N91-24612

Development of a Relatchable Cover Mechanism for a Cryogenic IR-Sensor

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ABSTRACT

A Cover Mechanism for use on the Infrared Background Signature Survey (IBSS) Cryostat has been developed. The IBSS IR-Instrument is scheduled for STS launch in early 1991 as a payload of the SPAS II satellite.

The cover is hinged, with a motorized rope drive. During ground processing, launch, entry and landing, the cryostat, which houses the IR-Instrument, is required to be a sealed vacuum tight container for cooling purposes and contamination prevention. When on orbit, the cover is opened to provide an unobstructed field of view for the IR-Instrument. A positive seal is accomplished through the use of a latch mechanism. The cover and the latch are driven by a common redundant actuator consisting of DC motors, spur gears and a differential gear. Hall probe limit switches and position sensors (rotary variable transformers) are used to determine the position of the cover and the latch. The Cover Mechanism has been successfully qualified for thermal vacuum (-25 to 35 °C), acoustic noise, vibration (6 G's sine, 9.7 G RMS) and life cycles.

This paper describes constricting requirements, mechanical and electronic control design, specific design details, test results of functional performance, environmental and life tests.

1. INTRODUCTION

The Infrared Background Signature Survey (IBSS) is an SDIO-sponsored program with the purpose of obtaining scientific data for use in the development of defense sensor systems. The IBSS payload will be carried by the Shuttle Payload Satellite (SPAS) II, an advanced version of the SPAS-01 spacecraft, which flew on space shuttle flights STS-7 and STS-11. Figure 1 illustrates the SPAS II spacecraft. The IBSS instrument (Figure 2) consists of four major functional units, which are the cryogenically cooled telescope, baffle, spectrometer and imaging radiometer. The instrument is mounted inside a cryostat equipped with a supercritical He cooling subsystem [1]. The cover mechanism described below is a constituent of the cryostat vessel and acts as an aperture door for the telescope. During ground operations, launch and landing, the cover must be closed and sealed to maintain the isolation vacuum essential for the cryostat.

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2. REQUIREMENTS

Key requirements for the cover mechanism are listed in Table 1. In addition, a design for low mass, power consumption and minimum contamination was required.

Opening angle	Nominal 110° Minimum 103°
Travel time (both motors)	
Without latching	Nominal 55 sec
With latching	Nominal 130 sec
Number of closing/opening operations	
Without latching	100
Number of latching operations	40
Motor drive	
Current limit	300 mA ± 30 %
Voltage	23 to 31.5 V dc
Cover position accuracy	± 1.5°
Cover limit switch accuracy	± 0.5°
Vacuum Tightness (GHe)	$\leq 10^{-7}$ mbar*l/sec
Diameter of cover	270 mm
Mass	≤ 6 kg

TABLE 1: COVER MECHANISM REQUIREMENTS

3. DESIGN DESCRIPTION

The principal functional scheme of the cover mechanism is shown in Figure 3. The Cover Mechanism comprises the following constituents:

- Cover with rope drive
- Latch
- Rotary Actuator
- Instrumentation
- Cover Drive Electronics

The principle adopted to actuate the cover provides the following major features:

- Only one actuator drives both cover and latch mechanism
- The sequencing of latch and cover motion is achieved by mechanical means
- The actuator is located close to the latch. Therefore the load path of highly loaded mechanism elements is kept as short as possible
- Cover lift-off is assisted by a cam
- Temperature excursion tolerant design by use of flexible bellows couplings, spherical bearings and appropriate tolerancing of bearing gaps

3.1 Cover

The cover as shown in Figure 4 is hinged, with a motorized rope drive. When required, a positive seal is accomplished through the use of a latch mechanism. The cover houses a light source to facilitate inflight check of IR sensor alignment. The cover is attached to the hinged yoke by a ball joint. This arrangement assures self aligning seating of the cover on the cryostat o-ring seal. The hinge design heritage is a space qualified solar panel hinge. Each of the two hinges (Figure 5) has a spherical bearing for self aligning of the cover tilting axis. The cover is actuated by redundant rope drives via the latch drive shaft. Two small pulleys connect the ropes from the large pulleys to the cover hinges. Spiral flat springs connect to the cryostat vessel and to the small pulleys. The springs apply tension in a direction which tends to close the cover. The springs take up slack in the rope pulleys.

