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A SUMMARY OF THE CHALK RIVER VALVE PACKING EVALUATION PROGRAM 1985 - 1990

SOMMAIRE DU PROGRAMME D'ÉVALUATION DES GARNITURES DE ROBINETS DE CHALK RIVER 1985 - 1990

J.A. AIKIN, G.L. DOUBT and C.R. LADE

Presented at The Bruce 'B' Maintenance Conference
Bruce Information Centre
March 15, 1990

Chalk River Laboratories

Laboratoires de Chalk River

Chalk River, Ontario K0J 1J0

December 1990 décembre

AECL Research

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EACL RECHERCHE

Sommaire du programme d'évaluation des garnitures de robinets de Chalk River

1985 - 1990

J.A. Aikin, G.L. Doubt, C.R. Lade

Résumé

L'abandon des matériaux à base d'amiante a suscité parmi les fabricants de robinets et de garnitures ainsi que les groupes d'utilisateurs une certaine inquiétude quant à la fiabilité et la sûreté à long terme des matériaux ne contenant pas d'amiante. Depuis 1985, EACL Recherche à Chalk River prend une part active à l'évaluation de ces nouveaux matériaux utilisés dans la fabrication de garnitures de robinets.

Le présent rapport fait état des travaux effectués à Chalk River de 1985 à 1990. Il comprend des études financées par le Groupe des propriétaires de centrales CANDU (GPC) et l'EPRI (Electric Power Research Institute). Il décrit les programmes d'essai et donne un bref résumé de la tenue en service des matériaux les plus résistants (graphite matricé, amiante tressé et matériaux tressés autres que l'amiante) à la friction, aux fuites autour de la tige de manoeuvre et à la consolidation.

EACL Recherche et Ontario Hydro ont approuvé l'utilisation des garnitures suivantes :

- Pour les robinets à garniture sans charge compensatrice, on recommande de remplacer les garnitures d'amiante tressé par une combinaison de garnitures de graphite souple.

- Pour les robinets d'eau lourde comportant à l'origine la pièce JC 187I, les garnitures de remplacement recommandées sont faites de matériaux d'amiante tressé homologués.

Mise au point de l'équipement mécanique
Laboratoires de Chalk River
Chalk River (Ontario) KOJ 1J0
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AECL RESEARCH

A SUMMARY OF THE CHALK RIVER VALVE PACKING EVALUATION PROGRAM

1985-1990

J.A. Aikin, G.L. Doubt, C.R. Lade

ABSTRACT

The move away from asbestos-based valve packing products has generated concern among valve manufacturers, packing manufacturers and user groups about the reliability and safety of non-asbestos based products for long-term use. AECL Research, Chalk River, has been actively evaluating these new valve packing products since 1985.

This report describes the work done at Chalk River from 1985 to 1990. The report includes both Electric Power Research Institute (EPRI) and CANDU Owners Group (COG) funded studies. A description of the test programs and a brief summary of the functional performance of the more successful materials (die-formed graphite, braided asbestos and braided non-asbestos) on friction, stem leakage and consolidation are provided.

At this time, Chalk River and Ontario Hydro have approved the following packing arrangements:

- For non-live-loaded valves, the recommended replacement packing for braided asbestos is combination flexible graphite packing sets.

- For heavy water valves originally designed with JC187I, the recommended replacement packing is approved braided-asbestos products.

Mechanical Equipment Development Branch
Chalk River Laboratories
Chalk River, Ontario K0J 1J0
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1. INTRODUCTION

The move away from asbestos-based valve packing products has generated concern among valve manufacturers, packing manufacturers and user groups. The main concern is the reliability and safety of non-asbestos based products during long-term use. Added to this concern is a developed scepticism towards packing manufacturers' reported test results on their own non-asbestos based products. To address this concern, there has been an increased effort placed on testing and qualifying non-asbestos based packing products [1].

One of the studies receiving industry interest is the EPRI-funded program "Valve Stem Packing Improvements", Project RP 2233-3) [2]. The testing for the EPRI program was conducted by AECL Research at Chalk River Laboratories by the Mechanical Equipment Development (MED) Branch, utilizing their extensive background in valve leakage reduction.

The program evaluated A.W. Chesterton's square and wedge graphite packing styles at both pressurized water reactor (PWR) and boiling water reactor (BWR) conditions with and without live-loading (live-loading is the technique developed at Chalk River [3,4] using disk springs to maintain a constant gland load on the packing). The EPRI test program showed that, with proper application, a five-ring flexible graphite packing set (three die-formed rings bracketed by two braided end rings) is capable of providing reliable sealing for a wide range of valve and stuffing box designs.

