REMOTE INSTALLATION AND REMOVAL OF SHIELDING AND EQUIPMENT IN THE CYCLOTRON TANK

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Summary

Access to the TRIUMF cyclotron is achieved by raising the top of the 19 m diameter x 0.5 m high vacuum tank about 1 m. Remote handling is routinely achieved by transporting equipment on a service bridge that is inserted into the open cyclotron with one end supported on a bearing on the center post while the other end is supported on powered wheels that can propel the bridge through 360°. A series of trollies has been built to travel on the bridge, giving positioning to any point in the tank to ±1 mm. The first trolley built was a travelling platform for technicians and their tools. The main components requiring servicing are the 80 resonator panels that weigh ~200 kg, have water connections and are somewhat flimsy. The resonator trollies have 8 degrees of freedom. A nut-runner trolley is used to do/undo all fasteners with torque and revolution control. Four manipulative arms travel outboard on the bridge and handle cameras, leak-checking, and other miscellaneous tasks. The control console installed in an adjacent building contains all the video (including 3D), bridge, trolley and manipulator controls, and programming capability. Ten tonnes of shadow shields are remotely installed and removed for every scheduled shutdown.

Introduction

The TRIUMF isochronous cyclotron at the University of British Columbia in Vancouver, Canada has a residual radiation build-up in the cyclotron components, vacuum tank, sector-focused magnets and facility structure that is seriously hampering hands-on servicing and upgrading. After nine years of operation with energies from 180 to 520 MeV with over 100 μA intensity the radiation levels in some components exceed 100 rem/h immediately after a high energy run, and with decay of a few days levels over 1 rem/h exist generally at the main vacuum tank periphery.

A system for transporting and positioning people, equipment and shielding in the cyclotron has been developed over the past nine years, and it consists primarily of a service bridge which is installed in the tank when the upper half is raised 130 cm, with one end resting on a bearing on a center post, and the other end driven in a circular path through 360° by wheels that run on a peripheral surface just outside the tank (Fig. 1). A family of trollies has been developed that run radially on the service bridge, and they can thus access (verticle axis cylindrical coordinates) any point in the cyclotron proper. These trollies include

