

F I N A L R E P O R T
AIRCRAFT INSTALLATION AND OPERATION OF AN
EXTINGUISHING-AGENT CONCENTRATION RECORDER
TECHNICAL DEVELOPMENT REPORT NO. 403

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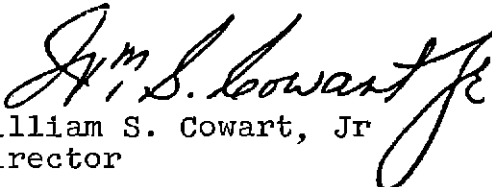
Subject: Final Report on Technical Development Center
Project No. 59-216, titled "Aircraft Installation and Operation of an Extinguishing-Agent Concentration Recorder," Technical Development Report No. 403

Dear Sir:

This report was prepared under Wright Air Development Contract No. AF33(616)57-1, Amendment No. 1 (58-683), and Technical Development Center Project No. 59-216. All work on this project was accomplished at the Technical Development Center, Indianapolis, Indiana.

The Final Technical Development Report, titled "Aircraft Installation and Operation of an Extinguishing-Agent Concentration Recorder," is herewith enclosed.

Sincerely,


William S. Cowart, Jr.
Director

Enclosure - 1

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ABSTRACT

This report covers the utilization of a gas-analyzing instrument for evaluating aircraft fire-extinguishing systems. This instrument records the extinguishing-agent air concentrations resulting when the extinguishing system is discharged, and thereby provides a means of evaluating the aircraft extinguishing system under actual flight conditions.

This report is intended to serve as an instruction manual for installation and operation of the instrument. Calibration data based on available information to aid in the reduction and interpretation of the test data obtained also are included. The instrument and the principles of operation are described briefly.

PURPOSE

To develop an instrument capable of recording continuously the amount and duration of agent concentration produced by discharge of the system in flight.

SUMMARY

A difficult problem associated with fire protection is the proper evaluation of powerplant fire-extinguishing systems. In most instances, a fire testing program is not possible, and extinguishing systems have been evaluated on the basis of a review of design calculations, agent distribution measurements, and observations of agent discharge. Such evaluation did not provide an indication of the ability of the system to extinguish fire under various flight conditions. However, the agent concentration recorder provides a practical means for evaluating fire-extinguishing systems and may be used as a tool for such evaluation by manufacturers, operators, or safety inspectors.

INTRODUCTION

The Model GA-2A concentration recorder is based on a development described in Air Force Exhibit TSEPE-8E-4-A, dated January 31, 1947. The instrument was built under contract with Statham Laboratories, Inc., 12401 West Olympic Boulevard, Los Angeles 64, Calif., and was designed as airborne equipment for the evaluation of aircraft fire-extinguishing systems. The original work done on the practical application of this instrument as a means for evaluating aircraft fire-extinguishing systems is covered in an earlier report.¹

The instrument was calibrated by conducting numerous tests of aircraft fire-extinguishing systems in which the agent concentrations required for extinguishing full-scale powerplant fires were determined. From these tests, the minimum safe concentrations necessary to insure extinguishment, as measured by the instrument, were established tentatively for the various extinguishing agents.

With the experience gained from this work, a number of in-flight evaluations of the extinguishing systems of such airplanes as the Convair B-36, Lockheed 749, 1049G, and 1649 Constellations, Lockheed C-130, and Cessna 620 were made. The data obtained during these evaluations have indicated that the fire-extinguishing systems were adequate. Further calibration work conducted on the instrument has resulted in the development of curves whereby the agent concentration data can be reduced to volumetric or gravimetric percentages.

DESCRIPTION OF INSTRUMENT

The instrument and its accessories provide a high-speed system capable of recording remotely the concentrations of extinguishing agent in air mixtures, and the duration of these concentrations at 12 different locations simultaneously in an aircraft powerplant nacelle while the airplane is in flight.

¹James D. New and Charles M. Middlesworth, "Aircraft Fire Extinguishment, Part III, An Instrument for Evaluating Extinguishing Systems," Technical Development Report No. 206, June 1953.

The Model GA-2A agent concentration recorder and its accessories, shown in Figs. 1 to 5, consist of the following components: analyzer units, control unit, oscillograph recorder, vacuum pump, and heater-type sampling tubes.

PRINCIPLES OF OPERATION

The operation of the instrument is based on the difference in pressure drop across a porous metal plug for different gases or gas mixtures when the sample is passed through the plug at constant volumetric flow. In passing through a first porous plug, thermal equilibrium is achieved. In passing through a second porous plug, a differential pressure results across the plug which varies with the constituent gases of the sample. A critical orifice regulates the pressure from the vacuum line. The pressure differential across the second porous plug operates a pressure transducer, the output of which is recorded by a remotely connected oscillograph.

The theory and principles of operation of the agent concentration recorder are described fully in another report.²

INSTALLATION OF EQUIPMENT FOR IN-FLIGHT TESTS

The Model GA-2A agent concentration recorder is designed for operation at a nominal voltage of 26 volts d-c at 25 amperes, and 115 volts, 400 cps at 3 amperes. When heated sampling tubes are used, the a-c load requirement is increased to 25 amperes. The instrument will operate properly over a voltage range of 24 to 28 volts d-c, and 110 to 120 volts, 400 cps plus or minus 20 cps.

If the portion of the extinguishing system in any one nacelle is identical to that in the other nacelle or nacelles of the airplane, only one nacelle need be instrumented for the test. The nacelle most remote from the agent containers usually is selected for test because it has the longest length of tubing between the supply and the discharge nozzles, since this affects agent concentration adversely. However, other factors also may affect agent concentration and should be considered; for example, a four-engine aircraft in which volume or ventilation differences exist between inboard and outboard nacelles.

²New and Middlesworth, op. cit.

Before mounting any of the components in the aircraft, the 12 sampling locations should be determined. The criteria to be considered when selecting these sampling locations are given below. Installation of the components may follow in the order described herein. A typical installation diagram is shown in Fig. 6.

a. Analyzer Units: Each of the analyzer units shown in Figs. 1 and 2 contains four analyzer cells with their associated vacuum and electrical connections. The analyzer units may be mounted in any position but must be shock-mounted to eliminate excessive vibration. Each unit should be mounted in the center of the region where samples from four of the locations selected can be drawn conveniently.

Figure 7 shows an analyzer unit mounted in the accessory section of a DC-3 airplane. The individual cells of the analyzer units are arranged consecutively in ascending order from right to left as viewed from the name plate. The cell number and corresponding sampling location should be noted for each of the four cells of the analyzer units as they are installed.

When mounted in the aircraft, the units must be protected from moisture, such as may be encountered when the aircraft is parked out-of-doors. The analyzer units should not be mounted in regions where temperatures above 250° F. will be encountered.

After the analyzer units are mounted, the vacuum manifold fitting which is a part of the equipment may be located so that the 1/4-inch-diameter vacuum lines from the manifold to the analyzer units are as short as possible. These lines may be of seamless copper tubing or AN-6271-4 vacuum-type hose.

b. Sampling Tubes: The Model GA-2A gas analyzer is designed to analyze samples in the gaseous state or in a finely divided suspension. For use in applications where the boiling point of the extinguishing agent is higher than the ambient air temperature, a special set of sampling tubes complete with heater and insulating jacket is furnished. These sampling tubes can be supplied in either 3- or 6-foot lengths. A 6-foot sampling tube of this type is shown in Fig. 5. Bromochloromethane, which boils at 152.6° F., is an example of an agent requiring heated sampling tubes.

For applications where the boiling point of the extinguishing agent is lower than the ambient temperature,

the sampling tubes may be fabricated of 1/4-inch-diameter, soft, seamless copper tubing or of a standard AN-6271-4 hose assembly of cotton-reinforced synthetic rubber hose. These tubes are not furnished with the equipment, since the exact length of the sampling tubes will be determined by the location of the analyzer units with reference to the sampling locations.

In order to prevent the analyzer cells from becoming clogged with any fine suspensions that may be carried by the gas, each sampling tube is terminated at the analyzer in a filter consisting of a porous disc contained within a melamine plastic coupling piece.

The location of the points from which concentration samples are drawn is a very important part of every evaluation. Since the number of points which can be checked during any one test is limited, careful consideration should be given to each point chosen. The value of the data collected is dependent on the location of the sampling points, therefore, a drawing showing the locations should be presented with test data.

The open ends of the sampling tubes should be located in recessed spaces where leaking fuel may collect and at places where the least concentration due to airflow or remoteness from an agent discharge nozzle is expected. The open ends of the sampling tubes should be installed normal to the local airstream. When heated sampling tubes are used, care should be exercised in the orientation of the mouth of the sampling tubes so that a stream of liquid from the agent discharge nozzle will not enter the tubes. The sampling tubes to each unit should be of equal length, if possible, although small variations in length are permissible. After cutting the tubes to length, the cut ends should be reamed to insure that both ends of each tube are free of burrs and open to the full inside diameter.

In coupling the sampling tubes to the analyzer units, a small amount of high-vacuum grease should be used on the threads to insure a good seal. Care should be taken to prevent grease from entering the coupling with the possibility of closing the porous plugs. Care also should be used when applying a wrench to make the connections since the melamine couplings, to which the sampling tubes are attached, are easily broken.

c. Vacuum Pump: The vacuum pump shown in Figs. 1 and 2 operates on 24 volts d-c and provides the means by which the gas samples are drawn through the 12 analyzer cells. The minimum requirement for the vacuum pump is 100 liters per minute or 3.5 cfm free air capacity and 0.005 mm Hg vacuum. The pump may be operated from a remote position, and therefore can be mounted in any existing space adjacent to the powerplant nacelle being tested, but should be mounted as close to the manifold as possible. It is not necessary to shock-mount the pump. A 3/8-inch-diameter line is required to connect the vacuum pump to the manifold. This line may be of seamless copper tubing or AN-6271-6 vacuum-type hose.

When the ambient temperature of the region in which the pump is installed falls below 40° F., a means of heating the pump must be provided. This has been accomplished by means of a simple heater-blower system. If desired, the pressure side of the pump may be vented overboard by attaching a suitable line to the exhaust port of the pump and extending the line to an overboard vent.

d. Oscillograph Recorder and Control Unit: The control unit shown in Figs. 3 and 4 contains the regulated power supply and control circuits for the analyzer units and also for the heater-type sampling tubes.

The input voltage to the Statham transducers in each analyzer unit is maintained constant despite fluctuations of the line voltage by means of three Type OC3 regulator tubes. Three Type OA3 tubes act as a ballast to prevent overloading of the regulator tubes in the event the power supply is turned on before the analyzer units are connected to the circuit.

