THE DEVELOPMENT OF A MOBILE HOT CELL FACILITY FOR THE CONDITIONING OF SPENT HIGH ACTIVITY RADIOACTIVE SOURCES (SHARS)

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ABSTRACT

The International Atomic Energy Agency (IAEA) Waste Technology Section with additional support from the U.S. National Nuclear Security Agency (NNSA) through the IAEA Nuclear Security Fund has funded the design, fabrication, evaluation, and testing of a portable hot cell intended to address the problem of disused SHARS in obsolete irradiation devices such as teletherapy heads and dry irradiators. The project is initially targeting the African continent but expected soon to expand to Latin America and Asia. This hot cell would allow source removal, characterization, consolidation, repackaging in modern storage shields, and secure storage of high risk SHARS at single sites in each IAEA Member State.

The mobile hot cell and related equipment is transported in two shipping containers to a specific country where the following process takes place:

- Assembly of hot cell
- Removal of SHARS from working shields, encapsulation into a stainless steel capsule and placement into a long term storage shield
- Conditioning of any other spent sources the country may require.
- Dismantling of the hot cell
- Shipping equipment out of country

The operation in a specific country is planned to be executed over a three week period.

This presentation will discuss the development of the mobile hot cell facility as well as the demonstration of the state of readiness of the system for manipulation of SHARS and the planned execution of the conditioning operations. As a result of this project, excess SHARS could be managed safely and securely and possibly be more easily repatriated to their country of origin for appropriate final disposition.

BACKGROUND

The application of sealed radioactive sources is widespread with sources of different types and activities used for a very wide range of applications. The activities of such sources range from very low activities for sources such as reference sources to Spent High Activity Radioactive Sources (SHARS) with activities in excess of 10kCi. During the earlier years mainly Radium sources were used in mostly medical applications. Since the early 1950's, however, a greater variety of isotopes became available for use in medical as well in industrial applications. Today thousands of sources are used all over the world in developed as well as in developing countries.

The proper management of sealed radioactive sources, once they have reached the end of their useful life has become a worldwide problem. In many countries there is a lack of proper management due to a poor or absent accounting infrastructure. Some countries do not have legislation in place to regulate the control over spent sources. The problem exists in both developing and developed countries with some differences:

Developing Countries: Many sources are lost due to inadequate accounting systems or as a result of a lack of expertise or funds.

Developed countries: A large number of sources are normally found in these countries. This makes record keeping and accountability very difficult. A small percentage of sources lost may still account to a large number of sources.

The management of SHARS is specifically very problematic. No standard procedures or suitable technologies exist for the handling of SHARS outside of their original working shields, other than countries or facilities with hot cell facilities and remote handling equipment. SHARS, after use, are often kept in storage in their original working shields in the same facilities where it was used. These facilities, in many instances, have little or no physical security measures in place and much is relied on the fact that it is difficult to move these units due to the weight thereof. It is, however, fairly easy to remove the SHARS from such a working shield.

During earlier years the main concern with the management of sealed sources mainly revolved around safety issues. This has now changed where the security aspects related to sources has become a major driver for the proper management of especially spent radioactive sources. This due to the continuous threat of sources being used in acts of terrorism.

The International Atomic Energy Agency (IAEA) has during the early 1990’s identified the need for better management of sealed radioactive sources and has since implemented various programmes to address this need. One such programme is the very successful radium conditioning programme where expert teams would move into a country (mostly developing countries) to condition or “make safe” the radium source inventory in that country by collecting the sources, sealing it in stainless steel capsules and sealing it in a lead shield inside a concrete drum, thus ensuring that it is safe and more secure. The drum with sources is then placed under the supervision of the responsible organization in that specific country.

Following on the success of the radium conditioning programme, and also the need to find solutions for the proper management of SHARS, the IAEA Waste Technology Section, during 2003, identified the need for a mobile unit to handle SHARS. Such a unit could then be shipped to countries without the required infrastructure to handle SHARS and thereafter be shipped out of the country again.