However, for many valves in the heavy water circuit in CANDU[1] Nuclear Generating Stations (NGS), there is insufficient room in the stuffing box to accommodate the extra packing rings required. The design of a double-packed stuffing box (Figure 1) shows a 3x2 packing ring arrangement with a lantern ring. Since the lantern ring and related leak-off port are required to limit tritium and heavy water loss, they must remain as part of the valve design. This makes it difficult to install standard die-formed packing sets because of the additional packing rings required.

Compounding the problem with these valves was the unavailability of the asbestos-based valve packing product JC-187I. This precipitated a significant concern for the owners of CANDU NGS as this material was the only product specified for use in the double-packed valves. A high priority R&D program, funded by the CANDU Owners Group (COG), was established to identify a suitable asbestos-based substitute for JC-187I. The asbestos-based substitute was needed to avoid changing existing stuffing box configurations, which provided live-loads up to 12 000 psi, and allowed little space to install additional rings required with proven alternatives to asbestos. A total of ten possible asbestos replacement candidates were put through a screening and endurance testing program. Three products were selected and are now in use in most of the

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[1] **CANada Deuterium Uranium. Registered trademark.**

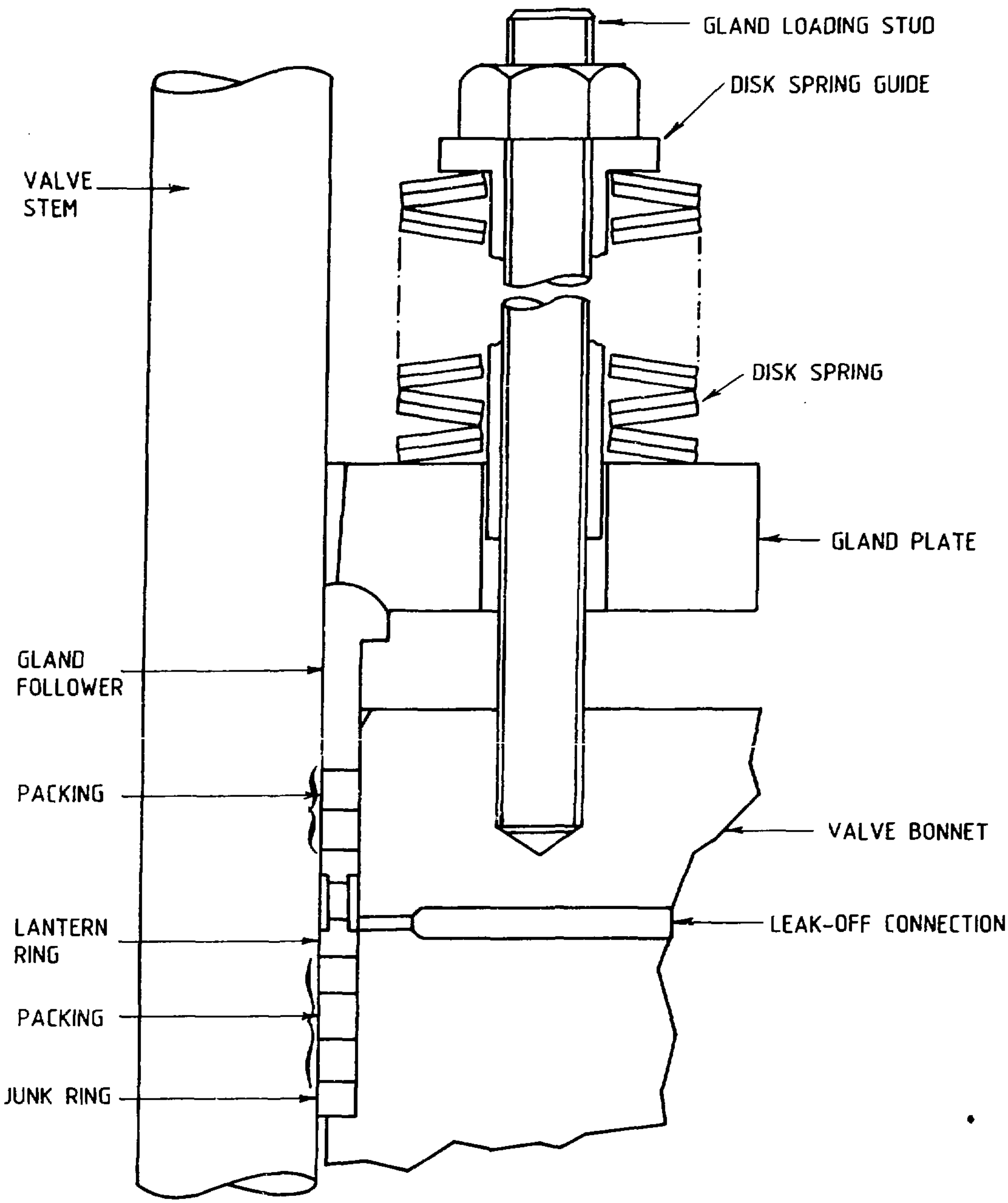

FIGURE 1: SKETCH OF DOUBLE-PACKED VALVE

operating CANDU NGS. The results of this study have been reported in AECL Report RC-120 (COG-90-146), "John Crane 187I Substitution", G.L. Doubt et al. [5].

Part way into the JC-187I replacement program, another study was initiated to evaluate the new braided non-asbestos valve packing materials. Nineteen braided non-asbestos packings from seven different manufacturers were investigated. These products were processed through the Chalk River screening and endurance testing program. Investigation is still active on this study; however, a product has been identified that has improved functional qualities. This work is reported in COG-90-150, expected to be available in late 1990 or early 1991 [6].

The remainder of this report describes the Chalk River test program since 1985 and provides a brief summary of the functional performance of the more successful materials (die-formed graphite, braided asbestos and braided non-asbestos) on friction, stem leakage and material consolidation.

2. PACKING MATERIALS

The present evaluation program at Chalk River has evaluated more than thirty different valve packing materials. Many were found to be unacceptable due to the use of blocking agents and failure of the fibre construction. The following summary does not give the results of all the packings but rather has classified the materials into three groups: die-formed graphite, braided asbestos and braided non-asbestos. The trade names of the materials listed in Table 1 have been coded because detailed results are not available for general release at this time.

3. EVALUATION PROGRAM

The evaluation program was a two-phase process. The first phase subjected the selected materials to a series of short-term screening tests. The second phase was a long-term endurance test using the Chalk River Valve Packing Test Rig (Figure 2).

