FUEL CHANNEL INSTALLATION TOOLING
FOR RETUBING BRUCE REACTORS

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ABSTRACT

Installing replacement fuel channels in CANDU reactors as part of a large scale fuel channel replacement program ("retubing") involves the use of a large number and variety of highly specialized tools. During the retubing of the Pickering reactors, the tooling proved to be a key factor in outage time, dose consumption and the final quality of the installed channels.

As the Pickering A units were successively retubed, the tools underwent continuous development and refinement. Today, many of these tools form the basis of a new generation of tools currently being developed for retubing the Bruce A reactors.

1. GENERAL

The actual work performed at the reactor face to retube a CANDU reactor is divided into two main phases, namely, the complete removal of all fuel channels in the vessel and the installation of new channels. This paper is concerned only with tooling used during the installation phase.

Installation of the new channels is carried out by personnel working in large elevating shield cabinets, one of which is located at each end of the reactor (see Figure 1). Each cabinet is equipped with a retube tool carrier (RTC) used for craning tools and components. Two work tables are provided in each cabinet for tool support and alignment.

2. FUEL CHANNEL INSTALLATION SEQUENCE

The basic sequence for installing replacement fuel channels is to complete the installation on one row before moving onto the next. As each channel is removed, a temporary shield plug and an extension sleeve are inserted into the lattice tube of the empty site. The extension sleeve allows tools to be transported between the shield cabinet and the lattice site and provides support for the loose feeders.

The main installation steps for each fuel channel of each row are as follows:

1. Clean the lattice tube and remove any debris from the calandria tube;

2. Visually inspect the lattice site (including the calandria tube);

3. Install the replacement pressure tube as a subassembly (Each subassembly includes the replacement west end fitting and the garter springs);

4. Position the garter springs at the correct locations on the pressure tube and confirm the location of the springs;

5. Weld the west end fitting to the existing stop collar;

6. Install the replacement east end fitting;

7. Roll the east joint; and

8. Weld the east end fitting to the existing bellows.

3. CLEANING AND REFURBISHING

The main cleaning operation involves brushing and vacuuming the bore of each lattice tube. This is accomplished using a combined vacuum and brushing tool which is cantilevered from a carriage mounted on a work table, as shown in Figure 2. The carriage is used to insert and extract the tool from the lattice tube at each lattice site.

The tool incorporates a rotating brush head with suction ports which vacuum debris and dust as the lattice site is brushed. The brush head, designed specifically for the cleaning tool, is comprised of a set of nylon bristles tipped with 1/2 inch diameter carbide balls. As the brush is rotated, the abrasive carbide tips remove surface debris from the lattice tube and the bearing surfaces while leaving a honed finish equal to or better than the original surface finish.

Refurbishment of the lattice site is limited to a manual deburring of the leading edge of the stop collar and bellows. The burrs are a result of removal operations and could prevent full insertion of a new end fitting. The tools used are simple hand tools equipped with hard tipped cutters that scrape the burrs away during manual rotation of the tools. Burr removal is confirmed by the use of plug gauge tools which are inserted into each bellows and stop collar.

4. INSPECTION AND MEASURING

Three visual inspections are carried out during retubing. These are: forward viewing down the length of each lattice tube and calandria tube; right angle viewing of the calandria tube insert and inboard bearing sleeve; and right angle viewing in the region of the new pressure tube rolled joint.

Visual inspection is carried out using closed circuit television (CCTV) cameras mounted in special housings. Unlike the Pickering video inspection tools, which were entirely custom built, each Bruce tool is of a completely new design which incorporates a pre-packaged nuclear camera system that can be controlled from outside the shield cabinet. The camera systems used in these tools are built by the supplier specifically for the rigorous environment of nuclear maintenance. The cameras are housed in rugged casings and are supplied with integral lights, lenses, right angle prisms, cables, etc. The control units are not dedicated to specific cameras. This allows several cameras to be controlled by one control unit while eliminating the necessity of readjusting the equipment when alternating from one camera to another. The control unit, along with a CCTV monitor, is mounted on a rail in the shield cabinet.

4.1 Forward Viewing Inspection

Once the cleaning of the lattice tube has been completed, visual inspections of the lattice tube and calandria tube bores are carried out using the forward viewing tool. The forward viewing tool has been designed to travel down the lattice tube as far as the calandria tube insert, allowing personnel to view down the length of a lattice tube and calandria tube in search of loose debris.

The forward viewing tool is initially supported in a housing which is attached to a rail inside the shield cabinet, as shown in Figure 3. The design of the housing attachment allows the tool to be moved horizontally along the rail to any fuel channel site.

The forward viewing tool operation involves aligning the housing with an open site and connecting it to a lattice tube extension sleeve already installed in the major bore of the lattice tube. A trolley containing the camera is driven out of the housing and down the lattice site. The camera, equipped with remote focus and zoom control, can detect objects as small as 1/8 inch diameter from a distance of 20 feet.

Among the design requirements for installation tooling is the necessity that each tool be capable of coping with a calandria tube sag of up to 2 inches. The forward viewing tool satisfies this requirement by incorporating a powered tilt mechanism which allows the camera to view the sagged bottom of a calandria tube.

4.2 Right Angle Viewing

With the exception of a right angle viewing head, the right angle viewing tools use the same video components as the forward viewing tool. Areas that cannot be viewed with the forward viewing tool, those in the vicinity of the calandria tube insert and the inboard lattice tube bearing, are inspected using the first of two right angle viewing tools. During this inspection, the tool is required to first detect and then retrieve loose debris. A vacuum nozzle on the inboard end of the tool is used to capture any visible debris, and is capable of retrieving particles as large as a 1 inch length of broken garter spring. A schematic of the arrangement is shown in Figure 4.

