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Operation Manual
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# HALL STATION AND CAMERA SYSTEM OPERATION AND MAINTENANCE MANUAL

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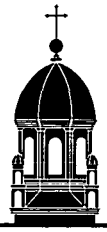

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# SECTION 1

# INTRODUCTION

The Hall camera is a diagnostic tool with a relatively long recording time and a lack of special triggering requirements. It is used to determine projectile velocity and orientation and to diagnose sabot functioning. The strip of 16 mm film used to record passage of the projectile or projectile and sabot also provides a permanent record of the event.

A high-speed camera, operating in a streak mode, is used to simultaneously view and photograph objects that pass openings in a section of the range. Collection of the images (shadowgraphs) from each opening is accomplished with a system of mirrors that direct the images into the camera lens. Enhancement of image definition is achieved by viewing the range through a pair of slits that are backlit by collimated, high-intensity light sources. A diagram of a Hall camera system is shown in Figure 1.

The Hall film record of the event actually provides the time of flight of the projectile between the slits. A time mark generator is used to supply extremely short pulses of light at a known frequency. These pulses of light are used to produce "timing marks" on the edge of the film. Comparison of the spacing of these marks with the spacing of the projectile images provides the information necessary to determine the time of flight of the projectile. Since the slits are installed with a known separation distance, calculation of the velocity of any object passing both slits is a simple matter.

# HALL VELOCITY STATION

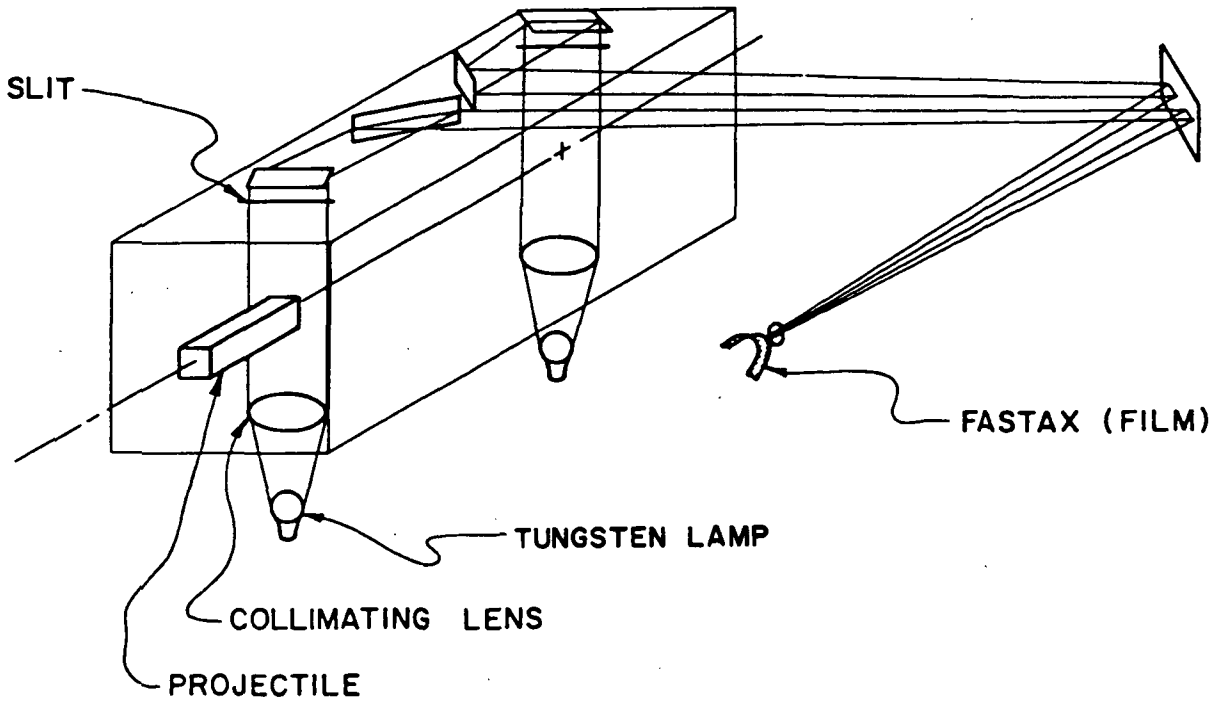



Figure 1. Diagram of Hall Station and Camera System.

