By Jean V. Reid, PhD, P.Eng1, Director, IRDI, A division of Georgian College of Applied Arts and Technology

IRDI - An Overview
IRDI (Industrial Research + Development Institute) is located in Midland, Ontario, Canada. IRDI was founded in 1992 by two local business entrepreneurs as an industry-driven research institute. IRDI moved to its current location in 1995, and is still housed within this industrial-scale 55,000 square foot facility that was acquired by Georgian College of Applied Arts and Technology (Barrie, Ontario) in July 2003.

IRDI bridges the gap between the laboratory and the shop floor. Studies range from laboratory testing and data analysis using bench top to production-scale equipment on the shop floor. IRDI’s focus is research and technology development in the field of tribology, specifically as it relates to metal forming processes such as hydroforming, drawing and stamping. In addition, our focus expands to include formability studies as well as a general systems approach to solve problems related to the friction and wear of surfaces (metals, plastics or composites) in contact.

How We Work
IRDI works on R&D projects either by contract with individual clients or consortia, or on projects funded by provincial or federal agencies and leveraged by industry dollars.

IRDI also manufactures the Twist Compression and the Drawbead Simulator under exclusive license from Prof. J.A. Schey. The license allows IRDI to maintain the integrity and robustness of his original mechanical design but also include laboratory-proven enhancements for user-friendly operation and reliability. An example of one of these improvements is seen in the data acquisition software. IRDI’s software, a Windows®-based application, developed by Mr. J.A. Lock of IRDI, is continually updated and changed, according to customer feedback which adds to client satisfaction and proven results.

Twist Compression
The twist compression (TC) is a bench-top tribological test for evaluating material/lubricant combinations [1]. In this boundary lubrication test, an annular specimen contacts a flat specimen retained in a horizontal position. The lower flat specimen is raised under a preset hydraulic pressure while the annular specimen is rotated. Friction is calculated from a measured torque and normal load; the test can be operated in either a static or dynamic mode. Both specimens can be inspected for metal transfer and surface damage. The test was originally developed by Prof. J.A. Schey to study applications under lubricant starvation conditions such as found in certain areas of forging, extrusion and drawing. It has also found extensive use in the study of stamping and hydroforming.

In recent years, there has been an increased interest in the use of the test to study low-load sliding applications of plastics and composites. In response to this need, IRDI modified the TC for contact interface pressures in the 2-100 PSI range.

Problem/Objective
A project was performed for Honeywell Limited4 to investigate the feasibility of using laboratory tribology tests to assist in the elimination of the wear and sticking problems encountered in their water heating control valve. The subject of this paper is the use of the low-load twist compression test to assist in solving this friction and wear problem.

The heating control valve consists of a Noryl® outer barrel, a Ryton® sleeve and an EPDM rubber seal (Figure 1). The common seal material used is an 80-durometer® rubber; 70-durometer rubber was also used for a short time.

Figure 1. A photograph of sectioned Honeywell Limited water heating control valve. (Photograph courtesy of Honeywell Limited)

Background
Honeywell Limited extensively researched the cause of the problem and identified that the failures came from a variety of sources; however, the returned products were from a very limited number of clients.

The most common returns were from industrial heating systems that received no regular maintenance and/or had higher levels of contamination and minerals in the water. Problems were also encountered in systems that handled higher volumes of water than normal or had been subjected to aggressive cleaners at the end of the heating system. Cleaners that were beneficial in thoroughly cleaning the sys-
tem also removed the lubricant that is applied in the valve (during assembly and maintenance) to allow efficient operation of the valve.

Examples of failed valves are shown in Figure 2. Common surface contamination found in sticking valves is magnetite and iron phosphate. The condition of returned valves ranged from being stuck to being slow to return. Some valves were not stuck but rusty and required maintenance (cleaning and lubricating) prior to being returned to service.

In the early phases of the project discussion, Honeywell Limited outsourced water-spray off and water washout tests (ASTM D-1264) to compare lubricants submitted, by lubricant companies, as potential replacement products for the one currently in use. Five lubricants (Table 1) identified as A to E; were tested. Product A, the product currently in use was the control product.

### Experimental Plan

**Step 1.** Lubricants for the application were sourced and the products, with a short description, chosen for evaluations are included in Table 2.

**Step 2.** The twist compression was modified for low load by changing the hydraulic application of the load to an electrically controlled load application system; the load cells were replaced for load and torque measurement in the range required (Figure 3). The upper annular specimens were machined from plastic plaques and the lower flat specimens were prepared from rubber seal plaques (Figure 4), page 42.

