SCOPE

This ATM details the investigation to determine the reliability characteristics of the Teledyne 421, latching relay used to generate the "3-month" output signal of the ALSEP Solid State Timer. The investigation was performed to establish the susceptibility of the relay to "cold welding" over the two-year operational life of the ALSEP system.

CONCLUSIONS

The Teledyne relay is pressurized to one (1) atmosphere when manufactured. For ALSEP application the calculated rate of outgassing would take a minimum of five (5) years to achieve even a mild vacuum. It was concluded that cold-welding is not probable over the mission life of the ALSEP system and does not constitute a reliability hazard. Therefore, the Teledyne 421 relay is approved for use in the Solid State Timer.

Prepared by: P. Sondeen
P. Sondeen
Group Supervisor,
Parts & Materials

Approved by: S. J. Ellison
S. J. Ellison
Manager,
ALSEP Reliability Dept.

1.0 Background Data

The Teledyne 421 series latching relay is an approved part for ALSEP flight hardware. The relay is applied in the PDU where it is used as a current sensing circuit breaker. One coil of the relay is a low resistance winding and the reset coil is a normal 28 VDC winding. The relay is procured to BSD drawing 2330151 which incorporates screening requirements of GSFC-S-601-100 change 2 dated July 19, 1967. This screening procedure calls out operating the relay 1000 times in each of 6 orientation to detect any particular contamination. This procedure was imposed in response to a failure analysis report FAR-06-004 dated 8-31-67. (Refer to references 1. and 3. It should be noted that FAR-06-004 is not associated with a "cold welding" problem.

Because of its prior approval and current use on ALSEP, the 421 series relay was approved for use in the solid state timer.

2.0 Reliability Characteristics of Magnetic Latching Relays

Because the relay is an electromechanical device with moving parts and subject to failure from frictional wear, it is often considered a reliability hazard. It performs a unique function, however, which cannot be achieved in any other way and for this reason has been used in critical high-reliability application. Because of its failure potential, much extra care is used in its manufacture to preclude the known failure modes which are:

1. Contact contamination — gas & particle
2. Armature blockage — particles and burrs, mechanical abuse
3. Contact welding — from load current errosion.

The primary feature of contamination control is cleanliness by frequently cleaning the parts during assembly and by a thorough cleaning immediately prior to sealing. In addition, a bake-out in a controlled atmosphere is used to drive off possible vapor contamination. Stable plastics such as Teflon and Kapton are used as insulation. The back-fill of 90% N_2, 10% He is checked with a residual gas analyzer to further preclude contamination. This relay does not use a getter.

3.0 Application of the 421 Relay in the Solid State Timer

For the ALSEP application, the predicted reliability based on the number of operating cycles is extremely favorable, and the wearout due to contact errosion is considered a negligible failure mechanism. However, another failure mode, "cold-welding," is of special interest. This mode relates to the application over a long time period (2 years for ALSEP) with very few energizing cycles. If the inert gas within the relay leaks out, the resultant hard vacuum condition could induce cold-welding of the movable metal to metal contacts.

Teledyne was contacted to determine if they would consider lubricating the metal-to-metal contacts. The response was an emphatic no. During the manufacturing process, emphasis is placed on relay cleanliness to minimize the process of contamination. The addition of a lubricant on the metal surfaces would create a serious potential contamination problem.

The leak rate of the subject relays was evaluated over two years ago. The time required for the gas to evacuate in a vacuum environment was calculated to be a minimum of five (5) years to produce even a mild vacuum (0.1 mm Hg) in the relay. (reference #2) The calculation did not consider two factors which are opposing in nature and tend to cancel each other. The first, consideration is an increased leakage rate cause by degradation in the seal integrity induced by installation, shipping, handling, etc. The second consideration is the presence of an artificial atmosphere which exists around the relay in the form of a potting, conformal coating, and partial sealing of higher assembly levels. The later condition would retard the leak rate, thus minimizing the probability for a "cold-welding" failure occurring.

4.0 Cold Welding Mechanisms

To assess the reliability hazard resulting from a greatly increased leak rate, the metal-to-metal contacts within the 421 relay were identified by a call to Mr. Bates at Teledyne: Memo 9721-1469 (reference 4). The relay construction is shown in Figure 1.

A number of reports concerning the cold welding mechanism were noted in the bibliography "Lubrication, Corrosion and Wear" NASA SP-7020, SP-7020(01) and SP-7020(02). These reports are listed in Table I.

A report by APIC describing work done by Hughes was reviewed ("Study of Adhesion and Cohesion in Vacuum," Contract NAS 8-11066, Report P64-62 and P65-94). This report states that for copper-to-copper contact no cohesion or adhesion occurred at 150°C. Copper formed a weak bond (82 PSI) to itself at 300°C under 3600 PSI load for 19.4 hours in a vacuum of 5×10^{-9} mm Hg.

This report states that chrome-nickel stainless steels and high nickel alloys have no tendency to bond to themselves or to each other under the test conditions (static) of maximum severity (500°C, 16 KSI min, 5×10^{-9} mm Hg, 19.4 hours).