## SECTION 2

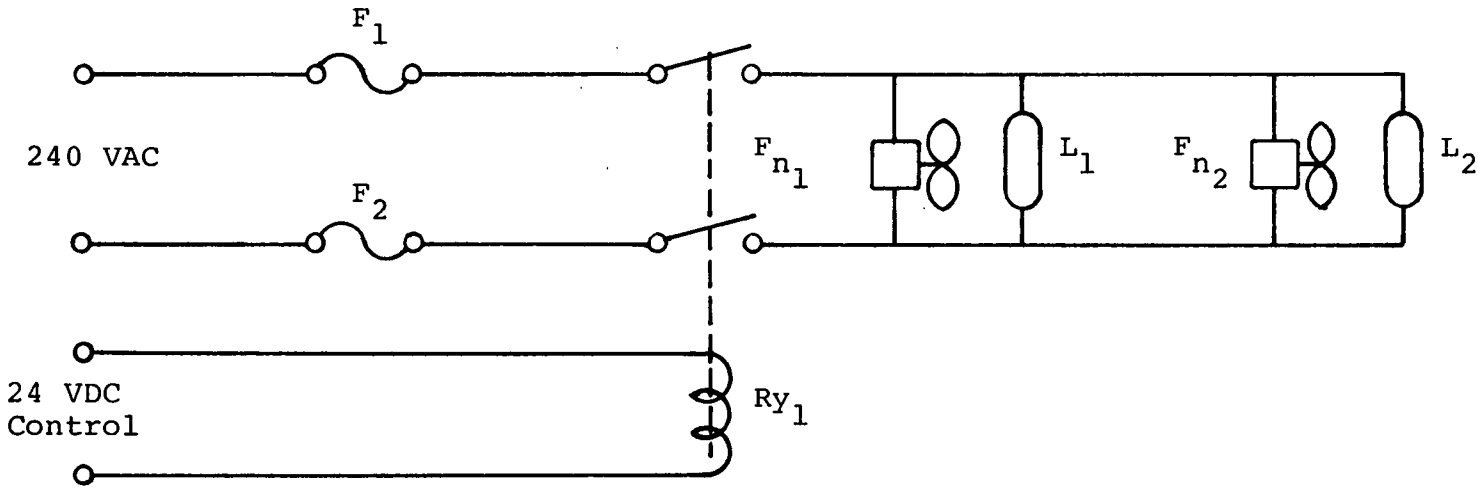
## SYSTEM DESCRIPTION

The Hall station and camera system consists of several major components. These components are: (1) a section of range tankage, (2) a high-intensity light source, (3) a mirror system, (4) a high-speed 16 mm camera modified to operate in a streak mode, and (5) a time-mark generator. A separate programmable controller has also been furnished. Use of the controller to initiate firing of the gun at the appropriate time during the run of the high-speed camera insures proper sequencing of the camera and light source functions and facilitates and enhances use of the Hall camera system.

Both the light source and mirror system are mounted on a specially fabricated section of range tankage. In addition to having end flanges for attachment of the unit to adjacent range sections, the tank also has four, large openings to provide working access to its interior and two pairs of long, slotted openings on opposite sides of the tank for viewing the objects which move down-range. The large openings are equipped with easily removed or installed aluminum cover plates. The slotted openings have provisions for the installation and attachment of quick opening and closing window assemblies. Each of the openings in the tank is made vacuum tight by using O-ring seals at the appropriate mating surfaces.

Two high-intensity lamps and appropriate lenses are mounted in a fan-cooled enclosure which is attached to the bottom of the range tank. This enclosure also contains several electrical components for switching and distribution of power to the lamps (see Figure 2). Approximately 3 kw of power at 240 VAC is required to fully illuminate the lamps.