In December 2003 the IAEA Waste Technology Section contracted the South African Nuclear Energy Corporation (Necsa) to develop a basic design for a mobile SHARS conditioning unit. This work was completed in 2004 whereafter Necsa was contracted in 2005 to perform the detail design, fabrication, evaluation and testing of a mobile SHARS conditioning unit. The IAEA Waste Technology Section with additional support from the U.S. National Nuclear Security Agency (NNSA) through the IAEA Nuclear Security Fund has funded the project.

The aim is to initially implement the concept on the African continent and then later to expand the programme also to include Latin America, Asia and possibly some European countries.

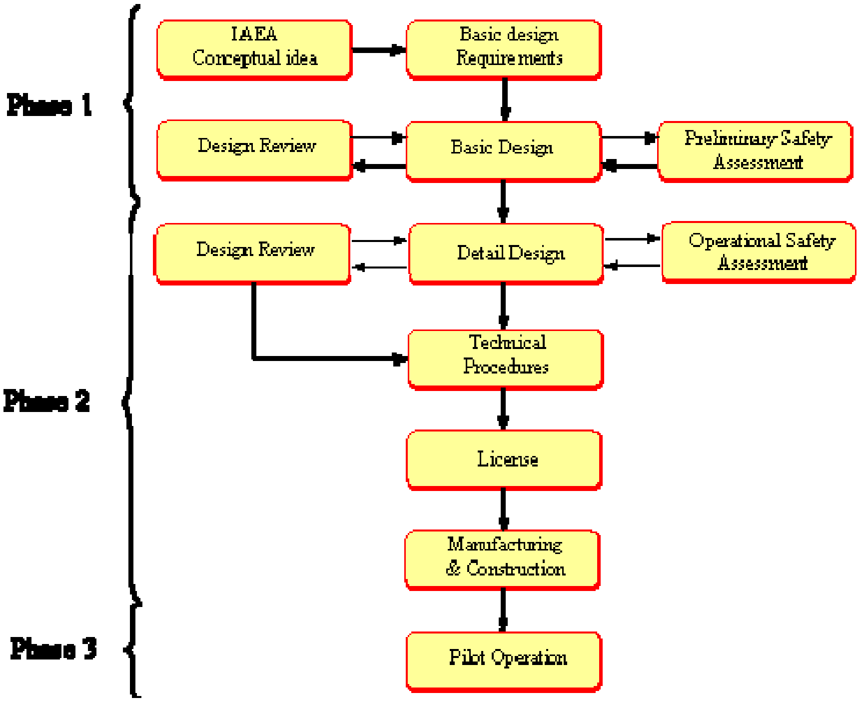
PROJECT DEVELOPMENT

The development of the SHARS conditioning unit involved three phases namely:

Phase 1: Basic Design and Preliminary Safety Assessment.

Phase 2: Detailed Design and Manufacturing
Phase 3: Demonstration of the unit with a pilot operation.

A schematic description of the different elements in the development process is presented below.



Phase 1 also entailed an opinion by the South African regulator on whether it was possible to license the SHARS conditioning unit. The regulator concluded that it was in fact possible and that the basic design [1] would render a safe configuration for the manipulation of SHARS.

During 2004, after completion of Phase 1, the IAEA contracted an international team of experts to evaluate the basic design. This team consisted of experts from the USA, United Kingdom, Belgium, Austria, Sudan and South Africa. The team evaluated the design and preliminary safety assessment during a week long session in South Africa and concluded that, with a few minor modifications, it was a workable concept that would provide sufficient protection during the manipulation of SHARS.

After completion of the detailed design [2] in 2005 the team of experts again evaluated the design and was satisfied that the design is sound and safe. Thereafter the manufacturing process commenced.

DESIGN OF THE SHARS CONDITIONING UNIT

The instruction from the IAEA was to design a mobile SHARS conditioning unit in accordance with the following requirements:

- The design must allow for the handling of sealed sources with an activity of 1000 Ci Co-60 equivalent.
- The design must allow for easy transport and should therefore be able to fit into shipping containers
- The unit should be easy to handle, easy to assemble and dismantle.
- The design should make use of components that are easy to maintain.
- The design should be cost-effective

In order to design a mobile hot cell with the requirements as mentioned above provided a big challenge. Firstly, it has not been done before and there was nowhere to find any information from other than from existing static, built-inn hot cells. It meant that from the start the development team had to think "out-of-the-box". Normal shielding like lead or concrete, for instance, could not be utilized as it would be impracticable due handle to its mere weight. Water as shielding material would be ideal but the availability of water in some remote areas where SHARS will be conditioned is too uncertain.

