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VALVE LEAKAGE INSPECTION TESTING AND MAINTENANCE PROCESS

RECHERCHE DES FUITES ET VÉRIFICATION ET ENTRETIEN DES ROBINETS

by

J.A. AIKIN, J.W. REINWALD AND C.A. KITTMER

Presented at ANS Conference 1989 Annual Meeting Atlanta, Georgia, 1989 June 4-8.

Chalk River Laboratories

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RÉSUMÉ

L'entretien des robinets exige que la garniture des tiges de manoeuvre soit remplacée périodiquement soit au cours de l'entretien courant, soit lors d'une réparation effectuée pour arrêter une fuite ou pour rétablir le bon fonctionnement du robinet. Les outils et les méthodes employés actuellement pour l'enlèvement des garnitures et l'inspection sont plus ou moins efficaces en raison des problèmes que posent l'accès à la garniture et l'inspection même. EACL Recherche a mis au point une méthode qui a permis de surmonter ces obstacles. Cette méthode utilise la pression d'un fluide incompressible et permet de vérifier rapidement et efficacement l'intégrité du siège du robinet, d'enlever les garnitures d'étanchéité difficiles d'accès et de vérifier l'étanchéité du robinet pourvu d'une nouvelle garniture.

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ABSTRACT

In valve maintenance, packing rings that prevent leakage along the valve stem must periodically be replaced, either during routine maintenance or to correct a leak or valve malfunction. Tools and procedures currently in use for valve packing removal and inspection are generally of limited value due to various access and application problems. A process has been developed by AECL Research that addresses these problems. The process, using incompressible fluid pressure, quickly and efficiently confirms the integrity of the valve backseat, extracts hard-to-remove valve packing sets, and verifies the leak tightness of the repacked valve.

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1. INTRODUCTION

The CANDU-PHW (CANada Deuterium Uranium - Pressurized Heavy Water) reactor has achieved world-wide recognition for its reliable performance. To achieve this, special attention was given to the reliability and maintainability of components in the heavy water circuits. This included detailed assessment on outages due to component failures, excessive leakage of precious heavy water and radiation exposure during equipment maintenance -- all having expensive penalties that must be kept to a minimum in order to realize economic generation of low cost power.

Development programs were initiated by AECL early in the development of the CANDU reactor to improve the effectiveness of the valves and static seals (as commercial equipment then available gave unacceptable performance) [1]. This led to the development of live-loading to account for packing material consolidation under service conditions (Figure 1), and detailed design procedures [2]. Details of the work on seals, valves, bellows, friction and wear have been published and presented at numerous conferences, thereby facilitating "technology transfer" to any industry making use of valves and gaskets, particularly in Canada and the United States.

