containers.

STM, now also present on the Canadian market with its own subsidiary, has recently successfully performed the world´s first free fall drop test with a 40 foot ISO freight container. The drop test took place in Bremen (Germany) at the dry dock of the former Vulkan ship yard on September 25, 1998. This drop test had to be performed to qualify the ISO Boxcontainer as a Type IP-2,3 package in accordance with the new IAEA Safety Standards Series No. ST-1 (1996 Edition) paragraph § 627 “Alternative Requirements for IP-2,3 Packages”. This IAEA paragraph has been included in the new Canadian Packaging and Transport Regulations under chapter Interpretation and Application, section application in subsection 3 (replaces paragraph 523 of the IAEA Safety Series No.6 Regulations, 1985 Edition, as amended 1990). This paragraph requires dynamic impact testing for freight containers to be qualified as Type IP-2,3 packages.

STM has gone the way of fulfilling the dynamic impact requirements in performing a full scale free fall drop test.

Ontario Power Generation Inc. triggered the early development of the 40 ft LONGFORCE® freight container through an order to STM in February 1998 (Figure 1).

The 40 ft ISO freight container prototype (L x W x H = 12192 mm x 2438 mm x 2491 mm) was fully loaded with 28 tons of steel plates together with shock absorbing material to simulate the load and load securing system. The total drop test weight was 35.6 tons.

In accordance with the new Canadian Transport Regulations and IAEA ST-1 requirements, the so called LONGFORCE® container was dropped onto an unyielding foundation in a position which suffered the maximum damage in respect of the package safety features. The package was dropped on its corner, door side down on the roof, with the center of gravity over the impact area (slap-down drop). The container was lifted 12.6 m high (highest point) respectively 0.3 m (lowest point) under a drop angle of 70°. The drop test pad (a combined mass of the concrete block and the steel plate) was way above 100 times that of the container test specimen. The first impact resulted in an acceleration of about 100 g where the maximum was near the impact. The second impact, however, turned out to be decisive showing maximum acceleration readings in the range of 250 g.

The container was inspected after the drop test. Only deformations of the container rear corner castings (area second impact) and a small weld crack in one of the corner castings welds were found. On the container floor one third of transverse profiles showed S-form distortion. The LONGFORCE® container was leak-tested prior and after the drop test in compliance with the STM leak-test procedure. The leak tests consisted of filling the container with pressurized air up to 5 kPa and record a possible pressure drop over a determined test period. The container was considered leak tight prior to and after the drop test based on the permissible limits set in the leak test procedure.

The free fall drop test is considered a full success qualifying the 40 ft LONGFORCE® container as Type IP-2, 3 package in compliance with the new IAEA Safety Standards Series No. ST-1 requirements and the new Canadian Transport Regulations.

CONTAINER DESIGN REQUIREMENTS

Codes of regulations, norms and standards

The design requirements for freight containers carrying radioactive material are embodied particularly in the IAEA Safety Standards Series No. 6 /1/ and the new IAEA ST-1 requirements /2/. The Canadian Nuclear Safety Commission has based the new Packaging and Transport Regulations /3/ on the IAEA SS 6 regulation with the exception of paragraph 523 which deals with the requirements for industrial packages. The Canadian Transport Regulations replaces paragraph 523 of IAEA SS 6 with paragraph 627 “Alternative Requirements for IP-2,3 Packages” of the IAEA ST-1. The exact same wording is given in the Canadian Packaging and Transport Regulations under chapter Interpretation and Application, section application in subsection 3. This paragraph requires dynamic impact testing for freight containers to be qualified as Type IP-2,3 packages. This was the absolute right decision based on STM´s scientific analyses to implement these requirements in an early stage into the new Canadian Regulations which drastically increases the safety of ISO freight containers. STM scientific analyses (drop tests, ram tests etc.) have shown a tremendous deficiency in the design of regular ISO freight container which are even used for the transport of radioactive materials world-wide today. The regular containers are only designed to take static forces

