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Electrical and Electronic Subsystems of a Nuclear Waste Tank Annulus Inspection System

R.J. Evenson

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Rockwell International

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ELECTRICAL AND ELECTRONIC SUBSYSTEMS
OF A NUCLEAR WASTE TANK
ANNULUS INSPECTION SYSTEM

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Design and Development

June 1981

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ABSTRACT

The nuclear waste tank annulus inspection system is designed specifically for use at the Nuclear Regulatory Commission's Nuclear Fuel Services Facility at West Valley, New York. This system sends a television and photographic camera into the space between the walls of a double-shell nuclear waste tank to obtain images of the inner and outer walls at precisely known locations. The system is capable of inspecting a wall section 14 ft wide by 27 ft high. Due to the high temperature and radiation of the annulus environment, the operating life for the inspection device is uncertain, but is expected to be at least 100 hr, with 1,000 R/hr at 82°C.

The film camera is shielded with 1/2 in. of lead to minimize radiation fogging of the film during a 25-min picture taking excursion. The operation of the inspection system is semiautomated with remote manual prepositioning of the camera, followed by a computer controlled wall scan. This apparatus is currently set up to take an array of contiguous pictures, but is adaptable to other modes of operation.

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1.0 INTRODUCTION

1.1 HISTORY

The Nuclear Regulatory Commission (NRC) and Nuclear Fuel Services Corporation (NFS), by decommissioning the Nuclear Fuel Reprocessing Center at West Valley, New York, have the task of evaluating the facility's nuclear waste containment systems. The nuclear waste tanks are an area of special concern. Each tank consists of a steel-shelled container, placed in an underground concrete vault. There is a 30-in. annular space between the vault and tank walls. A 4-ft-high steel pan rests beneath the tank and above the vault floor. The hollow space (annulus) is the point from which leakage may be pumped, and provides clear access to the tank walls through a riser hole from the ground surface.

One of the evaluation tasks is to make a recorded inspection of the waste tank walls. This will require a detailed photographic survey inside the annulus. Since the annulus is a high radiation zone, human entry can not be permitted. The only feasible method of entry is with a machine fabricated to make the required inspection. A contract to build such a machine was let by NRC to Rockwell Hanford Operations (Rockwell) of Richland, Washington. Rockwell subsequently assigned the project to its Development Engineering Department (DED). The inspection device has been named annulus scanner. This report deals with the electrical and electronic aspects of the annulus scanner.

1.2 GENERAL INSPECTION REQUIREMENTS

Requirements to be met by the annulus inspection system included those outlined below.

- The entire assembly must be supported from the top end and be narrow enough to pass through the 30 in. diameter riser hole into the annulus
- The imaging equipment carried into the annulus must be tolerant of gamma radiation from the nuclear waste
- The assembly must tolerate temperatures in excess of 82°C, and must photograph as much tank and vault wall as possible.

Rockwell proposed a system which basically met all of these requirements. The system, now under construction, can carry a partially shielded camera into the annulus and photograph a section of tank wall 14 ft wide by 27 ft high. The camera can be pointed in or out, to photograph either side of the annulus.

2.0 PHYSICAL DESCRIPTION

2.1 MECHANICAL CONFIGURATION

The annulus scanner (Figure 1) consists of a long vertical rail, and a crossmember and camera carriage which ride on the rail. The camera carriage is driven horizontally along the crossmember by a stepping motor coupled with rack and pinion gear. The crossmember is mounted to another carriage, along the vertical rail also driven by a stepping motor. This gives the camera an "X-Y" scanning capability over the given section of a tank wall. The crossmember consists of two retractable arms which fold upward to allow passage through the riser hole (Figure 2). The camera carriage is held at a fixed distance from the wall by two rigid struts which unfold from the crossarms.

2.2 IMAGING PACKAGE

The camera carriage holds a NikonTM F-2 35-mm slide camera with automatic film advance, remote controlled shutter, extended film magazine, and numerical data insertion apparatus. The camera is accompanied by an Edo WesternTM miniature vidicon TV camera that aids in real time inspection. Two 300-W quartz lamps ride along to provide the necessary illumination. The film camera is housed in a 1/2-in.-thick lead shield. This is adequate for 25 min of camera operation in a 500 R/hr gamma radiation field when using EktachromeTM slide duplicating film (ASA-4). Even under these conditions, radiation fogging of the film is expected, and must be compensated for in later stages of processing.

2.3 ELECTRICAL AND ELECTRONIC SUBSYSTEMS

The annulus scanner is based on a variety of electrical and electronic components and systems which must be coordinated to gather the required images. A list of these systems is given below.

FIGURE 1. Installation of Scanner in Tank Annulus
(Cutaway View).

FIGURE 2. Annulus Scanner Mechanical Assembly
(Overall View).

Systems designed and assembled at a components level specifically for this project are designated with a *. Other items were procured as preassembled packages. Each of these items will be discussed with greater detail in the next section. The systems are:

- stepping motors
- stepping motor controller drivers
- microcomputer controller
- computer interface*
- X-Y position counter*
- video numeric inserter
- film camera data multiplexer
- camera data back
- camera remote control system (shutter and film advance)
- X-Y position reference and limiting system*
- TV camera drive electronics
- Vidicon TV camera
- video monitor and tape recorder
- primary alternating current (ac) power system*
- subsystem direct current (dc) power supplies
- camera lighting system*
- central control panel and electronics rack*
- interconnection cabling*

It should be noted that this system was designed to allow complete manual override of the microcomputer controller. Carriage excursion limit switches are fed directly to the stepping motor controllers to prevent accidental crashing of the mechanical apparatus. There are cam switch controlled indicators for reference points on the X and Y axis, and position switch controlled indicators to give the status of the cross arms. These indicators form an illuminated display independent of the microcomputer. The video camera also helps in the manual operation. The film camera shutter also can be manually overridden. The stepping motor controller can be switched from the computer to its own manual controls. Some of these controls can override the computer during the automated sequences. The position counters can be reset automatically and manually.

Some thought was given to having the position counter completely independent of the computer, but considerations for simplifying the numerical index display ruled against this for the photographic version of the scanner.

The X-Y coordinate position is recorded on camera film and on videotape in conjunction with the video system. The position counter can provide up to four digits of position information for each axis. These digits are fed to the numerical insertion apparatus. Punctuation markings also may be generated by the position counter.

The microcomputer reduces much of the human effort. It also speeds the filmed inspection to reduce gamma radiation exposure of the film. The computer interface has been designed to handle varying degrees of automation, based upon the level of programming supplied. Two controller interfaces are available; one setting allows manually set run lengths with computer activation of the direction and start of the run, and the other allows the run length, direction, and start to be handled by the computer.

Most electronic components for operation in the tank annulus were selected to operate reliably in a high radiation, high temperature environment. The temperature in the annulus is expected to be about 82°C (180°F), and the radiation dose rate is ~1000 R/hr. A gamma radiation dose of 500,000 R is approximately the maximum dose the electronic components can take before they start to fail. Under these conditions, at least 100 hrs of reliable operation are expected from the scanner. Components which cannot endure the high temperatures will be forced air cooled with air supplied through a hose network extending from outside the tank.

3.0 DETAILED DISCUSSION OF THE ELECTRICAL AND ELECTRONIC SYSTEMS

3.1 STEPPING MOTORS⁽¹⁾

The camera platform and crossarms are scanned in the horizontal and vertical directions (X and Y respectively) by a pair of stepping motors. These give a great degree of strength and positioning accuracy. The X motor has a top speed of 2,500 steps/sec and a peak torque of 600 oz-in. at 1,000 steps/sec. It has a holding torque of 450 oz-in. and draws 15.9 A at 1.45 dc V. The Y motor has a maximum speed of 1,200 steps/sec with a peak torque of 840 oz-in. from 200 to 600 steps/sec.⁽²⁾ The holding torque is 400 oz-in. and it draws 9.2 A at 2.1 V. These characteristics had to be derated for the actual system due to the 85-ft long interconnect cable (85 ft of 12-conductor cable; 6 conductors/motor, each 10 gage stranded copper wire). In summarizing, the X motor was chosen for speed while the Y motor was chosen for high torque.

The Y motor supports the 300-lb crossarms with a lead-shielded camera carriage. To accomplish its task, the motor must be coupled to the rack and pinion gear through a 10:1 worm gear speed reducer. A power failure brake is provided to hold the crossarms should the stepping motor system fail. This is to prevent the system from crashing to the bottom.

During testing, it was discovered that the Y stepping motor added a safety factor in that it provides some generator braking during a fall without power. Thus when the power fails, and the brake is off, the assembly glides slowly to the bottom.

3.2 STEPPING MOTOR CONTROLLERS⁽³⁾

The stepping motor driver controllers are key items in the scanner system. They can function alone or as the tail end of a computer interface. Each driver controller has two basic functions; first as the motor driver which steps a high current being fed to the motor, and second as the step indexer which generates the stepping sequence for the driver and thus controls the motor stepping motion.

Specific functions of the indexer control the direction, speed, acceleration, and rotational displacement of the stepping motor. The number of steps and direction is given by a programmable binary coded decimal (BCD) counter which can be loaded from the front panel of the controller, or from an externally signed BCD input supplied by a microcomputer. The rate (steps/sec) at which the BCD counter is operated determines the motor speed. The acceleration function slowly raises the counting rate until it reaches maximum speed, and then the deceleration function slows the rate down at some point near where the count runs out. This process insures accurate stepping and a smooth ride for the components.

Most of the controller functions are interfaced to the computer and motors according to manufacturer recommendations. The one exception is the resistors in series between the controller drivers and motors, which have been lowered in resistance value to compensate for power losses in the 85-ft interconnection cable. These resistors were intended for voltage transient suppression (according to the manufacturer). Values were experimentally determined to help restore optimum motor performance.

3.3 MICROCOMPUTER CONTROLLER^(4,5)

The microcomputer is a Rockwell 6502 based assembly. This system has 16 bit addressing to 64,000 bytes of memory consisting of 8-bit bytes (or words). For the scanner application, the memory consists of 4,000 bytes of random access memory (2114 static read/write random access memory (RAM)), and roughly 20,000 bytes of read-only memory (ROM) or erasable-programmable read only memory (EPROM). The interface is treated as memory and consists of three versatile interface adapters (6522 VIAs). One VIA connects to the microcomputer's keyboard controller and printer. The other two run the stepping motor controllers, position counters, and camera shutter. They also coordinate the handshake data to and from outside devices.