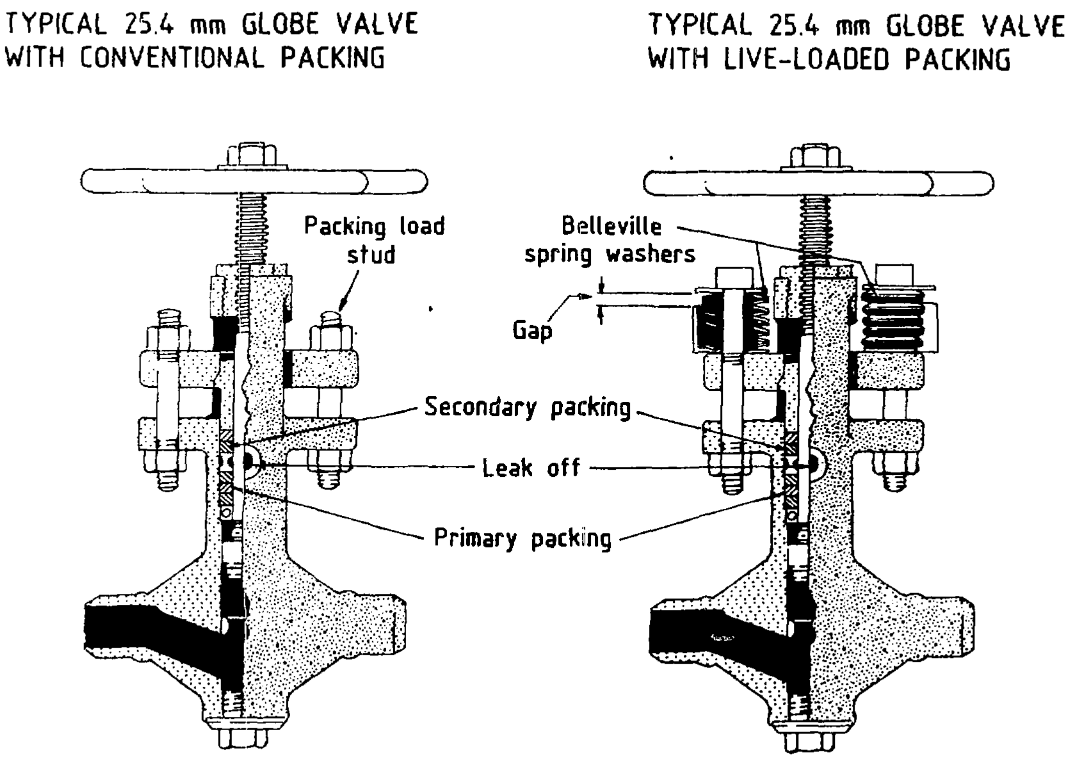

Figure 1: Typical Globe Valve With and Without Live-Loaded Packing

While this information was initially well utilized for CANDU applications, there has been a resurgence of interest in this work due to a developing awareness of the benefits of further improved static seals:

- reduced maintenance costs and radiation exposure,
- reduced contamination in the plant, and
- reduced risk of unscheduled outages due to packing failure in key components.

This has been further emphasized through changes in legislation limiting the use of asbestos-based packings and the unavailability of previously qualified asbestos-based packings (e.g., John Crane 187I).

The result has been an increased effort to define suitable replacement packing materials. One large program in which AECL played a major role was the EPRI-funded "Valve Packing Improvement Study" [3]. However, before newly qualified packing can be used, the old packing set must be completely removed. Difficulties in removing highly consolidated packings prompted AECL to develop a more efficient packing removal procedure that would reduce the time spent at the valve and provide a degree of confidence in the valve stem seal performance.

2. PROBLEM DEFINITION

The primary heat transport system of a CANDU-PWR reactor contains several hundred valves of various types and sizes (Table 1). In order to reduce the cumulative maintenance burden, the 600 to 700 valves that are in the Douglas Point and Pickering Nuclear Generating Stations was reduced to 200 to 300 in the Bruce and CANDU 6 designs.

A review of the maintenance reports for Pickering NGS indicates that valve packing removal can account for over 50% of the valve maintenance effort (excluding actuator repairs). Average packing removal time is over 4 hours per valve. Discussions with maintenance personnel in the field indicate that 8-12 hours is not uncommon to remove asbestos-based packing after it has been consolidated to a concrete-hard condition under PHWR operating conditions. The long hours spent at the valve contribute significantly to the cost of valve maintenance and repair in the nuclear industry, estimated at $100 million per year.

A majority of valve packings are currently removed using hand tools that are primarily of a "home-made" nature, consisting of corkscrew-type devices, modified screwdrivers, pieces of bent nail or piano wire. Some items of a similar concept are also available

TABLE 1: GENERAL TYPES AND SIZES OF VALVES AND PROBLEMS EXPERIENCED IN A CANDU-PHW REACTOR [4]	
Valve Type	Main Problems
Large Isolation Valves (15 to 56 cm)	- Stem Seal Leakage - Body-to-Bonnet Gasketted Joint Leakage
Small Isolation Gate and Globe Valves (0.6 to 15 cm)	- Stem Seal Leakage - Body-to-Bonnet Gasketted Joint Leakage
Control Valves (≈10 cm)	- Stem Seal Leakage
Check Valves (≈56 cm)	- Cover Gasketted Joint Leakage - Failure of Disc Shaft Bearings
Butterfly Isolation Valves (≈122 cm)	- Leakage Across Closed Vane - Shaft Seal Leakage
Instrument Valves (≈2 cm)	- Stem Seal Leakage - Stem Seizure
Relief Valves (2 to 15 cm)	- Passing at Seat

commercially. However, these tools (as well as more sophisticated devices employing elongated cutters and pulverizers), are of limited value because of:

- application difficulties due to restricted access to the gland area,
- ineffectiveness in removing hard, highly consolidated packings (e.g., asbestos-based packings after exposure to conditions of high pressure and temperature),
- ineffectiveness in removing soft, stratified packings that come out in flakes or small chunks (e.g., die-formed graphite packings),
- a high potential for mechanical damage to the stem and gland surfaces,
- significant man-rem exposure due to time spent at the valve,
- a potential health hazard risk to workers due to airborne contaminants such as asbestos fibers, and
- no effective method to confirm the condition of the valve backseat and the newly installed packing.

