

Fuel Handling System for the Qinshan Phase III Nuclear Power Plant

By

Lin Chuanqing* and Dennis C. Hancock**

*Third Qinshan Nuclear Power Company

**Atomic Energy of Canada Limited

General Description of the Fuel Handling System

The Fuel Handling System entails the entire cycle of receiving New Fuel bundles, in pallets, handling facilities, on power fuelling and storage of the irradiated bundles in pools of light water. The Canadian designed CANDU (Canadian deuterium uranium) system is based on a heavy water moderated and cooled reactor that currently operates on a once-through natural uranium fuel cycle. There is no need for enriched fuel in the CANDU system.

On power fuelling of CANDU reactors is a major contributor to the high capacity factors achieved in CANDU 6 plants currently operating in South Korea, Argentina, Romania and Canada. It was recognized at an early stage that CANDU reactors, burning natural uranium fuel with inherently low excess reactivity margins, would be more economical to operate if they utilized on-power fuelling.

Some other advantages of on-power fuelling are:

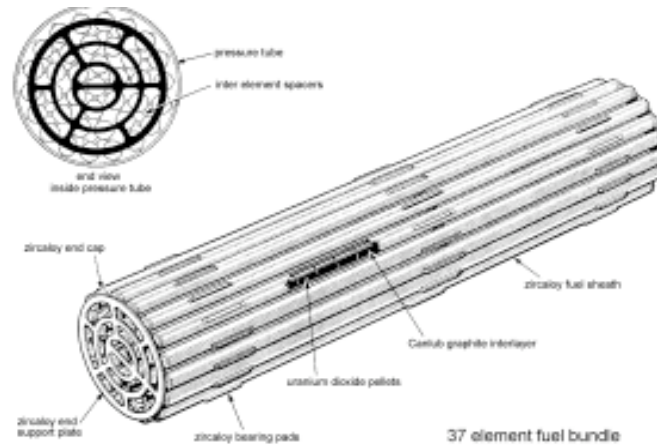
- (a) Higher fuel burnup and, therefore, lower fuel costs
- (b) Fewer fission products in the primary heat transport system, by early removal of defected fuel bundles
- (c) More flexibility to plan scheduled shutdown activities that do not have to include fuelling operations.

Once new fuel bundles have been inspected they enter the Fuel Handling system, in air, and are contained circumferentially until they are discharged at the irradiated fuel port. Once the F/M picks up new fuel, the bundles are immersed in heavy water and remain so until discharge at the irradiated fuel port. At this point there is a transition from heavy water to air and, within a limited time period, to regular light water used in the discharge and storage bays.

New Fuel

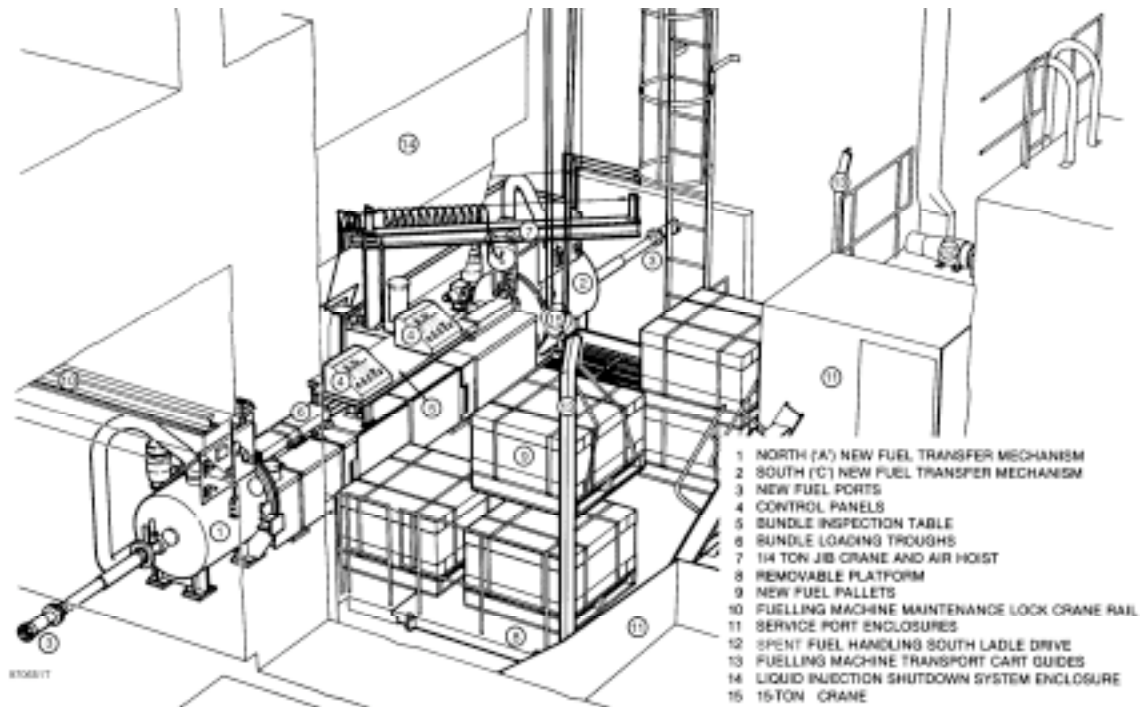
The new fuel bundles arrive at the station in wooden pallets containing 36 bundles each and are stored in a service building room, outside of containment. Each bundle is sealed in a polyethylene bag and supported in styrofoam for protection. Fuel pallets are brought into the reactor building by fork-lift truck, via the equipment air lock, to a new fuel loading area. Pallets are raised to the New Fuel Loading platform by an overhead crane and placed on a turntable. A typical CANDU 6 fuel bundle is made up of 37 elements in a bundle that is 102 mm (4.02 in.) diameter and 495 mm (19.5 in.) long as shown below. The natural uranium fuel bundles of CANDU reactors consist of a number of zirconium tube elements, containing sintered compacted uranium dioxide pellets and joined together by end plates. Small pads to maintain correct spacing for coolant flow, and support pads for sliding along the fuel channels during fuelling movements, are welded to the elements.