A portion of the memory is allocated to the microcomputer monitor ROM⁽⁶⁾ which handles the keyboard and printer interface commands. Routines within the monitor program can be called upon from the user machine language program for interface commands. Another portion of

memory holds the microcomputer's assembler ROM⁽⁷⁾ which is used in the development of machine language programs. The remaining microcomputer memory can hold ROMs for a basic language interpreter⁽⁸⁾ or 2716 EPROMs for permanent machine language programs.

3.4 COMPUTER INTERFACE

The computer interface (Figures 3 and 4) ties together microcomputer, machine, and display. Much of the design is based upon the interfacing needs of the stepping motor controllers, and thus was mostly conceived before programming started. The two VIA chips (U1 and U2 of Figure 4) are accessed by the microcomputer through P2 which sets up the interface terminals for P1 as inputs or outputs. The U1 circuitry controls the horizontal motion of the scanner and the U2 controls the vertical motion. The camera shuttering is done from U1; otherwise U1 and U2 are identical.

In addition, the interface is designed with two means of approaching the motor controllers. The first allows the microcomputer to feed the number of motor steps to a controller and start the run. The second starts a run after the number of steps is dialed in manually on the motor controller front panel. This change in interface is dealt with by two multiple switches inside the control panel (see Figure 3, top right and bottom right). Furthermore, relays K2 and K3 insure complete disconnection of the motor controller interface when the motor controllers are switched to manual operation.

The U1 interface should be examined in detail. Terminal CA2 sends a command ("Index" from CA2) to the motor controller to begin the operating sequence. When the command has been received by the controller, it returns a data stobe to terminal PA7 of U1. This signal activates the computer program in an operation which places a sequence of BCD numbers on terminals PA0 through PA3. The number sequence contains a signed five-digit number, read from the most significant to the least significant digit. The number represents the direction and number of steps that the motor is to travel. When the stobe has made its sixth transition, the motor starts. If PA0, PA1 and PA2 are disconnected, and the "Ext. Data" switch is closed, only the motor direction will be accepted by the

FIGURE 4. Schematic Diagram for the Computer Interface.

controller. The number of steps to be traveled will come from the motor controller front panel. When the motor has finished its run, a "Done" signal is returned to PB6 of the interface. Also returned to the microcomputer interface are the clockwise and counterclockwise pulse trains. These are fed through flip-flops U8 and U9, in order to stretch the pulse so that the microcomputer will be able to count them.

Terminals PB4 and CB1 receive signals concerning the manual operation status of the motor controllers, with U7 gating the status of both controllers. Terminals PB2 and PB3 output to the position counter which controls the numeric readout for the film and video systems. Terminal PB0 resets that counter. Terminal PA4 controls "High Speed" to give some control over operating speed of the motor. Terminal PA5 will activate the stepping motor as long as "Run" is in its active state. Finally, PB5 controls a relay that activates the camera shutter and film advance. The interface board layout and associated parts list are shown in Figures 5 and 6.

3.5 POSITION COUNTER

The position counter was specifically designed for the scanner system to keep track of the camera's position (Figures 7 and 8). The position counter contains two decade up-down counters which supply BCD numbers to the video numeric inserter and camera back data multiplexer. The schematic for one of the two identical counters is shown in Figure 8. Each counter contains two BCD up-down registers which can be expanded to five by replacing the 330-ohm pull-up modules with 74192 BCD counters. The pull-up modules blank out the unused digits on the numerical insertion devices. The four bit binary switches can be set for fixed number or punctuation codes which would cause a colon or decimal point to appear on the television monitor.

The input to the position counter comes from the up and down pulse outputs of the microcomputer interface board. However, in its original version, it had been intended to take the clockwise and counterclockwise pulses from the motor controllers. In the scanner's original concept, the attached displays would have given a readout in feet to .01 ft with an accuracy of about $\pm 2\%$.

FIGURE 5. Interface Board Layout.

QTY	PT. NO.	REF. DES.	DESCRIPTION	MATL/REF
	1		ASSEMBLY, COMPUTER INTERFACE PCB.	
	2		P.C. BOARD	DOUGLASS # 11-DE-3
	3	C1,2	CAPACITOR, .1UF 50V	
	4	R1-13	RESISTOR, 1K 1/4W 5%	
	5	U1,2	INTERFACE ADAPTER	T.I. SN 6522
	6	U4,5,6	OPEN COLLECTOR INVERTER	T.I. SN 7406
	7	U7	2 INPUT NAND	T.I. SN 7400
	8	U8,9	DUAL D FLIP FLOP	T.I. SN 7474
	9	K1	RELAY, MAGNACRAFT	172-DIP-5
	10		DIP SOCKET, 40 PIN,	T.I. C814004
	11		DIP SOCKET, 16 PIN,	T.I. C811654
	12		DIP SOCKET, 14 PIN,	T.I. C811454
	13		PROTECTIVE COVER	AMP#435238-5
	14		DIP JUMPER 12", 40 CONDUCTOR	A.P. PROD.#924136-12
	AR 15		WIRE WRAP WIRE, 30 G SOLID	KYNAR
	AR 16		" , 20 G "	ESSEX - DF422
	AR 17		WIRE, 20 G STRANDED	
	18	R14	RESISTOR, 22 Ω , 1/4 W, 5%	

FIGURE 6. Interface Board Parts List.

① ASSEMBLY
(COVER NOT SHOWN)

QTY	QTY	PT#	DESCRIPTION	MATL / REF
1	1	1	ASSEMBLY, POSITION COUNTER	
1	2	2	ASSEMBLY, PRINTED CIRCUIT CARD	H-2-91767
1	3	3	CLASSIS W/COVER 10" x 12" x 3"	ALUMIN., BUDD
1	4	4	FRONT PANEL, 5 1/4" x 19" x 1/8"	ALUMIN., ALCON
1	5	5	POWER SUPPLY, 5V, 6 AMP, 110 AC IP	ROSCOV T-150 H-5-6/0VP
2	6	6	CONNECTOR, CARDEDGE, 44 PIN	TEDEL # 22-30-1 CLARKE PRACTICE # 595, 5000 MONT
4	7	7	CARD GUIDE	
2	8	8	CONNECTOR, 50 PIN, FEMALE	ITT CANNON
1	9	9	CONNECTOR, 25 PIN, FEMALE	ITT CANNON DB-290
2	10	10	CONNECTOR, LEADS PANEL, W/ CONDUCTOR	LEWIS SA 1304 NYL
2	11	11	SWITCH, SPDT, MOMENTARY, W/ SWITCH GUARD	MILITARY LIFE LINE # 10-10 BLUDEN
1	12	12	FUSE HOLDER, PANEL, W/ 1/4 AMP FUSE	# 10-10 ITT CANNON
1	13	13	LINE CORD, W/ PLUG, AC	DIAGNOSTIC
3	14	14	SPRING LATCH ASSEMBLY	HYECCO, 9H-4
1	15	15	GROMMET, STRAIN RELIEF, PLASTIC 1/4"	
1	16	16	GROMMET, 1/4"	RUBBER
1	17	17	CLAMP, CABLE, PLASTIC, 3/16"	VOITREX EOE-3 32112 10
1	18	18	SCREW, ROUND HD, 6-32 x 1/2"	COMMERCIAL
1	19	19	SCREW, ROUND HD, 10-32 x 3/8"	
4	20	20	SPACER, # 10 x .40"	
5	21	21	NUT, HEX, 6-32	
8	22	22	SCREW, FLAT HD, 6-32 x 3/4"	
8	23	23	WASHER, LOCK, # 6	
6	24	24	SCREW, ROUND HD, 4-40 x 1/2"	
6	25	25	NUT, HEX, 4-40	
6	26	26	WASHER, LOCK, # 4	COMMERCIAL
2	27	27	SWITCH, 8 POSITION, SINGLE POLE, DIP	AMPHENOL # 7750
5	28	28	COUNTER, BCD UP/DOWN, DOWN	# 7492
5	29	29	SOCKET, 16 PIN, WIRE WRAP, DIP	TEXAS INSTRUMENTS # 74114-2
12	30	30	RESISTOR, 470 OHM, 1/2 WATT ± 5%	CARBON
1	31	31	RESISTOR, 10 OHM, 1/2 WATT ± 5%	CARBON
1	32	32	CAPACITOR, 0.1 μF, 50V, ± 20%	CENTREX LAB DOW CORN
1	33	33	BOARD, PC	11-10-2-3
3/4	34	34	WIRE, # 30 GAUGE, WIRE WRAP	KYNAR
3/4	35	35	WIRE, # 30 GAUGE, SOLID	DESSA # DESSA
4	36	36	NUT, HEX 10-32	INSULATION # 22 MIL W-BOND
3/4	37	37	WIRE, # 22 AWG, STRANDED 1/2", THINNED COPPER	W-BOND
1	38	38	CONNECTOR, 1 PIN, FEMALE	W-BOND

GENERAL NOTES

1. PERMANENTLY MARK DRAWING NO., PART NO. AND REVISION LEVEL USING .12 HIGH CHARACTERS PER AWS 10227, TYPE B.
2. PERMANENTLY MARK INFORMATION SHOWN USING .12 HIGH CHARACTERS LOCATED APPROX. AS SHOWN.
3. PART 13 U.L. LISTED.

FIGURE 8. Schematic of Position Counter Board.

In its present form, the counter is only intended to give two 2-digit frame index numbers for the X and Y position. The counter is resettable from its front panel or from the computer.

3.6 VIDEO NUMERIC INSERTER⁽⁹⁾

The numeric inserter takes the parallel BCD data from the position counter and keys it in as numbers over a television image. The inserter controls the size, shape, and position of the numeric characters. Also, it will display a decimal point if the BCD input lines contain a binary ten. Binary eleven input lines produce a colon, and binary fifteen input lines blank the characters. The unit performs this operation using National Television Standards Committee (NTSC) 525 line 60 fields/sec interlaced scan video from a 1 V peak-to-peak video source or from video and an external synchronization signal source. (See the equipment listing, Reference 2, for further reference to this device.)

3.7 FILM CAMERA DATA MULTIPLEXER⁽¹⁰⁾

The film camera data multiplexer performs a function for film analogous to that of the numeric inserter for video. It receives parallel BCD data from the position counter and then formats it to feed the seven-segment LED display inside the camera data back. The unit has been fitted with military standard transistor-transistor logic (TTL) chips because it will be operating in the harsh environment of the tank annulus. The multiplexer is located on the scanner platform near the camera.

