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AUTOMATIC WEATHER STATIONS

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FOREWORD

In the progressive establishment of a world-wide network of meteorological observing stations, one outstanding difficulty has been the provision of observations from sparsely populated or desert areas and also from ocean areas devoid of islands or remote from regular shipping lanes. It was in recognition of this difficulty that the Meteorological Division at its Second Session and the Meteorological Committees at several Regional Air Navigation Meetings recommended that the progress made in the development of automatic weather stations be given continuing study by the ICAO Meteorological Secretariat.

The Secretariat study has resulted in the compilation of the present ICAO Circular which includes a review of the automatic weather stations developed by certain states and now in use in different parts of the world. A number of illustrations is also included together with a short bibliography.

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AUTOMATIC WEATHER STATIONS

1.- INTRODUCTION

The development of automatic weather stations appears to have received its first important impetus during the years immediately preceding World War II when experiments were carried out in Europe and North America. Automatic stations have been developed by both civil and military organizations and seem to have conformed to a generally similar pattern, although differing in the methods used in recording and transmitting observations.

In Section 2, which represents the principal part of this circular, a full description, including a summary of specifications, is given for each of the types of station in operation on which information has been received by ICAO.

2.- TYPES OF AUTOMATIC WEATHER STATIONS NOW IN OPERATION

2.1.- Stations Established by the United States

2.1.1.- U.S. Automatic Weather Station (Model TDM-1)

One of the most successful types now in use, which has been employed by the United States Navy and the United States Army is based on the Modified Molchanoff System, details of which are given below:

Operation

The meteorological elements measured by this automatic station are atmospheric pressure, humidity, wind speed and direction and precipitation. The indications of the values of the meteorological elements being observed are converted into two-letter Morse code signals, the speed of transmission of which is approximately 12 words per minute. The transmission cycle is rapid and accurate. In practice each cycle of observation is repeated two or three times to ensure accurate reception. There is a distinct and different Morse Code signal for each increment in the data for each particular element being measured.

The observations are transmitted every three hours according to a preset twenty-four-hour sequence and each observation is preceded by a station call-sign for identification purposes, followed by the meteorological readings, repeated as necessary, and lasting approximately 15 minutes.

Degree of Accuracy

The long experiments carried out in connection with various types of automatic weather stations have resulted in the achievement of a high degree of accuracy in the observations as demonstrated by the following statistics in respect of the Molchanoff System:

a) Atmospheric pressure is measured to an accuracy within one millibar of a standard mercurial barometer;

b) Humidity readings are found to be within 5 percent of the actual humidity as obtained by a psychrometer;

c) The temperature unit is within one degree F. of the temperature obtained from the dry bulb thermometer;

d) Precipitation readings cause some difficulty on account of occasional freezing of rain-water in the funnel shaped opening. The average degree of accuracy has, however, been found to be within one hundredth of an inch;

e) On checking the accuracy of the wind unit with a hand anemometer, the wind direction was found to be exact and the velocity to be accurate within one to two knots in winds between fifteen and twenty knots.

Range

The effective reception range of the stations is clearly dependent upon the power of the transmitter but the average appears to be of the order of 400 miles. The location of the station is especially important and the effective range is influenced very greatly by the topography of the country between the station and the receiving point.

Power Supply

Both primary batteries and air or liquid-cooled gas engines have been used in experiments with trial stations but maintenance of such power units apparently requires the attendance of operating personnel at least every six months.

The best solution to this problem would be a wind-driven electric generator charging a bank of lead-acid storage batteries which gives promise of unattended operation for a period of one year or more if suitable storage batteries are used.

Costs

Reliable estimates of the costs of automatic weather stations are very difficult to obtain since they are still in the experimental stage and, where development work has been done by military organizations, costs are obviously not easily estimated. From data so far made available, however, cost per unit of a station of the Molchanoff type would appear to be between $12,000 to $15,000.

House and Instrument Shelter

A few instruments of this type have been manufactured for use by the United States Army and Navy. The compact recording and power units are sheltered in a well-insulated house on top of which is mounted a standard instrument shelter. The house is of the pre-fabricated type, easily erected on a suitable concrete foundation. The floor section is attached to the foundation by anchored bolts and is surrounded by a protective metal shield which prevents termites from entering the house. Four guy wires provide additional support for the instrument shelter. Screened ventilator openings with appropriate shields are located in the front and rear sections. The roof is made up of two copper covered sections joined in the centre. Two insulated antenna lead-in connectors are placed in the rear wall. An opening is also provided in the rear wall to admit the conduit for connecting the external instruments. Figures I, II and III are photographs showing both the exterior and interior views.