Three neon lamps are connected directly across the heaters in the analyzer units to indicate when the heaters are being energized. After the analyzer units have attained operating temperature, the lights go on and off intermittently as the thermostats control temperature. The sampling tube heaters are controlled by means of a sampling tube heater switch. This switch must always be in the off position until the analyzer units are brought up to operating temperature. A switch-type circuit breaker for the vacuum pump also is on the control unit panel.

The Model GA-2A gas analyzer is designed to be used with an oscillograph using Heiland Type 100-350B galvanometers or equivalent. The oscillograph and control

unit shown in Figs. 3 and 4 preferably are located in the cabin or other available area where they are accessible to the operator at all times during a test. These two units have their own shock mounts and may be mounted directly. A typical installation in the fuselage of a DC-3 airplane is shown in Fig. 8. The oscillograph and control unit outlet connections are shown in Fig. 4. The cable for connecting the oscillograph to the control unit can be furnished with the instrument. This cable is approximately 5 feet in length. The remaining cables are fabricated during installation. The wiring diagram for making up the power and outlet cables which connect the control unit with the analyzer units is shown in Fig. 9. The connectors shown in Fig. 9 also are listed in Table I. These are required for making up the cables. Table I also lists power supply cable connectors. The positive lead from the d-c power supply (Fig. 6) is connected to pin B as marked in the connector, and the negative lead is connected to pin A. Proper observance of three indexing positions on the AN connectors make it impossible to crisscross the analyzer unit connections.

An event timer is connected through a relay to the oscillograph and the aircraft fire-extinguishing discharge button to indicate the time when the agent is discharged. The event timer is powered through pins C and D in the power plug from a 4.5-volt d-c battery.

OPERATING PROCEDURE

After the various components of the agent concentration recorder have been installed in the aircraft, a thorough ground check of the operation of the equipment should be made. To bring the equipment up to operating temperature, the a-c power supply circuit breaker switch is turned on and the heat-range switch is turned to the HIGH position. All three heater neon lamps should fire. After an interval of 30 to 60 minutes, depending upon the ambient temperature, all three lamps should start to cycle on and off, indicating that the analyzer units are up to operating temperature. When this occurs, the heat-range switch is turned to the LOW heat position. Best temperature control is maintained in this position except at very low ambient temperatures. Under such conditions, it may be necessary to leave the heat-range switch in the HIGH heat position.

If the preheated sampling tubes are to be used, the sampling tube heater switch should not be turned on until

TABLE I
LIST OF CONNECTORS FOR
GA-2A FLIGHT MODEL GAS ANALYZER

<u>Connector</u>	<u>To Be Used On</u>	<u>For</u>
AN 3106A-18-1S	1-4 Analyzer Unit	Output
AN 3106A-18-1SW	5-8 Analyzer Unit	Output
AN 3106A-18-1SZ	9-12 Analyzer Unit	Output
AN 3106A-18-12S	1-4 Analyzer Unit	Power
AN 3106A-18-12SW	5-8 Analyzer Unit	Power
AN 3106A-18-12SZ	9-12 Analyzer Unit	Power
AN 3106A-18-1P	Control Unit	1-4 Output
AN 3106A-18-1PW	Control Unit	5-8 Output
AN 3106A-18-1PZ	Control Unit	9-12 Output
AN 3106A-18-12P	Control Unit	1-4 Power
AN 3106A-18-12PW	Control Unit	5-8 Power
AN 3106A-18-12PZ	Control Unit	9-12 Power
AN 3106A-20-23S	Control Unit, 115 Volts, 400 Cycles	
AN 3106A-16-11S	Control Unit, 28 Volts d-c	
AN 3106A-16-11P	Control Unit, Vacuum Pump	
AN 3106A-18-10S	Power Plug on Oscilloscope	

Other Materials Required

No 20 AWG 2-conductor shielded wire.
 No 12 AWG single-conductor shielded wire.
 (Above amounts to be determined by each installation.)

- 1 - 4.5-Volt d-c battery.
- 1 - Normally open relay, to be used in the fire-extinguishing circuit in conjunction with the event timer on the oscilloscope.

Sufficient quantity of 1/4-inch seamless copper tubing for fabrication of sampling tubes and for connecting the analyzer units to the vacuum manifold

Sufficient quantity of 3/8-inch-diameter seamless tubing or vacuum-type hose for connecting the vacuum pump to the vacuum manifold

Also, any materials needed for constructing mounting brackets for any parts of the GA-2A analyzer requiring mounting.

the neon lamps indicated that operating temperature has been attained in all three analyzer units. Because of their small thermal mass, the sampling tubes should come up to operating temperature in a few minutes. After the instrument has been brought up to operating temperature as indicated by the neon lights, the galvanometers are zeroed by aligning all 12 galvanometer traces manually so that they are spaced equally. This should be done in accordance with the procedure outlined in the operations manual which accompanies the oscillograph. The vacuum pump then is turned on. While it is in operation, the traces again are examined and readjusted as necessary for correct spacing and to insure that none falls outside the chart range. The procedure should be repeated several times to insure that all galvanometer traces are aligned and identified properly. With the vacuum pump in operation, a check is made of each galvanometer in regard to the location of each sampling pickup in its circuit. This may be done by directing a small jet of carbon dioxide (CO_2) from a small hand fire extinguisher at the open end of the sampling tube and noting the corresponding galvanometer deflection. Care should be taken to avoid flooding the entire area and thus affecting other pickups in addition to the one being checked.

The event timer also should be checked before an actual test is conducted. This is done by disconnecting the agent container discharge valve from the discharge button. The discharge button then is depressed and simultaneously, an interrupted light beam is observed in the oscillograph. The interruption of the light beam, when the discharge button is depressed, is indicated by a broken line on the record chart to record the interval during which the container was discharged. When conducting a test, the recorder chart speed should be adjusted to approximately 1.50 inches per second.

The flight conditions under which the test is conducted are determined by the test requirements. Tests usually are conducted during takeoff and normal cruise conditions. Also, tests occasionally are conducted to determine if the extinguishing system is effective against fires occurring on the ground, particularly if wheel-well spaces are protected. Before the equipment is airborne it should be warmed up on the ground; otherwise, it will be necessary to extend the flight time to allow for heating the equipment. After the desired altitude is reached, a final check is made on the alignment of the galvanometer traces. This should be done with the oscillograph on and the vacuum pump operating intermittently.

In conducting the test, the emergency fire shutdown procedure specified for the aircraft is followed. At least 20 seconds before the agent discharge button is depressed, the oscillograph is turned on and the chart is started. Approximately 10 seconds before the agent is discharged, the vacuum pump is turned on. The equipment should remain in operation approximately 30 seconds after the agent is discharged. At the time of the test, the ambient pressure, temperature, and humidity should be recorded. By following the above sequence of operation, the concentration recorder is calibrated for 100 per cent air sample before each test run is made. A typical oscillogram is shown in Fig. 10.

DATA REDUCTION

The oscillogram of the test shows the agent concentration buildup and decline at each of the 12 sampling locations on a time basis from the time of discharge until the agent is dissipated from the protected zone. Since the galvanometer deflection for a given channel is proportional to the pressure drop across the second porous plug, a definite deflection will result for each pure gas. Dry air in this case may be considered as a pure gas. Any mixture of two gases, such as air and an extinguishing agent, will produce a deflection somewhere between the respective values for the pure constituents. Subsequently, the relative concentration of an extinguishing agent in any mixture of the agent and air may be determined by the formula

$$\text{per cent relative concentration} = \frac{AD-MD}{AD-CD} \times 100 \quad (1)$$

where

AD = displacement for air, in inches

MD = displacement for mixture, in inches

CD = displacement for pure agent, in inches.

It is not necessary, and would be very difficult, to calibrate the instrument for 100 per cent concentration of the agent each time a test is conducted. By calibrating the instrument experimentally, the ratios for galvanometer deflection for 100 per cent agent to galvanometer deflection for 100 per cent air were determined for various agents. These ratios, determined as an average for all of the individual channels in operation within standard deviation limits, are given in Table II.

TABLE II
CALIBRATION RATIO

<u>Agent</u>	<u>Ratio</u>
Carbon Dioxide (CO_2)	0.717
Methyl Bromide (CH_3Br)	0.466
Bromochloromethane (CH_2BrCl)	0.395
Dibromodifluoromethane (CBr_2F_2)	0.319
Bromotrifluoromethane (CBrF_3)	0.401

The ratios are based upon the pressure drop obtained with dry air. If there is an appreciable amount of moisture in the air, a slight error will result from the use of these ratios. Figure 11 gives the correction factor by which the ratios must be multiplied to correct for the specific humidity and ambient temperature conditions existing at the time the test is conducted.

The following illustrates how the relative concentration may be determined for any channel, for a specific time interval, after the agent has been discharged. Figure 10 shows that on channel I the deflection for air is 3.08 inches. From Table II, the ratio for CO_2 agent is 0.717. The deflection corresponding to 100 per cent concentration of the agent then is determined as $3.08 \times 0.717 = 2.21$ inches. However, it usually is more convenient to make the air deflection line zero, or reference level. To compute the deflection from the air line corresponding to 100 per cent of the agent, subtract the deflection due to the agent from that due to air. For channel I, Fig. 10, this is given by $(3.08 - 2.21) = 0.87$. To determine the CO_2 concentration for channel I at 1 1/2 seconds after discharge, extend the air deflection line to the right and beyond the vertical time interval line, which indicates a time lapse of 1 1/2 seconds from discharge. Determine by measurement the deflection for channel I from the air line at this point. This was found to be 0.46 inch. The ratio of this deflection to the deflection from the reference line for 100 per cent concentration of the agent, expressed as a percentage, will give the concentration of the mixture. In this example, the CO_2 concentration equals

$$\left(\frac{0.46}{0.87} \times 100 \right) = 52.9 \text{ per cent.}$$

The concentration may be determined from the formula

$$\text{per cent relative concentration} = \frac{\text{MD}}{\text{AD} - ((\text{AD})(\text{CR}))} \times 100 \quad (2)$$

where

AD = displacement for air, in inches

MD = displacement for mixture in inches from air
displacement reference

CR = calibration ratio for the specific agent
from Table II.

The percentage of relative concentration determined is based on the ratio of displacements, but does not indicate the concentration percentage on a volumetric or weight basis. To convert to a volumetric percentage or weight percentage basis, the curves shown in Figs. 12, 13, 14, 15, and 16 may be used.

