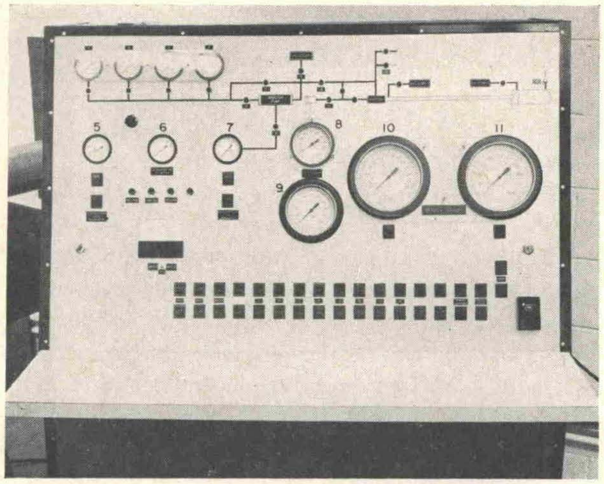

FIG. 13. Control panel.

entry of the bypass line into the high pressure side of the pump outlet to guard against the possibility of opening the bypass valve when the system pressure is above 135 bars.

The electrically driven pump accepts either N_2 or He at 31 bars or more and will compress it to 413 bars. If pumping is necessary, the operator may route the high pressure gas to a 28 liter storage reservoir for later use or pump directly into the breech reservoir.

It is normal procedure to fill the breech to 4 to 8 bars above the desired shooting pressure and then allow the gas pressure to stabilize at ambient temperature. Excess pressure is relieved through a normally open high pressure valve with restricted orifice open to the atmosphere. This valve (No. 11) is in parallel with the breech fill line. One other valve (No. 9) with a full orifice open to the atmosphere and also in parallel with the breech fill line is normally closed and is used for dumping the pressure in the breech in an emergency.

To facilitate the use of both breeches without having to make extensive changes in the system, valves No. 13 and 14 were incorporated into the system. Valve No. 10 is the firing valve for either breech. Valves No. 13 and 14 are on the same circuit and are operated in such a way that only one may be open at any time. By opening valve 14, valve 13 is simultaneously closed and the system is ready to accept the double diaphragm breech. With valve 13 open and valve 14 closed the system is used to operate the wrap-around breech.

2. *Control Panel*

The control panel (Fig. 13) is divided into two sections. One affords the control of operations and the other enables the operator to monitor the influence of the controlling action taken.

The control section, in the lower portion of the panel, consists of a double row of illuminated pushbuttons across the lower extremity of the panel face. The upper row is green and the lower red; one button of each pair activates a valve and the other deactivates it. These pushbuttons control all valves, both vacuum pumps, the projectile latch, and the oscilloscope camera shutters. The circuits are designed so that all lights must be green immediately before firing. This enables the operator to make a final check just before firing to be sure the system is "go." One pair of pushbuttons, at the right end of the row, is not in-line with the others. The upper of this pair is the dump actuating button. Upon depressing this pushbutton the previously mentioned dump valve is actuated and all other valve circuits are simultaneously opened, causing all other valves to close.

The upper section of the panel contains pressure monitoring gauges. Gauges 1–4 monitor the pressures in the supply bottles. Gauge No. 5 reads the regulated pressure of the bottle gas entering the high pressure pump. Directly below this gauge are two pushbuttons which actuate a motor driven pressure regulator, thus allowing for remote control of the pump inlet pressure. The vent gauge (No. 6) indicates the air pressure to the high pressure valve actuators. Gauge No. 7 reads the air inlet pressure to the pump. The two buttons below this gauge enable one to regulate the air inlet pressure to the pump.

Gauge No. 8 monitors the reservoir pressure; below this is No. 9, a thermocouple gauge readout which indicates the pressure in the evacuated barrel.

Breech pressure is monitored by the two large gauges on the right. Both gauges read to an accuracy of $\pm\frac{1}{4}\%$ of full scale. Number 10 is calibrated in 5 psi subdivisions and indicates pressures from 0 to 1500 psi. Number 11 is calibrated in 25 psi subdivisions and indicates pressures from 0 to 10 000 psi. These gauges are connected to the breech fill line by capillary tubing (0.317 cm o.d.×0.071 cm wall 316 SS). Number 10 may be remotely switched into or out of the breech pressure line. If the low pressure gauge is left in the system above 98 bars, a burst diaphragm will rupture and a surge check valve will close, thereby isolating it from the system.

On the upper portion of the control panel is a schematic representation of the high pressure piping system. Each

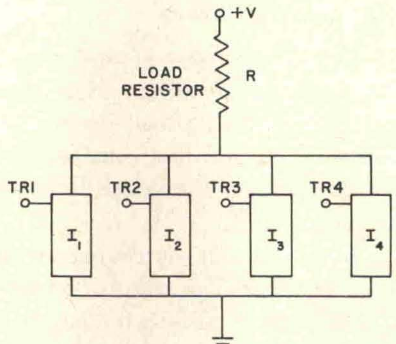

FIG. 14. Operational schematic of velocity and tilt circuits. TR1, TR2, TR3, TR4—trigger inputs.

