

THE AUTOMATIC METEOROLOGICAL STATION SYSTEM/AN-7140-30

(U) ARMY ELECTRONICS RESEARCH AND DEVELOPMENT COMMAND

WSMR NM ATMOSPHERIC SCIENCES LAB W J VECHIONE AUG 82

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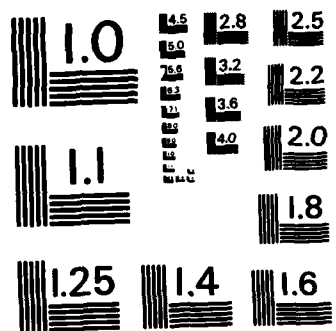
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THE AUTOMATIC METEOROLOGICAL STATION
SYSTEM AN/TM-30 ()

August 1982

By

William J. Vechione

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AN/TM-30. Transmission times are set hourly or half-hourly, with a mission duration after deployment of 14 days. Microprocessor data control and processing are used throughout the system concept, both in the remote sensor stations and the master station. Currently, the system is in the advanced development stage.

Hardware development was completed Jan 81. Acceptance and operational tests were accomplished between Feb and May 81. These tests included in-plant acceptance, specification compliance, and operational capability tests. Data collected were compared to calibrated standards. Presented are all tabulated and graphic representations, as well as field operation results. The results of the tests show the system's relative comparison with the standards. The future plans for system development are presented.

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1. INTRODUCTION

The state of the atmosphere in an area of tactical operations affects US Army operations within that area. When commanders and their staff cannot obtain current localized weather information from remote areas of the zone of operations, they are limited in acquiring vital information necessary for operational planning and execution. A system of unmanned, transportable, automatic surface weather stations is required to satisfy the need to supply this atmospheric information for day-to-day tactical operations and long-range operational planning.

Based on this need, a system was designed as an experimental prototype, tested, and used to establish technical feasibility for development. Subsequent progress in the program led to advanced development status, and a contract to develop advanced development equipment was awarded to RCA Government Systems Division in 1979. The resultant prototype system hardware was delivered to the US Army Atmospheric Sciences Laboratory (ASL) in January 1981. Tests and demonstrations conducted with this equipment have resulted in significant data being collected. These collected data are presented in this report, with an analysis that results in recommendations for future development and configuration.

The prototype system (figure 1) consists of two remote sensor stations with attendant hardware, a master receiving/reporting station, and a code programmer unit. The remote stations transmit, via radio frequency (RF) communications, digital data consisting of wind speed and direction, temperature, pressure, and a relative humidity. Data times are selectable at hourly or half-hourly intervals. The remote stations contain sufficient battery service for 14 days (minimum) of operation, and the master station operates 36 h on one battery service and can operate on AC power when available.

2. DEVELOPMENT OBJECTIVES

The need to develop a network of remote tactical meteorological sensor stations operating as a system, reporting their data to a central master station, was highlighted by a 1974 operational study conducted by the US Army's Intelligence Center. A means of gaining meteorological data from remote and planned operational areas was needed in order to plan airmobile, aviation, smoke employment, and target acquisition operations. A development program undertaken in 1975 to satisfy these needs had the following objectives:

- (1) providing the required meteorological surface parameters of wind speed, wind direction, temperature, barometric pressure, and relative humidity in the deployed area;
- (2) providing a means of validating those data acquired by other observation systems, such as weather radars and/or meteorological satellites;
- (3) developing a low-cost division asset system that can acquire such data and be considered expendable, but contain the capability for unit reuse by recovery, restoration, and replacement;

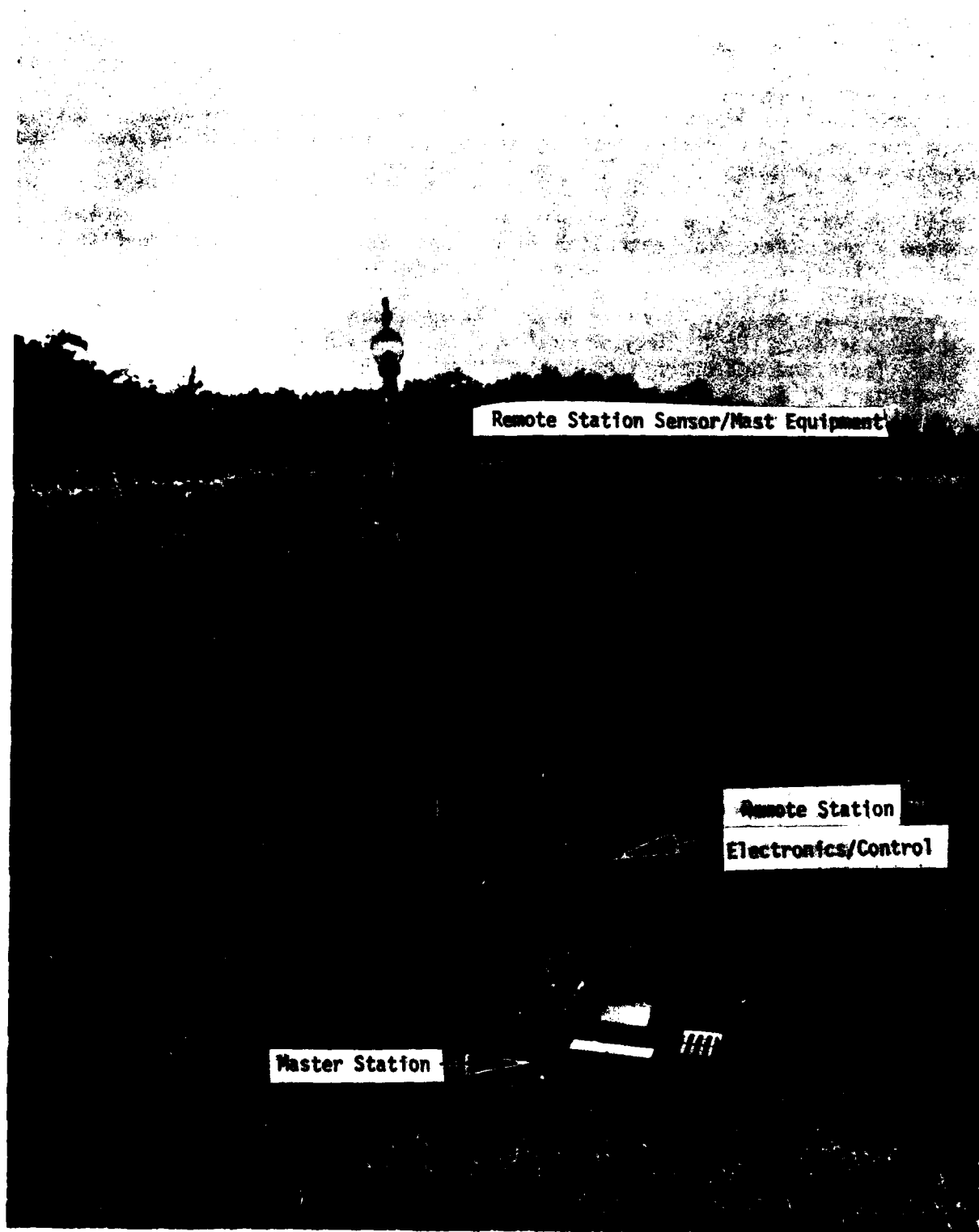


Figure 1. System photograph.

(4) developing a system with the meteorological data accuracies required by tactical systems, to enable use of meteorological data as a positive combat tool.

3. SYSTEM DESCRIPTION AND OPERATIONAL THEORY

3.1 General System Description

The AN/TMQ-30 System is a self-contained, programmable, automatic-reporting surface meteorological set designed to operate in remote field environments over a wide range of environmental conditions. When deployed, the remote stations will report the on-site surface meteorological conditions of wind speed and direction, temperature, atmospheric pressure, and relative humidity over an RF data communications channel to the master station. Battery condition, time on station, and two "spare" channels of information are also reported. The master station receives these meteorological data transmissions from all remote stations and provides a printed summary of each parameter in tabular format.

The AN/TMQ-30 can operate in two distinct modes in performing the mission: as a complete network, consisting of the master station and 20 to 36 remote sensing stations, or in a single stand-alone mode for use at Forward Armament and Refueling Points or tactical airfields.

The system will report windspeeds measured by a crossed-pair of resistive hot-wire elements, with wind direction also being derived from this hot-wire grouping. Temperature is measured with a platinum resistance spiral sensor connected as a Wien bridge. Relative humidity is measured by a polymer thin-film capacitance sensor.

The remote stations are programmed before operation by a code programmer, which is an article of hardware developed for, and associated with, the Remotely Monitored Battlefield Sensor System (REMBASS), a family of tactically employable intrusion detection sensors operated as a network. This code programmer inserts the proper identification (ID) and radio frequency channel number (a set frequency) in the transmitter/programmer module of the remote station. A remote station is packaged in two enclosures, the electronics/power module and a transport case containing the sensors and mast.

The master station is programmed for time, acceptable ID numbers, and RF data communications channel by means of the incorporated Keypad.

3.2 Operating Concept

With a full complement of remote stations, a network capable of sensing and reporting the meteorological parameters of interest can be deployed within an Army division's operating zone. According to a self-timed schedule of time-sharing (time-division multiplexing), each remote station in turn goes through the following sequence of operation:

- (a) apply power to sensors and associated electronics,
- (b) take meteorological measurements,

- (c) encode data into digital format,
- (d) organize encoded data into message format,
- (e) transmit formatted message,
- (f) "power down" to clock (standby) condition.

Time for initiation of the reporting sequence at a particular remote station is controlled by an electronic real-time clock that has been synchronized to all other station clocks during the deployment scheme. When time of day is equal to the preset value that is unique for each station in the reporting network, the station electronics initiate the above operating sequence.

3.2.1 Meteorological Parameters

Windspeed. Windspeed measurements are made over a range of 1 to 25 m/s with an accuracy of ± 1 m/s. The final value is an average of the sensed windspeed sample over a 1-min interval.

Wind Direction. Wind direction is measured over a range of 360° with an accuracy of $\pm 10^\circ$. The final value is an average of the sensed wind direction sampled over a 1-min interval. The low threshold windspeed required to make directional measurements is 0.5 m/s with an initial direction deviation of 20° .

Temperature. The temperature measurement range is 0° to $+50^\circ\text{C}$ with an accuracy of $\pm 1.6^\circ\text{C}$. The sensing element is shielded from direct and indirect solar radiation and is mounted to minimize stagnation during minimum wind conditions.

Relative Humidity. Relative humidity is measured over a range of 0% to 80% with an accuracy of $\pm 7\%$ and $\pm 11\%$ from 80 to 100% relative humidity. Humidity measurements are valid over an ambient temperature range of 0° to $+50^\circ\text{C}$. The sensor element recovers from an environment of 100% relative humidity in 1 min or less.

Pressure. The range of pressure measurements is 580 to 1080 mbar with an accuracy of ± 3 mbar. A differential measurement technique is used, whereby differential values measured by the sensor at the remote station are added to or subtracted from a reference value of 830 mbar at the master station to yield absolute pressure.

3.2.2 Other Data

Along with the five basic meteorological parameters, the remote station electronics contain circuitry that sense when battery power is approaching a low limit condition and transmit an "End of Life" (EOL) code as part of the data report message. Additionally, each report includes the number of days that the remote station has been deployed.

For data analysis purposes at the master station, the remote station transmits a code for a single character to be placed in front of the ID column, which indicates the type of message being sent. The characters are

T - Meteorological sensor test message

X - Transmit test message

F - A fault exists in one of the five sensor parameters

(No character) - Normal report

3.2.3 Message Characteristics

Data reports are organized into a 101-bit message stream. Within this structure, the first "field" of 20 bits contains the sync preamble, message start, message type, ID, and parity bits. The meteorological data fields are appended to this base. The data transmission rate is 1200 Bd; with a message length of 101 bits, message duration is 84 ms.

3.2.4 Timing/Control

The transmission schedule for a particular remote station is determined by a combination of the station ID and two other presettable parameters that select (a) one of the two half-hour periods within an hour and (b) the number of reports per hour (one or two). By assigning 6 bits for station ID a maximum of 64 unique IDs can be assigned. IDs 1 through 20 are assigned in the current TMQ-30 system.

Each remote station incorporates means for setting station ID (1 through 20), report start interval (0 or 1), and report repetition rate (1 or 2) into the electronic station clock function prior to or during system deployment. Since the station ID code by itself uniquely identifies the reporting station, only this code is transmitted in the report message for purposes of station identification.

The interval of time allocated to an individual station for message transmission is a unique time slot dedicated exclusively to that station. The station ID code defines the start time of one of 20 unique time slots, so that the actual time of transmission takes place at (station ID x 0.5 min) after the hour or half hour. Time slot duration is set to minimize the likelihood of more than one station transmitting simultaneously due to station clock drift. For the present system, the maximum allowable time slot duration is 30 s.