The second right angle viewing tool is used to inspect the condition of the east pressure tube rolled joint of the newly installed fuel channel. The purpose of the inspection is to search for possible damage in the rolled joint region and to confirm that the joint has been formed in the correct axial location. This tool uses the same major components as the tool used for right angled viewing of the lattice tube bore.

Each right angle viewing tool is mounted on a work table trough and is advanced into a lattice site using the powered axial drive of the trough. When used for viewing the rolled joint, the outer sleeve of the tool used for viewing the lattice tube bore is removed and replaced with a smaller diameter sleeve which allows the tool to fit inside the end fitting.

5. FUEL CHANNEL INSTALLATION TOOLING

Fuel channel installation tooling, which comprises the majority of the tooling, is used to insert, support, align and clamp replacement fuel channel components (pressure tubes, garter springs and end fittings) during installation of the components at each lattice site. Also included in fuel channel installation tooling is the detection equipment necessary for confirming the locations of the garter springs.

5.1 Subassembly Installation

A prefabricated subassembly is prepared which includes the replacement pressure tube and the west end fitting. The subassembly is inserted from the west end of the reactor using a special fixture attached to the RTC. The fixture, which is essentially a structural steel beam, is bolted to the RTC with the subassembly underslung from the beam by means of a carriage and roller support system.

5.2 Garter Spring Installation

To protect the pressure tube during installation, a nylon tube is placed over the full length of the pressure tube. Attached to the pressure tube protective sleeve, at the end fitting end, is a magazine device containing the four new garter springs. As the sleeve is pulled off of the pressure tube from the east end, after the subassembly has been inserted into the fuel channel, each garter spring is automatically ejected from the magazine at the appropriate axial location along the pressure tube.

The tooling that pulls the sleeve off of the pressure tube also includes the detection equipment used to confirm and record the position of each garter spring. As each spring is deposited on the pressure tube, the detection system confirms the correct location of the spring before the next spring is ejected from the magazine. Schematic arrangements of this tooling are shown in Figures 5 and 6.

5.3 End Fitting Installation

Once the subassembly and garter springs have been installed, the replacement end fitting can be installed at the east end of the reactor. An installation mandrel, which extends the full length of the replacement end fitting, is inserted into the bore of the end fitting. Once the end fitting is mounted on the mandrel, the end fitting and the mandrel are transported to the reactor face using the RTC. At the reactor face, the end fitting mandrel assembly is attached to a carriage mounted on the work table. When attached to the carriage, the installation mandrel provides a cantilevered support for the end fitting. The carriage provides axial motion to advance the end fitting into the lattice site.

Close to the rolled joint region of the end fitting, a set of electronic measuring probes is mounted in the mandrel. These probes are used immediately prior to the pressure tube entering the end fitting bore to measure any angular misalignment between the end fitting bore and the leading end of the pressure tube. A schematic arrangement is shown in Figure 7. It is particularly important that the angular misalignment between the two components be minimised. Misalignment of these components can make insertion of the pressure tube into the end fitting bore difficult and can lead to higher residual stresses in the finished rolled joint. In the event that the misalignment is outside the permissible tolerance, a small straightening tool is inserted into the pressure tube from the opposite (west) end of the reactor. The straightening tool is actuated until an acceptable alignment is achieved, at which point the pressure tube can be fully inserted into the end fitting bore. The straightening tool remains actuated in the pressure tube until the rolled joint has been made.

6. ROLLED JOINT TOOLING

Rolling of the east pressure tube joints for the Bruce retube involves several significant changes to both the geometry of the joint and the tooling required to roll the joint. The reasons for the changes are two fold. The first of these is the desire to reduce the time required to install fuel channels. The second is to increase the support provided to the inlet fuel bundle by the pressure tube. Each of these is briefly discussed below.

Rather that installing a liner assembly in an end fitting at the reactor face after rolling of the pressure tube, by installing a liner assembly in each east end fitting off of the reactor face prior to pressure tube rolling, both the time and dose required to install a fuel channel can be reduced. However, until now, installation of the liner assemblies in end fittings prior to rolling of the pressure tube has not been carried out at Bruce. This is due to the fact that, for the geometry of the rolled region of Bruce fuel channels, during the initial phase of rolling, the rollers will roll the liner assembly prior to rolling the pressure tube. To prevent rolling of the installed liner assembly, the geometry of the rolled joint and liner assembly has been modified. By shifting the axial position of the joint inboard by approximately one half inch, and lengthening the end of the liner assembly by the same amount, the inboard end of the liner assembly can be stepped to allow the rollers to pass without interference, as shown if Figure 8. The step does not affect the support provided to a fuel bundle by the liner.

In a conventional rolled joint, the wall thickness in a region at the end of a pressure tube is reduced by rolling. This results in the rolled region of the pressure tube being of a larger bore than the remainder of the tube. Historically, the enlarged bore of the rolled region of the inlet end of each pressure tube, has provided poor support for the outermost fuel bundle at the inlet end of the fuel channel. For the Bruce retube, on the inlet end only, the joint will be rolled in such a way as to eliminate the enlarged bore. Thus, after rolling, the rolled region of the pressure tube will be of the same diameter, that is, flush with the unrolled portion of the tube, as shown in Figure 9. The result of this is that, with the enlarged bore eliminated, the flush rolled joint improves the support provided by the inlet joint to the inlet fuel bundle.

Tooling used to make the flush rolled joint is similar to that used for the conventional joints. However, the flush rolled joint is slightly longer than the conventional joint and consequently the rollers in the rolling tool are longer. Also, the setting of the rolling tool diameter and the axial position of the joint are different from conventional joints. Since the flush rolled joint is made only on every other fuel channel (inlet ends only), alternating with conventional joints, the rolling tools will be colour coded to ensure that the correct tooling is inserted into each channel.