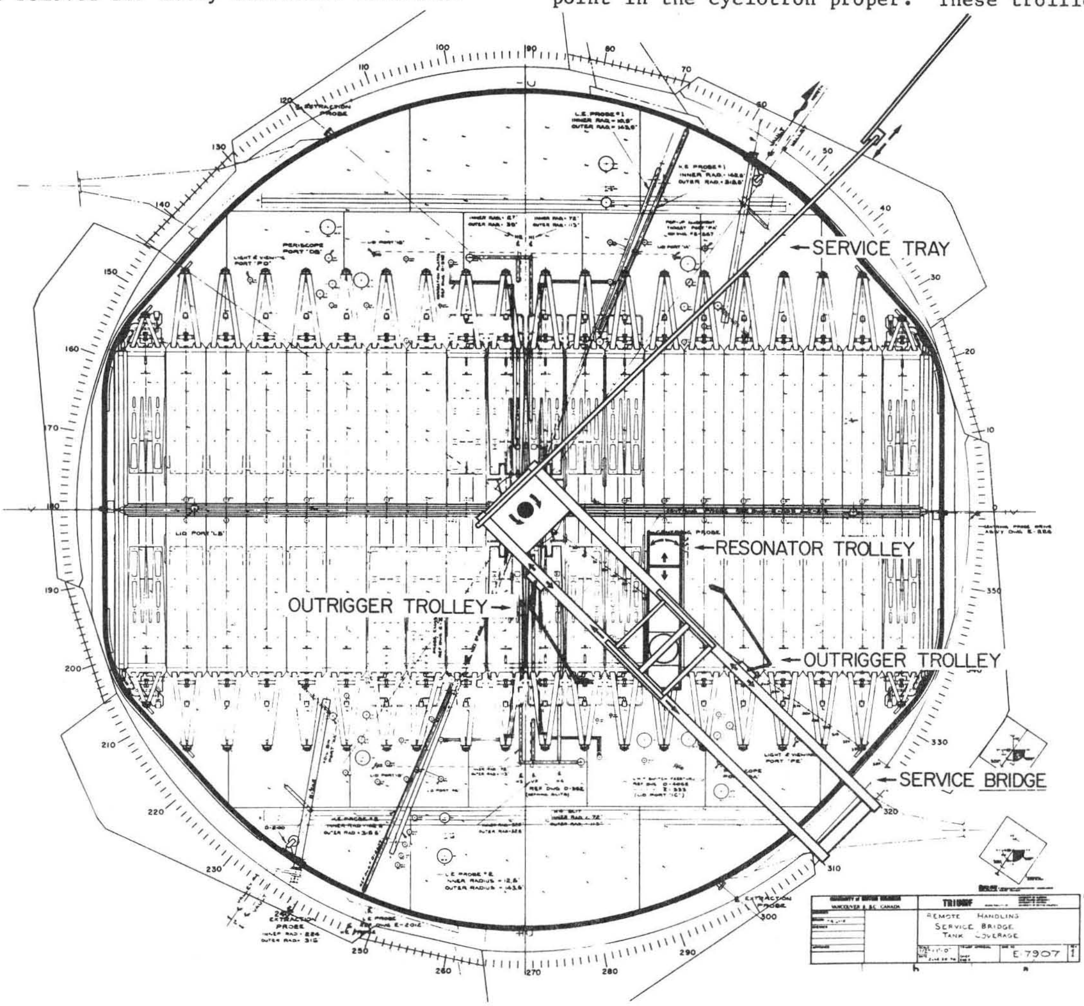

Fig. 1 Plan View of Open Cyclotron

a "manned" vehicle for personnel convenience, a "nut-runner" trolley for servicing all in-tank fasteners, a "lift" trolley that installs and removes some 10 tonnes of temporary shielding each shutdown, two special trollies for removal and replacement of the 80 resonator segments, and four travelling manipulators that are used for (viewing) camera manipulation, leak checking, and other miscellaneous tasks.

The cyclotron consists of a verticle axis cyclindrical vacuum vessel 19 meters in diameter and a half meter high, containing over 100 RF, diagnostic and vacuum pieces of equipment. A large support structure jacking system raises the "lid" of the vacuum tank and its associated equipment, along with the upper half of the 4000 tonne sector magnets (Figure 1).

Remote Handling

In 1977 a system for installing and removing Pb shielding was developed. There are 66 shields, each weighing about 160 kg and measuring 50 cm high and 1 m wide that are placed vertically just inside the vacuum tank wall. They mostly rest on the tank bottom but some are "hooked" on the tank edge, and they nominally have 5 mm clearance shield-to-shield. They are transported by a locking "bayonet" pick-up tool inserted into a socket on the top surface located at the center of gravity (Fig. 2).

A "lift" trolley riding on the service bridge insertion vehicle picks up each shield from a pallet just outside the cyclotron, and they travels onto the service bridge inside the tank. The service bridge is then rotated around to the correct angular position, and the trolley driven to the correct radial position, and then with careful viewing, using four video cameras, the shield is rotated to the correct orientation, eased into the correct peripheral location and lowered onto the floor of the tank, unlocked, the pick-up tool raised clear, and the lift trolley brought out of the tank. The total installation currently requires about 18 hours (two operators) and is scheduled on a continuous shift basis. The operation is performed at a portable console that is transported into the cyclotron vault each shutdown. The console contains all the service bridge and trolley drive controls as well as a switching video system for twelve monitors (Fig. 3).

Removal of the shielding requires running the lift trolley into approximately the correct shield position, and then the bayonet pick-up socket is centered ona video cross hair with a fifth horizontal camera viewing down vertically through a 45° mirror. After centering, the mirror is "flipped" out of the way of the verticle bayonet pick-up tool which is then driven vertically

