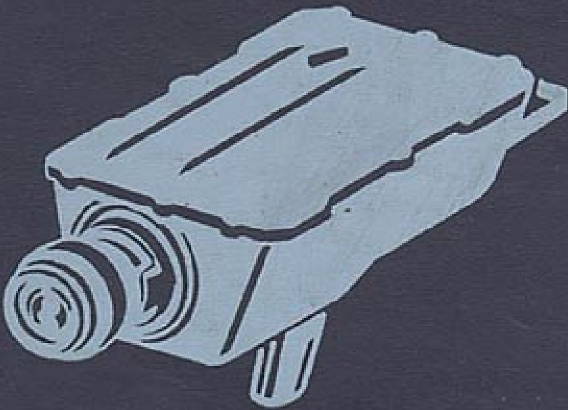

# APOLLO LUNAR TELEVISION CAMERA

# operations manual


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PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

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# APOLLO LUNAR TELEVISION CAMERA OPERATIONS MANUAL

30 August 1968

Prepared For

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Manned Spacecraft Center

Houston, Texas

By

WESTINGHOUSE DEFENSE AND SPACE CENTER

Aerospace Division

Baltimore, Maryland

TABLE OF CONTENTS

## LIST OF ILLUSTRATIONS

# 1. INTRODUCTION

## 1.1 PURPOSE

This document describes the operation and principal characteristics of a television camera for use with the Apollo Program. The camera employs a low light level sensing tube which, together with suitable lenses, enables operation over a wide range of illumination. The manual also describes the various accessories that are used such as lenses, cables, stowage brackets and lens holders.

In particular, attention is given to the operating constraints that should be observed. These primarily lie in the area of selecting the proper lens and the sequence to be followed during its use. Stowage of the equipment in the CM, the LM Cabin, and the LM Descent Stage is also described, as well as the various procedures to be followed for maintenance.

## 1.2 EFFECTIVITY OF DOCUMENT

From time to time it becomes necessary to add, delete, or replace information in a document. The effectivity of this document will be indicated by a printed statement at the bottom of the page giving the issue date. For example:

> in selecting scenes for viewing.
>
> 2-2
>
> Changed 1 December 1968

# 2. SYSTEM DESCRIPTION

The Apollo lunar television camera (shown in figure 2-1) is designed to operate either in the spacecraft or on the lunar surface. With the exception of the input 28-volt primary power and the outgoing video signal, the camera is completely self-contained. Scenes imaged on the sensor result in a mixed video output suitable for viewing directly on a monitor or for modulating a transmitter for transmission back to earth.

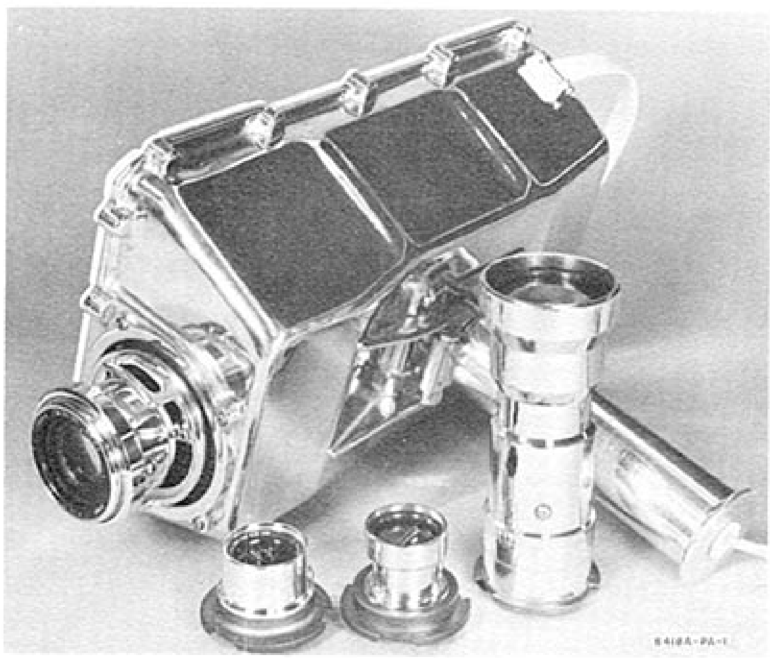


Figure 2-1. Apollo Lunar TV Camera

In selecting scenes for viewing, a choice of either a 10 or a 0.625-frame-per-second scanning mode is available by use of a switch on the camera's top surface. The only restrictions that must be observed when using the camera are: (1) limit the maximum light intensity into the sensing tube, and

(2) prevent the camera from becoming too cold or too hot. Instructions concerning the selection of lenses and the type of scenes to be avoided are given in section 3.5. This section also describes the use of a temperature indicator that is attached to the camera's back surface.

## 2.1 PHYSICAL/MECHANICAL CHARACTERISTICS

The following paragraphs present the overall dimensions, weight, materials, and finishes of the camera and its accessories.

### 2.1.1 Television Camera

The camera (an outline of which is shown in figure 2-2) has dimensions of about 11 x 6 x 3 inches, weighs 7.25 pounds, and uses 6.25 watts of power. It is designed to be hand-held during operation by grasping a tubular extension of the connecting electrical cable. It may also be held or carried by use of the flexible, plastic strap fastened on the back of the camera. The top of the camera is coated with a special, semi-hard white paint that helps provide a passive regulation of the camera's internal temperature. Care should be exercised NOT TO SCRATCH the paint since it has a relatively soft finish. The remainder of the camera has a highly reflective silver plate finish over a base metal of aluminum. This finish is used to reflect radiation from the lunar surface and therefore also forms a part of the camera's thermal control. There is no on/off switch for the camera; instead, it is operated simply by applying power to it through the connecting cable. There is a switch, however, on the top surface that is used to select a fast or slow scan mode. A temperature indicator is located on the back surface to warn the operator that exposure to excessively low or high temperatures, which might degrade performance, has occurred.

There are 14 different accessories that are used with the camera either during preflight checkout, stowage, or operation during the mission. These

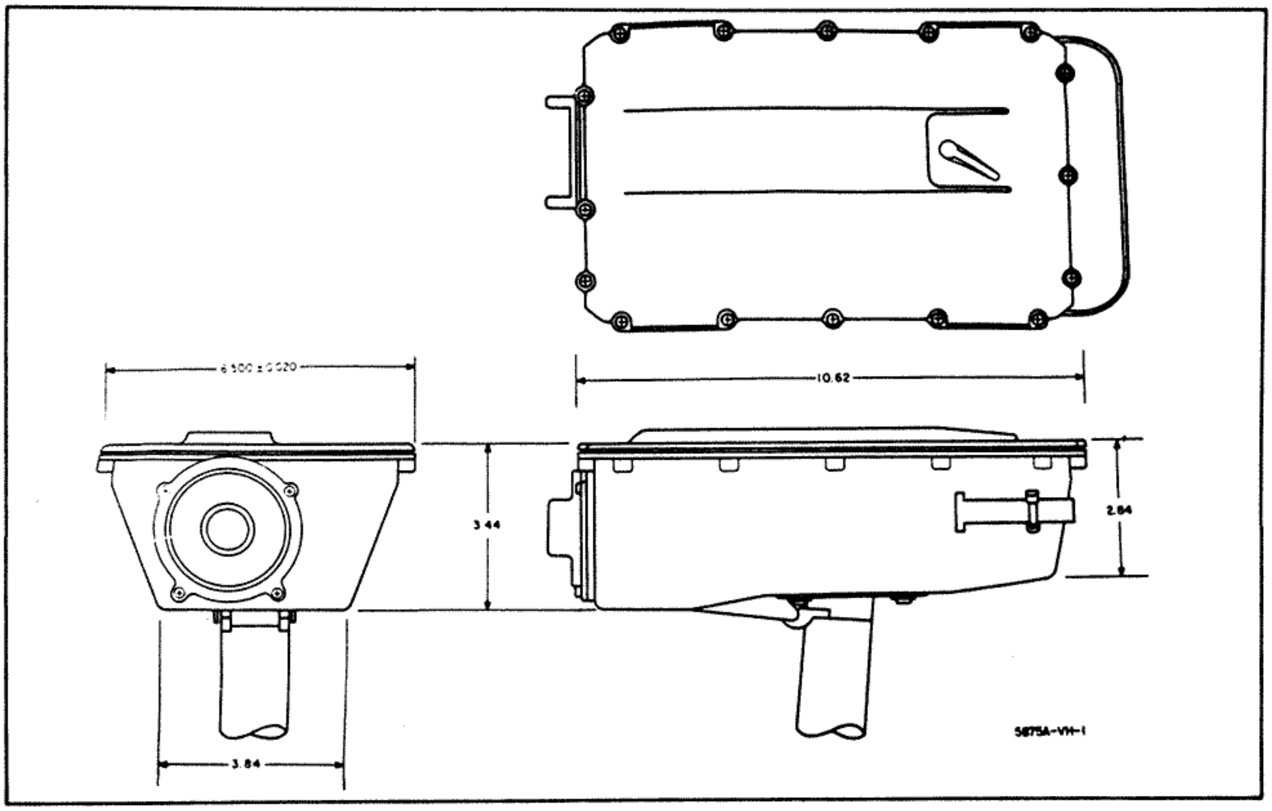
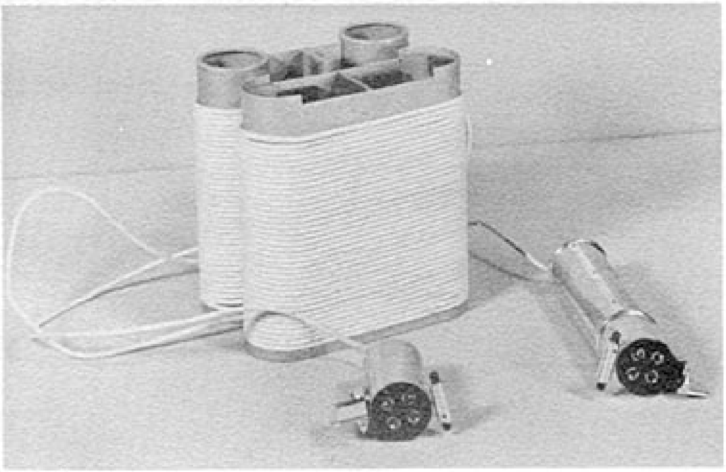



Figure 2-2. Apollo Lunar TV Camera Outline

accessories are listed below and are illustrated in figures 2-3, 2-4, 2-5 and 2-6:

Identification

| | |
|---|---|
| Lunar Day Lens | LM Stowage Frame |
| 100 mm Lens | CM Stowage Frame |
| Wide Angle Lens | Test Connector |
| Lunar Night Lens | Thermal Shields |
| Lunar Surface Cable | 100 mm Lens Holder |
| LM Cable | Lunar Day/Night Lens Holder |
| CM Cable | Bulkhead Receptacle |



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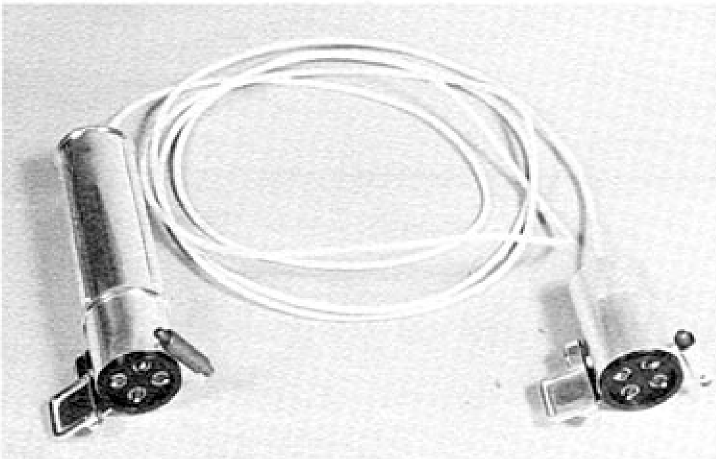

B

C

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Figure 2-3. Electrical Cables

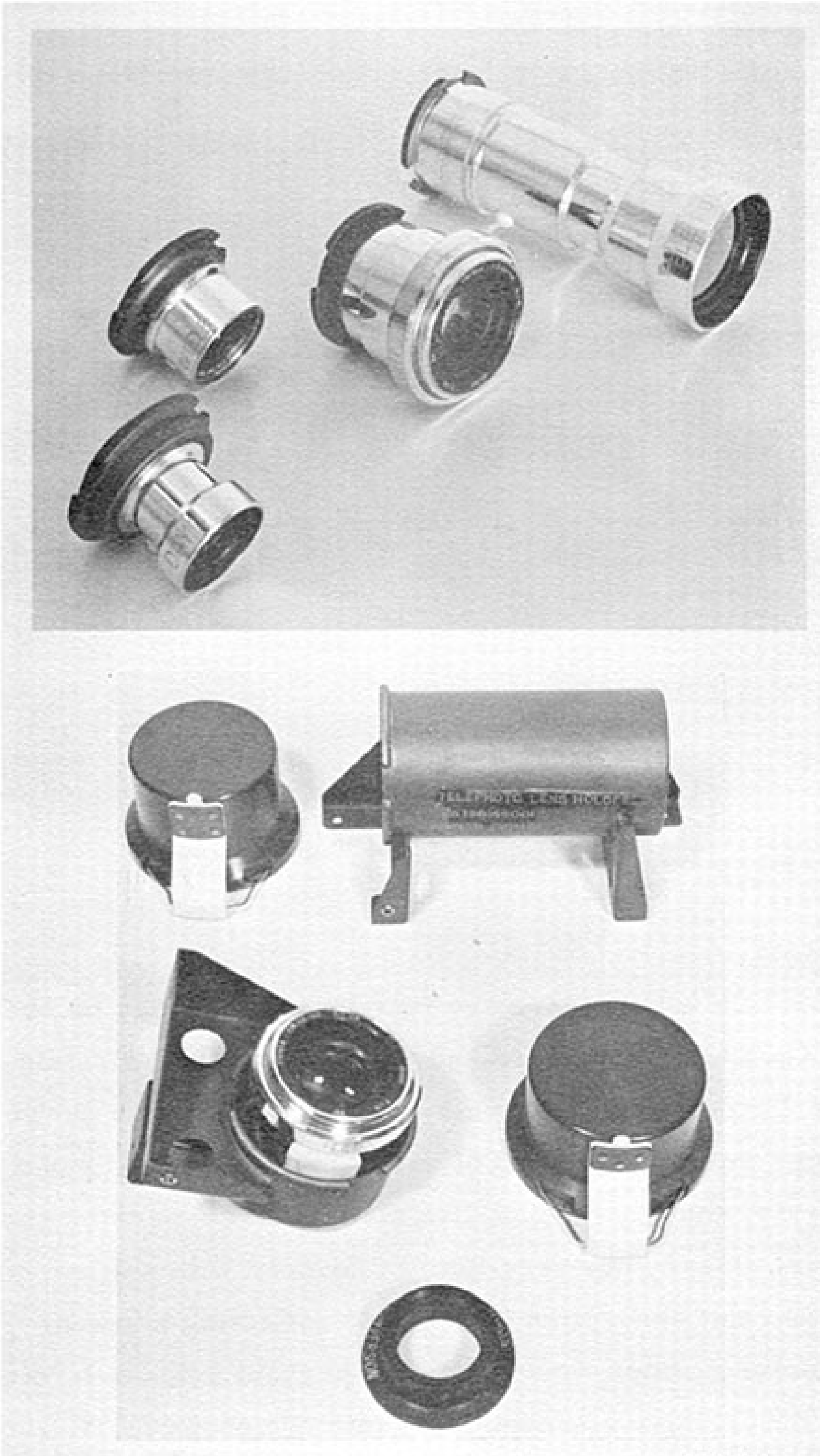

Figure 2-4. Lenses and Lens Holders

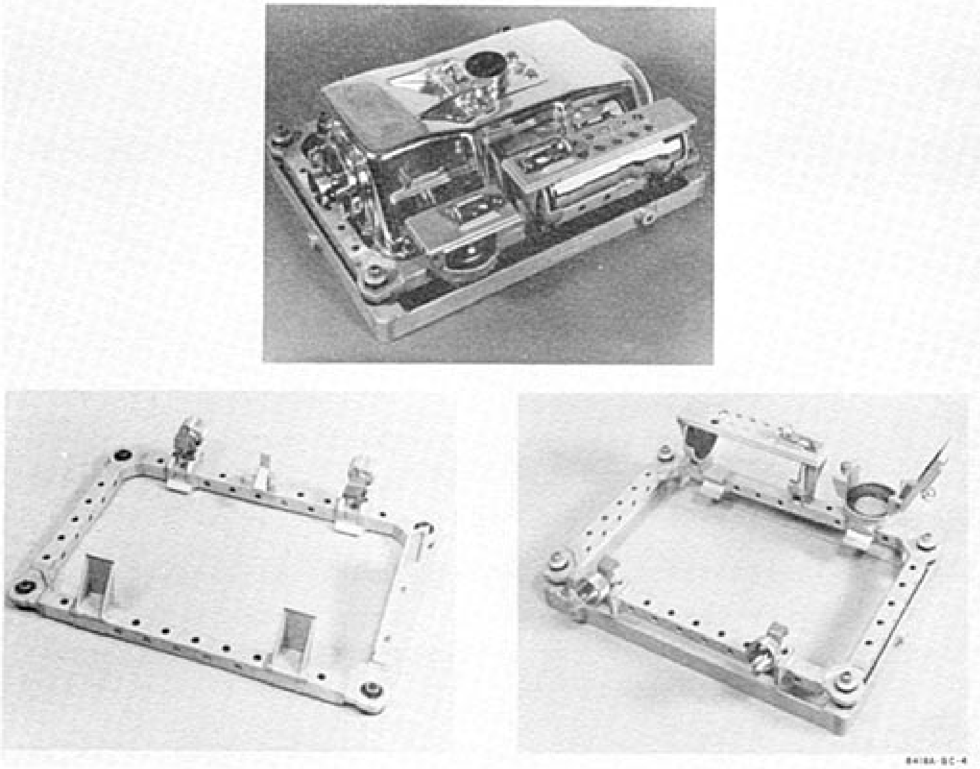

Figure 2-5. Stowage Brackets

2.1.2 Lenses

As previously noted, there are four lenses that may be used with the camera. They were developed and produced by the Fairchild Camera and Instrument Corporation and have overall dimensions as shown in figure 2-7. The housings were constructed of beryllium; this metal has a high strength-to-weight ratio and closely matches the thermal expansion characteristics of the optical glass. The beryllium is covered with a silver plating to minimize thermal absorption by a highly reflecting surface. The silver plating is in turn coated with a finish to prevent sulphur tarnish. This outer finish is a proprietary mercaptan organic compound by W. Hagerty and Sons Company of Chicago, Illinois. In addition to this outer finish, the 100 MM lens, due to its longer length and therefore greater thermal exposure, has the upper side of its housing coated with the white thermal paint that is used on the camera. With the exception of the telephoto lens, which uses the

