TRANSPORT OF Co-60 FROM ARGENTINA TO ABROAD

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The reactor of the Embalse Nuclear Power Plant is a CANDU 600 type and one of their mechanisms of reactivity control is formed by a set of 21 rods containing Co-59. As a result of its operation and due to the neutronic activation, Co-59 is converted into Co-60.

The rods are formed by bundles of 1, 3 or 4 cobalt pencils, and this number is depending on the position in the core.

The pencils are made out of "zircaloy", and they may contain cobalt as pellets or slugs, depending on the future application.

When only slugs are used, the whole cobalt mass may aproximately reach the 35 kg.

After the term of service in the core wich may be around one year, and depending on the load factor, the rods with slugs may reach a specific activity not lower than 3,7 x 10^{12} Bq/g (100 Ci/g), and those containing pellets can reach, after 3 years in the nucleus, 9,25 x 10^{12} Bq/g (300 Ci/g). Therefore, the removal of the rods from the core is a difficult task. Special work programs concerning personnel radioprotection were developed, and procedures for the removal of rods from the reactor, and their transfer to the pool, are applied.

The personnel has been trained in a simulator that reproduces the steps of the removal operations.

Among the special equipment used it is worth emphasizing the shielded container for the removal from the core and moving of each rod to the transfer and disassembling pool. This container allows transfer rods with activities up to $1,66 \times 10^{16}$ Bq (450.000 Ci).

Once this container is in the pool, other procedures are applied for disassembling of rods; calibration; dismantling of the bundles with special machine; pencils distribution in the corresponding carrier; loading the carrier in the container for transportation; etc.

For each type of package design there is a procedure that describes its empty entrance to pool, its loaded removal, and the shielding, contamination and temperature controls that take place before delivery.

Loaded containers are taken by highway from the Embalse Nuclear Power Plant to the Ezeiza Nuclear Research Center, and there from to the adjacent international airport, or to the port of Buenos Aires, either one located aproximately 700 km away from Embalse.

Until nowadays different type of containers have been used. Their active charging capacities vary from $2,22 \times 10^{15}$ Bq (60.000 Ci), to $1,48 \times 10^{16}$ Bq (400.000 Ci).

Shipping of containers are made in accordance with approved procedures by relevant authority and those prescribed by the "Safety Serie N° 6",IAEA 1973; rules for transportation of dangerous goods within Argentina, S.T. 1988; and the IMGD Code, London 1988.

In the Ezeiza Nuclear Research Center, Co-60 is encapsulated in AISI 316-L stainless steel thus creating sealed sources for medical and industrial use.

Sources are manufactured in accordance with I.A.E.A. requirements for the approval of the each new model, and pursuant to International Standard Organization rules for mass production, 1980 (E).

The manufacture and quality control of the sources are under different working groups. Each source is tested pursuant to several leak tests prescribed by ISO,1979 (E).Calibration takes place once each source has passed the tests.

First operation of rods removal from the reactor core, disassembling, calibration, load and transportation took place according to the agreement of cooperation between Argentina and Canada. The containers used were F-231 B (U) model, supplied by AECL. Calibration of the activity of cobalt pencils is performed under water in the transfer pool, pursuant to the technique used by the AECL, which also provided the equipment used.

OCEAN TRANSPORTATION.

While the above mentioned agreement was in vogue, encapsulated and in bulk Co-60 was shipped to Canada. Containers were taken by land to the port of Buenos Aires, and therefrom by ocean to Canada. The following are the details of shipment:

TRANSPORT TO CANADA

YEAR	Co-60	ACTIVITY
1984/85	IN-BULK	5,5 x 10^{16} Bq(1,5 x 10^{6} Ci)
1985/86		6,66 x 10^{16} Bq(1,8 x 10^{6} Ci)
1986/87	"	6,66 x 10^{16} Bq(1,8 x 10^{6} Ci)
1987	IND. SOURCE	7,43 X 10^{15} Bq(2,01x 10^{5} Ci)
1988	" "	7,84 x 10^{15} Bq(2,12x 10^{5} Ci)

Shipments by ocean were carried out to the United States of America and Mexico. In the case of USA, until nowadays 9 shipments of in bulk Co-60 have taken place as it is demonstrated in the following chart:

TRANSPORT TO USA:

YEAR	Co-60	ACTIVITY
1990	IN BULK	1,01 x 10^{16} Bq (2,75x10^{5} Ci)
"	" "	1,17 x 10^{16} Bq (3,17x10^{5} Ci)
"	" "	1,34 x 10^{16} Bq (3,62x10^{5} Ci)
"	" "	1,38 x 10^{16} Bq (3,75x10^{5} Ci)

1991	" "	2,03 x 10^{16} Bq (5,5 x10^{5} Ci)
"	" "	1,90 x 10^{16} Bq (5,16x10^{5} Ci)
"	" "	1,74 x 10^{16} Bq (4,71x10^{5} Ci)
"	" "	1,37 X 10^{16} Bq (3,7 x10^{5} Ci)
1992	" "	1,37 x 10^{16} Bq (3,7 x10^{5} Ci)

As it is shown in the following chart, sealed sources (FIS 60-03 model, similar to the C-188 canadian model), for industrial use were shipped to Mexico:

TRANSPORT TO MEXICO:

YEAR	Co-60	ACTIVITY
1990	IND. SOURCE	3,40 x 10^{15} Bq (9,2 x 10^{4} Ci)
1991	"	4,62 x 10^{15} Bq (1,25x10^{5} Ci)

The Nuclear Research National Institute was the consignee.

TERRESTRIAL TRANSPORTATION

Until nowadays the Nuclear Energy Commission of Chile has aproximately acquired 5,92 x10^{15} Bq (1,6 x10^{5} Ci) of Co-60 as sealed sources for industrial use (similar to the canadian model C-132), in two shipments. Different means of transport were studied: because the railroad transportation has been cut off since more than a decade, one of the option was ocean transportation, surrounding the south extreme of the continent. The other option was by road crossing the Andes mountains on a height of 3.000 m through the international tunnel that links Argentina and Chile. The chosen mean was by road. Dates of production and transport were arranged in such a way that it would not take place in winter time.

As it is shown in the following chart, two trips took place in order to fulfill both orders. In both cases a container type F-168 (canadian model) was used, under special arrengement.

YEAR	Co-60	ACTIVITY
1987	IND. USE	2,18x10^{15} Bq (5,9x10^{4} Ci)
1991	"	2,22x10^{15} Bq (6 x10^{4} Ci)

In 1991 the "Energetic an Nuclear Researchs Institute" of San Paulo, Brasil, bought a source for industrial use of aproximately 1,85x10^{14} Bq (5.000 Ci) with the purpose of restoring an experimental gamma-irradiator. The operation consisted in receiving the irradiator with low activity source, in the Ezeiza Nuclear Research Center, unloading the equipment in the hot cell, charging the new source and sending the irradiator to San Paulo. Thus the whole operation took place by terrestrial transportation, comprising aproximately 6.000 km.

One source for cobalt therapy was transported to Uruguay using a truck until the international railway connection. From there the container was transfered to a train, and by this media arrived to the city of Salto (activity aprox. 1,11 x 10^{11} Bq or 3.000 Ci).

AIR TRANSPORTATION

On december, 1991, 13 sealed sources, FIS 60-03 model, were exported to France.The sources were distributed in two SV 24 F/34-B(U) containers, provided by the consignee. The whole activity was about 5,92 x 10^{15} Bq (160.000 Ci). Once the licenses had been obtained from relevant authorities, the shipment took place on the 31st of december, in a cargo Boeing 747, and arrived to Paris on the following day.

CONCLUSIONS

Until nowadays the total activity of the in bulk material shipped reached 2,96 x 10^{17} Bq (8.000.000 Ci). In sealed sources, the total activity shipped is 3,4 x 10^{16} Bq (918.000 Ci).

In bulk cobalt sales have been carried out since 1984. The largest activity shipped was of 6,66 x 10^{15} Bq (1,8 x 10^{5} Ci), in five F-231, type B (u) containers, to Canada.

The following are the different types of containers used:

F-231 CDN/2047/B(u).

F-168 CDN/2012/B(u)

GE-1500 USA/5939/B( )f.

SV-24 F/34-B(u).

References:

- "International Maritime Dangerous Goods" (IMGD Code, London 1988).

- ISO. Technical Report N° 4826. 1979 (E). "Sealed radioactive Sources". Leak Tests Methods.

- ISO. Technical Report N° 2919. 1980 (E). "Sealed Radioactive Sources". Classification.

- "Safety Series N° 6". Regulations for the Safe Transport of Radioactive Material. 1973 Edition (As amended 1979).

- "Transporte de Materiales Peligrosos". Secretaría de Transporte de la República Argentina. 1988.