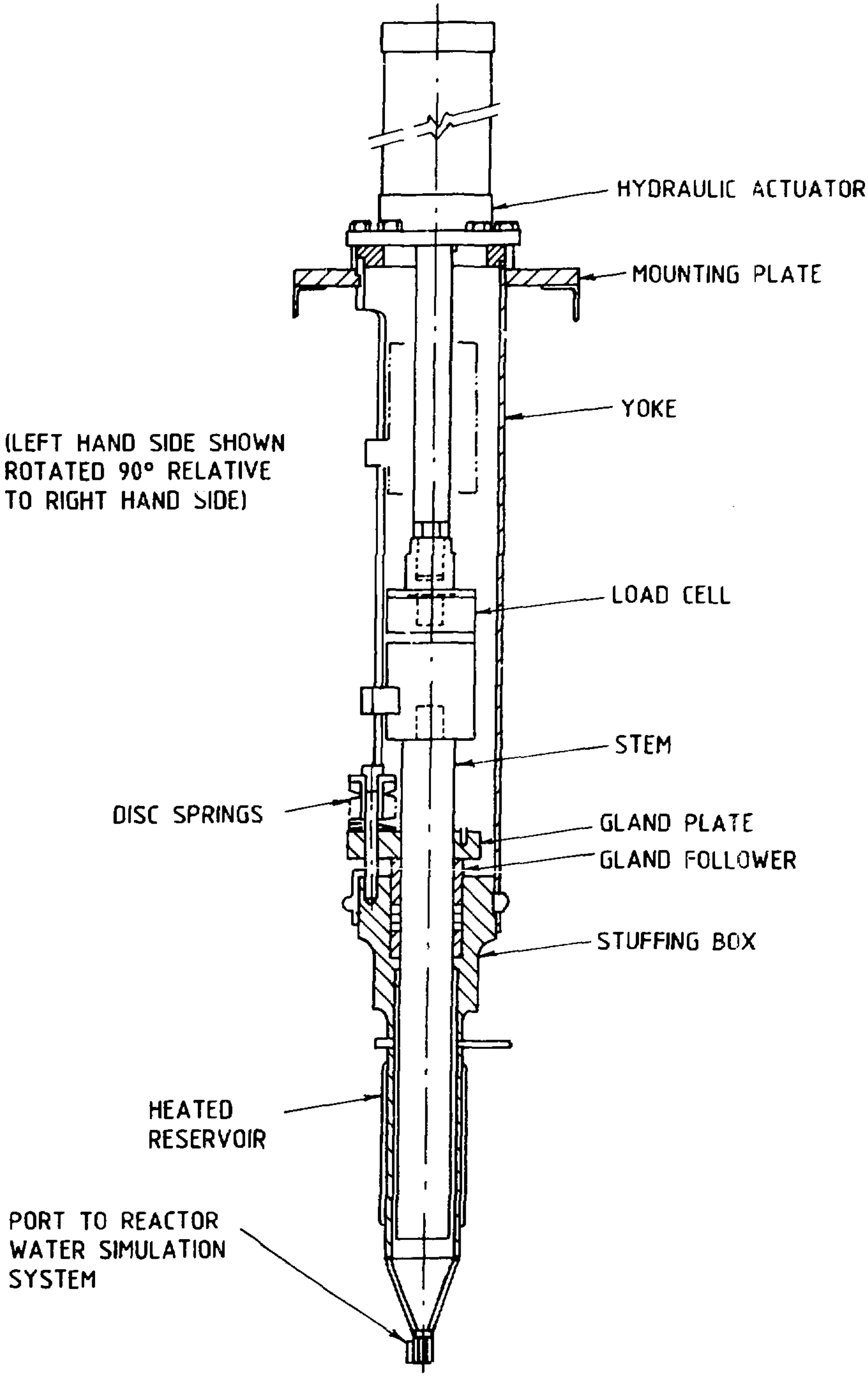

FIGURE 2: CHALK RIVER VALVE PACKING TEST RIG

TABLE 1: PACKING MATERIALS AND DESCRIPTION

Group 'A'	A five-ring packing set constructed of three rings of expandable die-formed graphite bracketed by two braided graphite or carbon anti-extrusion rings.
Group 'B'	A packing set constructed of three rings of braided-asbestos, Inconel wire reinforced, over an asbestos core impregnated with selected organic/graphite blocking materials.
Group 'C'	A packing set constructed of three rings of Inconel wire reinforced braided non-asbestos fibres, over a non-asbestos braided or plastic core impregnated with selected organic/graphite blocking materials.

3.1 Screening Program

Initial product selection was primarily on the basis of manufacturer ratings. Some of these appeared similar to packings that had failed during previous test programs. Because it was likely that many of the chosen materials would be unsuitable, the size of the test program was reduced by eliminating unlikely candidates through short screening tests. The methods used were as follows:

(a) Measurement of volatile materials content by weight loss during 24 hours in an oven at 300°C

In the past, this had been found to be a simple and inexpensive way to eliminate many materials with an unacceptably high fraction of unstable binders and lubricants. Based on past experience both in the lab and the field, a weight loss > 10% generally resulted in unacceptable performance.

(b) Assessment of material integrity after compressing to currently specified gland pressures (> 40 MPa)

It was discovered in a previous program that the fibre in some of the woven graphite fibre products would fracture extensively under relatively light gland loadings (27 MPA). This resulted in packing failure when the pulverized fibre washed out.

