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(Instrumentation)

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A REVERSING TIMER FOR PROTECTION OF UHV APPARATUS FROM PUMP FAILURE

by

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1. INTRODUCTION

Most synchrotron radiation experiments call for an open path from a source, through a monochromator and into an experimental assembly, all of which are evacuated to below 10^{-7} torr. If a beam line is shared by several experiments, as in the original Synchrotron Radiation Facility (SRF) at Daresbury, light may have to pass through several dormant monochromators to reach the active one. The assembly becomes tens of metres long and has to be pumped continuously by the monochromator pumps and perhaps one or two large pumps in between. Pumping it down to ultra high vacuum (UHV) after a spell at atmospheric pressure may take days; even with a smaller system a small mistake in rebuilding can set a programme back several hours.

From time to time individual sections have to be opened to the atmosphere, and so gate valves are mounted between them and UHV pump sets fitted to most of them. Access to a section may then be gained without spoiling the vacuum elsewhere. A control system is then needed to interlock the valves safely and to help supervise changes in the state of the line. Such a system was built for the SRF using 'mimic modules' to adapt quickly to changes in beam line configuration and a set of simulators for maintenance, demonstration and (in emergencies) bridging.

If a pump fails to keep up with the vacuum in the vessel it should be evacuating, the vacuum would be better still with it disconnected. Further, there is a risk of contamination from the oil in the pump, leading to ruin of a costly diffraction grating. One item in the SRF vacuum control system was designed to cover this risk in as realistic a way as possible.

2. IDENTIFYING THE PROTECTION PROBLEM

Figure 1 shows a typical monochromator assembly to be protected. Under normal conditions the pump keeps the vessel at UHV, the pump isolation (QS) valve is open and the gauges monitor the pressures in pump intake and vessel. If gauge B reads lower than gauge A there will be a net flow of gas molecules into the pump, i.e. the pump is effective. If it reads higher, gas and oil molecules will accumulate in the vessel.

If we wish to fix a limit on the quantity of substance leaked into the vessel before the QS valve cuts off the pump, we need to know the integral of pressure difference Pb-Pa so that if

$$\mathop{\mathrm{Lt}}_{T\to\infty}\int_0^T (Pb-Pa)\,dt > \text{allowable limit}$$

the pump is isolated. At present the cold-cathode gauges used for monitoring do not yield remote-reading outputs large or reliable enough to lend a magnitude to (Pb-Pa) but we may safely use its sign. We are therefore left with two quantities to use: the times elapsed while Pa>Pb and while Pa<Pb.

3. SOLUTIONS

3.1. Original

Earlier pump controls used the following sequence:

(1) Reading Pa falls below an arbitrary threshold Pt ahead of Pb.
(2) Timer starts, and only resets if Pb also attains the low threshold.
(3) After T1 (5-10 minutes) with Pa better than Pb, QS valve closes.
(4) If Pb has not caught up within T2 (15 s) the pump is switched off (QS stays closed).
(4A) If Pb does catch up the whole cycle resets.

Whilst this method did protect the assembly, it caused nuisance and was not always true to real needs because

(a) Setting of Pt was subject to drift, was never visible and yet should have been accurately matched for Pa and Pb because of the usually small difference between them;
(b) The test of state should preferably be valid over the whole range of Pa and Pb, not just referred to one threshold;
(c) T2 was set by tampering with switch levers inside the timer, so that one of the two switches operated about 15 s later than the other; in practice, T2 was fixed, and in most cases was far too short - 0.5 to 3 minutes would have been more realistic, and

harmless as the pump would be isolated at that time;

(d) Account could not be taken of the performance of the pump; in a borderline case it could be shut down unnecessarily, time after time, during initial pumpdown, or could be allowed generous access to the line when only just able to pump itself out.

3.2 New method

As was mentioned above, the sign of (Pb-Pa) was to be used but not the magnitude. Our attempt to use it as fully as possible consisted in debiting and crediting time from allowances T1 and T2 set on separate switches[1].