3.8 CAMERA DATA BACK⁽¹¹⁾

The camera data back rides on the photographic camera just behind the film gate. It contains an array of sixteen seven-segment LEDs. Eight LED characters in the array display the numerical data received from the multiplexer. The illuminated numerical information is then projected through a lens onto the back of the film. Film types having antihalation backings should not be used as these are opaque and prevent the LED image from traveling through the film base to the photographic

emulsion. The LED exposure is gated by the shutter control and flashes the numbers on the film as the picture is taken. The light provided by the LEDs is controlled by an adjustment on the data back. Also on the data back are eight decade switches which provide a preset number to the remaining LEDs in the array.

3.9 CAMERA REMOTE CONTROL SYSTEM

The signal to activate the camera shutter comes from a relay on the computer interface board. The contacts of this relay are paralleled with a pushbutton switch to allow for manual activation. The contacts gate a 5 V signal which is fed to the data back. This causes the LED array to be strobed and sends a signal to the camera's automatic winder to trigger the shutter and film advance. The camera winder motor is powered by a 15 V dc source.

3.10 X-Y POSITION REFERENCE AND LIMITING SYSTEM

The X-Y position reference and limiting system consists of a cam switch network located on the scanner assembly. Each switch will close if it comes into contact with its associated cam which would be located at a critical point on the scanner. Each switch will activate an indicator light on the control panel to show the scanner's position status (see Figures 3 and 9 for position indicated). In addition to position indication, the "Bottom," "Left," and "Right" switches cause a "Clear" signal to be sent to the controllers. This stops the stepping motors to prevent them from crashing the camera carriage into the mechanical stops. The "Top" limit switch will also generate a "Clear" signal if the arms are extended. When the arms are folded, the relay U1 is activated which prevents the "Top" switch from stopping the motor. This is so that the folded scanner carriage can be brought up and out of the annulus riser.

3.11 TV CAMERA DRIVE ELECTRONICS

The camera drive unit is located in the control panel assembly. It generates the master scanning signals and high voltage for the vidicon camera located on the camera carriage. It receives video signal from the camera and adds the synchronization pulses to create the composit video

FIGURE 9. Control Panel Detail.

(composit video signal is fed through the numeric inserter to a video monitor and video tape recorder). The drive electronics operate on 28 V dc. The drive and power supply are located in the indicator control panel (Nos. 15 and 17, Figure 10).

3.12 VIDICON TV CAMERA⁽¹¹⁾

The view finder television camera is a miniature vidicon camera measuring 1.6-in. in diameter and 4-in. long. The vidicon tube usage aperture is 0.21 by 0.28 in. This is coupled to a 10 mm focal length, f/1.6 (fixed stop) "C" mount lens to give a 58° diagonal viewing angle. The resolution of this system is given as 850 lines (425 black and white line pairs)⁽¹²⁾ with a signal to noise ratio (SNR) of 40 db. However, bandwidth limitations of the monitor and numeric inserter reduce this to no more than 450 lines resolution. The face plate of the vidicon has a sensitivity of 0.1-ft candle with an illumination range of 10,000 to 1.

The camera is designed to tolerate a dose of 10^6 Rad gamma radiation, which is well beyond the limits needed for the tank environment. The camera is also specified as resistant to mechanical shock. However, it has been observed that rough handling or dropping will cause material to flake from the sulfide target. This produces visible obstructions to the image. Likewise, extremely bright objects can burn the target, producing the same result. Therefore, care must be taken to prevent rough handling or pointing the camera directly at bright lights. The camera's thermal operating limit is +65°C with storage to +125°C (see Figures 11 and 12 for camera location). The camera will be forced air cooled for temperature control.

3.13 VIDEO MONITOR AND TAPE RECORDER

The video monitor is a standard black and white 525 line 60 field/sec system. The video signal is fed to it from the numeric inserter. The signal can be terminated at the monitor or looped through it to terminate at the video tape recorder. The video signal line is 75 ohm coaxial cable and therefore must be terminated at the monitor or video tape recorder with a 75 ohm resistive load.

QTY.	PT. NO.	DESCRIPTION	MATL / REF
1	1	ASSEMBLY	
1	2	CIRCUIT BOARD ASSEMBLY	
3	3	SECTIONAL CONTACT ASSEMBLY	
1	4	BASE PLATE, 15.00 X 18.00 X 1/4 THK.	ALUMINUM 6061-T6
1	5	FRONT PANEL, 15.00 X 10.50 X 1/8 THK.	ALUMINUM 6061-T6
2	6	BRACKET, 2 X 2 X 1/2, 90° EXTRUDED ANGLE	ALUMINUM 6061-T6
1	7	MOUNT CHANNEL, MINIATURE CONTACT TERMINAL	BUCHANAN #12
1	8	PUNCHED INSULATING BOARD, GLASS EPOXY 1/16 THK., .042 DIA. HOLES ON .01" GRID	VECTOR 169-P84
3	9	SOCKET, DUAL IN-LINE IC, 16 PIN	TEXAS INSTRUMENTS C 86104
3	10	RELAY, 8-PIN REED, CLASS 172 DDP, SPDT, WITH INTERNAL CLAMPING DIODE	MAGNACRAFT W172 DIP 5
4	11	RECTIFIER, SILICON	IN4004
25	12	SECTION, MINIATURE CONTACT TERMINAL	BUCHANAN #125
1	13	END SECTION, MINIATURE CONTACT TERMINAL	BUCHANAN #130
2	14	CHANNEL CLAMP, MINIATURE CONTACT TERMINAL	BUCHANAN #11
1	15	CAMERA CONTROL UNIT, EDO WESTERN	# 29555-1
1	16	VIDEO MONITOR	GBC TV CORP. MV-10A
1	17	POWER SUPPLY, 28VDC ADJUSTABLE, LAMBDA	LMC 28
1	18	POWER SUPPLY, 28V IN 15V OUT, ADJUSTABLE	ABBOTT LABORATORIES 21635
5	19	LIGHT SOCKET/ GREEN DIFFUSER	DIALSO 101-5030-0912-201
4	20	LIGHT SOCKET/ RED DIFFUSER	DIALSO 101-5030-0911-201
2	21	FUSE HOLDER	LITTLEFUSE NC # 344125
1	22	FUSE, 2 AMP	SLO-BLO 3AG-2 AMP
1	23	FUSE, 5 AMP	SLO-BLO 3AG-5 AMP
1	24	TOGGLE SWITCH, ON/OFF, SPDT 15A/125VAC	MS-35055-22
1	25	TERMINAL BLOCK	CINCH 10-141
1	26	MARKER STRIP, 10 TERMINAL	CINCH MS-10-141
1	27	MARKER STRIP, 7 TERMINAL	CINCH MS-7-140
1	28	SWITCH, PUSHBUTTON, DPDT, 5A/125VAC	CUTLER/HAMMER ECC-8
4	29	CABLE CLAMP, 1/2 I.D.	SFC TECHNOLOGY ECC-8
1	30	CABLE CLAMP, 3/8 I.D.	SFC TECHNOLOGY ECC-8
1	31	CABLE CLAMP, 1/4 I.D.	SFC TECHNOLOGY ECC-8
1	32	POWER CABLE, 6 FT., 3 CONDUCTOR, 18 AWG	BELEDON 17406
1	33	EDGE CONNECTOR, 44 PIN TRW/CINCH	50-4EE-30
1	34	CONNECTOR HOOD	STD APPLIED ENG. INC. # 8018
1	35	CABLE CONNECTOR, 12 SOCKET DEUTSH	DM 9408-125
2	36	CABLE CONNECTOR, 3 PIN/3 SOCKET	LEMO #1
1	37	CABLE CONNECTOR, 10 SOCKET	MS-3102A 10-105
1	38	CABLE CONNECTOR, 32 SOCKET	MS-3116F 12-105
2	39	CABLE, 6 FT., 9 SHIELDED PAIRS, 22 AWG	ALPHA 6014
1	40	CABLE, 6 FT., 12 CONDUCTOR, 20 AWG	BELEDON 9457

PARTS LIST CONTINUED ON SHEET 2.
FOR GENERAL NOTES, SEE SHEET 2.

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES.

TOLERANCES ON:

DECIMALS	ANGLES	FRACTIONS
XX ± .01	± 0° 30'	1/32
XXX ± .005		

DO NOT SCALE PRINT

FIGURE 10. Main Control Panel Assembly.

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FIGURE 11. Detail of Camera Carriage.

FIGURE 12. Detail of Camera Carriage (Side View).

3.14 PRIMARY ac POWER SYSTEM

Power input to the system is the fundamental single phase, 115 V ac, 60 Hz. This supplies power to the computer, the motor control units, lighting, video monitor, numeric inserters, and subsystem dc power supplies. Switches and fuses for lights and dc power supplies (labeled "camera") are on the indicator control panel (see Figure 9).

3.15 SUBSYSTEM dc POWER SUPPLIES

Several dc voltage buses are available for systems which do not have their own power supply. These are at 28 V dc, 15 V dc, and 5 V dc. The 28 V supply powers the television camera and the 28 V dc to 15 V dc converter. In turn, the converter supplies power to the film camera shutter and winder motor. The 5 V supply handles the position counter, the limit switch system, computer interface relays, and the camera shutter trigger. The 28 V and 15 V power supply are located in the central control panel (see Figure 10). The 5 V power supply is in the position counter panel (see Figure 7).

3.16 CAMERA LIGHTING SYSTEM

The camera lighting system consists of two 300 W reflectorized quartz lamps. They are mounted to the left and right of the television camera (see Figure 11). The lamps are connected to a variable autotransformer mounted on the bottom of the instrument rack. The autotransformer operates from the ac power line. The camera light switch is located on the central indicator panel (see Figure 9).