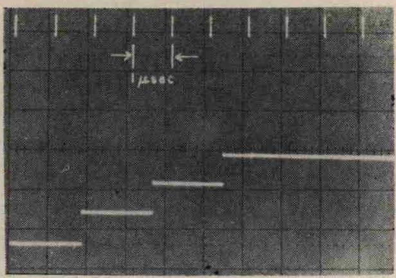

FIG. 15. Typical record for projectile velocity measurement.

valve in the system and its location with respect to the high pressure flow are denoted on the schematic by a numbered, red indicator light. The corresponding number is found between the two rows of pushbuttons. This feature reduces the possibility of actuating a critical valve at the wrong time.

INSTRUMENTATION AND ANCILLARY EQUIPMENT

In addition to the gun and control system, electronic instruments were either purchased or built to serve as recording devices. The principal instrumentation consists of 10 oscilloscopes. These include six Tektronix type 581/585, two Tektronix type 454, one Tektronix type 519, and one Tektronix type 555. These 'scopes provide 11 recording channels with a frequency response adequate for use with essentially all currently feasible measurement techniques.

The 'scopes are supplemented by a 100 MHz time interval counter, Hewlett–Packard type 5275A with crystal controlled oscillator, and a pulse generator, E-H Company model 120D. These are used principally for timing devices.

A number of electronic devices have been constructed by students to serve special purposes. These include timing and tilt pulse-shaping circuits, a quartz gauge calibration device, and a manganin gauge power supply. These devices are described in detail below.

In addition to electronic instruments other major auxiliary equipment includes a lapping machine, a toolmaker's microscope (which serves for measuring traces on films and other purposes), and a diamond cutoff saw.

A. Velocity and Tilt Circuits

Velocity and tilt circuits are identical in design and operation. The circuit for each consists of four triggerable constant current sources connected to a load resistor, as shown in Fig. 14. The trigger inputs for these constant current sources are the velocity pins for the velocity circuit and the tilt pins for the tilt circuit.

Once triggered these constant current sources remain on until reset manually by the operator. This feature prevents any one of the current sources from turning on and then off due to a loss in the ground connection at the pin input. Thus, the voltage across the load resistor is given by

$$V(t)=R[I_1H(t-t_1)+I_2H(t-t_2)+I_3H(t-t_3)+I_4H(t-t_4)], \quad (1)$$

where

$$H(\xi)=0, \quad \xi<0,$$
$$H(\xi)=1, \quad \xi\geq 0,$$

and t_1, t_2, t_3, and t_4 correspond to the times at which pins 1, 2, 3, and 4 for either the tilt or the velocity circuit are grounded by the projectile. Further, the current ratios $I_1::I_2::I_3::I_4$ determine the relative voltages across the load resistor R for the respective pin shortings 1, 2, 3, and 4. In the case of the velocity circuit the ratios are all 1:1 so that the voltage steps are equal for all pin shortings. Figure 15 shows an oscilloscope voltage–time record for a typical velocity measurement.

For the tilt circuit the current ratios have been set at 1::2::4::8 for the circuit inputs 1, 2, 3, and 4, respectively, These ratios were chosen so that the sequence of pin closures can be determined in case any two or more pins short simultaneously; i.e., any additive combination of 1. 2, 4, or 8 will correspond to a unique voltage combination on the measurement oscilloscope. Tilt and velocity circuits do not have zero risetimes as implied by Eq. (1). The combined risetime of either circuit and a type 585A Tektronix oscilloscope normally used for the measurement is typically 10 nsec for any pin closure. A typical tilt record is shown in Fig. 16.

Figure 17 is a block schematic of both velocity and tilt circuits. When the input pins are all ungrounded the circuit may be placed in a "reset" mode by depressing the reset key. Any subsequent input pin shorting will change the circuit from the reset mode to the "set" mode. To the operator these two modes are distinguishable by the use of an indicator lamp, which is turned on when the circuit is in the reset mode (see Fig. 17).

Describing the reset mode more specifically in terms of circuit operation, each pin input is clamped on electrically by means of a 220 Ω resistor connected to the 3.6 V supply at the input of nor gates G1–G4. The nor designation means that the sign of the output of the gate is opposite to the input. The outputs of nor gates G1, G2, G3, and G4

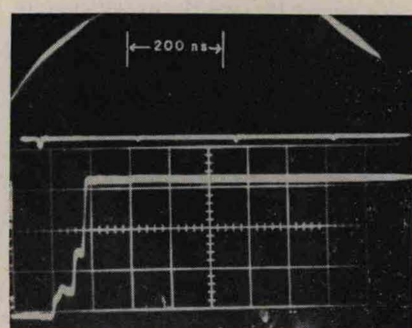

FIG. 16. Typical record for measuring tilt impacting surfaces.