A second enclosure containing several mirror mounts is attached to the top of the range tank. The slits through which the projectile is viewed are attached to the plate forming the base of this enclosure. The slits and mirrors are used to



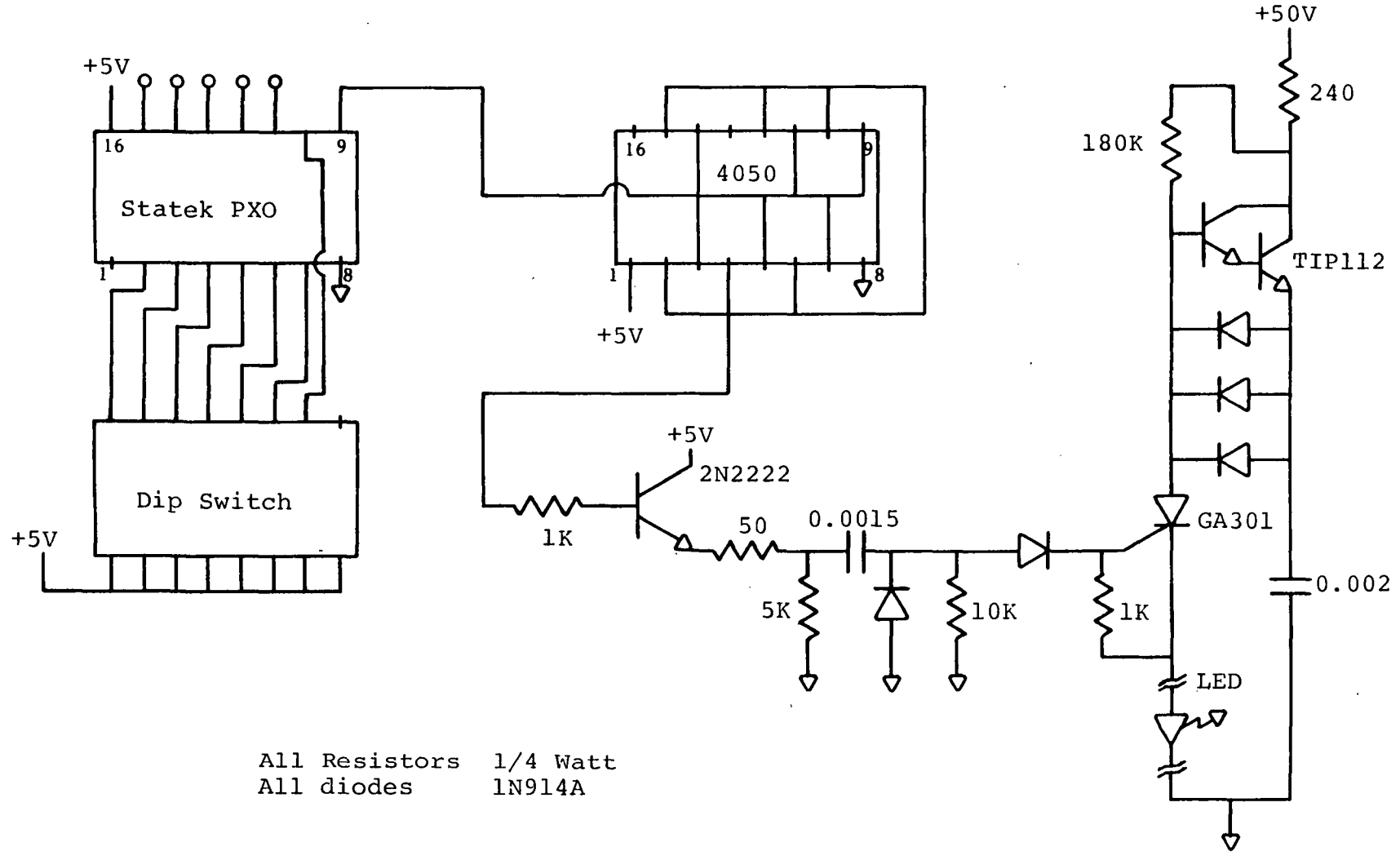

| | | |
|---|---|---|
| $F_1$, $F_2$ | - | Fuse, FRN-R20 |
| $F_{n_1}$, $F_{n_2}$ | - | Fan, Pamotor 8850D |
| $L_1$, $L_2$ | - | Lamp, Q1500T3-CL |
| $Ry_1$ | - | Relay, P&B PRD11DY0 (24 VDC) |

Figure 2. Hall Station Light Source Wiring Diagram.

produce and to direct, respectively, the projectile images, so that a continuous and simultaneous view of all objects passing by either slit is recorded by the camera.

