AN AUTOMATIC FILM READER (U)

J. L. Arrowood

RELEASED FOR ANNOUNCEMENT
IN NUCLEAR SCIENCE ABSTRACTS

UNION CARBIDE CORPORATION
NUCLEAR DIVISION
OAK RIDGE Y-12 PLANT

operated for the **ATOMIC ENERGY COMMISSION** *under* **U. S. GOVERNMENT Contract W-7405 eng 26**

**UNION
CARBIDE**

OAK RIDGE Y-12 PLANT
P. O. Box Y
OAK RIDGE, TENNESSEE 37831

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Printed in USA. Price \$2.00. Available from the Clearinghouse for Federal
Scientific and Technical Information, National Bureau of Standards,
U.S. Department of Commerce, Springfield, Virginia

— LEGAL NOTICE —

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

- A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

Date Issued: June 20, 1966

Report Number Y-1533

Instruments
TID-4500

CFSTI PRICES

H.C. \$ 2.00; MN .50

UNION CARBIDE CORPORATION
Nuclear Division

Y-12 PLANT

Contract W-7405-eng-26
With the U. S. Atomic Energy Commission

AN AUTOMATIC FILM READER (U)

J. L. Arrowood

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

RELEASED FOR ANNOUNCEMENT
IN NUCLEAR SCIENCE ABSTRACTS

Oak Ridge, Tennessee

Report Number Y-1533Instruments
TID-4500

Distribution:

Ackerson, R. D.	(AFSC)	Keller, C. A.	(AEC-ORO)(4)
Arrowood, J. L.	(15)	Kite, H. T.	
Bailey, E. W.		Lewis, F. O.	(ORGDP)
Ballenger, H. F.	(2)	McLendon, J. D.	
Bell, B. B.		Meeks, E. J.	(AFSC)
Bernander, N. K.		Mitchel, G. W.	
Briscoe, O. W.		Rader, D. H.	
Burkhart, L. E.		Stoner, H. H.	
Center, C. E.	(ORGDP)	Trotter, T. C.	
Christman, A. M.		Waters, J. L.	
Cowen, D. D.	(ORNL)	Whitson, W. K.	
Evans, G. W.		Williams, J. L.	
Harwell, W. L.	(ORGDP)(5)	Winkel, R. A.	(Paducah)
Hemphill, L. F.		Yaggi, W. J.	
Huber, A. P.	(ORGDP)	Zurcher, E.	
Jackson, V. C.		Y-12 Central Files	(5)
Jennings, D. A.		Y-12 Central Files	(Y-12RC)

In addition, this report is distributed in accordance with the category Instruments as given in the "USAEC Standard Distribution Lists for Unclassified Scientific and Technical Reports", TID-4500.

ABSTRACT

Automation techniques have been applied to the digitizing of analog data recorded on positive transparent oscillograms. The system provides a rapid and economical method of obtaining accurate data from these oscillograms.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

CONTENTS

INTRODUCTION	7
SUMMARY	9
DESCRIPTION AND OPERATION OF THE AUTOMATIC FILM READER . . .	11
Description of the System	11
Film Reader Equipment	13
Cathode Ray Tube (CRT)	13
Photomultiplier Tube (PMT)	13
Pulse Amplifier and Shaper	13
Gating and Trigger Circuit	14
Clock-Pulse Generator	16
Vertical Counter	16
Punch Scanner and Control	16
Horizontal Counter	17
Digital-to-Analog Converter	18
Film Holder and Photomultiplier Tube Housing	18
Control Panel	18
Logic Cards	20
High-Voltage Power Supply	21
Low-Level Power Supply	21
Monitor Oscilloscope	22
Operating the Film Reader	22
Performance Tests	22
Operating Instructions	24
Horizontal Calibration Check	26
Reading the Oscillogram	28
Miscellaneous Instructions	29
Maintenance	30
Preventative Measures	30
Repair Procedure	30
APPENDIX (DETAILED DRAWINGS OF THE AUTOMATIC FILM READER) . .	33

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

INTRODUCTION

The most often used method of observing time-dependent transient phenomena is photography of the trace as displayed on a cathode ray oscilloscope. In a majority of cases, visual examination of the photograph and qualitative evaluation of the data are sufficient. However, in some cases a quantitative analysis of the waveform is necessary to obtain the desired information from the trace. To obtain accurate quantitative data from these traces, it is necessary to enlarge the photographs and transform the analog information in the trace to digital form. The usual method for obtaining data from these traces consists of enlarging the film with the aid of an optical comparator, measuring the amplitude of the trace at predetermined intervals, and manually recording these values. This procedure yields the desired results, but it is extremely time consuming and, consequently, expensive. This procedure also introduces human errors such as inaccurate determinations due to fatigue, shifting zero reference, and skipping points. The system discussed in this report provides a method of digitizing oscilloscope data at a much faster rate while minimizing human error.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