The fuel handling system is designed to limit axial compressive loads imposed on irradiated fuel bundles during normal operation to less than 18 kN. Side or radial loads are normally held to the same value as would be generated by the bundle weight when on its normal support pads.



New Fuel Loading

New CANDU fuel bundles of natural uranium fuel, before irradiation in the reactor, are essentially non-radioactive. They can be handled by personnel without biological shielding. The operator uncrates the bundles, inspects and gauges them using an air-balancing hoist and ring gauge. The serial number is recorded and the bundles are placed in a loading trough. The operator uses a local control panel to load the fuel bundles into the New Fuel Magazine to await pickup by the Fuelling Machine.



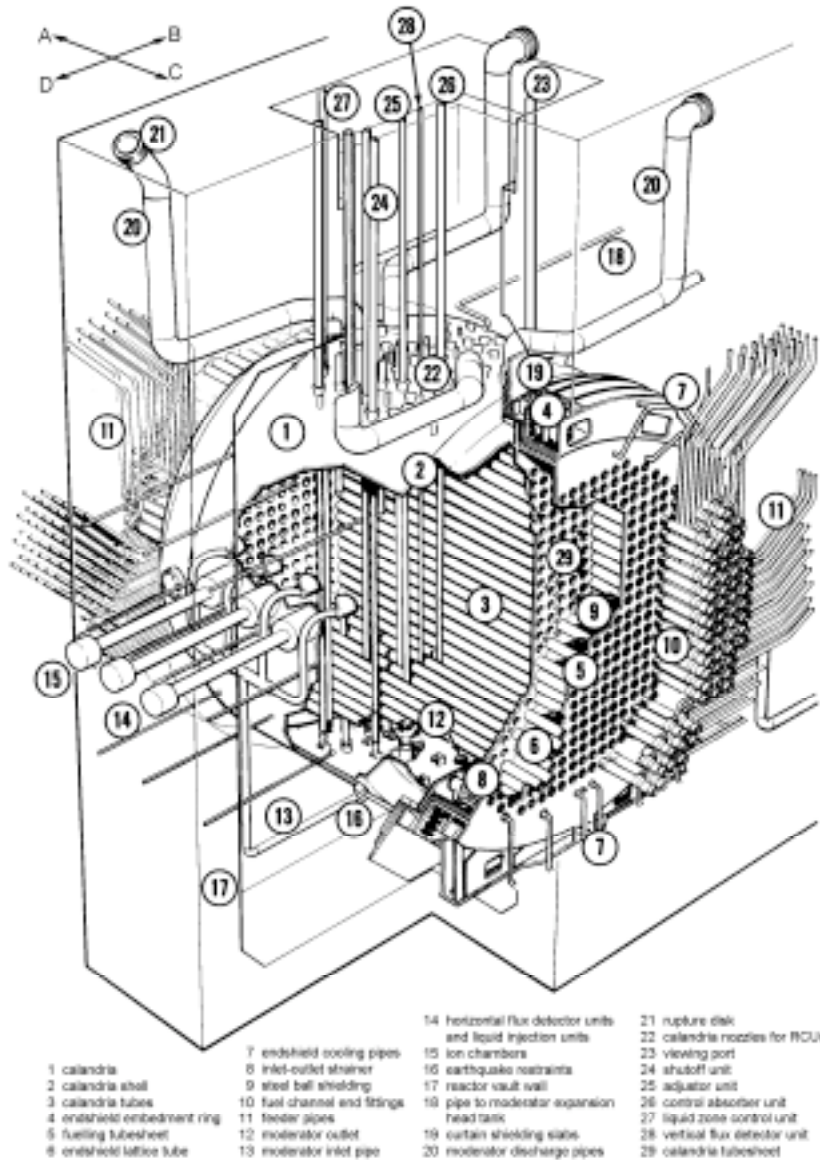
There is one central area for New Fuel Loading that provides fuel to both New Fuel Magazines. Each New Fuel Magazine contains seven tubular channels, six for the new fuel bundles (two per tube) and one for the Transfer Mechanism Shield Plug that is normally located in the New Fuel Port to reduce radiation streaming into the New Fuel Loading area.