A healthy state is assumed, until:

(1) Pa drifts below Pb (anywhere in range) and an 'excess pressure in pump' signal is sent from the pumped section mimic/control module in the remote control area;

(2) A timer counts from zero towards T1 (debiting) and continues while Pb>Pa. If the pump vacuum outstrips Pa again, the timer reverses, thus crediting up to the maximum T1 (at zero count);

(3) If the debit time reaches T1 the QS valve closes and a new count now proceeds from zero to T2. (In the prototype the count rate was then increased tenfold because T2 was expected to be much less than T1.) The debit-credit system applies to this count period as to the first;

(4) When allowance T2 is exhausted the pump is switched off and the unit stays in the 'inhibit pump' condition (revealing the cause of the stoppage as distinct from cooling water failure etc.) or resets.

As the sequence does not allow short cuts back to the start, if the pump spends time in a suspect state it is obliged to spend just as long clearing up the mess it has caused before being reconnected and regaining its full time allowance.

4. IMPLEMENTATION

4.1 Controls and operation

The new protection scheme is meant to obviate attention before a fault develops. If it succeeds, only the indicators and the latch/clear switch need be mounted on the front panel. Standard indicators are:

Time down
Recover
Standby (the starting condition - confirms 'power on')
Active (some of interval T1 elapsed)
Isolate (QS valve cannot open; some of T2 elapsed)
Stop (end of T2; pump switched off)

A digital display, to be seen from the front of the unit, may be fitted and wired as shown in an inset to DL 01/9227. It serves to show the elapsed time (in counts up to T1 or T2 - the active/isolate signals show which one applies) and only lights up in and beyond the active state. The design provides for it in case users prefer to keep a watch on the timing process.

The latch/clear switch, in latch mode, causes the unit to latch on reaching the stop state until reset by switching to clear, or, if left in clear mode, to clear itself when the 'HVP ON' signal from the pump control circuits disappears.

The other switches preset and test the unit and would be mounted out of sight. These are:

Auto/manual pump stop (normally set to 'auto')
Set interval T1 preceding isolation (thumbwheel)
Set interval T2, isolation to shutdown (ditto)
Push to test cycle.

A front panel layout suitable for most applications is shown in fig. 2.

Under time-down conditions control can shift all the way from standby to stop if conditions persist. Under recover, though, the only automatic stage shift is back from stage 3 (T2 period) to 2 (T1 period). Stage 4 (stop) must cause a 'stop pump' command to be sent to the pump control circuits. If the auto/manual switch keeps the pump running the protection unit freezes in the stop stage whatever happens to Pa,Pb and the QS valve. In stage 2 (active) if recovery persists until the T1 time is credited back to zero count, the unit remains at stage 2, indicating active instead of reverting to standby, as a warning that protection has been running since pumping started. Standby will return when the QS valve is closed.

4.2 <u>Input and output signals</u> (See Ref. 1)

The signals and the resulting actions are as follows:

SIGNAL	ACTION
Excess pressure in pump	Sets direction to time down instead of recover
Pressure Pb below a threshold assumed to be at the lowest usable reading (110 V drive - formerly to stop clock motor)	Effective only after timer has closed QS valve and is within isolation time T2. Then freezes the count; when it disappears the count can continue up or down according to conditions.
HV pump on (+ 24 V drive)	Enables timer to proceed. Reset operates when this signal disappears, unless unit switched to latch mode.
'QS Closed'	Inhibits shift from standby to active. i.e. If pump is isolated the unit does not become involved, whatever the conditions.

4.3 <u>Interfacing</u>

Although the new circuit could have been added to the existing pump controls in a slightly more efficient way, it was intended to serve first as a direct replacement for the Londex timer used as described in

Section 3.1. Therefore there are interface circuits attached to the main circuit: at the inputs the TTL circuit is interfaced with the 110 V a.c. drives intended for the clutch and motor of the Londex timer, and outputs are floating changeover contacts corresponding to the two tampered-with timer contacts. An interface for 110 V a.c. to isolated TTL is shown in fig. 3.

