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SELF-CHECKING ALARM TECHNIQUE FOR EXHAUSTER SYSTEMS ON ACTIVITY ENCLOSURES

Author
Peck, J. Stafford.

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ABSTRACT

Alarm systems used with glove-box exhaust manifolds at Lawrence Radiation Laboratory formerly relied on vane-operated switches to sense total manifold flow. These devices, however, neither measured the entity that produced box draft nor indicated flow failure reliably (primarily because of exposure to corrosive atmospheres). The system was not fail-safe because it functioned only upon positive indication of failure. Suction switches were used to overcome the shortcomings of the flow switches, and alarm circuits were modified accordingly.

The self-checking alarm technique is based on the theory of cycling and "ferrying" of electric quanta to prevent drop-out of a trigger. A circuit developed by Rowell (of Scully Signal Corporation) was adapted to the alarm systems. The adaptation was at first unsatisfactory because it required large-value condensers whose instability with regard to capacity made them unsuitable; the sensitive relay that had to be used because of capacitor size limitations was neither tamper-proof nor completely reliable. Further development of the circuit resulted in almost foolproof reliability. The sensitive relay was replaced with a grid-controlled gas rectifier, and smaller electrolytic condensers (made possible by the thyratron trigger and a different type of solenoid valve in the sensing unit) were used.

A year of operating experience has shown the technique highly reliable. The system, although apparently complex, has proven well worth the effort of development.

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INTRODUCTION

Requirements for ventilation of activity enclosures are familiar to researchers and industry. At the Berkeley site of the Lawrence Radiation Laboratory, glove-box enclosures are vented to manifold systems; each system is equipped with dual exhausters, one in service and one in stand-by position. Exhauster-control systems installed prior to 1957 used a vane as a flow detector in the duct work downstream from the service exhauster. When air flow failed, this vane dropped, closing a microswitch to energize a contactor which then supplied power to the stand-by exhauster, and also rang an alarm. The vane system had many drawbacks:

1. The vane, being exposed to the stack fumes of chemistry operations, often became corroded and inoperative.

2. The vane detected total manifold flow, whereas it is suction that produces draft in individual enclosures.

3. The vane technique depends on a positive indication of failure, whereas a positive indication of proper function would be more desirable.

4. This alarm system included a mechanical time delay to block the alarm in order to permit the exhauster to come up to speed when the service was restored. This delay device was subject to frequent failure.

Development

The spring of 1957 saw two major changes in the control systems. The first and perhaps most significant development was the use of a device which detected the negative pressure in the manifold itself. A "suction switch," a diaphragm-operated microswitch that closed when suction fell below about 0.6 in. W. G., replaced the vane switch in the alarm circuit. Since the suction switch did not know which exhauster is producing negative pressure in the manifold, a "lock-in" circuit prevented restoration of the tripped alarm when the stand-by exhauster came on stream, thereby preventing interruption of stand-by suction. The significance of this development is that it gave us control over the parameter of prime concern. By policing the suction in the manifold, this detector system insured adequate ventilation in the glove boxes, barring malfunction of system components.

The second development at this time is the more interesting one. This was the inauguration of the "self-checking" alarm system, based on an invention by Mr. Rowell of Scully Signal Corp. This "Scully-Rowell" circuit, coupled with the suction-switch concept, gave us a technique for automatic routine checking for failure of suction in the manifold, the suction switch, or any of its components--in effect, almost the entire control system. This control technique is the subject of this discussion.

System Theory

The sketch in Fig. 1 helps to explain the operation. Switch SW-1 is the suction switch coupled to the diaphragm that senses suction in the manifold. A loss of suction closes the switch.

Solenoid valve C-5, when energized, bleeds air to the switch diaphragm, thus simulating a suction failure.

Diode RE-1, ballast resistor R-2, and capacitor C-2 constitute a direct-current power supply. When dc is turned on, a charging current runs from the dc supply, through the relay coil, to capacitor C-2, and thence to ground. The product of the coil of relay L-1 and the capacitor C-2 is the RC time constant. As the charging current falls off exponentially, it reaches a point at which the relay no longer holds in. When the relay relaxes, the contacts connected to pin 5 energize solenoid L-5, which bleeds air into the diaphragm chamber of the suction switch. The switch, now feeling no suction, closes; and since it is connected parallel to C-2 and R-2, C-2 discharges. Now that C-2 is discharged, the charging current through the relay coil is restored, the relay pulls in, and L-5, de-energized, closes the valve and restores suction to the suction switch. Initial conditions having been restored, the cycle starts over. The period of the cycle is controlled by the time constant, L-1 and C-2, already mentioned. We chose a 6-second cycling period as a compromise between time of alarm response and rate of mechanical wear.