The purpose of the New Fuel Transfer System is to provide a safe and reliable way of supplying the two fuelling machines with sufficient quantities of new fuel in order to maintain full-power operation. This is the only requirement for personnel entry into the Reactor Building during normal operation.

On-Power Fuelling

General

CANDU PHWRs use horizontal fuel channels arranged in a square lattice grid. The Fuelling Machine gains access to the fuel channels by means of a bridge structure supported by columns. The fuelling Machine has three degrees of motion, vertical motion of the bridge, horizontal motion across the reactor face and axial motion to advance onto the fuel channel. These fuel channels are sealed at each end with closures remotely operable by the fuelling machine for fuelling access.



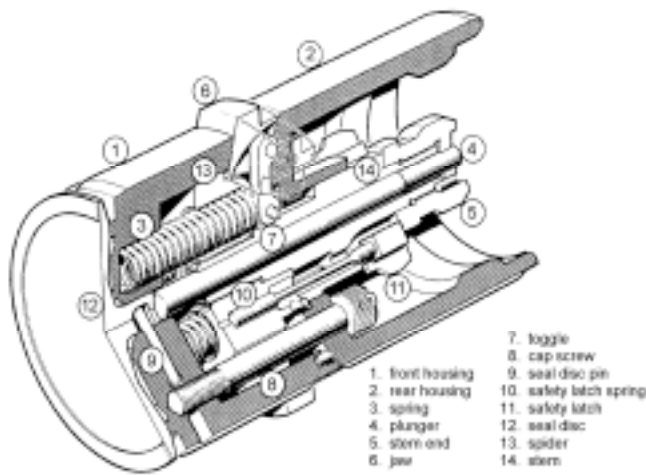
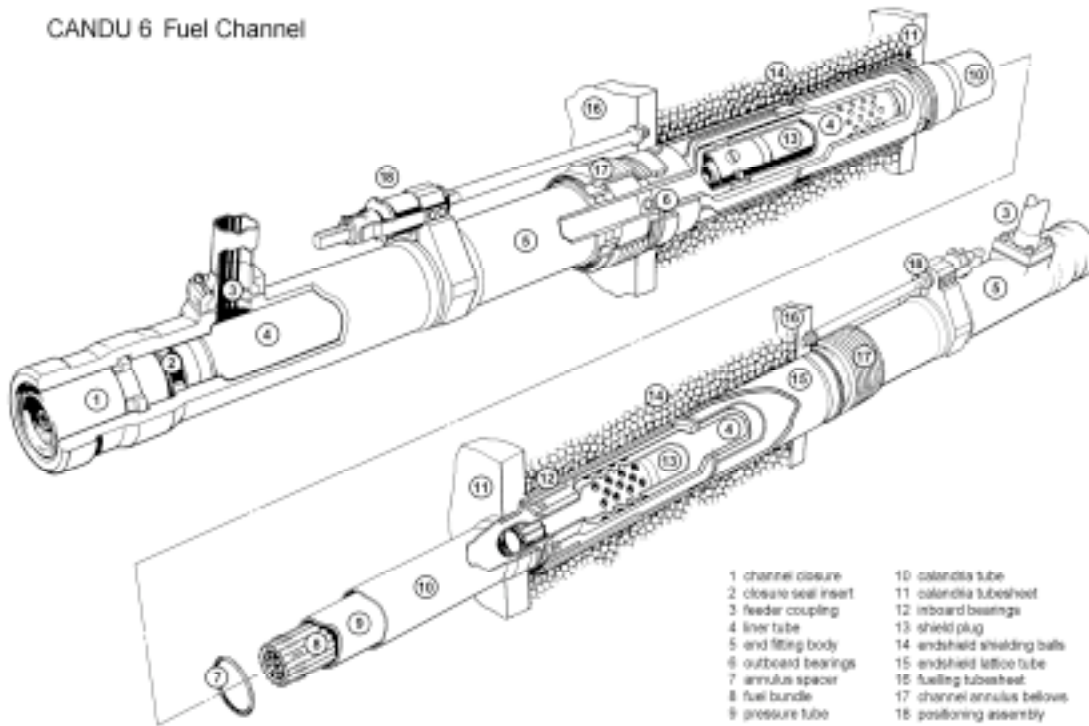
In addition to the fuel bundles, the shield plugs and closures are handled by the machine during fuelling. The fuel bundles are not mechanically attached to one another but are held together by the coolant flow hydraulic drag forces which push the string of bundles against a downstream stop in the fuel channel, or against a latched channel shield plug assembly.

