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Rocketdyne
North American Rockwell

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R-8962

HIGH-PRESSURE OXYGEN IMPACT TESTER

(Final Report)

APPENDIX A, OPERATING MANUAL

NAS8-27480

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FOREWORD

This is the final report for Contract NAS8-27480 describing the work accomplished in a 9-month period of design, develop, and install at NASA/MSFC (Huntsville, Alabama), a high-pressure oxygen impact tester. The work reported herein was sponsored by the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Alabama, with Mr. John Austin, Jr., as Project Engineer.

The work was conducted within the Advanced Programs Division of Rocketdyne, a Division of North American Rockwell Corporation, with Messrs. T. A. Coultas, and L. P. Combs as Program Managers, and M. T. Constantine as Project Supervisor. Mr. F. D. Raniere was the Responsible Engineer for the program with major contributions from Messrs. G. A. Hood and H. E. Marker. Consulting on the effort was Mr. G. E. Williams. Also contributing to this program were Messrs. C. Ackerman, B. J. Gerik, R. B. Guilliams, and W. Buck.

This report has been assigned the Rocketdyne identification number R-8962.

ABSTRACT

This appendix is a complete operating manual for the Rocketdyne High Pressure Oxygen Impact Tester. A detailed description and operating procedures for impact testing up to 6.9×10^4 newton/m^2 (10,000 psig) oxygen pressure over a temperature range from the normal boiling point of liquid oxygen to 394 K (121 C) is presented. The tester was designed to deliver 97.63 joules (72 ft-lb) of impact energy; however, variable height and weight can be achieved for threshold analysis.

The system is completely remote and highly automated to furnish safe, reliable operation. High-frequency, fast-response instrumentation capabilities are provided to ensure maximum information output with the hope of minimizing the number of tests required for material acceptance.

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ILLUSTRATIONS

GENERAL DESCRIPTION

The Rocketdyne oxygen compatibility tester is, in essence, a high-pressure oxygen impact tester. Energy (0 to 137 joules, 100 ft-lb) is transmitted to an enclosed sample via a pressure-balanced striker shaft. The energy is supplied by the kinetic energy of a falling weight impacting the externally exposed end of the striker shaft.

A sample (0.0175m, 11/16 inch-diameter disk) of the material to be evaluated is located in a removable cup with a replaceable striker tip resting on top. The strike shaft is equipped with a high-pressure dynamic seal and a diaphragm for pressure balancing. Gaseous nitrogen balance pressure is supplied to a sealed cavity around the diaphragm. The balance pressure is automatically controlled by electronic comparison of cell and balance pressures to ensure that the striker is floating (neutral) at all times.

The base of the impact cell provides both heat and cooling passages to permit testing from liquid oxygen normal boiling point to 394 K (121 C). Two thermocouples in the cell base are located very close to the sample cup for monitoring temperature.

Control of the high-pressure oxygen feed system is accomplished remotely through a combination graphic display (system schematic) and switching panel. Various electronic interlocks and logic circuits are used to facilitate operation, enhance overall safety, and prevent premature plummet dropping. High-pressure oxygen is automatically pumped up to any predetermined pressure via a two-stage diaphragm compressor. The system is completely flexible and will operate over a pressure range of ambient to 6.9 X 10^4 newton/m^2(10,000 psig). A surge tank is provided for storing oxygen between tests as desired.

Instrumentation output includes continuous direct digital readout of cell temperature and pressure to the nearest tenth of a degree Centigrade and psi, respectively. A completely flexible, fast-response readout is provided by a four-channel, dual-beam oscilloscope (Tektronix 565). Sweep times can be varied from seconds to microseconds. Scope triggers can be internal or external with predetermined time delays between channels. The scope has been set up with an external velocity gate trigger to furnish instantaneous event (moment of impact) recording of velocity, flash as received by a photocell, high-frequency pressure response, and impact load cell response. This analog output is recorded on Polaroid film at the moment of impact.

The system is conveniently packaged in three easily separable units:

1. Impact tower and cell assembly
2. High-pressure oxygen feed system enclosure (pneumatic enclosure)
3. Control and instrumentation console

The Rocketdyne oxygen compatibility tester was developed with three basic goals in mind:

1. Relevance to actual dynamic conditions under which the materials to be tested are exposed
2. Similarity to the standard ABMA ambient LOX impact test as described in MSFC-SPEC-106B. This will preserve continuity of evaluation and data correlation so that the Rocketdyne tester will serve as a reliable extension to the open-cup ambient test.
3. Convenience, safety, and cost effectiveness of operation

The first two objectives are hardly separable since the impact event has been established by the ambient LOX tester (ABMA) as the most appropriate dynamic compatible test.

The convenient, safe, economic operation of the impact tester is related to: (1) the number of tests that must be conducted per sample evaluation, (2) the simplicity and reliability of conducting each test, and (3) minimization of tester component replacement and/or adjustment between tests. The very nature of an acceptance test requires multiple testing to obtain statistically valid results. By making the test conditions as reproducible as practical and obtaining the maximum information available from each test, the number of tests required to establish statistically valid results can be minimized.

The simplicity of conducting an individual test is primarily related to the ease of sample preparation and loading. The design provides for a convenient and rapid means of sealing and unsealing of the pressure cell to load the sample. In addition, the sample cup and striker are easily replaced for resurfacing between tests. Various electronic interlocks and logic circuits are used to remotely operate the high-pressure oxygen feed system for safe, reproducible operation.

Minimization of equipment and hardware replacement is essentially related to the durability and integrity of test hardware and the isolation of the reaction process in the event of a positive test. This is accomplished by minimizing (through reduction of the sample cavity size) the amount of high-pressure oxygen exposed to the impact stimulus (without affecting the results of the test) and providing for the rapid quench (by heat conduction through proper design and selection of materials) of the reaction.

DETAILED DESCRIPTION

IMPACT CELL

The impact test cell assembly (Fig. A-1, A-2, and A-3) includes the base, specimen cup assembly, and striker balanced piston assembly.

Base Assembly

Two sets of heating and cooling passages are drilled in the base assembly; each can be used independent of the other resulting in either a parallel or series flow. Access ports into the cell are sized to minimize the overall oxygen volume of the high-pressure cavity. Measurements made after inlet and outlet plumbing were attached indicate an internal volume of 9.1cc (0.555 cu in.) without the sample disk. Standard high-pressure tubing fittings are used in all ports drilled to the high-pressure cavity. The base assembly is bolted directly to the impact tower base as a semipermanent installation with all instrumentation and feed systems attached. The striker assembly may be removed and replaced and the unit cleaned in preparation for the next test without disturbing the base installation.

Striker Assembly

The purpose of the striker is to transfer the energy from the plummet to the specimen with minimum loss due to deformation, friction, etc. Since the striker is exposed to the high-pressure cavity, it is subjected to the spring action of the pressure tending to force the striker out of the cavity. To overcome this force, a diaphragm was added to the striker so that an external pressure source can be used to balance the loading caused by cavity pressure.

Two types of seals are used to retain the pressure in the system. A static seal (conoseal) is used between the base assembly and the striker housing, while three Omniseals are used as the dynamic seals on the striker shaft, diaphragm, and diaphragm housing. The high-pressure oxygen Omniseal (as shown in Fig. A-1) is backed

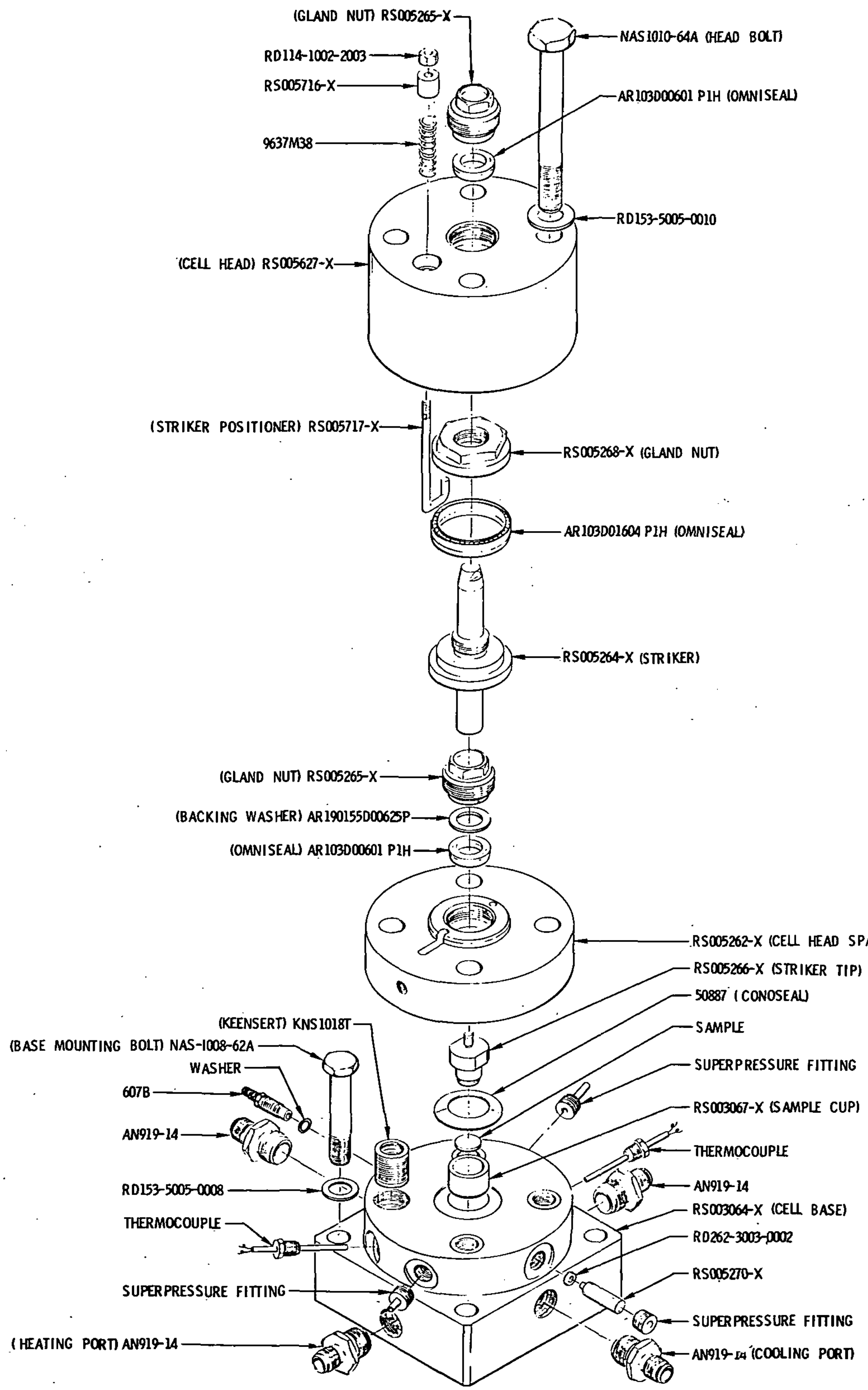
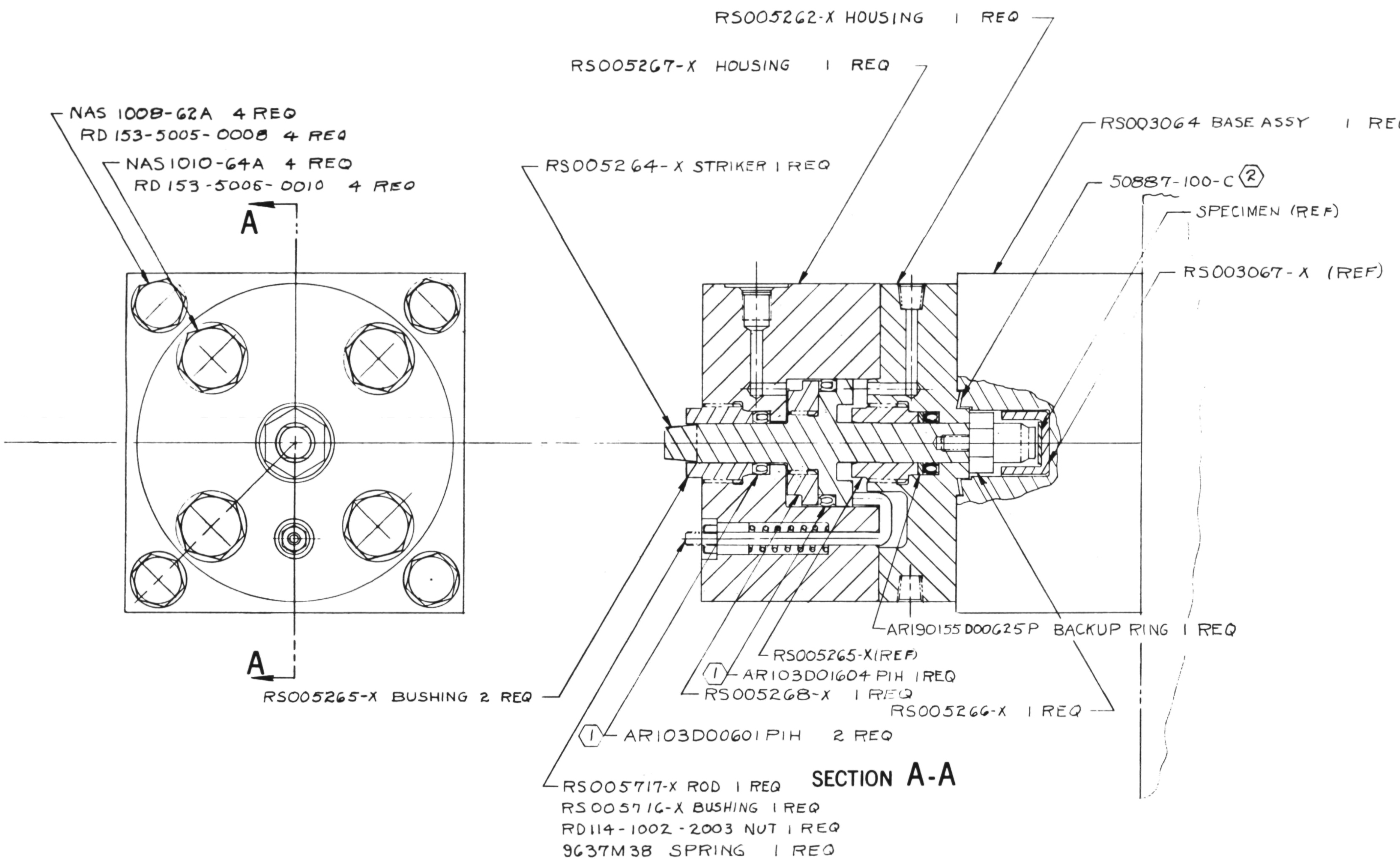


Figure A-1. Impact Test Cell



3 MAY BE PURCHASED FROM McMASTER-CARR SUPPLY CO. L.A. CA.
2 MAY BE PURCHASED FROM AEROQUIP MARMAN DIVISION.
1. MAY BE PURCHASED FROM AEROQUIP CORP.
NOTE: UNLESS OTHERWISE SPECIFIED

Figure A-2. Striker Assembly

by a loading washer to obtain good seals at high pressures. A position indicator was added to indicate the striker position prior to testing. A microswitch, actuated by the position indicator, transmits a signal to the control console allowing the operator to determine if the striker is down. The striker consists of a two-piece assembly (the striker shaft and tip). The tip is detachable to allow refacing the impact edge following tests to ensure normality and flatness of the surface. The removable tip allows rework without removing the striker assembly and disturbing the dynamic seals. All detail parts, except seals, backup rings, and position indicator parts are fabricated from Inconel 718 material. The striker and the removable tip are heat treated to obtain a Rockwell hardness (rc) of 38. The hardened material is required to withstand frequent rework.

Figure A-3. Impact Cell Assembly

Features

Since the base assembly contains all the instrumentation and cooling-heating cavities, it may be bolted to the main tester base and left in that position. This eliminates the need to disconnect and reconnect any plumbing between tests. The sample cup is placed into the base cavity to hold the specimen and to accept damage caused by positive reactions. The cup will be removed after each test, examined, cleaned, and reworked, if necessary. Keensert inserts are incorporated into the base and are easily replaced should the threads become damaged during repeated use. Replacement is accomplished by following instructions furnished by the manufacturer and included as an enclosure of this manual.

Two fluid passages used for heating and cooling the specimens are incorporated into the base assembly. Capability for either a series or parallel connection is provided adding flexibility to the system. A zirconium oxide coating (0.003 to 0.005 inch thick) plasma sprayed on the interface between the impact test cell base and the large tester base, minimizes the heat transfer into the large base.

The striker assembly is bolted to the base assembly by means of four bolts allowing easy accessibility to the sample cavity. A flexible, high-pressure line is attached to the diaphragm housing providing the gaseous nitrogen pressure to the striker diaphragm cavity. Positioning of the striker with respect to the specimen is controlled by this pressure source.

When assembling the striker assembly to the base, a new conoseal is installed each time to ensure a positive seal. The bolts must be periodically lubricated with Molykote to prevent galling with the threaded inserts. To load the static seal properly, the bolts must be tightened evenly. This is accomplished by alternately tightening the bolts as the striker assembly is drawn down to the base assembly. The bolts should be tightened to a torque of 130 ft-lb.

The structural evaluation of the test cell was based on using K-monel material with a safety factor of 4. Since Inconel 718 is used in lieu of K-monel, a considerable gain in safety factor was achieved. The maximum designed pressure in the oxygen cavity is 10.2×10^4 newton/m^2 (15,000 psig). Proof pressure of the impact test cell was accomplished at 10.2×10^4 newton/m^2 (15,000 psig).

Instrumentation

Four modes of instrumentation are coupled directly to the impact cell:

1. Two thermocouples are attached to the cell base as shown in Fig. A-1 through thermocouple wells that are located very close to the sample cavity. The thermocouples are copper-constantan (Type T) to give good response at low temperatures (liquid oxygen).
2. A high-frequency pressure transducer port specially machined for a Kistler 607-C-3 transducer is located in the base assembly. A seal is made with a standard Kistler copper washer. The transducer is slightly removed from the sample cavity via a narrow channel to provide protection in the event of a positive result.

3. A photocell (Texas Instrument, Type IN2175) is situated behind a Dynasil fused silica window to record a flash in the sample cavity in the event of a positive test. The window is sealed with a Teflon gasket as shown in Fig. A-1 (Part No. RD262-3003-0002).

4. A microswitch located on the top of impact cell head senses whether or not the striker is down. A 24-vdc signal is switched on or off depending on the striker position. The switch is easily adjusted by the slotted mounting bracket.

As previously mentioned, all instrumentation except for the microswitch is mounted to the base assembly so that it is undisturbed during normal sample changing operations. This is important particularly with the coaxial cable and connector to the Kistler pressure transducer. Reference should be made to the vendor's (Kistler's) instruction manual for the specifics of maintaining good transducer connections. The connections have been sealed with shrinkable Teflon and electrical tape in an attempt to eliminate the possibility of moisture contamination.