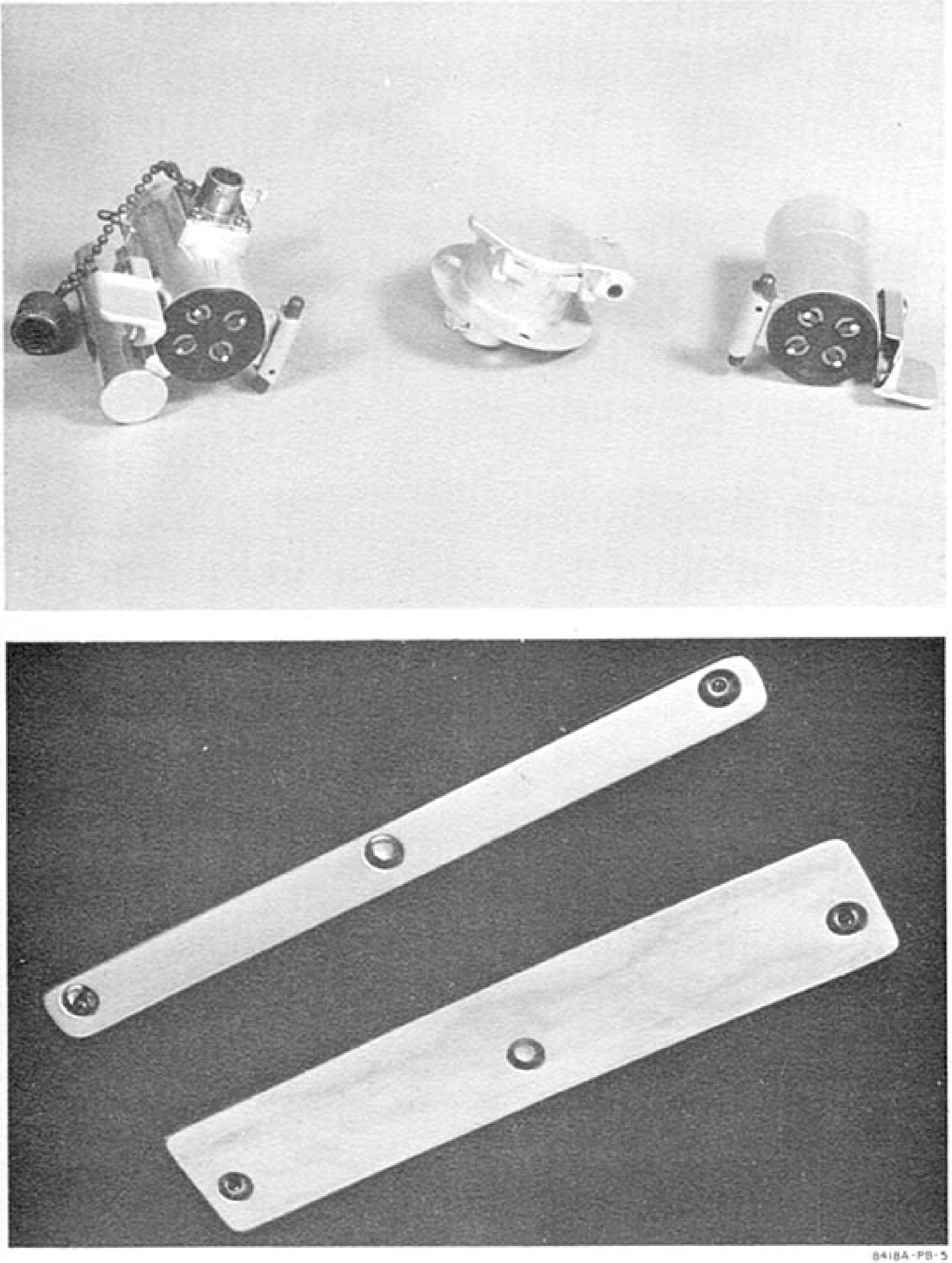

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Figure 2-6. Connectors and Thermal Shields

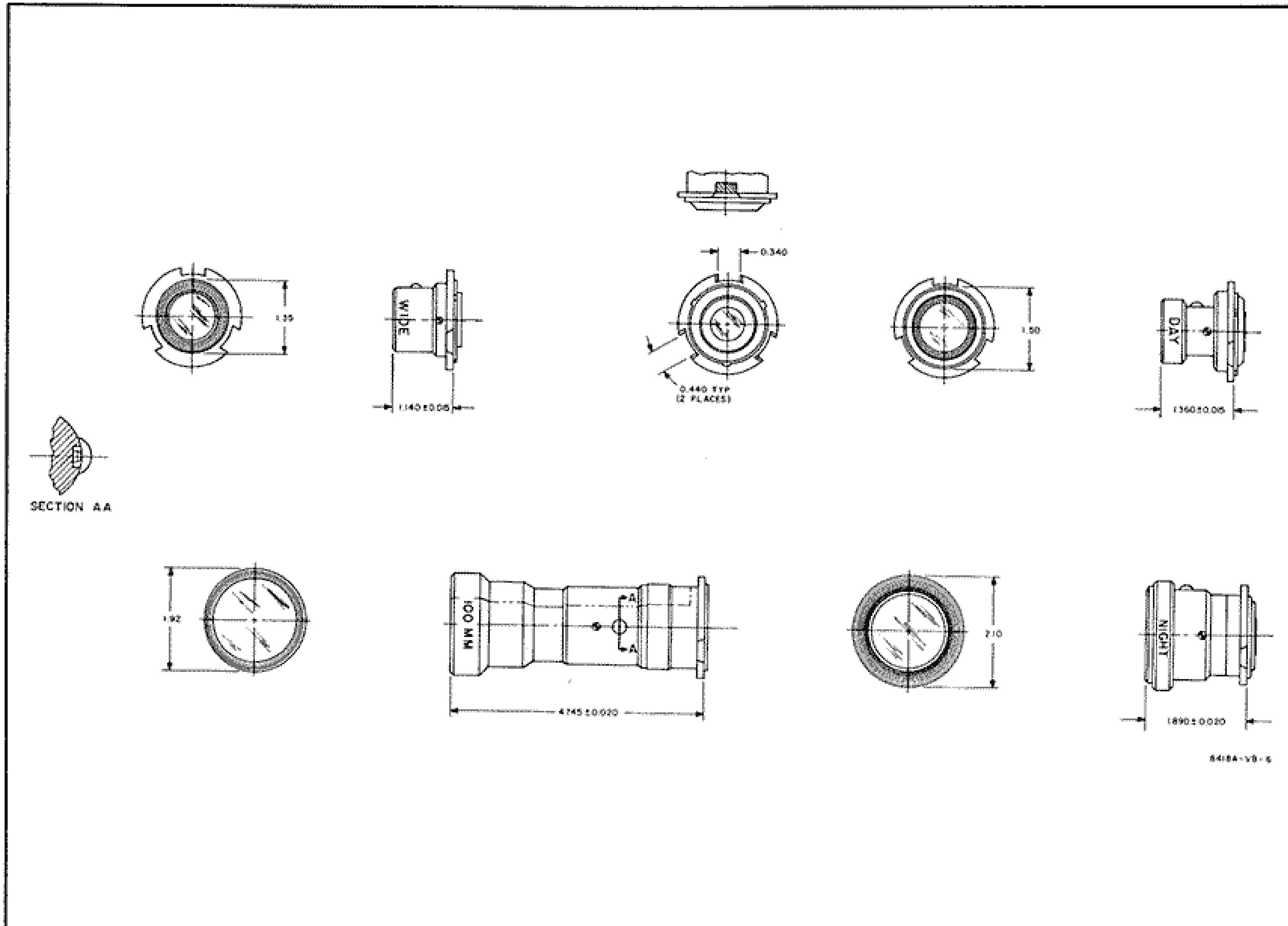


Figure 2-7. Lens Outline

metal alloy known as INVAR, the mounting flanges that interface with the camera are made of stainless steel (416). The flanges, which are shown in figure 2-8, are coated with Martin Hard Coat, are lubricated by impregnated molydisulfide, and contain three slots which are used to guide and secure the lenses to the camera. One of these slots, which is smaller than the other two, has the adjacent surface painted white to provide a means of easily locating the top surface of the lens. The lens is installed by first aligning the white slot with the top of the camera. It is then installed in accordance with the procedures stated in Section 3.2. Identification of each lens is engraved on the housing or outer rim.


Figure 2-8. Lens Flange Detail

As will be discussed in Section 5, Maintenance and Storage, the lenses must be internally flushed with an inert gas 60 days prior to flight to eliminate moisture contamination. Each of the lenses, therefore, contains a sealed fitting on the side of the housing. The sealant that is used over the fitting is a white, silicon-based elastic compound known as RTV 112, supplied by the Silicone Products Department of the General Electric Company, Waterford, New York.

### 2.1.3 Electrical Cables

Any one of the three electrical cables described below may be employed with the camera depending upon whether usage is from the lunar surface, the LM or the CM spacecraft.

#### 2.1.3.1 Lunar Surface Cable

The Lunar Surface Cable shown in figure 2-3A is 100 feet in length and contains a specially designed electrical connector, designed and manufactured by Westinghouse, at either end to permit engagement and disengagement in either the spacecraft or lunar surface environments. Although the two connectors are identical, one of them has a tubular extension that serves as a handle for holding the camera when in use. The other connector is used to connect the cable to a bulkhead receptacle within the LM spacecraft. Each connector has four electrical terminals that are used to join two 28-volt power leads and two coaxial video signal leads of the cable to the connector. The bulkhead connector contains a 28-ohm precision resistor soldered across the two video signal terminals that is used to match the output impedance of the cable and camera with the input impedance of the communications receiver. The physical characteristics of the coaxial cable leads and the power leads are given below and are illustrated in figure 2-9:

| | Coaxial Leads |
|---|---|
| Inner Conductor Strands | 7 |
| Inner Conductor Material | Copper-coated steel wire |
| Inner Strand Diameter | 0.0043 inch |
| Inner Conductor Insulation | Polytetrafluorethylene (PTFE) |
| Outer Conductor Material | #39 braid silver coated copper |

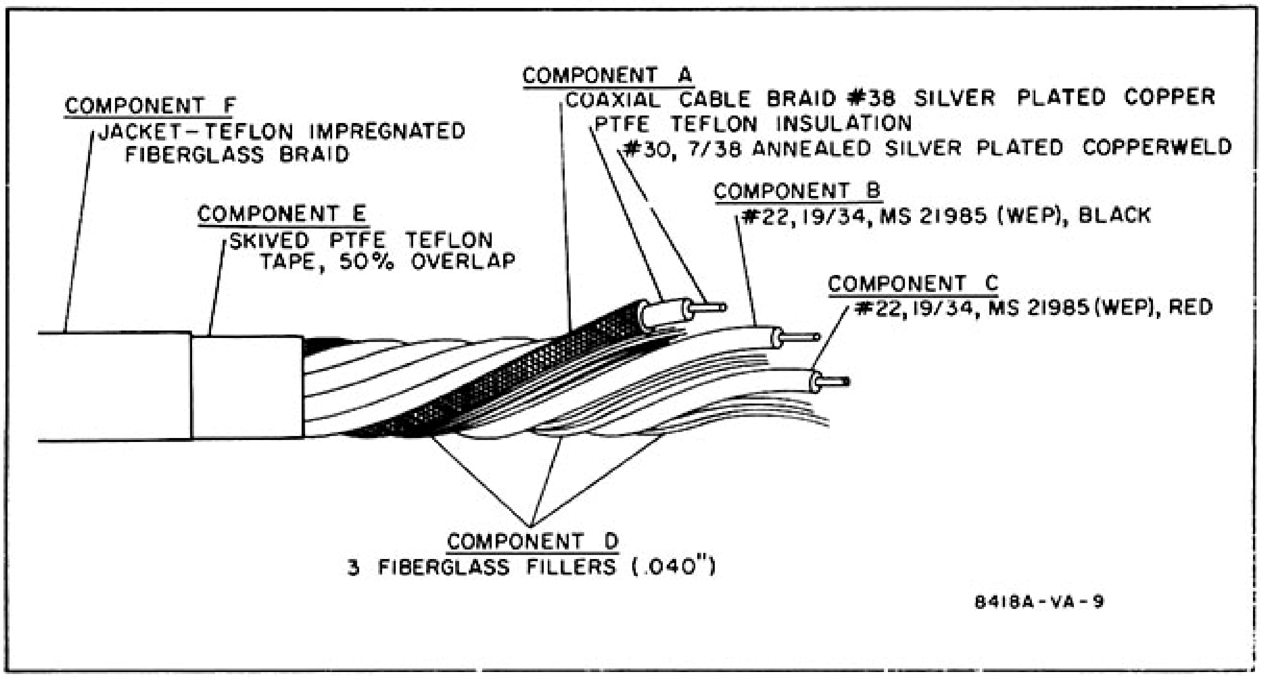


Figure 2-9. Cable Wire Detail

| | Power Leads |
|---|---|
| Number of strands | 19 |
| Strand diameter | 0.0063 inch |
| Strand material | Silver-plated copper |
| Insulation | Polytetrafluorethylene - (PTFE) |

As shown in figure 2-9, these four cable leads are combined with fiberglass insulation filters into a composite cable that is in turn wrapped with teflon tape and then enclosed within a white jacket of teflon impregnated fiberglass braid that is approximately 0.140 inch in diameter.

2.1.3.2 LM Cable

The LM Cable (figure 2-3B) is physically identical to the Lunar Surface Cable with the exception that it is 9 feet in length and instead of containing a single 28-ohm resistor, it contains both a 13- and 36-ohm impedance matching resistor in the handle-connector. The LM Cable is to be used when operating the camera within the cabin of the LM spacecraft. (See Section 2.3 for other electrical characteristics.

2.1.3.3 CM Cable

The CM Cable (figure 2-3C) is 12 feet in length, 0.24 inch in diameter, is functionally identical to the LM cable, and is to be used when operating the camera within the CM spacecraft. Unlike the LM and the Lunar Surface Cables however, it does not contain any precision impedance matching resistors, since the signal conditioning is accomplished within the CM spacecraft. In addition, the end of the cable that is connected to the spacecraft bulkhead contains two connectors; one is used for the power leads and the other for the video leads. Construction and insulation of the two power leads of the CM Cable is identical to that described above for the Lunar Surface Cable. However, due to the different electrical interface characteristics of the LM and CM, the electrical characteristics, and therefore the mechanical construction of the coaxial cable, differs with that of the LM and Lunar Surface Cables. From a physical standpoint, their difference is reflected by an increase in the cable outer diameter from 0.140 inch to 0.240 inch.

2.1.4 Equipment Stowage Brackets and Lens Holders

Brackets are provided for stowing the camera in both the CM and LM spacecraft. As shown in figure 2-10, the CM bracket is also used to stow the wide angle and 100-mm lenses. Stowage of the 100 mm, the day and night lenses in the LM, however, is accomplished by separate lens holders as shown in figure 2-11. The smaller of the two holders may be adapted to stow either a day or a night lens. The LM stowage bracket is shown in figure 2-12.

Both the CM and the LM brackets are constructed from perforated, rectangular, aluminum tubes welded together to form a rigid structure for containing the camera. The structure contains four vibration isolators, manufactured by the Lord Manufacturing Company, and two hinged fasteners

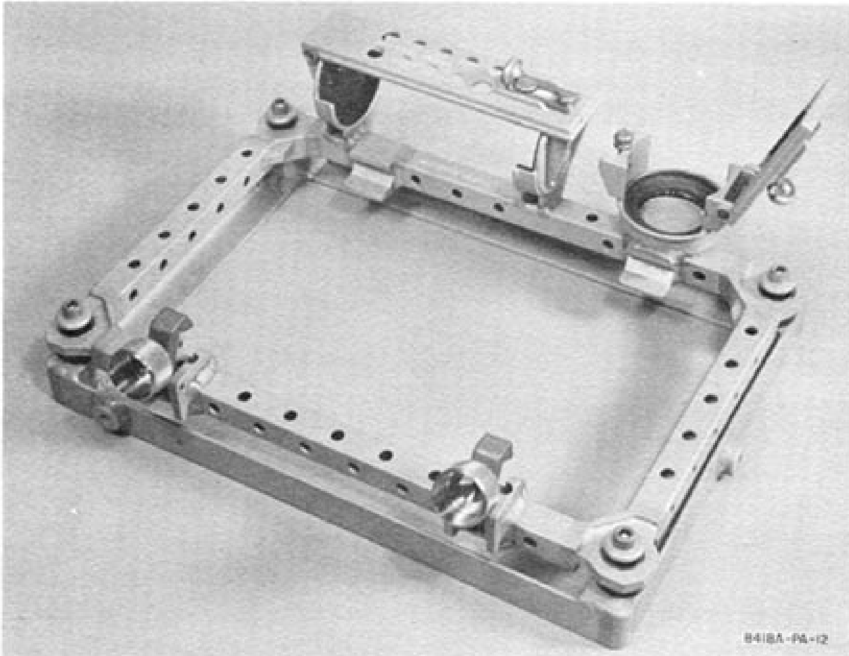

Figure 2-10. CM Stowage Frame

for locking the camera in the bracket. The fasteners, supplied by the Calfax Company have knurled head grips that are rotated clockwise for tightening, counterclockwise for loosening. Unlike the LM bracket, the CM bracket contains two smaller, unsealed structures or brackets that, as mentioned above, are used to integrally stow the 100 mm and wide angle lenses. These two brackets retain the lenses by hinged lids that are fastened by sliding snap-in spring clips. The two lens brackets also contain various silicone rubber pads that protect the finish of the lenses and provide an elastic retaining force so that the lenses are snugly stowed.

