Model 710 ISS Dry Cycle

Brian Rages

10/24/00

PURPOSE

The purpose of this test was to evaluate the reliability of the Model 710 ISS for Model 710 DAT.

CONCLUSIONS

Five ISS units were each cycled 5,000 times. Each unit passed function tests before and after being cycled.

The peak torque required to lock and unlock the ISS unit dropped about 30% after 5,000 cycles.

One ISS unit was cycled an additional 5,000 cycles. After 10,000 cycles, the peak lock torque had risen 5%. The peak unlock torque had dropped an additional 16%.

Each of the 5,000-cycle ISS units was disassembled. Wear was visible on the parts inside, but the parts did not appear worn out.

PROCEDURE

Bolts were selected from five guns. These guns had undergone proof testing but no other use. Bolts were selected from guns marked B1, B2, B3, B4, and B6. The ISS system in each bolt was put through the following function test:

- The ISS was set to the locked position and an attempt to close the bolt was made. An inability to close the bolt indicated proper function.
- The ISS was set to the unlocked position and the bolt was closed. Proper function of the ISS allowed the bolt to close.
- An attempt was made to turn the ISS from the unlocked to locked position while the bolt was closed. Proper function does not allow this action.

All five guns passed the function test. The torque required to lock and unlock the ISS was measured. To measure the lock and unlock torque, an ISS key was fitted with an arm made from a flat piece of spring steel. A strain gage was placed on the arm next to the key. This device may be seen in Figure 1.

To measure the torque, the bolt containing the ISS unit to be measured was clamped in a vise. The torque-measuring key was placed in the ISS and the key was rotated slowly to turn the ISS to the locked position. The force to turn the key was applied by hand to the end of the metal arm. This force caused the arm to flex. The flexing of the arm was measured by the strain gage, then recorded and converted to torque. After the ISS had been locked, the key was turned the opposite direction to unlock it. The locking and unlocking of the ISS were performed within a 20-second sampling period. This torque measurement was taken twice for each of the ISS units.

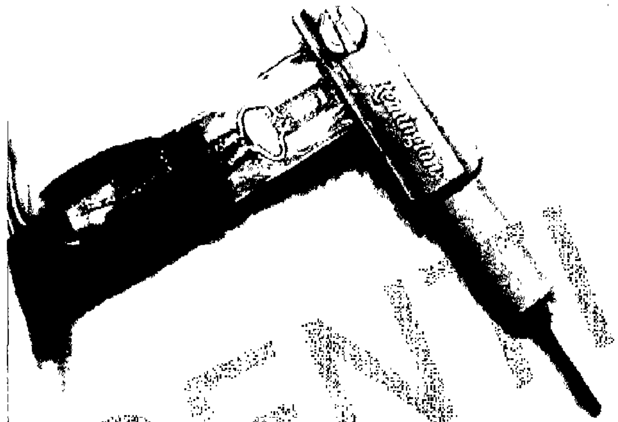

Figure 1. ISS torque measuring device.

The strain gage, a 120-ohm unit, was run into a Measurements Group Model 2311 Signal Conditioning Amplifier. The strain gage amplifier was set to a 3.5 V excitation with a wideband filter. The gain was adjusted to 575 to give a 1mV/microstrain calibration.

The National Instruments BNC-2110 was used as an input device for a laptop PC. Data was collected over a 20 second period with a 0.01-second sampling rate. The strain reading was multiplied by 0.7705 to convert microstrain to inch-pounds of torque. Derivation of this conversion factor is covered in the "results" section of this report.

No lubrication was added to any of the ISS cylinders, and no cleaning was performed on them. Each ISS was cycled through its 180° travel 5,000 times using a pneumatic rotary indexer. Figure 2 shows the dry-cycle fixture used.