A Redlake Corporation, Fastax II, Model 46-0007 16-mm, high speed camera and appropriate lens is used to record the event. This camera uses 30-m-long (100 ft) reels of film with high-speed perforations and has a maximum film speed of approximately 55 m/sec, to provide an overall recording time of about 1 second. The timing light block furnished with this camera has been modified to accept the high-speed time marker used to place fiducial marks along the edge of the film. In addition, a BNC connector has been installed on the rear of the camera to permit electrical connection to the light emitting diode (LED) in the timing light block. When in use, the camera should be installed on the camera mount so that the film plane of the camera is approximately 4.2 meters away from the range centerline. Refer to the operating manual furnished with the camera for film loading instructions and camera care and maintenance procedures.

Timing marks or light pulses approximately 100 ns long are generated at the rate of 10 kHz by the time-mark generator. A schematic drawing of the generator is presented in Figure 3. The 10 kHz signal is derived by dividing the output of a 1 MHz crystal oscillator by 100. Basic crystal frequency for the oscillator is $\pm$ 0.015 percent; a maximum aging effect of 10 ppm results during the first year of operation. Signal output from the generator is supplied to the camera by a BNC cable which should not exceed 2 m in length. Since a high driving current is supplied to the LED, the time mark generator should not be activated for more than a minimum length of time before a test. A replacement LED has been supplied with the system. Assistance in replacing the LED is available from personnel of the Impact Physics Group at the University of Dayton Research Institute.




All Resistors 1/4 Watt
All diodes 1N914A

Figure 3. Schematic Diagram of Time Mark Generator.

## SECTION 3

## OPERATING AND ALIGNMENT PROCEDURES

The Hall Station and Camera System components were adjusted and aligned prior to shipment. Consequently, minimal adjustment of the light source components and mirror systems should be required after the system has been installed on the range.

### ACCESS PORTS AND WINDOW ASSEMBLIES

Removal and installation of the access ports is a straight forward process. In the event the 1 1/2-inch-long, 3/8-16 socket head screws which form the "studs" used to secure the access port covers become damaged or require replacement, merely remove the damaged screw using a 5/16-inch-Allen wrench from inside the tank. Remove foreign material from the area of the tank wall which was in contact with the underside of the bolt head. Prior to installing a new bolt, place a small bead of a silicone-type sealant (RTV) around the base of the screw head. When the screw is tightened, extrusion of the sealant will provide a vacuum-tight joint.

Each time a port cover is removed, inspect the O-ring seal for damage and/or debris contamination. The sealing surface of the ring should be cleaned and coated with vacuum grease before returning it to the range. In the event an access port O ring needs to be replaced, use precision Uniform Size Number 451, Buna N, O rings.

The window assemblies were designed to eliminate the need to work in the close space between the tank and the light and mirror assembly enclosures. The assemblies can be installed and removed from either side of the tank. Installation of the windows is made by inserting the brass posts, at the open end of the window assembly, into the slots in the sides of the block with the

slotted opening (see Figure 4a). Note that the yoke with the hand screw should be in the full forward position (lying on top the assembly). Slowly push the assembly over the slotted opening until further motion is blocked by the end plate of the assembly. Use the index finer of one hand to hold the assembly in place against the block (see Figure 4b) and pull the yoke out and down until the ball end of the screw can be placed in the shallow hole in the end plate. Pulling this yoke forward will cause the window assembly to be cammed down against the block. Once the ball end of the screw has been seated, the brass pins, initially used to guide the assembly, will hold the assembly in place on the block. Careful tightening of the hand screw compresses the O-ring seals in the top of the block and completes installation of the window.

Figure 4. Installation of Window Assembly. (a) Engagement of Brass Guide Pins in Slots (b) Locking Window in Place.

CAUTION

PRIOR TO THE INSTALLATION OF A WINDOW ASSEMBLY THE TOP SURFACE OF THE BLOCK SHOULD BE INSPECTED FOR FOREIGN MATERIAL. PRESENCE OF A SMALL CHIP OF METAL OR TARGET DEBRIS CAN CAUSE A WINDOW TO BREAK WHEN THE HAND SCREW IS USED TO DRAW THE WINDOW DOWN

CAUTION

Removal of the window assembly is accomplished by reversing the order of installation.

The O-ring seal in the top of the block should be cleaned, inspected, and lightly greased before each use. In the event replacement is required, Precision Uniform Size Number 254, Buna N, O rings should be used. The windows are pieces of ordinary 1/4-inch thick plate glass, 2 1/8 inches wide by 9 1/2 inches long. The area of the window over the slotted opening should be thoroughly cleaned and inspected before each use. Small inclusions of target debris, etc., which embed in the glass usually do not impair the usefulness of a window. Close inspection of the 16 mm film will indicate when replacement of a window is required. Replacement of a window is accomplished by removing the bracket from one end of the glass, loosening the bracket at the other end of the glass, and removing the old glass. During installation of the new glass, care should be taken to insure that the rubber cushions between the bracket and the glass are in place.