When station time approaches the exact hour or half hour, the sequence of events for energizing the sensors and accumulating the data starts. When station time coincides exactly with the preassigned transmit time, message transmission occurs. To avoid mutual interference among stations, all station clocks must be synchronized. Control of time slot overlap is provided by the inherent accuracy of individual station clocks.

3.3 Master Station

3.3.1 Operating Concept

The master station is located within RF communication range of all remote stations in the reporting network and monitors the channel frequency assigned to the network. As each remote station reports in turn, the master station receives the messages and provides a printed output of the measured meteorological data.

The master station is a complete monitor center, consisting of an antenna subsystem, RF receiver, processing electronics, real-time clock, printer, and power supply. The master station electronics, are centered on three RCA CP1802 microprocessors: one each for system electronics, receiver/front-end control, and printer function control (figure 2). Upon receipt of a transmission, the master station validates the incoming message, generates an audible alarm to indicate reception of a valid message, decodes the meteorological data, performs required calculations or manipulation of measured data, and prints out these data along with the time of message reception.

The Receiver/Synthesizer Unit receives transmissions via the antenna of the master station. This data is passed to the Front-End Processing Module for decoding and validity checking. Meteorological and station information and the parity status are passed to the Control Processor Module for display. The Control Processor Module reads the Real-Time Clock so that the time of message reception may be included in the displayed data; the data is then displayed on the printer.

The Receiver/Synthesizer Unit included in the master station may be set to any one of 600 channels (frequencies). Future expansion involving the simultaneous use of two frequencies can be accommodated with the inclusion of a second Receiver/Synthesizer Unit. The wiring for this extra unit has been included in the present master station.

The Keypad provides the means of controlling the master station. In general, any keystroke causes a display corresponding to the depressed key to appear on the 8-digit readout located directly above the Keypad. The Keypad-display combination functions much like a pocket calculator. Provision has been made to enable the operator to set or read the clock of the master station and to set, modify, or examine the RF channels (frequencies) to which the master station's Receiver/Synthesizers are tuned. Any one of the 600 channels is allowed. The Keypad can also be used as an 8-digit, four-function calculator.

Also provided is a reference time source for synchronizing remote station clocks prior to system deployment. Using the master station time display as a reference, a remote station clock can be set slightly ahead in time and then held in an idle condition until a convenient time mark (such as a minute mark) is reached by the master station clock. As this mark is reached, the remote station hour clock (counting minutes and seconds) is started, and the two station clocks are synchronized. The absolute accuracy of the master station clock is not critical; only relative time among remote stations is important in controlling the message transmission schedule within a network.

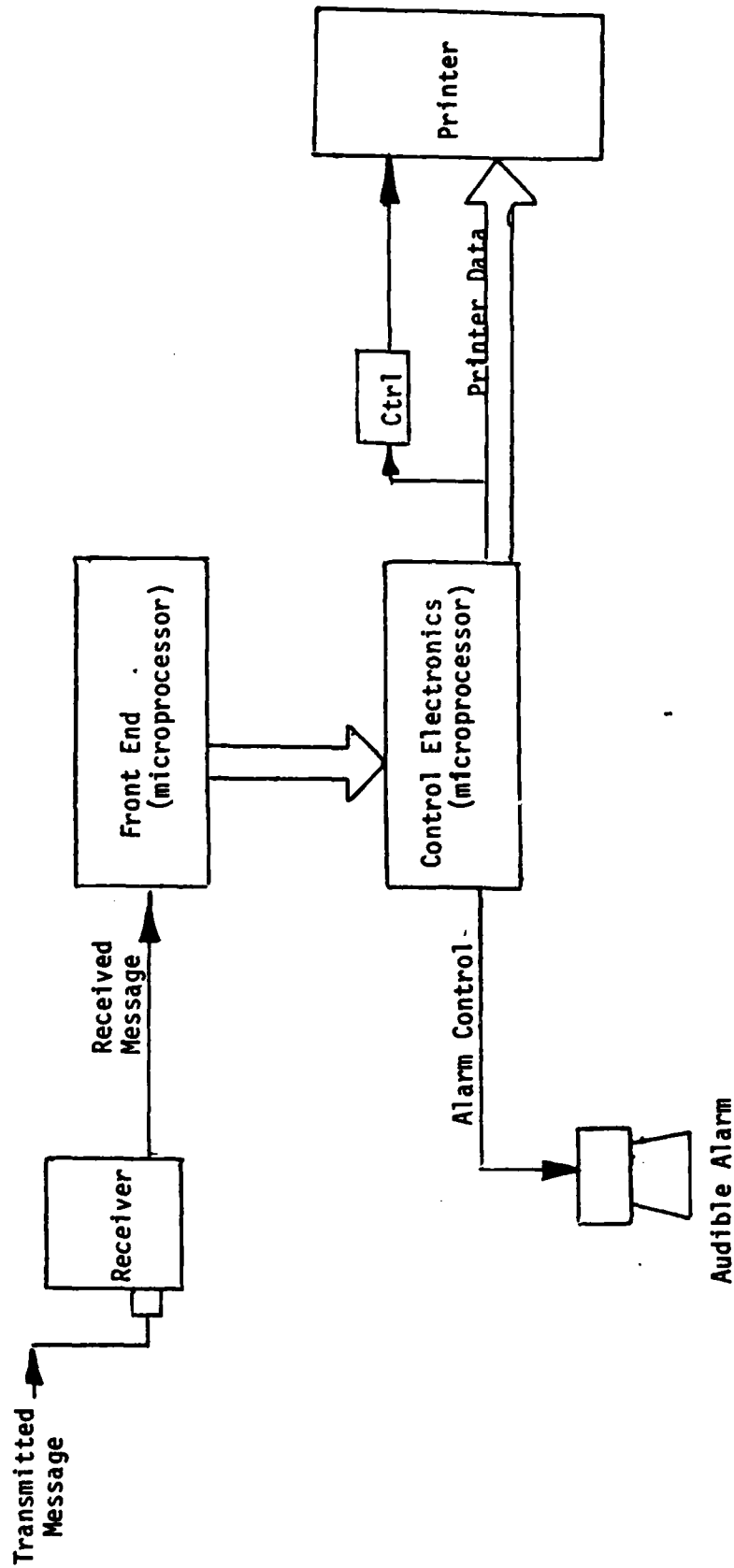


Figure 2. Master station flow diagram.

3.3.2 Message Description

The transmitted message containing the sensed meteorological data includes a "core" message, station power status, and deployed time on station data.

The core message of 20 bits is sent out first, and the ensuing bits contain the required meteorological data. A total of 101 bits constitute a message. The core consists of a message header containing a synchronization pattern (8 bits), a message start bit, a message type field (4 bits), a station ID field (6 bits), and a core message parity bit. The master station synchronizes its data decoding logic with the synchronization and start bit pattern, and then proceeds to decode the remaining data in the core message. Checks are performed for odd parity over bits 10 through 20 and for the TMQ-30 message type (0011 pattern). If, in addition, the parity bit for the first data field (bit 20) is correct and if the reporting ID is enabled, the message is considered valid.

A valid message activates the audible alarm and displays the message data on the printer. The time of day is extracted from the master station clock and displayed along with data contained in the part of the message following the core message.

The meteorological data message is recorded on a printer display. A parity check is performed on each of the measured parameters, and only valid data is printed. Asterisks are printed in place of invalid data. Columnar message information is as follows:

<u>PARAMETER</u>	<u>PERMISSIBLE VALUES</u>
1. Station ID	1 to 20
2. Windspeed (meters per second)	0 to 25
3. Wind Direction (degrees)	0 to 360
4. Temperature (degrees Celsius)	-40 to +50
5. Relative Humidity (percent)	10 to 100
6. Atmospheric Pressure (millibars)	580 to 1080
7. Battery Power Status	OK or EOL
8. Number of Days on Station	0 to 30

Another parameter, relating to the master station electronics, is also displayed. When low battery power at the master station is sensed, both an audible alarm and a visual indication are provided. The visual indication is presented on the Keypad display.

3.4 Remote Stations

3.4.1 Operating Concept

The remote station is located within RF communication range of the master station and transmits sensed and formatted meteorological data to the master station over any one of 600 RF channels, programmed prior to deployment. This unit will report meteorological conditions existent at the site of deployment, at its preprogrammed intervals. The data collected from the sensors, which are attached to the electronics box, are formatted and transmitted serially over an RF data link at a 1200-Bd rate. Like the master station, the remote

station electronics are centered on an RCA CP1802 microprocessor, which controls the remote sequence of operation. The remote units are structured in a modular manner. Modules incorporated are as follows:

- Monitor
- Read data
- Format
- Transmit

3.4.2 Monitor Module

When power is first applied, the microprocessor is reset and the program is initialized. After initialization, the program enters the monitor module, where the microprocessor checks for a test meteorological data or a test transmitter request. These are constantly being checked. In addition, each 30 min timing marks are sent to the microprocessor interrupt line, resulting in system sense activity startup.

Each occurrence of the 30-min interrupt will increment a counter by one. When this counter reaches 48, the time-on-station counter (days) is incremented. If the system is set to report when the 30-min timer mark occurs, power is applied to the meteorological sensors. If a test condition is required (test meteorological data or test transmitter), flags are set and that test routine is generated. Circuitry exists to store some data from a regular station activate cycle if one of those test conditions is occurring during a regular cycle period. A normal report is not made under these conditions. Control is passed to the read data module under all conditions.

3.4.3 Read Data Module

This module performs a calculation of gain/offset errors to compensate the analog circuitry, reads data taken and offsets by the resultant compensation, collects and adds 128 wind samples, reads all other meteorological data into random access memory (RAM), and reads station ID and battery condition separately from the signal acquisition subroutine. Control is passed to the format module when the meteorological sensors are powered down.

3.4.4 Format Module

The format module formats and stores in RAM, the complete message in the correct field and bit order, according to the predefined message structure. This module also performs the wind data averaging calculation and tests the meteorological data for out-of-range conditions. Control is passed to the transmit module from the format module.

3.4.5 Transmit Module

The transmit module controls the transmitter enable lines and supplies the message data to the transmitter at a precise rate of 1200 Bd. This rate is obtainable to within 4 μ s using microprocessor-controlled timing loops.

3.4.6 End-of-Life Battery Condition

The remote station's electronics detect the impending of the station's battery. When this condition occurs, an EOL bit is set in the message. The master station then displays an "EOL" in the "BAT" column of the resulting printed record.

3.4.7 Software/Hardware Organization

The data processing section of the remote station is microprocessor-controlled and consists of an RCA 1802 microprocessor, read-only memory (ROM), RAM, and input/output ports. The entire remote station program is contained within 2400 bytes of ROM. Two 2716 EPROMs (erasable, programmable read-only memories) (4096 bytes total) are incorporated, resulting in a program growth potential of 1696 bytes without adding additional EPROM. The microprocessor board is wired to accept four 2716 EPROMs, which allows for a maximum program size of 8192 bytes without adding additional memory boards to the system. The microprocessor RAM allocation is currently 4096 bytes, of which 83 bytes are currently used.

3.4.8 Sensors

Windspeed¹. Windspeed is measured by means of an Environmental Instruments, Inc., series 200 Dual Component Wind Set, which provides the measurement of two 90° wind components, windspeed, and barometric pressure. The wind components are measured by two pairs of heated resistive sensing elements, placed at right angles to each other in the horizontal plane. The outputs of these elements are processed in a manner that yields sine and cosine functions of the wind vector blowing against the sensing elements.

Ambient temperature is measured by a platinum resistance temperature sensor, which exhibits a resistance of approximately 200 Ω at 0°C and is calibrated over a range of -70°C to +40°C.

Each wind component is measured by a film resistance sensor constructed of two closely spaced wire elements. These elements are supported in a manner that provides thermal isolation between the elements, to determine instantaneous wind speed and wind direction. The pair is continuously joined along their length, and one element serves as a leading wire. Flow between the elements is prevented by the bridging material. Their cross-sectional area (1.4 mm) is much smaller than their length (31 mm). Each element consists of a ceramic substrate supporting a metallic film, which is in turn protected by a glazed fused silica coating. The metallic film is stable and has a high positive temperature coefficient of resistance. Wires are attached to both ends of the elements, which then form two series resistances in one arm of a Wheatstone bridge. The wires are electrically excited so that total resistance is constantly maintained by a closed loop feedback amplifier. The potential at the junction of the two series-connected resistive elements is sensed to derive the sign (+ or -), which indicates the wind direction across the

¹Operator's Manual, Series 200, Model 255, Environmental Instruments, Incorporated, 4 Mercer Road, Natick, MA 07760.

element pair. The reference arm of the Wheatstone bridge incorporates a temperature sensor whose temperature coefficient is adjusted to compensate the wind sensing element pair. This temperature sensor is best described as a heat-loss, mass-flow sensor and is operated at a constant temperature elevation above sensed ambient temperature.

The total voltage appearing across the sensing element pair is used to indicate P_v , mass flow. The windspeed output signal is nonlinear and contains the constant zero velocity self-heating signal, a fourth root term as a function of airflow velocity, and turbulence components that result from gustiness in the airflow. The signal conditioning electronics within the probe are used to zero the output for zero wind conditions and set the full-scale output signal for each axis.

