MAKER OF SEALED MINIATURE SWITCH MULTIPLIES LIFE TWENTY-FOLD WITH ELECTRODEPOSITED NICKEL BELLOWS

When a manufacturer of miniature switches for aircraft and other applications wanted to extend the life of its hermetic switches, their engineers sought a flexible solution. To isolate the internal parts of the switch from the atmosphere, a flexible seal had to deform when the actuator closed the connection. The ideal seal could permit no significant leakage despite changes in altitude and temperature. It had to flex with minimal resistance yet provide exceptional fatigue life and stand up to chemicals. Experience showed plastic shields were vulnerable to fuel and other fluids, and the thin metal diaphragms in earlier switches were not reliable beyond 25,000 cycles. Haydon Switch and Instrument, Inc. in Waterbury, CT made its critical-duty switch last 20 times longer with electro-deposited nickel bellows from Servometer® in Cedar Grove, NJ.

Critical Applications

Haydon Switch has manufactured electric motors and switches for around 50 years, including sealed switches used on the Space Shuttle. Commercial and military aircraft commonly use the company's hermetically sealed switches to signal landing gear, flap, and rudder positions. The switches also indicate when doors are locked, and they sense or sequence thrust reversers and other engine functions.

When Haydon engineers set out three years ago to design a hermetic switch to last 250,000 cycles in harsh environments, seal technology posed a challenge. To meet military standards, the switch would have to maintain a near-perfect seal despite extreme temperatures and contact with common aviation fluids. According to vice president of engineering, Keith Kowalski, "We make switches with elastomeric seals, but the really critical applications demand the lowest possible leak rate. You need a metallic membrane to isolate the switch from the outside air."

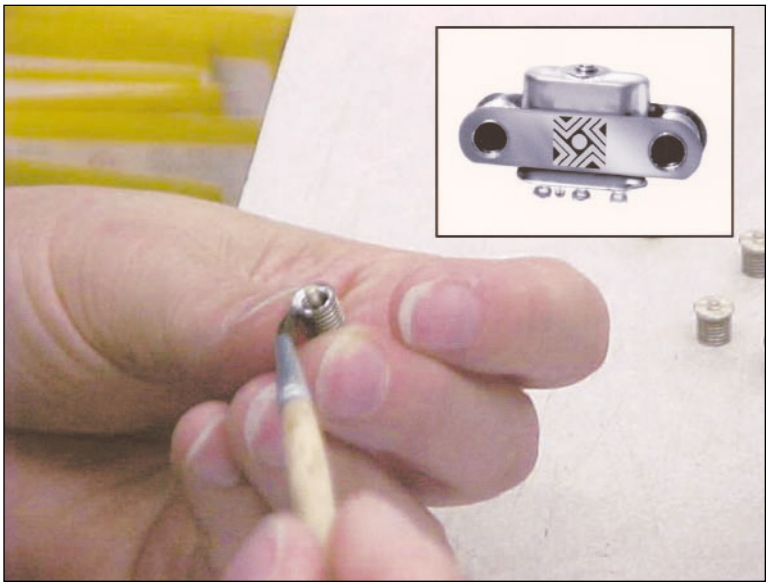

Figure 1

A standard electrodeposited nickel bellows from Servometer® seals the actuator of the Haydon Series 6600 hermetic switch from the outside atmosphere.

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Fatigue Life

While metals stand up to fuel, de-icing fluid, and other common aviation chemicals, flexible metal diaphragms are still limited by their fatigue life. Haydon engineers used thin metal diaphragms successfully to seal critical duty switches, but the thin metal seals developed microcracks after 25,000 cycles. “Without a hermetic seal, contamination comes in,” explains Mr. Kowalski. “These switches typically carry a very low current, so any contamination changes contact resistance.” The new, longer-life 6600 Series hermetic switch was designed to operate below 5 mA at 28 Vdc and required a maximum leak rate of $1x10^{-8}$ atmosphere/cc/second. Mr. Kowalski notes, “At that leak rate, it would take approximately 25 years to evacuate the volume of the switch housing.”

The return action of the new switch was to come exclusively from the spring action of the blade. Low spring forces in the seal were therefore important to maintain low actuation forces. “Preferably, we would have had no spring action in the seal at all,” admits Mr. Kowalski.

Haydon engineers wanted to maintain a contamination-free environment within a metal housing 0.625 in. high, 0.750 in. wide, and 0.360 in. deep. “Our primary objective was longer cycle life in the smallest possible package,” says Mr. Kowalski. “Size was obviously a concern.”

Bellows Benefits

The search for a long-life metal seal led to consultations with Servometer® about electrodeposited (ED) nickel bellows. Electrodeposition makes highly flexible bellows down to 0.035 in. diameter, and the dynamic properties of nickel can provide an essentially infinite life of $1x10^{16}$ cycles. The seamless, non-porous bellows are tested leak-tight to $1x10^{-9}$ cc of Helium per second. Electrodeposition also makes bellows walls about a quarter the thickness of those produced by common mechanical hydroforming. ED bellows consequently provide one-fifth to one-tenth the spring rate or resistance of hydroformed brass bellows of the same size.

As seals, nickel bellows will not corrode in contact with most chemicals and will not oxidize in air. Haydon Switch engineers wanted to use them to isolate the interior of the switch housing from the outside atmosphere. Inside the bellows, an actuating pin travels up and down through the top of the housing surrounded by ambient air. Under the pin and between the bellows exterior and the sealed housing interior, the switch actuates in an inert atmosphere.

Pressure on the actuating pin extends the bellows and actuates the blade to close the circuit. Releasing pressure on the pin allows the spring-action of the blades to lift the actuator and compress the bellows. The Series 6600 switch has a maximum movement differential of just 0.005 in. and a minimum release force of 6 ounces.

Initially, Haydon Switch designs’ called for a custom bellows to seal the actuator in the housing. However, talks with Servometer® engineers refined the design around a cost-saving standard nickel bellows. The flexible nickel seal has a 0.250 in. outside diameter and 0.150 in. inside diameter, and walls 0.0015 in. thick. “That was our biggest challenge,” recalls Mr. Kowalski. “We had some work attaching the bellows to the housing due to the material and the wall thickness of the bellows.” The standard nickel composition selected by Haydon lends itself to soldering at both ends of the bellows. Servometer® also offers sulfur-free nickel bellows for welded or brazed assemblies.

With six convolutions, the 0.185 in. long bellows have a maximum extension of 0.024 in. and a maximum compression of 0.032 in. Spring rate is just 23.63 lb/in.

Long Life Seal

Haydon conducted accelerated life cycle testing at temperatures from -65 to +400°F and discovered the electrodeposited nickel bellows exceeded the company’s original design goals. “We found that 250,000 cycles was a pretty conservative number,” recalls Mr. Kowalski. “Our testing far exceeded that.” The production Series 6600

switch has a hermetic life of 500,000 cycles, 20 times the life of diaphragm-sealed switches. The Series 6600 switch with its ED nickel bellows withstood random vibration testing to 50.3 G at 5 to 2,000 Hz. It also underwent shock testing at 65 G minimum peek, 11 milliseconds duration with a saw-tooth waveform.

Service experience with Series 6600 bellow-sealed hermetic switch has been excellent, and Haydon switch is exploring broader markets. “We’re looking at industrial applications in some really harsh environments where someone needs a switch,” says Mr. Kowalski.