4.4 <u>TTL control circuit</u> ('E' numbers apply to Ref. 2)

A 4-bit bidirectional shift register E11, loaded with 1,0,0,0 on resetting, acts as master output control. During time-down the '1' moves from left to right, acting on the stage indicator and relay circuits as it does so. (1,0,0,0 is stage 1 and 0,0,0,1 stage 4.) Recovery shifts the '1' the opposite way. Time intervals are measured by bidirectional counter E2, adding debit counts up to the limit during time-down and subtracting credit counts down to zero during recovery.

The whole circuit runs through a recurring cycle of steps, only one of which adds or subtracts a time count. A strobe generator, driven by a 1455 timer, issues commands to the sub-circuits in the following order:

1. Test conditions (Pa Vs. Pb)
2. Pause
3. Count 1/100th of a T1 count or 1/10th of a T2 count, or do nothing, depending on stage in the protection sequence
4. Pause
5. Store any just cause for shifting to next stage
6. Pause
7. Carry out shift, if request left from step 5
8. Pause
9. Strobe reset when request present
10. Load timer with zero (before upward count) or limit T1 (just after shifting from stage 3 to stage 2) according to stage and direction.

The direction of counting and shifting (time-down and recovery) is controlled by two flip-flops E1A and E1B. The combination of their outputs controls E2 (up/down) and E11 (left/right/load). Conditions which demand a shift at the next strobe are latched into E10 at step 5, whereupon the new stage in the sequence applies new criteria and the shift request disappears. The requests originate from the limit circuitry for upward counting, from 'max/min' output from E2 for downward, from reset and from the condition (standby.Time-down.QS-not-closed). Limit circuitry is arranged to supply a switch-set limit for comparison, load the limit itself prior to counting down and load zero prior to counting up. The comparisons are done by simple exclusive-or circuits with outputs fed to shift request logic. A reduced version of the circuit is shown in fig. 4.

5. FURTHER DEVELOPMENT AND APPLICATIONS

The basic scheme may be adapted to other situations where a number of status signals can be reduced logically to one 'deteriorating/recovering' signal and where ground gained or lost varies symmetrically with time. A rate control could be included by substituting a voltage-controlled oscillator for the fixed oscillator and controlling the frequency with the Pb-Pa signal or equivalent; symmetry would not then have to be assumed and the greater the stimulus the more swift would be the response.

For more complicated sequences the control register, and for improved resolution the counter and time limit switches, could be extended without changing the principle of the circuit. A more compact version could be made if some of the random logic were replaced by read-only memories, which attract a range of users wider now than when the unit was first conceived, if PROM-programming facilities are available. A CMOS version could easily be produced.

6. CONCLUSION

A unit has been designed, and a successful prototype made, to safeguard an assembly with slow characteristics, using time elapsed to assess deterioration and recovery. The design places as few constraints as possible on the grouping and interaction of assemblies, which may need to be self-contained and free from central or computer-based control. It also aims at the least possible distraction for users. Scope exists for adaptation to other systems.

7. ACKNOWLEDGEMENT

The author wishes to thank Mr. S.D. Billing for very rapid construction of a viable protorype from a set of circuit sketches.

REFERENCES

1. Block diagram: DL 01/8490.

2. Circuit diagram: DL 01/9227.

FIGURE CAPTIONS

Fig. 1 Typical pumped section.

Fig. 2 Layout suitable for front panel.

Fig. 3 Isolated interface for 110 V a.c. to TTL.

Fig. 4 Reduced version of limit (one switch) and shift request circuit.

