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ELECTRONIC POSITION INDICATOR FOR LATCHING SOLENOID VALVES

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ABSTRACT

The design and operation of an electronic position indicator for a double-latching solenoid valve are presented. Valve stem position in the solenoid coils is detected by sensing the resistive component of the coil impedance. Four units utilizing this principle have operated successfully for over 1400 hours in a test facility.

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SUMMARY

The design and operation of an electronic position indicator for a double-latching solenoid valve are presented. The method of indication presented requires no modification of the valve, and the position indicator does not have to be mounted near the valve. Valve stem position in the solenoid coils is detected by sensing the resistive component of the coil impedance.

The electronic circuitry determines if the valve is fully opened or closed. It consists of a one-kilohertz oscillator, an amplifier stage, and separate bridge and detection-indication stages for each solenoid coil.

Four units utilizing this principle have operated successfully for over 1400 hours in a test facility. Bench tests have shown that these position indicators are capable of detecting valve position errors of less than 0.05 inch (0.13 cm) from a fully opened or closed valve position for the valve used in the test facility.

INTRODUCTION

Being sure a valve has been properly activated is a critical problem in many systems. This is particularly true of the electrically operated, double-latching solenoid gate valves used in the SNAP-8 ground test facility at Lewis Research Center. (For further information see ref. 1.) Failure of these valves to fully activate can be caused, for example, by an electrical switching malfunction or a mechanical failure of the valve.

Conventional methods of detecting valve position utilize some extension of the valve assembly to activate either limit switches, a variable resistor or a linear voltage differential transformer. If the system requires a completely sealed valve assembly, as is necessitated by the severe environments of the SNAP-8 system (ref. 2), conventional position detection methods could not be used.

The ideal position indicator for this type of solenoid valve should be sensitive enough to detect very small valve position errors and yet require no modification of the valve.

The impedance of the solenoid coil is a function of (1) the design of the coil assembly, and (2) the position of the valve stem. A Maxwell bridge was used to measure coil impedance and therefore indicate the position of the valve stem. Further electronic circuitry then provided an indication of whether the valve was fully opened or closed.

PRINCIPLE OF OPERATION

The design and successful operation of this valve position indicator is primarily dependent on the difference between the resistive component of the solenoid coil impedance for fully opened or closed valve positions. It was found that the change in the reactive component of the impedance was negligible. The change in the resistive component is due to change in the core losses of the solenoid coils, which increases with frequency and flux level (refs. 3 and 4). At a fixed frequency, the resistive component is a function of (1) the electrical properties of the coil winding, (2) the position of the valve stem in the coil, and (3) the materials used in the construction of the valve. All these parameters except the valve stem position will remain constant for any given valve, and therefore the resistive component of the coil impedance will be solely a function of valve stem position. A simplified diagram of this type of valve is shown in figure 1.

Figure 2 shows a graph of the resistive component of coil impedance against valve stem position in the coil for a typical double-latching solenoid valve. Since there was a significant difference in the resistive component between the fully opened and fully closed valve stem positions, it was possible to construct an indicator that would detect whether the valve was at either of these positions.

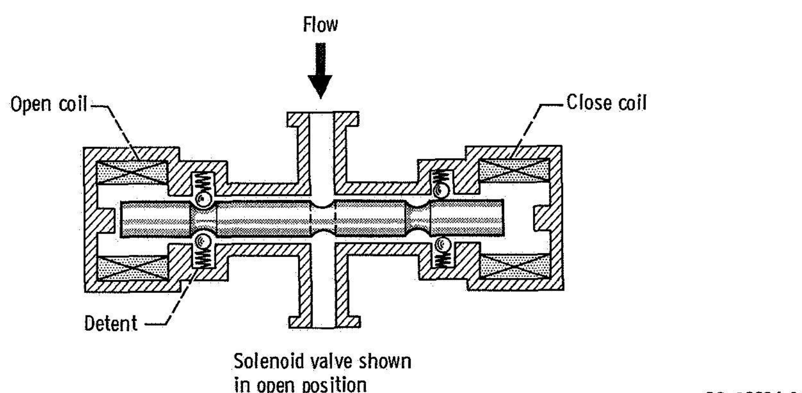

Figure 1. - Simplified diagram of typical double-latching solenoid valve.