LIGHT SOURCE ASSEMBLY

Refer to Drawing Numbers 93421-21-1 and 93421-21-2 "LIGHT SOURCE ASSEMBLY" for detail numbers given in the following steps.

| WARNING<br>STEPS 1 THROUGH 5 SHOULD BE PEFORMED WITH THE POWER OFF AND/OR DISCONNECTED<br>WARNING |
|---|

The following steps list procedures which are to be followed when installating components and preparing the light source assembly for alignment.

Step 1. Remove the cover on the mirror assembly by removing the four screws on top the cover and lifting the cover straight up.

Step 2. Remove window assemblies from tank.

Step 3. Remove the light source cover by taking out the eight screws (Detail 24, four each side) along the long dimension of the top edges of cover. Only these eight screws need to be removed. Lift the cover assembly straight up about 20 mm (3/4 inch) and slide the cover, with the louvered endplates, sideways to remove it from the unit.

Step 4. If the high-intensity lamps are not in place, install Q1500 T-3/CL lamps (Detail 35) in their holders (Detail 30) by pushing the spring loaded ceramic sections of the holders back and allowing the lamp to slip into place. Any smudges or fingerprints on the lamps should be completely removed before proceding with the alignment. Failure to do so will result in the foreign material being baked onto the lens envelope when the lamps are turned on.

Step 5. Install the 24 x 169 mm, 44 mm focal length plano-cylindrical lenses (Detail 32) in their mounts (Detail 34) and tighten the spring clips (Detail 33).

WARNING

WITH THE ILLUMINATOR COVER REMOVED, LINE VOLTAGE IS EXPOSED TO PERSONNEL. THE VARIABLE TRANSFORMER IN STEP 6 SHOULD BE ISOLATED FROM THE LINE OR AN APPROPRIATE GROUND FAULT INTERRUPTER (GFI) SHOULD BE INSTALLED IN THE CIRCUIT. PERSONNEL PEFORMING THE ALIGNMENT SHOULD BE PROPERLY TRAINED AND EXHIBIT EXTREME CARE DURING THE FOLLOWING ALIGNMENT PROCEDURES.

WARNING

Step 6. Connect the large cable from the illuminator to a variable transformer capable of supplying 5A at

120 VAC. Be sure that the green earth ground wire is properly grounded.

Step 7. The relay ($Ry_1$ Fig. 2) in the light source must be activated to check the alignment of the lenses and lamps. This may be accomplished by forcing output 0002 of the Programmable Controller "ON". Refer to Section 6 of Gould Micro 84 Programmable Control Users Manual. Plug the Programmer into the Controller. Turn the Memory Protect switch "OFF". Move the cursor to output 0002 in the first network. Press SHIFT then press DISABLE (shifted FORCE). Press FORCE. The relay should be activated. When the alignment check is complete, press the SHIFT then FORCE key.

Step 8. Turn power "ON" to the variable transformer and adjust the voltage until the lamps glow. This will require a transformer output of approximately 30 volts.

The next two steps are followed to check and/or adjust the alignment of the plano-cylindrical lenses.

Step 9. Observe the pattern of light falling on the slits (located in the mirror assembly). If this pattern is not centered on and parallel to the slits, loosen the 1/4-20 bolts (Detail 19) and slide the lense mounts (Detail 34) from side to side until the center of the bright area is in the desired position. Use care during this adjustment to keep the lenses horizontal and parallel with the lamps.

Step 10. When the lighted areas are correctly positioned on the slits, tighten the lens holder mounting bolts.

The lampholders were aligned before shipment of the system and should not require adjustment. However, the following procedures are to be followed if adjustment should become necessary.

Step 11. Turn power to lamps "OFF".

Step 12. Loosen the 6-32 screws (Detail 2) until the lamp holders can be moved.

Step 13. Turn power and power transformer "ON". Set voltage to approximately 30 V.

Step 14. Move lampholders up or down until the illuminated area beneath the slits is constant in width. A slight vertical misalignment of the mounts may be necessary to achieve the desired light pattern.