General results given in this report are: (1) In most cases, like metal couples bonded more readily than unlike couples and (2) bonds form more readily under dynamic (rubbing) tests than static tests.

The metal-to-metal bonds relevant to the Teledyne 421 relay are:

Copper plate to nickel plate
Copper plate to Alnico V
Soft gold plate to hard gold plate

At Mr. Bates suggestion, Mr. Swyler at GSFC was contacted to learn if GSFC had run any long term tests of Teledyne relays in vacuum. Mr. Swyler's response was that they had done a test on a different relay with the case punctured and did not expect that cold-welding would occur in the Teledyne relay because the contact forces are very low.

CONTACT MATERIAL

Pole Piece	- Nickle plated
Armature	- Copper plated
Electrical Contacts	- Soft/Hard GOLD PLATE

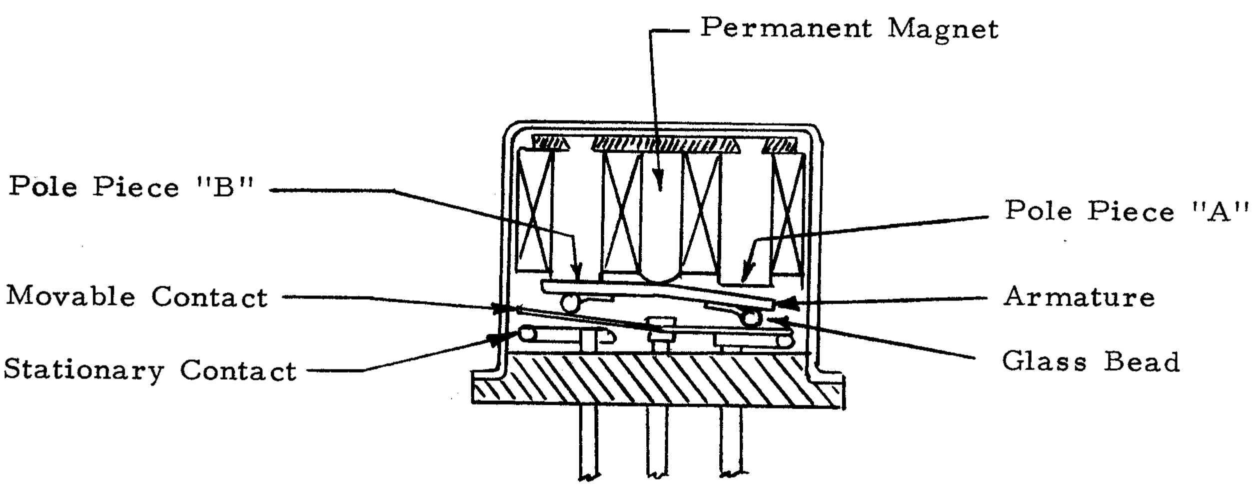

Figure 1

TELEDYNE #421 RELAY CONSTRUCTION

Table I

Metals in Contact in Vacuum Selected
Literature References

1.	A67-13271	The Influence of Various Physical Properties of Metals on their Friction and Wear Behavior in Vacuum D. H. Buckley, NASA/Lewis
2.	A67-13754	Friction and Adhesion of Copper in Vacuum R. D. Brown & R. A. Burton, Southwest Research Inst.
3.	A67-35839	Cold-Welding Tendencies and Frictional Studies of Clean Metals in Ultra-High Vacuum C. E. Moeller, M. C. Noland, Midwest Research Inst.
4.	N66-27676	Surface Temperatures at Sliding Interface in Vacua and Metal Adhesion Rensselaer Polytech Inst.
5.	A66-15937	Vapor Deposited Gold Thin Films as Lubricants in Vacuum (10^{-11} mm Hg) T. Spalvins & D. H. Buckley, NASA/Lewis

5.0 Conclusions and Recommendations

It has been concluded from this investigation that "cold welding" will not occur during the anticipated two year ALSEP mission. This conclusion is predicted on the following:

1. The leak rate of this relay was calculated to take a minimum of five years to achieve even a mild vacuum.

2. The results of cold welding investigations performed under various government contracts indicate that the 421 series relay will not cold weld even if a hard vacuum is achieved.

3. There is no known documented evidence (e.g. NASA ALERTS, FAR's, etc.) of a hermetically sealed relay having experienced a cold weld condition.

On the basis of the foregoing discussion, the Teledyne 421 series relay is approved for use in the Solid State Timer.

References

1. Memo 9721-41, dated 11 July 1966, from A. Davis to L. Lewis/ S. Ellison
Subject: Teledyne Series 421 TD-5 Can Size Relays for the ALSEP

2. Memo 9721-584, dated 1 Sept. 1967, from P. Sondeen to H. Reinhold
Subject: Leak Rate of Relays

3. Contract Letter 67-970-1582, dated 12 Dec. 1967 from J. F. Clayton to J. W. Small
Subject: Use of Teledyne Relays on ALSEP

4. Memo 9721-1469, dated 2 Dec. 1969 from P. Sondeen to P. McGinnis
Subject: Contact Report, Mr. R. Bates of Teledyne Relay