The assessment was made by dissection and visual inspection after compressing samples in a stuffing box-shaped die, 17 mm ID and 49 mm OD, to 40, 60, and 80 MPa. Only materials with a high degree of fibre breakage at low gland pressure were rejected on this basis (i.e., materials whose fibre breakage was comparable to that of a previously tested material that had failed in functional testing for this reason).

An attempt was made to objectively measure the degree of internal fracture by comparing load deflection and hysteresis characteristics while cycling the gland pressure; however, the correlation between fibre breakage and load/deflection characteristic was not clear enough to be of value in screening.

(c) Twenty-four hour functional test and visual examination - live-loaded

Packings were loaded into large endurance test rigs (76 mm dia. stem, 95 mm dia. stuffing box, 360 mm stroke), and live-loaded to 38 MPa. Heaters were turned on, stem stroking initiated immediately at room temperature, and continuous measurements of leakage, stem friction and packing consolidation started. The test was stopped at 140 cycles and the packing removed for visual examination. A complete stroke cycle occupied about 10 minutes with the stem inserted for about 4 minutes, withdrawn for about 4 minutes, and in transit for the balance.

Although this was not the quickest screening method employed, it provided the most definitive results. It eliminated all borderline materials from the previous tests, as well as others that had appeared promising to this point.

(d) Twenty-four hour functional test and visual examination - conventionally-loaded

The only difference between this and the previous test was the absence of live-load spring stacks over the gland plate. During these tests, there was no measurable consolidation because there was no mechanism to follow up on packing relaxation.

This test revealed large differences in leak rate between materials that were not apparent under live-loading.