INTERPRETATION OF DATA

The minimum relative concentration required for extinguishment as determined by the concentration recorder has been established on the basis of available information. This was obtained from numerous fire-extinguishing tests conducted on full-scale powerplant installations at the Technical Development Center. These requirements were based on the concentration determination for minimum quantities of agent required for extinguishing all test fires in the protected zones. In order that the system be considered adequate, the minimum relative concentrations for the various extinguishing agents shown in Table III should be maintained not less than 1/2-second for all sampling locations during the same period.

Since the relative concentration as determined by the concentration recorder is based on the ratio of displacements without reference to volumetric proportions, it was necessary to calibrate the instrument experimentally in order to convert the recorder data to a percentage by volume. This work was done through the cooperation and assistance of E. I. Du Pont de Nemours and Co., Inc., Freon Products Laboratory, Wilmington, Del. Numerous tests were conducted in which the percentage of agent concentration by volume in air was determined by gas chromatograph for corresponding recorder concentrations. Figures 12, 13, 14, 15, and 16 show the calibration curves for the various agents as determined from these tests. By calculation, the volumetric percentages were converted to weight percentages

TABLE III
EXTINGUISHING AGENT RELATIVE
CONCENTRATION REQUIREMENTS

<u>Agent</u>	<u>Required Minimum Relative Concentration at All Locations for 1/2-Second Period (per cent)</u>
Carbon Dioxide (CO_2)	40
Bromochloromethane (CH_2BrCl)	25
Methyl Bromide (CH_3Br)	15
Dibromodifluoromethane (CBr_2F_2)	15
Bromotrifluoromethane (CBrF_3)	15

as shown by the lower curve in each of the above figures.
These curves provide a means of comparing the instrument
data with similar data obtained by other methods of analysis.

CONCLUSIONS

The description of the FAA agent concentration recorder and the instructions for installation, operation of the instrument, and data interpretation contained herein represent a practical and reliable means of evaluating aircraft fire-extinguishing systems.

RECOMMENDATIONS

Use of the above described instrument and method for evaluating aircraft fire-extinguishing systems is recommended as superior to other evaluation methods.

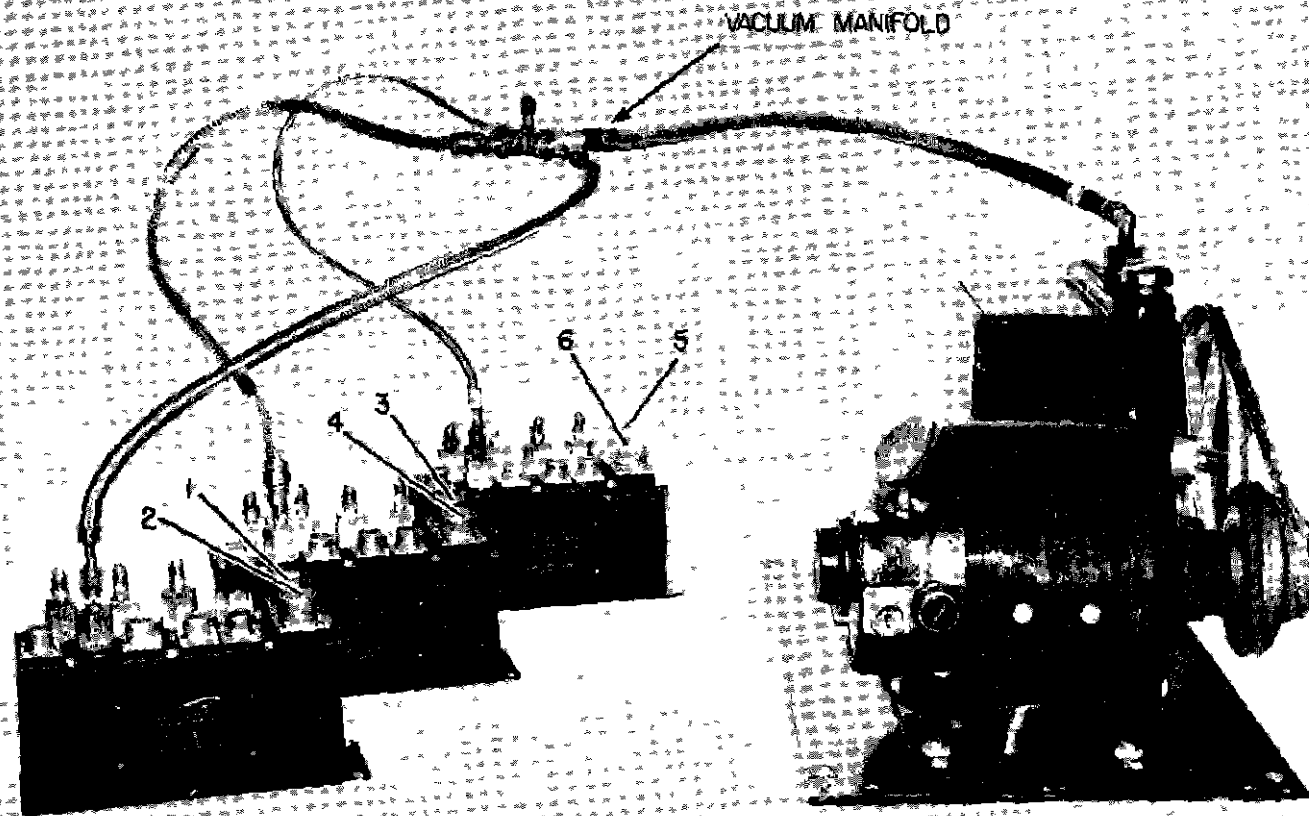


FIG. 1. FRONT VIEW OF ANALYZER UNITS AND VACUUM PUMP

GA-1000-10
DEVELOPMENT DESIGN
INSTRUMENTS DIVISION

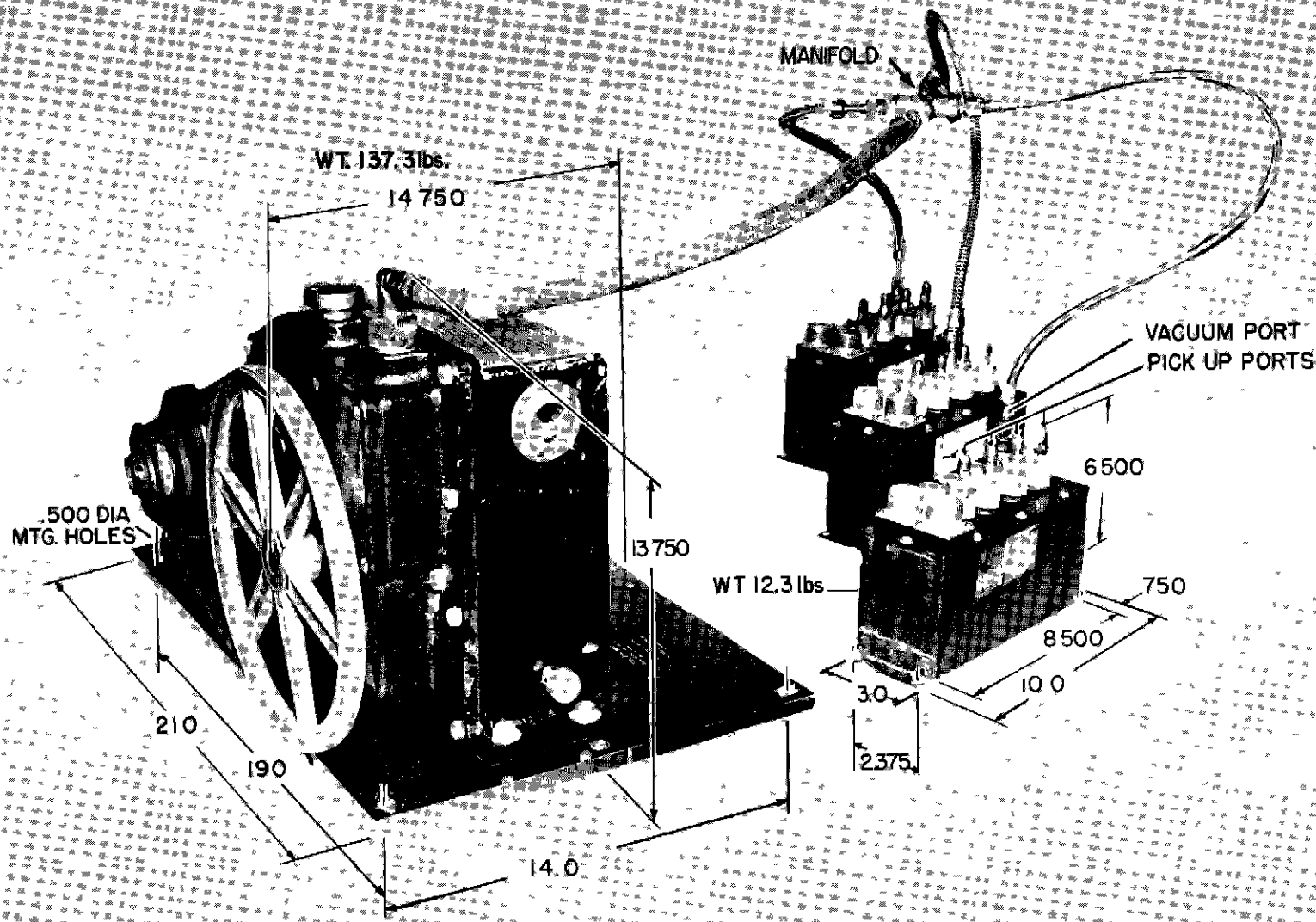


FIG 2 REAR VIEW OF ANALYZER UNITS AND VACUUM PUMP

CALTECH
DEVELOPMENT CENTER
PASADENA, CALIF.