The project team eventually came up with the following design:

- Biological Shield (Hot Cell)
    - The cell walls consisting of a double cavity wall 1,55 m wide filled with ordinary river sand as shielding material. The sand, with a density of 1,6 reduce the dose-rate from a 1000 Ci Co-60 source to acceptable working levels.
    - The walls consist of ordinary mild steel shuttering plates of which some has been modified to allow for the respective ports and other openings. Steels rods are installed between the inner and outer walls to provide for further strength of the walls.
    - A working volume inside the cell of 2,5 m x 1,6 m x 3 m high.
    - The roof consisting of three 0,23 m thick concrete slabs.
    - The window consists of an oval shaped steel container with polycarbonate ends. The window is filled with a 50 % zinc-bromide solution that will reduce the dose-rate on the outer surface of the window to a modeled 0,062 mSv/h.
    - Telescopic master-slave manipulators with a lifting capacity of 20 kg were decided upon.
    - The cell is fitted with a jib-crane on the inside of the cell.
- In order to create a negative pressure inside the cell an exhaust ventilation unit was installed together with a hepa- filter (absolute filter)
- The cell is fitted inside with 4 video cameras allowing views at any position inside the cell.
- The cell is further fitted with a table that covers the complete surface are of the cell, five sodium lights, each with 300 Watts capacity, welding machine, leak test unit and a magnifying glass.
- Long Term Storage Shield
    - A long term storage shield (LTSS) was designed by RWE NUKEM in the UK for use by the SHARS project. The shield has 4 drawers in a rotating carousel that has a total design capacity of 10 kCi.
    - The LTSS was not designed as a Type B container (transport container). The design of the LTSS is loosely based on that of the MS Nordion F147 transport container. The purpose of this was to allow for the possible transfer of source drawers between the F147 and the LTSS in case of source repatriation.
    - It was decided during the development project to place the LTSS on the outside of the biological shell and to transfer the source drawer between the inside of the cell and the LTSS through a transfer port in the wall.
- Overhead Crane
    - An a-frame overhead crane is designed to assist during assembly/disassembly, to lift the concrete slabs and to lift components such as teletherapy heads into and out of the cell.
    - The crane moves on wheels on a rail and moves across the cell.

SAFETY ASSESSMENT [3]

The safety of personnel involved in the SHARS conditioning operations as well as the public in the vicinity of such operations played the most important consideration during the design of the unit. The safety philosophy that was followed had to ensure

- the safety of personnel and the public during operation of the unit.
- that operational exposure is kept ALARA
- that reasonable measure are taken to prevent accidents or to mitigate their consequences
- that consequences of accidents will be less than the prescribed limits

- that all relevant international (IAEA) standards and criteria are adhered to

In order to perform the safety assessment the following assumptions and dose targets were decided upon:

- A single conditioning team consisting of 5 persons would perform 4 – 5 conditioning operations per year with a total exposure time of 9 hours per operation.
- ALARA dose targets of 5 mSv and 0,02 mSv occupational and public exposure respectively per operation.
- The annual dose limits for occupational and public exposure as recommended in [4] will be adhered to.

Direct gamma exposure and inhalation of radioactive material due to a leaking source were regarded as the only credible exposure pathways.

The MicroShield and MicroSkyshine modeling programmes were used to estimate the occupational and public exposures due to direct gamma radiation and "skyshine". The inhalation pathway was regarded as negligible due to procedural aspects such as frequent swipe tests to test whether sources is leaking, maintaining a negative pressure inside the cell, the hepa filters etc.
The dose due to external radiation during normal operation was calculated for one conditioning exercise.