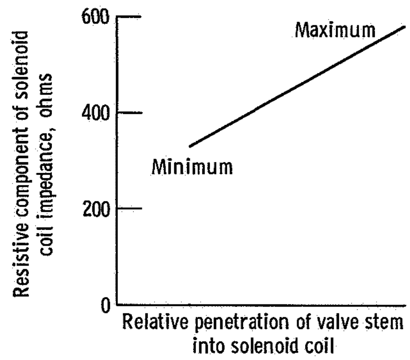

Figure 2. - Resistive component of coil impedance versus relative penetration of valve stem into solenoid coil.

DISCUSSION OF CIRCUITRY

A block diagram of the valve position indicator is shown in figure 3. A photograph of the breadboard indicator is presented in figure 4. The position indicator consists of a one-kilohertz oscillator and an amplifier supplying a signal to two identical impedance bridges and detection-indication stages. Each solenoid coil is connected to a separate bridge stage by means of a relay. To activate the valve, the appropriate solenoid coil is

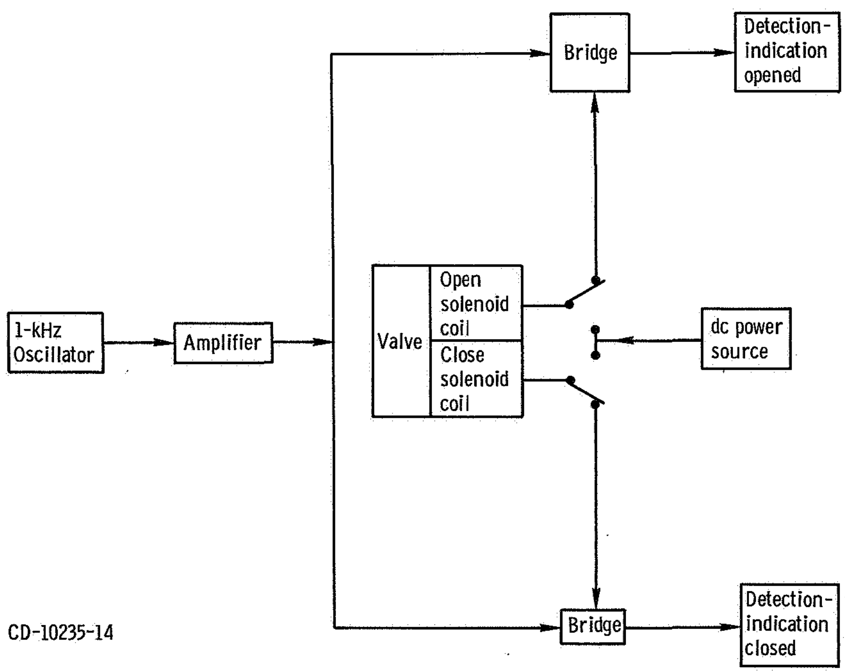

Figure 3. - Block diagram of valve position indicator.

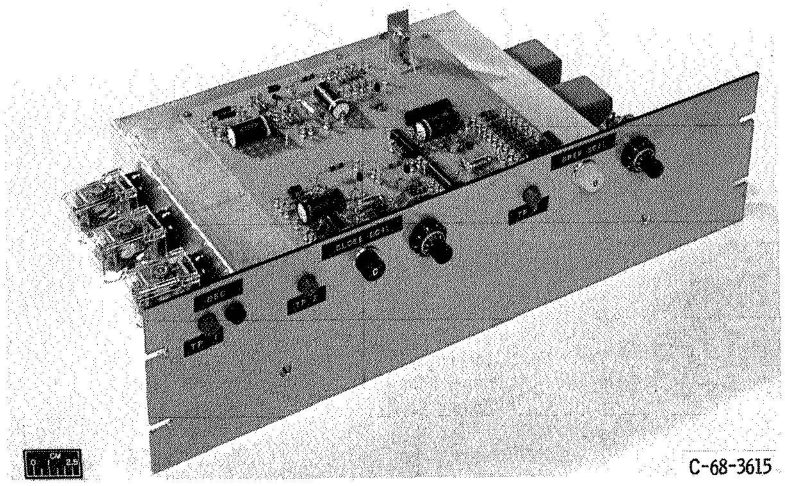

Figure 4. - Position indicator.

switched from the bridge stage to a dc power supply, following which the solenoid coil is reconnected to the bridge stage for an affirmation of valve stem position. This solenoid switching operation was automated by using a time delay relay for each solenoid coil to ensure valve transfer.