The recent introduction of water jetting to cut or fragment the packing for withdrawal from the stuffing box does improve the process, but removal of lantern rings and continuous rope-type packing sets is difficult.

To address these problems, AECL has developed a unique valve maintenance process designed to reduce man-rem exposures, reduce the risk of scoring the stem or stuffing box, improve the engineering quality of valve repair and reduce maintenance costs.

3. SOLUTION: TRI-FUNCTION PROCESS

AECL's "Valve Leakage Inspection, Testing and Maintenance Process" or 'Tri-Function Process' (patent application filed) is an efficient valve packing inspection process. It consists of leak testing the valve backseat, removing the old packing in an unbroken assembly and, after the valve has been repacked, performing a hydrostatic pressure test on the new packing. Using a variable pressure pump, a metered volume of an incompressible fluid is injected into a stuffing box through an auxiliary opening such as a leak-off port (Figure 2).

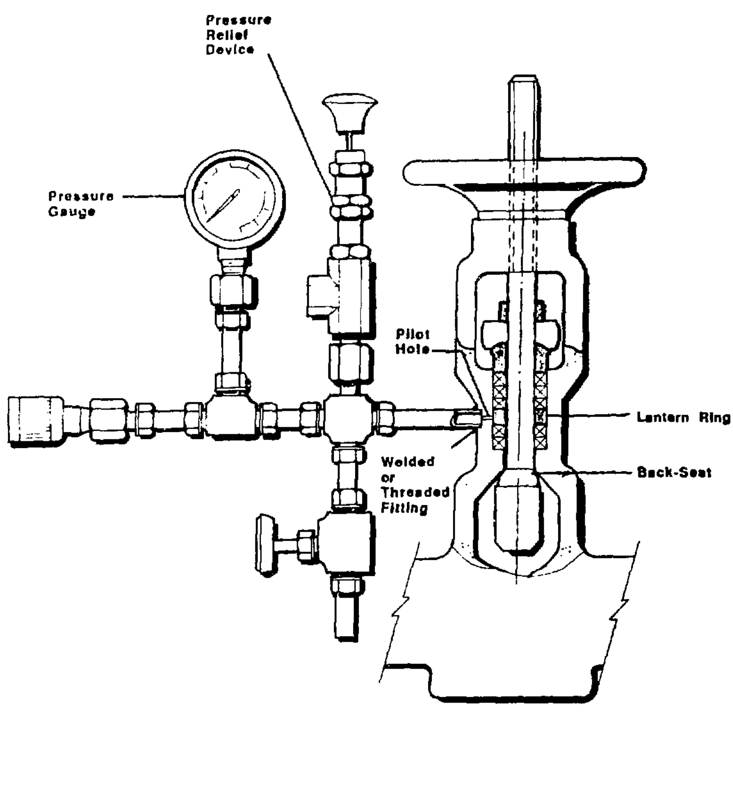

Figure 2: Typical Tri-Function Inspection Process Set-up

Built-in elasticity of the high pressure test equipment allows for easily observed pressure decays. For valves not equipped with access ports to the stuffing box, effective non-destructive methods have been developed to confirm stuffing-box configuration and permit field adaptation.

Figure 3 is a representative pressure vs time plot that an operator might see for a given valve using the pressure-decay inspection procedure. The sharply decaying curve (A-B) would be indicative of a unacceptable backseat. The slower change in fluid pressure at the lower pressures is due to the reduced flow rate and the inherent elasticity of the high pressure hose and the packing set.

Plot ACDE shows a pressure increase (C-D) after a period of decay A-C. In this case, the backseat is acceptable.

The slower initial decay is from the fluid filling the stuffing box cavity through the tortuous leak path of the valve packing material. The pressure increase is due to activating the test equipment to the initial test pressure. After this, the test pressure remains essentially constant, indicating an acceptable backseat and packing assembly. By using this inherent testing procedure, significant savings can be realized by reducing the number of costly and sometimes unnecessary valve tear-downs, and by providing a qualitative check on valve operating conditions.

