CHAPTER IX

PRESSURIZED-CELL EXPERIMENT

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SECTION I - INTRODUCTION

Pressurized-cell detectors were developed and constructed at the Langley Research Center to obtain a direct measurement of the micrometeoroid puncture hazard to thin structural material. A total of 160 detectors were mounted around the periphery of the rocket motor used on the Explorer XIII satellite. (See fig. IX-1.) Material thicknesses of 0.001, 0.0015, 0.002, 0.0025, and 0.005 inch were used on the detectors. The exposed surface of the test material of each detector was 21.8 square inches and the total exposed surface of the 160 detectors was 24.2 square feet. The average weight of the detectors was 68 grams.

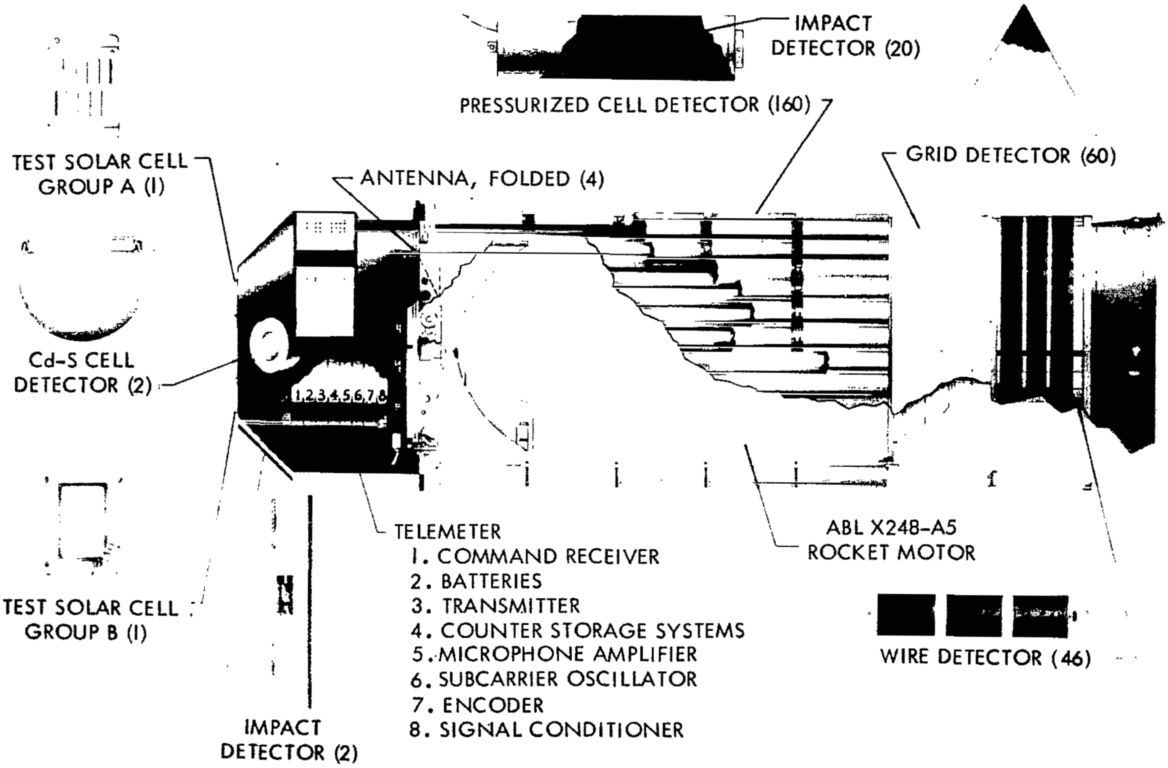

Figure IX-1.- Cut-away view of micrometeoroid satellite.

SECTION II - DESCRIPTION

The pressurized-cell detector was designed so that a puncture of the thin test material by a micrometeoroid would allow the pressurized helium to leak out. This pressure loss would create a pressure change across a pressure-sensitive metal-corrugated diaphragm. The deflection of the diaphragm was transmitted to a snap-action switch which was used to signal the telemeter of the puncture. Details of the detector are shown in figure IX-2.