3.2 Latch

The latch mechanism shown in Figure 6 is connected directly to the axle shaft between the large rope pulleys. The latch mechanism uses an overcenter link to obtain a high mechanical advantage and to holddown the cover in a selflocking manner. The latch provides a nominal holddown force of 4700 N. A cam attached to the latch drive shaft is implemented to provide a lift assist for the potential critical phase, when the cover takes off from the seal. The cam performs a direct levering beneath a shoulder rigidly attached to the cover with a force capacity greater than 950 N. If this force had to be applied via the hinge shafts, an actuator torque in excess of 700 Nm would be required. This would have resulted in a much larger and heavier actuator and obviously considerably higher peak power demands. For on-orbit operations the cover can be closed but left unlatched to shorten the opening and closing times and to avoid unnecessary use of the latch mechanism.

3.3 Rotary Actuator

The rotary actuator is composed of redundant dc-motor/spur gear trains, a differential, and a worm gear drive with a built-in overrunning clutch. The clutch provides adjustable limiting of output shaft travel. The mounting plate of the actuator is equipped with heaters and thermostats. The heaters keep the actuator temperature above 0 °C in a cold temperature environment. The stall torque of the actuator is 22 Nm. The static load capability without damage is 41 Nm.

3.4 Instrumentation

The cover is equipped with limit switches, position indicators, temperature sensors and strain gauges. The position indicators are of the rotary variable transformer type. The strain gauges are used for force adjustment and testing only. Miniature hall probes are used to sense the end positions of cover and latch. The cover qualification model was equipped with an additional torque transducer to allow for measurement of the actuation torque.

3.5 Lubrication

All bearings of cover and latch are MoS_2 dry lubricated. The actuator uses a grease lubrication. The bearings are equipped with dust covers to prevent contamination of the IR telescope.

3.6 Materials

The cover is made from aluminum 6061 T4 (same material as used for the cryostat vessel). The design aimed for minimum usage of plastic materials to minimize contamination. Highly loaded parts of the latch and cover hinges are made from titanium or corrosion resistant steel. A steel/bronze material pairing is being used on the spherical bearing of cover hinges and latch.

3.7 Cover Drive Electronics

The cover drive electronics comprises two separate power and logic switching units for redundant cover operation and latching. Each system has its own set of commands. Logic switching unit no. 1 uses the four hall probe limit switches to determine the position of the cover and latch while logic switching unit 2 uses the two position indicators. An override command is built-in to overcome a failure of limit switches, position indicators or logic unit. In the override mode the motors are activated directly by manual power on/off commands. Each motor current is limited in order to prevent a high current draw in the event of a short, jam, or motor stall.

The cover drive electronics are housed in the cryostat electronic box and includes telemetry signal conditioning of limit switches, position indicators, motor currents, and temperatures.

Power to the electronics is supplied by orbiter fuel cells in the attached mode or by two batteries in the detached mode. Redundant converters supply regulated power for the logic switching units.

4. TESTING

The Cover Mechanism Qualification model has been successfully qualified for thermal vacuum (-25 to 35 °C), acoustic noise (OASPL 138 dB), vibration (6 G's sine, 9.7 G RMS), vacuum tightness (GHe $2*10^{-8}$mbar*L/sec) and life cycles. The thermal vacuum testing included a simulation of worst case thermal gradients of 35°C between yoke and cover hinge baseplate by means of heaters attached to the yoke. The life cycle testing covered more than 200 operating cycles in different modes including cover closing without latching and single motor operation. The cover also passed EMC testing performed together with the cover drive electronics.

