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TESTS OF A FAIL-SAFE VACUUM BEAM LINE USING ACOUSTIC DELAY AND A FAST-CLOSING VALVE*

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Summary

An operational fail-safe line would consist of the following elements, listed in order of appearance as one proceeds from the beam exit foil window toward the accelerator: (1) pressure-rise detector; (2) acoustic-delay section; (3) fast-closing valve; and (4) straight-through liquid nitrogen trap, isolated by bakeable vacuum valves. Because of the thermal velocity distribution in the entering gas, it is practically impossible to stop all of it by the fast valve. The trap, however, will be effective in catching contaminants if the flow through the trap is well within the molecular flow regime at all times. The purpose of these tests is to ensure that this condition can be realized in a practical way.

Description of the Apparatus

The primary means of simulating vacuum failure was by rupturing the foil window with a knife. To facilitate testing, a flap inlet valve was installed in place of the foil. It consists of a hinged plate that seals a 2-1/2-in.-diam port. It was opened by striking with a hammer, admitting a burst of air sufficient to bring the pressure in the line up to 10 to 50 Torr. It was estimated to open the first 0.1 in. in 1 ms. A McClure discharge device was used to detect vacuum failure.[1] A strong glow discharge occurs suddenly when the pressure rises to 5×10^{-3} Torr, providing a generous pulse to trigger the fast valve. The detector was mounted in a 3-in.-diam tee off the test beam tube, 7 in. from the foil window. The acoustic delay line consists of eight coned cells each with 2-in.-diam orifice, 8-in. diam, 3-in. axial length.[2]

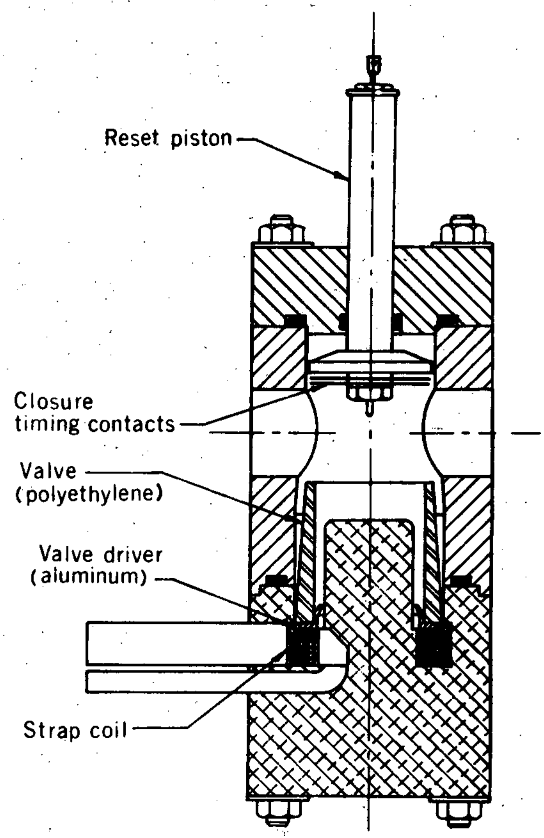

Fig. 2. Fast-closing valve. One in. clear bore. Eleven-turn coil insulated from driver by 10 mils of epoxy.

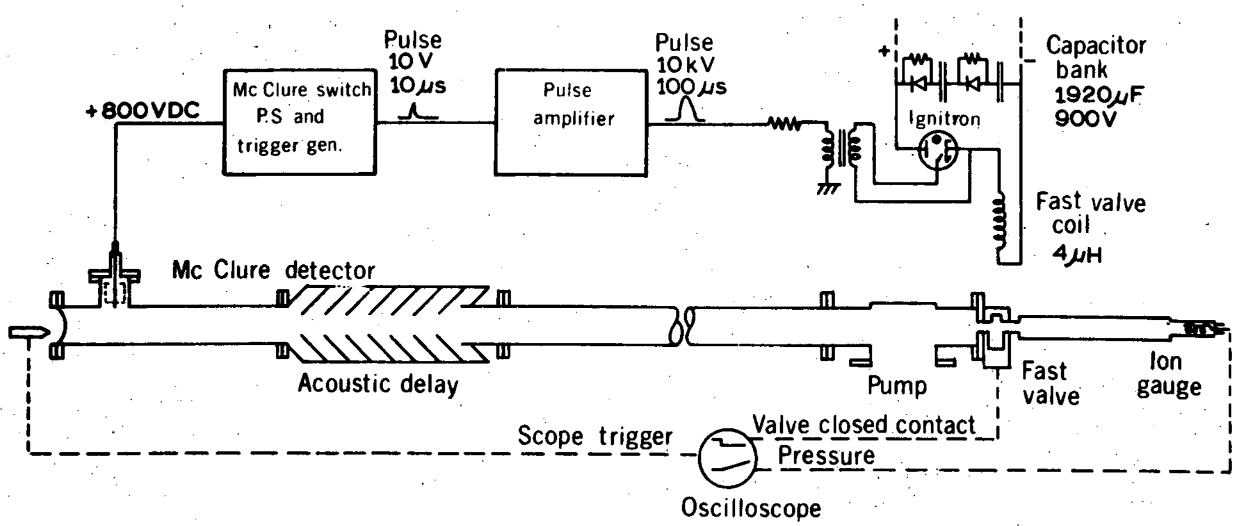

Fig. 1. Overall sketch of the fail-safe line tested. Beam tube 4 in. diam.