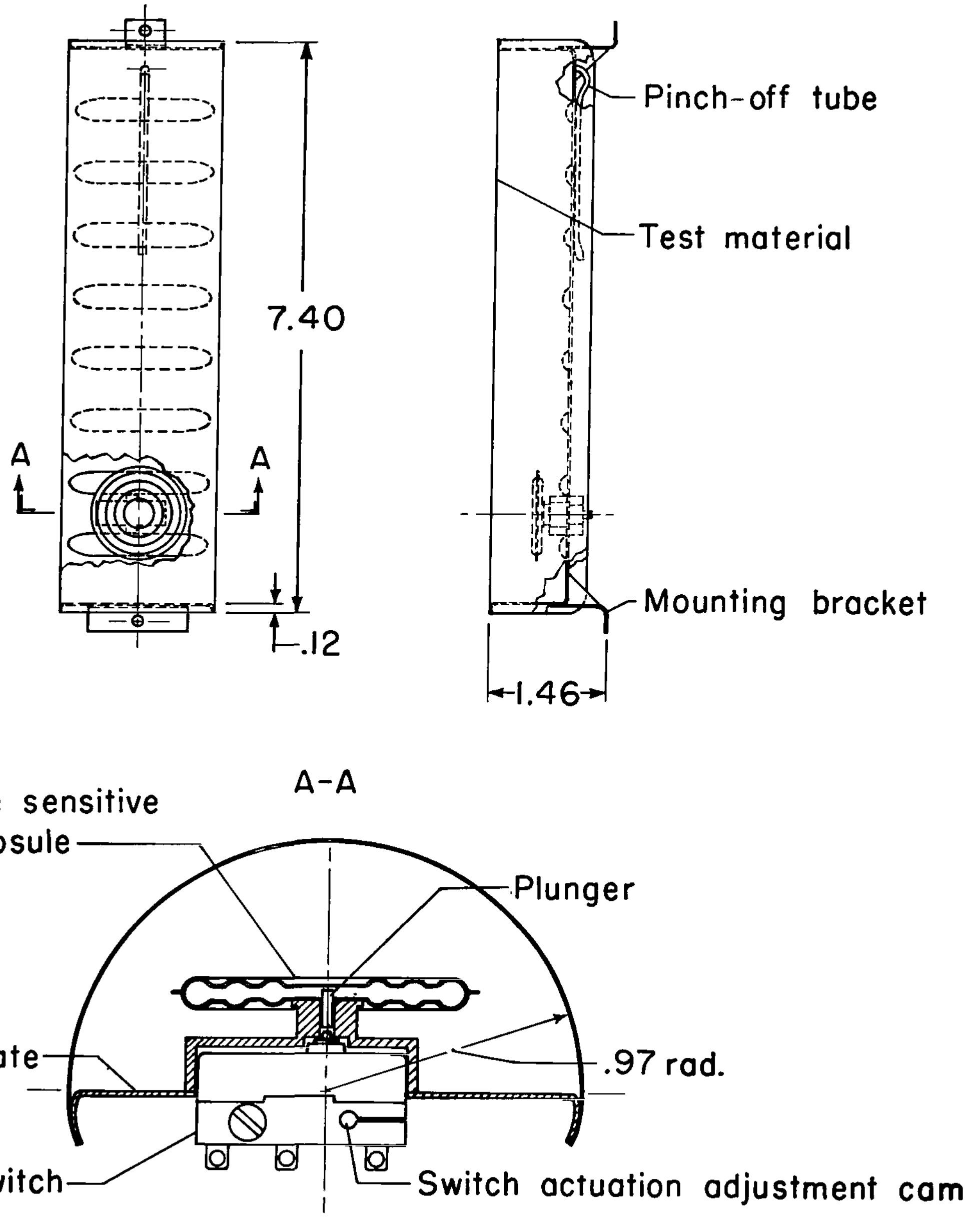

Figure IX-2.- Pressurized-cell detector. Dimensions are in inches.

The material used in the thin test section of the detector was beryllium copper. Carefully selected fine-grain pressure-diaphragm stock was used because it could be rolled to very thin sheets and still be impervious to the internal gas. Figure IX-3 shows all the component parts of the detector and the sequence of fabrication. The base assembly was fabricated from beryllium-copper sheet material with a thickness of 0.014 inch. The material was placed in a forming die (see fig. IX-4 and fig. IX-5) where 8 corrugations were formed with hydraulic pressure to rigidize the base plate. The strip was then placed in a die which formed a rim around the outer edge of the base plate. (See fig. IX-6.) A bending fixture was used to complete the fabrication of the base plate by turning up the semicircular ends and punching the holes for the switch body and the fill tube. (See fig. IX-7.)