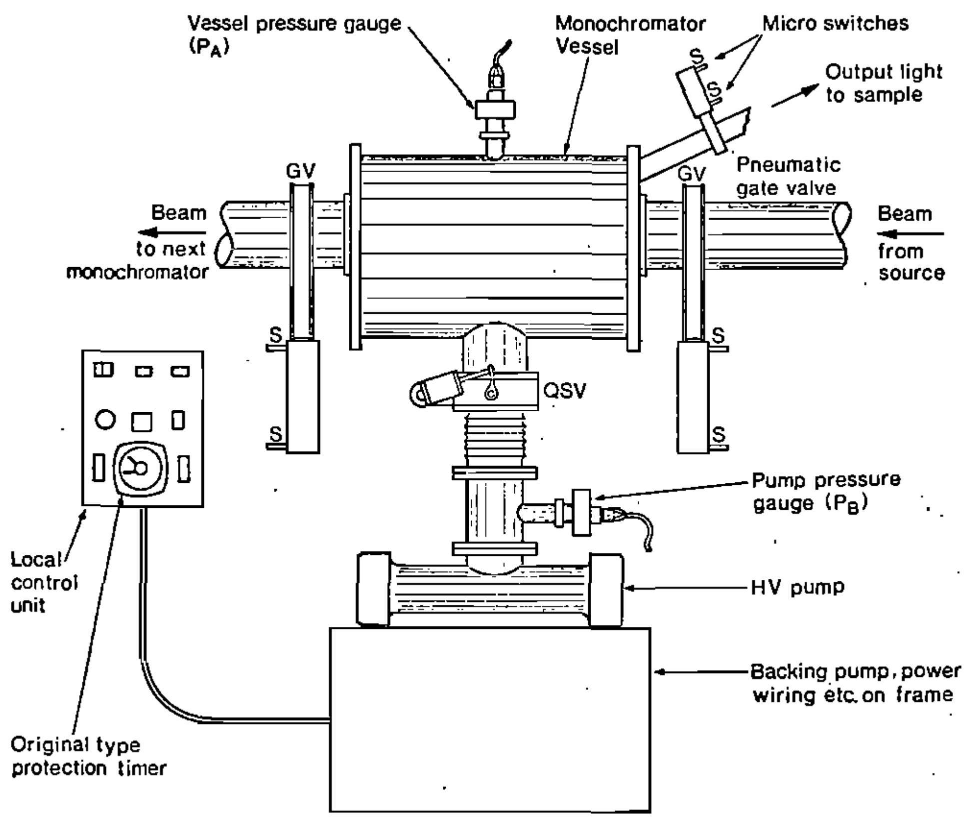

Vessel pressure gauge
(P_A)
Monochromator
Vessel
Micro switches
S
S
Output light
to sample
GV
GV
Pneumatic
gate valve
Beam
to next
monochromator
Beam
from
source
S
S
S
S
QSV
Pump pressure
gauge (P_B)
Local
control
unit
HV pump
Backing pump, power
wiring etc. on frame
Original type
protection timer