SUMMARY

The method most often used to record time-dependent transient phenomena is photography of the trace as displayed on a cathode ray oscilloscope. In cases where it is desired to quantitatively analyze the waveform, it is necessary to transform the analog information in the trace to digital form. A system has been designed to automatically digitize and record this analog information. Statistical evaluation of the test data indicates that the system has a precision of ± 0.0058 centimeter and an accuracy of ± 0.007 centimeter.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

DESCRIPTION AND OPERATION OF THE AUTOMATIC FILM READER

DESCRIPTION OF THE SYSTEM

The automatic film reader (AFR) employs a rapidly traversing spot of light on the face of a cathode ray tube (CRT) to scan a positive transparency of a previously recorded scope trace. A block diagram of the system showing the principles of operation is presented in Figure 1. An overall view of the system is given in Figure 2.

Figure 1. THE AUTOMATIC FILM-READER SYSTEM.

The trace to be analyzed is recorded on a positive transparency along with the reference line which may be either above or below the data line but not intersecting the line. The positive transparency is then placed on the face of the CRT of a standard synchronous oscilloscope which has been modified to allow a linear sawtooth waveform to be applied to the vertical deflection plates causing a beam to be swept in the vertical direction at a constant rate. The light beam of the CRT is then placed to the left edge of the transparency and below the data line. A photomultiplier tube (PMT) encased in a light-tight shield is placed over the face of the CRT then the high voltage to the PMT is turned on. The linear sawtooth waveform applied to the vertical deflection plates of the oscilloscope is triggered at this time. The beam begins to move in a vertical direction; and, on crossing the base line or the data line, whichever comes first, the pulse of light from the CRT spot passes through the

117283(U)

Figure 2. AUTOMATIC FILM READER. (Overall View)

transparent portion of the film and is detected by the PMT. The PMT converts the light pulse into a current pulse which is then fed into a pulse amplifier and shaping circuit which transforms the pulse into a signal usable by the logic circuitry of the system.

This pulse is then fed into the gating and trigger circuit, allowing the clock pulses from the clock-pulse generator to be fed into a 4-decade 1-2-4-8 binary coded

decimal (BDC) counter. The spot continues its uniform vertical travel. On crossing the second trace, another pulse results which is fed into the gating circuit causing the gating circuit to close and inhibit the flow of clock pulses to the vertical counter. The contents of the vertical counter are then proportional to the distance between the first line and the second line. At the end of the second pulse from the PMT, the punch scanning and control circuits are actuated to punch into paper tape the contents of the vertical counter. After punching is completed, the horizontal counter is incremented by one. The count is then converted to an analog voltage in the digital-to-analog converter and applied to the horizontal input of the oscilloscope. This action indexes the beam horizontally one unit of distance. During the punching operation, the beam of the CRT has returned to the bottom of the transparency and is ready to be triggered again upon command. The vertical sweep is then retriggered and the process described is repeated for a predetermined number of times until the complete trace has been scanned. Any number of readings from one to 127 may be taken from a trace up to ten centimeters long.

FILM READER EQUIPMENT

Cathode Ray Tube (CRT)

The cathode ray tube is used as a source for a beam of light that can be swept vertically at a constant rate and positioned horizontally as desired. The AFR uses a standard commercially available synchronous oscilloscope. The oscillogram to be read is placed on the face of the CRT in such a manner that the vertical sweep of the light beam will traverse the entire height of the oscillogram. The oscillogram must also be oriented so the vertical sweep is perpendicular to the reference baseline.

Photomultiplier Tube (PMT)

The PMT is used to detect the light pulses generated by the light beam of the CRT as it passes the transparent line on the oscillogram. The light pulses fall on a light-sensitive photocathode causing this cathode to emit free electrons. These electrons are then focused and amplified by the PMT to produce a current pulse that is amplified and shaped in the pulse amplifier and shaper circuit. The type of PMT used in this system is an RCA Type 6655-A with a current gain of approximately one million. The tube is housed in a light-tight shield, shown in Figure 3.

Pulse Amplifier and Shaper

Current pulses from the PMT are amplified by the pulse amplifier and shaper and converted to voltage pulses of sufficient magnitude and proper polarity to be used in the switching circuitry that follows. These pulses must be negative-going pulses with magnitudes of six volts and fall times of less than 1.5 microseconds. The circuit employs two inverting amplifiers, a low-output-impedance noninverting driver, a Schmitt trigger, and a single-shot multivibrator to provide the gating signal to the

117285(U)

Figure 3. READING OSCILLOSCOPE WITH THE PHOTOMULTIPLIER TUBE HOUSING.

gating and trigger circuit. A schematic diagram of this section is shown in Figure A-2 in the appendix. Figure 4 gives a rear view of the chassis containing the amplifiers and driver (PA1, PA2, and PD1).