Upon failure of any of the above parameters the relay comes to a halt in one position or the other, depending on the nature of the failure; but in any event, cycling ceases.

In the circuit represented in the sketch, another dc charging current flowed from the source to pin 4 of the relay, and out pin 1 to charge capacitor C-3. When the cycling relay was energized, C-3 discharged to produce yet another charging current from pin 1, through the relay, and out pin 4 to condenser C-4. The cycling process now ferried quanta of electricity from supply to C-3, thence from C-3 to C-4, thus maintaining C-4 in a charged state. A sensitive relay L-2 formed the load for C-4. As long as there was sufficient charge at C-4, the sensitive relay L-2 held in. This is the final point in the system which Scully calls "fail-safe." Failure of the self-checking features of the system to keep C-4 charged presumably permitted the sensitive relay to relax, ring the alarm, and call in the stand-by exhausters.

This MK-I version of the self-checking system proved unsatisfactory for several reasons:

1. The sensitive relay worked well if left to its own devices; but it was somewhat vibration-sensitive, and it was not proof against adjustment with a 10-inch screw-driver.

2. A 6-second cycling period and the current requirements of the sensitive relay required capacitors ranging in value from 60 μf to 324 μf. The type chosen was motor-starting capacitors, and the values varied widely at the outset, and varied further with use.

The solenoid valve gave us considerable trouble. The first version of suction switch used was a device fabricated in our own shops, which included the valve arrangement in the unit. The solenoid, with frequent regularity, stuck, presumably because dust and grit got in with the sliding parts.

Sometimes the valve seat would come loose, and sometimes there was mechanical fatigue of the metal parts of the diaphragm components, even though the diaphragm itself was made of either polyvinylchloride or polyethylene sheet.

A further operational improvement came as a result of efforts to remove the solenoid problem. We tried commercial products, the first of which was known for its reliability. This valve was of simple design simple design as well as being inexpensive, but it suffered the same failure as the home-built product. About this time, we learned from General Controls Company that they would soon have a 110-v ac-operated valve on the market. When this valve became available early in 1959, we purchased one, along with a General Controls suction switch of the mercury-switch type. The cost of these two items together came to about 40% of one home-made unit. The valve unit is a pilot-operated type, and there was considerable concern over its ability to operate on the low pressure gradients available. The General Controls combination, tested in the field, held up very well. The valve unit, however, required 2 or 3 seconds' operating time.

As a further development of the self-checking control the MK-II version became available at about this stage. This final result is shown on dwg. 6Z2553. Essentially three basic changes in the MK-I version debugged this system beautifully:

1. The use of the diaphragm type valve with its inherent time delay proved advantageous, because the capacitor value in the RC time delay could now be reduced to one-third to give the same cycling period: 2 to 3 seconds for RC time, plus 4 or 6 seconds' valve delay.

2. The sensitive relay was replaced with a thyratron tube. This change eliminated the mechanical Achilles' Heel of the former model, and it reduced considerably the current requirements of the alarm trigger.

3. The lower current demands of the thyratron led to a reduction in value of the "ferrying" capacitors also. Now, all capacitors in the system are inexpensive, common, reliable types.

Other Features

The original bread-board of this control circuit indicated we might have a noise problem with relays or solenoid. Our first solenoid valves created quite a clatter at 6 second intervals; and for fear this noise might annoy the researcher, we mounted these units at the exhauster locations on the roof. This site is often two stories removed from where the suction should be measured. The General Controls valve, though, is absolutely quiet, so now the unit is mounted on the extreme end of the manifold in the laboratory. The cycling relay is an enclosed type, and produces very little noise.

This over-all system eliminates time delays of any description. Start-up is manual, and the operator knows start-up is complete when the red light goes out. The red light is connected parallel to the thyratron to give an actual indication of the state of the alarm-trigger.

Figure 2 shows a "blower transfer" switch S-2. This switch is a concession to the mechanical foibles of the exhausting fans and motors. S-2 merely has the effect of exchanging the places of the two motors, giving the motor in "stand-by" position an opportunity to exercise in "main" service. This switch is thrown manually each week.

This is one shortcoming in this circuit which will permit a failure without tripping the alarm trigger. The thyratron type 2D21 used here is a gas-filled grid-controlled tetrode rectifier, and it requires a minus potential with respect to the cathode on the screen grid in order to quench the tube when the control grid potential drops below a predetermined positive value. Therefore, failure of the screen supply will have the effect of blocking the alarm. One way to bypass this difficulty would be to bias the cathode with a voltage divider; but then we would be using the same sort of components with the same reliability, but with some instability of function. We feel that the reliability of the screen supply justifies its use in this position.