A comparator is connected across the sensing element pair to detect the electrical change of the sensing element midpoint as the wind shifts in direction on either side of the sensing element pair. The comparator output is connected to an external pack that contains linearization circuitry and a polarity output amplifier whose output sign switches between positive and negative as the wind shifts direction.

In general, the final output is in the form of

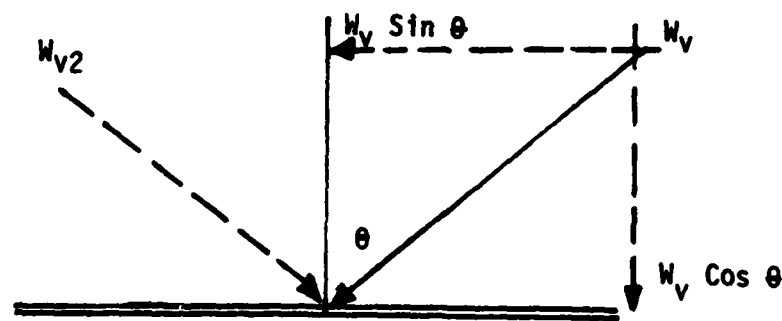
$$\frac{P_a}{P_r} = V_w \text{ Cosine } \alpha \text{ for the crosswind axis,}$$

and

$$\frac{P_a}{P_r} = V_w \text{ Sine } \alpha \text{ for the headwind axis,}$$

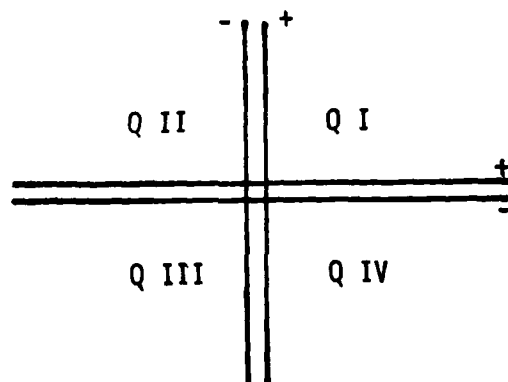
where P_a is the ambient air density, P_r is reference density at standard conditions, V_w is the windspeed and α is the azimuth angle of the wind vector.

Wind Direction. The wind direction probe is constructed with two sensor wires arranged as paired coplanar axial elements. Within each sensor pair, one wire element is biased positively and one negatively. The wires exposed to horizontal windflow will exhibit a positive output when the positively biased wire is upstream and allow a negative output when the negatively biased wire is upstream. The theory requires the elements to be maintained at a steady heat state. Therefore, in the presence of wind, cooling by its passage, the elements require greater current and voltage to the upstream wire. This voltage rise is proportional to the output. Since the probe is fixed, any wind other than from 90° (i.e., directly perpendicular to the wire pair) will result in a vector of wind impinging the sensor pair. Thus, using only one pair, the angle of wind vector will result in two force components, $W_v \text{ Cos } \theta$ and $W_v \text{ Sin } \theta$. However, the force component values from θ in the first quadrant or second quadrant are equivalent:



Wire Pair X
Winds W_v and W_{v2} yield equal output from wire pair X
(i.e., no direction is discernible).

The value of concern is $W_v \cos \theta$, because $W_v \sin \theta$ is parallel to the wire elements and impinges only the diametric cross section of the wire pair, not the main perpendicular area. Therefore, the wind velocity of interest to this pair of wire elements is essentially equal to $W_v \cos \theta$. By positioning a second set of wire elements perpendicular to the original pair, biased in the same manner, the actual direction can be derived. Positive bias is on the right element of the vertical pair and the top element of the horizontal pair, as shown below.



Therefore, for finding directivity, a wind from Quadrant I will result in a positive output from both elements. In contrast, a wind from quadrant III will result in negative outputs from both elements.

Temperature. The ambient temperature transducer is a platinum resistance spiral contained within an aluminum oxide shell. It is mounted on two posts alongside the pressure release port of the sensor head. The temperature transducer is a device whose resistance is characterized as a function of temperature. Temperature signal-conditioning amplifiers are contained within the probe and provide scaling and offset corrections for the temperature output signal to the external electronics.

Pressure. The pressure transducer is a variable-capacitance ceramic device. The symmetrical ceramic capsule deforms proportionally to the applied pressure. As the pressure increases, the electrodes move closer, thus increasing the capacitance. A reference pressure is made by sealing the capsule under high vacuum. The incorporated range of interest for meteorological sensing is 580 to 1080 mbar.

Relative Humidity. The basic probe has a plastic grid, a sensor guard, and a 1.5-m connecting cable. The measurement technique is based upon the capacitance change of a polymer thin-film capacitor. A $1\mu\text{m}$ thick dielectric

polymer layer absorbs water molecules through a thin metal electrode and causes a capacitance change proportional to the relative humidity. The thin polymer layer reacts very quickly, and the response time is therefore very short: less than 1s to 90% of the final value of relative humidity. The sensor responds to the full range from 0% to 100% relative humidity. The response is essentially linear, with small hysteresis and negligible temperature dependence.

The sensor is mounted in a small probe that contains all the electronics necessary to provide a millivolt output for indicating or recording. The output of the probe electronics is linear from 0% to 100% relative humidity. Since the capacitance change of the sensor is sensitive only to the ambient humidity, temperature compensation is not required for this application. The probe body is watertight and made of corrosion-resistant aluminum. Immersion in water does not affect the calibration. When used outdoors, the presence of sulphur dioxide may cause some corrosion of the metal electrodes of the sensor; therefore, a sintered 12 μ m brass filter is used as an atmospheric guard.

3.5 Power

Both master and remote stations operate on battery power, with the master station capable of AC power operation through the use of a power converter unit. Both units use BA-5590/U Primary Lithium Organic batteries, each of which is constructed 10 Li-SO₂ D cells. Voltage output is 12 or 24 V, depending on the connections made, and the contained capacity at 70°F is 10 Ah (30-h rate). This battery is used because it is the highest energy density system known to date. Four BA-5590 batteries will yield approximately 21 days of operation at 70°F (see test results in section 4.1.4). One BA-5590 will operate the master station an average of 35 h with reports generated half-hourly.

A substitute for the BA-5590 is the BB-5590/U sealed Nickel-Cadmium Battery, which is a 12- or 24-V, 1.5-Ah battery. The power density is less than one-sixth that of the BA-5590, but the battery can be recharged, thus making it cost-effective for testing purposes.

Current costs of these batteries are \$62.50 each for the BA-5590 and \$250.00 each for the BB-5590.

4. TEST RESULTS

Three series of tests were made on the prototype AN/TMQ-30 System: in-plant acceptance tests at the RCA facilities in Burlington, MA; performance tests and government acceptance tests for specification conformance at White Sands Missile Range (WSMR), NM; and field/operational capability tests at Yakima Firing Center, Yakima, WA. Each series of testing was designed to achieve specific purposes.

4.1 In-Plant Acceptance Tests

The in-plant testing was designed to ascertain that the TMQ-30 system was capable of

a. Measuring humidity readings to within specified accuracies. (WSMR humidity measurement capabilities were not available for independent government tests.)

NOTE: All measurement accuracies are specified to apply over a temperature range of -18°C to +50°C.

b. Providing a mission life of at least 7 days.

c. Accurately transmitting data to the master station within the specifications of range and total system accuracy.

d. Adequately displaying the reported data.

The following tests were made

a. Humidity cycling tests

b. Twenty-four hour operational test

c. Simulated meteorological parameter tests

d. Operational life power consumption tests (to calculate operational life)

e. Multiple system performance tests

f. Master station function tests

4.1.1 Humidity Cycling Tests

The humidity sensor/circuitry checks were made in a humidity chamber at the RCA plant facilities on 14 Jan 81. Table 1 shows the data collected, which are represented graphically in figure 3.

TABLE 1. RELATIVE HUMIDITY RESULTS, IN-PLANT TESTS

Chamber RH (%)	10	20	30	40	50	58	60	70	90
S/N 1639, AN/TMQ-30	9	19	27	37	48	54	56	70	92
S/N 1781, AN/TMQ-30	8	18	26	37	47	56	59	71	90

4.1.2 Twenty-Four Hour Operational Test

This test was conducted to verify operations in existing ambient conditions over a 24-h period. Data on clock drift, low temperature operation, and distance transmission resulted. The tests were conducted in the two-reports-per-hour mode, with the exact time set in both master and remote units. The time was verified prior to test initiation. The remote stations were transported 1 km from the master station. Table 2 shows a synopsis of data transmission success during the 24-h period.

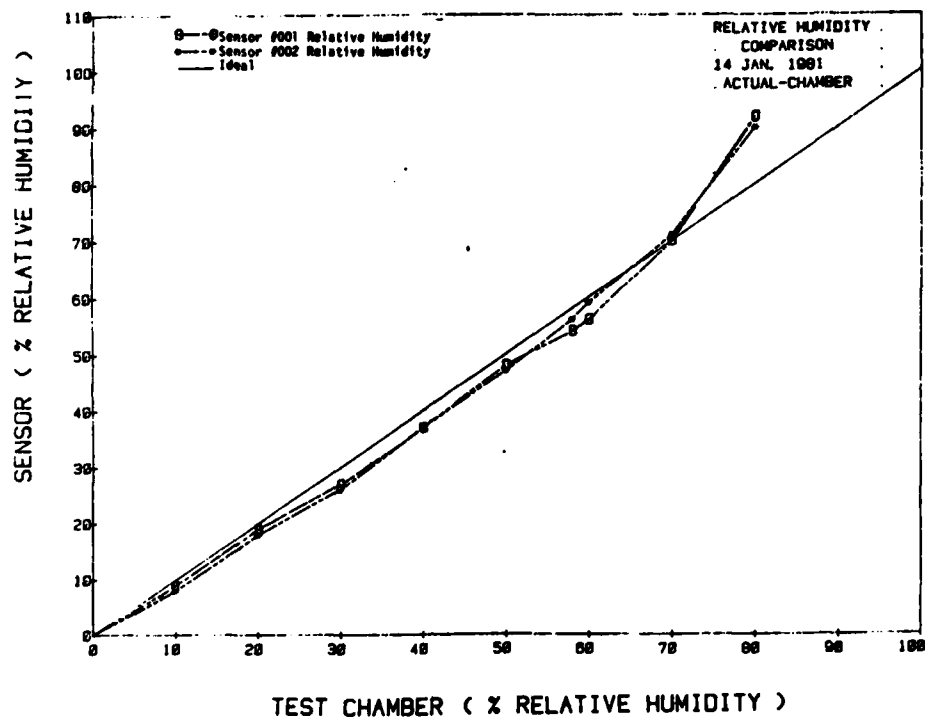


Figure 3. Relative Humidity.

Discrepancies were noted also in a 4-s overall time change of the master station clock. This occurred in two 2-s steps, at the 1430 and 0900 reporting times. After the acceptance test period completion, RCA personnel performed troubleshooting to determine the cause of these variances (time changes and missed reports). Replacing the master station data processing CPU (central processing unit) chip corrected both problems.

4.1.3 Simulated Meteorological Parameter Tests

These tests were designed to verify operation of the system data transfer handling, and presentation functions with controlled, simulated sensor inputs. Repeatability of system transfer function characteristics was also a test objective.

In this test, a met simulator device was used as input to the remote station electronics. The simulator was a series of voltage dividers fabricated with 10-turn precision potentiometers in order to precisely control voltages simulating sensor outputs. Four tests were made, as shown in table 3.

The remote station electronics are designed so that if an out-of-range meteorological sensor voltage is sampled, the MET TEST lamp will blink for 5 s. Also, when this condition exists, the master station printout will indicate a fault (but will not indicate which sensor is at fault) by inserting

"F" prior to the station ID number reporting. An examination of reported data should show clearly the sensor at fault. Both functions operated satisfactorily.

TABLE 2. RESULTS OF 24-H TEST, 14 AND 15 JAN 1981.
(MISSED MESSAGES INDICATED BY "X.")