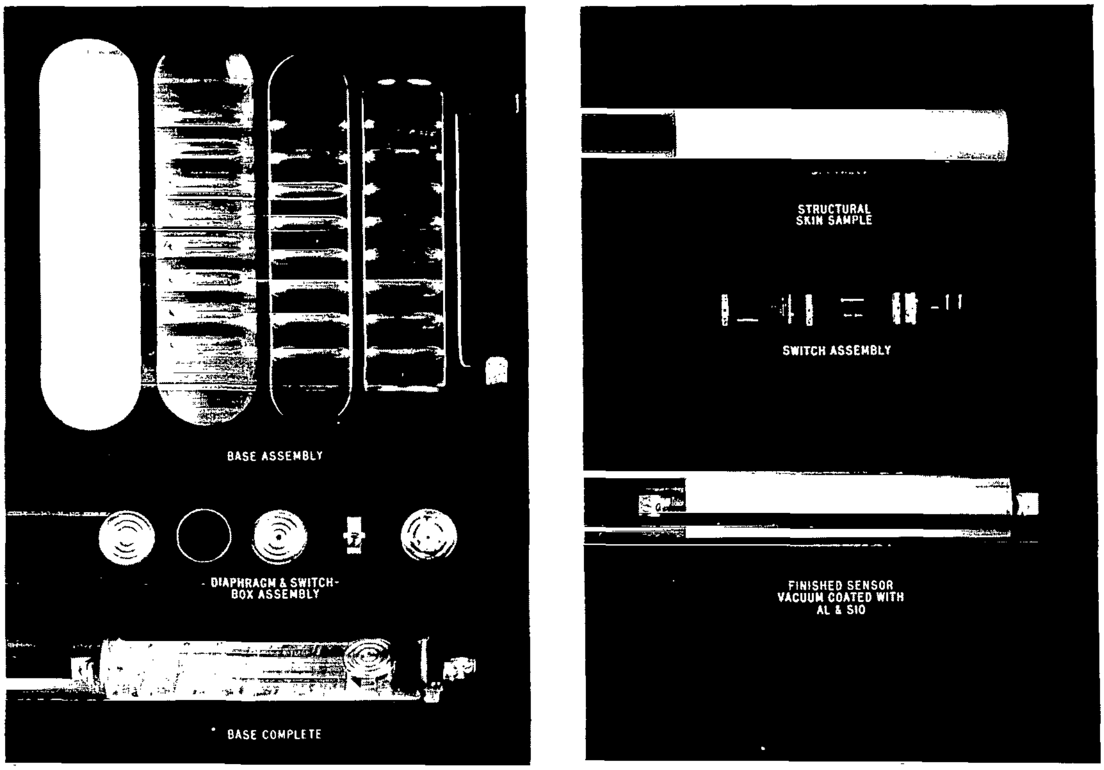

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Figure IX-3.- Component parts of pressurized-cell detector.

The pressure capsule was fabricated from two pressure-sensitive diaphragms which were hydraulically formed from 0.008-inch-thick beryllium-copper sheet material. Figure IX-8 shows the die used to fabricate the diaphragm. The diaphragms were silver-brazed together to form a pressure-tight capsule and were then silver-brazed to the switchbox by induction heating. (See fig. IX-9.) Figure IX-3 shows the parts of the diaphragm switchbox assembly and the assembled unit. A fixture was constructed to position the diaphragm-switchbox assembly,

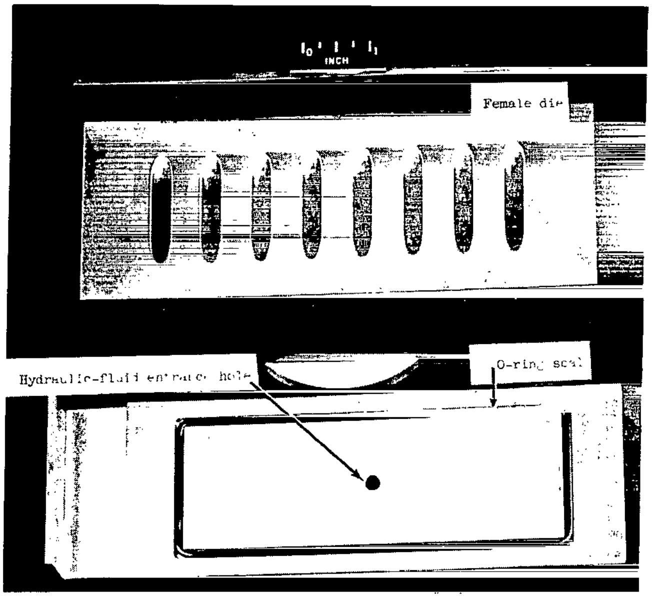

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Figure IX-4.- Detector-base forming die.

