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Fast-Closing Vacuum Valve*

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A swinging-gate type valve with associated triggering mechanism is employed as a protective device for quickly stopping a sudden accidental inrush of air to a vacuum system. The electrical triggering mechanism uses no vacuum tubes. For a large inrush of air, the valve will close in less than 0.01 sec.

IN work with the Stanford Mark III linear accelerator,[1] it is often desirable to make a direct pipe connection between the high vacuum of the accelerator and an evacuated experimental setup whose structure may embody fragile windows of metal foil or plastic film. In the event that such a window breaks there is a very fast inrush of air to the accelerator, which can cause considerable damage to diffusion pumps, ion gauges, and other connected equipment. Our valve, with its electrical triggering mechanism, will close in less than 0.01 sec after the start of an inrush of air. In this time interval the high vacuum in the accelerator is usually lost but oil in the diffusion pumps as well as filaments in the ion gauges[2] are saved from damage.

Since charged particles pass through the valve when it is open, the valve is of the "straight through" type. The operation of the valve can be understood from Fig. 1.

An electrical impulse from the triggering mechanism, initiated by the sudden buildup of pressure, energizes and closes solenoid *a* which swings lever *b* on its pivot axis *c*. The motion of *b* is transmitted to the vacuum inside the valve through the flexible metallic bellows to the sliding release tongue *e*, thus releasing catch *g*. The cap-like closure *h* mounted on the arms *i* swings closed on the pivot shaft *j* by the urging of the stiff coiled spring *k*. The closing of *h* is cushioned by the neoprene washer *l* and the vacuum seal is made at the O-ring *m*. When *h* is closed, the buildup of atmospheric pressure against it makes the O-ring seal vacuum tight.

When there is no appreciable pressure difference existing between the two sides of *h*, the valve can be opened and placed in its cocked position. This is done by lifting the cocking arm *n* which turns the O-ring sealed shaft *j* and the lifting finger *O*. A spring *p* returns the cocking arm and lifting finger to their precocking position. These parts do not, therefore, take part in the fast-closing motion of the valve, and this makes for faster closing of *h*. The pumpout *q* is for providing a guard vacuum for the seal of *j* in case a vacuum seal of the guarded type is desired. The shaft *j* and other parts of the valve are sealed with O-rings.

The triggering mechanism and associated circuit are shown in Fig. 2. The trigger operates on the principle that a spark gap can hold off a high voltage in a good vacuum, but will break down as soon as the pressure rises above a certain critical value. Our spark gap consists of two $\frac{5}{16}$-in. diameter stainless-steel spheres. One sphere connects to the ground through a piece of stiff brass wire which can be bent to vary the gap spacing. The other sphere is rigidly held by means of a Kovar-to-glass seal and connects to the secondary of high-voltage transformer TR_2. The solenoid used for triggering the valve is connected in series with the primary of the transformer and the voltage is supplied from a Variac TR_1. When the vacuum is good, the spark gap does not break down and the transformer is operating under essentially no-load conditions. The primary current is, therefore, low and not much current goes through the solenoid. When the pressure rises, the gap quickly breaks down and large currents flow in both secondary and primary. The increased current in the primary causes the solenoid to close, permitting the valve gate to swing shut. In our spark-gap setup, the critical pressure for breakdown is about 30μ. This critical breakdown pressure could be expected, however, to depend strongly on the spacing of the spark-gap balls.

It is convenient to provide a pair of switch contacts actuated by the swinging gate inside the valve. These contacts open and close with the gate. They are useful for switching on and off monitor lights and for turning off the power on the spark-gap system after it has closed the valve.

It is important to have good alignment between the cap *h* (Fig. 1) and the O-ring *m*. Alignment is achieved by providing generous clearance between the machine screws *r* and the arms *i*. The valve parts are swung to their closed position while the nuts on *r* are loose and cap *h* well seated on *m*. The alignment will then be automatically correct, and tightening the nuts will keep it so.

The triggering gap need not, and in fact should not be close to the place where air might be expected to be rushing in. There is danger that the rushing air might blow out the spark before the solenoid has had a chance

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[1] Chodorow, Ginzton, Hansen, Kyhl, Neal, Panofsky, and staff, Rev. Sci. Instr. 26, 134 (1955).

[2] The ion gauge filaments are, in addition, protected with an electronic filament current turn-off device. Without the fast-closing valve, this turn off device has been found, however, not to be effective in preventing filament burnouts for the case of sudden inrush of air up to atmospheric pressure.