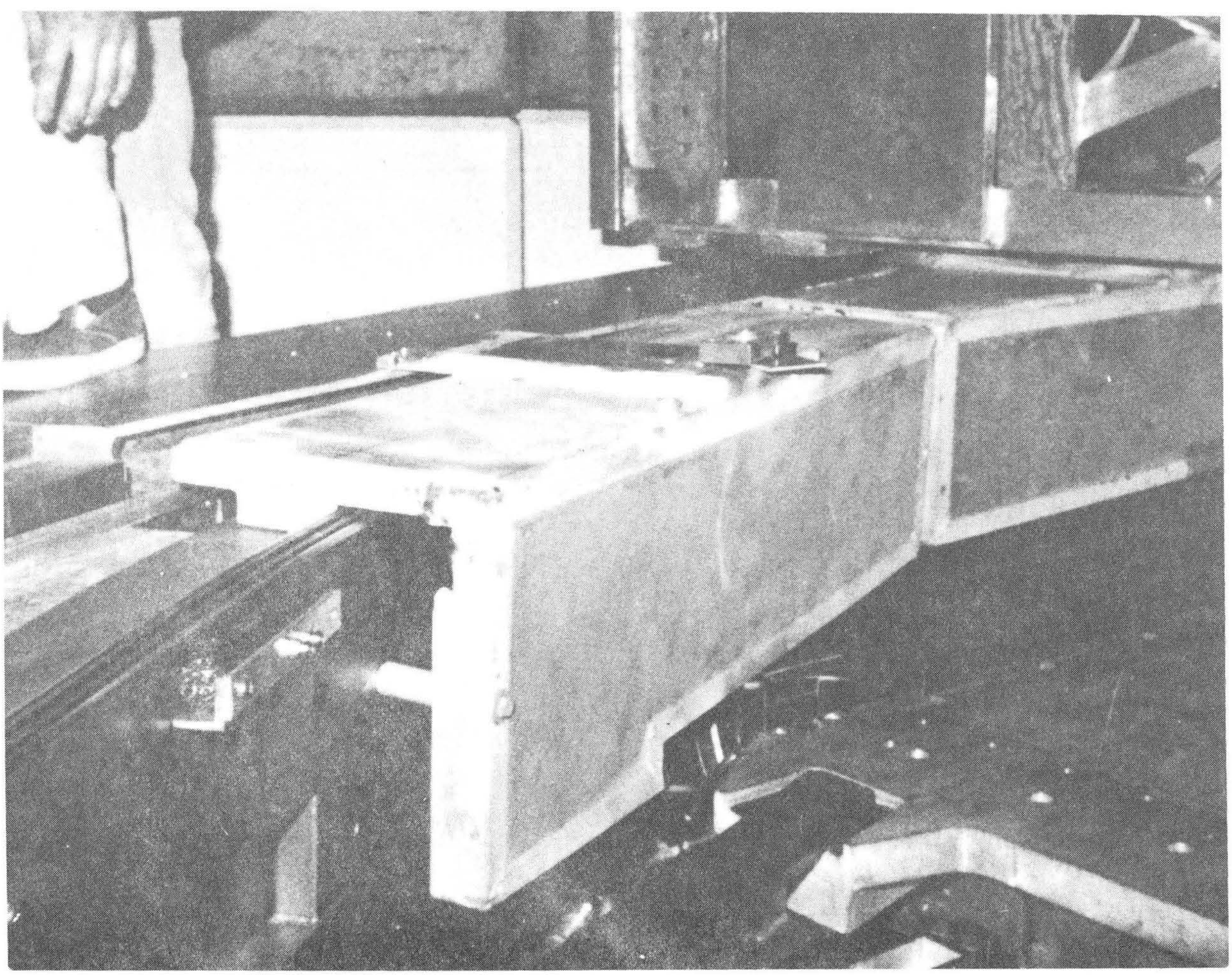

Fig. 2 Shadow Shields

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down into the bayonet socket. Insertion is now viewed by the same horizontal camera, and locking can be viewed and confirmed by a viewed flag. The shield is then carefully raised and moved away from the tank wall, and the lift trolley is brought out of the tank onto the insertion vehicle, where the shield is deposited onto a pallet.

The residual radiation is reduced by a factor of three and brings most areas in the vacuum tank down to a level where the TRIUMF Safety Rules allow for hands-on servicing (less than 1 rem/h).

There are over 400 fasteners in the vacuum tank, and a "nut-runner" trolley has been in operation for six years. The position, location, number of turns and optimum torque for all fasteners is documented. The nut-runner trolley can operate vertically up or down, or horizontally. It has two optional power heads, one a pneumatic powered reversible ratchet mechanism that rotates 36° (1/10 turn) per command, with two torque controls (one desired remotely adjustable and one actual feedback) that range from 0.1 to 15 kg/m. The second power head is a high speed reversible electric unit with one preset torque control. It is a smaller unit and is for running smaller fasteners (1/4 - 20 NC etc.) Items mounted on the lower surface of the vacuum tank lid are "latched" to the lid so when the fasteners are loosened the item still "hangs" in place.

unlocking and disengaging (sliding) RF finger stock contacts, for driving twin (split flange) bolts, for directing and controlling a helium leak-check nozzle, and for manipulating a vacuum cleaner and wand (rotation and verticle position) while sweeping the tank.