As previously stated, the LM stowage bracket does not have provision for integrally stowing any of the lenses. Instead, on the side of the bracket opposite to the Calfax fasteners, two small, vertical aluminum plates are welded to the structure for the purpose of providing a stop when installing the camera. The stop is necessary due to the location of the stowage bracket

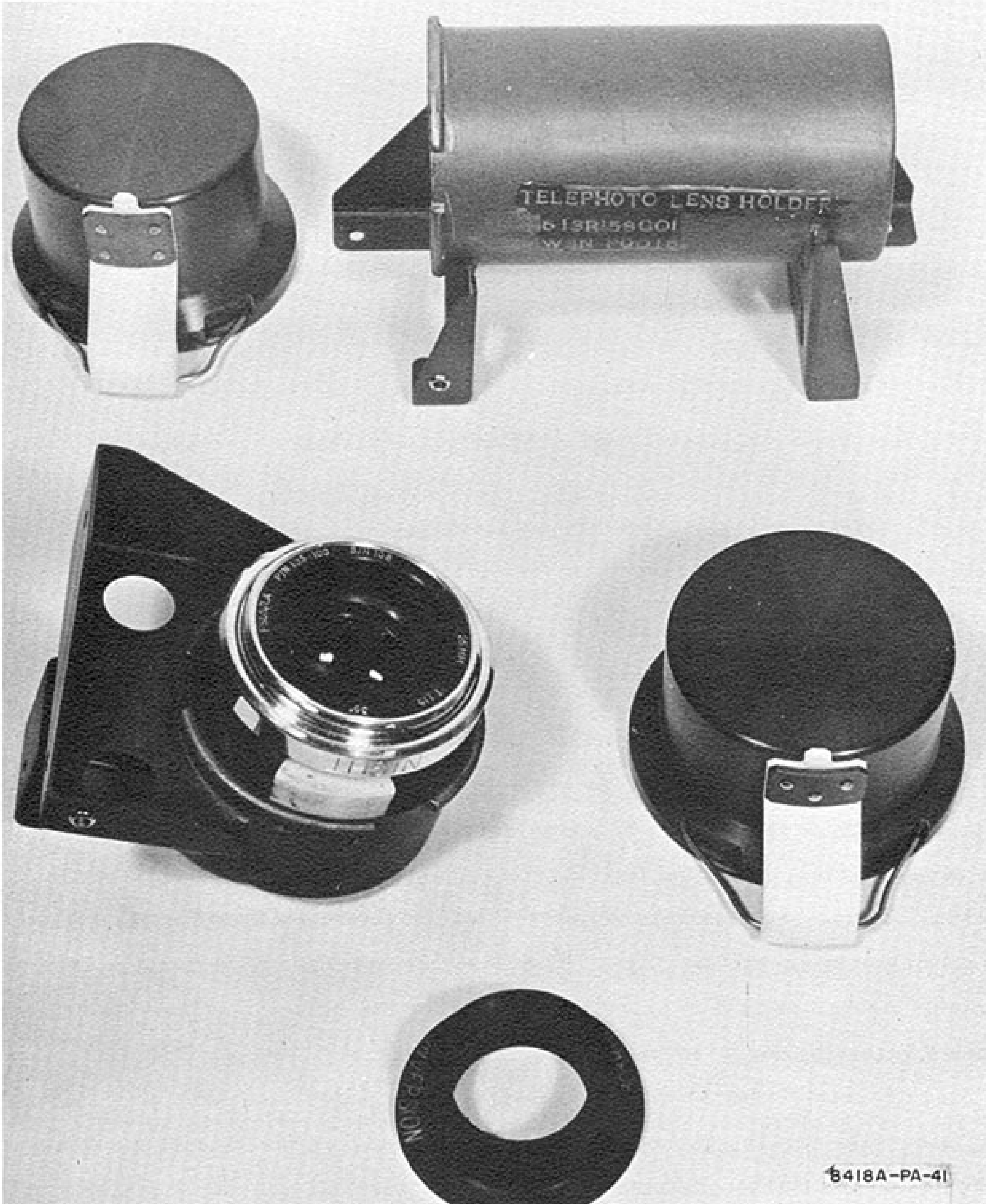


Figure 2-11. Lens Holders

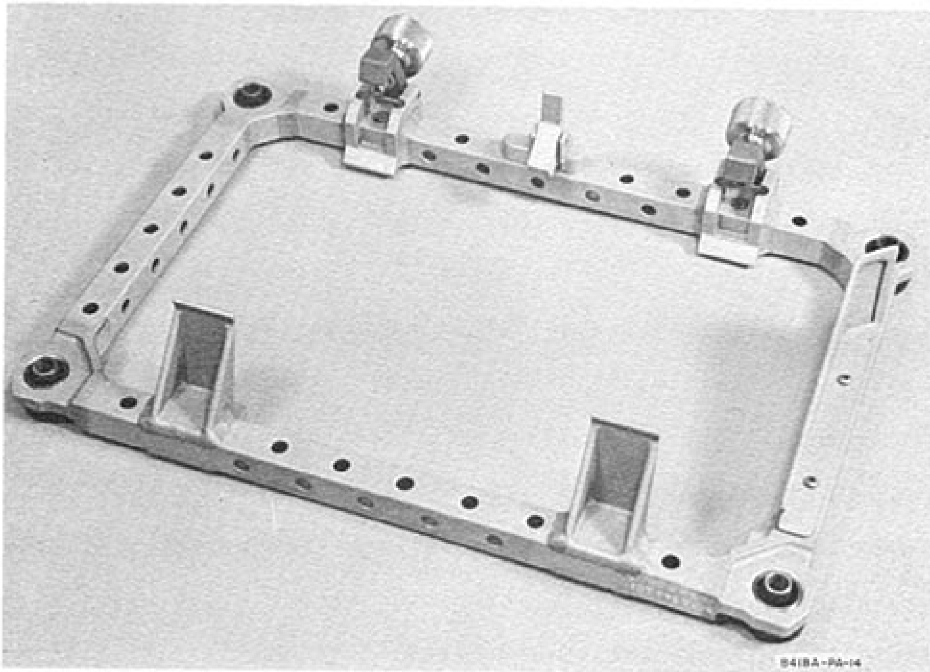

Figure 2-12. LM Stowage Frame

in the cabin of the LM spacecraft, which requires that the camera be stowed and unstowed with the bracket out of view.

The two lens holders used with the LM were designed for use by an unsuited astronaut. As shown in figure 2-11 they are tubular aluminum cylinders that have been given a Martin hard-coat anodize that has a dark appearance, and provides a surface that is highly resistant to wear. Teflon bushings are cemented over silicone rubber pads in the bottom of both cylinders and covers to provide a non-abrasive surface for the lenses. The normally white teflon has been darkened as a result of being etched for bonding to the smooth hard anodize surface. A conversion bushing, or spacer, (see figure 2-11) is provided for the smaller of the lens holders which, when removed, increases the internal length of the cap and converts the assembly from a lunar DAY lens holder to a lunar NIGHT lens holder. Each cover contains a wide teflon pad which is used to depress a spring-type latching mechanism that fastens the cover to the cylinder.

### 2.1.5 Test Connector

A test connector is to be used with the camera during its ground checkout. The test connector assembly which contains three connectors, and a Running Time Indicator, is a Nonflight item. It is installed by fastening one end to the camera and the other end to the camera's electrical cable. The third connector is a means by which the video signal and input power can be monitored.

The Running Time Indicator (MS-90386WP2) is located within a cylindrical appendage of the Test Connector and operates on the basis of electro-chemical interaction. The indicator has a maximum range of 1000 hours and an accuracy of 3 percent. The scale, which is shown in figure 2-13, contains 20 divisions with each division equal to an incremental time of 50 hours. As shown, the scale also contains the numbers 0, 0.05, and 1.0; these correspond to 0, 500, and 1000 hours.

### 2.1.6 Heat Shields

Two silver-plated aluminum heat shields, as shown in figure 2-14 installed on the camera are provided for retaining heat within the camera during the sub-zero thermal environment of a lunar night mission. It is assumed that the lunar night mission will be known prior to flight at which time the heat shields can readily be installed. The shields are attached to the camera by first removing the four phillips-head screws on the top of the camera that are thinly covered by the thermal paint. The shields are then fastened to the camera over the paint by using other special screws that are supplied with the shields.

## 2.2 ELECTRICAL/OPTICAL CHARACTERISTICS

With reference to figure 2-15, a light image of the scene being viewed by the camera is formed on the front (faceplate) of the SEC tube by the lens. The photocathode, which is on the inner surface of the faceplate, converts this to an electrical image that is then accelerated by a high-voltage potential

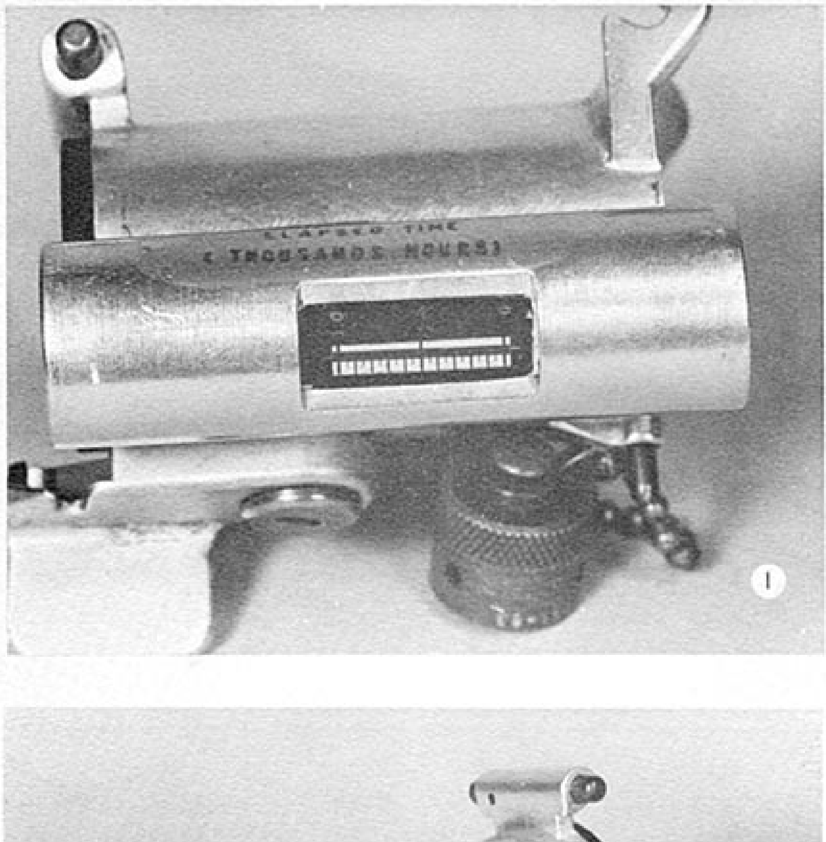


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Figure 2-13. Test Connector

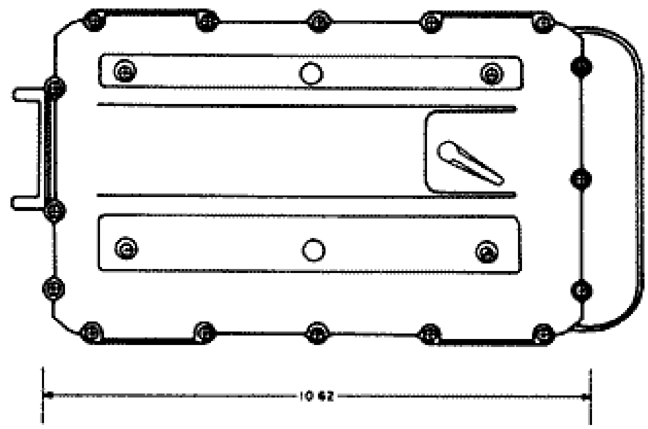


Figure 2-14. Camera With Thermal Shields

to the target surface where it is converted to video signals by a scanning electron beam. Using the video output voltage as a reference, internal circuits vary the amplifier and tube sensitivities to produce a uniform picture over a wide range of scene brightness. Synchronizing signals are added to the video to permit synchronization of monitors with the beam scan so that the video can be reconverted to a light image for viewing. Deflection circuitry controls the motion of the tube's electron beam as it scans the target and "reads out" the scene's image.

2.2.1 Power Requirements

The camera is designed such that all internal power requirements are derived from the 28-Vdc input. An input regulator assembly converts and regulates the incoming 28 volts, which may vary between 24 and 32 volts, to

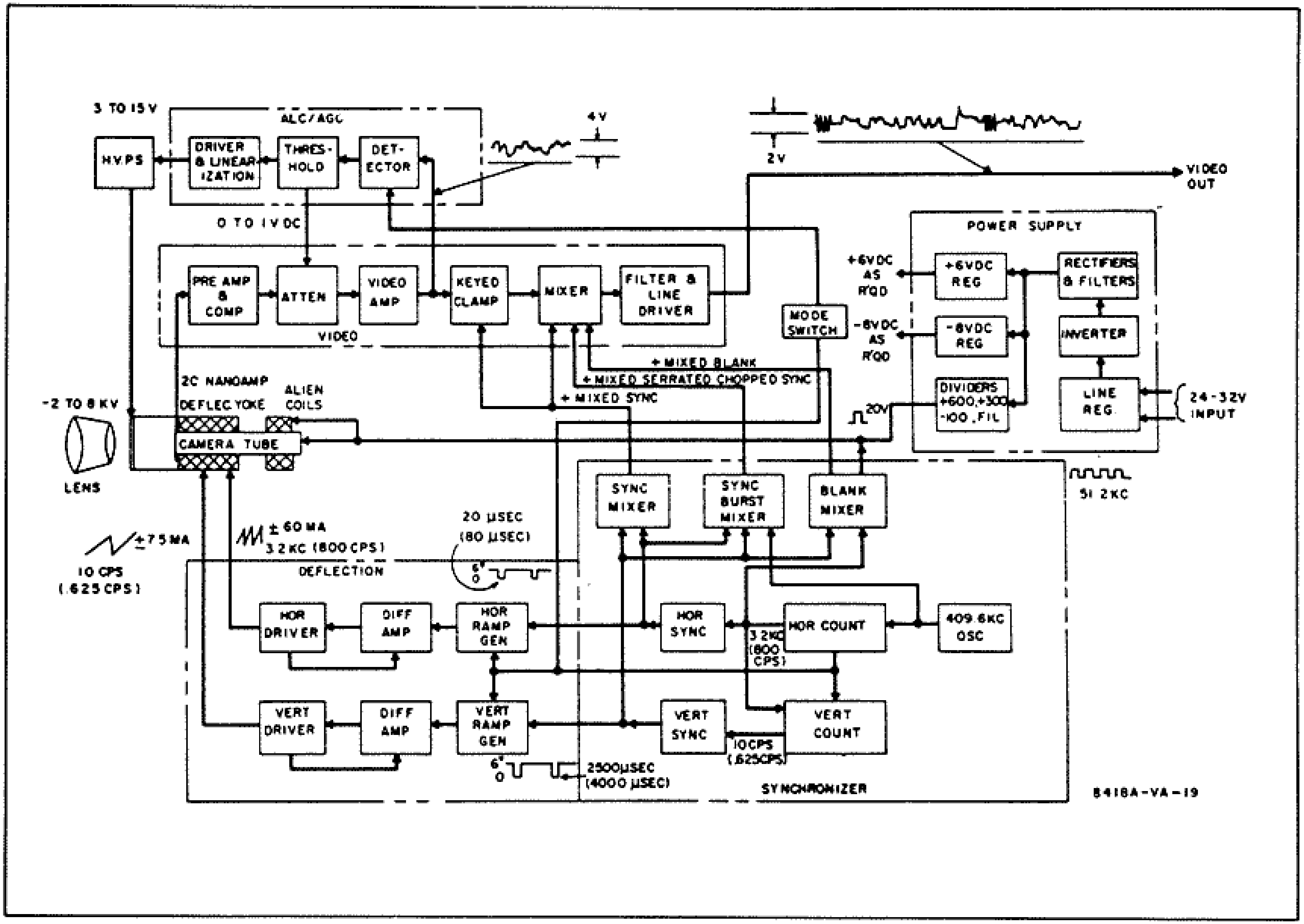


Figure 2-15. Functional Diagram

a constant 18-vdc output. Included with the input regulator assembly is an electromagnetic interference filter using an LC network that blocks incoming noise on the power line as well as outgoing noise that might result from the power supply's inverter.

The inverter changes the 18-Vdc output of the input regulator to an ac voltage that is transformed and then rectified to produce a number of different dc voltages ranging from plus 600 V to minus 8000 V. Two of these voltages are further processed through an output regulator assembly that is used to regulate them to about 1 percent of their nominal output. The minus 8 kV referred to is used to accelerate the electron image from the photocathode to the target and is a part of the automatic gain control loop. Variation of this voltage between -2kV and -8kV effects a variation in the gain of the SEC tube.

### 2.2.2 Video Generation and Output Signal

The scanning of the target in the SEC tube by the electron beam produces a voltage drop across a series resistor that is proportional to the light information from the scene being viewed. This voltage is sent through a series of amplifiers where it is regulated to have a constant output level over a wide range of scene brightness. After regulation, and immediately prior to transmission through the connecting coaxial cable, the video signal is blanked and mixed with synchronization signals during both the horizontal and vertical retrace periods of the scan.

Regulation of the video signal strength is accomplished by two functionally concentric automatic gain control circuits that are designated as the AGC and ALC (automatic light control) loops. Both loops use the amplitude of the amplified video voltage as an input signal which is then regulated by comparing it to two different reference voltages. The AGC, operating as the inner loop, first provides regulation by changing the gain of a voltage controled amplifier in the video amplifier chain. When the range of control of this loop is exceeded the outer ALC loop provides additional regulation by proportionately changing the high voltage potential between the photocathode and target of the tube.

The overall bandwidth of the video signal extends from 4 Hz to 500 kHz. The amplitude response is flat within ±3 dB from 4 Hz to 1 kHz; from 1 kHz to 250 kHz it is constant within ±1 dB; from 250 kHz to 500 kHz it is constant within ±3 dB. And at 1 MHz it is 20 dB below the amplitude at 250 kHz. The composite video output is 20 mAp/p and 2.0 volts p/p into a 100 load or 1 volt p/p into a 50-ohm load which is referenced to 0.3 ±0.1 volt black level. Figure 2-16 shows the composite video signal which contains synchronizing information during both the horizontal and vertical retrace periods.

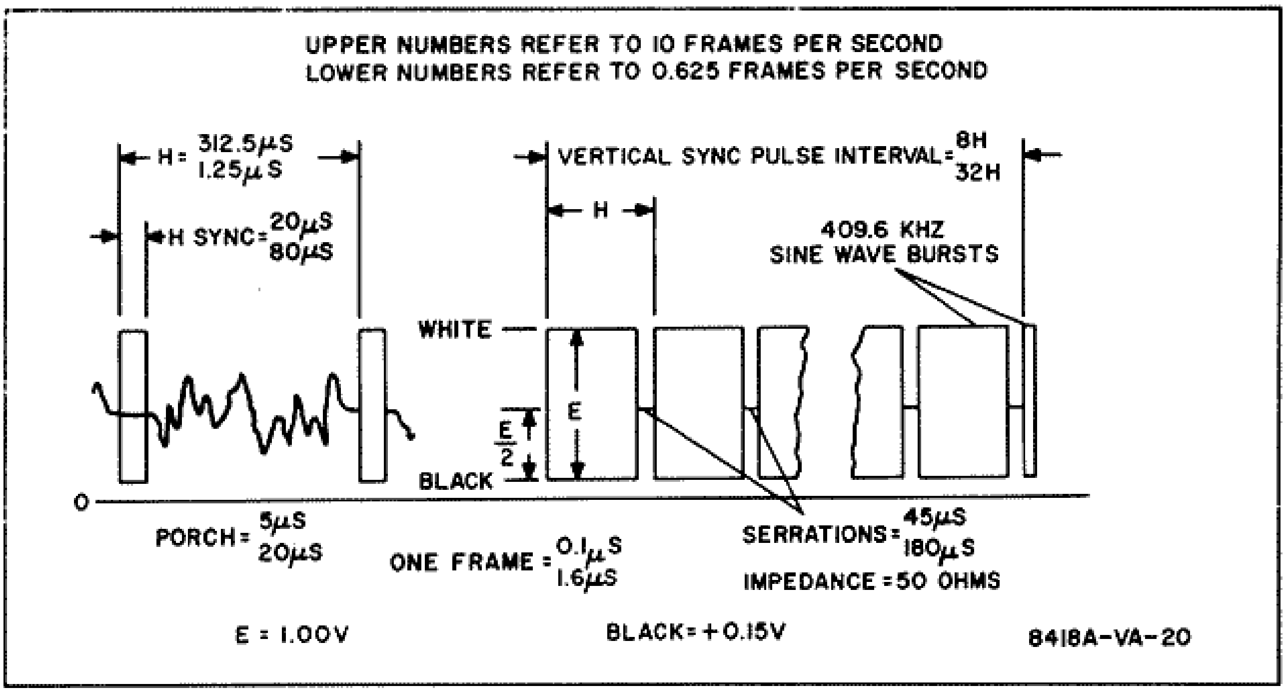


Figure 2-16. Video Waveform

## 2.2.3 Scanning Modes and Resolution

Two scanning modes are provided with the camera that permit operation at either 10 frames per second or 0.625 fps. One mode or the other is selected by deflecting a two-position rotary switch on the top of the camera. When pointing the camera at a scene, the 10 fps mode is selected by moving the switch to the left. The 10 fps mode has 320 scan lines per frame while the slower mode has 1280 lines scan lines per frame. Since the slower mode requires 1.6 seconds to complete the scan of one frame, this mode is to be used only for viewing scenes of scientific interest where there is no motion involved.