A complete schematic of the valve position indicator is shown in figure 5. Since the dc power source for the indicator was a facility supply, a zener diode was used to further regulate and reduce the dc voltage for the electronic section of the indicator.

The first stage of the position indicator is the oscillator. This is a twin-tee oscillator employing stabilized bias. This oscillator was designed to operate at one kilohertz, which is the source frequency used in most impedance bridges.

In order to minimize the loading on the oscillator, an amplification stage was used. This stage consisted of one transistor (Q2) used in an emitter follower configuration for current gain. A test point (TP1) was provided to monitor the output of this stage.

The one kilohertz signal from the amplifier is supplied to each of the two bridges by a coupling transformer (T1). Coupling transformers (T2 and T3) were used on the output of each bridge with test points (TP2 and TP3) provided so that bridge output could be measured. The coupling transformers used on the input and output of the bridges were needed to isolate the bridges from the circuit ground required for the remainder of the circuitry.

Each bridge stage is a four-leg Maxwell impedance bridge. The solenoid coil is placed in one of the bridge legs by means of a double-pole double-throw relay. As previously discussed, a relay was used to connect the solenoid coil to the dc power source in order to activate the valve and then reconnect the solenoid coil to the bridge circuit for valve position detection and indication.

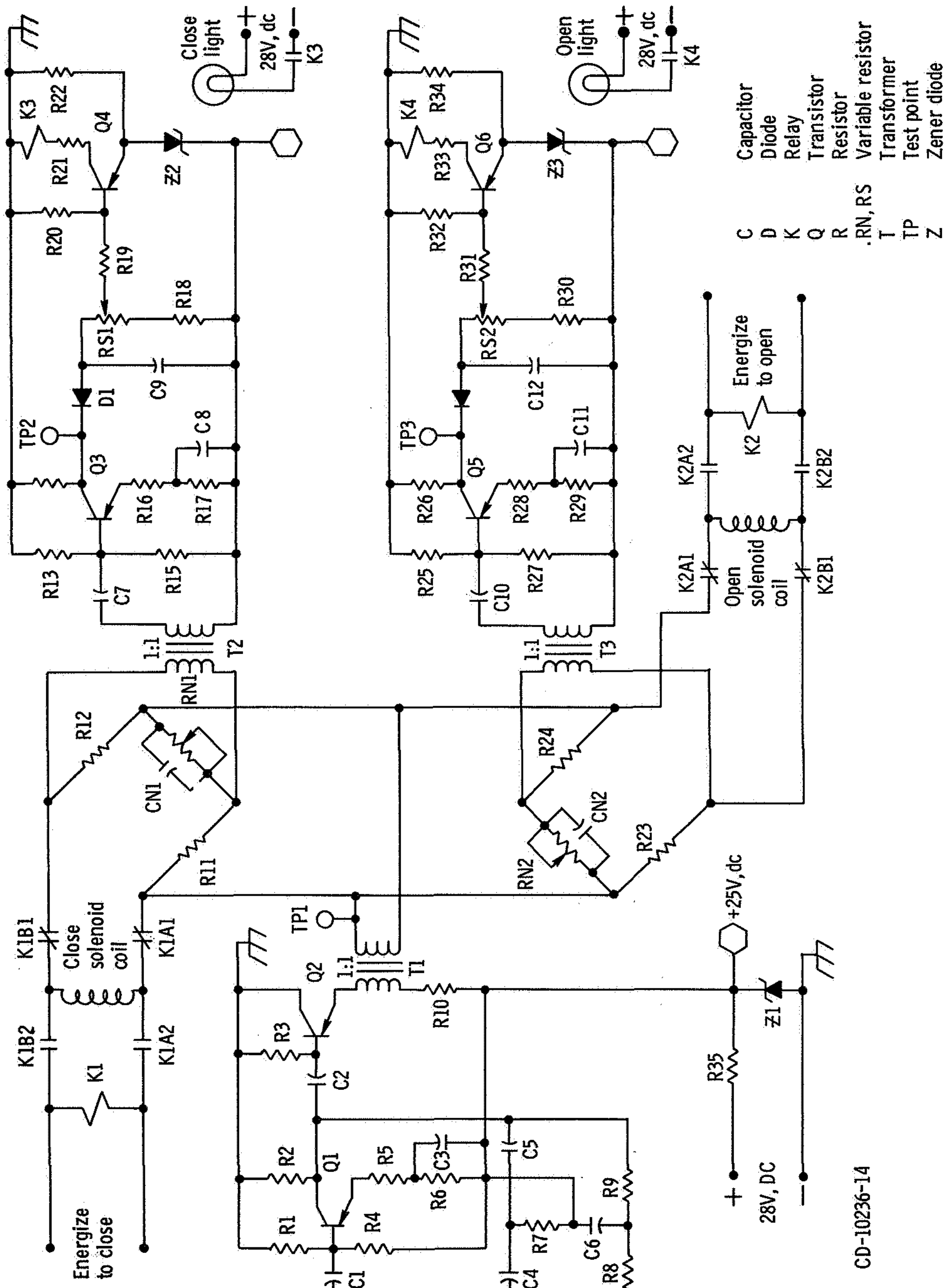

Figure 5. Schematic diagram of valve position indicator.

A distance between the solenoid coil and the bridge stage of up to 75 feet (25 m) is not an important factor, as was determined by testing in the facility.

The bridge leg opposite the solenoid coil consists of a variable resistor (RN1 or RN2) and capacitor (CN1 or CN2) connected in parallel. The other two legs are resistive. In order for the bridge stages to function properly they must be nulled. To null the bridge connected to the "open" coil, the valve was closed by energizing the "close" solenoid coil. This was done in order to place the valve stem in a position of minimum penetration into the "open" solenoid coil. With the one kilohertz signal supplied by the oscillator and amplification stage to the bridge, the capacitor (CN2) and variable resistor (RN2) in the bridge output was obtained as monitored at TP2. The bridge connected to the "close" solenoid coil was nulled in a similar manner after the "open" solenoid coil was energized. Any deviation of the valve stem position from the position used to balance the bridge results in a change in the resistive component of the solenoid coil impedance, thus unbalancing the bridge and increasing bridge output. Maximum bridge output is obtained when the valve stem position is at maximum penetration into the solenoid coil.