3.17 CENTRAL CONTROL PANEL AND ELECTRONICS RACK

The electronics rack is shown in Figure 5. All items for controlling the scanner are fitted into an Electronics Industry Association (EIA) standard 19 in. relay rack (No. 2, Figure 13). The rack is fitted with a cooling fan and a ventilation port to keep the

QTY	PT#	DESCRIPTION	MATL / REF
1	1	RACK ASSEMBLY	
1	2	INSTRUMENT RACK (SEE NOTE 1)	OPTIMA-R10M24
1	3	MICRO COMPUTER	ROCKWELL DATA 60
1	4	POSITION COUNTER	ROCKWELL DATA 60
1	5	X-POSITION MOTOR CONTROLLER	
1	6	Y-POSITION MOTOR CONTROLLER	
1	7	VIDEO MONITOR & POSITION INDICATOR	
1	8	VIDEO-NUMERICAL INSERTER	
1	9	BLOWER	OPTIMA CB-3200A
1	10	RETRACTABLE WRITING SURFACE	OPTIMA WS-81224
1	11	VENTILATING GRILL	OPTIMA SA-814
1	12	CASTER PLATE	OPTIMA CPA-86
1	13	DRAWER, 10" DEEP	OPTIMA DS-104714
1	14	PANEL, BLANK, $2\frac{1}{2} \times 19 \times \frac{1}{8}$ "	
1	15	PANEL BLANK $1\frac{1}{2} \times 19 \times \frac{1}{8}$ "	
1	16	LIFTING EYES	OPTIMA HW-60

GENERAL NOTES

1. INSTRUMENT RACK ASSEMBLY FOR 19 INCH PANELS WITH A HEIGHT OF 70 INCH AND DEPTH BETWEEN PANELS OF 24 INCH. RACK SHALL INCLUDE THE FOLLOWING OPTIONS:
 REAR DOOR NO. D-7019LH, 10 PAIR SUPPORT ANGLES NO. SA24, POWER OUTLET NO. 15CB-15.

FIGURE 13. Control Panel Assembly.

equipment as close to the ambient air temperature as possible. The instrument panels are laid out as follows:

- Top position counter (No. 4, Figure 13)
- X motor controller (No. 5, Figure 13)
- Y motor controller (No. 6, Figure 13)
- Indicator control panel assembly (No. 7, Figure 13; also see Figure 7)
- AIM-65 Microcomputer (No. 3, Figure 13)
- Video numeric inserter (No. 8, Figure 13)

Other items in the rack are mechanical conveniences such as the drawer, table, and blank panels to fill in the spaces.

A block diagram of the control panel instruments showing their interconnect cabling runs is shown in Figure 14. Cable runs to instruments on the scanner platforms are also shown (see Figure 14).

3.18 CENTRAL CONTROL AND INDICATOR PANEL

Central to the system is the indicator control panel (see Figures 3, 9, and 10). This item houses the limit switch indicator lights, video monitor and camera driver, power supplies, switches, fuses, and the manual camera shutter control. It provides a platform for wiring exchange to most of the instruments in the system. The major wiring exchange (see Figure 8) is provided between the computer interface board (located in the microcomputer) and the motor controllers. Another wiring exchange is provided to the position counter for data and the 5 V power supply. Other wiring exchanges include the limit switches and power.

3.19 CABLE INTERCONNECTIONS

The block diagram in Figure 7 shows the cable interconnections. Most of these are large multiconductor shielded cables terminated with military standard multiple pin connectors. Cables used between the X and Y scanner platforms are coiled retractable cables. Those leading from

FIGURE 14. Electrical System Block Diagram.

the control panel to the Y platform are straight. The stepping motor cable is the most massive holding 12 conductors of No. 10 American Wire Gauge (AWG) stranded wire terminated with a clamp and spade lugs to minimize connection loss.

4.0 PROGRAM OF OPERATION

4.1 OPERATION SEQUENCE AND MONITORING

The purpose of the annulus scanner is to send a camera into the annulus of a nuclear waste tank and to make a detailed photographic record of the tank wall. The operation begins by sending the scanner and crossarms down through the riser and into the annulus (see Figures 1 and 2). The scanner is sent to the bottom of the vertical rail so that the crossarms can be manually cranked open. Once the crossarms are open, the camera carriage can be sent to the left. It is stopped near the left end of the horizontal rail and takes a picture. Then the camera is moved right one frame, takes another picture, and so on until it is at the right hand end. Then, the crossarms and carriage are moved upward one frame and the process is repeated, right to left, and so on until the camera is out of film or the top of the tank annulus is reached. The camera is then moved to center, and along with the crossarms assembly, is moved downward so that the arms can be folded up. Finally the assembly is pulled upward out of the annulus, through the riser, and into the open so that the film load can be changed and the process continued. At this point, the process can also be discontinued so that the scanner can be completely removed, for possible use in some other tank. The maximum time the camera film should be in the annulus is about 25 minutes because of the possibility of radiation fogging of the film.

The process can be monitored using the computer display, control light on the indicator panel, and to some extent the video system. The "X-Ref" and "Y-Ref" lights are set up to go on just before the camera carriage reaches "Left" and "Bottom" respectively. If the reference or "Ref" points are passed over into "Bottom" and "Left," the limit switches would be activated which would kill stepping motor operation. If this condition occurs, the carriage is removed by switching the motor controller to manual and jogging it out one step at a time. To allow the system to crash the stops could cause damage that might inhibit the system's removal.

FIGURE 15. Simplified Block Diagram.

There are four indicator lights which are activated by the critical limit switches. These are "Top," "Bottom," "Left," and "Right." The "Top" limit switch is deactivated when the "Arms folded" light comes on. These five items have a cutoff effect upon the motor controllers. The "X-Ref" and "Y-Ref" are interfaced to the microcomputer and their effect depends upon the prevailing program. The "Center" and "Extended" indicators have no effect other than to turn on the lights. However the camera carriage should not be moved unless the "Extended" light is on. Otherwise it might foul up on the track. Likewise the crossarms must not be folded up unless the camera carriage is at "Center."

4.2 COMPUTER OPERATION^(6,7)

In its current edition, the computer program operates the scanner only during picture taking sequences. Since the crossarms must be manually cranked open, and their status checked on the indicator panel lights, it was felt that preliminary operations and prepositioning also should be done manually. Once the "Extended" light comes on and the X and Y reference positions are reached, the current computer automated sequence can begin safely. Current operation has the frame size set manually on the controller dials. The dials are set for X = 850 motor steps (or 10 in.) and Y = 3,448 motor steps (or 6 1/2 in.). This provides an adequate overlap between adjacent frames when using a 35 mm focal length lens on the film camera. The computer is programmed to take 15 frames horizontally. The number of vertically contiguous frames is limited only by the top limit switch and the number of frames on a roll of film.

The computer operation begins by the operator calling up the scanner operation program. The computer operator interface is through the keyboard, LED display, and thermal printer. The scanner program is called by pressing No. 5 on the keyboard while the computer is in executive monitor operation. This causes the computer to jump to the ROM address (hexidecimal B000) and execute the machine language program which begins there.

The scanner control program begins with a cold start routine by clearing data stored by previous scans and setting up the interface registers. If it is desired to save information from the previous scan and/or add to it, the operator begins the program by depressing No. 6 on the keyboard instead of No. 5. This bypasses the cold start and moves right into the scan. The computer then executes a sequence of subroutine calls which control detailed phases of operation. The first subroutine asks the operator for data input. These data are the Y offset (Auto Y - #) and the number of pictures to be taken (Take = #). They are entered on the keyboard and stored in RAM memory. The scanning procedure is intended to start from "X-Ref" and "Y-Ref" points.

When the computer scan begins, the vertical movement offsets the camera carriage the number of frames entered in "Auto Y = " from the "Y-Ref." The Y axis position counter is incremented once for each frame offset. The horizontal scan then begins with an execution of the shutter routine which takes the first picture. Next, the X stepping motor routine is called. The camera carriage moves horizontally one frame and stops. The X position counter is incremented. Another picture is taken, and so on for 15 pictures. Then the Y stepping motor routine is called to move the carriage and crossarms upward one frame. The Y position counter is incremented, and another scan of 15 pictures is made. This continues until the number of pictures called for is complete, as entered in "Take = ". When the entire automated scan has ended, the program cycles back to request new data for the Y offset and number of picture to be taken. If at this point the camera is out of film, the Y position number on the video display should be noted as it will probably become the next Y offset when the scan is continued.

Then, the scanner must be manually sent to "Center" and "Y-Ref" positions so that the arms may be folded and the camera brought out for service. If the scan is continued after reloading, the position counter must be manually reset and the scanner located at "X-Ref" and "Y-Ref" as before. For continuing, the program would be reactivated by keying in No. 6 (if the computer has been returned to the monitor during servicing). If power is lost to the computer, the scanner program must be cold started (Key No. 5).

The computer program is equipped with two fail safe features to prevent abnormal operation. The Y offset is limited to 30 frames. If a larger number is entered, the computer will print the words "Too Large" and then wait for a second value. If a nondecimal number or character is entered, the computer will print the word "Error" and then return to monitor.

During operation, the display will indicate the motor operation by showing the words "Drive In Progress." Also shown will be the number of photos taken.

The entire control program has been encoded in machine language and recorded in EPROM for starting in hex address location B000. This makes it possible to start operation without going through a tape or disc loading procedure. This results in a greater simplicity of operation, and greater speed in regaining control of the system after a power dropout.

5.0 CONCLUSIONS

As of May 1981, the scanner was partially assembled and installed between the walls of a double-shell tank mockup at Hanford's T Plant 271-T Laboratory Facility. With the exception of the limit switches, the electrical system has been installed. These are being simulated for test purposes with a set of dummy switches. The electrical system has been found to be correctly assembled and in good operating order.

The only electrical problem encountered so far has to do with the occasional loss of vertical synchronization in the video system. This occurs when the camera shutter is activated, and results in a frame roll on the television monitor. Apparently, activation of the camera winder motor produces enough of a surge to the dc-to-dc down converter, that it works its way back to the 28 V supply which is also held in common with the television camera. The solution is expected to be an independent 15 V supply which will be exchanged with the converter.

Some questions remain about the thermal and radiation tolerance of components which will enter the annulus. Most of the integrated circuits are rated at military standard temperature specifications (-55°C to $+125^{\circ}\text{C}$). Other components are forced air cooled. Temperature testing is being planned to check the cooling and thermal behavior. Radiation tolerance estimates are that at least 100 hours of operation can be expected for all in-tank components. This is considered adequate to accomplish the work schedule planned for the scanner.

