206 bars with a safety factor of 1.5; some of the projectiles have been tested to an outside pressure of 309 bars.

Projectile and barrel dimensions limit the angle between projectile and barrel axes to 0.5 mrad or less when the projectile contacts the target (i.e., when the projectile protrudes 5 cm from the muzzle). The O-rings help to center the projectile in the barrel, and close tolerances are held on these grooves, both in concentricity (0.002 cm T.I.R.) and size ($\pm$0.002 cm). The O-rings are Teflon-coated Parker O-rings No. 2-342 made of buna-N rubber with a 70 durometer hardness.

The projectile weight of 1.1 kg limits the maximum velocity in the wrap-around breech to 0.6 mm/μsec with nitrogen as the driver gas and 0.9 mm/μsec with helium or 1.05 mm/μsec with special projectile.

The impacting surface of the projectile is lapped flat and brought into square with the axis of the projectile with a lapping machine. To check the impacting face for perpendicularity with respect to the axis of the projectile, the projectile is placed impacting face down on a surface plate and rotated against a reference pin. A dial indicator measures any runout of the top with reference to the pin. The runout is kept within 0.0012 cm. This means the impacting surface is perpendicular to the axis of the projectile to within 0.1 mrad. Any deviation is removed during the lapping process by eccentrically weighting the projectile.

F. Recoil and Catcher System

The most unusual feature of the gun compared to others of its type is that it is allowed to recoil freely until after impact has occurred; after impact the gun is decelerated by velocity sensitive shock absorbers. The target is mounted rigidly on the muzzle room wall and is therefore stationary. This arrangement essentially eliminates all problems of vibration of the target prior to impact. Further, standard shock absorbers can be used to stop the gun with maximum forces which are much less than the maximum unbalanced force on the gun during firing. Two shock absorbers of 17×10^6 g·cm capacity and 7.6 cm travel bear against one of the barrel flanges and against a steel frame that transfers the momentum to the I-beam (Fig. 3).

The catcher tank consists of two sections. One section (the target chamber) is permanently mounted to the wall of the muzzle room (Fig. 3). This section is evacuated prior to the shot. The second section is mounted on casters and joins the first section by means of quick disconnect devices. This section contains the projectile-stopping mechanism and is not evacuated. A Mylar diaphragm 45.7 cm in diameter and 0.018 cm thick provides an easily perforated seal between the two sections.

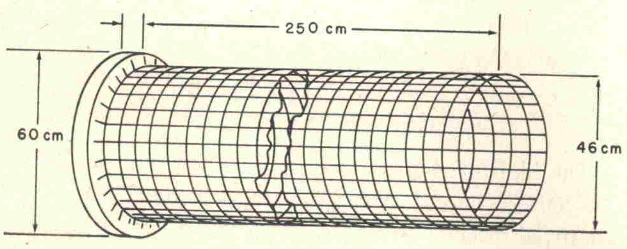

FIG. 9. Wire cage for stopping projectile. In operation the cage is stuffed with rags. Cage woven from 1.27 cm high carbon steel.

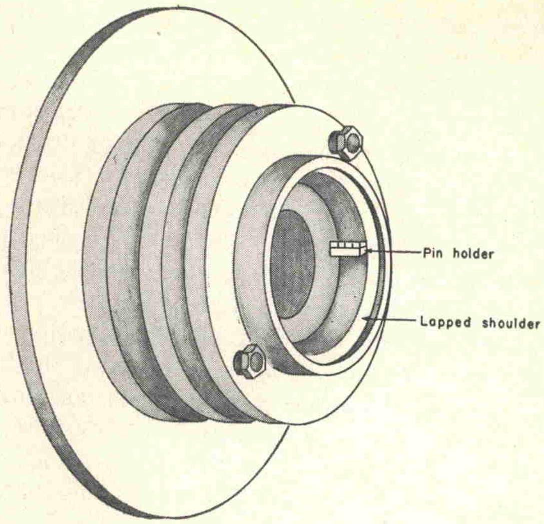

FIG. 10. Target holder.

The projectile-stopping mechanism consists of a heavy wire cage, 45.7 cm in diameter and 2.5 m long, stuffed with nylon or Dacron rags (Fig. 9). At the rear of the cage is bolted a 10 cm thick by 61 cm diam steel plate weighing 225 kg; the total weight of the cage, rags, and steel plate is about 450 kg. This assembly is suspended on a rail and achieves a maximum velocity of about 2 m/sec when the maximum momentum of the projectile ($\sim10^8$ dynes·sec) is absorbed by it. The force required to stop the assembly within 7.6 cm of travel is therefore less than 31 000 N and is achieved with shock absorbers bearing against the rear of the tank.

G. Target Holder and Alignment Tools

The target holder is a ring with a lapped shoulder against which the target is held by small breakaway tabs (Fig. 10). Adjustment of the orientation of the target holder is accomplished with three differential screws that provide high strength and fine adjustment capability.

The tools used to align the target holder perpendicular to the axis of the barrel are a brass gauge plug and a gauging fixture which carries a sensitive dial indicator. The gauge plug is a 35 cm solid brass bar with the diameter machined 0.0025 to 0.0038 cm smaller than the exit diameter of the gun muzzle. A 5 cm tapered section is machined on the leading end to facilitate fitting the plug into the barrel. The gauging face of the plug is flat and perpendicular to the axis to within 0.05 mrad and is periodically checked with the same fixture used to check the projectiles. The gauge plug is solid to provide a heat sink so that handling does not change its dimensions or straightness.