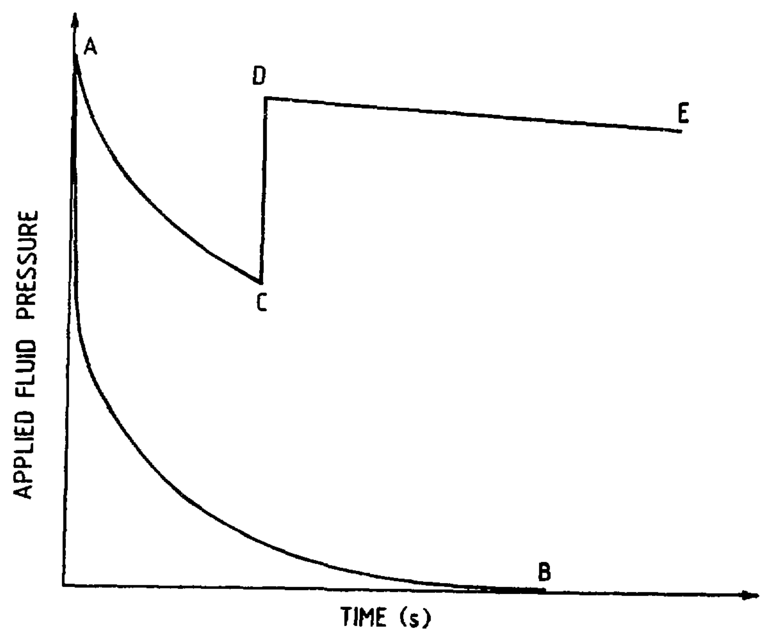

Figure 3: Representative Pressure-Decay Plot For Tri-Function Process Test Equipment

3.1 Laboratory Tests and Field Trials

The Tri-Function Process has been successfully demonstrated in shop-type environments both to nuclear and petro/chemical maintenance staff. A good backseat will hold the applied pressure for 5-10 minutes with less than a 5% pressure decay. Decay rates between an unacceptable and acceptable backseat or stem packing have been found to be > 16:1.

Using the pressure hydraulic packing extraction process, the complete packing set can be lifted in a controlled manner allowing easy removal from the stem (Figure 4). Experience has shown that the packing removal pressure may vary from 3.4 MPa (500 psi) to 22.1 MPa (3 200 psi). The removal pressure is dependent on the packing style and operating history. Complete packing removal, including testing and set-up time, usually requires ~30 minutes. Since the packing is removed from the stem outside the stuffing box, the risk of stem or stuffing box damage is lowered and time spent at the valve is significantly reduced.

Figure 4: Packing Set Lifted Using Pressure Process For Easy Removal From Stem

After the replacement packing has been installed, the integrity of the repacked valve can be pressure tested and signed off. The test pressure for this procedure should not exceed 1.75 - 2.0 times the system pressure or equivalent gland load. Incorporating a packing pressure test with installation procedures would identify improperly packed valves and thus reduce the risk of a delayed plant start-up.

4. CODE CONCERNS

For those valves not provided with an opening for auxiliary fittings, the use of radiography or X-rays is effective in confirming the location of the stuffing box shoulder. Small send/receive ultrasonic probes can also be used to confirm valve body wall thickness, and define the location of the stuffing box shoulder if the valve geometry is known. A small opening can now be drilled through the stuffing box wall, just above the stuffing box shoulder (meeting the requirements for auxiliary connections of ANSI B16.34 Section 6.3, and where applicable, requirements of ASME NB-3330, NC-3330 or ND-3330). A high pressure fitting can then be threaded or welded in the stuffing box wall or bonnet flange and connected to the fluid power source, or simply capped for future use.

Drilling just above the bottom of the stuffing box is practical for those valves that have very deep stuffing boxes and are packed with 10 or more packing rings. However, the trend is to use fewer rings of packing and fill the lower portion of the stuffing box with a spacer. To stay with the state-of-the-art in packing installation, it is recommended that the pressure hole be located 60% to 75% of the stuffing box depth referenced from the top. This depth will be below the lantern ring for removal during repacking at a later date, but above the junk ring, which should not require future removal.

The jacking pressure required to remove old packing is often well below the design pressure for the valve as described in Tables 2-2.1 through to 2-3.8 of ANSI B16.34-1981. As a safety precaution, the recommended procedure when testing and inspecting a valve is to install a pressure relief device that is set to trip at the design operating pressure of the valve at 37.7°C (100°F). If the device trips before the packing set has been lifted, a careful check of why this has occurred should be carried out. The maximum recommended pressure used to remove a packing set is 1.5 x design operating pressure, as stated in ANSI B16.34.

