EVALUATION OF PROTECTIVE MASKS BY USE OF RADIO TELEMETRY

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Summary A telemetering system developed to enable research and development personnel to evaluate physical performance aspects-of US Army protective masks on a quantitative basis is described. Respiration, acceleration, and temperature data generated by a subject wearing a mask can be monitored simultaneously at a point remote from the mask wearer. The system operates in the 216-235 MH_z telemetry band using an FM/FM mode. Data transmission in excess of 1/2 mile (via ground wave) has been obtained without experiencing signal deterioration. Data generated can either be recorded directly on a strip chart recorder, magnetic tape recorder or both simultaneously. Data recorded on magnetic tape can be analyzed by use of an Analog Computer. Measurements obtained using this equipment compare in accuracy with that obtained through use of conventional laboratory instrumentation.

Introduction Suitable instrumentation for measuring dynamic performance for protective masks by remote means has long been desired. Conventional laboratory instrumentation has been used for approximately twenty (20) years to measure flow and pressure drop within a protective mask worn by a subject exercising on a treadmill. Normally, these measurements are made using two differential pressure transducers mounted on a laboratory bench and connected to the subject using mechanical linkage (plastic tubing) and to an amplifier-recording console using electrical cables. Movement of the subject was restricted to walking in place on a treadmill or cycling on a stationary bicycle. It was never certain that data obtained through use of the above setup described indicated what was happening to the same mask being worn by a subject in the field, wherein his movement was not restricted.

Approximately (12) twelve years ago a portable respiratory recording system was developed for the US Army under Contract DA18-108-CML-5948. The heart of the system developed was a flow sensor of the strain gage type, containing bonded strain gages mounted on stainless steel vanes, that move back and forth with changing airflow. After electronically conditioning and amplifying, the signal was recorded on a portable (backmounted) magnetic tape recorder which was activated and deactivates from a remote transmitter. The primary function of the equipment was to measure minute inhaled volumes of air before a mask was donned by a subject exposed to a simulated gas attack, in addition to breath-holding time required from the initial don mask command and the actual donning of the mask. The radio equipment used in conjunction with this system operated in the 27 MH_z (Citizen Radio Band) and in the amplitude modulation mode. The circuit employed closely resembled those used by hobbyist in the control of model aircraft and boats.

The system described in this paper differs considerably from the above since it was designed to dynamically measure airflow, pressure drop, temperature, and acceleration simultaneously for a subject wearing a protective mask.

General Description The system developed for the US Army under US Government Contract DA18-108-AMC-228 by Spacelabs, Inc. Van Nuys, California in 1964 operates in the frequency modulated mode. Up to eight data channels per subject are sensed, conditioned, and transmitted to a remote ground station for detection and recording. Earlier backpack designs were only capable of measuring flow and pressure drop within a mask. The earlier units did not contain a separate removable battery unit as does the latest model backpack. The latest model backpack as shown in photograph-il consist of the following: (1) An upper compartment containing two differential pressure transducers, electronic conditioning circuits required by the accelerometer, voltage controlled oscillators, conditioning circuits for temperature sensors, and an FM transmitter, (2) A lower compartment containing rechargeable nickel cadmium battery as shown in photograph #2. A block diagram of this backpack is shown in Figure 1. Components contained in the backpack are as follows: Two (2) Pace Wiancko Model 109D variable reluctance type differential pressure transducers used to sense flow and pressure drop within the mask. The output from each transducer is fed into a Pace Carrier Demodulator Model CD32, which applies an excitation of $5KH_z$ to a bridge, including the two inductance ratio arms of the transducers.

A solid state amplifier and demodulator converts the bridge outputs to dc. The dc outputs from each carrier demodulator is used to drive a voltage controlled oscillator.

Temperature measurements within the protective mask cavity are made using three (3) thermistor probes which use as a reference voltage the output of a 2280 volt reference supply located inside of the backpack. This output is amplified by a signal conditioner and then applied to a voltage controlled oscillator.

An Endevco triaxial accelerometer is used in combination with three signal conditioners in order to measure vibrational effects associated with mask wear under conditions of stress. The accelerometer has a nominal range of ±5 g's and a frequency response of 3 to 160 Hz between 3db points. The outputs from the accelerometer signal conditioners (3) are used to drive three voltage controlled oscillators.