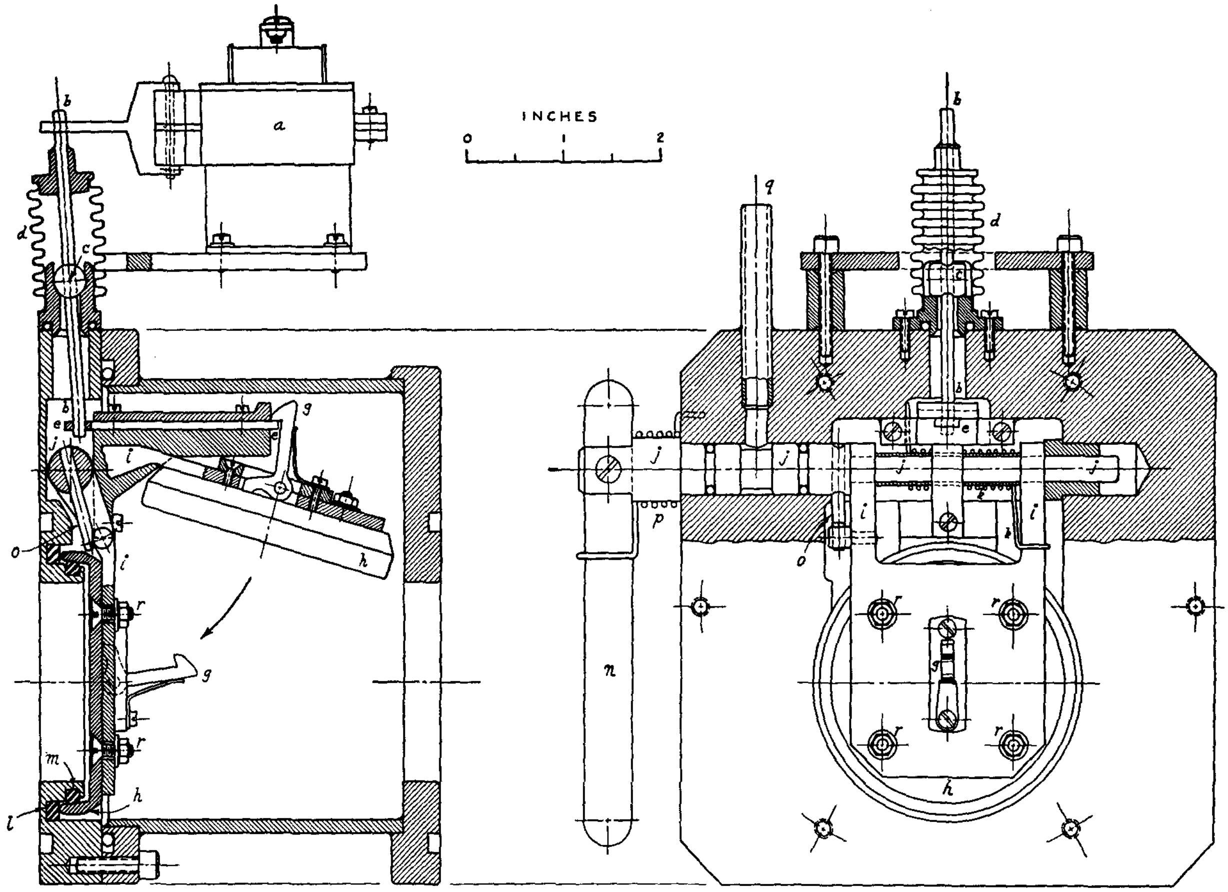

FIG. 1. A fast-closing valve of 2-in. aperture. The electrical switch inside the valve has been omitted for clarity. Left—Valve with swinging gate shown in both open and closed positions. Right—Valve in closed position; solenoid and vacuum-tight enclosure are omitted in this view.

to act. It is preferable to locate the spark gap a little out of the way of a possible air blast, say at the end of a "dead end" side tube (see Fig. 2). This precaution will not appreciably lengthen the time of response, but will eliminate the danger of spark blowout.

A ready test of the valve's alertness to operate can be had if an air inlet valve, such as a Hoke No. 456 toggle valve, is provided at the spark gap. With the fast-closing valve open, vacuum good, and power on, one places his thumb over the air inlet of the toggle valve, imprisoning thereby a small quantity of air. On momentarily opening the toggle valve, the imprisoned air finds exit to the vacuum, firing the gap and closing the valve in the process. The amount of air admitted by this test is usually so small that its effect will go unnoticed on the gauges of a large vacuum system, but it will fire the trigger gap every time.

The speed of operation of the valve was tested under essentially operating conditions. The valve was connected through a length of 3-in. i.d. pipe to a test chamber of 7-cu ft capacity. On the air influx side of the valve a short piece of 4-in. pipe was connected, the open end being closed off with a $2\frac{3}{4}$-in. diameter Mylar plastic window, 1 mil thick. The triggering gap was attached at a convenient place in the test chamber, as was a regular 0–30-in. Bourdon-type vacuum gauge. The entire system was pumped down to a pressure of less than 30μ and the valve and trigger made ready. A brutal jab through the Mylar with a large screwdriver broke the window, the inrushing air breaking down the gap and

