Technical, Logistical, and Administrative Aspects of Decommissioning and Shipping Overseas a Used Cyclotron

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A model CS-22 cyclotron, built by the Cyclotron Corporation of Berkeley, CA, which had been in operation at the DOE-UCLA Laboratory of Structural Biology and Molecular Medicine since 1970, was taken out of service and decommissioned in the spring of 1994. The cyclotron magnet and some of the internal components had become activated over many years of use. However, rather than simply burying the machine at a disposal site, a recipient at a university in Beijing, China, was found which would accept donation of the cyclotron "as is" and would commit the effort and resources to refurbish and recommission it as part of an isotope-producing and research facility.

The process of decommissioning, staging, and packing the cyclotron for shipment overseas was relatively straightforward: The machine was disassembled and moved from UCLA to a licensed facility in Berkeley. The components of the cyclotron were all surveyed, and the appropriate labels and shipping declarations completed.

However, the process of finding a freight company who would accept the cargo was extremely challenging. These difficulties were exacerbated further by some unfortunate miscues and miscommunications with regulatory authorities, most notably the U.S. Coast Guard. Finally, in the spring of 1996, all of the problems were overcome and the last of the activated components of the cyclotron reached their destination in Beijing.

Initial Decommissioning and Transport Off-Site

The CS-22 cyclotron was decommissioned and dismantled as part of a program to refurbish and modernize the facility for installation of a new, self-shielded compact cyclotron to produce isotopes for medical research and clinical diagnostic nuclear medicine. The "hands-on" work of dismantling was performed by personnel from IT Corporation under the supervision of one of the authors (Fred Ramsey).

The CS-22 cyclotron was then shipped by truck to a secondary staging site in Berkeley, CA, which had originally been the manufacturing and test facility for cyclotrons built by the Cyclotron Corporation. (The facility Radioactive Materials License had been maintained by CTI Cyclotron Systems, the successor to the Cyclotron Corporation.) The activated components were stored in vacant cyclotron test vaults until preparations for shipment overseas were completed.

Radiation Survey, Packing, and Transport Documentation

A complete inventory, identification, and surveying of all activated components and subsystems of the cyclotron was performed. The most intensely activated parts, such as beam-probe tips, extractor septa, target windows, etc., had been left at UCLA for disposal. Less-activated components, such as Dees, ion sources, etc., which were in good mechanical shape were surveyed and boxed for shipment.

Activation by several reaction processes, including direct proton (p,n) and secondary, neutron-induced (n,p), (n,α), and (n,γ) on copper, steel, tungsten and aluminum, was noted and confirmed by gamma-ray spectroscopy utilizing a 1.25" diameter x 1.50" deep NaI(Tl) detector/photomultiplier tube calibrated against standard sources – ^{137}Cs, ^{22}Na, and ^{60}Co.

The spectroscopy data were qualitative, serving to identify the various peaks which were present and not to establish the quantity of radioactive material present in any given sample. Although most samples contained more than one nuclide, typically there was only one principal nuclide per component. A semi-quantitative estimate for each component was obtained by assuming that the principal nuclide was the only nuclide present, measuring the exposure dose rate at a convenient distance from the source and utilizing the well-known relationship:

$$D = 5.7\ CE / R^2$$

where
D = measured exposure dose rate in roentgens per hour;
C = number of curies in the sample, assuming a "point-like" source distribution;
E = energy per decay of the principal nuclide;
R = source-detector distance in feet.

A "convenient" distance from the source meant a distance sufficiently close to get a reliable survey reading, but sufficiently far as to render the source distribution "point-like." All measurements were made referring to the "hottest" activation hot-spot on any given component. No correction for self-attenuation was attempted. Table 1 gives a summary of survey results.

Only those components which had been activated by direct, proton-induced nuclear reactions had any notable external exposure dose rate. Those components which had been activated by secondary, neutron-induced reactions generally showed external exposure dose rates which were low enough to ship in plain, unlabelled packages or as Radioactive I ("White Label").