The gauging fixture is simply a ring, ground flat, and large enough to mate to the target aligning surface. A sensitive dial indicator is rigidly supported through the ring to sweep a 9 cm diam circle on the face of the gauge plug. It measures the change in distance between the plane of the target holder and the face of the plug.

To align the target ring the gauge plug is positioned in the barrel and the gauging fixture is placed in the target holder and held with spring clips against the aligning surface. The dial indicator is then adjusted to touch the surface of the gauge plug and to give a null reading. The aligning fixture is then rotated and the dial indicator readings noted. The alignment nuts (differential nuts) are adjusted until a 360° rotation of the aligning fixture in both directions shows no greater than 0.0005 cm variation in readings. This corresponds to a misalignment of 0.06 mrad or less. The gauge plug is then rotated and the alignment rechecked.

H. Projectile Velocity Pins

Projectile velocity is measured with a series of four pins, spaced 1 cm apart, which make electrical contact with the projectile. To insure a good ground each pin has a companion grounding pin which is positioned to make contact shortly before the active pin. The pins are machined from 0.158 cm brass rod; a whisker 0.025 cm in diameter and 0.25–0.35 cm long is turned on one end. These eight pins are positioned in a block so that the projectile contacts one third of the whisker length.

The velocity pin block is designed to insulate each of the active pins (velocity pins) from each other and from ground and to provide a BNC connection for each (Fig. 11). The

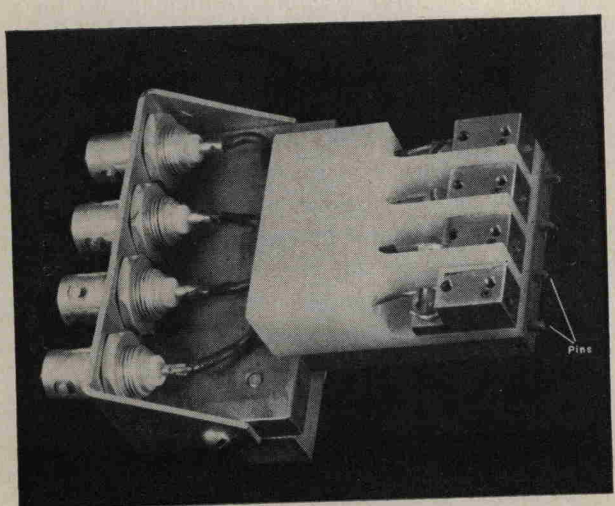

FIG. 11. Velocity pin holder.

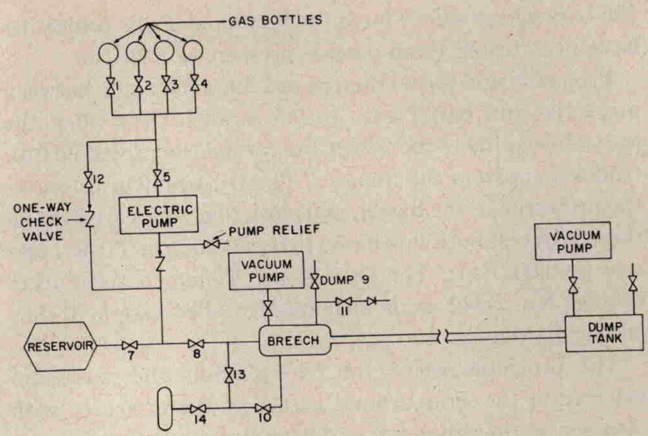

FIG. 12. Gas flow circuit.

velocity pins are stair stepped so that each pin makes contact with the projectile on fresh metal to insure accurate knowledge of spacing. The spacing of each pin pair is measured with a Gaertner toolmaker's microscope. The average of three sets of measurements yields an accuracy of $\pm 10\ \mu$, or about 0.1%.

Before firing, the velocity pin block is slipped into a close fitting hole in the target ring and the electrical connections are made. The first velocity pin makes contact with the projectile at a distance of 3.5 cm in front of the target and triggers the velocity measuring 'scope. The three intervals available provide redundant measurements of velocity and acceleration to provide a consistency check.

I. Control System

The control system was designed with the following criteria in mind:

(i) It must handle pressures up to 413 bars remotely.

(ii) It must be essentially failsafe, yet contain a minimum of interlocks.

(iii) It must indicate, at a glance from the operator, the complete status of the system at any time, particularly just before firing.

(iv) It must be easily adaptable to both breeches.

The above specifications were met by coupling two subsystems to the main high pressure system. A 110 V ac electrical system controls a low pressure (4 bars) air system, through the use of electrically operated three-way solenoid valves. These in turn control the actuators of the high pressure (413 bars) valves.

1. High Pressure System (*Fig. 12*)

The high pressure system is built entirely of 0.635 cm o.d.×0.276 cm i.d. 316 SS annealed tubing. Gas may be admitted directly from bottles to the reservoir through a bypass line from the pump inlet to the outlet (valve No. 12). A one-way check valve is inserted just before the