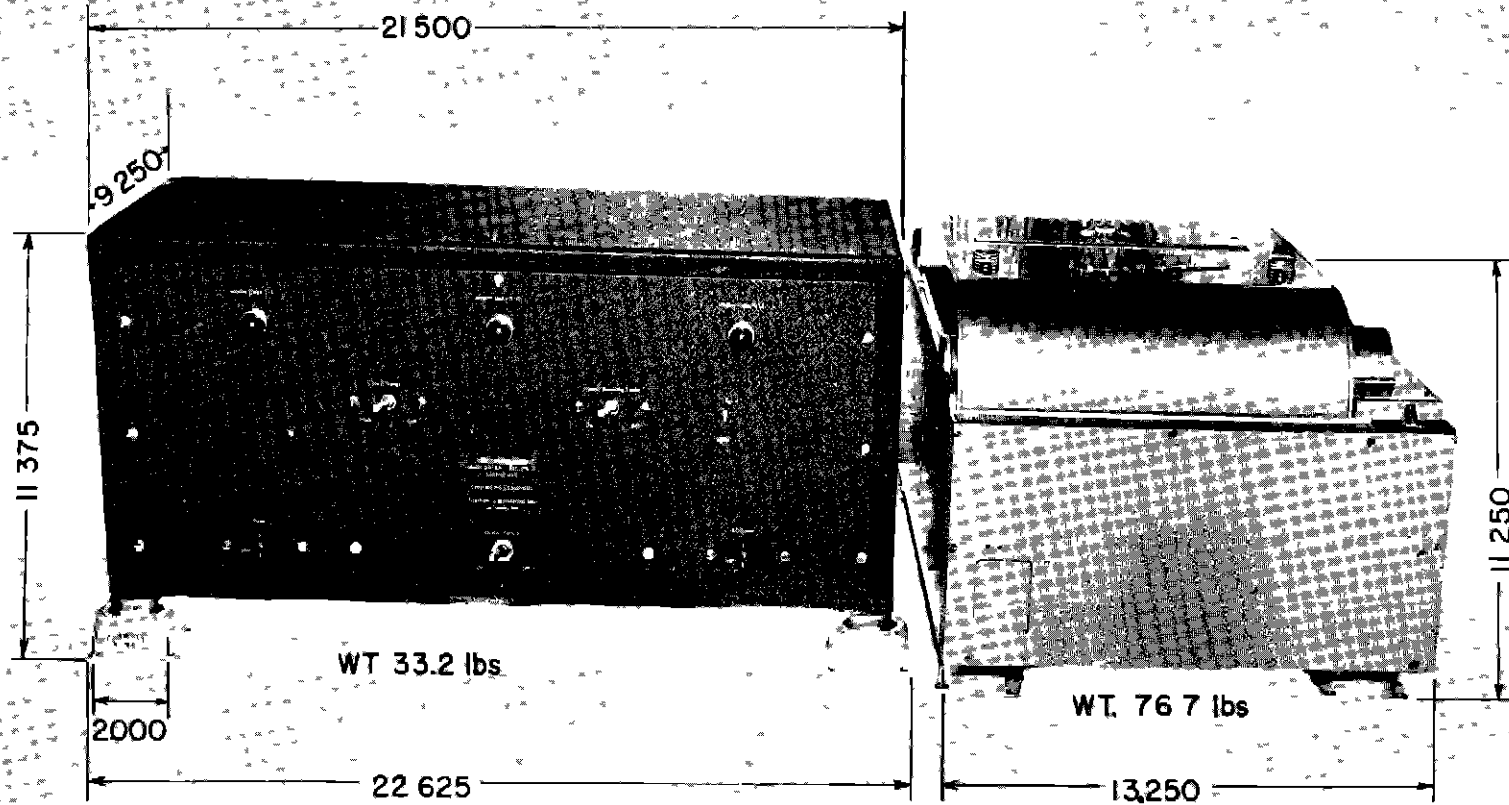
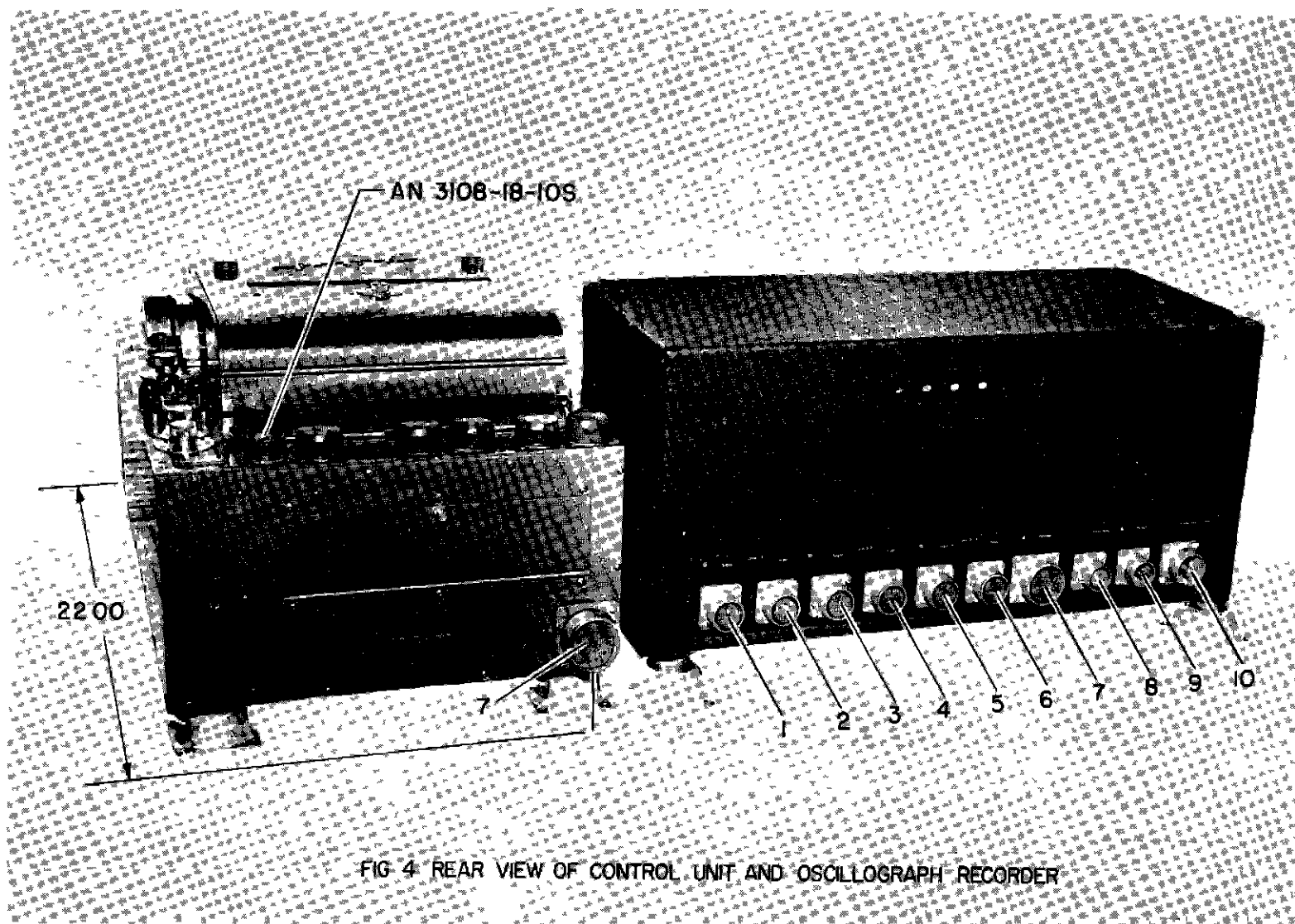