REFERENCES

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2. Stepping Motors and Driver Controller Units, Superior Electric Company, Bristol, Connecticut, 06010.
 SLO-SYN^R Type SP 155A-1230 Indexer with
 M112-FJ326 Motor
 450 oz. in. Holding Torque
 600 oz. in. at 750 steps per second peak
 200 steps per revolution
 300 oz. in. at 2,500 steps per second
 Current and Voltage 15.9A, 1.45V, 840 oz. in. rating

 SLO-SYN^R Type SP 155A-1218 Indexer with
 M112-FJ327 Motor
 600 oz. in. Holding Torque
 840 oz. in. at 450 steps per second peak
 400 oz. in. at 1,200 steps per second peak
 200 steps per revolution
 Current and Voltage 9.2 A 2.1 V 840 oz. in. rating
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System Technical Manual, Operating and Maintenance Instructions
Camera.

Multiplexer

Dearing Latch and BCD Multiplexer
Model 8LM Militarized
October 1978, 093/476-10/78.

Dearing Numeric Data OrderTM System
Models 16-35-DN1 or 2
August 1978, 093-452-8/78

11. Camera Head and Driver (Television), Edo Western Corp., 2645 S. 300 West Street, Salt Lake City, Utah, 84115.// Head CH-1831/30531 // Control Unit CCU-1430/29595-1, 24138-1, 22454.
12. Television Waveform Processing Circuits, Tektronix Inc. 1968, Pages 5 to 8, Beaverton, Oregon,

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APPENDIX A

COMPUTER PROGRAM LISTING - COLD START

(Text, Assembly, Operational Code [Op-Code], and
Dissassembly of Op-Code from EPROM)

```
.PAGE 'NFS SCANNER'  
.PAGE 'COLRM'  
STP=$B600  
*=$B000  
JMP COL  
JMP HOT  
COL LDA #$00  
STA $06  
STA $07  
HOT LDA #$00  
STA $00  
STA $01  
LDA #$0C  
STA $A000  
STA $A001  
STA $9000  
STA $9001  
LDA #$0A  
STA $0D  
STA $0E  
LDA #$08  
STA $A003  
STA $9003  
LDA #$2C  
STA $A002  
LDA #$0C  
STA $9002  
LDA #$CD  
STA $A00C  
STA $900C  
JSR STP  
JMP HOT  
.PAGE 'PAGE 1'  
.PAGE '
```

NFS SCANNER

COLRM

==0000 STP=\$B600

==0000

*=\$B000

==B000

4C06B0 JMP COL

4C0CB0 JMP HOT

==B006 COL

A900 LDA #\$00

8506 STA \$06

8507 STA \$07

==B00C HOT

A900 LDA #\$00

8500 STA \$00

8501 STA \$01

A90C LDA #\$0C

8D00A0 STA \$A000

8D01A0 STA \$A001

;17B0004C06B04C0CB0A90085068507A90085008501A90C8D00A00827

8D0090 STA \$9000

==B01D

8D0190 STA \$9001

A90A LDA #\$0A

850D STA \$0D

850E STA \$0E

A908 LDA #\$08

8D03A0 STA \$A003

8D0390 STA \$9003

==B02E

A92C LDA #\$2C

;17B0178D01A08D00908D0190A90A850D850EA9088D03A08D03900920

8D02A0 STA \$A002

A90C LDA #\$0C

8D0290 STA \$9002

A9CD LDA #\$CD

8D0CA0 STA \$A00C

8D0C90 STA \$900C

==B040

2000B6 JSR STP

4C0CB0 JMP HOT

PAGE 1

ERRORS= 0000
;18B02EA92C8D02A0A90C8D0290A9CD8DOCA08DOC902000B64COCB00A84
;000004C004

<

L

PASS 1

PASS 2

;17B0004C06B04C0CB0A90085068507A9008500850.1A90C8D00A00827
;17B0178D01A08D00908D0190A90A850D850EA9088D03A08D03900920
ERRORS= 0000
;18B02EA92C8D02A0A90C8D0290A9CD8D0CA08DOC902000B64C0CB00A84
;0000040004

<L

;18B0004C06B04C0CB0A90085068507A9008500850.1A90C8D00A08D08B5
;18B01801A08D00908D0190A902850D850EA9088D03A08D0390A92C0962
;18B0308D02A0A90C8D0290A9CD8D0CA08DOC902000B64C0CB0FFFF0BAF
;09B048FFFFFFFFFFFFFFFFFFFF09F8
MORE?

0
B000 4C JMP B006
B003 4C JMP B00C
B006 A9 LDA #00
B008 85 STA 06
B00A 85 STA 07
B00C A9 LDA #00
B00E 85 STA 00
B010 85 STA 01
B012 A9 LDA #0C
B014 8D STA A000
B017 8D STA A001
B01A 8D STA 9000
B01D 8D STA 9001
B020 A9 LDA #02
B022 85 STA 0D
B024 85 STA 0E
B026 A9 LDA #08
B028 8D STA A003
B02B 8D STA 9003
B02E A9 LDA #2C
B030 8D STA A002
B033 A9 LDA #0C
B035 8D STA 9002
B038 A9 LDA #CD
B03A 8D STA A00C
B03D 8D STA 900C
B040 20 JSR B600
B043 4C JMP B00C
B046 FF ???
B047 FF ???
B048 FF ???
B049 FF ???
B04A FF ???
B04B FF ???
B04C FF ???
B04D FF ???
B04E FF ???
B04F FF ???
B050 FF ???
B051 FF ???
B052 FF ???
B053

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APPENDIX B

COMPUTER PROGRAM LISTING - OPERATION SEQUENCE

(Text, Assembly, Op-Code, and Disassembly of Op-Code from EPROM)


```

.PAGE 'NSF SCANNER'
.PAGE 'OPSEQ'
YPOSTN=$B177
XDRIVE=$B18E
YDRIVE=$B1EC
NOUT=$EA51
NUMA=$EA46
ADDNE=$EAB1
PICTRE=$B24A
PHOTOS=$B72A
WAIT20=$B28A
WAIT=$B28C
MESSAGE=$B29D
LOOPZ=$B2A0
OUTPUT=$E97A
*=$B600
AUTO LDY #$40 ; SET UP FOR MESSAGE
JSR MESSAGE ; 'AUTO Y='
JSR ADDNE ; MONITOR INPUT SUB SEE 'FROM' AIM MANUAL PG 7-68
LDA $A41C ; INPUT DATA
STA $05 ; TEMP SAVE
SEC
SED
LDA $B7F1 ; YMAX
SBC $A41C ; INPUT DATA
BCS GOOD
TOLRG LDY #$D0
JSR MESSAGE ; 'TOO LARGE'
LDA $0A ; WAIT 1 SEC
JSR WAIT
RTS
;
GOOD LDY #$48
.PAGE 'PAGE 1'
.PAGE '

```

```

JSR LOOPZ ; MESSAGE ROUTINE
JSR ADDNE ; MONITOR ROUTINE
BCS GOOD
LDA #SOD
JSR OUTPUT
LDA $A41D ; L. O. INPUT BYTE
STA $08
LDA $A41C ; H. O. BYTE
STA $09
BNE MOVEUP
LDA $08
BNE MOVEUP
RTS
;
MOVEUP LDA $05 ; RECALL Y POSITION INPUT
JSR YPOSTN
;
;
SCAN JSR MINUS1
JSR PICTURE
LDA $B7F0 ; GET XMAX
STA $0A
PZERO1 LDA $09 ; PICTURES LEFT=0?
BNE CONT1 ; IF NOT BRANCH
LDA $08
BNE CONT1
QUIT RTS
CONT1 LDA #$08 ; NEG (RIGHT)X DRIVE
JSR XDRIVE
JSR MINUS1
JSR PICTURE
DEC $0A
BNE PZERO1
.PAGE 'PAGE 2'
.PAGE

```

```
PZERO2 LDA $09 ; PLEFT=0?
BNE CONT2
LDA $08
BNE CONT2
RTS
CONT2 LDA $B7F1 ; AT TOP?
CMP $01
BEQ QUIT
LDA #$08 ; NEG Y DRIVE (UP)
JSR YDRIVE
JSR MINUS1
JSR PICTURE
LDA $B7F0 ; GET XMAX
STA $0A
PZERO3 LDA $09
BNE CONT3
LDA $08
BNE CONT3
RTS
CONT3 LDA #00 ; POS X DRIVE (LEFT FACING TANK)
JSR XDRIVE
JSR MINUS1
JSR PICTURE
DEC $0A
BNE PZERO3
LDA $09 ; PLEFT=0?
BNE CONT4
LDA $08
BNE CONT4
RTS
CONT4 LDA $B7F1 ; AT TOP OF SCAN?
CMP $01
BEQ QUIT
.PAGE 'PAGE 3'
.PAGE '
```

```

LDA #08
JSR YDRIVE
JMP SCAN
;
;
;   *** MINUS1 SUBROUTINE   ***
;
;   DECIMAL SUBTRACTS 1 FROM PLEFT
;
MINUS1 LDA $09
SED
SEC
SBC #01
STA $09
LDA $08
SBC #00
STA $08
CLD
RTS
.PAGE /PAGE 4/
.PAGE /

```

 NSF SCANNER

 OPSEQ

```

==0000 YPOSTN=$B177
==0000 XDRIVE=$B18E
==0000 YDRIVE=$B1EC
==0000 NOUT=$EA51
==0000 NUMA=$EA46
==0000 ADDNE=$EAB1
==0000 PICTURE=$B24A
==0000 PHOTOS=$B72A
==0000 WAIT20=$B28A
==0000 WAIT=$B28C
==0000 MESSAGE=$B29D
==0000 LOOPZ=$B2A0
==0000 OUTPUT=$E97A
==0000
      *=$B600
==B600 AUTO
A040 LDY #$40
; SET UP FOR MESSAGE
209DB2 JSR MESSAGE
; 'AUTO Y='
20B1EA JSR ADDNE
; MONITOR INPUT SUB SEE 'FROM' AIM MANUAL PG 7-68
AD1CA4 LDA $A41C
; INPUT DATA
8505 STA $05
; TEMP SAVE
38 SEC
F8 SED
ADF1B7 LDA $B7F1
; YMAX
==B612
ED1CA4 SEC $A41C
; INPUT DATA
B00B BCS GOOD
==B617 TOLRG
A0D0 LDY #$D0
; 17B600A040209DB220B1EAAD1CA4850538F8ADF1B7ED1CA4B00BOCB
209DB2 JSR MESSAGE
; 'TOO LARGE'
A50A LDA $0A
; WAIT 1 SEC
208CB2 JSR WAIT
60 RTS
;
==B622 GOOD
A048 LDY #$48