Operator dose rates in Table1 for steps 1-5 and 10-12 were based on conservative estimates, based on experience accumulated at Necsa and during source conditioning exercises in South Africa and in the rest of Africa.

Public dose rates for these steps were derived from the operational values based on a member of the public being 10 m from the source and the operator being 0.5 m away from the source.

During steps 1-5 the source is still in the original source shield and in steps 10-12 the source is in the LTSS. Thus, the skyshine dose to a member of the public during these steps is negligible and only the direct external radiation needs to be calculated.

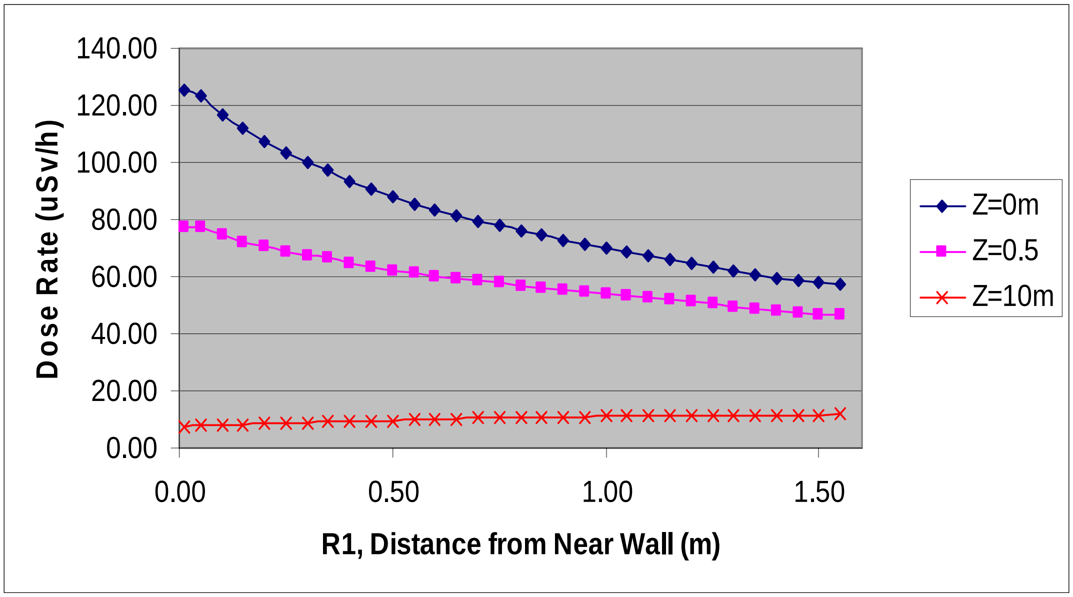
Table 1: Operator and Public Doses per Conditioning Exercise

Operation	**Duration (Minutes)**	**Operator Dose: Sand shield + 0.23m roof (µSv)**	**Public Dose (µSv)**
1. Remove Original Source Shield from Machine	120	50	1.3E-1
2. Transport to site	120	4.0	1.0E-1
3. Prepare for introduction into cell	15	2.5	6.3E-3
4. Lift Original Source Shield into cell	5	2.1	5.3E-3
5. Close Cell	20	0.7	1.7E-2
6. Remove source	60	77	12
7. Test for ID and integrity	20	26	3.9
8. Encapsulation and test	20	26	3.9
9. Place source into LTSS	10	4.2	2.0
10. Disengage and prepare for transport	15	13	3.3E-2
11. Transport to storage	120	4.0	1.0E-1
12. Store	20	3.3	8.3E-3
Total	**545**	**221**	**22**

Dose rates for steps 9 - 12 were calculated using the modeling software described above.

A graph of the total exposure, that is, the sum of the direct external dose rate from MicroShield and skyshine dose rate from MicroSkyshine, was plotted for different distances from the near wall of the cell. These are presented in Figure1.

