NATIONAL BUREAU OF STANDARDS REPORT

7006

A HIGH VACUUM PROTECTIVE CIRCUIT

by

E. P. Levine*
R. M. Mills

*Participating in Junior Scientist and Engineer Program 1960

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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ABSTRACT

An alarm device is described which protects the vacuum system of a mass spectrometer in the event of a malfunction during the operator's absence. The vacuum pressure is monitored by a thermocouple vacuum gauge which is connected to a meter-relay. If the thermocouple reading falls below a certain predetermined level, indicating a loss of vacuum, or if the diffusion pump cooling system fails, a system of relays is made to act in such a way that the diffusion pumps are turned off, a calibrated meter replaces the meter-relay to give an accurate reading of the vacuum level, and an alarm bell is sounded.

INTRODUCTION

A time-of-flight mass spectrometer is under construction here which will be used to study ionic reactions in a flame. The mass spectrometer has three sections: a flame chamber operated at several centimeters of pressure, an intermediate vacuum region which is kept between 10^{-3} and 10^{-4} mm of Hg, and a final, high vacuum, drift tube region maintained at about 10^{-5} mm of Hg. Oil diffusion pumps are used in the last two sections. It is often desirable to allow the vacuum pumps to run when the operator is not at the controls of the mass spectrometer. However, if a leak in the vacuum system develops, or if the diffusion pump cooling system fails, serious damage will be done to the pumps if they are not turned off. The device described was designed to automatically protect the vacuum system from such damage.

Thermocouple tubes may be used to detect a loss of vacuum in time to protect the diffusion pumps, but at pressures below 10^{-3} mm of Hg, they are not capable of furnishing accurate vacuum readings. An ionization vacuum gauge is therefore used in the drift tube section to indicate when a suitably high vacuum has been reached. However, as with the diffusion pumps, damage will be done to the ionization gauge if it is operated at pressures above 10^{-3} mm of Hg and thus the protective circuit turns off the ionization gauge together with the diffusion pumps if it is being used at the time of an alarm.

DESIGN

The protective system can be operated without the automatic arrangements described above when switch, S_1, shown in figure (2) is in the manual position. In this position the circuit alarms only in the event of a cooling water failure. A micro-ammeter which has been calibrated to give pressure readings is connected to one of the two thermocouple tubes, depending on the position of switch S_2 shown in figure (2). Relay R_6 is essentially an on-off switch for the thermocouple gauge heaters. The circuit is used in the manual position in the early part of the pumping operation before high vacuum has been reached. After the diffusion pumps begin to operate, the circuit may be switched to the automatic position. Figure (1) is a block diagram of the system in the automatic position. If the thermocouple readings are maintained at a sufficiently high level and if water flows through the diffusion pumps cooling jackets at a satisfactory rate, the relay switching system supplies power to the diffusion pumps. The wiring is such that the mechanical pump switch must be on in order for the power to reach the diffusion pumps. Likewise, the ionization gauge can be operated only if one or both of the diffusion pumps are on. In the automatic position, the thermocouple tubes are no longer connected to the micro-ammeter; instead the thermocouple tube outputs are placed in series and connected to the meter relay. If low emf values from either gauge cause the indicating pointer of the meter relay to fall below an adjustable level, the power to the diffusion pumps is cut off, the alarm bell is sounded, and the calibrated micro-ammeter replaces the meter relay so the operator can quickly observe where the vacuum failure has occurred.

Closing the circuit between the indicating and adjustable pointers in the meter relay shorts current away from relay R_2, causing it to deactuate. Resistors R_8 and R_9 were chosen so that (a) sufficient current flows when the meter relay circuit is open to actuate relay R_2, (b) a sufficiently small current flows through R_2 when it is shorted by the closed meter relay circuit to deactuate relay R_2, and (c) the maximum allowable current through the meter relay is not exceeded. Relay R_3 is actuated whenever R_2 is actuated. It is used to connect either the meter relay or microammeter to the thermocouple vacuum gauges.

The outlet of the cooling tubing is impeded slightly so that there is a pressure rise when water is flowing properly. It is this pressure rise that causes a pressure sensitive switch to make when the water is on and break when water is not flowing. It was necessary to use relay R_5 with the pressure switch to handle the power requirements of the diffusion pump heaters. Note that power from relay R_5 must pass through the diffusion pump switches before reaching the alarm bell. This prevents the alarm from sounding when both the diffusion pumps and water are turned off.