FIG 3 FRONT VIEW OF CONTROL UNIT AND OSCILLOGRAPH RECORDER



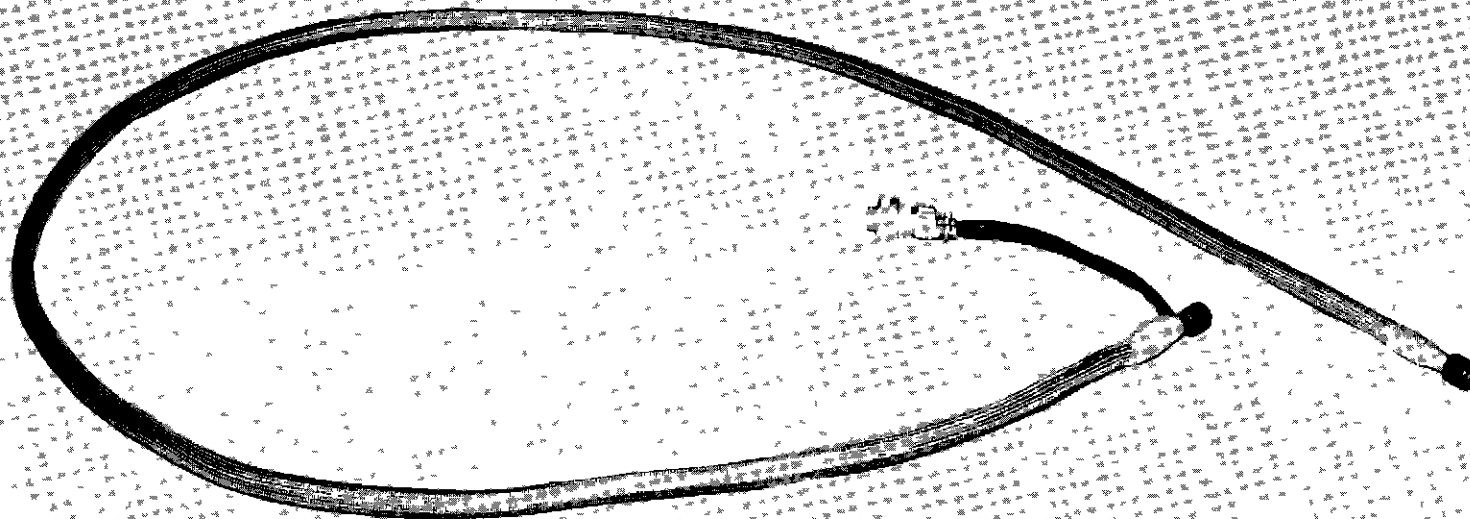


FIG. 5 SIX-FOOT HEATED SAMPLING TUBE WITH 4 AN FITTINGS AND POWER PLUG
WEIGHT - 1.1 POUNDS

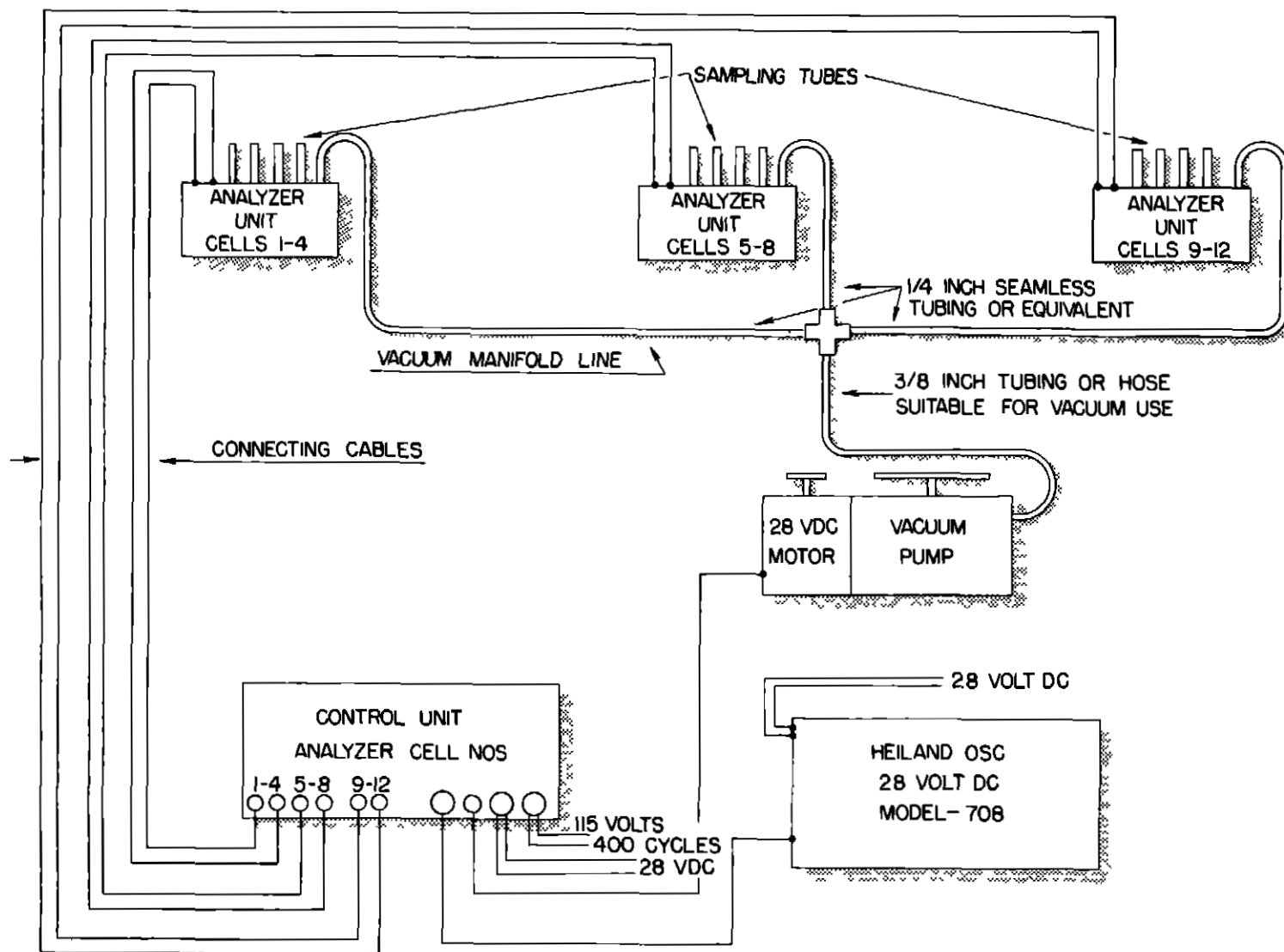


FIG 6 GA-2A AGENT CONCENTRATION RECORDER INSTALLATION DIAGRAM

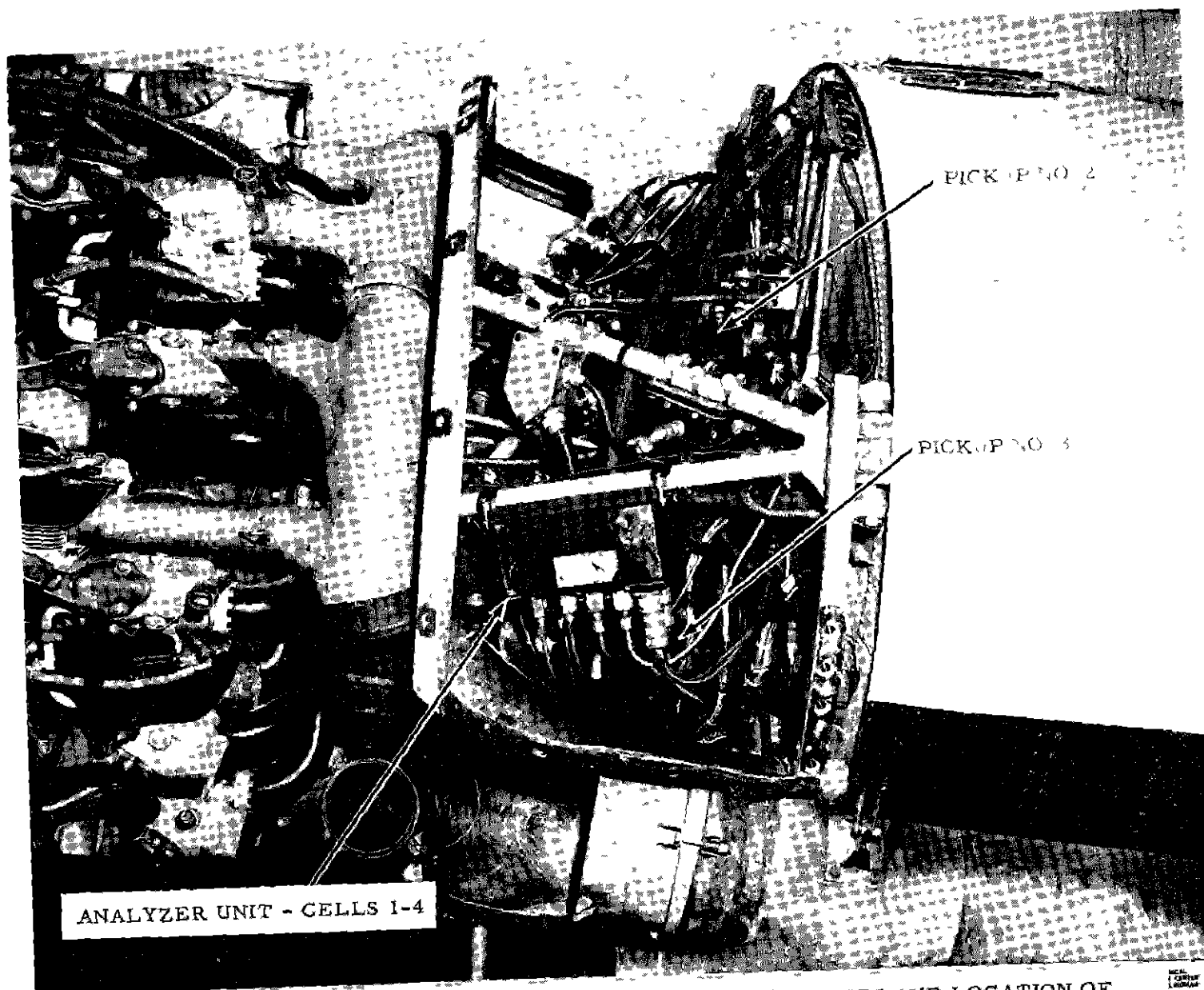


FIG. 7 LOCATION OF ANALYZER UNIT FOR NOS. 1 TO 4 PICKUPS AND LOCATION OF NOS. 2 AND 3 PICKUPS IN ACCESSORY SECTION OF A DC-3 AIRPLANE

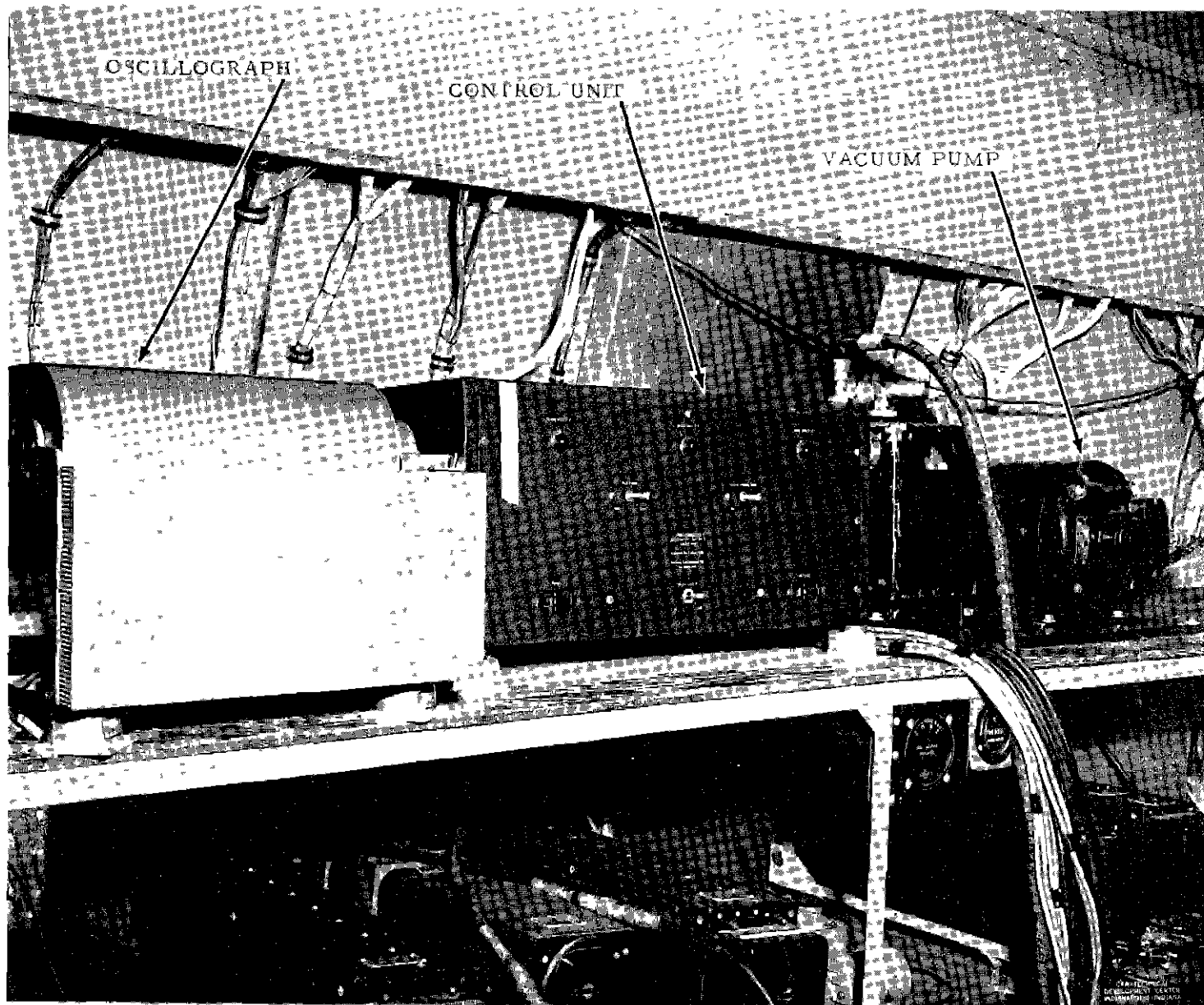
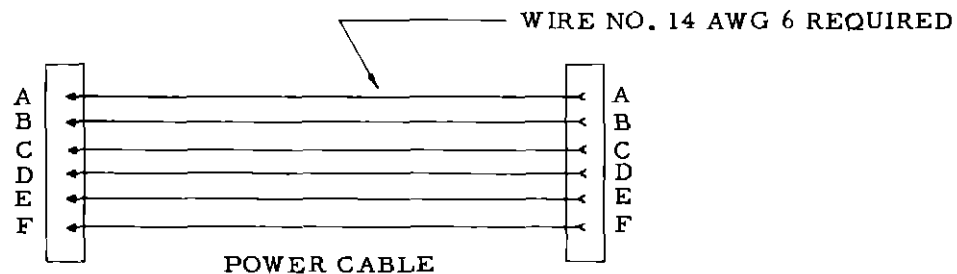
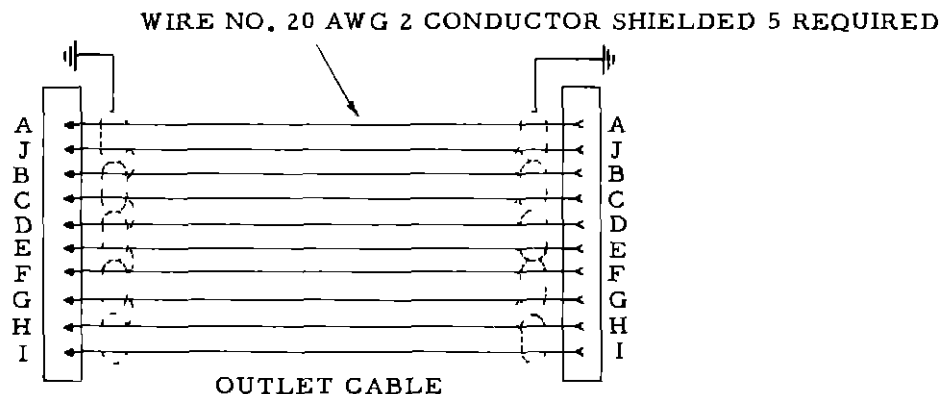