<u>Time</u>	<u>STN 1</u>	<u>STN 2</u>	<u>Time</u>	<u>STN 1</u>	<u>STN 2</u>	<u>Time</u>	<u>STN 1</u>	<u>STN 2</u>	<u>Time</u>	<u>STN 1</u>	<u>STN 2</u>
1130		X	1730			2330			0530	X	
1200		X	1800			2400			0600		
1230	X		1830	X		0030			0630		
1300			1900			0100			0700		
1330	X		1930		X	0130			0730		
1400			2000			0200			0800		
1430	X		2030			0230			0830		
1500	X		2100			0300			0900		
1530			2130			0330			0930		
1600	X		2200			0400			1000		
1630			2230	X		0430	X		1030		
1700			2300		X	0500			1100		

TABLE 3. METEOROLOGICAL SIMULATOR SETTINGS

<u>Simulation Function</u>	<u>Potentiometer Setting</u>	<u>Meteorological Equivalent</u>
TEST 1		
Vx	+.707 V	5 m/s
Vw	+.707 V	45°
HUM.	+10 mV	10%
TEMP.	0.0 V	0°C
PRES.	+2.500 V	830 mb
TEST 2		
Vx	+1.88 V	10 m/s
Vy	-6.84 V	110°
HUM.	+50 mV	50%
TEMP.	+10 V	50°C
PRES.	+4.904 V	1080 mb
TEST 3		
Vx	-2.758 V	18 m/s
Vy	-2.314 V	230°
HUM.	+90 mV	90%
TEMP.	-9 V	-45°C
PRES.	+.096 V	580 mb
TEST 4		
Vx	-.868 V	25 m/s
Vy	+4.924 V	350°
HUM.	+75 mV	75%
TEMP.	+5 V	25°C
PRES.	+3.654 V	950 mb

4.1 Operational Life Power Consumption Tests

The remote system power supply was monitored for quiescent (standby) current and active sensor/transmit cycle current, with the following results:

24-V standby current = 23.3 mA
24-V active current = 1.1 A

Since the remote unit accomodates 4 BA5590 batteries rated at 10 Ah each (40 Ah total),

$$\text{LIFE (days)} = \frac{40 \text{ Ah}}{I_s + \frac{3}{60} (I_a - I_s)} + 24 ,$$

where 3/60 = Active time, estimated at 3 min per hour,

$I_a = 1.1 \text{ A}$, and

$I_s = 23.3 \times 10^{-3} \text{ A}$.

Therefore Life in Days = 21.6 days

NOTE: All calculations apply at 75°F (24°C).

Master station power capability was specified at 24 h per battery. However, in field tests, times in excess of 36 h were experienced. During the 24-h testing, the master station power operated fully throughout the test, thereby meeting the specified criteria.

Multiple system performance was certified in the 24-h test.

4.1.5 Master Station Function Tests

These tests were performed to assure functionality of all Master station interoperability functions. The following sequence was performed to assure all functions operated normally.

<u>Function</u>	<u>Result</u>
Power Switch to BAT	Key Segments clear in one second
Printer Switch ON	Complete header printed out
Printer Switch SLEW	Printer advances the paper rapidly
Printer Illumination	Electroluminescent panel lights up. Verify intensity variation using the Printer Illumination control.
Display Lite Control	Keypad display illumination.

Verify intensity variation by use of this control.

"+" key

SONALERT Activation

Keypad activation was verified through the following sequence:

<u>Activation</u>	<u>Resultant Display</u>
Alarm Test	All Segments Activated
Bite	B
Call Patch	CP
Patch	P
DELE	--
Time Set	NONE
Call Time	Station Time (Hour, Minute, and Second)
RF SET	NONE
Call RF	NONE
A	CA-currently programmed RF channel No.
(	NONE
)	NONE
+	NONE
1	1
2	12
3	123
X	123
4	4
5	45
6	456
-	56088
7	7
8	78
9	789
+	55299
C	<u>NONE</u>
0	0
.	0.
=/EX	55299

Built-in test equipment was tested in the following sequence:

<u>INPUT</u>	<u>KEYPAD DISPLAY</u>
BITE 0 =/EX (RAM)	NO ERR
BITE 1 =/EM (ROM)	NO ERR
BITE 2 =/EM (CHANNEL FLAG)	NO ERR
BITE 3 =/EM (CHANNEL DATA)	NO ERR
BITE 4 =/EM (PRINTER)	NO ERR
BITE 5 =/EM (POWER)	NO ERR
BITE 6 =/EM (PRINTER POWER)	NO ERR
ALM TEST =/EX	(all segments of Keypad Display)

A "keep-alive" function, wherein all patch-table functions and the RF channel set are saved while the battery is removed for up to 5 min from the master station, is incorporated to allow battery changing without loss of these functions. Only the time of day has to be reset into the master station when the battery is changed. A low-battery condition is signaled by an audible "knock" from the sonalert when the battery is approaching end-of-life. Approximately 3 h then remain for operation. This function was tested and performed satisfactorily.

4.2 Performance Tests

The acceptance tests performed at the RCA plant assured operation of the system. The accuracy of the system met reports was tested at WSMR after delivery of the system.

No meaningful relative humidity tests were made during performance testing, due to the unavailability of a properly certified chamber during the test period. Unsupported readings were taken, which indicated the TMQ-30 relative humidity results were generally lower than others, such as sling psychrometer readings. It was determined during field/operational capability tests that TMQ-30 results averaged 14% below sling psychrometer results.

4.2.1 Wind Tunnel Tests

Wind tunnel testing was done at the ASL wind tunnel facility, which is a closed-loop tunnel with a 4- by 4- by 6-ft test area. Velocity capability of the tunnel is 85 mi/h and is measured by two sensors: below 10 mi/h by a Pitot-tube-eddy shedding hot wire anemometer, and above 10 mi/h by a manometer. Wind measurements were accomplished in the following manner: (1) the sensor was mounted on a rotating table within the test area and connected to the system electronics and master station outside the tunnel test area, (2) the wind velocity was stabilized at one of four tested velocities,

and (3) measurements were made as the test instrument was rotated in 20° increments through 360°. Measured wind speeds and directions and the tunnel wind speeds and table headings were recorded and plotted.

Figure 4 shows the wind tunnel equipment setup in various views. Figures 5 through 8 are comparative plots of values for S/N 001 (sensor number 2090), and figure 9 indicates the pattern of rotation of the differences. Figures 10 through 13 are comparative plots of values for S/N 002 (sensor number 2089), and figure 14 indicates the pattern of rotation of the differences. Figures 15 and 16 are system-indicated windspeed plots of 5, 15, and 25 m/s vs. direction, S/N 001 and 002 respectively. Plots of 2 m/s are not shown, since deviation was minimal.

4.2.2 Temperature Tests

Temperature laboratory comparison testing was done at the WSMR calibration laboratory. The AN/TMQ-30 sensors were tested against National Bureau of Standards (NBS) traceable baseline instrumentation. Temperature measurements were made in a Tenny "TH-Jr" Model 76H502 temperature/humidity chamber with a calibrated readout using a platinum resistance thermometer sensor. Testing commenced after a 4-h stabilization cycle and was cycled low-high-low. Table 4 contains the readings taken during the tests, while figure 17 is a plot of the same values.

TABLE 4. TEMPERATURE DATA

<u>Test Chamber (°C)</u>	<u>S/N #001 (°C)</u>	<u>S/N #002 (°C)</u>
-40.0	-39.0	-39.0
-30.0	-28.0	-31.0
-20.0	-21.0	-22.0
-10.0	-11.0	-11.0
0.0	-2.0	-1.0
10.0	9.0	9.0
20.0	18.0	19.0
30.0	28.0	29.0
40.0	40.0	39.0
50.0	48.0	49.0

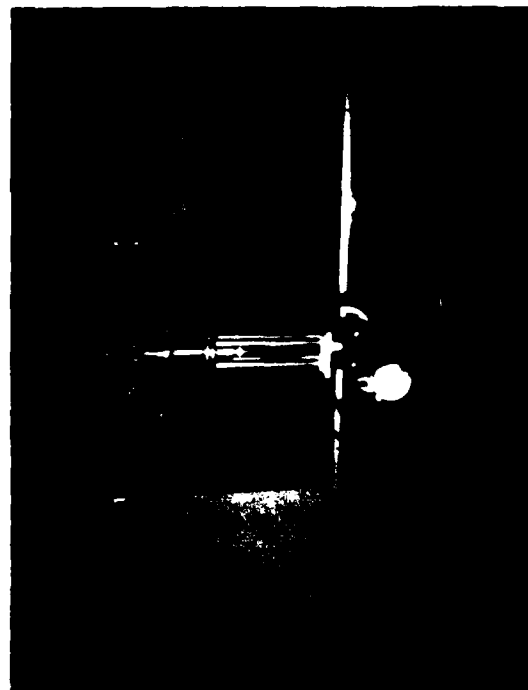
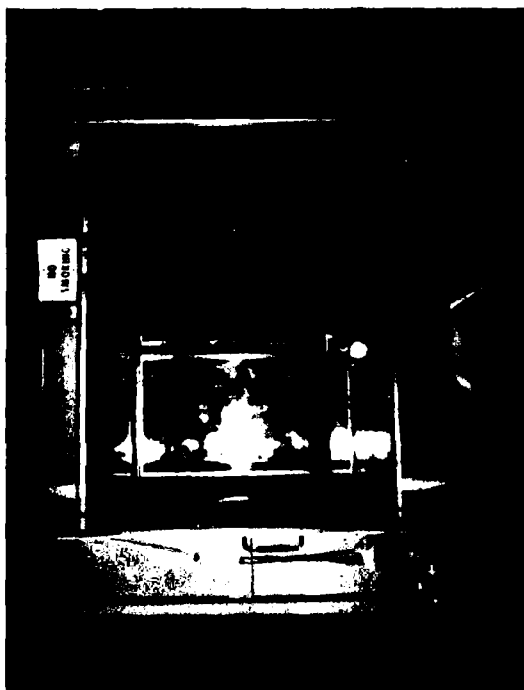


Figure 4. Wind tunnel test setup.

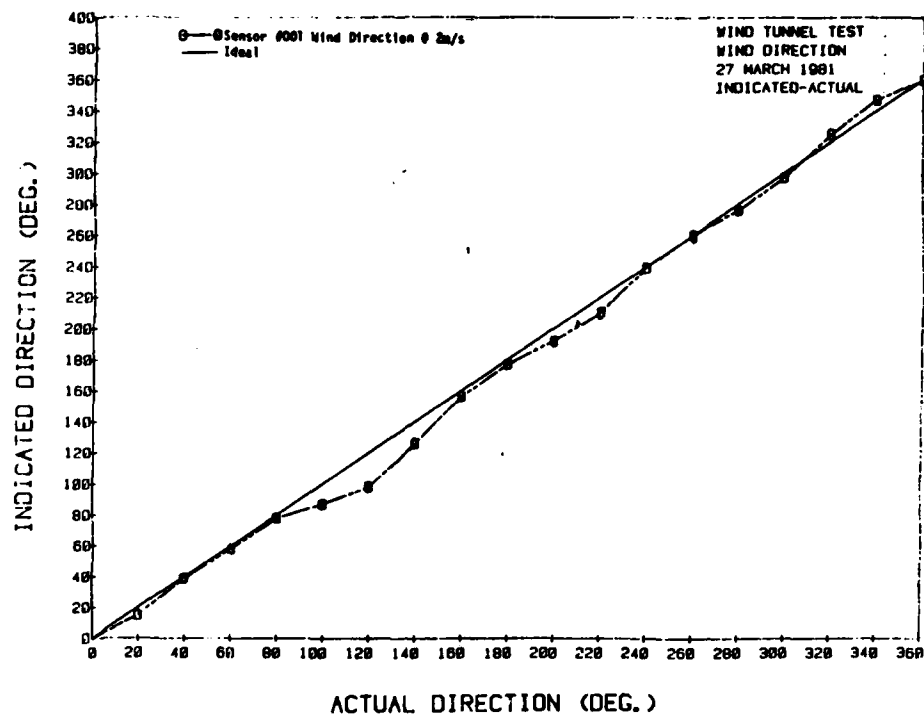


Figure 5. Wind direction, 2 m/s, S/N 01 (sensor number 2090).

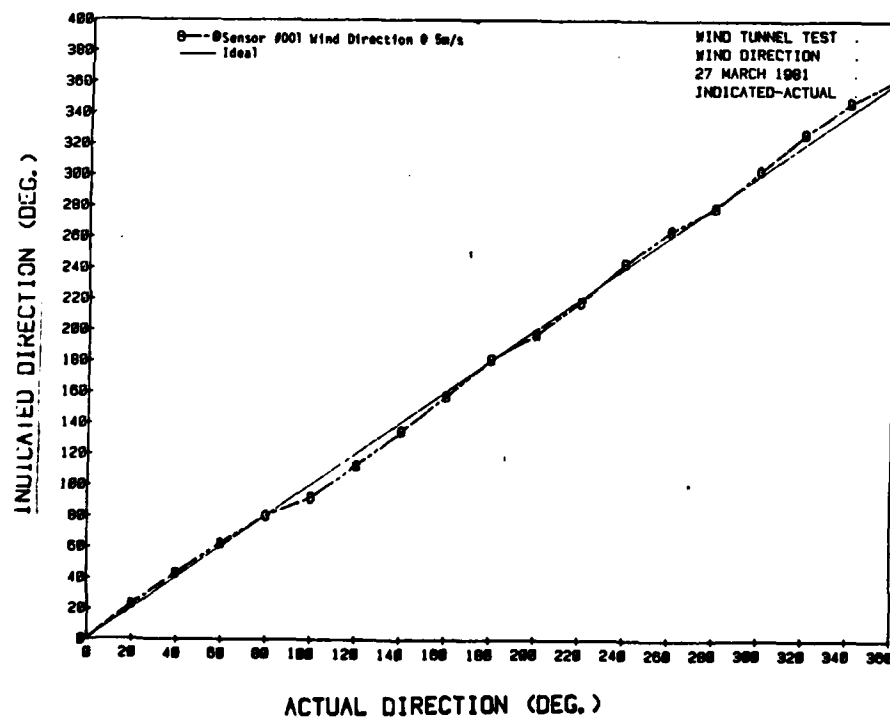


Figure 6. Wind direction, 5 m/s, S/N 01 (sensor number 2090).