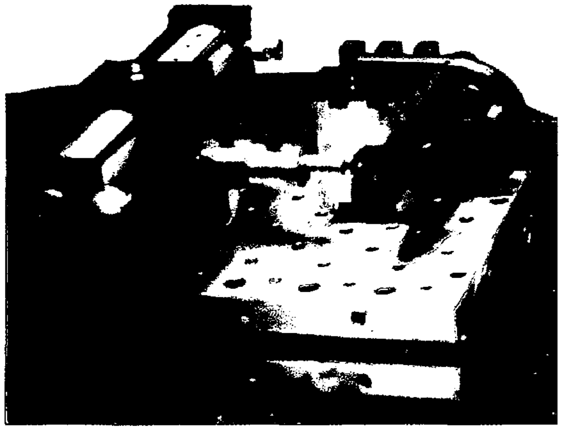

Figure 2. ISS dry cycle fixture.

The ISS key in the dry cycle device broke while testing the ISS unit in the third bolt. The breakage was noticed when the machine was checked around 2,000 cycles. The key had over 20,000 cycles on it, but it did not fail due to fatigue. The key broke because the bolt had worked loose in the fixture causing the key to become twisted. A new key was set in the indexer and, because the fixture had not been monitored to catch the exact time the key broke, 5,000 additional cycles were placed on the ISS in that bolt.

After all five ISS units had been cycled 5,000 times, the lock and unlock torques were measured using the same equipment and procedure as previously described.

On four of the bolts, the rear of the bolt plug was cut off and the parts of the ISS were removed for inspection. The fifth bolt was cycled an additional 5,000 times for a total of 10,000 cycles and its lock and unlock torques were measured again.

RESULTS

A function test, described in the "procedure" section of this report, was applied to each of the ISS units before and after being cycled. To pass this test, the ISS unit must, when locked, keep the bolt from closing. When unlocked, the ISS unit must allow the bolt to close. The ISS unit also must not allow itself to be locked when the bolt is closed. Each unit passed this test before and after being cycled.

The conversion between strain reading and torque was arrived at through a mechanics of materials analysis performed on the metal arm on the torque-measuring device. The moment at the strain gage was calculated from two relationships. The first was the relationship between strain and stress:

$$\sigma = E\varepsilon$$

where σ is stress, ε is strain, and E is the modulus of elasticity of steel, 30×10^6 psi. The second was the relationship between stress and moment:

$$\sigma = \frac{Mc}{I} \quad or \quad M = \frac{Ic}{\sigma}$$

in which M is the moment at the strain gage, I is the moment of inertia of the steel lever's cross-section, given by

$$I = \frac{1}{12}bh^3 = \frac{1}{12}(0.5040)(0.0155)^3 = 1.564 \times 10^{-7}\,in^4$$

and c is the distance from the neutral axis of the cross-section to the surface, or half the thickness of the steel arm: 0.00775 in.

Substituting above gives

$$M = \frac{E\varepsilon I}{c} = \frac{(30\times 10^6)(1.564\times 10^{-7})\varepsilon}{0.00775} = 605.4\varepsilon$$

83

To convert moment at the strain gage to moment at the axis of the torque-measuring key, the strain gage moment was divided by 1.76, the distance in inches from the gage to the arm end, to find force on the arm end. This force was multiplied by 2.24, the distance from the arm end to the axis of the key, to find the torque on the ISS device:

$$T_{ISS} = \frac{2.240}{1.760}605.4\,\varepsilon = 770.5\,\varepsilon$$

However, the strain gage amplifier outputs in mV/microstrain. The computer collected data in volts, so the data generated by the computer was multiplied by 1,000 to convert to millivolts. Since the amplifier was calibrated to 1mV/microstrain, the data was divided by 10^6 to convert microstrain to strain. Including these steps in the conversion constant gives

$$T_{ISS} = 0.7705\,V$$

where V is the output of the strain gage amplifier in volts and T_{ISS} is the torque on the ISS in inch-pounds.

On each unit, torque was measured over time during locking and unlocking. Each measurement was made twice. Before cycling, the average peak torque required to lock was 0.986 in-lbs. The highest lock torque was 1.27 in-lbs; the lowest peak torque was 0.858 in-lbs. Peak unlock torque ranged from 0.963 to 0.511 in-lbs, with an average of 0.700 in-lbs.