Use

We now have about 1 year's operational experience with this over-all system, with eighteen such units to date. Incidence of failure, exclusive of exhauster failures, has been small:

one mechanical failure in the suction switch (broken wire);

four electronic failures (one diode, three thyratrons).

Conclusions

Very rarely does one recommend the adoption of a replacement system with the prediction that "it will give more trouble than the old one." Yet, such was the case this time, the reason being that this self-checking concept "rings the bell" when something goes wrong, whereas several things could go wrong simultaneously with the former controls, and no one would be the wiser until someone looked for trouble. The prediction notwithstanding, the Scully-Rowell is here to stay.

This circuit is covered by U. S. and Foreign patents held by the Scully Signal Corp. Lawrence Radiation Laboratory is licensed to make these controls for its own use only.

Acknowledgments

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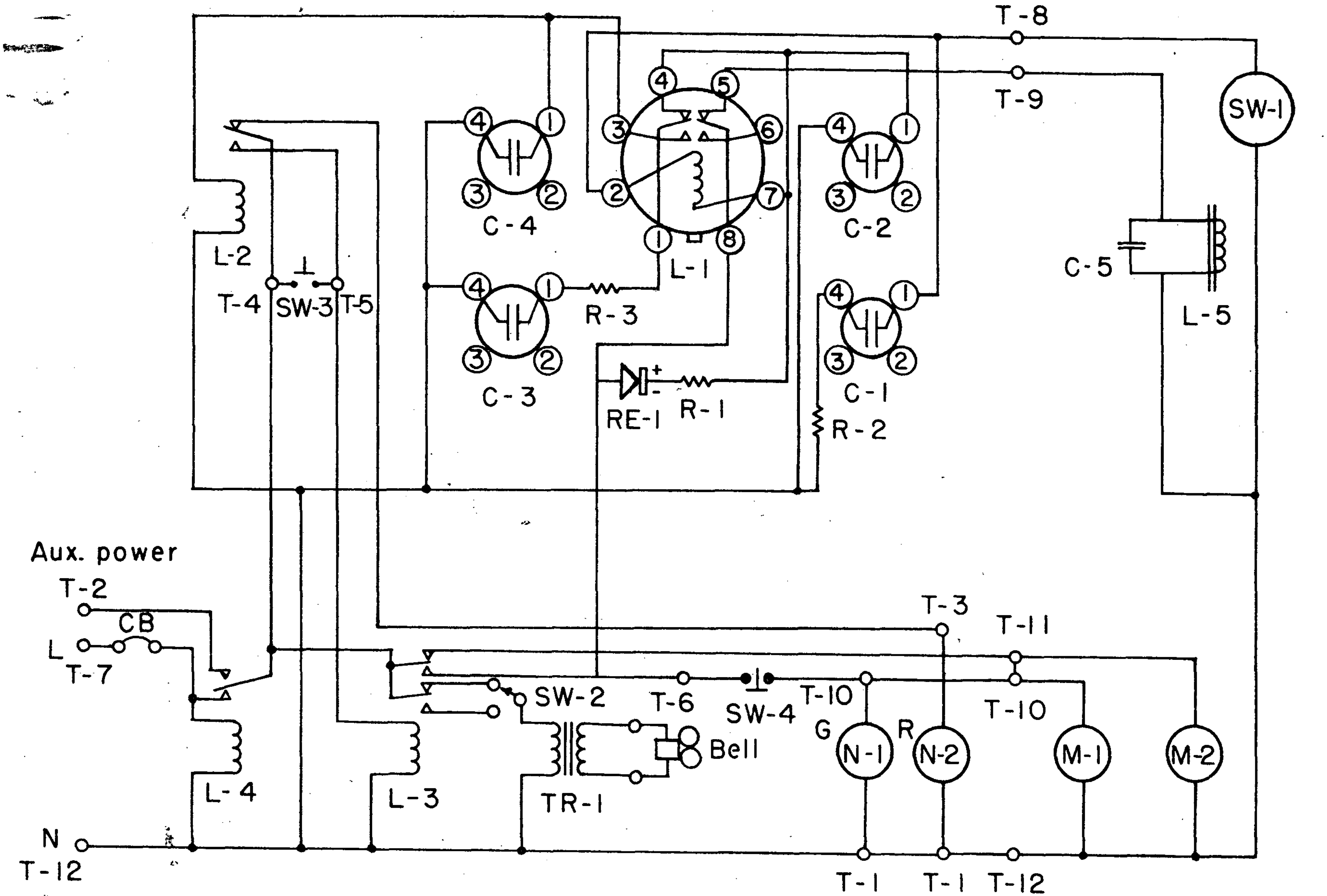