Gating and Trigger Circuit

The gating portion of the gating and trigger circuit consists of a flip-flop and a 2-input nandgate. One input to the gate is the output of the flip-flop which serves as a controlling signal; the other input is a chain of clock pulses from the clock-pulse generator. The first light pulse detected by the photomultiplier tube, after amplification and shaping, sets the flip-flop thereby removing the inhibiting signal to the 2-input gate. Removal of the inhibiting signal from the input of the gate allows the clock pulses from the clock-pulse generator to be passed through the gate and routed to the vertical counter which follows. The second pulse detected resets the flip-flop, disabling the gate, and stopping the flow of clock pulses to the vertical counter. It is in this circuit that provisions are made for a switch-selected option to punch either the sum of ten determinations of a single point or one determination of the same point (readings-per-point switch, Figure 5). When the system is reading each point on a trace one time, a signal is generated in this section to trigger the sweep at the end of the punch cycle. When the system is reading a single point on a trace ten consecutive times, a signal is generated to trigger the sweep at the end

117289(U)

Figure 4. PULSE AMPLIFIER AND DIGITAL-TO-ANALOG CONVERTER. (Rear View)

117288(U)

Figure 5. AUTOMATIC FILM READER CONTROL PANEL. (Front View)

of each of the first nine readings. When the tenth reading has been completed and the total punched out, the sweep is again triggered.

Clock-Pulse Generator

The clock-pulse generator is an astable multivibrator with a basic free-running frequency of approximately 175 kilocycles. Fine control of the frequency is accomplished by an adjustment of a potentiometer mounted on the printed circuit board containing the multivibrator circuit. The frequency is made adjustable over this finite range to permit a control of the frequency to a predetermined value. The output of the clock-pulse generator is fed into the gating and trigger circuitry and then into the vertical counter for a period determined by the time between pulses from the PMT and pulse amplifier and shaper circuitry.

Vertical Counter

The vertical counter is a 4-decade 1-2-4-8 BCD counter. The counter is composed of flip-flops and gates connected in such a manner that it will count any number of clock pulses from 1 to 9999. A lockout is provided so if more than 9999 pulses are fed into the counter, it resets as it overflows and the output is zero. The BCD equivalent of the number of clock pulses passed by the gating and trigger circuit is always present at the flip-flop output if the capacity of the counter has not been exceeded. The outputs of the flip-flops in each decade are monitored by lights located on the control panel (Figure 5).

Punch Scanner and Control

The punch scanner and control is a multi-purpose circuit that performs the following functions: (1) scans the vertical counter during the punching operation; (2) provides timing pulses for the tape perforator; (3) controls the power for the tape perforator; (4) provides parity and zero detection; (5) generates an end-of-block signal; (6) generates a pulse to increment the horizontal counter at the end of each punching cycle, and (7) generates the tape leader.

Action of this circuit is initiated by receipt of a signal from the gating and trigger circuit at the end of the second pulse from the pulse amplifier and shaper. Punch-control pulses are also used to increment a scan circuit that controls and determines which decade of the vertical counter is to be punched at any particular time. The punching sequence provides the most significant bit first, second most significant bit, down to the least significant bit. After the least significant bit has been punched out, an end-of-data signal is generated that punches a Channel 8 in the tape. At the end of the Channel 8 punch, a signal is generated to trigger the sawtooth generator allowing the sweep of the CRT to once again traverse the transparency in the vertical direction. A circuit in the punch scanner and control samples the output of each counter decade before it is punched into the paper tape and checks the

parity, inserting a parity punch when necessary. This system uses odd parity. A zero detection circuit is also incorporated in the section that checks the output of each counter decade and causes a zero punch (Channel 6) to be punched if no output is present. Circuitry is also provided to cause the tape perforator to advance the tape for a predetermined length of time to generate some tape leader. This circuit may be activated as many times as necessary to generate the amount of tape leader required.

Horizontal Counter

The horizontal counter is a simple binary counter that counts the pulses generated by the punch scanner and control at the end of each punch cycle and provides a binary output that is equal to the total number of vertical sweeps completed. The output of the horizontal counter is monitored on the front control panel with the lights (the points-per-trace lights shown in Figure 5) in the form of a binary format indicative of which flip-flop is set at any one particular time. The outputs of the horizontal counter are fed through the points-per-trace switches (Figure 5) and the contacts of Relays K1 and K2 (Figure 6) to the digital-to-analog converter. The switches select the number of points to be read on the film. The relays replace the flip-flop outputs with an equivalent voltage for horizontal calibration purposes. After the

117284(U)

Figure 6. AUTOMATIC FILM READER CONTROL PANEL. (Rear View)

AFR has scanned the desired number of points on the film, a signal is generated to block the input to the pulse amplifier and shaper circuit thereby stopping the reading operation. A detailed discussion of the horizontal calibration procedure and points-per-trace selection procedure is given in the sections on Horizontal Calibration Check and Reading the Oscillogram, Pages 26 and 28.