After 5,000 rounds had been placed on each unit, the torques were measured again. Average peak lock torque dropped 28% to 0.710 in-lbs. The greatest decline in torque was 32%; the least was 26%. Peak unlock torque dropped an average of 32%, with a maximum drop of 47% and a minimum drop of 15%. This data is shown graphically in Figures 3 and 4.

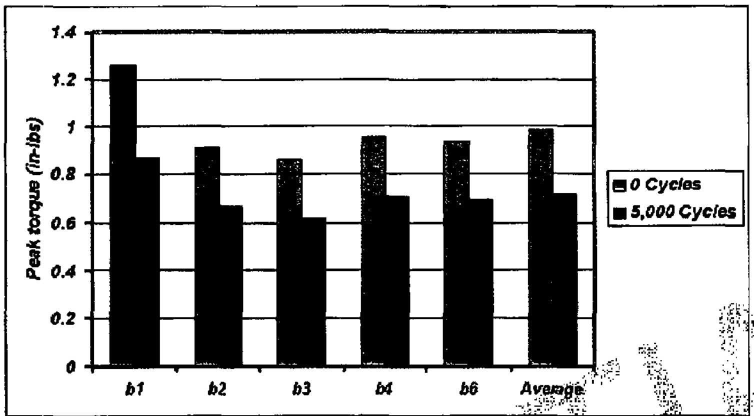

Figure 3. Peak locking torques, before and after 5,000 cycles, average of two measurements.

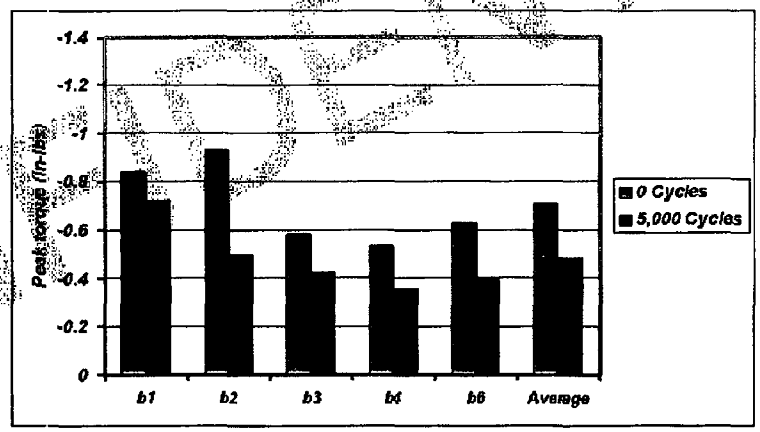

Figure 4. Unlocking torques, before and after 5,000 cycles, average of two measurements.

To track the decline in torques as cycles increase, bolt B6 was taken to a total of 10,000 cycles and its torques were measured again. All the torque/time curves taken for B6 were adjusted to synchronize their peaks, duration, and end times. The data for the curves was then averaged to provide data for the creation of average curves. The averaged curves may be seen in Figures 5 and 6. Because the curves were created by averaging other curves, sharp peaks that were not consistent between measurements were cancelled somewhat, causing some of the results to differ from the peak values displayed in Figures 3 and 4.

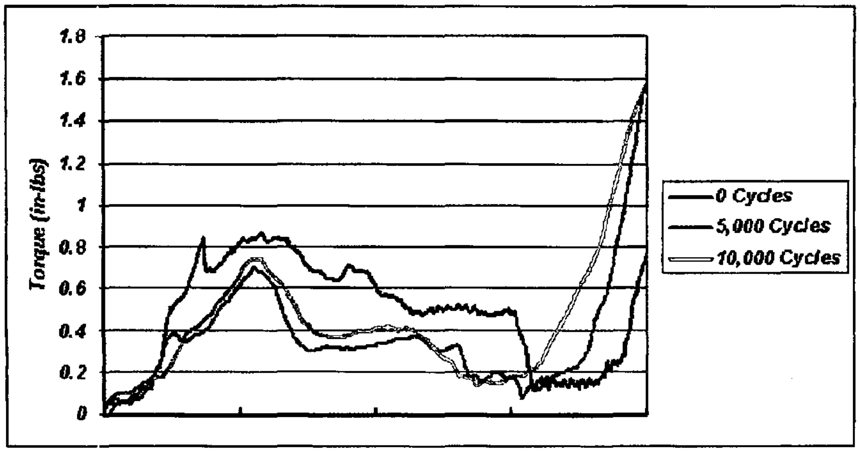

Figure 5. ISS locking torque curves.