Reactor Fuel Channel Hardware

In order to perform on-power fuelling, the Fuelling Machine must first clamp onto the fuel channel and remove the channel closure plug. Next the fuelling machine inserts a sleeve to breach the gap created by

the removal of the channel closure plug, which forms a face seal inside the channel. Once the sleeve is in place, providing a smooth bore between the pressure tube and fuelling machine rotor tubes, the fuelling machine then unlatches the shield plug and begins the fuelling process.

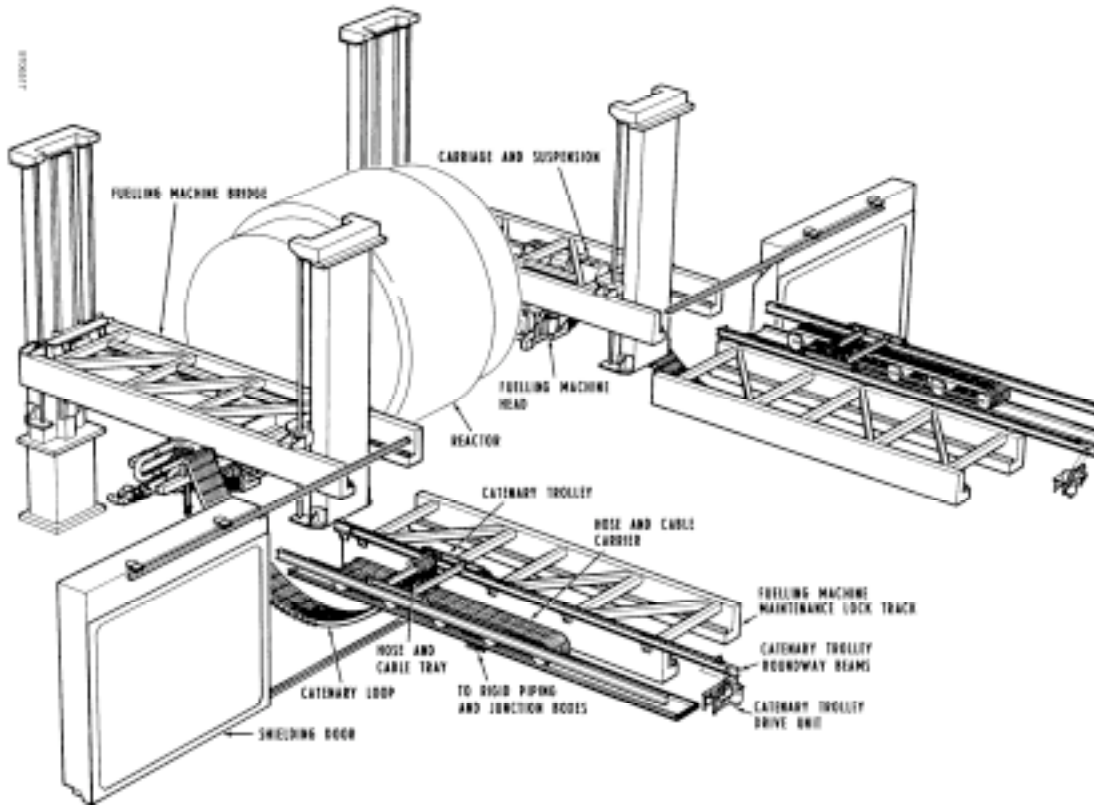
CANDU 6 Fuel Channel



Channel Closure Plug

Reactor Access via Fuelling Machine Bridge & Columns