Input and ground terminals, in addition to a series of test points, are also provided on the matrix board, the output of any channel can be connected to the input of any voltage controlled oscillator simply by means of the appropriate interconnection. The output of the voltage controlled oscillators is summed in a mixing amplifier which in turn provides the modulating drive voltage to the transmitter.

The frequency modulated transmitter operates with true frequency modulation at a minimum radiated power of 1 watt. The transmitter is solid state with a crystal stabilized reference oscillator, assuring frequency stability within 0.001% of center frequency. Filters are provided to suppress spurious radiation well below levels where intermodulation with other equipment and spurious receiving responses can impair quality of transmitted data.

The modulating frequency range is flat within 3db from 20 to 300,000 H_z assuring more than adequate the capacity for the subcarrier frequencies employed.

The antenna is a simple stub antenna terminated with a type N Connector. A 10 db and 20 db coaxial attenuator are used with the backpack to reduce the amount of radiated power and allow the use of the system with the antenna in the laboratory.

A block diagram of the Ground Receiving Station is shown in Figure 2.

The Ground Receiving Station shown in Photograph 3 consists of (10) ten frequency modulated receivers, a multicoupler, a multichannel, CEC Data Graph Strip Chart Recorder, a tape recorder channel selector and eight EMR Subcarrier Discriminators covering the following center frequencies; 1.70, 2.30, 3.00, 3.90, 5.40, 7.35, 10.5 and 14.5KH_z. An Ampex FR 1300 magnetic tape recorder is also included for storage of subcarrier frequency data to be analyzed at a future date. A real time tape speed compensation circuit is also included in the console in order to correct for variations in tape speed (referred to as wow and flutter) during recording or reproduction.

An EMR, Five Point Frequency Calibrator is also included in the ground receiving console for calibrating each of the eight subcarrier discriminators (bandedge and balance adjustments).

Performance To date, both laboratory and field tests have been conducted in order to compare the overall accuracy of the field telemetry system to conventional laboratory equipment. Tests originating in the laboratory were conducted with subjects fitted with instrumented masks and exercising on an electronic bicycle (Ergometer). Photograph #4 shows a subject wearing an instrumented mask in conjunction with a Model 802 Backpack while exercising on an Ergometer.

Photograph #5 shows a subject wearing a mask while being monitored for pressure drop and flow through use of conventional laboratory equipment. Recorded data generated from both systems (related to respiration measurements) is similar, all being equivalent in regard to amplitude level.

Field tests using the telemetry equipment were conducted in a field in front of the laboratory building. A subject wearing a protective mask and equipped with a Model 802 Backpack, exercised by jogging and walking up and down a measured test course of 50 yards. A ground plane antenna mounted on top of the building (approximately (40) forty feet high) is used for the reception of data transmitted from the subject in the field. The data consisting of flow and pressure measurements are comparable to that generated within the laboratory using the same system and conventional laboratory equipment as shown in Figure #3.

Although the Model 802 Backpack contains acceleration and temperature channels as shown in Photograph #6, extensive dynamic testing has been limited to the flow and pressure channels. Neither the temperature or acceleration channels have been evaluated as extensively as the flow and pressure channels. A preliminary evaluation of the temperature channels has revealed that the response time of the sensors (thermistors) used are too slow to accurately measure temperature changes occurring within the mask while a subject is breathing. The best that can be expected from the present setup is an average temperature measurement within the mask cavity.

Future plans involve the evaluation of other thermistors such as a small bead type deposited on a thin film for use as a temperature sensor. Metro Physics, Santa Barbara, California, a company involved in this type of development indicate that their sensor has a response time less than 100 milliseconds, which should be sufficient for measuring temperature changes in step with respiration.

It is also planned to incorporate a carbon dioxide detector into new telemetry backpacks that will serve as a dynamic monitor to measure “dead space volume” within a mask cavity.

Work is also underway to modify the present telemetry system now operating in the 216-235 MH_z telemetry band to “S” Band (2300 MH_z).

