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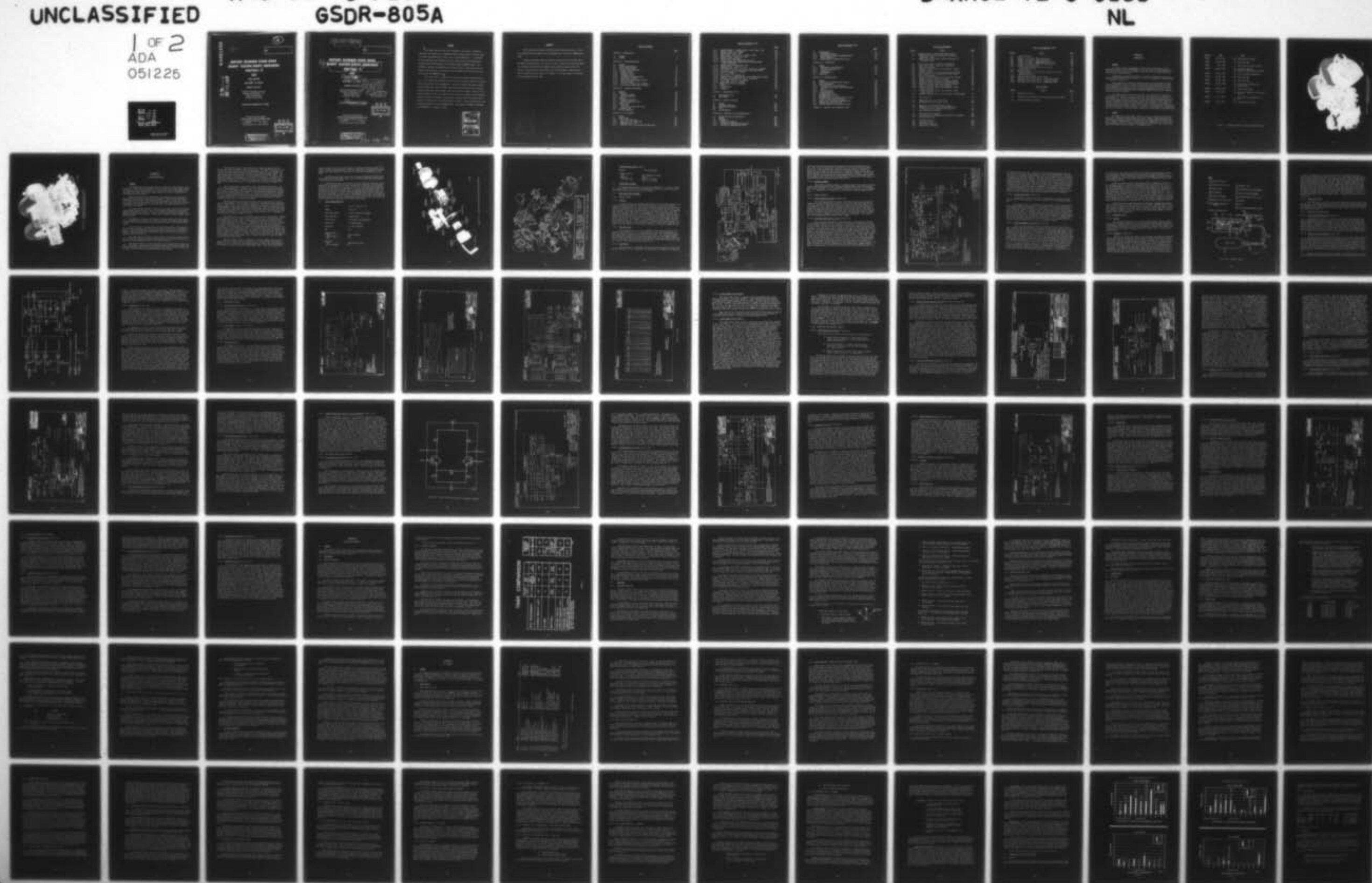

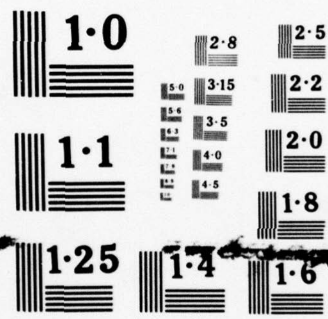
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REPORT NUMBER GSDR 805A
NIGHT VISION SIGHT, INFRARED
AN/TAS-3
(U)

FINAL REPORT

AUTHOR — G. PECK

AUGUST 30, 1975

United States Army Mobility Equipment
Research and Development Center
R&D Procurement Office
Fort Belvoir, Virginia 22060

Contract No. DAAK02-72-C-0156

GOVERNMENT SYSTEMS DIVISION
PHILIPS AUDIO VIDEO SYSTEMS CORP.
91 McKEE DRIVE, MAHWAH, N. J. 07430
TEL: 201-529-3800 TWX: 710-988-5348
A NORTH AMERICAN PHILIPS COMPANY

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NIGHT VISION SIGHT, INFRARED AN/TAS-3.

(U)

9 FINAL REPORT.

AUTHOR – G. PECK

10 George Peck

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GOVERNMENT SYSTEMS DIVISION
PHILIPS AUDIO VIDEO SYSTEMS CORP.
91 McKEE DRIVE, MAHWAH, N. J. 07430
TEL: 201-529-3800 TWX: 710-988-5348
A NORTH AMERICAN PHILIPS COMPANY

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SUMMARY

This report describes the effort expended in the design, development, fabrication and testing of a lightweight battery powered passive infrared imaging system, designated Night Vision Sight, Infrared AN/TAS-3( ). The AN/TAS-3( ) was designed to be integrated with and deployed with the Guided Missile Surface Attack, SM47 Medium Anti-tank/Assault Weapon (DRAGON) System. The AN/TAS-3( ) enables the DRAGON gunner to search, detect, recognize and aim at targets during the hours of darkness and to accurately track the target during the flight of the DRAGON missile.

This report details the efforts involved from contract award on November 1, 1971 through the completion of OT II testing in May of 1974 and is divided into nine sections plus two appendices. Section I presents the overall program aims and objectives, Section II the system description and Section II the major problems encountered during design, fabrication and test phases. Section IV provides a summary of field tests and training, Section V a summary of environmental testing, Section VI a summary of the Quality Assurance effort and Section VII a summary of the Reliability and Maintainability effort. Section VIII provides conclusions and Section IX the recommendations. The appendix provides an analyses of the AN/TAS-3( ) cryogenic system.

FOREWORD

This project was performed by Philips Audio Video Systems Corp., Government Systems Division, Mahwah, New Jersey 07430 under Contract No. DAAK02-72-C-0156.

Cognizant government agencies guiding and monitoring this program were the Night Vision Laboratory, Ft. Belvoir, Virginia, the United States Army Mobility Equipment, Research and Development Center, R&D Procurement Office, Ft. Belvoir, Virginia and the United States Army Missile Command, DRAGON Project Office, Redstone Arsenal, Huntsville, Alabama. Mr. Al Van Landuyt of the Night Vision Laboratory was the COTR.

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SECTION I

INTRODUCTION

1.1 GENERAL

An initial contract was awarded to Philips Audio Video Systems Corp., Government Systems Division (PAVSC/GSD) on 1 November 1971 to design, develop and fabricate twenty-one units of an equipment that was officially designated Night Vision Sight, Infrared AN/TAS-3.

Subsequent contracted modifications increased the quantity of units to a total of 29 and added ancillary equipment. A list of contractually added equipment is presented in Figure 1-1.

This program was performed by PAVSC/GSD under Contract DAAK02-72-C-0156. Cognizant Government agencies guiding and monitoring this program were the Night Vision Laboratory, Ft. Belvoir, Virginia, the United States Army Mobility Equipment, Research and Development Center, R&D Procurement Office, Ft. Belvoir, Virginia and the United States Army Missile Command, DRAGON Project Office, Redstone Arsenal, Huntsville, Alabama.

This report details the efforts involved from contract award through the completion of OT II testing in May of 1974, and is divided into nine sections, plus appendices. Section I presents the overall program aims and objectives, Section II the system description, Section III the major problems encountered during design, fabrication and the test phases, Section IV a summary of field tests and training, Section V a summary of environmental testing, Section VI a summary of the Quality Assurance effort, Section VII a summary of the Reliability and Maintainability effort, Section VIII conclusion and Section IX recommendations. Appendices provide an analyses of the NVS cryogenic system and a final report on Optoelectronics.

1.2 SYSTEM

The Night Vision Sight (NVS), Figures 1-2 and 1-3, satisfies the requirements for a lightweight, battery-powered, passive imaging system integrated with and deployed with the Guided Missile System Surface Attack, SM47 Medium Anti-Tank/Assault Weapon (DRAGON) System. The NVS enables the DRAGON gunner to search, detect, recognize, and aim at targets during the hours of darkness and to accurately track the target during the flight of the DRAGON missile.

Mod. #	Date	Item
P0005	29 June 1972	(8) TOW Interface Brackets
P0009	30 June 1972	(2) Additional NVS
P00011	7 Dec. 1972	(1) Boresight Verification Device
P00013	29 Dec. 1972	(2) Additional NVS and (1) Additional TOW Interface Bracket
P00014	27 Dec. 1972	(3) Plastic Eyepiece Assemblies
P00016	27 Dec. 1972	(2) Additional NVS
P00017	26 Feb. 1973	(2) Additional NVS
P00018	26 Feb. 1973	(1) Launch Blast Simulator and (2) NVS Mock-ups
P00019	26 Feb. 1973	(1) NVS Cut-away Model
P00023	11 Apr 1973	(2) Additional Boresight Verification Devices
P00032	17 Jan 1974	(2) Add Remote Video Capability to NVS
P00033	17 Jan 1974	(5) Launch Blast Simulators

Figure 1-1. Equipment Added by Contractual Modifications

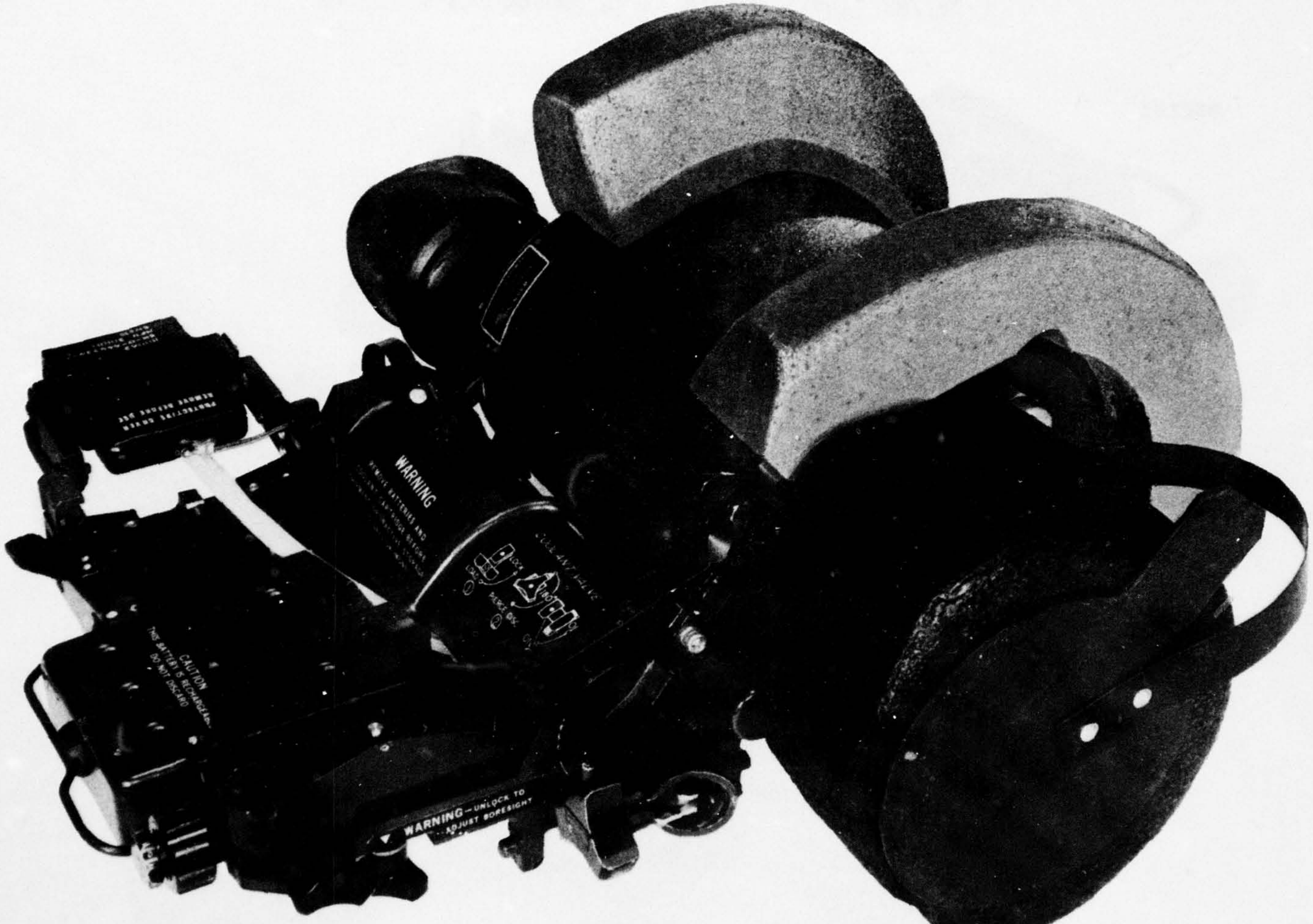

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Figure 1-2. DRAGON Night Vision Sight AN/TAS-3
Engineering Development Model

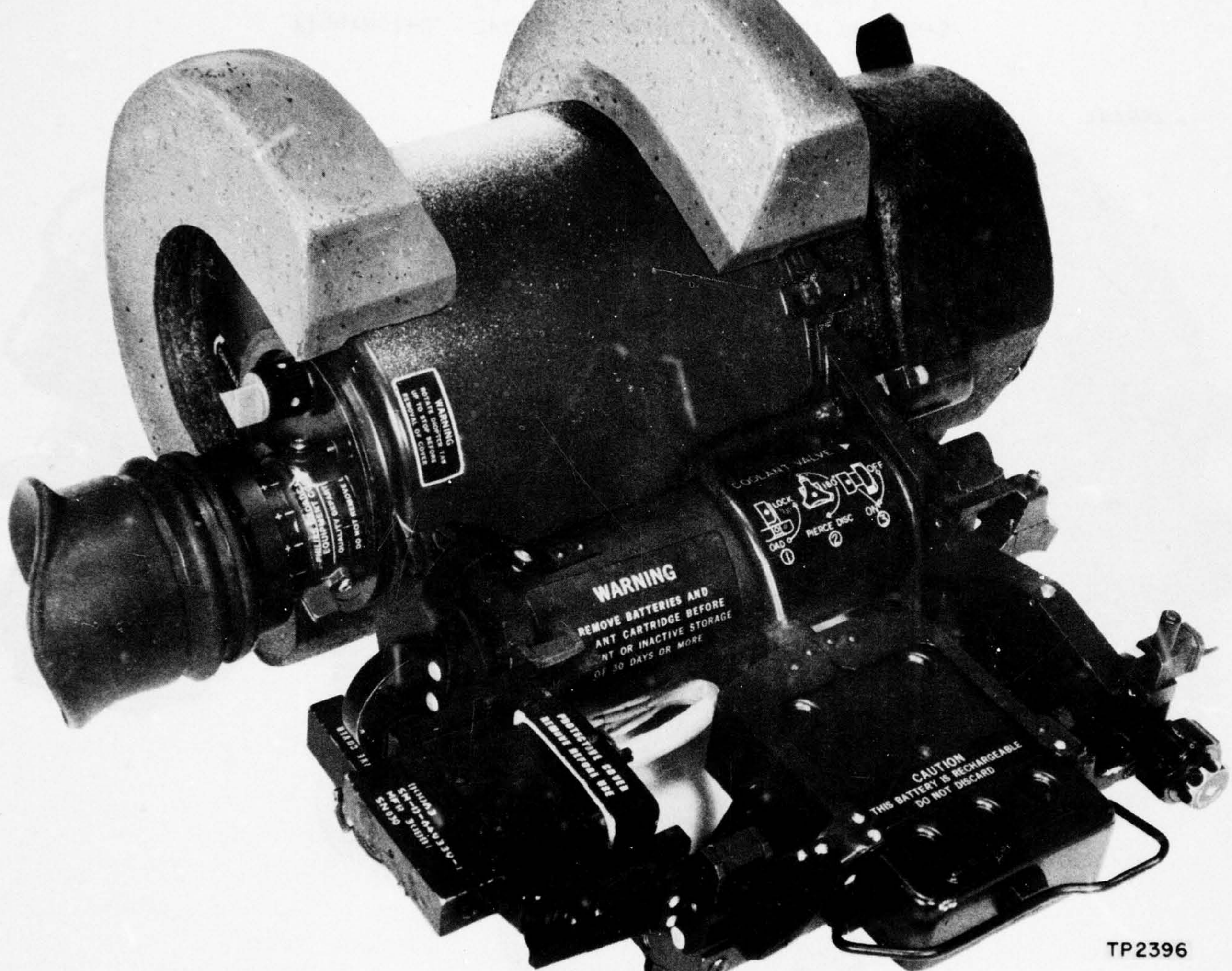

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Figure 1-3. DRAGON Night Vision Sight, AN/TAS-3
Engineering Development Model

SECTION II

SYSTEM DESCRIPTION

2.1 GENERAL

The DRAGON Night Vision Sight system is a passive infrared thermal imaging device. Infrared energy emanating from the scene being viewed passes through the objective lens to a scanning mirror. The scanning mirror, reciprocating at the system scan rate, reflects the energy bundle to an array of vertically oriented Lead Selenide detectors.

Operating efficiency of the detectors is dependent on cold temperature maintained in the detector housing called a Dewar. High pressure Freon gas is forced through a cryostat in the Dewar changing the gas to a liquid at -128°C. This action causes a heat transfer from the detectors to the liquid Freon causing the detectors to cool and the liquid to boil off. The resulting gas is then vented out of the system.

The Lead Selenide detectors, sensitive to infrared, convert the reflected energy bundle to an electrical signal. The detectors form part of a resistive network through which a current is forced. As the infrared energy impinges the detectors, the resistance balance of the network changes, causing a change in the network voltage.

The change in voltage is converted to a usable level by high gain amplifiers associated with each detector. These levels are time gated to the display circuits where the levels become video representing "hot or cold" objects being viewed.

The time gating is accomplished by a 300 kHz oscillator. The output of the oscillator is converted to clock pulses which are used to drive eight multiplexers. The multiplexers gate the parallel signal levels to serial levels by groups of eight, resulting in a train of 64 pulses of electrical energy being passed to the video amplifier.

The video amplifier converts the 64 pulses to video signals which are applied to the CRT, representing the scene being viewed in terms of hot and cold. The hotter objects appearing brighter, cold objects darker.

The display circuits of the system are not like conventional display circuits. The video is swept vertically from the bottom to the top of the CRT, from left to right then right to left; conventional sweeps are from left to right, top to bottom, with the horizontal sweep controlling the display.

The horizontal sweep in the NVS system is created by modulating the 300 kHz oscillator at the scan rate of the system. The modulator consists of the scanner mirror and capacitor plates located behind the mirror. During the reciprocating action of the mirror, the area of the capacitor plates change. The area change causes the capacitance to vary modulating the 300 kHz signal. The amplitude change is proportional to the scan mirror position. The output of the mechanical modulator is demodulated, resulting in a triangular waveform representing the mirror position. The signal is amplified and fed to the horizontal sweep circuits where the signal is transformed into the horizontal sweep of the CRT.

The vertical sweep is controlled by the multiplexer timing logic. The vertical sweep generator is allowed to run until the multiplexer logic reaches a count of 64. During this time, the video is being displayed "channel by channel" in a vertical row starting with channel 1 on the bottom to channel 64 at the top. When the multiplexer reaches this count, the vertical sweep generator is turned off for a count of eight. During this time, the vertical beam is repositioned to the bottom of the CRT. The "on-off" of the vertical sweep generator creates a sawtooth waveform which is the vertical sweep.

The NVS system also provides electronically produced cross hair which is used for boresighting. The horizontal cross hair is controlled by the multiplexer timing. When a count of 32 is reached--representing the center of the vertically stacked detectors--the multiplexer logic inhibits the "video" from passing to the video amplifier. This action causes the CRT to become slightly "more intensified" at the end of the 32nd count, the video is allowed to pass. During the next vertical sweep, the operation is repeated until an "intensified line" is presented on the CRT, which is the horizontal cross hair.

The vertical cross hair is produced mechanically and electrically. Mounted on the scanner mirror is a smaller optical pick-off mirror, reciprocating at the same speed of the scanner mirror. Associated with the optical pick-off mirror are a Light Emitting Diode (LED) and a Phototransistor, both of which are mounted in a tubular assembly. The assembly is arranged so that the mirror, when it is in the center of scan position, will reflect the light from the LED to the phototransistor. The electronics associated with the phototransistor generate a mirror position pulse to the multiplexer logic. This pulse inhibits the multiplexer from passing video to the video amplifier. This inhibit action causes the inhibit video level to intensify, creating a brighter display for 1 vertical sweep. This intensified sweep is the vertical cross hair. The vertical cross hair is displayed only during one-half of the scan cycle. This is done to prevent the cross hair from moving about the center point.

Power for the NVS system is provided by a nickel cadmium battery with an output of 6 volts. The 6 volts is applied to a low voltage power supply which produces +5, -6, -20 volts for the microminiature circuits. The low voltage supply provides an input to the high voltage power supply. The high voltage power supply produces 12.5 VAC for the CRT heater, -950V and +100V for the CRT. The system is over-current protected in that if over-current is sensed in the power supply, the power supply will shut down until the over current source is removed.

The NVS also provides a mount and a boresight mechanism for the Tracker which allows the tracker optical axis to be accurately positioned with respect to the optical axis of the NVS.

Exploded views showing the internal configuration and interface of major assemblies and subassemblies are shown in Figures 2-1 and 2-2. All electronic assemblies are mounted on the scanner assembly and are of the "plug-in module" type for ease of removal and replacement. The main frame assembly contains the receptacle for the plug-in battery and a receptacle tube and control valve for the coolant cartridge. The main frame also provides the mounting surfaces and electrical connectors for mounting and interconnecting the night vision sight to the round launch tube and the tracker to the night vision sight. The electrical connectors provide electrical interconnection of the launch tube and tracker and are not electrically connected to the night vision sight.

2.2 SYSTEM CHARACTERISTICS

Size	13-1/2" x 12-3/4" x 6"
Weight	10.15 lbs
Power Requirement	6 volts nominal at 1 ampere
Power available	1 ampere hour
Field of View	4° vertical x 6° horizontal
Frame Rate	15 frames/second
Resolution	1 mr (milliradian)
NET	0.15
Objective Lens	
Type	Silicon Doublet
Focal length	3.6
F/#	1.2
Detectors	
Type	PbSe-Vertical Array
No. of Elements	64

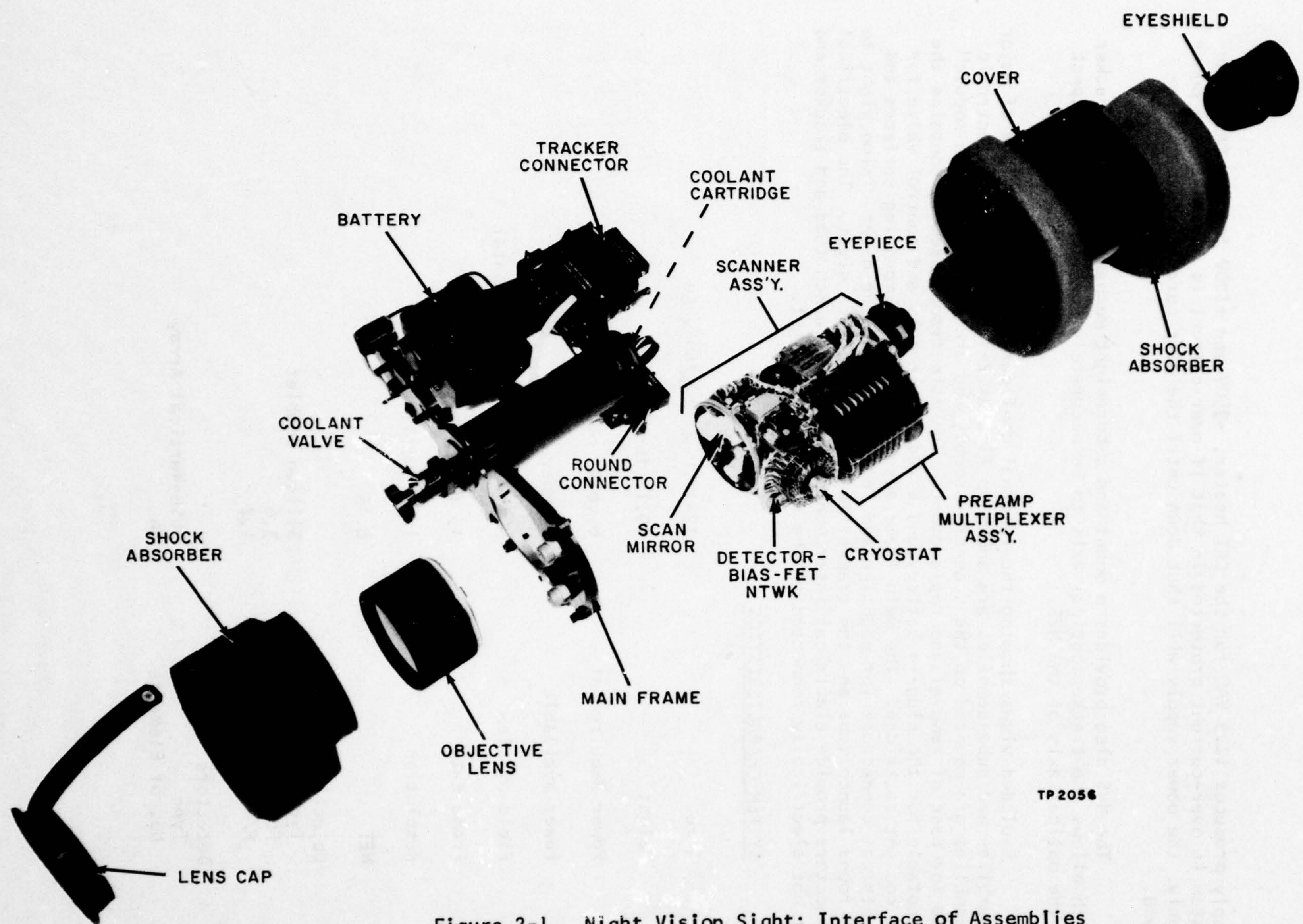
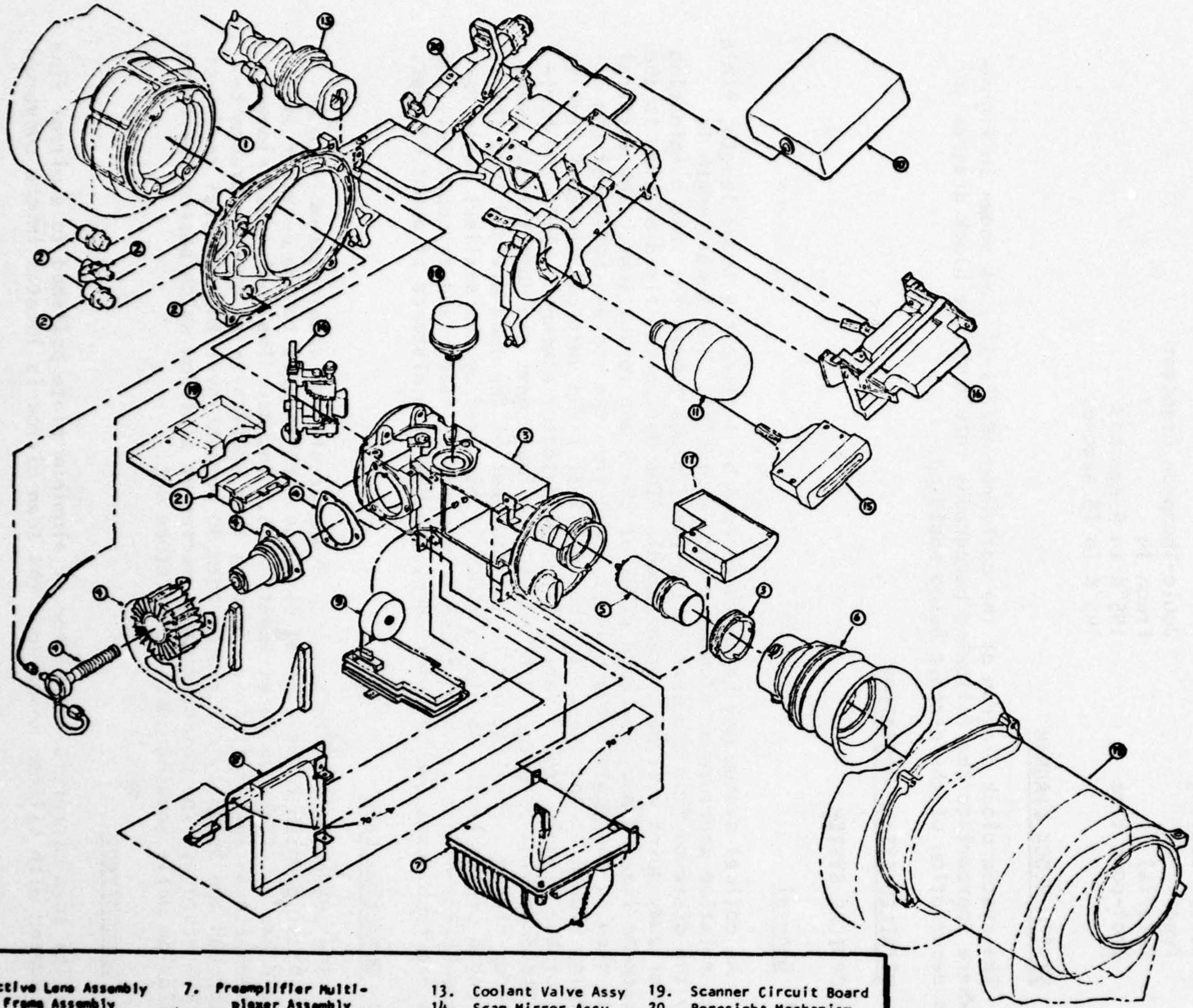


Figure 2-1. Night Vision Sight; Interface of Assemblies



Legend

1. Objective Lens Assembly	7. Preamplifier Multi-plexer Assembly	13. Coolant Valve Assy	19. Scanner Circuit Board
2. Main Frame Assembly	8. Display Electronics Assy	14. Scan Mirror Assy	20. Boresight Mechanism
3. Scanner Assembly	9. Power Supply Assembly	15. Round Connector	21. Angular Position Detector Assy.
4. Detector Cooler and Bias Assembly	10. Battery and Housing Assy	16. Tracker Connector	
5. Cathode Ray Tube	11. Cartridge and Valve Assy	17. Hi Voltage Cover	
6. Eyepiece Assembly	12. Cover Assy	18. Scan Motor	

Figure 2-2. Night Vision Sight; Interface of Assemblies

System Characteristics (Cont)

Display	1 inch CRT-Eyepiece
Detector Cooling	
Type	Joule-Thompson Cryostat
Material	Freon 14
Cool-down time	195°K in 5 seconds 145°K in 15 seconds

2.3 SYSTEM BLOCK DIAGRAM

The system block diagram of the delivered AN/TAS-3( ) is shown in Figure 2-3. Where appropriate the following paragraphs reference the block diagram to provide description of the circuit being analyzed.

2.4 DETAILED SYSTEM OPERATION

2.4.1 OPTICAL SYSTEM

2.4.1.1 General

An optical system may be characterized by listing the focal length, field of view, relative aperture or F/number, and resolution. The focal length is roughly the distance from the lens to the focal plane (where the rays originating from a far away point will be concentrated). The horizontal field of view is the angle between lines drawn from both sides of the scene to the lens. The vertical field of view is the angle between lines drawn from the top and bottom of the scene being viewed to the lens. In the AN/TAS-3( ) the vertical field of view is made up of the signals from a vertical row of detector elements, while the horizontal field of view is obtained by moving the image past the detectors by means of the scan mirror. The F/number is the diameter of the lens divided into the focal length of the lens. Resolving power is measured by the smallest angle between two object points at which these points can be recognized as separate. Two objects one inch apart can be resolved by the NVS at a distance of about 83 feet.

2.4.1.2 Objective Lens

The objective lens in a 3 inch diameter silicon double assembly in an aluminum housing which is at a fixed distance with respect to the detector assembly and has an effective focal length of 3.6 inches. The individual elements are coated with an anti-reflective coating that results in an average transmittance through the assembly of greater than 90 percent over the spectral region of 3.4 to 5.1 microns. The objective lens serves as a window which passes the infrared radiation while keeping dust and moisture out.

2.4.1.3 Scan Mirror

The scan mirror is fabricated of aluminum plate polished to a mirror finish and coated with silicon monoxide. The scan mirror is located in the converg-

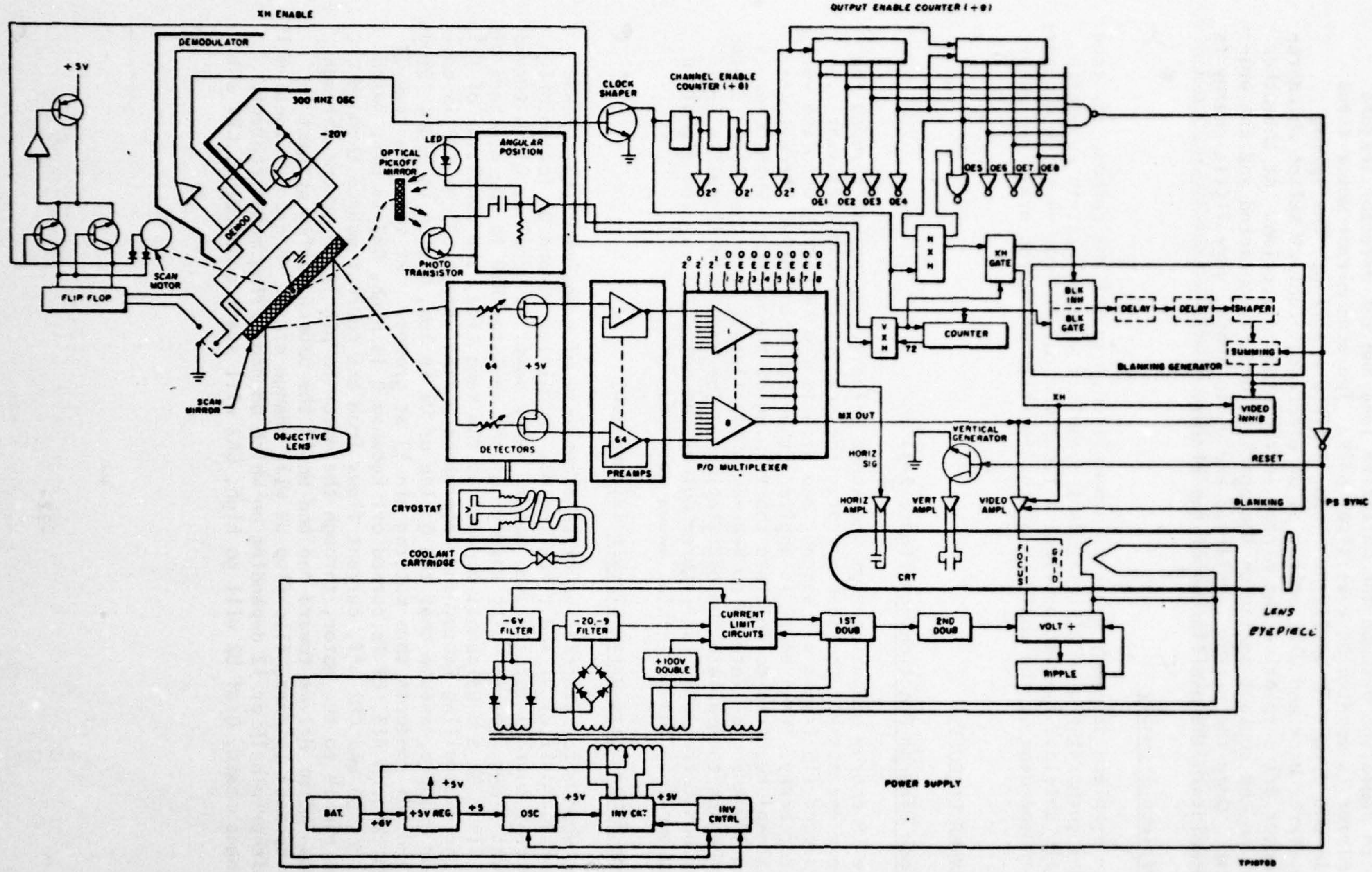


Figure 2-3 System Block Diagram
-11-

ing beam of IR radiation between the objective lens and the detector (Figure 2-3). The mirror is mounted on a vertical axis. The scan mirror motor turns the mirror in one direction until the mirror strikes a spring. The spring bounces the mirror back and also serves as an electrical contact switch which reverses the motor drive to drive the mirror in the other direction. At the other end of rotation the contact spring on the opposite end is contacted and the process repeated. Once the mirror is started and up to speed, very little energy is required to maintain the oscillation of the mirror.

2.4.1.4 Eyepiece Assembly

The eyepiece assembly presents a magnified image of the cathode ray tube display and incorporates a recoil resistant eyeshield with a built-in automatic light security shield. It also provides a focus control of from -4 to +4 diopters and it is independent of the position of the facially contoured eyeshield position.

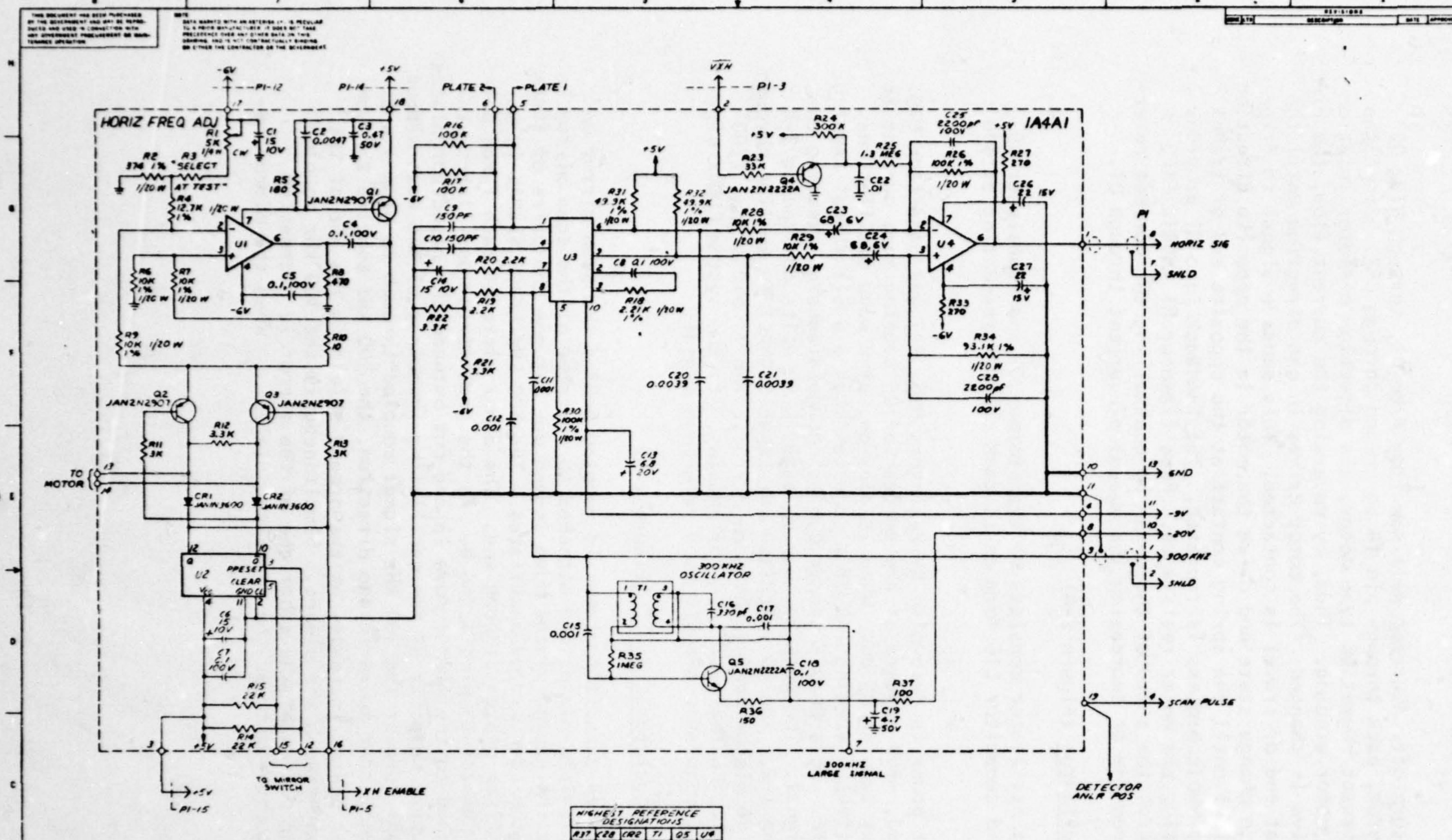
2.4.2 SCANNER CIRCUITS

2.4.2.1 Block Diagram Functioning (Figure 2-3)

The IR energy emanating from the scene being viewed passes through the objective lens and strikes the scan mirror. The scan mirror oscillates at 7.5 cycles per second (15 frames per second) and directs the IR energy onto the vertical detector array. When power is applied, the scan motor drive circuit develops the signal required to initiate the turning of the mirror. When power is applied, the 300 kHz oscillator also begins to oscillate. When the mirror starts turning, it begins to modulate the oscillations. The modulated signal is amplified and the basic frequency is filtered out by the demodulator. The signal is then used to generate the horizontal sweep voltage.

2.4.2.2 Scan Motor Start/Drive Circuit (Figure 2-4)

The scan motor start/drive circuit consists of transistors Q1, Q2 and Q3, operational amplifier U1 and flip-flop U2. Amplifier U1 and Q1 form a drive circuit (current source) for the scan motor. When power is applied, Q1 is turned on and current flows from +5 volts through Q1 and resistor R10 to the emitters of Q2 and Q3. Since Q2 and Q3 cannot conduct at the same time, the condition of flip-flop U2 is the controlling factor and determines whether diode CR1 or CR2 is conducting. For example, assume that the Q side of U2 is low, $\overline{Q}$ side is high. Diode CR2 is off and CR1 conducts thus putting pin 13 at ground. At the same time Q3 is turned on through R13, Q2 is turned off because $\overline{Q}$ is high, CR2 is off. With Q2 off, CR1 on, Q3 and CR2 off, current flows from the current source through Q1, R10, Q3, out pin 14 to the motor, through the motor to pin 13 to ground through CR1. The scan motor drives toward one end until the bounce spring contact is made. When contact is made, flip-flop U2 will change state. A ground signal will appear at either pin 15 or 12 depending on which bounce spring makes contact. When U2 changes state, Q of U2 will go high, CR2 will start conducting, CR1 will



HIGHEST REFERENCE DESIGNATIONS					
R37	C28	CR2	T1	Q5	U4

NOTES:

1. UNLESS OTHERWISE SPECIFIED
   RESISTANCE VALUES ARE IN OHMS, ±5%, 1/8W.
   CAPACITANCE VALUES ARE IN MICROFARADS, ±10%, 20GV.
2. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN, FOR COMPLETE DESIGNATION PREFIX WITH 1A4A1.
   EXAMPLE: R2 - 1A4A1R2
3. FOR REFERENCE:
   U1 AND U4 - USB7741312 (FAIRCHILD)
   U2 - SN54S72W-00 (TEXAS INSTRUMENT)
   U3 - MC1536G (MOTOROLA)

FIGURE 2-4

SCHEMATIC DIAGRAM
CIRCUIT CARD ASSEMBLY
SCANNER

E 80063 SM-E-649405

go off and Q3 will turn off. Current will now flow from Q1, through R10, Q2 and pin 13 to the motor, back through pin 14 to ground through CR2. Since the scan motor is a permanent magnet DC type motor, the direction of motor rotation is dependent on the motor winding. Thus, by reversing the current flow, the direction of motor drive is changed. The motor drives in one direction until the bounce spring at that end of travel is contacted. This sends a signal to flip-flop U2 causing U2 to change state and drive the motor in the opposite direction (reverses current flow) until the spring contact at the opposite end of travel is contacted and the whole process is repeated. The feedback into U1 provides resistance compensating the motor resistance. Potentiometer R1 (HORIZ FREQ ADJ) is used to control the speed of the motor by controlling the current reference to U1 thus increasing or decreasing the amount of current through Q1.

2.4.2.3 300 kHz Oscillator (Figure 2-4)

The 300 kHz oscillator consists of transformer T1 and transistor Q5. Winding 3-4 of T1 and capacitor C16 form an LC tank circuit resonating at 300 kHz.

The -20 volt power is decoupled by resistors R36, R37 and capacitor C19. When power is applied, -20V appears at the emitter of Q5 causing some current to flow through R35 thus turning Q5 on. When Q5 goes on, sine wave oscillations build up across T1 (3-4). Winding 1-2 of T1 couples back a small signal causing Q5 to turn ON and OFF. This ON/OFF causes C16 to charge/discharge creating the 300 kHz sine wave signal. The peak to peak voltage is 40 volts on winding 3-4 and 1 volt on winding 1-2. The 40 volt (300 kHz LARGE SIGNAL) is applied through C17 to the two outside plates behind the scan mirror. The 1 volt signal (300 kHz) is fed via C15 to the logic circuit for shaping into the system CLOCK signal and also to the demodulator circuit as a reference signal.

2.4.2.4 Modulator/Demodulator Circuit (Figure 2-4)

A pair of fixed capacitor plates is mounted behind the scan mirror on each side and ground shield plates are attached to the rear of the scan mirror in such a position that the ground plates move in and out between the pairs of fixed capacitor plates as the scan mirror oscillates. The 300 kHz LARGE SIGNAL is applied to one of the fixed plates at each end. The other plate of each fixed pair is connected to demodulator U3 pins 1 and 4. As the scan mirror oscillates, the ground shields attached to the mirror move in and out between the capacitor plates changing their effective capacity at the oscillating frequency of the scan mirror thus changing the amplitude of the 300 kHz signal coupled through to pins 1 and 4 of U3. As the scan mirror moves in one direction, the 300 kHz coupled through one pair of capacitor plates increases as the ground shield on the end of the mirror moves out from between the plates. Simultaneously the 300 kHz coupled through the capacitor plates at the other end of the mirror is decreasing as the ground shield moves between the capacitor plates. When the mirror reverses direction, the capacitive coupling also reverses and the capacitor formerly increasing now starts decreasing and the capacitor formerly decreasing now starts increasing. Thus the 300 kHz signals coupled through the capacitor plates is modulated at the mirror oscillating frequency (7.5 cycles/second) and are 180° out of phase at 7.5 Hz.

A 300 kHz reference signal from the oscillator is applied to U3 pin 8. This reference signal is used by U3 to demodulate the input signals on pins 1 and 4. The demodulated low frequency differential signals come out of U3 on pins 6 and 9 and are applied to pins 2 and 3 of operational amplifier U4. U4 converts the differential inputs received on pins 2 and 3 into a linear output at pin 6 by subtracting the signal applied to pin 2 from the signal applied to pin 3. The output at pin 6 is negative when the input on pin 2 is greater than pin 3 and positive when the input on pin 2 is less than the reference signal on pin 3. The resultant output at pin 6 (HORIZ SIG) is a triangular waveform entered around ground and in phase with the scan mirror oscillation. This signal is applied to the horizontal deflection amplifier to generate the horizontal sweep voltage for the CRT.

Transistor Q4 and associated circuitry momentarily stops the horizontal sweep during vertical cross hair presentation on the CRT. The $\overline{VHX}$ signal from the logic circuit is applied to the base of Q4 turning Q4 OFF when the vertical cross hair signal is present in the video output. When Q4 is OFF an equal but opposite ramp voltage is applied to pin 2 to stop the horizontal sweep momentarily during vertical cross hair presentation.

2.4.3 CRYOGENIC SYSTEM

2.4.3.1 General

The operating temperature of the lead selenide (PbSe) detector elements is critical for optimum sensitivity to the incoming IR energy being scanned onto the detector elements by the scan mirror (Figure 2-3). The cryogenic system provides the means of maintaining the detector elements at 145°K. The cryogenic system consists of the coolant cartridge and valve, coolant lines, filter and the cryostat cooler.

2.4.3.2 Operation (Figure 2-5)

Referring to Figure 2-5, Freon 14 gas at ambient and 3000 psi leaves the coolant cartridge (1) through the coolant shut-off valve (2) and passes through the coolant line (3) and filter/dryer (3a) to the cryostat (4). The gas circulates down inside the regenerative heat exchanger coil (8) and exits through the needle valve and orifice (5). As the gas leaves the orifice it expands, cools and enters the detector array and cold plate area (10) of the detector-dewar assembly (9). The expended cold gas then flows up and around the outside of the regenerator coils between the regenerator coils and the inner dewar wall and out through the vent (12), to the 0.5 pound coolant pressure relief valve on the front of the NVS which vents the gas into the atmosphere. As the gas continues

KEY

1. COOLANT CARTRIDGE
2. COOLANT SHUTOFF VALVE
3. COOLANT LINE
3a. FILTER/DRYER
4. CRYOSTAT ASSEMBLY
5. * NEEDLE VALVE AND ORIFICE
6. * BELLOWS TEMPERATURE SENSOR
7. MANDREL TUBE
8. REGENERATIVE HEAT EXCHANGER
9. DETECTOR-DEWAR ASSEMBLY
10. DETECTOR ARRAY & COLD PLATE
11. WINDOW
12. VENT
13. COOLANT PRESSURE RELIEF VALVE

* PART OF CRYOSTAT ASS'Y.