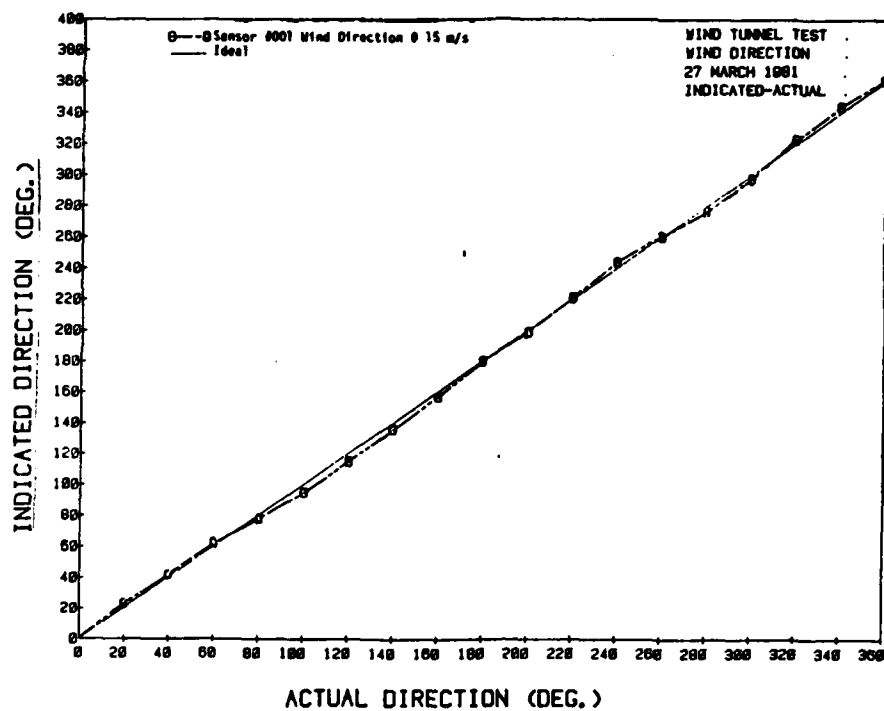


Figure 7. Wind direction, 15 m/s, S/N 01 (sensor number 2090).

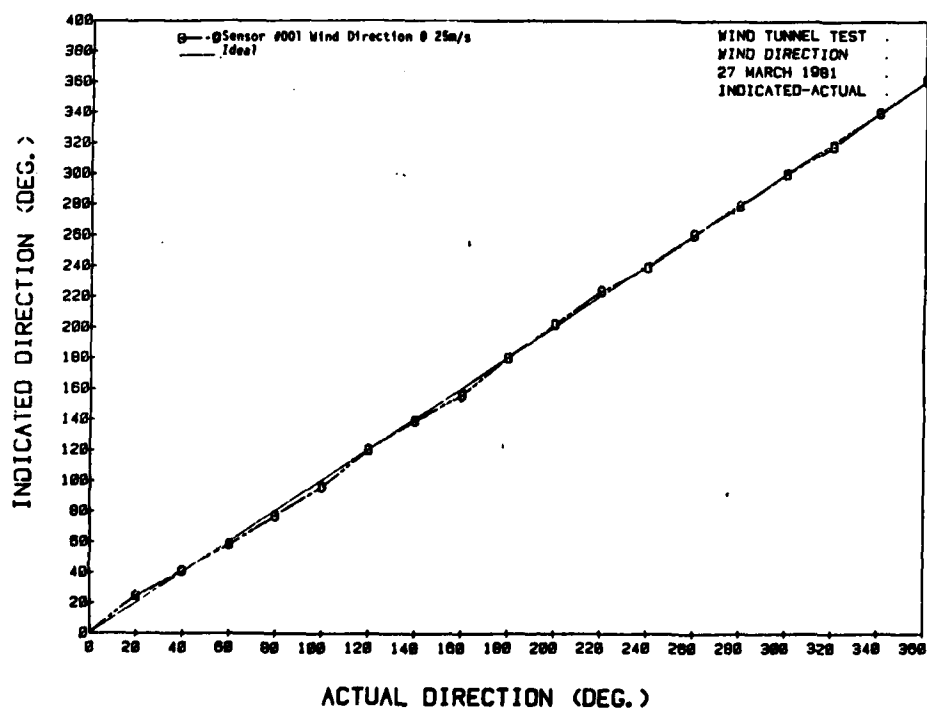


Figure 8. Wind direction, 25 m/s, S/N 01 (sensor number 2090).

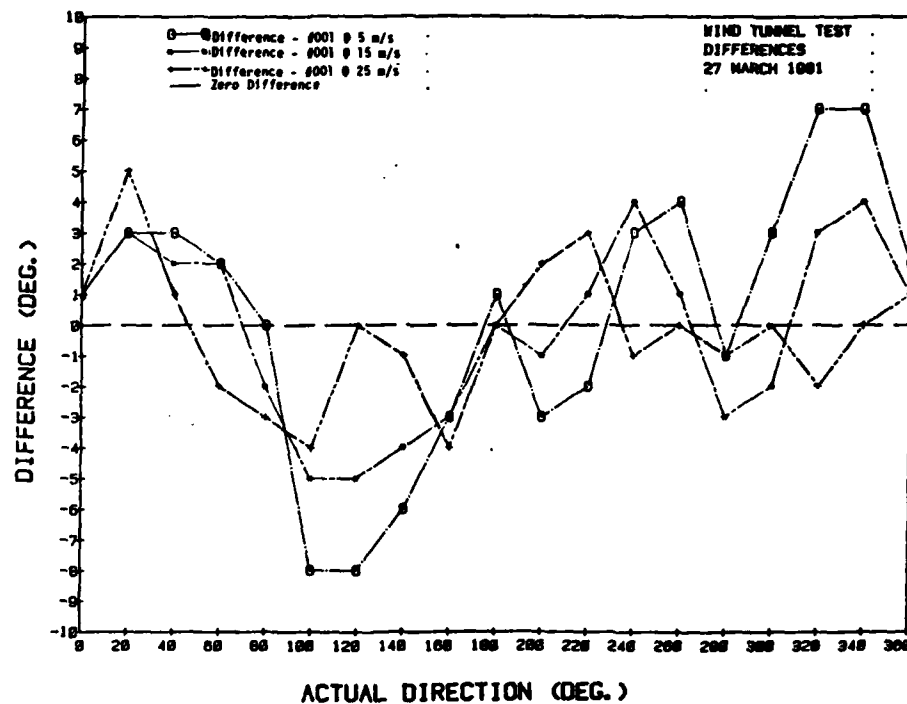


Figure 9. Difference values, wind direction, S/N 01 (sensor number 2090).

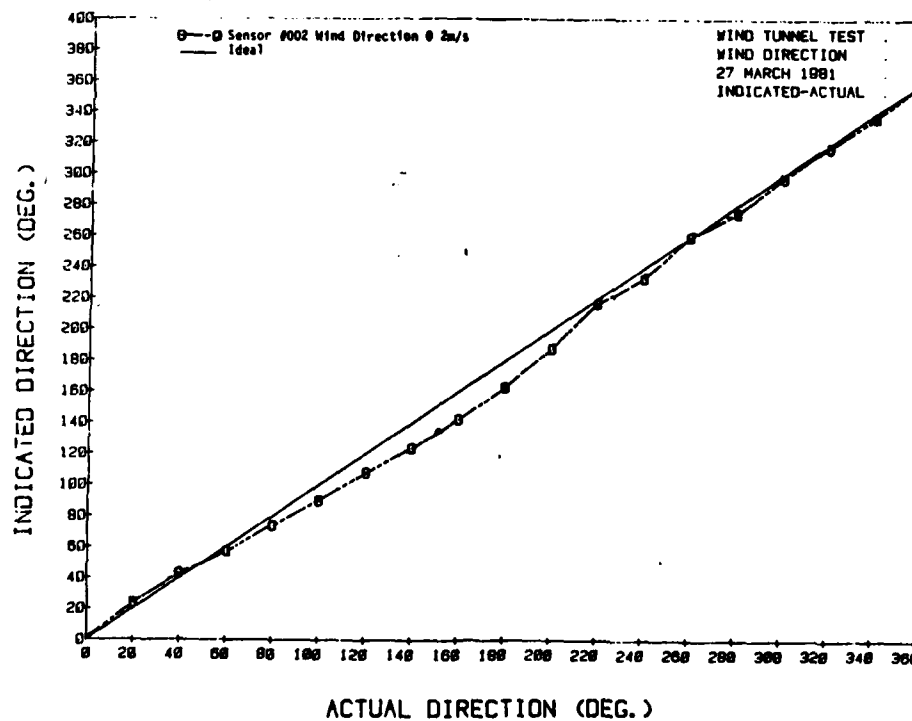


Figure 10. Wind direction, 2 m/s, S/N 02 (sensor number 2089).

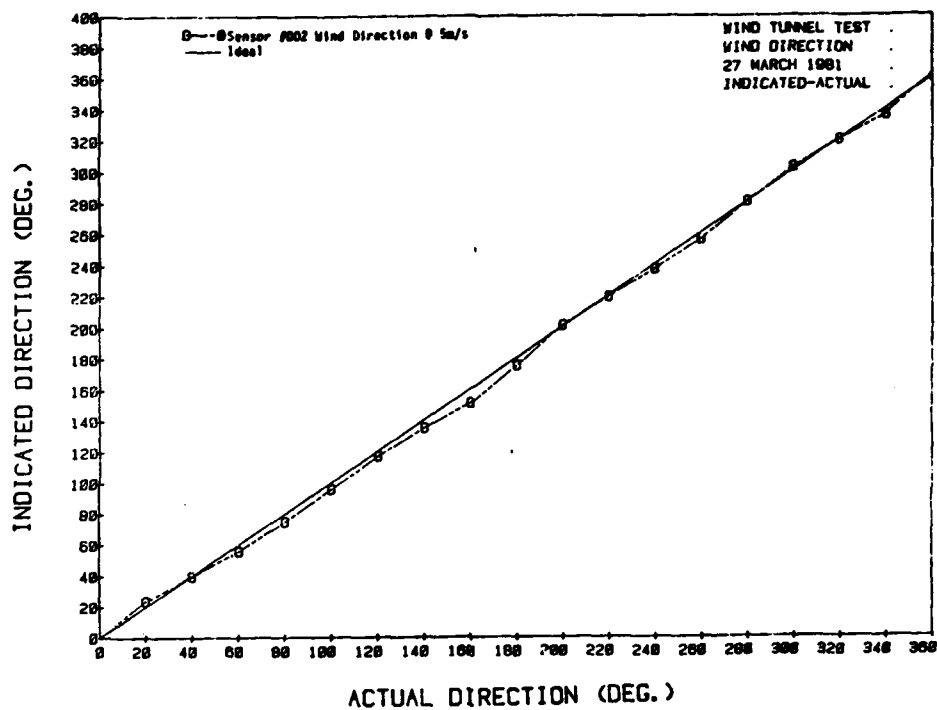


Figure 11. Wind direction, 5 m/s, S/N 02 (sensor number 2089).

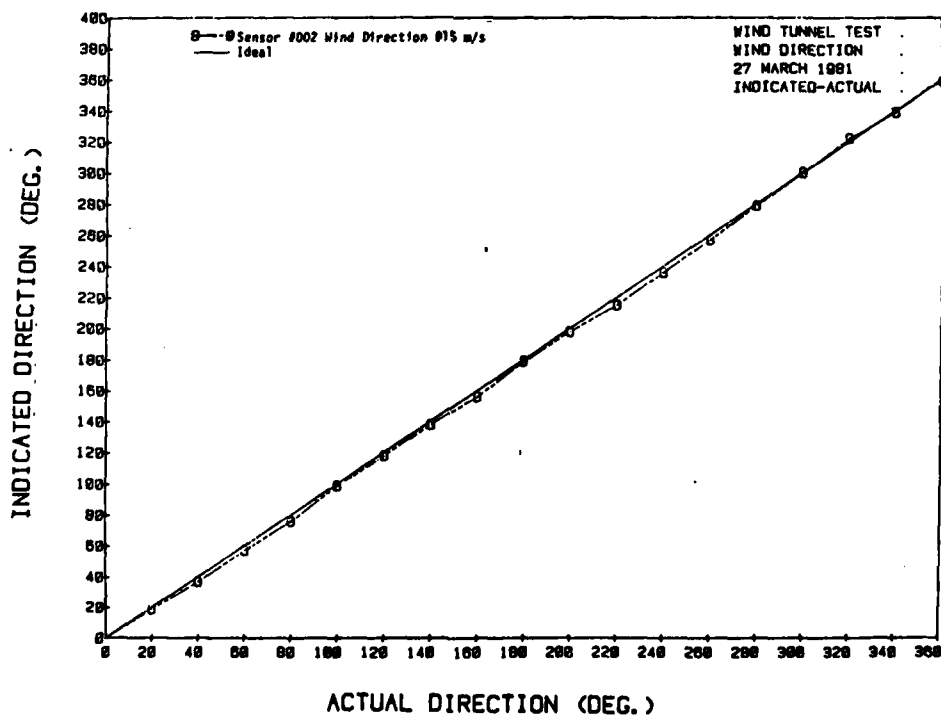


Figure 12. Wind direction, 15 m/s, S/N 02 (sensor number 2089).