7. CONCLUSION

Installing replacement fuel channels in CANDU reactors as part of a large scale fuel channel replacement program requires many specialized tools. While the tools developed during the retubing of Pickering form a basis for the tools to be used during the retubing of Bruce, the tools continue to evolve as part of the effort to improve the quality of the replacement fuel channels and reduce the time required to perform the retube. The number of tools newly developed for use at Bruce represents a significant contribution to that effort.

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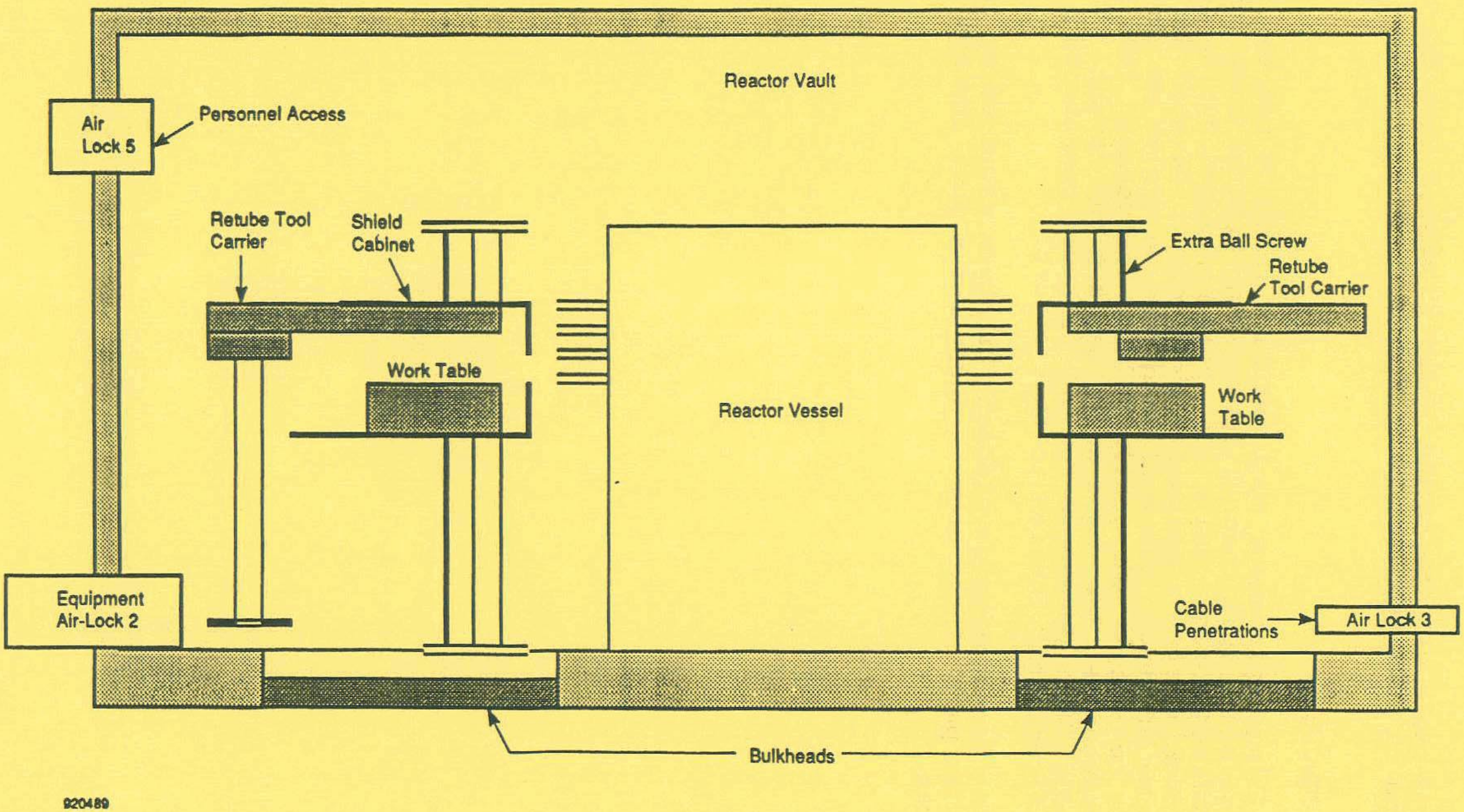