The resolution of the camera is determined by the response capabilities of both the SEC VIDICON and the camera electronics. The response of the SEC vidicon is about 500 lines per picture height. This means that if the camera's electronics had a flat response out to the frequency necessary to transmit 500 lines in the specified scan format, the tube would be the limiting factor in determining the overall resolution of the camera. The requirement that the video response be flat to only 500 kHz, however, limits the resolution capability in the 10 fps mode to about 260 lines per picture light. In the slow 0.625 fps mode, the 500 lines are easily transmitted without attenuation.

Since the aspect ratio is 4/3, the maximum horizontal resolution of the SEC vidicon is 500 x 1.3 or about 650 lines per picture width. This means that in any scene being viewed in the slow scan mode, the smallest detail that can be observed is 1/500 of the scene's vertical dimension and 1/650 of the scene's horizontal dimension.

### 2.2.4 Automatic Light Variation Control

As previously mentioned in paragraph 2.2.2, the automatic light control regulates the video output signal to compensate for a wide variation in light input in the camera. The effect of this regulation is shown in figure 2-17 which illustrates how the camera's light/current transfer characteristic is displaced over a light range of nearly 1000 to 1. Regulation occurs whenever the scene brightness requires an output signal that exceeds the "knee" of the transfer curve. This point is known as the "maximum operating point"

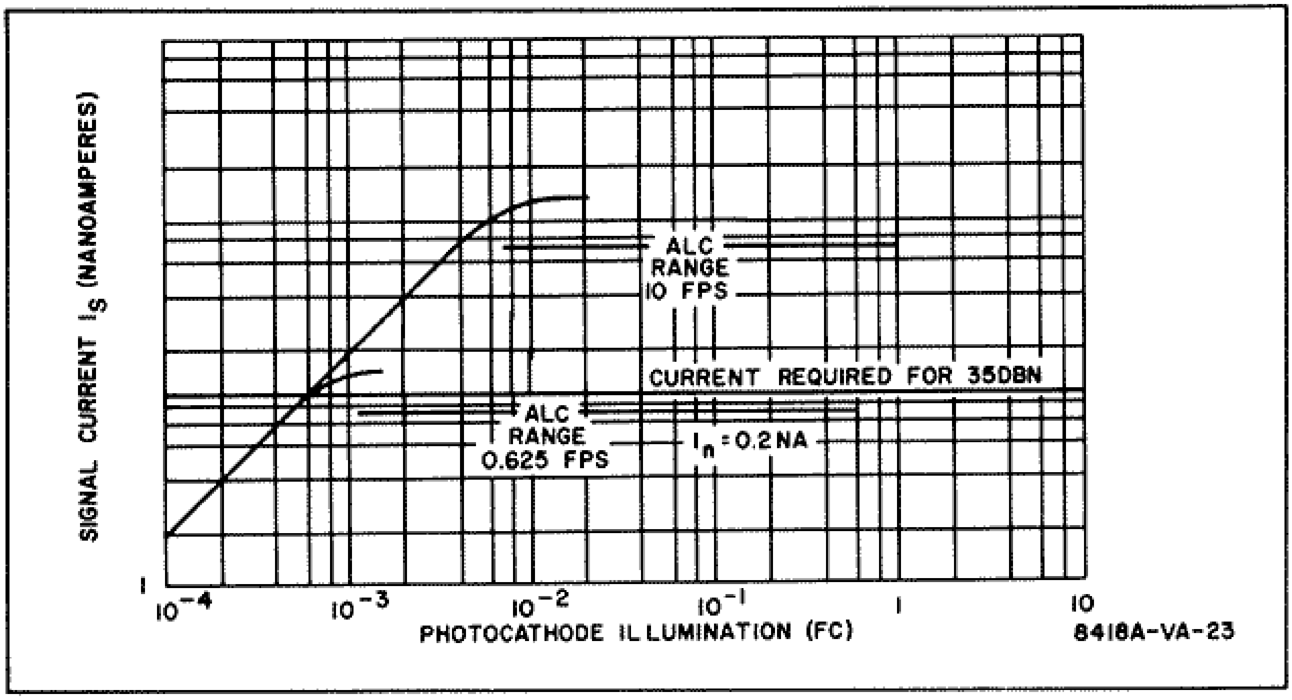


Figure 2-17. Transfer Effects of ALC

and is reached when the video output voltage reaches 2 volts; this point is also the point at which the signal-to-noise ratio reaches 28 dB. When the S/N ratio exceeds 28 dB, regulation by first the AGC loop and then the ALC loop occurs. The control of the AGC circuitry is such that it regulates up to about a 20 dB change in scene brightness whereas the ALC provides an additional 40 dB range of control. As previously mentioned in paragraph 2.2.2, the AGC loop functions by adjusting the gain of a voltage controlled amplifier in the video chain. The ALC loop however functions by commanding a variation in the output of the High Voltage Power Supply. This voltage provides the potential between the SEC vidicon's photocathode and target and may be varied from -2 kV to -8 kV. Changing the photocathode voltage within these limits produces a corresponding change in the tube's range of sensitivity.

### 2.2.5 Lenses

A set of four interchangeable lenses shown in figure 2-18 are provided with each camera. These include a Wide Angle lens for in-cabin use; two lenses, the Lunar Day and 100 mm, that can be used from the spacecraft or on the lunar surface during lunar day; and a Lunar Night lens for use during lunar night mission.

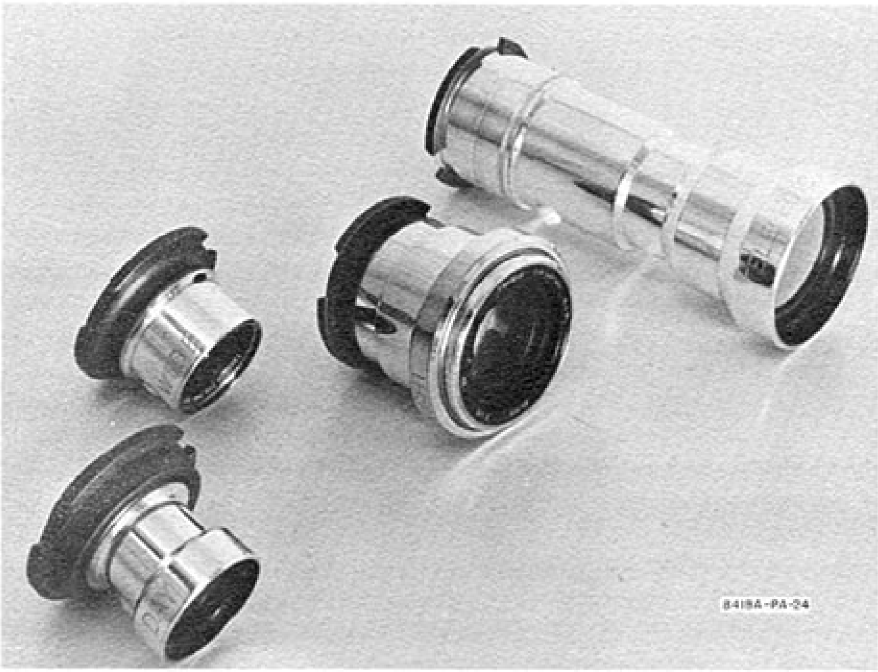

Figure 2-18. Lenses

The principal characteristics of each lens, including the minimum and maximum allowable scene brightness, are given in table 2-1.

TABLE 2-1

LENS CHARACTERISTICS

| Name | f/# | T/# | Diagonal Field of View | Length Inches | Wt. Lbs. | Depth of Focus | Peak Focus | Min/Max Scene Brightness Ft. Lamberts |
|---|---|---|---|---|---|---|---|---|
| Wide Angle | 4 | 4.8 | 80° | 1.31 | 0.22 | 20 in.- α | 40 in. | 0.15/90.0 |
| 100 MM | 4 | 60 | 9.3° | 4.95 | 0.92 | 143 ft. - α | 287 ft. | 23/12,600 |
| Lunar Day | 4 | 60 | 35° | 1.53 | 0.22 | 11 ft. - α | 23 ft. | 23/12,600 |
| Lunar Night | 1 | 1.15 | 35° | 2.10 | 0.44 | 37 ft. - α | 74 ft. | 0.01/5.0 |

The scene brightness values are based on illumination from scenes that reflect diffused light instead of light from a concentrated, or point source. The lenses reduce these maximum values to a maximum sensor faceplate illumination of 1 foot candle. If the camera is used with scene brightness exceeding the values in table 2-1, degradation of the SEC vidicon sensor will result. Therefore, special caution must be exercised if Command Module floodlights are in the field of view, or if when viewing the LM from the lunar surface, there are regions with specular characteristics that could reflect the sun directly into the camera's field of view. Under most conditions, regulation by the ALC will operate to lower the photocathode voltage and thereby provide protection; however, IT IS possible to damage the camera in the time it takes for the regulation to occur.

## 2.3 ELECTRICAL INTERFACES

An electrical interface exists for the camera in both the Command Module and the Lunar Module. The interface occurs at the connection of the two camera electrical cables to their respective bulkheads in these spacecraft. At each connection, 28 Vdc is supplied as input power to the camera, and the camera supplies in constant 20 milliamps output video signal to the spacecraft.

### 2.3.1 Television/Command Module

The electrical cable (see figure 2-3) that is used for the camera in the Command Module makes two separate connections to the spacecraft's bulkhead. One of these is through a two-pin standard connector with a red and black twisted lead pigtail from the camera cable. The other connection, also a pigtail from the camera cable, is through a single brown lead into a coaxial connector. The cable which is shown both in figures 2-19 and 2-20, is 12 feet in length, has a characteristic impedance of 95 ±5 ohms, a capacitance of about 180 pF, and a resistance of about 1.3 ohms.

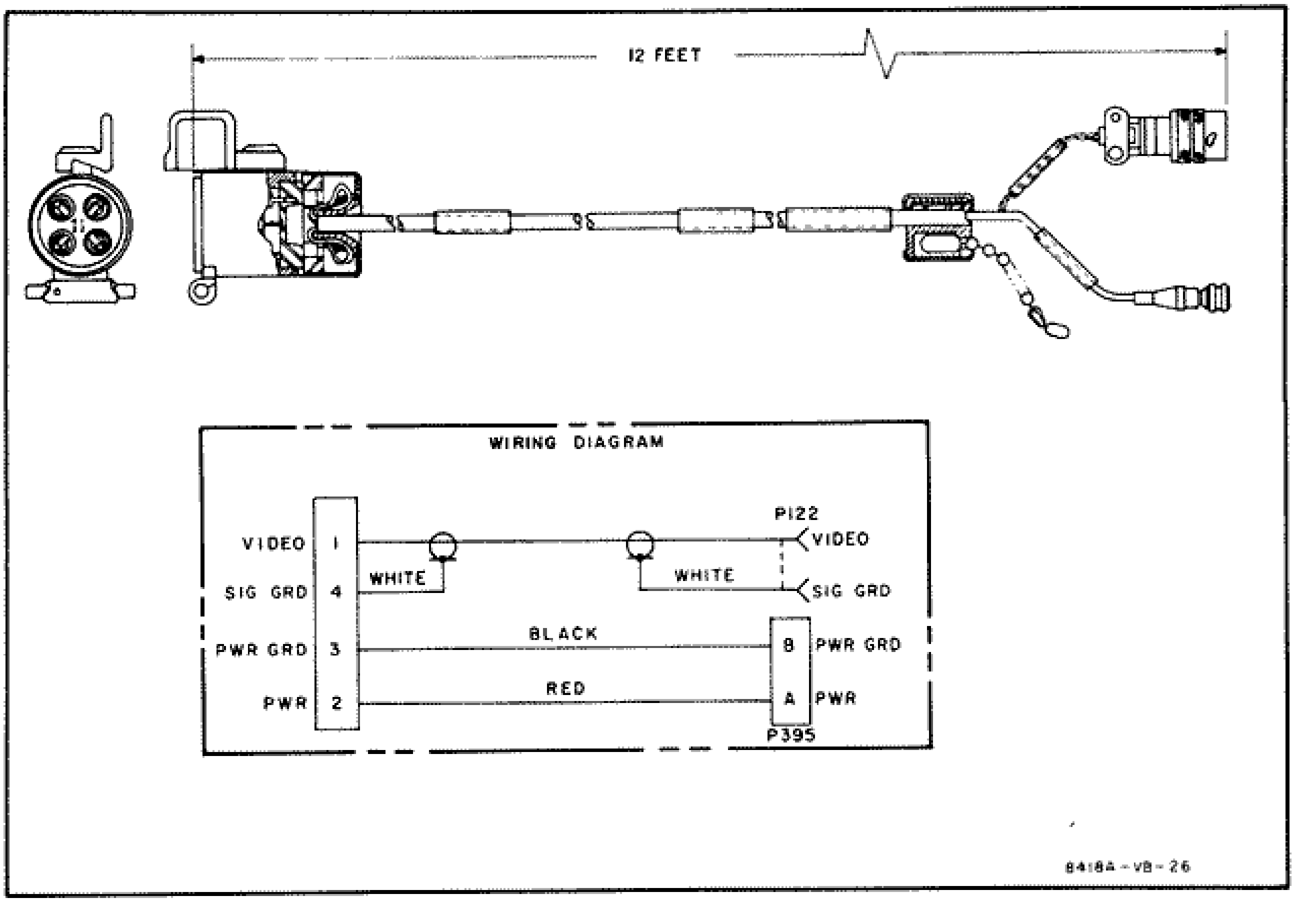


Figure 2-19. CM Cable Outline

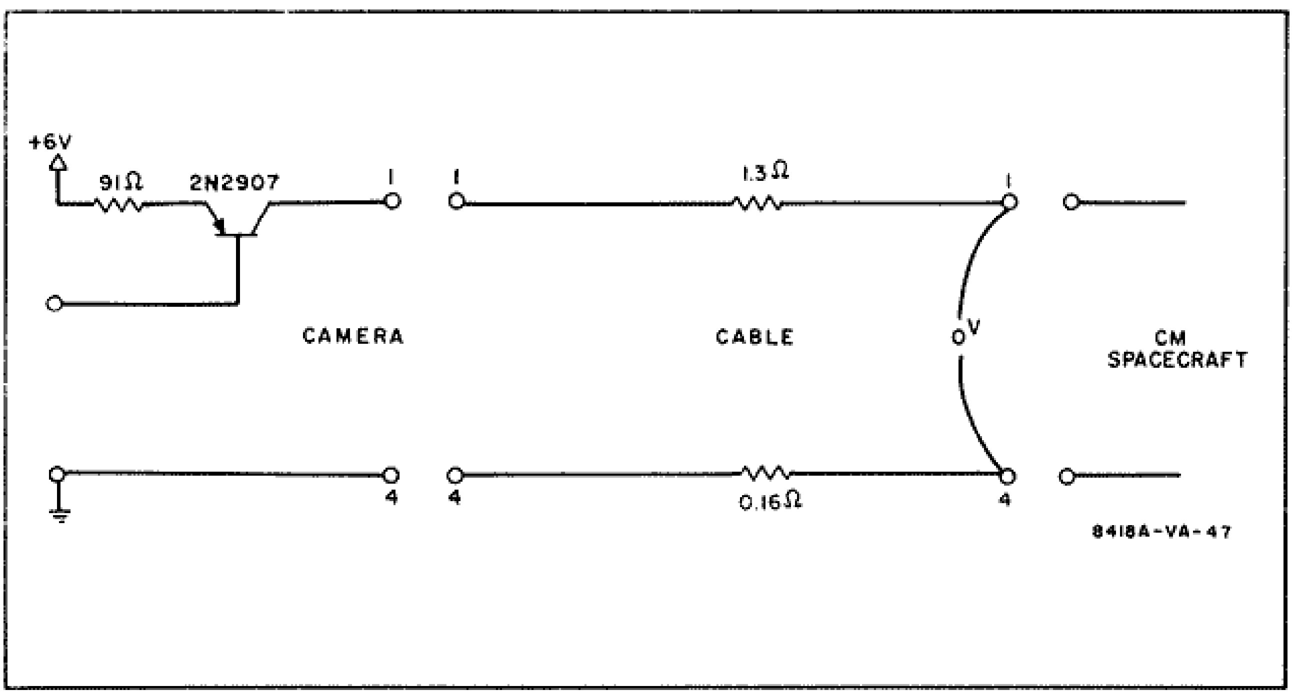


Figure 2-20. CM Cable Resistance Schematic

Since the camera's output circuitry provides a constant 20-milliamp output current, no voltage will be measured at the output terminals 1 and 4 of the CM cable unless a load resistor is connected across them.

2.3.2 Television/Lunar Module - Cabin

The electrical cable that is used for the camera in the Lunar Module spacecraft differs from the Command Module cable in that a single connector provides the interface with the spacecraft bulkhead. The cable, which is illustrated both in figure 2-21 and 2-22 is 9 feet long, has a characteristic impedance of 50 ±2 ohms, a capacitance of about 270 pF, an inner conductor lead resistance of about 2.2 ohms, and an outer conductor or shield lead resistance of about 1.16 ohms. In addition to this lead resistance, two precision resistors are installed in the cable connector that fastens to the camera to optimize the video signal from the camera into the spacecraft. The camera signal provides a constant 20 mA output that in turn develops 0.26 volt across the 49-ohm load in the LM spacecraft. A schematic of this circuitry is shown in figure 2-22.

It can be seen that a resistance measurement between terminals 1 and 4 of the cable connector that is fastened to the camera would measure 25.5 ohms. A resistance measurement across terminals 1 and 4 of the connector that fastens to the bulkhead of the LM spacecraft, on the other hand, would measure the resistance of both coaxial leads (2.2 and 0.16Ω), as well as the 23.7-ohm resistance in series with the video lead. The total value of this measurement would be about 51 ohms.

The two power leads have negligible resistance.