The European transport laws for the transport of dangerous goods /4/ and /5/ have fully incorporated the IAEA SS 6 and will also fully incorporate the new ST-1 requirements which are scheduled to come into force in January 2001. Table 1 shows a comparison of acceleration factors (dynamic loads) published by the IAEA in their Safety standards No. 37 /6/ and ST-2 /7/. The ISO Norm 1496 part 1 /8/ is also listed in table 1 because freight containers must satisfy the design and static testing specification. However, the ISO Standard for freight containers lacks the requirement for dynamic tests to certify that packages retain and contain their contents during accelerations occurring in routine transport. After review by international transport safety experts, the IAEA decided to elevate international safety standards by including dynamic test requirements in the new ST-1´s paragraph § 627 “Alternative Requirements for IP-2,3 Packages”.

The ST-1 has included dynamic impact requirements for freight containers during routine conditions of transport. ST-2 lists specific acceleration factors which are recommended values for the design of freight containers. For example, the listed acceleration factor for package retention system design for rail in longitudinal direction is 5g (see table 1). The requirements for the resistance of general freight containers to dynamic loads arising during routine transport operations are also established by the various European railway associations (e.g. German Railways, Swiss Federal Railways etc.) with the RIV /9/ railway loading procedures which set a longitudinal acceleration standard of 4 g with no shunting restrictions.

Description of the LONGFORCE® 40 ft Freight Container

The overall dimensions of the LONGFORCE® container are: length 12192 mm (40 ft) ; width 2438 mm (8 ft) ; height 2491 mm (8 ft 6 in). The LONGFORCE® is built out of steel profiles and plates. The lateral walls are corrugated and the roof is slightly convex. The longitudinal and transverse support beams together with the floor are constructed in the form of a basin. The front wall (door end) is made to form a basin in order to give the container floor more stiffness.
The material utilised for the LONGFORCE® Container is carbon steel, resistant to low temperature brittle fracture (minimum impact energy absorption of 20 J at -40 °C) which has been produced in accordance with ASTM specification A 570/A 570 M-96 grade 50.This material complies with the requirement set in § 528 of IAEA SS 6 for Type A packages. This was also a requirement set by Ontario Power Generation Inc. which through an order placed with STM triggered the early development of the 40 ft freight container qualified as an IP-2, 3 package.

The front wall (door end) consists of a pair of hinged doors. The doors internal and external perimeter include a continuous seal. They are firmly shut by means of bolts and bars.
The entire container is coated inside and outside with the CORROBESCH - DF – Nuclear coating material.

The CORROBESCH - DF – Nuclear coating material is a highly resistant anti-corrosion and anti-scratch enamel finish. This finish confers excellent abrasion, chemical, thermal and radiation resistance to the wall surfaces and allows for easy decontamination.

The LONGFORCE® is watertight from the outside and leak-tight from the inside to outside. The container includes a vent (pressure equalization vent) with a stainless steel filter near the roof whose purpose is to contain aerosols while ensuring that the container interior cannot become pressurised. On either side of the container interior walls there are 63 load anchor points (126 total) ranging from 1.0 up to 5 metric tons for easy tie-down of the load.

The LONGFORCE® 40 ft container doors are equipped with a seal system which consists of horizontally and vertically arranged EPDM rubber seals. The seal has a geometric form (lip seal) which creates pre-tension and therefore increases the tightness. When the inner container pressure is increased, the pressure will push the door seal tighter against the seal surface resulting in the increase of the door's seal tightness.

Table 2 gives the technical specification of the 40 ft IP-2,3 ISO and Type A Freight Container.

FULL SCALE DROP TEST

Calculations prior to the drop test

Calculations prior to the drop test were performed by the University of Hannover /10/ to determine the most damaging drop test orientation and angle for the free drop test which is required by the IAEA and Canadian Regulations.

Drop test calculation results:

- First impact (0.3 m drop) receives the highest forces of 1020 kN. The reason is, that the whole payload weight of 28 tons is moving during the first impact towards the doors.
- Container drop angle should be 70° and to be dropped towards the roof (dropping on the roof is more vulnerable than on the container floor); in the 80° angle position is the centre of gravity over the impact area on the roof.
- Second impact (slap-down) from a height of 12.6 m (highest point) is predicted to be less stringent than the first impact. The calculated force was in the order of 410 kN.

