CRUD TOLERANT FUEL CHANNEL CLOSURE FOR BRUCE GS A

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ABSTRACT

This development project was originated by Ontario Hydro because of the serious difficulties being encountered in replacing fuel channel closures by the fuelling machine (f/m) at Bruce Nuclear Generating Station A as a result of debris being present in the locking lugs and seal face area of the fuel channel end fittings. The design aimed at a mechanical means of scooping the debris with a modified channel closure which would replace the regular channel closure presently carried in the fuelling machine magazine as a spare.

INTRODUCTION AND BACKGROUND

It is during channel closure replacement, following refuelling that the crud related problems occur. To date many specific crud occurrences and sources have been identified that led to closure sealing problems. See Table 1.

The work aimed at a device designed to replace the spare fuel channel closure presently stored in the fuelling machine magazine, which could remove remotely small pieces of construction welds and other debris found from time to time in the closure lugs area of the end fitting. The inside diameter of the end fitting has sixteen interrupted thread-like lugs which mate with corresponding lugs on the channel closure forming a breech type assembly.

Another required feature of the crud tolerant closure is that the scoop be retractable. This is necessary because when the closure is advanced into the end fitting to attempt a seal, the scoop must pass from the larger diameter of the locking lugs to the smaller diameter of the end fitting bore.

DESCRIPTION AND OPERATION

Several concepts evolved but the design shown in Figures 1 and 2 was chosen for further development and testing as it was the simplest, both physically and from an operating point of view.

Description (See Figures 1 and 2)

The crud tolerant closure is made up of a scooping mechanism cantilevered from the sealing disc of a standard channel closure. The sealing disc has an integral rectangular boss on the front of the flange, used to secure the scooping mechanism. Its operation is controlled by the fuelling machine drives through a closure adapter. A set of teeth, designed to sweep between the end fitting lugs, are fastened to the scoop. The teeth are chrome plated to aid their sliding characteristics, and are backed up by a set of wire brushes. The brushes ensure that the end fitting lug tapers are cleaned as well as the area between sets of lugs missed by the scoop teeth, during the 270° CCW sweeping motion.

TABLE 1: DEBRIS FOUND IN END FITTING LUGS AT BRUCE GS A

Jul 78 metal cuttings max size 6 mm x 3 mm	closure replacement problems led to 4 day outage
Dec 79 fuel bundle damaged 18 pencil shaped pieces as well as small debris	clean up required using manual tools
Mar 80 unidentified metal debris	closure removal problems, no outage
Dec 80 unidentified debris	closure replacement problems led to 5 day outage
Feb 81 f/m charge tube finger pin, 25 mm lg by 6 mm dia	closure replacement problems, no outage, some leakage
Feb 81 coil spring fragments coil dia = 9 mm, wire size = 1.5 mm	closure replacement problems,no outage
May 81 f/m charge tube head retaining bolt approx 35 mm lg by 16 mm dia	closure problems led to 3-1/2 day outage
Oct 81 unknown debris	closure problems, no outage
Jan 82 tip of f/m charge tube finger, thin sliver sheared off	closure problems, no outage
May 84 f/m charge tube finger pin 25 mm lg by 6 mm dia	closure replacement problems, outage prevented by use of special closure *
Apr 85 f/m part 6 mm dia nut	closure replacement problems, outage prevented by use of special closure *

Note: In some instances crud sources are speculated.

* The special closure referred to in Table 1 is a standard channel closure fitted with a 10 lug closure body instead of the normal 16 lug body.