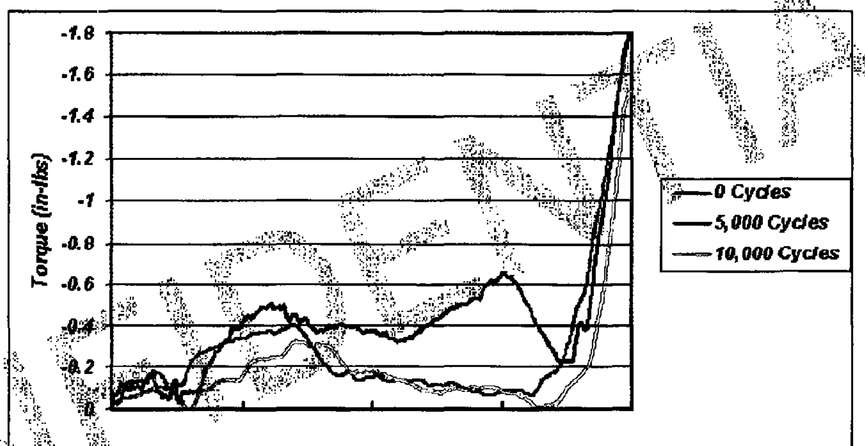

Figure 6. ISS unlocking torque curves.

Each of the curves rises sharply at the end of the graph. This occurs when pressure is put on the key after the ISS cylinder has reached the end of its travel.

The peak force required to lock the ISS can be seen to drop 19% after 5,000 cycles, from 0.864 in-lbs to 0.697. After 10,000 cycles, the peak locking torque rose by 5%, to 0.744 in-lbs.

The peak unlocking torque at 0 cycles was 0.652 in-lbs, occurring about three-fourths of the way through the cycle. This peak completely disappeared by 5,000 cycles. Another peak, at 0.510 in-lbs, can be seen in the 0 round torque curve. At 5,000 cycles this peak had dropped 20% to 0.405 in-lbs. The peak then dropped an additional 16% to 0.326 in-lbs at 10,000 cycles.

The first four bolt plugs were cut open and the ISS parts within were removed for inspection. Figure 7 contains pictures of the detent plungers.

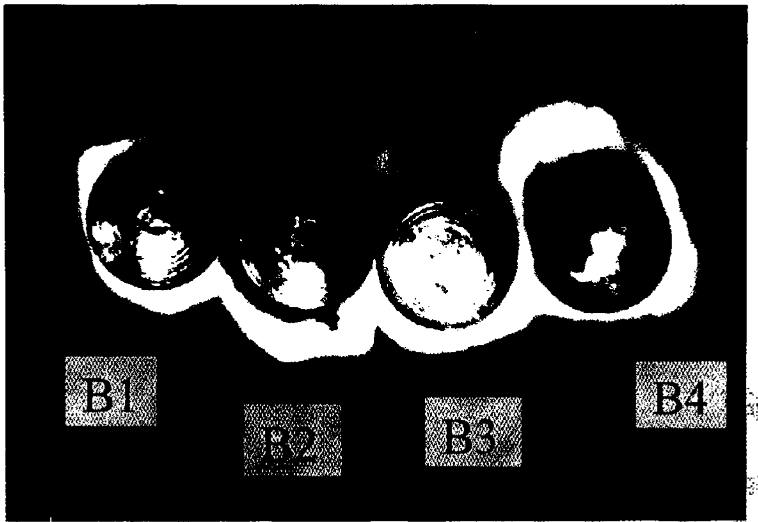

Figure 7. ISS detent plunger tips.

Each of the plungers can be seen to have a small shiny wear area at the tip. The plunger of bolt B3, however, showed more wear. Its entire head is smooth and shiny. Plunger B3 had as many as 2000 more cycles on it because the key broke during its first test.