Description of Meteorological Recording Apparatus

Pressure Unit.- The unit generally employed in automatic weather stations for the recording of pressure changes is a microbarograph, which has been modified by the removal of the clock mechanism and in which the chart drum is replaced by a resistance unit. The pressure sensitive element actuates a contact arm, the latter being moved to that contact of the resistance element which corresponds to the prevailing barometric pressure. The resistance element consists of a series of 101 resistors which are directly connected to the contact points. Therefore, the amount of resistance introduced depends upon the position of the contact arm. During transmission the contact arm is clamped securely to the contact point over which it was located at the beginning of the transmission. The instrument has a pressure range of 100 mbs, the maximum and minimum readings depending on the altitude of the instrument, i.e. from 850 to 950 mbs. or from 950 to 1050 mbs, etc. A photograph of the pressure unit is shown in Figure IV.

Temperature Unit.- The temperature unit consists of four small resistors connected in series. The resistors have a high negative temperature coefficient so that the resistance of the unit increases as the temperature drops and vice versa. This instrument is protected by a small louvred screen. Temperatures from -60° to + 100°F can be measured. A photograph of the temperature unit is shown in Figure V.

Humidity Unit.- Normally using strands of human hair, the humidity unit is a hygrograph, which has been modified by replacing the recording drum and clock mechanism with a suitable resistance element. The changes in length of the hair deflect a contact arm over the contacts connected to fifty resistors and the variations are transmitted in exactly the same way as the pressure changes described in Paragraph a). Relative humidities from 15 percent to 100 percent can be measured. A photograph of the humidity unit is shown in Figure VI.

Wind Unit.- The wind direction transmitter consists of sixteen cam-operated switches connected to sixteen resistors so that any motion of the wind vane will be followed exactly by the cam. Wind direction can therefore be measured to the sixteen points of the compass. Figures VII and VIII are photographs of the wind unit.

Wind velocity is recorded by means of a transmitter, which consists of a set of contact points operated by means of a gear and cam arrangement through the rotation of the anemometer cups. The contact points are closed once for each one hundred and twentieth part of a nautical mile of wind that passes the anemometer. Thus, the number of pulses counted during one half minute will give the wind velocity reading directly in knots.

Precipitation Recorder.- The instruments used for measurement of precipitation vary considerably but a common type in use is the tipping-bucket rain gauge which is so arranged that each time the bucket tips a contact is