The standard valve leak test pressure is 1.5 x design pressure rating at 37.7°C (100°F). It is recommended that system pressure be used when checking the integrity of a newly installed packing (the gland loading to squeeze the packing is generally 1.75 to 2.0 x system pressure). If the pressure applied to the packing is too high for the gland load, packing blowout can occur or cause high packing consolidation, which can lead to excessive valve stem leakage.

A see-through containment system may be used to restrict egress of fluid or packing material from the work area during application of the fluid pressure. Gravity drainage or suction may be used to remove old packing rings as required. The containment system may envelop the entire valve, or a portion thereof may be restricted to application in the immediate stem area.

Using the Tri-Function technique, the danger of explosive release of pressure, inherent in using bottled gas to lift the packing, is overcome [5]. Controlled flow of an incompressible fluid has no explosive potential. Using the fluid pressure jacking technique also reduces the risk of damaging the surfaces of the stem and stuffing box, a common occurrence with current hand tools. Set-up time is minimal with the use of quick disconnect bushings that only need to be installed once, because the same fitting can be used the next time repacking of the valve is required.

5. WATER JETTING

Although the pressure process is a safe, fast and effective method for removing valve packing, it is not suited to all valves. An alternative process is to use a high pressure water jet directed at the packing rings, where patent coverage is obtained [6].

With the jetting process, packing rings can be penetrated and lifted by directing a water jet 58.6 MPa (8 500 psi) to the top layers of the packing set from the top of the stuffing box. This process is effective in cleaning the stuffing box to allow easier removal of lantern and junk rings by conventional methods. The jetting process is also very effective for removing hardened gasket materials from the flange faces or splitting the hard packing sets from the stem (Figure 5).

The test equipment developed for the Tri-Function Process can also be used as an effective general purpose high pressure water decontaminating device. The apparatus is capable of delivering up to 82.7 MPa (12 000 psi) water flow through a 0.45 mm (0.018 in.) nozzle. The cutting force of this pressure will not damage steel parts found on most fluid components.

Fan-type jets are very effective at removing boric acid crystals and asbestos lagging contaminants from valve bodies and related piping components. Containment shielding is recommended for this operation to avoid the spread of contaminants.

Note that the jacking technique uses lower fluid pressures, less water and most of the water is contained in the stuffing box. This is considered an advantage over the jetting process by safety committees, because of the reduced risk of spreading contamination.

6. OPERATING PRINCIPLE

The principle component of the test equipment is an air-driven hydraulic pump. High pressure fluid is supplied by a 102 mm (4 in.) stroke air-driven pump. It works on an automatic reciprocating differential air piston principle that uses a large air-driven piston connected to a smaller area hydraulic piston to convert compressed air into higher pre-pressure hydraulic power. The hydraulic piston acts to induce liquid through an inlet check valve and force it out through the outlet check valve at high pressure in relation to the ratio of hydraulic piston to air piston areas (100:1 for the test equipment).

Figure 5: Water Jetting Used To Peal and Remove Lifted Packing Set From Stem

Air pressure is channelled to alternate sides of the air piston by a pilot-operated, unbalanced lightweight spool, causing the piston to reciprocate (cycle). When compressed air is first supplied to the pump, it will cycle at its maximum speed, filling the hydraulic system fluid. The pump will gradually start to cycle at a slower rate as the pressure builds up and offers more resistance to the reciprocating differential piston assembly, until it stops when the force balance is reached (e.g., when air supply pressure x air piston area = hydraulic outlet piston area).

7. SUMMARY

Development of this pressure process and its testing device represents a combination of technologies to address a widespread need within industry. AECL's strong background in valves and valve stem seals identified the need; the Tri-Function Process provides the method to satisfy that need.

The Tri-Function Process offers maintenance staff advantages in terms of safety, cost-savings and employee morale by allowing quick and safe inspection of the backseat seal, removal of all types of packing, including lantern rings and junk rings, and testing of the repacked valve for immediate sign-off. This process can reduce valve repacking costs by 60% and lower ALARA accounts significantly. The Tri-Function Process is the first step towards 'leak-free valves'. It saves time and money and reduces radiation exposure.

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