The ISS cylinders may be seen in Figures 8, 9, and 10. A thin vertical line of wear running up towards the red dot of each cylinder may be seen in Figure 8. Wear can also be seen in Figure 9. Pressure from the detent plunger wore a horizontal line on the small section of the ISS cylinder. The right end of that line terminates on the edge of the surface where the ISS plunger locks the cylinder. The slight curvature on that edge is evidence of wear. Figure 10 contains side views of the ISS cylinders. No prominent areas of wear are visible on the cylinder sides.

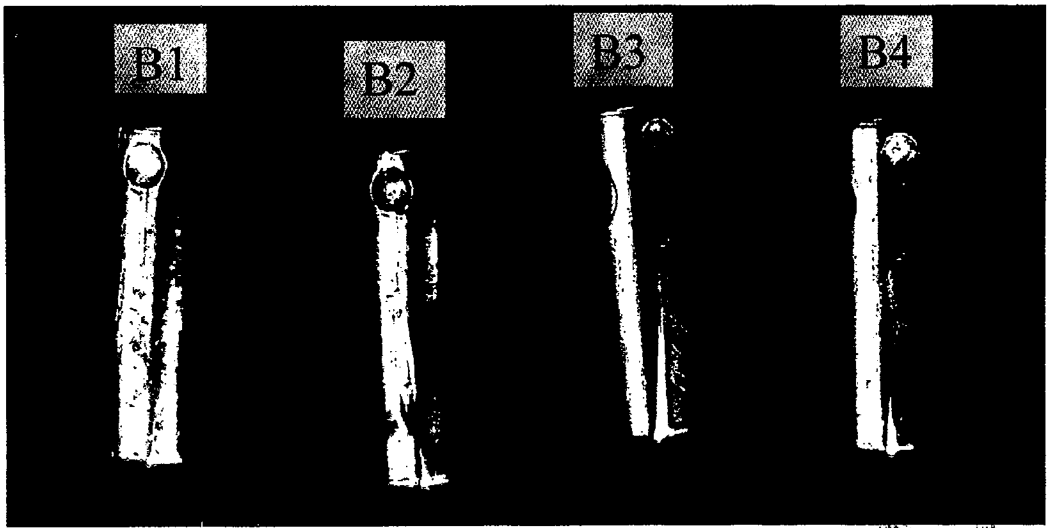

Figure 8. ISS cylinders, top view.

83

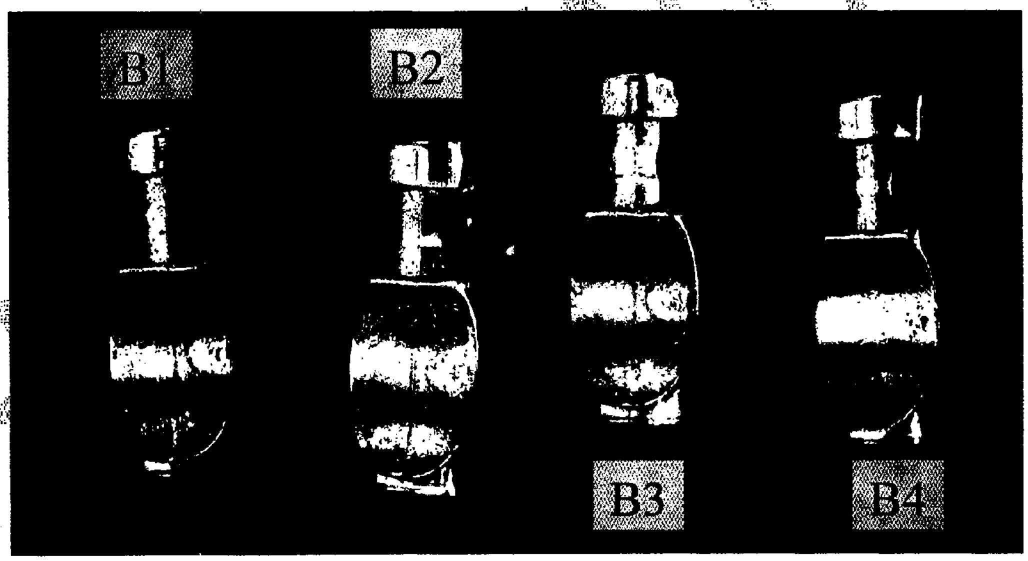

Figure 9. ISS cylinders, bottom view.