Figure 1
Retube Vault Arrangement

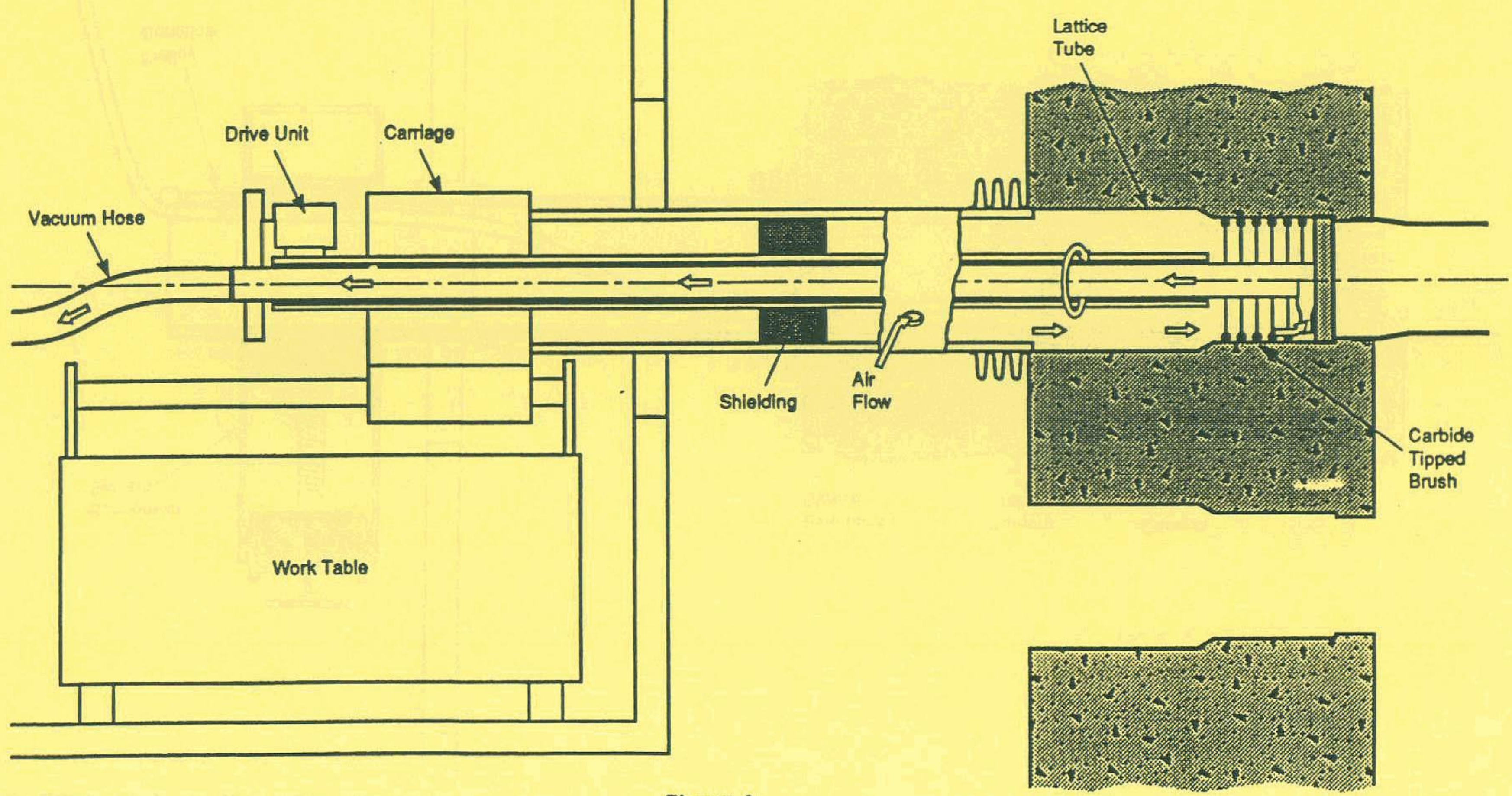

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Figure 2
Vacuum Brushing Tool

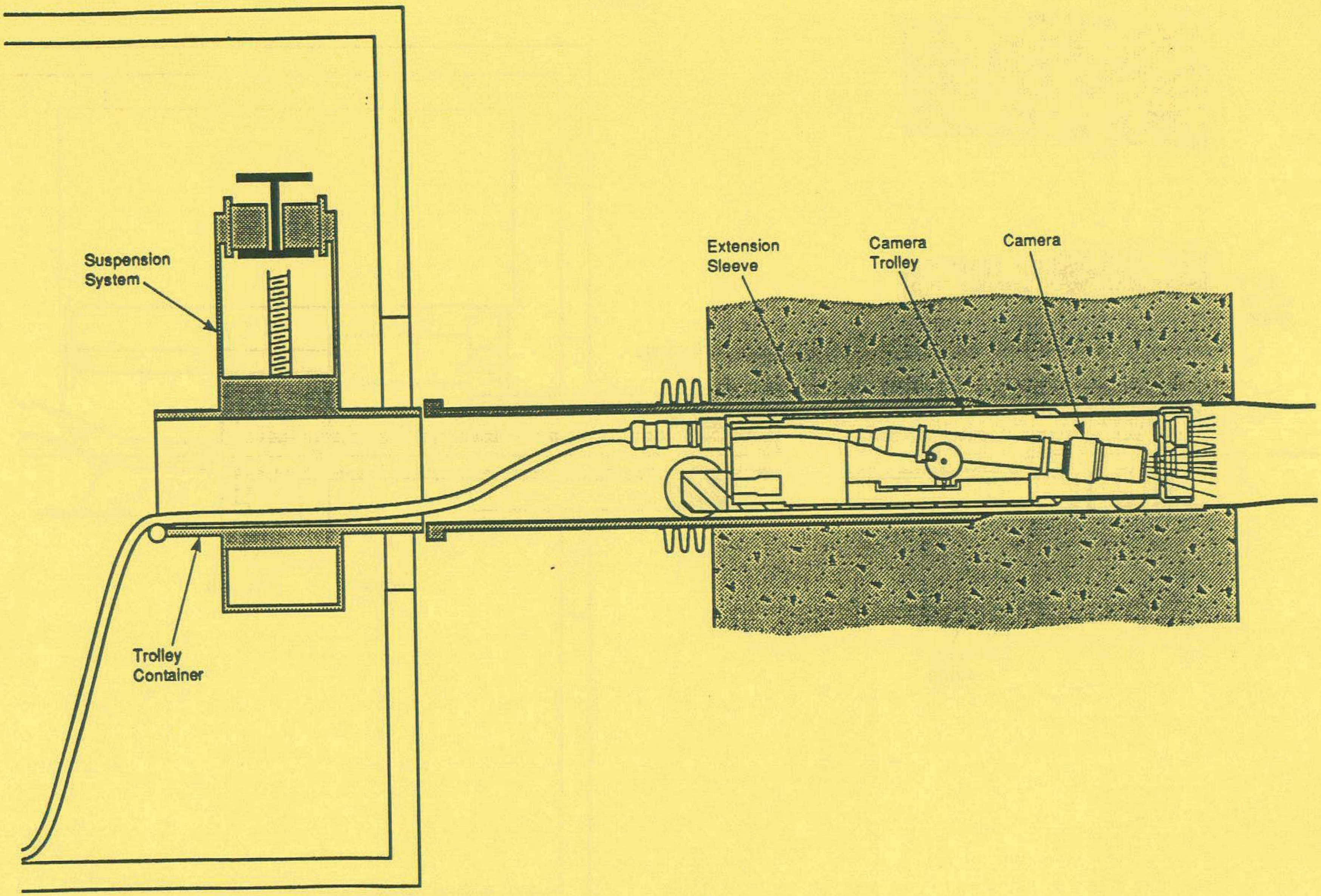

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Figure 3
Forward Viewing Tool