MODEL 802 BACKPACK BLOCK DIAGRAM

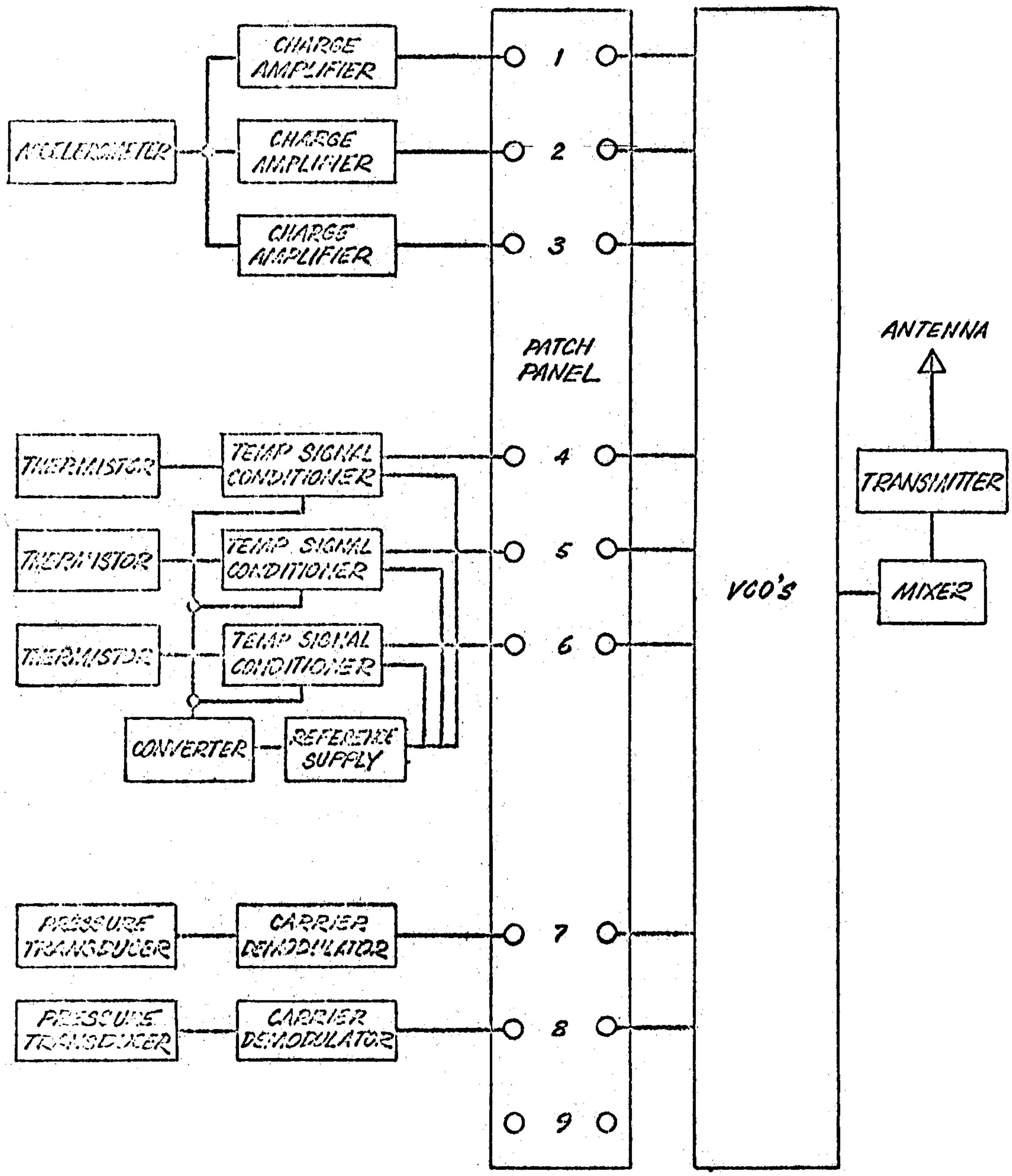


Figure 1

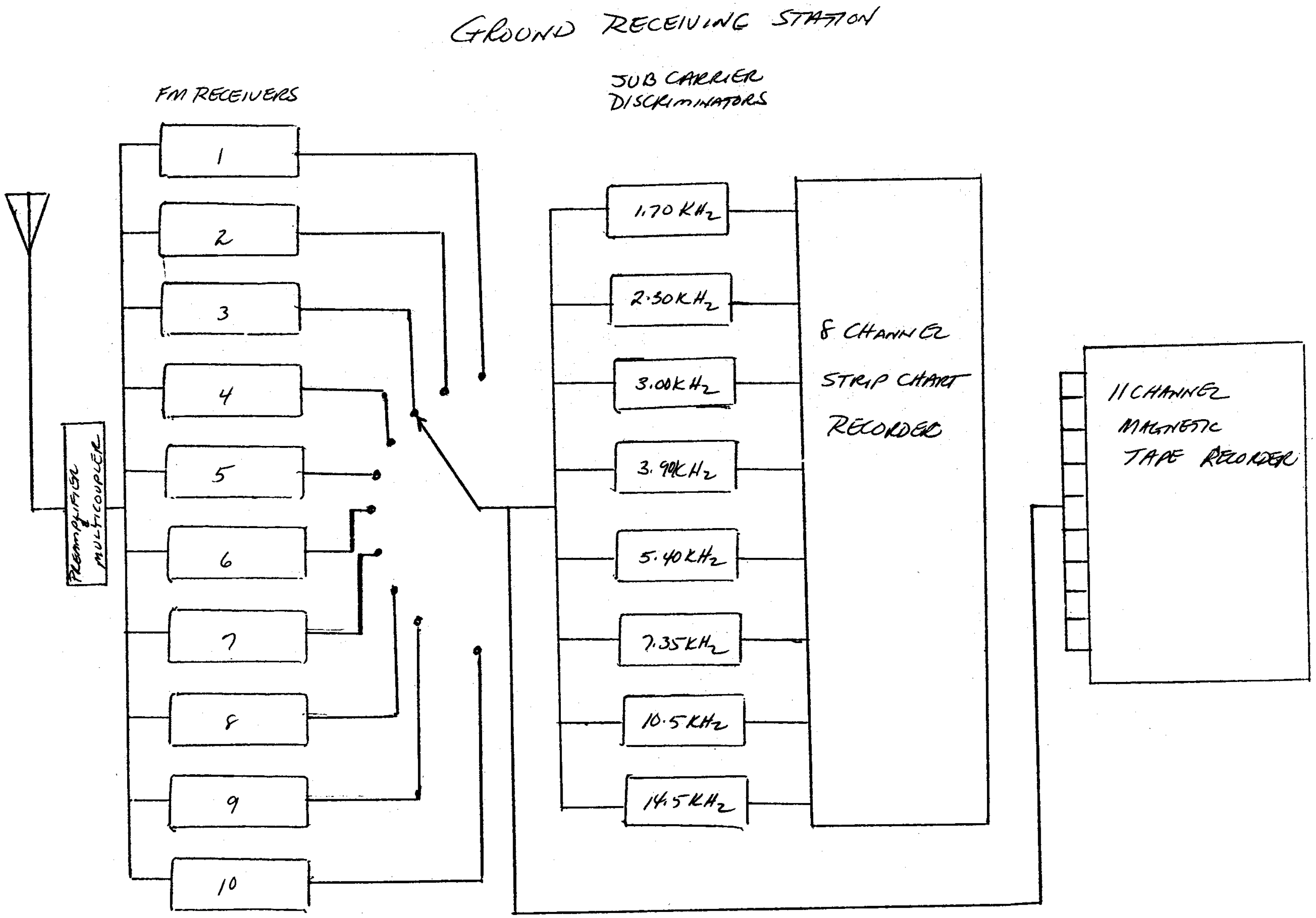

GROUND RECEIVING STATION
FM RECEIVERS
SUB CARRIER DISCRIMINATORS
1
2
3
4
5
6
7
8
9
10
PREAMPLIFIER & MULTICOUPLER
1.70 KHz
2.30 KHz
3.00 KHz
3.90 KHz
5.40 KHz
7.35 KHz
10.5 KHz
14.5 KHz
8 CHANNEL STRIP CHART RECORDER
11 CHANNEL MAGNETIC TAPE RECORDER