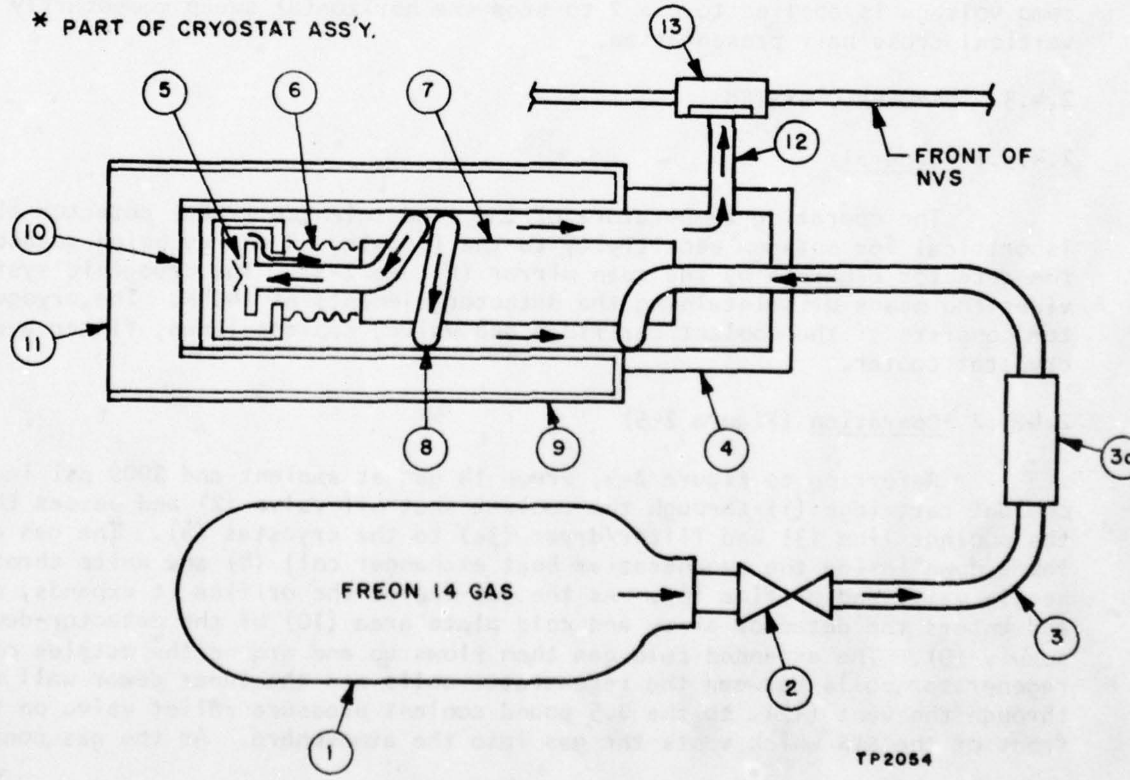


Figure 2-5. Cryogenic System

to flow the regenerator coils (8) get colder until the expanded gas finally liquifies as it emerges from the orifice (5). The liquid Freon impinges against the cold plate (10), absorbs heat from the detector array thereby converting the liquid through boiling to vapor. The vapor then flows up and around the coils (8) and the regeneration process continues. When the detector array and cold plate (10) are cooled to the liquid Freon temperature (145°K) the bellows temperature sensor (6) contracts pulling the needle valve into the orifice thereby restricting the flow of additional gas. As the liquid evaporates, due to heat absorption from the cold plate, the bellows expands allowing more gas to flow and the regeneration process is again established and regulation is achieved. The gas demand is highest during initial cool down. Once the detector is down to optimum temperature a very small amount of gas is required to maintain the 145°K temperature.

2.4.3.3 Coolant Cartridge

The cartridge is a 7 cubic inch cylinder capable of storing Freon 14 gas at 3200 psig. This rechargeable cartridge will supply enough coolant gas to operate the Night Vision Sight continuously for over two hours. The cartridge may be safely removed from the NVS after the seal has been ruptured while still containing coolant under pressure.

2.4.4 DETECTORS AND PREAMPLIFIERS

2.4.4.1 Block Diagram Functioning (Figure 2-3)

The detector consists of a linear vertical array of 64 lead selenide (PbSe) photoconductive elements mounted on the cold plate of the detector dewar. The resistance of the detector elements varies inversely with the incident IR radiation being scanned onto the elements by the scan mirror. Each of the 64 detector outputs is applied to a preamplifier stage through an FET which acts as a buffer stage between the detector element and preamplifier. The preamplifiers amplify the detected signal to a usable level. The 64 parallel preamplifier outputs are applied to the multiplexer for multiplexing into a serial video output.

2.4.4.2 Detector Bias-FET Networks (Figure 2-6)

The 64 detector bias-FET networks consists of 21 circuit cards each containing three load resistors and FET's (3 channels) and one circuit card containing one load resistor and FET and a bias resistor common to all channels. All load and bias resistors are selected at test to equalize all outputs to the same level for the same level input based on data received from the detector manufacturer. The 22 circuit cards are mounted around the detector-cryostat to maintain short lead lengths and minimize pickup and cross talk (Figure 2-1). Since all 64 channels are identical, one channel will be discussed (Channel 1 on Figure 2-6).

Electrically the detector element appears as a variable resistor. As IR energy strikes the detector element, its resistance decreases and the current in-

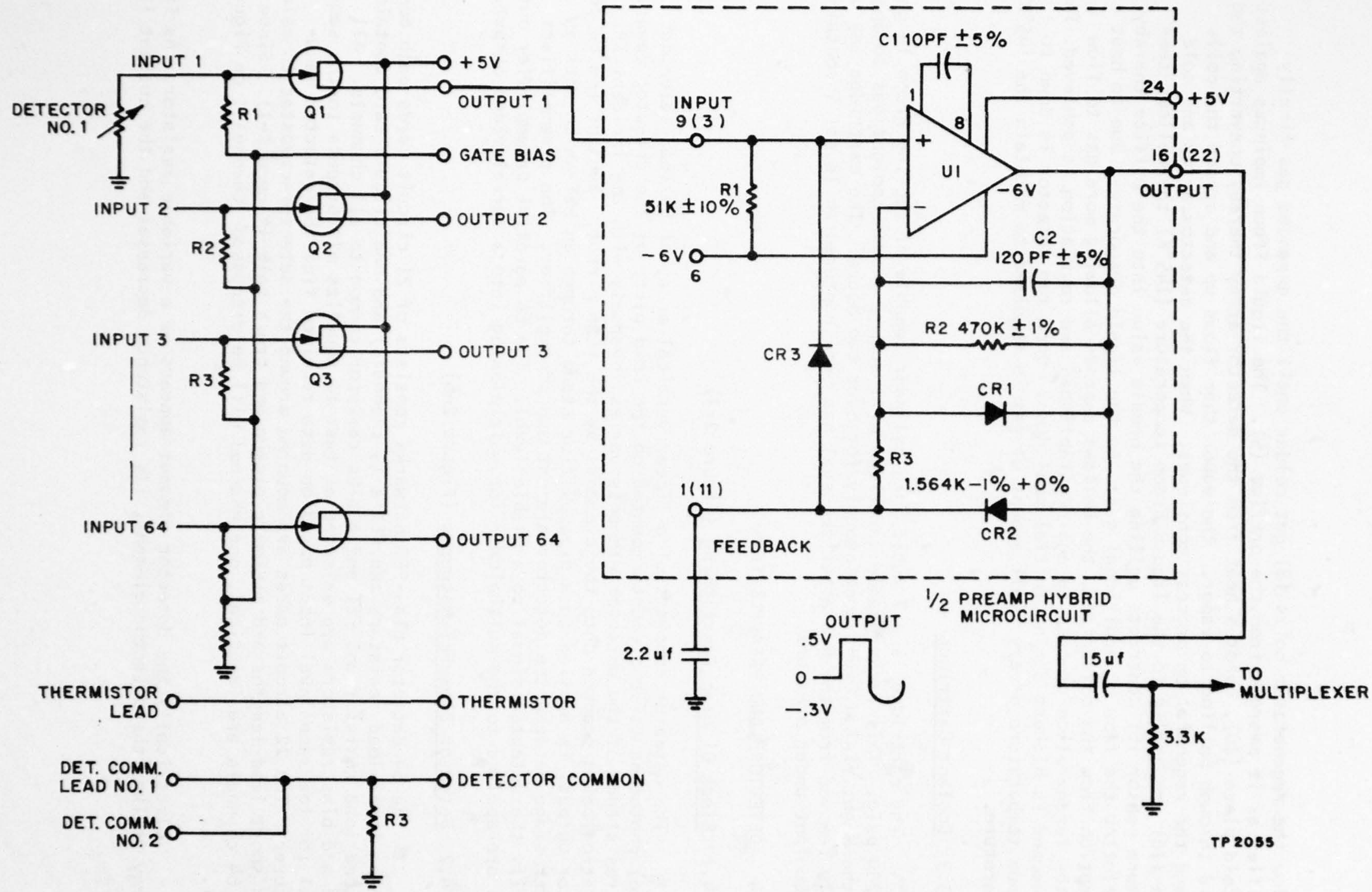


Figure 2-6. Detector/Preamplifier Simplified Schematic Diagram

creases. The hotter the target the greater the current. Thus the detector is a current signal. The voltage developed across the detector load resistor is fed to the FET. The FET input impedance is extremely high (megohms). All current through load resistor R1 goes through the FET which acts as a buffer stage preventing loading of the detector by the preamplifier circuit that follows. The source of the FET is connected through R1 in the preamplifier microcircuits to -6V (pin 6). Although R1 is in the preamplifier microcircuit it is actually part of the FET circuit.

2.4.4.3 Preamplifier (Figure 2-6)

The 64 preamplifier channels are provided by 32 hybrid dual amplifier microcircuit flatpacks. Each flatpack contains two preamplifier circuits. Since all preamplifier channels are identical, only one will be discussed. The FET (Q1) acts as a source follower and applies the detector output signal to the non-inverting input of operational amplifier U1. The gain of U1 is approximately 300 for normal signals and the amplifier bandpass is 50 Hz to 2 kHz. For small signals such as are present for normal targets, U1 acts as a linear amplifier. The input impedance is resistor R1 and the feedback circuit consists of resistors R1 and R2 and capacitors C2 and the 2.2 mfd external capacitor. For large signals, the amplifier becomes almost a logarithmic amplifier.

The feedback circuit has limiting diodes CR1, CR2 and CR3 which clip or limit the output to prevent saturation in the amplifier and coupling capacitor. This allows the amplifier to recover quickly from large amplitude signals.

As the input becomes very negative, CR3 conducts and limits the signal. For DC, the current through CR3 builds up a charge on the 2.2 mfd capacitor connected to pin 11 of the flatpack. When CR3 conducts, it limits the input by providing an AC ground for the feedback circuit. When the charge on the 2.2 mfd capacitor equals the voltage on the input, CR3 no longer conducts. Because of the gain, the output will reach conduction long before CR3 conducts. Therefore CR3 sets the gross input limit.

The limiting on the output is done by hot carrier diodes CR1 and CR2. When the output approaches approximately +0.5 volt, CR2 starts conducting slightly but since it is in parallel with the feedback (R2, C2), it very quickly limits the output signal. The signal can not get more positive than +0.5 volt and as it gets close to the +0.5 volt, the gain of the amplifier falls off very rapidly because CR2 starts conducting. On the negative side, as the output gets down -0.3 to -0.4 volt, CR1 starts conducting slightly and starts to affect the feedback in the same manner. Thus, while the amplifier is linear for normal signals it becomes almost a logarithmic amplifier when the output is above 1.2 volts. As the input gets larger, the output will always get a little larger as the gain goes to unity. For very large input signals the gain goes to unity because when CR1 is conducting the feedback impedance is only a few ohms compared to R3. For example, for an input of 1 millivolt, the output would be approximately 300 millivolts. However, for an input of 2 millivolts the output might only be 400 to 450 millivolts, 300 millivolts for the first millivolt of input but only an additional 100 millivolts for the second millivolt of input. The limiting feedback also provides a quick recover time by offering a discharge path through CR2 for the 2.2 mfd coupling capacitors, so that when a hot target disappears (such as the launch blast) the amplifier can recover quickly to present normal targets. Capacitor C1 provides compensation so that U1 will not go into oscillation. The output of the preamplifiers is applied to the multiplexer.

2.4.5 MULTIPLEXER CIRCUITS

2.4.5.1 <u>Block Diagram Functioning</u> (Figure 2-3)

The multiplexer circuits consist of a clock shaper, channel enable ($\div 8$) counter, an output enable ($\div 9$) counter, multiplexer gates and multiplex switches. The preamplfier output signals are time gated through the multiplexer switches (1 through 8). Signals enter the multiplexers in parallel. The outputs are still parallel but in groups of 8. Therefore the signals fed to the video amplifiers are serial trains of voltage which will be converted to video. The clock shaper receives the 300 kHz signal (sine wave) from the scanner circuit and shapes it into a clock pulse which is used to drive the channel enable and output enable counters to provide the enabling output signals to the multiplexers.

2.4.5.2 <u>Clock Shaper</u> (Figures 2-7 and 2-8)

The 300 kHz sine wave signal from the 300 kHz oscillator (paragraph 2.4.2.3) is applied to the base of the clock shaper transistor Q1. The 300 kHz sine wave overdrives Q1 into saturation thus clipping and shaping the sine wave to provide a 3.3 usec asymmetric square wave pulse as shown on the timing diagram (Figure 2-8). The square wave pulse is used as the basic timing signal (clock) for all logic circuit functions (multiplexer circuits discussed in this paragraph and the blanking and cross hair circuits are discussed in paragraph 2.4.6).

2.4.5.3 <u>General Operation</u>

The multiplexer driver U1 is a logic hybrid on the logic board of the preamplifier multiplexer assembly. The logic hybrid contains a divide by 8 ($\div 8$) ripple counter, two 4-channel shift registers interconnected to form a divide by 9 ($\div 9$) counter and associated gates and inverters. The $\div 8$ counter acts as the channel enable counter and provides the channel enable signals (2^0, 2^1 and 2^2). The $\div 9$ counter acts as the output enable counter to provide the output enable signals (OE1 through OE8). The output enable signals prime the 8 eight channel multiplexers on the preamplifier cards in sequence. As each one is primed, the channel enable counter counts to 8 to enable each of the eight channel switches in the multiplexer in sequence to pass the preamplifier output signals onto the multiplex out (MX OUT) line (Figure 2-9).

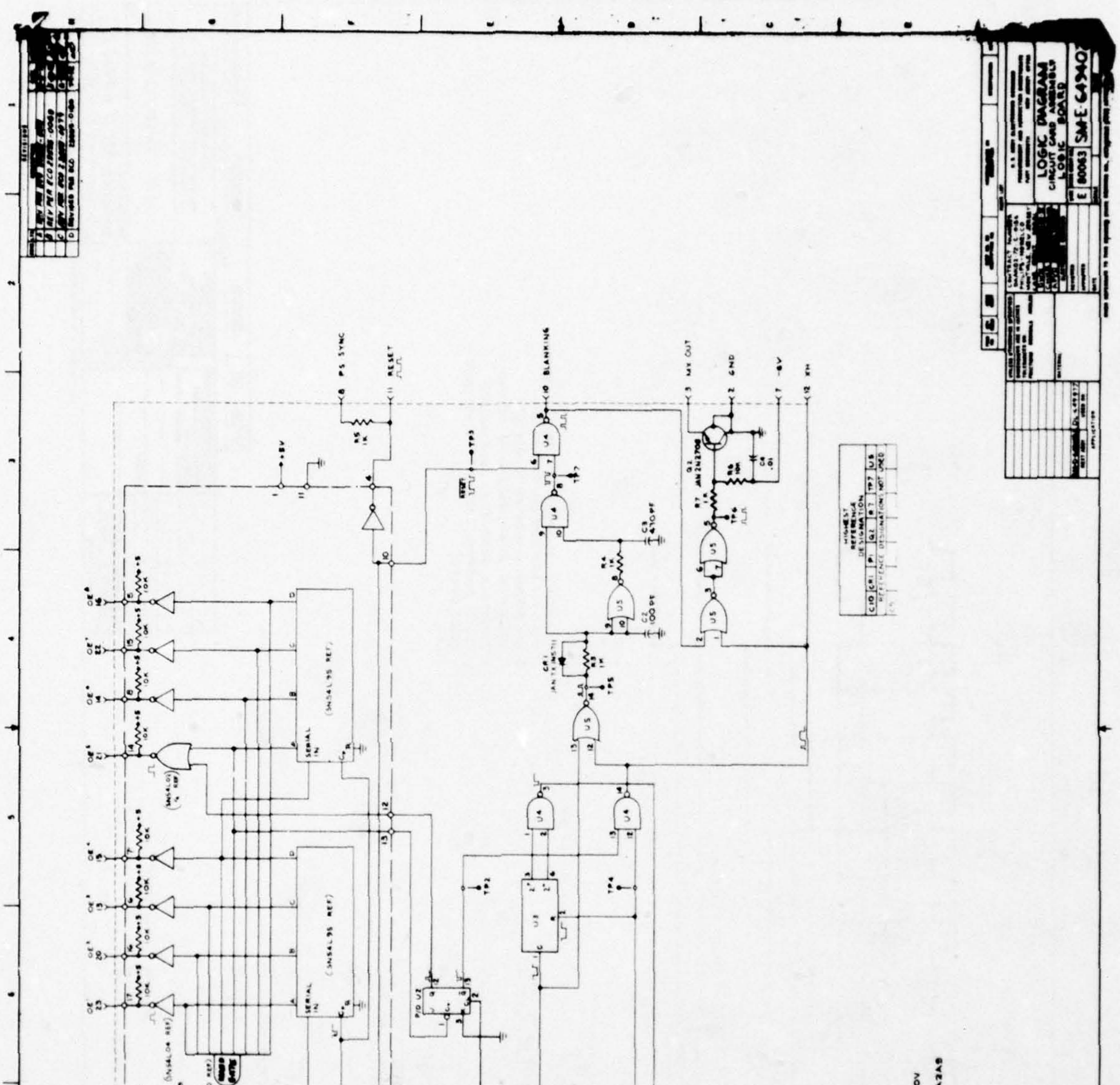


Figure 2-7

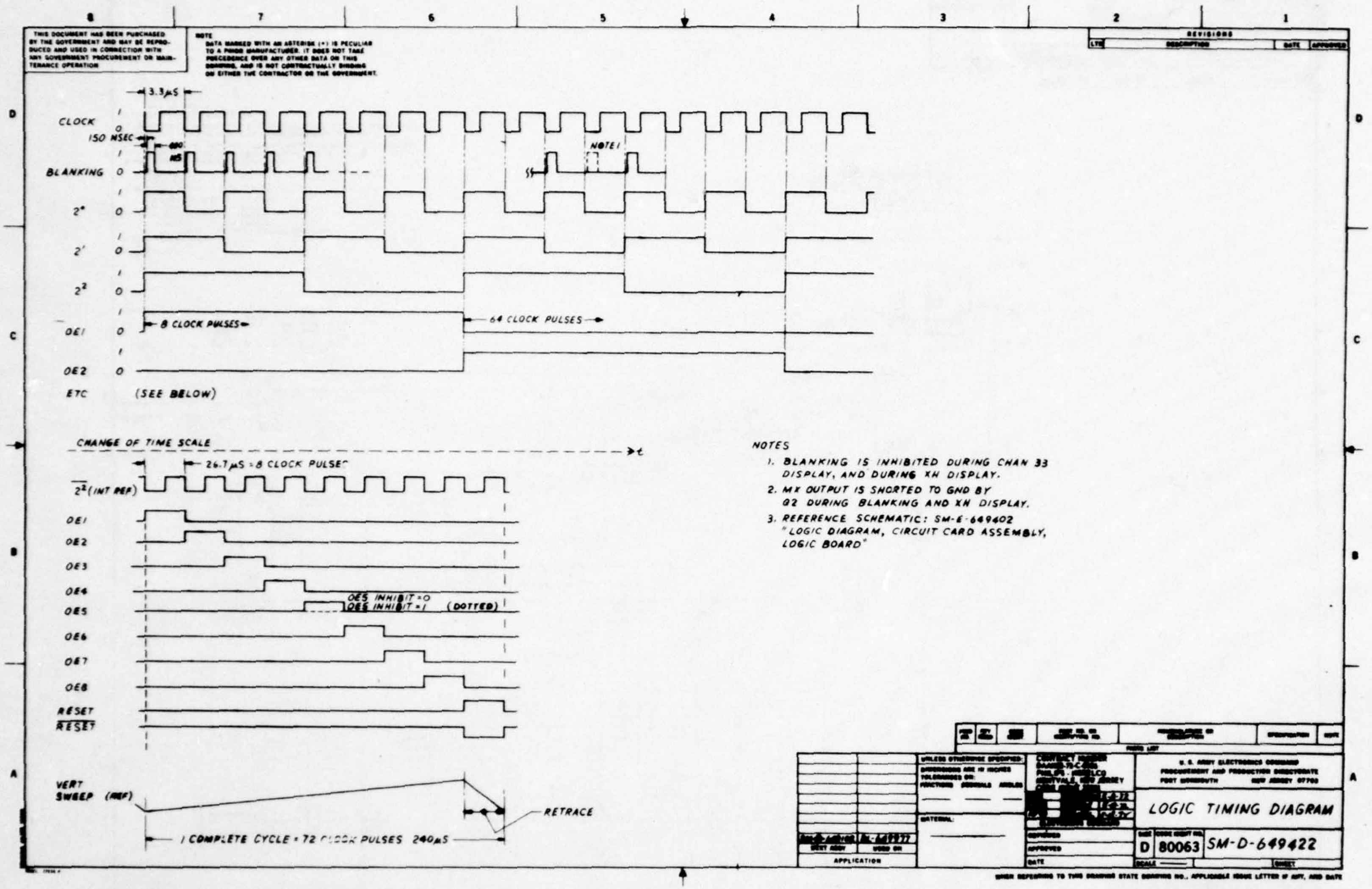

CLOCK
150 NSEC
BLANKING
NOTE 1
8 CLOCK PULSES
64 CLOCK PULSES
OE1
OE2
ETC
(SEE BELOW)
CHANGE OF TIME SCALE
26.7μS = 8 CLOCK PULSES
2² (INT REF)
OE3
OE4
OE5
OE6
OE7
OE8
OE5 INHIBIT = 0
OE5 INHIBIT = 1 (DOTTED)
RESET
VERT SWEEP (REF)
RETRACE
1 COMPLETE CYCLE = 72 CLOCK PULSES 240μS
NOTES
1. BLANKING IS INHIBITED DURING CHAN 33 DISPLAY, AND DURING XH DISPLAY.
2. MX OUTPUT IS SHORTED TO GND BY Q2 DURING BLANKING AND XH DISPLAY.
3. REFERENCE SCHEMATIC: SM-E-649402 "LOGIC DIAGRAM, CIRCUIT CARD ASSEMBLY, LOGIC BOARD"
LOGIC TIMING DIAGRAM
D 80063 SM-D-649422

Figure 2-8

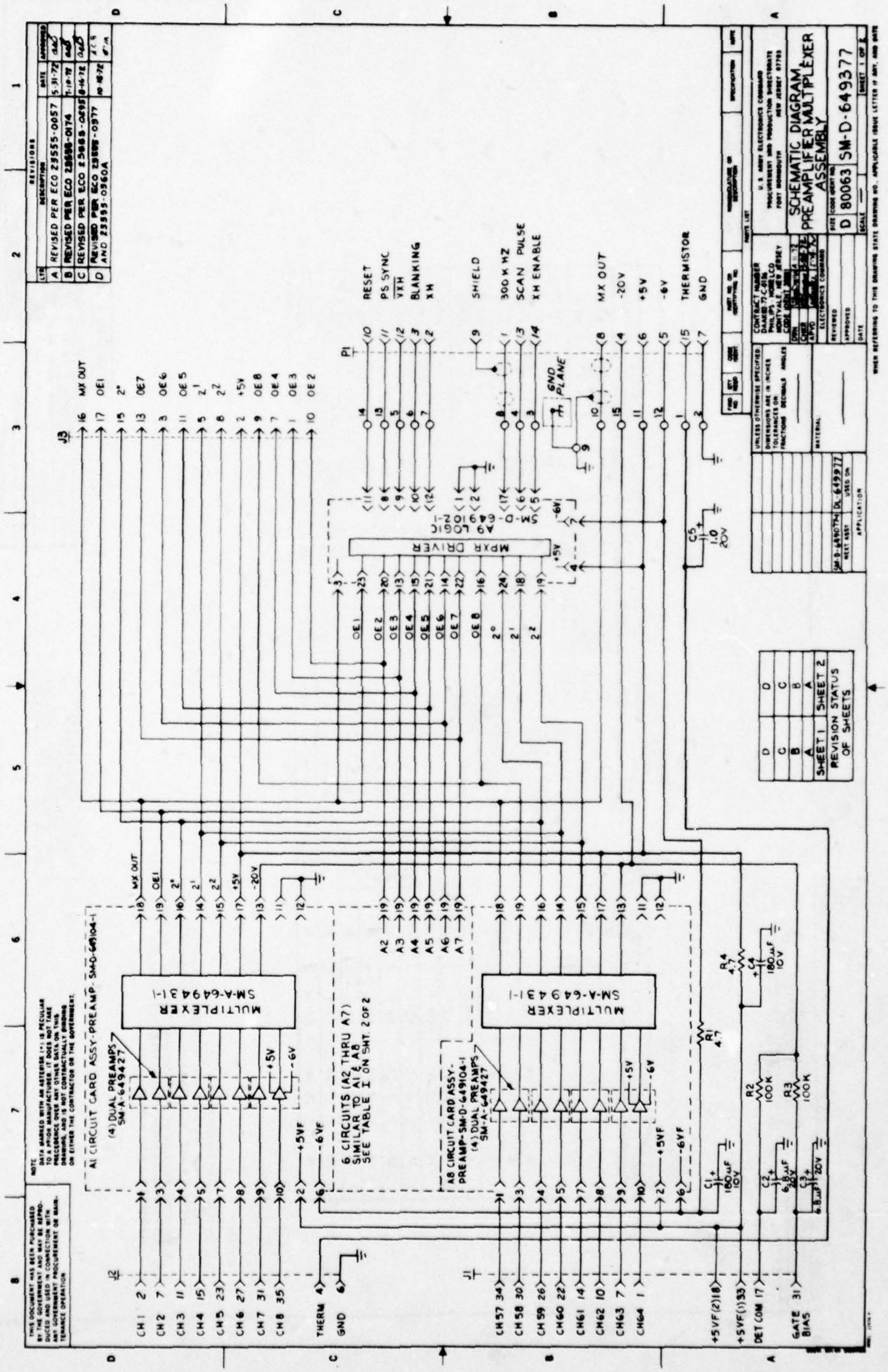

SCHEMATIC DIAGRAM PREAMPLIFIER MULTIPLEXER ASSEMBLY
D 80063 SM-D-649377
MULTIPLEXER SM-A-649431-1
MPXR DRIVER
A9 LOGIC SM-D-649102-1
A1 CIRCUIT CARD ASSY-PREAMP-SM-D-649104-1
A8 CIRCUIT CARD ASSY-PREAMP-SM-D-649104-1
6 CIRCUITS (A2 THRU A7) SIMILAR TO A1 & A8 SEE TABLE I ON SHT. 2 OF 2
REVISION STATUS OF SHEETS
REVISED PER ECO 23555-0057
RESET
PS SYNC
BLANKING
SHIELD
300 KHZ
SCAN PULSE
XH ENABLE
MX OUT
THERMISTOR
GND

Figure 2-9

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REVISIONS

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A	REVISED PER ECO 23655-0057	5-31-72	[illegible]
B	REVISED PER ECO [illegible]-0174	7-10-72	[illegible]
C	REVISED PER ECO 23668-0298	8-17-72	[illegible]
D	REVISED PER ECO 23555-0377 AND 23555-0360A	10-16-72	[illegible]

TABLE I

CHANNEL NO	CONN & PIN NO	INPUT	CHANNEL NO	CONN & PIN NO	INPUT	CHANNEL NO	CONN & PIN NO	INPUT	CHANNEL NO	CONN & PIN NO	INPUT
1	J2-2	A1-1	17	J2-1	A3-1	33	J1-32	A5-1	49	J1-36	A7-1
2	J2-7	A1-3	18	J2-8	A3-3	34	J1-28	A5-3	50	J1-29	A7-3
3	J2-11	A1-4	19	J2-12	A3-4	35	J1-24	A5-4	51	J1-25	A7-4
4	J2-15	A1-5	20	J2-16	A3-5	36	J1-20	A5-5	52	J1-21	A7-5
5	J2-23	A1-7	21	J2-22	A3-7	37	J1-16	A5-7	53	J1-13	A7-7
6	J2-27	A1-8	22	J2-26	A3-8	38	J1-12	A5-8	54	J1-9	A7-8
7	J2-31	A1-9	23	J2-30	A3-9	39	J1-8	A5-9	55	J1-5	A7-9
8	J2-35	A1-10	24	J2-34	A3-10	40	J1-6	A5-10	56	J1-2	A7-10
9	J2-3	A2-1	25	J2-5	A4-1	41	J1-35	A6-1	57	J1-34	A8-1
10	J2-9	A2-3	26	J2-10	A4-3	42	J1-27	A6-3	58	J1-30	A8-3
11	J2-13	A2-4	27	J2-14	A4-4	43	J1-23	A6-4	59	J1-26	A8-4
12	J2-17	A2-5	28	J2-18	A4-5	44	J1-19	A6-5	60	J1-22	A8-5
13	J2-24	A2-7	29	J2-21	A4-7	45	J1-15	A6-7	61	J1-14	A8-7
14	J2-28	A2-8	30	J2-25	A4-8	46	J1-11	A6-8	62	J1-10	A8-8
15	J2-32	A2-9	31	J2-29	A4-9	47	J1-3	A6-9	63	J1-7	A8-9
16	J2-36	A2-10	32	J2-33	A4-10	48	J1-4	A6-10	64	J1-1	A8-10

NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   RESISTANCE VALUES ARE IN OHMS, ±5%, 1/8 W.
   CAPACITANCE VALUES ARE IN MICROFARADS, ±10%
2. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN, FOR COMPLETE DESIGNATION PREFIX WITH 1A2
   EXAMPLE: R2 = 1A2R2.

HIGHEST REFERENCE DESIGNATIONS				
A9	C8	R4	J3	P1

PARTS LIST

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES ON: FRACTIONS DECIMALS ANGLES

MATERIAL:

SM-D-649077-1 | DL-649377
NEXT ASSY | USED ON
APPLICATION

CONTRACT NUMBER DAAK[illegible]-71-C-0156
PHILIPS - NORELCO
MONTVALE, NEW JERSEY

ELECTRONICS COMMAND
REVIEWED
APPROVED
DATE

U. S. ARMY ELECTRONICS COMMAND
PROCUREMENT AND PRODUCTION DIRECTORATE
FORT MONMOUTH NEW JERSEY 07703

SCHEMATIC DIAGRAM
PREAMPLIFER MULTIPLEXER
ASSEMBLY

SIZE D | CODE IDENT NO. 80063 | SM-D-649377

SCALE — SHEET 2 OF 2

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Figure 2-9 (Cont)

2.4.5.4 Channel Enable (÷ 8) Counter

The clock signal from Q1 is applied to the first flip-flop of a three stage ripple counter in the logic hybrid U1. Each time the clock goes negative, it triggers the flip-flop causing the $\overline{2^0}$ to switch. The 2^0 is fed to the second flip-flop and everytime the 2^0 goes negative it triggers the flip-flop causing the $\overline{2^1}$ to switch. The $\overline{2^1}$ is applied to the third flip-flop to switch and producing the 2^2. The count into the first flip-flop is one-half cycle, therefore the fastest counting frequency ($\overline{2^0}$) is one-half the clock frequency. The second count ($\overline{2^1}$) is one-quarter the clock frequency and the third ($\overline{2^2}$) is one-eighth the clock frequency.

These functions are inverted and the 2^0, 2^1 and 2^2 binary digits are applied to the multiplexers on the preamplifier cards to gate out the eight channels of video when the multiplexer is enabled by the output enable counter.

2.4.5.5 Output Enable (÷ 9) Counter

The output enable (÷9) counter is made up of two 4-stage shift registers in the logic hybrid U1. The 2^2 signal from the channel enable (÷ 8) counter acts as the "clock" for the ÷9 counter. Thus the ÷9 counter is clocked at one-eighth the system clock frequency. Assume that the outputs of the two shift registers (OE1 through OE8) are all logical "1". With all "1's" to the 8-input NAND-gate, the output is logical Ø. When the ÷8 counter reaches its maximum count of 7 (binary 111) and is ready to return to a count of 0, the transition from 7 to 0 causes a logical Ø to enter the first stage of the shift register. When the Ø has been entered, the output of A (OE1) is a logical Ø and will remain a Ø until the ÷ 8 counter again reaches a count of 7. The OE1 is inverted during the time the OE1 signal is a "1" (26.7 microseconds) it enables multiplexer 1 on the preamplifier card to gate channels 1 through 8 to the video amplifier via the MX OUT line. On the next transition of the ÷8 counter from 7 to 0, the logical Ø is shifted from A to B of the first shift register. OE1 becomes a logical "1" and OE2 becomes a logical Ø. Output enable signal OE2 now is a logical "1" and enables multiplexer 2 to gate out channels 9 - 16 to the MX OUT line. The shifting of the logical Ø continues down the shift register until OE8 is a logical Ø. At this time, channels 57 - 64 are gated to the MX OUT line. When the ÷ 8 reaches its next count of 8, the next transition causes the logical Ø to leave the register. At this point all the inputs to the NAND-gate are logical "1's" and the output is a logical Ø. (The output of a NAND-gate will go to Ø only when all the inputs are "1".) The logical Ø cannot enter the shift register until the ÷8 reaches its next count of 8 and then the ÷ 8 transition causes a logical Ø to enter the first shift register again. Thus it has taken 9 cycles of the ÷ 8 to cause a logical Ø to enter the shift register, travel down the shift register and out, then back into the first register again. During the first 8 cycles, channels 1 through 64 have been gated to the MX OUT line. At the 9th cycle while all the OE's are a logical "1" the multiplexer outputs are inhibited. During this time blanking of the video, retrace and power supply switching occurs.

Note that the circuitry on the OE5 output of U1 is different from the others. A NOR-gate is used on the $\overline{OE5}$ shift register output instead of the inverter used on the other shift register outputs. The first channel enabled while OE5 is ON is channel 33. It is on the first half of channel 33 that the horizontal cross hair is displayed. The NOR-gate is used to disable the OE5 output while the horizontal cross hair is displayed.

As the logical Ø is shifted through the shift register, through the inverters onto the output it appears that a logical "1" is being shifted. The timing diagram shows that the "1's" shift from OE1 to OE2, to 3, 4, 5, 6, 7 and 8. Then when the Ø shifts out the last shift register, they are all "1's". The "1's" are all inverted and therefore the outputs (OE1 - OE8) are all Ø's and the multiplexers are all shut off. At this time the output of the NAND-gate is Ø ready to put back into the first shift register. The Ø is brought out on pin 10 of U1 and is called $\overline{RESET}$. It is also inverted and brought on pin 4 of U1 as RESET. The RESET signal is used to trigger the vertical sweep of the display. It is also used (through resistor R5) for the power supply synchronization (PS SYNC). The $\overline{RESET}$ is used to enable the BLANKING signal.

2.4.6 CROSS HAIR AND BLANKING CIRCUITS

2.4.6.1 Block Diagram Functioning (Figure 2-3)

The cross hair and blanking circuits consists of the following:

(1) Angular Position Detector - light emitting diode (LED), optical pickoff mirror, phototransistor and operational amplifier.

(2) Cross hair Generator - vertical cross hair flip-flop (VXH), horizontal cross hair flip-flop (HXH), and sequence counter.

(3) Blanking Generator - clock/cross hair gate, 2 delays, shaper, summing network and a video inhibit.

An optical pickoff mirror attached to the scan mirror reflects light emanating from the LED (light emitting diode) onto the phototransistor when the scan mirror goes through the center of scan. (The light strikes the phototransistor only when the scan mirror is at center of scan.) When the light strikes the phototransistor it goes into conduction causing the differentiator and operational amplifier to produce a pulse. The SCAN PULSE is used to trigger the vertical cross hair flip-flop (VXH). The vertical cross hair flip-flop is controlled by the XH ENABLE signal received from the scan motor drive circuit. The horizontal cross hair flip-flop (HXH) receives its input from the output enable (÷ 9) counter. The vertical and horizontal cross hair outputs are applied to the blanking generator and video inhibit circuits. The blanking generator consists of the clock/cross hair gate which passes the clock or cross hair signals through two delay circuits to the shaper and summing network. These circuits cause blanking to occur when the multiplexer switches channels thus preventing any noise generated during switching from appearing on the CRT display. The video inhibit circuit disables the MX OUT line during blanking, cross hair display and retrace.

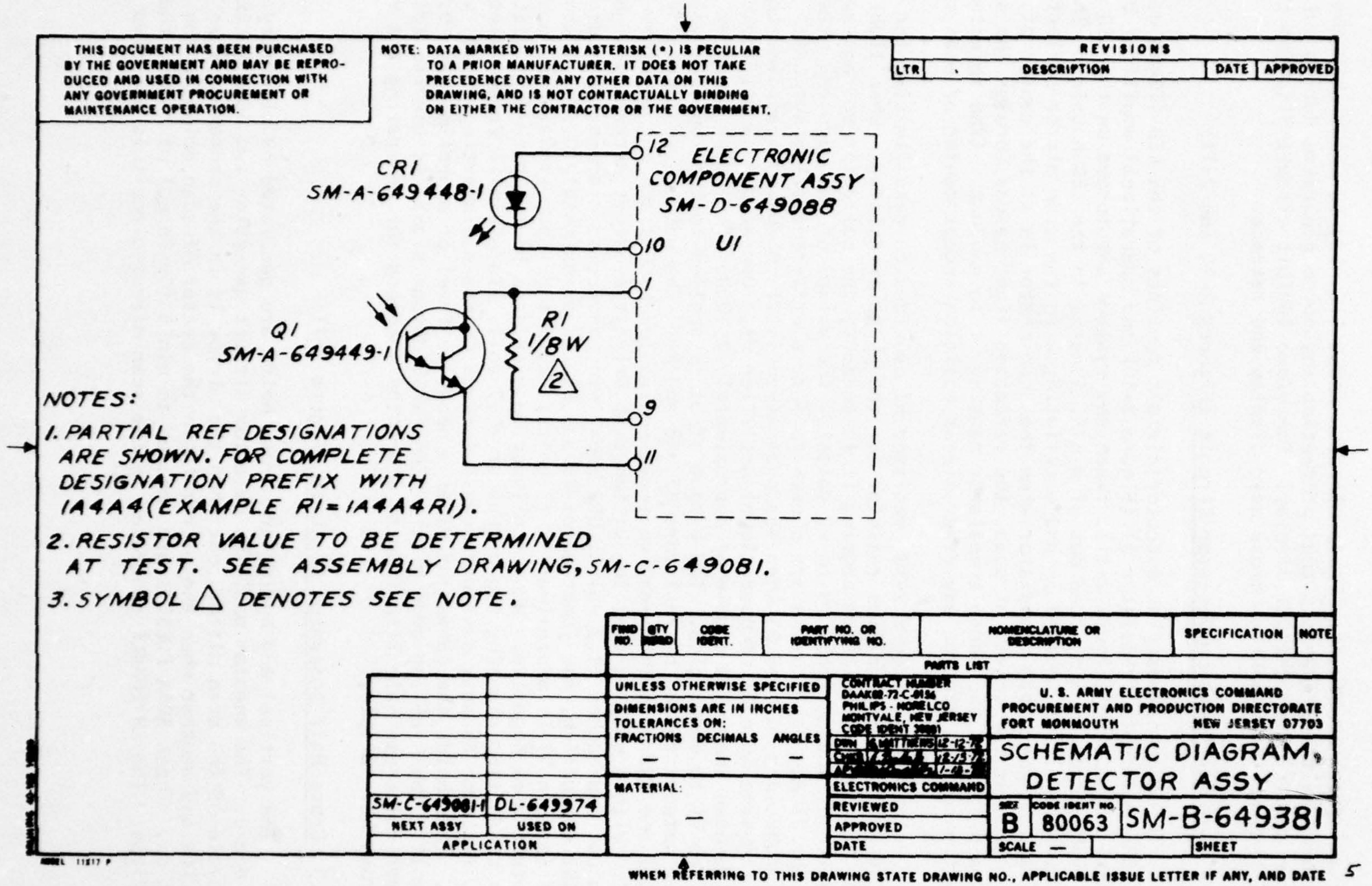
2.4.6.2 Angular Position Detector Circuit (Figures 2-10 and 2-11)

The angular position detector circuit consists of the LED (light emitting diode) CR1 and photo transistor Q1 (Figure 2-10) and operational amplifier U1 and associated circuitry (Figure 2-11). When the systems are turned on the LED produces light which is projected out of a slit located in the LED housing. The optical pickoff mirror mounted on and oscillating with the scan mirror reflects the light back to the photo transistor when the scan mirror is at the center of the scan cycle. At the center of scan, the reflected light passes through the same "slit" and strikes the photo transistor causing it to conduct. (The relected light does not enter the slot at any other mirror position except center of scan cycle.)

Referring to Figure 2-10, resistor R1 provides current limiting for the LED. Resistor R2 is the bias resistor for the photo transistor. When light strikes the photo transistor causing it to conduct, the collector voltage goes in a negative direction (from +4 to +2 volts). The values of the coupling network capacitor C1 and resistor R3 are chosen to form a differentiating network. The spike produced by C1 and R3 when the photo transistor conducts is applied to the inverting side (pin 2) of operational amplifier U1. Operational amplifier U1 is operated open loop with a gain of approximately 25,000. The spike produced by C1-R3 drives U1 to saturation. The output of U1 is applied to the top of a voltage divider network formed by resistors R7, R8 and R9. The output is clamped by diodes CR1 and CR2 with the negative limit controlled by CR1 and the positive limit by CR2. With a small signal in, U1 tends to drive the output extremely high. As the output approaches +3.7 volts, CR2 goes into conduction clamping the output. With CR2 conducting, the junction of R8 and R9 is approximately 0.7 volt and the OUTPUT (at pin 4) is approximately +3 volts. When the input signal goes positive, the output goes negative. When the junction of R7 and R8 reaches -0.7 volt, CR1 starts conducting clamping the output at -0.7 volt. To minimize false triggering of U1, resistor R6 puts a slight negative level on the noninverting input (pin 3) of U1. This holds the output of U1 at a negative level of approximately -0.5 to -0.7 volt. The trailing edge of the SCAN PULSE output signal is used to trigger the vertical cross hair flip-flop to start the sequence for generating the vertical cross hair display.

2.4.6.3 Cross Hair Generator Circuits (Figure 2-7)

The vertical and horizontal cross hairs are generated by circuitry on the logic board. The angular position detector circuit generates two SCAN PULSE's for each cycle of the scan mirror, one when the mirror is in the center of scan in one direction and another when the mirror is in the center of scan going in the other direction. These SCAN PULSE's are applied to pin 5 (Cp input) of one of the U2 flip-flops. The XH ENABLE generated in the scan mirror circuit is positive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REVISIONS
LTR
DESCRIPTION
DATE
APPROVED
CR1
SM-A-649448-1
12
10
ELECTRONIC COMPONENT ASSY
SM-D-649088
U1
Q1
SM-A-649449-1
R1
1/8W
2
1
9
11
NOTES:
1. PARTIAL REF DESIGNATIONS ARE SHOWN. FOR COMPLETE DESIGNATION PREFIX WITH 1A4A4 (EXAMPLE R1=1A4A4R1).
2. RESISTOR VALUE TO BE DETERMINED AT TEST. SEE ASSEMBLY DRAWING, SM-C-649081.
3. SYMBOL △ DENOTES SEE NOTE.
FIND NO.
QTY REQD
CODE IDENT.
PART NO. OR IDENTIFYING NO.
NOMENCLATURE OR DESCRIPTION
SPECIFICATION
NOTE
PARTS LIST
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON:
FRACTIONS DECIMALS ANGLES
MATERIAL:
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DATE
U. S. ARMY ELECTRONICS COMMAND
PROCUREMENT AND PRODUCTION DIRECTORATE
FORT MONMOUTH NEW JERSEY 07703
SCHEMATIC DIAGRAM, DETECTOR ASSY
SIZE B
CODE IDENT NO. 80063
SM-B-649381
SCALE —
SHEET
SM-C-649081-1
DL-649974
NEXT ASSY
USED ON
APPLICATION
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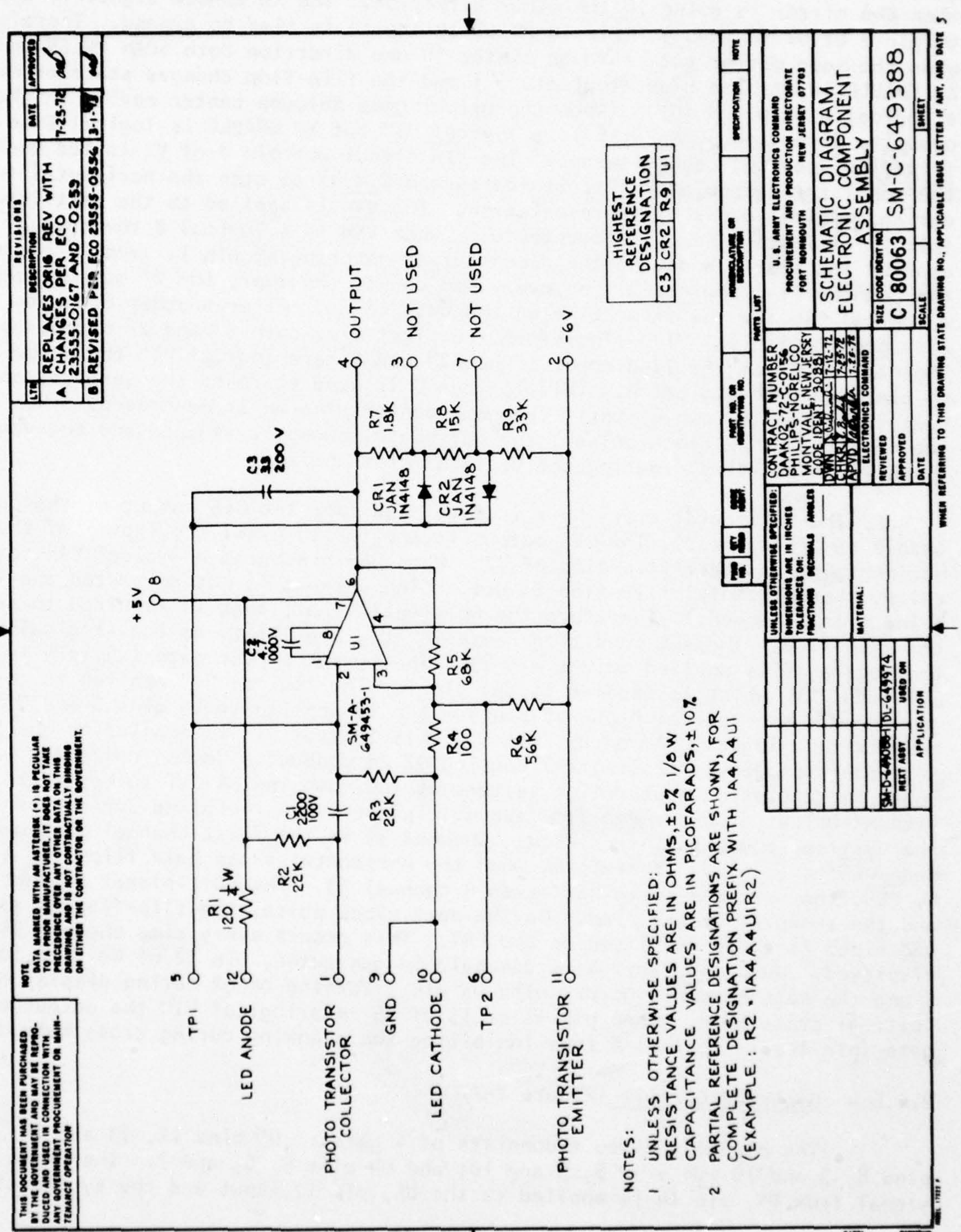
Figure 2-10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DESCRIPTION
DATE
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7-25-72
B
REVISED PER ECO 23535-0536
TP1
LED ANODE
PHOTO TRANSISTOR COLLECTOR
GND
LED CATHODE
TP2
PHOTO TRANSISTOR EMITTER
5
12
1
9
10
6
11
R1 120 ½W
R2 22K
C1 2200 100V
R3 22K
SM-A-649453-1
C2 4.7 1000V
R4 100
R5 68K
R6 56K
U1
+5V
8
C3 33 200V
CR1 JAN 1N4148
CR2 JAN 1N4148
R7 1.8K
R8 15K
R9 33K
4
OUTPUT
3
NOT USED
7
NOT USED
2
-6V
HIGHEST REFERENCE DESIGNATION
C3
CR2
R9
U1
NOTES:
1 UNLESS OTHERWISE SPECIFIED: RESISTANCE VALUES ARE IN OHMS, ±5% 1/8W CAPACITANCE VALUES ARE IN PICOFARADS, ±10%
2 PARTIAL REFERENCE DESIGNATIONS ARE SHOWN, FOR COMPLETE DESIGNATION PREFIX WITH 1A4A4U1 (EXAMPLE : R2 • 1A4A4U1R2)
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES
CONTRACT NUMBER DAAK02-72-C-0156
PHILIPS-NORELCO MONTVALE, NEW JERSEY
ELECTRONICS COMMAND
U.S. ARMY ELECTRONICS COMMAND
PROCUREMENT AND PRODUCTION DIRECTORATE
FORT MONMOUTH NEW JERSEY 07703
SCHEMATIC DIAGRAM ELECTRONIC COMPONENT ASSEMBLY
SIZE C
CODE IDENT NO. 80063
SM-C-649388
MATERIAL:
NEXT ASSY
USED ON
APPLICATION
DL-649374
REVIEWED
APPROVED
DATE
SCALE
SHEET
WHEN REFERRING TO THIS DRAWING STATE DRAWING NO., APPLICABLE ISSUE LETTER IF ANY, AND DATE

Figure 2-11

(logical "1") when the mirror is going in one direction and ground (logical Ø) when the mirror is going in the other direction. The XH ENABLE signal is applied to pin 7 of U2 (J input). Pin 10 of U2 (k input) is tied to ground. Therefore, when the scan mirror goes through center in one direction both SCAN PULSE and XH ENABLE inputs are high (logical "1") and the flip-flop changes state producing a logical Ø at pin 8 ($\overline{Q}$). (When the mirror goes through center moving in the opposite direction SCAN PULSE is a logical "1" but XH ENABLE is logical Ø so the flip-flop does not change state.) The VXH signal out pin 8 of U2 is fed back to the modulator/demodulator circuit (paragraph 2.4.4) to stop the horizontal sweep during vertical cross hair presentation. The $\overline{VXH}$ is applied to the rest input (pin 2) of 7-stage sequence counter U3. When $\overline{VXH}$ is a logical Ø the counter is enabled and starts counting the clock pulses entering at pin 1. the 2^4 output of the counter is a logical "1" on every 8th count. However, the 2^7 output goes to a logical "1" for the first time on the 64th count. After another 8 counts, 2^4 also goes to logical "1". Therefore the first time both 2^4 and 2^7 outputs are logical "1" is at the 72nd count. When 2^4 and 2^7 are logical "1" the output of U4 pin 3 goes to logical Ø. This logical Ø is used to reset the vertical cross hair flip-flop (U2 pin 6) until the next center of scan is generated. Thus during the counting of 72 clock pulses, the horizontal sweep is stopped and the vertical sweep is intensified creating the vertical cross hair.