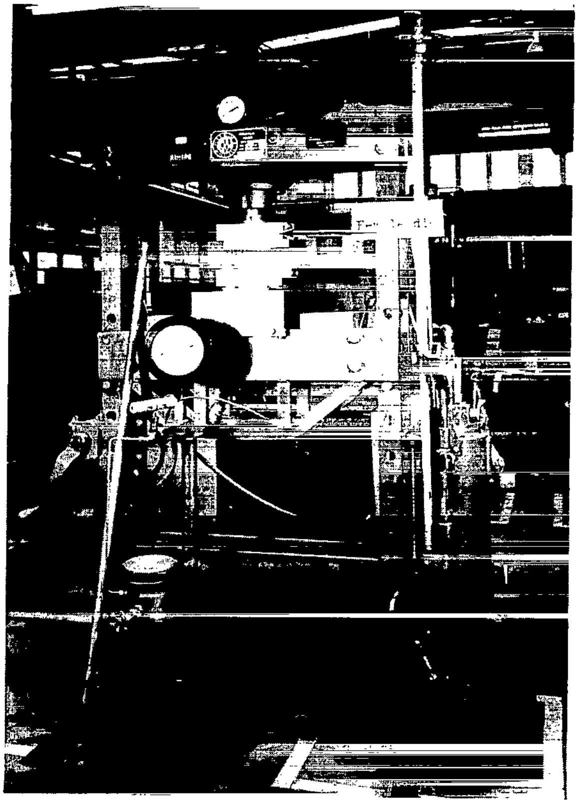

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Figure IX-5.- Detector-base forming apparatus.

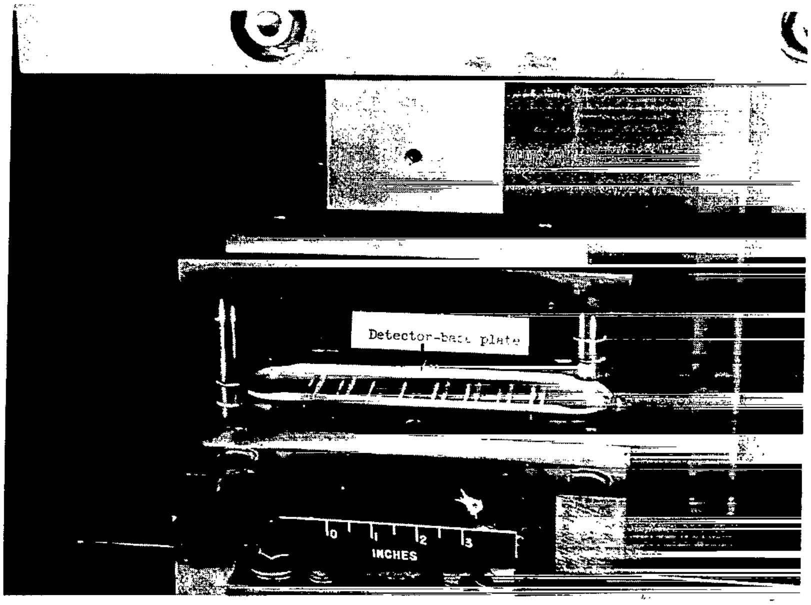

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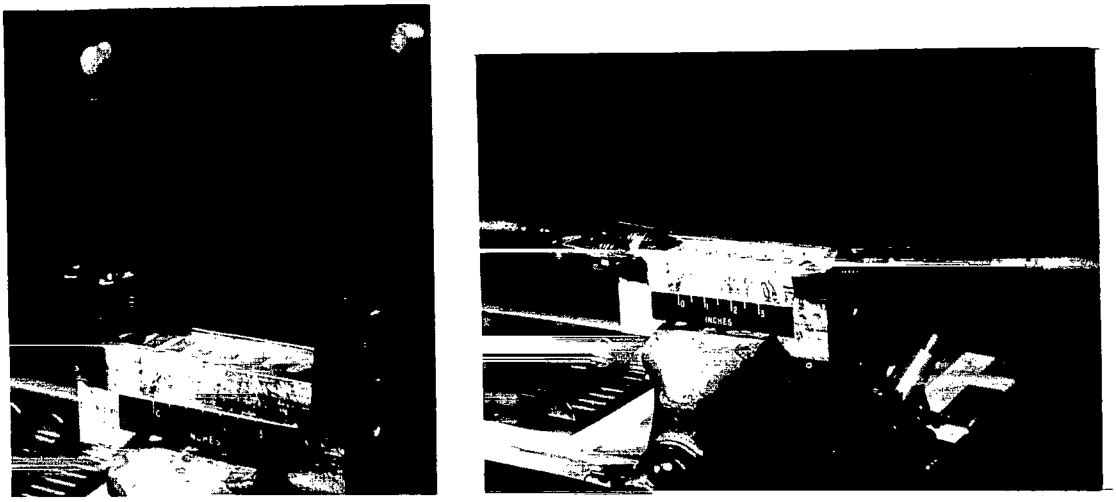
Figure IX-6.- Detector-base-rim forming die.