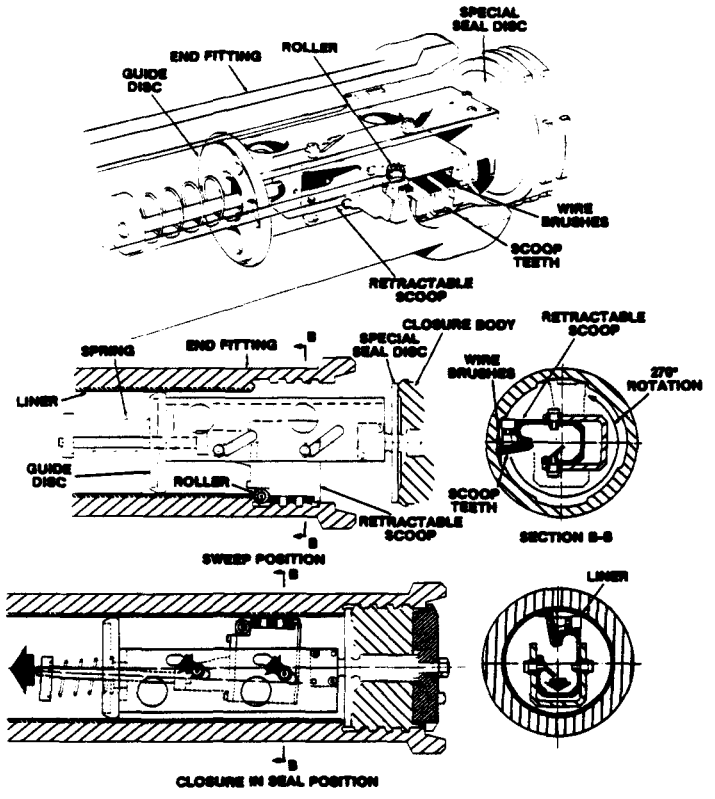

FIGURE 1: CRUD TOLERANT FUEL CHANNEL CLOSURE

The scoop body contains cavities to trap and hold the crud once picked up by the teeth/brushes. The scoop is fitted with pins that ride in angled slots machined in the scoop support bracket. When the crud tolerant closure is driven ahead axially, the scoop is forced to ride up the slots as the scoop climbs over the end fitting seal face. An aluminum-bronze roller, located at the front of the scoop body, rests against the end fitting seal face during the sweeping action and eases the climbing motion. The rear slot is steeper than the front to allow the scoop to ride on the wheel while inside the liner tube.

Fixed to the front of the U-shaped scoop support bracket is a chrome plated guide disc. The guide disc, which enters the liner tube as the crud tolerant closure is advanced into the end fitting lugs area, helps to centre the mechanism and provides an inboard support for the device. A coil compression spring, located on the front of the crud tolerant closure, ensures that the scoop body is normally at its sweeping diameter. Once the scoop is retracted the fuel channel can be closed with the crud tolerant closure using the same operations as with the normal fuel channel closure.

The crud tolerant channel closure is constructed entirely of corrosion resistant materials.

Operation (See Figures 1 and 2)

Operation of the crud tolerant closure is simple and straight forward. Should the fuelling machine encounter difficulties in replacing the standard channel closure, the crud tolerant closure can be brought forward from its fuelling machine magazine site. This requires a 285° clockwise rotation from the stop position while the tool is in the f/m snout. It is then advanced axially and positioned in its start sweep position (Figure 1, Section B-B) utilizing the fuelling machine encoder. The float provided in the bottom of the angled scoop retract slots ensures proper axial position with some spring pressure holding the scoop against the end fitting seal face. Float of 0.4 inch (10 mm) is provided, and, as the axial positioning capability of the fuelling machine is within ±0.2 inch (5 mm), no reference stop is required. Following this, a counter clockwise rotation of 270° is made to sweep the end fitting lugs with the scoop. (All rotations as viewed from outside the end fitting).

Upon completion of this operation the crud tolerant closure is to be returned to its f/m magazine site and the regular channel closure advanced to attempt a seal with a fully qualified closure. Should the regular closure fail to seal properly further sweeping with the scoop may sufficiently clean the end fitting lugs area to allow the regular closure to seal.

Failing several attempts to effect a seal with the regular closure, as a last resort, the assembly can be advanced following the 270° CCW sweep motion to retract the scoop and an attempt at seating the crud tolerant closure can be made. The seating operation for the crud tolerant closure is identical to a standard closure.

Following each 'use' of the crud tolerant closure, debris removal and inspection shall take place at the ancillary port at the earliest convenient time as dictated by fuel handling operations. 'Use' means either after a sweeping operation is performed or after sweeping and sealing a fuel channel.