The output of each bridge stage is supplied to a detection-indication stage. This stage energizes a relay at a predetermined voltage. This predetermined voltage corresponds to the bridge output when the valve stem position is at maximum penetration into the solenoid coil. Two transistors are used in the detection-indication stage. The first transistor (Q3 or Q5) is used in a common emitter configuration employing stabilized bias to amplify the bridge output voltage. The second transistor (Q4 or Q6) senses this amplified voltage and, at a voltage level determined by the trip point adjustment (RS1 or RS2), energizes a relay. This relay (K3 or K4) is used for panel indication of valve position. This stage is calibrated by adjusting the trip point so that the relay will not energize until maximum bridge output is obtained. If, after both detection-indication stages are calibrated, both relay indications are the same, then the valve is neither opened nor closed, but somewhere between these positions.

PERFORMANCE

Four units, utilizing the principle of detecting valve stem position by sensing the resistive component of solenoid coil impedance, were used in the SNAP-8 facility conducting a 1400-hour endurance test at Lewis Research Center. During this test period no failures occurred in these units. These units were subjected to operating temperatures of approximately 70° to 100° F (21° to 38° C) during these tests without any change in performance. The power requirements for a complete valve position indicator, excluding Z1 and R35, is about 650 milliwatts. Prior to installation in the test facility, the position indicators were bench tested and found capable of detecting position errors of less than 0.05 inch (0.13 cm) for a particular double-latching solenoid valve.

CONCLUDING REMARKS

1. The type of position indicator presented requires no modification of the valve.
2. A distance between the indicator and the solenoid valve of up to 75 feet (25 m) has no significant effect on the performance of the indicator.
3. The power consumption of the indicator is about 650 milliwatts.
4. This indicator was capable of detecting position errors of 0.05 inch (0.13 cm) for the solenoid valve used in the test facility.
5. The indicator has operated successfully for over 1400 hours.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, November 7, 1968,
701-04-00-02-22.

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