The horizontal cross hair is developed from the $\overline{OE5}$ output of the output enable (÷ 9) counter. The $\overline{OE5}$ output is applied to pin 1 (cp input) of the horizontal cross hair flip-flop of U2. When $\overline{OE5}$ goes grom a logical "1" to logical Ø, the horizontal flip-flop is set. (The J input is not connected and the K input is grounded.) Therefore the Cp signal is all that is required to set the flip-flop. The set condition causes $\overline{Q}$ (U2, pin 13) to go low (logical Ø). The logical Ø is applied to U4, pin 13. The output of the gate (U4, pin 14) is a logical "1" which is applied to U5, pin 1. The logical "1" applied to this gate produces a logical Ø out at pin 3 which is applied to U5 pins 6 and 7. This results in a logical "1" on U5, pin 5. This logical "1" is applied to the base of transistor Q2 via resistor R7 causing Q2 to conduct. Common collector Q2 conducts to saturation (saturation voltage is low) causing MX OUT to be at ground. With MX OUT at ground video from the multiplexers are inhibited during the time the vertical sweep is intensified. Channel 33 is the first channel displayed when OE5 is enabled. Therefore, when the horizontal cross hair flip-flop is set by $\overline{OE5}$, the vertical sweep has reached channel 33. The multiplexer is shut off and the sweep is intensified. On the next clock pulse, the flip-flop is reset and video is again displayed on the CRT. This occurs every time channel 33 is displayed. When the vertical cross hair is generated, pin 12 of U4 is a logical Ø and the scan sequence occurs with U5 pin 1 turning on Q2 during display of the vertical cross hair. When pin 12 or 13 of U5 is a logical "1" the output of this gate (pin 14) is logical Ø thus inhibiting the blanking during cross hair display.

2.4.6.4 Blanking Circuit (Figure 2-7)

The blanking circuit consists of 4 gates: U5 pins 12, 13 and 14; U5 pins 8, 9 and 10; U4 pins 8, 9 and 10; and U4 pins 5, 6, and 7. The cross hair signal from U4, pin 14 is applied to the U5, pin 12 input and the system clock is applied to the U5, pin 13 input. When no cross hair signals are present the XH input to pin 12 is a logical Ø. When the clock on U5, pin 13 is also a logical Ø, the output at pin 14 is a logical "1". When either input goes to a logical "1", the output is a logical Ø. Thus, when no cross hair is present, the output at U5, pin 14 will be the inverse of the clock. The output of U5, pin 14 is applied to U5 pins 9 and 10 and also to U4 pin 9. However, the signal is slightly delayed from the clock. The amount of delay is established by the time constant of the RC network formed by resistor R3 and capacitor C2. The output at U5, pin 8 is inverted, reshaped to digital form and applied to U4, pin 10. This signal is again delayed this time by the amount of time determined by the time constant of the resistor R4 and capacitor C3 RC networks. The delay between when the clock switches and when the blanking pulse first goes negative at U4, pin 8 (TP7) is determined by the time constant of R3 and C2. The length of time that the pulse stays negative (pulse width) is determined by the time constant of R3 and C3. This delayed pulse is applied to U4, pin 7. The RESET signal from the ÷ 8 and ÷ 9 counters (paragraph 2.7.5) is applied to U4, pin 6. When either pin 6 or 7 of the U4 gate is logical Ø, the output at pin 5 is logical "1". The delayed pulse applied to U4, pin 7 provides a short duration BLANKING pulse to inhibit any noise that might appear on the CRT due to the multiplexer switching. The $\overline{\text{RESET}}$ pulse appears as a logical Ø on U4, pin 6 when the ÷ 9 counter has reached its maximum count and the NAND-gate output goes to a logical Ø. At this time all 64 channels of video have been put on the MX OUT line. The $\overline{\text{RESET}}$ input to U4, pin 6 goes to a logical Ø and a BLANKING pulse of 8 clock count duration is produced at U5, pin 6 to allow time for retrace to begin the next vertical sweep.

At the same time the RESET signal is sent to the vertical sweep generator to reposition the vertical sweep. At this time the PS SYNC signal is also fed to the power supply. The power supply is an inverting type DC to DC converter. When the power supply inverts it generates noise spikes which could appear on the CRT display. The power supply is synchronized by the PS SYNC signal so that the power supply switching can only occur during blanking thus preventing the switching noise from appearing on the CRT display.

2.4.7 DISPLAY CIRCUITS

2.4.7.1 Block Diagram Functioning (Figure 2-3)

The display circuits consist of the video amplifier, the horizontal amplifier and the vertical deflection generator and amplifier. The video amplifier receives the serial video from the multiplexer circuit and the cross hair and blanking signals from the cross hair and blanking generators and amplifies and processes them into the composite video signal applied to the grid of the CRT.

2.4.7.2 Video Amplifier Circuit (Figure 2-12)

The video amplifier is comprised of a hybrid microcircuit flat pack U1 and associated components. Internally, U1 contains a two stage linear amplifier.

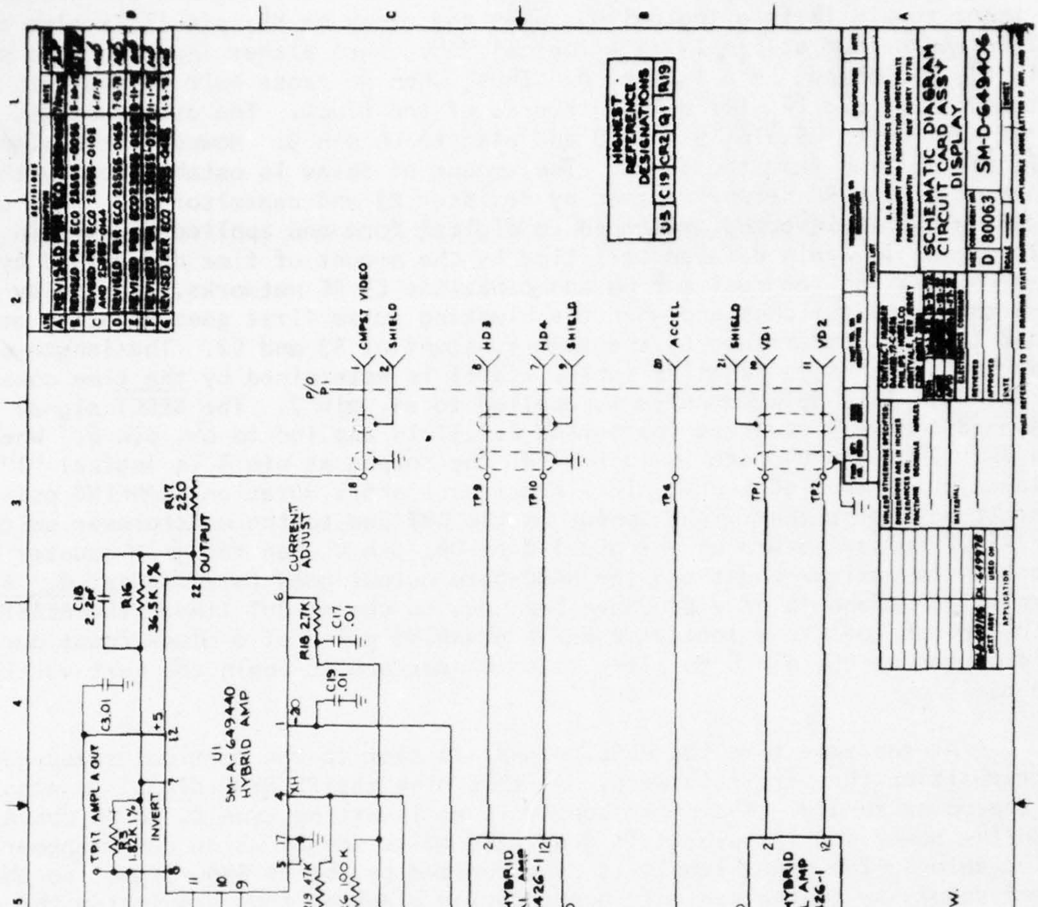

SCHEMATIC DIAGRAM
CIRCUIT CARD ASSY
DISPLAY
SM-D-649406
HIGHEST REFERENCE DESIGNATIONS
U3 C19 CR2 Q1 R19
U1 SM-A-649440 HYBRID AMP
U2 HORIZONTAL HYBRID DIFFERENTIAL AMP SM-A-649426-1
U3 VERTICAL HYBRID DIFFERENTIAL AMP SM-A-649426-1
NOTES:
1. UNLESS OTHERWISE SPECIFIED:
CAPACITOR VALUES ARE IN MICROFARADS, ±10%, 200V.
RESISTOR VALUES ARE IN OHMS, ±10%, 1/8 W, EXCEPT 1%, 1/20W.
2. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN, FOR COMPLETE DESIGNATION PREFIX WITH 1A3.

Figure 2-12

The first stage is a high gain amplifier whose output is coupled to the second stage through resistor R3 (external to U1). The second stage is also a high gain amplifier but with additional capability of being slewed to particular voltages at a fast slewing rate. The fast slewing to a preset value occurs when either the blanking or cross hair signal voltages are applied to the amplifier.

The video from the multiplexer (MX OUT) is applied to the top of the CONTRAST potentiometer. The arm of the potentiometer applies the signal (ATTEN VIDEO) to the non-inverting input (pin 11) of the first operational amplifier (Op Amp A) in flat pack U1. Capacitor C4 on the input line eliminates any high frequency noise that might be on the input. The output of Op Amp A (U1, pin 8) is coupled to the inverting input (pin 7) of the second stage (Op Amp B). Op Amp B inverts and further amplifiers the signal. The reference voltage of Op Amp B is ground (U1, pin 5). Resistor R18 acts as the current source for the Op Amp B differential amplifier. Resistor R16 and capacitor C18 is the Op Amp B feedback loop to provide compensation and prevent high frequency drift or oscillation. Capacitors C1, C2, C7 and C8 are filtering capacitors with C1 and C7 filtering out high frequency components and C2 and C8 filtering the low frequency noise.

Brightness of the video is controlled by regulating the DC bias level to the input stage of Op Amp B. The INTENSITY (Brightness) potentiometer and resistors R5 and R6 form a voltage divider. The voltage at the junction of R5 and R6 as established by the setting of the INTENSITY control is applied to the input (pin 7) of Op Amp B in U1. Since this voltage is the DC bias for Op Amp B it controls the brightness level of the video signal.

The BLANKING signal is applied to the input of Op Amp B (U1, pin 7) via diode CR1 and resistor R4. The amplifier is so designed that when the blanking pulse appears the input goes positive to the point where Op Amp B is shut off and the output saturates to a negative level of -19 volts. The output slews to the -19 volts very quickly. The slewing rate is approximately 60 volts per microsecond.

The cross hair (XH) signal is applied directly into Op Amp B via pin 4 of U1. When XH is present the output goes to a preset voltage level approximately 5 to 8 volts above the normal video. The slewing rate for this voltage is also very fast, the same as when blanking occurs. Brightness of the XH signal is established by feedback resistor R19. The cross hair is always approximately 5 volts brighter than the normal video for any setting of the INTENSITY control. The output of Op Amp B at U1, pin 22 is called CMPST VIDEO (composite video) because it contains the preset cross hair and blanking levels as well as video. The CMPST VIDEO level (brightness) depends on the setting of the INTENSITY control.

2.4.7.3 <u>Horizontal Amplifier Circuit</u> (Figure 2-12)

The horizontal deflection circuit consists of a hybrid differential amplifier, horizontal size and centering potentiometers and associated components. The triangular waveform horizontal signal (HORIZ SIG) from the scanner circuit (paragraph 2.4.4) is applied to the top of potentiometer R7 (HORIZONTAL SIZE) which is terminated to ground. A portion of the horizontal signal is picked off by the arm of R7, filtered by resistor R8 and capacitor C9 and applied to INPUT 1 (pin 3) of the horizontal hybrid differential amplifier U2. The filtering removes any 300 kHz that may be present on the signal. The DC reference level applied to INPUT 2 (U2, pin 11) is established by the voltage picked off by the arm of potentiometer R10 (HORIZONTAL CENTERING) which is part of a voltage divider formed by R10 and resistor R9, from the top of R10 to -6V, and resistor R14, from the bottom of R10 to +5V. Potentiometer R10 adjusts the relative levels of the two signals. When exactly balanced, the horizontal deflection of the display raster is centered on the CRT. The balanced outputs of U2 (pins 2 and 12) are applied to the horizontal deflection plates of the CRT. Basic operation of the hybrid amplifier U2 is described in paragraph 2.4.7.5.

2.4.7.4 <u>Vertical Deflection Circuit</u> (Figure 2-12)

The vertical deflection circuit consists of a vertical generator, a hybrid differential amplifier, the vertical size and centering potentiometers, and associated components. The RESET signal generated in the logic circuits of the multiplexer is applied to the base of vertical generator transistor Q1 via capacitor C14 and resistor R13. Zener diode CR2, potentiometer R11 (VERTICAL SIZE) and resistor R12 form a voltage divider. Since CR2 is a 39V zener connected to the +100 volt supply, the voltage at the top of R11 is +60 volts. This voltage is applied to the accelerator of the CRT.

The vertical sweep is generated in the following manner. Assume that Q1 has just shut off. With Q1 OFF, capacitor C15 starts charging to the voltage level established by R11 and R12. The charging rate is established by the time constant of C15 and R11 and R12. Since R12 is fixed, the amplitude is controlled by R11 (VERTICAL SIZE). While C15 is charging, the counter of the multiplexer is counting from 1 to 64. When it reaches 64, the RESET signal goes to logical "1". When the RESET signal goes to logical "1", it turns Q1 on putting the top of C15 at ground shutting off differential amplifier U3. When the RESET signal is removed (goes to logical Ø after 8 counts), Q1 turns off causing C15 to start charging again until the RESET signal goes to logical "1" again. The charge/discharge action of C15 creates the vertical sweep signal.

Capacitor C14 acts as a "speeder capacitor". Since the RESET signal is a square wave, Q1 must be turned on and off extremely fast to discharge C15 rapidly. When RESET is a logical "1", +5 volts is applied to one side of C14 and ground on the other (Q1 side). When the +5 volts (RESET) goes to ground (logical Ø), the other side of C14 (base of Q1) is at some negative charge. The negative charges on the base pulls the current out of the emitter causing Q1 to turn off quickly. The sawtooth signal generated by Q1 and C15 is applied to INPUT 1 (pin 3) of vertical hybrid differential amplifier U3. The DC reference level to INPUT 2 (pin 11) of U3 is provided by potentiometer R15 (VERTICAL CENTERING) which adjusts the relative levels of the two inputs. The balanced output of U3 (pins 2 and 12) are applied to the vertical deflection plates of the CRT.

2.4.7.5 Hybrid Differential Amplifier Basic Operation (Figure 2-13)

The horizontal and vertical hybrid differential amplifiers U2 and U3 (Figure 2-12) are identical internally. Therefore the following circuit description applies for both. How they are utilized in the horizontal and vertical deflection circuits is described in paragraphs 2.4.7.3 and 2.4.7.4 above. The schematic diagram of the internal circuitry in U2 and U3 is shown in Figure 2-13. Operation of the circuit is as follows. Resistors R1 and R2 are equal value matched 1 percent resistors. Resistors R4 and R5 are also equal value matched 1 percent resistors. Normally one input is the signal input and the other is the DC reference tied to ground. However, in this application the horizontal or vertical input signal is applied to INPUT 1 to the base of Q1. INPUT 2 to the base of Q2 is at some DC potential as established by the horizontal and vertical centering potentiometers which are adjusted for a balanced output. When the DC potential at the base of Q1 equals the DC potential at the base of Q2, current I through R1, Q1 and R4 = current I_2 through R2, Q2 and R5 and no current flows through coupling resistor R3. When the input to the base of Q1 goes positive, Q1 conducts harder increasing the current through R1 and causing the Q1 collector voltage to go negative. At the same time, the increase in current flows through R4 and also causes current to flow through R3. The current flowing through R3 tends to raise the voltage at the top of R5 raising the emitter voltage of Q2 goes up, the output at the collector of Q2 will go positive by the same amount as Q1 goes negative. Thus the outputs of Q1 and Q2 are equal amplitude but opposite polarity.

2.4.8 LOW VOLTAGE POWER SUPPLY CIRCUITS

2.4.8.1 *Block Diagram Functioning* (Figure 2-14)

The low voltage power supply consists of the following: +5 regulator, oscillator, inverter, and inverter control on circuit board 1A5A2; -6V and -20V rectifiers and filters, +100V doubler and filter, and current limit circuits on circuit board 1A5A1; and power transformer 1A5T1. (These circuits are also shown on Figure 2-3.)

The system battery voltage (SW +6V) is applied to the +5V regulator and to the center tap (terminal 3) of the transformer T1 primary winding. The output of the +5V regulator is applied to a free running oscillator. However, when the PS SYNC signal is applied to the oscillator, it causes the oscillator to speed up. The speed up locks the oscillator to the system vertical sweep frequency. This assures that tne inverter switching as controlled by the oscillator occurs only during blanking thus preventing any generated switching noise from appearing on the CRT display.

The inverter circuit consists of two transistors that are driven alternately "ON" and "OFF". The transistors are tied across terminals 1 and 5 of T1. When one transistor is ON current flows through T1 from terminal 3 to 1 causing a magnetic flux in T1 in one direction. When this transistor goes OFF and the other goes ON, the current flows in the opposite direction through terminals 3 to

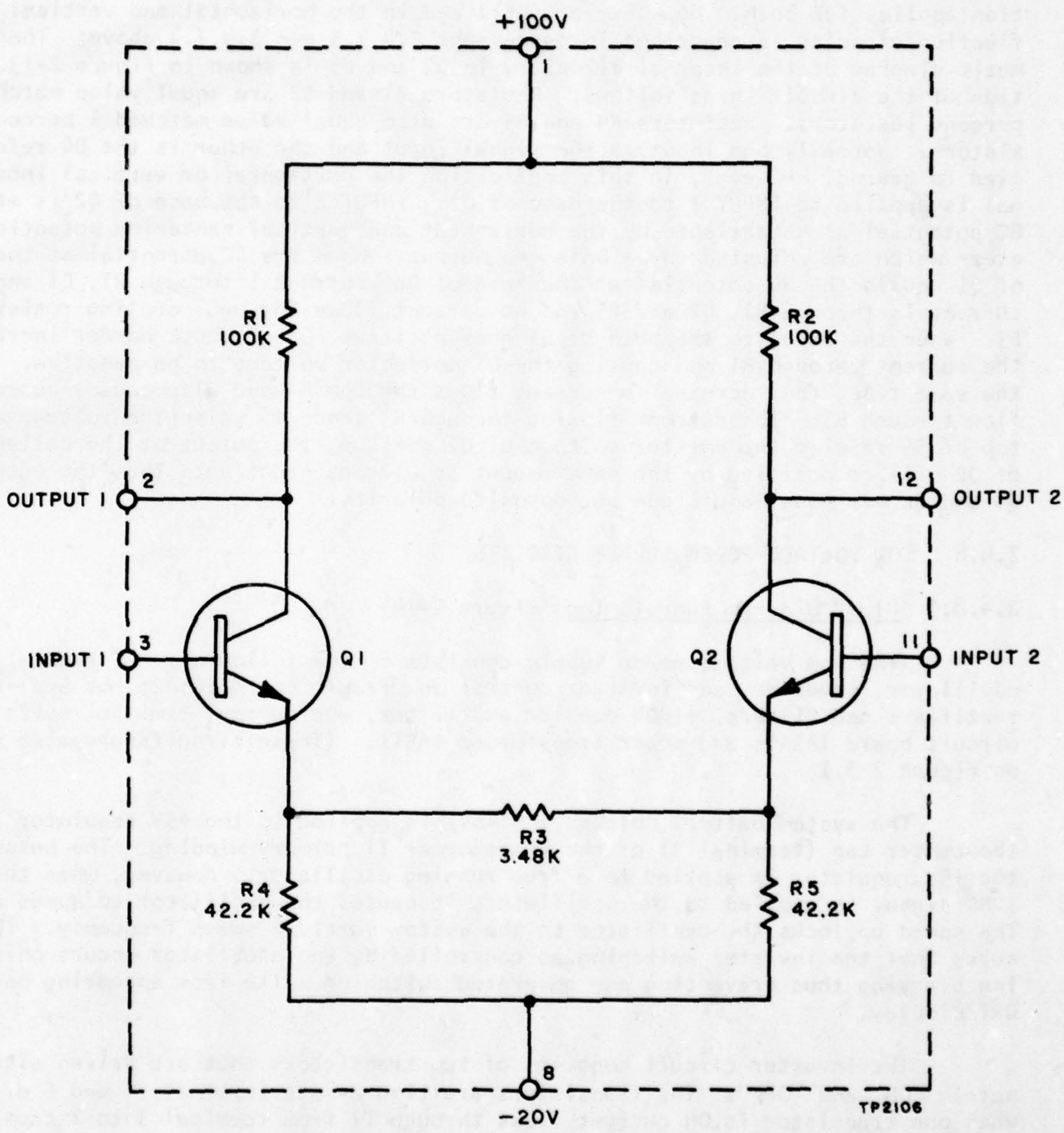


Figure 2-13. Hybrid Differential Amplifier Schematic Diagram

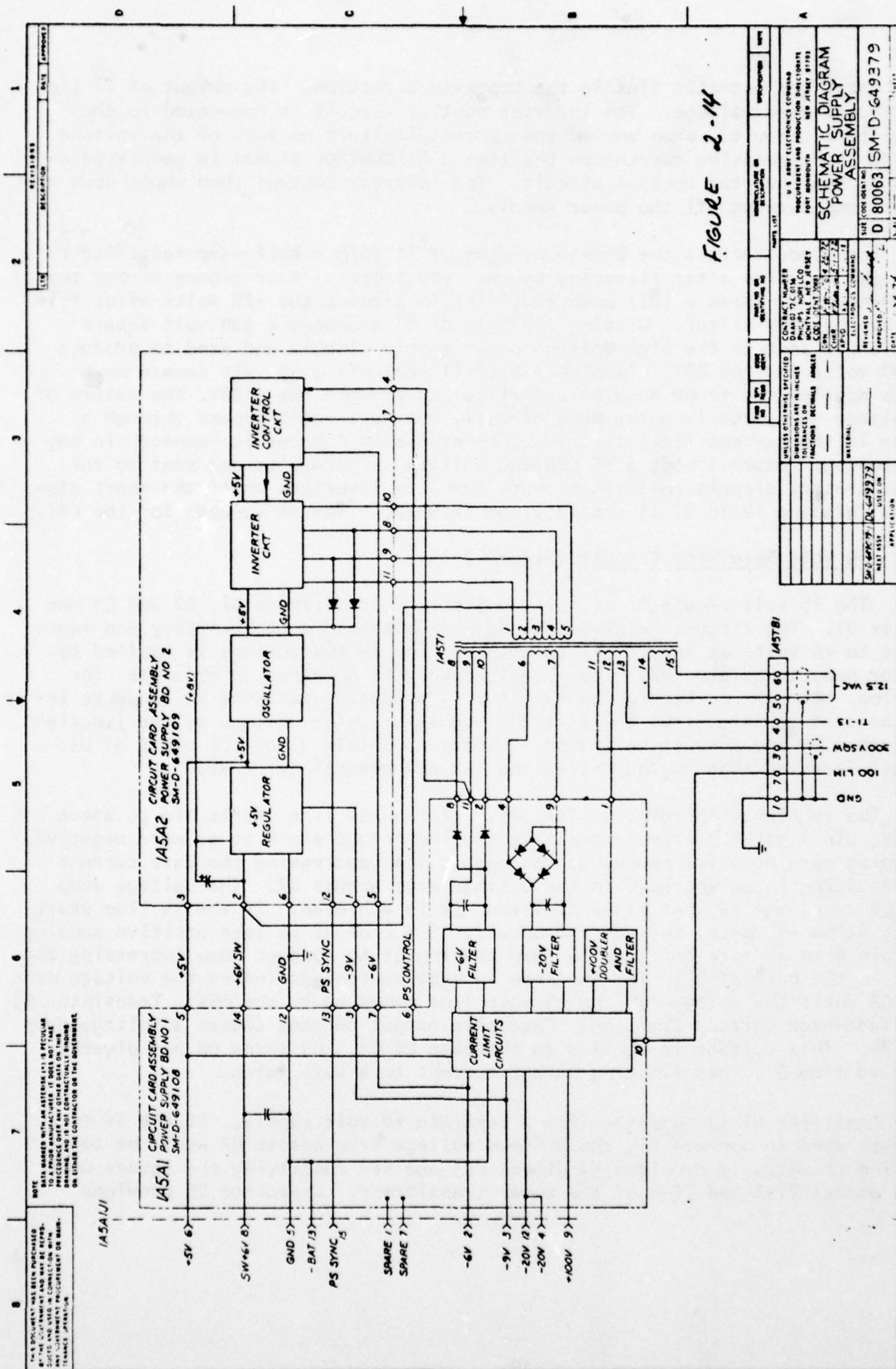


FIGURE 2-14

-37-

5 of T1 causing a magnetic flux in the opposite direction. The output of T1 is thus a square wave voltage. The inverter control circuit is connected to the current limit circuit. When any of the current limiters on each of the voltage lines "senses" excessive current on the line a PS CONTROL signal is generated and applied to the inverter control circuit. The inverter control then shuts down the inverter thus turning off the power supply.

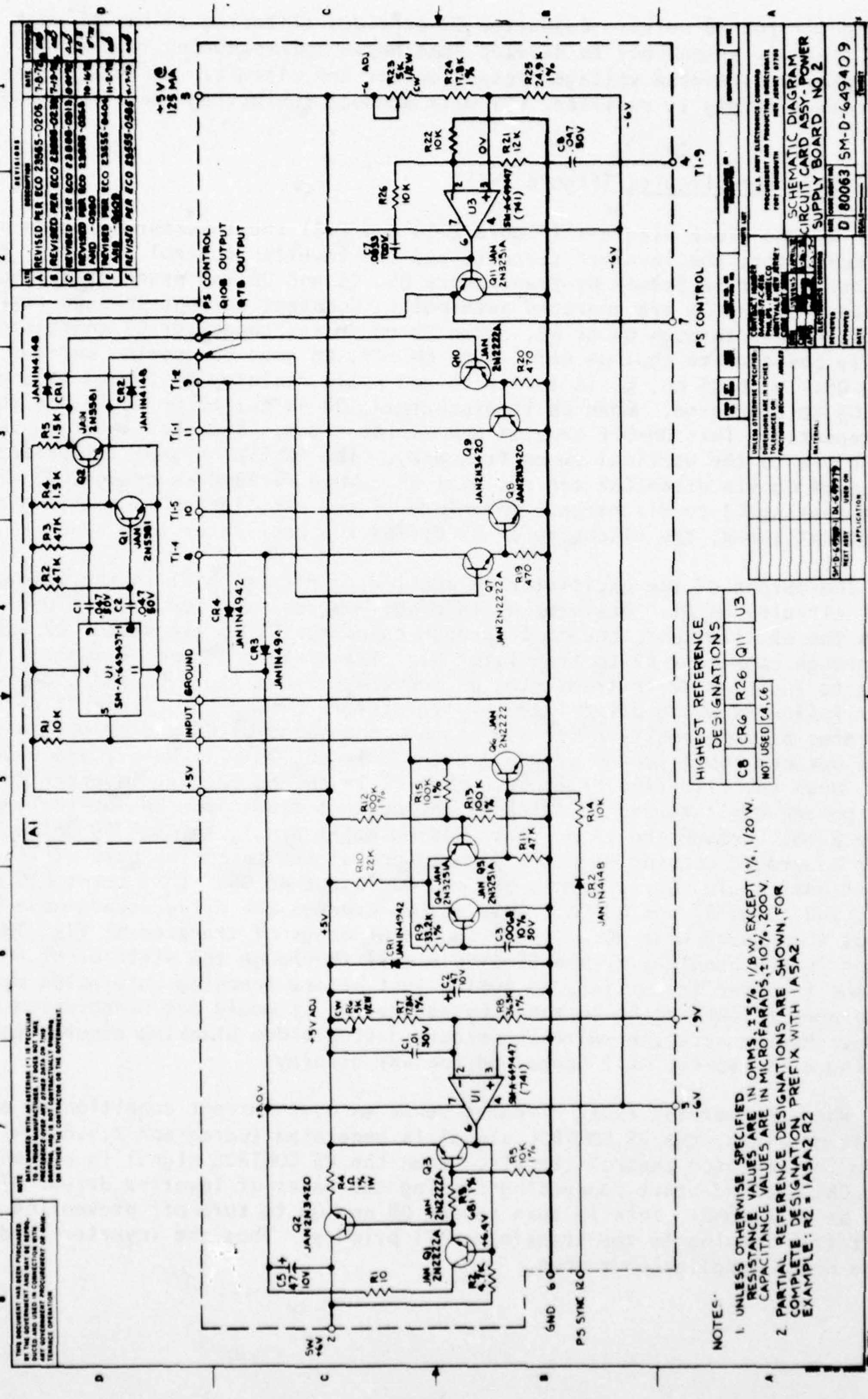
Two diodes across the 8-9-10 winding of T1 form a half-wave rectifier to produce the -6 volts after filtering by the -6V filter. Four diodes across the 6-7 winding of T1 forms a full wave rectifier to produce the -20 volts after filtering by the -20V filter. Winding 11-12-13 of T1 produces a 300 volt square wave which is sent to the high voltage power supply circuit and used to produce the -900 volts for the CRT. Terminal 12 of T1 taps off a 50 volt square wave which is applied the +100V doubler and filter to produce the +100V. The return of each voltage generated is not ground directly but must reach ground through a resistor in the current limit circuits. If excessive current is "sensed" in any of the voltage return lines, a PS CONTROL voltage is generated and sent to the inverter control circuit which then shuts down the inverters until the short disappears. Winding 14-15 of T1 provides the 12.5 VAC filament voltage for the CRT.

2.4.8.2 <u>+5 Volt Regulator Circuit</u> (Figure 2-15)

The +5 volt regulator circuit consists of transistors Q1, Q2 and Q3 and amplifier U1. The circuit receives the SW +6V voltage from the battery and regulates it to +5 volts at very close tolerance. The SW +6V voltage is applied to regulator pass transistor Q2. The +5 volt output is compared to -9 volts for regulation. At turn on before the -9 volts is produced, resistor R2 conducts into the base of transistor Q1 to start the regulator. The voltage at the junction of resistors R7 and R8 must be 5/9 of -9 volts to obtain a null at pin 2 of U1. The ratio is established by adjusting the +5V ADJ potentiometer R6.

The regulator operates as follows. If the +5V line starts to go above +5 volts, pin 2 of U1 goes more positive causing output pin 6 to go more negative. Pin 6 going more negative causes Q1 to conduct less decreasing the base current in Q2 resulting in an increase in the voltage drop across Q2. The voltage drop across Q2 drops the +5 volt line until the +5V is achieved. If the +5 line starts dropping below +5 volts, the reverse occurs. Pin 2 of U1 is less positive causing output pin 6 to go more positive in turn causing Q1 to conduct more increasing the current in the base of Q2. The increase in base current decreases the voltage drop across Q2 until the voltage on the +5 volt line comes up to the +5V. Transistor Q3 causes feed-back current limiting. Excessive output current causes a voltage drop across R4. This voltage is applied to the base of Q3. Q3 turns ON and diverts base drive from Q1, thus limiting output current to a safe value.

Amplifier U1 is operated from a separate +8 volt supply. If the SW +6 volts were used to operate U1, the minimum voltage drop across Q2 would be too high. The +8 volts is provided by diodes CR3 and CR4 rectifying the square wave voltage across T1-2 and T1-4 of the power transformer. Capacitor C5 provides



SCHEMATIC DIAGRAM
CIRCUIT CARD ASSY-POWER
SUPPLY BOARD NO 2
D 80063 SM-D-649409
HIGHEST REFERENCE DESIGNATIONS
C8 CR6 R26 Q11 U3
NOT USED C4, C6
NOTES:
1. UNLESS OTHERWISE SPECIFIED
RESISTANCE VALUES ARE IN OHMS, ±5%, 1/8W, EXCEPT 1%, 1/20W.
CAPACITANCE VALUES ARE IN MICROFARADS, ±10%, 200V.
2. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN, FOR
COMPLETE DESIGNATION PREFIX WITH 1A5A2.
EXAMPLE: R2 = 1A5A2R2
PS CONTROL
Q10B OUTPUT
Q7B OUTPUT
+5V @ 125 MA
INPUT GROUND
PS SYNC
GND

Figure 2-15

filtering for the +3 volts. Capacitor C2 provides filtering of the +5 volt line because there is a tendency to develop some noise spikes during regulation. Diode CR1 provides reverse voltage protection for the circuit. If the battery or input voltage supply is reversed, CR1 will conduct inhibiting the circuit operation.

2.4.8.3 Inverter Circuits (Figure 2-15)

On the block diagrams (Figure 2-14 and 2-3) the inverter circuits consist of an oscillator, the inverter circuit, and the inverter control circuit. The driver oscillator is formed by transistors Q4, Q5 and Q6 and associated components. Transistors Q4 and Q5 are operated push-pull. Constant current through resistor R10 flows either through Q4 or Q5. When Q4 conducts, capacitor C3 charges sufficiently positive to shut Q4 off. With Q4 off, Q5 goes on and the current flows through Q5. With Q5 on, Q6 is turned on and pulls resistor Q9 toward ground allowing C3 to discharge. When C3 is discharged, Q4 is turned on again and the cycle repeated. This ON-OFF creates the oscillations. The oscillator is designed to run close to the vertical sweep frequency. The PS SYNC signal is applied to the base of Q6 via diode CR2 and resistor R4. When PS SYNC is present Q6 will turn on causing C3 to discharge. Therefore if the oscillation is not in sync with the vertical sweep, the discharge of C3 brings the oscillator into sync.

The output of the oscillator is applied to flip-flop U1 in the inverter control circuits on A1. Resistor R1 is a pull-up resistor for U1. Flip-flop U1 divides the oscillations, one-half through capacitor C1 to transistor Q2 and one-half through capacitor C2 to transistor Q1. Transistors Q1 and Q2 amplify the signals to inverter drive transistor Q7 and Q10. Transistors Q7 and Q10 are emitter followers which drive inverter transistors Q8 and Q9. Since flip-flop U1 operates between positive (+) and ground, the bases of Q8 and Q9 will also operate between positive and ground. When Q8 is on, Q9 will be off and vice versa. When the flip-flop U1 is such that Q1 is on and Q2 off, inverter drive Q10 is on and Q9 is turned on. With Q9 on, current flows from SW +6V to T1-pin 3 (Figure 2-14) through the T1 primary winding to T1 pin 1, through Q9 collector-emitter to ground causing magnetic flux in one direction in the core of T1. On the next half cycle, Q1 is turned OFF and Q2 is turned ON. This turns Q10 and Q9 OFF, and turns Q7 and Q8 ON. This action creates the drive square wave that develops the square wave AC voltages in the windings of transformer T1. The oscillator is synchronized by the PS SYNC signal to change the state of U1 and cause the inverter transistors to switch just before reaching saturation because if they were allowed to be switched by saturation it would not synchronize to the display. Making sure the switching occurs during video blanking assures that no switching noise spikes will appear on the CRT display.

When the current limit circuits sense an over-current condition on any of the voltage lines, the PS CONTROL signal is generated (paragraph 2.4.8.6.4) and sent to the inverter control circuit. When the PS CONTROL signal is present, diodes CR1 and CR2 start conducting causing the bases of inverter driver Q7 and Q10 to be at ground. This in turn causes Q8 and Q9 to turn off preventing any current from flowing in the transformer T1 primary. Thus the inverter is disabled and the power supplies shut down.

2.4.8.4 -6 Volt Regulator Circuit (Figure 2-15)

The -6 volt regulator circuit consists of operational amplifier U3, transistor Q11 and associated components. The regulator compares the -6 volt output to a portion of the +5 volt output as established by the adjustment of the -6V ADJ potentiometer R23. This level is applied to the noninverting side (pin 3) of U3 and is compared to the DC reference voltage established on the inverting input (pin 2) of U3 by resistor R22 to ground. When the two inputs are balanced the input of U3 is at null. If the -6 volts starts to decrease (go more positive) the input is unbalanced and the output of U3 applied to the base of Q11 goes more positive causing Q11 to decrease in conduction. When Q11 decreases in conduction, the inverter drivers Q7 and Q10 are turned on harder via diodes CR1 and CR2 in the inverter control circuit until the -6 volts is back to proper value. If the -6 volts goes more negative, the output of U3 (pin 6) goes negative causing Q11 to increase in conduction resulting in a decrease in the drive to Q7 and Q10 until the -6 volts is back to proper value. The -6 volt regulator controls the inverter drive thus affecting all the voltages except the +5 volts. Note that the -6 volt regulator output is applied to the inverter drive transistors via CR1 and CR2 on the same line as the PS CONTROL signal previously discussed. However, the -6 volt regulator output to the inverter drive is a linear relation and only modifies the drive a small amount. It does not turn CR1 and CR2 on hard to turn the inverter drive completely off as occurs when the PS CONTROL signal from the current limiters appears.

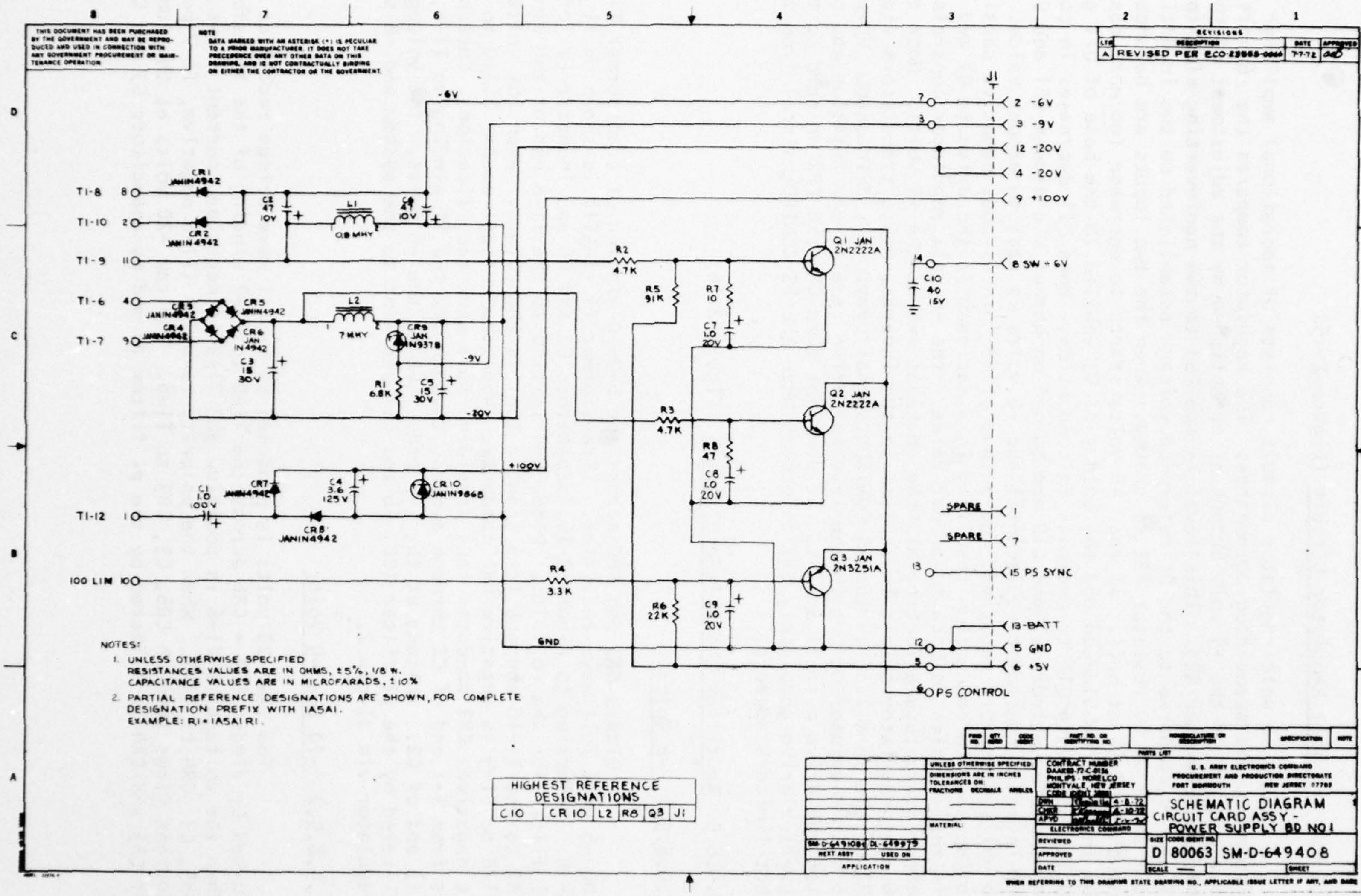
2.4.8.5 Rectifier and Filter Circuits (Figure 2-16)

2.4.8.5.1 -6 Volts

Diodes CR1 and CR2 across the 8-9-10 winding of transformer T1 form the -6 volt full wave rectifier. (Transformer T1 (1A5T1) is shown on Figure 2-14. Referring to Figure 2-16, capacitors C2 and C6 and inductor L1 form a pi filter for the -6 volts. Diode CR1 is tied to the T1-8 end of the winding, CR2 to the T1-10 end and T1-9 (center top) is the return. When the voltage from T1-8 to T1-9 is negative CR1 conducts. When the voltage across T1-10 to T1-9 is negative, CR2 conducts thus providing full wave rectification. Current flow is from (-) end of C2 through diodes, through 1/2 the T1 winding to T1-9, to the (+) end of C2. Voltage at the (-) end of C2 is the -6 volts. The voltage is filtered by the pi filter (C2, C6 and L1) and sent to the system and -6 volt regulator via J1-pin 2.

2.4.8.5.2 -20 and -9 Volts

The raw -20 volts is produced by a full wave bridge rectifier circuit formed by diodes CR3 - CR6 across the T1-6 to T1-7 winding of the transformer. When the voltage at T1-6 is positive and T1-9 is negative, current flows through CR5, C3, CR4 to T1-7. When the polarity reverses (T1-6 negative, T1-7 positive) current flows through CR6, C3, CR3 to T1-6. The raw -20 volts at the junction of CR3 and CR4 is filtered by the pi filter formed by capacitors C3 and C5 and



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REVISED PER ECO-23865-0066
T1-8
T1-10
T1-9
T1-6
T1-7
T1-12
100 LIM
CR1 JAN1N4942
CR2 JAN1N4942
C2 47 10V
L1 0.8 MHY
C6 47 10V
-6V
L2 7 MHY
CR9 JAN 1N937B
R1 6.8K
C5 15 30V
-9V
-20V
C3 15 30V
+100V
C1 1.0 100V
CR7 JAN1N4942
CR8 JAN1N4942
C4 3.6 125V
CR10 JAN1N986B
R2 4.7K
R5 91K
R7 10
C7 1.0 20V
R3 4.7K
R8 47
C8 1.0 20V
R4 3.3K
R6 22K
C9 1.0 20V
GND
Q1 JAN 2N2222A
Q2 JAN 2N2222A
Q3 JAN 2N3251A
C10 40 15V
J1
2 -6V
3 -9V
12 -20V
4 -20V
9 +100V
8 SW + 6V
SPARE 1
SPARE 7
15 PS SYNC
13-BATT
5 GND
6 +5V
PS CONTROL
NOTES:
1. UNLESS OTHERWISE SPECIFIED RESISTANCES VALUES ARE IN OHMS, ±5%, 1/8 W. CAPACITANCE VALUES ARE IN MICROFARADS, ±10%
2. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN, FOR COMPLETE DESIGNATION PREFIX WITH 1A5A1. EXAMPLE: R1=1A5A1R1.
HIGHEST REFERENCE DESIGNATIONS
C10 CR10 L2 R8 Q3 J1
U.S. ARMY ELECTRONICS COMMAND
SCHEMATIC DIAGRAM CIRCUIT CARD ASSY - POWER SUPPLY BD NO1
D 80063 SM-D-649408

Figure 2-16

inductor L2 and sent to the system via J1 - pins 2 and 4. The -9 volts is provided by zener diode CR9 and resistor R1. The -9 volts is clamped by CR9 and sent out via J1 - pin 3.

2.4.8.5.3 +100 Volts

A 100 volt peak to peak square wave from T1-12 is applied to diodes CR7 and CR8. The 100 volts is obtained from a tap (T1-12) on the 300 volt winding of the transformer that is used as the primary voltage source for the high voltage power supply. If something happens in the winding, C1 prevents damage to the +100 volt supply. The +100 volt circuit operates as follows. The 100 volt input is a peak to peak square wave which goes from approximately -50 volts to +50 volts. Assume that the initial condition is the input (T1-12) at -50 volts.

The voltage drop across C1 cannot change instantaneously, therefore the (+) side of C1 goes negative turning CR8 on. Current flows through C1, through CR8 to ground until the input square wave goes to ground. When the input square wave goes to +50 volts, again the voltage drop across C1 cannot change instantaneously. Therefore the (+) side of C1 will have a +100 volt potential. With a positive potential, CR8 is turned off and CR7 is turned on. Initially, C4 has no potential thus the (+) side of CR4 is at ground potential. Current now flows from C1, CR7, CR to ground. The actual voltage at the (+) side of C4 will be an average until continued applications of the (+) and (-) 50 volt square wave builds the level up to +100 volts. Each (+) half cycle of the input pumps current into C4. During the (-) half cycle CR7 blocks the potential stored in C4 so the current is stored in C4 until the next (+) pulse. Therefore the circuit acts as a voltage doubler 1/2 wave rectifier. Zener diode CR10 clamps the output at -100 volts sent out to the system via J1 - pin 9.

2.4.8.6 Current Limiting Circuits (Figure 2-16)

2.4.8.6.1 -6 Volt Current Limiting

The return path for the -6 volts is through CR1 or CR2, the center tap of the -6 volt transformer winding (T1-9), through inductor L1 to ground. Inductor L1 has a small but finite DC resistance. Therefore there is a finite voltage across L1. Capacitor C7 will charge to this voltage. The base of transistor Q1 is DC biased to just below cutoff by resistors R2, R5 and R7. If an over-current condition occurs on the -6 volt line, the voltage across L1 increases, increasing the voltage at the base of Q1 and turning Q1 on. When Q1 is turned on, the collector is essentially ground thus putting the PS CONTROL essentially to ground. The PS CONTROL line is sent to the inverter control circuit where it grounds the inverter drive turning off the inverters and shutting down the power supply. Capacitor C7 stabilizes the current feedback loop under overload or short circuit conditions.

2.4.8.6.2 -20 and -9 Volt Current Limiting

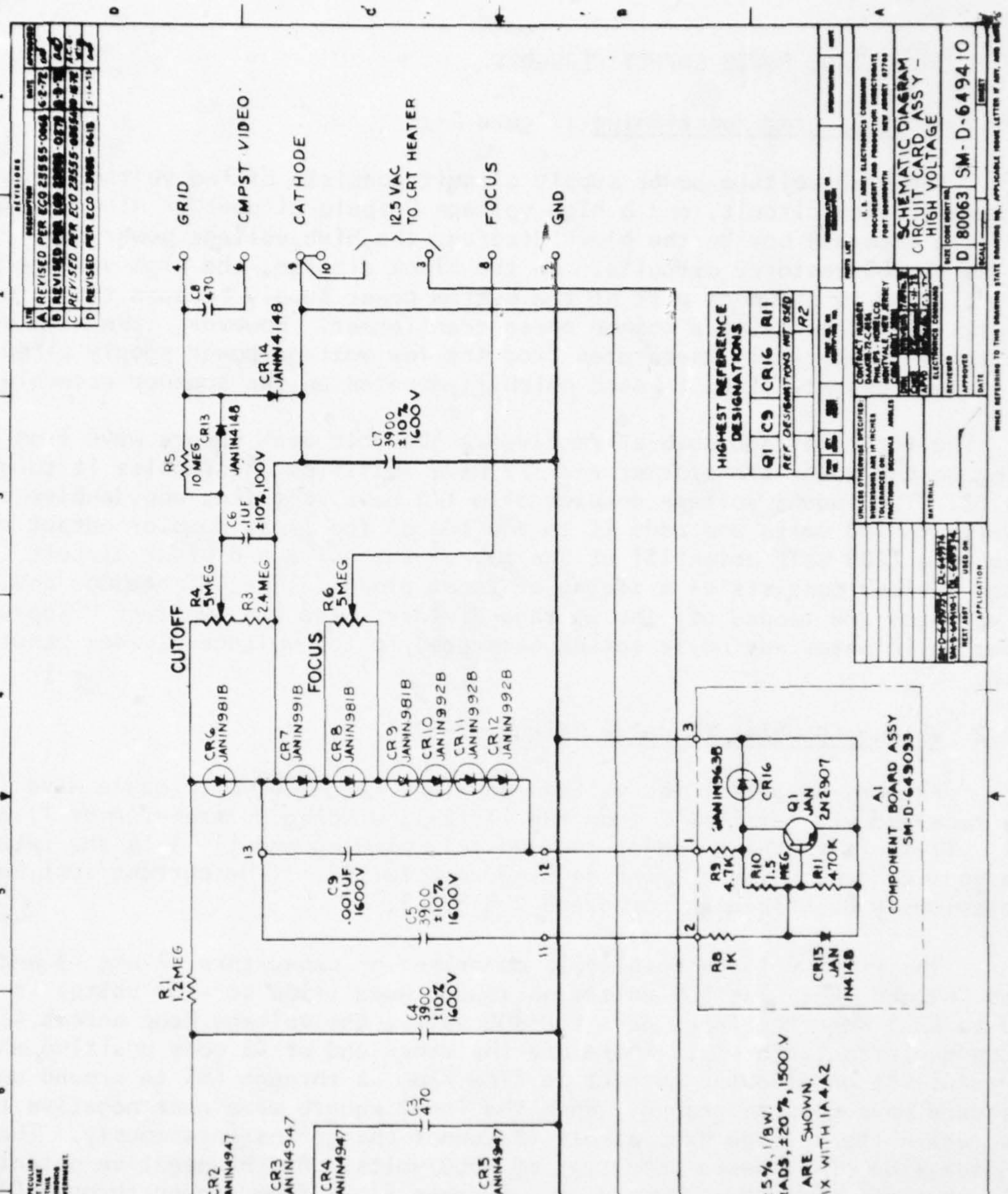
The -20 and -9 volt line current limiting operates in the same manner as the -6 volt current limiting circuit described above. The return path for the current is through diode CR5 or CR6, through inductor L2 to ground. Transistor Q2 is biased slightly below cut off by resistors R3 and R8. If an over-current condition occurs on the -20 volt line, the voltages across L2 increases, the bias on the base of Q2 increases turning Q2 on. With Q2 on PS CONTROL is essentially grounded shutting down the power supply. Capacitor C8 stabilizes the current feedback loop under overload or short circuit conditions.

2.4.8.6.3 +100 Volt Current Limiting

The +100 volt current limiting operates in the same manner as the circuits described above except the over-current is sensed by the voltage drop across a resistor in the return line. (There is no inductor in the line.) The +100 volt current limiting circuit consists of transistor Q3, capacitor C9, and resistors R4 and R6 on power supply board No. 1 (Figure 2-16) and diode CR1 and resistor R7 on the high voltage power supply board (Figure 2-17). The +100 volts is from T1-12 and the current is drawn from T1-11. Current flows through the transformer winding, through T1-13 and through R7 to ground causing a voltage across R7 which is applied to the +100 volt current limiting circuit via CR1 which rectifies the overload sensing voltage across R7. Referring to Figure 2-16, Q3 is biased slightly below cutoff by R4 and R6 with C9 charged to the voltage at the base of Q3. If an over-current condition occurs the voltage across R7 on the high voltage board increases and is applied to the base of Q3 via terminal 10 (100 LIM) causing the current through R4 to increase lowering the bias voltage on the base of Q3 thus turning Q3 on. With Q3 on the PS CONTROL line is again essentially grounded shutting down the power supply. Capacitor C9 stabilizes the current feedback loop as before.