Valve closure is initiated by discharging the capacitor bank through the coil. Closure and sealing is maintained by the wedging of the valve in the tapered bore (4^{o} half angle). The valve is manually reset by knocking the valve out of the taper with the reset piston. The valve falls back onto the driver and coil, where it is ready for the next closure.

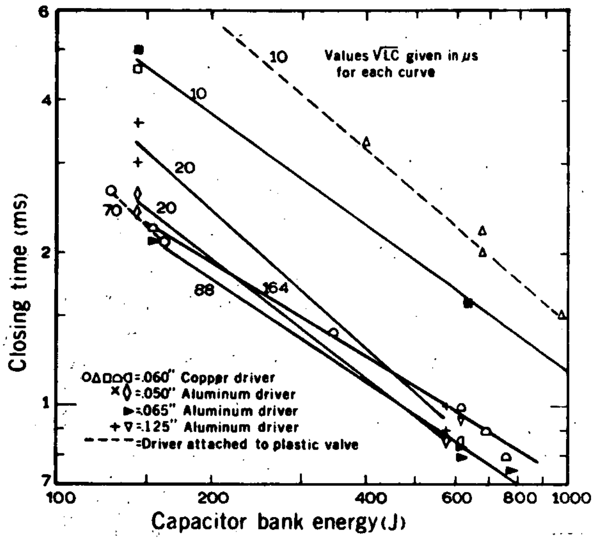

Fig. 3. Measured valve closing time. L = valve coil inductance, C = capacitor-bank capacitance. The thicknesses of the driver rings are given in the symbol list.

Closing times were measured with three different capacitor banks, two different coils, and a variety of drivers. Except for the two dashed curves, the valve was free to separate from the driver ring. Closing time is the elapsed time from initiation of the trigger signal for the valve power supply to the shorting of the timing contacts on the reset piston by the valve. One hard polyethylene valve piece used throughout the testing showed no damage. The polyethylene part weighs 19.4 g and the 0.065-in.-thick aluminum driver weighs 4.4 g. The valve was mounted in the test beam line 13 ft from the foil window. Following the valve was a 16-in. length of pipe closed at the end by a VG-1A ion gage. This volume, to be sealed off by the fast valve, is 0.8 *l*.

The capacitor bank is made up of 96 electrolytic capacitors. At 800 V, peak current is 20 kA. The network limits destruction if one capacitor fails.

Testing and Results

The line was evacuated to 2×10^{-5} Torr, and the pumps were valved off. The scope trace was manually triggered at a sweep speed of 0.5 s/cm, and the window was ruptured with a knife. At this sweep speed any gas burst passing through the fast valve would appear as a step function in the recorded pressure trace. No such step rise was observed. Further tests were made using the flap valve to simulate vacuum failure in which the scope was triggered by the hammer contact to the flap. The sweep speed was 5 ms/cm. The ion-gage trace showed only the linear rise characteristic of the outgassing rate of the sealed volume. Less than 4×10^{-6} Torr liters of air got past the valve, satisfying the protective requirements.

Test	Vacuum failure	Fast-valve closure time setting (ms)	Pressure-trace sensitivity (Torr/cm)
1	Foil	0.83	2.1×10^{-3}
2	Foil	0.83	2.1×10^{-4}
3	Foil	2.1	2.1×10^{-5}
4	Flap	2.1	2.1×10^{-5}
5	Flap	2.1	2.1×10^{-5}
6*	Flap	2.1	2.1×10^{-5}

*Acoustic delay section removed.

The McClure discharge occurred 2 to 2.4 ms after the hammer contact operating the flap valve.

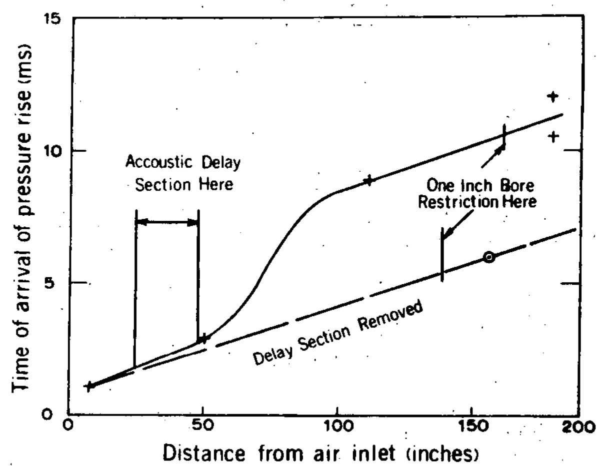

Fig. 4. Propagation of entering air into the vacuum line; initial pressure 3 to 6×10^{-5} Torr.

The propagation rate of air down the line was roughly determined by a sequence of tests using the flap valve with the ion gage mounted at various locations. The time of the first observable change of pressure was taken as the time of arrival. The pressure rise at the two locations behind the delay section were less sharp than at other locations. The offset at the origin is caused by the opening time of the flap valve and the response time of the ion gage.

Footnotes and References

*Work performed under auspices of U. S. Atomic Energy Commission.

1. R. Jean and J. Rauss LeVide 111, 123 (1964).

2. G. McClure Appl. Phys. Ltrs. 2, 233 (1963).

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