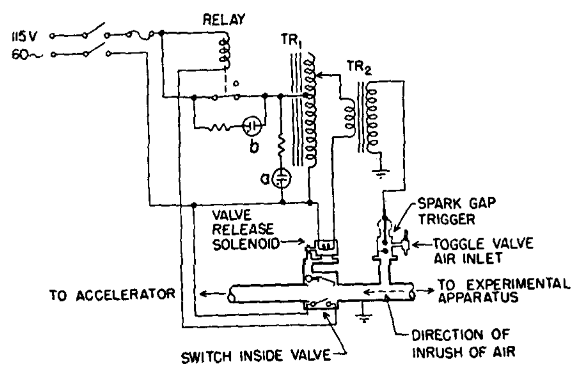

FIG. 2. Electrical circuit of valve and spark-gap trigger; TR_1—Variac; TR_2—High-voltage transformer, e.g., 115 v in, 2600 v out, Primary V-amp-450; Monitor neon lights, (a) lights when valve is open, (b) lights when valve is closed; Valve release solenoid, Allen Bradly, Bull. 860, size 3, wall mtg., coil No. RC-3301.

closing the valve. While no audible distinction could be made between the sound of the window breaking and the closing of the valve, enough air entered to bring up the pressure in the 7-cu ft test chamber from essentially zero in. Hg to about 1 in. Hg absolute as read on the Bourdon gauge. The mass of admitted air could then be determined, and when this mass and the known pipe dimensions were inserted in a compressed air flow formula,[3] the time of flow (i.e., the response time of the valve system) was calculated to be 8 msec. The shortness of this time can be explained only if it is assumed that the pressure of the inrushing air contributes to the total force acting to close the valve gate.

To obtain some idea of the reliability of the valve, the window-breaking tests were repeated about a dozen times and there were no failures. Two fast-closing valves are now in service in this laboratory and they have several times prevented costly shutdowns.

Our experience with a helium leak detector suggests that the valve, when closed with a high vacuum on both sides of the gate, is not completely vacuum tight. If, however, the pressure on the "atmospheric" side of the gate builds up to about 5 in. Hg or more, the valve will be completely tight. In stopping an air inrush from a broken window, the pressure against the gate will be a full atmosphere, and in that circumstance the valve is, of course, tight.

It is a pleasure to acknowledge the assistance of Mr. B. R. Chambers and Mr. H. D. Butler. Their careful construction work has contributed much to the success of the valves now in service in this laboratory

[3] J. S. Walter and S. Crocker, *Piping Handbook* (McGraw-Hill Book Company, Inc., New York, 1931), second edition, p. 127.

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High-Speed Scaling with a Decade-Counter Tube

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A E1T decade-counter tube is used in conjunction with an energy-storage counting circuit. The stray capacitance at the anode of the decade tube serves as the energy storage element, while the stabilizing characteristic of the tube itself makes the circuit completely aperiodic. A secondary-emission tube, type EFP60, produces a 0.15-μsec high current pulse for resetting the decade counter to zero at each tenth input pulse. Double-pulse resolution of <1 μsec and a continuous rate of above 10^6 pps have been achieved.

INTRODUCTION

DECADE-COUNTER tubes have recently been replacing more conventional scaling circuits because of their low power consumption and relatively small number of components required to achieve the same scaling factor. This is an important factor where multiple scaling is required, or where minimum maintenance and long life are of prime importance, e.g., in nuclear measurements where the scalers constitute only one component of an elaborate setup. The disadvantage of decade tubes lies chiefly in their slow counting speed, most of them being of the gas type.[1,2] The E1T, however, is a vacuum tube and should therefore be capable of faster counting rates, but so far no reliable circuit below 10 μsec resolution has come forth in publications.

GENERAL[3]

The E1T consists of an electron gun and a number of focusing electrodes to form a ribbon shaped beam of electrons. The beam passes a slotted anode which has ten apertures corresponding to the number of stable positions. A fluorescent layer behind the slotted anode serves for displaying the position of the beam. The tenth pulse is used to effect the reset of the beam to zero and to activate the following decade stage. Without special arrangements speed of operation of the E1T is limited by the long time constant in the anode circuit of the 1-megohm load resistor R_3 and the distributed capacitance (point A, Fig. 1). Full details on circuits down to 10 μsec resolution may be found in the literature.[4,5] A faster circuit described in the following has a resolving time of <1 μsec and, in contrast to the slower circuits, does not impose strict requirements on the shape and amplitude of the input pulse. In principle it is an energy storage device where the storage element consists of the anode to ground capacitance in parallel with the right deflector capacitance and any other stray capacitance to ground appearing at point A [Fig. 1(a)]. The tube itself serves to adjust circuit conditions and

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[1] A. B. Thomas, J. Brit. Inst. Radio Engrs. 13, 414 (1953).
[2] J. C. Baker and G. G. Eichholz, Nucleonics 12, No. 4, 44–49 (1954).
[3] For a detailed description of the E1T see references 4 and 5.
[4] Jonker, van Overbeek, and deBeurs, Philips Research Repts. 7, 81–111 (1952).
[5] R. van Houten, Electronic Appl. Bull. (Philips Gloeilampenfabrieken, Eindhoven, Holland) 15, No. 3 (1954).