The calculations performed show higher loads for the first impact of the corner drop versus the second impact of the slap-down. Therefore, STM drop-tested the LONGFORCE® 40 ft container in the following drop test position:

- corner drop under an angle of 70°, door side down onto the container roof (see figure 2).

This was also the drop test position for the BOXFORCE® 20 ft container which was drop tested in 1994 /11/, /12/, /13/.

Drop test foundation

The drop test foundation should be of an essentially unyielding surface. The drop test target should fulfil the following conditions:

- the combined mass of the concrete foundation and a steel plate should be at least 100 times that of the drop test specimen
- the concrete foundation should be covered with a 40 mm thick steel plate.

The test specimen (LONGFORCE® package) was weighing fully loaded 35.6 tons. The whole dry dock foundation consisted of a single block structure with the dimension of approx. 55 m x 300 m x 1.25 m (width x length x thickness). In the test arrangement a section of 40 x 40 m x 1.25 m (width x length x thickness) was selected as the drop test target area. The density of the steel reinforced concrete foundation was $\rho = 2.4\ t/m^3$. This equals to a mass foundation of 4,800 t. The surface of the concrete foundation was covered by a steel plate of 40 mm thickness with a mass of approx. 9.5 t. Therefore, the drop test target represented effectively an infinite unyielding surface. The combined mass of the concrete block and the steel plate (4,810 t) was larger than 100 times the mass of the container test specimen (35.6 t).

Drop test instrumentation

The Germanischer Lloyd (GL), an independent inspection agency and surveyor, was contracted to install the measuring equipment, record the measurement and write a report about the findings. For the purpose of measuring the resulting accelerations the LONGFORCE® 40 ft container was instrumented with 24 accelerometers. Two of the accelerometers were placed on the drop test concrete foundation to record the vibration of the unyielding foundation during the drop . The measuring locations supplied the data necessary to determine the forces arising as a result of the LONGFORCE® 40 ft free fall impact test.

Meeting the new Canadian Transport Regulations and the IAEA ST-1 requirements

Dynamic impact requirements have now become mandatory in compliance with the new IAEA ST-1 requirements paragraph § 627 “Alternative Requirements for IP-2,3 Packages” and the Canadian Packaging and Transport Regulations under chapter Interpretation and Application, section application in subsection 3.

STM has met the challenge to fulfill the dynamic impact requirements in performing a full scale drop test. This qualifies the 40 ft LONGFORCE® container in accordance with the following IP-2, 3 drop test requirements:

- Accelerations occurring during routine conditions of transport (§ 627 in IAEA ST-1 or Canadian Regulations)
- Free drop test (§ 622 in IAEA SS 6 or Canadian Regulations)

- To prevent loss or dispersal of the radioactive contents (§ 627 IAEA ST-1 or Canadian Regulations and § 537 in IAEA SS 6 or Canadian Regulations)

The requirement "loss or dispersal of the radioactive contents" is met by fulfilling the requirements for leak tightness. A leak test (pressure test and bubble test; overpressure ≥ 5 kPa over a period of 5 hours) was successfully performed before and after the drop test to prove the leak tightness of the drop test container.

The requirement "loss or dispersal of radioactive contents" stated in § 627 (IAEA ST-1 or Canadian Regulations) demands the leak tightness of the container containment. Further, § 462 of IAEA SS 6 requires load securing during normal conditions of transport. Table AVII-1 in IAEA SS 37 gives acceleration values which could be expected to occur under normal conditions of transport for various transport modes e.g. for rail ± 10 g in longitudinal direction is listed (see table 1). All these requirements must be fulfilled when qualifying a freight container as Type IP-2 or IP-3 package even under the IAEA regulations or Canadian Regulations.

Summary of drop test results

On September 25, 1998 STM successfully performed a full scale free drop test with a 40 ft ISO freight container. The independent inspection agency GL in Hamburg was contracted by STM to carry out an independent acceleration measurement program consisting of a drop test plan prior to the test, installing the accelerometers, performing the measurements and writing a drop test report /14/.