For the 600 MWe reactor two fuelling machine bridge and carriage assemblies are provided, one at each face as shown below. The bridge spans the face of the reactor and it supports a carriage that in turn supports a fuelling machine head. Each bridge moves vertically on two guide columns to provide the coarse 'Y' motion of the fuelling machine head, while the carriage moves along the bridge to provide the coarse and fine 'X' motions of the head. Fine 'Y' motion is provided by a mechanism contained within the carriage assembly.

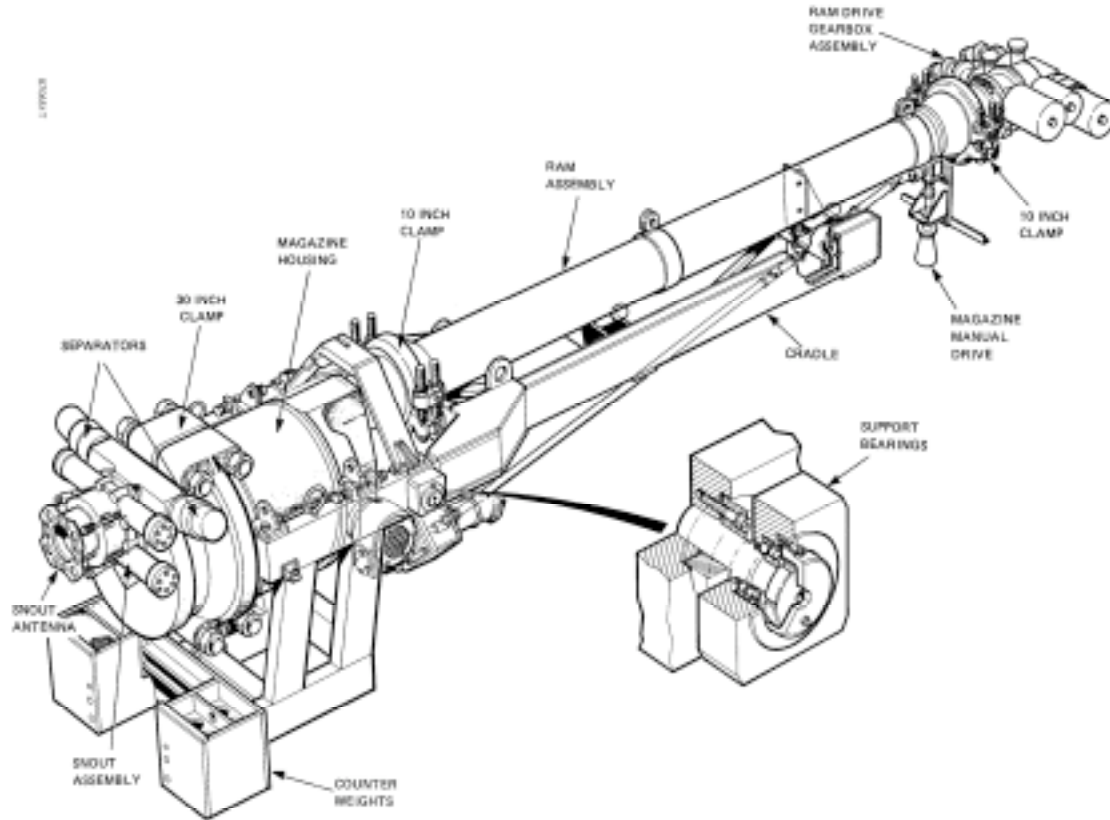


With the bridge in its lowest position, the carriage-rails on the bridge are aligned with similar rails on the maintenance lock tracks, enabling the carriage with the fuelling machine head to transfer from the reactor vault to the maintenance lock area to access the new fuel and or irradiated fuel ports.