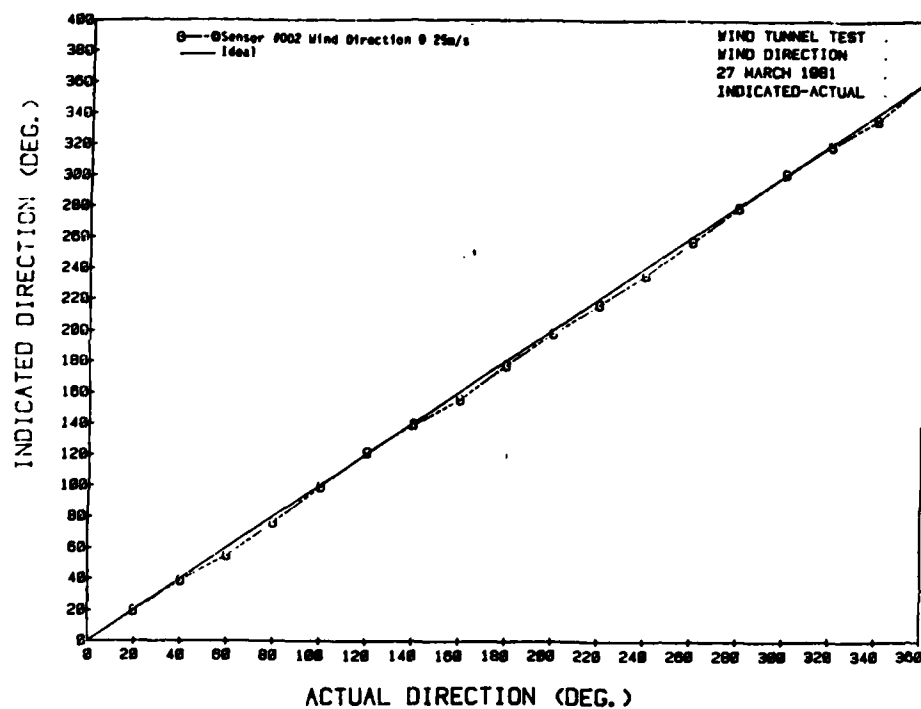


Figure 13. Wind direction, 25 m/s, S/N 02 (sensor number 2089).

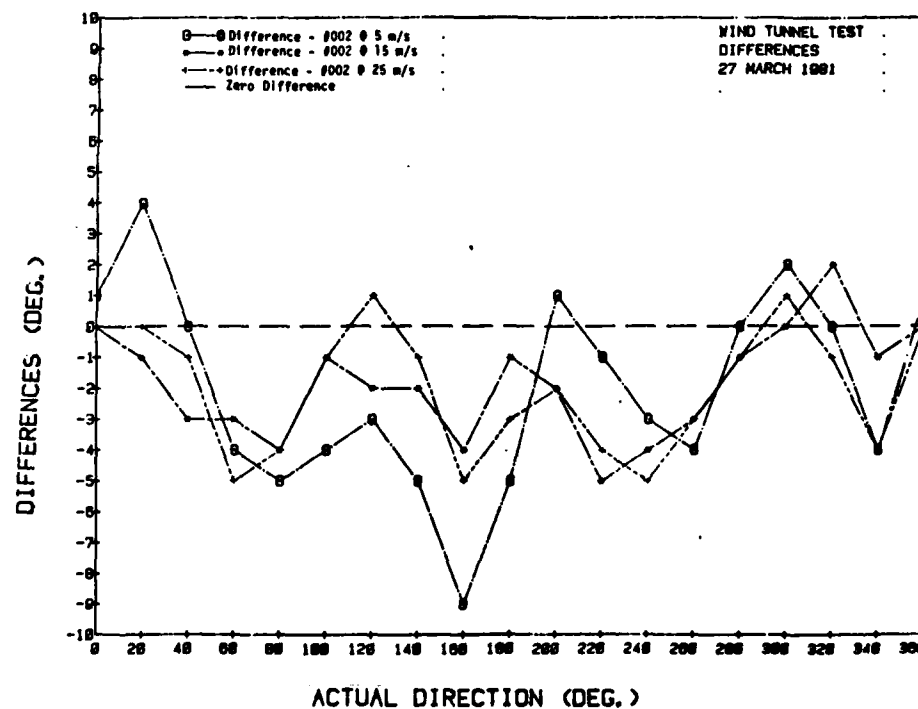


Figure 14. Difference values, wind direction, S/N 02 (sensor number 2089).

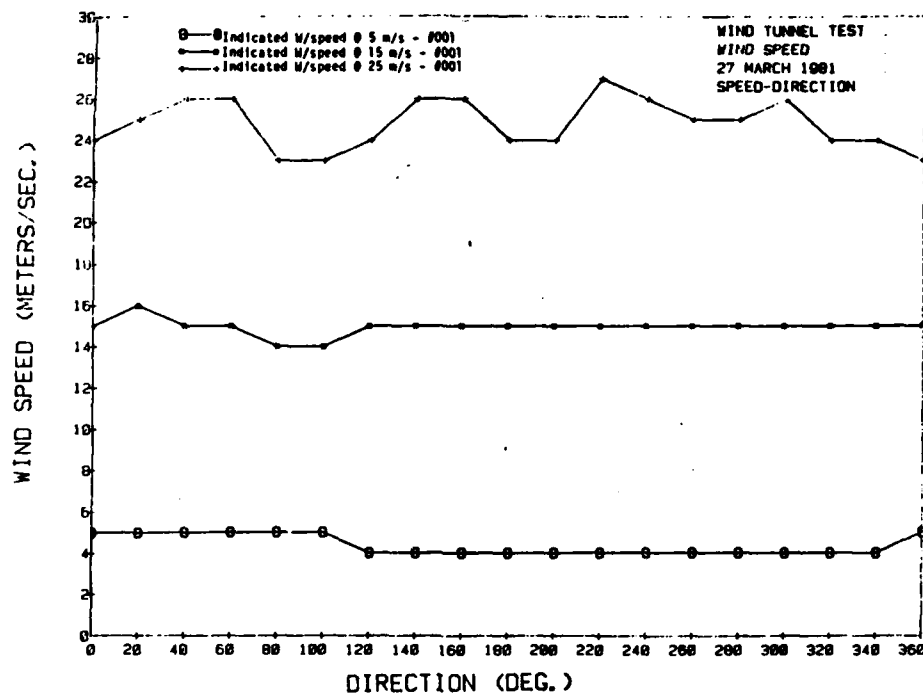


Figure 15. Windspeed, S/N 01 (sensor number 2090).

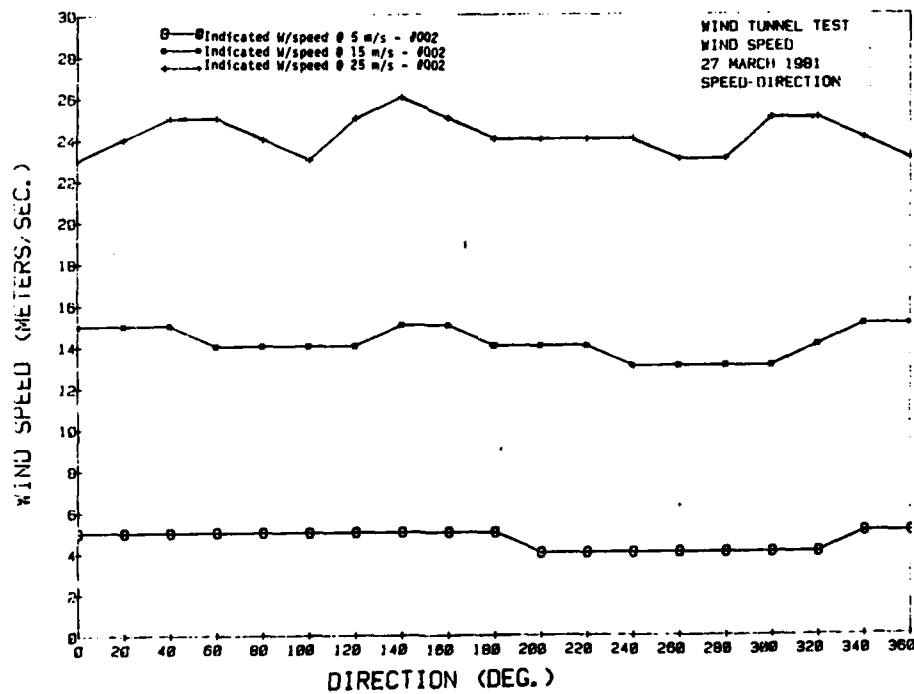


Figure 16. Windspeed, S/N 02 (sensor number 2089).

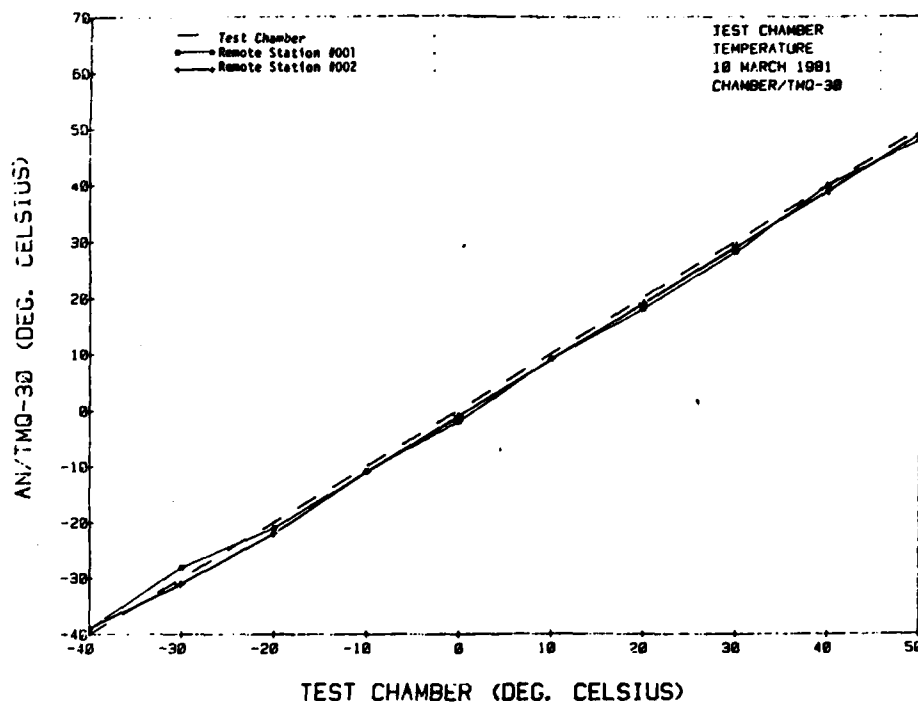


Figure 17. Temperature.

4.2.3 Pressure Tests

Pressure tests were made at the WSMR calibration laboratory in a pressure chamber using a Quartz Bourdon pressure readout calibrated with a dead weight piston gauge. Table 5 shows the results of these tests, and figure 18 shows the plot of the values.

4.3 Field/Operational Capability Tests

Field/operational testing was accomplished at Yakima Firing Center, Yakima, WA, in conjunction with a 9th Infantry Division Field Training Exercise from 4 through 8 May 81. The AN/TMQ-30 was deployed with the Division Staff Weather Officer's (SWO) element of the Tactical Operations Center. The master station was placed at the SWO's operational element in the All-Sources Analysis Center

(ASAC). One remote station was located with an AN/TMQ-22 Meteorological Measuring Set, approximately 500 m from the master station location figure 19. The other remote was located on a hillside approximately 1 km from the master station site. The AN/TMQ-30 data were compared to that of the AN/TMQ-22, with the exception of relative humidity, which was compared to sling psychrometer results.

The AN/TMQ-22 is a field instrument designed to give readings of wind speed and direction, air temperature, dew-point temperature, barometric pressure, snow depth, and rainfall. It is operated from self-contained batteries and

designed to be used with the operator holding the sensing devices or with these devices elevated on a mast. This system was being used by the SWO as the surface meteorological system for local forecast data.