The package was hanging in a crane hook equipped with a special release device, each corner attached to an individual rope. The container drop position was inclined by about 70 degree angle to the vertical axis, the lower edge of the door side at a distance of 30 cm and the upper edge was 12.6 m (highest point) from the unyielding surface (see figure 2). In total 24 accelerometers were installed by the GL, two of which were placed on the drop test foundation in the vicinity of the impacts to record the acceleration of the dock floor. The recording of the measurements were started well before the container was released.

The time between the first and the last impact was about 2 seconds.

The drop consisted of three impacts. The first impact (see figure 3) onto the lower corner edge of the doors did not damage the container. The impact resulted in acceleration values of maximum 100 g in vertical and longitudinal direction of the door side.

The 2nd impact in general yielded in a far higher acceleration values in vertical direction of 160 up to 200 g.

The vertical acceleration in the centre of the side wall did show unexpected high acceleration of about 200 up to 250 g. Detailed investigation showed that these accelerations occurred slightly after the rear corner castings touched the steel plate. The reason for the high accelerations cannot clearly be derived. However, the reason might be a sort of bouncing back (vertical bending of the container) resulting in a 3rd impact (see figure 4, 5).

The LONGFORCE® container was inspected after the drop test. Only deformations of the container rear corner castings (area second impact) and a small weld crack in one of the corner castings welds were found. On the container floor one third of transverse profiles showed S-form distortion. The LONGFORCE® container was leak tested prior and after the drop test in compliance with the STM leak test procedure. The leak tests consisted of filling the container with pressurized air up to 5 kPa and record a possible pressure drop over a determined test period. The container was considered leak tight prior to and after the drop test based on the permissible limits set in the leak test procedure.

CONCLUSIONS

The world's first 40 ft ISO freight container has been qualified as a Type IP-2, IP-3 package in compliance with the new IAEA ST-1 requirements and the new Canadian Packaging and Transport Regulations. Ontario Power Generation Inc. triggered the early development of the 40 ft LONGFORCE® freight container through an order which was placed in February 1998. So far, STM has supplied OPGI Bruce Power Station with two (2) 20 ft BOXFORCE® and six (6) 40 ft LONGFORCE® IP-2 freight containers.

The 40 ft ISO freight container was drop tested onto an unyielding foundation in a position which suffered the maximum damage in respect of package safety features. The container was lifted 12.6 m high (highest point) respectively 0.3 m (lowest point) under a drop angle of 70° (slap-down drop).

The first impact resulted in an acceleration of about 100 g where the maximum was near the impact. The second and third impact, however, turned out to be decisive showing maximum acceleration readings in the range of 250 g. There were only minor damages on two ISO corners and a few transverse plates in the floor region were bent.

Dynamic impact requirements become mandatory for freight containers to be qualified as Type IP-2,3 packages in compliance with IAEA ST-1 paragraph § 627 "Alternative Require-ments for IP-2,3 Packages" and the new Canadian Packaging and Transport Regulations under chapter Interpretation and Application, section application in subsection 3 which is already in force since June 1, 2000. STM has gone the way of fulfilling the dynamic impact requirements in performing a full scale drop test.

STM is convinced that this container design is a major contribution to the safe transport of dangerous goods including radioactive material and helps to reach better acceptance of such shipments in public.

TRANSPORT MODE	Longitudinal	Lateral	Vertical
Road - SS 37 - ST-2	 + 2 g 2 g	 ± 1g 1g	 3 g down, 2 g up 3 g down, 2 g up
Rail - SS 37 - ST-2	 ± 10 g 5 g	 ± 2 g 2 g	 ± 4 g 2 g down, 2 g up
Sea - SS 37 - ST-2	 ± 2 g 2 g	 ± 2 g 2 g	 ± 2 g 2 g down, 2 g up
Air - SS 37 - ST-2	 9 g, - 1.5 g aft 1.5 g (9 g forward)	 ± 1.5 g 1.5 g	 6 g down, 2 g up 6 g down, 2 g up
SS 37 Radioactive material packages in USA	10 g	5 g	2 g
ISO 1496 part 1	2 g static	-	-