Step 15. Tighten the lampholder mounting screws.

This completes assembly and alignment procedures for the LIGHT SOURCE. The assembly cover should now be returned to the unit.

## CAMERA INSTALLATION AND ALIGNMENT

The camera mount should be bolted to a wall or other rigid structure located a perpendicular distance of approximately 4.2 m (14 feet) from the range centerline. The top surface of the mount should be level and 23.8 cm (9 3/8 in.) above the range centerline. Attach the camera to the mount.

Install the lens on the camera (refer to the Operating Instructions for Fastax II - 100 ft. cameras, Section 6, also Figure 12, page 34). Install the focusing film and position the horizontal line on the film in the center of the field of view. To aid in this operation, remove the frame mask (Item 32, Figure 12) and install the mask with the largest slit. Install the camera door and boresight.

The focal length of the lens provided with the camera was chosen so that the shadow (image) of a projectile travelling at

4.1 km/sec will travel at the same velocity as the film in the camera. This requires, for a 50 mm lens, that the film plane of the camera be located approximately 4.2 meters from the range centerline. This distance should be measured along the optical path of the image through the slit and mirrors of the Hall station. Small compromises of this distance may be made because of physical restraints of camera location options. The demagnification (83 to 1) established by this nominal distance has proven to be adequate for resolution of objects as small as 2.38 mm diameter travelling at velocities of 6 km/sec.

MIRROR ASSEMBLY ALIGNMENT

The following procedures are followed to provide a rough alignment of the mirrors. In both these procedures and the final alignment procedures refer to Drawing 93421-20-1 for detail numbers.

Step 1. Remove the knife edges (Detail 5) forming th slits at both slit locations. Refer to Steps 6 and 7 in the LIGHT SOURCE ASSEMBLY Section and dimly illuminate the lamps.

Step 2. Loosen the various mirror mount clamp bolts and rotate the mirrors until the images of the lamps are centered on the slit mask in the camera and viewed through the boresight. During these adjustments, take note of the effect of image motion provided by movement of each component.

Step 3. Place a short piece of threaded rod in the tank and position it so that its' long axis is coincident with the range centerline. Adjust the focus of the camera to obtain the best image of the rod. Record the distance setting shown on the lens. Reference to this setting, if the lens should be accidently moved, will eliminate the need to remove the pair of slits for refocussing of the lens. Remove the threaded rod from the tank.

Step 4. Replace one of the knife edges at each slit location. Carefully adjust the distance between the knife edges to 609.6 mm (24.00 inches $\pm$ 0.010) and ensure that they are perpendicular to the range centerline. Tighten their mounting bolts and recheck the alignment of the knife edges.

Step 5. Loosely install the other knife edges to form the slits. Use a piece of 0.25-mm- (0.010 in.) thick shimstock or a thickness gauge to space the knife edges and tighten their mounting screws. Remove the shims.

In the following steps, the final alignment of the Hall station mirrors is made.

Step 6. Rotate the sprocket in the camera until the line on the focusing film is exactly centered on the slit opening. This may require several interactions of inspection through the boresight, removing the camera door, rotating the sprocket slightly, re-installing the door, etc.

Step 7. Align the mirrors until the images of the light passing through the slits are exactly parallel to the line on the focusing film and lie in the center of the slit mask. Replace the wide slit with the finest slit. If the images of the slits are not fully visible and parallel, further adjustment is necessary. If the images are parallel to but above or below the slit, the camera mount must be moved up or down. Be careful to keep the mount level during this adjustment. If the images are not parallel, further mirror adjustment is required. When all alignments are complete, tighten all bolts loosened during the procedure and replace the mirror assembly cover. Re-enable the lamp relay on the controller and connect the lamps to the 240 VAC circuit.

Set the camera lens to f2. A test film should be run after alignment of the Hall station and mirror system to verify that the slits are fully illuminated. If the film is fogged by extraneous light, suitable shrouds should be installed to prevent this light from entering the camera lens.

## SECTION 4

## FILM PROCESSING AND DATA REDUCTION PROCEDURES

### FILM AND FILM PROCESSING

Kodak RAR2479 (catalog no. 1714724) is recommended for use with the Hall Station camera. For best results process this film for 4 minutes in Kodak D-19 developer at 80°F. Processing time and/or camera f stop setting may be changed to produce the desired image density. The entire film can be machine processsed or a small length, 3 to 4 m (10 to 12 ft) can be processed by hand.