Fuelling Sequence

The on-power fuel changing equipment consists of two identical F/M's at each end of the reactor, suspended on a carriage from tracks on a bridge that extends the full length of the shielded vault at each end of the reactor. Vertical and horizontal traverse of the F/M is provided to allow access to all the fuel channel end fittings. Powered shielding doors separate the reactor vault from the maintenance lock and, when closed, allow access to the F/M in the maintenance lock while the reactor is operating.

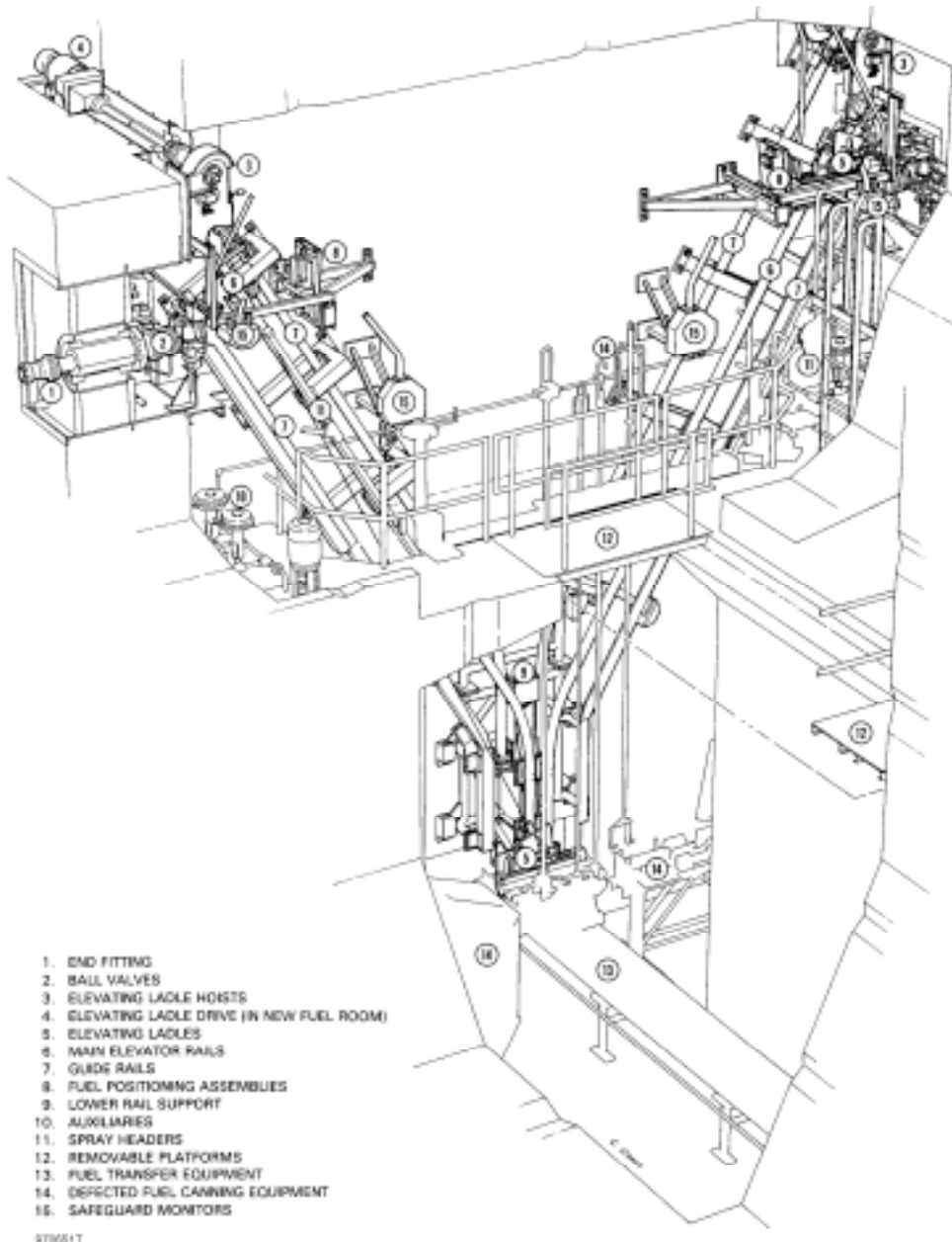
While in the maintenance lock, the F/M's also have access to the new fuel ports to receive new fuel, to the service ports for calibration or service, or to the rehearsal facility. Fuelling operations are performed with the equipment under remote automatic computer control via the station control computer. The shielding doors are opened and the two F/M's travel along the tracks at each face of the reactor and are positioned on each end of the selected fuel channel.