IMPACT TOWER

The impact tower assembly (shown in Fig. A-4 and A-5) consists of a support base (P/N RS003071X) plate with four vertical guide rails (P/N RS003072X and RS003073X) mounted between the base and upper support plate (P/N RS003075X). Three of the guide rails are used to guide the 9.08 kilogram (20-pound) plummet assembly (P/N RS005257-X) to the impact cell (P/N RS005269X) attached to the base. The fourth guide rail (P/N RS003073X) is used to support the electromagnet and velocity gate (P/N RS005721-X-003,5) in any desired vertical position. Centering dowel pins are used to align the guide rails to both the base and upper support. These were used to ensure that repeated disassembly and assembly retain good alignment of the guide rails. They will allow some rotation for final adjustment prior to tightening the bolts at either end forming a rigid structure. A plummet lift mechanism consisting of an air cylinder cable and lift support is used to return the plummet assembly to its initial position against the electromagnet. This mechanism is automatically actuated by

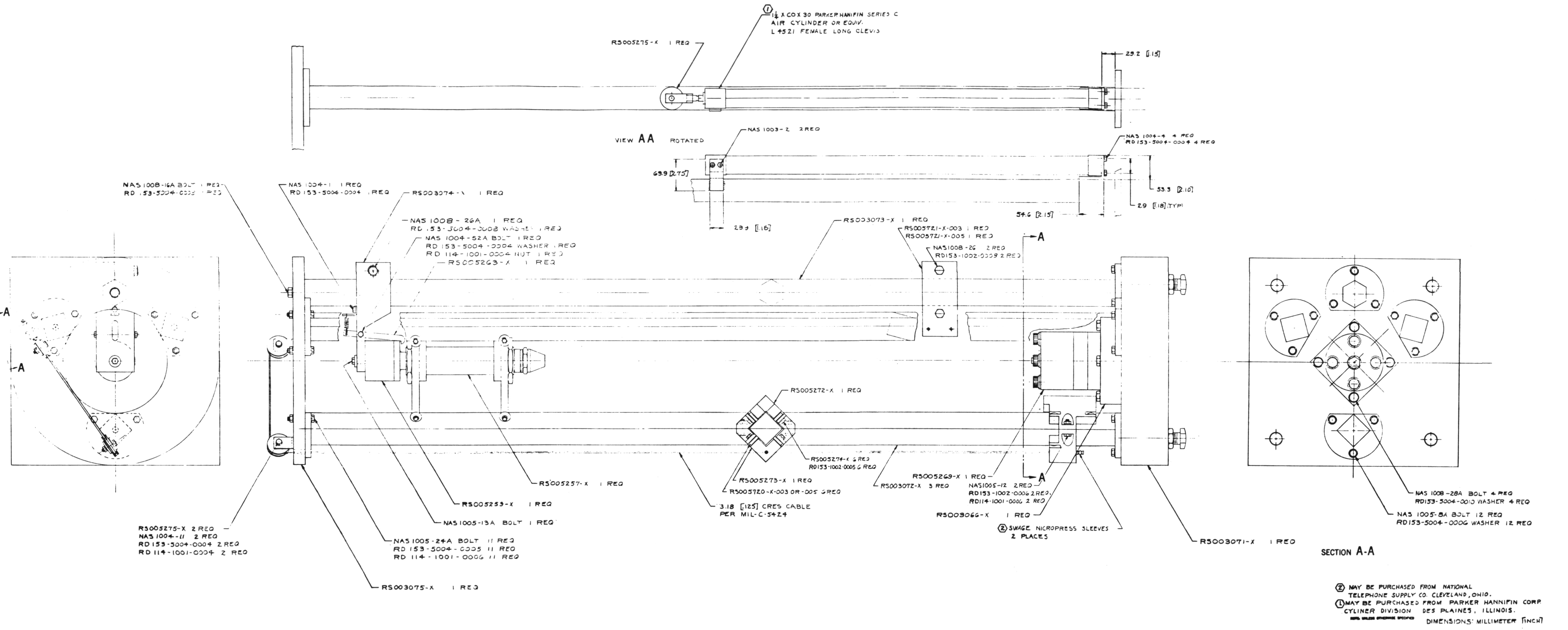


Figure A-4. Impact Tower Assembly

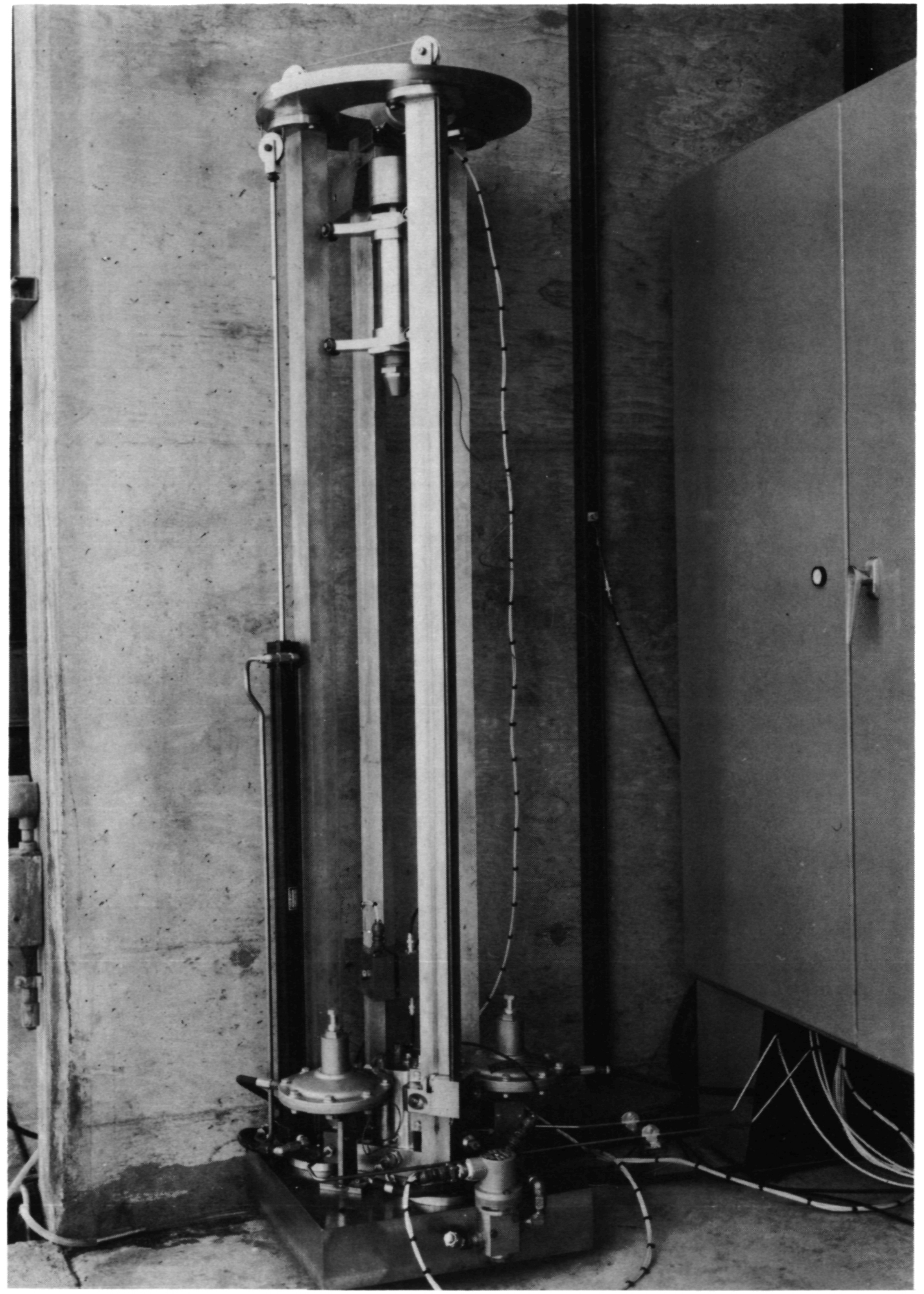


Figure A-5. Impact Tower

the velocity gate to catch the plummet after the initial contact with the impact cell striker so that no rebound impacts are seen by the sample.

A safety latch actuated by a solenoid is attached to the electromagnet, providing a plummet locking device should a malfunction occur in the electromagnet. The locking device is a necessity with personnel working around the impact tester replacing specimens, cleaning, etc. Adjustable leveling lugs are supplied in the base of the tower to maintain level conditions regardless of the floor condition.

The material used in the impact tower assembly was primarily 300-series stainless steel to prevent corrosion and rusting yet minimize costs. The exception to this material was the impact nosepiece of the plummet and the electromagnet. The plummet nose (P/N RS005255X) was fabricated from 400C CRES because of the hardness (Rc55-60) required to withstand the continuous impact of many test series. The plummet support (P/N RS005255X) and the electromagnet body and core (P/N RS005259X-003) were both fabricated from 416 CRES because a magnetic steel was required. Materials throughout the design were selected because of their corrosion resistant properties so that reasonable appearance could be ensured with minimum care through years of testing.

Plummet Assembly

The plummet assembly (Fig. A-6) is assembled with a centerbody (P/N RS005251X), and two interchangeable spider assemblies (P/N RS005252X) incorporating roller bearings, and two nuts used to attach the spiders to the centerbody. Alignment pins are used to maintain proper alignment of the rollers to the guide rails. The plummet support is attached to the aft end of the body and is assembled nearest the electromagnet. The plummet nose screws into the forward end of the body sandwiching the load cell (P/N 900A) and associated parts between it and the main body.

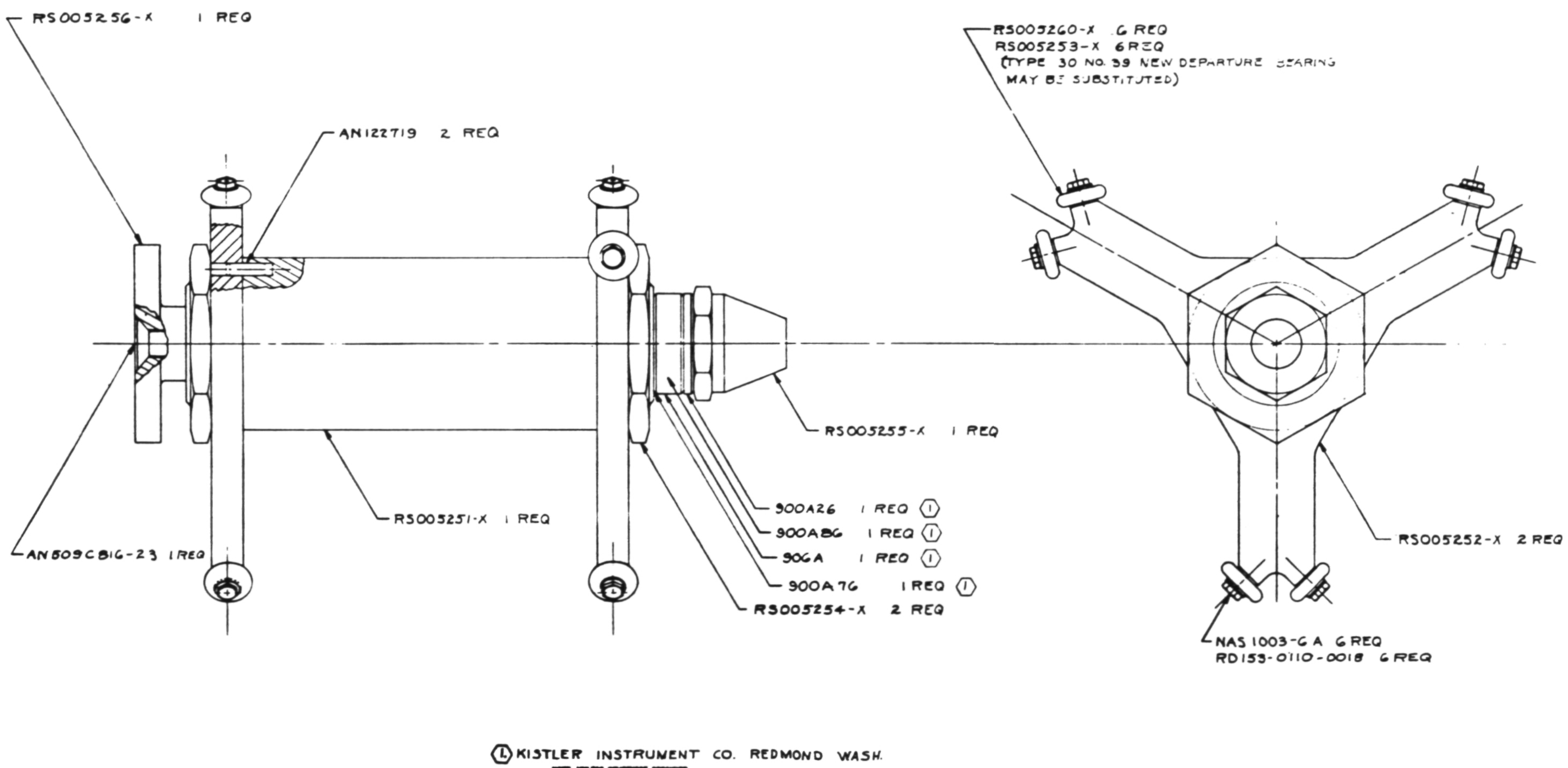


Figure A-6. Plummet Assembly

CAUTION: Install a spacer between the nose of the plummet and body when not actually conducting load cell tests to prevent damage to the load cell.

The plummet assembly is installed into the guide rails by removing the rollers and reassembling when the plummet is in position. The weight of the plummet with either the load cell or the blank spacer is 9.08 kilograms (20 pounds) ±0.1 percent. Three added weights are provided: in 1-, 2-, and 3-pound clamp-on configurations. These weights can be added quite easily by merely clamping to the body of the plummet.

Instrumentation and Control

Impact tower instrumentation consists of a load cell washer (Kistler 906A) located behind the impact tip of the plummet (Fig. A-7), and a velocity gate assembly, which is clamped at any desired position along the travel of the plummet (Fig. A-8).

The load cell will measure instantaneous loads to 200,000 newtons (45,000 pounds) and survives impacts to 445,000 newtons (100,000 pounds). Care must, therefore, be taken when testing hard samples to avoid overranging and damaging this device. For example, if the sample deformation is only 0.002 inch at 72 ft/lb impact energy,

$$W(\text{loading, lb}) = \frac{E(\text{drop energy, ft-lb})}{X(\text{deformation, ft})} \tag{1}$$

$$W = \frac{72}{\frac{0.002}{12}} = 432{,}000 \text{ lb } (1{,}922{,}490 \text{ newtons})$$

Again, extreme care should be taken to preserve the integrity of the coax cable and connectors as recommended in the Kistler instruction manual.

The velocity gate is an exact 2-inch 0.0508m) spacing of two photocells adjacent to two 24-vdc lights. A gating blade on the plummet interrupts the photocells output, which actuate a pair of latching trigger relays to perform various functions such as:

1. Furnish velocity timing

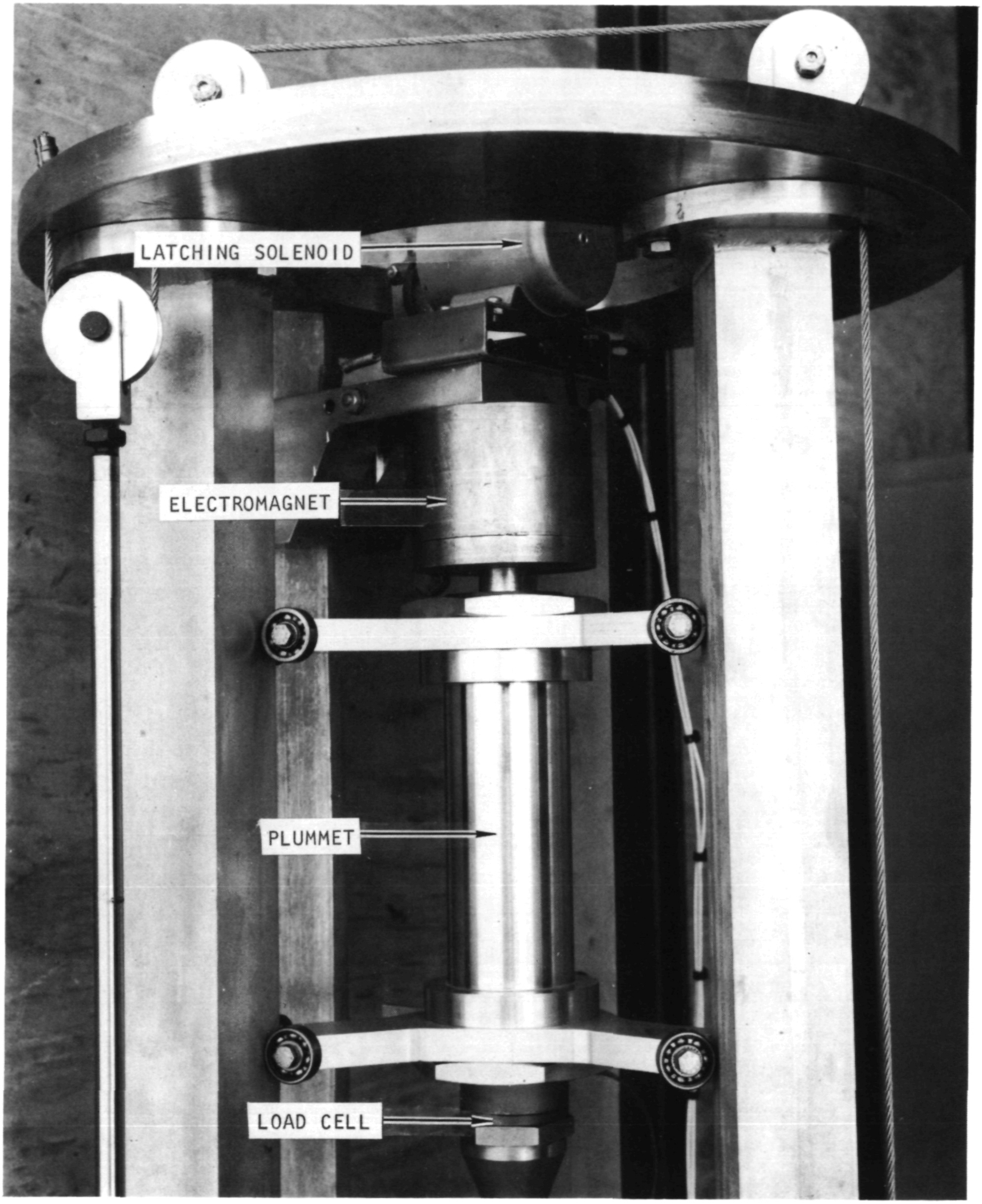


Figure A-7. Plummet Assembly

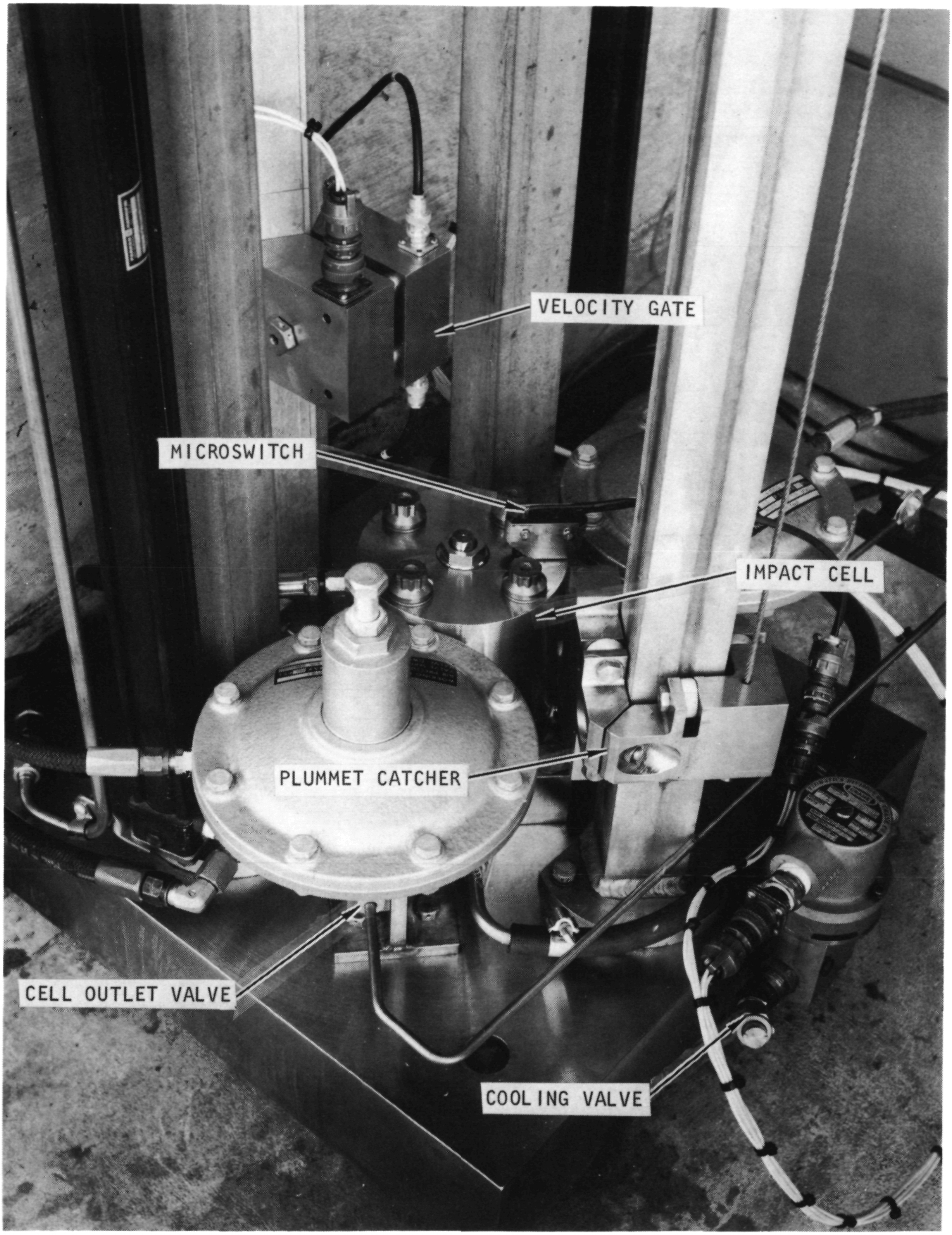


Figure A-8. Tester Base Assembly

2. Trigger plummet catch mechanism

3. Trigger oscilloscope sweep

Outputs from the photocells are connected to the pneumatic enclosure to supply the automatic triggering of the plummet catcher from the top photocell. The catch mechanism is reset by a push button switch on the door of the enclosure (convenient to the impact tower).

Impact tower controls (24 vdc) include the electromagnet, plummet locking solenoid, and cryogenic cooling valve (Flowmatic, Model T-92-8V-NC, Fig. A-7 and A-8). The valve is solenoid operated and remotely controlled from the control console. All actuation wires are equipped with diodes to prevent stray triggering and interference to adjacent instrumentation circuits.

HIGH-PRESSURE OXYGEN SUPPLY SYSTEM

Pneumatic Enclosure

The bulk of the oxygen feed and pressure-balancing system is housed in a two-door NEMA Type 12 electrical panel enclosure (see Fig. A-9 and A-10). A schematic of the plumbing in this enclosure is presented in Fig. A-11. This arrangement provides a safe, clean, easily portable module for mounting these critical components. As seen in Fig. A-9, the faces of the system pressure gages and handles of the manual valves protrude through the front of the enclosure to give safe, easy access for convenient operation. Table A-1 is a detailed list of the components in the oxygen feed and pressure-balance systems.