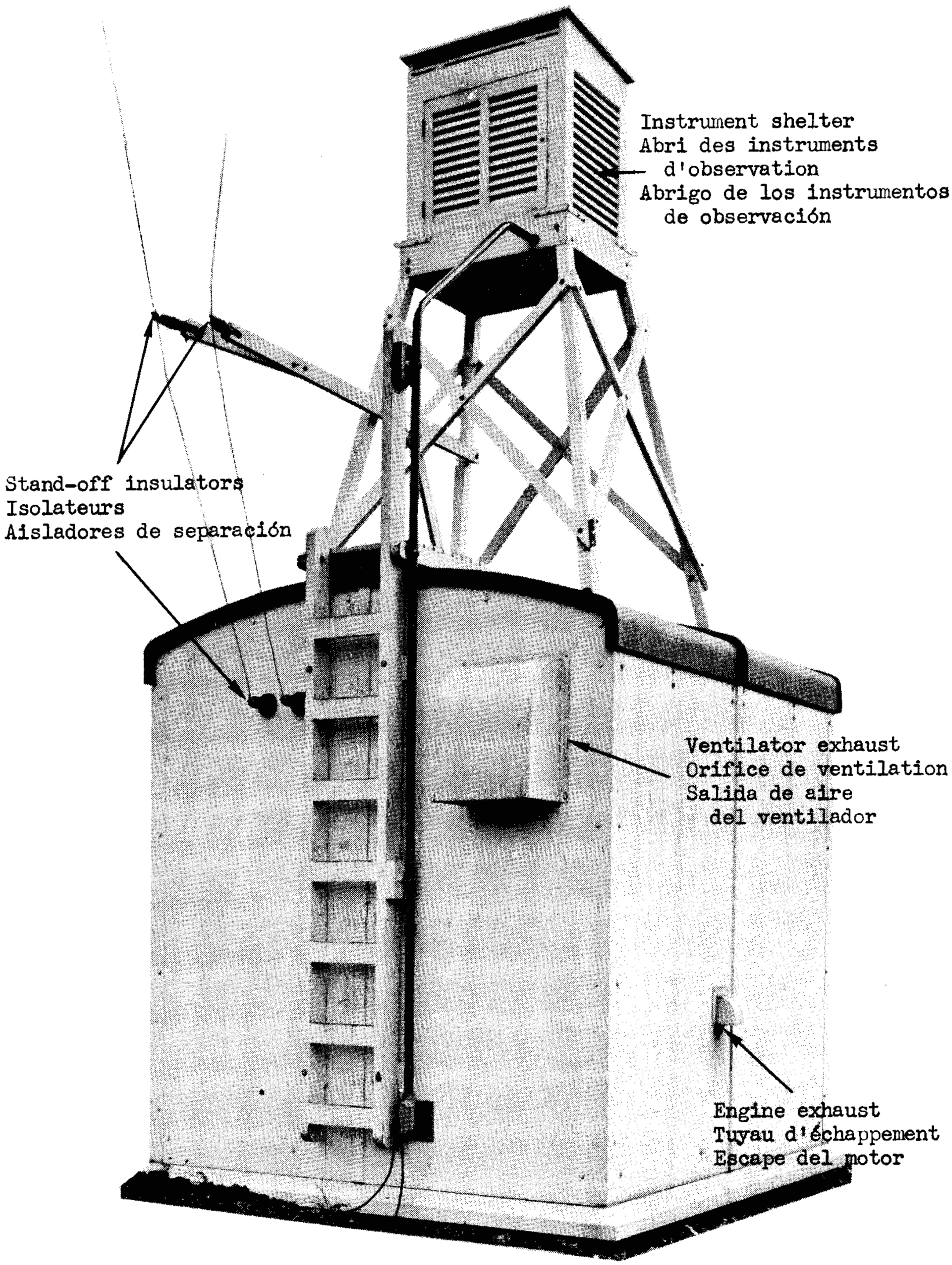

Fig. I

House and Instrument Shelter
Cabine et abri des instruments
Cabina y abrigo de instrumentos

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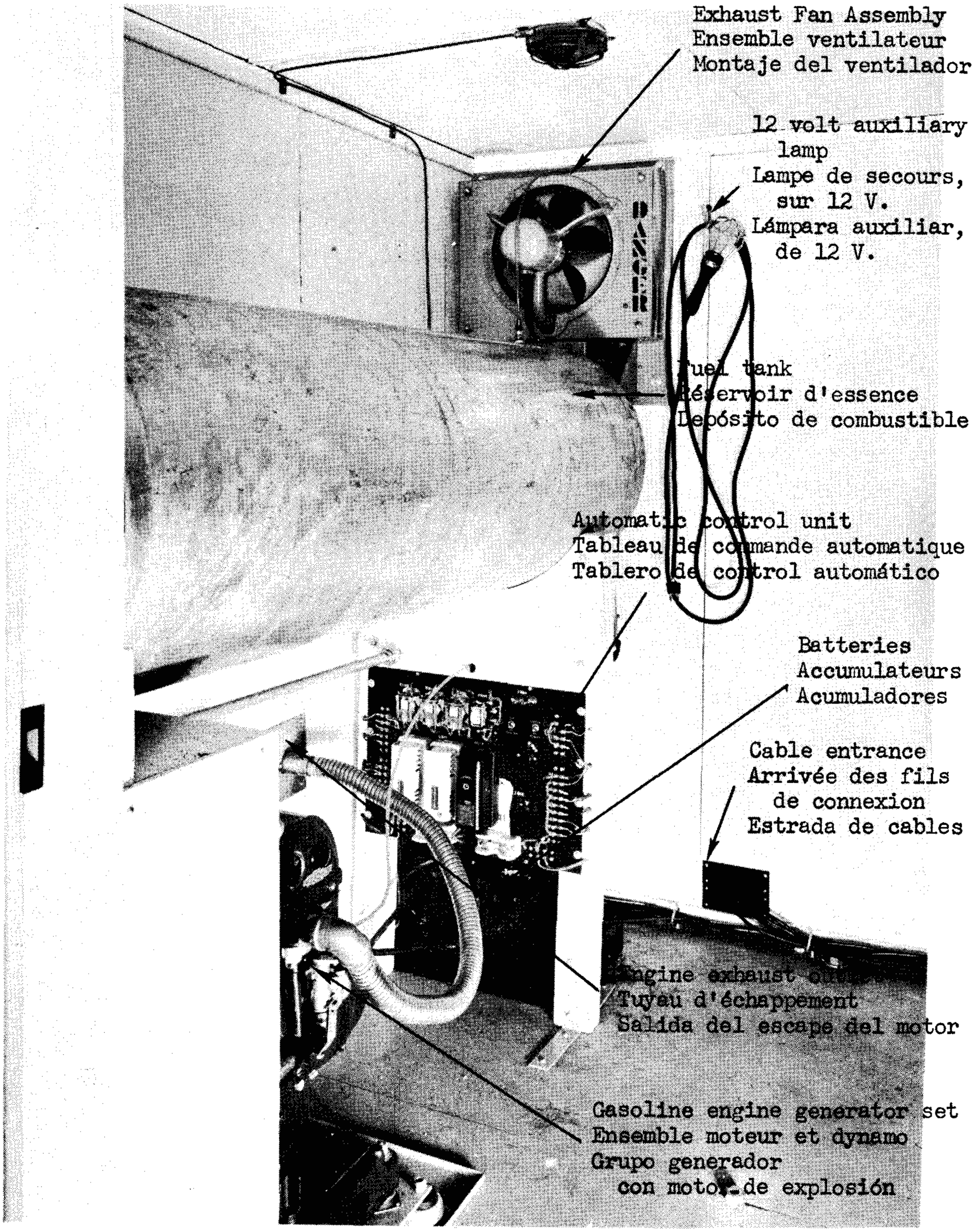