(a) Before bending. L-64-3092

(b) After bending. L-64-3093

Figure IX-7.- Detector-base-end forming die.

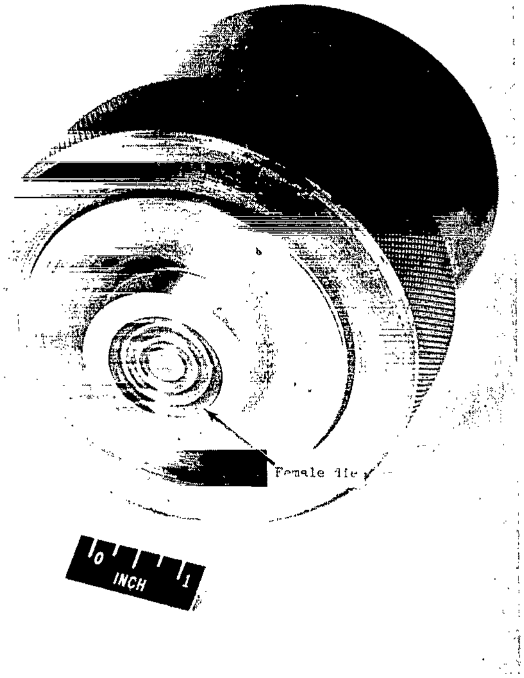


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Figure IX-8.- Detector pressure-sensitive diaphragm die.

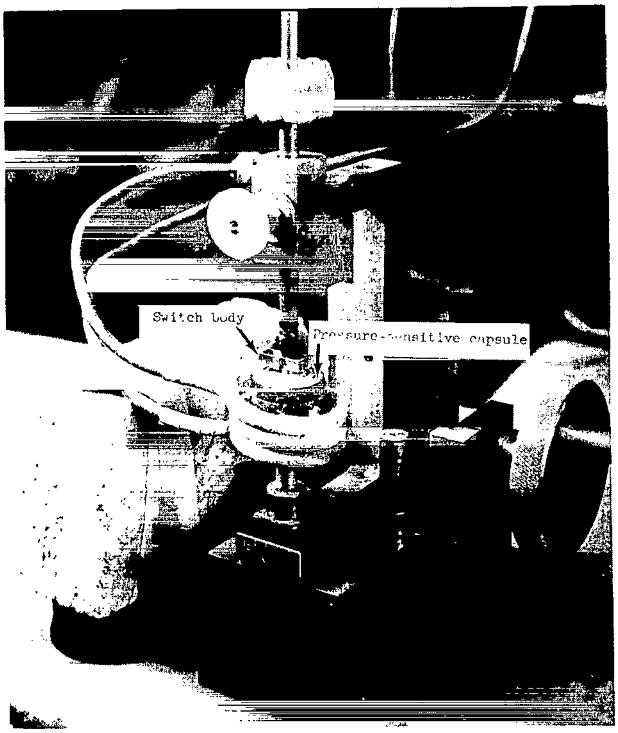

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Figure IX-9.- Induction-heating fixture for silver-brazing pressure capsule and switch body assembly.

fill-tube, and mounting feet while they were silver-brazed in place. A heat-treating fixture was designed and constructed to hold 10 complete base assemblies during the precipitation hardening cycle. The fixture held the critical surfaces in position during the stress-relieving and hardening cycle. (See fig. IX-10.) The age hardening of the beryllium copper was accomplished by controlling the temperature at 600° F for 3 hours.

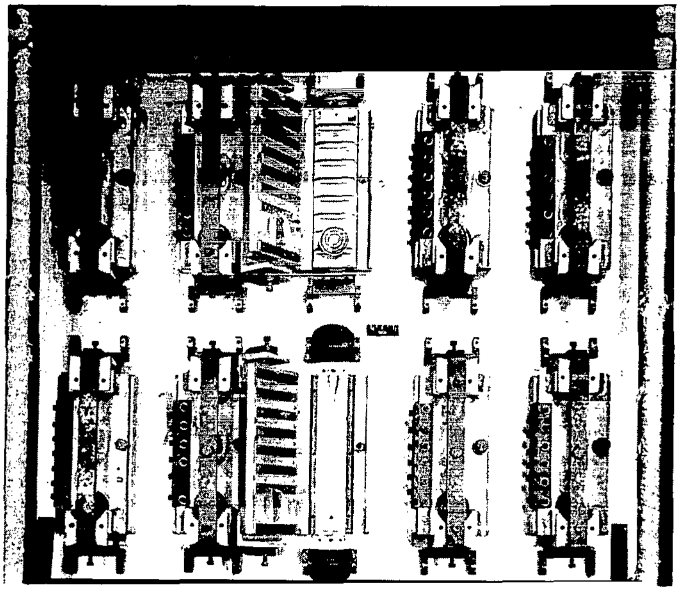

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Figure IX-10.- Detector-base-assembly heat-treating fixture.