Two special 8° of freedom trolleys have been commissioned for removal and installation of the resonator sections after the fasteners are loosened. The resonators are located, mated to, locked on to, and then the resonator is unlatched by the trolley, and removed from the tank. The resonators are a meter wide, 4 meters long, 15 cm thick and weigh about 200 Kg. When being installed a resonator must clear the adjacent resonators by $\pm$ 1 mm. This is done with no one in the tank by using ten video cameras.

The outrigger trollies travel on the sides of the service bridge and can pass other trollies. They are articulated arms that must fold flat against the bridge (15 cm clearance maximum during bridge insertion) but they can reach out 3 meters when fully deployed. The shoulders can be raised or lowered to reach over or under the bridge. The arms can be disconnected at the shoulder or elbow for special tasks. Normally the hand holds pan-tilt-zoom video cameras but special end effectors are used for discrete tasks. There is an electrical diagnostic probe and a He leak check probe, as well as a hand (gripper) for manipulative tasks such as moving wires, reinserting seals, retrieving tools, etc.

Fig. 3 Control Console

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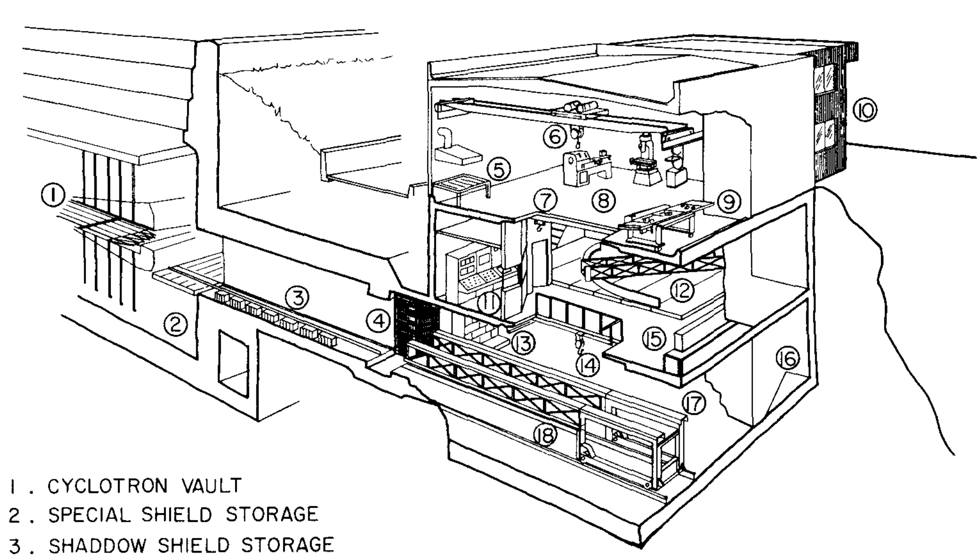
Future Plans

The tempoary shield installation and removal has proven so valuable in allowing continual in-tank hands-on upgrading that a new remote handling building (Fig. 4) has been constructed (and is just now being commissioned) that will allow for much faster and more reliable operation. A new lift rolley and shield configuration has been designed that will allow for five shields at a time being transported in/out of the tank, and this will allow for complete installation or removal in less than one shift. The control console is a permanent part of the new building and will not require moving each shutdown. All operations will be performed from the new building. The lower basement is connected by a tunnel to the cyclotron vault and protected by a 120 tonne shielding door. The cyclotron (and insertion vehicle) are now stored in the new building during cyclotron operation, and can be serviced and updated during normal experiment scheduling. For a shutdown the shield door is opened, the insertion vehicle and service bridge driven into the vault and the bridge installed in the tank. Operation of the bridge and trolley is then controlled from the upper basement of the new building. A 1/4 tank mock-up is installed next to the Remote Handling Control Room and new equipment may be tried out and finalized in the mock-up during cyclotron operation. Normal remote handling operations should, within a year, require no one in the cyclotron vault.



1. CYCLOTRON VAULT
2. SPECIAL SHIELD STORAGE
3. SHADDOW SHIELD STORAGE
4. SHIELD DOOR
5. HOT WELDING
6. 7.5 TON CRANE TO 263' LEVEL
7. 2 TON CRANE
8. HOT SHOP
9. TROLLY STORAGE
10. OFFICES, DESIGN GROUP ENG.
11. CONTROL ROOM
12. CYCLOTRON MOCK-UP
13. CLEAN BARRIER
14. 2 TON CRANE
15. ELECTRONIC AREA
16. STAIRWELL
17. CLEAN SET-UP AREA
18. SERVICE BRIDGE AND CARRIER

Fig. 4 New Remote Handling Building