Nearly all of the high-pressure oxygen system plumbing and hardware (as shown by the cross-hatched lines in Fig. A-11) is constructed of monel. Monel has good compatibility with oxygen and adequate strength to withstand the high pressures required in this feed system. The only exception is the 1-liter surge tank, which is constructed of 316 stainless steel. A vessel of this size and pressure

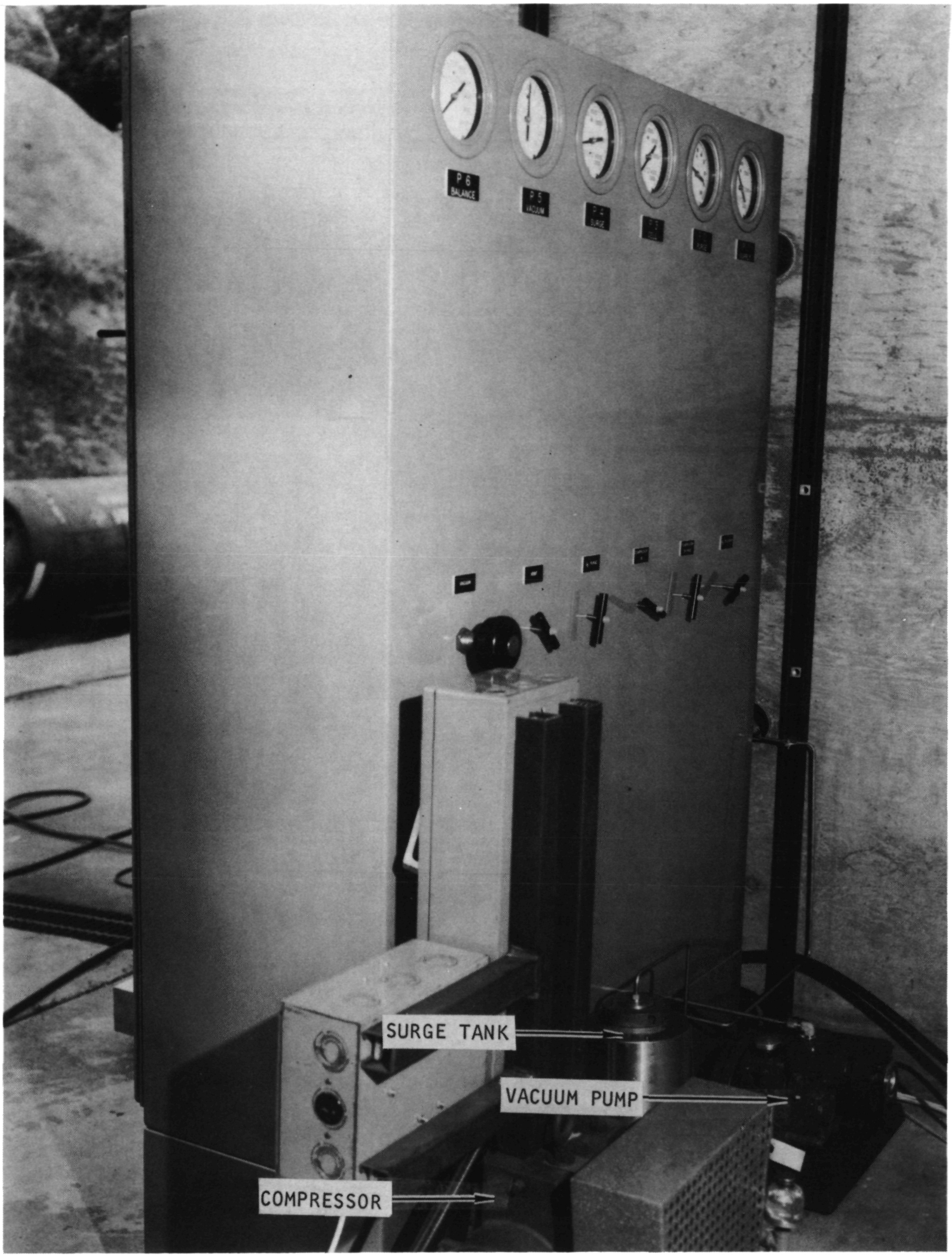


Figure A-9. Pneumatic Enclosure

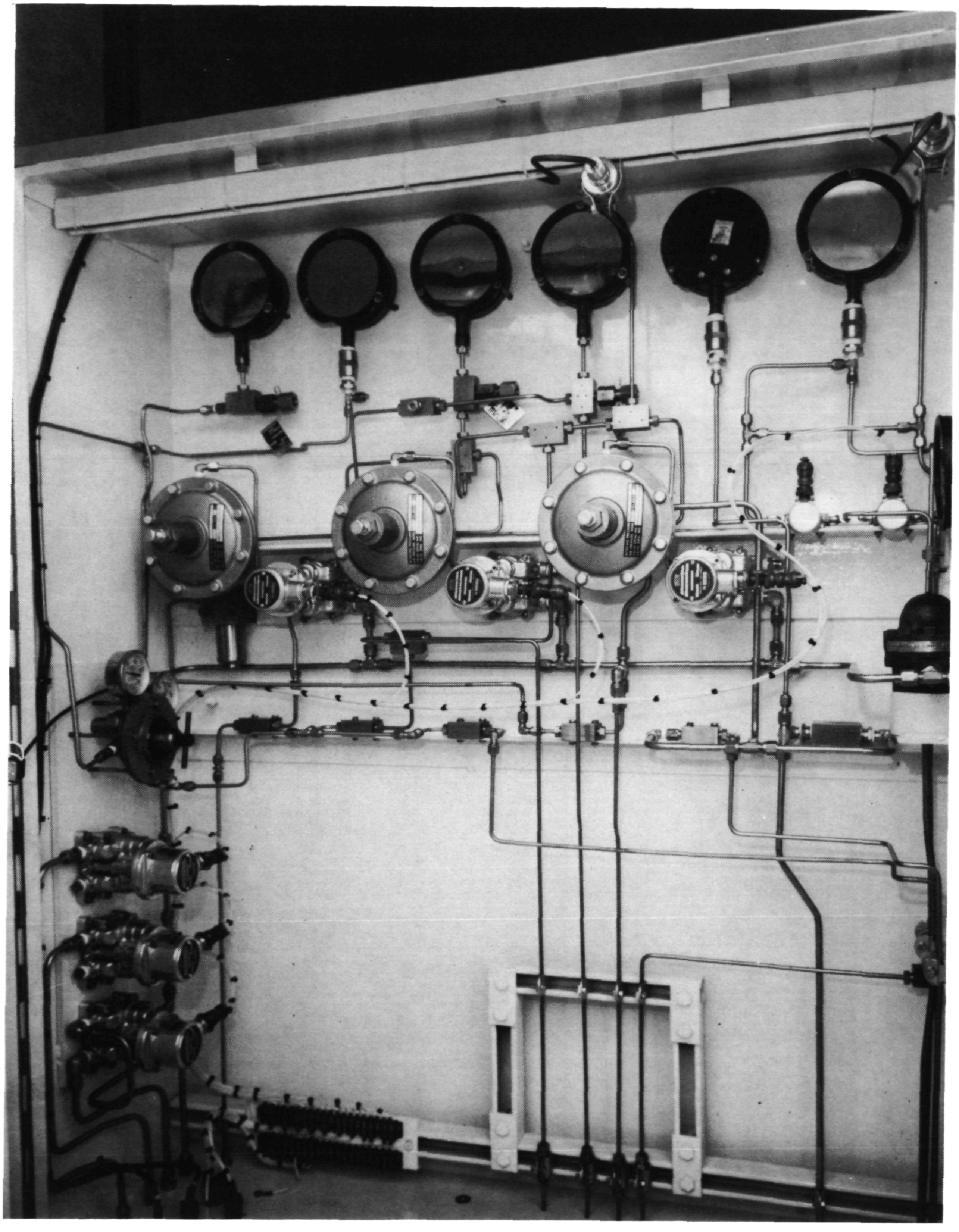


Figure A-10. Pneumatic Enclosure (Inside)

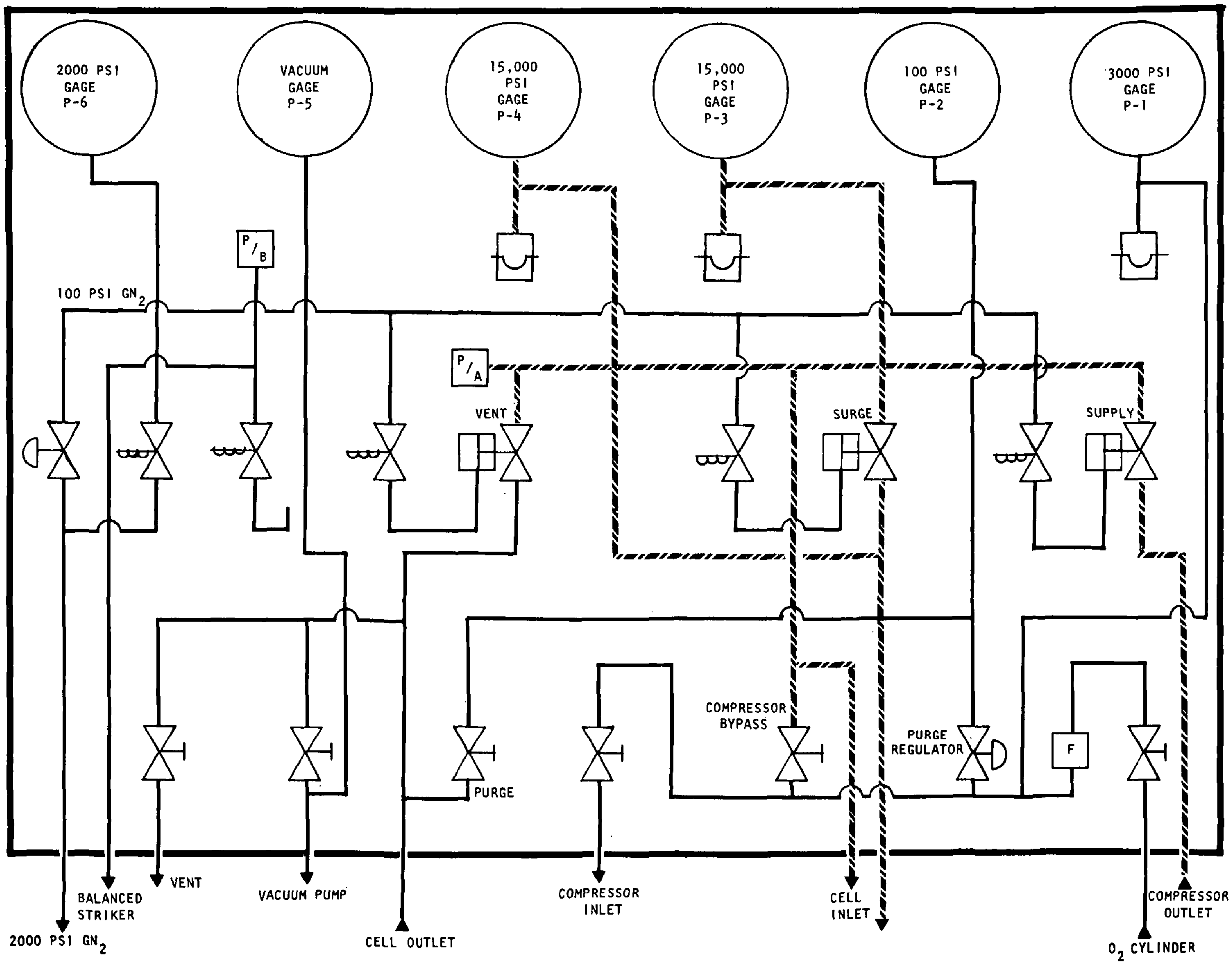


Figure A-11. Pneumatic Enclosure Schematic

TABLE A-1. PNEUMATIC ENCLOSURE HARDWARE

Item	Description	Material	Size	Working Pressure	Quantity
1	Hand Valve, Autoclave No. 30VM-4071-OM	Monel	1/4 AE	12,000	5
2	Pneumatic Valve, Autoclave No. 30VM-4071-OM	Monel	1/4 AE	12,000	5
3	Pressure Gage, Autoclave No. P483	316SS	1/4 AE	0 to 15,000	2
4.	Pressure Gage, Autoclave No. P480	316SS	1/4 AE	0 to 3000	1
5.	Burst Diaphragm Holder Autoclave No. CS4600	Monel	1/4 AE	12,000	3
6.	Burst Disk	Monel	1/4 AE	15,000	2
7.	Burst Disk	Monel	1/4 AE	3000	1
8.	Solenoid Valves, Barksdale No. 12453	Brass	3/8 NPT	150	6
9.	Miscellaneous High-Pressure Fittings	Monel	1/4 AE	12,000	
	Autoclave No. CX4444-CROSS				4
	Autoclave No. CT4440-TEE				5
	Autoclave No. CL4400-ELBOWS				1
	Autoclave No. 60M42B8-ADAPTER				4
	Autoclave No. 60F4433-COUPLING				4
	Autoclave No. CP-40-PLUG				3
10.	Solenoid Valve, Marotta No. MV-100	SS	1/4 AN	3000	2
11.	Filter, Aircraft Porous Media, Model No. AC4098-82Y2	SS	1/4 AN	3000	1
12.	Pressure Transducer, BLH Electronics Type DHF	SS	1/4 AN	1000	1
13.	Pressure Transducer, BLH Electronics Type DHF	SS	1/4 AN	1000	1
14.	Pressure Gage, Ashcroft No. 1279	SS	1/4 NPT	VAC-15	1
15.	Pressure Gage, Ashcroft No. 1279	SS	1/4 NPT	100	1
16.	Pressure Gage, Ashcroft No. 1279	SS	1/4 NPT	2000	1
17.	Hand Valve, Control Component MV-6008	SS	1/2 NPT	6000	1
18.	Regulator, Matheson No. 8-540	Brass	1/4 NPT	3000	1

would require a monel-clad structure to furnish the required tensile strength. This type of construction was considered to be more questionable from a safety standpoint than 316 stainless steel since other investigators* have used 316 stainless steel with high-pressure oxygen. The compressor is also 316 stainless steel, again, because experience has shown good success with this material in this application. All connections are standard high-pressure fittings (i.e., superpressure, AE cone, etc.).

Equipment not mounted in the enclosure includes the cell inlet and outlet valves, since they must be located as close as possible to the impact cell. The arrangement of these valves on the impact tower base may be seen in Fig. A-8. As seen in Fig. A-9, the compressor, vacuum pump, surge cylinder, and oxygen supply cylinder are not included in the enclosure. Capabilities, installation requirements, troubleshooting, and maintenance for the oxygen compressor (AMINCO Model 46-13426) are included in the vendor's instruction manual as an enclosure to this appendix.

Instrumentation and Controls

The only instrumentation in the pneumatic enclosure are the oxygen system pressure transducer (P-A) and the pressure-balance system transducer (P-B). Both are BLH, Model DHF, pressure transducer with 10,000- and 1000-psig pressure ranges, respectively. The transducers are constructed of 17-4PH stainless steel. The oxygen transducer contains no nonmetallic parts. These units can be safely overloaded to 150 percent of their maximum ratings. The outputs of these transducers are attached to connectors in the bottom of the enclosure where they are interfaced with tie-in cables to the control console. A thermocouple is located in the surge tank to enable temperature monitoring while pressurizing. All of the control circuit wiring (24 vdc)** for valve operation, pump actuation, and magnet and solenoid operation is routed through a terminal strip located in the enclosure (see Fig. A-10). This provides a central location for all control wiring to be tied together in the immediate vicinity of the impact tower. Again, diodes are used to isolate each circuit from adjacent instrumentation wiring. A schematic of this terminal strip is shown in Fig. A-12.

*Telephone communication with J. S. Stradling, Test Operations Director, Lab. Branch, NASA, White Sands Test Facility, Las Cruces, New Mexico.

**The original instrument and control wiring at Rocketdyne was 28 vdc.

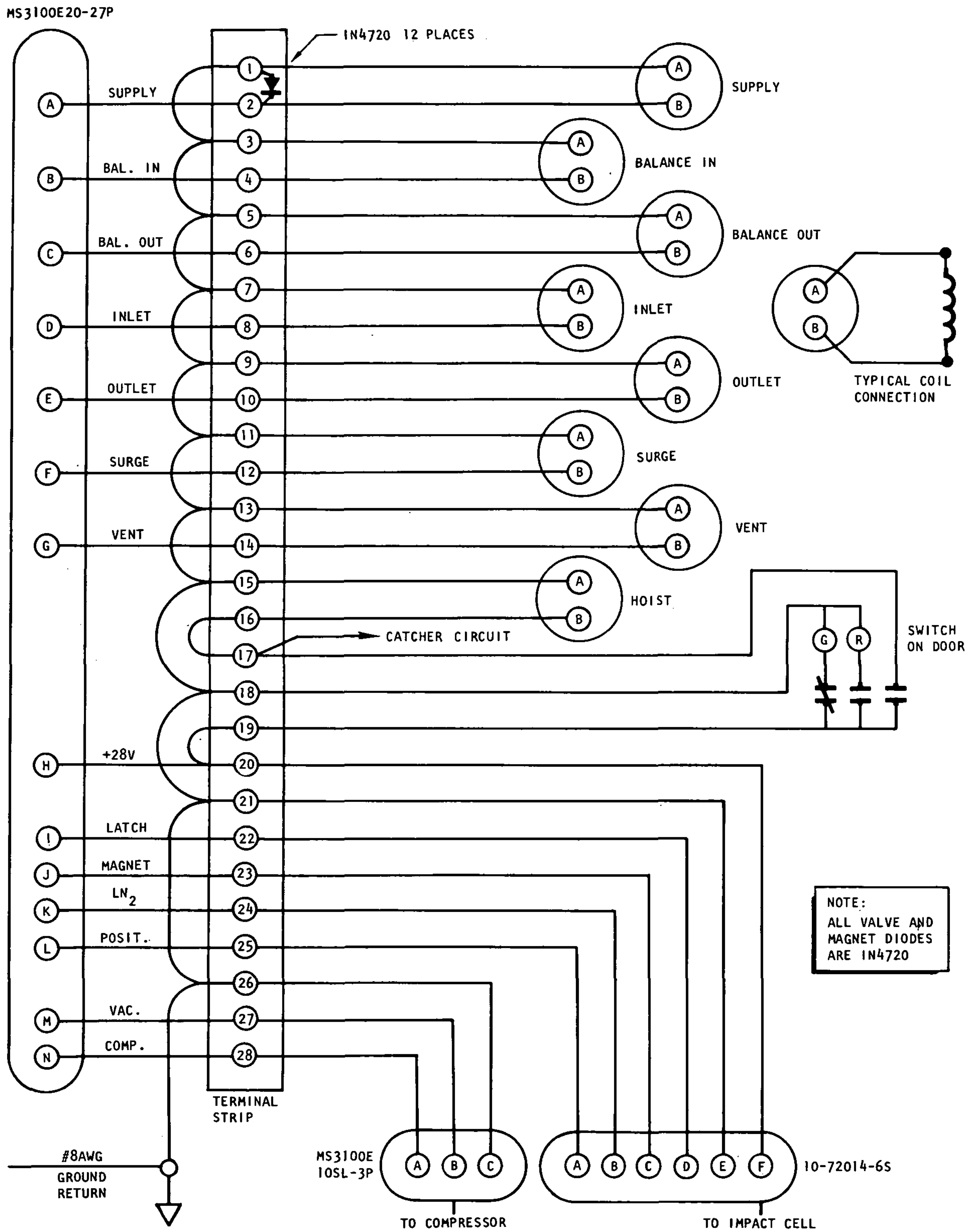


Figure A-12. Wiring-Pneumatic Console

All connections, plumbing, and wiring are made through the bottom of the enclosure via convenient waterproof connectors and standard bulkhead fittings and couplings. GN_2 at 0.83×10^4 to 2.06×10^4 newton/m^2 (1200 to 3000 psig) should be plumbed to the enclosure to furnish adequate pressure for the balance system and to actuate the pneumatic operators on the high-pressure valves. The actuation pressure is developed by routing the GN_2 supply pressure through a preset Grove dome regulator set at 95 to 115 psig. This actuation pressure also drives the pneumatic cylinder on the plummet catcher mechanism.

All control wiring is 24 vdc, even the operating wires for the vacuum pump and compressor which are 110 and 220 vac, respectively. Relays are located in an electrical starter box adjacent to the compressor where the 24-vdc control signals actuates the appropriate relay for compressor and/or pump operation. The box also contains a motor starter (220 vac, three phase) for the compressor. Necessary fuses (15 amperes) and overload heaters are included. Wiring and appropriate connectors are provided for plugging these a-c lines into facility outlets.