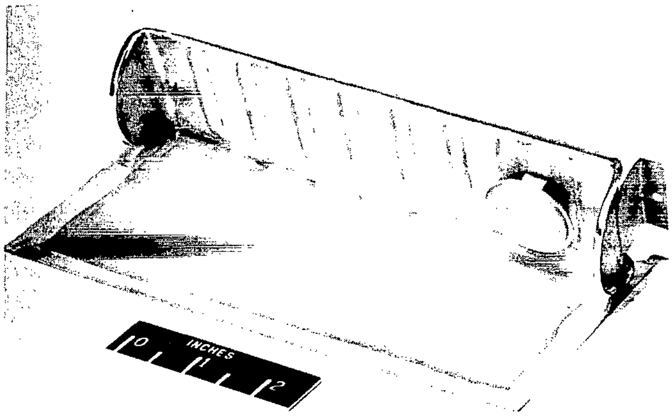

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Figure IX-11.- Assembly of detector base and test material.

After the heat-treating cycle was completed, the oxides were removed from the base assembly with a solution of phosphoric acid and then the edges were tinned with 100-percent-tin solder. The test material was tinned around the outer edge and then thoroughly cleaned of flux and foreign matter. The test material was wrapped on the base plate (see fig. IX-11), the joints were crimped and then sweat soldered in place. One-hundred-percent tin, which had a melting point of 450° F, was used to solder the joints.

The detector was charged with helium to a pressure of 25 psia after the fabrication and assembly were completed. The fill tube was used to admit the gas to the detector and was then sealed by mechanical crimping and soldering. Each detector was checked for leaks in the vacuum chamber of a helium leak detector (see fig. IX-12) and discarded if there was any indication of a leak. The sensitivity of the leak detector was sufficient to indicate a leak of 2×10^{-5} micron cubic feet per hour which would have given the pressurized-cell detector a lifetime of 3.5×10^{4} years before leaking to the switch-actuation pressure. Pressurized-cell detectors that indicated no leak were marked with a serial number and complete records were maintained on each unit so marked throughout the test program. The last step in the construction program consisted of vapor depositing thin films of aluminum and silicon monoxide on the detectors for temperature control in the space environment.

The pressure-sensitive-capsule switch assembly was designed so that the force-transmitting member and the pressure switch were installed on the outside of the pressure chamber. This eliminated the need for electrical and mechanical feed throughs in the pressure-chamber wall. Switch-actuation pressure could also be adjusted without disturbing any pressure seals in the chamber. The switch contacts were in a closed position until the sensor was punctured and the helium allowed to escape. This switching arrangement eliminated the possibility of foreign matter collecting on the contacts while the vehicle was being assembled, and allowed the switch-contact resistance to be monitored during the prelaunch checks.

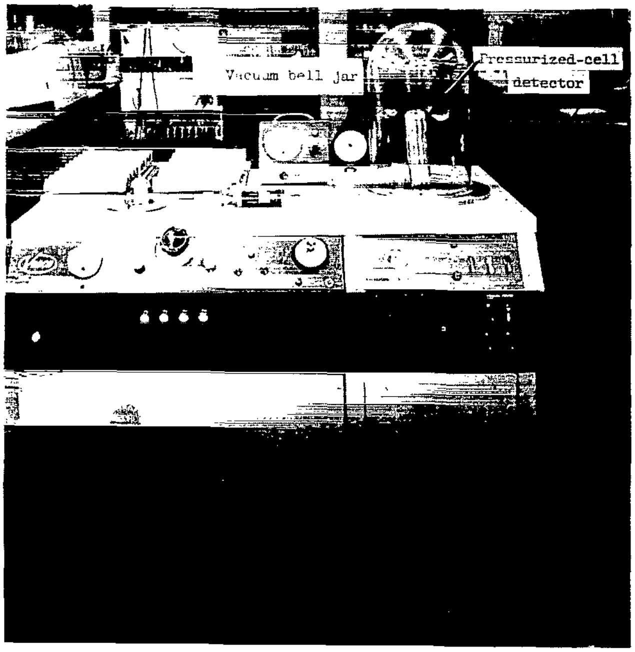

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Figure IX-12.- Pressurized-cell-detector leak-checking system.