Table 1. **Comparison of acceleration factors (dynamic load) published by the IAEA in their Safety Standards SS No. 37 /6/ and ST-2 /7/**

40 ft LONGFORCE® ISO Boxcontainer

Packaging type	IP-2, IP-3, Type A
Solid radioactive materials	LSA I,II,III; SCO I,II
Dangerous goods	Class 1 to 9
Permissible gross weight	35,000 kg
Maximum payload	28,100 kg
Tare weight (empty container)	7,560 kg
External dimensions	12192 mm x 2438 mm x 2591 mm
Lashing points	126 points (1,000 to 5,000 kg load)
Material	ASTM A 570/A 570 M grade 50 min. impact energy absorption of 20 J at -40^0 C
Coating	CORROBESCH-DF-Nuclear, anti-corrosion finish, high protection and easy decontamination
Door-, frontal wall test load	510 kN
Side wall test load	412 kN
Leak tightness	Leak-tight (test pressure ≥ 5 kPa)
Overpressure system	Pressure equalization vent with aerosol filter Load
securing system	Customs designed and to be certified by calculations (specially developed computer code)
Dynamic design loads	
Longitudinal	10 g
Lateral	3 g
Vertical, upwards	3 g
Vertical, downwards	10 g

Table 2. **Technical specification of the STM 40 ft ISO Freight Container qualified as Type IP-2,3 and Type A package for the transport of radioactive and other hazardous material**

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Figure 1. 40 ft LONGFORCE Ontario Power Generation Inc. container

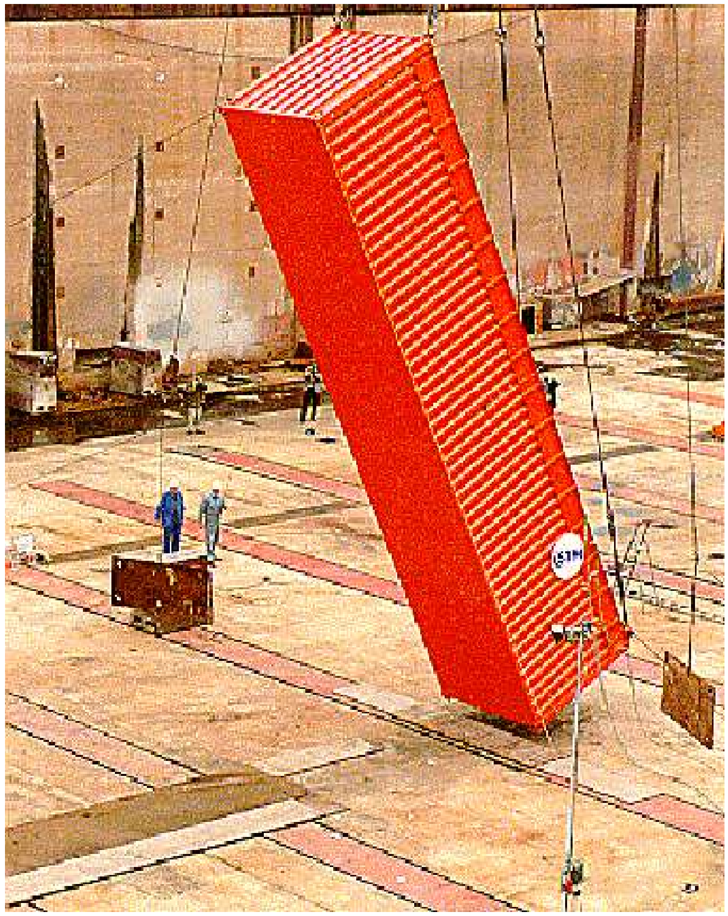

Figure 2. 40 ft ISO Boxcontainer hanging in the drop test position (70 ^{0} angle) shortly before the drop test