2.3.3 Television/Lunar Surface Cable

A 100-foot cable is provided for use with the camera on the lunar surface. With the exception of the length and the precision resistors in the connector, this cable is identical to the LM Cabin Cable previously described. Since it is 100 feet in length, the capacitance of the coaxial leads is nominally

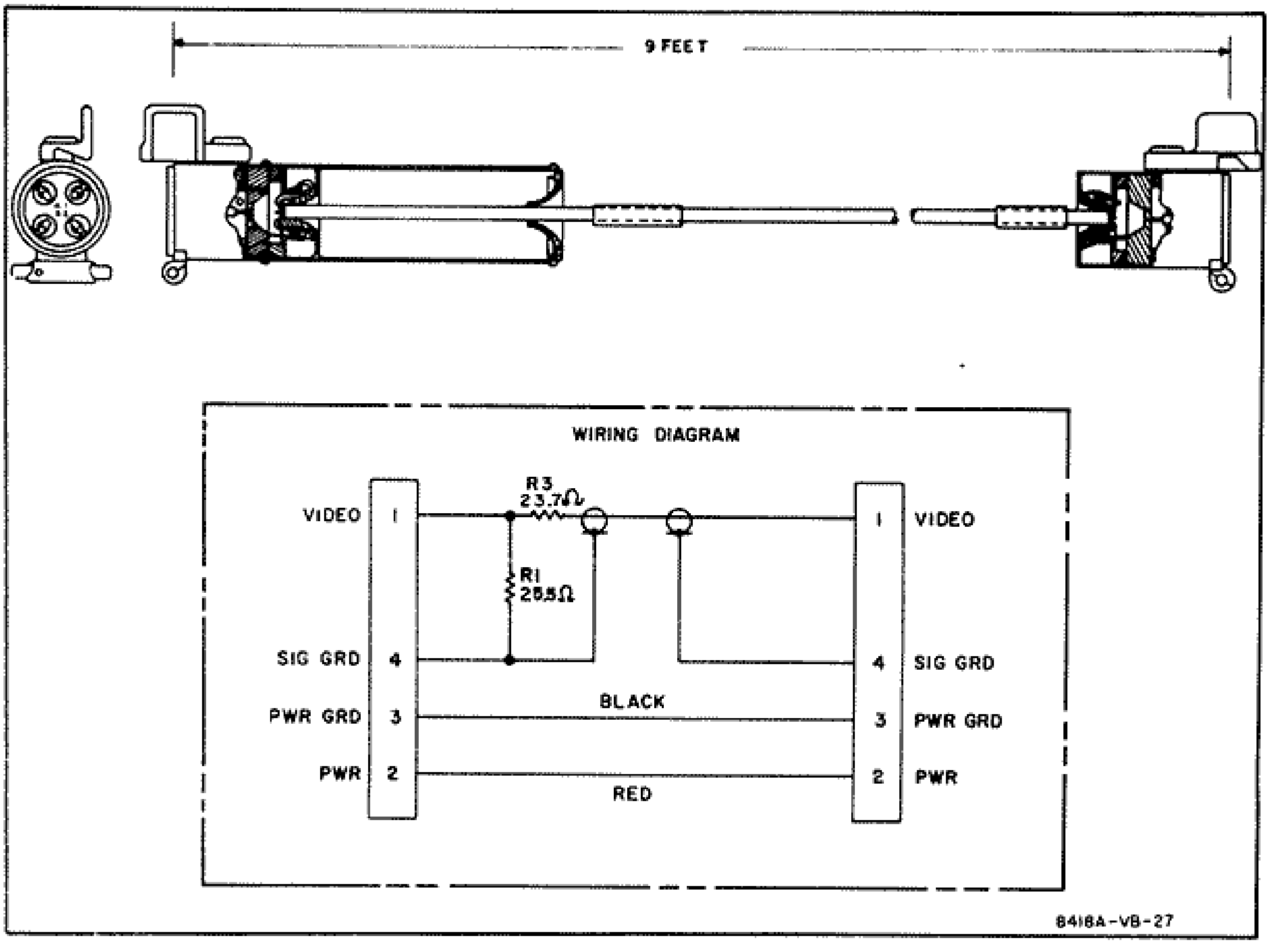


Figure 2-21. LM Cable Outline

3000 pF, the resistance of the inner conductor is approximately 22 ohms, and the resistance of the outer conductor is approximately 1.6 ohms. The resistance of each of the two power leads is about 1.46 ohms. Unlike the LM Cabin Cable, a single precision resistor of 17.8 ohms is installed between terminals 1 and 4 of the cable connector that fastens to the LM Spacecraft. A schematic of the cable/spacecraft circuit is shown in figure 2-23, and an outline of the overall cable is shown in figure 2-24.

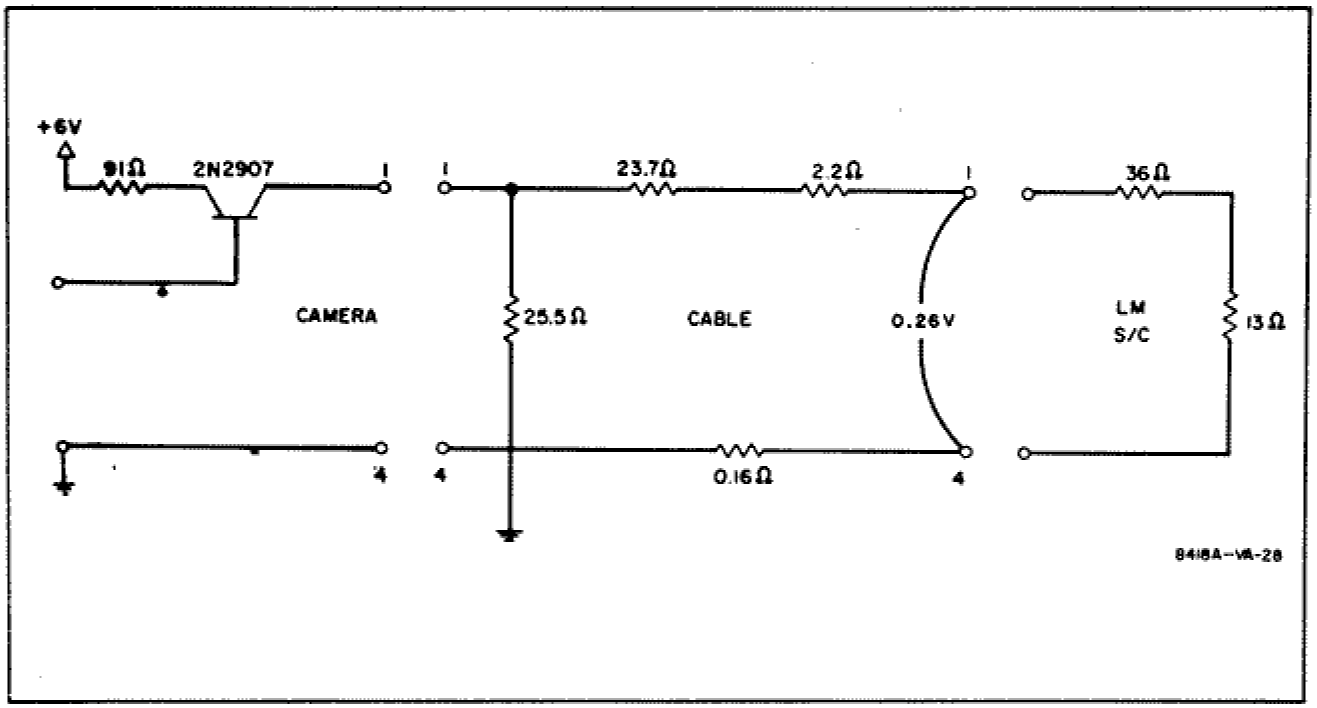


Figure 2-22. LM Cable Resistance Schematic

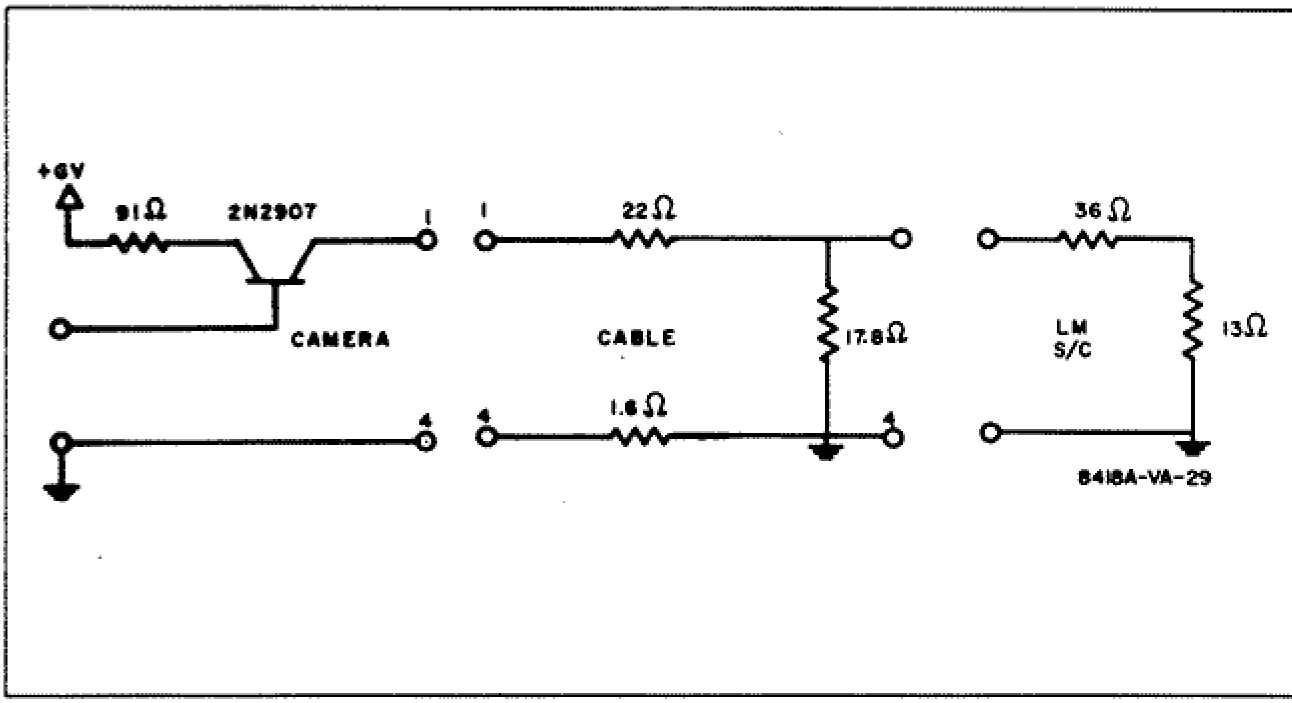


Figure 2-23. LS Cable Resistance Schematic Diagram

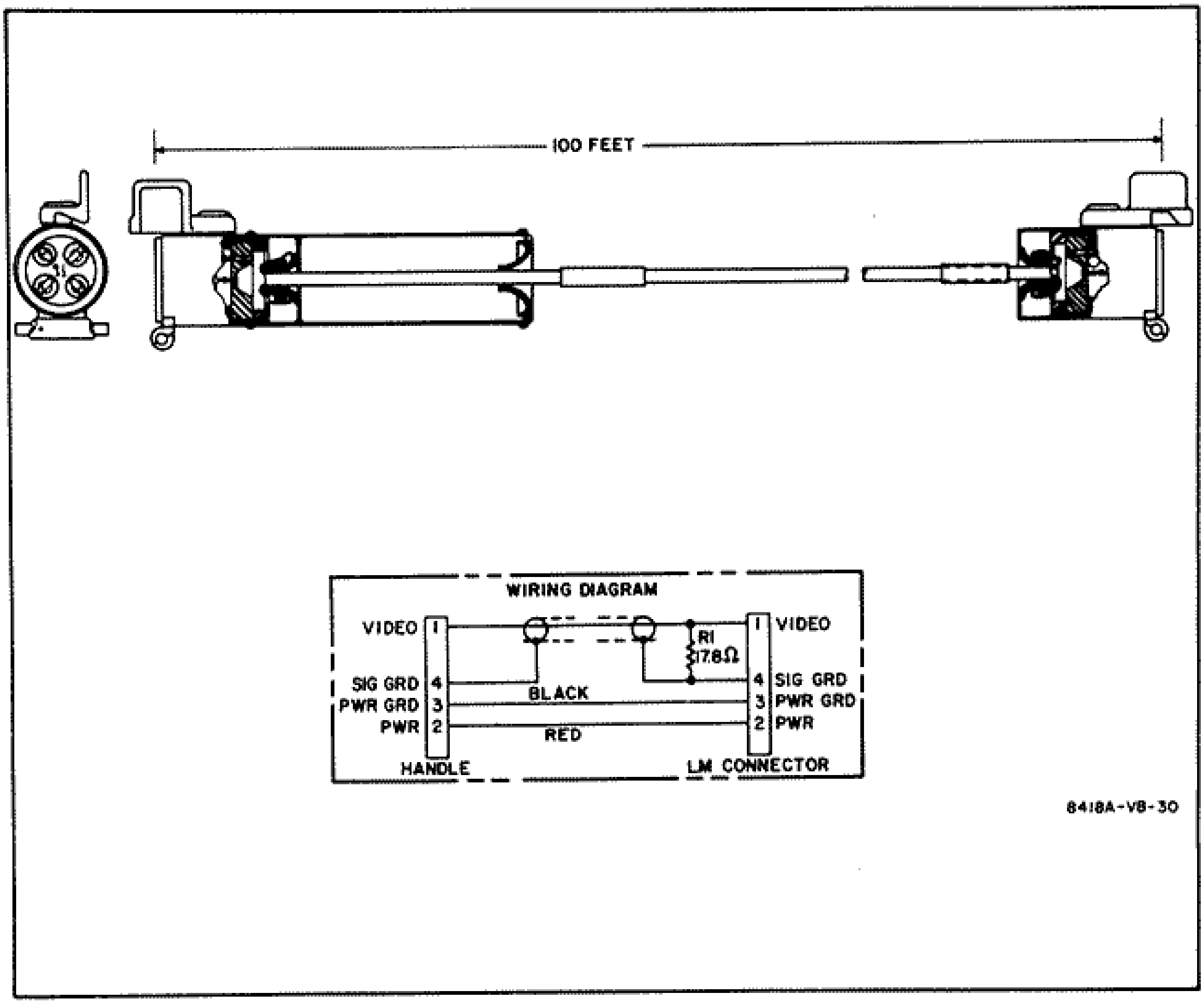


Figure 2-24. LS Cable Outline

# 3. SYSTEM OPERATION

Operation of the television camera requires only that one of the appropriate lenses be installed and that power be applied to the camera through one of the three power-video cables. The video television picture information can then be transmitted out of the camera through coaxial lines within the above cable. Selection of either of two operating modes is provided by a switch on the camera top. During the 10 frames per second mode, the camera may be hand-held for viewing scenes of general interest and those in which motion occurs. The second mode, which scans at 0.625, enables the viewing of scenes of scientific interest in which higher resolution pictures are desired. Since relative motion between the camera and the scene being viewed at this lower frame rate would produce a smeared picture, the camera must be rigidly supported during the slower operating mode.

Inasmuch as the camera can reproduce scenes at light conditions 100 times lower than those viewed by conventional vidicon cameras, it may be possible to damage it if certain precautions are not followed. First of all, lenses should never be changed while power is applied unless the level of light exposed to the front of the camera is very dim (no more than one foot candle). Secondly, the camera should never be pointed at any bright, concentrated, source of light. This situation might possibly exist if the camera is used in the Command Module with the spotlights in the field of view. The camera should obviously never be pointed directly at the sun or at a reflection of the sun.

The camera has been designed to operate on the lunar surface in either the day or nighttime environment. However, some precaution should also be exercised when operating under these conditions. During the lunar day, the camera should not be tilted more than about 30 degrees from the vertical for extended periods of time or the camera may become overheated. Prior to use during the lunar night, care should be taken to install two metallic strips known as thermal shields on the top of the camera to keep the camera temperature within normal operating limits. The combination of thermal paint on the camera top and the highly reflecting silver finish on the remainder of the camera will provide a satisfactory regulation of internal temperatures if these procedures are followed. Under emergency cabin conditions within the spacecraft, a remote possibility exists that prolonged high temperatures may result in sensor degradation. A temperature indicator mounted on the back of the camera will warn if this has happened.

## 3.1 SELECTION OF LENSES

The selection of the lens to use is determined by the angular dimension (field of view) of the scene to be viewed, the distance of the scene from the camera, and the illumination of the scene. Four lenses have been provided that permit use of the camera over a wide range of these parameters. As previously stated, the lenses are designated as Wide Angle, 100 mm, Lunar Day, and Lunar Night. Table 3-1 summarizes their characteristics.

TABLE 3-1

LENS CHARACTERISTICS

| Lens | Field of View - Degrees | Minimum Focus Distance | Illumination Range Ft. Lamberts Minimum - Maximum |
|---|---|---|---|
| Wide Angle | 80 | 20 in. | 0.15 - 90 |
| 100 mm | 9.3 | 143 ft. | 23 - 12,600 |
| Lunar Day | 35 | 11 ft. | 23 - 12,600 |
| Lunar Night | 35 | 37 ft. | 0.01 - 5 |

### 3.1.1 Wide Angle Lens

Since all lenses other than the Wide Angle lens have a minimum focus distance that exceeds the interior dimension of either the CM or the LM, the wide angle lens must be used whenever scenes within the spacecraft are to be viewed. Since the maximum scene illumination of 90 foot lamberts cannot be exceeded when using the Wide Angle lens, its use on the lunar surface is limited to scenes of indirect solar illumination. The lunar surface can be viewed, however, when it is under direct solar illumination from the interior of the CM or LM since the spacecraft windows provide the necessary light attenuation. The wide field of view of this lens makes it ideal for overall viewing of the earth or moon at relatively low altitudes. For example the earth and moon subtend 80-degree angles at altitudes of approximately 2000 and 350 nautical miles respectively.

3.1.2 100 mm Lens

Both the narrow field of view and the minimum focus distance make it apparent that this lens is to be used only when viewing distant scenes. Since the lens contains a neutral density filter that provides a uniform attenuation of scene illumination, it may be used on the lunar surface during daylight illumination of 12,600 foot lamberts. Its narrow field of view makes it ideal for viewing the entire earth from altitudes greater than 40,000 nautical miles or the entire moon from altitudes of greater than 10,000 nautical miles. At lower altitudes of course, smaller segments of either the moon or the earth can be viewed.

3.1.3 Lunar Day Lens

The 35-degree field of view and the scene illumination range of this lens make it ideally suited for use on the lunar surface. Like the 100 mm lens, it could also be used to view the earth or moon from flight since they subtend an angle of 35 degrees from altitudes of about 11,000 and 3,000 nautical miles respectively.

3.1.4 Lunar Night Lens

The lunar night lens has a maximum scene brightness limit of 5.0 foot lamberts and a minimum scene brightness of 0.01 foot lamberts. This restricts the use of this lens on the lunar surface to viewing scenes that are illuminated by light reflected from the earth. As with the 100 mm and Lunar Day Lens, the minimum focus distance prohibits its use for viewing scenes within the spacecraft.

## 3.2 ATTACHMENT OF LENS TO THE CAMERA

As discussed in paragraph 2.1.2, each of the lenses has a mounting flange containing three slots. The slots secure the lens to the camera through a Locking Ring that rotates to fasten the lens in place. One of the three slots is smaller than the other two and has the adjacent surface painted white. This slot locates the top of the lens which must be aligned with the top of the camera for installation. In addition to the slots in the mounting flange, the back of each lens contains an annular surface that must interface correctly with an outer ring of the camera's faceplate. There are three radial keys that extend about one-eighth of an inch from this ring that must insert into three matching cavities in the faceplate ring. With reference to figure 3-1, the procedure for attaching a lens then is as follows:

1. Rotate the Locking Ring (1) counterclockwise to the open position. Rotation from the locked position to the open position covers an angle of 30 degrees.

2. Rotate the lens (2) until the white slot is up; this aligns the top of the lens with the top of the camera.

3. Insert the lens through the locking ring (3) and seat it against the faceplate outer ring, making sure that the three lens keys engage the faceplate ring cavities. (See Figure 2-8 for lens detail.)

4. Rotate the camera Locking Ring 30 degrees counterclockwise (4) to secure the lens.

## 3.3. REMOVAL OF LENS FROM LENS HOLDERS

To remove the lens from the lens holders the following procedures should be followed:

1. Depress the white Teflon tab that is fastened to the cover of the lens holder. This elongates a semi-circular spring thereby permitting removal of the cover from the body of the lens holder.