Fig. II

Interior View of House showing Engine and Control Unit
Cabine - Vue intérieure montrant le moteur et le tableau de commande
Cabina - Vista del interior con motor y mandos

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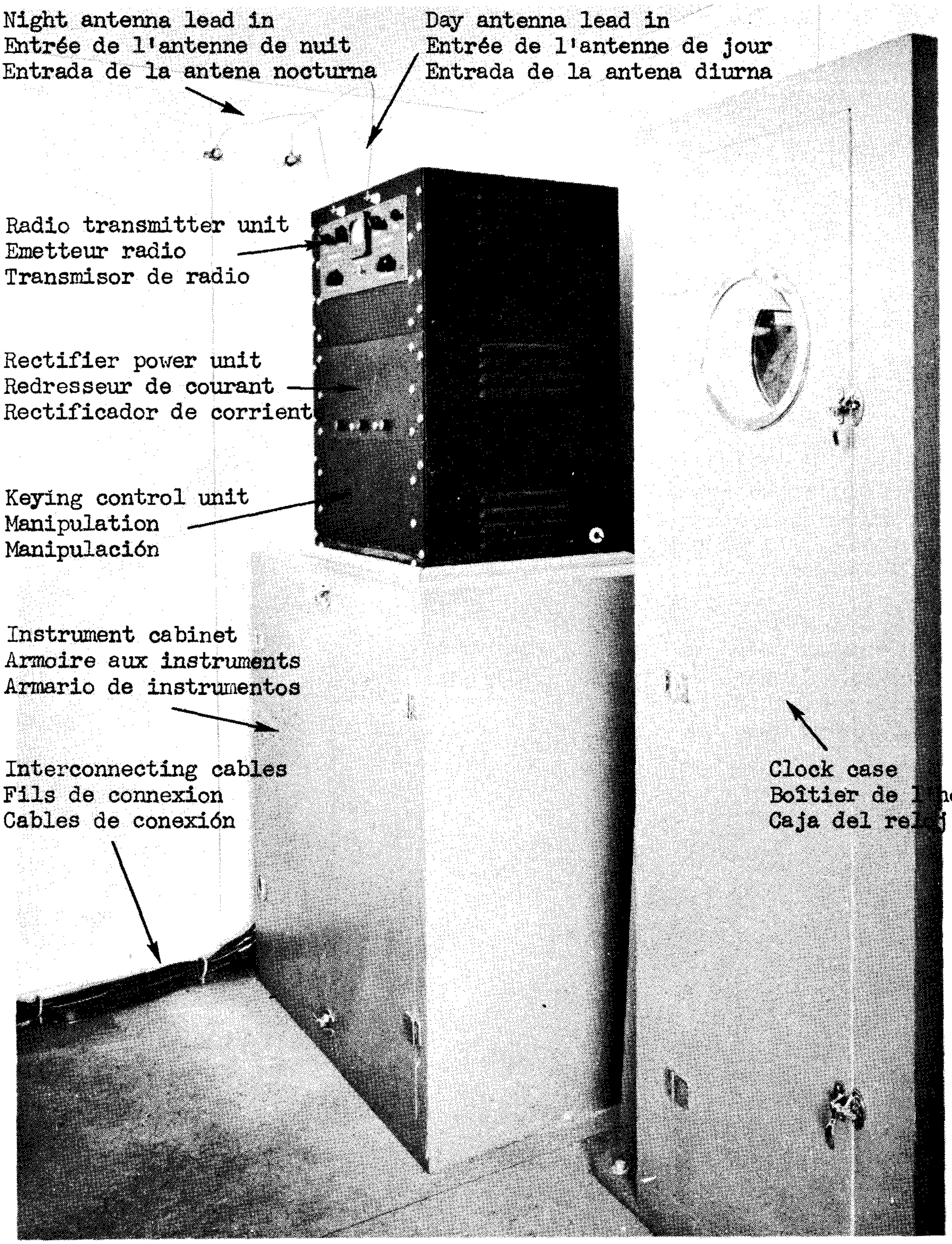