Securing Overseas Transport of a Slightly Radioactive Cyclotron

The Beijing recipient of the CS-22 cyclotron was reponsible for securing overseas shipment. Carroll-Ramsey Associates provided local liaison and technical support. A manager at one of the large international freight forwarding companies (Schenker International) very kindly provided us with a copy of the International Maritime Dangerous Goods (IMDG) regulations. We soon learned more than we ever wanted to know about the problems associated with shipping an activated cyclotron to China.

Steamship companies are in the business of shipping – all subsidiary issues relating to customs, hazardous materials, paperwork, etc., are generally left to a freight-forwarder, who serves as the interface between the shipper and/or recipient and the steamship company. The freight forwarder, in principle, takes all the worry and grief out of the process, receiving payment from commissions based on a percentage of the shipping fees charged by the steamship company.

Table 1. Survey date August 1994.

Component	Activation reaction	Half-life	Principal emission	Dose rate at 1 m
Dees	$^{65}Cu(p,n)^{65}Zn$	245 d	β^+, 511 keV 1115 keV	0.05 mSv h^{-1}
Extractor (copper parts)	"	"	"	0.03 mSv h^{-1}
Extractor (septum)	$^{184}W(p,n)^{184}Re$	165 d 70 d	100 keV 161 keV	
Magnetic channel, ion-source	$^{56}Fe(p,n)^{56}Co$	78 d	β^+, 511 keV 846 keV	0.03 mSv h^{-1}
Motors, transformers, etc.	$^{59}Co(n,\gamma)^{60}Co$ $^{54}Fe(n,p)^{54}Mn$	5.27 y 312 d	1.17, 1.33 MeV 835 keV	–
Misc. copper parts	$^{63}Cu(n,\alpha)^{60}Co$	5.27 y	1.17, 1.33 MeV	–
Misc. aluminum alloy parts	$^{25}Mg(n,\alpha)^{22}Na$	2.6 y	β^+, 511 keV 1.275 MeV	–

Unfortunately, this particular service orientation cuts two ways. The very essence of the freight-forwarder's business is the management of information, but when a really knotty problem comes up, it is very difficult to work collaboratively to arrive at a solution. There is simply no way to pay for all the extra work involved. In the end, Carroll-Ramsey Associates had to perform essentially all of the work required to facilitate the shipment. There were two interlocking problems: 1) Reluctance of most carriers to handle any cargo labelled "Radioactive." 2) Stringent regulations at transit ports-of-call regarding radioactive materials.

It seems that all shipments by major steamship lines between the West Coast of the United States and Mainland China make one or more stops in Japan or Hong Kong. It may be possible to book shipment on a smaller boat which sails directly to Mainland China, but one would, in effect, have to charter the whole ship for one's self.

Many, though not all, steamship companies flatly refuse to consider accepting the cargo. Of those that stepped forward to accept the cargo, all except one eventually begged out due to stated difficulties at transit ports, most notably those in Japan. The Chinese National Shipping Line (COSCO) had initially refused to accept the cargo, but was eventually persuaded by the recipient to carry it, presumably in the national interest.

The CS-22 cyclotron was crated up and packed into sea-going containers. The main magnet (23.5 metric tons) was secured to a 20-ft. "flat rack" container. The rest of the cyclotron and its subsystems (14.2 metric tons) were loaded into a 40 ft. "rag top" container. The exposure dose rates measured at 1 m from the sides of the containers were 1 μSv (0.1 mR) for the flat rack and 4 μSv h^{-1} (0.4 mR h^{-1}) for the rag top, respectively. Loading of the containers was done on the premises in Berkeley using a pair of large-capacity overhead cranes originally installed by the Cyclotron Corporation. The containers were then trucked back to COSCO facilities at the Port of Long Beach.

Resolution of Difficulties with Port Authorities

When the containers arrived at Long Beach, the shipping documents and dangerous goods declarations were reviewed by the U.S. Coast Guard, which is the agency responsible for assuring compliance with hazardous materials regulations for ocean shipment. Our paperwork identified the various nuclides and their quantities, all in the range of a few tens of mCi or less, in each of the respective containers.