```

 PAGE 1

```

20A0B2 JSR LOOPZ
; MESSAGE ROUTINE
20B1EA JSR ADDNE
; MONITOR ROUTINE
B0F6 BCS GOOD
A90D LDA #S0D
207AE9 JSR OUTPUT
;17B617A0D0209DB2A50A208CB260A04820A0B220B1EAB0F6A90DOCA1
AD1DA4 LDA $A41D
; L. O. INPUT BYTE
==B634
8508 STA $08
AD1CA4 LDA $A41C
; H. O. BYTE
8509 STA $09
D005 BNE MOVEUP
A508 LDA $08
D001 BNE MOVEUP
60 RTS
;
==B642 MOVEUP
A505 LDA $05
; RECALL Y POSITION INPUT
2077B1 JSR YPOSTN
;16B62E207AE9AD1DA48508AD1CA48509D005A508D00160A50509D0
;
;
==B647 SCAN
20BAB6 JSR MINUS1
204AB2 JSR PICTURE
ADF0B7 LDA $B7F0
; GET XMAX
850A STA $0A
==B652 PZERO1
A509 LDA $09
; PICTURES LEFT=0?
D005 BNE CONT1
; IF NOT BRANCH
A508 LDA $08
D001 BNE CONT1
==B65A QUIT
60 RTS
==B65B CONT1
A908 LDA #S08
; NEG (RIGHT)X DRIVE
;17B6442077B120BAB6204AB2ADF0B7850AA509D005A508D001600B49
208EB1 JSR XDRIVE
20BAB6 JSR MINUS1
204AB2 JSR PICTURE
C60A DEC $0A
D0E8 BNE PZERO1

```

```

==B66A PZER02
A509 LDA $09
; PLEFT=0?
D005 BNE CONT2
A508 LDA $08
D001 BNE CONT2
60 RTS
==B673 CONT2
ADF1B7 LDA $B7F1
; AT TOP?
;18B65BA908208EB120BAB6204AB2C60AD0E8A509D005A508D001600BCE
C501 CMP $01
FOE0 BEQ QUIT
A908 LDA #$08
; NEG Y DRIVE (UP)
20ECB1 JSR YDRIVE
20BAB6 JSR MINUS1
204AB2 JSR PICTURE
==B685
ADF0B7 LDA $B7F0
; GET XMAX
850A STA $0A
==B68A PZER03
A509 LDA $09
;17B673ADF1B7C501FOE0A90820ECB120BAB6204AB2ADF0B7850A0E28
D005 BNE CONT3
A508 LDA $08
D001 BNE CONT3
60 RTS
==B693 CONT3
A900 LDA #00
; POS X DRIVE (LEFT FACING TANK)
208EB1 JSR XDRIVE
20BAB6 JSR MINUS1
204AB2 JSR PICTURE
C60A DEC $0A
DOE3 BNE PZER03
A509 LDA $09
; PLEFT=0?
;18B68AA509D005A508D00160A900208EB120BAB6204AB2C60AD0E80BF5
==B6A4
D005 BNE CONT4
A508 LDA $08
D001 BNE CONT4
60 RTS
==B6AB CONT4
ADF1B7 LDA $B7F1
; AT TOP OF SCAN?
C501 CMP $01
FOA8 BEQ QUIT

```

A908 LDA #S08
 20ECB1 JSR YDRIVE
 4C47B6 JMP SCAN

;
 ;
 ;
 ;
 ;
 ;
 ;

*** MINUS1 SUBROUTINE ***

DECIMAL SUBTRACTS 1 FROM PLEFT

==B6BA MINUS1

A509 LDA \$09

;18B6A2A509D005A508D00160ADF1B7C501FOA8A90820ECB14C47B60D3B

F8 SED

38 SEC

E901 SBC #01

8509 STA \$09

A508 LDA \$08

E900 SBC #00

8508 STA \$08

D8 CLD

60 RTS

PAGE 4

```

      A MINUS1
A509  LDA $09
;18B6A2A509D005A508D00160ADF1B7C501F0A8A90820ECB14C47B60D3B
F8    SED
38    SEC
E901  SBC #01
8509  STA $09
A508  LDA $08
E900  SBC #00
8508  STA $08
D8    CLD
60    RTS
==B6CA
      RTS
ERRORS= 0000
;10B6BAA509F838E9018509A508E9008508D8600831
;00000A000A

```

<L

Y

OBJ-OUT=L

PASS 1

PASS 2

```

;17B600A040209DB220B1EAAD1CA4850538F8ADF1B7ED1CA4R00BOCBF
;17B617A0D0209DB2A50A208CB260A04820A0B220B1EAB0F6A90DOCA1
;16B62E207AE9AD1DA48508AD1CA48509D005A508D00160A50509D0
;17B6442077B120BAB6204AB2ADF0B7850AA509D005A508D001600B49
;18B65BA908208EB120BAB6204AB2C60AD0E8A509D005A508D001600BCE
;17B673ADF1B7C501F0E0A90820ECB120BAB6204AB2ADF0B7850A0E28
;18B68AA509D005A508D00160A900208EB120BAB6204AB2C60AD0E80BF5
;18B6A2A509D005A508D00160ADF1B7C501F0A8A90820ECB14C47B60D3B
ERRORS= 0000
;10B6BAA509F838E9018509A508E9008508D8600831
;00000A000A

```

<

L

;18B600A040209DB220B1EAAD1CA4850538F8ADF1B7ED1CA4B00BA00D5C
;18B618D0209DB2A50A208CB260A04820A0B220B1EAB0F6A90D207A0C9D
;18B630E9AD1DA48508AD1CA48509D005A508D00160A5052077B1200AA2
;18B648BAB6204AB2ADF0B7850AA509D005A508D00160A908208EB10BF6
;18B66020BAB6204AB2C60AD0E8A509D005A508D00160ADF1B7C5010CDE
;18B678F0E0A90820ECB120BAB6204AB2ADF0B7850AA509D005A5080D43
;18B690D00160A900208EB120BAB6204AB2C60AD0E8A509D005A5080BFB
;18B6A8D00160ADF1B7C501F0A8A90820ECB14C47B6A509F838E9010DD9
;10B6C08509A508E9008508D860FFFFFFFFFFFFFFFF0B69
MORE?

9

```

B600 A0 LDY #40
B602 20 JSR B29D
B605 20 JSR EAB1
B608 AD LDA A41C
B60B 85 STA 05
B60D 38 SEC
B60E F8 SED
B60F AD LDA B7F1
B612 ED SBC A41C
B615 B0 BCS B622
B617 A0 LDY #D0
B619 20 JSR B29D
B61C A5 LDA 0A
B61E 20 JSR B28C
B621 60 RTS
B622 A0 LDY #48
B624 20 JSR B2A0
B627 20 JSR EAB1
B62A B0 BCS B622
B62C A9 LDA #0D
B62E 20 JSR E97A
B631 AD LDA A41D
B634 85 STA 08
B636 AD LDA A41C
B639 85 STA 09
B63B D0 BNE B642
B63D A5 LDA 08
B63F D0 BNE B642
B641 60 RTS
B642 A5 LDA 05
B644 20 JSR B177
B647 20 JSR B6BA
B64A 20 JSR B24A
B64D AD LDA B7F0
B650 85 STA 0A
B652 A5 LDA 09
B654 D0 BNE B65B
B656 A5 LDA 08
B658 D0 BNE B65B
B65A 60 RTS
B65B A9 LDA #08
B65D 20 JSR B18E
B660 20 JSR B6BA
B663 20 JSR B24A
B666 C6 DEC 0A
B668 D0 BNE B652
B66A A5 LDA 09
B66C D0 BNE B673
B66E A5 LDA 08
B670 D0 BNE B673
B672 60 RTS
B673 AD LDA B7F1
B6

```

76 C5 CMP 01
B678 F0 BEQ B65A
B67A A9 LDA #08
B67C 20 JSR B1EC
B67F 20 JSR B6BA
B682 20 JSR B24A
B685 AD LDA B7F0
B688 85 STA 0A
B68A A5 LDA 09
B68C D0 BNE B693
B68E A5 LDA 08
B690 D0 BNE B693
B692 60 RTS
B693 A9 LDA #00
B695 20 JSR B18E
B698 20 JSR B6BA
B69B 20 JSR B24A
B69E C6 DEC 0A
B6A0 D0 BNE B68A
B6A2 A5 LDA 09
B6A4 D0 BNE B6AB.
B6A6 A5 LDA 08
B6A8 D0 BNE B6AB
B6AA 60 RTS
B6AB AD LDA B7F1
B6AE C5 CMP 01
B6B0 F0 BEQ B65A
B6B2 A9 LDA #08
B6B4 20 JSR B1EC
B6B7 4C JMP B647
B6BA A5 LDA 09
B6BC F8 SED
B6BD 38 SEC
B6BE E9 SBC #01
B6C0 85 STA 09
B6C2 A5 LDA 08
B6C4 E9 SBC #00
B6C6 85 STA 08
B6C8 D8 CLD
B6C9 60 RTS
B6CA FF ???
B6CB FF ???
B6CC FF ???
B6CD FF ???
B6CE FF ???
B6C

RHO-SA-221

APPENDIX C

COMPUTER PROGRAM LISTING - INTERFACE SUBROUTINES

(Text, Assembly, Op-Code, and Disassembly of Op-Code from EPROM)

```

.PAGE 'MSF SCANNER'
.PAGE 'INSUB'
NOUT=$EA51
NUMA=$EA46
ADDNE=$EAB1
*=$B160
XPOSTN STA $04
BEQ RTN
DRIVE1 LDA #$08 ; NEGATIVE (RIGHT) DRIVE
JSR XDRIVE
SED
SEC
LDA $04
SBC #$01
STA $04
CMP #00 ; IN DECIMAL Z FLAG NOT VALID
CLD
BNE DRIVE1
RTS
YPOSTN STA $05
BEQ RTN
DRIVE2 LDA #$08
JSR YDRIVE
SED
SEC
LDA $05
SBC #01
STA $05
CMP #00
CLD
BNE DRIVE2
RTN RTS
XDRIVE STA $A001 ; ENTER WITH A=00 FOR POS DRIVE, 08 FOR NEG
PHA
LDA #$CF
STA $A00C
JSR WAIT20
LDA #$00
STA $A001
.PAGE 'PAGE 1'
.PAGE '