FIG. 8 LOCATIONS OF TEST EQUIPMENT IN FUSELAGE OF A DC-3 AIRPLANE



TO CONTROL UNIT (POWER)	TO ANALYZER UNITS	
CABLE NO. 2 AN3106A-18-12P	AN 3106A-18-12S (1-4)	1 REQUIRED
CABLE NO. 4 AN3106A-18-12PW	AN 3106A-18-12SW (5-8)	1 REQUIRED
CABLE NO. 6 AN3106A-18-12PZ	AN 3106A-18-12SZ (9-12)	1 REQUIRED



TO CONTROL UNIT (OUTPUT)	TO ANALYZER UNITS	
CABLE NO. 1 AN 3106A-18-1P	AN 3106A-18-1S (1-4)	1 REQUIRED
CABLE NO. 3 AN 3106A-18-1PW	AN 3106A-18-1SW (5-8)	1 REQUIRED
CABLE NO 5 AN 3106A-18-1PZ	AN 3106A-18-1SZ (9-12)	1 REQUIRED

NOTE CABLE WIRING TO BE CUT TO REQUIRED LENGTH FOR EACH INSTALLATION

NOTE CABLE NUMBERS CORRESPOND TO OUTLET NUMBERS ON FIG. 4

FIG. 9 ANALYZER CABLES - SCHEMATIC DIAGRAM

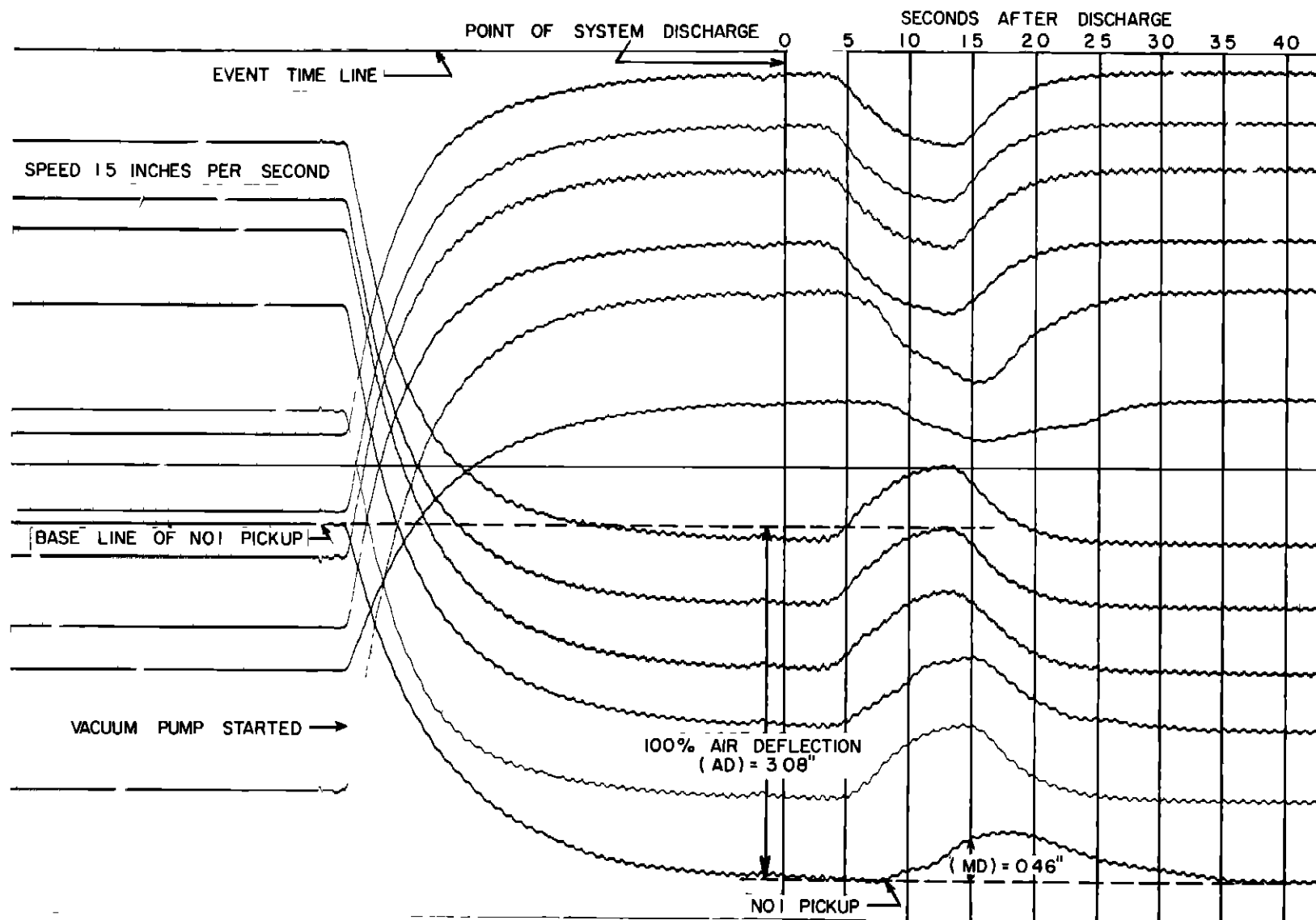


FIG 10 OSCILLOGRAM OF A TEST RUN

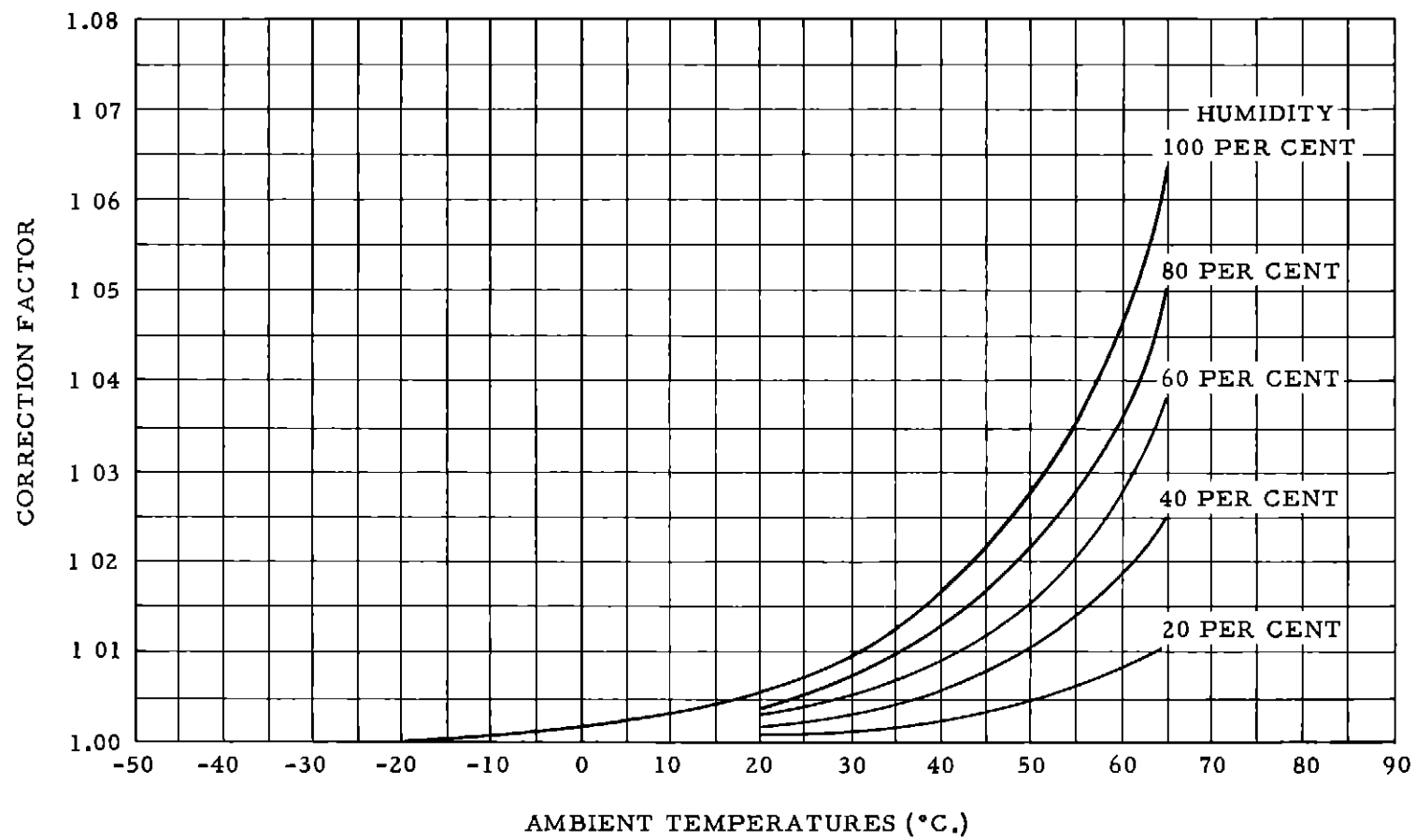


FIG. 11 HUMIDITY CORRECTION FACTORS

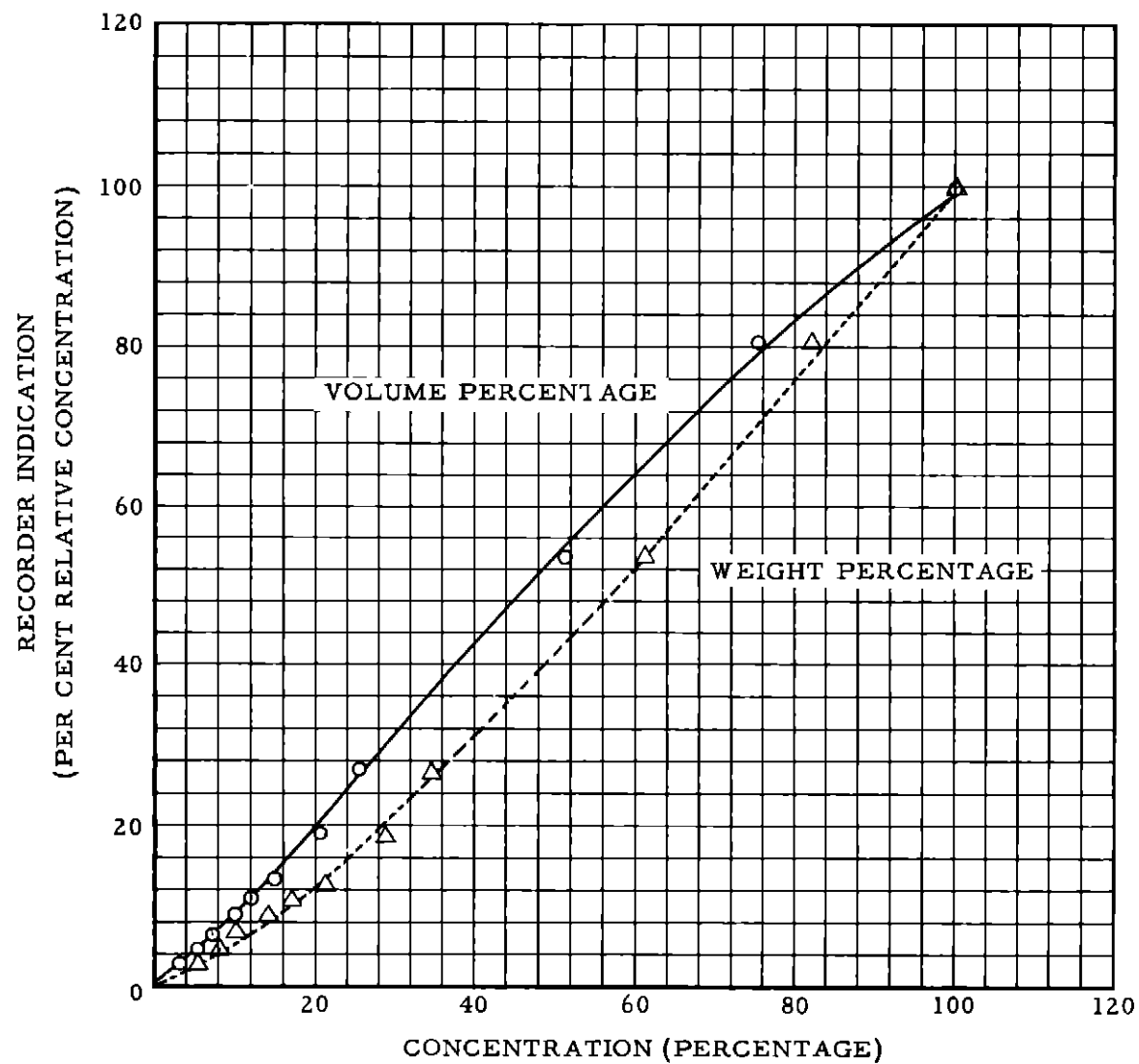


FIG. 12 CURVE FOR CONVERTING RELATIVE CONCENTRATION TO VOLUME AND WEIGHT PERCENTAGES OF CARBON DIOXIDE IN AIR

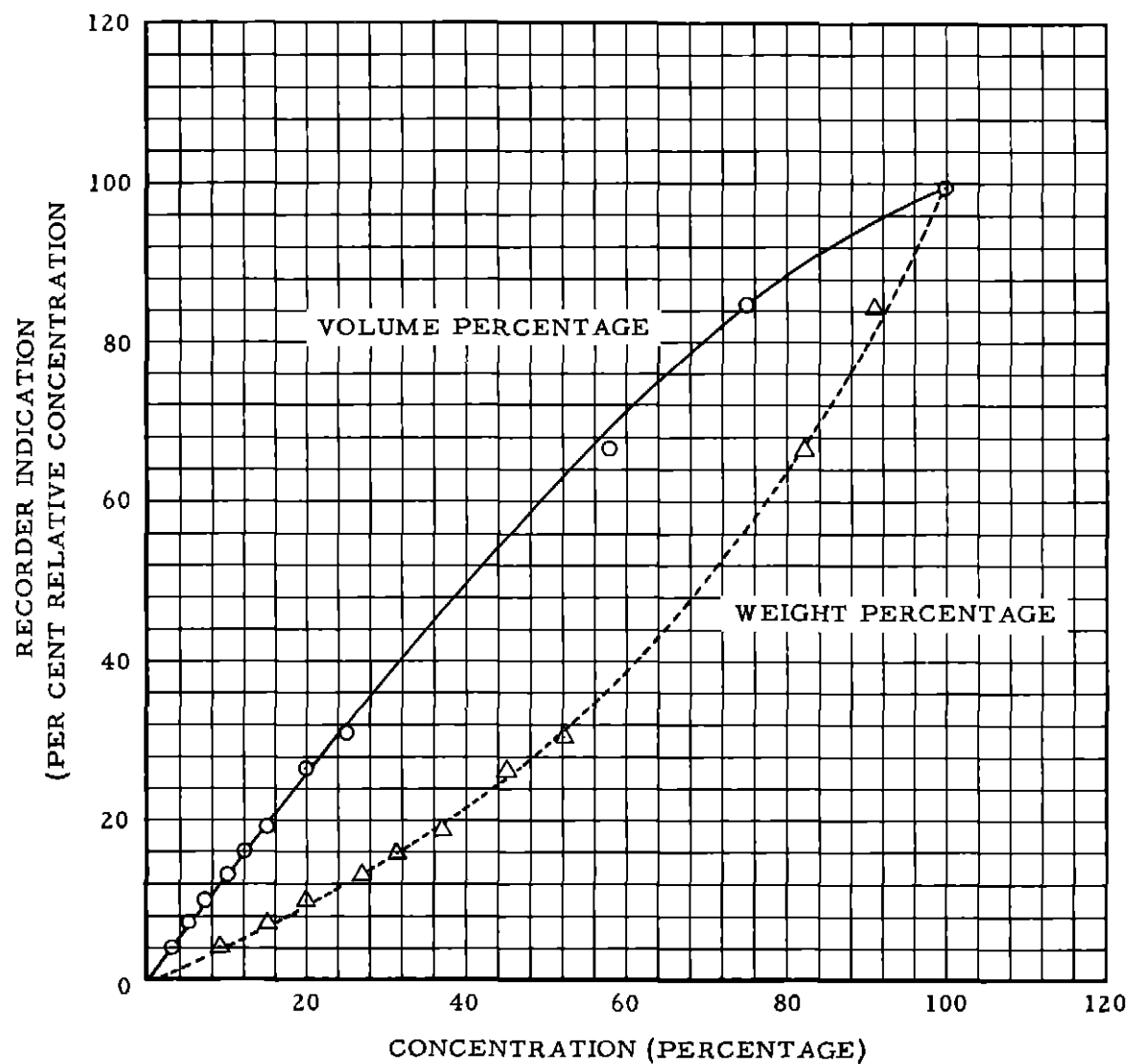