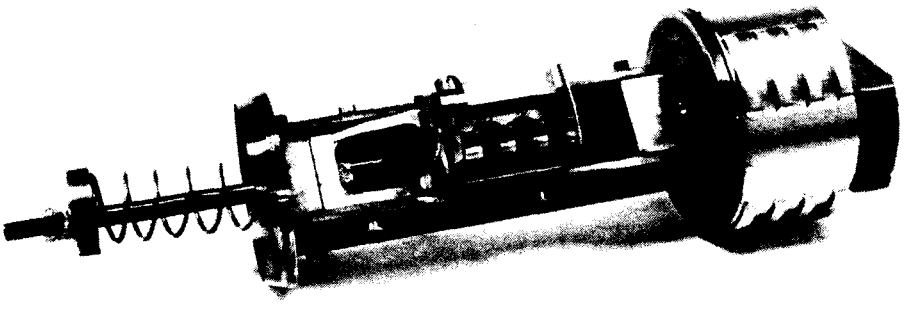

FIGURE 2: CRUD TOLERANT FUEL CHANNEL CLOSURE MOCK-UP

Removal of loose debris from the scoop into a special container can be performed at the ancillary port or at other f/m locations, by reversing the sweeping motion or/and with the aid of an air blast. In addition, the front cover of the scoop can be lifted by removing the fasteners to facilitate debris removal.

TESTING

For testing purposes a mock-up crud tolerant closure was manufactured to test the mechanical operation of the scoop while attached to a closure adapter and operated by the fuelling machine drives.

The mock up was manufactured in such a way as to make it unsuitable for reactor use in that the scooping mechanism was welded to the channel closure sealing disc thus distorting both the properties and geometry of this component. In addition material selection was not compatible for use in the reactor environment.

The tests were used to confirm the following:

1) That under reactor operating conditions the crud tolerant closure can be advanced to its seating position forcing the scoop to retract up inside the liner.

2) That under reactor operating conditions the crud tolerant closure can sweep and remove crud from the end fitting lugs/seal face region.

3) That no damage, in the form of nicks or scratches, occurs to the highly critical end fitting seal face area from any of the scoop operations.

As the fuelling machine test time was limited due to fuelling machine head delivery requirements, bench tests were also performed using the crud tolerant closure assembly to provide additional data to supplement the fuelling machine work. These tests were used to further demonstrate the sweeping capability of the scoop teeth and brush arrangement.

Initially, tests were performed to determine the optimum scoop teeth geometry and brush arrangement for scooping up various pieces of debris.

For this purpose a set of scoop teeth, made from a plastic mold of the end fitting lugs, was mounted on a crank which, in turn, was supported on clear plastic bearings which fitted into the end fitting liner bore and the open end of the fitting. A section of a standard shop wire brush was attached behind the scoop to assist in picking up debris missed by the scoop teeth. To test this model, sample crud was positioned in the bottom of the end fitting lugs seal face area and the scoop was rotated 270° counter-clockwise in a simulated pick-up.

Fuelling Machine Tests

Testing, using a Bruce GS B fuelling machine head, consisted of the following:

A) A test under reactor operating conditions to ensure satisfactory mechanical operation of the crud tolerant closure (no crud present). This test involved bringing the crud tolerant closure forward axially to its proper start sweep position, followed by the 270° CCW sweep, followed by further advancing the crud tolerant closure axially to its seating position.

B) Four scoop sweep cycles with crud present performed in the cold, unpressurized condition with the f/m backed off axially from an end fitting after first homing and locking to ensure proper alignment. The crud samples present and results of each sweep are listed in Table 2. This method of testing was followed because less time was required, so that the sweeping operation could be observed and there was no danger of losing crud in the system.

C) A single test under reactor operating conditions with a 1/4 inch (6 mm) x 1 inch (25 mm) long hex head bolt present in the end fitting lugs region. See Table 2 for results.

TABLE 2: FUELLING MACHINE TEST RESULTS

Test/ Sweep	Crud Sample	Results
B 1	1/4 in (6 mm) nut 1/4 in (6 mm) bolt	both items picked up by the scoop
B 2	1/2 in (13 mm) nut 1/4 in (6 mm) nut No 6 nuts (2) No 8 screw	all items picked up except a single No 6 nut, the scoop teeth rode over this nut
B 3	1/4 in (6 mm) x 1 in (25 mm) long bolt 1/4 in (6 mm) x 1/2 in (13mm) long bolt No 6 x 1/2 in (13 mm) long bolt (2) No 8 nut	all items picked up except the two No 6 bolts
B 4	1/4 in (6 mm) x 1 in (25 mm) long bolt	picked up
C 1	1/4 in (6 mm) x 1 in (25 mm) long bolt	picked up

REMARKS: Sweep number C 1 was made at reactor operating conditions (ie pressure, temperature, flow).

Following these tests inspection of the end fitting seal face, scoop teeth and bristles showed no damage.