Figure (3) shows the front panels of the vacuum protective and control systems.

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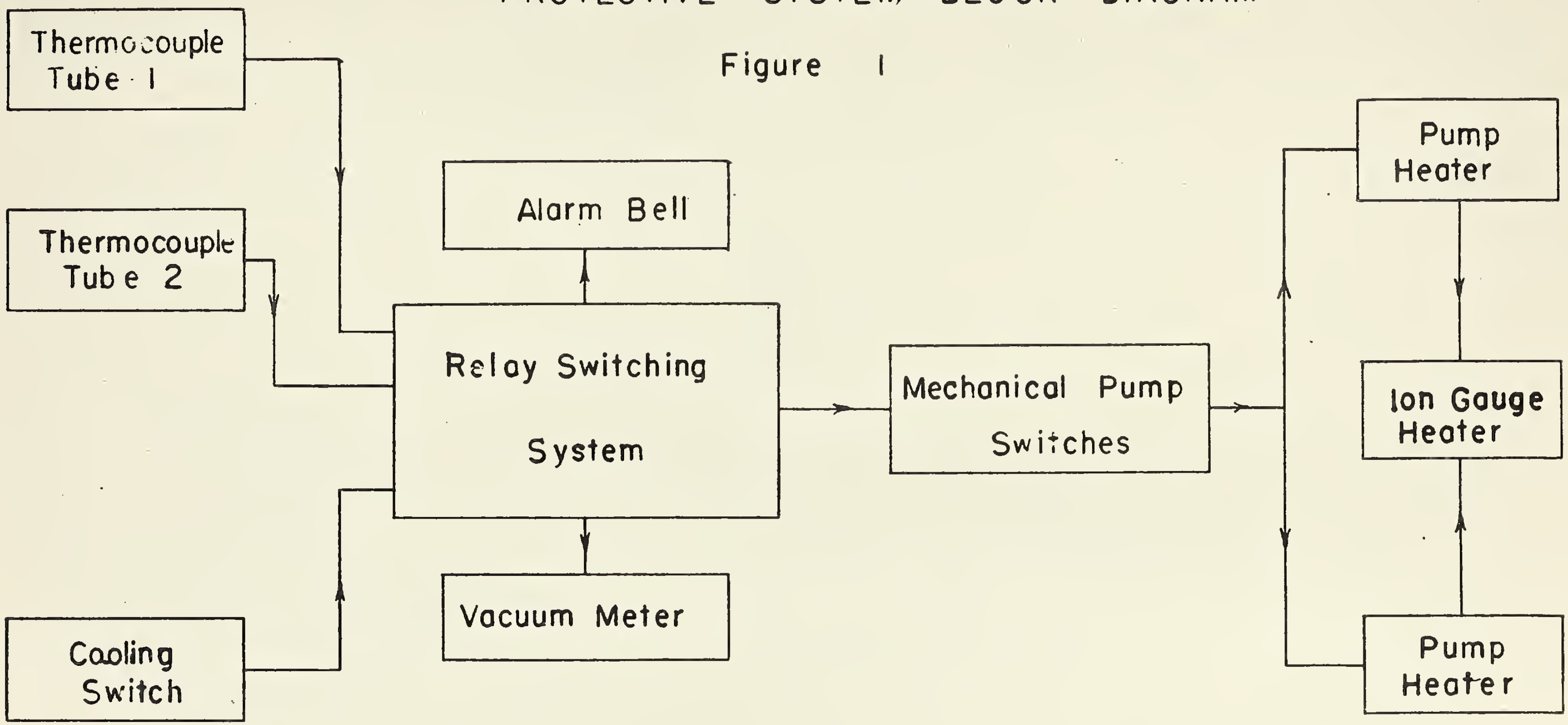
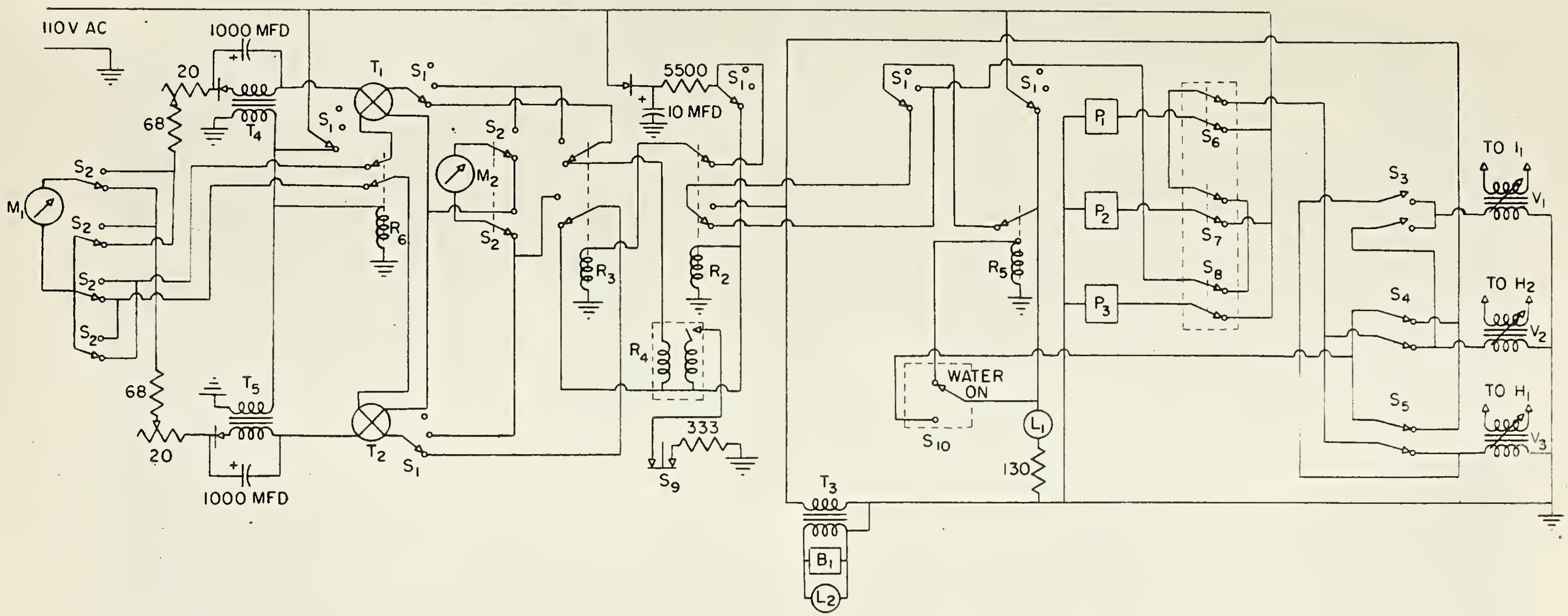
PROTECTIVE SYSTEM BLOCK DIAGRAM