Fig. III

Interior View of House showing Transmitter
Cabine - Vue intérieure montrant l'émetteur
Cabina - Vista interior con el transmisor

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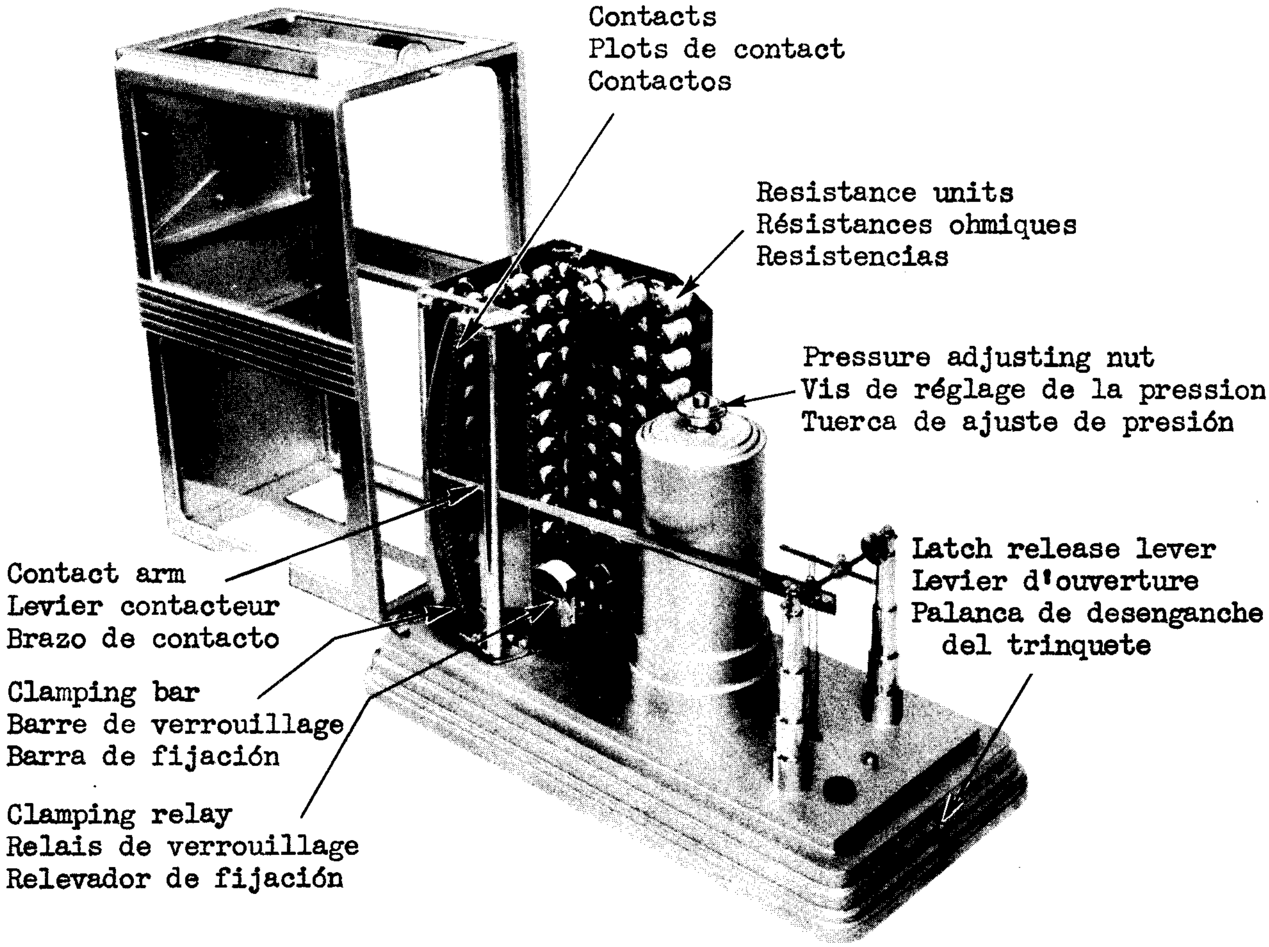