2.4.6.6.4 PS CONTROL Line

From the circuit descriptions of the current limiting circuits above it can be seen that if any of the voltage lines develop a short that draws excessive current, the current sensing transistor on that voltage return line (Q1, Q2 or Q3) will turn on. The transistor on causes the PS CONTROL line to go to a low potential (essentially ground). The PS CONTROL signal causes current to flow through diodes CR1 and CR2 of the inverter control circuit on power supply board No. 2 (Figure 2-15). With CR1 and CR2 on, the inverter drivers (Q7 and Q10) are turned off shutting down the inverters (Q8 and Q9). With the inverters off, reduced current flows through the transformer, thus reducing output voltage to a safe value. When the overload or shorted condition is removed, the PS CONTROL line goes positive, restoring drive to inverter and full output voltage. This prevents the short from exceeding the power ratings of the components thus preventing damage to the components.



SCHEMATIC DIAGRAM
CIRCUIT CARD ASSY - HIGH VOLTAGE
D 80063 SM-D-649410
REVISIONS
A REVISED PER ECO 23595-0066 6-2-72
B REVISED PER ECO 23595-0179
C REVISED PER ECO 23595-0085
D REVISED PER ECO 23595-0418
GRID
CMPST VIDEO
CATHODE
12.5 VAC TO CRT HEATER
FOCUS
GND
CUTOFF
FOCUS
R5 10 MEG
CR13 JAN1N4148
C6 .1UF ±10%,100V
R4 5MEG
R3 2.4 MEG
R6 5MEG
C7 3900 ±10% 1600V
C8 470
CR14 JAN1N4148
CR6 JAN1N981B
CR7 JAN1N991B
CR8 JAN1N981B
CR9 JAN1N981B
CR10 JAN1N992B
CR11 JAN1N992B
CR12 JAN1N992B
C9 .001UF 1600V
C5 3900 ±10% 1600V
C4 3900 ±10% 1600V
C3 470
C2 470
C1 470
R1 1.2 MEG
R7 220
CR1 JAN1N4148
CR2 JAN1N4947
CR3 JAN1N4947
CR4 JAN1N4947
CR5 JAN1N4947
300 VSQW
100 LIM
T1-13
12.5 VAC
HIGHEST REFERENCE DESIGNATIONS
Q1 C9 CR16 R11
R8 1K
R9 4.7K
R10 1.5 MEG
R11 470K
Q1 JAN 2N2907
CR16 JAN1N963B
CR15 JAN 1N4148
A1 COMPONENT BOARD ASSY SM-D-649093
NOTES:
1. UNLESS OTHER WISE SPECIFIED RESISTANCE VALUES ARE IN OHMS, ±5%, 1/8W. CAPACITANCE VALUES ARE IN PICOFARADS, ±20%, 1500 V
2. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN. FOR COMPLETE DESIGNATION PREFIX WITH 1A4A2
EXAMPLES: R1 = 1A4A2R1 R8 = 1A4A2A1R8

Figure 2-17

2.4.9 HIGH VOLTAGE POWER SUPPLY CIRCUITS

2.4.9.1 Block Diagram Functioning (Figure 2-3)

The high voltage power supply circuit consists of two voltage doublers, a voltage divider circuit, and a high voltage "ripple clipper". Although not shown as a separate box on the block diagram, the high voltage power supply also contains the DC restorer circuits. On the block diagram, the high voltage power supply circuit is shown as part of the system power supply because they are electrically related by using a common power transformer. However, the high voltage circuit is physically separated from the low voltage power supply circuits and is on a separate circuit board which is mounted on the scanner assembly.

The first voltage doubler receives a 300 volt peak square wave from a winding on the power transformer and 1/2 wave rectifies and doubles it to 600 volts DC. The second voltage doubler also 1/2 wave rectifies and doubles the 300 volts to 600 volts and adds it to the top of the first doubler output resulting in a 1200 volt potential at the top of the voltage divider circuit. The voltage divider consists of a string of zener diodes. The CRT cathode and focus grid voltages are tapped off the voltage divider. The high voltage "ripple clipper" eliminates any noise spikes generated in the voltage divider zener string.

2.4.9.2 Voltage Doubler Circuits (Figure 2-17)

Primary power for the voltage doublers is a 300 volt square wave (300 VSQW) received via terminal 2 from the 11-12-13 winding on transformer T1 (Figure 2-14). T1-11 is the high end of the 300 volt winding and T1-13 is the return which goes to ground via current sensing resistor R7. (The current sensing was previously described in paragraph 2.4.8.6.3.)

The first voltage doubler is comprised of capacitors C2 and C3 and diodes CR4 and CR5. The 300 volt peak square wave (+300 to -300 volts) is applied to C2. When the input goes to +300 volts, the voltage drop across C2 cannot change instantaneously. Therefore the other end of C2 goes positive which also turns CR5 on allowing current to flow from C2 through CR5 to ground until the square wave goes to ground. When the input square wave goes negative to -300 volts, again the voltage drop across C2 cannot change instantaneously. Therefore the diode side of C2 has a potential of -600 volts. At the negative potential CR5 is shut off and CR4 is turned on. Current flows from ground through C3, through CR4 to C2. The actual voltage at the junction of C3 and CR4 will be an average until, through applications of the 300 volt square wave, the level is built up to -600 volts (less circuit losses).

The second voltage doubler is comprised of capacitors C1 and C2 and diodes CR2 and CR3. This voltage doubler operates in the same manner as the one described above except that the return is to the -600 volts instead of ground.

The 300 volt square wave is applied to C1. When the input applied to C1 goes positive (+300V), CR3 conducts through C3. When the input goes negative (-300V) CR2 conducts charging C4 in the manner previously described. However, since the reference point is -600 volts, the junction of CR2 and C4 is built up to approximately -1200 volts through application of the 300 volt square wave. Due to circuit losses, the voltage actually does not reach -1200 volts but is around -1000 volts which is applied to the top of the voltage divider via resistor R1.

2.4.9.3 Voltage Divider Circuit (Figure 2-17)

The voltage divider is comprised of zener diodes CR7 through CR12. The zener string divides down the voltage applied to the top of the string to various system levels and regulates for approximately 930 volts. Diodes CR6, CR8 and CR9 are 68 volts zeners. However, for this circuit they clamp at 60 volts because the current is very low. Diode CR7 is a 150 volt zener and CR10, CR11 and CR12 are 200 volt zeners. Starting at the bottom of the zener string and considering termina 12 to be essentially ground, there will be -200 volts at the junction of CR12 and CR11, -400 volts at the junction of CR11 and CR10 and -600 volts at the junction of CR10 and CR9. There will be -660 volts at the junction of CR9 and CR8, -720 volts at the junction of CR8 and CR7, -870 volts at the junction of CR7 and CR6, and -930 volts at the top of the divider string.

The -870 volts at the junction of CR6 and CR7 is applied to the cathode of the CRT. The 60 volts across CR8 is applied across the FOCUS potentiometer R6. The arm of R6 is applied to the focus grid of the CRT. The focus grid is an extra grid in the CRT which aids in keeping the electron beam narrow (spot size small). The 60 volts across CR6 is applied across CUTOFF potentiometer R4 and resistor R3. Approximately 20 volts is dropped across R3 thus R4 provides a 40 volt swing to establish the cutoff bias on the grid. The cutoff voltage will be described in more detail in paragraph 2.4.9.5.

The voltage doubler provides a convenient way of getting high voltage but the square wave input tends to produce noise in the zener string. Capacitor C7 filters the voltage applied to the cathode and prevents noise from appearing on the cathode. Capacitor C6 filters off any AC noise on the grid bias. Capacitors C5 and C9 filter noise spikes on the zener string and also couples large spikes to the ripple clipper circuit.

The heater (filament) of the CRT is tied to 12.5 VAC. The cathode is at approximately -900 volts. Since the heater and cathode are physically close internally in the CRT, there could be arcing between the elements because of the large voltage difference. To prevent arcing between the elements from occurring, one side of the heater is tied to the cathode. Thus the 12.5 VAC rides on top of the -900 volts. The 12.5 VAC is obtained from the 14-15 winding on transformer T1 (Figure 2-14).

2.4.9.4 Ripple Clipper Circuit (Figure 2-17)

The ripple clipper circuit consists of transistor Q1, diodes CR15 and CR16, and associated components on component board assembly A1. Ideally, the cathode voltage at the junction of CR6 and CR7 is a clean DC voltage. However, there may be spikes on it which would represent a signal. Should a spike appear it is applied via C5 and R8 to the base of Q1 which amplifies the signal. The amplified signal is applied to the bottom of CR12 causing the whole zener string to "float". The noise is thus transferred from the top of the string to the bottom where they are close to ground and are only a few volts compared to the -900 and thus will not affect operation. Resistors R10 and R11 establish the bias for Q1. Diodes CR15 and CR16 acts as a limiter. When the system is turned on, extremely large noise spikes may appear. CR15 and CR16 "clip" these spikes.

2.4.9.5 DC Restorer Circuit (Figure 2-17)

The DC restorer circuit consists of capacitor C8, diode CR13 and resistor R5. The composite video (CMPST VIDEO) signal from the video amplifier is applied to the CRT signal grid via capacitor C8. The signal is called composite video since it contains both the video information and the square wave blanking pulses. The DC restorer operates as follows. When the square wave voltage input to C8 goes positive, the capacitor cannot change instantaneously, thus the R5-CR13 end of C8 goes positive also. Capacitor C8 starts discharging through R5 but at a slow rate due to the large resistance (10 megohms). When the input goes negative, C8 charges through diode CR13. The charging rate is fast because CR13 is forward biased thus offering a low impedance. Therefore the voltage on C8 builds up and a potential is developed across R5 making the CRT grid more positive than the cutoff bias established by the setting of potentiometer R4 (CUTOFF). The DC voltage on the arm of R4 is set to establish the minimum brightness of the display. R4 is adjusted to assure that the CRT has a very faint raster when the system INTENSITY control is turned down (fully counterclockwise). When the INTENSITY control is turned up increasing the CMPST VIDEO signal amplitude, the DC restorer circuit provides a DC voltage that makes the grid more positive making the CRT display brighter. Thus the brightness of the display depends on the setting of the INTENSITY control and is controllable by the operator. Diode CR14 prevents forward bias on the grid by preventing the grid from going positive in relation to the cathode and drawing current.

SECTION III

PROBLEMS ENCOUNTERED

3.1 GENERAL

This section of the report will briefly describe the major problems encountered during the design, fabrication and test phases of the Night Vision Sight and the resolution of these problems.

3.2 CRYOGENICS

3.2.1 COOLANT CARTRIDGE

The original Prime Item Development Specification (PIDS) directed that the total weight of the NVS including battery pack and sufficient coolant to operate the NVS for 20 operating cycles (an operating cycle is defined as five minutes on and five minutes off) could not exceed 10 pounds. Early in the program an analysis of the NVS cryogenic system and its compatibility with the cycling requirement was completed and it showed that the cycling requirements were not consistent with a weight limitation of 1.0 pound for the cooling system, PBEC's assigned target weight for the valve, a filled cartridge, tubing and cryostat. An analysis of the NVS cryogenic system is presented in Appendix 1.

In order to meet all the requirements of MIL-R-8573 including the "Gunfire" test and meet the assigned weight limitation, a 5 cubic inch cartridge was decided upon. This cartridge operated the NVS for a total of 7 cycles.

In the fall of 1972 the requirement for gunfire tests was deleted and the cartridge hydrostatic cycling requirements were reduced to 9000 cycles and 1000 hydrostatic pressure cycles. This reduction enabled the cartridge vendor to reduce the wall thickness of the bottle resulting in a larger 7 cubic inch assembly with a filled weight of 0.59 pound, the same as the previous 5 cubic inch cartridge. This larger cartridge added 2 cool-down cycles to the previous capability of 7 for the 5 cubic inch cartridge and it will continuously maintain proper detector operating temperature for over 2 hours for a one shot operation.

In June of 1972 a contract was awarded to Arde Inc., of Mahwah, N.J., for the development of a lightweight, metal lined filament wound tank. The metal liner of the composite material would be made of the cryoformed stretch process and the outer material would be glass fibers wound with an initial tension in successive layers to achieve very low stress in the steel liner when the tank was at working pressure. During the period liaison with Arde was directed toward familiarizing them with the 7 cubic inch cartrdige and valve design.

A paper design was submitted to PAVSC in September of 1972 by Arde for a composite tank. Further action was postponed at this time because cost and delivery of a prototype unit was not compatible with the contractual requirements of the program.

A chart of the various types of tanks is presented in Figure 3-1.

3.2.2 CRYOSTAT FREEZE-UP

No cryostat problems were experienced until PAVSC received the first shipment of charged 7 cubic inch cartridges from TAVCO. Prior to this the NVS systems were being operated using 5 cubic inch tactical bottles and 20 cubic inch test bottles obtained from W. Kidde and charged with coolant gas utilizing the PAVSC designed charging station. Prior to charging the tactical bottles they were thoroughly cleaned. The charging station incorporated gas dryers and filters and a time tested procedure was followed while charging the bottles.

When factory filled cartridges from TAVCO were first used an occasional cryostat freeze-up occurred. TAVCO was contacted and they assured us that they utilized dryers in their charging system. A program of bottle cleaning and charging station maintenance was established at TAVCO and the freeze-up problem disdipated.

During the training phase prior to DT II tests some freeze-up occurred out on the range. These failures were attributed to extremely high humidity conditions coupled with the fact that the trainees were prematurely removing pressurized cartridges from the NVS causing a condensation of moisture on the valve bottle piercing mechanism. The frequency of freeze-ups were reduced considerably as the trainees became more experienced in NVS operation.

During DT II testing occasional cryostat freeze-ups persisted. An in-depth investigation was initiated at PAVSC to determine the effects of water in the refrigerant on cryostat operation.

Injection of only .002 cc of water into the line feeding a test cryostat caused somewhat erratic operation. Injection of an additional .004 cc caused very erratic operation and at one time apparently caused the cryostat demand valve to freeze in the wide open position.

After drying the cryostat, the operation was normal. An experimental dryer-filter was then installed in the feed line to the cryostat. Water was injected ahead of the dryer in successive quantities of .005, .005, .005, .015, and .030 cc for a total cumulative amount of .060 cc. With minor brief exceptions, the system started and operated normally after each addition of water.

The dryer-filter was removed and .005 cc injected. The system started and operated erratically with low flow rate. After being turned off for an hour, it started and ran erratically but after a few minutes it stabilized to normal operation.

TANK COMPARISON

	ORIGINAL BUY	FINAL BUY		PROPOSED COMPOSITE DESIGN	
SPEC REQUIREMENT	MIL-R-8573	NO GUNFIRE REDUCED CYCLE	NO GUNFIRE	MIL-R-8573	MIL-R-8573
CHARGED WEIGHT (LBS.)	.59	.59	1.04	.59	.83
VOLUME	5	7	15	1 7.7/9.6 2	15
MATERIAL	4130 STEEL	4130 STEEL	4130 STEEL	CRYOFORMED 304 ST. ST. S.901 FIBERGLASS	
COOLING CYCLES 5 MIN ON/5 MIN OFF (75°F)	7	9	21	1 10/13 2	21
COOLING CYCLES 5 MIN OF/30 MIN OFF (75°F)	4	5	12	6/7	12

1 WITH EXISTING MACHINES
2 WITH IMPROVED MACHINES

TP2452

FIGURE 3-1

Although this was a very limited test on only one cryostat, it was concluded that the use of even a small dryer would greatly reduce the problems with moisture contamination in the refrigerant.

The experimental dryer/filter weighed about 12 grams. It had a theoretical moisture capacity of 0.23 gram, but it would normally be used to about one half of theoretical, or about 0.12 gram. The specified maximum moisture content in the NVS cartridge is 5 ppm by weight, or about 0.0005 gram per 7 cubic inch cartridge. Moisture can also be injected into the system from condensation in the neck of the cartridge and the valve probe. It was assumed that an average of 0.001 gram of water is injected per cartridge use and therefore the dryer-filter should last for the operating time of 120 cartridges.

Microscopic inspection of the refill mechanism taken from several bottles that had been recharged a number of times revealed a build-up of moisture in various recesses. The recharging procedure was revised to include more thorough cleaning of the various refill mechanisms of the cartridge and the purging duration was lengthened. The revised procedure was instituted near the end of DT II testing at Ft. Benning and no more cryostat malfunctions were experienced.

A vacuum/purge system was installed in a charging station and the filter-dryer installed on several systems. This hardware was used, and the revised cleaning procedure followed, during CADRE training prior to OT II tests and all during OT II tests in Germany. No cryostat malfunction has since occurred. The in-line filter-dryer is now incorporated into the NVS.

3.3 BORESIGHT

3.3.1 BORESIGHT RETENTION

In August of 1972, "Early Look" test firings were conducted at Redstone Arsenal. During the test minor problems were encountered in maintaining boresight between the NVS, S/N-1, and the Tracker. It was thought to be due to the forward hold down latch not having sufficient force. A temporary field fix was installed and seemed to help but on return to the plant the real difficulty was found to be due to interference between the boresight saddle in the NVS and the bottom sheet-metal on the Tracker. The saddle was modified and the interference was eliminated.

In late September during "Early Look, Phase 2" testing at MDAC/TICO while performing compatibility tests of the NVS and training equipment a boresight instability between the NVS and the Tracker was noted. This caused the Tracker to aim consistently one to two milliradians high.

The effect was attributed to the combined forces of the gunner's hand pulling down on the trigger mechanism and the launch recoil causing the Tracker to shift aft in its mount, in turn, resulting in a flexing of the rear connector mounting plate and a lowering of the rear of the Tracker. When the gunner would release the hand pressure, the Tracker would return to its normal position and boresight would be re-established.

In late September, a stiffener plate was added to the rear connector linkage and PAVSC was confident that the problem was corrected. A verification test was tentatively scheduled for early October at MICOM.

During the first portion of the handling tests conducted during the week of 2 October at MICOM a short evaluation test for the boresight shift problem was conducted. The test set up included a Launch Effects Trainer, Monitoring Set, a Beacon, a Tracker and a NVS. The MDAC gunner was used since he was the gunner at the time the problem was discovered. There was no detectable shift but the data was not conclusive because there was no finite aim point to determine a small angle boresight shift. Further evaluation was scheduled during the tracking tests in November.

The data taken during the tracking tests, slug and guided flight firings in Nov-Dec indicated that there were no boresight shifts beyond the specified boresight requirement of 0.5 milliradian between the NVS and the Tracker.

In an attempt to determine the cause of a 6 milliradian miss of a missile during guided flight tests at Ft. Greely, Alaska in January of 1973, it was found that a 0.5 milliradian error could be introduced between the Tracker and the NVS by pulling down very hard in opposite directions on the Tracker and NVS.

In early April Boresight Verification Device (BVD) evaluation tests were conducted at TICO. The system was boresighted using a target of opportunity (jeep). The boresight was then verified with the BVD. The difference in the boresight was 0.16 milliradian. The BVD was removed and the LET fired three times. The BVD was again positioned on the system. The boresight had shifted, the shift noted was within specification. An additional 15 to 20 firings were conducted with a boresight check made after the firings. Boresight shift was again noted. The shift obtained was within specification.

In late April and in May a NVS training program for TECOM personnel was conducted at Redstone Arsenal. At the conclusion of the training three guided missiles were fired by the students and boresight shifts were reported after all three flights. Immediate action was taken by PAVSC and a series of boresight retention tests were initiated; shifts reported as a result of the guided flight launches were overstated by a factor of 3.6 due to a misunderstanding of the visible spot size the Boresight Verification Device presents to the Tracker (1/6 mr vs. 0.6 mr).

On 7 June PAVSC ran a series of retention tests utilizing Tracker S/N-111, NVS S/N-7, BVD S/N-1 and the GFE Launch Effect Trainer. Ten rounds were fired through the LET and shift data recorded after each five rounds. Additional shift data was recorded using simulated shock. Boresight repeatability data was also recorded as well as BVD spot size analysis and accuracy verification. The maximum shift obtainable was less than 0.2 milliradian, well below maximum allowable.

During guided flight tests at WSMR (DT II tests) during August and September boresight shift was detected on several occasions utilizing the Boresight Verification Device. It was determined that a gunner could pull the Tracker off boresight as he pulls the system back and down while preparing to fire the DRAGON round. A makeshift brace and shim was added to the test unit and the boresight shift was reduced to below maximum limits. Several guided flight misses were attributed to this problem. PAVSC again initiated investigative action.

On 20 October PAVSC visited WSMR along with NVL representatives to witness a demonstration of the boresight shift. WSMR test personnel showed that under the heavy pull down conditions (which some gunners exert), a boresight shift can occur. Forces were estimated to be in the 50 to 70 pound range in contrast to the 20 pound limitation listed in the NVS/XM47 DRAGON (PAVSC/McDonnell) Interface Specification (reference GSD Report No. 464). All previous PAVSC tests which showed boresight retention and mechanism to be satisfactory were checked to the NVS/McDonnell Interface specification level.

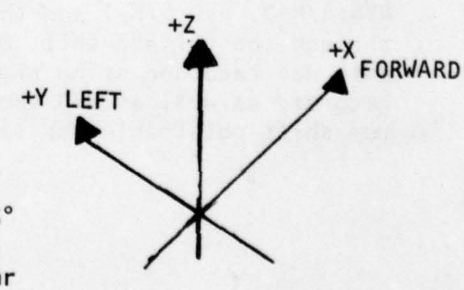
The temporary fixes used at WSMR (shims and a block of metal as wedges) could not be used as equipment fixes. Therefore, an extensive effort was put into resolving boresighting problems uncovered at White Sands Missile Range. Three independent solutions were developed during the course of the month, detailed and fabricated in PAVSC Shop. Two of these possible modifications were tested and found to be improvements over the existing design; but it was deemed they did not reach the level PAVSC wanted to achieve as a fix to this problem.

On 14 November PAVSC conducted boresight stability and retention tests on NVS S/N-10 which had been modified to incorporate "Mod 3" of the proposed boresight mechanism redesign. "Mod 3" consists of: removal of the Tracker connector latching mechanism and the front Tracker latch; addition of a simplified connector bracket to hold the Tracker mating connector in a fixed position; the addition of two Tracker pin guides to the rear frame member and two guides to the front boresight saddle; the addition of a boresight cradle locking mechanism to the boresight cradle.

The "Mod 3" system was chosen over the other two proposed modifications because it simplified the mating of the Tracker and the NVS (especially under tactile conditions), offered the most stable mechanism and reduced weight of the NVS by about 0.1 pound.

Procedures and results of the tests for boresight shift conducted on 14 November are as follows:

S/N-10 NVS, Tracker 111, S/N-1 BVD



1. Boresight Tracker to NVS using BVD

2. Push against trigger guard of Tracker 15° off vertical down and rear with 100 lbs. Tracker XH moved up approximately 1/12 mr and stayed.

3. Pull on Tracker trigger guard in -y direction with 50 lbs. Tracker XH moved right less than 1/12 mr and returned.

4. Push in +y direction with 50 lbs. No detectable movement.

5. Push in -z direction with 100 lbs. Tracker XH moved down less than 1/12 mr and returned.

6. Push in -x direction with 100 lbs. Tracker XH moved left approximately 1/12 mr and stayed.

At this point the Tracker XH was up and left about 1/12 mr. The Tracker was re-boresighted to the NVS to 0 - 0.

7. Step (2) was repeated. Tracker XH moved right and down approximately 1/12 mr and stayed.

8. An operator sat under the tube and applied typical maximum firing pressure to Tracker trigger and NVS. No detectable motion was observed.

The tests were repeated on 15 November using NVS S/N-13, Tracker S/N-111 and BVD S/N-1 as follows:

1. BS Tracker to NVS using BVD to 0 - 0.

2. Repeat step (2). Tracker XH moved down and left less than 1/12 mr and stayed.

3. Repeat step (3). Tracker XH returned to center and stayed.

4. Repeat step (4). Tracker XH moved down approximately 1/12 mr and left about 1/6 mr and stayed.

5. Repeat step (5). Tracker XH moved down about 1/6 mr and returned.

6. Repeat step (6). Tracker XH moved left about 1/3 mr and returned.

At this point the Tracker XH was down about 1/12 mr and left about 1/4 mr. The Tracker XH was re-boresighted to the NVS to 0 - 0.

7. Repeat step (2). The Tracker XH went up about 1/3 mr and returned to 0 EL and about 1/12 mr right.

8. Repeat step (8). No detectable movement of the Tracker XH was observed.

On 19 November PAVSC and NVL personnel traveled to MDAC/TICO, Titusville, Florida to demonstrate the "Mod 3" boresight fix and to test NVS systems #10 and #13 to a NVL generated test plan. Gunners from MICOM, WSMR and MDAC participated in the tests. The test results were very favorable. Any detectable boresight was less than 0.5 mr under all conditions of mating and remating, LET firings and maximum gunner pull under static conditions.

Favorable comment was received regarding the ease of installation of the Tracker to the NVS compared to the present method. The gunners quickly developed techniques to position themselves to apply the force required to engage the Tracker guide pins with the NVS squeeze guides and lock assembly.

Based upon these results six systems were returned from Ft. Benning DT II testing for retrofitting and were re-inserted into the DT II operation in December. Eventually four more systems were modified to incorporate this improvement and all ten systems were used during OT II tests in Germany. Some minor problems were experienced with the Cradle Lock Knob roll pins and the retrofit of improved parts was accomplished at PAVSC and in the field.

3.3.2 IMPROVED BORESIGHT STUDY

During the early design stages of the DRAGON Night Sight Engineering Test Models, information relevant to the tracker indicated that a boresight adjustment range of 1.5° off-axis would be required to compensate for misalignment of tracker optical axes to its mounting pins.

Assuming the Night Sight might require another 0.5° for tolerance variations, the boresight mechanism was designed to provide at least 2° off-axis compensation.

Later in the project activity, new information about the tracker indicated its alignment was more accurate; namely, $\pm0.3^\circ$ in elevation and $\pm0.7^\circ$ in azimuth as minor and major axes of an elliptical off-axis contour.

This data opened the possibility of almost halving the required correction and would eliminate the coarse and fine elevation correction method now used. This means a simpler mechanism. The desire also was expressed that captivation of all control knobs be accomplished, operation of the knob be made easier if possible, and locking of the boresight setting be more positive. As a result, the contract was modified in March of 1973 to include a study and experimental activity to improve the boresight mechanism.

A delay in the completion of this study occurred when testing at White Sands revealed that Operator manual forces imposed even higher loads than specifications called for and caused occasional boresight shifts. This required further examination, experimentation, and tests with regard to the basic boresighting design and ultimately negated some of the experimental work carried out on the original design during the early part of the Study Program.

PAVSC Report GSDR No. 660 issued in January of 1974 described this effort.

A statistical study of the boresight adjustment range required indicated that the adjustment can be decreased from two degrees off-axis to approximately one and one quarter degrees, permitting a more simplified and lighter boresight mechanism. This was prototyped and appears satisfactory.

Three experimental approaches (following test results from White Sands Proving Ground) have been implemented to improve boresight retention and the third approach based on wedging the Tracker to the Night Sight has given satisfactory results. The weight of the system has been reduced by about 0.1 pound, and many parts have been eliminated, and the ease of mating the Tracker to the Night Sight has been greatly improved.

This design approach has eliminated boresight shift problems, reduced weight, and simplified mountings.

The above design changes all offer improvements and greater simplicity, and will be incorporated into the "APE" units.

3.4 CHANNEL NOISE

3.4.1 DETECTORS

The first major problem involving detectors occurred during the testing of NVS S/N-1 in June of 1972. A number of channels developed noisy or intermittent output signals. The problem was traced to the fabrication method used by the detector vendor (Santa Barbara Research Center) to attach external leads to internal element leads. A low temperature solder (183°C) was used to attach the .002 inch external leads to the .003 inch internal leads just outside the ceramic dewar feed-through. When PAVSC, using experienced wire girls and approved wiring methods, attempted to attach a wiring harness to the detector leads some heat from the soldering iron would travel down the .020 inch lead and melt the solder at the junction of the .003 and .020 leads, in spite of heat sinking. This resulted in a series of intermittent or open connections. This problem existed on the first seven detector assemblies received from SBRC. Various methods were used to repair these units including welding, where possible, high temperature (300°C) resoldering as the next best repair and low temperature resoldering fortified by an epoxy (Torr Seal) overcoat as a last resort. The potting foam was stiffened to add more support to the lead structure and Torr Seal was added to the .020 inch leads where they immerged from the potting surface for additional rigidity. SBRC, at this point, concluded that their initial design was fragile and that, in most cases, the broken lead problem was a product of the design. All future units incorporated welded joints and a Torr seal bead where the leads immerged from the potting compound. No further problem of this nature occurred for the duration of the program.

In the spring of 1972 PAVSC contracted Optoelectronics, Inc., of Petaluma, California, for a quantity of detectors. The contract was canceled in August of

1973. In the interim seven detectors were delivered by Optoelectronics and for various reasons all of them failed at one time or another. The three main problems encountered were soft vacuum, inability to withstand specified shock environment and uniformity of response. In March of 1973, in an effort to help Optoelectronics solve their detector fabrication problem, PAVSC retained the services of a specialist in this field and stationed him at the vendor's facility for an indefinite period. This support was terminated in August of 1973. Since that time period, conditions at Optoelectronics have changed and they are in a position to deliver 48 element TE Cooled Detectors.

During the course of DT II testing four Equipment Performance Reports (EPR's) were written against the NVS that were directly related to detector malfunctions. Two against NVS S/N-20 were traced to open and intermittent elements internal to the detector. The detector in S/N-13 developed a short circuit between the array common lead and the assembly mounting ring external to the dewar envelope. The detector in S/N-25 developed a soft vacuum and was returned to the vendor for analysis of the failure.

Generally channel failure attributed to the detector has turned out to be broken leads inside the dewar assembly in the area of the interconnection between the InSb slug and the sunburst disc or the interface between the sunburst disc and the dewar internal wiring. Causes for vacuum loss are not as well defined and this problem is under continued investigation by SBRC.

3.4.2 FIELD EFFECT TRANSISTORS (FET)

In June of 1972 concurrent with the detector problems discovered while testing NVS S/N-1 problems were also encountered with the bias boards, which apply electrical biasing to the detector elements, in the form of a quantity of low reliability FET's. The FET vendor was contacted and more stringent burn-in procedures were initiated as well as an in-house screening program to weed out potential failures. An alternate source was developed and these units proved to be substantially more reliable. One rash of FET failures was traced to an inexperienced wiring and assembly girl who failed to properly heat sink the FET's on installation. In-house corrective actions were taken to avoid recurrence.

3.4.3 PREAMPLIFIERS

In August of 1973 during DT II testing at Ft. Benning, Ga., an EPR was written against NVS S/N-26 for a channel failure, two channels removed from the horizontal cross hair. An investigation of the failure revealed that a dual amplifier microcircuit manufactured by Collins Radio Co., had failed. This particular type of microcircuit was referred to as the "-20" type. In the ensuing four months seven more failures were attributed to the "-20" microcircuits, all at Ft. Benning.

A meeting was held at PAVSC on 15 November with representatives of Collins Radio Co., attending. The purpose of the meeting was to review the failure of the

"-20" preamplifier microcircuits and define corrective action. A review of the efforts to date revealed the following:

1. The original "-10" mircocircuits supplied by Collins exhibited no problem when used in the NVS preamplifiers.

2. Down-stream in the production of "-10's", Collins changed vendors of an operational amplifier used internally in the "-10". This opamp exhibited an improved high frequency response forcing Collins to restabilize the feedback circuit in the hybrid. This resulted in critical circuit performance that evolved as oscillations at a very high frequency in some hybrids. This oscillation was not detectable in PBEC incoming electrical inspection and was eventually detected in final test. Degradation in picture quality was limited to a slight smearing effect under certain contrast settings.

3. These "-10" hybrids were not physically different from the original non-oscillating "-10" units. Oscillating "-10" units were replaced by non-oscillating units when electrically detected during the test phase.

4. Collins then redesigned and restabilized the hybrid. In the process, a stabilizing capacitor was changed to a larger valve (also a vendor change). The new hybrid was called a "-20" version of the microcircuit. This version was used in preamplifier boards that were installed in later systems, predominately the Ft. Benning systems.

5. Extensive failure of the "-20" microcircuits developed as previously reported.

A review of the investigation of eight hybrids returned to Collins previous to this meeting revealed the following:

S/N	Failure Mode	Analysis
101040	No output pin 22	Could not verify
150761	No output pin 16	Unit lost by CRC
160161	No output pin 22	C1 leaky
160316	No output pin 22	C1 leaky
270058	No output pin 22	C1 leaky
160159	No output pin 16	C3 leaky
070447	No output pin 22	C1 leaky
150386	No output pin 22	C1 leaky

Units S/N 0161, 0316 and 0058 were tested at room ambient conditions and subjected to temperature/voltage cycling tests. Leakage verified under all conditions.

Units S/N 0447 and 0159 were verified at room ambient conditions; however, after re-liding, the two pieces functioned normally. They were temperature/voltage cycled (85°C to -40°C) and continued to function normally. It should be noted that this particular de-liding process requires the application of heat to break the bond and allow the lid to be removed.

S/N 0386 verified at room ambient conditions, was sent to CRC's components group for analysis of the capacitor. This group had facilities for mechanical removal of the lid.

Varadyne Corporation, manufacturers of the suspect capacitor, was called in by CRC to assist in the investigation and analysis of problems. At least two possibilities for the cause of leakage were being investigated.

1. Voids in the capacitor dielectric causing leaking paths to develop.

2. The leakage could be external to the capacitor, caused by the protective film applied to the hybrid package prior to application of the lid.

The leakage being external to the capacitor was supported somewhat by the fact that one of the units returned to CRC on October 11 exhibited leakage at room ambient and during temperature/voltage cycling tests. However, after removal of the protective film, no leakage was present and the unit functioned normally.

Following is a defect summary of the fifteen pieces that were returned to CRC to this point.

Qty	Defect
1	Op Amp U1, 2 volt offset
1	Unit lost by CRC
3	Could not verify
10	Leaky capacitor, C1 or C3

NOTE: C1 and C3 are identical caps; one for each of the dual amplifiers.

Result of the meeting held on 11-15-73 at PAVSC to resolve the subject item failures at Ft. Benning disclosed the following.

Reported failures, of the Rev. E type, had been confined primarily to the systems undergoing test at Ft. Benning. Failures occurred between 50 and 120 hours of operation. Initial failures were reported in September.

Collins investigated the problem using infrared, OJ spectro analysis, microscopic photography and other techniques. In addition, they called in the services of the Sandia Corporation as of 11-14-73 to assist in isolating the basic fault. They encountered the same symptom in another major program. Approximately six personnel from various groups spent 60 - 80 percent of their time in an attempt to solve this matter.

The "-20" version of this hybrid contained a 100 PF Varadyne capacitor in a higher impedance application as opposed to a 10 PF capacitor in a lower impedance application in prior revision levels (-10's). Circuit performance in the "-20" version was very sensitive to leakage. Collins encountered from 10 - 18 picoamperes of leakage in suspect capacitors which normally would not be cause for concern. Examination of the suspect Varadyne capacitors revealed the existence of a vaporized epoxy coating on the surface and excessive voids and delaminations. Collins obtained capacitors from alternate sources and hybrids incorporating these capacitors were fabricated.

On 28 November PAVSC visited Collins Radio Company with the following results:

Further analysis, since the 11-15-73 PAVSC meeting, revealed that leakage was in the nano amp range and not pico amp as originally indicated by Collins. Leakage resistance as low as 200K ohm had been observed as opposed to a spec of greater than 180 megohms. Leakage resistance less than one megohm would result in 0.5 volt offset and catastrophic clamping.

Collins indicated that with 180 megohm resistance offset was +30 mV, with 15 megohm resistance offset was +150 mV, with 1 megohm resistance off-set was +490 mV and gain decreased 17 dB.

Collins also advised that the original "010" version with the 10 pF capacitor and the original National chip did not present a problem. When National improved the high frequency response of their chip, Collins had to reduce the 10 pF to 7 pF resulting in critical circuit performance that would break into oscillations under some conditions. They subsequently redesigned the circuit using a Varadyne 100 pF capacitor in the feedback loop. This version was not susceptible to low level leakage as originally indicated by Collins.

Collins exhausted both their own and neighboring TI's analysis capability in attempting to determine the media that combines with the voids in the Varadyne capacitor and results in the intermittent leakage condition. They collected atmospheric samples at 12 separate locations in their clean room. Both atmospheric samples and suspect capacitors were analyzed by the Sandia Corporation using Ion Microprobe and X-ray diffraction techniques.

Collins had the Varadyne capacitors in stock since the last quarter of 1973. Physical Acceptance criteria was:

1. No delaminations exiting the body of the capacitor.

2. None in excess of 50 percent of capacitor length.

3. No voids or delaminations within 20 percent of the end terminations.

Barium Titanate is the insulating material and is somewhat porous.

Varadyne capacitors removed from defective hybrids were cross sectioned, examined under 50X stereo microscopes and found to have delaminations or voids in excess of acceptance criteria.

As interim corrective action, Collins reprocessed all existing units using a higher quality Viclan capacitor and an additional vacuum bake-out.

Final version utilized ATC capacitors which contain a proprietary porcelain glass, super cooled, non-crystalline insulation material. Initial deliveries were not available until March 1974.

Collins exhibited a high confidence level that capacitor replacement would completely resolve the problem independently of the possible existence of an atmospheric contaminant. Sandia continued their analysis in this area and Collins continued to scrutinize their bake-out, leakage, and other processes that might possibly contribute to this problem.

A decision was made, through NVL, to replace all of the preamplifier cards in system returned from Ft. Benning with cards containing only "-10" non-oscillating hybrids pending final resolution of the problem.

In January a small number of the new hybrids, labeled "-30" units, were received at PAVSC and they were immediately installed on spare preamplifier boards. Subsequent test results indicated that the units were stable and that performance was satisfactory. Sufficient quantity was not available to install on units scheduled for OT II tests in Germany but all spare preamplifier cards and units to be retrofitted would incorporate the "-30" hybrids.

3.5 BATTERY CONNECTORS

In July of 1973 an EPR was generated at WSMR pertaining to a battery failure. It was reported that a battery became very hot immediately after being installed in a Night Vision Sight. In the completion of DT II testing at WSMR and Ft. Benning some 15 EPR's were generated against batteries and the male battery connector in the NVS main frame.

Previously, on or about 4 April 1973, the Reliability Demonstration Test of the Battery and Housing Assembly was successfully completed with no failures registered after 600 cumulative insertions and withdrawals of a battery into a NVS.

After an intensive investigation of the problem it was determined that the durometer of the rubber used in the male and female connectors was too low. This soft rubber allowed the male connector to flex excessively to the point where, under a slight amount of misalignment normal to the battery/NVS interface, the lead contact ring in the male connector would hook the lead contact ring in the battery's female connector forcing the two battery contact rings together resulting in a short across the battery cells. Heavy current would flow in the battery causing heating of the internal interconnections followed by smoke from burning potting compound. Sometimes, when withdrawing the battery from the NVS, the rings would hook together and the outermost contact ring on the battery would be pulled out of the connector body.

In addition to the contact ring problem the flare at the tip of the male connector, put there to enhance the self-cleaning feature of this type connector, would wear off after a number of insertions and withdrawals.

As a solution to these problems the durometer rating on both the male and female connector was increased from 60 ± 5 to 75 ± 5, and the male connector was reshaped to eliminate the flare tip. A number of new connectors were ordered and several were installed in systems assigned to the OT II tests in Germany.

Near the end of the OT II troop training phase, during an LSS familiarization firing exercise, one NVS system developed an intermittent condition. The problem was traced to the interface between the battery and the NVS, more specifically to the new type of male connector. Closer investigation revealed that one of the connector leads was fractured internal to the connector assembly. The same problem occurred on another system. In both cases the new type connector was installed in the field and the test personnel concluded that the connectors were damaged during installation. Further tests revealed that although the improved connector, incorporating the higher durometer rubber and a redesigned tip shape, solved the previous problem of excessive war and contact ring displacement, loss of continuity through some connectors after moderate usage developed.

Initially, it was felt that the problem was excessive wicking of a soldering joint (causing a loss of joint flexibility). This condition did exist on numerous vendor supplied connectors and could cause an installation failure; however, it was also determined upon return of the units from Germany that several of the contact rings were undersized. Inspection was done on a sampling basis in the past, and we are now performing a 100 percent inspection on all connectors of this type. In addition, PAVSC ran a series of insertion tests on one set of the latest connectors commencing in June of 1974. Through the following September over 2000 insertions were performed with no sign of wear or intermittent operation. This data indicates that the basic connector performs satisfactorily when fabricated, inspected, installed, and lubricated properly.

SECTION IV

TEST PROGRAM

4.1 GENERAL

The field test program on the AN/TAS-3 started with the first "Early Look" exercise at MICOM, RSA, Huntsville, Alabama, in August of 1972 and ended with the completion of Operational Test II, conducted by OTEA at Hohenfels, Germany, in May of 1974. A synopsis of each event, in the form of excerpts from trip reports, is presented in this section. Table 4-1 lists all tests and a summary is provided in Paragraph 4.3.

4.2 MAJOR EVENTS

4.2.1 EARLY LOOK TEST, RSA

PAVSC personnel spent the week of 21 August 1972 at Redstone Arsenal, Huntsville, with NVS #1 for the firing of five DRAGONS. Eleven McDonnel personnel, armed with a detailed, step-by-step test plan, assumed direction of the test. Extensive instrumentation alignment and checkout, and several target flare failures consumed the largest part of the test range time.

The first night was given over to checkout of systems. Dense fog obscured targets completely at 58.5 percent maximum range, both IR and visible (jeep headlights). The same targets were visible in excess of 38.5 percent range with the IR system. This situation did not re-occur during the rest of the week.

NVS was used as the primary sight for direction of one slug (no missile flight), and two gunner-manned missiles. A misfire on the slug delayed the first shot until 2300 hours, Wednesday, at which time the NVS gas valve failed, further delaying the shot until the next evening. One missile shot at 100 percent maximum range was unsuccessful due to a faulty guidance wire. The other successfully hit a tank target at 58.5 percent maximum range with a live warhead.

Film was taken through the NVS eyepiece during two "tie-down" shots (no gunner). The night sight was not used to direct the "tie-down" shots. The first shot missed; the second shot hit. The "quad-pod" frame used to mount the system is a heavy pipe frame bolted to the concrete pad, but fine adjustment of the electrical tracker error signals was made by McDonnell men "kicking" the pod left or right. Investigation after firing assured there had been no shift of boresight between the NVS and tracker cross hairs. This was verified by NVL personnel.

Arrangements were made through MICOM to have a carrying case bag fabricated at Huntsville from a print supplied by PAVSC.

PARA.	EVENT	LOCATION	DATE
4.2.1	Early Look Test	RSA (1)	AUGUST 1972
4.2.2	Early Look Test	MDAC/TICO (2)	SEPTEMBER 1972
4.2.3	Handling Tests	RSA	OCTOBER 1972
4.2.4	Boresight Fix Verification	MDAC/TICO	OCTOBER 1972
4.2.5	Gunner Training - Tracking Tests & Slug Firing	RSA	NOVEMBER 1972
4.2.6	Handling Tests	Ft. Benning, Georgia	NOVEMBER 1972
4.2.7	Guided Flight Tests	RSA	DECEMBER 1972
4.2.8	Arctic Early Look Tests	Ft. Greely, Alaska	JANUARY 1973
4.2.9	DRAGON Filming	MDAC/TICO & RSA	FEBRUARY 1973
4.2.10	Germany Early Look Tests	Grafenwehr, Germany	MARCH 1973
4.2.11	TOW NVS Tests	EPG Aberdeen & A.P. Hill	APRIL 1973
4.2.12	After Burn/BVD Evaluation Tests	MDAC/TICO	APRIL 1973
4.2.13	DRAGON Night Sight Training	RSA	APRIL 1973
4.2.14	Handling Tests	A.P. Hill	APRIL 1973
4.2.15	Countermeasures Tests	EPG Ft. Belvoir & A.P. Hill	MAY 1973
4.2.16	DT II Tests	White Sands, New Mexico	MAY 1973
4.2.17	Training Program	Ft. Benning, Georgia	JULY 1973
4.2.18	DT II Tests	Ft. Benning, Georgia	AUG 73/JAN 74
4.2.20	Boresight Demonstration	White Sands, New Mexico	OCTOBER 1973
4.2.21	Boresight Verification Test	MDAC/TICO	NOV. 1973
4.2.22	OT II Cadre Training	FT. Benning, Eeorgia	FEB. 1974
4.2.23	OT II Tests	Hohenfels, Germany	MARCH-MAY 1974

(1) RSA - Redstone Arsenal

(2) McDonnell Douglas, Titusville, Florida

Table 4-1. AN/TAS-3 Field Tests

The NVS high pressure gas valve failed in operation and was replaced with our spare valve. The replacement valve had a tendency to shut itself off. A continuing gas flow to the cryostat was temporarily assured by taping the valve handle to the frame in the "ON" position.

A lack of clearance between the bottom of the McDonnell tracker and the main frame of the NVS required greater pressure on the mounting pins of the tracker by the NVS front latch. This was temporarily accomplished by limiting the latch lever to its maximum pressure position with pressure pads between the lever and frame. An increased clearance can be obtained by rounding two corners on our main frame saddle just above the two coarse boresight adjustments.

A problem in mating between the Sanders connectors of the NVS and launch tube was temporarily corrected by shimming the NVS connector approximately 1/16 inch to the rear. Engineering investigated the discrepancy and recommended the addition of .040" of shims to stay nominally within tolerances.

The McDonnell gunner complained that the rear portion of the NVS battery retaining clip pressed into his hand when in the firing position. Human Factors engineering was made aware of this problem.

The gunner was able to use the NVS with the large, 20 cubic inch bottle of Freon without any difficulty, although it did protrude from the rear of the sight. Trouble was experienced in removing the 5 cubic inch bottle (no ejection spring installed). The sight and launch tube had to be lifted and tilted back.

Adjustment of the rubber eyeguard to a comfortable position for each gunner might be made easier with a lubricant to permit rotation. This was the McDonnell gunner's recommendation as it is used on their tracker.

The NVS cross hairs appeared excessively bright and broad when viewed under partially dark-adapted conditions. A point source target, or a small target at medium to extreme range was totally obscured by the cross hair. Engineering was instructed to investigate a reduction in XH brightness.

4.2.2 EARLY LOOK TESTS MDAC/TICO

During the four-day period of 19 September through 22 September 1972 the Early Look tests were continued at MDAC, Titusville, Fla. Purpose of these tests were to determine the compatibility of the Night Vision Sight and the training equipment.

In the course of evaluating the compatibility of the NVS and training equipment a boresight instability between the Tracker and the NVS was noted. This caused the Tracker to aim consistently one to two milliradians high.

The effect was attributed to the combined forces of the gunner's hand pulling down on the trigger mechanism and the launch recoil causing the Tracker to shift aft in its mount, in turn, resulting in a flexing of the rear connector mounting plate and a lowering of the rear of the Tracker. When the gunner would release the hand pressure, the Tracker would return to its normal position and boresight would be re-established.

In late September, a stiffener plate was added to the rear connector linkage and PAVSC was confident that the problem was corrected. A verification test was tentatively scheduled for early October at MICOM.

While handling the NVS during the Early Look tests the shock absorbers came detached from the access cover. MDAC described the method they use to attach the shock pads to the Tracker and these MIS documents were forwarded to PAVSC through NVL. These proven methods were to be incorporated into the NVS fabrication procedures.

4.2.3 HANDLING TESTS - RSA

The first portion of the handling tests were conducted the week of 2 October 1972 at Redstone Arsenal. The tests consisted of a filming program and a field handling exercise. The film was gathered to prepare the training film for the DRAGON NVS gunner. The film data included targets at different ranges, different orientations, different times of night and some data on different environmental (fog) conditions. The field handling was also filmed. The activities included site selection and set up for fire.

4.2.4 BORESIGHT SHIFT FIX VERIFICATION MDAC/TICO

A short evaluation test, for the boresight shift problem, was conducted on 3 October 1972. The test was for the purpose of evaluating the corrective action for the shifting boresight noted in earlier tests. The test set-up included the LET, Monitoring Set, a Beacon, a Tracker and a NVS. The data was not conclusive; however, the boresight stability was markedly improved. The data was not conclusive because there was no finite aim point to determine a small angle boresight shift.

A target board was designed and built by MDAC for use during the tracking tests. The intent was to establish the weapon performance and to subsequently provide the training to give a gunner the capability of picking out a finite aim point. The system presentation did not allow a gunner, who was not familiar with a thermal display, to pick out a finite aim point. The board presented a well defined target and PAVSC felt that it would be a useful training tool.

A brief evaluation of a MDAC designed Launch Blast Simulator was conducted without any definite conclusions being reached because electronic problems were experienced with the breadboard hardware and no obscuration could be generated.

4.2.5 GUNNER TRAINING - TRACKING TESTS & SLUG FIRING - RSA

Three gunners were trained to use the DRAGON Night Vision Sight at Redstone Arsenal from 6 November through 17 November 1972. With the launch effect trainer (LET) and a simulated one second blast obscuration, they were trained to recognize, acquire, select aim point, fire at and track an armored personnel carrier (APC). Varying weather conditions provided differences in thermal signatures for gunner training and study. Gunner tracking data was recorded on magnetic tape and was fed to a computer to determine the night sight hit probability. Night sight to tracker boresight verification and retention data was recorded after every 15 LET firings. MDAC supplied PAVSC with copies of this data. The data showed the gunners had attained good hit probability at all ranges out to 3/4 day sight range.

The three gunners fired a total of 390 LET rounds against MDAC's artificial target and the APC. A total of 425 rounds were recorded for official data in the kneeling and sitting position against the APC moving and stationary, at 1/8, 1/4, 1/2 and 3/4 day sight ranges.

Systems S/N #1, initially used and subjected to 150 LET firings, exhibited problems caused by preamplifier cards coming loose due to not having proper lock down bar. System S/N #7 initially had problems with input power connector, tracker lock down clamp brackets falling off and forward mount tracker interference. System S/N #7 repaired and put into service was subjected to a total of 625 LET firings and 60 hours operation without any malfunction.

During the training it became evident to MDAC and MICOM that training gunners to recognize and fire at various vehicular targets under varying thermal conditions was more of a problem than initially envisioned. They suggested that perhaps NVL should come up with a procedural paper for gunner training. It was PAVSC's opinion that the success of the DRAGON Night Sight would largely depend on how well this training was given. NVL was in agreement.

Slug firing commenced on 26 November. Each of three gunners fired six slug rounds. The tracking data from the slug firings were recorded in the same format as the tracking test data. The gunners complained of longer obscuration than they expected during the slug firings. MDAC recorded the afterburn of the last six slug firings on video tape. Two of the six firings had afterburn which lasted approximately two seconds. The data taken during the tracking test and the slug firings did indicate that there were no boresight shifts beyond the specified boresight requirement between the NVS and the day tracker.