```



```

LDA #SCD
STA $A00C
LDY #S15
JSR MESSAGE
LOOPA LDA $A000
ASL A
BMI LOOPA
PLA
BEQ XDOWN
XUP LDA $A000
EOR #$04
STA $A000
JSR WAIT20
LDA $A000
ORA #$04
STA $A000
SED
CLC
LDA $00
ADC #$01
STA $00
CLD
RTS
XDOWN LDA $A000
EOR #$08
STA $A000
JSR WAIT20
LDA $A000
ORA #$08
STA $A000
SED
SEC
LDA $00
SBC #$01
STA $00
CLD
RTS
; COMMENTS AND FLOW FOR YDRIVE ARE SAME AS XDRIVE
YDRIVE STA $9001
.PAGE 'PAGE 2'
.PAGE '

```

```
PHA
LDA #SCF
STA $900C
JSR WAIT20
LDA #S00
STA $9001
LDA #SCD
STA $900C
LDY #S15
JSR MESSAGE
LOOPB LDA $9000
ASL A
BMI LOOPB
PLA
BEQ YDOWN
YUP LDA $9000
EOR #S04
STA $9000
JSR WAIT20
LDA $9000
ORA #S04
STA $9000
SED
CLC
LDA $01
ADC #S01
STA $01
CLD
RTS
YDOWN LDA $9000
EOR #S08
STA $9000
JSR WAIT20
LDA $9000
ORA #S08
STA $9000
SED
SEC
LDA $01
SBC #S01
STA $01
CLD
RTS
.PAGE 'PAGE 3'
.PAGE '
```

```

PICTRE SED
CLC
LDA $07
ADC #$01
STA $07
LDA $06
ADC #$00
STA $06
CLD
JSR PHOTOS
LDA $0D
JSR WAIT
LDA $A000
ORA #$20
STA $A000
JSR WAIT20
LDA $A000
EOR #$20
STA $A000
LDA $0E
JSR WAIT
RTS
PHOTOS LDA #$2A
JSR MESSAGE ; 'PHOTOS TAKEN='
LDA $06
JSR NOUT ; MONITOR ROUTINE; OUTPUTS NUMBER IN LSD OF A
LDA $07
JSR NUMA ; MONITOR ROUTINE; OUTPUTS 2 NUMBERS IN A
WAIT20 LDA #01
WAIT STA $0C
LOOP3 LDY #$4D
LOOP2 LDX #$FF
LOOP1 DEX
BNE LOOP1
DEY
BNE LOOP2
DEC $0C
BNE LOOP3
RTS
.PAGE 'PAGE 4'
.PAGE '

```

```
MESSAGE JSR $EB44 ; 'CLR' MONITOR ROUTINE
LOOPZ LDA $B300,Y
CMP #';' ; CHECK FOR SEMICOLON
BEQ DONE
INY
JSR $E97A ; 'OUTPUT' MONITOR ROUTINE
JMP LOOPZ
DONE RTS
.PAGE 'PAGE 5'
.PAGE '
```

NSF. SCANNER

INSUB

```

==0000 NOUT=$EA51
==0000 NUMA=$EA46
==0000 ADDNE=$EAB1
==0000
      *=$B160
==B160 XPOSTN
8504 STA $04
F029 BEQ RTN
==B164 DRIVE1
A908 LDA #$08
; NEGATIVE (RIGHT) DRIVE
208EB1 JSR XDRIVE
F8 SED
38 SEC
A504 LDA $04
E901 SBC #$01
8504 STA $04
C900 CMP #00
; IN DECIMAL Z FLAG NOT VALID
D8 CLD
==B174
DOEE BNE DRIVE1
60 RTS
==B177 YPOSTN
8505 STA $05
; 17B1608504F029A908208EB1F838A504E9018504C900D8DOEE600BE5
F012 BEQ RTN
==B17B DRIVE2
A908 LDA #$08
20ECB1 JSR YDRIVE
F8 SED
38 SEC
A505 LDA $05
E901 SBC #01
8505 STA $05
C900 CMP #00
D8 CLD
==B18B
DOEE BNE DRIVE2
==B18D RTN
60 RTS
==B18E XDRIVE
8D01A0 STA $A001
; ENTER WITH A=00 FOR POS DRIVE, 08 FOR NEG
; 17B1778505F012A90820ECB1F838A505E9018505C900D8DOEE600C46
48 PHA
A9CF LDA #$CF
8DOCA0 STA $A00C
2089B2 JSR WAIT20
A900 LDA #$00
8D01A0 STA $A001

```

PAGE 1

```

==B19F
A9CD LDA #SCD
8DOCA0 STA $A00C
A015 LDY #S15
209CB2 JSR MESSAGE
;18B18E8D01A048A9CF8DOCA02089B2A9008D01A0A9CD8DOCA0A0150C14
==B1A9 LOOPA
AD00A0 LDA $A000
0A ASL A
30FA BMI LOOPA
68 PLA
F01D BEQ XDOWN
==B1B2 XUP
AD00A0 LDA $A000
4904 EOR #S04
8D00A0 STA $A000
2089B2 JSR WAIT20
AD00A0 LDA $A000
;17B1A6209CB2AD00A00A30FA68F01DAD00A049048D00A02089B20AF4
0904 ORA #S04
==B1C2
8D00A0 STA $A000
F8 SED
18 CLC
A500 LDA $00
6901 ADC #S01
8500 STA $00
D8 CLD
60 RTS
==B1CF XDOWN
AD00A0 LDA $A000
4908 EOR #S08
8D00A0 STA $A000
;17B1BDAD00A009048D00A0F818A50069018500D860AD00A049080986
2089B2 JSR WAIT20
AD00A0 LDA $A000
0908 ORA #S08
==B1DF
8D00A0 STA $A000
F8 SED
38 SEC
A500 LDA $00
E901 SBC #S01
8500 STA $00
D8 CLD
60 RTS
; COMMENTS AND FLOW FOR YDRIVE ARE SAME AS XDRIVE
==B1EC YDRIVE
8D0190 STA $9001
;18B1D48D00A02089B2AD00A009088D00A0F838A500E9018500D8600B2C

```



```

48      PHA
A9CF    LDA #SCF
8DOC90  STA $900C
2089B2  JSR WAIT20
A900    LDA #S00
8D0190  STA $9001
==B1FD
A9CD    LDA #SCD
8DOC90  STA $900C
A015    LDY #S15
209CB2  JSR MESSAGE
;18B1EC8D019048A9CF8D0C902089B2A9008D0190A9CD8DOC90A0150C32
==B207  LOOPB
AD0090  LDA $9000
0A      ASL A
30FA    BMI LOOPB
68      PLA
F01D    BEQ YDOWN
==B210  YUP
AD0090  LDA $9000
4904    EOR #S04
8D0090  STA $9000
2089B2  JSR WAIT20
AD0090  LDA $9000
;17B204209CB2AD00900A30FA68F01DAD009049048D00902089B20A23
0904    ORA #S04
==B220
8D0090  STA $9000
F8      SED
18      CLC
A501    LDA $01
6901    ADC #S01
8501    STA $01
D8      CLD
60      RTS
==B22D  YDOWN
AD0090  LDA $9000
4908    EOR #S08
8D0090  STA $9000
;17B21BAD009009048D0090F818A50169018501D860AD0090490808B7
2089B2  JSR WAIT20
AD0090  LDA $9000
0908    ORA #S08
==B23D
8D0090  STA $9000
F8      SED
38      SEC
A501    LDA $01
E901    SBC #S01
8501    STA $01
D8      CLD
60      RTS

```

```

==B24A PICTURE
F8      SED
;18B2328D00902089B2AD009009088D0090F838A501E9018501D8600A5D
18      CLC
A507    LDA $07
6901    ADC #$01
8507    STA $07
A506    LDA $06
6900    ADC #$00
8506    STA $06
D8      CLD
207AB2  JSR PHOTOS
==B25C
A50D    LDA $0D
208BB2  JSR WAIT
AD00A0  LDA $A000
;17B24AF818A50769018507A50669008506D8207AB2450D208BB20997
0920    ORA #$20
8D00A0  STA $A000
2089B2  JSR WAIT20
==B26C
AD00A0  LDA $A000
4920    EOR #$20
8D00A0  STA $A000
A50E    LDA $0E
208BB2  JSR WAIT
60      RTS
;18B261AD00A009208D00A02089B2AD00A049208D00A0A50E208BB20A1C
==B27A PHOTOS
A92A    LDA #$2A
209CB2  JSR MESSAGE
; 'PHOTOS TAKEN='
A506    LDA $06
2051EA  JSR NOUT
; MONITOR ROUTINE: OUTPUTS NUMBER IN LSD OF A
A507    LDA $07
2046EA  JSR NUMA
; MONITOR ROUTINE: OUTPUTS 2 NUMBERS IN A
==B289 WAIT20
A901    LDA #01
==B28B WAIT
850C    STA $0C
==B28D LOOP3
A04D    LDY #$4D
==B28F LOOP2
A2FF    LDX #$FF
==B291 LOOP1
CA      DEX
;18B27960A92A209CB2A5062051EAA5072046EAA901850CA04DA2FF0BAF
D0FD    BNE LOOP1
88      DEY
D0F8    BNE LOOP2
C60C    DEC $0C
D0F2    BNE LOOP3
60      RTS

```

```

==B29C MESSAGE
2044EB JSR $EB44
; 'CLR' MONITOR ROUTINE
==B29F LOOPZ
B900B3 LDA $B300,Y
C93B    CMP #';'
; CHECK FOR SEMICOLON
F007    BEQ DONE
C8      INY
207AE9 JSR $E97A
; 'OUTPUT' MONITOR ROUTINE
;16B291CADOFD88DOF8C60CDOF2602044EBB900B3C93BF007C80EB2
4C9FB2 JMP LOOPZ
==B2AD DONE
60      RTS

```

PAGE 5

```

00B3 LDA $B300,Y
C93B CMP #' ':'
; CHECK FOR SEMICOLON
F007 BEQ DONE
C8 INY
207AE9 JSR $E97A
; 'OUTPUT' MONITOR ROUTINE
;16B291CADOFD88DOF8C60CDOF2602044EBB900B3C93BF007C80EB2
4C9FB2 JMP LOOPZ
==B2AD DONE
60 RTS
    DONE RTS
ERRORS= 0000
;07B2A7207AE94C9FB26004E0
;0000100010