In order to allow for functional cover tests on the integrated evacuated cryostat at cold conditions, a vacuum tight test bulkhead was used.

Typical records of cover and latch position angles versus time obtained during opening and closing operation are shown in Figure 6. Figure 7 presents the cover holddown force and actuator torque versus latch drive angle. The measured total power consumption of the motors was less than 6 watts.

5. CONCLUSION

A reusable cover and latch mechanism compatible for use on space borne telescopes has been developed and successfully qualified. The design features vacuum tight sealing, high holddown force, redundancy, low mass and power. The instrumentation and electronics allow for appropriate redundant control and monitoring.

ACKNOWLEDGMENT

This work has been funded by a SDIO contract and MBB funds. The authors wish to express their thanks to all MBB personnel who contributed to the program. In particular, we wish to thank F. Diewald for his contribution to the electronics design.

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"A Supercritical Helium Dewar for the Infrared Background Signature Survey Experiment"
SPIE Technical Symposium, San Diego, CA., 1990, July 9-13

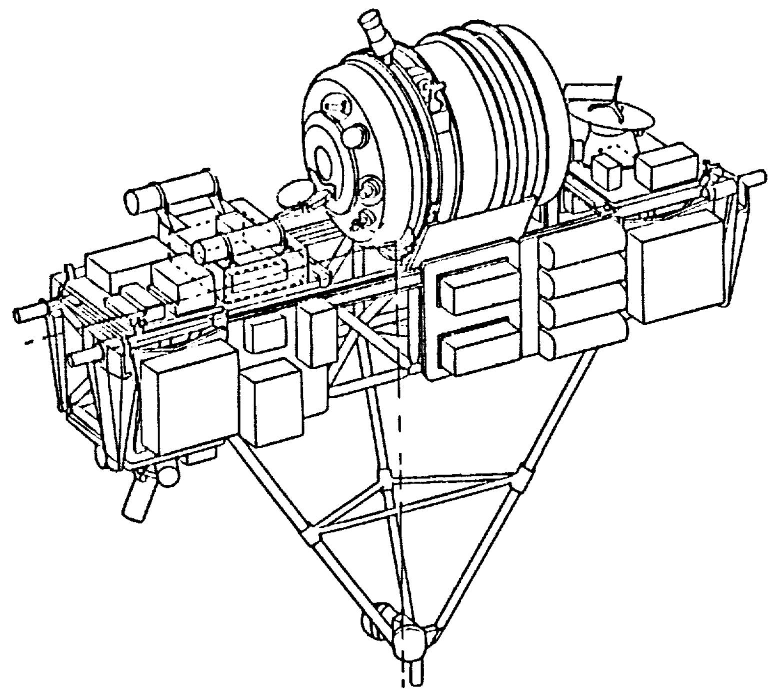

Figure 1: SPAS II Satellite

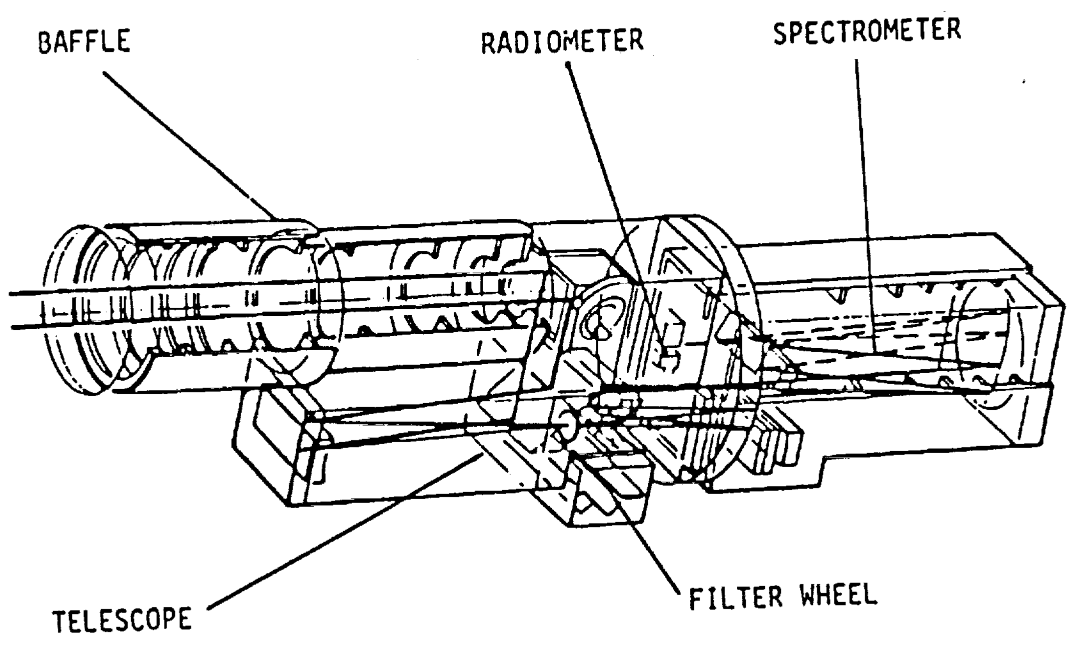

Figure 2: IBSS IR Instrument

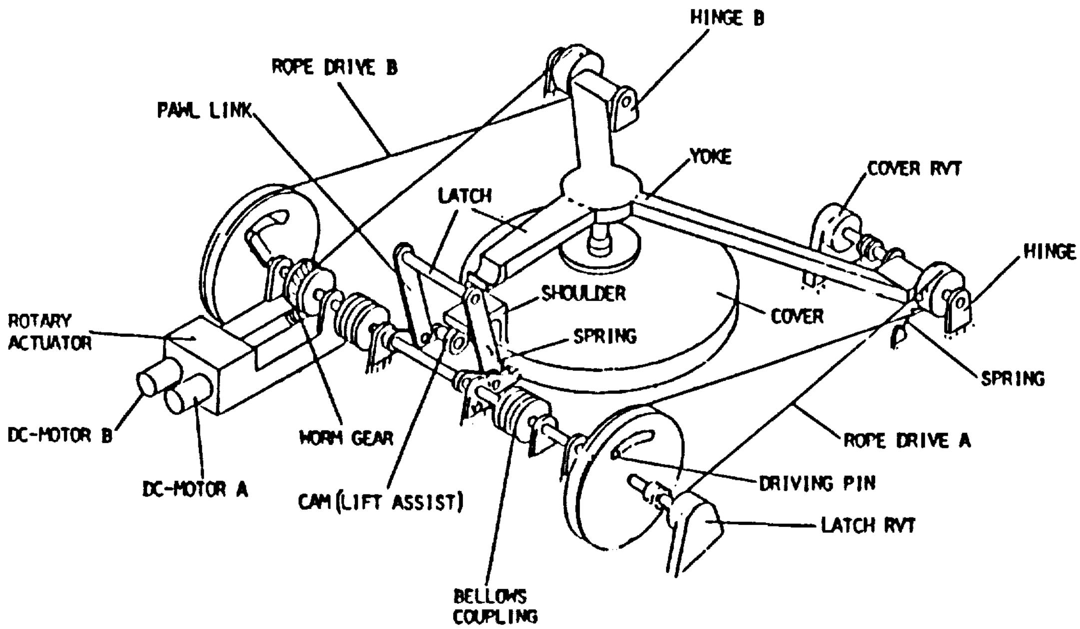