Figure 1





B_1 ALARM BELL

$H_1 H_2$ OIL DIFFUSION PUMP HEATERS

I_1 IONIZATION GUAGES

L_1 PILOT LAMP NE51

L_2 PILOT LAMP 47

M_1 THERMOCOUPLE HEATER CURRENT METER

M_2 THERMOCOUPLE VACUUM METER

$P_1 P_2 P_3$ MECHANICAL PUMPS

$R_2 R_3$ DPDL RELAYS

R_4 METER RELAY

$R_5 R_6$ SPDT AC RELAY

S_1 MASTER SWITCH

S_2 THERMOCOUPLE GUAGE SELECTOR

S_3 IONIZATION GUAGE SWITCH

$S_4 S_5$ OIL DIFFUSION PUMP HEATER SWITCHES

$S_6 S_7 S_8$ MECHANICAL PUMP SWITCHES

S_9 RESET BUTTON

S_{10} WATER PRESSURE SWITCH

$T_1 T_2$ THERMOCOUPLE TUBES

$T_3 T_4 T_5$ 6 VOLT FILAMENT TRANSFORMERS

$V_1 V_2 V_3$ VARIABLE TRANSFORMERS

FIG. 2 - PROTECTIVE SYSTEM IN NORMAL OPERATING STATE

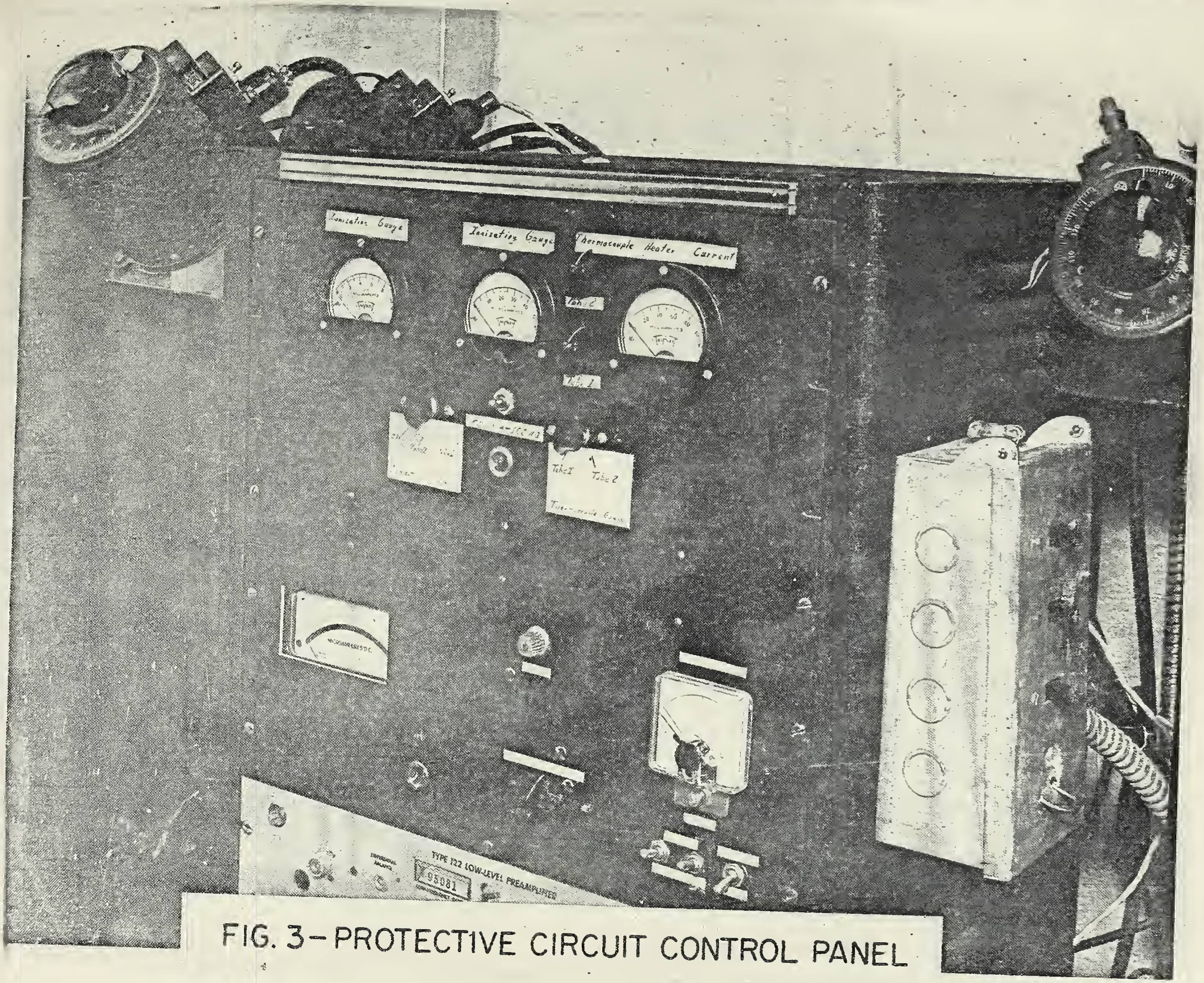


FIG. 3 – PROTECTIVE CIRCUIT CONTROL PANEL

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Frederick H. Mueller, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

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MECHANICS. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Combustion Controls.

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METALLURGY. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

MINERAL PRODUCTS. Engineering Ceramics. Glass. Refractories. Enameled Metals. Constitution and Microstructure.

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Office of Weights and Measures.

BOULDER, COLO.

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IONOSPHERE RESEARCH AND PROPAGATION. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services.

RADIO PROPAGATION ENGINEERING. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

RADIO STANDARDS. High frequency Electrical Standards. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time Standards. Electronic Calibration Center. Millimeter-Wave Research. Microwave Circuit Standards.

RADIO SYSTEMS. High Frequency and Very High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Space Telecommunications.

UPPER ATMOSPHERE AND SPACE PHYSICS. Upper Atmosphere and Plasma Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

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