TABLE 5. PRESSURE DATA (mbar)

CHAMBER	S/N001	S/N002
888.48	900	894
847.03	848	846
770.51	764	772
698.26	696	
700.92		698

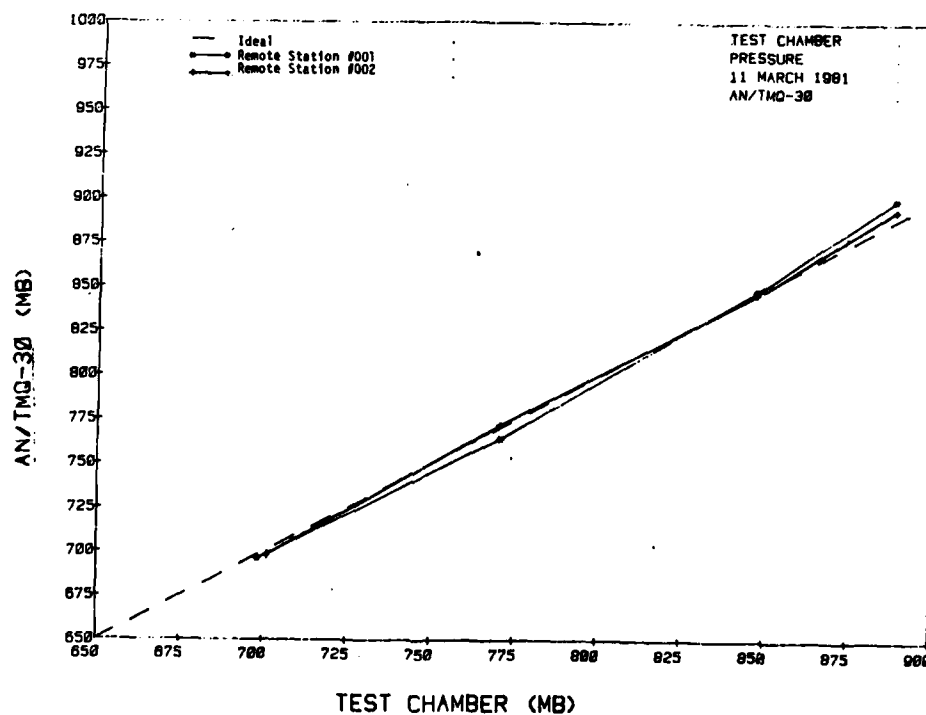


Figure 18. Pressure.

Data were taken at hourly intervals for comparison, even though the AN/TMQ-30 system was reporting observations twice per hour from two locations. Table 6 is comparative data taken from 5 through 7 May 81 at the site of the TMQ-30 and TMQ-22. Again, the relative humidity is compared to sling psychrometer data taken on site. Figures 20 through 24 show comparative plots of wind speed, wind direction, temperature, pressure, and relative humidity, respectively.

These tests proved the real workability of the system, since the units were deployed in an operational arena. Transportation of the equipment was accomplished within the maneuver area by tactical vehicles, and the equipment was subjected to actual operating conditions. The Yakima Firing Center was subjected to extremely heavy volcanic fallout during the major eruption in 1980 of Mt. St. Helens, and the ash, mixed with the naturally dusty condition of the area, created an unusually harsh atmospheric environment for prototype system evaluation. All flat, horizontal surfaces of the remote stations were covered with one-half to three-eighths in. of this dust mixture when the remote stations were recovered. Transportation of the equipment in a 1/4-ton truck trailer resulted in cosmetic damage to all units, but no electronic/mechanical problems resulted. When deployed, no failures or lost transmission resulted.

5. CONCLUSIONS AND FUTURE PLANS

The system has been studied in both engineering and operational tests, and recommendations for change have resulted.

The remote stations are larger than desired and cumbersome to deploy, primarily due to the need for guying the meteorological mast. Size reductions are indeed planned for the remote station. A mockup of the potential future remote station is shown in figure 25. This is an 85% volume reduction from the present system remote station. To address the deployment complexity/time recommendation, tripod support, similar to the one shown in figure 26, can be incorporated. Deployment of this type of support will require significantly less time than the current system using the guyed supports. Sensor inaccuracies noted will be addressed in future developments in order to minimize sensor-introduced errors.

In order to increase the range of transmission between remote and master stations, plans to include a relay station exist. The relay station has been developed and is now a component part of REMBASS. The use of the relay is directly transferable to the TMQ-30. Transmission distances can be increased fourfold by use of these units.

System life-cycle development currently is held at advanced development, pending validation of engineering development documentation and fund allocation. When validated, the system will be developed to the deployment phase of life-cycle development.

TABLE 6. FIELD TEST COMPARATIVE DATA

Date/ Time (PST)	Winds m/s				Temp °C		Pressure (mbar)		Relative Humidity	
	TMQ-30		TMQ-22		TMQ-30	TMQ-22	TMQ-30	TMQ-22	TMQ-30	Sling Psychrometer
	SP	DIR	SP	DIR						
5/1300	04	161	3.5	180	09	11	752	951.6	47	57
5/1400	04	183	02	180	09	12	952	951.6	32	47
5/1500	03	131	3.5	140	11	12	952	951.6	28	50
5/1600	03	114	03	090	12	12	952	951.6	25	44
5/1700	01	047	25	090	14	12	952	951.6	25	44
5/1800	08	250	05	290	07	08	953	951.6	55	65
5/1900	05	262	04	250	06	06	953	951.6	57	65
5/2000	03	269	04	240	06	06	953	951.6	60	60
5/2100	04	269	04	240	04	04	953	951.6	81	75
5/2200	03	235	03	240	02	02	954	951.6	94	87
5/2300	04	265	03	260	03	03	953	951.9	86	87
6/0000	03	238	2.5	230	02	02	953	951.9	88	87
6/0100	01	230	00	-	02	02	953	951.9	80	80
6/0200	03	242	2.5	220	01	01	954	951.6	89	87
6/0300	03	242	02	220	02	01	954	951.6	79	87
6/0400	03	224	02	220	02	00	954	951.6	83	80
6/0500	04	234	2.5	220	-01	00	954	951.6	89	80
6/0600	03	243	03	240	02	00	954	951.6	72	80
6/0700	03	251	03	270	05	04	954	951.6	56	60
6/0800	05	256	04	270	08	09	954	952.9	41	43
6/0900	05	246	3.5	260	11	11	954	952.9	32	46
6/1000	04	236	04	250	11	12	954	952.9	32	43
6/1100	02	303	03	260	11	11	954	953.3	32	46
6/1200	03	032	2.5	280	11	11	954	953.3	30	46
6/1300	05	256	02	250	11	12	954	953.3	31	40
6/1400	06	247	3.5	250	09	09	954	952.9	49	61
6/1500	03	247	03	270	10	10	954	952.9	40	57
6/1600	04	241	01	290	13	14	953	951.9	23	38
6/1700	03	295	01	270	13	13	953	951.9	25	44
6/1800	03	251	1.5	250	13	12	952	951.9	29	40
6/1900	02	336	02	300	10	12	952	951.9	38	50
6/2000	04	280	3.5	270	10	09	952	951.9	42	53
NOTE 1										
7/0700	03	262	3.5	280	07	07	952	951.6	55	49
7/0800	02	284	1.5	220	10	11	952	951.6	38	43
7/0900	03	279	3.5	290	14	12	952	951.6	29	47
7/1000	02	204	2.5	250	11	13	952	951.6	32	50
7/1100	02	100	02	110	11	11	952	951.6	37	58
7/1200	02	145	03	180	10	09	952	951.2	52	61
7/1300	02	048	02	060	09	09	951	951.2	73	66
7/1400	00	270	00	000	10	09	951	951.2	71	70
7/1500	03	170	06	180	10	10	951	951.2	57	71

NOTE 1: The master station battery failed. No personnel were in attendance to change the battery; therefore, data between 6 May 2000 and 7 May 0700 were not taken.



Figure 19. Field test remote station comparative setup.

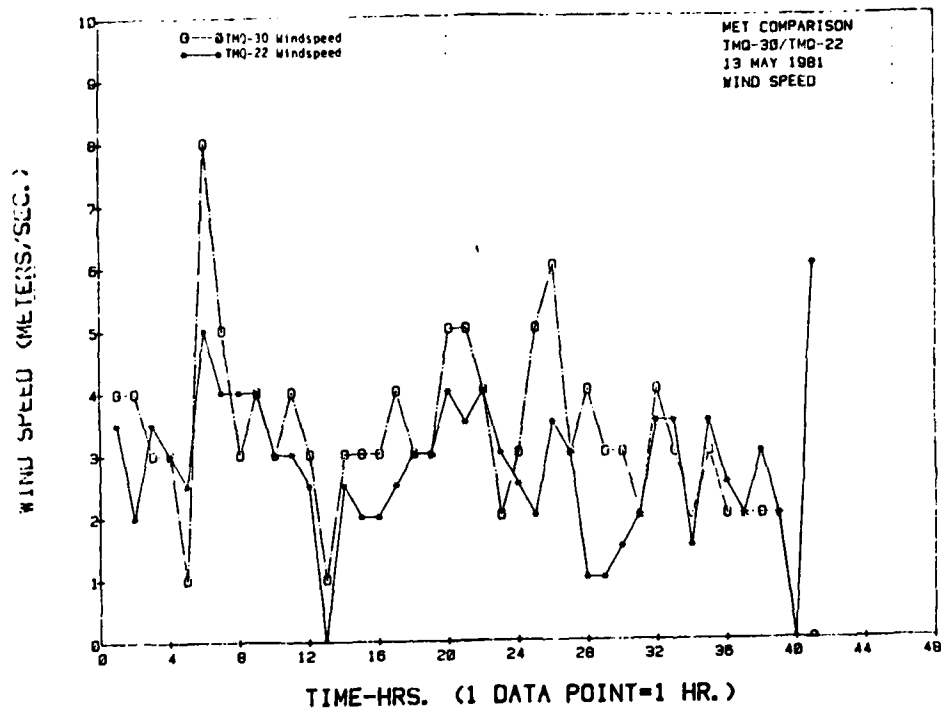


Figure 20. Field test--windspeed.

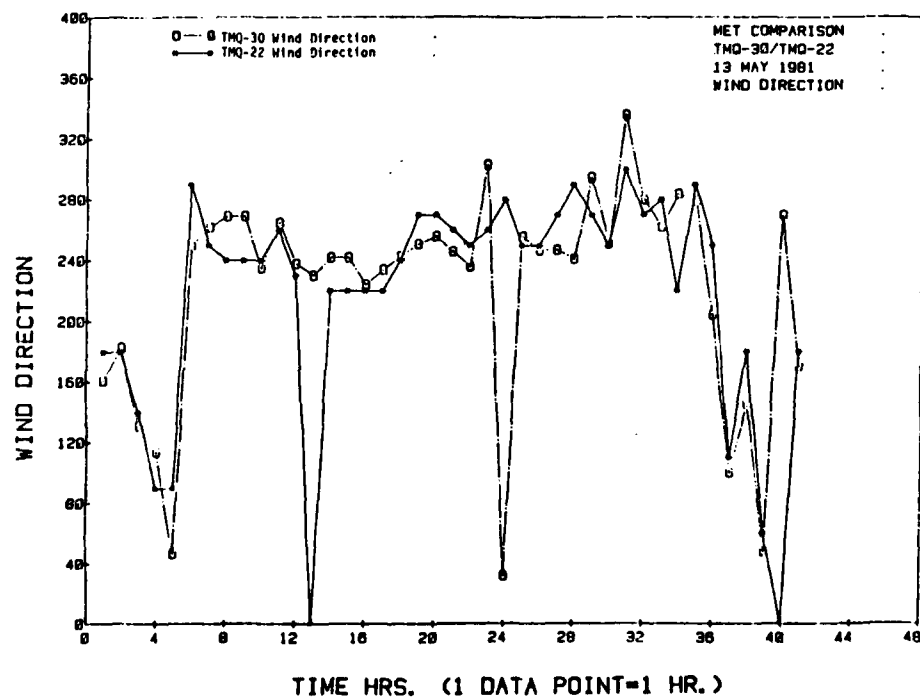


Figure 21. Field test--wind direction.

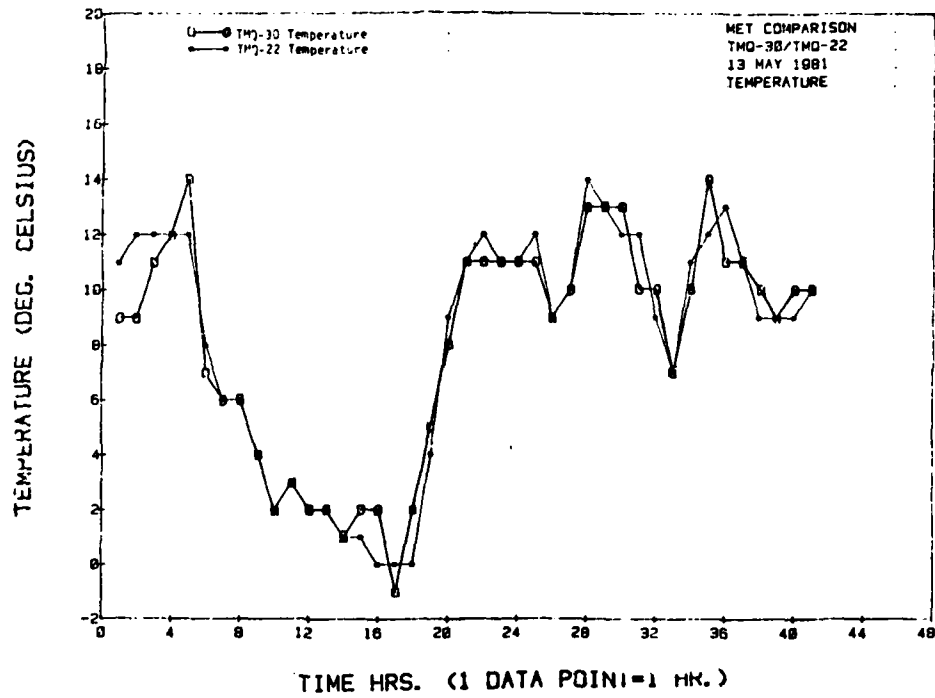


Figure 22. Field test--temperature.