Figure 2

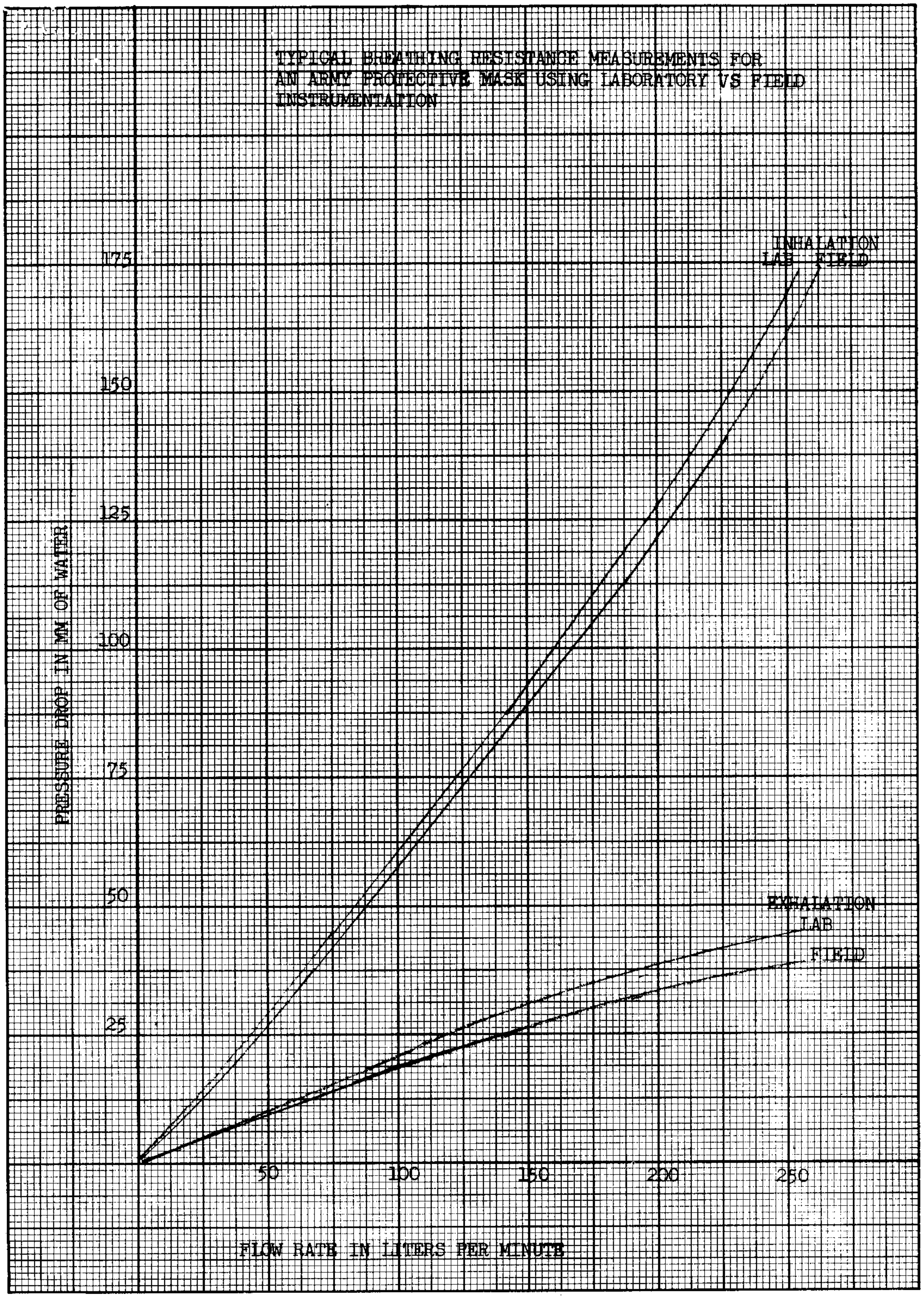
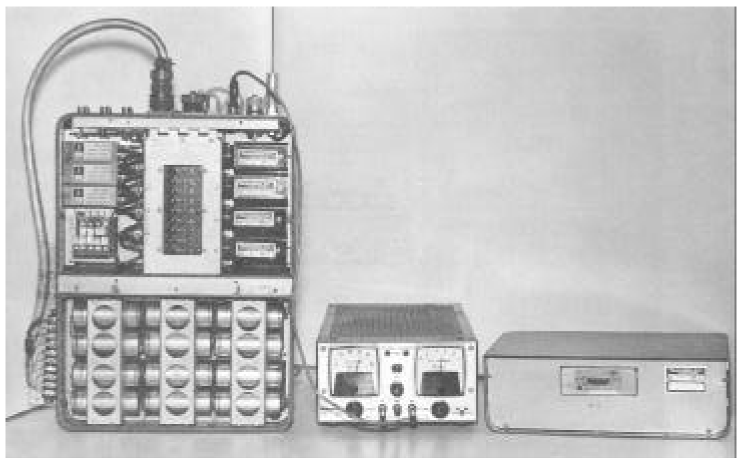
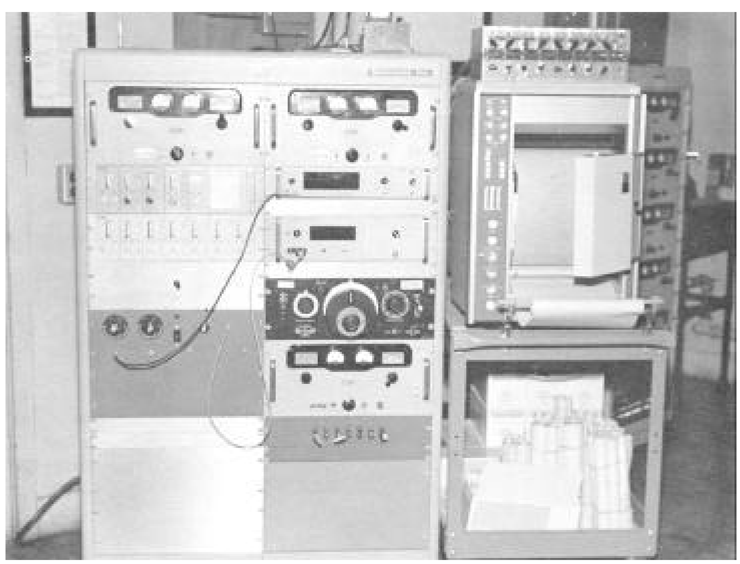