The gunners did have a problem of target recognition on the second night of slug firings. The target presentation (cold target) had no detail that would help the gunner pick out a defined aim point for tracking purposes. The target presentation on the third night was very good. The gunner performance revealed the fact that the performance is proportional to his ability to recognize target detail.

4.2.6 HANDLING TESTS - FT. BENNING

The handling tests were conducted at Ft. Benning on 14, 15, 16 and 17 November 1972. The tests consisted of two teeams making cross country hikes, conducting hunter/killer scenarios and establishing defensive positions. The data was recorded on audio/video tape. The data will be reduced to a report identifying the findings of the tests.

The handling tests were conducted using two different configurations of carrying bags for the NVS. One bag had the protective insert which is designed to carry only the NVS. The other bag was not configured with the insert so the combined tracker/NVS was carried in this bag. Comments were such that further investigations should be made using a bag for both the NVS and day tracker.

4.2.7 GUIDED FLIGHT TESTS - RSA

Guided Flight tests were conducted the week of 11 December 1972. Weather during the entire week was rainy, windy, cold, and overcast resulting in IR target visibility ranging from poor to mediocre. Although the tank target engine compartment was visible at all times and the thermal signatures apparent to a trained observer, the Army gunners had difficulty in selecting an aim point. This problem was compounded by the fact that the gunners have been trained to keep contrast and brightness levels to a minimum to reduce the effects of missile flash and afterburn on the display. While this may be desirable when a strong thermal signature is present, it appears the tradeoff is strongly in favor of contrast and brightness settings to optimize target visibility regardless of where these settings might be. In fact system gain was deliberately increased to enhance visibility of weak targets. Reducing the contrast setting frustrates this design objective.

A total of 8 missiles were fired at an M-48 target using Sight S/N #7, six of which hit the target. The two misses were attributed to obscuration from afterburn. During these firings system 1 was used to video record launch tube afterburn and system S/N #6 was used by secondary gunner/observers to monitor missile flights.

During the boresighting operation for the Guided Flight Tests, an interference between the tracker brow pad and the Night Sight connector engagement bracket was noted. MDAC had already incorporated a design change which eliminated the interference on production trackers.

4.2.8 ARCTIC EARLY LOOK TESTS, FT. GREELY, ALASKA

Early Look tests were conducted at Ft. Greely, Alaska from 9 January through 18 January 1973.

The test plan for the "Quick Look" tests, generated by MDAC, was reviewed and potential schedule changes discussed. USAATC informed us that the NVS tests were to be performed on a non-interference basis with DRAGON EST and that they would cooperate with us to the best of their ability. One major deviation to the plan was that a heated tank hulk would be used for the guided flight test target instead of a tactical tank.

On 9 January S/N #8 was taken out of cold storage. The unit had been stored in its carrying bag for 4 days at a low temperature of -25°F. A functional test was performed utilizing the stored 5 cubic inch bottle and a room temperature battery installed in the Arctic kit. Targets of opportunity, were viewed and the unit performed satisfactorily.

A cycling test was initiated in conjunction with the functional test. At an ambient temperature of +5°F the coolant bottle performed for 16 complete 5 minute on -- 5 minute off coolant cycles. The battery lasted for 13 complete cycles (65 operating minutes). The ambient temperature at the end of the test was +13°F.

The battery that had been stored with the unit was installed in the NVS and the NVS performed satisfactorily. No time duration was recorded.

On 10 January preliminary training on the DRAGON system with the NVS commenced. A contingent of troops under the direction of Major Key were first subjected to a familiarization exercise and video film presentations of various targets as seen through the NVS. A question and answer period was held at the conclusion of the exercise.

The group moved outside where preliminary field handling of the DRAGON/NVS interface and viewing of targets of opportunity through S/N #8 was performed.

It was soon apparent that it was impossible to install the 5 cubic inch bottle and operate the coolant valve when in the firing position while wearing the Arctic mittens. It was extremely difficult to perform these operations while wearing the three finger mittens. However, if the round was lowered to the lap, the gunner could perform bottle and valve handling with the three finger mittens. The assistant gunner would have extreme difficulty installing the 5 cubic inch bottle with the Arctic mittens but could perform this operation with relative ease while wearing the three finger mittens. It is noted here that a 7 cubic inch bottle, being almost 1 inch longer than the 5, would give considerably less trouble while wearing the Arctic mittens. The ambient temperature during this operation was +14°F.

At dusk the test group visited the firing range. S/N #8 was installed on the tripod and the general scene was viewed. The ambient temperature was +12°F and the sky heavily overcast. Attempted to view two vehicle hulks at approximately 300 and 500 meters with success. A dirt road that had been chewed up by tracked vehicles was barely visible. No difference was noted between the distant terrains and the sky; no break at the horizon. Nearby pine trees were faintly visible against the sky background. The rental car was driven out to around 500 meters and it presented a very strong high contrast target. A person was clearly visible when he emerged from the car and walked around.

On 11 January the DRAGON contingent moved out to the TOW range for LET firing. The ambient temperature was +4°F, heavily overcast with a light snow falling.

All the troops fired at 300 meters at a stationary and moving APC equipped with a tactical flare. The DRAGON Field Test Set was used to indicate gunner errors. NVS S/N #7 was mounted on the LET and all troops used the Arctic kit to power the NVS. The APC provided an excellent target at this range.

The target APC was moved to 500 meters and the exercise repeated with good signature and good results. MDAC video-filmed the target through NVS S/N #9 at various ranges and aspect angles. Both IR system worked very well.

On 12 January no formal testing was scheduled. The temperature fell to -35°F and the NVS systems, S/N #1, #7 and #8 were stowed in the trunk of a car in the AM. Ice fog had developed in the area.

The contractor test group drove to the Gulkana Glacier area, sight of the proposed handling tests, to access the suitability of the area. High winds with gusts of up to 50 mph, blowing snow and a temperature of -35°F made meaningful observation impossible. The entourage returned to base.

On Saturday, 13 January the troops under Major Key, and MDAC, MICON, NVL and PAVSC personnel departed for Gulkana Glacier to conduct the handling tests. The temperature at Fort Greely was -65°F with heavy ice fog. Arrived at the glacier area in high winds with 50 mph gusts and a temperature of -40°F resulting in an equivalent chill temperature of -115°F with extreme white-out conditions due to the blowing snow. Tests were canceled and the group returned to base.

NVL and PAVSC set up S/N #7 system on a highway shoulder in Delta Junction to observe targets of opportunity through the heavy ice fog present in the area. The time was 1500 hours and in an ambient temperature of -50°F. Cars and trucks were readily visible at a range exceeding 800 yards. A relatively good picture was obtained without cooling. The system was returned to the car trunk for continued cold storage.

On Sunday, 14 January, the temperature fell to -65°F in the morning and rose to a high of -50°F. Heavy ice fog was in the area.

On Monday, 15 January the outside temperature was -55°F to -65°F with heavy ice fog in the area. All tests were canceled because of priority on other DRAGON testing. PAVSC proposed that unscheduled filming could be acquired of various military targets at the test range. Major Key, however, decreed that all unnecessary vehicles be restricted from the test area to cut down on ice fog generation. No further NVS testing was performed.

On 16 January, Tuesday, arrived at the test range at 1100 hours in heavy ice fog with an ambient temperature of -50°F. MDAC and PAVSC set up to film and video tape various vehicles at various ranges and aspect angles. AC generator trouble delayed PAVSC filming for about 1 hour. PAVSC ran one roll of film only -- too difficult to change film at the test site in the cold.

Photographed a tracked tank retriever and a cargo carrier at 500 and 300 meters. The ice fog seemed to have very little effect on the IR signature. The PAVSC thermal camera box worked very well. The scan mirror in S/N #7 was a bit balky at starting at the -50°F temperature. A 5 cubic inch tactical bottle ran the system for over two hours and contained substantial pressure at the end of the filming.

On Wednesday, 17 January, the guided flight tests were canceled because the temperature was -65°F in the morning and rose to a high of -50°F.

Thursday, 18 January, the guided flight tests were conducted at the test range. The temperature was -35°F at the start of the activity and fell to -40°F at the time of the actual firing of the two rounds. NVS S/N #1 was set up on the port side of the round and was used by PAVSC to film the missile flights. S/N #7 was used to fire the rounds and S/N #8 was located on the starboard side of the rounds and was used to video film the missile flights. SSG Billy McKeithe was the gunner. Medium ice fog developed before the firings took place.

The target was a stationary M-41 tank hulk heated by two portable gasoline heaters and located at a range of 500 meters. It took about 1-1/2 hours to heat the tank up sufficiently to present a reasonable target to S/N #7 system. The test was again delayed because of a failure of the two 3 kW generators necessary to run the PAVSC camera box, the MDAC camera box and the Army camera heaters.

The first missile was fired at about 1700 hours and flew about 20 feet over the target. The gunner complained that the NVS presentation was intermittent during the entire missile flight and that he held high intentionally hoping that the image would stabilize. The trouble was traced to an intermittent connection between the Arctic kit battery simulator connector and the connector on the NVS.

It was decided to bypass the Arctic kit on the second shot which went off at about 1830 hours. Again the missile flew over the target but not as high as in the first shot. The gunner claimed that he held on the target for the entire missile flight. A post check of the Tracker using the TTS indicated that some problem areas possibly existed in the Tracker (assuming that the Tracker Test Set was performing properly). A boresight check of the NVS/Tracker was overlooked at the time. The NVS presentation appeared normal after the firing with good target visibility. The gunner reported normal target obscuration at launch.

After returning to the base the MDAC representative and PAVSC mounted the Tracker onto the NVS and ran a boresight check on available targets. The systems were mated and a street light, about 300 meters distant, was observed through the NVS and the optical sight on the Tracker. No apparent shift was noted and boresight appeared correct. No further action occurred.

On Friday, 19 January, the group departed for the glacier area at 0700 hours to perform handling tests. The weather was clear with a temperature of -30°F. The troops executed various walks on snowshoes carrying the round, the NVS in its carrying bag and another NVS mated to a tracker in the combination bag developed by MICOM. Simulated firings were conducted. MDAC recorded the show on video tape. It was agreed that PAVSC could shorten the line cord on the Arctic kit by two feet. The PAVSC contingent departed the area before the conclusion of the tests.

On Saturday, 20 January, PAVSC personnel returned to New Jersey with NVS S/N #7. System #8 was retained by MDAC to enable them to complete training film generation in California.

4.2.9 DRAGON FILMING - MDAC/TICO & RSA

PAVSC traveled to MICOM, Redstone Arsenal, on February 12 and 13, 1973 at the request of NVL. Purpose of the trip was to review the first cut of the training film generated by MDAC. People present were representatives of MDAC, MICON (DRAGON & TOW), NVL and PAVSC.

Many comments were made and suggested corrections to the scenario registered with MDAC. NVL and PAVSC responded negatively toward the quality of some of the shots taken through the NVS with the video tape set-up, especially during the field boresight demonstration and the closing guided flight scene (taken in Alaska of a miss).

It was decided that the boresight scene through the NVS should be refilmed ASAP and a date of February 19 was set to refilm at TICO.

PAVSC traveled to TICO on February 19 and 20 at the request of NVL to assist in refilming the boresight procedure sequence taken of a target through the NVS. System #14 was used for the filming results on video tape were excellent and the tape was rushed to the MDAC film factory in California for incorporation into the second cut of the training film.

4.2.10 GERMANY EARLY LOOK TESTS

From 14 March through 23 March 1973 a total of nine nights of testing was conducted at the Combined Arms Training Center, Grafenwohr, Germany. The anticipated adverse weather conditions never materialized. Measured visible and IR transmission on the range was mostly 85 percent or better throughout the entire testing. Weather conditions of 32°F with no rain, fog, or appreciable wind were consistent. Days were mostly heavily overcast, but a couple of sunny days were encountered. In spite of the good weather, NVL proceeded with the tests and collected a large number of still thermal photographs of targets under many varied documented conditions.

GI tank gunners were trained as observers by showing them track vehicles at close range and progressively moving the targets out to more distant ranges. Targets were set up and the observers were asked to recognize them. Photographs were then taken and meteorological data, visible and IR transmission recorded. The observers, experienced gunners, being thoroughly familiar with the vehicles used, quickly became confident and knowledgeable of the thermal signatures they were viewing.

Tests consisted of search, acquisition, and recognition of M-60 tanks, armored personnel carriers, gama-goat, and jeeps at various ranges. Camouflage tests were conducted using camouflage nets and evergreen branches. A water truck was used to hose down a tank to simulate rain. Vehicles were placed in wooded areas and behind densely wooded areas. They were also placed in defilade, half hidden behind mounds. Since the vehicles were constantly moved around for set-up with personnel heaters running, the thermal signatures were, in general, good. Some tests were conducted without personnel heaters running, and in one test a tank was placed in the field early in the afternoon and photographed hourly through the following morning. This signature became weak, but always recognizable.

Both NVS systems performed well throughout the tests although some problems were encountered. Both systems were exhibiting internal Freon 14 leaks, building up pressure, causing the eyepiece diopter adjustment to severely bind. The problem was temporarily solved by permanently opening the pressure relief valve to bleed off the excess pressure. MICOM was quite disturbed with this problem, pointing out that they had seen this problem before at previous tests. Both systems exhibited problems removing the cartridge in the valve release position. Both systems' cartridge tube dust cover straps broke off.

4.2.11 TOW NVS TESTS, EPG ABERDEEN AND A.P. HILL

During March and April 1973, field experiments were run at EPG, Aberdeen and A.P. Hill to determine the man-viewer performance of the DRAGON Night Sight. Primarily detection, recognition and identification data was collected under various atmospheric conditions both man-made and natural. Methodologies, observers and target scenarios were manipulated to develop a broad look at how an observer might expect the system to perform under a variety of tactical conditions. The tests were concluded on 27 April after a series of search tests were conducted using GI observers placed in stationary positions and also with systems mounted in jeeps. Tests were conducted with targets obscured by smoke, dust and aluminum particles. Some adverse weather conditions were encountered consisting of rain and fog. System motion pictures were taken. The NVS system performed well with no malfunctions. Weekly MRT tests were made by NVL Visionics and results showed that optimum performance was maintained. The results of these tests and of the Early Look tests conducted at Vilseck, Germany are documented in a report generated by the Visionics Technical Area of NVL in January of 1974 and titled "A Performance Evaluation of the DRAGON Night Sight".

4.2.12 AFTERBURN/BORESIGHT VERIFICATION DEVICE EVALUATION TESTS - MDAC/TICO

On 17 and 18 April 1973 Launch obscuration tests were conducted at MDAC/TICO. The purpose of the testing was to collect data which would allow evaluation of the affects on the NVS presentation of the infrared environment generated during the DRAGON launch.

Eight DRAGON slug-rounds were fired with a DRAGON Night Sight (NVS) mounted near to the normal NVS position during the firings. A television camera or a synchronized film camera was located to record the NVS presentation during each slug firing. A quarter-ton truck (jeep) was positioned in the NVS field of view to present a realistic thermal target for the NVS. High-speed film coverage of the launch was acquired.

The NVS was configured with a special electrical connector which enabled synchronization of a movie camera with the NVS Cathode Ray Tube (CRT).

The slug round was installed in a tripod-mounted support fixture. The aim of the slug-round was adjusted so that there was no danger of hitting an IR target positioned in the field (Army jeep), and so that a nominal launch elevation was obtained. The NVS was installed in a separate tripod-mounted support fixture and positioned adjacent to, but not touching, the slug-round. The camera (TV or film) was then mounted on the NVS support fixture and aimed so that the NVS CRT presentation could be recorded. The IR target was positioned so that it was in the NVS field of view and near 200 meters down-range. The target vehicle was oriented to present a side view. Numerous trees and other terrain features were also present in the NVS field of view.

Two high-speed (400 frames-per-second) cameras were positioned to document heat and flame in front of the NVS. One camera employed IR sensitive film and a visible light excluding filter, and the other camera employed standard color film. When the TV system was not used to record the NVS presentation, it was positioned to document smoke and flame in front of the NVS.

The local wind conditions were adverse to the desired flow of hot gases in front of the NVS, so an eight-foot wide and twelve-foot high barrier was erected to block the wind for the last four slug-round firings.

The eight tests were conducted in the daylight on 17 and 18 April 1973. Slug-round performance appeared to have been normal. The NVS functioned properly for all tests. During Test #3, due to operator error, the NVS battery voltage was allowed to decay so that no video picture was acquired. No visible afterburn occurred during Test #3, so it is believed that no NVS obscuration would have occurred had the NVS been operating.

Wind conditions during the tests were 10 mph, gusting to 18 mph, coming from the forward left quadrant. This wind condition was considered adverse to production of hot gases in front of the NVS. Hence, for Tests #3 and #4, launch was initiated when the wind appeared to have been in a lull. For Tests #5 through #8, a wind shield was erected. The shield resulted in a somehwat turbulent wind condition at the launcher, with an average velocity that was low and in the forward direction.

Excellent film of typical obscuration was obtained from the last three shots showing an obscuration duration of from 2.13 to 3.74 seconds. Good tape data was obtained on the first and fifth shot with obscuration of 1.22 second and 2.54 seconds. Wind apparently blew the hot gases away from the NVS FOV on the second through fourth shots. The film data was later used in various training programs to initially introduce the gunner to launch and afterburn obscuration.

Boresight Verification Device (BVD) evaluation tests were conducted at TICO. The system was boresighted using a target of opportunity (jeep). The boresight was then verified with the BVD. The difference in the boresight was 0.16 milliradian. The BVD was removed and the LET fired three times. The BVD was again positioned on the system. The boresight shift noted was within specification. An additional 15 to 20 firings were conducted with a boresight check made after the firings. Boresight shifts noted were again within specification.

4.2.13 DRAGON NIGHT SIGHT TRAINING - RSA

From 23 April through 4 May 1973, the NVS Training Course was conducted at RSA for gunners from WSMR and the NET group from ECOM, Ft. Monmouth culminating in slug and guided flight firing. The training course followed the Plan of Instruction generated by PAVSC under the basic contract and included classroom instruction, DRI exercises, dry and wet LET firings and LET firing for score. The PAVSC Launch Blast Simulator was used during the LET firings.

Some boresight shift was noted during LET firings. PAVSC field personnel inspected the NVS units and discovered some loose hardware in the "butterfly bracket" of both systems and on the bracket that supports the tracker mating connector. After repairs were made the LET scores were remarkably higher than the previous two nights of firing.

Training was concluded with the firing of three slugs during the day and three missiles fired at targets after dark. Two missiles were fired at stationary targets and one at a moving target. One hit and two misses resulted. Boresight shifts were reported on all three firings. One miss was attributed to the boresight shifts which occurred. One miss was attributed to gunner error (low aimpoint). Gunner interviews were accomplished by MDAC personnel. Obscuration training with the PAVSC device appeared to prepare the gunner's adequately for this phenomenon.

4.2.14 HANDLING TESTS - CAMP A.P. HILL

Handling tests were conducted at A.P. Hill, Virginia, directed by Night Vision Laboratory, from 9 April through 12 April 1973. Three NVS systems were used for the tests along with standard components of the DRAGON weapon system. Two squads deployed with the systems and performed cross-country hikes during daytime and nighttime over a variety of terrain. The adequacy of the carrying bag and the ability of the troops to set up and mock fire rapidly, when tactile handling, were evaluated through a series of interviews during the course of the exercise.

4.2.15 COUNTERMEASURES TESTS - A.P. HILL and EPG, FT. BELVOIR

At the request of NVL, PAVSC visited A.P. Hill during the week ending 26 May 1973 and EPG during the week ending 2 June to help conduct Countermeasures Tests on the Night Vision Sight. DRAGON System #7, #8 and #10 were utilized for the tests.

The tests at A.P. Hill consisted of observing the effect on the NVS presentation by looking directly at the illumination from two different types of Zenon searchlights at various ranges with the searchlight in two different modes of operation. Still photographs were taken through the NVS and several observers were critiqued after viewing through the NVS.

Further tests were conducted to determine the obscuration effect of chemically generated smoke placed between target (M-113 APC and M-48 Tank) and the NVS at various ranges. Again, film data, both moving pictures and stills, were taken through the NVS and comments of various observers recorded.

The following week the tests were moved to EPG, Ft. Belvoir and consisted of observing the effects of two types of lasers, CO_2 and GaAs, on the NVS. The NVS was placed downrange at various distances and the laster beam was directed directly at the NVS and at various aspect angles. Observer comments were recorded and some still pictures obtained.

In addition, at A.P. Hill, still pictures were taken through the NVS of an M-48 tank and M-113 APC at 250, 500 and 750 meters at four aspect angles. These pictures were to be used for gunner training at Ft. Belvoir.

4.2.16 DT II TESTS - WHITE SANDS MISSILE RANGE, NEW MEXICO

On 9 May 1973, PAVSC commenced coverage of the DT II TECOM test effort at WSMR. A program for responding to Equipment Performance Reports was ini-ated at PAVSC. During the course of evaluation testing a total of 107 EPR's were written against the NVS and associated equipments with the bulk of the EPR's dealing with coolant problems, battery connector failure, channel noise and boresight shift. These problems and their solutions are detailed in Section III of this report.

During the later phase of the program thirty-four guided flights were accomplished. Fifteen hits were recorded on an M-48 tank target at various ranges, both static and moving, and under a variety of environmental conditions. Thirteen misses were attributed to gunner error, four misses to NVS mechanical and electrical failure (boresight shift and battery connector intermittency), and two misses to possible missile failure. The tests were concluded on 7 November 1973. Details of these tests are described in a report titled "Engineering Test (DT II) of Night Vision Sight, Infrared AN/TAS-3( ), for DRAGON and TOW Antitank Assault Weapons Systems" issued by TECOM, U.S. Army WSMR in March of 1974.

4.2.17 TRAINING PROGRAM - FT. BENNING

During the last three weeks in July of 1973 a NVS training program, under the direction of the USAIB of Ft. Benning, was conducted by PAVSC following a modified Program of Instruction. Twenty-six students from the USAIB, the USAATC and the USATTC participated. At the conclusion of the program a segment of the troops traveled to RSA for guided flight firing and three out of four hits were registered during night firing exercises. The students from the USAIB were eventually used as instructors to train test soldiers participating in DT II tests at Ft. Benning.

4.2.18 DT II - FT. BRAGG

PAVSC support of the air drop tests commenced at the Army Airborne Communication and Electronics Board (USAACEBD), Ft. Bragg on 16 July 1973. Two NVS systems were supplied for the tests which consisted of a series of static drops in Army mules, air drops with the NVS system palletized, air drops with the NVS system packed in jeeps and assault landings with the NVS system packed in a jeep being carried by a C-130 cargo plane and a CH-47 helicopter. Minor system problems were encountered and 5 EPR's were written against the equipment, none attributed to the rigors of air drop environments. The test officers were impressed with the ruggedness of the AN/TAS-3 according to the PAVSC field engineers. Tests were concluded on 15 August.

4.2.19 DT II TESTS - FT. BENNING, GA.

On 6 August 1973 PAVSC commenced coverage of the DT II USAIB test effort at Ft. Benning. Six NVS systems were made available for the tests.

During the course of the evaluation 53 EPR's were written against the NVS system and associated equipment. Over 60 percent of these failures were associated with cooling problems, preamplifier microcircuit problems, battery and battery connector problems and boresight lock mechanism roll pin failure. Cooling, preamplifier and battery problems are discussed in Section III of this report. The roll pin problem was a result of the boresight shift modification to the systems (as described in Section III) and this weakness was analyzed and the affected parts successfully modified before the start of the OT II tests in Germany.

On 14 January 1974 the test group moved to RSA for guided flight firing. Thirty-six DRAGON rounds were fired resulting in 20 hits and eighteen TOW rounds were fired with 11 hits recorded. The majority of the test soldiers indicated that there were no adverse effects on their ability to track the target due to launch effects and that they had no problems in locating and tracking targets using the night sight. Details of these tests are described in a report titled "Developmental Test II (SP) of Night Vision Sight, Infrared AN/TAS-3 for Use on DRAGON and TOW Weapon Systems" issued by USAIB, Ft. Benning, March of 1974. The tests were concluded on or about 21 February 1974.

4.2.20 BORESIGHT SHIFT DEMONSTRATION - WHITE SANDS MISSILE RANGE

Representatives of PAVSC and NVL visited WSMR on 20 October 1973 to investigate the boresight shift problem. The results of this visit are discussed in Section III of this report.

4.2.21 BORESIGHT FIX VERIFICATION TESTS - MDAC/TICO

DRAGON/NVS boresight verification testing was conducted at MDAC on 19 November 1973. Two modified PAVSC Night Sights S/N #10 and #13 were tested with DRAGON Tracker S/N #128. DRAGON gunners from MDAC, MICOM and WSMR participated in the testing. Testing was accomplished to verify PAVSC design changes to the NVS tracker mounting provisions. Modifications were required because of gunner introduced boresight shifts encountered during missile firings at WSMR. Tests were conducted in three phases:

I. Boresight retention
II. Static gunner induced shifts
III. Dynamic gunner induced shifts.

Phase I was accomplished by mating and demating the tracker to both night sights and determining any boresight changes utilizing the BVD.

Phase II required each gunner to apply normal firing mode loads to the NVS system with the tracker installed and the BVD installed. Boresight shifts were noted by an observer viewing the boresight spot through the tracker optics while the gunner applied the load to the system.

Phase III required actual firing of the LET by the gunner at stationary and moving targets. Boresight shifts were monitored by the observers. This was accomplished by utilizing the Monitor Set and recorder to accumulate tracker data and an instrumented NVS which allowed real time monitoring of the sight display. In this way any large dispersion from boresight between the tracker and night sight was recorded.

Results of the testing indicated that some slight boresight shift did occur. However, these shifts were quite small and were within the system requirements under all conditions of mating and re-mating, LET firings and maximum gunner pull under static conditions.

Favorable comment was received regarding the ease of installation of the Tracker to the NVS compared to the present method. The gunners quickly developed techniques to position themselves to apply the force required to engage the Tracker guide pins with the NVS squeeze guides and lock assembly. Based on the results of these tests the systems at Ft. Benning (DT II) were modified accordingly. No further boresight shift was reported during subsequent firings during DT II and OT II testing.

4.2.22 OT II CADRE TRAINING, FT. BENNING

The PAVSC training contingent, with the support of Capt. Heider of the U.S. Army Infantry School, conducted the OT II Cadre Training Program at Ft. Benning commencing 4 February and concluding 15 February 1974. The class of ten students, all but one non-commissioned officers, were trained in accordance with the PAVSC Program of Instruction for the DRAGON Night Sight. Seven students were trained with the DRAGON weapon system and three with the TOW weapon system.

During classroom instruction, the thermal signature viewgraphs were shown and discussed in detail stressing image interpretation and selection of aim points. These viewgraphs, once again, were found to be excellent training aids. Sgt. W. McKeithe from MICOM was present and he also instructed the students in image interpretation and the proper selection of aim points.

PAVSC BVD was used by the students to verify their Field Aim Point method of boresighting. This procedure was followed each and every night prior to the start of any exercise.

The PAVSC Launch Blast Simulator (LBS) was approved for use by MICOM, during the latter part of the first week when it was concluded that the LBS was a valuable and necessary aid in training. The LBS was used during the second week for the four firing tables. PAVSC instructors maintain that LBS training is necessary and should definitely be used in any future training programs.

A remote view video monitor was used on one position each evening. This enabled the instructors to see the aim point selected by the student and observe tracking capabilities for moving targets. The remote monitor was found to be a valuable aid in coaching the student and verifying his progress. Its use is strongly recommended in any future training program.

USAIS and PAVSC personnel did not concur on targets to be used for the firing tables. USAIS maintained that it was not necessary to use actual targets for the firing tables since the students had become familiar with these targets during the Image Familiarization and Target Acquisition Tables. They recommended the jeep mounted DRAGON target board at 250 meters. PAVSC personnel insisted the actual target signature was necessary to train the student in selecting and tracking the target signature aim points. USAIS then complied. The DRAGON target source was mounted on a tank. The first three Firing Tables were run at 250 meters, adjusting speed to compensate for range. The fourth table was run at 500 meters.

A Launch Signature Simulator (LSS) was fired by each student at night. The LSS is a DRAGON launch tube with an explosive charge followed by an afterburn similar to a DRAGON missile firing. This enables the student to view the launch obscuration through the night sight and subjects him to the shock of the initial firing without the high cost of an actual firing.

A problem was found using the DRAGON Night Sight with the TOW XM70 Training Set. The tight envelope required to score a hit is less than the resolution limits of the DNS. Students were able to score hits with careful and concentrated aiming. Should future TOW training become necessary, this problem should be looked into.

On the final day of training the students were given a written examination. Two students fired DRAGON missiles during daytime, scoring hits at a stationary APC at 500 meters. Five students fired five DRAGON missiles at night with the DNS scoring five hits at a stationary APC at 500 meters. No TOW missiles were fired.

Comments received from the Infantry Board and Infantry School military personnel indicate they feel the night sight training program could be considerably shortened. PAVSC instructors who conducted this and previous training programs feel everything in the present Program of Instruction is necessary to the training of a DRAGON gunner. The following items mentioned are essential and should not be eliminated or minimized.

1. Target signature interpretation, familiarization, and acquisition.

2. Use of actual target vehicles for firing tables and not a jeep with a target board.

3. Use of the Launch Blast Simulator.

4. Use of the Remote Video Monitor.

4.2.23 OPERATIONAL TEST II - GERMANY

PAVSC personnel arrived in Frankfurt on 26 February 1974, and drove to Seventh Army HQ in Heidelberg. After completing the necessary in-processing, PAVSC departed to Hohenfels, arriving on 27 February 1974. From February 27 to March 17 PAVSC personnel set up the maintenance area, checked all of the equipment for proper operation, charged all of the cartridges and batteries, reviewed the OT II test plan with OTEA personnel, and assisted in the generation of plans to modify the Evasive Target Tank (ETT).

Troop Training - OT II troop training at Hohenfels was started on 18 March and completed on 5 April, an extension of the original schedule of one week. Some additional training was required on field boresighting procedures, the main reason for the delay. A summary of the various aspects of the OT II exercise is presented herein: The Cadre PAVSC trained at Ft. Benning were the instructors at Hohenfels with PAVSC as technical back-up. Due to scheduling by the first Battalion of the 51st Infantry, the support group who supplied equipment and students as well as the Cadre, the instructors did not have time to prepare their training course, or practice using the POI as originally planned. Therefore, their instruction was not the best.

Boresighting turned out to be the most difficult task the students encountered. The BVD was just too difficult to attach to the NVS and then operate. Eight locking shafts were broken during the course of the training, six by students and two by the Cadre. It was apparent that the BVD, as then designed, was not suitable for field handling. Methods of attachment to the NVS, ease of attachment, and resistance to abuse have been improved on the ruggedized model.

Field boresight instruction had to be repeated twice to a number of the students before they were able to understand and perform the operation reasonably well. During the field exercise portion of the OT II, the students would field boresight the systems and PAVSC or NVL would verify using the BVD.

It is apparent that the POI should be modified to include more "hands-on" exercises during training. The Army's philosophy of a "designated" gunner rather than a "dedicated" gunner emphasizes the need for thorough training the first time around, simple operator controls and a "GI proof" mechanical system, the latter a most difficult task to achieve.

Support During Training - As previously stated, the 1st Battalion of the 51st Infantry, stationed at Crailsheim, Germany, supplied the students and Cadre. Target vehicles were supplied by the 1st Armored Division. The training schedule, at the onset of the program, clashed with the Operational Readiness Tests scheduled for the battalion at Hohenfels. For the first two weeks, the students had to perform housekeeping and guard duty for the 1st/51st as well as attend training sessions. As a result, they seemed fatigued and many were unattentive during the classroom phase of the training. Much of the general support (3Ø power, maintenance, shop facilities, schedules of events, etc.), were lacking during the early phases of the program but improved later on.

Test Phase - Objectives of the test phase were as follows:

1. Evaluate the DRAGON and TOW as tactical night weapons.

2. Evaluate the DRAGON system at night using the Tracker under illumination and the NVS.

3. Determine survivability of the DRAGON against threat force counterfire.

4. Establish the degree of logistic support at the operator/direct support level.

5. Evaluate reliability and maintainability of the NVS and its support equipment and the DRAGON training equipment.

6. Evaluate the effects of the DRAGON training program.

The Launch Signature Simulator (LSS), developed by Picatinny Arsenal, received extensive usage at OT II. PAVSC first saw it at Ft. Benning, and it was used during the Hohenfels training to acquaint the gunners with the loud band and afterburn of missile firing. It was also used to simulate missile firing for the Survivability Evaluation.

Evasive Target Tank (ETT) - The ETT was to be the only armor fired upon during OT II. If it became disabled due to missile slug impact on the road wheels or mechanical failure and it could not be readily repaired, they would fire at tank hulks. The ETT had been further modified since PAVSC saw it at Ft. Knox on 17 January. Extra armor was added resulting in double cooled surfaces and the fiberglass turret had been removed reducing the height of the vehicle to about 2 meters. When TOW fired at it, additional armor was added creating an additional cooled surface. Under ideal conditions (warm sunlit day followed by a cool early evening) the ETT is a good target at 600 meters. After that, the main body of the tank quickly loses signature but the engine compartment remains hot. It is the opinion of PAVSC that the ETT is not a good target vehicle to use for system evaluation.

Pilot Tests - Pilot tests commenced on 6 April. The purpose of the pilot test was to set up the range, run a comparison test of thermal signatures between an M-60 tank and the ETT, and then run a full dress rehearsal of the detection, recognition, firing, and survivability tests. The only data to be collected during the pilot tests was the survivability data. The range in which the firing exercises were conducted was undulating and there were noticeable berms at 800 and 1,375 meters.

At the onset of the pilot tests the test directorate stated that they were not after reliability data and therefore, would not try to assess the system reliability; they did try to ballpark system usage by attempting to extract the number of batteries and bottles consumed during the field exercisescises from our daily log. PAVSC cautioned that this was not an accurate way to determine system cycling for many obvious reasons.

PAVSC did not accurately log the number of times batteries were recharged because batteries returned from the field each night were mixed, i.e., fully charged, partially or fully discharged. Battery life fluctuated also due to the typical characteristics of aged NiCad batteries recharged by GFE Battery Charger Adapters.

Field Tests - Field tests commenced on 15 April and ended on 4 May with the last TOW firings. A typical week consisted of two days of detection, recognition, and survivability exercises, and two to three days of DRAGON and TOW missile firings. A graphic presentation of the firing results is shown in Figures 4-1 and 4-2. It is to be noted that the hit record at 800 meters with the DRAGON and at 1,375 meters with the TOW is not consistent with the weapon performance at adjacent ranges. A discussion with our field representative brought out the fact that the terrain at these two particular ranges was very undulating and that the ETT would be partially obscured for much of its run.

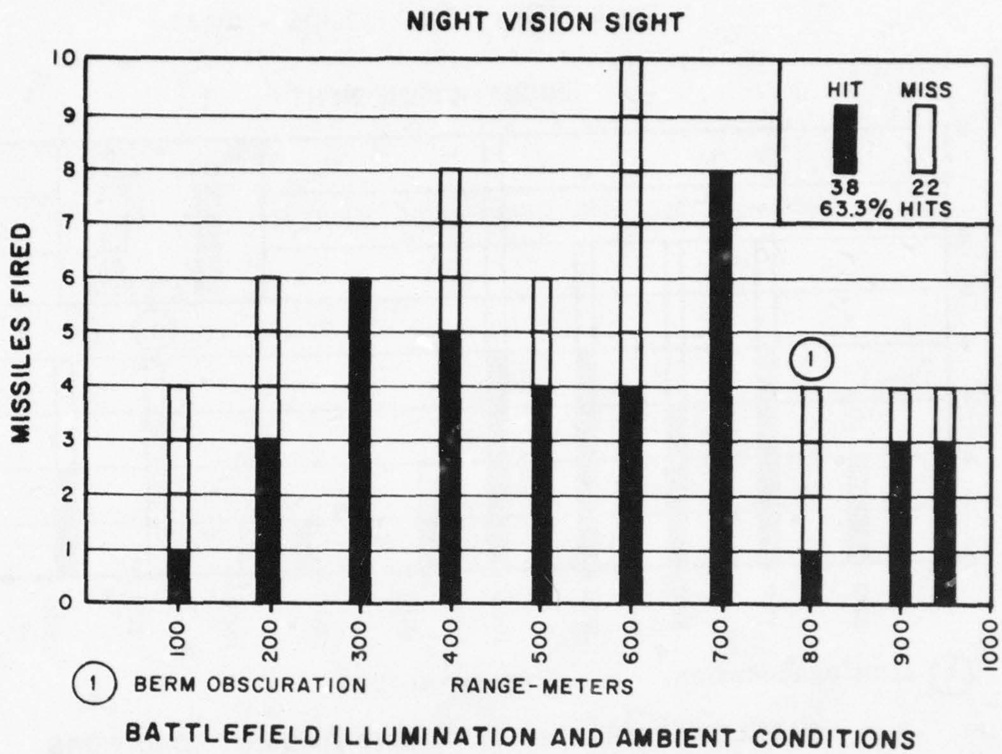
Another apparent inconsistency is the excellent hit/miss ratio of the TOW on 3 May (12 for 16) and the comparatively poor showing on 4 May (7 for 16). Again, our field man was informed by the TOW gunners that a spirited competition was in effect the last night of TOW firings to the extent that the gunners were attempting to disable the ETT by hitting the road wheels (disregarding the center of mass aim point). Of the 9 misses recorded on this night, four missiles hit the ground in front of the ETT compared to one the previous night.

Testing was concluded on 4 May with the final TOW firings.

4.3 SUMMARY FIELD TESTS AND TRAINING

4.3.1 GENERAL

During the course of this program, from August 1972, through April 1974, PAVSC participated in 23 separate field and training exercises. The experience


NIGHT VISION SIGHT
HIT
MISS
38
22
63.3% HITS
MISSILES FIRED
0
1
2
3
4
5
6
7
8
9
10
100
200
300
400
500
600
700
800
900
1000
1
BERM OBSCURATION
RANGE-METERS
BATTLEFIELD ILLUMINATION AND AMBIENT CONDITIONS

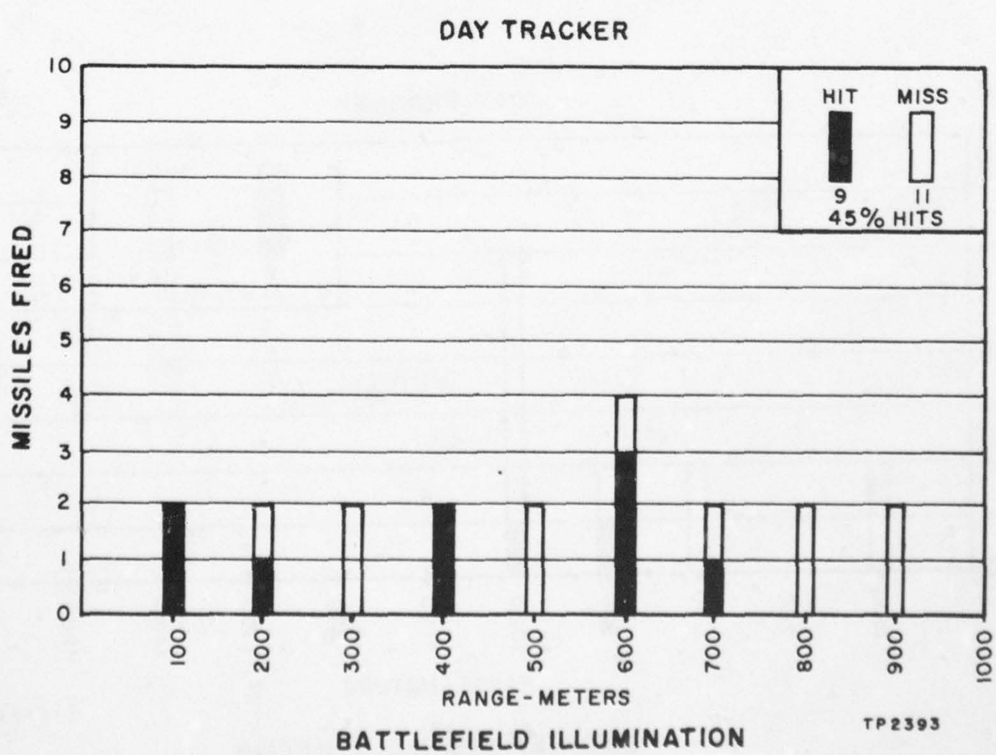
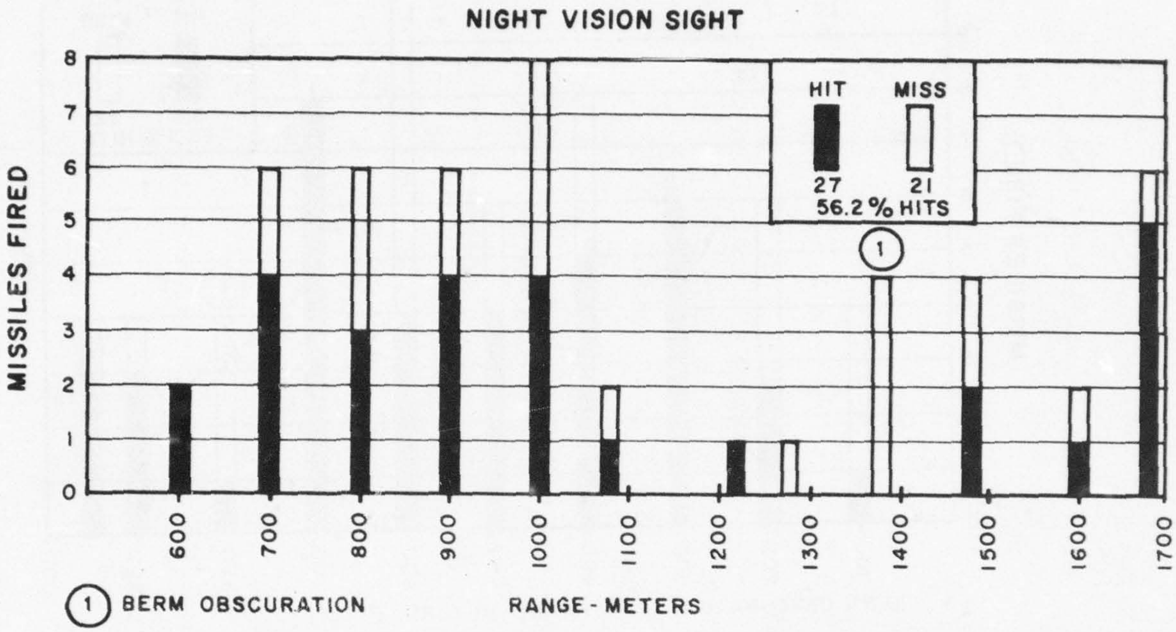
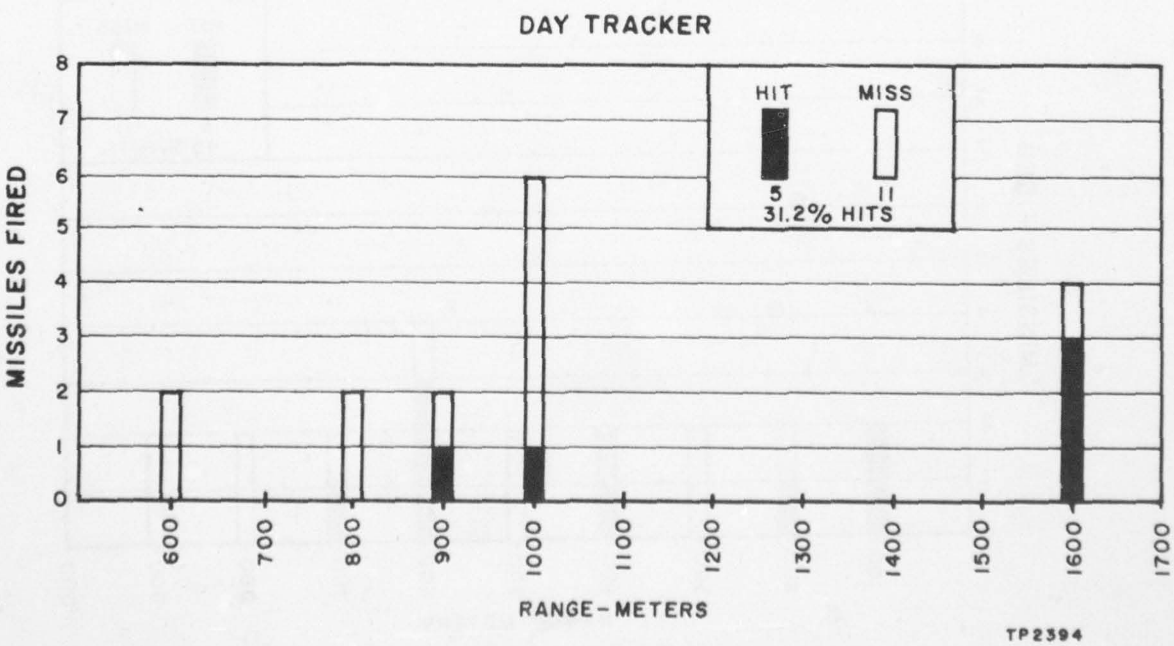

DAY TRACKER
HIT
MISS
9
11
45% HITS
MISSILES FIRED
0
1
2
3
4
5
6
7
8
9
10
100
200
300
400
500
600
700
800
900
1000
RANGE-METERS
BATTLEFIELD ILLUMINATION
TP2393

Figure 4-1

TOW GUIDED MISSILE FLIGHTS - OT II



BATTLEFIELD ILLUMINATION AND AMBIENT CONDITIONS



BATTLEFIELD ILLUMINATION

Figure 4-2

and data gathered at these exercises proved valuable in aiding the successful completion of the program and established a baseline for forthcoming APE models.

4.3.2 FIELD TESTING

Two major problems that were revealed during the earlier phases of field testing were boresight shift and cryogenic freeze-up. PAVSC continued to work on these problems; and prior to the start of OT II testing, all units subjected to the tests were modified to incorporate an improved day tracker mounting configuration and a cryogenic dryer/filter. These modifications proved successful in that no cryogenic freeze-ups were encountered nor were any, out of specification, boresight shifts reported.

Results of the OT II firings were very encouraging especially when compared to comparison firing of the Day Tracker under battlefield illumination condition. The results are summarized below:

Sight	Weapon	Hits	Misses	Total	% Hits	Light Conditions
Night Vision	DRAGON	38	22	60	63.3%	B.I.[1] & Ambient
Day Tracker	DRAGON	9	11	20	45.0%	B.I. and Ambient
Night Vision	TOW	27	21	48	56.2%	B.I. and Ambient
Day Tracker	TOW	5	11	16	31.2%	B.I. and Ambient

[1] Battlefield Illumination.

4.3.3 TRAINING

Experience gathered during training and subsequent troop field tests show that a thorough training program is essential. This is especially true when considering the Army's philosophy of a "designated" gunner.

During training a feasibility model BVD was used and although it was suitable to perform its intended function, it was found to be inadequate with respect to the field handling it was subjected to. This resulted in a program to develop a ruggedized, fully qualified BVD at PAVSC. This program has been completed and all required tests were successfully passed.

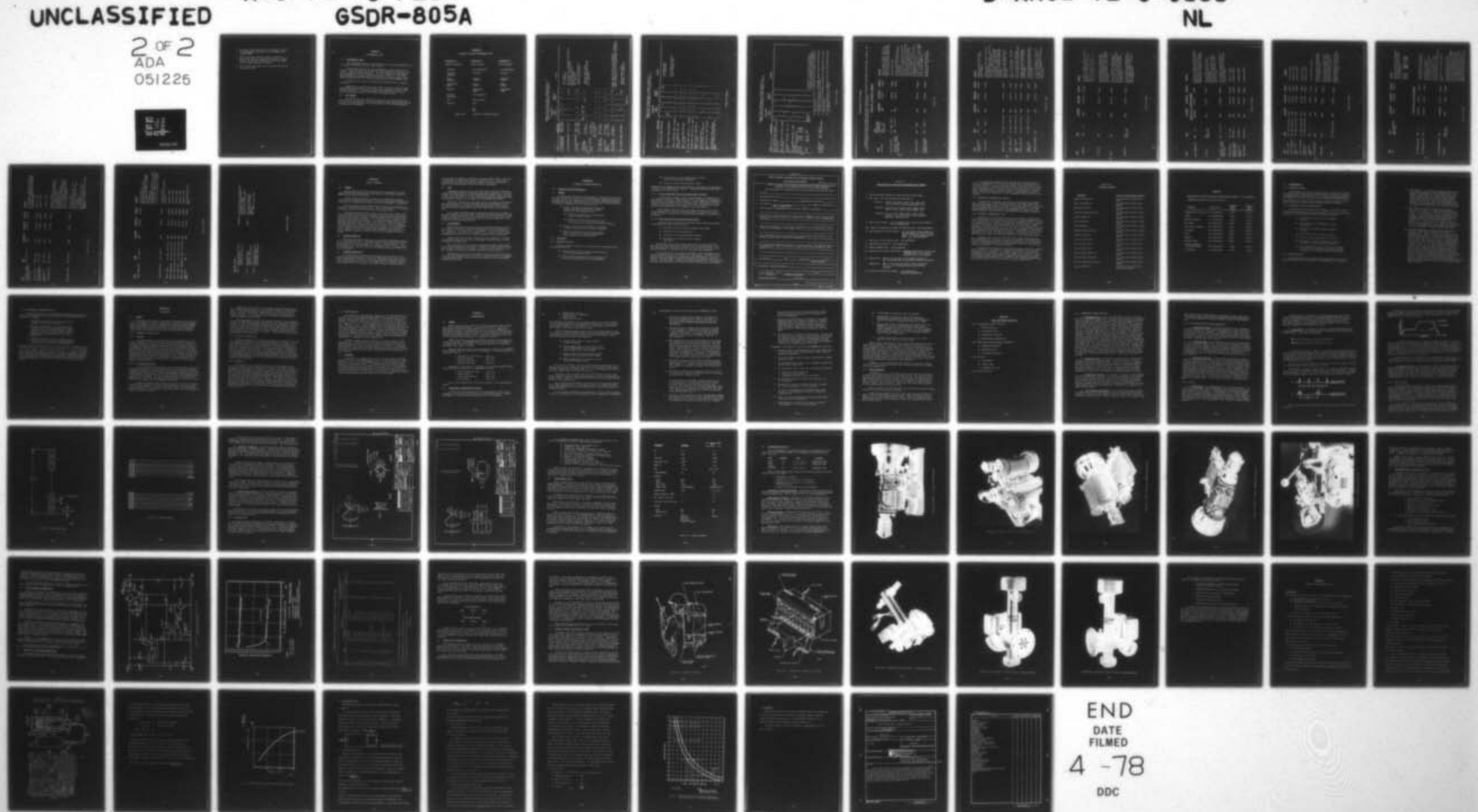
PAVSC recommendations resulting from the training program are as follows:

1. Modify the POI to include additional hands-on training particularly in the area of field boresighting.

2. Emphasis and possibly expand target signature interpretation, familiarization and acquisition.

AD-A051 225 PHILIPS AUDIO VIDEO SYSTEMS CORP MAHWAH NJ GOVERNMEN--ETC F/G 17/5
NIGHT VISION SIGHT, INFRARED AN/TAS-3.(U)
AUG 75 G PECK DAAK02-72-C-0156
UNCLASSIFIED GSDR-805A NL

2 OF 2
ADA
051225



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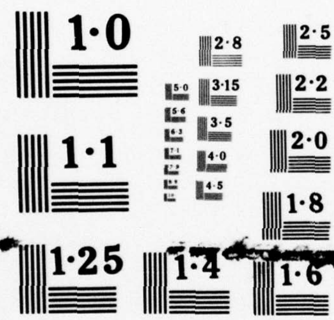

NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

3. Use actual target vehicles for firing tables. The use of jeep-mounted target boards is not considered adequate by PAVSC.