Both F/M's move forward to home and lock onto the fuel channel. After a leak test on the clamp seal, each F/M, which is filled with heavy water, is then pressurized to match the heat transport system conditions. The F/M's remove the F/M snout plug and channel closure, and store them in the F/M magazines. Guide sleeves are installed and the shield plugs are then removed from the fuel channel. New fuel is inserted at one end while irradiated fuel is discharged from the other end of the same fuel channel. Fuelling is done with the flow and on high flow channels it is referred to as FAF (flow assist fuelling) whereas on lower flow channels it is referred to as F.A.R.E (flow assisted Ram Extension) fuelling.

Two fuel bundles can be inserted from each magazine position containing new fuel in the F/M. Four to eight new fuel bundles are generally inserted on each visit, thus replacing four to eight of the fuel bundles in the fuel channel. Either F/M can load or accept fuel, depending on the direction of flow in the particular fuel channel being serviced. When the required number of fuel bundles has been inserted, the shield plugs, channel closures and snout plugs are replaced and the closures are leak tested by the F/M. The two F/M's then traverse to the Irradiated fuel ports where the irradiated fuel is unloaded.

With four-bundle shift fuelling, the F/M can fuel one channel and then fuel a second one, before returning to the irradiated fuel ports. For a CANDU 6 reactor, fuelling is required on about fourteen fuel channels per week, with eight fuel bundles being discharged at each visit to the reactor. Once the F/M has unloaded the irradiated fuel, It goes to the new fuel port to pick up new fuel bundles, and traverses back to the reactor face to become the upstream F/M for the next channel to be fueled. The other F/M, having remained at the reactor face, will also home onto the next channel and perform the functions required at the downstream end. Articulated TV cameras, one in each F/M vault at the reactor face and one at the irradiated fuel discharge bay are provided to permit monitoring of operations.