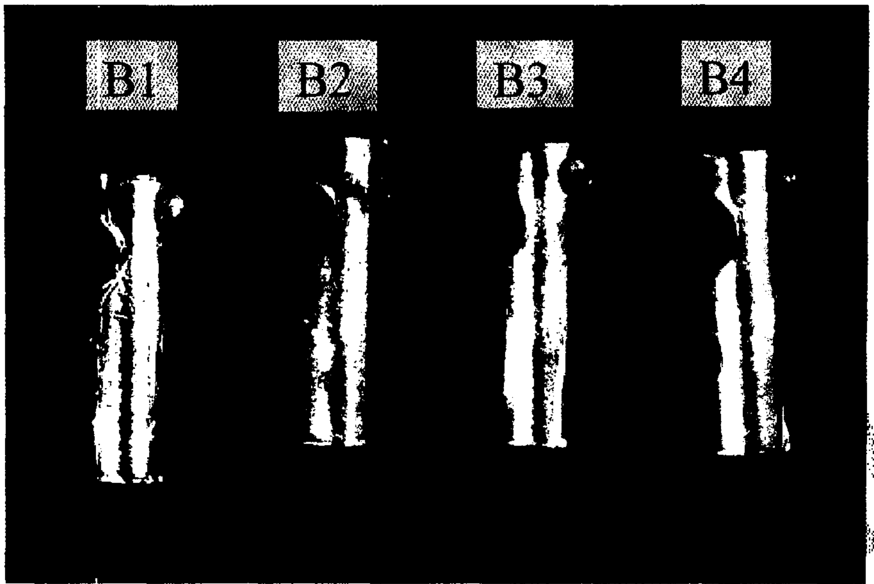

Figure 10. ISS cylinders, side view.

DATA

Attached is a table of each of the peak lock and unlock torques measured.

These are peak values and are slightly higher than values taken from the averaged curves.

	Bolt	Meas. #	B1	B2	B3	B4	B6	Average
0 Cycles	**Lock Torque**	*1*	1.260206	0.884534	0.866474	0.961098	0.973702	0.9892027
	(in-lbs)	*2*	1.265474	0.940217	0.857633	0.953009	0.902029	0.9836721
	Unlock Torque	*1*	-0.87155	-0.9626	-0.59276	-0.54235	-0.51206	-0.696265
	(in-lbs)	*2*	-0.81023	-0.90466	-0.55909	-0.51131	-0.7425	-0.705557
	Average Lock		1.26284	0.912375	0.862053	0.957053	0.937865	0.9864374
	Average Unlock		-0.84089	-0.93363	-0.57593	-0.52683	-0.62728	-0.700911
5,000 Cycles	**Lock Torque**	*1*	0.878137	0.649197	0.614207	0.70187	0.693969	0.7074763
	(in-lbs)	*2*	0.852365	0.688702	0.619098	0.70789	0.694722	0.7125555
	Unlock Torque	*1*	-0.69435	-0.47782	-0.40389	-0.34802	-0.36834	-0.458483
	(in-lbs)	*2*	-0.7442	-0.5051	-0.43305	-0.35667	-0.43004	-0.493811
	Average Lock		0.865251	0.66895	0.616653	0.70488	0.694346	0.7100159
	Average Unlock		-0.71927	-0.49146	-0.41847	-0.35235	-0.39919	-0.476147
	Change in Lock Torque		-31.48%	-26.68%	-28.47%	-26.35%	-25.97%	-28.02%
	Change in Unlock Torque		-14.46%	-47.36%	-27.34%	-33.12%	-36.36%	-32.07%
	B6, 10,000 Cycles		**Lock 1**	**Lock 2**	**Lock 3**	**Unlock 1**	**Unlock 2**	**Unlock 3**
			0.707138	0.737174	0.752215	-0.34633	-0.31723	-0.41111
			Average Lock	**0.732176**		**Average Unlock**	**-0.35822**	