4. Use a Launch Blast Simulator (LBS) to familiarize gunners with afterburn characteristics prior to actual firing. The LBS will significantly reduce the number of live rounds required for training.

5. Use a remote video monitor for both gunner familiarization and critique.

SECTION V

ENVIRONMENTAL TESTS

5.1 ENVIRONMENTAL TESTS

The environmental tests for the Night Vision Sight were performed during the period of September 18, 1972 to May 1, 1973.

Three systems were used for the environmental program, Serial No.'s 2, 3 and 4. The test program was divided into three separate test sequence categories: temperate, desert and Arctic. The tests conducted in each sequence and the system used for that sequence are listed in Figure 5-1. All tests were performed in accordance with and as detailed in the approved test plans; Engineering Design Test Plan, GSDR No. 399, and EMI Test Plan, GSDR No. 364.

A tabulation for rapid overview of the environmental tests is shown in Figure 5-2.

Summaries of the various tests are listed in Figure 5-3 which includes the applicable specification, test location, date completed and results. When noteworthy problems or circumstances were encountered during testing, the area of interest and condition are listed in the remarks column.

5.2 TEST RESULTS

Test results show that the Night Vision Sight, with the indicated corrective actions incorporated, successfully passed the environmental test requirement and the system complies with the requirements of Prime Item Development Specification, B1 23020100B.

FIGURE 5-1

SEQUENTIAL SIMULATED ENVIRONMENT TESTS

System No. 2	System No. 3	System No. 4
Temperate Sequence	Desert Sequence	Arctic Sequence
Altitude	High Temperature	Low Temperature
Vibration (Ambient)	Altitude	Altitude
Shock (Ambient)	Vibration (+145°F)	Vibration (-40°F)
Temperature Shock	Shock (+125°F)	Shock (-40°F)
Humidity	Temperature Shock	Temperature Shock
Salt Sea Atmosphere	Solar Radiation	
Rain	Sand and Dust	
Immersion	Wind	
	EMC EMI	

Fungus Test: Performed on Material Samples.

DRAGON NIGHT VISION SIGHT INFRARED AN/TAS-3 ( )
QUALIFICATION ENVIRONMENTAL TEST RESULTS

TEST	CONDITION	PERFORMED ON SYSTEM 2	PERFORMED ON SYSTEM 3	PERFORMED ON SYSTEM 4	RESULTS SYSTEM 2	RESULTS SYSTEM 3	RESULTS SYSTEM 4	REMARKS
	STORE OPER.							
HIGH TEMPERATURE	155°F 125°F		x			P		
LOW TEMPERATURE	-65°F -40°F			x			F	CRT Cracked. F.R. 23555-005
LOW TEMPERATURE (R)	-65°F -40°F			x			F(1)	CRT as above. F.R. 23555-009 incorporated new material for CRT collar. Scanner Motor Bearing Material Change F.R. 23555-010
LOW TEMPERATURE (R)	-65°F -40°F			x			P	
ALTITUDE	-65°F -40°F 40K Ft. 10Kft	x	x	x	P	F	P (2)	Scanner Motor Bearing As Above F.R. 23555-008
VIBRATION		AMB	145°	-40°				
LOOSE CARGO BOUNCE	Half-Hour/ face 284 RPM	x	x	x	F(3)	P	P	IMPROVED PREAMP BOARD AND PLUG RETAINING DEVICES. F.R. 23555-007
COMMON CARRIER SINE	45 min/axis 1.3g, 5-27 Hz .036 in. 27-52 Hz 5g, 52-500 Hz	x	x	x	P	P	P	
MIL. VEHICLE COMPOSITE ROAD	80 min/axis 1.3g, 9-500 Hz	x	x	x	P	P	P	
MIL. VEHICLE CROSS COUNTRY	80 min/axis 1 in., 5-7 Hz 2.5g, 7-500 Hz	x	x	x	P	P	P	
MIL. VEHICLE TRACK VEHICLE	2hr/axis 4g, 5-500 Hz	x	x	x	F	P	F (4)	(S/N2) Longer Roll Pin. F.R. 23555-011 (S/N4) Loctite to CRT Retaining Ring, F.R.23555-016 (S/N4) Lockwasher Mirror Counterweight, F.R.23555-017
MIL. VEHICLE TRACK VEHICLE (R)				x			F(4)	Improved Mother Board Brackets. F.R. 23555-019

Figure 5-2

DRAGON NIGHT VISION SIGHT, INFRARED, AN/TAS-3( )
QUALIFICATION ENVIRONMENTAL TEST RESULTS (cont'd)

TEST CONDITION	PERFORMED ON SYSTEM 2	3	4	RESULTS SYSTEM 2	3	4	REMARKS
MIL. VEHICLE TRACK VEHICLE(R)			x			F(4)	Stronger Rivets F.R. 23555-023
MIL. VEHICLE TRACK VEHICLE(R)	-40°F x			P			S/N 2 Used For Only This Arctic Sequence Test.
SHOCK, LAUNCH 8g, 20ms, 7 shocks	x	x	x	P	P	P	
SHOCK, MECHANICAL 70g, 10ms, 18 shocks	x	x	x	P	P	P	
SHOCK, TRANSIT DROP 26 drops, 3ft. concrete	x	x	x	P	P	P	
SHOCK, DROP, DIRT 12 in., 7 drops	x	x	x	P	P	P	
TEMPERATURE SHOCK 155°F to -40°F	x	x	x	P	P	P	
HUMIDITY 94% RH, Temp 68°F to 149°F, 10 days	x			P			
SOLAR RADIATION 48 hrs., 360 BTU/f+2/hr. Air Temp 113°F		x			P		
SALT FOG 48 hrs., 95°F, 5% Salt Fog	x			P			
SAND AND DUST 24 hrs. blowing sand. 3.5 MPH to 20 MPH, 73°F to 145°F		x			P		

Figure 5-2 (Cont)

DRAGON NIGHT VISION SIGHT INFRARED AN/TAS-3 ( )
QUALIFICATION ENVIRONMENTAL TEST RESULTS (cont'd)

TEST	CONDITION	PERFORMED ON SYSTEM 2	PERFORMED ON SYSTEM 3	PERFORMED ON SYSTEM 4	RESULTS SYSTEM 2	RESULTS SYSTEM 3	RESULTS SYSTEM 4	REMARKS
RAIN-	half hour per exposed face. Rate 5 in./hr to 12 in./hr. Wind 40 MPH	x			P			
WIND	30 minutes, 30 knots, gusts to 45 knots		x			P		
IMMERSION	5 minutes, 3 ft. of water	x			P			
EMI	Radiated emission, 14KHz to 1Ghz Radiated Susceptibility 10 v/m 14 KHz 2 MHz 50 v/m 2 MHz 75 MHz 10 v/m 75 MHz 10 GHz		x			P		
Fungus	28 days, 84°F, 95% R.H.	Material Samples				F		Bag material, eye shield, male battery connector, supported some fungus growth ECO 23585-0078 details corrective measures.

(1) Corrective actions of F.R. 23555-009 and 010 validated by subsequent test on S/N 4.

(2) Corrective action of F.R. 23555-008, change in Motor bearing material, validated by subsequent test on S/N 4.

(3) Corrective action of 23555-007 validated by subsequent Test on uniits S/N 3 and S/N 4.

(4) Corrective actions of F.R. 23555-011, 016, 017, 019 and 023 validated by subsequent final Test on S/N 2.

X= Performed
P= Passed
F= Failed

(R) = Retest
F.R.= Failure Report

Figure 5-2 (Cont)

ENVIRONMENTAL TEST SUMMARY

Following is an overall summary of the environmental tests performed on the Night Vision Sight. Results, and corrective measures implemented when applicable, are included.

SERIAL NO. 2 TEMPERATE SEQUENCE

TEST	SPEC MIL-STD-810B METHOD-PROC	LOCATION*	COMPLETED	RESULTS	REMARKS
Altitude	500 II (modified)	SKPV	9-19-72	Passed	Twelve hours at -65°F, 40K ft.; then to -40°F, 10K ft. Stabilize. Operate five missions. (Mission: five minutes on; five minutes off)
Audio Security	BI, Para. 4.2.3.1	NU	9-22-72	Passed	Demonstration Test
Vibration, Transportation, Bounce, Loose Cargo	514 XI, Pt 2	SKPV	9-26-72	Failed	System on package tester, in carrying bag, 1/2 hr bounce/face at 284 RPM. Preamp Boards and Plugs on Preamp Multiplexer Assembly became unseated. Failure Report 23555-007 ECO 23555-0415 incorporated an improved Preamp Board retaining system, and positive plug retaining devices. Validated by subsequent Test on S/N 3 and S/N 4, on 10-25-72 and 11-10-72.
Common Carrier	514 X,AB	SKLF	10-2-72	Passed	System in transit drum, 45 minutes/axis. 1.3g, 5-27 Hz; .036 in. DA, 27-52 Hz; 5g, 52-500 Hz.
Military Vehicle Composite Road	514 VIII, V	SKLF	10-3-72	Passed	System in transit drum, 80 minutes/axis. 1.3g, 9-500 Hz.

Figure 5-3

TEST	SPEC		LOCATION*	COMPLETED	RESULTS	REMARKS
Cross Country Terrain	514	VIII, Y	SKLF	10-6-72	Passed	System in transit drum, 80 minutes/axis. 1 in., 5-7 Hz; 2.5g, 7-500 Hz.
Track Vehicle	514	VIII, W	SKLF	10-6-72	Failed	System in carrying bag 2 hrs/axis. 4g, 5-500 Hz. System operated normally. Roll pin in tracker mating connector mounting assembly had fallen out. F.R. 23555-011. ECO 23555-0398 incorporates a longer roll pin. Validated by subsequent tests on S/N 3 and S/N 4, on 11-2-72 and 11-16-72.
Shock, Launch	B1, Para. 4.2.4.15.3		SKPV	10-12-72	Passed	Mission operation configuration. Seven shocks, 8g, 20 ms, aft direction.
Shock, Mechanical	B1, Para. 4.2.4.15.1		SKPV	10-12-72	Passed	Unit in carrying bag. Eighteen shocks, 70 g, 10 ms.
Shock, Transit Drop	B1, Para. 4.2.4.15.2		SKPV	10-17-72	Passed	Unit in transit drum; 26 drops onto concrete from a height of 3 ft.
Shock, Drop, Dirt	B1, Para. 4.2.4.15.2		SKPV	10-18-72	Passed	Mission operation configuration; 9 drops onto dirt from a height of 12 inches.
Shock, Drop, Concrete	B1, Para. 4.2.4.15.2		SKPV	10-18-72	Passed	Mission operation configuration; 9 drops onto concrete from a height of 12 inches.
Temperature Shock	503	I	SKPV	10-31-72	Passed	Unit in transit drum. Four hours at 155°F, to -65°F within five minutes, hold for four hours, = one cycle. Repeated for a total of three cycles.

Figure 5-3 (Cont)

TEST	SPEC		LOCATION*	COMPLETED	RESULTS	REMARKS
Humidity	507	II	SKPV	11-21-72	Passed	24 hours at 129°F. uncontrolled R.H. 24 hours at 73°F. 50% R.H. 240 hours cycling 68°F to 149°F. 94% R.H. 24 hours at 73°F. 50% R.H. Unit operated for 5 missions every 24 hours during cycling.
Salt Fog	509	I	SKPV	12-11-72	Passed	Mission operation configuration. 48 hour exposure at 95°F to Salt Fog using a solution of 5% salt, 95% distilled water; wash; then 48 hour drying period at room ambient conditions.
Rain	506	I	SKPV	12-14-72	Passed	Mission operation configuration. Each of the four sides exposed for 1/2 hr., for a total of 2 hours. Rainfall rate range; 5 inches/hr. to 12 inches/hr. Wind 40 MPH. Operated during last 10 minutes of each 1/2 hr.
Immersion	512 (modified)	I	SKPV	12-15-72	Passed	Mission operation configuration Under 3 feet of water for 5 minutes Water temperature 64° ± 10°F. Unit temperature 80° ± 5°F above water temperature.

Figure 5-3 (Cont)

TEST	SPEC	LOCATION*	COMPLETED	RESULTS	REMARKS
		SERIAL NO. 3 - DESERT SEQUENCE			
High Temperature	501 II	PBEC/GSD	9-21-72	Passed	6 hours at +120°F, to 155°F within 1 hour, hold at 155°F for 4 hours, to 120°F with 1 hour = 1 cycle. Repeated for a total of 3 cycles. Then to 125°F, stabilize, operate.
Altitude	500 II (modified)	SKPV	9-27-72	Failed	Test condition as for S/N2. Intermittent scan motor start FR 23555-008 Scanner Motor bearings changed from steel to beryllium copper. Validated by subsequent test on S/N 4, 11-3-72
Vibration, Transportation, Bounce, Loose Cargo	514 X1, Pt. 2	SKPV	10-25-72	Passed	All vibration and shock conditions as for S/N 2, except tested at elevated temperature as indicated. Tested at 145°F.
Common Carrier	514, X, AB	SKLF	10-31-72	Passed	Tested at +145°F
Military Vehicle Composite Road	514 VIII, V	SKLF	10-31-72	Passed	Tested at +145°F
Cross Country Terrain	514 VIII, V	SKLF	10-31-72	Passed	Tested at +145°F
Track Vehicle	514 VIII, W	SKLF	11-2-72	Passed	Tested at +145°F

Figure 5-3 (Cont)

TEST	SPEC	LOCATION*	COMPLETED	RESULTS	REMARKS
Shock, Launch	B1, Para. 4.2.4.15.3	SKPV	11-3-72	Passed	Tested at +125°F
Shock, Mechanical	B1, Para. 4.2.4.15.1	SKPV	11-3-72	Passed	Tested at +145°F
Shock, Transit Drop	B1, Para. 4.2.4.15.2	SKPV	11-16-72	Passed	Tested at +145°F
Shock, Drop, Dirt	B1, Para. 4.2.4.15.2	SKPV	11-17-72	Passed	Tested at +125°F
Shock, Drop, Concrete	B1, Para. 4.2.4.15.2	SKPV	11-17-72	Passed	Tested at +125°F
Temperature Shock	503 I	SKPV	11-22-72	Passed	Test conditions as S/N 2.
Solar Radiation	505 I	SKPV	11-30-72	Passed	Mission operation configuration. 48 hour exposure, 360 BTU/ft^2/hr. air temperature 113°F.
Sand & Dust	510 I	SKPV	12-7-72	Passed	Mission operation configuration. 24 hour exposure blowing sand Temperature range 73°F to 145°F. Humidity range 22% to 10%. Wind velocity 3.5 MPH to 20 MPH.
Wind	B1, Para. 4.2.4.12	SKPV	12-14-72	Passed	Mission operation configuration. Exposure 30 minutes. Wind velocity 30 knots with gusts to 45 knots.

Figure 5-3 (Cont)

TEST	SPEC	LOCATION*	COMPLETED	RESULTS	REMARKS
EMI	MIL-STD-461/462 RE02, R503	AELSC	12-22-72	Passed	Radiated Emission; no detectable emissions 14 to kHz to 1 GHZ. No susceptibility indications when subjected to: 10 V/M 14kHZ - 2 MHZ 50 V/M 2MHZ - 75 MHZ 10 V/M; 75MHZ - 10 GHZ
SERIAL NO. 4 - ARCTIC SEQUENCE					
Low Temperature #1	502 I	PAVSC/GSD	9-29-72	Failed	Cracked CRT F.R. 23555-005. Test repeated on S/N4,10-5-72.
Low Temperature #2	502 I	PAVSC/GSD	10-5-72	Failed	Cracked CRT. Intermittent FR 23555-009 and 010 ECO 23555-0406 incorporates a stainless steel spacer for the CRT. Scan motor bearings changed from steel beryllium copper. Validated by subsequent test on S/N4 11-1-72.
Low Temperature #3	502 I	PAVSC/GSD	11-1-72	Passed	Improved motor and CRT spacer used.
Altitude	500 II (modified)	SKPV	11-3-72	Passed	Test conditions as for S/N 2 At NVL request operation was attempted with a battery subjected to the test environment at -40°F. The battery operated the unit for two complete missions; the unit ceased operation at approximately 1 3/4 minutes of the third mission. The remaining missions were then completed under the required conditions; battery at room ambient.

Figure 5-3 (Cont)

TEST	SPEC	LOCATION*	COMPLETED	RESULTS	REMARKS
Vibration, Transportation, Bounce, Loose Cargo	514 XI, Pt. 2	SKPV	11-10-72	Passed	All vibration and shock conditions as for S/N 2, except tests performed at reduced temperatures as indicated. Tested at -40°F
Common Carrier	514 X, AB	SKLF	11-15-72	Passed	Tested at -40°F
Military Vehicle Composite Road	514 VIII, V	SKLF	11-15-72	Passed	Tested at -40°F
Cross Country Terrain	514 VIII, W	SKLF	11-15-72	Passed	Tested at -40°F
Track Vehicle #1	514 VIII, W	SKLF	11-16-72	Failed	Tested at -40°F CRT unseated. (Loose retaining nut). Scan mirror counter-weight found loose in unit. F.R. 23555-016 & 017. ECR 23555-0497 & 0534 add loctite to the CRT retaining ring and a lock washer to the counter-weight. Validated by subseouent test on S/N 2, 1-25-73.
Track Vehicle #2	514 VIII, W	SKPV	12-5-72	Failed	Tested at -40°F Unit operated after test, but brackets supporting Pre-amp Multiplexer Assembly were found to be broken. F.R. 23555-019 ECO 23555-0473 & 0476 changes bracket design and material. Validated by subsequent test on S/N 2, 1-25-73.

Figure 5-3 (Cont)

TEST	SPEC	LOCATION*	COMPLETED	RESULTS	REMARKS
Track Vehicle #3	514 VIII, W	SKPV	1-18-73	Failed	Tested at -40°F Unit operated after test. Rivets securing support brackets for Preamp Multiplexer Assembly sheared. F.R. 23555-023 ECO 23555-0534 incorporates a rivet approximately three times as strong as those that sheared. Validated by subsequent test on S/N 2, 1-25-73.
Track Vehicle #4	514 VIII, W	SKPV	1-25-73	Passed	Tested at -40°F S/N 2 used for this Arctic test only.
Shock, Launch	B1, Para. 4.2.4.15.3	SKPV	1-24-73	Passed	Tested at -40°F
Shock, Mechanical	B1, Para. 4.2.4.15.1	SKPV	1-29-73	Passed	Tested at -40°F
Shock, Transit Drop	B1, Para. 4.2.4.15.2	SKPV	2-1-73	Passed	Tested at -40°F
Shock, Drop, Dirt	B1, Para. 4.2.4.15.2	SKPV	2-1-73	Passed	Tested at -40°F
Shock, Drop, Concrete	B1, Para. 4.2.4.15.2	SKPV	2-1-73	Passed	Tested at -40°F
Temperature Shock	503 1	SKPV	2-7-73	Passed	Test conditions as for S/N 2.

Figure 5-3 (Cont)

Location Legend

SKPV = Singer Kearfott Division
63 Bedford Road
Pleasantville, New York

NU = Noise Unlimited
130 Center Street
Somerville, New Jersey

SKLF = Singer Kearfott Division
1150 McBride Avenue
Little Falls, New Jersey

PAVSC/GSD = Philips Audio Video Systems Corp.
Government Systems Division
One Philips Parkway
Montvale, New Jersey 07645

AELSC = AEL Service Corporation
Monmouth County Airport
Route 34
Well Township, New Jersey

Figure 5-3 (Cont)

SECTION VI

QUALITY ASSURANCE

6.1 GENERAL

Quality Assurance involvement commenced with the receipt of the contract and continued throughout the entire program in compliance with MIL-Q-9858A quality program requirements.

Quality Assurance engineering personnel, upon completing a comprehensive review of contractual documents to determine each operating groups total responsibility, disseminated pertinent contractual requirements to each group.

During the design and procurement phase, compliance to contractual requirements was monitored through review, comment, and sign-off of all drawings, engineering change orders, specifications, and purchase orders.

Previously accumulated vendor history files from similar programs (AN/PAS-7 and AN/VAS-1 Programs) were researched to determine those vendors whose performance and products reflected a thorough understanding of the contractual technical and delivery requirements. This information was forwarded to the engineering and purchasing departments. To the maximum extent possible, these approved vendors were used as sources. New vendors, or vendors for whom insufficient historical data was available, were surveyed prior to procurement, with engineering and purchasing personnel as required, to verify the adequacy of their inspection and calibration procedures, equipment, and personnel. Source inspection was used as necessary when expediency and/or complexity of testing dictated. Analysis of results attests to the soundness of this approach.

6.2 INCOMING INSPECTION

The Incoming Inspection Department has accumulated considerable records of all vendor-supplied items. From these records can be selected those sources who now have the controls and capability to supply a quality product in production quantities. These records will be maintained and will serve as a basis and justification for tooling, fixturing, and sampling inspection controls for future procurements.

6.3 IN-PROCESS INSPECTION

In-Process Inspection monitored and documented each operation of the manufacturing process through the use of flow charts and control tags. History files, established for each unit, reflect all subassembly and system fabrication, inspection and test activity. All documentation is retained in the individual system history file together with shipment records. Complete system configuration can readily be identified by reviewing these records. Each file, as appropriate, is updated with repair or retrofit activity, field report activity when available, and other data germane to the unit and that will be beneficial for design analysis efforts on future procurements.

6.4 TEST

Subassembly and system test of the Night Vision Sight was accomplished through the combined efforts of Engineering and Quality Assurance. In the subassembly test phase, Quality Assurance Engineering provided a support and monitor function by periodic audit of the testing and by reviewing accumulated data and engineering notebooks in accordance with MIL-Q-9858A requirements.

System test responsibility was shared jointly and equally by Engineering and Quality Assurance. A quality assurance engineer was assigned as part of the acceptance test team throughout the ED program, thereby serving a dual function of monitoring test activity and data, and performing the acceptance test.

This standard PAVSC/GSD operating procedure provided extra dividends in that while assigning a minimum number of Quality Assurance personnel during the ED phase, through the dual function role described, an experienced well trained nucleus was formed for future production volume testing, in which Quality Assurance will have prime responsibility.

6.5 QA ENGINEERING

Quality Assurance engineering personnel conducted and administered the environmental test program including the preparation of the test plans and test summaries. Final results were in compliance with contractual/specification requirements and reflected the adequacy of the design, and those changes incorporated as a result of minor problems encountered during a few tests.

Support effort was provided by Quality Assurance engineering personnel for government conducted high level electromagnetic radiation tests, and the electrostatic discharge tests.

Field test activity and problems were monitored jointly by Quality Assurance and the Engineering departments. Equipment Performance Reports (EPR's) were reviewed, evaluated, and responded to, detailing action required to correct a problem or clarifying situations requiring no further action.

Recommendations for product improvement resulting from total test activity, as well as recommendations in the areas of volume producibility, automated, or semi-automated inspection and testing were forwarded to program management throughout the program.

SECTION VII

RELIABILITY AND MAINTAINABILITY

7.0 RELIABILITY AND MAINTAINABILITY

7.1 GENERAL

To achieve the reliability and maintainability objectives specified for the Night Vision Sight, reliability and maintainability engineering procedures and practices were instituted during the initial design stages and continued throughout the program. Responsibilities of the Reliability and Maintainability Engineering Department for this program were to:

(1) Assist, contribute to and monitor engineering design, and establish guidelines to ensure Night Vision Sight Compliance with:

(a) functional performance for the specified number of "ON-OFF" cycles

(b) Mean-Corrective-Maintenance-Downtime (M_{ct}) and Maximum-Corrective-Maintenance-Downtime ($M_{max_{ct}}$)

(2) Assess reliability and maintainability parameters by means of predictions as the design progressed

(3) Measure the achieved reliability and maintainability performance by means of demonstration tests subsequent to design completion.

7.2 RELIABILITY

7.2.1 INHERENT RELIABILITY

Since the inherent reliability of the Night Vision Sight would be determined primarily by:

(1) Circuit design--the use of proved mature electronic circuitry and mechanical design

(2) Parts selection and application--parts adequately derated and commensurate with the requirements

(3) The utilization of the minimum number of parts to perform the required functions.

(4) The use of parts having low failure rates.

Procedures were implemented that would enable the achievement of these characteristics to the maximum extent feasible. These areas are briefly discussed in paragraphs 7.2.1.1 and 7.2.1.2.

7.2.1.1 Circuit Design/Utilization of Minimum Number of Parts

Circuits were designed to use the minimum number of components to perform specified functions. Complex designs using large numbers of components were avoided to the maximum extent feasible. Circuit modules were subjected to electrical and environmental tests to determine their compliance with the applicable specifications and then compatibility with interconnecting circuits prior to incorporating the circuit modules in the final design.

Formal scheduled design reviews and frequent reviews of the circuitry and the packaging by a reliability and maintainability engineer were accomplished in order to optimize the reliability and maintainability parameters of the design.

7.2.1.2 Parts Selection and Application/Failure Rates

The parts used in the design of the Night Vision Sight were selected in accordance with the following criteria:

(1) Applicable electrical and environmental requirements.

(2) Preferred military standard parts.

(3) Standardized to the maximum extent possible.

(4) Parts which could comply with the intended applications.

In the event that a preferred MIL part could not be used, the use of other MIL parts were investigated. Should a MIL part not be available, or if the incorporation of a MIL part would result in an impractical design, a non-MIL part, selected in accordance with the requirements was considered.

Prior to the use of any non-MIL part, however, design engineers were required to substantiate the need to Reliability Engineering. Reliability Engineering control and approval of non-MIL parts were implemented by the use of a standard "in-house" PAVSC form "PAVSC Non-Standard Parts Request", Figures 7-1 and 7-2. When appropriate, requests for Government approval of non-MIL electrical parts were then submitted in accordance with the contractual data requirements.

Figure 7-1

PHILIPS BROADCAST EQUIPMENT CORP./GOVERNMENT SYSTEMS DIVISION

NON-STANDARD PARTS REQUEST NO.______________

NOTE: No Source Control Drawing or Specification Control Drawing will be considered for generation until this form has been completed.

(See instructions for completing this form on the reverse side of this sheet.)

1. Project:______________________________

2. Non-Standard Part Type:______________________________

3. Manufacturer's Name:______________ Manufacturer's Part No.______________

4. Part used in:______________________ 5. Number of times used:______
(Name of Subassembly)

6. Drawing Number of Subassembly and Part Circuit Symbol (if available):______________

____

7. Description of non-standard part (list pertinent information such as voltage and/or current rating, power rating, size, weight, etc.) or attach a copy of Manufacturer's Data Sheet:______________________________

____

8. Application information (list pertinent information such as voltage and/or current stress, power dissipation, size, weight, etc.):______________________________

____

9. What standard part (and its related military specification) comes closest to complying with your specific application requirements:______________________________

____

10. Why cannot the standard part described in 9 above be used? (Give specific details, not generalities. State differences in voltage rating, power dissipation, size, weight, etc.):______________________________

____

____

11. Initiated By:__________ Date:__________ Approved By:______________ Date:________
Project Engineer

12. Reliability Engineering Comments:______________________________

____

Request Approved / Disapproved By:______________________ Date:______________
Reliability Engineer

SCD Number Assigned:______________ SCD Title:______________________________

____

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Figure 7-2

INSTRUCTIONS FOR COMPLETING NON-STANDARD PARTS REQUEST

1. Record applicable project for which this part will be used.

2. Part Type: List the specific part type such as:

   Resistor: (Carbon composition, carbon film, metal film, power wirewound, precision wirewound, etc.)

   Capacitor: (Tantalum foil, tantalum solid, paper, mylar, glass, ceramic, glass piston trimmer, etc.)

   Transistor (n-p-n, p-n-p); diode (signal, power, zener, varactor); tube (cathode ray, local oscillator, magnetron); connector; etc.

3. Name and part number: List the Manufacturer's name and part number of the non-standard part.

4&5. Name of subassembly and number of times part used: Self-explanatory.

6. Drawing Number and Circuit Symbol: List the Philips drawing number of the subassembly and the part circuit symbol. If drawing number does not exist, state "Not available".

7. Description of Non-standard part: Self-explanatory.

8. Application Information: Self-explanatory.

9. Closest Standard Part: Self-explanatory.

10. Reasons for not using standard part: Specific reasons must be stated why a standard part is not usable. Generalities are not acceptable.

11. Initiated By: Name of the cognizant design engineer specifying the non-standard part and the date the form is completed.

    Approved By: Name of the cognizant project engineer approving the use of the non-standard part, and the date reviewed.

12. Reliability Engineering Comments: To be completed by Reliability Engineering.

To further ensure compliance with the quantitative and qualitative reliability requirements, failure rates of the piece parts utilized had to be as low as feasible. Since a prime factor having a significant effect on piece part failure rates is the electrical stress to which the piece parts are subjected, adequate derating of electrical parts was made mandatory. Therefore, electrical stress design limits were imposed in accordance with the values shown in Figure 7-3. Deviations from this requirement required specific justification.

7.2.2 RELIABILITY ASSESSMENT AND ANALYSIS

At the onset of the design, maximum Mean-Time-Between-Failures (MTBF) were allocated to each of the assemblies comprising the Night Vision Sight. During the development stages of the Night Vision Sight, reliability prodictions were performed to assure compliance with the allocated MTBF's. In all cases the predicted MTBF values for each of the assemblies were greater than the MTBF's allocated. The predicted and allocated MTBF's are shown in Table 7-1.

7.2.3 RELIABILITY DEMONSTRATION TESTS

Subsequent to the completion of the design, reliability demonstration tests were performed to verify the Night Vision Sight compliance with the reliability requirements. Two Night Vision Sights were subjected to test in an ambient temperature of 50°C; operated 5 minutes "ON", 5 minutes "OFF" (1 operating cycle) for 3-1/2 hours, then turned "OFF" for 1/2 hour; and vibrated for an average of 10 minutes for every 1 hour of "ON" time. This operating profile was then repeated until 6200 operating cycles had been accumulated. Five failures were allowed during the performance of this test. One failure occurred. At the completion of this test, the test was extended, for information only, for an additional 3153 cycles. Two additional failures occurred during this period.

Concurrent with the test of the Night Vision Sights, two Battery and Housing Assemblies were subjected to "insertion and removal" tests (300 insertions and removals for each Battery and Housing Assembly); and a Valve was subjected to a mechanical operating test (6204 "ON-OFF" operation; 1034 Cartridge insertion and removals). No failures occurred.

The Night Vision Sight, Battery and Housing Assembly, and Valve, complied with the reliability requirements. A complete description of the reliability demonstration test, including a test summary, requirements, conclusions and recommendations, factual data, and the test procedure, are described in classified documents GSDR No. 580 "Reliability Demonstration Test Report for Night Vision Sight, Infrared AN/TAS-3( )" and GSDR No. 618 "Reliability Demonstration Test Extension Report for Night Vision Sight, Infrared, AN/TAS-3( )".

Figure 7-3
ELECTRICAL DERATING

Component	Electrical Stress Design Limits
Composition Resistors	less than 10% of nominal power rating
Metal Film Resistors	less than 20% of nominal power rating
Wirewound Resistors	less than 20% of nominal power rating
Variable Wirewound Resistors	less than 10% of nominal current rating
Ceramic Capacitors	less than 10% of nominal voltage rating
Glass Capacitors	less than 10% of nominal voltage rating
Paper Capacitors	less than 10% of nominal voltage rating
Variable Piston Capacitors	less than 10% of nominal voltage rating
Tantalum Capacitors	less than 60% of nominal voltage rating
Silicon Signal Diodes	less than 10% of nominal power rating
Silicon Power Diodes	less than 50% of nominal power rating
Silicon Zener Diodes	less than 10% of nominal power rating
Silicon Signal Transistors	less than 10% of nominal power rating
Silicon Power Transistors	less than 50% of nominal power rating
Silicon Controlled Rectifiers	less than 20% of nominal power rating
Inductive Windings	30°C below the maximum rated hot-spot temperature

Table 7-1

Predicted and allocated Mean-Time-Between-Failures (MTBF) for the Assemblies comprising the Night Vision Sight AN/TAS-3( ).

Assembly	Specification	Allocated MTBF (Hours)	Predicted MTBF (Hours)
Preamplifier, Multiplexer	C2b 230201010200	1,900	33,753
Scanner	C2b 230201010300	1,400	14,748
Battery & Housing	C3 230201010400	7,000	62,457
Main Frame	C2b 230201010500	28,000	100,000
Circuit Card, Display	C2b 230201010600	2,300	56,979
Cartridge	C2a 230201010710	24,000	100,000
Valve	C2a 230201010720	24,000	66,667
Eyepiece	C2b 230201010800	40,000	50,000
Objective Lens	C2b 230201010900	28,000	100,000
Detector, Cryostat and Circuit Cards	C2b 230201011000	1,900	19,675
Power Supply	C2b 230201011100	2,300	33,325

7.3 MAINTAINABILITY

7.3.1 MAINTENANCE CONCEPT

The maintenance philosophy on which the basic maintainability features of the Night Vision Sight were predicated was based on the specific quantitative maintainability requirements, i.e., a mean-corrective-maintenance-downtime ($\bar{M}_{ct}$) of 0.5 hour and a maximum corrective-maintenance-downtime ($M_{max_{ct}}$) (95 percent) of 1.0 hour, to locate a fault to a specific assembly, interchange the defective assembly with an operable assembly, and retest.

7.3.2 MAINTAINABILITY DESIGN CHARACTERISTICS

To comply with the quantitative $\bar{M}_{ct}$ and $M_{max_{ct}}$ requirements, design criteria were established as follows, and complied with to the maximum extent consistent with the performance, weight and space requirements:

(1) Each assembly shall perform an independent function

(2) Each assembly shall be designed for ease of replacement

(3) Provide for commonality between assemblies and tools

(4) Comply with weight and space constraints

(5) Fastener sizes and types shall be minimized

(6) Subassemblies, modules and assemblies shall be polarized to prevent incorrect installation

(7) All subassemblies, modules, piece parts, locations, test points and connectors shall be clearly marked or labeled with the appropriate reference symbols.

7.3.3 DESIGN TRADE-OFFS

During the design stages trade-offs were accomplished, some of which impacted favorably and some unfavorably on maintainability. For example:

(1) Bias assembly: A trade-off was conducted which resulted in higher performance and lower weight with some compromise in maintainability. Hard wired printed wiring component boards were used instead of plug-in printed wiring component boards. This decision was based on the fact that low signal levels are involved and performance has a higher priority than other design characteristics, such as maintainability. Maintainability was not degraded significantly as a result of this trade-off.

(2) Video Amplifier, Deflection Amplifier, Multiplexer - Driver Circuit (Logic): A trade-off was performed which resulted in a reduction in total parts at some increase in cost. In this application, hybrid integrated circuits mounted on plug-in printed wiring component boards were selected instead of discrete parts. This decision was prompted by the need to reduce weight which had a high priority. Significantly, this trade-off impacted favorably on maintainability since a part failure occurring on one of these boards now simply requires the removal of the plug-in board and replacement with another board.

(3) Power Supply Assembly: A trade-off was conducted which resulted in lower weight with minimal decrease in maintainability. The high voltage circuit associated with the power supply assembly could have been mounted in two different configurations. In the first configuration the high voltage circuit could be mounted in a module together with the power supply assembly, however, this would require enlarging the size of the casting with a corresponding increase in weight. In the second configuration the high voltage circuit could be mounted external to the module in which the power supply assembly is mounted, however, this would require an interconnecting cable between the high voltage circuit and power supply assembly. In addition, 4 wires would have to be unsoldered to remove the high voltage circuit. A trade-off between weight and maintainability resulted in the selection of the second configuration. A saving in weight with only a minimal decrease in maintainability conformed to the established priority of characteristics for design trade-offs.

7.3.4 MAINTAINABILITY DEMONSTRATION TEST

After design completion, a maintainability demonstration test was performed to verify Night Vision Sight compliance with the maintainability requirements, as follows:

1. A randomly selected fault was introduced into an assembly of the Night Vision Sight.

2. The fault was localized to the faulted assembly, the Night Vision Sight disassembled to the level required to remove the faulted assembly, a good assembly re-installed, the Night Vision Sight reassembled and a test performed to verify proper performance.

3. Twenty-six different faults were introduced into the Night Vision Sight and the procedure described in (2) repeated for each of the inserted faults.

The Night Vision Sight complied with the $\overline{M}_{ct}$ of 30 minutes. The NVS also complied with the $M_{max_{ct}}$ of 1.0 hours in 21 of 26 trials. In 5 trials the $M_{max_{ct}}$ was exceeded by times ranging from 0.008 to 0.12 hours. A complete description of the maintainability demonstration test, including a test summary, requirements, conclusions and recommendations, factual data, an analysis and evaluation of the data, and the test procedure are described in GSDR No. 566 "Maintainability Demonstration Test Report for Night Vision Sight, Infrared AN/TAS-3( )".

SECTION VIII

CONCLUSIONS

8.1 GENERAL

This program has resulted in the design, fabrication, test and evaluation of a lightweight, reliable, rugged passive infrared real time imaging night vision sight for use with the Medium Antitank/Assault Weapon (DRAGON) System. Essentially all of the requirements of the Prime Item Development Specification (PIDS) were met with priority directed toward performance, weight, safety, maintainability and reliability as specified in the PIDS.

8.1.1 PERFORMANCE CHARACTERISTICS

8.1.1.1 General

All electro-optical requirements of the specification were met including field-of-view, resolution, noise equivalent temperature, minimum resolvable temperature difference, optical transfer function and system magnification. Boresight retention proved to be a major performance problem and the mechanical interface between the Tracker and the Night Vision Sight was modified three times before a satisfactory solution was derived. The requirement for one hour of system operation at 70°F from the battery pack proved to be marginal and the cause of the marginal battery life has been traced to the method used to charge the sealed nickel-cadmium cells. A PAVSC developed recharging circuit has resulted in an increase in the average battery life of over 15 percent compared to previous batteries recharged using GFE charger-adapters and power supplies.

8.1.1.2 Environmental Testing

In the PCA baseline configuration, the Night Vision Sight and ancillary equipments encountered no physical deterioration or impairment of performance by exposure to operating and non-operating environments as defined in the Prime Item Development Specification. Marginal low temperature scanner operation was noticed during "Early Look" tests at Ft. Greely, Alaska, and recorded during the engineering tests at WSMR. To ensure specified operation at low temperature, scanner mirror torque motor requirements will be upgraded for APE units and the drive circuitry checked for cold temperature operation.

A number of mechanical design changes, primarily in the area of internal electronic board supporting structures, were incorporated into the system as a result of failures that occurred during vibration tests. The qualification units were submitted to environmental retest after modification and successfully withstood the applied stresses.

Fungus tests were conducted in accordance with MIL-STD-810B, Method 508. Problems were encountered in three areas; bag material, finished surfaces of the eyeshield assembly, rubber portions at the base of the male battery connector. Corrective action has been taken on the eyeshield and battery connector. The bag material will be treated for fungicide when production quantities are ordered.

The NVS successfully passed Electromagnetic Radiation tests conducted at PAVSC and MDAC/TICO and Nuclear Survivability tests conducted at Picatinny Arsenal. In July of 1973 Radiation Hazards tests were conducted at Picatinny Arsenal and several areas of EMI were encountered. PAVSC, working closely with the Arsenal staff, developed a series of mechanical modifications that were incorporated into the test unit. Retest indicated that the NVS could withstand the effects of high level radiation. These modifications have been incorporated into the APE units.

8.1.2 PHYSICAL CHARACTERISTICS

During the evaluation of the mechanical design of the Night Vision Sight major emphasis was placed on achieving a maximum weight of 10 pounds. The prime area of compromise was in the amount of coolant gas that could be supplied consistent with system weight limitations. In final configuration a seven cubic inch coolant cartridge, containing enough coolant to operate the NVS for a minimum of seven 5 minute on - 5 minute off cycles or two hours of continuous operation, was fabricated. The battery marginally met the original requirement of one hour of continuous NVS operation at 70°F as described in the previous paragraph. The maximum measured weight of the last 19 systems fabricated (PCA baseline units) was 10.3 pounds with the average weight calculated to be 10.15 pounds.

8.1.3 RELIABILITY

The Night Vision Sight complied with the reliability requirements as outlined in the Prime Item Development Specification. Specifically the NVS demonstrated a MCBF, based on 5 minutes on - 5 minutes off cycle as defined in the PIDS under environmental stresses of temperature cycling and vibration, of 3105, well above the PIDS requirement of 2000. The final test report of the DT II test series issued by TECOM developed a MCBF of 322 based upon data collected during evaluation at WSMR/ET and USAIB/ST. WSMR used a 5 minute on - 30 minute off cycle and USAIB used the 5 minute on - 5 minute off criteria for their mini-ram test. Of the 37 failures recorded, twenty-five were associated with battery connectors, cooling problems, faulty field effect transistors and preamplifier microcircuits, roll pins and cradle lock knob on the boresight mechanism; all areas where design changes were incorporated have been successfully field tested.

8.1.4 MAINTAINABILITY

The Night Vision Sight basically complied with the maintainability requirements of the Prime Item Development Specification demonstrating an average mean-time-to-repair (MTTR) of substantially less than the specified 30 minutes. The maximum time-to-repair criteria of 1.0 hour was also met in 21 out of 26 trials. In 5 trials the maximum time was exceeded by times ranging from 0.008 to 0.12 hour. These extended repair times were associated with faults introduced into the scanner assembly and are attributed to the fact that the scanner mechanism is the inner assembly of all the subassemblies and is the most difficult to expose for repair. The design philosophy dictated that the scanner subassembly would be the main mounting vehicle for other subassemblies in the interest of weight saving, a higher priority consideration than maintainability. In actual field use the scanner mechanism experienced very few failures in comparison to other subassemblies.

The MTTR recorded in the DT II report was 1.41 hours with a 1.5 hour acceptable limit. The OTEA final report lists the MTTR as 1.02 hour and it should be noted that the OT II repair time was to the piece part level, not the subassembly level, which the requirements are stated for. The improved MTTR is due to the fact that all major problems encountered during DT II evaluation were solved and corrective modifications made to the equipment prior to OT II testing.

8.2 CONCLUSION

The AN/TAS-3 is a fully qualified and field tested Night Vision Sight designed for use with the DRAGON Weapon System. Its range capability is most effective near the limit of the DRAGON missile range and has proven very effective at 1/2 TOW maximum range. An Advanced Production Engineering (APE) program has successfully been conducted at PAVSC resulting in the fabrication of 4 pre-production units and over one million dollars worth of Special Acceptance and Inspection Equipment (SAIE) to be used for a production test effort. This APE program is in addition to the 29 Engineering Development models already fabricated and extensively laboratory and field tested.

SECTION IX

RECOMMENDATIONS

9.1 GENERAL

Reports from the recent conflicts in Asia and the Middle East indicate that warfare has become a 24-hour, round-the-clock activity. The Army urgently needs a Night Warfare (NW) capability if it is to be combat-ready in the 1970's and beyond. To implement the broad new concepts of offense and defense which are already emerging for NW, it is vital that thermal night vision equipment be developed rapidly to build the equipment inventory and the reservoir of trained personnel necessary for successful operations.

PAVSC believes that the existing AN/TAS-3 satisfies the requirement for a night vision sight for the DRAGON Missile system and that it is suitable as an interim sight for the TOW weapon. Significant operational and logistics improvements can, however, be made.

Based on experience gained during development and testing of the AN/TAS-3, PAVSC recommends that four major areas of improvement to the existing design be considered. They are:

- o Thermoelectric (TE) Cooling - Para. 9.2
- o Image Improvement - Para. 9.3
- o Extended Range Optics - Para. 9.4
- o Dedicated TOW Sight - Para. 9.5

Additionally, other areas of improvement for the existing AN/TAS-3 Night Sights and ancillary equipment are recommended as follows:

- o Existing AN/TAS-3--3 NVS - Para. 9.6
- o Battery Charger - Para. 9.7
- o Launch Blast Simulator - Para. 9.8
- o Carrying Bag - Para. 9.9

Each of the preceding items is briefly discussed in the indicated paragraphs.

9.2 CONVERSION TO THERMOELECTRIC COOLING

A factor that adds cost and delay to the development of night vision equipment is the choice of method for cooling infrared detectors to cryogenic temperatures. Cooling may be accomplished by one of three methods:

a. Thermoelectric cooling
b. Bottle cooling by liquefied or pressurized gas
c. Closed cycle coolers.

Contributing to the complexity of the cooling problem is the need to modularize new equipment designs so that commonality of components (to a varying degree for each equipment) can yield benefits in reduced costs, simplified logistic support, and orderly technological growth.

There are enough performance data on the various methods used for cooling detectors in thermal imaging systems for Army applications that the optimum cooling method for each particular application has become evident. Applications may be divided into four broad categories:

(a) Thermal weapon sights or viewers operated by the foot soldier.

(b) Thermal weapon sights or viewers for driving aids on lightweight and thin skinned vehicles; such as jeeps, trucks, ARSV and MICV.

(c) Thermal weapon sights and viewers for heavy vehicles; such as the M-60 and XM-1 Tanks.

(d) Thermal weapon sights and viewers for fixed wing and helicopter aircraft.

For the first category, the design and performance requirements are imposed by the individual infantryman who must carry his weapons and who cannot be readily supported or resupplied under fire. His life depends on his ability as a basic combat element to perform his function.

Accordingly, thermal weapon sights for the foot-soldier must be lightweight, capable of operating after prolonged exposure to dirt and moisture, and must be simple to support. Thermoelectric cooling is the only feasible cooling method for these applications.

The reliability of thermoelectrical cooling and the (acceptable) operational range achievable with 3 - 5 micrometer systems, far outweigh the additional range performance that could be obtained with a gas bottle cooled 8 - 14 micrometer system.

In the following paragraphs the disadvantages of the gas bottle approach as well as the advantages of the thermoelectric cooling approach will be detailed.

Disadvantages of the Gas Bottle Cooler for the DRAGON Night Sight are:

1. With two consumables (battery power and gas pressure) the rate of consumption is in general, not equal. The rate of consumption depends upon usage (cycling time and number of start-ups) and environmental conditions (temperature).

2. The operator has no reliable way to determine the status of his consumables. Status indicators must be readable in total darkness, add little or no weight, and must be inexpensive and reliable. Practical indicators of this type do not exist and, until developed, constitute a major objection.

3. When the pressure runs low, the gas bottle must be changed. This operation must frequently be performed at night with Arctic gloves or in the battlefield under fire. The possibility of contaminating the gas lines during the bottle change requires that an in-line molecular filter located close to the cryostat be included. Like the bottle, this filter must be changed when its useful life has expired. The useful life expectancy of the filter is unpredictable. Changing of the filters can be difficult and awkward under field combat conditions, particularly at night.

4. Gas bottles as part of a night sight inherently represent a hazard to the foot soldier since they are pressurized at 3000 to 6000 psi. A fragment striking the gas bottle could prove lethal to the gunner even though it did not hit him directly.

5. Gas bottles and fill station equipment as well as the gas for refilling the bottles represent new items for an already overburdened Army inventory system.

   U.S. Navy history with nitrogen cryogenic bottle refills on aircraft carriers indicates that the bottle remained an unsatisfactorily resolved problem aboard aircraft carriers. The problem of refilling gas bottles under field combat conditions is expected to be much greater than aboard ship. Sophisticated field charging stations are necessary to provide gas bottle refills.

6. The level of skill required by night sight operations demands more training for gas bottles than for thermoelectric cooling. Additionally, special training is required for charging station attendants, who perform no other function in combat.

The continuing need to refill these bottles and replace filters represent a mounting cost for the entire life cycle of the equipment.

7. Because high pressure bottles are necessary, the present technology shows little promise of achieving a low-cost expendable bottle; for example, projected price for initial procurement of high pressure bottles are approximately $25 each in quantities of 10,000 or $100 each in quantities of 100. To this must be added the refilling costs.

8. Gas bottles have a limited refilling lifetime. In order not to exceed this, the bottles must be marked at each refilling. The vulnerability of a defense, depending upon a gas stock pile and gas charging stations is considerable since the destruction of the station could neutralize the NW capability of entire force depending upon it for supply.

Advantages of Thermoelectric Cooling for the DRAGON Night Sight are:

1. Energy consumed by the thermoelectrically cooled night sight is from a single source, the same battery that is used to operate the electronics.

2. Only spare batteries need be carried by the gunner or supply support activity.

3. The thermoelectrically cooled unit is lighter in weight than the gas bottle cooled unit.

4. The thermoelectrically cooled unit is of higher reliability.

   a. It does not suffer freeze ups
   b. There are no moving parts
   c. Thermoelectric cooling is all solid state.

5. No additional training is required for handling or refilling bottles.

6. No additional items are introduced into Army inventory (no filters, gas bottles, or fill stations).

7. A force using thermoelectrically cooled sights cannot be neutralized by destroying a bottle fill station or a gas stockpile.

8. There is no additional hazard to the gunner which might result from gas bottle pressure.

9. Theremoelectrically cooled night sights will operate uninterruptedly for the life of the battery.

10. A lower demand for personnel skill is required.

11. Theremoelectric cooling has proved field experience. The HHV using thermoelectric cooling has been successfully used in Viet Nam and in operational tests at Ft. Bragg.

12. When the total cost of ownership over the life cycle of the equipment is considered, the thermoelectrically cooled systems represent only their first cost. The bottle cooling systems represent continuing re-supply costs, more components to be added to inventory, cost of filling stations and the labor to operate those stations.

13. To conserve battery use, night sight operation from power supplied by Army vehicles can be provided.

PAVSC strongly recommends that night vision applications requiring moderate system resolution for ranges out to 2000 meters be covered with 3 - 5 micron thermoelectrically cooled equipments. Near future improved system performance appears to be available through recent advances in TE cooler materials and fabrication techniques as well as through new and improved detector materials, better application of available detector performance capability, cold filtering and other techniques. Considering the operational advantages, the available performance growth potential and the expected lower cost of the thermoelectrically cooled approach it appears highly desirable to develop a family of low to medium performance systems using standard modules.

Therefore, it is recommended that the AN/TAS-3 be converted to thermoelectric cooling and that as an interim step, the existing ED units be modified to TE (see paragraph 9.6).

9.3 IMAGE IMPROVEMENT

The DRAGON Night Vision Sight (NVS) signal processing has been designed to combine high sensitivity with fast overload recovery. This was done to optimize the image from weak targets at maximum weapon range. The combination of these design characteristics has resulted in a signal dynamic range of 25-30 dB which is sufficient for low contrast targets but results in a image from high contrast targets, such as vehicles at close range, that have a definite white on black appearance with loss of grey scale.

Other criticisms of the NVS image have been directed toward raster flicker, perceptive line structure and low brightness.