CONTROL CONSOLE

Operational Graphic Control Panel

As shown in Fig. A-13 and A-14, a graphic display of the system schematic, with push button switches at appropriate positions, is located at the top of the control console. Push button switches are lighted when valves are open or pumps are on. Pressure gage locations along the top of the schematic are in identical sequence with the actual gages as they appear in the top of the pneumatic enclosure (Fig. A-9). This display minimizes confusion and allows easy informative operation of the tester system. Lights are color coded to signify various parts of the system:

1. Red, high-pressure oxygen
2. Yellow, support systems (main power, vacuum, heat)
3. White, GN_2 system
4. Blue, cooling (LN_2)
5. Green, readiness of automatic pressurization and firing system

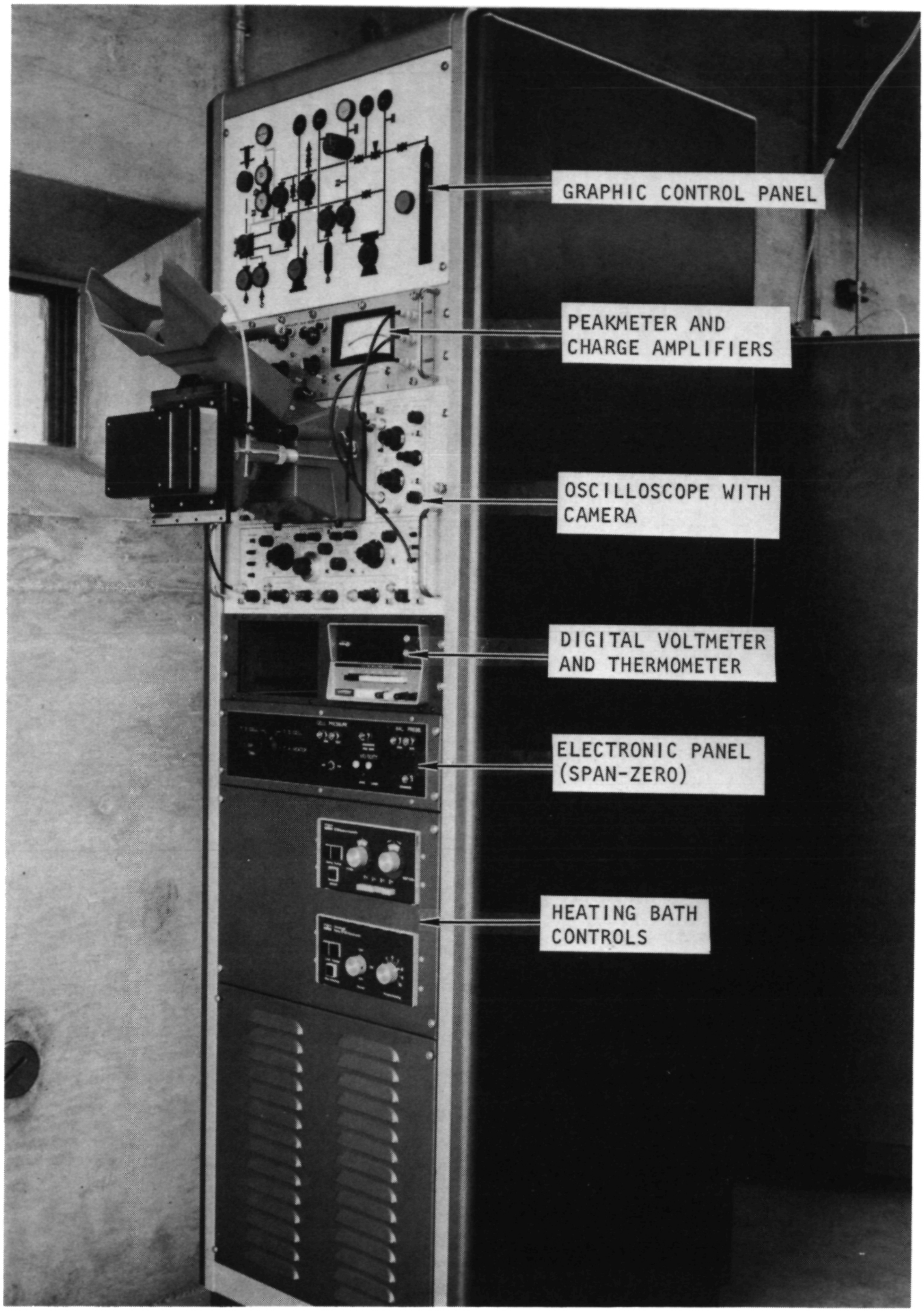


Figure A-13. Control Console

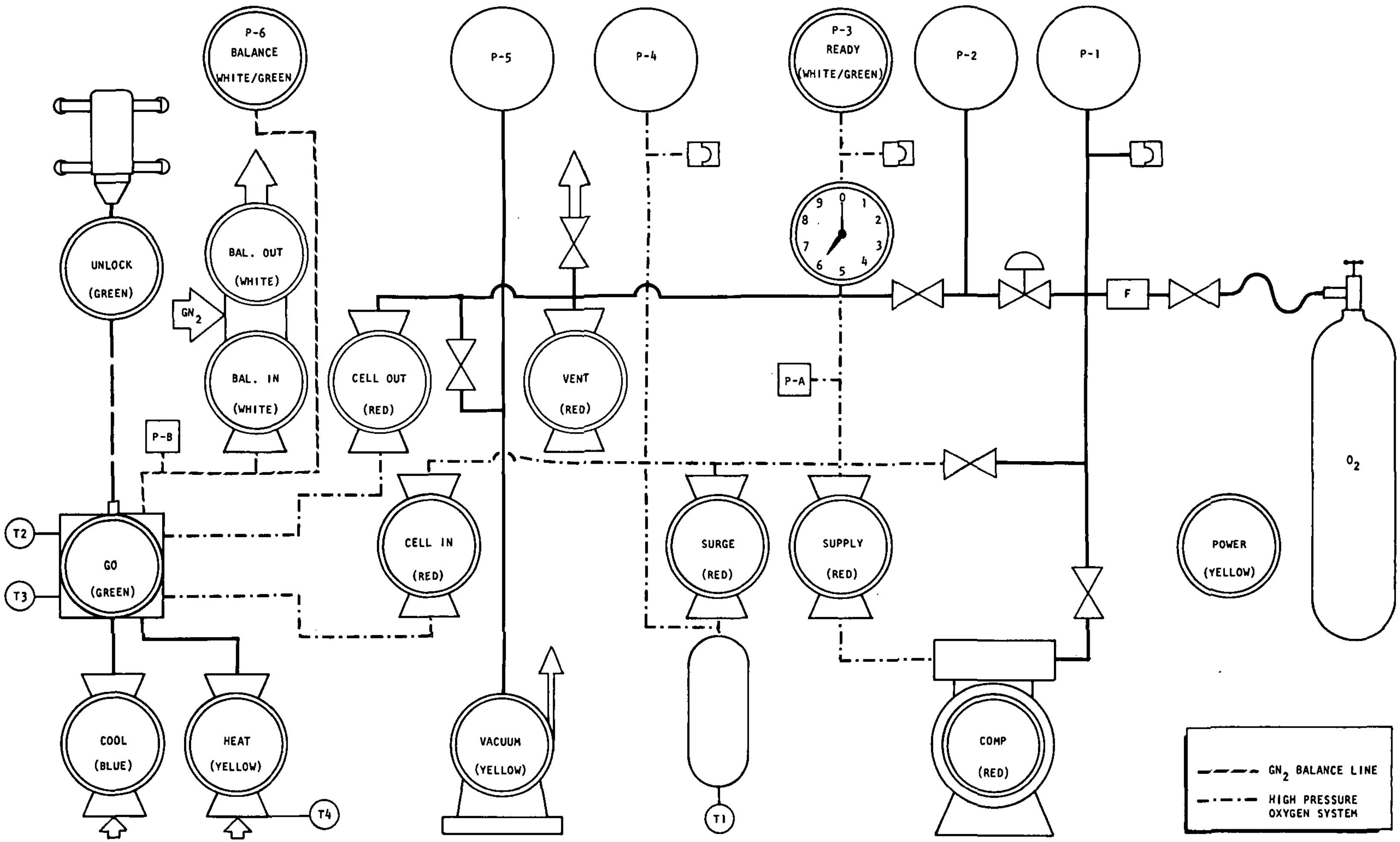


Figure A-14. Graphic Control Panel

To achieve optimum control and consequently maximum safety of operation, the graphic control panel was designed with a number of interlocks and logic circuits:

1. Automatic pressurization to predetermined (preset) operating pressures via a 10-turn indicating potentiometer (kilo psig). Logic circuits provide continuous analog comparison between the preset pressure and the actual pressure (P-A) to control the operation of the compressor and supply valve. Attainment of the desired pressure is indicated by a green light in the "Ready," P-3, position.

2. Pressure-balancing of the striker, as the operating pressure is varied, is automatically controlled by a preprogrammed digital comparator. This device continuously compares the operating pressure (P-A) to the GN_2 balancing pressure (P-B) and makes the appropriate correction on the balance system (vent or pressurize).

   Simultaneously the position of the striker (up or down) is indicated by the "Balance" (P-6) light; upper half light, striker up, lower half light, striker down. If the pressure is balanced between (P-A) and (P-B) the light turns green. The logic is presently fixed to only give a green light when the striker is down when balance is reached. No green light will appear even if the pressure is balanced while the striker is up. The automatic balancing system can be deactivated by turning the balance switch (located on a lower panel of the console) from Auto to Manual. The vent and pressurization valves can be operated manually by pushing the appropriate buttons on the display.

3. An interlocking circuit prohibits dropping of the plummet until the following conditions are met:

   a. Pressurization to preset value, ready light green
   b. Balanced striker and striker down, balance light green
   c. Disengagement of the plummet locking solenoid
   d. Closure of both cell in and out valves

   At this time, the GO switch will light, indicating that the plummet can be dropped by pushing the switch.

These built-in electronic control circuits add a great deal to the overall efficiency, reliability, and safety of the operation by positively preventing premature dropping of the plummet.

Wiring diagrams for the relay and switch panel are shown in Fig. A-15 through A-25. The switch panel contains all the operating switches for the electrical control of the tester, and is located on the upper face of the console. The relay panel is located on the top of the console beneath the perforated top panel. Access to the relay terminal strip is by removal of the top panel. The switch and relay panels are permanently interwired and must be removed as a unit.

Location and designation of switches is shown in Fig. A-15, their function is shown on Fig. A-16. Figure A-17 is a simplified circuit of the whole panel. Details are shown in Fig. A-18 through A-22.

Compressor operation is shown in Fig. A-19. In operation, a predetermined pressure is set on the potentiometer located on the switch panel and the compressor is started by closing S2. The output voltage of the potentiometer is compared to the amplified output voltage of the cell pressure transducer. When the transducer output exceeds the preset voltage, a comparator closes R8. As long as the transducer output exceeds the preset voltage, R8 remains closed. When R8 first closes, it pulls in R3 which latches in through its normally open contact R3B and through the normally closed switch S15 stopping the compressor and turning S15 green. The drop logic circuit is energized through the R8A normally open contact. Should a system leak occur and pressure leak off, the comparator will open R8 turning S15 yellow and de-energizing the drop logic circuit preventing a test with low pressure. The compressor can be restarted by pressing S15. The compressor supply valve is automatically activated with the compressor through R2; however, it can be independently operated by S14 through the isolating diodes.

Balance pressure and cell pressure are measured and compared in a window comparator located on the electronics panel. The three comparator outputs are relay closures to +24 volts. Thus, the three terminals 23, 24, and 25 on Fig. A-20 are sequentially activated by changes in pressure. When the balance pressure is low, R5 is energized providing power to the pressurize valve. When the balance pressure is high, R4 is energized providing power to the vent valve. When the pressures are balanced, R6 is closed. R6 is part of the "drop" logic chain. It also changes the color of I-1 from yellow to green indicating a balanced condition. The vent and pressurizer can

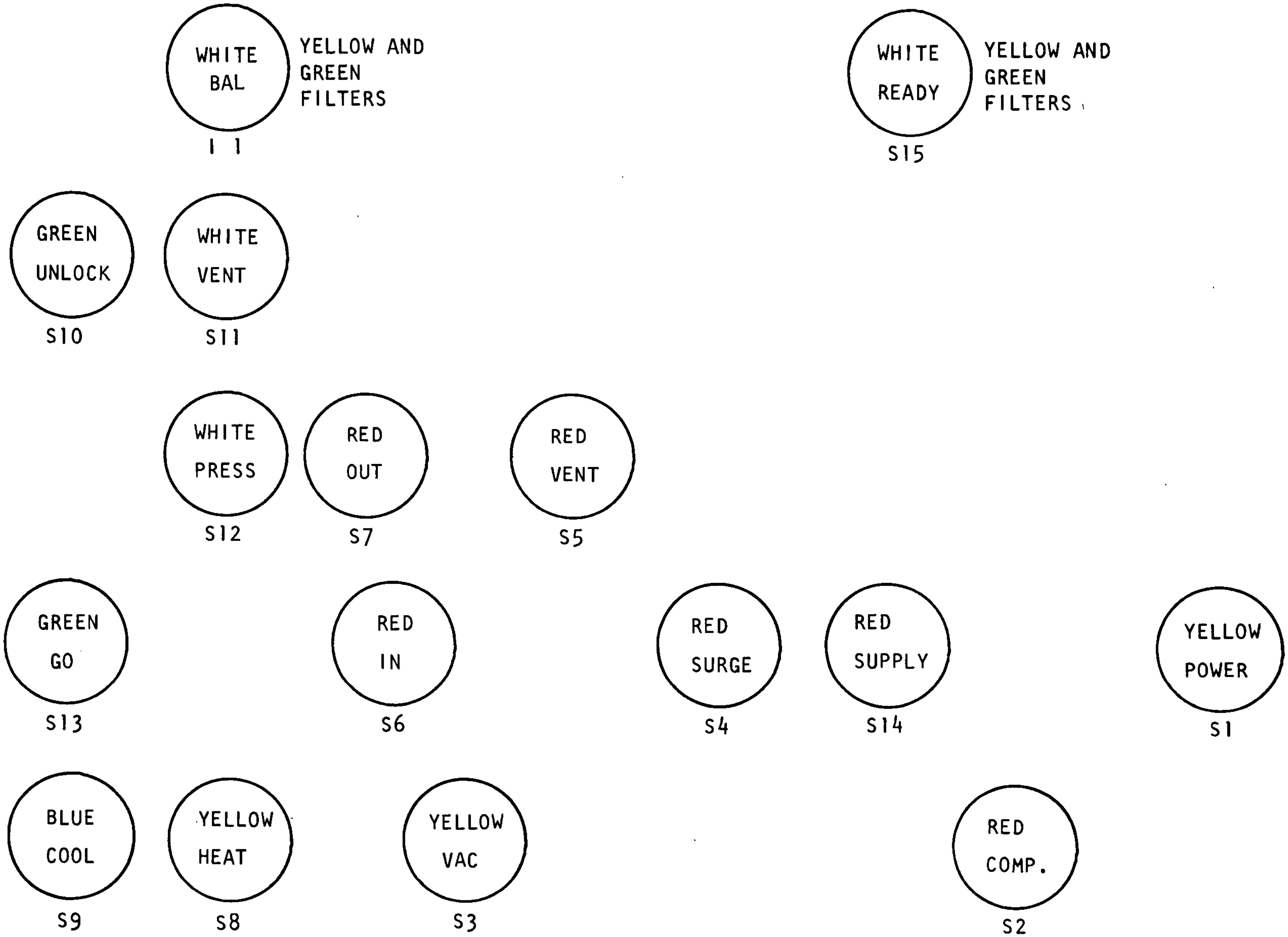


Figure A-15. Switch and Relay Panel Switch Designation

SWITCH	INSERT	FILTER	LEGEND	ACTION	CONTROL FUNCTION
S 1	YELLOW	—	POWER	ALT	ENERGIZE 28-VOLT BUS
S 2	RED	—	COMPRESSION	ALT	COMPRESSOR SWITCH
S 3	YELLOW	—	VACUUM	ALT	VACUUM PUMP SWITCH
S 4	RED	—	SURGE	ALT	SURGE TANK VALVE
S 5	RED	—	VENT	ALT	VENT VALVE
S 6	RED	—	IN	ALT	CELL INLET VALVE
S 7	RED	—	OUT	ALT	CELL OUTLET VALVE
I 2	YELLOW	—	HEAT		INDICATES STATE OF HEATER POWER
S 9	BLUE	—	COOL	ALT	LIQUID NITROGEN VALVE
S10	GREEN	—	UNLOCK	ALT	LATCH SOLENOID
S11	WHITE	—	DECREASE	MOM	BALANCE PRESSURE VENT
S12	WHITE	—	INCREASE	MOM	BALANCE PRESSURE LOAD
S13	WHITE	GREEN	GO	MOM	PLUMMET MAGNET
S14	RED	—	SUPPLY	MOM	COMPRESOR OUTLET VALVE
S15	WHITE	YELLOW (2) GREEN (2)	READY	MOM	INDICATES PRESSURE (RESETS PRESSURE LIMIT)
I 1	WHITE	YELLOW (2) GREEN (2)	BALANCE	NONE	INDICATES FORCE BALANCE