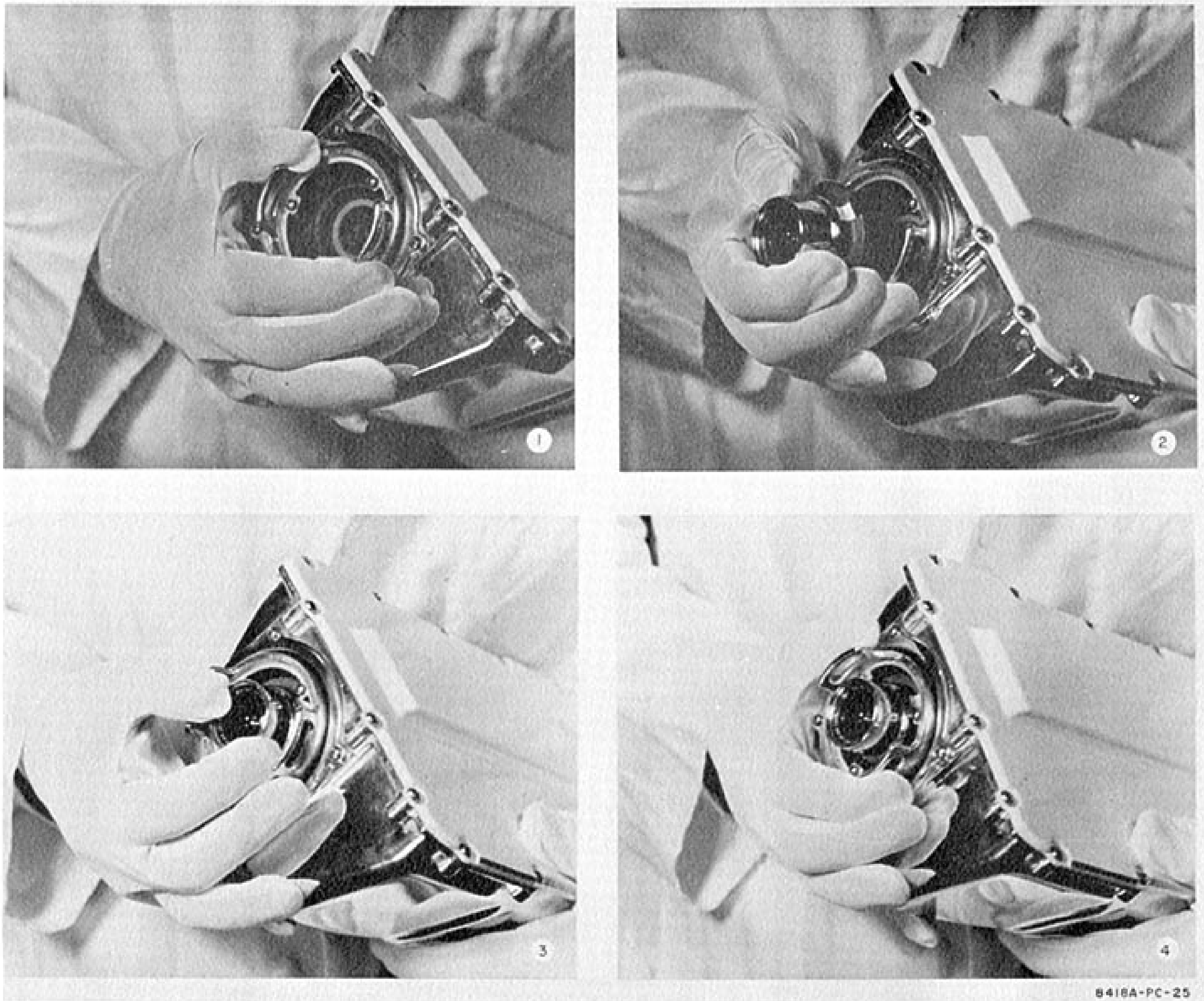


Figure 3-1. Lens Installation Process in Camera

2. Removal of the 100 mm and the Lunar Day lens from the long and short holders is readily accomplished. The Lunar Day lens and the Lunar Night lens use the same holder, since it is assumed that it will be known in advance whether or not the camera will be used for a day or night mission. The holder for the Lunar Day lens uses a brown Teflon spacer installed in the cover. This spacer is removed when the holder is used for a Lunar Night lens, and a white Teflon stop is inserted in the body of the holder. The stop prevents the larger Lunar Day lens from falling out of the holder at the instant the cover is removed.

3. When removing the Lunar Night lens, the white teflon stop described above is withdrawn from the body of the lens holder. Caution must be exercised to prevent the lens from dropping out of the lens holder and being damaged.

## 3.4. HANDLE ATTACHMENT AND POWER APPLICATION

(See figure 3-2.) One of the connectors of each of the three electrical cables that is used with the camera contains a tubular extension that serves as a handle for supporting the camera during operation. The handle/connector is fastened to the camera by means of a hinge bolt and spring-loaded latch. These join with the electrical receptacle on the bottom of the camera that in turn contains two hinge slots and a latching pin. Two tapered rail-like projections extend from the camera receptacle that serve as a guide for the handle during engagement. The procedure for attaching the handle/connector to the camera is as follows:

1. Rotate the handle until the hinge bolt is parallel to, and is the closest part of the handle to the bottom of the camera (1).

2. Move the handle along the camera surface between the tapered guide rails until the hinge bolt bottoms in the two hinge slots (2).

3. Rotate the handle/connector about the hinge until the thumb actuated latch is close to the locking pin that extends from the camera receptacle (3). A force of about three pounds will be required during the last 25 degrees leading up to and snapping the latch which locks the connector in place (4). Even though the connector has been designed to minimize arcing of power from the connector to the camera during engagement, it is recommended that the cable not be energized with power until after connection has been made.

## 3.5 OPERATING CONSTRAINTS

The operating constraints of the camera lie in four general areas, namely, light intensity of scenes to be viewed, temperature levels in which the camera may be operated, handling, and sequence of operation. Failure to observe these constraints could result in serious damage to the camera.

### 3.5.1 Light Intensity Variation

A light intensity of 1.0 foot candle may be imposed on the faceplate of the camera's SEC Vidicon for an indefinite length of time. If this value is

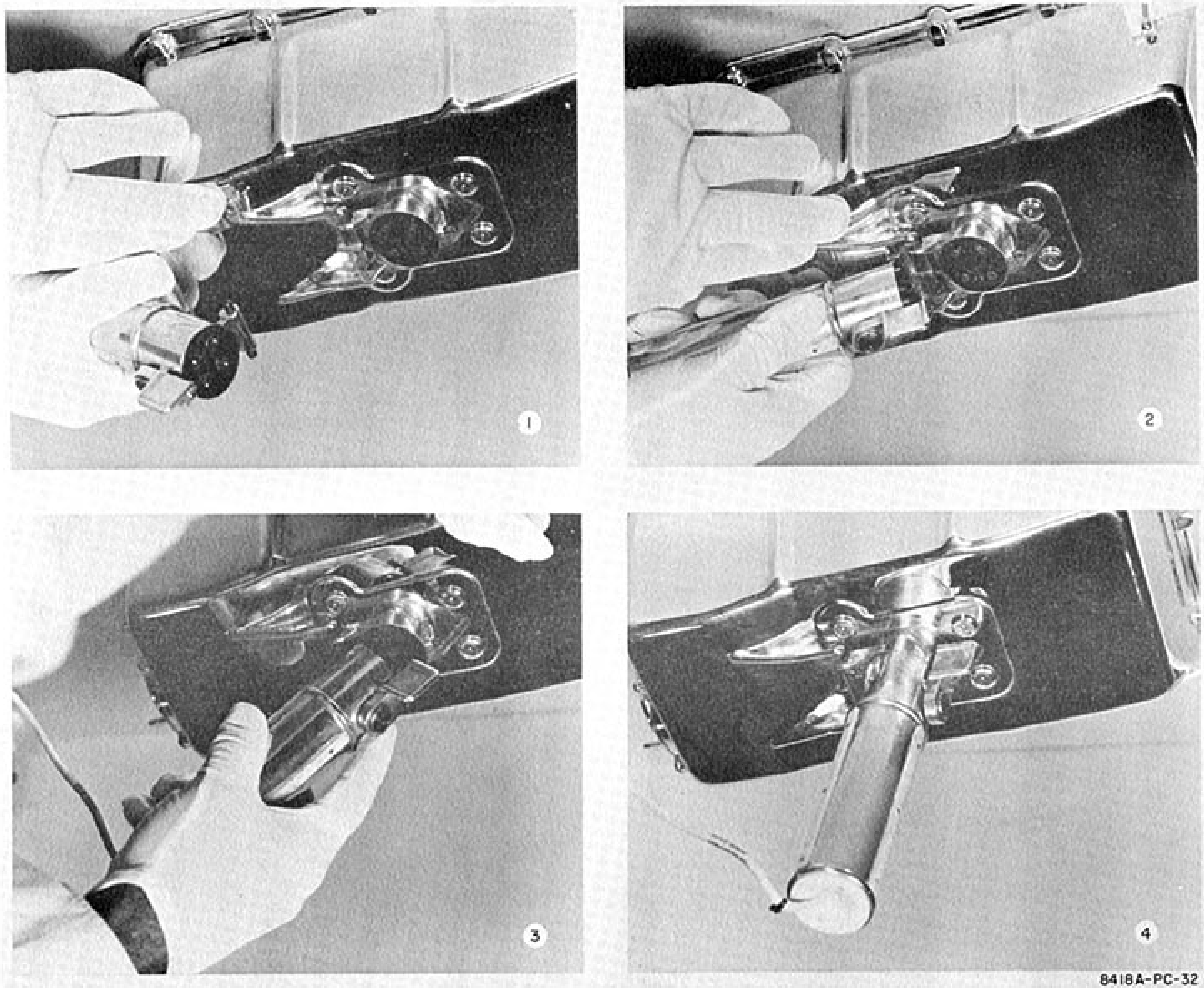


Figure 3-2. Handle Connector Installation

significantly exceeded, however, permanent damage may occur. Therefore, each of the four lenses has been designed such that with a specified maximum light intensity into the lens the equivalent of 1.0 foot candle will be produced on the camera's faceplate. These maximum values are given below:

| | | |
|---|---|---|
| Wide Angle | - | 100 foot lamberts |
| 100 mm | - | 12,600 foot lamberts |
| Lunar Day | - | 12,600 foot lamberts |
| Lunar Night | - | 5 foot lamberts |

Since one foot candle is equivalent to about 2 percent of the illumination that exists in a normally illuminated room, the camera must never be operated without the lenses unless it is installed within a light controlled test device.

In addition, the camera, even with the 100 mm or Lunar Day lens installed, should not be pointed directly at the sun or directly at bright lamps.

3.5.2 Temperature Extremes

THE CAMERA CASE SHOULD NEVER BE ALLOWED TO REACH A TEMPERATURE COLDER THAN MINUS 30°F OR HOTTER THAN PLUS 120°F. Failure to observe these limits will result in permanent damage to the camera. A passive thermal control system will always keep the camera warmer than minus 30°F, providing the power is turned on and the camera is operated. This same thermal control system will also prevent the camera's temperature from exceeding plus 120°F, although the lunar surface temperature may reach plus 250°F. When operating the camera on the lunar surface in a plus 250°F environment, the top of the camera can be tilted up to any 30 degrees from the vertical for an indefinite length of time. Tilt angles of about any 45 degrees for a period of 30 minutes and any 90 degrees for a period of 5 would not result in damage to the camera.

In order for an operator to easily determine whether or not the temperature has been kept within the proper limits, a Temperature Indicator has been mounted directly to the case on the back of the camera. The operation of the Indicator is similar to that of the conventional medical thermometer, with fluid motion expanding and contracting in a column in proportion to temperature. As shown in figure 3-3, the Indicator has two viewing ports and is read as follows:

1. If the fluid is not visible in either port, the camera is too cold and may have been damaged.

2. If the fluid is visible in both ports, the camera is too hot and may have been damaged. If this should occur turn camera's power off until it has cooled to operating temperature.

3. If the fluid is visible in the left port, but <u>not</u> the right port, the camera's temperature is satisfactory.

### 3.5.3 Handling

As discussed in Section 2.1, Physical Characteristics, the top of the camera is coated with a special rubber-like thermal paint with the rest of the camera having a highly polished silverplate finish. In order that neither of these finishes be excessively damaged from scratching or scraping, it is recommended that nylon gloves be used wherever possible in handling the camera during non-flight operations.

Similar precaution should be followed in handling the lenses. In particular, care should be exercised not to get finger prints or otherwise soil either of the two optical surfaces on the lenses, or the faceplate of the camera's SEC Vidicon.

Whenever the camera or lenses are being transported locally from one site to another, they should be stowed in the carrying case (see figure 3-4) that was designed for this purpose. It is important to remember that the camera is a relatively fragile scientific instrument that has been fully qualified for use in the Apollo Mission, but which must be handled with care.

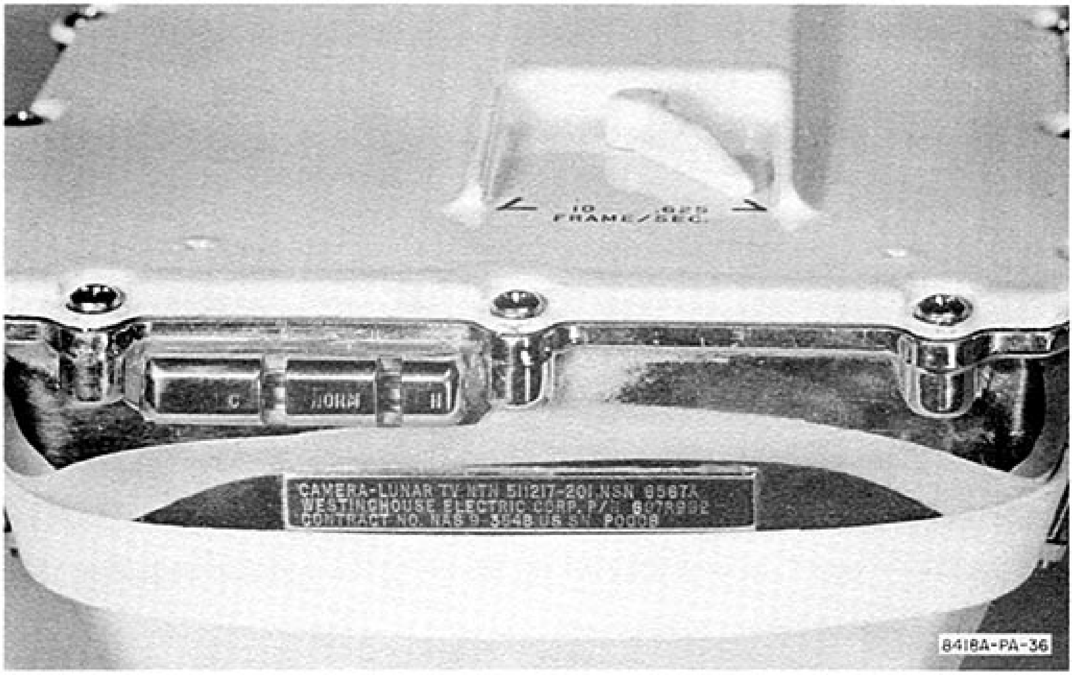


Figure 3-3. Temperature Indicator


Figure 3-4. Camera Carrying Case

### 3.5.4 Sequence of Operations

With reference to Section 3 which generally describes the operations of the camera, the specific sequence of operation is as follows:

1. Remove the camera from its stowed position in the CM, LM Cabin or LM Descent Stage.

2. Remove the electrical cable from its stowed position and connect the handle connector to the camera in accordance with the procedures stated in 3.3. If it is not already connected, connect the other end of the electrical cable to the bulkhead in the CM, LM Cabin, or LM Descent State.

3. Select either the 10 frame per second or the 0.625 fps mode by moving the mode switch to the left or right position. (See Figure 3-5.) If the 0.625 mode is used, there should be no relative motion between the camera and the scene being viewed.

4. Determine the maximum light level that the camera will be operated in and select the appropriate lens.

| Lens | Max. Light Level - Foot Lamberts |
|---|---|
| Wide Angle | 90 |
| 100 mm | 12,600 |
| Lunar Day | 12,600 |
| Lunar Night | 5 |

5. If the light level is such that more than one lens may be used, select the lens on the basis of either the field of view that is desired, or the distance separating the scene to be viewed and the camera. Figures 3-6, 3-7, 3-8, and 3-9 relate scene dimensions with distances on the lunar surface for each of the lenses.