TYPICAL BREATHING RESISTANCE MEASUREMENTS FOR
AN ARMY PROTECTIVE MASK USING LABORATORY VS FIELD
INSTRUMENTATION
INHALATION
LAB FIELD
EXHALATION
LAB
FIELD
PRESSURE DROP IN MM OF WATER
175
150
125
100
75
50
25
50
100
150
200
250
FLOW RATE IN LITERS PER MINUTE

Figure 3

Photograph 1



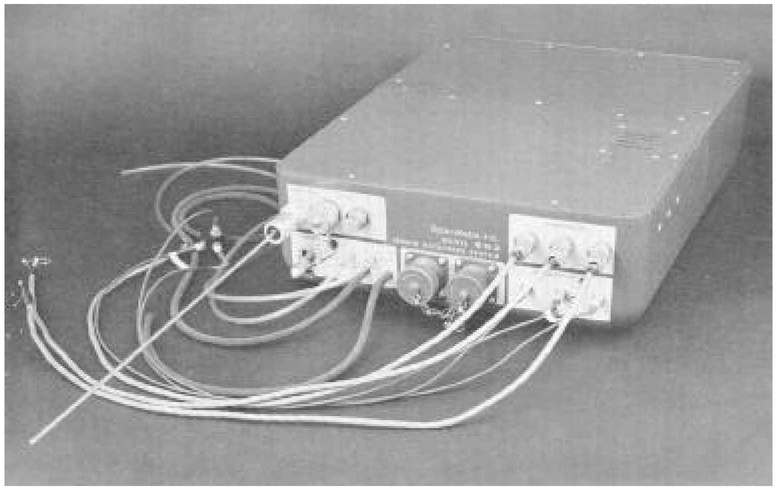
Photograph 2



Photograph 3

Photograph 4

Photograph 5



Photograph 6