Digital-to-Analog Converter

The digital-to-analog converter changes the binary output of the horizontal counter into an analog voltage that is proportional to the number registered in the counter. Each count in the horizontal counter increases the output of the digital-to-analog converter by 1/127th of the full range of the converter (10 volts DC). The DC voltage is applied to the horizontal deflection circuitry of the oscilloscope, thereby controlling the horizontal position of the beam.

Film Holder and Photomultiplier Tube Housing

The film holder and PMT housing are attached to the front of the oscilloscope directly over the CRT. The oscillogram to be scanned is placed in the window opening of the film holder and the cover plate is lowered over the film and secured with a latch, as illustrated in Figure 7. At the left edge of the window opening, two narrow slits one centimeter apart are located. These two slits serve as a standard reference. Before each film is read, the beam is moved to the left directly beneath these two slits and is scanned so a reference number in terms of counts per centimeter is known. After the film is secured in the film holder, the PMT housing is swung into position over the face of the CRT and latched. Latching the PMT housing energizes a relay through which high voltage to the PMT is supplied. This feature prevents the accidental exposure of the PMT to room light when the high voltage is on.

Control Panel

The control panel shown in Figure 5 contains all switches and indicators necessary for operation of the AFR. A rear view of the control panel and chassis is given in Figure 6. The switches on the control panel are arranged in the sequence of operation normally encountered. Lights, meters, and test points are provided so critical points in the system may be checked as necessary. The functions of the switches and controls are:

Power Switch - The power switch provides AC voltage to all components of the system.

High-Voltage Switch - The high-voltage switch provides DC voltage to the PMT through the PMT housing interlock circuit.

Go Switch - The go switch connects the pulses from the PMT to the pulse shaper and amplifier circuit. This switch must be energized before the reading can proceed.

117286(U)

Figure 7. INSERTING AN OSCILLOGRAM INTO THE AUTOMATIC FILM READER FILM HOLDER.

Punch Switch - The punch switch provides primary AC and DC voltage to the tape perforator.

Vertical Calibration Switch - The vertical calibration switch is used in conjunction with the vertical calibration potentiometer located at the bottom left of the control panel. Operating the vertical calibration switch changes the input to the horizontal deflection circuits from the horizontal counter to the vertical calibration potentiometer. This voltage is a negative voltage which causes the beam to be moved to the left when applied to the horizontal deflection circuitry of the oscilloscope, and is adjusted so the beam is moved to the left directly beneath the one-centimeter calibrating slits.

Horizontal Calibration Switch - The horizontal calibration switch is used to energize Relays K1 and K2 in the horizontal counter circuit. When this switch is energized, the horizontal counter flip-flop outputs are replaced by an equivalent voltage as selected by the points-per-trace switches.

Start Switch - The start switch is used to trigger the sawtooth generator for the first sweep of the oscillogram. The gating and trigger circuits initialize subsequent sweeps.

Reset Switch - Energizing the reset switch clears both the horizontal and vertical counters. This switch is momentarily energized before starting the reading process.

Buzz Switch - Energizing this switch provides a trigger to the tape-leader generating circuitry located in the punch scanner and control section. This switch is a momentary contact switch and may be energized more than once to provide the amount of leader necessary for each application.

Readings-Per-Point Switch - A two-position switch that selects whether each point on the oscillogram is scanned one time or ten times before advancing to the next point.

Points-Per-Trace Switches - Items that select the total number of points to be scanned on the oscillogram. The switches add; that is, flipping the 64, 16, and 8 switches to the right will allow the AFR to scan 88 points before stopping.

Meter Selector Switch - The meter selector switch selects the power supply output that is to be monitored.

Calibration Position Potentiometer - This instrument controls the voltage applied to the horizontal deflection circuit of the reading oscilloscope when the vertical calibration switch is energized.

Logic Cards

All logic in this system is built by the interconnection of standard logic modules. The logic modules are built on printed circuit cards and are contained in a plug-in card rack. Interconnection between the logic modules is accomplished by connecting the proper pins of the card-rack connectors together. This type of interconnection facilitates the exchange of logic units in the event of a fault in the logic circuitry. Circuit diagrams and other data pertaining to the individual logic modules may be obtained from the manufacturer's data sheets. Figure 8 is a rear view of the AFR console with the logic card rack lowered.