Fig. 1

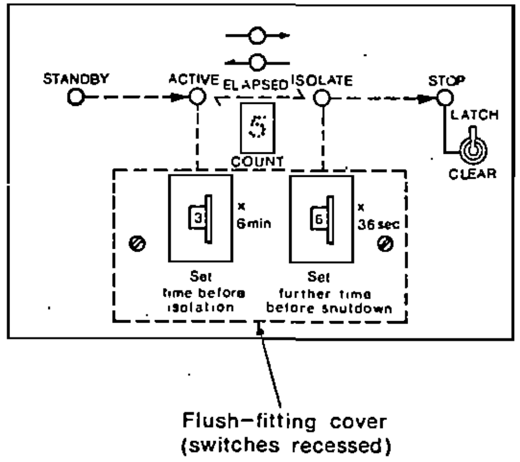
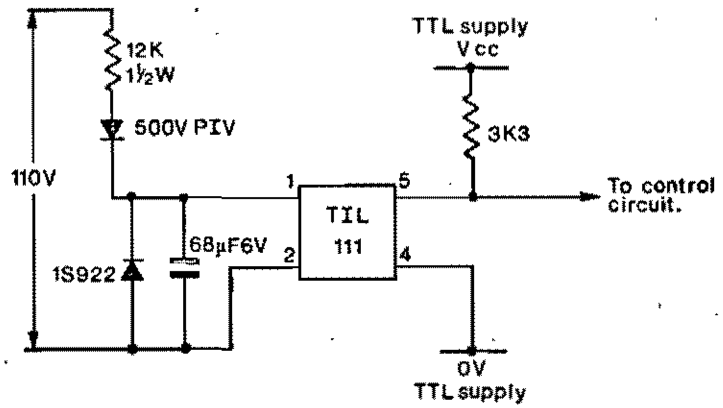
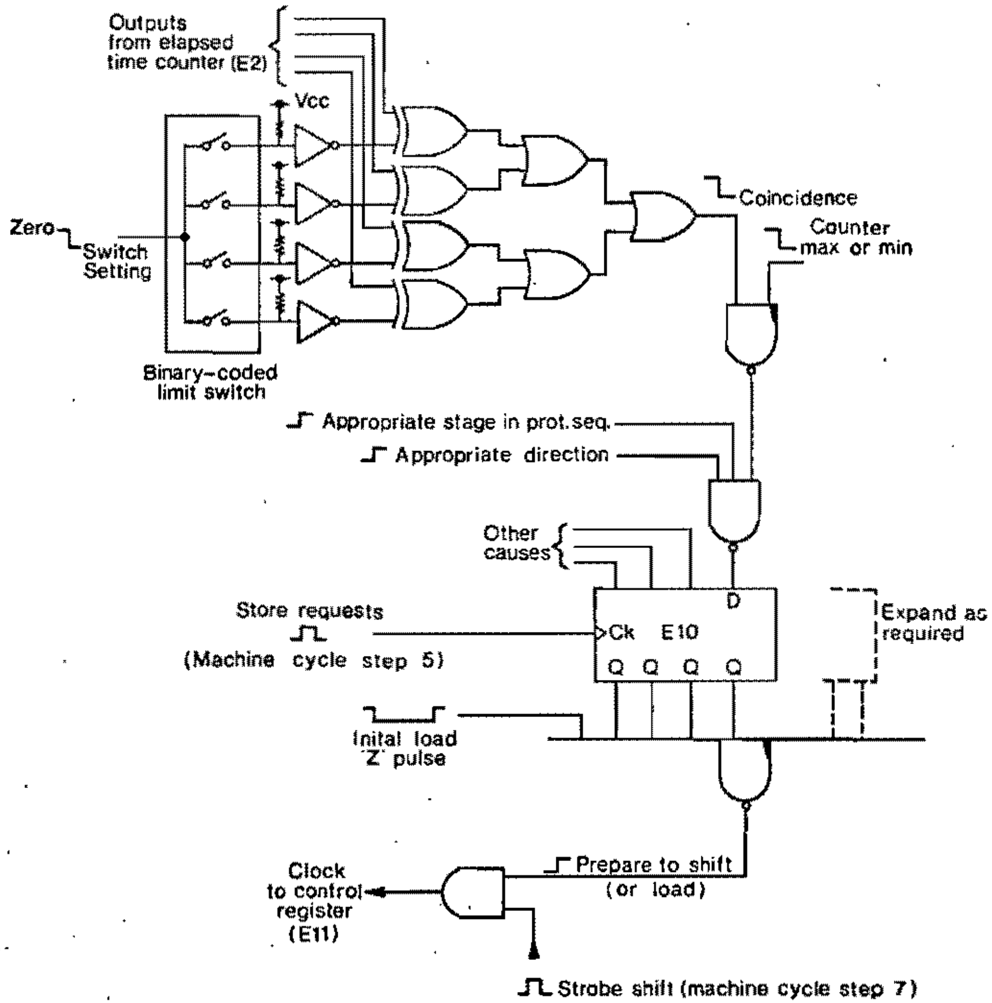

STANDBY
ACTIVE
ELAPSED
ISOLATE
STOP
LATCH
5
COUNT
CLEAR
3
x
6min
6
x
36 sec
Set
time before
isolation
Set
further time
before shutdown
Flush-fitting cover
(switches recessed)

Fig. 2



12K
1½W
500V PIV
110V
1S922
68μF6V
TTL supply
Vcc
3K3
1
5
2
4
TIL
111
To control circuit.
0V
TTL supply

Fig.3



Outputs from elapsed time counter (E2)
Vcc
Zero
Switch Setting
Binary-coded limit switch
Coincidence
Counter max or min
Appropriate stage in prot.seq.
Appropriate direction
Other causes
D
Store requests
(Machine cycle step 5)
Ck E10
Q Q Q Q
Expand as required
Inital load 'Z' pulse
Prepare to shift (or load)
Clock to control register (E11)
Strobe shift (machine cycle step 7)

Fig. 4