NOTE: ALL SWITCHES ARE HONEYWELL MICROSWITCH

Figure A-16. Switch and Relay Panel Switch Nomenclature

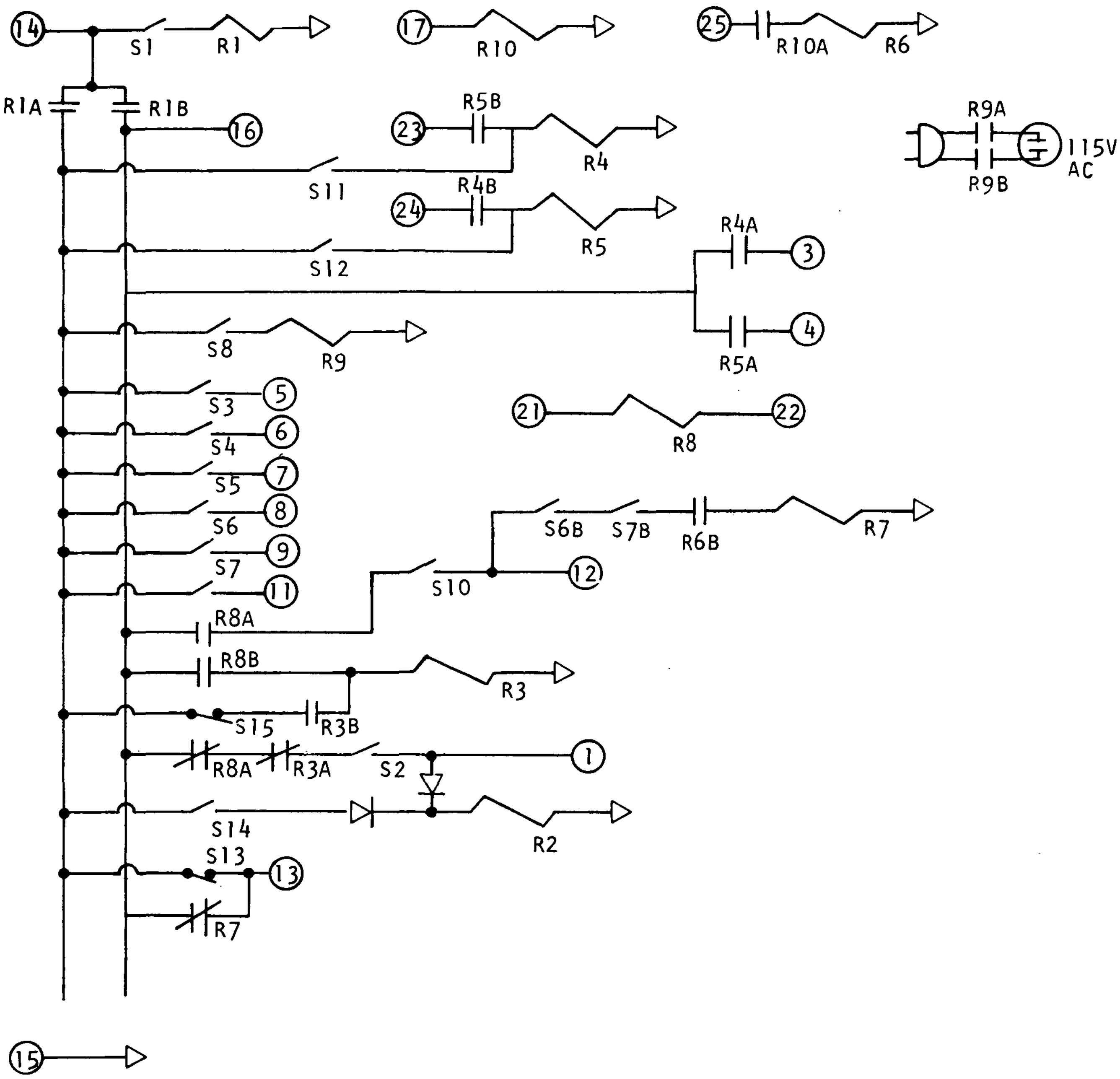


Figure A-17. Simplified Circuit Relays and Switches

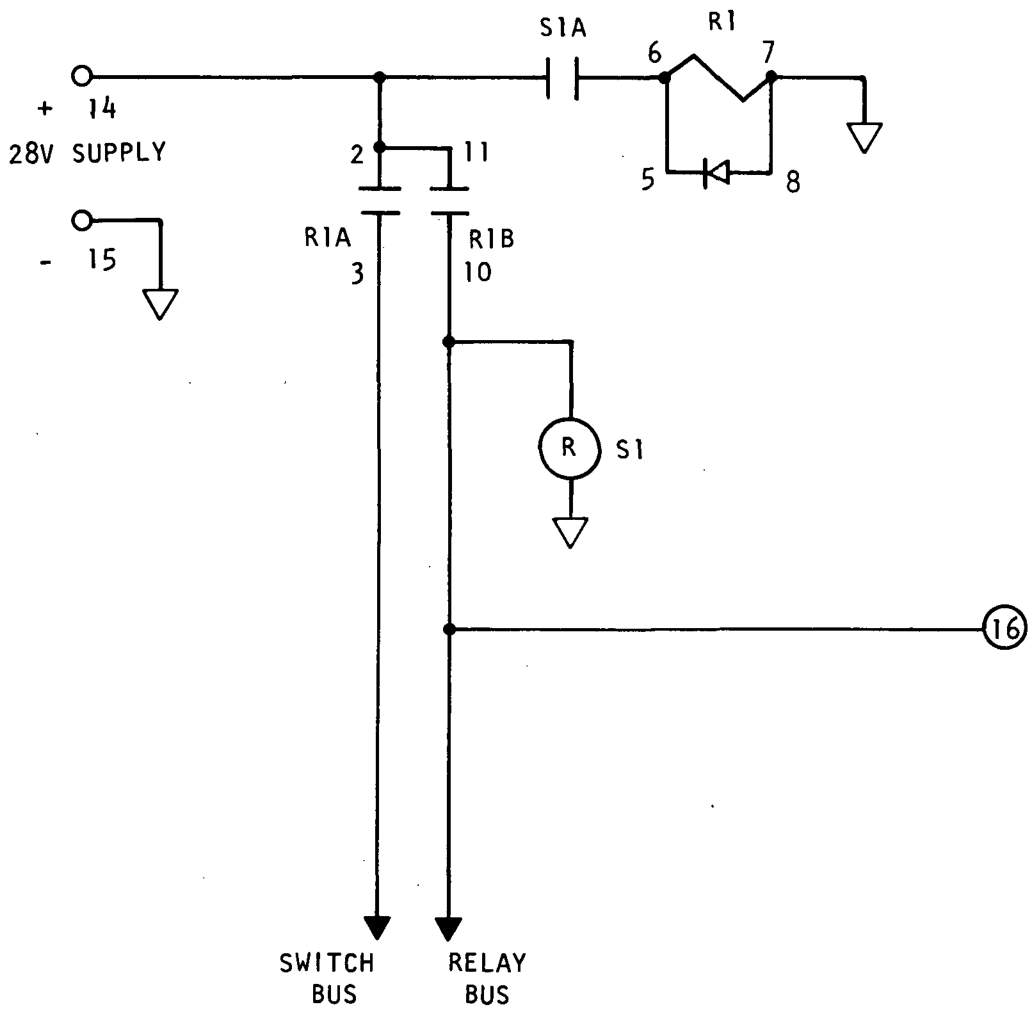


Figure A-18. Switch and Relay Panel Main Power

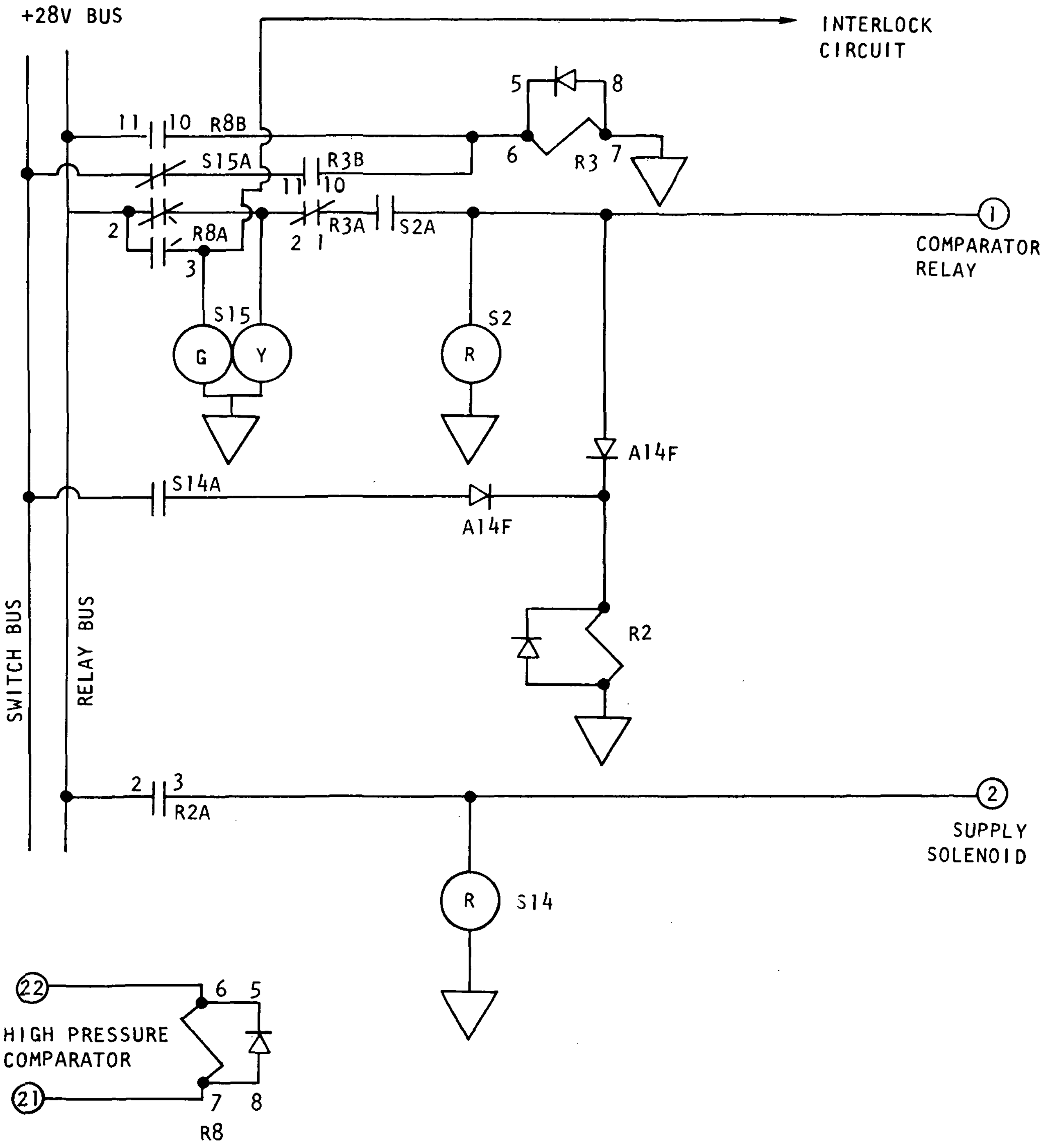


Figure A-19. Switch and Relay Panel Compresser Operation

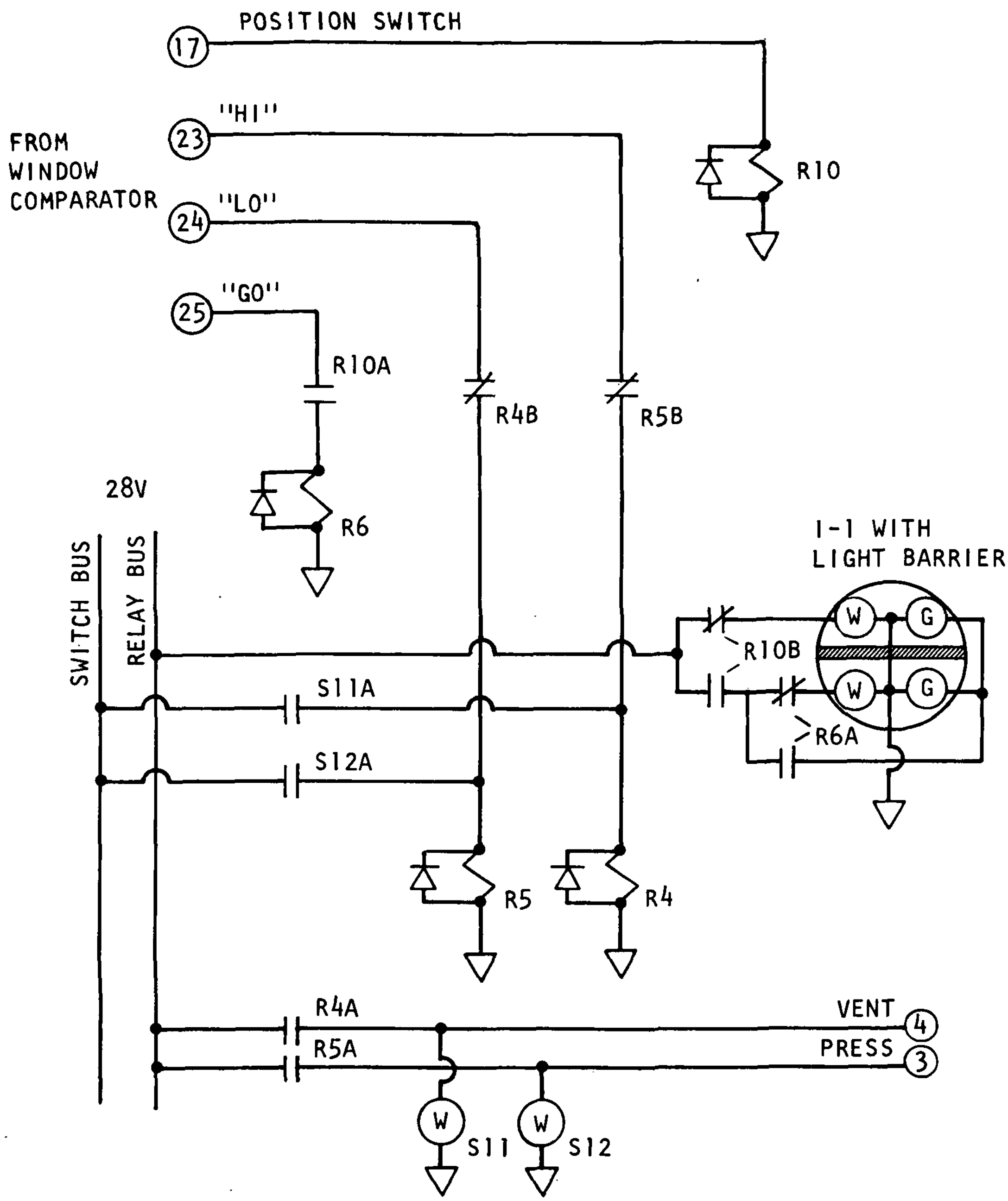


Figure A-20. Switch and Relay Panel

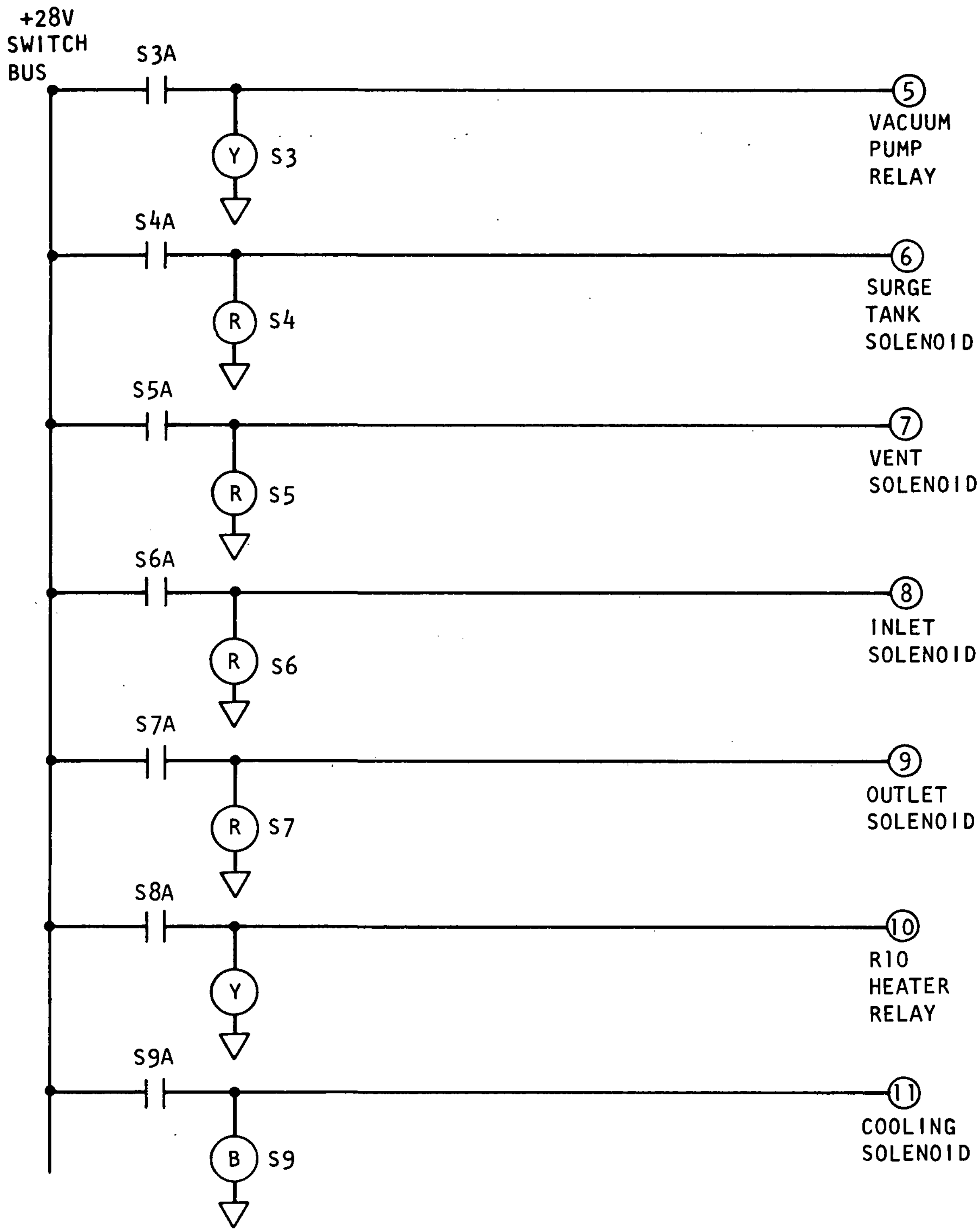


Figure A-21. Switch and Relay Panel Miscellaneous Circuits

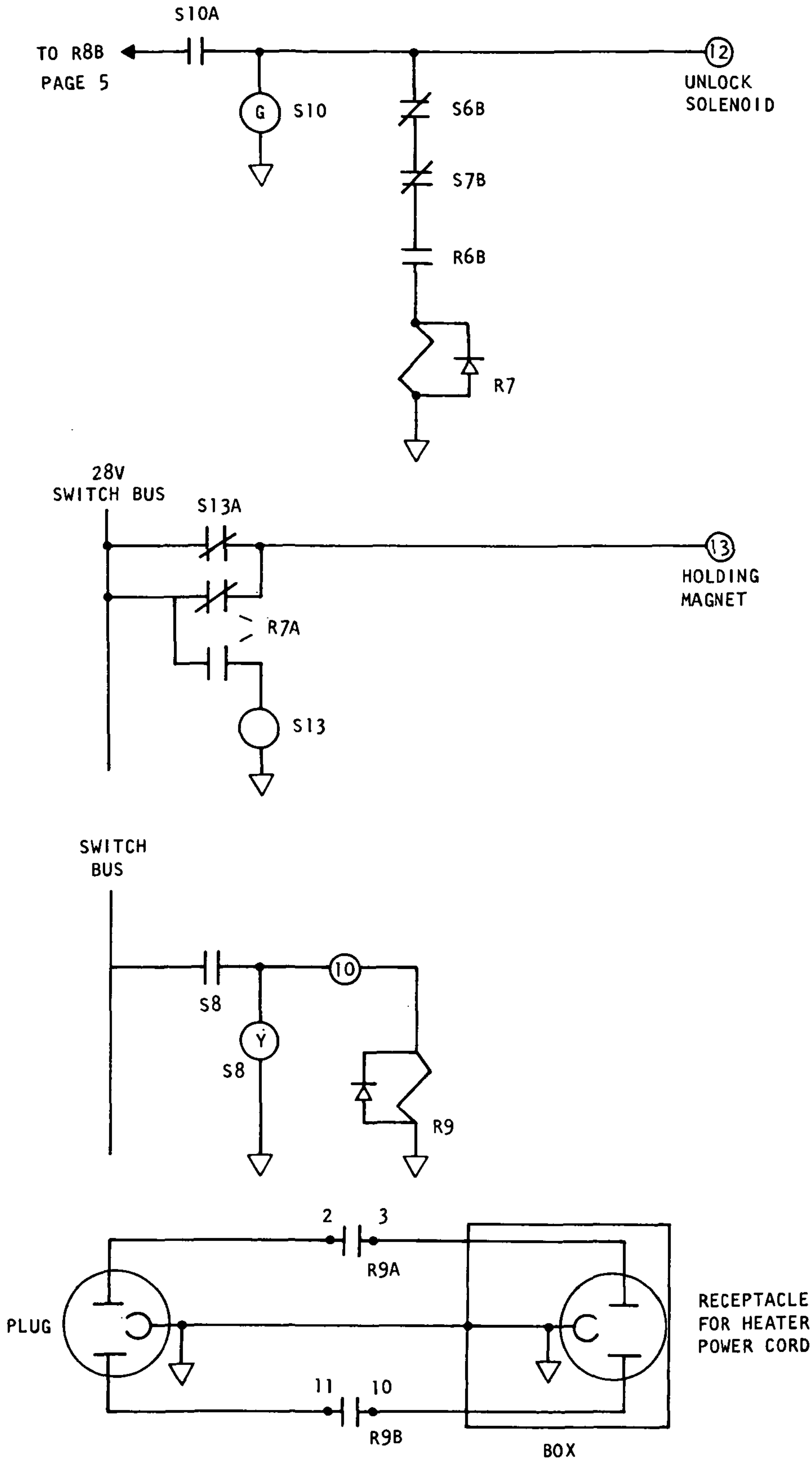
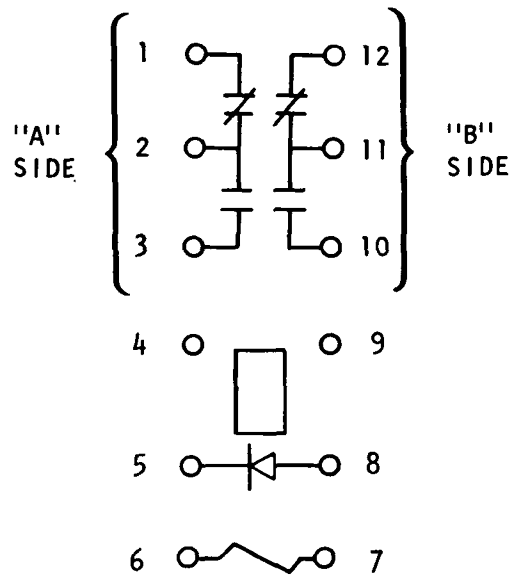


Figure A-22. Switch and Relay Panel Drop Interlock

(1) (VIEW FROM TOP OF RELAY
AT JACK AND TERMINALS)

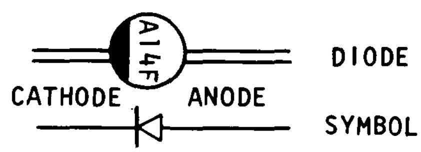


STRUTHERS DUNN
219 XBX-P RELAY

RELAY MODIFICATION

DIODE ADDED

G. E. A14F



(2) ALL SOLENOIDS, SOLENOID VALVES AND RELAYS HAVE DIODES INSTALLED AS CLOSE TO THE COIL AS PRACTICAL RELAYS - A14F. SOLENOIDS - IN4720

(3) ONLY TWO LIGHTS IN EACH SWITCH ARE USED - DIAGONALLY OPPOSIT-WHEN COLOR CHANGE IS REQUIRED FOUR LIGHTS ARE USED IN PAIRS