117287(U)

Figure 8. AUTOMATIC FILM READER WITH THE LOGIC CARD RACK LOWERED. (Rear View)

High-Voltage Power Supply

The power supply in this system is a Victoreen Model 683A variable high-voltage power supply used to supply high voltage to the PMT. This power supply has been modified to allow the high-voltage line to be broken by deenergizing a switch marked "High Voltage" located on the control panel and also when the PMT housing is unlatched from the face of the reading CRT. Operating characteristics, specifications, troubleshooting data, and schematics may be obtained from the manufacturer's operating manual.

Low-Level Power Supply

There are two low-level power supplies used in this system. One is a 24-volt high-current power supply used to supply voltages to the tape perforator and indicator circuits. The other power supply is used to supply various voltages required in the

logic circuit cards used to implement the various logic sections in this system. Operating characteristics, specifications, troubleshooting data, and schematics may be obtained from the manual supplied by the manufacturer of the power supplies.

Monitor Oscilloscope

The oscilloscope located in the top of the equipment rack is used for troubleshooting purposes and to monitor the input pulses to the gating and trigger circuit from the pulse amplifier and shaper. This monitor oscilloscope is used to view the input pulses to the gating and trigger circuit for adjustment of the intensity control on the main reading oscilloscope. These pulses must be of sufficient amplitude to drive the gating and trigger circuitry. The pulse height necessary to drive the circuitry is between eight and ten volts. It should also be noted that the voltage output of the pulse amplifier, present at Test Point 2, between pulses should be less than two volts. This return to near zero between pulses is determined by the film density. The contrast between the data trace and the background should be as high as possible. It is controlled by correctly setting the aperture and exposure time on the camera when the oscillogram is made. Polaroid Type 46L positive transparency film with a developing time of two minutes has desirable characteristics for use with the AFR.

OPERATING THE FILM READER

Performance Tests

Tests were run on the AFR to determine the system's precision, accuracy, and ability to read slopes.

The tests consisted of measuring the spacing between the reference line and data line at a number of points on test films with an optical comparator and comparing these values point for point with measurements obtained on the AFR. The first test film contained five parallel, horizontal lines spaced approximately one centimeter apart. One line served as a reference or base line and the amplitudes of the other four lines were measured with reference to this line. The second test film contained a base line and four sloping lines. These lines consisted of two pairs of mirror-image slopes with one pair having a slope approximately four times the other. A reproduction of the test films showing the points that were measured is presented in Figure 9.

The first test used the film containing the parallel, horizontal lines and was run to determine the precision and accuracy of the AFR. The film was first marked at the desired reading points at the left, middle, and right of the film as indicated in Figure 9(a). Several determinations of the spaces between the various lines at the three points were made with a magnifying optical comparator. The film was then

(a) Test 1

(b) Test 2

Figure 9. REPRODUCTION OF TEST FILMS.

placed in the AFR and the same points measured a number of times. All the measurements were then statistically evaluated. Table 1 lists the measurements and the statistical variations. The precision of the AFR (that is, reproducibility in reading at any one location of a film) was ± 0.0058 centimeter (95% confidence LE). This precision was the same for all amplitudes accepted by the AFR. The accuracy of the AFR in measuring amplitudes (that is, the ability of the AFR to record the true vertical dimensions as estimated by gage measurements) was ± 0.007 centimeter average and ± 0.015 centimeter for the worst case. This value includes precision and a bias variation which is based on an AFR minus the optical comparator data.

The second test performed used the film containing the four sloping lines shown in Figure 9(b). This test was designed to determine the ability of the AFR to read upward and downward slopes and the accuracy obtained in these slope determinations. The film was marked at the desired reading points (Points 1 through 8). The film was then subjected to the same two measurement routines and the data obtained from these measurements were evaluated statistically. The accuracy of the AFR in measuring slopes (that is, the ability of the instrument to record the true slope as estimated by gage measurements) was ± 0.020 slope units (Table 2). This estimate is based on the A minus B data in Table 2. The ability of the AFR to read upward and downward slopes alike is shown by comparing the differences in Table 2. Although vertical accuracies at different positions on the film mask an exact comparison, the upward and downward slopes appear to agree reasonably well.

Operating Instructions

The operation of this system is relatively straightforward providing the following precautions are observed:

1. The base line and the data line should not intersect at any point on the oscillogram.
2. The background of the oscillogram should be as dark as possible with no scratches or pin holes where light may seep through in an unwanted place giving a false trigger.
3. The base line and data trace should be sharp, well defined, and clear. These conditions can be assured by proper camera settings and proper intensity and focus levels on the oscilloscope when the oscillogram is made.