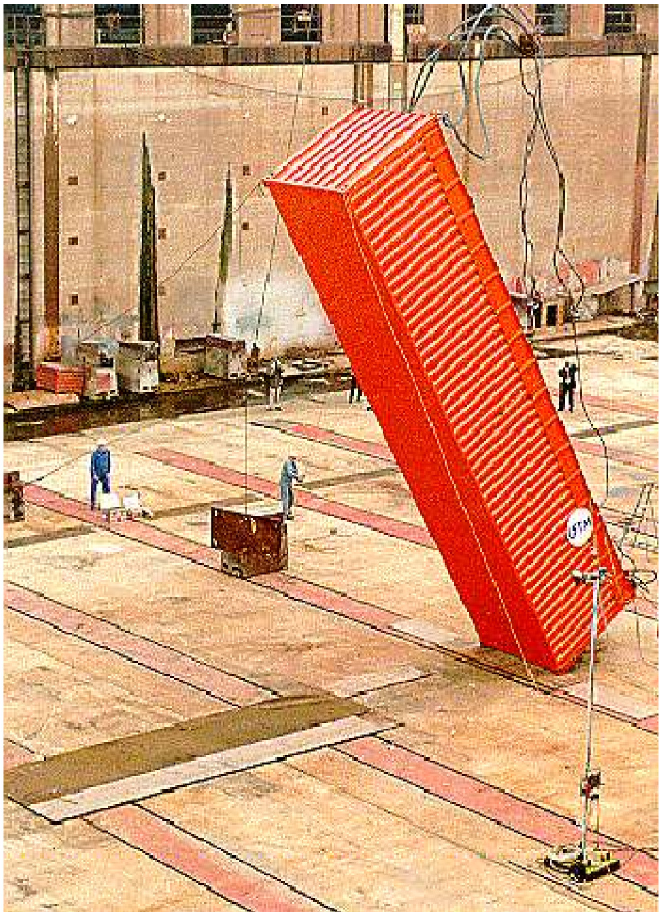

Figure 3. The picture shows the first impact on the unyielding foundation (lower corner edge on the door side)

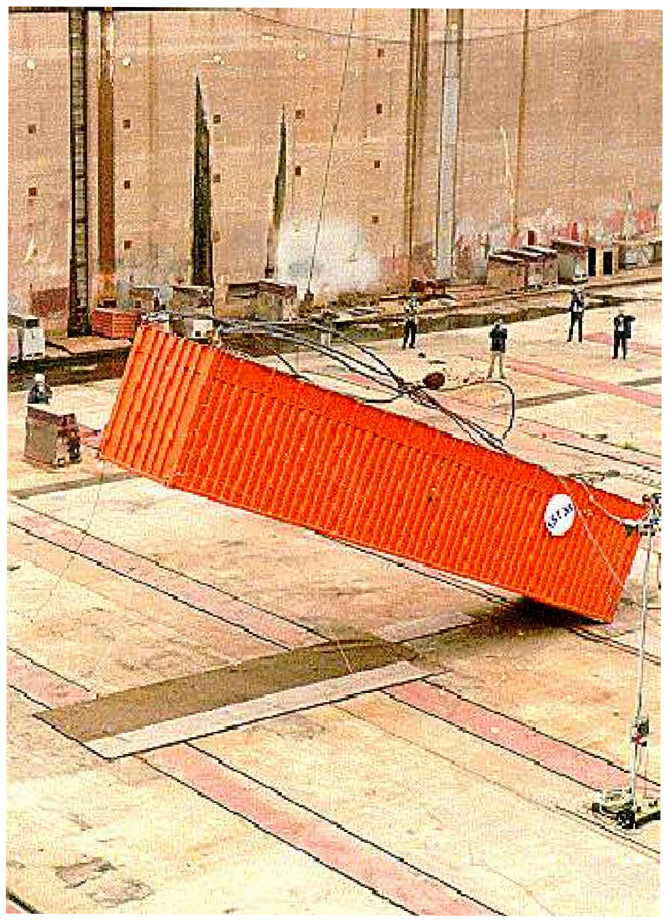

Figure 4. **The picture shows the package during the drop test shortly before the upper corner castings hitting the foundation**

Figure 5. **The picture shows the container shortly after hitting the drop test unyielding foundation**