6. Install the lens following the procedure described in paragraph 3.2.

7. Apply power to camera and proceed to use. Always turn power <u>off</u> the camera before changing lenses.

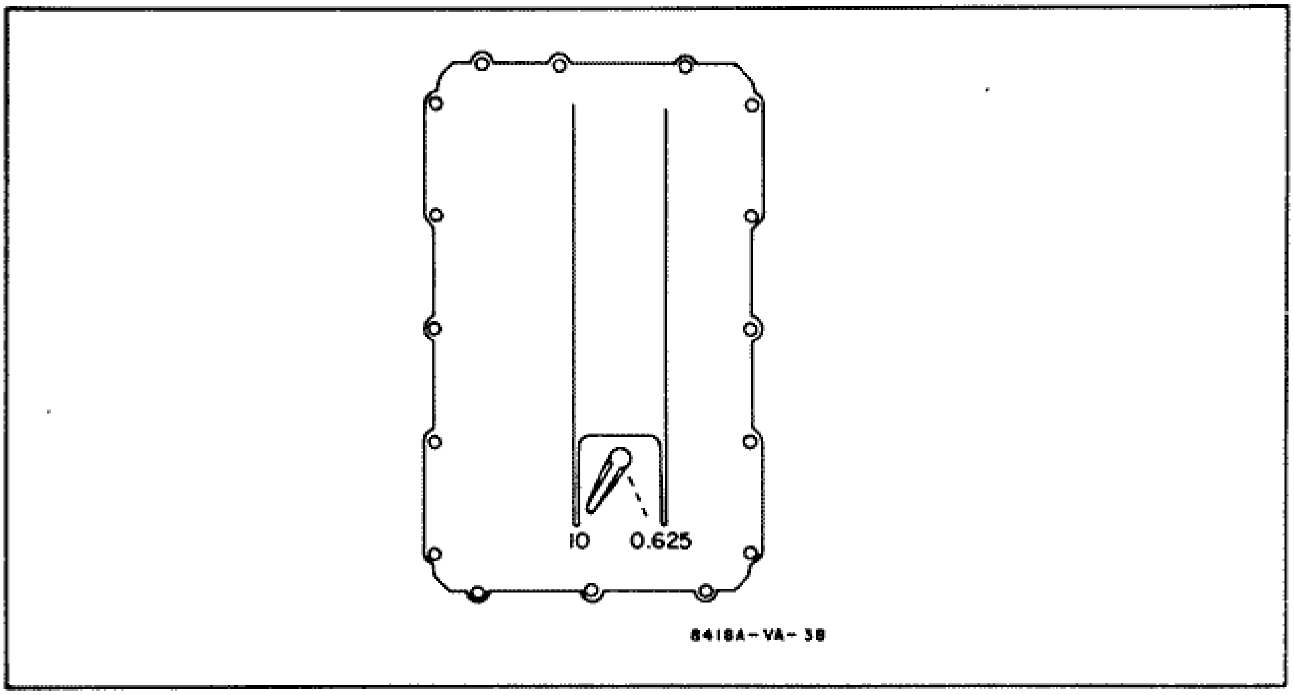


Figure 3-5. Top of Camera, Showing Mode Selector Switch

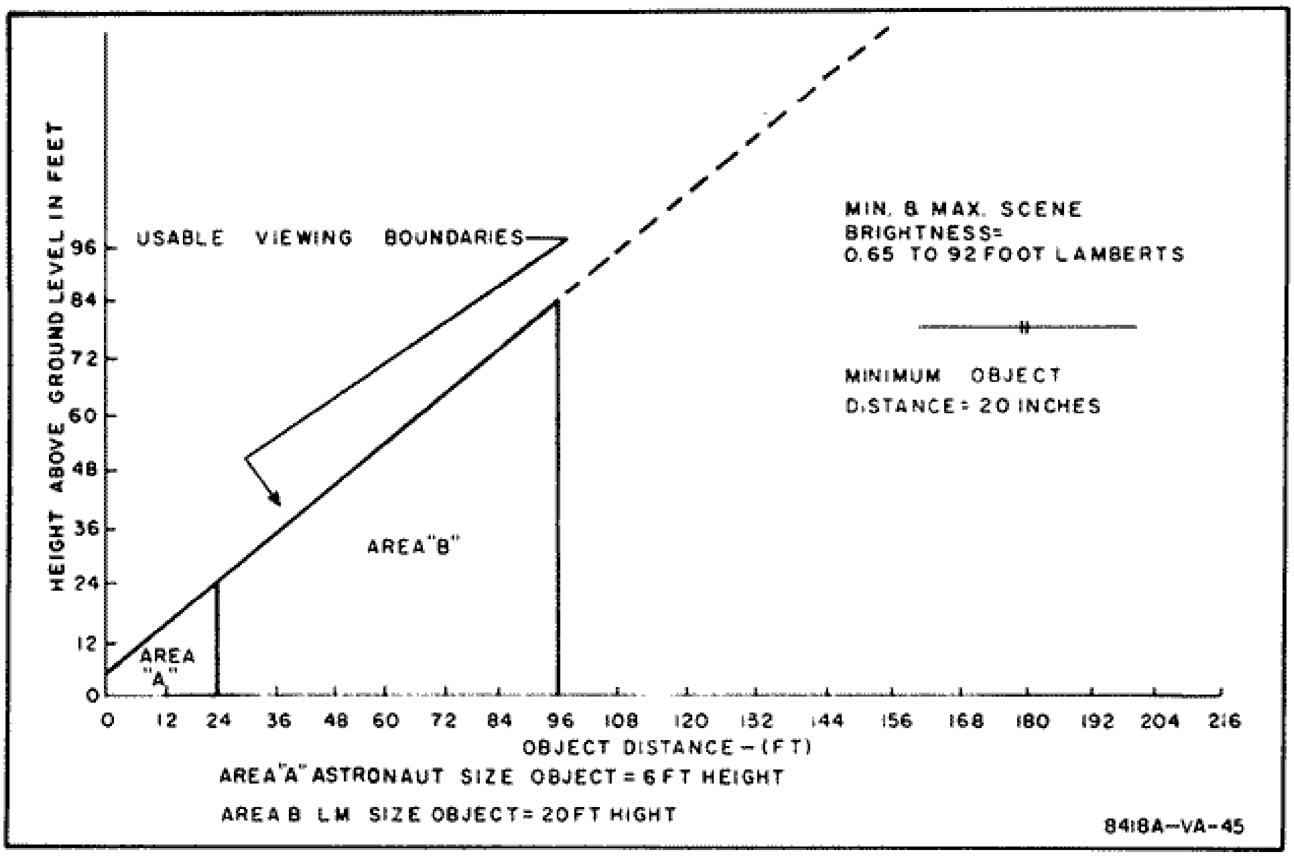


Figure 3-6. Wide Angle Lens Viewing Constraints Chart

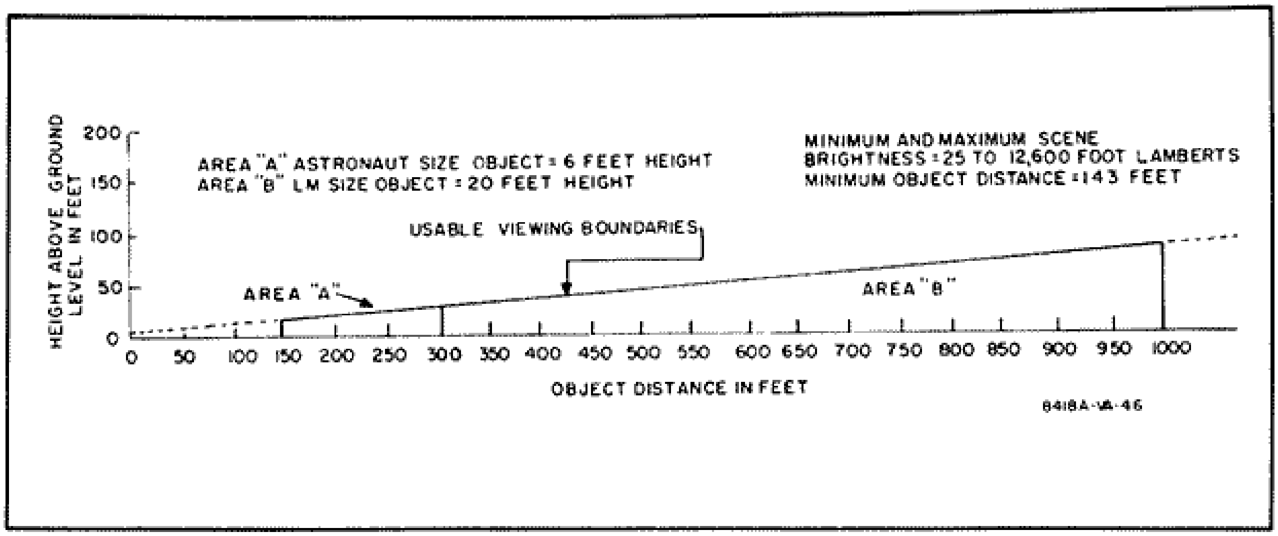


Figure 3-7. 100 mm Lens Viewing Constraints Chart

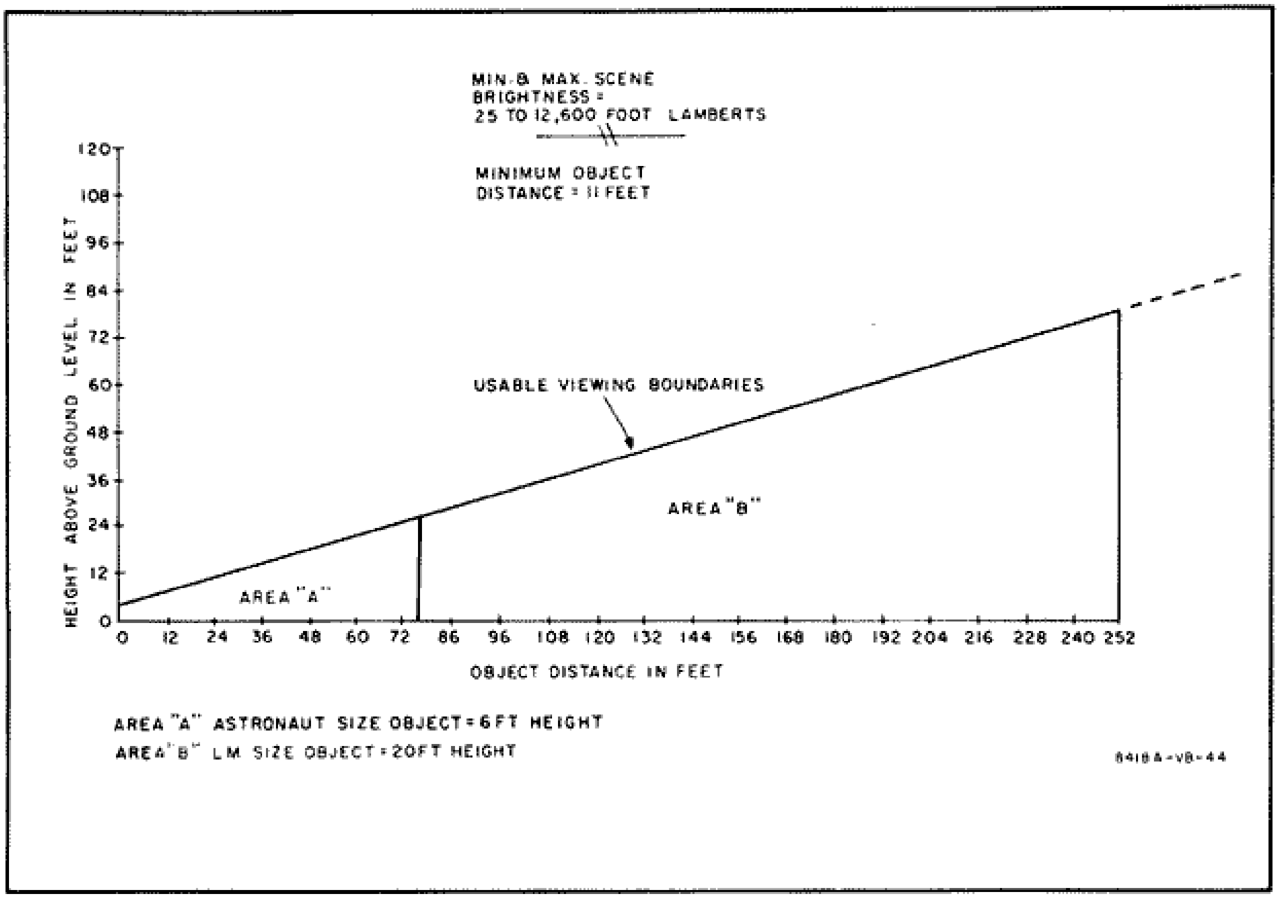


Figure 3-8. Lunar Day Lens Viewing Constraints Chart

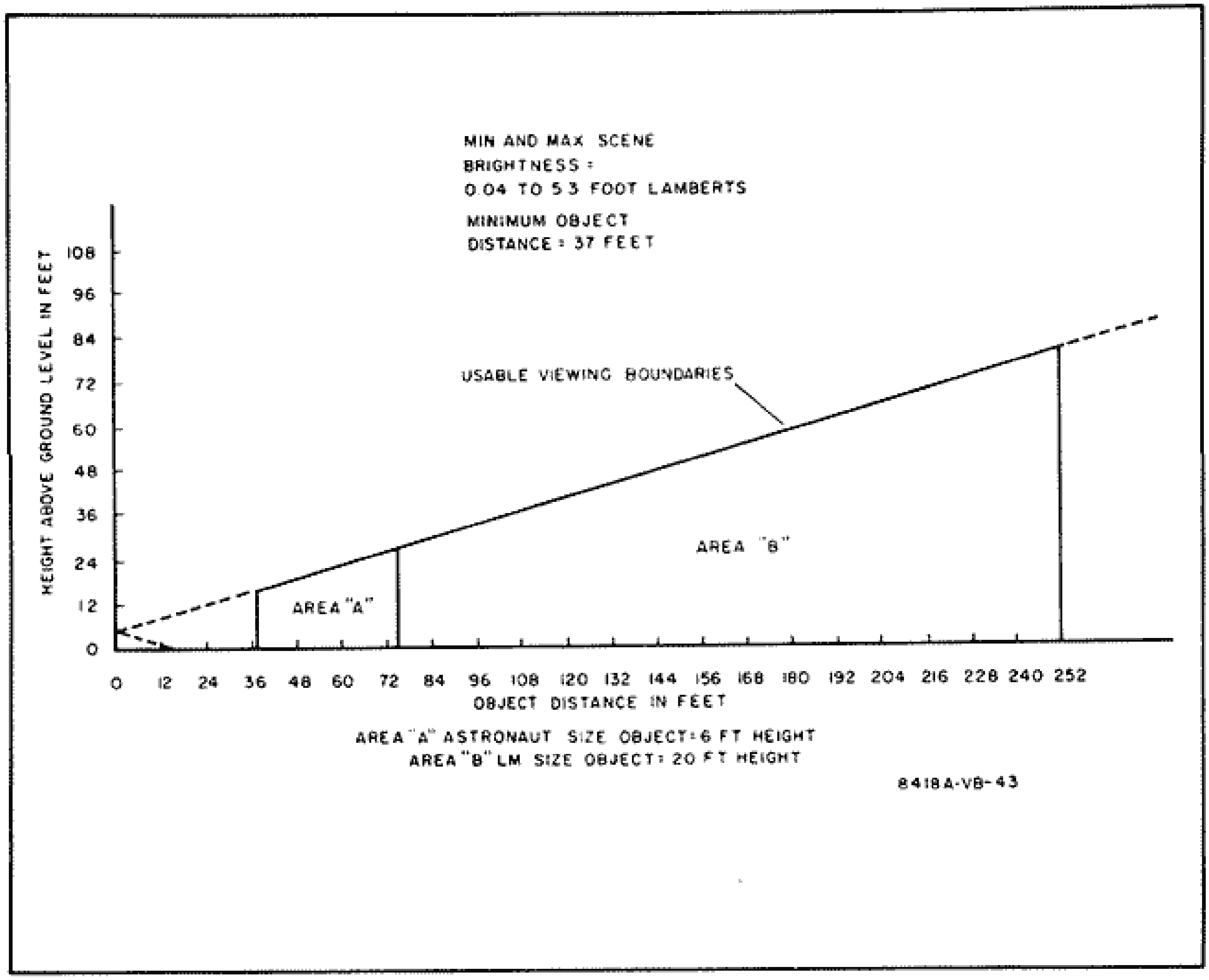


Figure 3-9. Lunar Night Lens Viewing Constraints Chart

# 4. TV EQUIPMENT STOWAGE

## 4.1 CM STOWAGE

Stowage is required for the television camera, the lenses with dust covers and filter, and the 12-foot CM television cable.

Stowage equipment consists of the television camera stowage bracket (figure 4-1) with two built-in lens holders and a television cable locker. The camera stowage bracket consists of two rectangular frames which are attached together on each corner by shock mounts. The lower base frame portion is bonded solidly to the S/C and the top frame is a semi-floating frame which holds the camera. The camera is held into the upper frame by four notched clips which fit snugly around four tapered hard points on the upper edges of the camera. Camera loading and removal from the bracket is accomplished by engaging or disengaging the two Calfax fasteners which hold one-half of the notched clip holders in position. When these fasteners are disengaged, one-half of two of these clips fold outward, permitting the camera to be lifted out of the bracket.

The camera lenses are stowed in two cylindrical-shaped holders which are attached to the side of the camera stowage bracket. Stowage loading/ removal of the camera lenses is accomplished by operating the snap slide fastener on the holder cover and raising the top cover plate.

The television camera cable is stowed in a locker which is built into the S/C near the lower tunnel area. A bracket is provided inside this cabinet which holds the cable. The cable is stowed by coiling it around this bracket in a figure-eight configuration. Due to the small size of the connectors used on the bulkhead end of the television cable, they are connected to the S/C prior to launch. Cable stowing is also performed prior to launch. Cable removal is accomplished by starting at the handle end of the cable and removing each cable convolution in sequence from the bracket.

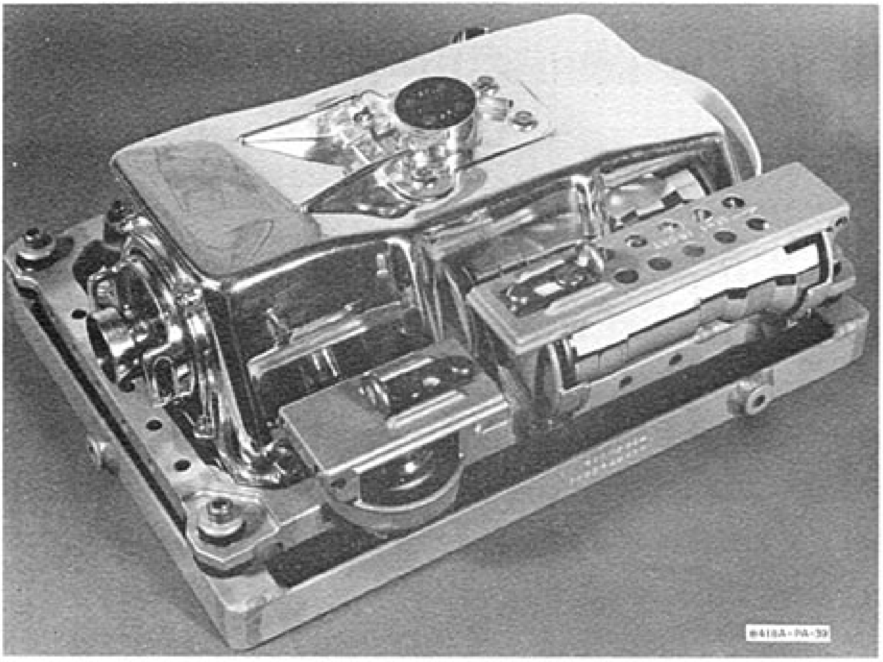

Figure 4-1. CM Stowage Frame With Camera

## 4.2 LM STOWAGE (ASCENT STAGE)

Stowage is required for the lunar television camera, lenses, and 9 ft. LM television cable. Design of the stowage equipment was predicated on its use by an unsuited astronaut.

The stowage equipment consists of a television camera stowage bracket, two lens holders, and a television and a television cable stowage bag. (See figures 4-2, 4-3, and 4-4.) The camera stowage bracket (figure 4-2) consists of a rectangular frame which is attached to the vehicle with four shock mounts. The camera is seated in the frame on four tabs that interface with four bearing surfaces on the top of the camera ( painted surface). The camera is installed by first seating the camera into the bracket with the connector side exposed, and then fastening the two knurled Calfax fasteners so that the camera is firmly clamped in place.

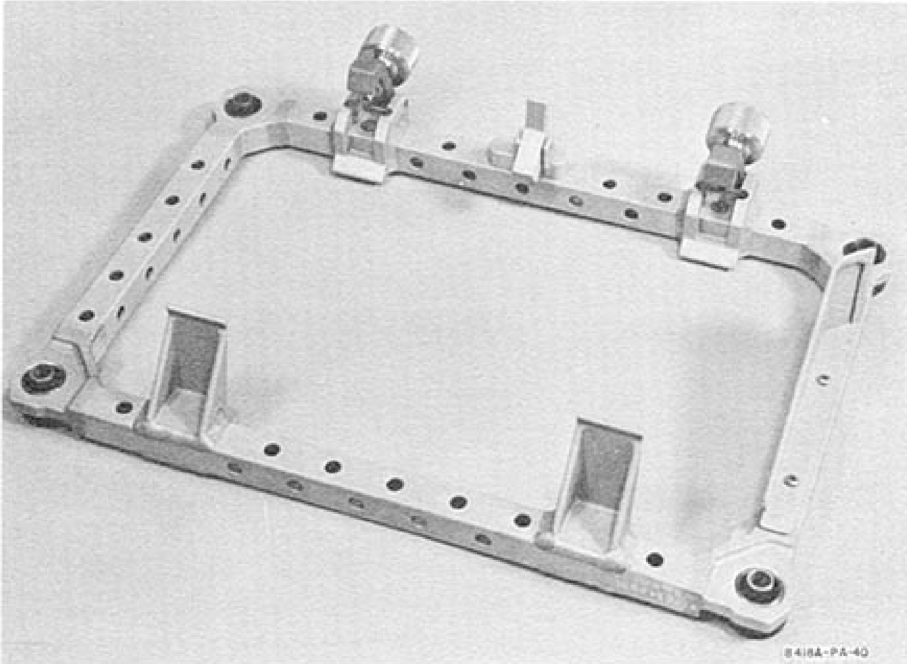

Figure 4-2. LM Stowage Bracket

The camera lenses are stowed in two cylindrical-shaped holders (figure 4-3) which are mounted separately in the vehicle near the camera stowage bracket. Removal of the lens from the holder is accomplished by first depressing the white teflon tab that opens a semi-circular spring clip fastening the cover to the body of the holder. With the cover removed, the lens is then withdrawn from the holder. The lens is reinstalled by first inserting the black flange end of the lens into the holder. The cover of the holder is fastened by depressing the white tab and slipping the cover in place such that the semi-circular spring grips the holder beyond the raised edge.