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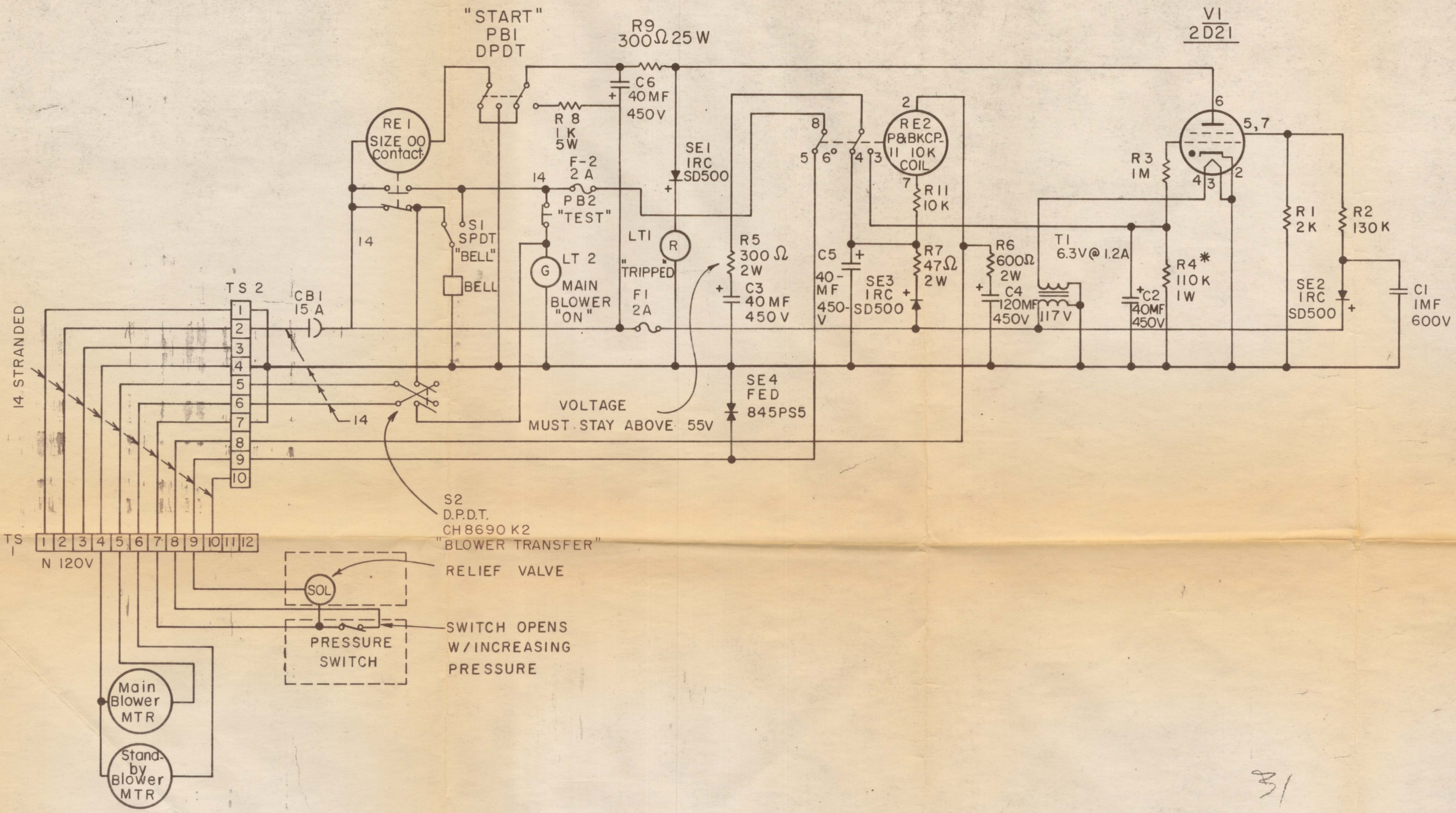
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IRC
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R7
47Ω
2W
R6
600Ω
2W
C4
120MF
450V
T1
6.3V@1.2A
117V
C2
40MF
450V
R4*
110K
1W
R1
2K
R2
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SE2
IRC
SD500
C1
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600V
TS 2
CB1
15 A
14 STRANDED
SE4
FED
845PS5
VOLTAGE
MUST STAY ABOVE 55V
S2
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"BLOWER TRANSFER"
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PRESSURE
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Main
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