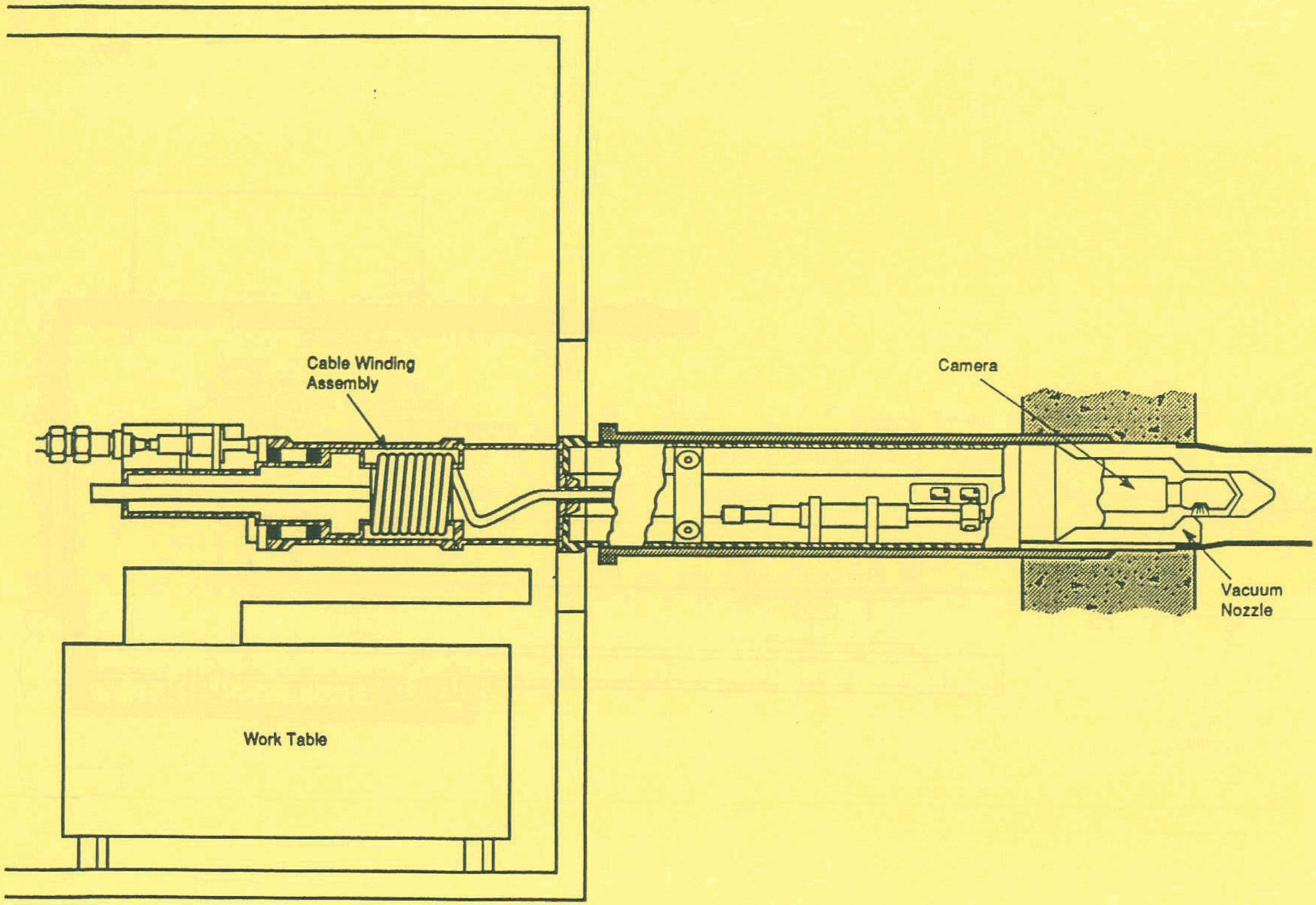

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Figure 4
Right Angle Viewing Tool