(e) Chemical analysis

Total chlorine and fluorine were measured on selected products by heating at 500°C to 550°C in flowing oxygen, and scrubbing the gas stream for Cl^- and F^- in 0.1 M NaOH. Cl^- was measured by an ion selective electrode and F^- by ion chromatography.

During functional testing most of the materials produced filmy extrusions both inward and outward along the stem, composed of dry lubricant and elastomeric or plastic binder. It was suspected that in some cases the extruded material would be largely PTFE, which is added to some packings as a lubricant and blocking agent. Such extrusions stand a high chance of being released to the system and, in nuclear circuits, would constitute a localized corrosion hazard due to radiolytic breakdown and localized release of fluorine, if they later became lodged against an in-core component.

3.2 Endurance Testing

The final test, for the remaining products, was a 1500 stem stroke endurance test at simulated operating conditions of 10.3 MPa @ 295°C. The packings were live-loaded to 38 MPa for the initial test. However, extensive extrusion was noted for the non-asbestos products. Therefore, the gland load was reduced to 27 MPa for Group 'C' products. The cycle period was increased to 15 minutes to allow about twice the time interval for stem cooling during the retracted phase. This resulted in a slightly greater stem diameter variation due to temperature differentials and produced higher stress on the packing.

The rig was pressurized, the heaters turned on, and cycling started from a shut-down condition. Stem cycling was interrupted after each 300-stroke cycle by a 24-hour static period with the rig pressurized and at operating temperature. Leak rates measured during such static periods are more representative of these to be expected in the field; however, they may still be somewhat higher since leakage may decrease with time over longer field static periods. Stem friction, packing consolidation and stem leakage were continuously monitored and recorded. Start-up and end-of-period friction profiles were recorded for each period change.

4. RESULTS

4.1 General

Table 2 summarizes and compares the performance of the three product types. The leakage performance of 'C,' live-loaded, is encouraging. It is the only product that showed no detectable leak rate after 1500 stem stroke cycles. Initial friction values for 'A' and 'C' live-loaded were similar, measuring 8.9 KN and 5.7 KN, respectively. The increase in the in-stroke friction with stem stroke cycles for 'C' is a weakness with this type of product. There is also some concern about the high consolidation observed with Group 'C', which is a nuisance for live-loading, and indicates a lack of elasticity needed for conventionally-loaded applications. Under conventional loading, 'C' required re-loading at 599 cycles. Although the sealing was much better than would be expected from braided asbestos 'B' with conventional-loading, it did not approach the long-term integrity of flexible graphite, Group 'A', with conventional-loading.

TABLE 2: SUMMARY OF TEST DATA									
PACKING STYLE	No OF STROKE CYCLES	GLAND PRESS NOMINAL MPa/psi	LEAKAGE		AVG. FRIC. DOWN [kN]			CONSOLIDATION	
			DYNAMIC [1](L/Cyc)	STATIC [mL/h]	CYCLE 1	CYCLE 600	CYCLE 1200	PRE-SERVICE [%]	IN-SERVICE [%]
GROUP 'A' Square CL	2882	14.5/2100	155(0.05)	3.8	4.8	1.9	1.9	25.2	0.1
Square LL	2598	14.5/2100	4(0.002)	1.0	8.9	5.3	4.4	22.7	1.4
GROUP'B'LL	936	38/5500	96(0.10)	52.7	17.7	12.2	5.2[1]	16.0	4.0
GROUP'C'CL	599	27/3900	38(0.03)	0.43	4.5	0.4	--	27.8	0.4
	599-1463	34/5000[2]	16(0.01)	0.02	--	1.4	1.6	--	6.2/0.33
LL	1463	27/3900	0(0)	0.0	5.7	7.2	10.8	25.4	11.1

NOTES:

The data shown for Group'A' is taken from the EPRI-funded program "Valve Stem Packing Improvements"
CL Conventional-loading
LL Live-loading

[1] Stroke cycling was stopped due to uncontrollable leakage. The friction value is for cycle 936.

[2] The packing was re-loaded to 34.4 MPa due to high leakage at the initial gland load of 27 MPa.

4.2 Leakage

Figure 3 shows the cumulative leakage vs stem stroke cycle for the three products at the different gland loads. Braided non-asbestos live-loaded (LL'C') had no detectable stem leakage. A very similar performance was seen with live-loaded die-formed graphite (LL'A'). The high leakage observed for Group 'C', conventional-loading (CL'C') is a concern. The leak rate was approaching a state of uncontrollable leakage (> 1.2 L/h) for the test set-up. It was decided to re-load the packing to about 34 MPa rather than stop the test. At the end of the test, the leak rate was about 0.4 L/h.