Figure A-23. Switch and Relay Panel Notes

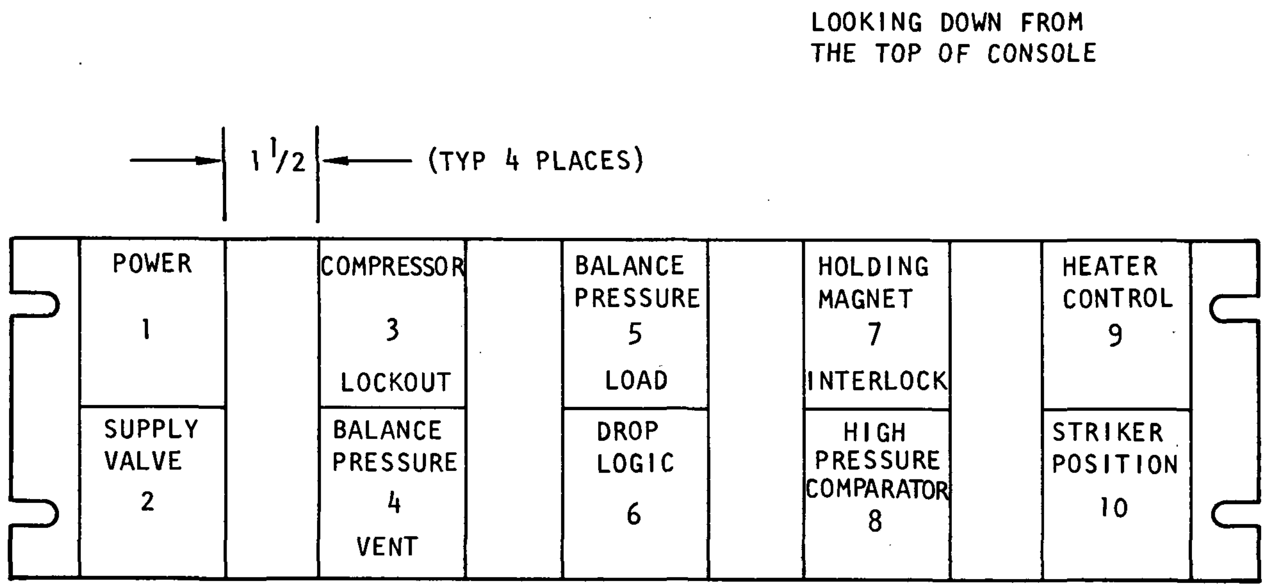


Figure A-24. Relay Panel

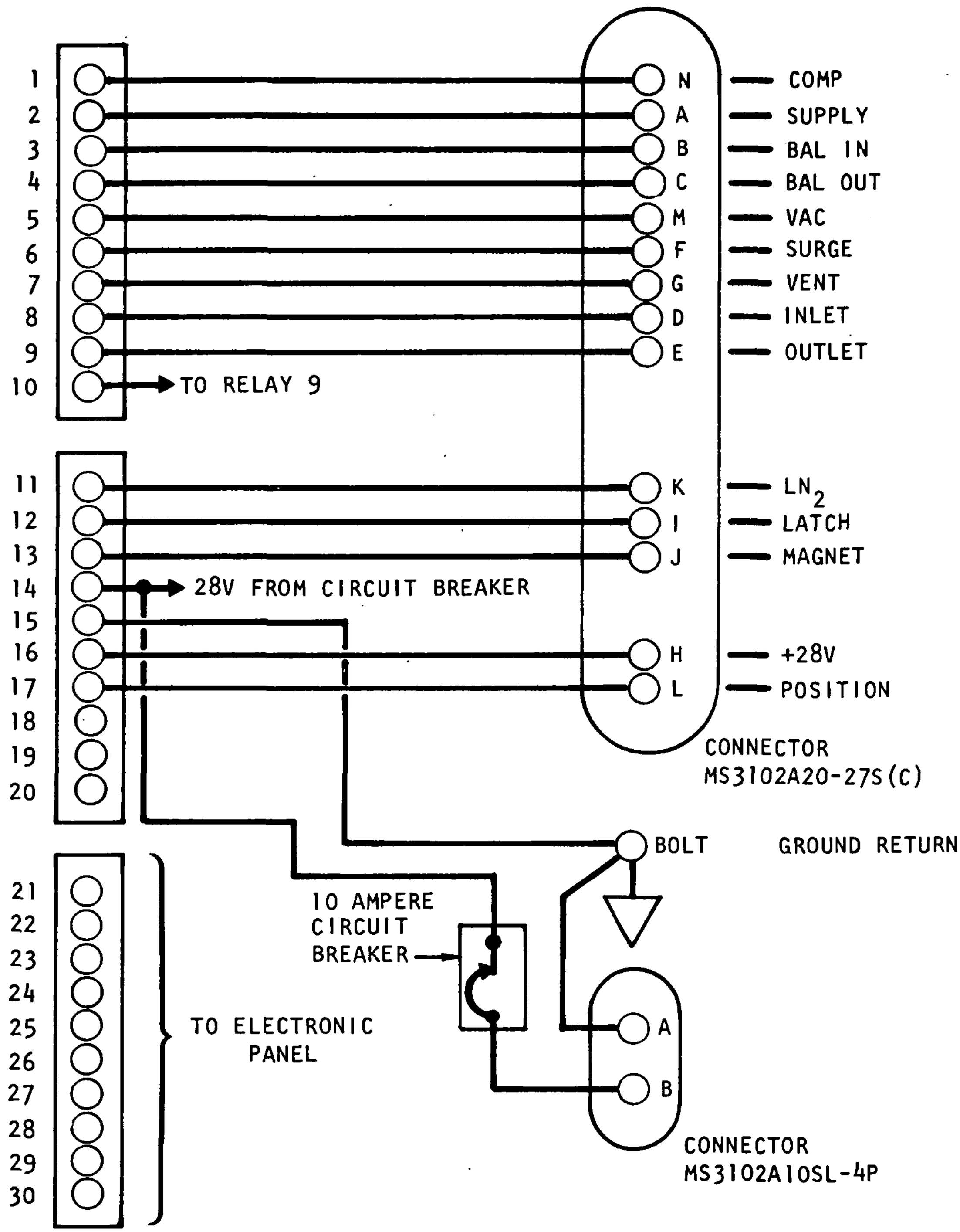


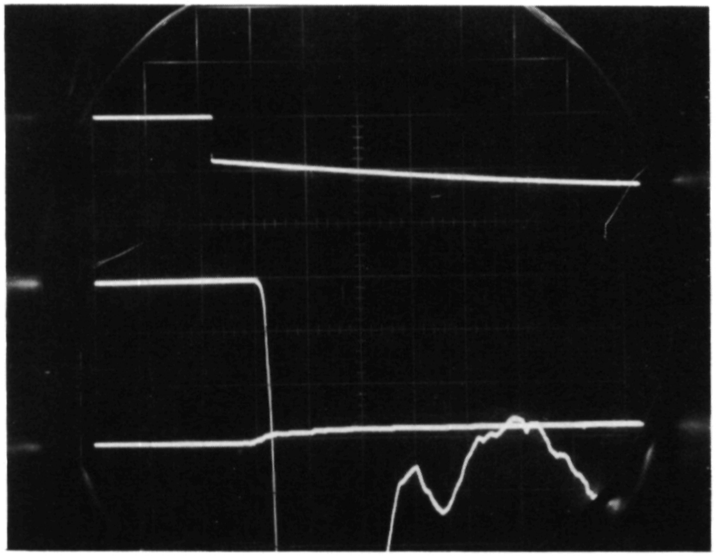
Figure A-25. Relay Panel Terminal Strip to Cable Connector Wiring be disconnected from automatic operation by a switch on the electronics panel marked AUTO-MAN. This switch removes the 24 volts from the high- and low-comparator relays. The relays R4 and R5 can be operated manually through S11 and S12. The normally closed contacts R4B and R5B are used to "override" the comparator. Located in the cell body is a switch than senses piston position. This switch operates R10 which is part of the drop logic. R10 also indicates piston position on I-1. When the piston is up, the upper half of I-1 is illuminated (yellow) and a green light cannot be obtained at balance. This indicates to the operator that the striker is not in the proper position for a test. Generally a tap on S12 will move the piston down. When the piston is down and pressure balanced, R6 will close. There are seven functions controlled by switches that are not in the logic loops. These functions are shown in Fig. A-21.

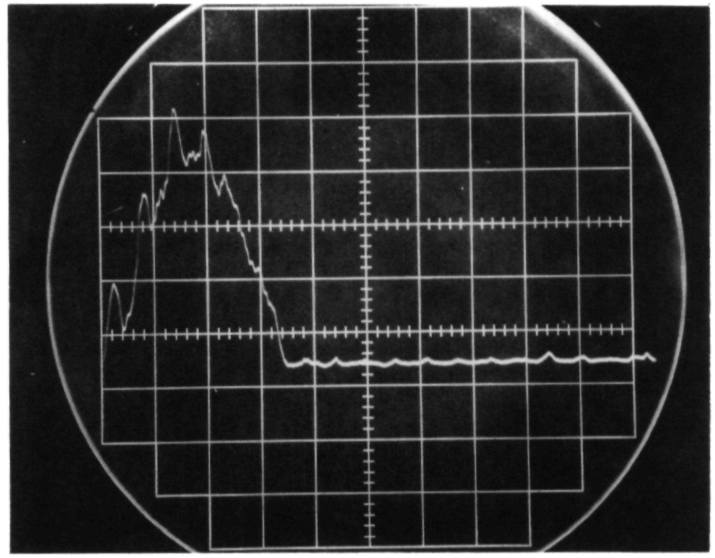
Figure A-22 shows the logic chain for the drop circuit. When the compressor has reached the cutoff pressure, R8 closes. The safety catch can now be retracted through S10. If the cell inlet valve S6 and outlet valve S7 are closed, and R6 is closed (balanced pressure, piston down, Fig. A-20) R7 will close. R7 closure removes a short (R7A) across the normally closed switch S13, the holding magnet switch. At the same time S13 goes "green" through R7A indicating the system is ready.

Oscilloscope

All analog measurements are made using the oscilloscope and camera. The oscilloscope (Tektronix 565) is essentially two single-beam oscilloscopes sharing a common cathode-ray tube and power supply. Each beam has separate vertical and horizontal deflection systems, focus, and intensity controls. The vertical amplifiers are dual-trace Type 3A6. The horizontal amplifiers are built-in and can be driven by either of two sweep systems, either simultaneously or independently.

The versatility of this system is endless. As an example, two vastly different traces are shown in Fig. A-26 . The figure on the left was made using three of the four channels and a common time base. The event was a Teflon coupon contaminated with oil. The measurements were: upper trace, velocity; center trace, light;





- Upper trace- lower velocity photocell
- Center trace-light
- Bottom trace-high frequency pressure
- Common time base 5 milliseconds/division
- Triggered from upper photocell

- Single trace of output of load cell
- 200 microseconds/division
- 20,000 lbf/division-vertical
- Internal trigger

Figure A-26 Oscilloscope Traces

and bottom trace, pressure. The load cell was removed for this test. The sweep was set at 5 milliseconds per division and was triggered when the plummet passed the upper velocity photocell. The plummet passed the second velocity photocell approximately 11 milliseconds later (upper trace). There is no significance in the negative going signal. In future tests it should be inverted (front panel switch) to get it "out of the way." Interpreting this trace, 11 milliseconds for 2 inches is equal to 66 milliseconds for 1 foot or 15.15 ft/sec (4.62 m/sec). Table A-2 is a list of average velocities over the 2-inch gate for various gate times. The second trace is the output of the light-sensing photocell located in the cell base. In this instance, the light was brighter than anticipated and the trace was driven off screen. Again this trace was also inverted. The bottom trace was the output of the Kistler pressure transducer and was set for 13.78×10^4 newton/m^2 (20,000 psi) per division. As can be seen, the pressure increased about 2.7×10^4 newton/m^2 (4000 psi). Inasmuch as vertical amplifiers are identical, any parameter can go in any position. The selection of amplifiers should be made inside the console (via patch cables) rather than across the face of the oscilloscope.

A schematic of the velocity gating circuit is presented in Fig. A-27. This circuit is used for external scope triggers and plummet catcher actuation.

A very different type of measurement is shown on the right of Fig. A-26. In this instance one parameter (force) was examined in detail. The single channel was on "B" time base, single sweep, and internal trigger. This permitted the sweep to be triggered by the event itself. Prior to the test, the time base was set to the desired sweep speed (in this photo 200 microseconds per division). The input to the vertical amplifier was disconnected and a jumper cable (furnished with the oscilloscope) was used to connect the amplitude calibrator to the vertical amplifier input. The amplitude calibrator was set to an amplitude of approximately 10 percent of the anticipated signal. The sweep trigger was adjusted for reliable operation at the 10 percent level. After removing the jumper and reconnecting the cable, the drop was made. No external trigger was required. Whenever internal trigger is used, a portion of the waveform leading edge is lost. However, if triggering occurs at 10 percent or less, the leading edge is usually reasonable abrupt and its prior history can be inferred from the trace. The load cell trace is quite similar to response predicted in pretest analysis.

TABLE A-2. PLUMMET VELOCITY (FREE-FALL) AT VARIOUS GATE TIMES

Gate Time, milliseconds	Velocity, ft/sec	Gate Time. milliseconds	Velocity, ft/sec
10	16.67	20	8.33
10.2	16.34	20.2	8.25
10.4	16.03	20.4	8.17
10.6	15.72	20.6	8.09
10.8	15.43	20.8	8.01
11.	15.15	21.	7.94
11.2	14.88	21.2	7.86
11.4	14.62	21.4	7.79
11.6	14.37	21.6	7.72
11.8	14.12	21.8	7.65
12.	13.89	22.	7.58
12.2	13.66	22.2	7.51
12.4	13.44	22.4	7.44
12.6	13.23	22.6	7.37
12.8	13.02	22.8	7.31
13.	12.82	23.	7.25
13.2	12.63	23.2	7.18
13.4	12.44	23.4	7.12
13.6	12.25	23.6	7.06
13.8	12.08	23.8	7
14.	11.9	24.	6.94
14.2	11.74	24.2	6.89
14.4	11.57	24.4	6.83
14.6	11.42	24.6	6.78
14.8	11.26	24.8	6.72
15.	11.11	25.	6.67
15.2	10.96	25.2	6.61
15.4	10.82	25.4	6.56
15.6	10.68	25.6	6.51
15.8	10.55	25.8	6.46
16.	10.42	26.	6.41
16.2	10.29	26.2	6.36
16.4	10.16	26.4	6.31
16.6	10.04	26.6	6.27
16.8	9.92	26.8	6.22
17.	9.8	27.	6.17
17.2	9.69	27.2	6.13
17.4	9.58	27.4	6.08
17.6	9.47	27.6	6.04
17.8	9.36	27.8	6
18.	9.26	28.	5.95
18.2	9.16	28.2	5.91
18.4	9.06	28.4	5.87
18.6	8.96	28.6	5.83
18.8	8.87	28.8	5.79
19.	8.77	29.	5.75
19.2	8.68	29.2	5.71
19.4	8.59	29.6	5.63
19.8	8.42	29.8	5.59

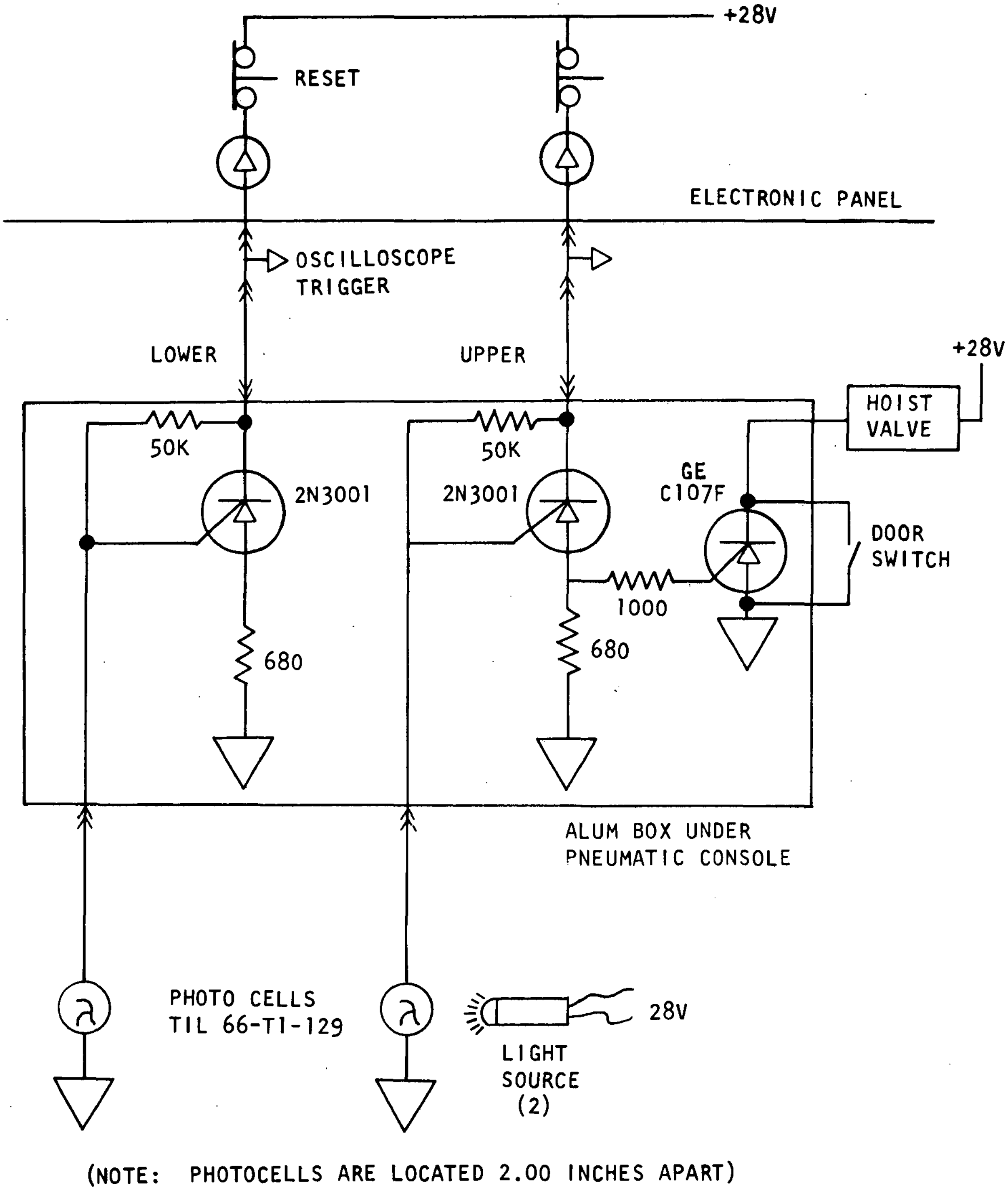


Figure A-27. Velocity Circuit

The exact requirements for testing will be developed through experience. However, a starting point can be given here:

1. Connect "B" time base external trigger to the upper photocell. Set both amplifiers to time base "B." Set sweep speed to 5 milliseconds per division and the operating mode to single sweep
2. Connect lower photocell to lefthand amplifier upper trace, set range to 5 volts per division
3. Connect output of load washer charge amplifier to lefthand scope amplifier-lower trace, and set range of 2 volts per division
4. Connect light-sensing photocell to righthand upper trace. Set range to 5 volts per division
5. Connect output of high-frequency pressure transducer charge amplifier to righthand scope amplifier-lower trace. Set range to 5 volts. Turn "B" time base function switch to normal sweep and turn trigger control to free run. Adjust traces to desired position on the screen. Reset function switch to single sweep, return trigger level control to the negative side of vertical. A few checks with the upper velocity photocell reset button will determine a reliable triggering point. The trigger should be set as near to zero as possible without spurious triggering. Once the trigger is set, the system is ready for test. Trigger reset should be checked just prior to dropping the plummet.

Measurement and Control Electronics (Digital Voltmeter)

Cell Pressure and Balance Pressure Logic. Cell and balance pressures are sensed by strain gage pressure transducers located in the pneumatic console. The transducer excitation is dc obtained from individual voltage regulators located behind the electronic panel. The electrical output of each transducer is amplified to 10 volts full scale in a series of amplifiers located on the printed circuit board. The digital voltmeter (dvm) continuously monitors the amplified output of the cell transducer; the 10 volts representing 10,000 psi. The balance pressure signal is brought out after the first amplifier stage where it is at the 1-volt, full-scale level. A pushbutton switch is available to transfer the dvm to the balance pressure signal where the 1-volt represents 1000 psi.

A third voltage regulator identical to the two transducer excitation regulators is used to provide a stable 10-volt reference signal. The reference is used in conjunction with the comparator circuits.

Comparator Circuits. Two separate electrical comparators are used. One shuts the compressor off when a preset pressure has been reached. The second comparator controls the balance pressure to maintain a fixed ratio between cell pressure and balance pressure. The compressor shutoff circuit consists of a two-input comparator in which the 10-volt output of the cell pressure amplifier is compared to a preset voltage. When the cell pressure signal exceeds the preset voltage, a relay is actuated stopping the compressor. The preset voltage is developed by a 10-turn potentiometer across the 10-volt reference. The dial on the potentiometer is graduated 0 to 1000, which corresponds to a 0 to 10,000 psi pressure signal.

The balance pressure comparator is a three-input or window comparator. The three inputs are input signal, set-point input, and window-width input. The comparator also has three mutually exclusive outputs: HIGH, GO, and LOW.

The window width is a deadband centered on the set-point input that determines the width of the GO signal. The three inputs are from a fixed source (window-width), cell pressure (set point), and balance pressure (input). In operation, as the cell is pressurized the set-point input increases in voltage, raising both upper and lower window limits. As soon as the lower window limit exceeds the input signal (balance pressure) the pressurizing valve (Bal IN) is opened increasing balance pressure bringing the input signal back into the window. Likewise, if the balance pressure input signal exceeds the upper window limit, the vent valve is opened and the pressure is reduced into the window value.

Electronic Panel. The electronic panel contains the electronics for the two strain gage pressure transducers, their associated controls and amplifiers, the two comparators, the velocity gate reset circuits, and the necessary power supplies.