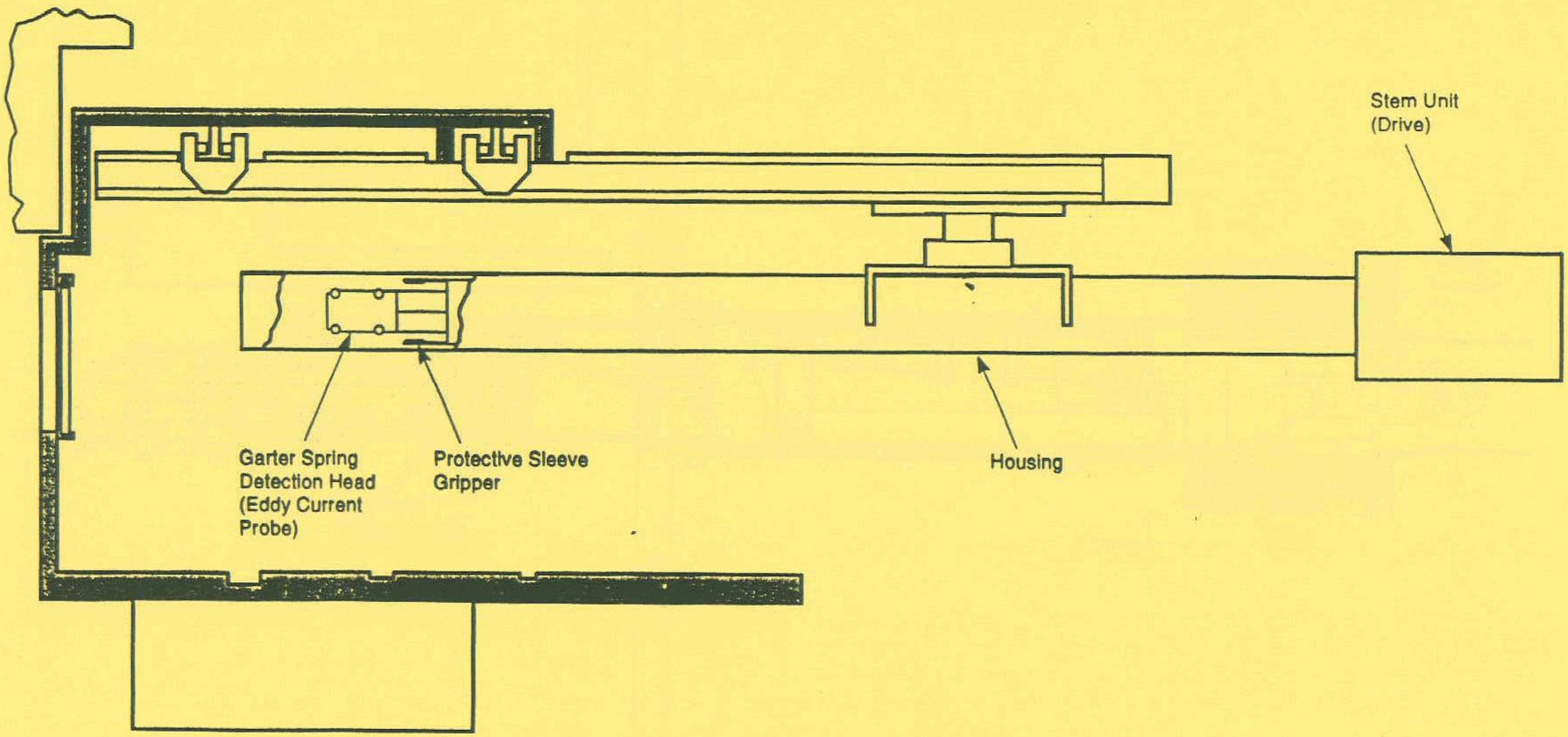

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Figure 5
Protective Sleeve Removal Tool (East End)