Pin holes or scratches on the oscillogram must be covered with some type of opaquing material. This procedure may also be used in some cases where the background is too light. Experience has shown that this is a very tedious and time-consuming operation, but it can be eliminated at the time the oscillogram is taken by using proper exposure parameters, fresh film, and care in handling the sensitive material.

Table 1
VERTICAL DISTANCE MEASUREMENTS BETWEEN PARALLEL, HORIZONTAL LINES

Distance ⁽²⁾	Points Measured ⁽¹⁾								
	Left			Middle			Right		
	AFR ⁽³⁾	Optical Comparator	AFR Minus Optical Comparator	AFR ⁽³⁾	Optical Comparator	AFR Minus Optical Comparator	AFR ⁽³⁾	Optical Comparator	AFR Minus Optical Comparator
M	1.00204	0.99955	0.00249 ± 0.00073 ⁽⁴⁾	0.99916	1.00120	-0.00204 ± 0.00073	0.99074	1.00487	-0.01413 ± 0.00073
L	0.99965	1.00190	-0.00225 ± 0.00073	1.00715	1.00203	0.00512 ± 0.00073	1.00024	0.99828	0.00196 ± 0.00073
K	0.99717	1.00057	-0.00340 ± 0.00073	0.99658	0.99809	-0.00151 ± 0.00073	1.00082	0.99879	0.00203 ± 0.00073
J	1.00769	1.00292	0.00477 ± 0.00073	1.00233	1.00425	-0.00192 ± 0.00073	0.99454	1.00425	-0.00971 ± 0.00073
Total	4.00655	4.00494	0.00161 ± 0.00146	4.00522	4.00557	-0.00035 ± 0.00146	3.98634	4.00619	-0.01985 ± 0.00146
Mean Difference			0.00040 ± 0.00036			-0.00009 ± 0.00036			-0.00496 ± 0.00036
Q	4.00596	4.00368	0.00228 ± 0.00082	4.00362	4.00653	-0.00291 ± 0.00082	3.99453	4.00806	-0.01353 ± 0.00082
P	3.00475	3.00457	0.00018 ± 0.00082	3.00753	3.00552	0.00201 ± 0.00082	2.99672	3.00158	-0.00486 ± 0.00082
O	2.00622	2.00247	0.00375 ± 0.00082	2.00056	2.00362	-0.00306 ± 0.00082	1.99633	2.00317	-0.00684 ± 0.00082
N	1.00793	1.00197	0.00596 ± 0.00082	1.00184	1.00438	-0.00254 ± 0.00082	0.99926	1.00400	-0.00474 ± 0.00082

(1) All results in centimeters.

(2) Refer to Figure 10.

(3) AFR Measurement = Counts x Average Centimeters/Count (Centimeters/Count = Optical Comparator Measurement/Counts).

(4) The ± value is the limit of error (LE) for the mean at 95% confidence.

Table 2
VERTICAL DISTANCE MEASUREMENT BETWEEN BASE LINE AND SLOPING LINE

Sloping Line(3)	Slope Measurements(1)		(A) Minus (B)
	A(2) ΔY by AFR(4); ΔX by Optical Comparator	B(2) ΔY and ΔX by Optical Comparator	
A	$\frac{0.87852}{0.69128} = 1.2709 \pm 0.0014^{(5)}$	$\frac{0.87281}{0.69128} = 1.2626 \pm 0.0010$	0.0083 ± 0.0017
AA	$\frac{0.80997}{0.64832} = 1.2493 \pm 0.0014$	$\frac{0.81401}{0.64832} = 1.2556 \pm 0.0010$	-0.0063 ± 0.0017
Difference	0.0216	0.0070	
B	$\frac{2.67774}{0.60460} = 4.4289 \pm 0.0030$	$\frac{2.66742}{0.60460} = 4.4119 \pm 0.0028$	0.0170 ± 0.0041
BB	$\frac{2.65320}{0.60288} = 4.4009 \pm 0.0030$	$\frac{2.64458}{0.60288} = 4.3866 \pm 0.0028$	0.0143 ± 0.0041
Difference	0.0280	0.0253	

(1) All readings in centimeters.

(2) Slope = $\frac{\Delta Y}{\Delta X}$.

(3) Refer to Figure 10(b).

(4) AFR Measurement of ΔY = Counts x Average Centimeters/Count (Centimeters/Count = Optical Comparator Measurement/Counts).

(5) $\pm$ LE of the mean (95% confidence).

In starting the system, the following procedure should be observed:

1. Turn all instrument power on by depressing the "power" switch.
2. Remove the chad box on the tape perforator daily and check the oil level in the perforator mechanism.
3. Energize the "high voltage" switch.
4. Check to see that all power lights on the power supply and scopes are lit.
5. The instrument should be allowed to warm up for at least one hour following a shutdown period.