A number of improvements to enhance image quality have been devised and tested in various PAVSC Thermal Imaging systems. These improvements are discussed in the following paragraphs as set forth in Table 9-1 noting that these image problems are not entirely separable--improving one characteristic may or may not affect others.

TABLE 9-1

IMAGE IMPROVEMENT TECHNIQUES

9.3.1 Preamplifier Signal Processing

a. Overload Recovery

b. Preamplifier Gains

c. Preamplifier Bandwidth

d. High Frequency Compensation

9.3.2 Multiplexer and Video Signal Processing

a. Improved Multiplexer

b. Multiplexer Rate

c. Interchannel Blanking

9.3.3 Display

a. CRT Phosphor

b. Image Flicker

c. Increased frame rate

9.3.4 Quasi-Interlace

9.3.1 PREAMPLIFIER SIGNAL PROCESSING

a. Overload Recovery - A fast overload recovery circuit is incorporated into the AN/TAS-3 preamplifier. This allows fast recovery from saturation due to extremely hot flashes such as is experienced at the moment of missile launch and ensuing launch tube afterburn. This overload recovery circuit, a form of signal limiter, is one cause of dynamic range loss. The preamplifier noise output level is typically 10-15 millivolts p-p and the limited output level is typically 300-400 millivolts. Dynamic range therefore, varies from 40 to 20. On an experimental basis with limiting removed, the preamplifier output level has been measured at over 4 volts p-p resulting in a 20 dB improvement in dynamic range and a corresponding improvement in scene grey scale rendition. With this limiting removed, laboratory tests to simulate launch blast were conducted and no significant increase in recovery time was noted. On two systems, the Vehicle Austere Night Sight (VANS) a system incorporating NVS signal processing, and a thermoelectrically cooled version of the NVS with an extended range lens, the limiting level of the recovery circuit was raised by a factor of 4. This modification was installed along with a reduction of preamplifier gain increasing the dynamic range to about 45 dB. The VANS underwent a series of field test firings with the 105 mm rifle, 20 mm cannon and 50 cal machine gun. No excessive overload was noticed and scene grey scale was noticeably enhanced. The extended range TE cooled system was not exposed to field test firings although recovery time is expected to be the same in the VANS.

b. Preamplifier Gain - The AN/TAS-3 preamplifier gain of 295 was established to overcome multiplexer noise. This noise exists in the form of switching spikes during which no signal is present at the output. Reducing preamplifier gain does improve the dynamic range (by reducing the preamplifier noise output) but at the expense of S/N ratio. The ability to detect low contrast targets of around 0.1°K delta is decreased and inter-channel dead bands increase in width. A decrease in preamplifier gain must be accompanied by a reduction of multiplexer spikes (see paragragh 9.3.2 below).

c. Preamplifier Bandwidth - An increase in the upper cut-off frequency of the NVS preamplifiers from 2 kHz to 5 kHz was implemented in the VANS and the TE cooled, extended range NVS. Since the detector noise is essentially 1/f, increasing the upper cut-off frequency will not substantially degrade S/N but will improve the image quality by reason of an increased MTF. Although no comparative data is available, increased bandwidth (along with other image improving modifications) substantially improved picture resolution of small detailed targets.

d. High Frequency Compensation - On the original TE cooled, extended range NVS with the frame rate increased to 20, high frequency peaking was incorporated to extend the high frequency roll-off to about 3 kHz. This modification in conjunction with a reduced preamplifier gain of 150 enhanced image grey scale and small target detection as observed in various field tests. The effect of higher scan rates and increased high frequency response need to be further evaluated to determine the overall effect on image improvement.

9.3.2 MULTIPLEXER AND VIDEO SIGNAL PROCESSING

a. Improved Multiplexer - Decreasing preamplifier gain (paragraph 9.3.1.b) requires the use of a better multiplexer with a lower level switching spike in order not to lose S/N. On the VANS and the latest version of the TE cooled, extended range NVS a multiplexer with a noise energy output per pulse of 1/5 to 1/10 of the AN/TAS-3 multiplexer was used. The preamplifier gain was reduced by a factor of 2.5 without losing S/N, thereby increasing dynamic range and grey scale rendition.

b. Multiplexer Rate - On the VANS and the improved TE cooled ER/NVS the frame rate was increased to 30. This required a corresponding increase in the vertical scan frequency (and the master clock from 30 kHz to 650 kHz) in order to provide an adequate number of incremental samples and to preserve a merged raster. The preamplifier bandwidth was also increased as discussed in paragraph 9.3.1.c. The improved multiplexer could also handle the corresponding increase in multiplexer switching rate (72 times the vertical scan frequency).

c. Interchannel Blanking - On the AN/TAS-3 multiplexer, switching spikes are removed from the video by a short interchannel blanking pulse fed into the video output stage. On the VANS and on the improved version of the TE cooled ER/NVS the use of the high speed multiplexers with their extremely narrow switching spikes obviated the need for this blanking pulse and it was removed resulting in a more homogeneous display. This is because the scan efficiency goes from 80 percent (not counting retrace) to 100 percent. Further improvement in dynamic range can be achieved by changing a transistor shunt switch on the output of the multiplexer (still required for horizontal cross hair blanking) to a FET switch thereby eliminating clipping of the video signal at this stage. The resulting improvement in cross hair brightness must be weighed against circuit changes required to incorporate this FET.

9.3.3 DISPLAY

a. CRT Phosphors - The AN/TAS-3 uses a CRT with a P20 phosphor. This is a bright yellow-green display (5600Å peak) with a persistence of 0.2 millisecond. Two other CRT's, one with a P28 phosphor and one with a P45 phosphor were evaluated in the laboratory. The P28 phosphor is yellow-green (5500Å peak) with a relatively slow 500 millisecond persistence. It was thought that this slow persistence might tend to reduce the flicker effect but a side-by-side comparison with a standard AN/TAS-3 display revealed an overall degradation of picture quality to an unacceptable level, according to several trained observers.

The P45 phosphor is white with a 1.7 millisecond persistence. A brief evaluation was conducted and relatively favorable comments were received regarding a somewhat reduced level of flicker although more testing is needed on this type of phosphor. The P45 phosphor has been successfully used on two other PAVSC imaging systems and apparently has less phosphor burn-in than the P20 type, an important consideration for the NVS.

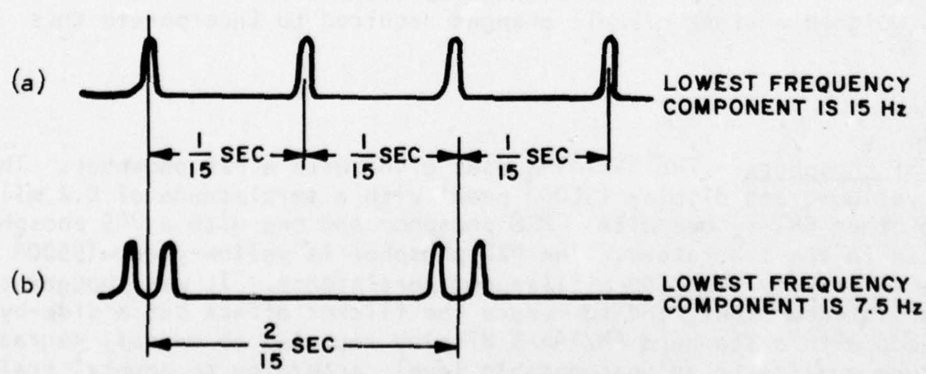
b. Image Flicker - As previously stated the present AN/TAS-3 operates at a frame rate of 15 fps. The effective display frame rate seen by the eye may be one half that or 7.5 fps due to two effects.

- Limited low frequency response of amplifiers.
- Edge flicker caused by back and forth scan.

The limited low frequency response on the DNS was purposely chosen so as to provide rapid recovery from strong thermal targets and also to reduce the visibility of the detector 1/f noise. However, the limited low frequency response produces differentiation of the video wave form particularly for extended targets. The image presented on the CRT will therefore be slightly different during the scan from left to right than from right to left.

The eye is particularly sensitive to this and views the two images as different frames and thus in effect, sees a 7.5 fps image.

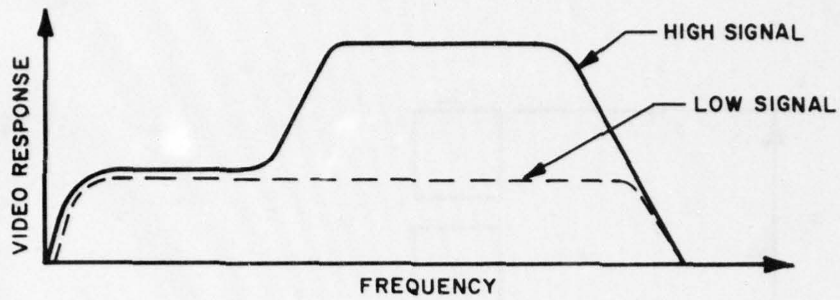
Edge flicker is caused by another effect. This may be explained by considering first a target in the exact center of the field of view and secondly, a target near the edge of the field of view. With the target in the center, the video waveform would appear as shown in (a) and with the target near the edge as in (b).



Of the two flicker producing effects, the edge flicker effect appears to be the lesser.

New signal processing techniques are being investigated on the Common Modules Program that appear to have application to the flicker, recovery and image quality problems of the DNS. Specifically, a non linear technique which produces a video response such as is shown in (c) below.

(c)



For weak video signals, the frequency response is extended to very low frequencies and thus will produce nearly identical frames from right to left and from left to right. For very bright extended targets, the video bandpass is reduced in the low frequency end. This helps to improve the recovery. The expected benefit of this technique is that the normai background which contains relatively weak video signals will be seen at the frame rate of the scanner and with less fatigue producing flicker. Strong target visibility will possible be enhanced since the flicker frequency will be one half that of the scanner.

Another important benefit expected from this technique is the reduction or virtual elimination of black streaking to the right and left of bright targets. This should substantially reduce the obscuration of weak targets near bright targets.

c. Increased frame rate - On the AN/TAS-3, because of AC coupling and the edge flicker effect discussed above, the apparent flicker frequency is equal to one half the frame rate rather than being equal to the frame rate. On the VANS and on the improved TE cooled ER/NVS the scan rate was increased from 15 to 30 frames per second. The higher frame rate does increase the apparent flicker frequency and definitely improves the image quality. The increased scan rate requires changes in the preamplifier and multiplexer as previously discussed.

9.3.4 QUASI-INTERLACE

The present AN/TAS-3 design uses a simple back and forth azimuth scan motion. The scanned area is covered by a linear array consisting of 64 nearly contiguous elements. The array geometry is depicted in Figure 9-1. It will be noted that the inter-element spacing is normally 0.0008 inch and the element size is normally 0.00315 inch. The actual detectors as delivered have an average element spacing closer to the upper tolerance limit of 0.001 inch and an average element size closer to the lower tolerance limit of 0.003 inch. There exists therefore a gap of roughly 33 percent in the scanned area coverage (not counting optics spot blurring).

It is possible by interlacing two successive scan fields to double the number of raster lines in the display (see Figure 9-2). This type of interlace will completely eliminate the 33 percent gap. The interlace will provide some overlap of scanned lines resulting in a more uniform display raster. The higher number of vertical sample points is expected to also improve the vertical MTF.

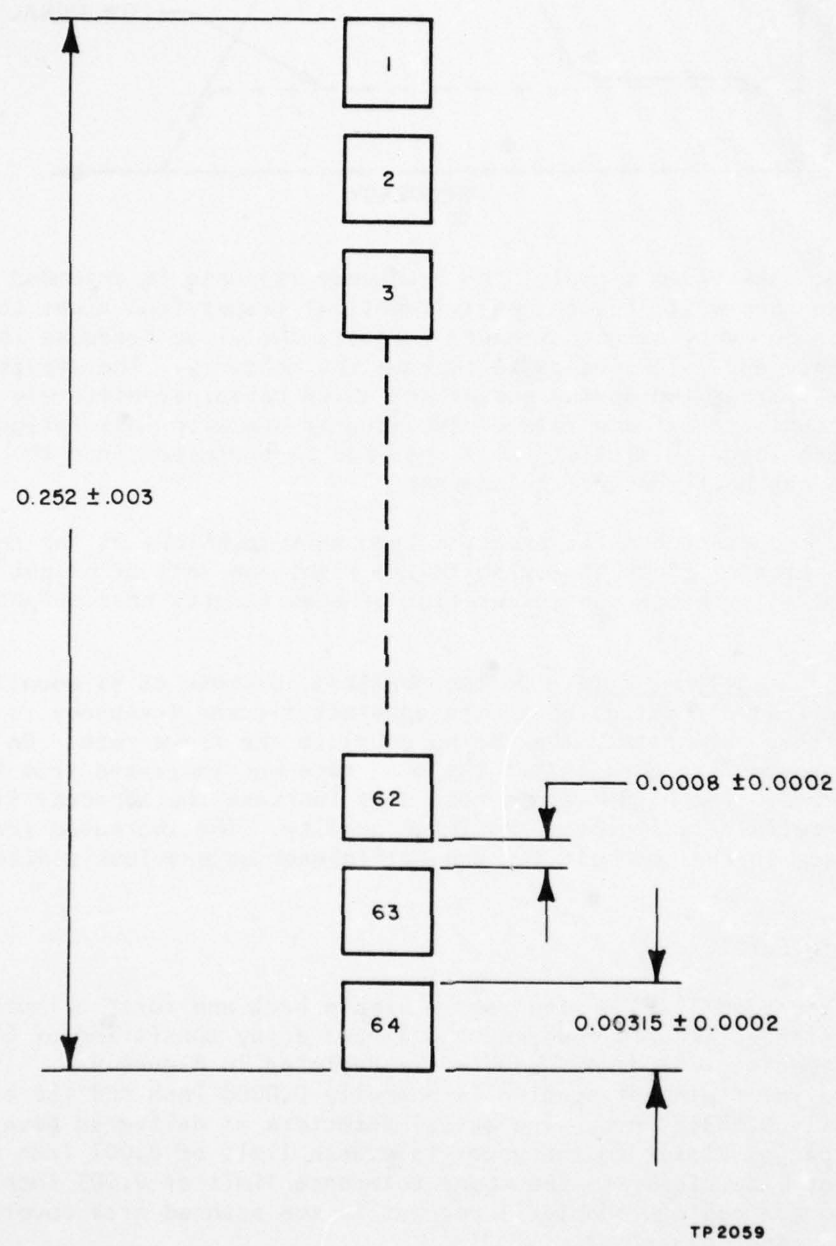


Figure 9-1. NVS Detector Array

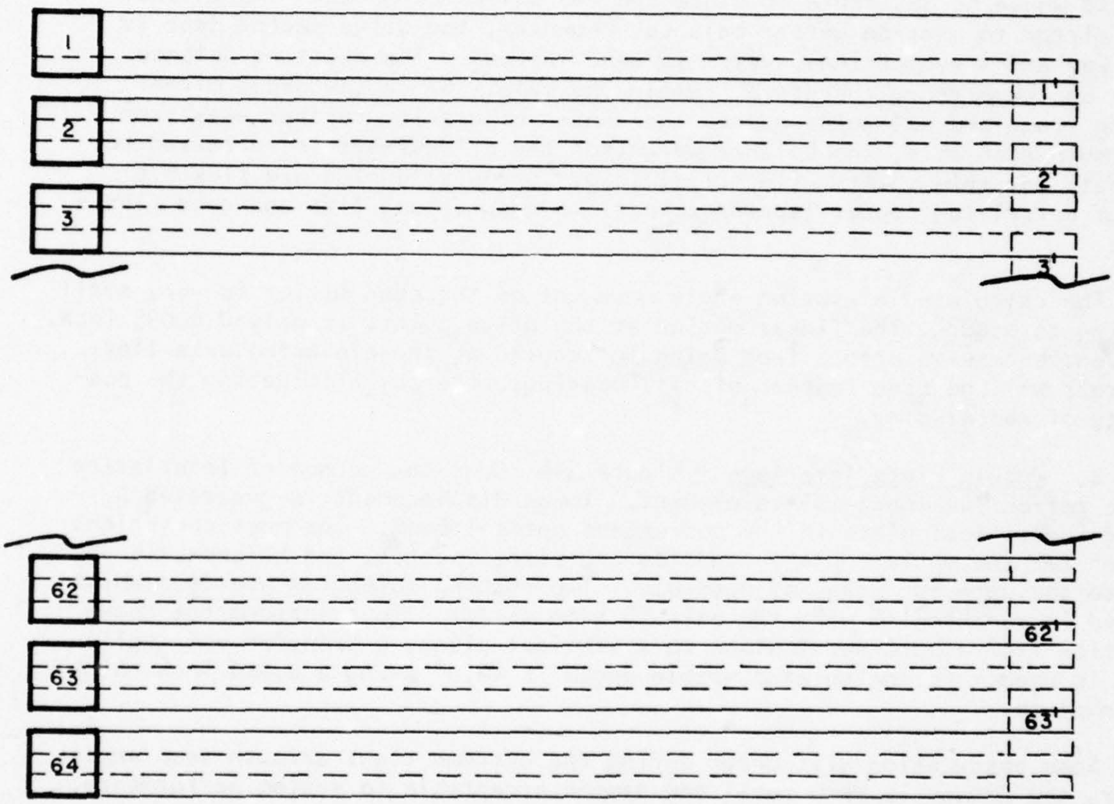


Figure 9-2. Interlace Scheme

To achieve these desired improvements PAVSC proposes to investigate two methods for implementing the required interlace scan motion. A preliminary evaluation of the two methods has shown that each can be designed into the existing DRAGON Night Sight package with minimum redesign. The two methods are:

a. Scan Mirror Interlace - Figure 9-3 shows the method of interlacing with the scan mirror. The elevation axis is placed on the optical axis to prevent axial displacement, and hence defocus, with interlace. The interlace drive elements are two push solenoids which are actuated in synchronism with the azimuth scan mirror. The existing bounce/contact springs can be used for solenoid programming. Two adjustable stops are provided to accurately adjust the excursion.

It would be desirable to place the two solenoids on the "short" end of the mirror to provide better balance. However, the drive sector gear is in the way and a symmetrical system is used instead. The existing balance weights on the mirror, therefore, remain the same. Since the added mirror mounting frame and solenoids pushes the center of gravity further away from the azimuth scan axis, the balance weight on the drive shaft is increased to compensate for this shift. Electrical leads to the solenoids are flexible wires of beryllium copper (spring temper) to ensure long life and good flexibility.

The calculated elevation angle movement of the scan mirror is very small amounting to 0.088°. The linear motion at the drive points is only 0.00095 inch. To prevent excessive errors from being introduced at the elevation axis flexure pivots will be used instead of ball bearings, thereby eliminating the possibility of radial play.

b. Wobble Plate Interlace - Figure 9-4 shows the method of interlacing using a refractive wobble plate element. Image displacement is generated by tilting the optical plate in the convergent optical beam. The most convenient location for the optical plate, considering size, inertia, and balance, is as close to the detector array as possible. Two rocking solenoids are used which actuated in synchronism with the azimuth scan mirror. To transform the rocking motion from a horizontal plane to a vertical plane, a transfer arm (bell crank) is used. The calculated wobble angle is ±4.0° using a 0.020 inch thick silicon plate.

Some obscuration will occur during the extreme right azimuth scan angle. However, the amount is very small and deemed acceptable to system performance. A preliminary investigation indicates the magnitude of the obscuration to be equal to or less than 5 percent.

9.3.5 RECOMMENDATIONS

Most image improvement techniques discussed in paragraphs 9.3.1 through 9.3.3 have been successfully implemented in two imaging systems, the VANS and the TE cooled extended range version of the AN/TAS-3. A substantial degree of improvement has been achieved in reduced raster flicker, grey scale rendition and display homogenity as well as improved MRT and MTF. These improvements have been realized without a major redesign effort and are readily adaptable to present AN/TAS-3 hardware.

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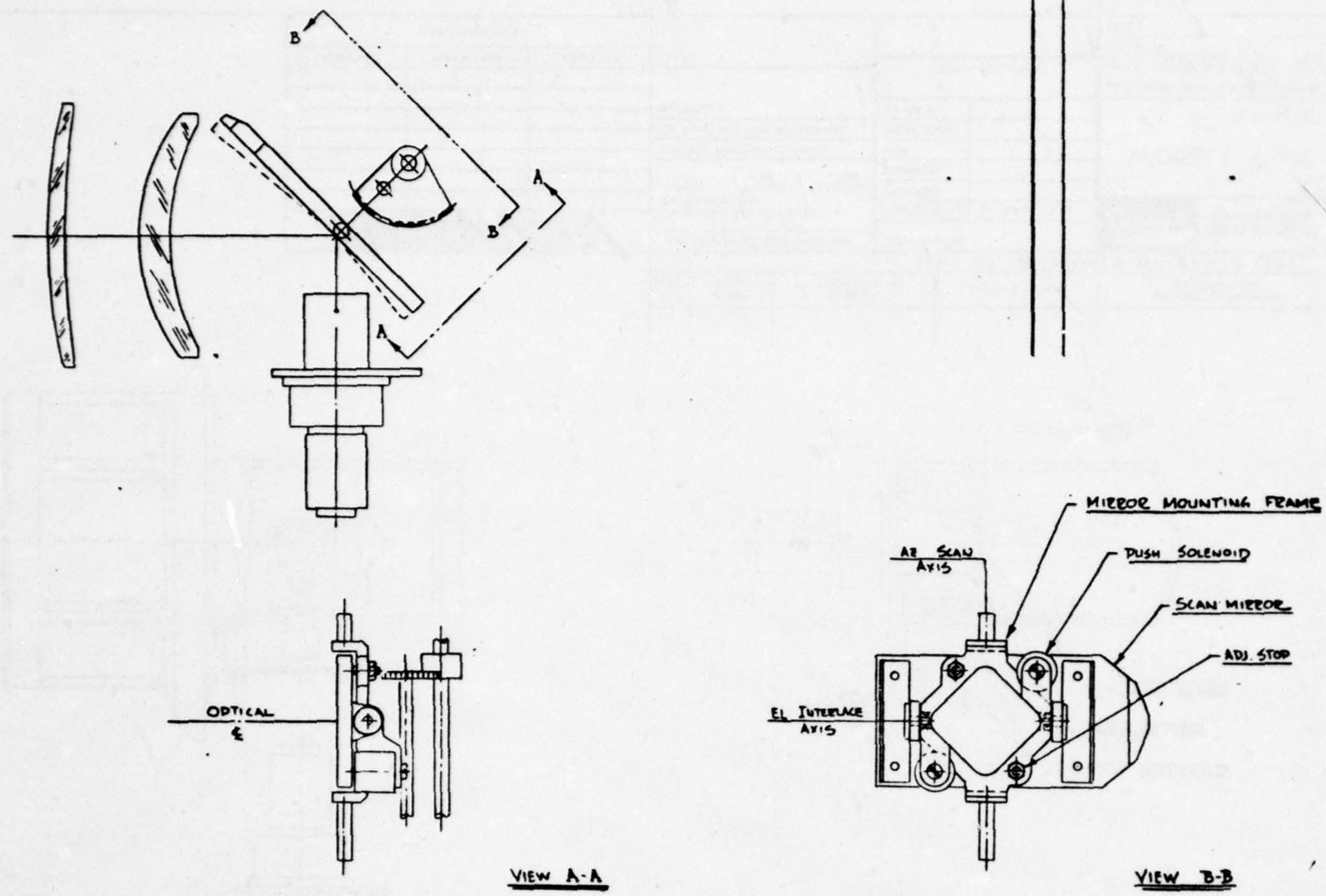
REVISIONS			



QTY REQD	CODE IDENT	PART OR IDENTIFYING NO	SPECIFICATION	NOMENCLATURE OR DESCRIPTION	MATERIALS OR REMARKS	ITEM NO

LIST OF MATERIALS OR PARTS LIST

PART NO	NEXT ASSY	USED ON
APPLICATION		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON:
ANGLES ± 1° 2 PL DEC ± .02 3 PL DEC ± .005
SURFACE ROUGHNESS (RMS)
DIM TO BE MET BEFORE FINISHING
MATERIAL:
FINISH:

CONTRACT NO
DRAWN 9/10/? R. BASTIAN
CHECKED
ENGINEER
MFG
RELBL ENGR
QA ENGR
DESIGN ACT APPVL

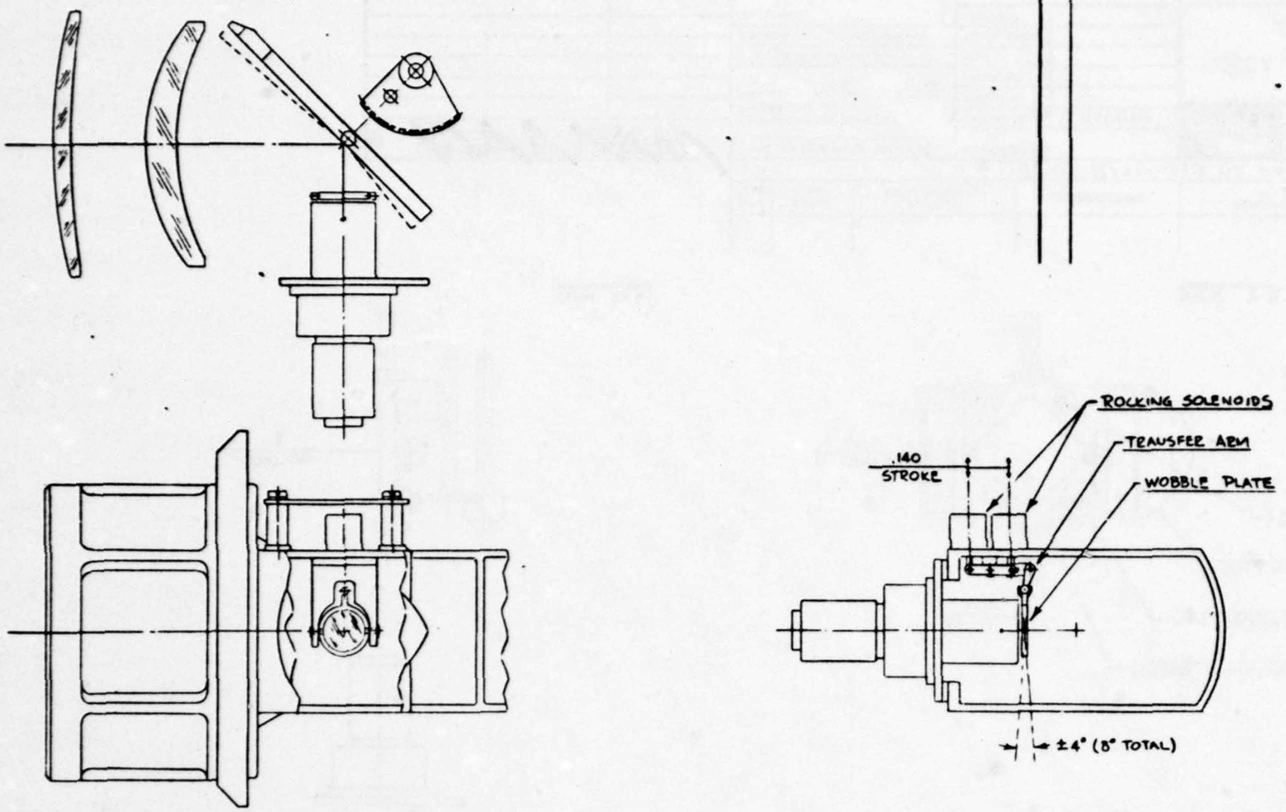
Norelco PHILIPS BROADCAST EQUIPMENT CORP.
GOVERNMENT SYSTEMS DIVISION MONTVALE, N.J.

SCAN MIRROR INTERLACE
FIGURE 9-3

SIZE C | CODE IDENT NO 30881 | DRAWING NO X 3001512
SCALE 1:1 | SHEET
DISTR 13478

3001512

-130-



QTY REQD	CODE IDENT	PART OR IDENTIFYING NO	SPECIFICATION	NOMENCLATURE OR DESCRIPTION	MATERIALS OR REMARKS	ITEM NO

LIST OF MATERIALS OR PARTS LIST

PART NO	NEXT ASSY	USED ON
APPLICATION		

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON:
ANGLES ± 1° 2 PL DEC ± .02 3 PL DEC ± .005
SURFACE ROUGHNESS (RMS)
DIM TO BE MET BEFORE FINISHING
MATERIAL:
FINISH:

CONTRACT NO
DRAWN 10/1/73 R. BASTIAN
CHECKED
ENGINEER
MFG
RELBL ENGR
QA ENGR
DESIGN ACT APPVL

Norelco PHILIPS BROADCAST EQUIPMENT CORP. GOVERNMENT SYSTEMS DIVISION MONTVALE, N.J.

WOBBLE PLATE INTERLACE
FIGURE 9-4

SIZE	CODE IDENT NO	DRAWING NO
C	30881	X 3001513

SCALE 1:1 SHEET

DISTR 13478

3001513

It is therefore recommended that, as a minimum, future versions of the AN/TAS-3 incorporate the specific modifications listed below.

a. Overload recovery circuit modification
b. Preamplifier gain reduction
c. Preamplifier bandwidth increase (Hi-f cutoff)
d. High Frequency Compensation (further study required)
e. New type multiplexer with reduced switching spikes
f. Increase in multiplexer switching rate (master clock)
g. Removal of interchannel blanking
h. Increase frame rate to at least 30
i. Replace transistor shunt with FET shunt
j. Change CRT phosphor (further study required)
k. Evaluate signal processing techniques from Common Module Program.

Quasi-interlace, as discussed in paragraph 9.3.4, would provide a more uniform display raster and also improve the vertical MTF. However, the methods of achieving the interlace have not been mechanically or electrically implemented and the affect on system weight and power consumption evaluated. Further study of quasi-interlace is required.

9.4 EXTENDED RANGE OPTICS

Based on PAVSC observations of many missile firings, discussions with DRAGON gunners and a review of a compilation of most missile firings to date utilizing the NVS, it appears that the optimum firing range for the DRAGON system guided by the AN/TAS-3 against a tank size target is about 750 meters. The resolution and sensitivity of the NVS is sufficient to afford the gunner a good sight picture of a tank size target under most field conditions at this range.

At 750 meters the gunner has about 8 seconds for his sight picture to clear from launch blast and afterburn, to recover from launch shock and to reestablish a smooth track and/or stable aim point.

Recent TOW firings during OT II test phase at Hehenfels, Germany, has resulted in a 60 percent hit capability from 600 to 1000 meters using the NVS as compared to a 17 percent hit record using the day tracker under illumination. An unexpected result was a 75 percent hit record at 1500 to 1675 meters with TOW.

PAVSC recommends that the NVS be outfitted with a somewhat larger objective lens 4.9" fl/f/1.2, to give the DRAGON weapon, guided by the NVS, an optimum hit range of 1000 meters, the maximum wire length of the DRAGON missile. The extended range NVS would also make the NVS very effective for the TOW missile system giving the weapon a good hit probability in the 1600 to 2000 meter range, and providing a good survivability range against threat force night counterfire, such as that from 50 caliber weapons.

A comparison of the parameters of the AN/TAS-3 and a modified system incorporating an extended range lens to give the DRAGON system an optimum range of 1,000 meters is presented in Figure 9-5. Thermoelectric cooling parameters are included.

PARAMETER	AN/TAS-3	FULL DRAGON RANGE NVS
f#	1.2	1.2
f_L	3.6"	4.9"
Lens Dia	3.0"	4.08"
Resolution (mr)	0.86	0.63
NETD °C	0.14	0.14
FOV	4° x 6°	2.9° x 4.4°
Frame Rate/Sec	15	30
Detector		
Type	PbSe	PbSe
Number	64	64
Oper. Temp	145°K	195°K
Cooler Type	Joule-Thompson	Thermoelectric
Weight (lbs)	10.3	11.5 est.
Battery Capacity (AH)	1	3 6
Cont. Oper. Time (Hr)	1	1.8
5 Min ON, 5 Min OFF cycles	6	21
Display		
Type	CRT	CRT
Magnification	4.8	6.5
Logistics	Battery Freon 14 Gas Bottle Charging Station	Battery

Figure 9-5. System Parameters

9.5 RECOMMENDATIONS FOR TOW

During the ED phase of the AN/TAS-3 program several adaptations of the Night Vision Sight (NVS) were made for the TOW weapon, Figures 9-6 through 9-10. They are:

Sight	Cooling	Lens	Contract
TE/NVS	TE	7.2" FL, f/1.2	DAAK02-72-C-0483
ER/NVS	JT	7.2" FL, f/1.2	DAAK02-73-C-0022
AN/TAS-3 w/TOW Bkt	JT	3.6" FL, f/1.2	DAAK02-72-C-0156

These programs demonstrated a number of significant features of the basic AN/TAS-3 design, as follows:

- o Commonality of modules
- o Adaptability for conversion to TE cooling
- o Adaptability for conversion to a dedicated TOW configuration
- o Capability of performance with the TOW weapon.

Commonality of Modules DRAGON/TOW - The inherent design configuration of AN/TAS-3 will permit the complete scanner assembly to be interchangeable between a TOW and DRAGON system. This is true for a JT or TE final configuration.

Conversion of TE Cooling - Completion of the TE-DNVS demonstrated that the existing AN/TAS-3 JT design can readily be converted to TE cooling with relatively minor changes. These are: removal of the cryogenic cooling system, replacement of the Detector/Bias Assembly, modification of the detector mounting surface, modification of main frame battery bracket and replacement of the battery. All electronic components, with the exception of the detector and battery remain identical. Refer to Figures 9-7 and 9-9.

TOW Configuration - A dedicated TOW configuration of the NVS is illustrated in Figures 9-6 and 9-7. This JT cooled unit includes an integral boresighting mechanism which attaches to the TOW weapon and incorporates a 7.2" focal length lens. The entire scanner assembly of this unit is identical to the AN/TAS-3. In a TE cooled unit, the outer housing will be substantially simplified by elimination of the tube portion of the housing required for the gas bottle and valve.

TOW Firings - TOW firings during OT II tests in Germany, April 1974, showed the effectiveness (56.2% hits) of the AN/TAS-3 when used with TOW. Refer to Figure 4-2, page 86. It is expected that hit percentage would have improved had not berm obscuration and gunner attitude been questionable

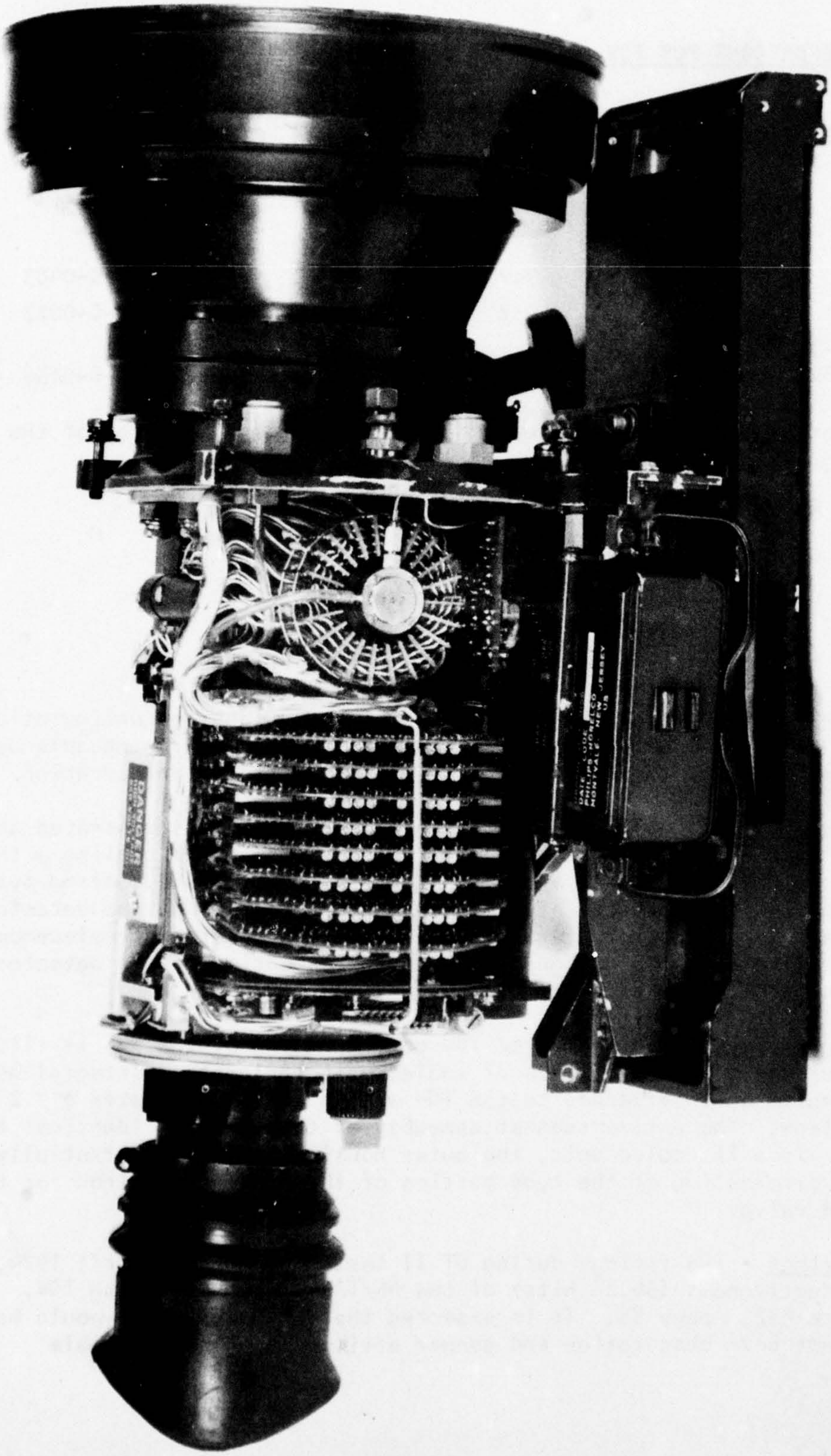


Figure 9-6. ER/NVS - J-T Cooled - TOW Configuration

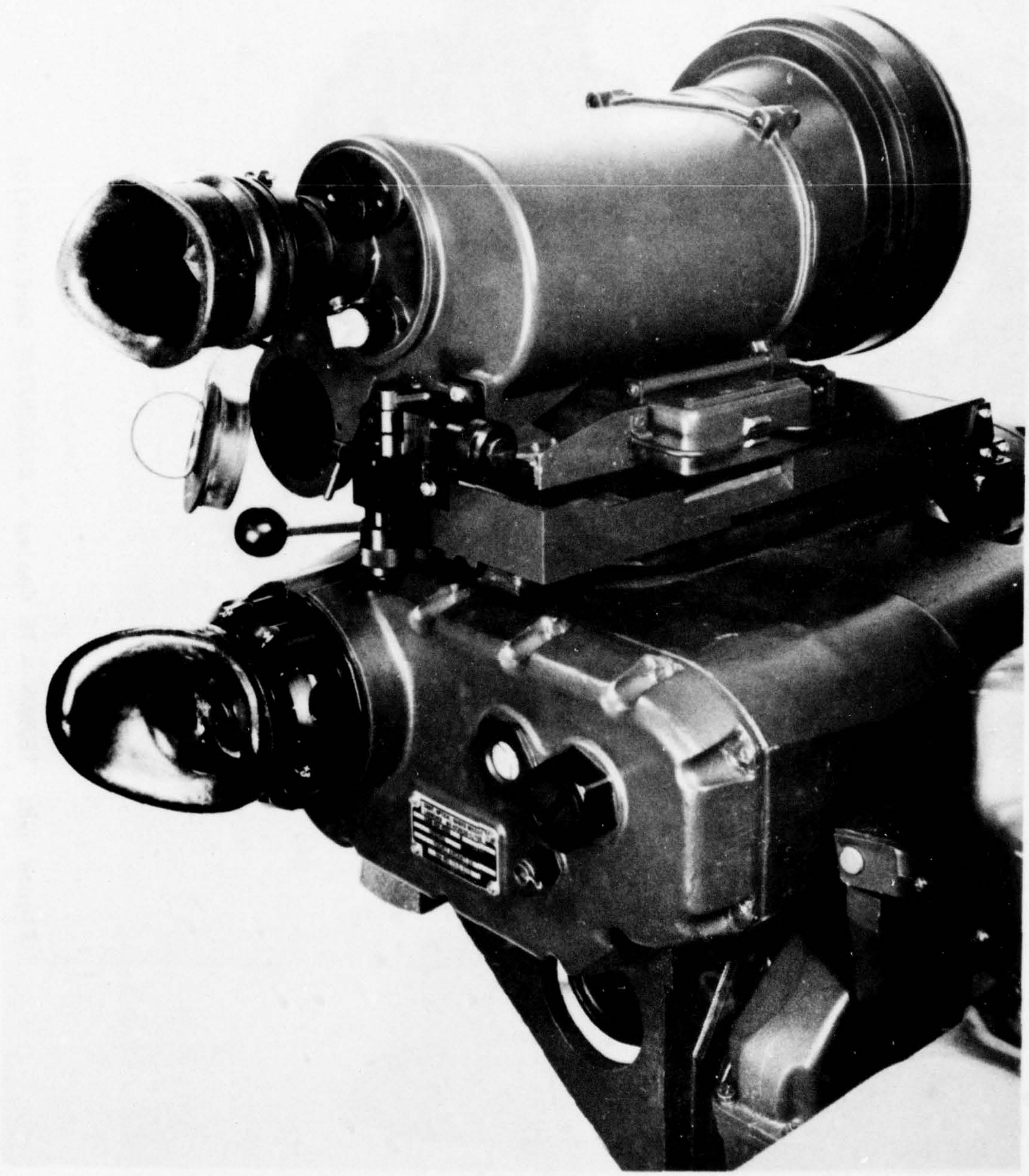


Figure 9-7. ER/NVS - J-T Cooled - TOW Configuration

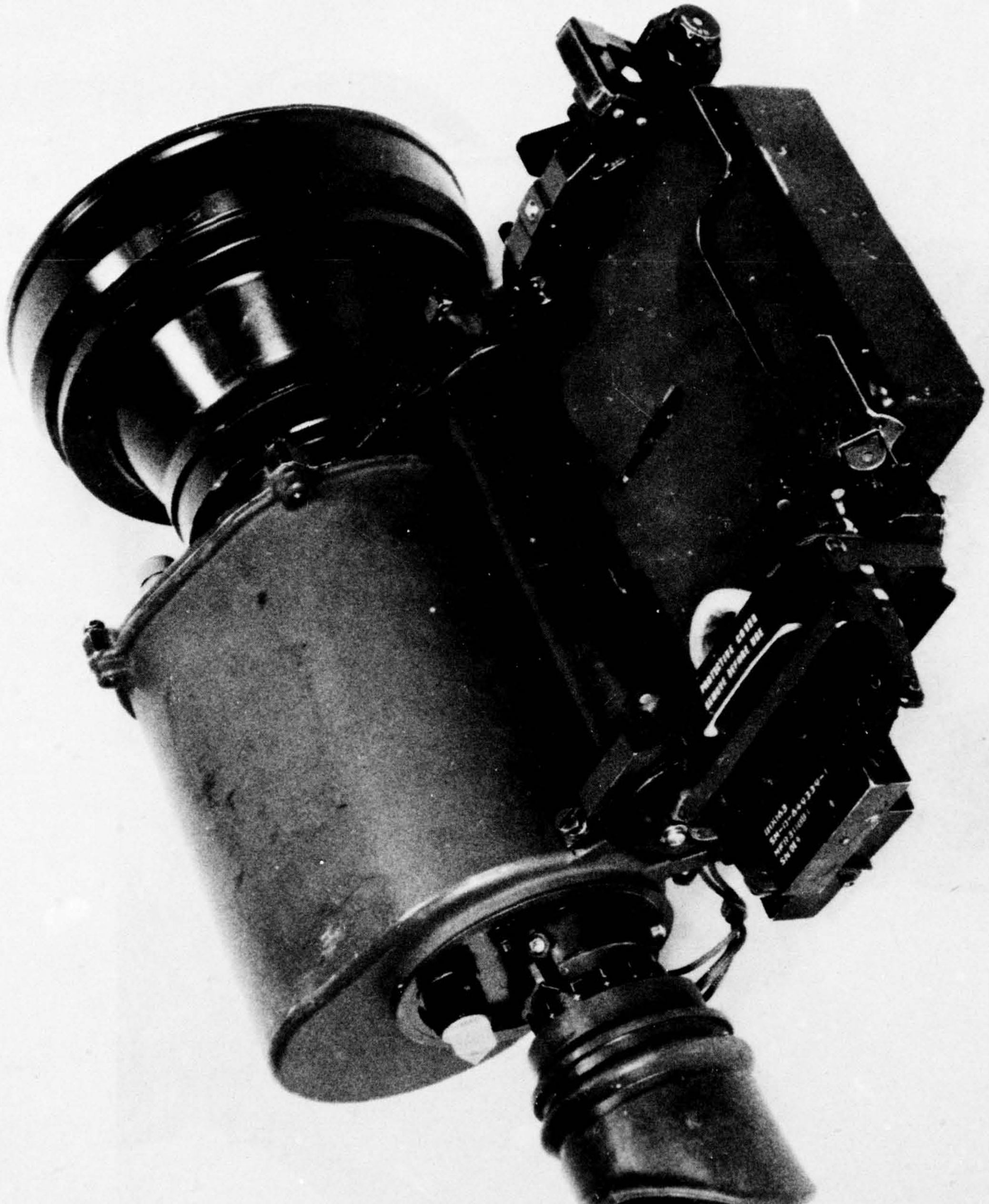


Figure 9-8. TE/NVS - TE Cooled - DRAGON/TOW Configuration

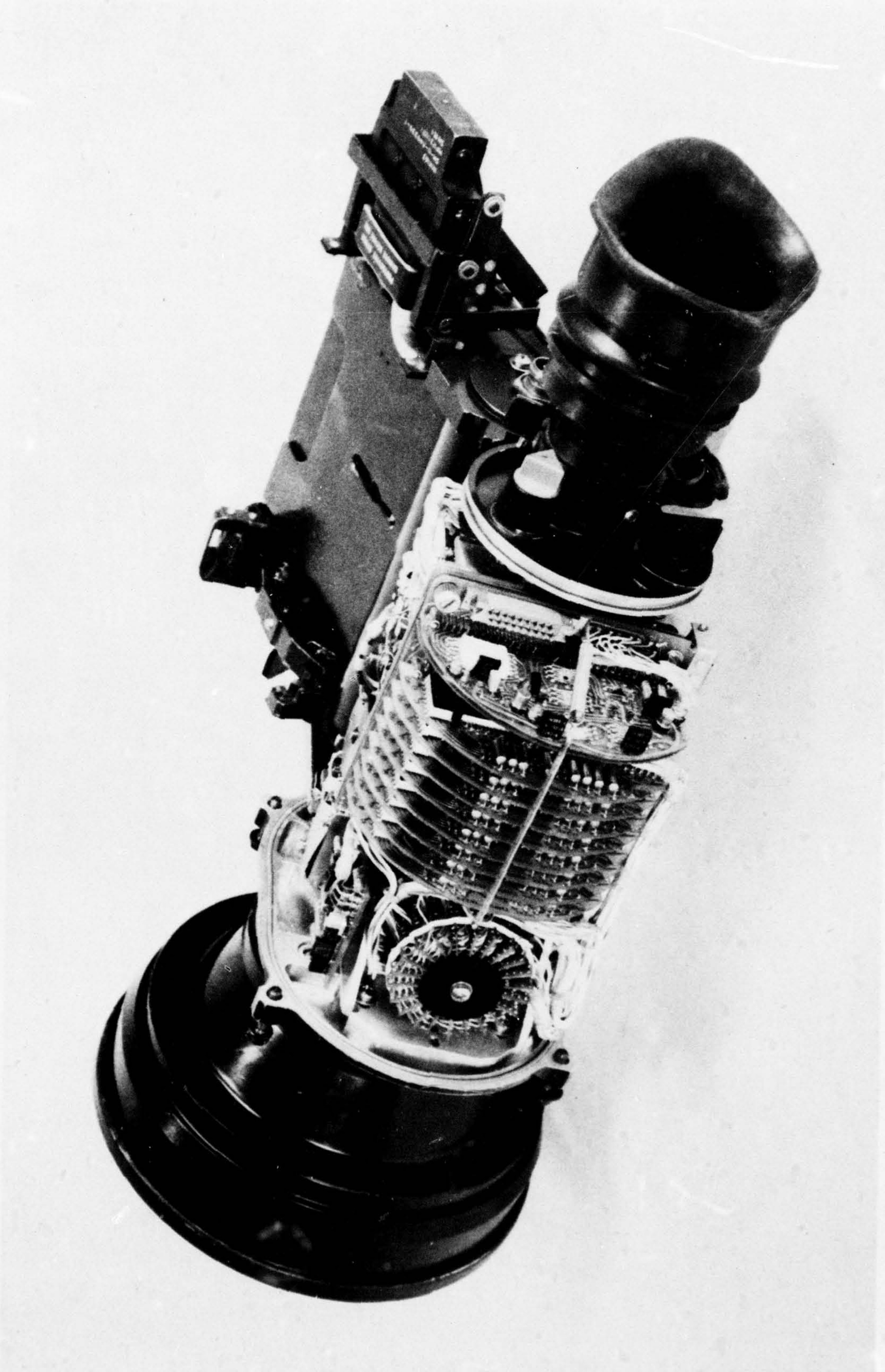


Figure 9-9. TE/NVS - TE Cooled - DRAGON/TOW Configuration

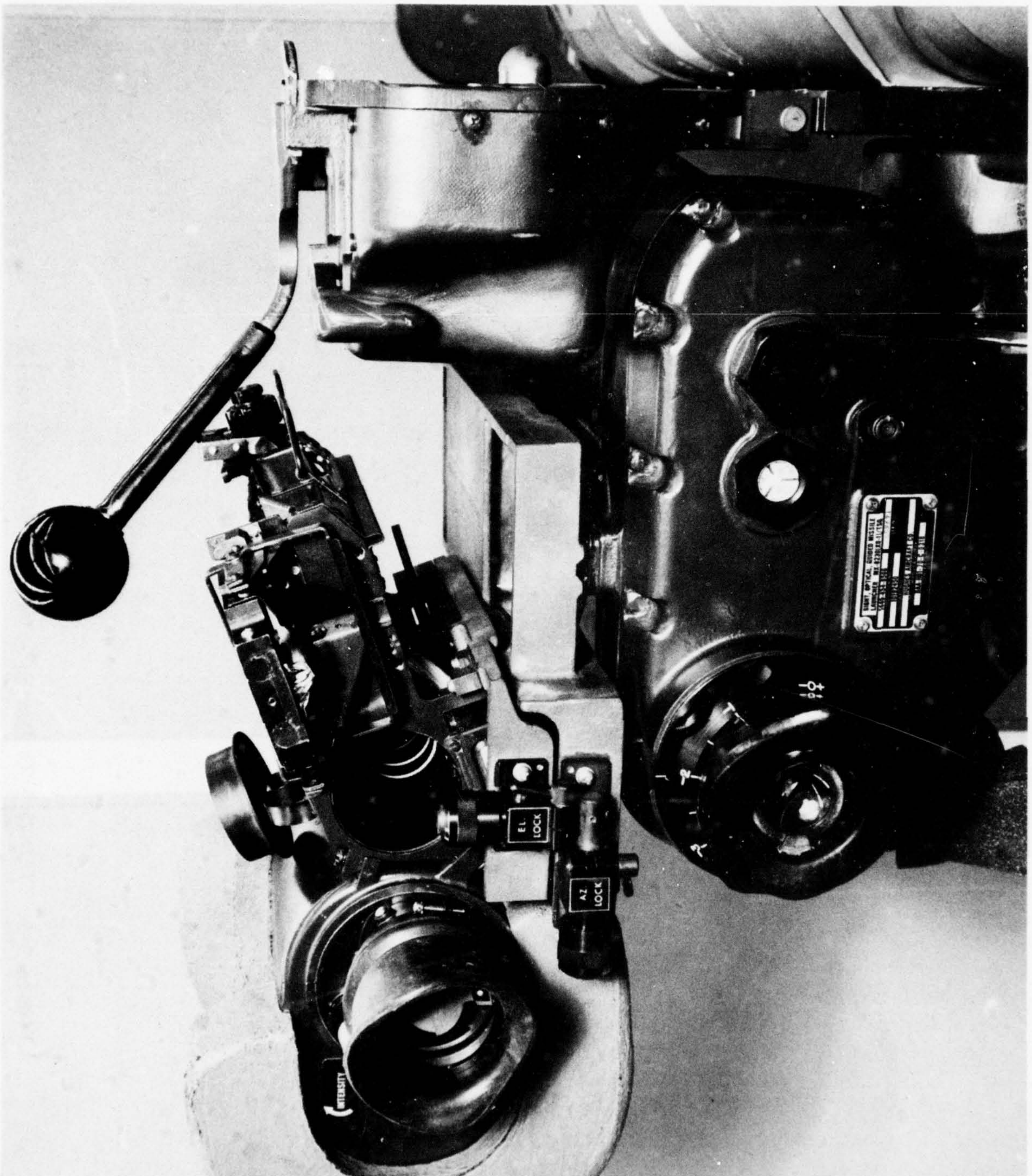


Figure 9-10. AN/TAS-3 with TOW Bracket

factors as indicated in the PAVSC field test report. Refer to page 84. Furthermore, it is anticipated that if the full DRAGON range optics recommended in paragraph 9.4, page 132, or the TOW dedicated extended range optics is adopted, performances will be substantially improved.