The test matrix is shown in Table 3, page 42. The upper annular specimens were machined from Ryton® and the lower specimens were prepared from EPDM rubber (70 and 80 durometer). Six lubricants were evaluated at an interface pressure of 50-PSI and a speed of 1.5-RPM. The speed and pressure were determined with Honeywell Limited and were based on the conditions existing during the operation of the valve. The test duration was set as 5 minutes.

The lubricants were initially tested in the twist compression, and then subjected to cleaning followed by retesting in the twist compression to compare the coefficient of friction values for before and after cleaning conditions. After the initial friction tests, the lubricated samples were ultrasonically cleaned in a 2.5% solution of International Products Corporation Micro-90 at 60°C for one hour. A limited number of tests were also performed using a 4-hour cleaning cycle for a comparison of two chosen lubricants.

### Results & Discussion

The nominal coefficient of friction values for the evaluated products are plotted as a function of time for Ryton® vs. 80-durometer EPDM rubber (Figure 5), page 42. After the samples were cleaned ultrasonically for 1 hour, they were retested in the twist compression test to determine how well the lubricant was able to adhere to the substrate without being removed during cleaning (Figure 6), page 42. The best results, in terms of lowest friction, after cleaning were obtained with Products A, I and J. The results from one test from each product are shown in Figures 5 and 6; several replicates were made for each product. In some tests, Product A resulted in the lowest coefficient of friction (as shown in Figures 5 and 6). However, the nominal coefficient

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**Table 1. Results of water spray-off and water washout tests (ASTM D-1264) for Products A to E.**

<table>
<thead>
<tr>
<th>Lubricant</th>
<th>Water Spray-Off (%)</th>
<th>Water Washout (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>1.32</td>
<td>9.40</td>
</tr>
<tr>
<td>C</td>
<td>2.16</td>
<td>0.71</td>
</tr>
<tr>
<td>A</td>
<td>24.07</td>
<td>1.35</td>
</tr>
<tr>
<td>D</td>
<td>64.30</td>
<td>0.01</td>
</tr>
<tr>
<td>E</td>
<td>86.55</td>
<td>0.04</td>
</tr>
</tbody>
</table>

**Table 2. Descriptions of the products chosen for evaluation for the water heating control valve.**

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Clear dimethyl siloxane polymer</td>
</tr>
<tr>
<td>F</td>
<td>Grade 2; Silica thickened silicone grease; E.P. additives</td>
</tr>
<tr>
<td>G</td>
<td>Silica thickened polyfluoropolyether (PFPE); resistant to chemicals</td>
</tr>
<tr>
<td>H</td>
<td>Boric acid technology; boron – hard, low friction; needs heat and moisture to be effective; bonds to metal and provides protective film</td>
</tr>
<tr>
<td>I</td>
<td>Flour polymers; expensive; completely inert</td>
</tr>
<tr>
<td>J</td>
<td>Very hydrophobic; tacky (high viscous base oil); food</td>
</tr>
<tr>
<td>K</td>
<td>Hard ceramic coating; reported that it could be applied to plastics; it was not successfully applied to a high temperature plastic sample that was provided</td>
</tr>
</tbody>
</table>
of friction obtained with Product J was similar in tests performed before and after cleaning conditions. Products A, F, G and J were chosen for testing using the Ryton vs. the 70-durometer EPDM rubber. After cleaning, the samples were retested. As was observed for 80-durometer rubber, the best performance for the 70-durometer EPDM rubber was also obtained with Products A and J. However, as observed with testing the 80-durometer EPDM rubber, the coefficient of friction obtained with Product J was similar for before and after cleaning conditions. That is, Product J was the product that most consistently remained on the surface of the specimens when subjected to the cleaning process.

A limited number of tests were performed, in which Products A and J were subjected to a 4-hour cleaning process. Additional tests are required to develop a larger database to determine if the longer cleaning period provides for a better correlation with the production application.

**Recommendation**

Based on a consideration of all the results and the observed surface appearances after testing, it was recommended that Product J be compared to Product A in a field evaluation.

**Current Status**

Honeywell Limited has conducted evaluations in a laboratory test designed to simulate the operation of the valve, to compare their current product with Product J. Improved results were obtained with Product J. A field evaluation is currently in progress.

Acknowledgements. The project was funded by Honeywell Limited ([www.Honeywell.com](http://www.Honeywell.com)) and is published with permission. The project was led at Honeywell Limited by Ms. A. Serbanescu. The author gratefully acknowledges the invaluable assistance of Mr. M. Holmes in performing tests, developing procedures and analyzing data. The upper annular specimens were manufactured by Mr. H. Herbert.

**References**


1. Contact: jreid@irdi.com or 705.526.2163 x235
2. Windows is a registered trademark of Microsoft Corporation in the United States and other countries.
3. [www.honeywell.com](http://www.honeywell.com)
4. Durometer is a measure of the hardness of a rubber compound.