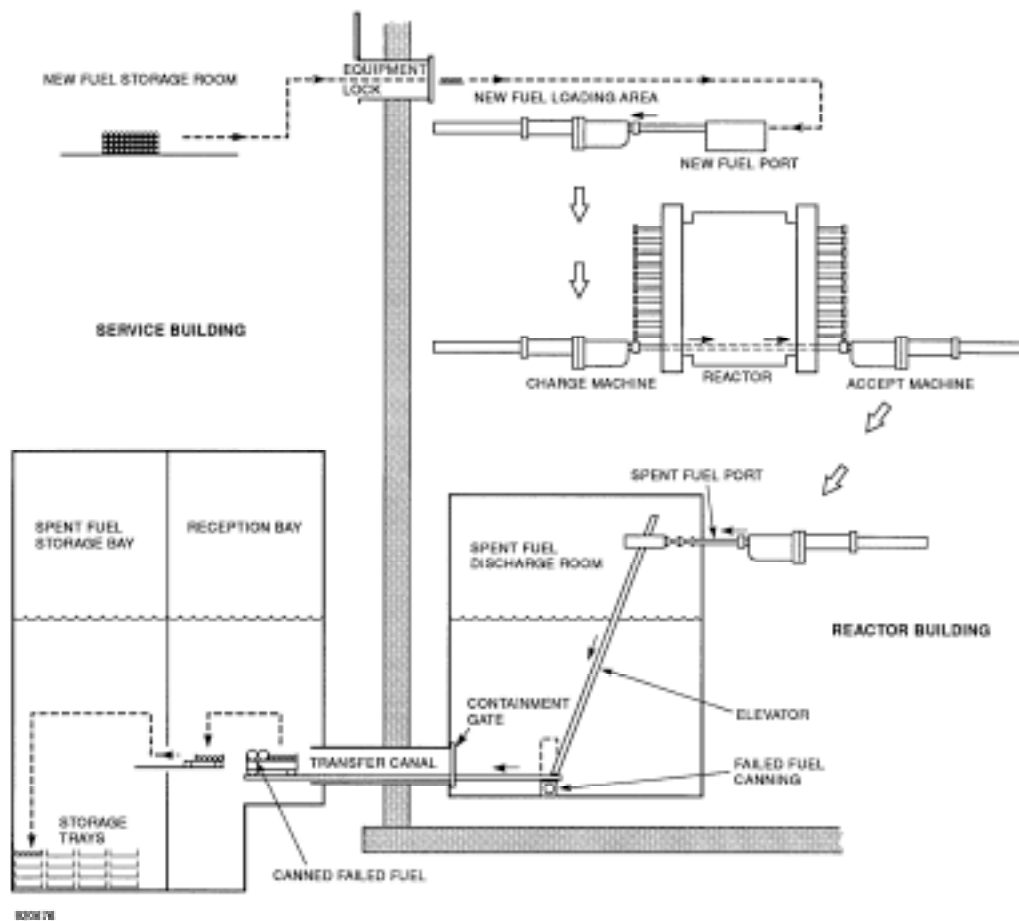


1. END FITTING
2. BALL VALVES
3. ELEVATING LADLE HOISTS
4. ELEVATING LADLE DRIVE (IN NEW FUEL ROOM)
5. ELEVATING LADLES
6. MAIN ELEVATOR RAILS
7. GUIDE RAILS
8. FUEL POSITIONING ASSEMBLIES
9. LOWER RAIL SUPPORT
10. AUXILIARIES
11. SPRAY HEADERS
12. REMOVABLE PLATFORMS
13. FUEL TRANSFER EQUIPMENT
14. DEFECTED FUEL CANNING EQUIPMENT
15. SAFEGUARD MONITORS

9795517

Irradiated Fuel Transfer

Once the fuel bundles have been irradiated, they must be handled remotely with automated fuelling machines and special fuel transfer equipment. After spent fuel is received two bundles at a time from the fuelling machine via the irradiated fuel port, the elevator lowers the bundles into the water of the discharge bay, and deposits them on a rack. The rack is supported and indexed by a cart that engages the pins of the discharge bay conveyor chain with two slotted brackets. Normally the rack carries eight spent fuel bundles, but it can carry up to twelve. On route from the discharge bay to the reception bay, there is a reception bay conveyor in line with the discharge bay conveyor. The two conveyors are driven by electrical motors mounted above water on the bay walkway floors. The motor moves the cart on the discharge bay conveyor through an above-water



drive unit, a power transmitting shaft, an under water gearbox, conveyor sprockets and chain. Once the cart reaches the gap between the two conveyors, one slotted bracket of the cart disengages the pins of the chain as the pins go around the sprocket of the discharge bay conveyor. This automatically aligns the other slotted bracket of the cart to engage the pins of the chain of the reception bay conveyor that drives the cart further to the reception bay. The cart will stop at its end travel in the reception bay. After

stopping, an operator on the reception bay walkway floor picks up the loaded rack from the cart by using a long tube-handling tool, and then places an empty rack on the cart. The cart will be driven back to the discharge bay to the rack first-row-bundles loading position under the elevator ladle for the next loading.

Irradiated Fuel Storage

Once the irradiated fuel is in the reception bay the operator manually transfers it to the irradiated storage tray. Each tray holds 24 bundles placed in two rows. The Trays are then moved onto the storage tray conveyor that allows the tray to be transferred from the reception bay via an opening underwater in the wall, to the irradiated fuel storage bay. A grid pattern of Tray Supports located on the storage bay floor ensures that the irradiated bundles are properly distanced from the walls and bay liner. Trays are then stacked on the Trays Supports to a level that is both seismically qualified and meets the storage bay capacity requirements.

Maintenance Facilities

The Fuelling Machine Rehearsal channel, Service Ports and Ram Force Calibration facilities are provided in the Maintenance Lock area between the New Fuel Port and the Irradiated Fuel Port. These auxiliary ports provide the necessary operating calibration and set-up features for the Fuelling Machine.

Fuelling Machine Cold Test Facility is outside containment and is used for major overhaul set-up and calibrations prior to returning the Fuelling Machine to the Reactor building

Defected Fuel Handling Facilities

Fuel bundles are manufactured with great precision and quality assurance and have resulted in < 0.06% defect rates. As soon as a defect occurs it is monitored and removed from the fuel channel to avoid spreading any activation products. The carousel, located in the Irradiated Discharge Bay, allows the gaseous releases to be contained. Once the bundle is stable with no further releases, it is canned and moved to the Irradiated Reception Bay.