Based on the preceding factors, PAVSC recommends that, as a minimum, the AN/TAS-3 be considered as an interim night sight for TOW. It is further recommended that to improve performance, minimize logistics and to optimize human factors considerations for the gunner that a dedicated night sight for TOW be configured with extended range optics (4.9" FL, f/1.2), TE cooling and a housing dedicated for the TOW weapon.

9.6 RECOMMENDATION FOR EXISTING AN/TAS-3 NVS

In December 1974, the Army decided not to procure production quantities of the AN/TAS-3. Since that time, interest in the Night Vision Sight (NVS) has been renewed and apparently will continue to increase. This renewed interest and continuing Government requests for units to be available for tests and demonstrations have indicated a need to have all 29 ED systems refurbished and updated to a common level and maintained on a standby basis. Standby systems will provide an immediate NVS capability at minimum cost and provide maximum utilization of the large expenditure of time and Government funds that have been invested in the existing system.

Modifications and improvements determined during field testing have not been incorporated into all 29 ED systems. Therefore, PAVSC recommends that all ED models be updated, as required, to include the following items:

- Improved Boresight Modification
- Refurbishment to eliminate degraded detectors
- Addition of Freon dryer/filter
- Modification to accept ruggedized BVD
- Replacement of eyeshields
- Addition of noise suppressor valve
- Replacement of soft rubber battery connectors.

It is also recommended that the following APE improvements be included:

- Low Voltage Power Supply
- High Voltage Power Supply
- Scanner Printed Circuit Assembly.

The preceding modifications will provide a source of immediate night sight capability with JT cooling. It has, however, long been PAVSC's contention that man portable type Night Vision systems should employ TE instead of

JT-type cooling to enhance "Designated Gunner" and operation and minimize logistics problems and life cycle costs (refer to paragraph 9.2). It is, therefore, strongly recommended that, in addition to the modifications, all or a portion of the 29 units be converted to TE cooling and modified to incorporate a 4.9 inch focal length full DRAGON range lens.

It has already been demonstrated on Contract DAAK02-72-C-0483 and by in-house effort that this TE conversion can readily be accomplished.

9.7 BATTERY CHARGER RECOMMENDATIONS

During field testing of the DRAGON Night Sight reports were received of degraded battery performance, that is, discharge time under field operation averaged somewhat less than the normal 60 minutes. This led to comparison test between the Battery Charger Adapter, NVL847 (schematic SC-D-770955) which was being used in field tests, and a battery charging circuit in use at PAVSC.

The PAVSC charging circuit is shown schematically in Figure 9-11. Two DRAGON batteries SM-D-770180 containing Gulton 5R125 cells, SM-A-770338, were used for the test.

Results of the test are plotted in Figure 9-12 and tabulated in Figure 9-13. As shown, there is a vast improvement in battery performance when using the PAVSC charging circuit. It is to be noted that in the last charging cycle (cycle 19) the batteries were interchanged on the charges. As shown, the resulting discharge times were comparable to those previously obtained. This further confirms the relationship between charging methods and discharge time.

The most significant feature of the PAVSC design is considered to be the preconditioning cycle which automatically discharges the DRAGON battery mode. Additionally, in the charging mode, the charging current is controlled and tapered. Control of the current is maintained by sensing the battery terminal voltage. This combination of characteristics in the PAVSC charger eliminates the possibility of battery polarity reversal and thermal runaway. These conditions are considered to be principle causes of reduced battery performance when charged in the NVL847 charger.

Therefore, it is recommended that a battery charger suitable for field use be developed using the PAVSC circuit. Additionally, the charger should be capable of operation from 50, 60, 400 cycles and vehicle battery power.

The preceding test results and recommendations were documented in a report to NVL dated 28 February 1975, GSDR No. 793.

9.8 LAUNCH BLAST SIMULATOR RECOMMENDATIONS

In a 60-day program, under modification P00018 to this contract, PAVSC developed an experimental model of a Launch Blast Simulator (LBS). Results of

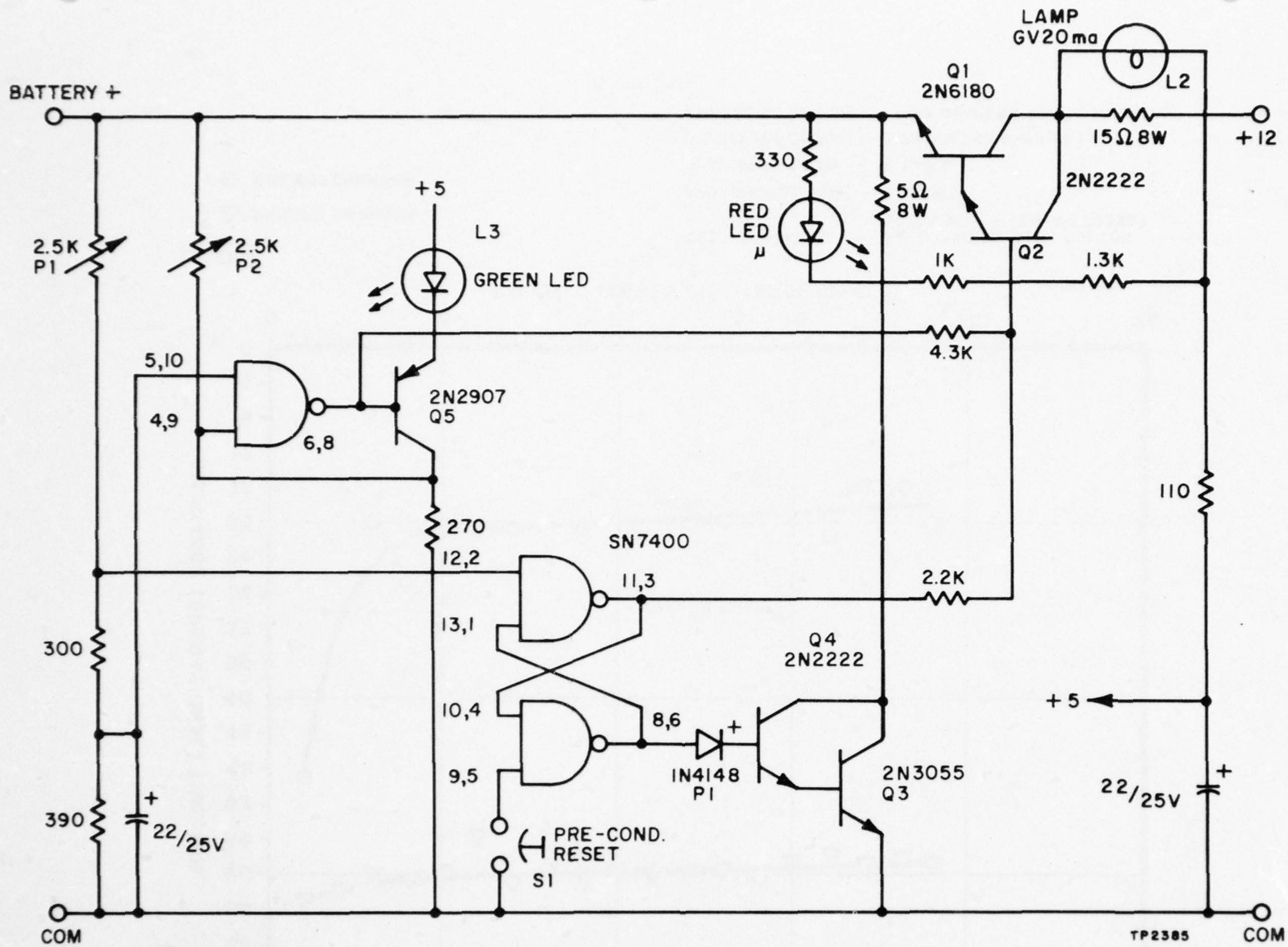
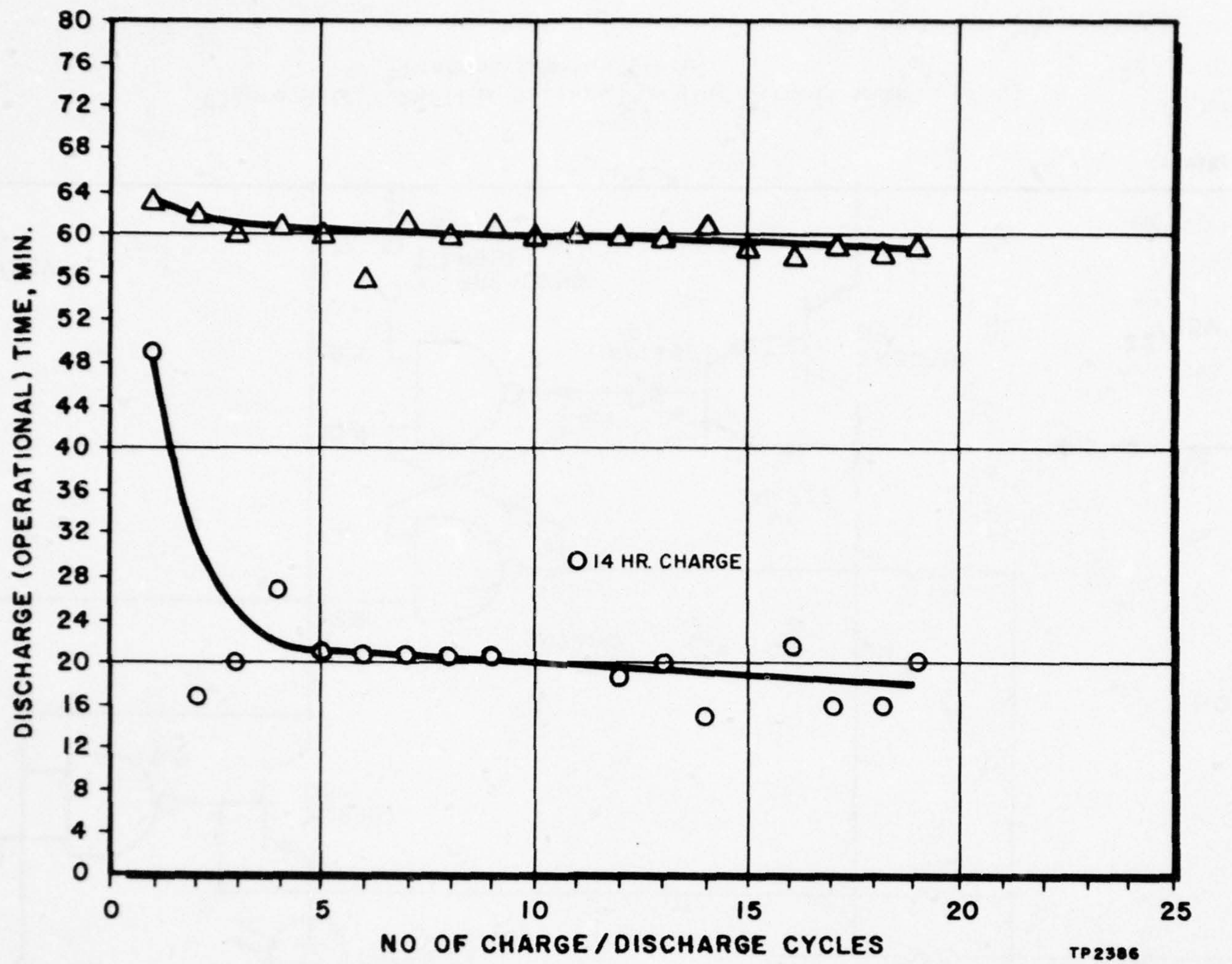


Figure 9-11. Philips Battery Charging Circuit with Preconditioning Circuit



LEGEND:

△ PHILIPS CHARGER

O NVL 847 CHARGER

TEST BATTERIES — SM-D-770180 WITH GULTON 5R125 CELLS (SM-A-770338)

AVG. CHARGE TIME — 6 HOURS

DISCHARGE LOAD — 6 OHMS

DISCHARGE CUTOFF — 5.78 VOLTS (APPROX.)

CHARGE CONDITION — ROOM AMBIENT (70° F NOMINAL)

Figure 9-12

COMPARISON DATA - PHILIPS BATTERY CHARGER VS. NVL847 BATTERY CHARGER

DATE	CYCLE	CHARGE TIME NVL847	CHARGE TIME PHILIPS (1)	DISCHARGE/OPERATIONAL TIME MINUTES (2) NVL	DISCHARGE/OPERATIONAL TIME MINUTES (2) PBEC
10/2	1	Not Recorded	Not Recorded	49	63
10/3	2	10 hr	10 hr	17	62
10/4	3	6 hr 40 min	6 hr 5 min	20	60
10/7	4	9 hr 30 min	9 hr 25 min	27	61
10/8	5	7 hr 20 min	7 hr 16 min	21	60
10/10	6	8 hr 50 min	8 hr 50 min	21	56
10/10	7	7 hr 5 min	6 hr 28 min	21	62
10/11	8	8 hr 1 min	6 hr 2 min	21	60
10/14	9	8 hr 25 min	7 hr 7 min	21	61
10/15	10	Chg cont'd next day	5 hr 43 min	-	60
10/16	11	14 hr 29 min	5 hr 38 min	30	60
10/17	12	6 hr 2 min	5 hr 30 min	18	60
10/18	13	5 hr 51 min	5 hr 48 min	20	60
10/21	14	5 hr 41 min	5 hr 36 min	15	61
10/22	15	Chg. cont'd next day	5 hr 43 min	-	59
10/23	16	8 hr 55 min	5 hr 41 min	22	58
10/24	17	6 hr 3 min	5 hr 53 min	16	59
10/25	18	5 hr 45 min	5 hr 41 min	16	58
10/28 (3)	19	7 hr	6 hr 55 min	20	59

(1) All Philips Charging Times include preconditioning time of approximately 25 min.

(2) Discharged to approximately 5.78V each discharge cycle.

(3) On this charge cycle batteries were interchanged on chargers.

Figure 9-13

this effort are fully described in a final report dated 2 August 1973, PAVSC GSDR No. 565. The LBS was designed as a simulator to produce an effect of the Night Vision Sight display similar to that produced by the initial missile blast and ensuing afterburn.

In an Army feasibility test final report dated March 20, 1974, six of eight test soldiers stated that the LBS simulator training "would benefit a Night Sight gunner". In the same report, the U.S. Army Infantry Board, in part, concluded that "An obscuration device for use with the DRAGON Training Equipment and Night Sight to train gunners is desirable and feasible".

During and after gunner training conducted by both PAVSC and the Army, PAVSC observed 'first round" firings by student gunners. These observations showed that first round hits were 52 percent greater by gunners trained using the LBS then by gunners trained without use of the LBS. First round firings observed are listed below.

With LBS Training

Hits	Firings	% Hits
19	30	63.3

Without LBS Training

Hits	Firings	% Hits
9	12	41.6

Based on the Army report and the available PAVSC data, it is recommended that a launch blast simulator be included in any future NVS training. Use of the LBS should substantially reduce training costs associated with live firings. It is also recommended that the existing experimental PAVSC LBS design be improved and ruggedized to make available a unit suitable for field training applications.

9.9 CARRYING BAG RECOMMENDATION

There have been numerous suggestions during the course of the DRAGON program for modifications to the Night Vision Sight (NVS) carrying bag that would improve its utility in the field. Among the most important was recommendation that the carrier be changed to a back pack configuration, with, or without, the use of a back pack frame.

In a technical proposal dated 23 May 1974, PAVSC/GSDR No. 712, PAVSC recommended that the existing NVS carrying bag design be modified for use with the standard Army All-Purpose Lightweight Individual Carrying Equipment System (ALICE). It was also recommended that a supplementary carrier be designed to transport sufficient batteries and coolant bottles to support ten hours of continuous operation. The proposed concept is illustrated in Figure 9-14. It is to be noted that in the event TE cooling is implemented, the concept can readily be modified to eliminate storage for the coolant bottles.

The present NVS carrying bag can be easily modified for use with the ALICE system of hardware by the addition of the standard design attaching envelope to the surface of the bag. The back pack can also be used without the frame by attaching the standard shoulder straps directly to metal loops and rings fastened to the bag. A shortened version of the present carrying strap will remain for use when the night sight must be hand carried.

The design for the supplementary carrier for battery and coolant bottles is illustrated in Figure 9-15. The basic component in the construction of this carrier is a simple molding of closed cell polyethylene foam, the same material that is used for the night sight and tracker shock cushions. This molding will be approximately 3-1/2 inches wide by 7 inches high x 7 inches deep, and will have three cavities for the support of two batteries and one bottle or the equivalent of two hours of system operation. Side by side attachment of up to five of these modules, as shown, will give the required ten hours of operation in a package 17 inches long by 7 inches high by 5 inches deep. A further amplification of this concept might include the addition of the Boresight Verification Device to the package.

PAVSC recommends that this concept be given consideration in any future effort concerning the DRAGON Night Vision Sight.

9.10 IMPROVED BORESIGHT VERIFICATION DEVICE

In February 1973, PAVSC completed the design and fabrication of the first three experimental models of a Boresight Verification Device (BVD) to be used during testing and evaluation of the Night Vision Sight (NVS). These experimental BVD's established the feasibility of using a lightweight collimating device to enable field boresighting between the NVS and the tracker, in lieu of a distant aiming point. A distant aiming point necessitates finding or setting up of a common IR and visible radiation source which is remote from the DRAGON gunner. The experimental BVD is shown in Figure 9-16. Although the experimental BVD's performed their intended function, they lacked the ruggedness and ease of operation required for military field use.

In March 1974, PAVSC proposed a program to NVL to ruggedize the BVD and modify its design to simplify field operation and installation. Authorization to proceed with this program was given in June 1974, at which time PAVSC began the redesign effort. Fabrication and alignment of the Ruggedized Boresight Verification Devices (R-BVD) was completed in February 1975 and environmental tests were successfully completed in March. Figures 9-17 and 9-18 show the R-BVD.

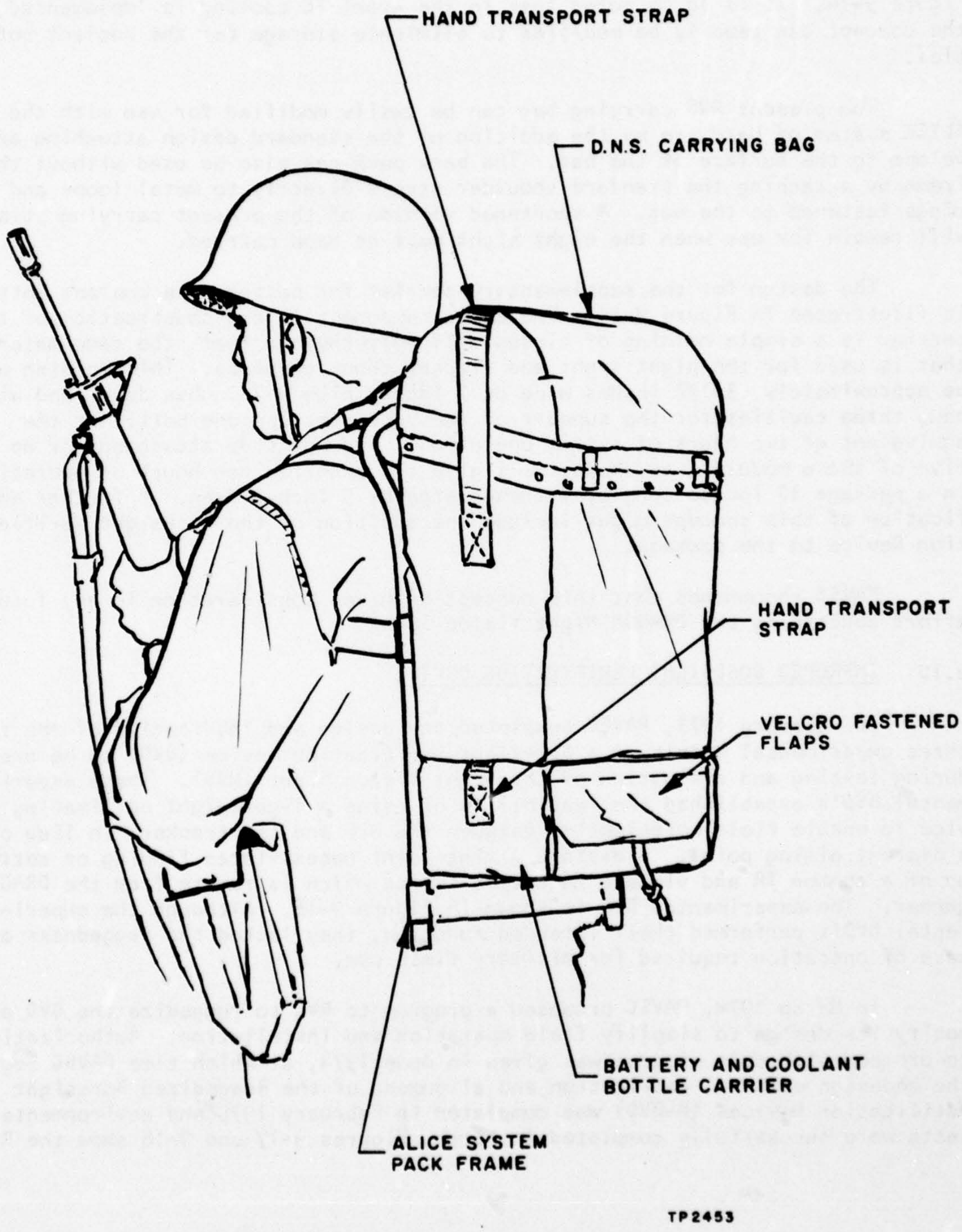


Figure 9-14. "ALICE" Carrying Bag

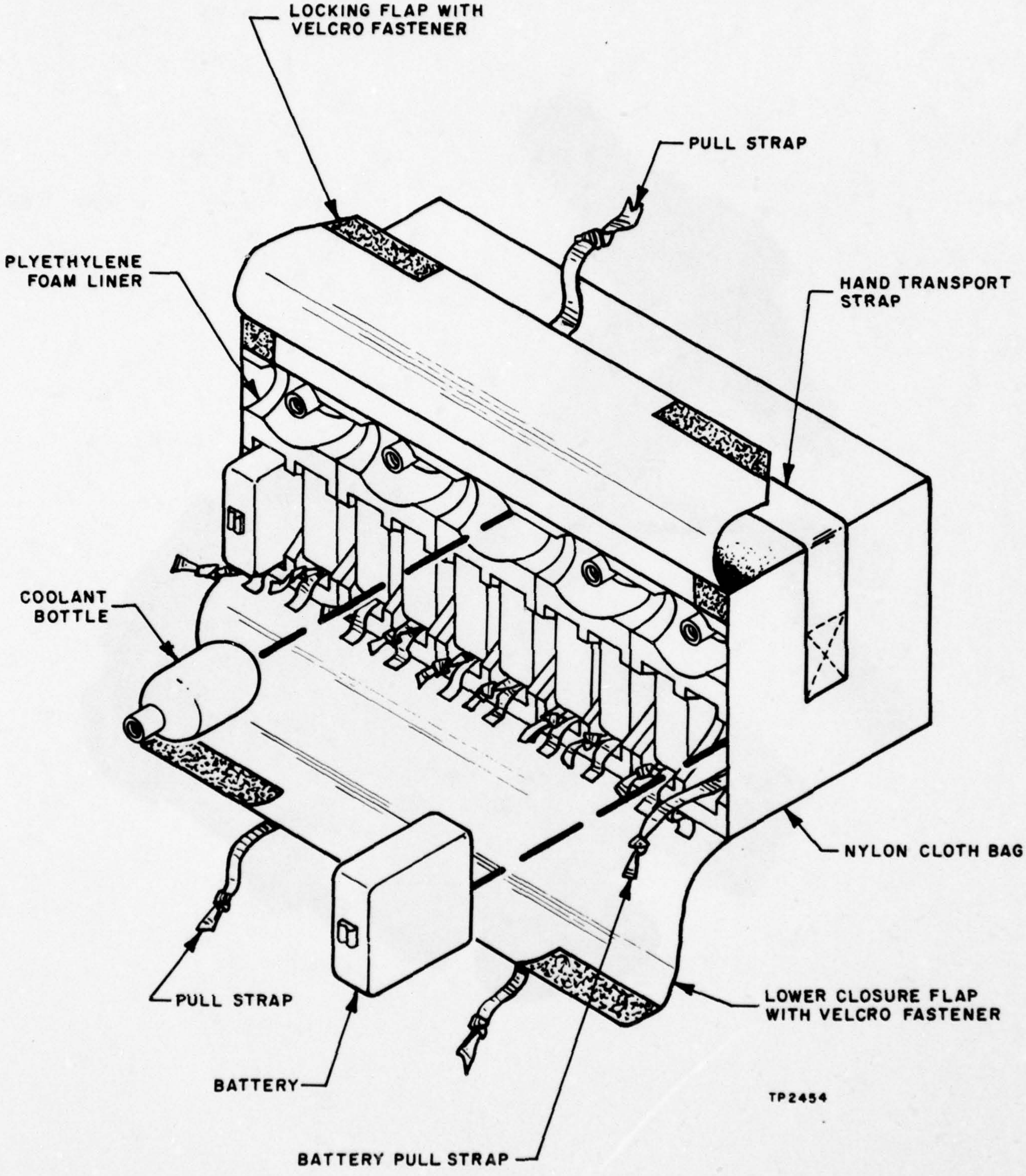


Figure 9-15. Internal View - "ALICE" Carrying Bag

Figure 9-16. Boresight Verification Device - Experimental Model

Figure 9-17. Boresight Verification Device - Ruggedized Model

Figure 9-18. Boresight Verification Device - Ruggedized Model

All of the known shortcomings of the experimental models were corrected in the R-BVD. Improvements included:

- Simplified attachment to the NVS and elimination of the weak attaching latches.
- Increased brightness of the visible target image.
- Improved design to withstand field handling.
- Elimination of exposed cables.
- Simplified machining of parts.
- Simplified internal optical alignment and test.

A review of the completed R-BVD design has indicated that a weight saving in the order of 0.1 to 0.2 pound can be realized in future units by reducing some thick steel sections in the inner optical assembly. Actual weight of the present unit is 2.95 pounds excluding the battery weight of approximately 0.76 pound. In addition an improvement in the visible images of the R-BVD can be made to facilitate laboratory tests of the units. The present visible images are satisfactory when the R-BVD is installed in a combined Tracker-NVS. It is recommended that these additional improvements be incorporated in any future production units.

APPENDIX I

ANALYSIS, NVS CRYOGENIC SYSTEM

Introduction

The amount of gas that is consumed during a given time interval depends upon

1) the refrigeration capabilities of Freon 14.
2) efficiency of the cryostat
3) the nature of the load, i.e. the value of the equivalent thermal capacity and conductance of the detector/cold shield/cold filter/dewar.
4) the mode of operation i.e. steady-state or cyclic.

On the other hand, the weight of the cooling system depends upon

1) the amount of gas required.
2) the weight of the tank necessary to contain the gas.
3) the weight of the valve, control mechanism, and cryostat .

Each of the above factors will be discussed in the following paragraphs with the objective of determining theoretically the maximum number of cycles that can be obtained from a Freon 14 cryogenic cooling system with a weight limitation of 1#.

In this analysis, the following assumptions have been made:

1. Perfect heat exchanger
2. Cryostat efficiency of 95% for low flow rates; 60% during high flow rates (i.e. cooldown).
3. A simplified thermal model.

(The three assumptions made above are reasonable and appear to be justified in view of the correspondence obtained between calculated and experimentally obtained results).

1. Brief Description of the Joule-Thompson Cryogenic Cooling System and the refrigeration capabilities of Freon 14.

Operation of the cooling system may be described by reference to Figure 1. The lettered references identify items of equipment as follows:

A. Refrigerant container (tank)

B. Refrigerant Shutoff Valve

C. Supply Line to Cryostat

D. Cryostat Assembly

D-1 Flow Regulator - Needle Valve and Orifice

D-2 Flow Regulator - Bellows Temperature Sensor

D-3 Mandrel Tube

D-4 Regenerative Heat Exchanger

E Detector-Dewar Assembly

E-1 Detector and Cold Plate

E-2 Window

Circled numbers in Figure 1 and the discussion below identify the thermodynamic condition of the refrigerant as shown in the P-H (pressure-enthalpy) diagram of Figure 1.

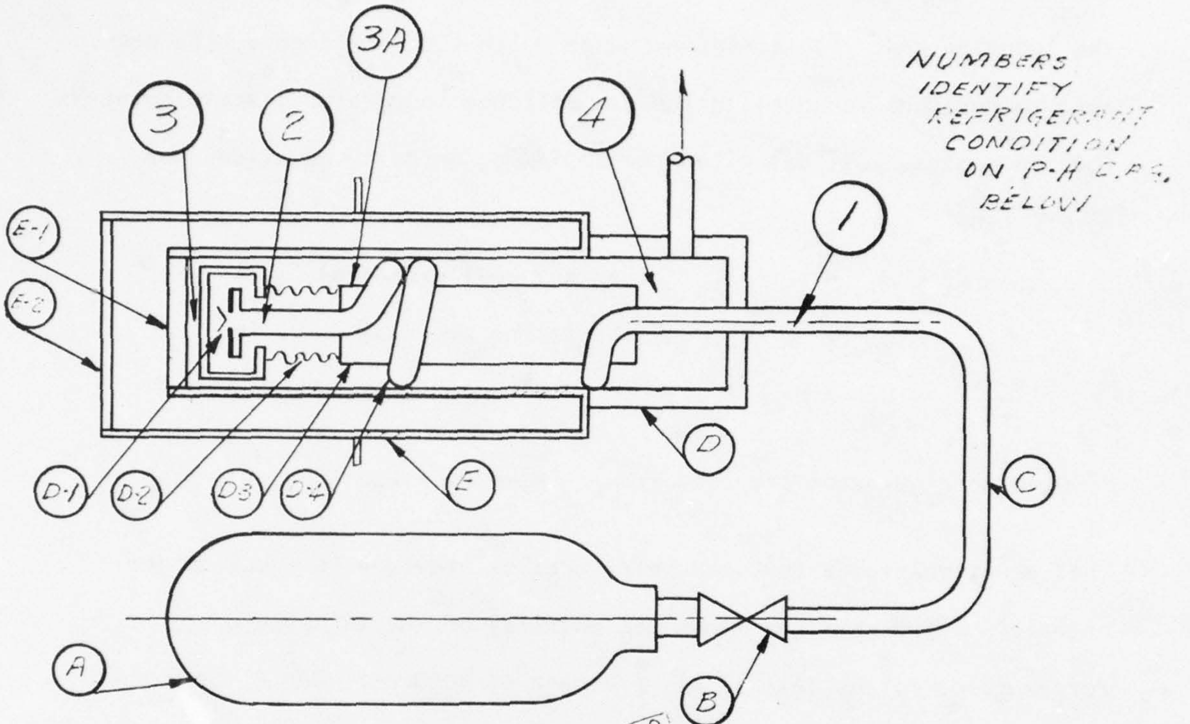
The coiled tube, D-4, in the cryostat assembly forms a regenerative heat exchanger in which the incoming refrigerant is cooled by means of the outflowing cold gas.

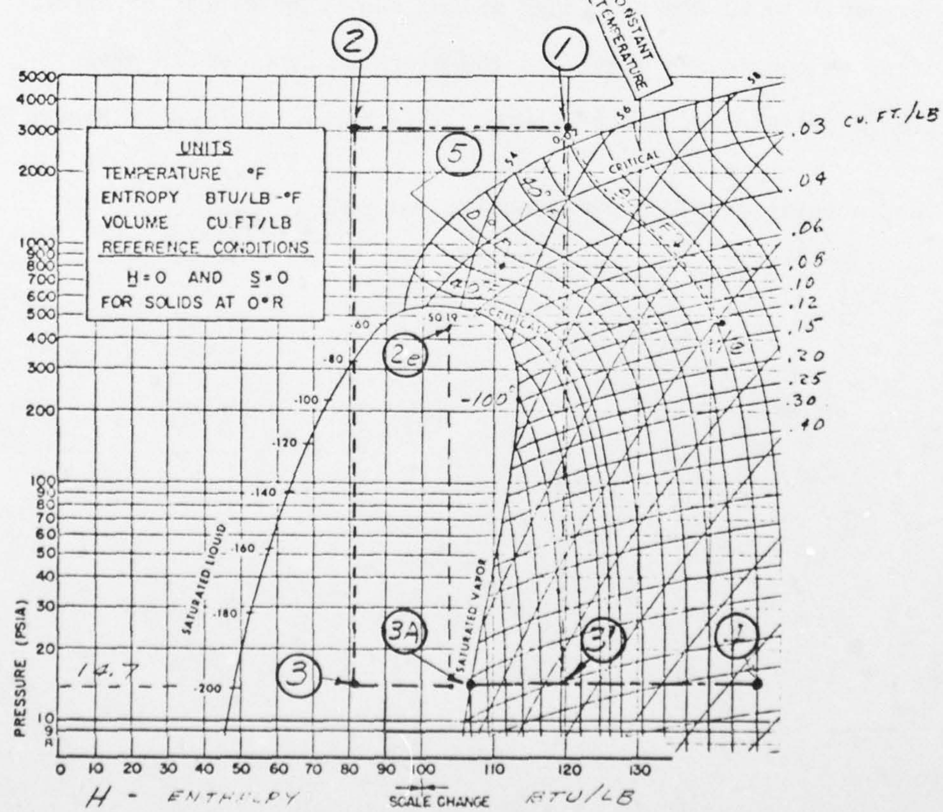
The process (to a first order approximation) may then be traced through the system as follows:

1. Gas, at temperature 80° F, and 3000 psi, 1, flows through the heat exchanger, at constant pressure, transfers heat to the outgoing gas and is cooled to state point 2. Expansion to atmospheric pressure through the orifice (throttling process) results in the gas/liquid mixture being at state point 3. Heat from the detector is then absorbed by the liquid, converting the liquid to vapor, and cools the detector in the process; 3A

Figure 1

CRYOSTAT - DETECTOR SCHEMATIC





The cold vapor then flows out the heat exchanger, absorbing heat from the incoming gas. For a heat exchanger with 100% efficiency, the gas exit temperature is equal to the gas entrance temperature, state point ④. For the process just described the following enthalpy equations can be written:

$$H_1 - H_2 = H_4 - H_{3A} \quad \text{(perfect heat exchange)}$$

$$H_2 = H_3 \quad \text{(throttling process)}$$

$$\therefore H_1 - H_3 = H_4 - H_{3A}$$

$$Q_R = \text{Refrigeration provided} = H_{3A} - H_3 = H_4 - H_1$$

This equation states that the refrigeration provided is equal to the enthalpy of the exit gas minus the enthalpy of the incoming gas. For example, for an initial gas pressure of 3000 psi, 80° F, from the graph, Q_R is equal to 27 BTU/#. Other values can be obtained for other gas pressures. A continuous curve can therefore be drawn which gives refrigeration available vs. gas pressure. This curve is shown in Figure 2.

(Q_R is given in units of $\frac{\text{BTU}}{\#}$ and its equivalent $\frac{\text{watt - min}}{\text{atmos. - liter}}$)

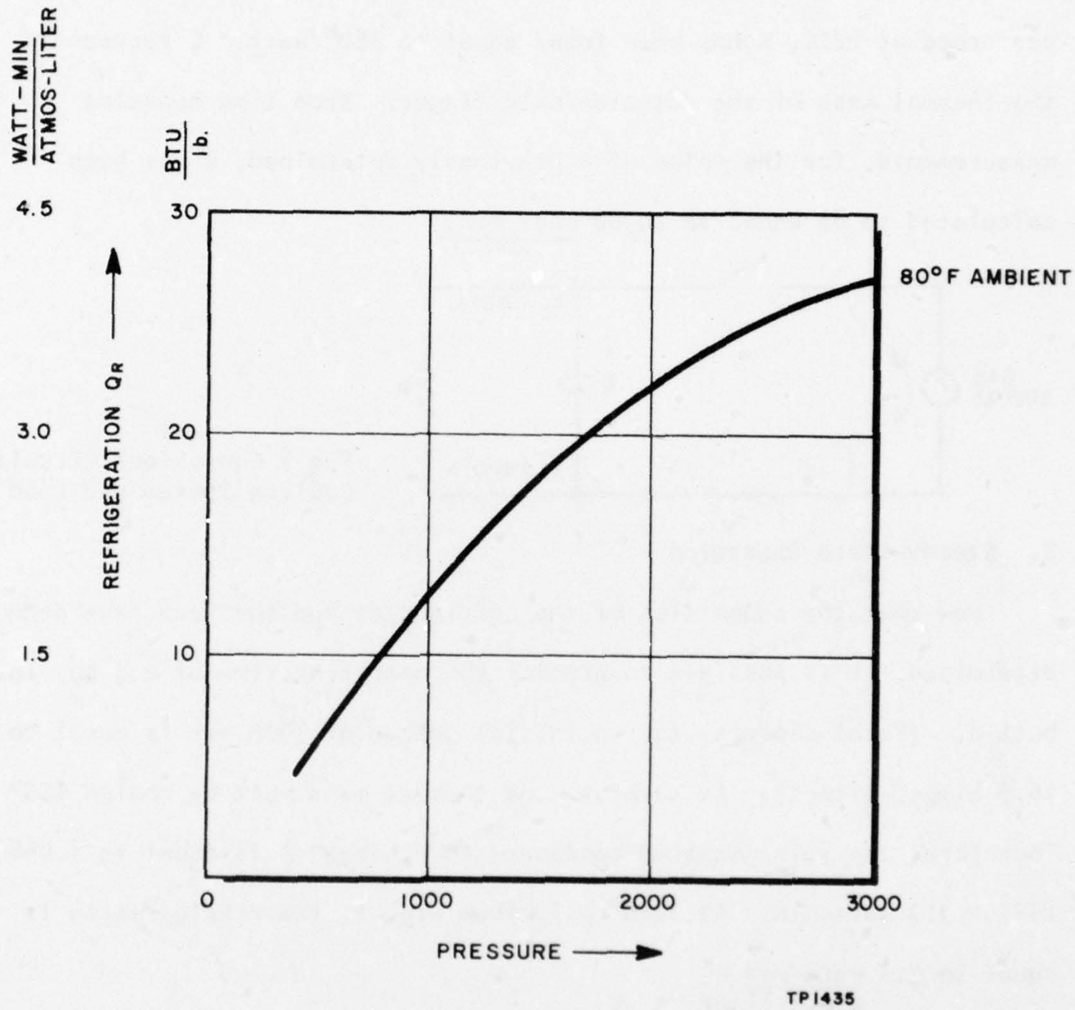


Fig. 2 REFRIGERATION AS A FUNCTION OF PRESSURE FOR FREON 14

2. Equivalent Circuit

The derived equivalent circuit of the cooling system is shown in Figure 3.

R is the equivalent thermal load; it represents all the possible heat leaks between the detector/cold finger and ambient. From tests performed at PBEC, R has been found equal to 390°/watt. C represents the thermal mass of the detector/cold finger. From time constant measurements, for the value of R previously determined, C has been calculated to be equal to .0486 $\frac{\text{watt-min.}}{K^{o}}$

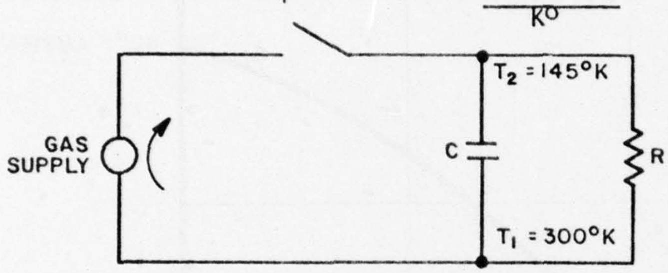


Fig 3 Equivalent Circuit of Cooling System and Load

3. Steady-state Operation

Now that the properties of the refrigerant and the load have been determined, it is possible to predict the operating time of a 5 cu. in. bottle. (Total capacity for an initial charge of 3000 psi is equal to 16.5 atmos.-liters). At turn-on, the thermal mass must be cooled 155° K. Therefore, the refrigeration necessary to "charge" C is equal to (.0486 x 155) = 7.7 watt-min. At 3000° psi, from Fig. 1, the refrigeration is equal to 4.1 $\frac{\text{watt-min}}{\text{atmos-liter}}$

With an initial efficiency of 60%, the amount of refrigeration required therefore, is 3.1 atmos-liters.

The remaining gas must now be used to supply a continuous heat load of $\left[\frac{155^{o}}{390^{o}/\text{watt}}\right]$ = .4 watt.

Since the refrigeration properties of the gas changes as a function of pressure, and the pressure is continally dropping, an integration must be performed to determine the total operating time. For an efficiency of 95%,

$$T = \frac{.95}{.4 \text{ watt}} \int_{o}^{13.4} Q_R(P) \quad \Delta P$$

This integration was approximated by a summation and T was found equal to 96 minutes.

This result compares rather favorably with the actual operating time, determined experimentally as 88 minutes.

4. Cyclic Operation

The same equivalent circuit may also be used to obtain the total number of cycles (5 min. on, 5 min. off) which may be obtained with a 5 in^3 tank, at 80^o F.

For example, during the first cycle 3.1 atmos.-liters are used to "charge" C while .45 atmos.-liters are used to supply the thermal load. During the second cycle, the requirements for C drops to 1 atmos.-liter (since the temperature differential is not as great) while the requirements for the thermal resistance increase to .47 atmos-liters (since the refrigeration properties of the gas are decreasing with the decreasing pressure). Continuing in this fashion, the total number of cycles theoretically available until all of the useful gas has been used up may be calculated and has been found to be 7.5 cycles. This value also agrees rather favorably with experimentally determined values of 7.8, 7.6 and 7.2.

The major difference between steady state and cyclic operation is that the thermal mass has to be "charged" up only once during steady-state while in the cyclic mode it has to be replenished after every off period.

5. Weight Requirements for Steel Tanks

In the investigation of trade-offs relating to the building of light-weight gas reservoirs, one area for consideration is the test requirements of MIL-R-8573 as compared to the weight of the reservoir. An increase in gas volume can be achieved for any given total weight of tank plus gas by reducing the weight of the tank. For any known material, the weight of the tank can be reduced by permitting the allowable wall stress to increase.

The stresses for various thicknesses of wall can be readily calculated. Fig. 4 is a curve of stress versus wall thickness for gas reservoirs made of 4130 alloy steel for both welded and non-welded tanks. The stress curves are based on a burst pressure of 6660 psi which, in turn, is based on 3000 psi service pressure. To obtain a design wall thickness, the allowable stress levels for the test requirements must be matched with the stresses at burst pressure. The allowable stresses for the test requirements (of MIL-R-8573), however, cannot be calculated. They are obtained empirically, that is, through the actual testing of many tanks.

Over the years, Walter Kidde has established safe stress levels through the testing of many tanks. These various allowable stresses are shown on the curve as GUNFIRE, 20,000 cycles, 5,000 cyles, 1,000 cycles. The wall thickness corresponding to the stresses at these points is the safe stress to be used for each test requirement. The tank which Philips is supplying will meet all the requirements of MIL-R-8573 and, therefore, the controlling stress for this design is the stress needed to pass the gunfire test. This is shown as 89,000 psi. The corresponding wall thickness (for available welded tanks) therefore is .075 inches.

6. Overall Weight

The weight of a 5 in^3 system may now be calculated to be

1)	welded tank (.075")	=	.45#
2)	gas (5 cu. $in.^3$)	=	.17#
3)	valve and control	=	.30#
4)	cryostat		.06#
	Total		.98#

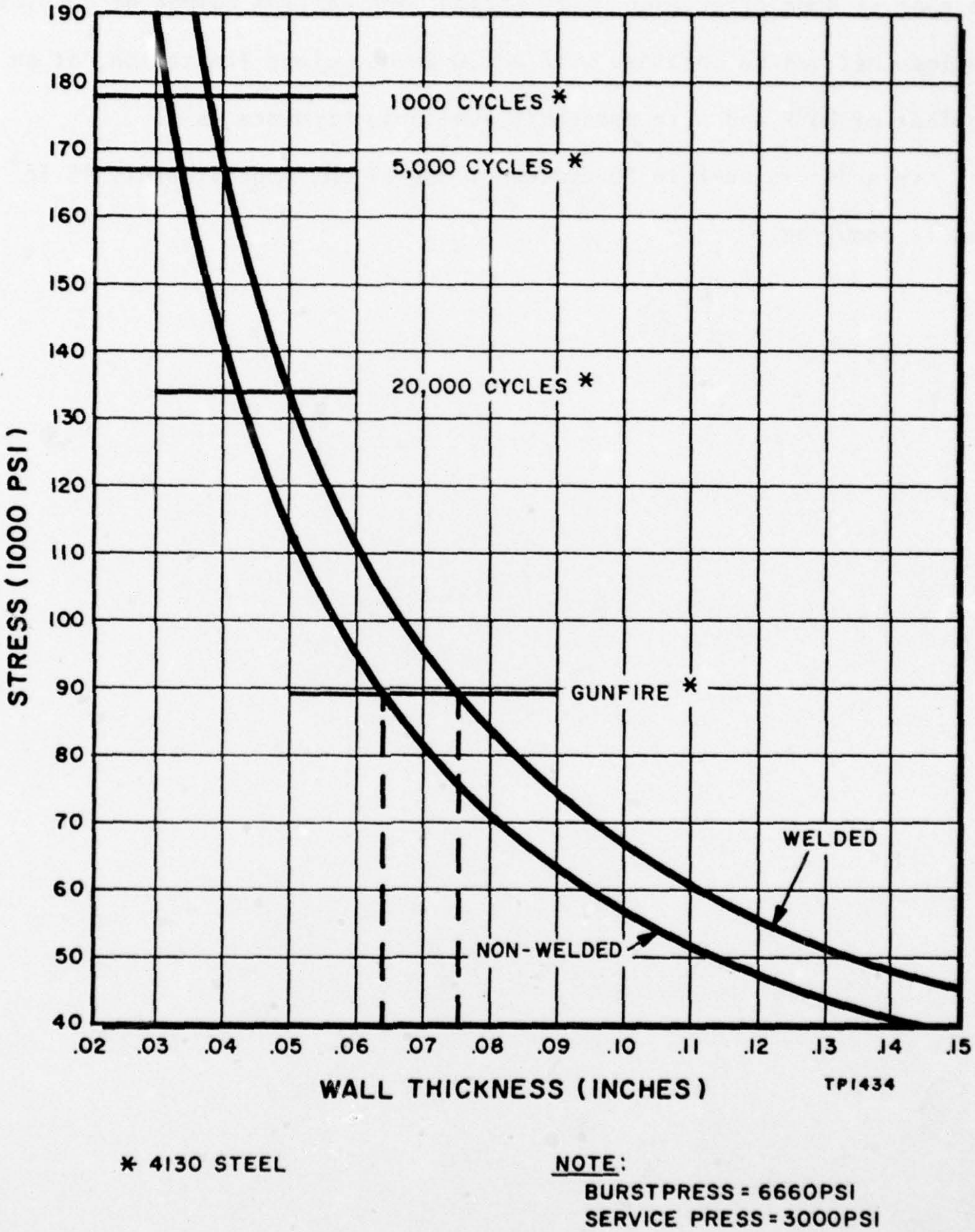


Figure 4. Allowable Stress as a Function of Cartridge Wall Thickness for a Cylindrical Gas Reservoir

7. Conclusion

Because the thermal mass requires a significant amount of refrigeration to cool it down after each "off" period, the maximum number of complete cycles that can be obtained with a 1.0 pound weight limitation, at an ambient of 80°F and with presently available hardware is 7.

In order to achieve 20 cycles of operation, approximately 15 in^3 of gas is required.

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13. ABSTRACT

This report describes the effort expended in the design, development, fabrication and testing of a lightweight, battery powered passive infrared imaging system, designation Night Vision Sight, Infrared AN/TAS-3( ). It was designed to be integrated with and deployed with the Guided Missile Surface Attack, SM47 Medium Anti-tank/Assault Weapon (DRAGON) System. The AN/TAS-3( ) enables the DRAGON gunner to search, detect, recognize and aim at targets during the hours of darkness and to accurately track and target during the flight of the DRAGON missile.

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
DRAGON						
SYSTEM DESCRIPTION						
OBJECTIVE LENS						
SCAN MIRROR						
EYEPIECE ASSEMBLY						
SCANNER						
CRYOGENICS						
DETECTORS						
PREAMPLIFIER						
MULTIPLEXER						
CROSS HAIR AND BLANKING						
DISPLAY CIRCUITS						
LOW VOLTAGE POWER SUPPLY						
HIGH VOLTAGE POWER SUPPLY						
BORESIGHT						
BORESIGHT VERIFICATION DEVICE						
CHANNEL NOISE						
BATTERY						
BATTERY CONNECTOR						
FIELD TESTS						
OT II TESTS						
TRAINING						
ENVIRONMENTAL TESTS						
QUALITY ASSURANCE						
RELIABILITY						
MAINTAINABILITY						
CONCLUSIONS						
RECOMMENDATIONSTHERMOELECTRIC COOLING						
EXTENDED RANGE OPTICS						
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