Figure 3: Actuation Scheme of Cover

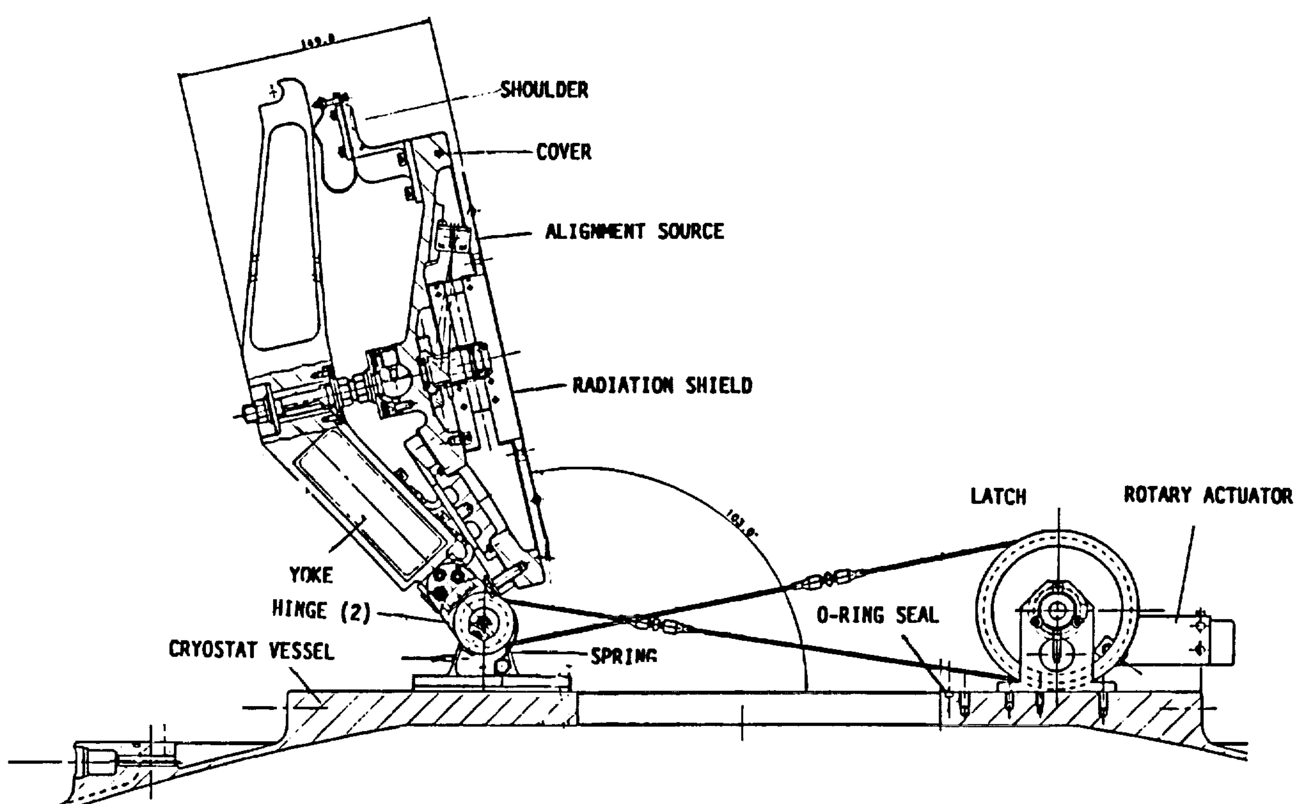

Figure 4: Cover

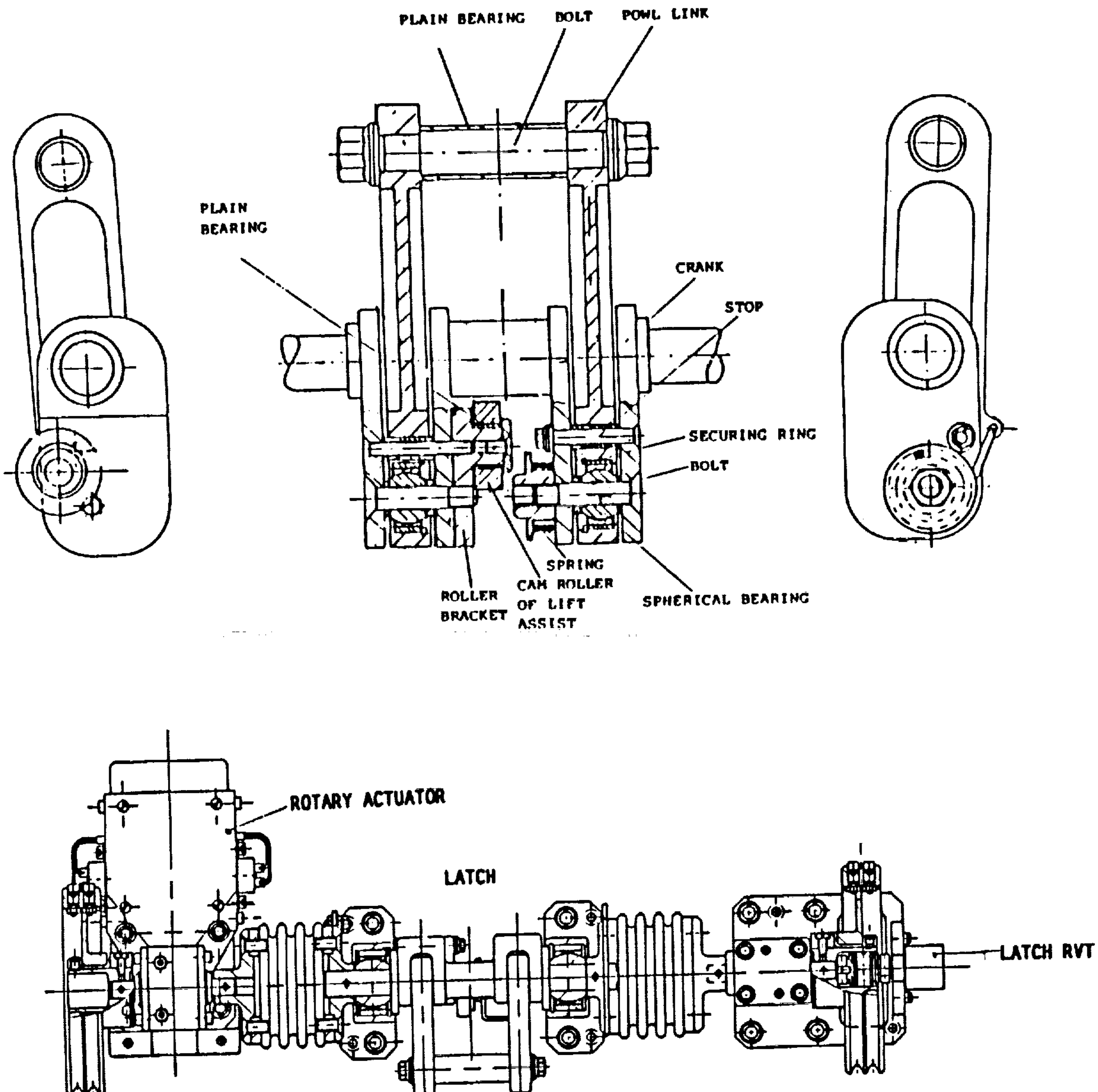

Figure 5: Latch Mechanism

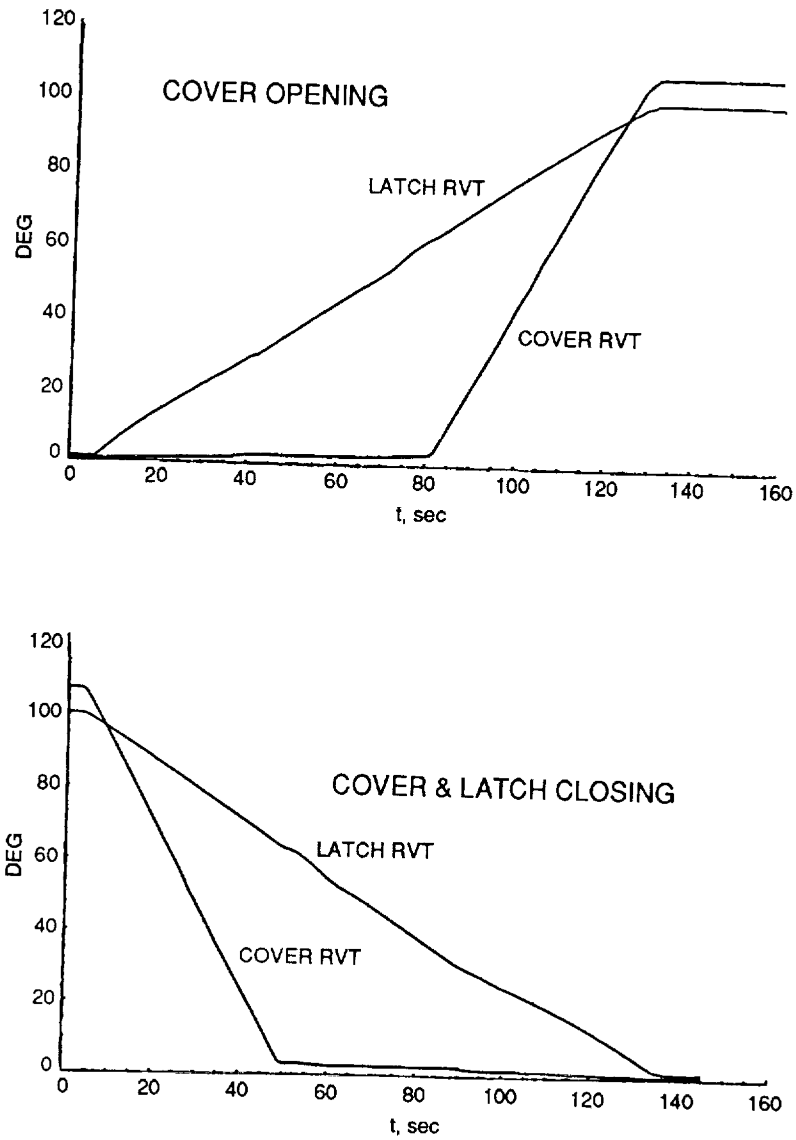

Figure 6: Record of Cover and Latch Angle vs. Time

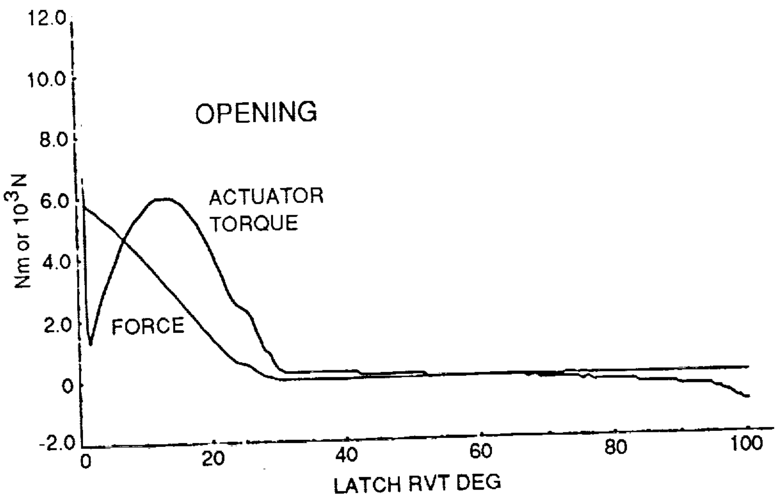

Figure 7: Record of Actuation Torque and Holddown Force vs. Latch Angle