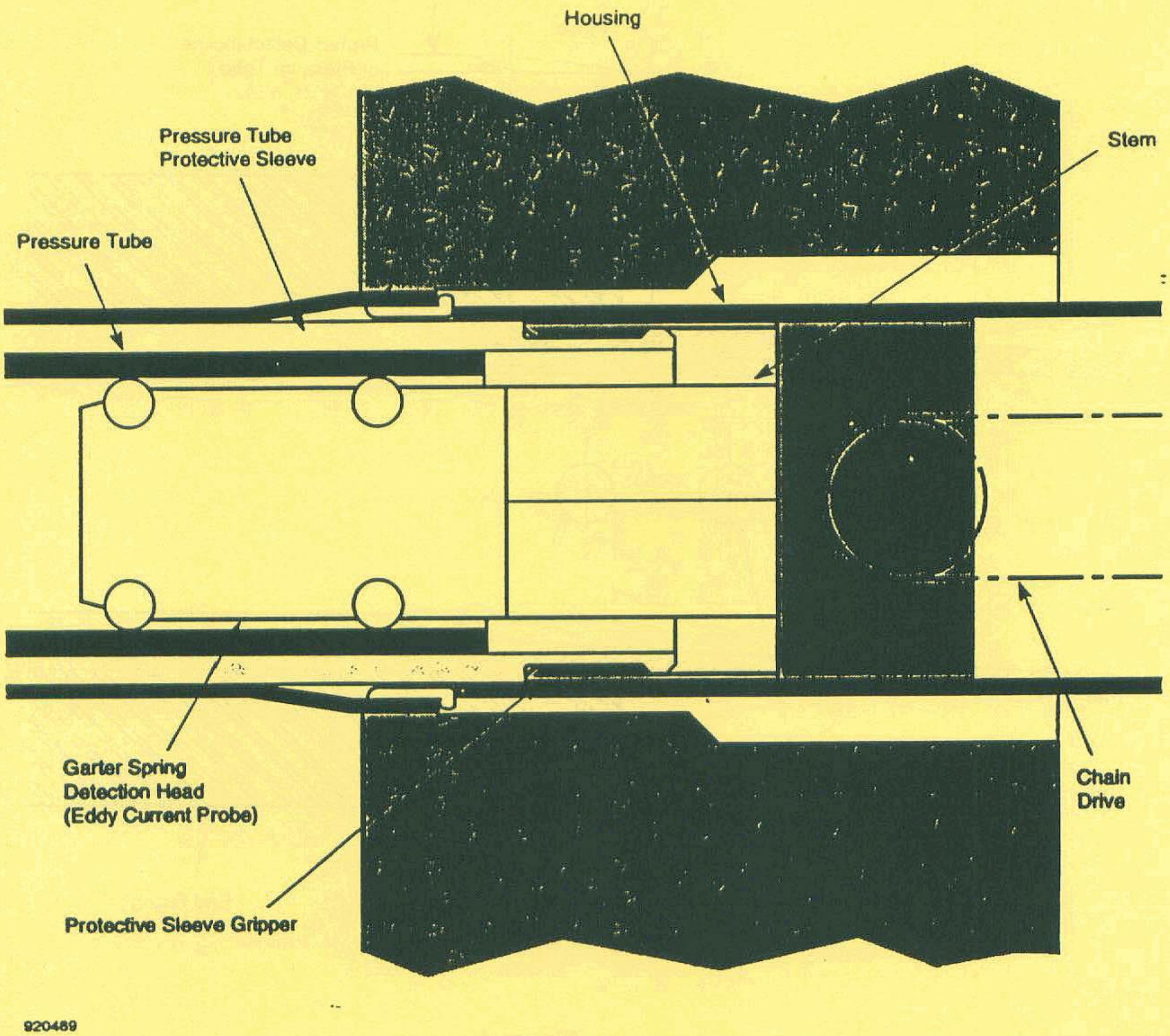

Figure 6
Protective Sleeve Removal and Garter Spring Detection

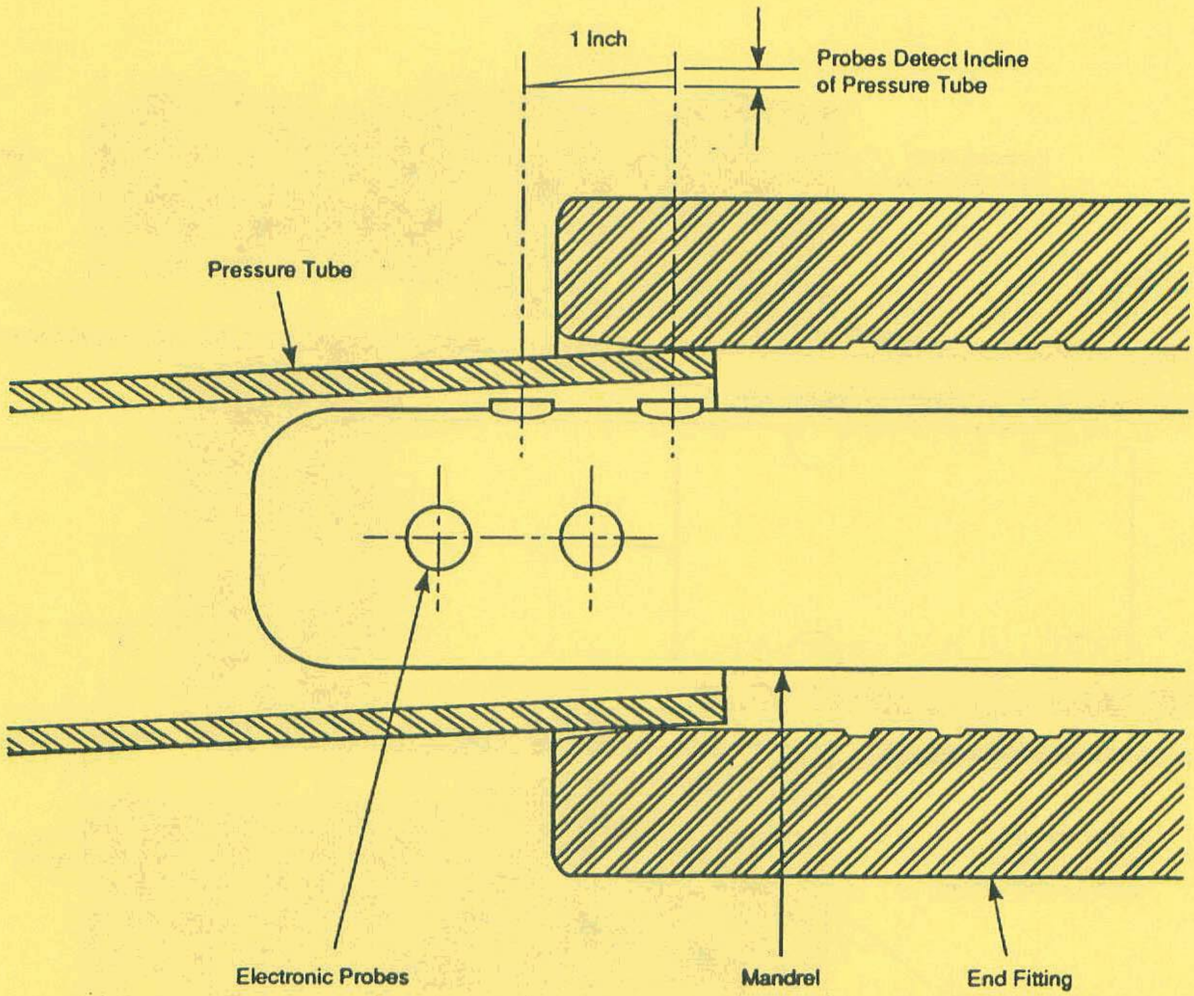

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Figure 7
Pressure Tube Alignment