Unfortunately, the inspectors were not well-informed regarding radioactive material units of measure and their abbreviations. In particular, the distinction between "MCi" and "mCi" was not understood, leading to frantic telephone calls from Long Beach, the essence of which were, "You can't ship this stuff over the road, let alone on the ocean." We were able to persuade the authorities that the prefix "m" stands for "milli" not "Mega" and that the quantities of activity on the manifest were all well within allowable quantities for safe transport.

This settled, attention now turned to the particular style of containers used to carry the cargo. We had packed the cyclotron subsystems, power supplies, etc., in wooden crates which were then loaded into an open-top container. We had used this style of container because it allowed us to utilize the overhead crane for loading of heavy components. By our interpretation, the regulations permit the use of an open-top (actually a cloth-covered or "rag-top") container provided the load is properly crated to ensure against breakage or leakage.

Container configurations are defined in paragraphs 2.13 and 2.15 of the IMDG Code (Class 7, Radioactive Materials, page 7008) excerpted below:

Freight Container (2.13)

For the purposes of this class, freight container has the meaning assigned in section 12 of the general introduction but must be of the "closed type" defined in 12.1.5 of that section.....

..... A freight container may be used as packaging if the applicable requirements are met. It may also be used to perform the function of an overpack.

Overpack (2.15)

Overpack means an enclosure, such as a box or bag, which need not meet the requirements of a freight container and which is used by a single consignor to consolidate into one handling unit a consignment of two or more packages for convenience of handling, stowage, and transport.

A literal reading of 2.13 above requires that the container shall be of the "closed type," but since all the components were in their own crates, we were using the container as an "overpack" in which case paragraph 2.15 applied. Indeed, the coast guard had no quarrel at all with the fact that the magnet (in its crate) was secured to a completely open "flat rack" container, but they were unwilling to sign off on the "rag top."

We took the question up the chain of command – all the way to the Divisions of Research and Special Projects, and Hazardous Materials Standards, at the Department of Transport in Washington. We were treated most graciously by those officials, who acknowledged that by packing the components in wooden crates we had, indeed, met the intent of the regulations. The "rag top" container was acceptable for shipment of this cargo. This was passed back down the chain of command as a directive to the local Coast Guard office at Long Beach.

Resolution of Difficulties with Port Authorities

By now, however, the steamship company, COSCO, was getting very nervous and was beginning to have second thoughts about accepting the cargo. Moreover, the question of transit through Japanese ports had not been resolved. The Japanese authorities had indicated that, indeed, they would not permit the cargo, as configured, to stop at a Japanese port. We proposed shipping via Hong Kong as an alternative, where the transit license procedures and paperwork are tedious but straghtforward. This proposal was rejected for internal COSCO Company Policy reasons.

It had been 18 mo since the CS-22 had been decommissioned, surveyed, and packed for overseas shipment. The activity levels had decayed with time, and the whole issue was becoming academic. By now, however, everyone within the Steamship Company and Port Authority Regulatory hierarchies had to feel some comfort and sense of compromise. We finally resolved the problem by agreeing to remove the two "hottest" crates – those with "Radioactive III" labels with transport indexes of "3" and "5," respectively (referenced to August 1994) – from the rag-top container and shipping them separately to China by air freight.

Final Disposition

Because of longshore union jurisdiction and work rules, we were not permitted to gain access to our container to remove any of the contents. Instead, we had to make arrangements through a third party to have the container trucked off-site to a warehouse where a qualified HAZ-MAT operator could remove the contents to reach the crates in question, then send the container back to the dock. The CS-22 cyclotron finally left for China in January 1996. The remaining two "hot" crates (which, of course, had cooled substantially) were left in the hands of the HAZ-MAT forwarder who succeeded in getting them on a plane bound for Beijing in May 1996.

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References

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