Figure 1: Total Exposure with Source at Various Positions Inside Cell



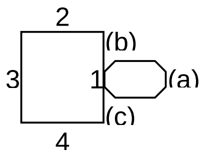
DEMONSTRATION OPERATION

The demonstration of the SHARS conditioning unit took place from 12 to 16 March 2007. This coincided then also with the final evaluation of the concept by the team of international experts. The team consisted this time of experts from the USA (2 persons from Los Alamos National Laboratories, 1 person from DOE and 1 from SWRI), the UK, Belgium, Sudan, South Africa as well as an observer from Tanzania and a representative from the Nuclear Security section of the IAEA and the IAEA technical officer responsible for the project.

The demonstration entailed the conditioning of a “dummy” source that was followed by the conditioning of a live source. Although the SHARS conditioning unit was designed for a 1000 Ci Co-60 source, the teletherapy head available for the demonstration contained a 2133 Ci Co-60 source. This, however, proved to be no problem with the cell performing better than expected.
Measurements taken around the cell during the demonstration operation, which confirm the results of the safety assessment, are presented in Table 2 below.

Table 2: With source out of drawer (normalized for 1000 Curie)

AREA/PORTION DESCRIPTION	POSITION	CONTACT	0.5m	1m	10m
	1. On sand	11.3 mSv/h			
	2. On edge	0.14 mSv/h			
	3. On concrete	29.4 µSv/h			
EAST WALL	1. Middle	17 µSv/h	20 µSv/h		

AREA/PORTION DESCRIPTION	**POSITION**	**CONTACT**	**0.5m**	**1m**	**10m**
WEST WALL	1. On window	34 µSv/h	8 µSv/h		
	2. One m left of the window	4 µ/Sv/h			
	3. Below window	177 µSv/h	42 µSv/h		
	4. Above window	8 µSv/h			
SOUTH WALL	1. Above shield in middle	23 µSv/h	14 µSv/h		
NORTH WALL	1. Middle	12 µSv/h	12 µSv/h		
SOURCE AGAINST WALLS 	1. South Wall (a) At empty port (b) Right side (c) Under Shield	 100 µSv/h 124 µSv/h 159 µSv/h			
	2. East Wall	104 µSv/h		70 µSv/h	8 µSv/h
	3. North Wall	52 µSv/h		32 µSv/h	8 µSv/h
	4. West Wall against window	22 µSv/h	14 µSv/h operator		
	5. Below window	188-234 µSv/h			

The team of experts concluded that

- The design is adequate to condition sealed high activity sources in countries that do not have facilities for these operations.
- The Necsa team is fully qualified to safely perform the required operations with the SHARS installation.
- Technical recommendations for further improvements (e.g. finalization of operational procedures, enhancement of shields in specific locations, etc.) need to be considered.

FURTHER DEVELOPMENTS

There has been continuous involvement by various international institutions, whether as expert consultants to evaluate the project or direct involvement in design issues such as the design of the long term storage shield. International cooperation, through the facilitation of the IAEA, is paramount for a project of this magnitude to be a success and was highly appreciated. This involvement currently continues in the form of some supplementary actions as discussed below:

- The contract with the IAEA for the SHARS conditioning unit development did not include “special form” certification of the capsules in which the sources will be conditioned as only long term storage in the respective countries was envisaged. It was, however, considered necessary to have special form certification for the capsules in order to facilitate the possible repatriation of sources to their countries of origin. This view was particularly supported by the United States. Los Alamos National Laboratories subsequently placed a contract on Necsa to obtain special form certification for the stainless steel capsules in which the sources will be conditioned. The final delivery date for certification of the capsules is end February 2008.

- The certification of the Long Term Storage Container as a transport container is also currently being considered. This will allow for the easy repatriation of conditioned sources to its country of origin.

CONCLUSION

The successful demonstration of the SHARS conditioning unit has proven that the concept works and that the unit is ready for deployment. The conditioning operations will commence with operations to Sudan and Tanzania, planned for the first half of 2008. The pre-missions to these countries in order to plan and make final arrangements already took place in June 2007.

As was mentioned before, this programme aims to assist in bringing the world-wide problem with the proper management of Spent High Activity Radioactive Sources under control. Through international involvement, especially the IAEA and also the USA, it will ensured that sources are managed and stored safely and especially securely thereby eliminating the risk of overexposure to the public and also possible covert actions.

REFERENCES

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