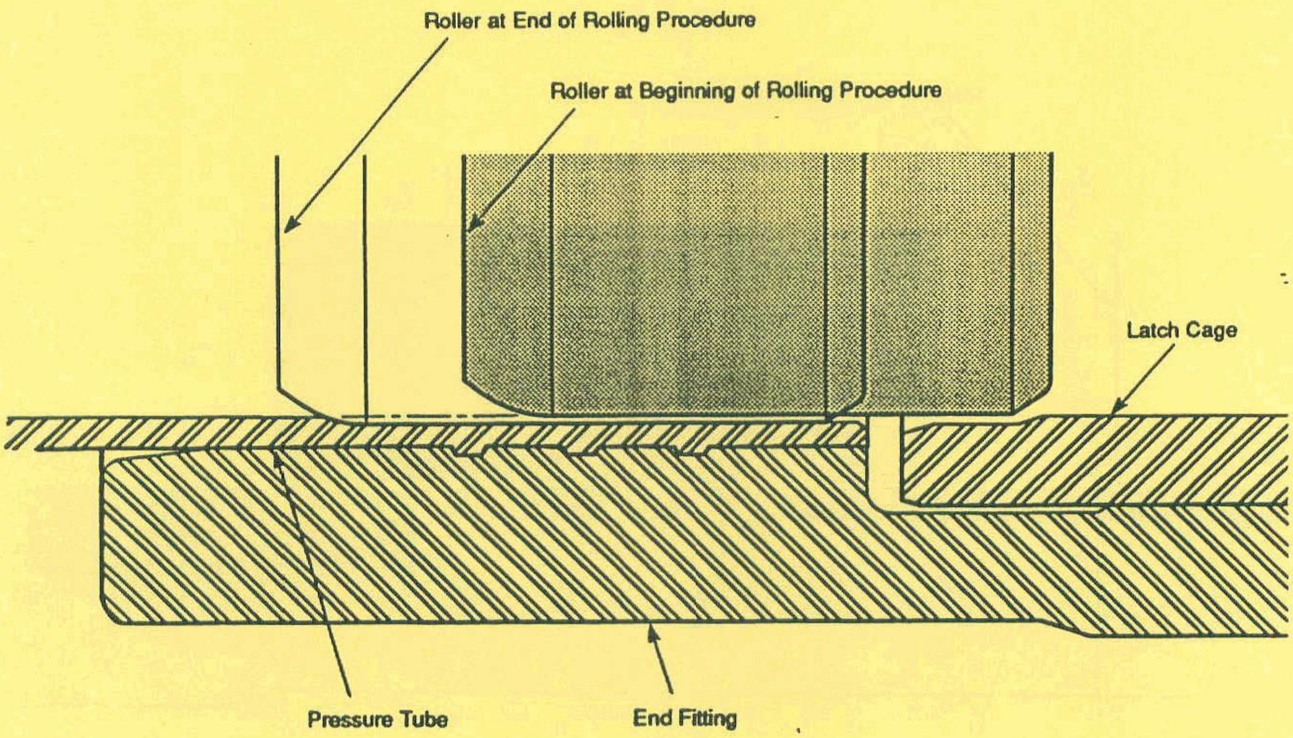

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Figure 8
Conventional Rolled Joint

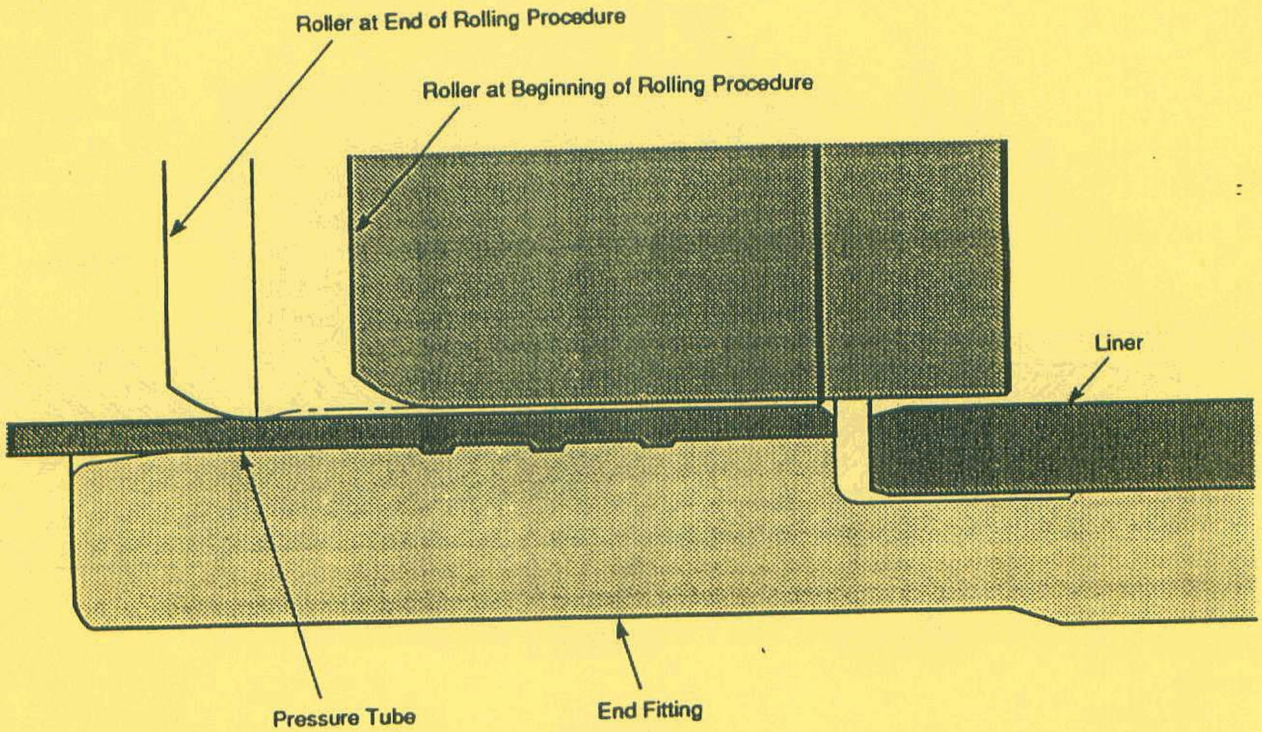

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Figure 9
Flush Rolled Joint