Television cable stowage is accomplished by coiling the cable (figure 4-4) into spiral-shaped coils and placing it into a small bag. This bag is normally located near the camera during stowage.

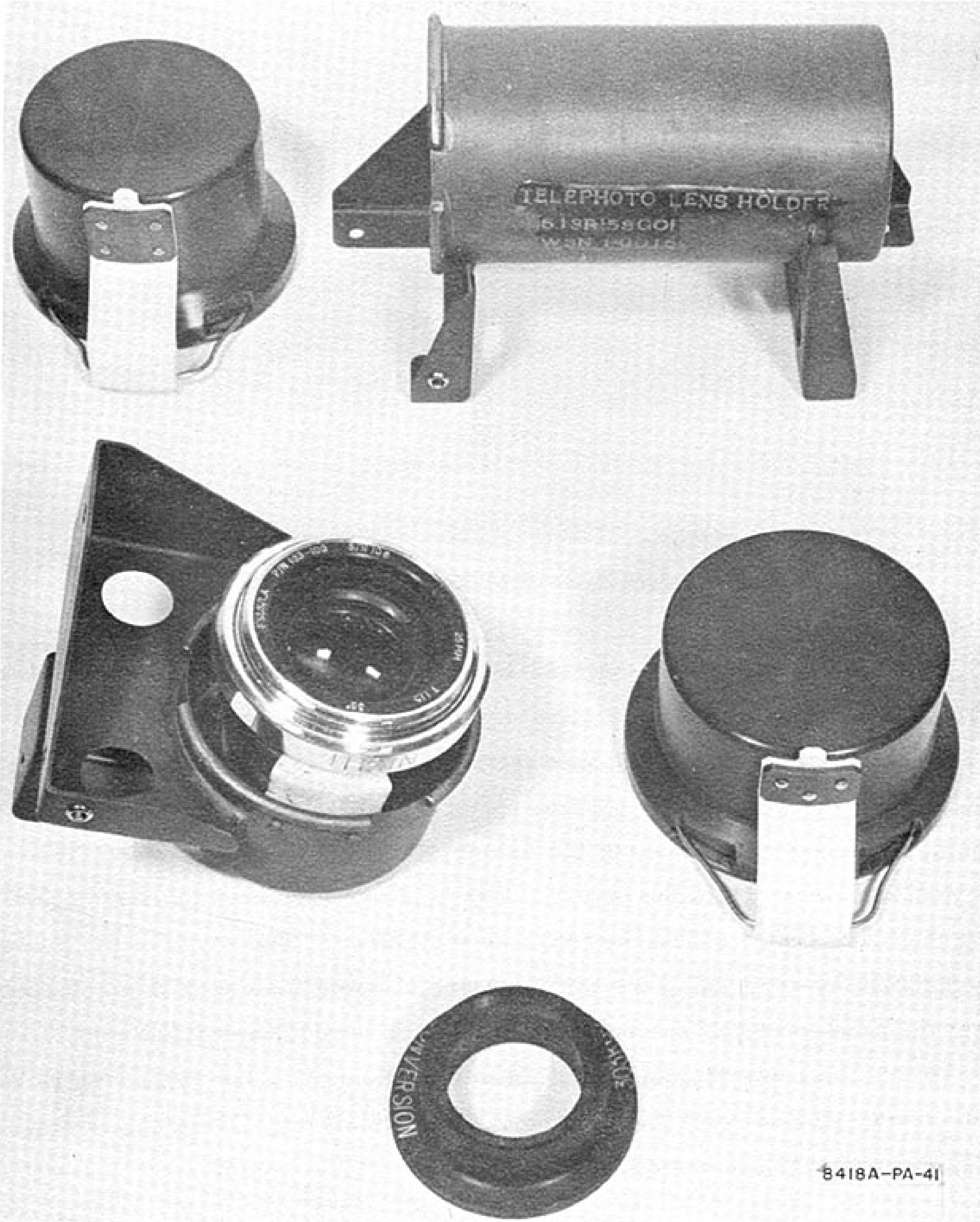


Figure 4-3. Lens Holders

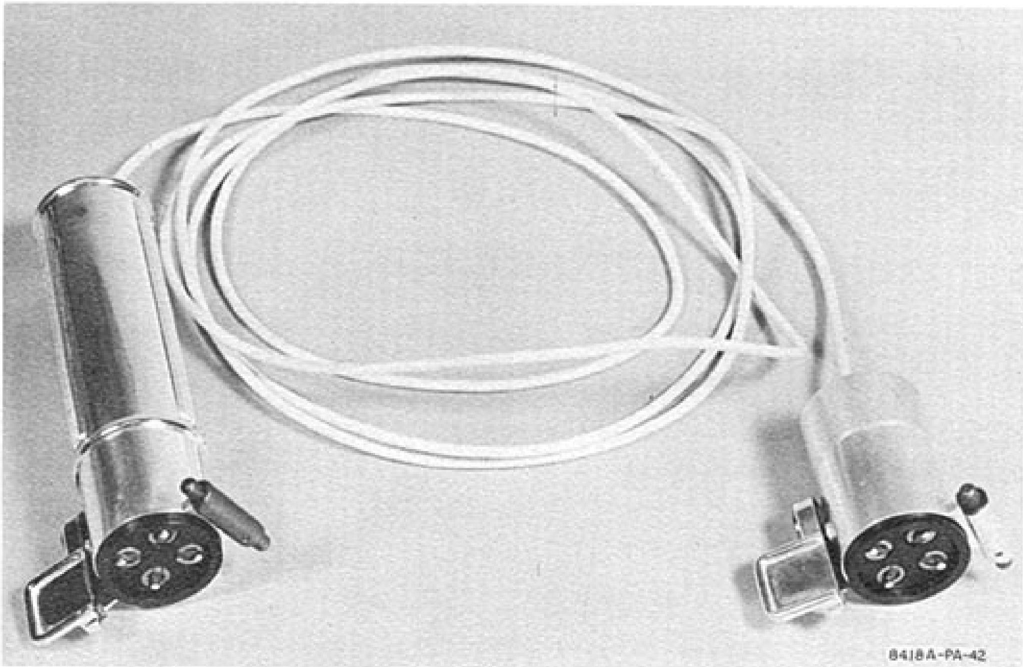


Figure 4-4. LM Cable

## 4.3 LM STOWAGE (DESCENT STAGE)

Stowage is required for the lunar camera, lenses and 100-foot television cable.

The stowage equipment consists of a television camera bracket, (figure 4-2) two lens holders (figure 4-3) and a television cable bracket (figure 4-5). The television camera stowage bracket is located on the M.E.S.S. pallet of the LM descent stage which is immediately left of the ladder. The camera stowage bracket consists of a rectangular frame which is attached to the vehicle with four shock mounts. The camera is seated in the frame on four tabs that interface with four bearing surfaces on the top of the camera (painted surface). The camera is installed by first seating the camera into the bracket with the connector side exposed, and then fastening the two knurled Calfax fasteners so that the camera is firmly clamped in place.

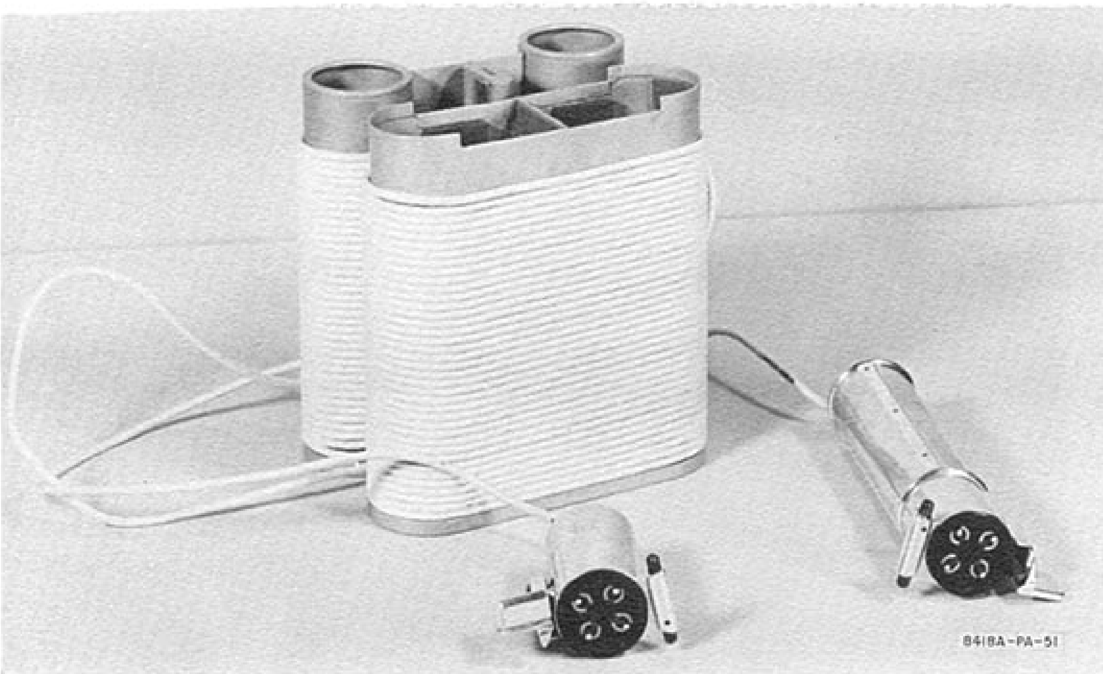

Figure 4-5. LS Cable

The camera lenses are stowed in two cylindrical-shaped holders which are mounted separately in the vehicle near the camera stowage bracket. Removal of the lens from the holder is accomplished by first depressing the white teflon tab that opens a semi-circular spring clip fastening the cover to the body of the holder. With the cover removed, the lens is then withdrawn from the holder. The lens is reinstalled by first inserting the black flange end of the lens into the holder. The cover of the holder is fastened by depressing the white tab and slipping the cover in place such that the semi-circular spring grips the holder beyond the raised edge.

Lunar television cable (100 ft) stowage is accomplished by wrapping the cable around a specially designed stowage form. This form is shaped so that it will fit into a 5" x 6" x 7" container. Due to the special method used in winding the cable around the form, it will be wound by Westinghouse on delivery and should not be unwound until used.

To remove the cable from the form, the bulkhead connector end of the cable should be pulled out approximately 10 ft. and connected to the bulkhead connector. After the above is accomplished, the handle end of the cable can be removed by pulling on the handle and allowing the cable convolutions to slide out of the cable form.

# 5. MAINTENANCE AND STORAGE

This section of the Handbook describes the Maintenance and Storage requirements for the camera and its accessories. These requirements lie in five general areas: Periodic Operation, Cleaning and Handling, Lens Purging, Repair, and Packing for Shipment. In general, when the camera is not in use, it should be stowed in its carrying case.

## 5.1 PERIODIC OPERATION

Since there are little data available concerning the shelf life of the SEC vidicon, it is recommended that the camera be operated periodically. This should be done once every 3 to 6 months for a period of one hour, using the wide angle lens.

## 5.2 CLEANING

Latex gloves should be used during cleaning of the camera or any of its accessories. After the cleaning has been completed, lint-free gloves should be used in handling the equipment. Procedures for cleaning are as follows:

### 5.2.1 Television Camera Radiation Surface (White Paint)

Clean all contaminated painted surfaces by wiping with polyurethane sponge wipes that are dampened with distilled water. If the contamination is still present, wipe with a lint free cloth dampened with 10 percent (by volume) of ammonium hydroxide and distilled water solution. After using the ammonium hydroxide solution, wipe off cleaned surfaces with polyurethane sponge wipes dampened with distilled water.

### 5.2.2 Silver Plated Surfaces of Camera, Connectors and Lenses

Clean contaminated surfaces by wiping with absorbent cotton dampened with distilled water. If the contamination is still present, wipe with absorbent cotton dampened with 10 percent (by volume) of ammonium hydroxide and distilled water solution. After using the ammonium hydroxide solution, wipe off cleaned surfaces dampened with distilled water. When the 10 percent ammonium hydroxide solution is used for cleaning, apply tarnish preventive (Hagerty R-22) with absorbent cotton. Hagerty R-22 can be purchased from the Wm. Hagerty Company whose address is given in the Appendix.

5.2.3 Lens Optical Surfaces, Camera Vidicon Window

Clean dirt and dust from all optical surfaces by brushing gently with a camel's hair brush. If dirt or fingerprints remain on the optical surfaces, clean by gently wiping surfaces with polyurethane sponge wipes dampened with isopropryl alcohol or acetone. Cleaning fluid must be applied to sponge and not directly to the optical surfaces. The cleaning fluid should not be allowed to seep between optical surfaces and the surrounding structure.

CAUTION

The SEC Vidicon window is pressure-sensitive and must be cleaned carefully. Excessive pressure can misalign or damage the SEC Vidicon and must be avoided.

5.2.4 Stowage Frames, Cables and Lens Holders

Clean contaminated surfaces by wiping with polyurethane sponge wipes dampened with Freon-TF, MSC Specification 237A. (Precision cleaning solvent).

5.2.5 Transportation of Cleaned Parts

If it is necessary to move the cleaned parts from one clean area to another, place each part in a separate polyethylene bag and seal the end. Do not use elastic bands, cord, etc., around the bag, such that hard contact is made with the surface of the part being carried, since this will leave marks. The part should be free in the bag.

### 5.2.6 Handling of Clean Flight Hardware

Nylon gloves or their equivalent, must be worn when handling or using the television camera or its accessories. During ground test camera operation, every effort should be made to protect the camera's thermal paint and polished surfaces. In addition, the cables should also be protected from becoming soiled and contaminated with grease or other foreign materials. The camera, or its accessories, should never be placed on any type of rough surface that may scratch or otherwise damage their finishes.

## 5.3 LENS PURGING

The inside of the lenses are filled with a moisture free, optically transparent, inert gas. If moisture were to unexpectedly leak through the lens seals, the cold temperatures of the space environment could cause this moisture to condense on the optical surfaces and "fog" the lenses. In order to minimize the possibility of this occurring, it is therefore recommended that 60 days prior to flight, the lenses be purged with a dry gas mixture in accordance with procedures especially developed by the ARDEL Corporation of Glendale, California. The purging procedure that is to be followed is designated as #100-205. Following completion of this process, the lenses must be given a Seal Integrity Test in accordance with ARDEL procedure 100-206.

Prior to evacuating and purging, the silicone sealant covering the purge port of the lens must be removed. In order to avoid scratching the silver finish, it is recommended this be done with a wooden or plastic pick. At the conclusion of the seal integrity test the sealant should be used to refill the counterbore over the purging port. It should be applied to a height of about 0.15 inch, overlapping slightly onto the silver plating of the lens barrel and allowed to cure at room temperature for a period of at least 24 hours. The sealant is designated as RTV-112 and may be purchased from the Silicone Products Department of the General Electric Company in Waterford, New York.

## 5.4 REPAIR

No repairs are to be made on the camera by a spacecraft contractor. In the event the camera becomes inoperative, or its performance becomes degraded, the NASA Television Subsystem Manager at the Manned Spacecraft Center is to be notified for disposition instructions.

## 5.5 PACKING FOR SHIPMENT

As previously discussed, in order that the camera and its accessories always be kept in as clean a condition as possible, handling of the equipment should be done with lint-free gloves. When packaging for shipment, this same procedure should obviously be followed. If the shipment is to be moved from one local site to another, then the carrying case shown in figure 3-4 should be used. The camera and the accessories are first placed in clean nylon bags, and then inserted in the various spaces allocated for them in the case's polyurethane cushioning. This cushioning, and the rigid aluminum structure of the case, will provide more than adequate protection against the shock loads that might be encountered during normal, hand carried, transportation of the equipment from one site to another.

When packing the camera and its accessories for shipment to remote locations whether by truck, railway or airplane, a larger, more ruggedized container is to be used. Packing procedures of course remain the same as those described above. This heavier, more durable case however is impervious to fungus growth, will withstand 200 hours of salt-laden moisture, as defined in MIL-E-5272, and is waterproof. As noted on the side of the case, a relief valve is to be opened before opening the case and closed after the case is closed. The dimensions of the case are 25 x 19 x 12 inches, weighs 20 lbs., and is manufactured by the Haliburton Company.

# APPENDIX

## APOLLO LUNAR TV CAMERA SYSTEM EQUIPMENT PART NUMBERS AND SUPPLIERS

### A. 1. EQUIPMENT

| | Identification | Westinghouse Part No. | Supplier | Supplier Part No. |
|---|---|---|---|---|
| 1 | Camera | 607R962 | - | - |
| 2 | Wide Angle Lens | 578R159-1 | Fairchild | 100-100 |
| 3 | 100 mm Lens | 578R159-2 | Fairchild | 101-100 |
| 4 | Lunar Day Lens | 578R159-3 | Fairchild | 102-100 |
| 5 | Lunar Night Lens | 578R159-4 | Fairchild | 103-100 |
| 6 | CM Electrical Cable | 508R835 | - | - |
| 7 | CM Cable-Camera Connector | 612R160 | - | - |
| 8 | CM Cable-Power Leads Connector | - | *North American | ME414-0102-002 |
| 9 | CM Cable-Video Leads Connector | - | **North American | ME414-0345-003 |
| 10 | LM Electrical Cable | 508R836 | - | - |
| 11 | LM Electrical Connectors | (Same as item 6) | | |
| 12 | Lunar Surface Electrical Cable | 513R387 | - | - |
| 13 | CM Stowage Bracket | 612R542 | - | - |
| 14 | LM Stowage Bracket | 612R037 | - | - |
| 15 | 100 mm Lens Holder | 513R158 | - | - |
| 16 | Lunar Day Lens Holder | 513R159 | - | - |
| 17 | Lunar Night Lens Holder | 513R159 | - | - |

*Cannon Co. Part #KPT-6F8-2P18

**Cannon Co. Part #CX-PL3-F-15

| | Identification | Westinghouse Part No. | Supplier | Supplier Part No. |
|---|---|---|---|---|
| 18 | Thermal Shield | 513R027 | - | - |
| 19 | Thermal Shield | 513R028 | - | - |
| 20 | Test Connector | 612R155 | - | - |
| 21 | Connector Plug | 607R948 | - | - |
| 22 | Connector Receptacle | 607R959 | - | - |

A.2. SUPPLIERS

The following identifies the suppliers of special materials, processes that are referenced throughout the Handbook.

| | Material Or Process | Supplier |
|---|---|---|
| 1 | Hagerty Silver Finish | Wm. Hagerty & Sons Inc.<br>Chicago, Illinois |
| 2 | Electrical Cable | Haveg Industries<br>Winooski, Vermont |
| 3 | RTV 112 Silicon Sealant | Silicone Products Dept.<br>General Electric Corp.<br>Waterford, New York |
| 4 | Stowage Bracket Vibration Isolators | Lord Manufacturing Co.<br>Division of Lord Corp.<br>Erie, Pennsylvania |
| 5 | Lenses | Fairchild Camera & Instrument Corp.<br>Los Angeles, California |
| 6 | Lens Purging | Ardell Corporation<br>Glendale, California |