Bench Tests

For the bench tests, an important adjustment was made to the crud tolerant closure mock-up. The scoop teeth were lowered such that the gap between the bottom of the teeth and the end fitting bore measured 0.025 inch (0.6 mm). For the fuelling machine tests this gap was measured to be 0.080 inch (1.3 mm).

This was done to enable the scoop teeth to pick up thinner objects eg. in fuelling machine test B sweep 2 the scoop teeth rode over a No 6 nut (thickness = 0.108 inch (2.7 mm)).

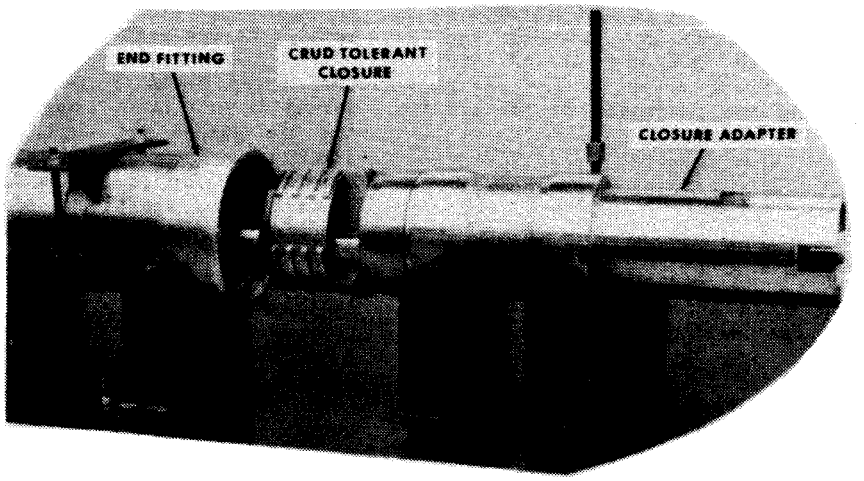

FIGURE 3: BENCH TEST SET UP

TABLE 3: BENCH TEST RESULTS

Sweep	Crud Sample	Results
1	1/4 in (6 mm) long bolt	picked up
2	1/2 in (13 mm) long bolt	picked up
3	1/4 in (6 mm)x 1 in (25 mm) long bolt	picked up
4	1/2 in (13 mm) x 2 in (51 mm) long bolt	-bolt jammed between scoop cover and end fitting lugs when placed lengthwise, -picked up when placed crosswise
5	1/8 in (3 mm) nut	picked up
6	1/4 in (6 mm) nut	picked up
7	1/2 in (13 mm) nut	picked up
8	tip of socket head cap screw	picked up
9	various pieces of weld spatter	all picked up
10	f/m charge tube finger pin-1/4 in (6 mm) dia x 1 in (25 mm) long	picked up
11	coil spring fragment wire size 0.058 in (1.5 mm) coil dia 0.341 in (9 mm) length 1/4 in (6 mm)	-picked up when spring laid on its side -jammed when spring laid on its end as bottom coil wedged between scoop teeth and end fitting
12	f/m charge tube head retaining screw	picked up
13	1 in (25 mm) long cotter pin	picked up

The test set up was as shown in Figure 3. Care was taken to ensure that the closure adapter and end fitting were parallel and on the same centreline.

The crud samples used and the results of each sweep are contained in Table 3. Single samples of crud were used for each sweep. The crud sample was positioned in the bottom of the end fitting lugs area and for each crud sample both lengthwise along the end fitting and crosswise positioning was used.

CONCLUSIONS

The sweeping action of the crud tolerant closure worked quite well based on the test results. Of the 13 crud samples used during bench testing, each positioned both lengthwise and crossways in the end fitting, only twice did the tool jam during the sweep motion. On one occasion, a 1/2 inch (13 mm) diameter bolt jammed between the end fitting lug radius and the scoop cover. On the other occasion a 0.341 inch (9 mm) diameter by 1/4 inch (6 mm) long coil spring placed on its end, jammed when one of the coils became wedged under the scoop teeth. Reducing the clearance between the scoop teeth and the end fitting inner diameter could possibly have prevented this occurrence. In future, this clearance will be designed to be 0.006 inch (0.15 mm). However unlikely, it is possible that a certain size crud sample could cause the scoop to jam during the sweep motion. Should jamming occur a small backwards rotation followed by continuation of the sweeping motion should free up the crud sample.

Procurement of two reactor grade prototypes is now underway for further testing and, assuming good performance, for use at Bruce NGS A.