Horizontal Calibration Check

The following steps should be observed in checking the horizontal counter:

1. Check the power-supply voltages by rotating the meter range knob on the control panel. On the +1.5, -6, -12, and -24 volt ranges, the meter should read center scale. With the knob in the digital-to-analog converter (DAC) position, the meter will indicate the relative horizontal position of the light beam with zero

referring to the extreme left and full scale referring to the extreme right-hand position of the oscillogram.

2. Open the PMT housing and insert the horizontal calibration film which has two narrow, clear lines spaced seven centimeters apart. Verify that the left-hand edge of the film does not cover the area under the one-centimeter slits in the left edge of the film holder. Check for any light leaks around the perimeter of the film, masking any that are present.
3. Set the sweep and triggering on the 3B4 time base unit to the following settings:
 - (a) Set the time-per-division switch on "External Horizontal" and adjust the position knobs so the light spot will be centered vertically.
 - (b) Reset the time-per-division switch to 10 milliseconds per division, expanded to 2 msec/division.
 - (c) Set the triggering for negative slope, AC coupling, and normal mode. Adjust the trigger level to properly trigger the oscilloscope.
4. Set the focus knob for a minimum beam width and the intensity for a comfortably visible trace.
5. Turn the horizontal calibration switch on the control panel of the AFR to "on" and make sure that the vertical calibration switch is off.
6. Flip all the points-per-trace switches to the left and adjust the position knob of the horizontal amplifier so the sweep on the CRT is under the left-hand mark of the calibration film.
7. Set the main volts-per-division knob on the horizontal amplifier to 0.5 volt/division. Flip the 64, 32, and 16 points-per-trace switches to the right and adjust the vernier volts-per-division adjustment on the horizontal amplifier until the trace is directly under the right-hand calibration mark. Lock the vernier adjustment in this position.

Note: This procedure sets the AFR to scan 16 points per centimeter. When it is desired to read less than 16 points per centimeter, it will be necessary to change the calibration procedure. Instead of flipping the 64, 32, and 16 points-per-trace switches, it will be necessary to flip a number of switches that will total the number of points to be read in a 7-centimeter interval. For example, if it is desired to read 10 points per centimeter (8-centimeter interval), the 64, 4, and 2 points-per-division switches would be flipped to the right in Step 7 and the 64 and 16 points-per-division switches would be flipped to the right before starting the oscillogram reading process.

8. Close the PMT housing and plug the monitor oscilloscope into Test Point 2 on the front control panel. Energize the start switch and repeat Steps 6 and 7, readjusting the controls for maximum pulse height at each point by observing the PMT output on the monitor oscilloscope.
9. Turn the horizontal calibration switch off and the vertical calibration switch on. Adjust the calibration-position control knob on the control panel until the trace (noticeable by the presence of two short duration pulses on the monitor oscilloscope) is under the one-centimeter calibration slits at the left edge of the film holder. Lock the calibration position control at this setting and deenergize the start and vertical calibration switches. The AFR is now correctly calibrated and ready to read an oscillogram. Remove the test film from the film holder and insert the oscillogram to be read.

Reading the Oscillogram

To read the oscillogram correctly, follow these steps:

1. With the time-base source switch in line mode and the beam sweeping, place the oscillogram in the film holder and orient the oscillogram so the trace on the CRT is exactly perpendicular to the base line on the film. This alignment is achieved by using a knurled knob located at the bottom of the film holder and rotating the entire assembly to the desired position and locking the knob at this point.
2. Adjust the position knob on the horizontal amplifier unit so the beam is at the desired starting point.
3. Change the trigger source-switch setting on the time-base unit from line trigger to external trigger. Adjust the trigger level for proper triggering while the start switch is energized; deenergize this switch after completing the adjustment.
4. Close the PMT housing and lock it in place. Locking the housing energizes the high-voltage circuit to the PMT.

Note: If the film contains more than one set of data traces, all but one set must be masked since the AFR can only accommodate one set of traces at a time.

5. Verify that all the front panel switches are lit except the punch, horizontal calibration, and start switches.
6. Turn all points-per-trace switches off (to the left) except Switches 8 and 2.
7. Energize the punch switch.

8. Make sure that the readings-per-point switch is at the desired position. It should be noted that the readings-per-point counter operates only when the readings-per-point switch is in the X10 position.
9. Energize the reset switch momentarily to clear both the horizontal and vertical counters.
10. Energize the start switch to trigger the first trace. The AFR will now scan the one-centimeter calibration slits ten times and punch out these ten determinations.
11. After the reader has read the vertical calibration slits ten times, deenergize the vertical calibration and start switches and flip the points-per-trace switches to right to obtain the total number of points it is desired to scan.
12. Momentarily depress the buzz switch to advance the tape. This gives a space between the calibration readings and the data readings taken from the oscillogram.
13. Momentarily depress the reset switch to clear the counters of any accidental accumulation of counts.
14. Energize the start switch to begin the reading process. If the reader stops during the reading process, deenergize the start switch and energize it again to resume operation.