Since all operations related to running the camera and firing the gun are controlled by the firing sequence controller, the very small piece of film, usually less than 25 mm long, which holds the projectile images is usually located in about the same position with respect to the end of the film. The position of the projectile on the film may be moved by using the footage thumbwheel located at the rear of the camera. Adjustment should be made only after the "jitter" time of the firing sequence has been determined, to insure that the image is recorded before the camera runs out of film.

It is recommended that the position of the data on the film be determined by hand processing pieces of film 3 to 4 m long, starting from the end of the roll as it was removed from the camera. Once the approximate location of the images has been determined, subsequent films can be processed by discarding the film after the projectile image and developing only the 3 to 4 m long piece which contains the projectile images.

### DATA REDUCTION

Projectile velocity is determined by measuring the distance between the images on the film, converting this distance to a time, and then dividing the distance between the slits [609.6 mm (24 inches)] by this time. The distance between images can be

measured using a Gaertner Scientific or similar travelling microscope with about 10X magnification. The measuring instrument should be capable of transversing an area 100 mm x 20 mm and have a resolution of 0.001 mm in the long direction.

The film to be examined is placed under the microscope and aligned so that the long axis of the film is parallel to the measurement axis of the reading device. A suitable light source should be used to illuminate the film so that the projectile images are clearly visible. Examine both tracks in the film and select some feature of the projectile which can be readily identified in both film tracks. Use the travelling microscope to accurately determine the distance, on the film, between these two points. Next, measure the distance between timing marks for the purpose of determining the distance the film has travelled during a given time increment. The selection of timing marks which are examined should be centered above the portion of film that contains the projectile images. Generally, the distance between 10 successive marks is averaged for the purpose of determining the movement of the film during 0.1 msec, the time between timing marks.

The time of flight, $t_f$, of the projectile between the slits is determined using the following relationship:

$$t_f \text{ (in seconds)} = \frac{d_p}{d_t \times 10^4}$$

where $d_p$ = distance between projectile images on film

where $d_t$ = average distance between successive timing marks on film where marks are generated at rate of $10^4$ per second

Computation of projectile velocity is made by dividing the distance between the slits, 0.6096 m (2 ft), by the time of flight, $t_f$.

## SECTION 5

## FIRING SEQUENCE CONTROLLER

A Gould Micro 84 Programmable Controller has been provided to control the operation of the Hall Station and Camera System and the firing of the gun. The Programmable Controller is a microcomputer-based device which can be programmed in simple, relay-ladder logic to perform timing and control functions. The Users Manual provided with the Micro 84 controller provides information regarding use and operation of this device.

The Programmable Controller output is used to control closing of several relays which turn on the Hall Station light source, control operation of the Fastax camera, and complete the firing circuit of the gun. A status panel has been provided to indicate the state of the controller sequence.

The sequence is started when the firing relay in the existing firing circuit is closed. An extra contact on this relay is used to provide a 24VDC signal to the Programmable Controller (PC) on input 1001. The PC then turns on output 0002 which activates the start lamp on the status panel and closes relay K1 which turns on the Hall Illuminator lamps.

Output 0002 also starts a 0.5 second delay (4001). This delay allows the lamps to come to full brightness. At the end of the 0.5 second delay, output 0003 supplies 24VDC to K2 which starts the Fastax Camera. After a predetermined amount of film (controlled by the setting of the Event FT thumbwheel switch on the camera) is used by the camera, a 24VDC signal is applied to input 1002 on the PC. This allows the film to accelerate to the desired film speed.

When input 1002 is activated, output 0004, which supplied 24VDC to K3, is also activated. This results in the FIRE indicator turning on and the completion of the firing circuit of the gun.

Time delay 4002 is activated by output 0004. After 1 second, outputs 0001 through 0004 are turned off and output 0005 is activated. Output 0005 supplies 24VDC to K4 which stops the camera. The controller will remain in this condition until the firing relay contacts open. When the 24VDC is removed from input 0001, the controller resets to the ready status.

If the firing relay contacts open at any time in the sequence, the controller will reset to the ready status. However, the camera will continue to run until it is out of film. When power is first applied to the controller, outputs may activate briefly. Care must be taken that this action will not cause damage or hazards.