SECTION III - ENVIRONMENTAL TESTING

Pressurized-cell detectors were exposed to numerous pressure and temperature cycles and vibration tests to yield information concerning the expected life of the detector. The thermal-design study of the vehicle indicated the maximum orbital temperature of the pressurized cells should be approximately 117° F and the coldest orbital temperature approximately 10° F. Since the pressurized-cell detector was sealed at 25 psia at 70° F, the pressure over the expected orbital-temperature extremes could have ranged from 22.2 psia to 27.2 psia. Pressure-cycling apparatus was set up to apply a linear pressure pulse between the pressures of 14 and 34 psi. A group of 12 detectors was exposed to 6,600 cycles to determine if there were any areas that showed metal fatigue. The helium leak detector indicated no leak in any of the tested detectors.

The ultimate strength of the detectors covered with 0.001-inch-thick material was tested by applying pressure until a rupture occurred. Ten detectors were tested and all failed within the pressure range of 65 to 75 psi.

Temperature-cycling apparatus consisting of a 260° F glycerin bath, a 70° F water bath, and a -10° alcohol bath was used to expose the detectors to a cyclic accelerated temperature test. The water bath was used between the hot glycerin and the cold alcohol bath. This served as a rinse since both alcohol and glycerin were soluble in water and minimized the contamination of the baths. The water bath also brought the detector to an intermediate temperature and reduced the amount of thermal capacity required to maintain uniform temperatures in the baths.

A group of 10 detectors sustained 2,000 cycles through the baths without any failures. The temperature of the detectors was measured with thermocouples. The detectors were allowed to soak in the hot and cold baths until they were within 5° F of the bath temperature.

This type of testing subjected the detectors to thermal shock which was much more severe than would exist in the space environment. Although severe, this procedure was a means of obtaining a large number of temperature cycles in a relatively short period of time.

The pressure switch was set to actuate when the internal pressure reached 5 psig. The stability of the setting was checked through various stages of the environmental testing by placing the detector in a glass tubular pressure chamber. (See fig. IX-13.) Electrical connections from the detector were fed through the pressure chamber to an ohmeter which monitored the switch actuation; the internal pressure of the detector was determined by noting the pressure applied to the chamber when the thin test material of the detector began to deflect. When the external pressure exceeded the internal pressure by only a