The sealing performance for the non-asbestos, conventionally-loaded, Group (CL'C') was not much worse than for live-loaded asbestos (LL'B'). Referring to Figure 3 and extrapolating the first ramp on curve CL'C' and the ramp on curve LL'B', the cumulative leakage for 1600 cycles would be at least 340 L for both packing styles. After 599 stem strokes at 38 MPa, live-loaded asbestos had a cumulative leakage of 11 L vs 38 L for the braided non-asbestos. Testing on the asbestos Group (LL'B') ended at 936 cycles because of unmanageable leakage. The leakage performance of die-formed graphite, conventionally-loaded (CL'A') is somewhat higher than the other groups, but was also at a lower applied gland load (Table 2).

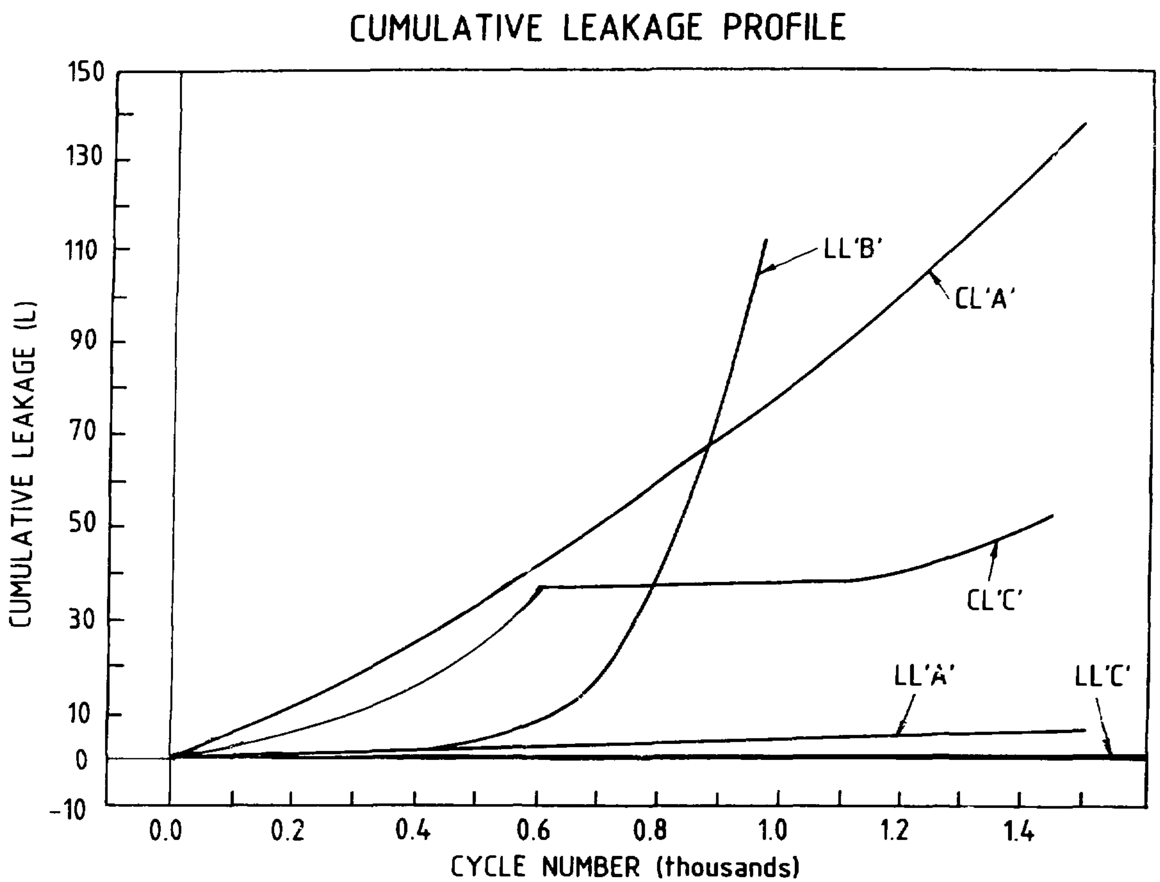

FIGURE 3: CUMULATIVE LEAKAGE VS. STEM CYCLES

4.3 Friction

Figure 4 shows the average in-stroke friction vs stem stroke cycle for the three groups at the respective applied gland loads. The increase in friction with increasing stoke cycling is a concern with live-loaded braided non-asbestos (LL'C'). This type of increase in stem friction could be a potential problem for small motor-operated valves (MOVs), where the actuator is close to its design limits. This characteristic is different than other products tested where friction declines with increasing stem cycle, as seen with the die-formed graphite (LL'A' and CL'A') and braided asbestos (LL'B').