The entire electronics panel operates from the 24-vdc facility power. There are three identical voltage regulators providing excitation for the cell pressure transducer, excitation for the balance pressure transducer, and 10 volts for the reference voltage. In addition to the three voltage regulators, a Burr Brown Model 528 power supply is used to provide ±15 vdc for the operational amplifiers and the comparators. The 24 vdc is connected to the three relays on the window comparator. A switch on the front panel can interrupt the 24-vdc power to the high and low comparator relays, thus disabling the automatic pressurization system and permitting manual operation (see Fig. A-28). The three voltage regulators are Motorola MC1560R. The circuit is shown in Fig. A-29, while operating curves are on vendor information sheets (enclosure 2 to this appendix).

On the front panel are six pushbutton switches. Two are reset switches for the velocity gates while four control the input to the digital voltmeter. The digital voltmeter normally displays the output of the cell pressure transducer circuit (10-volt level). Whenever one of the four switches is pushed the digital voltmeter is transferred to one of these four sense points: (1) voltage regulator (cell transducer) output, (2) voltage regulator (balance transducer) output, (3) voltage regulator (reference voltage) output, or (4) to the output of the balance pressure transducer circuit, 1-volt level (see Fig. A-30).

Mounted on the back of the electronics panel is the printed circuit (pc) board. This board contains the transducer voltage amplifiers and the two comparators (Fig. A- 31). The output of each transducer is 20 millivolts for full-scale pressure. The output voltage is amplified 50 times in the first amplifier stage (A1 and A2). At this point, it is at the 1-volt (full scale) level and is tapped off of the balance pressure transducer side for the pressure reading displayed on the digital voltmeter. The second amplifier stage of the cell transducer A3 has a gain of 10, bringing the full-scale signal to 10 volts. This is the operating

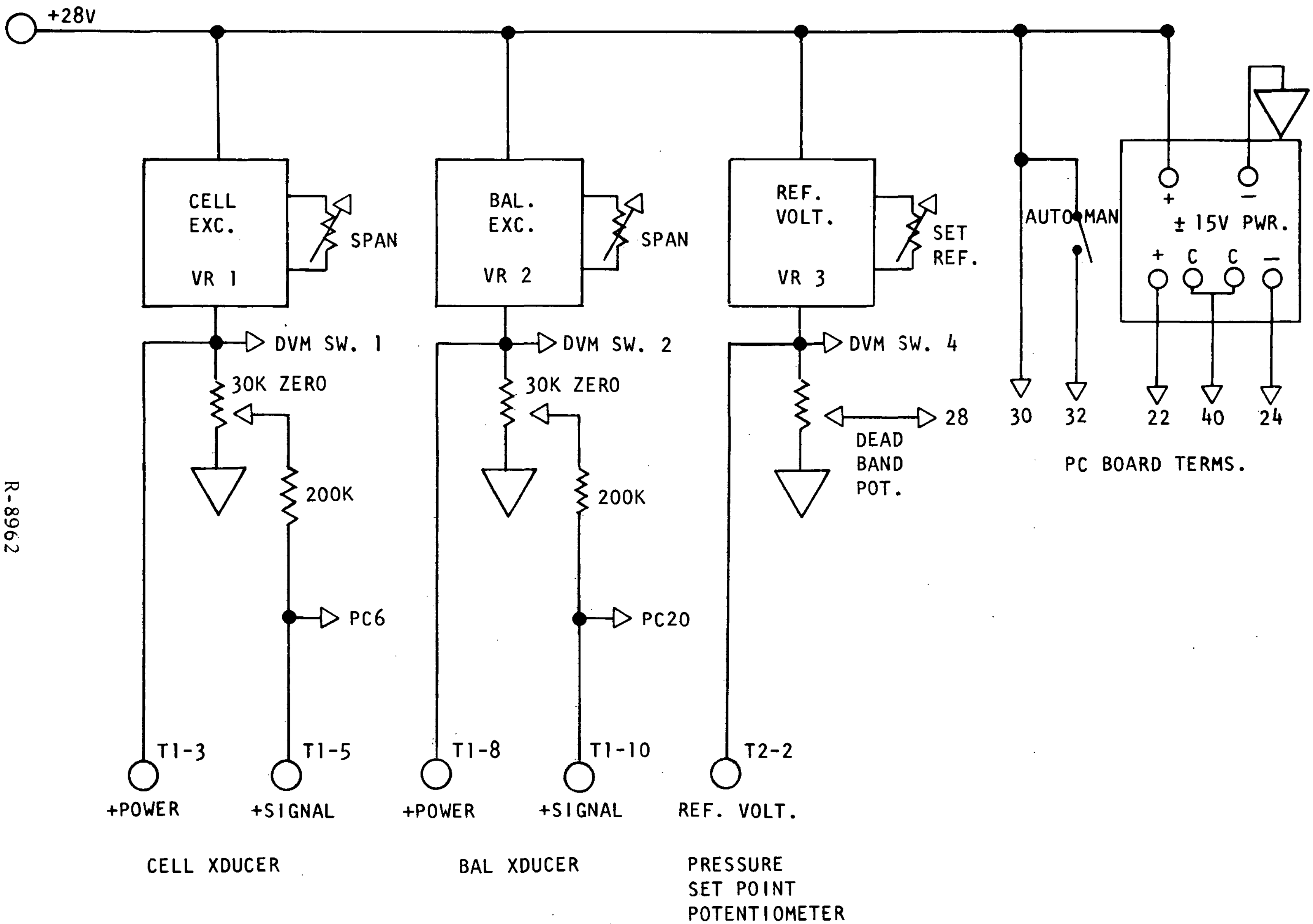
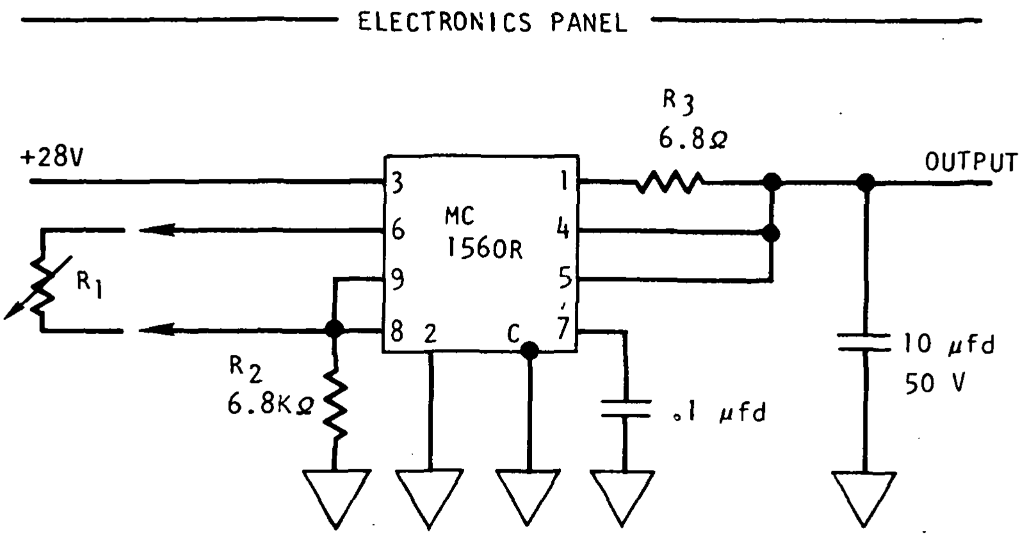


Figure A-28. Electronic Panel Wiring

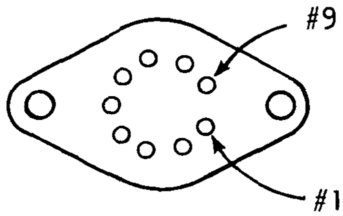


R_1 = 10 TURN POTENTIOMETER ON FRONT PANEL (10KΩ)
IN SERIES WITH A 5K FIXED RESISTOR.

R_3 = CURRENT LIMITING RESISTOR CHOSEN FOR 60
MILLIAMPERE SHORT-CIRCUIT CURRENT

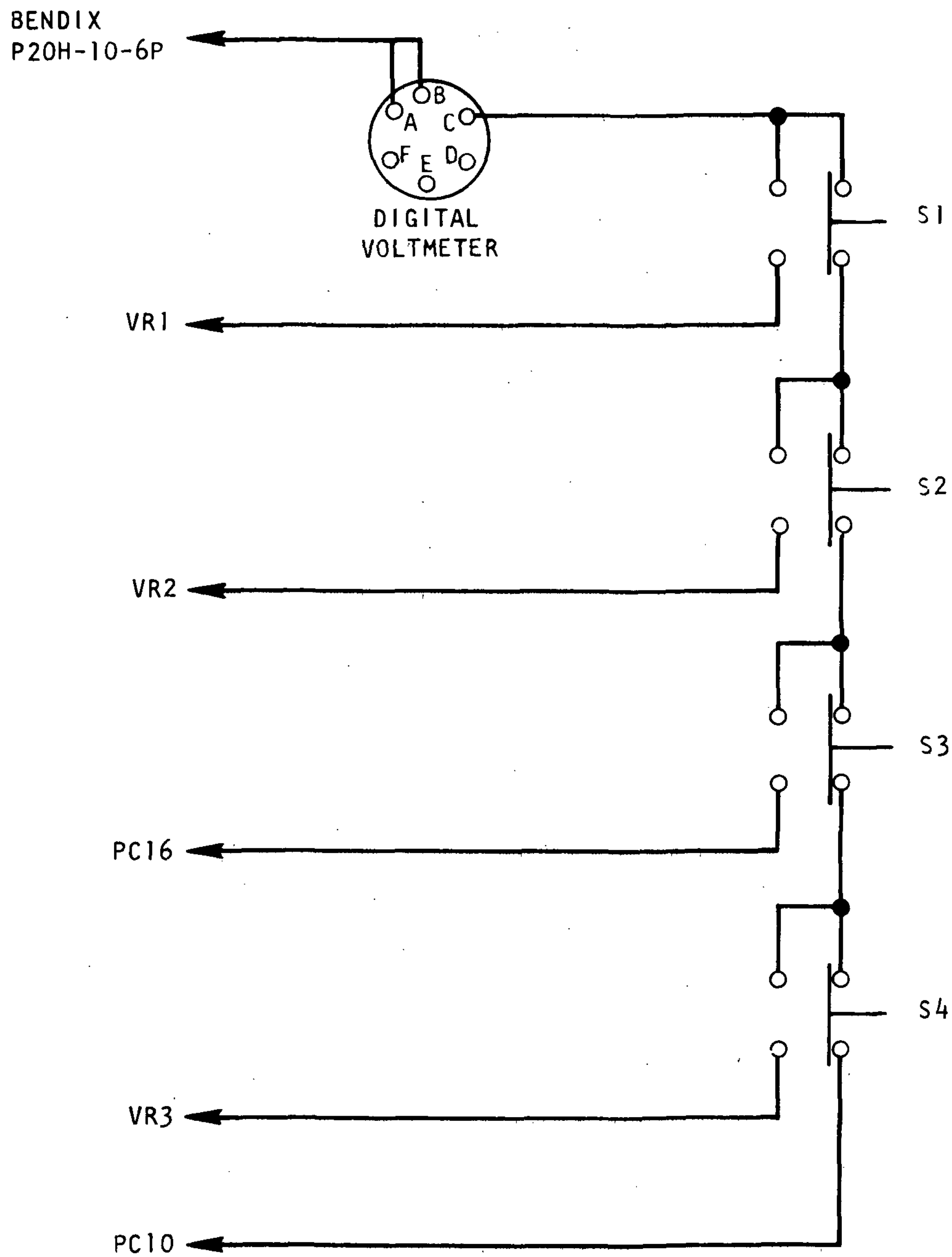
THIS CIRCUIT IS TYPICAL FOR:

VR3 REFERENCE VOLTAGE
VR1 CELL PRESSURE TRANSDUCER EXCITATION
VR2 BALANCE PRESSURE TRANSDUCER EXCITATION



MC1560R BOTTOM VIEW

Figure A-29. Voltage Regulator



S1 CELL PRESSURE TRANSDUCER EXCITATION

S2 BAL PRESSURE TRANSDUCER EXCITATION

S3 READ BALANCE PRESSURE

S4 REFERENCE VOLTAGE (IDV)

DIRECT: READ CELL PRESSURE

Figure A-30. DVM Input Circuit

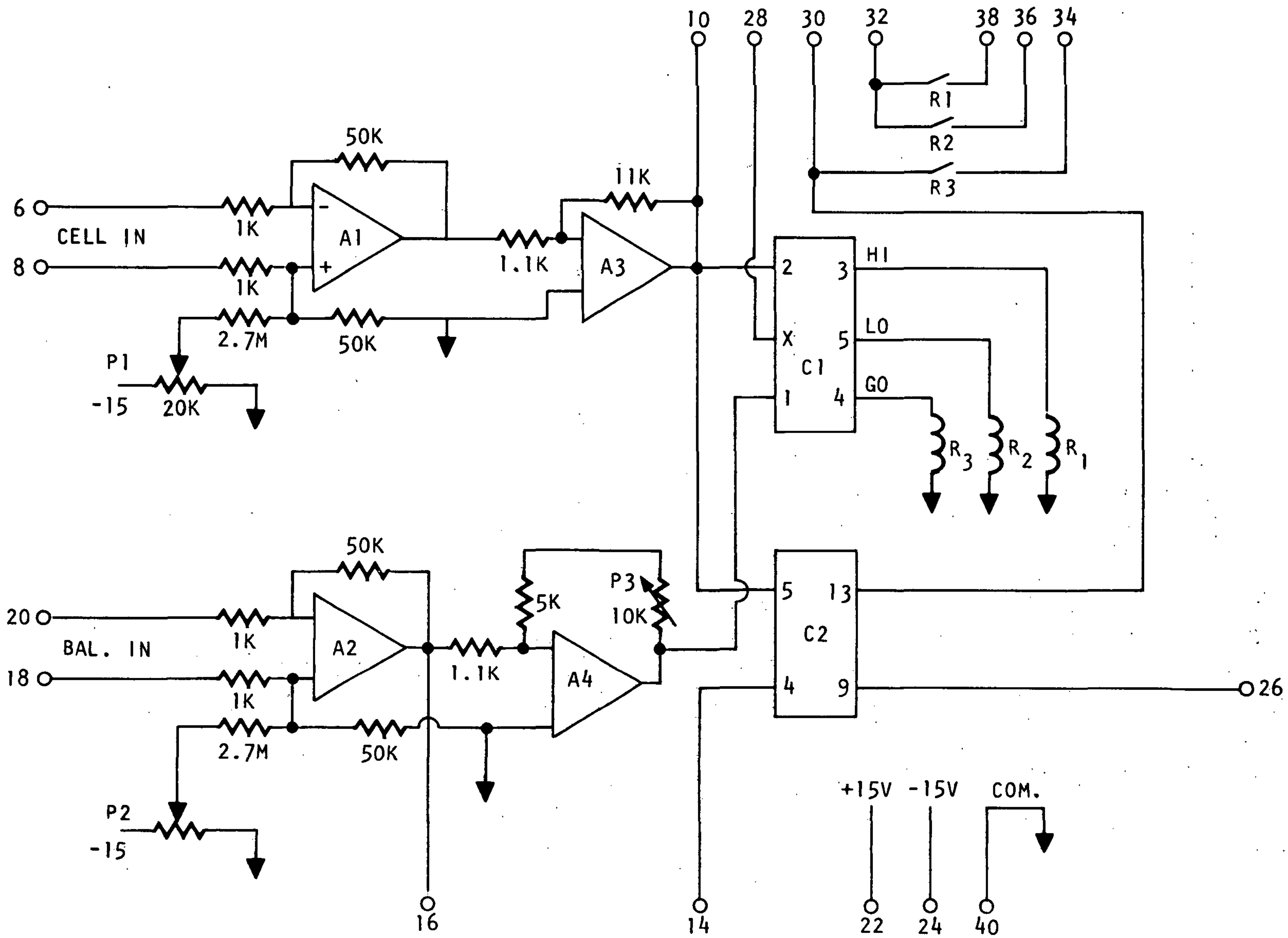


Figure A-31. Plug In Board

level of the comparators. The cell pressure output is connected to the digital voltmeter, to the high-pressure comparator (C2) and to the set-point input of the window comparator (C1). Each of the two input amplifiers has a zero balance potentiometer. This is used during initial set-up to compensate for unbalances in transducer wiring. The second amplifier stage of the balance pressure transducer has an adjustable gain so that the 10-volt output level can be obtained at some pressure that exactly balances the cell pressure. The exact balance-pressure-to-cell-pressure ratio is a function of the area ratio between the balance piston and the striker shaft (which is presently 10.23). Figure A-32 shows the parts layout on the pc board, and Fig. A-33 shows the electronic box terminal.

Calibration Procedures

Pressure Transducers. Calibration of the cell transducer requires a 6.9×10^{-4} newton/m^2 (10,000-psi) pressure gage as a working standard. A deadweight tester using distilled water is acceptable. (DO NOT USE OIL.) Turn on the 24-vdc power and the digital voltmeter 30 minutes before calibrating. Connect the standard to system through the compressor bypass handvalve. With the transducer vented, check the zero control to see if zero occurs somewhere between the second and eighth turn of the zero potentiometer. If zero occurs closer than two turns to the end of the potentiometer, return the potentiometer to the midpoint and using the zero balance on the pc board bring the system to zero. Exercise the system by applying full-scale pressure either from an external source or with the compressor and then venting. Reset the zero using the front panel control. Apply exactly full-scale pressure and adjust the span control to get full-scale reading on the dvm. Vent and check zero; correct if required. Check full-scale again; trim if required. Several intermediate points can be checked for linearity, if desired. The system is now calibrated.

Exactly the same procedure is followed calibrating the balance pressure transducer except that the scrupulous cleanliness required for a high-pressure oxygen system is not required for the pressure-balance GN_2 system. After calibrating the two transducers, their excitation voltages should be recorded in the log book.