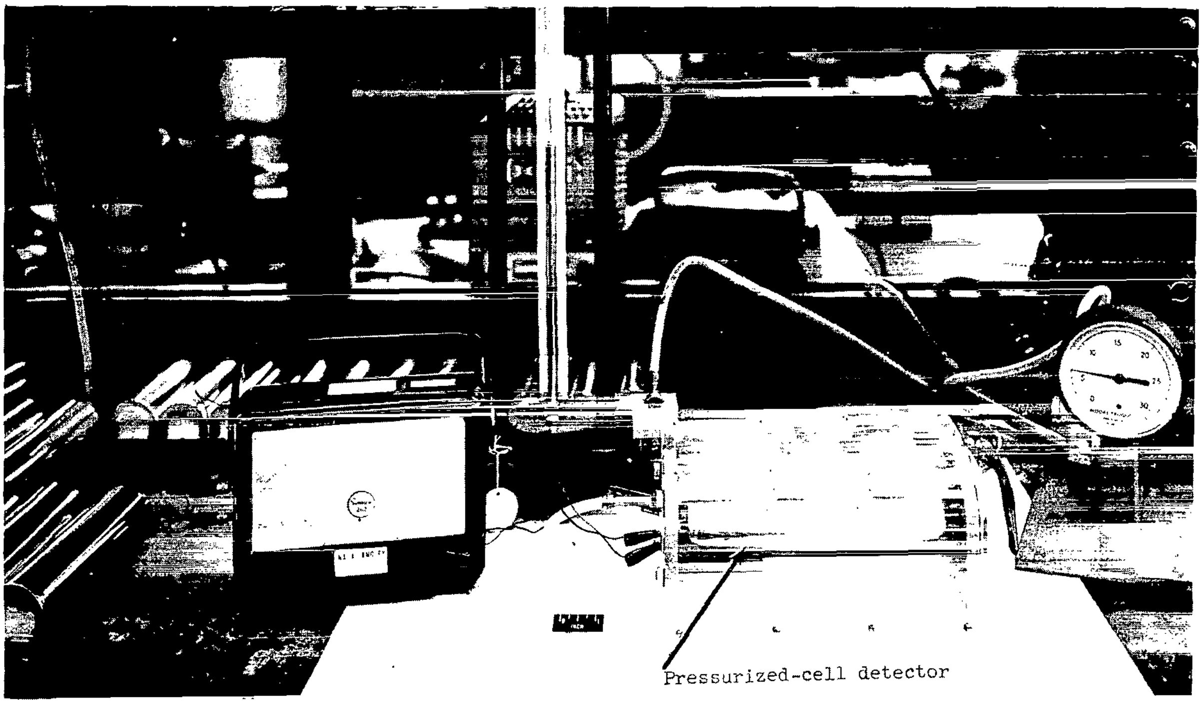

Figure IX-13.- Pressurized-cell detector switch-setting chamber. L-62-336 few hundredths of a pound, large inward deflections of the thin test material would occur. All the pressurized-cell detectors used in the Explorer XIII payload were checked in this manner as well as in the helium leak detector after the payload environmental test program. Switch settings were within 2 percent of their initial setting in all cases, and there was no indication of any leak or loss of pressure in any of the detectors. Details of the payload environmental test program are covered in chapter VII.

SECTION IV - CALIBRATION

The pressurized-cell detectors used 16 time channels in the telemetering system to transmit the 160 bits of information. The information from 10 detectors was transmitted by each channel. The full-scale range of the telemetering channel was divided into 10 steps. Each time a detector switch opened, a permanent change of one step (approximately 10 percent of full scale) occurred in the telemetry channel. The telemeter zero- and full-scale values were transmitted each time a channel was read to indicate any changes that may have occurred from environmental temperature effects. Since the pressurized-cell-detector signal consisted of a switch opening, the temperature of the detector did not affect the accuracy of the telemeter. Continuous monitoring of the detectors by the telemeter (or use of a storage device) was not required because once the detector is punctured, the switch will remain in the open position, and the data are thus maintained in a nondestructive state. The telemeters could be turned on by a command signal from the ground station and would transmit data for approximately 1 minute before they were automatically cut off. A calibration of one of the telemetry channels containing 10 pressurized-cell detectors is shown in figure IX-14.

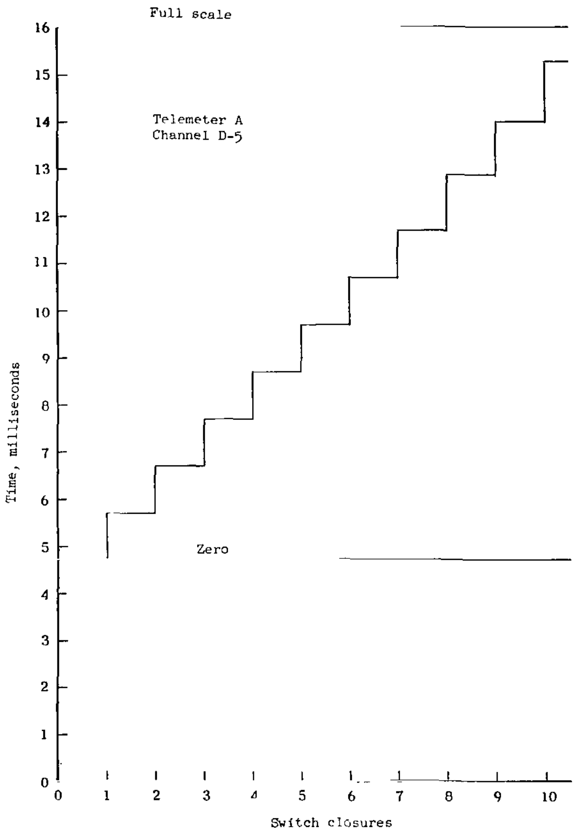

Figure 14.- Calibration of telemeter channel D-5 containing 10 pressurized-cell detectors. (These data are time coded on telemetry system.)

SECTION V - FLIGHT RESULTS

The payload was launched into orbit and information was telemetered and recorded through the twenty-ninth pass. There were no switch openings of the pressurized-cell detectors during this time. Data were processed from tape recordings taken on orbits 1, 9, 13, 14, 15, 21, 22, 23, and 28. The last recording was taken 45 hours after launch. Pressure-cell temperatures recorded during the flight are shown in figure VI-10. The maximum temperature recorded was 133° F which occurred on the first orbit and the minimum temperature was 80° F which occurred in the fourteenth orbit. The temperature readings are taken during the time the telemeter is transmitting to the ground station which represents a small portion of the orbital time. With the limited number of temperature recordings, it is difficult to determine the maximum and minimum temperatures that were obtained during the flight. There was no indication of any malfunctioning of the 160 pressurized-cell detectors during the launch and orbital life of the vehicle.