FIG. 13 CURVE FOR CONVERTING RELATIVE CONCENTRATION TO VOLUME AND WEIGHT PERCENTAGES OF METHYL BROMIDE IN AIR

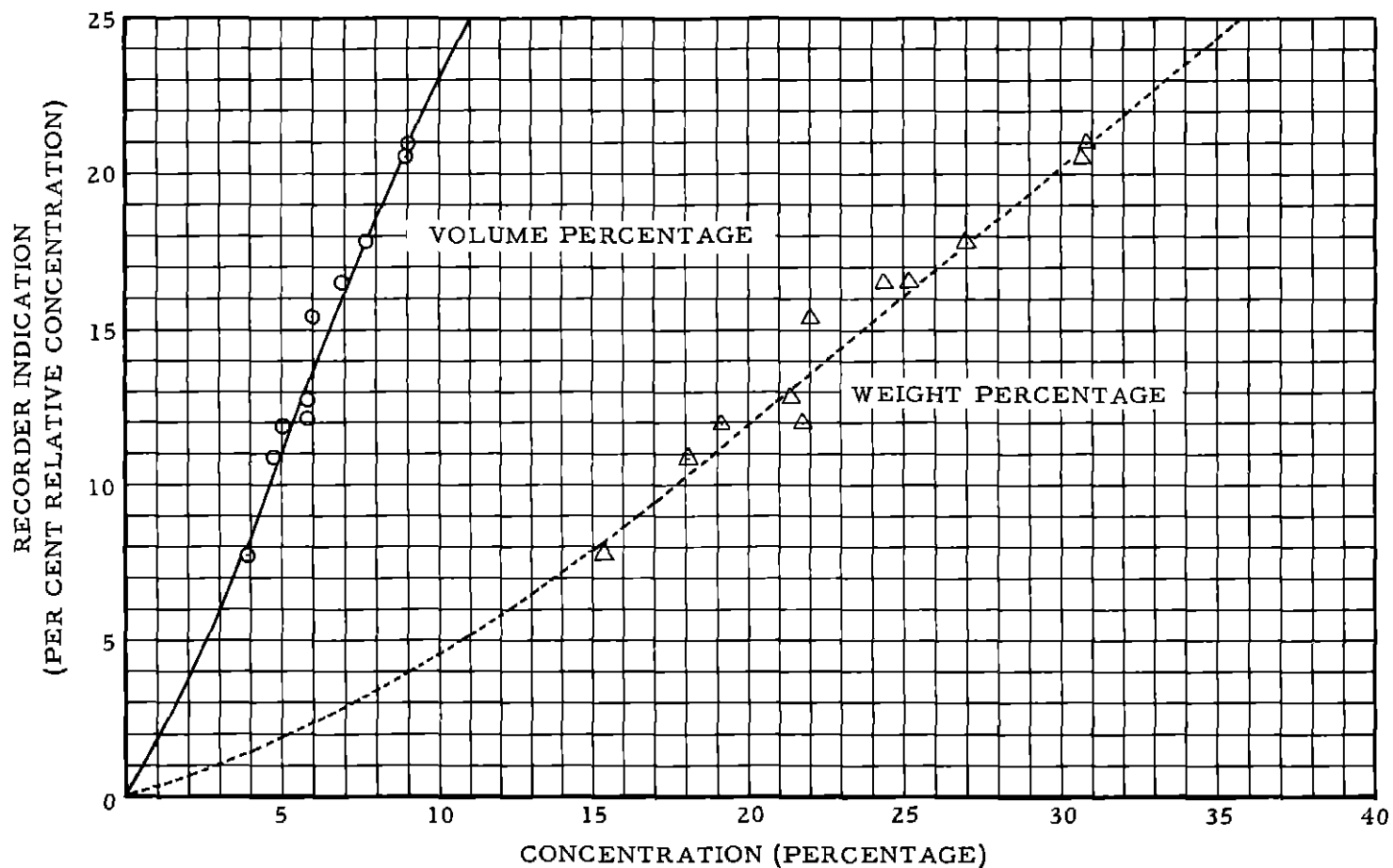


FIG. 14 CURVE FOR CONVERTING RELATIVE CONCENTRATION TO VOLUME AND WEIGHT PERCENTAGES OF BROMOCHLOROMETHANE IN AIR

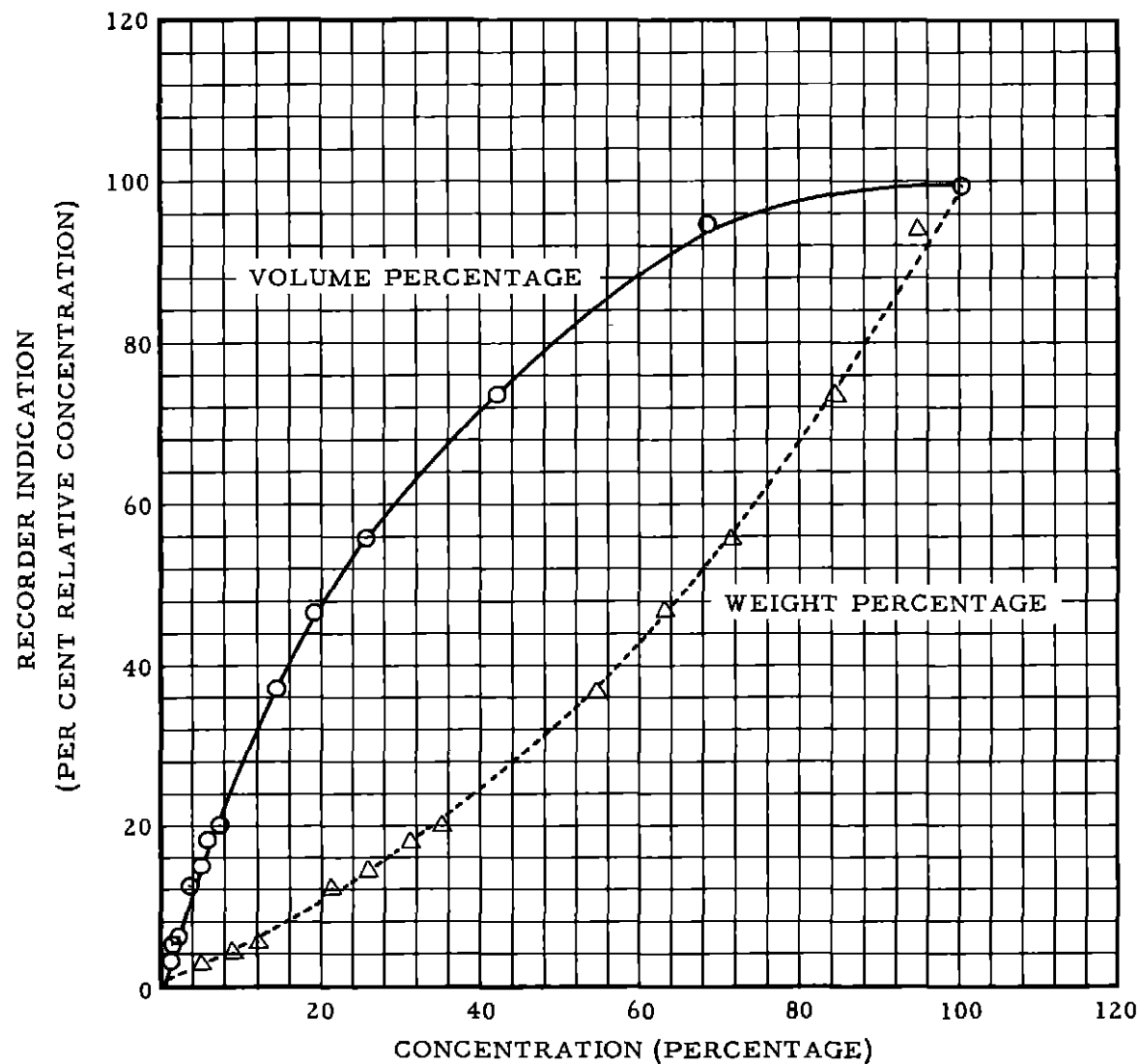


FIG. 15 CURVE FOR CONVERTING RELATIVE CONCENTRATION TO VOLUME AND WEIGHT PERCENTAGES OF DIBROMODIFLUOROMETHANE IN AIR

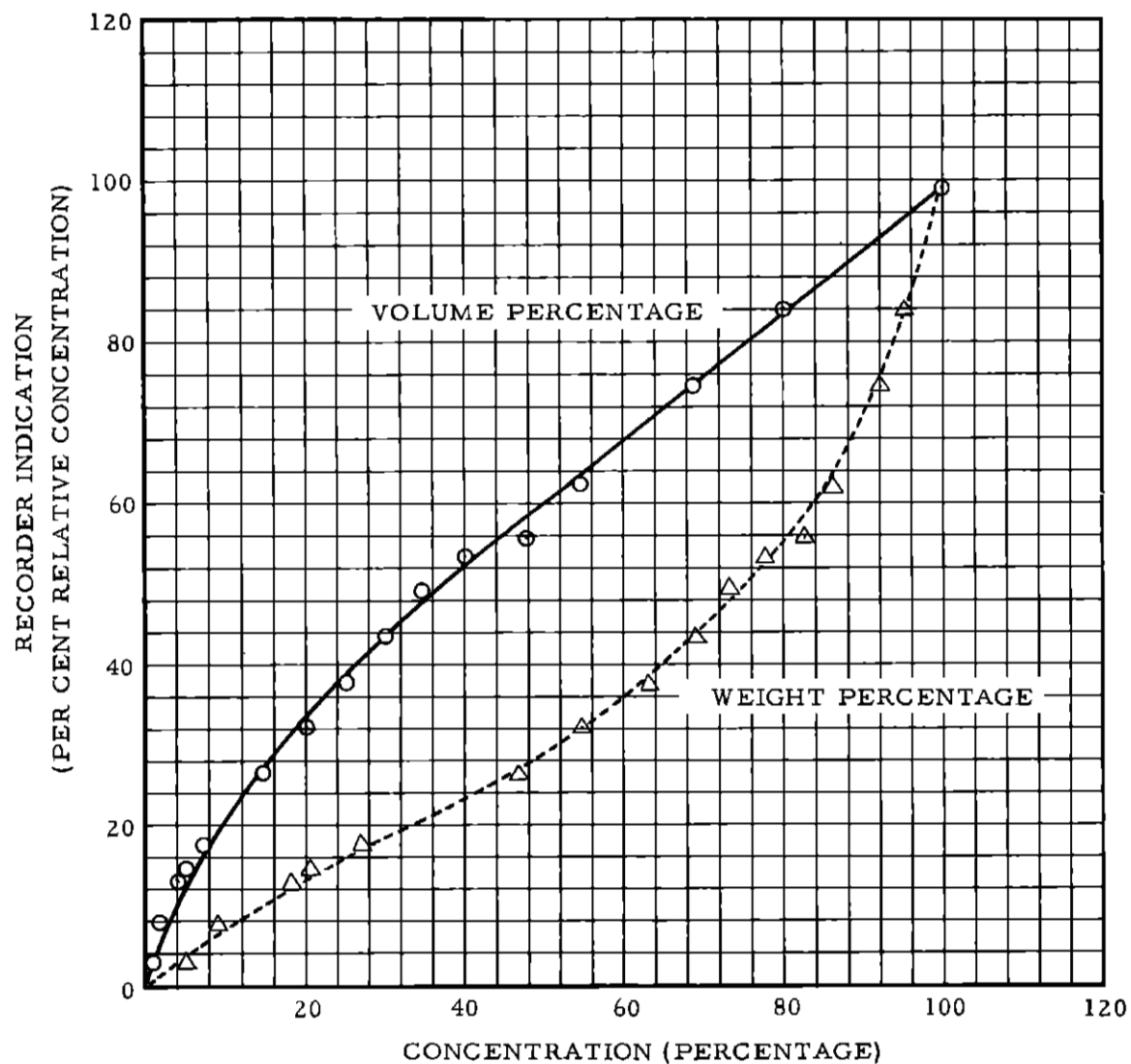


FIG 16 CURVE FOR CONVERTING RELATIVE CONCENTRATION TO VOLUME AND WEIGHT PERCENTAGES OF BROMOTRIFLUOROMETHANE IN AIR