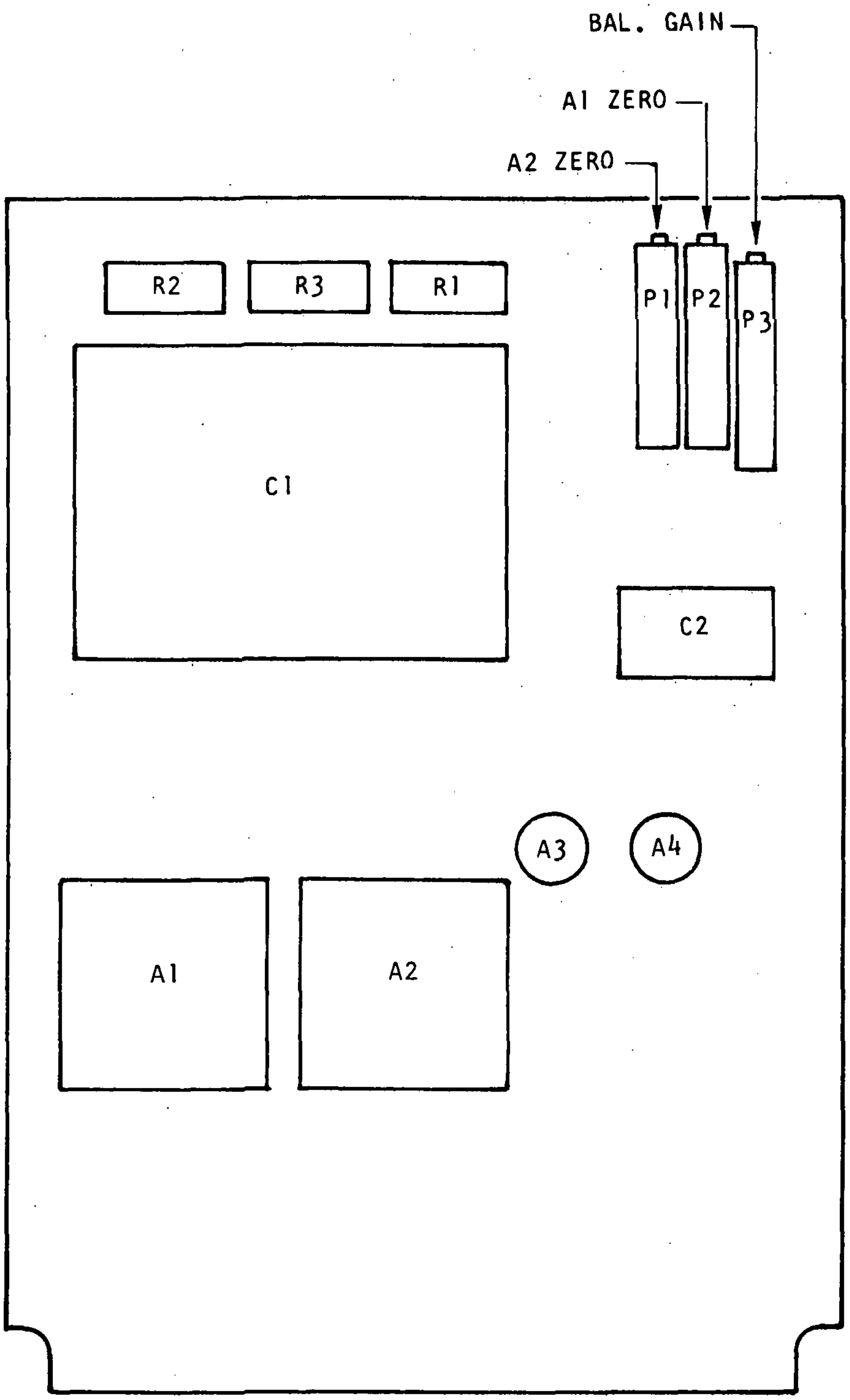


Figure A-32. Parts Layout PC Board

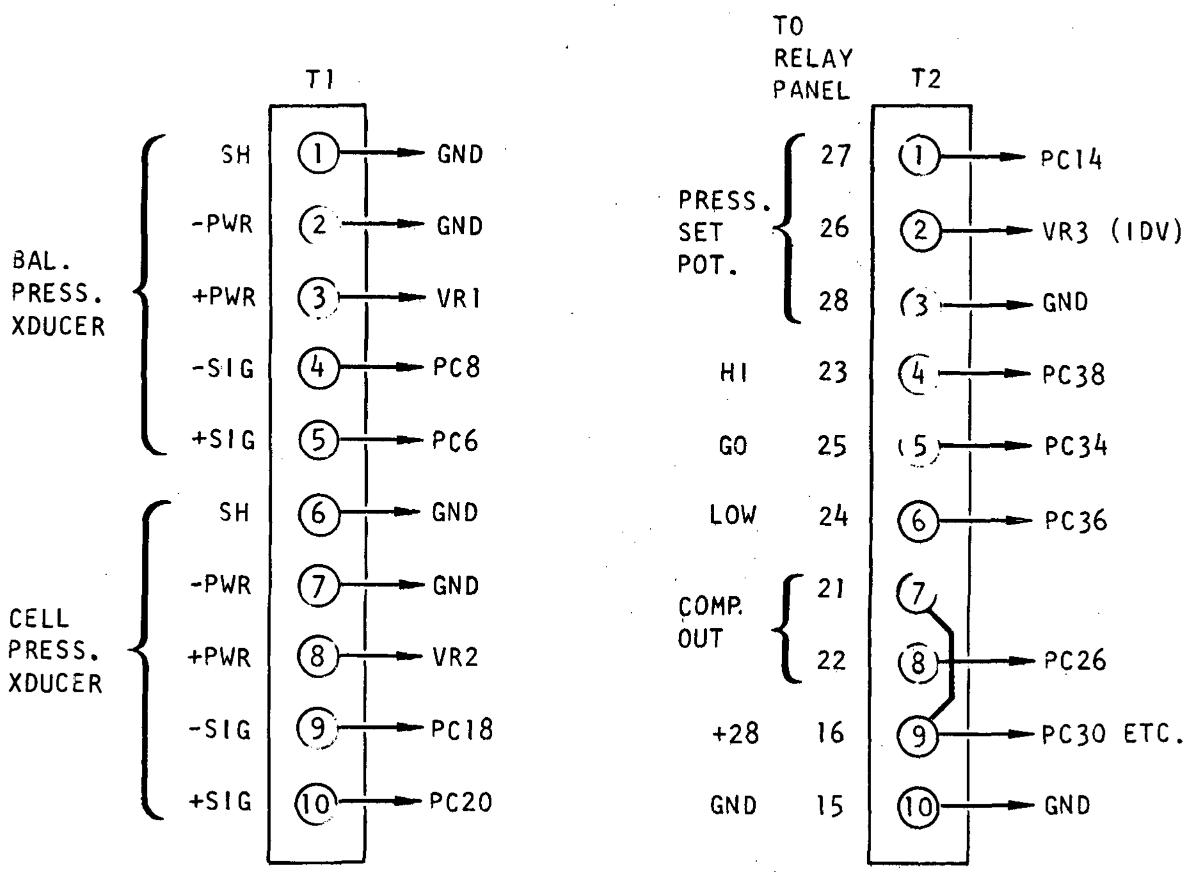


Figure A-33. Electronic Box Terminal

Kistler Pressure Transducer. Calibration of the 69 x 10^4 newton/m^2 (100,000 psi) pressure transducer over its entire range is a difficult laboratory procedure. A simple quick check of performance can be made: set the gain on the charge amplifier to 1000 psi/volt. Pressurize the cell to some relatively high pressure (7000 to 10,000 psi). Zero the pickup by pressing the ground button on the charge amplifier. Close the cell inlet valve and vent the cell. A negative going signal equal to the full-scale pressure should be observe in the amplifier output. This can be measured using the oscilloscope or a voltmeter. (If using a voltmeter, set the charge amplifier on long-time constant.) If the transducer fails to give this response, return it to the manufacturer for repair and calibration. A spare transducer is supplied with the tester.

Load Cell. The same difficulty of calibration as with the pressure pickup exists with the load washer. A calibration can be made using a hydraulic press or dead weights. To get a relatively fast change it is best to work in the negative direction (i.e., unload the weight rather than apply it). As in the case of the pressure transducer, a simple performance check will suffice in lieu of an elaborate calibration. Choose a standard specimen and make periodic low-energy drops. If the oscilloscope traces repeat, the transducer is working. If the traces suddenly change, the transducer should be returned to the manufacturer for inspection and calibration.

Digital Thermometer. Thermocouple temperatures are indicated on a Digitec (Model 560 TCO) digital thermometer. Four positions can be selected--two impact cell positions, one in the surge tank, and one in the heating bath. Calibration of the thermocouple lead is easily accomplished by first pushing the ICE point button and adjusting the top knob to exactly zero on the meter. Likewise, adjust calibrator circuit to 388.8 on meter. All thermocouples must be copper-constantan. Detailed instructions can be found in the Digitec Manual.

Temperature Control Bath

A temperature control bath is located in the bottom of the control console. The bath is a Lauda NBS-HT high-temperature circulating bath with all-stainless-steel construction. The internal volume is 7-1/2 gallons and the heater is rated at 2000 watts. Integral cooling coils in the cover plate provide refluxing of the hot oil vapors that are generated at high temperatures.

The unit is equipped with an electronic relay (R-10) for proportional heater control and a digital thermoregulator (R-20) for automatic temperature control. A platinum resistance thermometer is used to give accurate temperature feedback. The circulating pump will pump 3.5 gpm at zero head. Maximum head capacity is 14 feet. The unit is connected to the impact cell heating channels via high-temperature-resistant rubber hoses. Dow Corning silicon oil (No. 200) is used as the heating fluid. A valve on the pump provides on/off circulation control.

The heating surface in the impact cell may be doubled by jumpering the heating and cooling passages so that the hot oil has a two-pass exposure to the cell base. This arrangement can also be used in cooling the impact cell. However, the convenience of having separate cooling and heating channels must be sacrificed.

The heating bath is turned on by merely pushing the "heat" button on the graphic control panel. A 24-vdc relay turns the 120 vac on to the electronic relay and controller. For maximum heating rate during initial warmup, depress the MAX HEATING button on the R-10 electronic relay. This bypasses the proportional control until the control point is first reached.

OPERATING PROCEDURES

The following stepwise procedures are presented as a guide to efficient operation of the Rocketdyne oxygen compatibility tester. The sequence and the procedures themselves should be modified as more experience is gained in operating this unit. Also future modifications will necessarily require procedural changes.

STARTUP

1. Open GN_2 and GOX cylinder valves to pneumatic enclosure (GN_2 >1200, GOX >500 psig).
2. Turn all power on:
   a. Plug in control console, vacuum pump, and compressor to appropriate outlets.
   b. Push POWER button on graphic display to turn on 24 vdc system. Make certain that the compressor does not come on when the POWER button is actuated. The only lights that should be on are the VENT, CELL OUT, READY, and BALANCE.
   c. Turn on charge amplifiers and peak meter.
   d. Turn on oscilloscope.
   e. Turn on digital thermometer and voltmeter.
   f. Turn on heating bath if required (also circulate water through cover plate).
3. Allow 20 to 30 minutes for warmup.
4. Check calibrations of thermometer and voltmeter as recommended by Digitec Instruction Manual.
5. Check scope setting for proper range and trigger sensitivity.
6. Make sure pressure-balance system is vented by checking pressure gage (P-6) on the pneumatic enclosure. If not zero, push white BAL OUT button on the balance system until vented.

7. Manually disengage plummet and lower by hand down to the top velocity light so that the catcher will actuate and cock the plummet back to the electromagnet.

CAUTION

Keep arms and fingers away from catcher rail and catch/plummet mating surface.

8. Remove load cell washer and install spacer on the plummet nose if loadings of over 445,000 newtons (1000,000 pounds) are expected (see Eq. 1).

SAMPLE EVALUATION

1. Remove impact cell head, striker assembly (see Fig. A-1). Disconnect microswitch wire and pressure balance flex line.

2. Remove old sample, clean, and install new sample as recommended by sample preparation procedures.

3. Replace body seal, striker tip, and sample cup as required.

4. Reinstall impact cell head and reconnect microswitch wire and balance pressure hose.

5. Evacuate and purge impact cell three times to ensure the removal of all cleaning solvent and air. This is accomplished by manual manipulation of hand valves on front of pneumatic enclosure. The manual vent valve (see Fig. A-9, A-11, and A-15) must be closed and the CELL OUT valve opened during this operation. After the last cell purge pressurization close the CELL OUT valve, close purge valve, and open the manual vent valve. Turn the vacuum pump off and vent vacuum line by opening vacuum hand valve until gage (P-5) is zero. Close vacuum hand valve, and make certain that the purge valve is closed and vent (hand) valve is open.

6. Reset velocity gates and plummet catcher (catcher should be down).

7. Adjust height and plummet weight to the desired values.

8. Turn pressure-balance system switch to AUTO.

9. Open CELL IN by pushing appropriate button on graphic display.

10. Set desired test pressure on potentiometer (reading in kilo psig) and push READY light to reset automatic pressurization circuit.

11. Push COMP button to turn on compressor. Supply valve will automatically open also.

12. The pressurization system will now pump the impact cell and associated plumbing to the desired pressure and shut off the compressor and supply valve automatically. While the system is pressurizing, watch pressure P-3 and the transducer P-A output on the digital voltmeter (calibrated in kilo psig) for compressor malfunction or gross system leaks.

13. Pressure-balance should be attained automatically as the system is pressurized. Watch for green light on BALANCE. Striker will be down on sample and balanced with respect to static pressures.

    NOTE: Initial pressurization in cold hardware will result in pressure decay. When the green READY light goes out merely reset by depressing the light so that the pressure will be returned to the desired level.

14. Reset peak meter and velocity gates.

15. Take a picture (Polaroid) of the scope-scale background by turning the scale illumination to desired level and opening the camera shutter for three seconds. Turn the scale illumination off after taking the picture.

16. Check green lights on READY and BALANCE. Reset if required.

17. Unlock plummet latching solenoid. Light will not turn green if BALANCE and READY are not green.

18. Reset trigger on scope (single sweep mode) so that only top velocity gate reset button will trigger (negative triggering slope).

19. Read and record operating pressure and temperature from digital readouts.

20. Close CELL IN. At this time the green GO light should come on indicating a GO condition for dropping the plummet.

21. Open the camera shutter, watch the scope, and push the GO button.

22. Release GO button and camera shutter.

23. Lock plummet latch solenoid.

24. Open vent valve and cell out.

25. Reset velocity gates, and push COMP button to turn compressor off automatic pressurization mode.

26. Remove the picture from the camera and record pertinent information.

27. Make certain impact cell and feed system are vented by noting P-3 cell pressure gage, and digital voltmeter. Likewise, examine P-6 balance pressure to determine if pressure-balance system is vented. Push BAL OUT if required until pressure is zero.

> NOTE: This is the proper point to shut down for the day, if more samples are not going to be tested. To continue testing new samples, merely repeat the Sample Evaluation procedure (1 through 27).

SHUTDOWN

1. Turn heating bath off. Leave coverplate cooling water on.
2. Reset velocity gates, and plummet catcher (down).
3. Close oxygen feed cylinder valve.
4. Turn power off all instruments and controls as indicated in STARTUP, step 2.

Sample Preparation

Specific cleaning procedures and sample preparation techniques have been left to the discretion of the user. Extension of the specifications in MSFC-SPEC-106B would be a good basis for high-pressure oxygen sample preparation since sample size is the same.

Some considerations worth mentioning are the in situ cleaning of the impact cell base, vacuum capability, and system passivation. Because the base of the cell remains attached to the impact tower between tests, satisfactory on-location type cleaning procedures must be devised. A triple swabbing with technical grade trichloroethylene on clean (nonshredding) cheesecloth was used for development and qualification testing.

Since the impact cell is closed after a new sample is installed, a good vacuum can be pulled on the sample cavity to remove any residue solvent and, of course, the included air. A low-pressure oxygen purge allows prepressurization between evacuations, so that a series of evacuations can be used to ensure cleanliness and removal of all air.

System passivation is recommended when installing new hardware into the high-pressure oxygen supply system. The amount of increased oxidation at high oxygen concentrations is not known; therefore, slow sequential pressurization to operating pressures is recommended with new or recently cleaned hardware.

MAINTENANCE CONSIDERATIONS

Throughout the description and procedures sections of this manual, various precautions were noted. These considerations, along with other maintenance suggestions, are presented in this section. Specific maintenance procedures for commercially manufactured equipment and hardware should be obtained from the Vendor Instruction Manuals (see Enclosure 2).

IMPACT TOWER AND CELL ASSEMBLY

During the hardware design phase, maintenance was considered as a major factor because of the length of time the tester would be expected to operate with little or no maintenance. Corrosion-resistant steels were used throughout requiring only periodic cleaning to maintain finish luster.

Maintenance of the impact cell includes: (1) regular striker tip and sample cup resurfacing to maintain the normality and flatness of these impact surfaces; (2) checking the striker for straightness, changes in diameter, and sealing surface damage; and (3) periodic inspection of the cell body inserts and lubrication of the associated bolts.

As mentioned previously, the coax cables to the high-frequency pressure transducer and load cell (both Kistler) must be protected from damage and connections must be dry.

The plummet and catcher rollers should be inspected for cracks and nicks and replaced, as required. The air cylinder on the plummet catcher is prelubricated for a period of 12 months. When lubrication is required, disassemble by removing the end caps and lubricate the moving parts with a high-pressure grease. Lubricate pulleys and rollers on the impact tower with a light machine oil whenever necessary.

PNEUMATIC ENCLOSURE

Reference should be made to vendor instruction manuals particularly for the diaphragm compressor. Most hardware in the enclosure is maintenance-free. The valve actuation pressure should be maintained at between 90 to 115 psig.

Periodic inspection for leaks in the high-pressure oxygen supply system can be conducted by pressurizing with GN_2 instead of GOX to minimize safety hazards. Leaks can be readily detected on the digital voltmeter pressure readout since the meter reads in units of pressure (psi).

CONTROL CONSOLE

Most of the equipment in this unit is made by commercial manufacturers. The respective instruction manuals should be used for proper maintenance procedures (see Enclosure 2). Some added suggestions are: (1) use charge amplifier ground buttons when connecting or disconnecting any device on the amplifier input cables; and (2) when using the heating bath, make sure the oil vapors are not condensing in the control console but are confined to the water-cooled coverplate and glass condenser.

ENCLOSURE 1

HARDWARE BLUEPRINTS AND ROCKETDYNE DRAWING NUMBERS

(Provided to MSFC Only)

MATERIAL INSPECTION AND RECEIVING REPORT

1. PROC. INSTRUMENT IDEN (CONTRACT): NAS8-27480
ORDER NO.:
6. INVOICE NO.: DATE:
7. PAGE 1 OF 1
8. ACCEPTANCE POINT: D

2. SHIPMENT NO.: ERC 0017
3. DATE SHIPPED: 72APR04
4. B/L TCN: (G)
5. DISCOUNT TERMS:

9. PRIME CONTRACTOR CODE:
Rocketdyne Division
North American Rockwell Corporation

10. ADMINISTERED BY CODE:
NASA/MSFC

11. SHIPPED FROM (IF OTHER THAN 9) CODE: FOB:

12. PAYMENT WILL BE MADE BY CODE:
Financial Management Office
NASA/MSFC, Ala. 35812
Attn: A&TS-FIN-AG

13. SHIPPED TO CODE:
National Aeronautics & Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, Ala.
35812

14. MARKED FOR CODE:
Attn: S&E-ASTN-MCP
(Mr. John G. Austin, Jr.)

15. ITEM NO.	16. STOCK/PART NO. DESCRIPTION (INDICATE NUMBER OF SHIPPING CONTAINERS-TYPE OF CONTAINER-CONTAINER NO.)			17. QUANTITY SHIP'D/REC'D.	18. UNIT	19. UNIT PRICE	20. AMOUNT
*SEE BELOW	One (1) copy each of the following dwgs:			42			
	RS003064-X	RS003075-X	RS005261-X	RS005271-X			
	RS003065-X	RS005251-X	RS005262-X	RS005274-X			
	RS003066-X	RS005252-X	RS005263-X	RS005275-X			
	RS003067-X	RS005253-X	RS005264-X	RS005272-X			
	RS003068-X	RS005254-X	RS005265-X	RS005273-X			
	RS003069-X	RS005255-X	RS005266-X	RS005716-X			
	RS003070-X	RS005256-X	RS005267-X	RS005717-X			
	RS003071-S	RS005257-X	RS005268-X	RS005719-X			
	RS003072-X	RS005258-X	RS005269-X	RS005720-X			
	RS003073-X	RS005259-X	RS005270-X	RS005721-X			
	RS003074-X	RS005260-X					

21. PROCUREMENT QUALITY ASSURANCE

A. ORIGIN
[ ] PQA [ ] ACCEPTANCE OF LISTED ITEMS HAS BEEN MADE BY ME OR UNDER MY SUPERVISION AND THEY CONFORM TO CONTRACT, EXCEPT AS NOTED HEREIN OR ON SUPPORTING DOCUMENTS.
DATE — SIGNATURE OF AUTH GOVT REP
TYPED NAME AND OFFICE

B. DESTINATION
[ ] PQA [ ] ACCEPTANCE OF LISTED ITEMS HAS BEEN MADE BY ME OR UNDER MY SUPERVISION AND THEY CONFORM TO CONTRACT, EXCEPT AS NOTED HEREIN OR ON SUPPORTING DOCUMENTS.
DATE — SIGNATURE OF AUTH GOVT REP
TYPED NAME AND TITLE

22. RECEIVER'S USE
QUANTITIES SHOWN IN COLUMN 17 WERE RECEIVED IN APPARENT GOOD CONDITION EXCEPT AS NOTED.
DATE — SIGNATURE OF AUTH GOVT REP
TYPED NAME AND OFFICE
* IF QUANTITY RECEIVED BY THE GOVERNMENT IS THE SAME AS QUANTITY SHIPPED, INDICATE BY (✓) MARK, IF DIFFERENT, ENTER ACTUAL QUANTITY RECEIVED BELOW QUANTITY SHIPPED AND ENCIRCLE.

23. CONTRACTOR USE ONLY
A. G.O.: 9361 | B. SUB-ACCT | C. | D.
E. CONTROL NUMBERS
F. | G. GROSS WT. | H. CUBE
I. LENGTH | J. WIDTH | K. HEIGHT

OTHER CONTRACTOR INFORMATION:
P. * FOR REVIEW AND APPROVAL IN COMPLIANCE WITH EXHIBIT "A", PARA. "E", ITEM 2.

UNCLASSIFIED

L. CERTIFICATION - INSPECTION & CONTRACT PERFORMANCE: [signature] 72APR04
M. PACKAGING INFORMATION: GOLDENROD
N. PREP DATE: 72APR04
O. PACKING LIST NO.: Z-72-6680 bfp

DD FORM 250, AUG 67 — REPLACES EDITION OF 1 OCT. 1966 WHICH MAY BE USED

ENCLOSURE 2

MANUFACTURER SUPPLIER INSTRUCTION MANUAL AND INFORMATION SHEETS
(Provided to MSFC Only)

1. Ballistics (High Frequency) Pressure Transducer, Model 207C(X) and 607C(X), Kistler Instrument Co.
2. Quartz Load Washer, Model 900A Series, Kistler Instrument Co.
3. Peak Meter Indicator, Model 538A, Kistler Instrument Co.
4. Dual Mode (Charge) Amplifier, Model 504D, Kistler Instrument Co.
5. Oscilloscope, Type RM565 (Serial No. 4524), Tektronix, Inc.
6. Oscilloscope Camera System (Serial No. 9140), Tektronix, Inc.
7. Dual Trace Amplifier, Type 3A6 Plug-In (Serial No. 13485 and 13488) Tektronix, Inc.
8. OMNI Seals, Catalog 114, Aeroquip Corp.
9. Constant Temperature Circulator, Manual #124A, Launda, Inc.
10. Diaphragm Comp ssor, Aminco #46, Hand Operated or Motor Driven, Amenican Instrument Co.
11. Digital Thermocouple Thermometer, Series 590, M1-1387, Digitec, United System Corp.
12. Digital Voltmeter, Model 268, M1-1391, Digitec, United System Corp.
13. Pressure Cell, DHF, (15-DHF-2), BLH Electronic, Inc.
14. Power Supply, Dual 15 VDC, Model 528
15. Comparators, Catalog PDS-221, Burr-Brown Research Corp.
16. Integrated Circuits, 3500 Series, Burr-Brown Research Corp.
17. Miscellaneous Information Sheets.