```

<L

PASS 1

PASS 2

```

;17B1608504F029A908208EB1F838A504E9018504C900D8D0EE600BE5
;17B1778505F012A90820ECB1F838A505E9018505C900D8D0EE600C46
;18B18E8D01A048A9CF8DOCA02089B2A9008D01A0A9CD8DOCA0A0150C14
;17B1A6209CB2AD00A00A30FA68F01DAD00A049048D00A02089B20AF4
;17B1BDAD00A009048D00A0F818A50069018500D860AD00A049080986
;18B1D48D00A02089B2AD00A009088D00A0F838A500E9018500D8600B2C
;18B1EC8D019048A9CF8DOC902089B2A9008D0190A9CD8DOC90A0150C32
;17B204209CB2AD00900A30FA68F01DAD009049048D00902089B2CA23
;17B21BAD009009048D0090F818A50169018501D860AD0090490808B7
;18B2328D00902089B2AD009009088D0090F838A501E9018501D8600A5D
;17B24AF818A50769018507A50669008506D8207AB2A50D208BB20997
;18B261AD00A009208D00A02089B2AD00A049208D00A0A50E208BB20A1C
;18B27960A92A209CB2A5062051EAA5072046EAA901850CA04DA2FF0BAF
;16B291CADOFD88DOF8C60CDOF2602044EBB900B3C93BF007C80EB2
ERRORS= 0000
;07B2A7207AE94C9FB26004E0
;0000100010

```

<

L

```
;18B1608504F029A908208EB1F838A504E9018504C900D8D0EE60850C6B
;18B17805F012A90820ECB1F838A505E9018505C900D8D0EE608D010C51
;18B190A048A9CF8DOCA0208AB2A9008D01A0A9CD8DOCA0A015209D0C46
;18B1A8B2AD00A00A30FA68F01DAD00A049048D00A0208AB2AD00A00B89
;18B1C009048D00A0F818A50069018500D860AD00A049088D00A020098A
;18B1D88AB2AD00A009088D00A0F838A500E9018500D8608D0190480B4A
;18B1F0A9CF8DOC90208AB2A9008D0190A9CD8DOC90A015209DB2AD0CED
;18B20800900A30FA68F01DAD009049048D0090208AB2AD009009040958
;18B2208D0090F818A50169018501D860AD009049088D0090208AB209EC
;18B238AD009009088D0090F838A501E9018501D860F818A50769010A11
;18B2508507A50669008506D8207AB2A50D208CB2AD00A009208D00097C
;18B268A0208AB2AD00A049208D00A0A50E208CB260A02A209DB2A50B60
;18B280062051EAA5072046EA60A901850CA04DA2FFCAD0FD88DCFF80DB7
;18B298C60CD0F2602044EBB900B3C93BF007C8207AE94CA0B260FF0E54
;18B2B0FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF1962
;02B2C8FFFFF037A
MORE?
```

F
 B160 85 STA 04
 B162 F0 BEQ B18D
 B164 A9 LDA #08
 B166 20 JSR B18E
 B169 F8 SED
 B16A 38 SEC
 B16B A5 LDA 04
 B16D E9 SBC #01
 B16F 85 STA 04
 B171 C9 CMP #00
 B173 D8 CLD
 B174 D0 BNE B164
 B176 60 RTS
 B177 85 STA 05
 B179 F0 BEQ B18D
 B17B A9 LDA #08
 B17D 20 JSR B1EC
 B180 F8 SED
 B181 38 SEC
 B182 A5 LDA 05
 B184 E9 SBC #01
 B186 85 STA 05
 B188 C9 CMP #00
 B18A D8 CLD
 B18B D0 BNE B17B
 B18D 60 RTS
 B18E 8D STA A001
 B191 48 PHA
 B192 A9 LDA #CF
 B194 8D STA A00C
 B197 20 JSR B28A
 B19A A9 LDA #00
 B19C 8D STA A001
 B19F A9 LDA #CD
 B1A1 8D STA A00C
 B1A4 A0 LDY #15
 B1A6 20 JSR B29D
 B1A9 AD LDA A000
 B1AC 0A ASL .A
 B1AD 30 BMI B1A9
 B1AF 68 PLA
 B1B0 F0 BEQ B1CF
 B1B2 AD LDA A000
 B1B5 49 EOR #04
 B1B7 8D STA A000
 B1BA 20 JSR B28A
 B1BD AD LDA A000
 B1C0 09 ORA #04
 B1C2 8D STA A000
 B1C5 F8 SED
 B1C6 18 CLC
 B1C7 A5 LDA 00
 B1C9 69 ADC #01
 B1CB 85 STA 00


```

B1CD D8 CLD
B1CE 60 RTS
B1CF AD LDA A000
B1D2 49 EOR #08
B1D4 8D STA A000
B1D7 20 JSR B28A
B1DA AD LDA A000
B1DD 09 ORA #08
B1DF 8D STA A000
B1E2 F8 SED
B1E3 38 SEC
B1E4 A5 LDA 00
B1E6 E9 SBC #01
B1E8 85 STA 00
B1EA D8 CLD
B1EB 60 RTS
B1EC 8D STA 9001
B1EF 48 PHA
B1F0 A9 LDA #CF
B1F2 8D STA 900C
B1F5 20 JSR B28A
B1F8 A9 LDA #00
B1FA 8D STA 9001
B1FD A9 LDA #CD
B1FF 8D STA 900C
B202 A0 LDY #15
B204 20 JSR B29D
B207 AD LDA 9000
B20A 0A ASL .A
B20B 30 BMI B207
B20D 68 PLA
B20E F0 BEQ B22D
B210 AD LDA 9000
B213 49 EOR #04
B215 8D STA 9000
B218 20 JSR B28A
B21B AD LDA 9000
B21E 09 ORA #04
B220 8D STA 9000
B223 F8 SED
B224 18 CLC
B225 A5 LDA 01
B227 69 ADC #01
B229 85 STA 01
B22B D8 CLD
B22C 60 RTS
B22D AD LDA 9000
B230 49 EOR #08
B232 8D STA 9000
B235 20 JSR B28A
B238 AD LDA 9000
B23B 09 ORA #08
B23D 8D STA 9000
B240 F8 SED
B241 38 SEC
B242 A5 LDA 01

```

B

```

244 E9 SBC #01
B246 85 STA 01
B248 D8 CLD
B249 60 RTS
B24A F8 SED
B24B 18 CLC
B24C A5 LDA 07
B24E 69 ADC #01
B250 85 STA 07
B252 A5 LDA 06
B254 69 ADC #00
B256 85 STA 06
B258 D8 CLD
B259 20 JSR B27A
B25C A5 LDA 0D
B25E 20 JSR B28C
B261 AD LDA A000
B264 09 ORA #20
B266 8D STA A000
B269 20 JSR B28A
B26C AD LDA A000
B26F 49 EOR #20
B271 8D STA A000
B274 A5 LDA 0E
B276 20 JSR B28C
B279 60 RTS
B27A A0 LDY #2A
B27C 20 JSR B29D
B27F A5 LDA 06
B281 20 JSR EA51
B284 A5 LDA 07
B286 20 JSR EA46
B289 60 RTS
B28A A9 LDA #01
B28C 85 STA 0C
B28E A0 LDY #4D
B290 A2 LDX #FF
B292 CA DEX
B293 D0 BNE B292
B295 88 DEY
B296 D0 BNE B290
B298 C6 DEC 0C
B29A D0 BNE B28E
B29C 60 RTS
B29D 20 JSR EB44
B2A0 B9 LDA B300,Y
B2A3 C9 CMP #3B
B2A5 F0 BEQ B2AE
B2A7 C8 INY
B2A8 20 JSR E97A
B2AB 4C JMP B2A0
B2AE 60 RTS
B2AF FF ???
B2B0 FF ???
B2B1 FF ???

```

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APPENDIX D

COMPUTER PROGRAM LISTING - PROGRAM VOCABULARY

(Decoded Text, Operational Code [Op-Code] for Test Programmed
Numerical Constants in Hex)

WNFS SCANNER SYSTEM
 DRIVE IN PROGRESS
 PHOTOS TAKEN=
 AUTO Y=
 TAKE=
 ZERO
 LEFT
 RIGHT
 UP
 DOWN

T(x) LARGE

L

```

;18B3004E4653205343414E4E45522053595354454D3BFFFF44524908F9
;18B318564520494E2050524F47524553533BFFFFFF50484F544F5309DF
;18B3302054414B454E3D3BFFFFFFFFFFFFFFFF4155544F20593D3B0D28
;18B34854414B453D3B5A45524F3B4C4546543BFFFFFFFFFFFFFFFF0D89
;18B36052494748543BFFFFFFFFFFFFFFFF55503BFFFFFFFF12B5
;18B378FFFFFFFFFFFFFFFF444F574E3BFFFFFFFFFFFFFFFF15A3
;18B390FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF1943
;18B3A8FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF195B
;18B3C0FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF544F4F204C41524713B3
;18B3D8453BFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF180D
;04B3F0FFFFFFFFF05A3
MORE?
  
```

L
 NUMBER OF PICTURES PER HORIZONTAL SCAN:

M>=B7F0 0E

LIMIT OF VERTICAL SCAN:

<M>=B7F1 30

END

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APPENDIX E

COMPUTER PROGRAM LISTING - COMPUTER-OPERATOR INTERFACE,
COMPUTER OPERATING SEQUENCE

COMPUTER OPERATING SEQUENCES

Y INPUT TOO LARGE
 PROPER INPUT
 DISPLAY
 OUTPUT
 SEQUENCE

AIM-65 PRINTER
 DISPLAY
 IMPROPER INPUT

PROPER INPUT

1ST RUN

2ND RUN

<5>AUTO Y = 40 TOO LARGE
 AUTO Y = 2 TAKE = 150
 DRIVE IN PROGRESS
 PHOTOS TAKEN = 001
 DRIVE IN PROGRESS

ROCKWELL AIM 65

AUTO Y = X ERROR
 TAKE = Z ERROR

(
 ROCKWELL AIM 65

AUTO Y =
 AUTO Y = 2 TAKE 30
 AUTO Y =
 (M) = 6 00 30 00 00

ROCKWELL AIM 65
 AUTO Y = 4 TAKE = 15
 AUTO Y =
 (M) = 6 00 45 00 00

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