Miscellaneous Instructions

Test Run - In most cases it will be desirable to make a test run with the punch turned off to be sure that all adjustments are set correctly. When there is difficulty in reading certain points on an oscillogram, the oscilloscope intensity may have to be readjusted. A different intensity setting is usually required for each oscillogram. If this adjustment does not cure the problem, the high voltage to the PMT may be adjusted, although this is usually unnecessary. In almost all cases, the high voltage should be set at 1000 volts. However, the high voltage to the PMT should never be set any higher than 1200 volts.

Trigger Level - The reading oscilloscope trigger level should be set so the trigger input will start the sweep reliably.

Focus and Astigmatism - The focus and astigmatism controls should be adjusted for a very narrow trace which is the same width at any point on the face of the reading oscilloscope.

MAINTENANCE

Preventative Measures

Periodic maintenance is an important factor in assuring system stability and optimum performance. The following procedure should be scheduled and performed at 90-day intervals:

1. Check and adjust, if necessary, all voltage outputs of the various power supplies.
2. Check the digital-to-analog converter output with an accurate digital voltmeter. Adjust for an output of 78 millivolts per bit.
3. Check reading and monitor the oscilloscope completely; recalibrate, when necessary, using the instructions given in the manufacturer's instruction manual.
4. Inspect all controls and switches for proper operation. Tighten any loose knobs and repair or replace items which are defective.
5. Lubricate the tape perforator using the procedure and lubricants specified in the manufacturer's instruction manual.

Repair Procedure

If trouble occurs in the system, the following 4-step procedure may be used for repair work.

Confirmation of Trouble - First, confirm that the trouble exists. Improper control settings may give a false indication of trouble. Therefore, make sure that the apparent trouble is not caused by improper control settings on the control panel, reading oscilloscope, or other units within the system. Familiarity with the operation section will prevent false trouble indication due to improper control settings.

Isolating the Trouble - When the system fails to operate properly, the trouble must be isolated to one of the system's subunits or to the logic system. First, check the power supplies for proper voltage output. Next, check for proper interconnection of all cabling. If the proper voltages are present and the cables are properly connected, the next step is to isolate the faulty section by observing the waveform shapes and amplitudes present at the test points located on the control panel. These points may be checked for correctness by comparison with the waveforms tabulated in Figure 10.

The absence of the proper waveform at Test Points 1 and 2 indicates a trouble somewhere other than within the logic circuitry. The loss of the pulses at these test points may be caused by: (1) an intensity setting on the reading oscilloscope that

Figure 10. TEST-POINT WAVEFORMS.

is too low; (2) no high voltage to the PMT; (3) bad connection from the PMT to the pulse amplifier, or (4) a defective pulse amplifier.

Localizing Trouble in the Logic Circuitry - If the proper waveforms are present at Test Points 1 and 2, proceed to check the waveforms at the other test points with the aid of Figure 10 and the circuit diagrams given in the Appendix. When a waveform is missing or is found to be of the wrong shape or amplitude, locate the logic circuit associated with generating the waveform at that test point. Pulses will appear at TP6 and TP15 only when the punch switch is energized. When it is known

which circuit contains the trouble, that circuit can be checked for defective components.

Circuit Troubleshooting - Once the faulty logic circuit has been isolated, locate the logic module associated with this circuit and make sure that all inputs to the section are correct. If all inputs are correct, replace the logic module associated with the circuit. If more than one module is associated with the circuit, replace each module (one at a time) until the defective module is located. If no spare modules are available, it will be necessary to troubleshoot the module and replace any defective components found.

APPENDIX

"No representation or warranty, expressed or implied, is made that the use or disclosure of any information, apparatus, method or process disclosed in these drawings may not infringe private rights of others. No liability is assumed with respect to the use of or for damages resulting from the use of, any information, apparatus, method or process disclosed in these drawings. The drawings are being made available for information to bidder and are not to be used for other purposes, and are to be returned upon request of the forwarding contractor."

Figure A-1. AUTOMATIC FILM READER VERTICAL CENTERING.

Figure A-2. AUTOMATIC FILM READER HORIZONTAL COUNTER.

Figure A-3. AUTOMATIC FILM READER CONTROL.

D-I-35355(U)

Figure A-4. AUTOMATIC FILM READER DRIVER AND PARITY.

D-I-35356(U)

Figure A-6. AUTOMATIC FILM READER PM AND HV CIRCUITS.

C-I-30856(U)