The friction for conventional-loaded conditions is very low and tends to decrease with stem stroke cycling corresponding to higher leakage. The step increase, at stem cycle 599, for CL'C' is from re-loading the packing to 34 MPa. Again, the friction slowly declines with stem stroke cycling, resulting in an increasing leak rate.

4.4 Consolidation

Figure 5 shows the in-service consolidation profile for the three products at live-loaded conditions (conventional-loading does not show a profile because the gland follower position is nearly fixed, except for a small degree of stretch in the gland stud). The profile shows the change in consolidation during stroke cycling expressed as a percent relative to the free packing height. This is not total consolidation but an indication of packing height loss at live-loaded conditions. The profile for the braided non-asbestos material (LL'C') is significantly higher than for LL'A' and LL'B' at similar conditions. The relatively high consolidation is a nuisance for live-loading design and indicates a lack of elasticity needed for conventionally-loaded applications.

5. RECOMMENDATIONS

Endurance testing of braided non-asbestos material (LL'C') has proven that the product is one of the better products tested to date in the Chalk River Valve Packing Endurance Test Rig, with respect to sealability. Unfortunately, there are some concerns with the use of the lubricant/binders in a radiation environment and their increasing friction characteristics with stem cycling. Discussions with the end users and the manufacturers are in progress to resolve these concerns.

At this time, Chalk River and Ontario Hydro have approved the following products for use in CANDU NGS:

1) Except for valves originally designed with live-loaded glands, the recommended packing material to replace Group 'B' (braided-asbestos packing) is Group 'A' (die-formed graphite sets). The graphite packing set for the NGS is a die-formed graphite ring bracketed by two braided carbon rings.

2) Valves originally designed with braided asbestos packing (JC-187I) and live-loaded (i.e., those on the PHT System) will use Group 'B' (a braided-asbestos packing) at the design loads, as specified in Ontario Hydro Provisional Specification L-942M-81. Design and space limitation does not allow the use of the die-formed graphite sets.

The accepted products are now being used at both Bruce 'A' and 'B' NGS, and selectively at other CANDU reactors.

6. REFERENCES

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[6] Aikin, J.A., Doubt, G.L., "Braided Non-Asbestos Alternatives to John Crane 187I", COG-90-150 (In Printing).*

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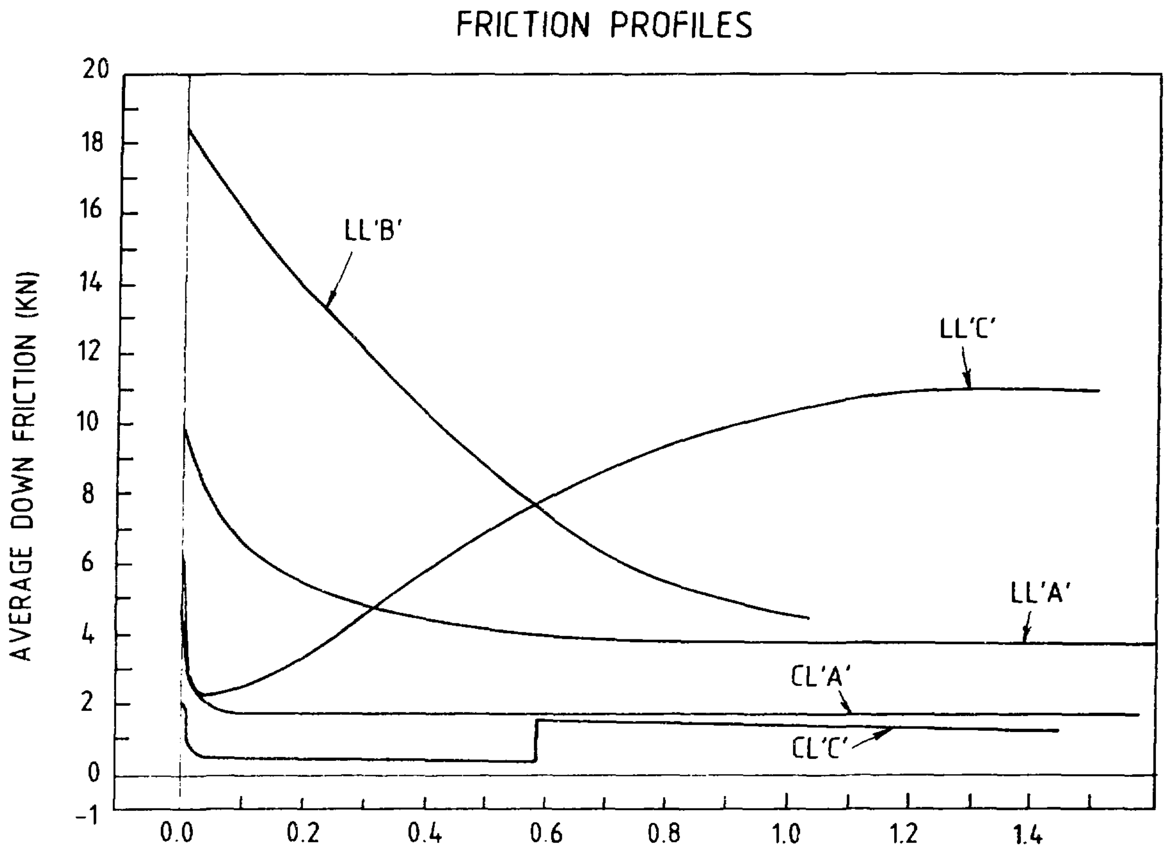