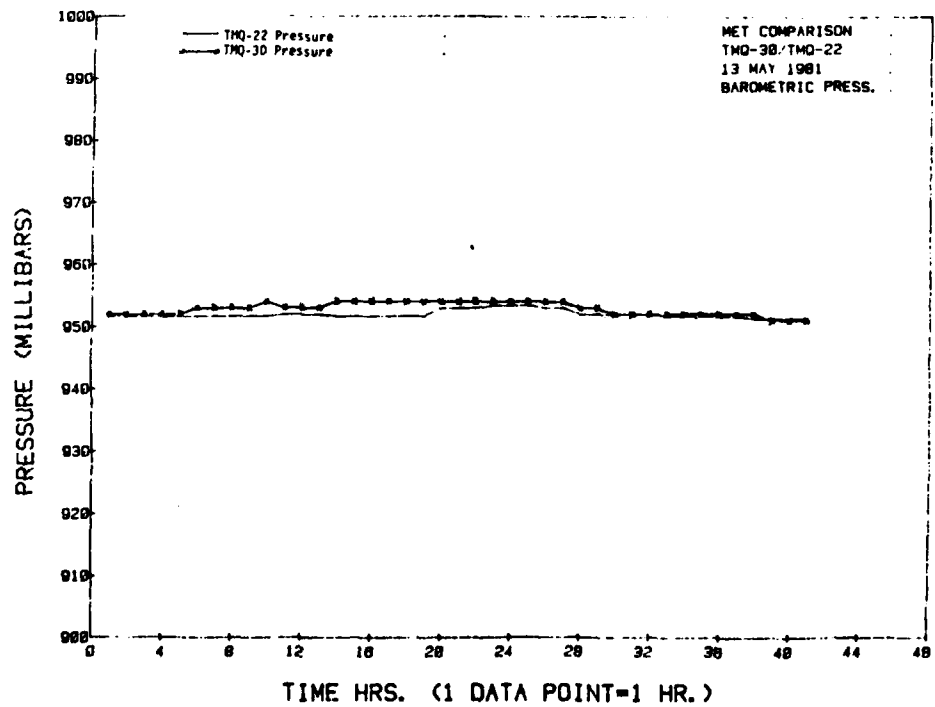


Figure 23. Field test--pressure.

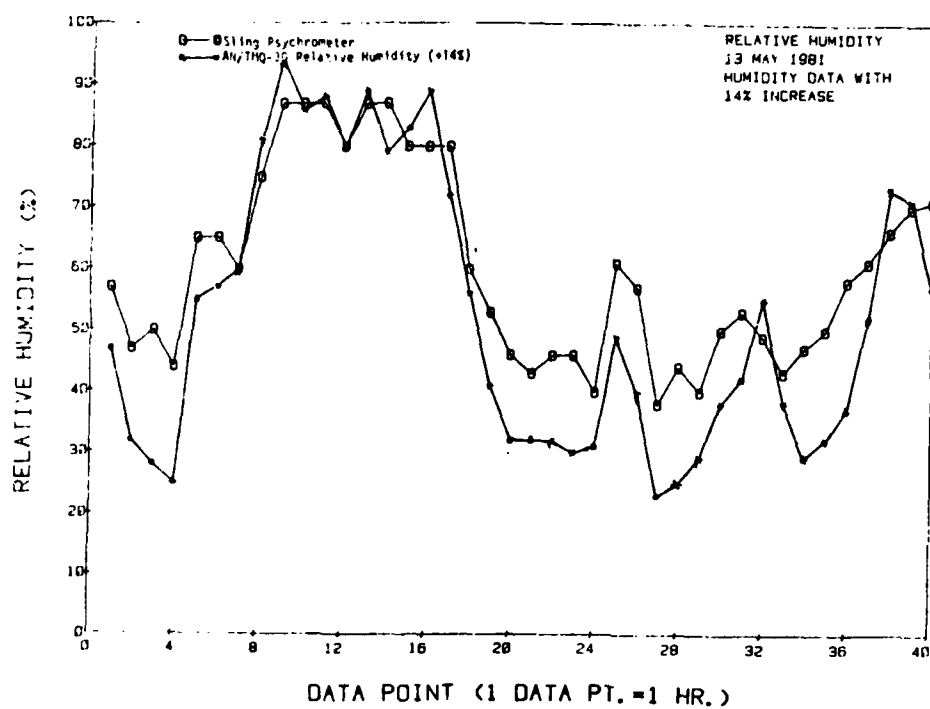


Figure 24. Field test--relative humidity.

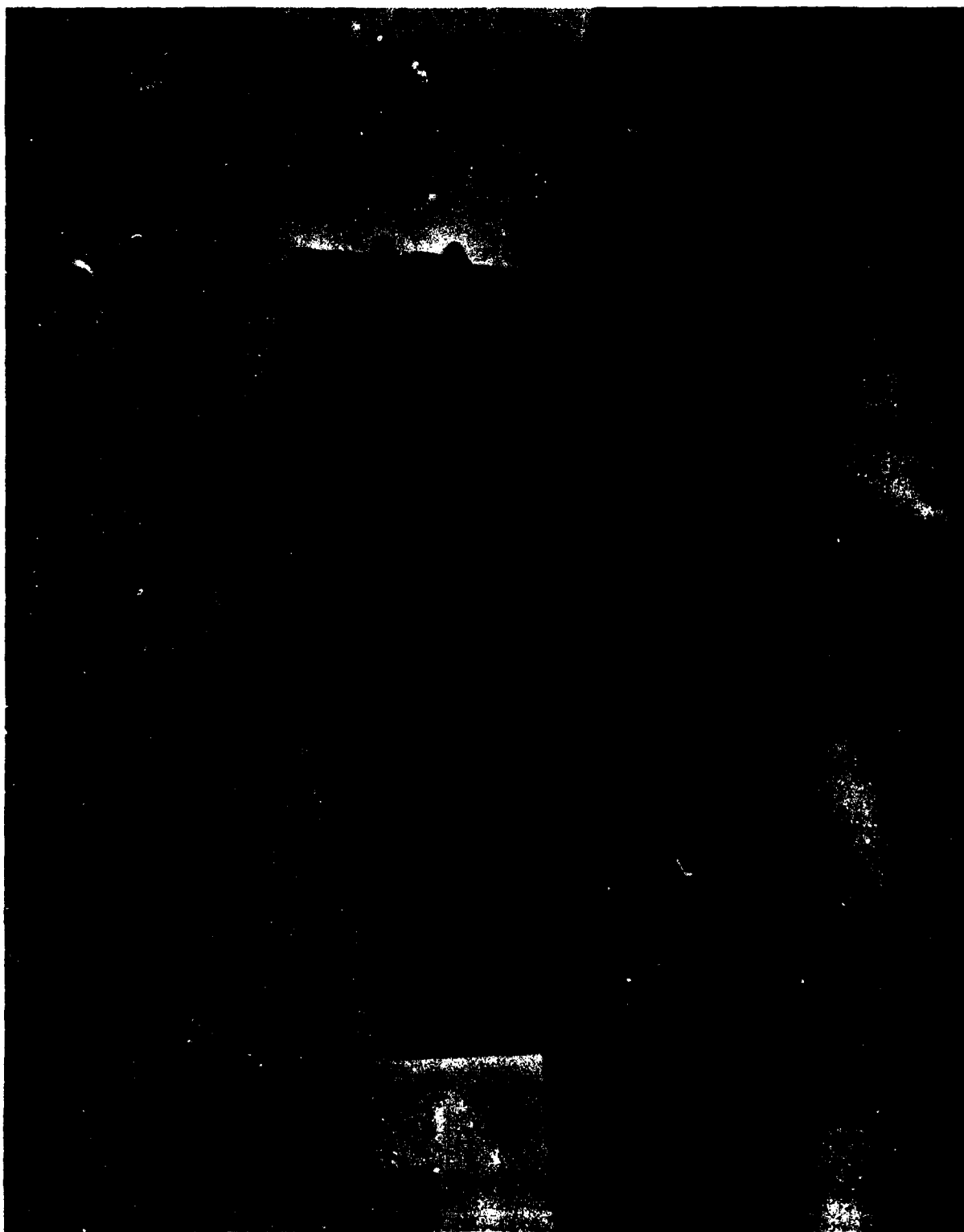


Figure 25. Remote station--future (mockup).

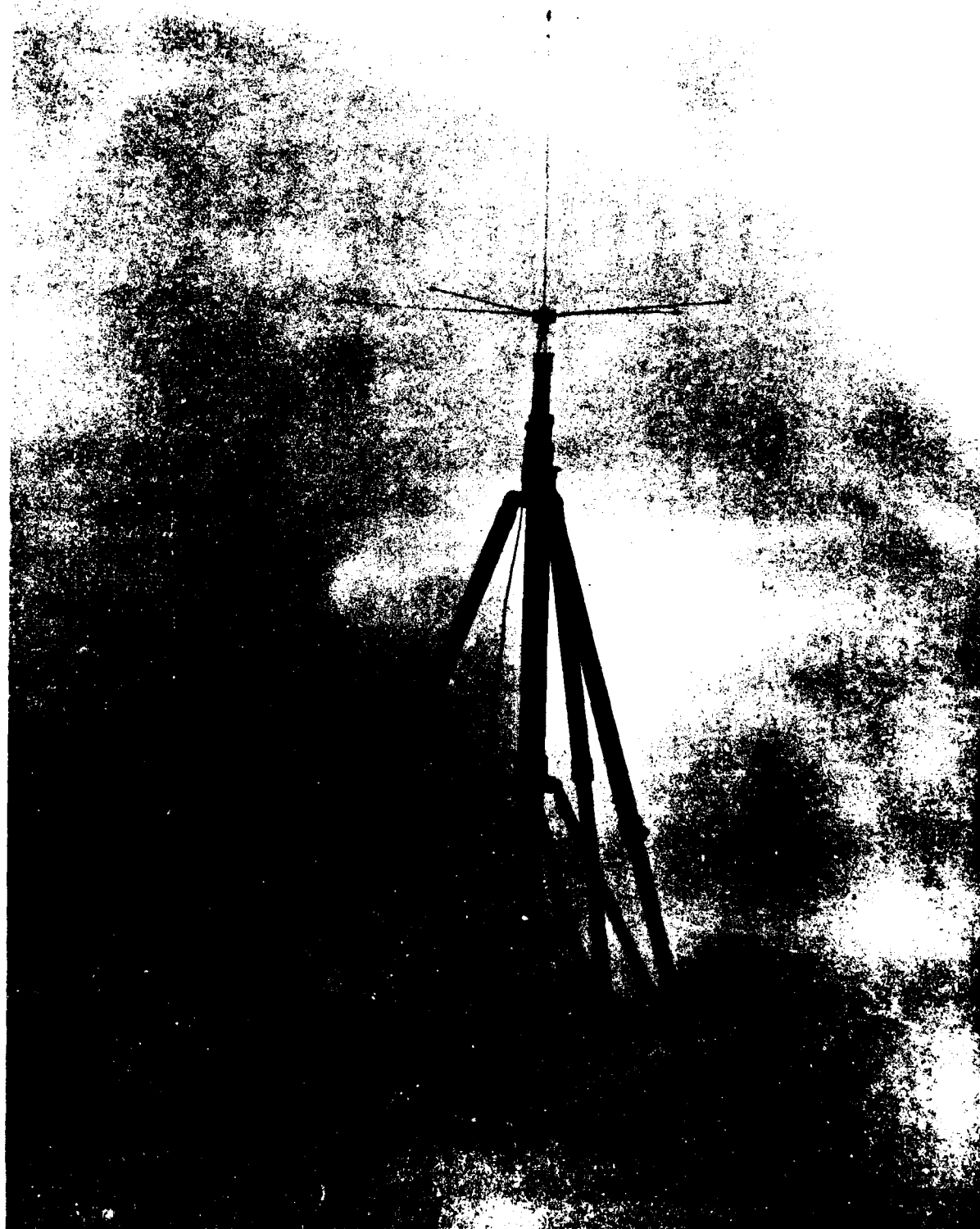


Figure 26. Remote station--future (tripod).

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