FIGURE 4: IN-STROKE FRICTION STEM CYCLES

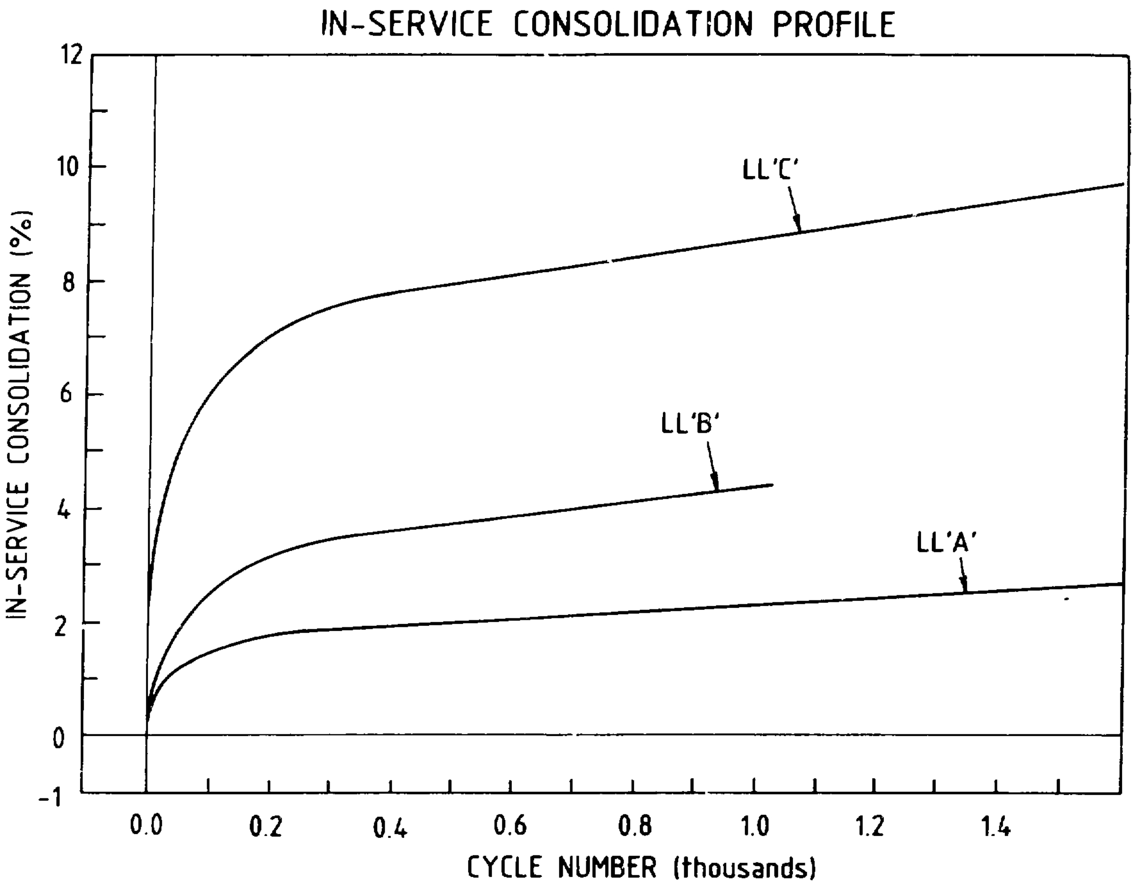

FIGURE 5: IN-SERVICE CONSOLIDATION VS. STEM CYCLE

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