Fig. IV

Pressure Unit
Elément barométrique
Elemento barométrico

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Temperature sensitive resistors
Résistances ohmiques fonctions de la température
Resistencias sensibles a la temperatura

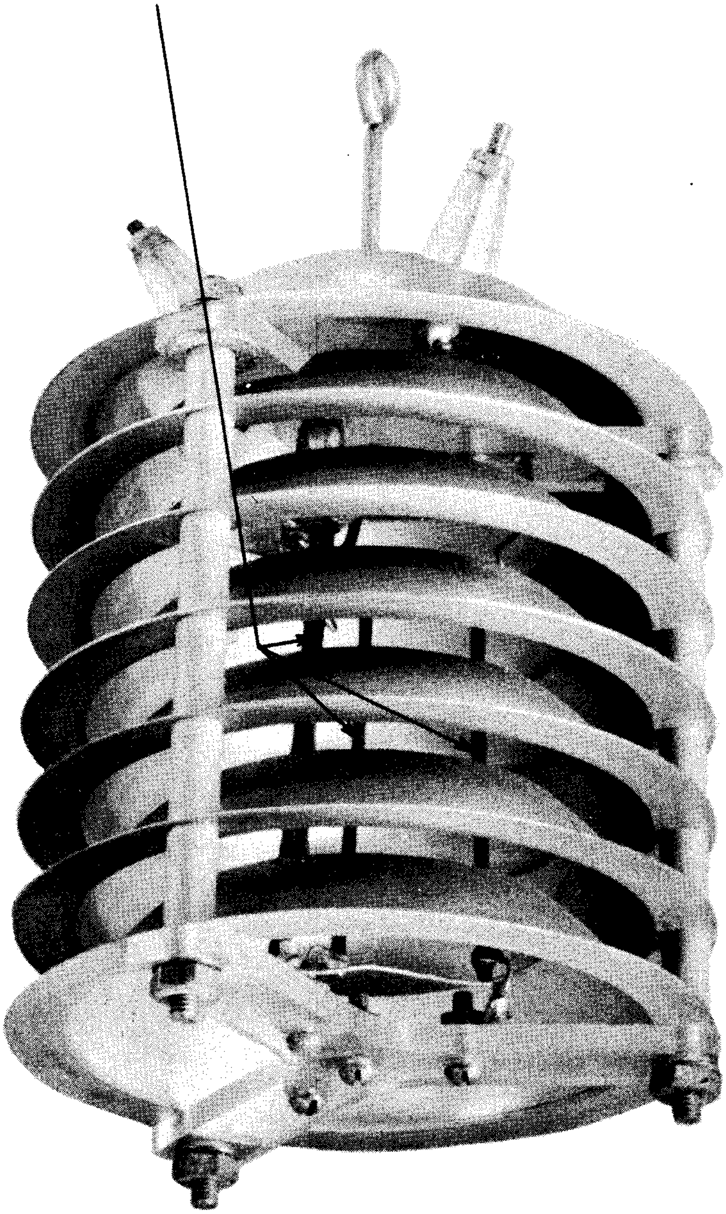

Fig. V

Temperature Unit
Elément thermométrique
Elemento termométrico

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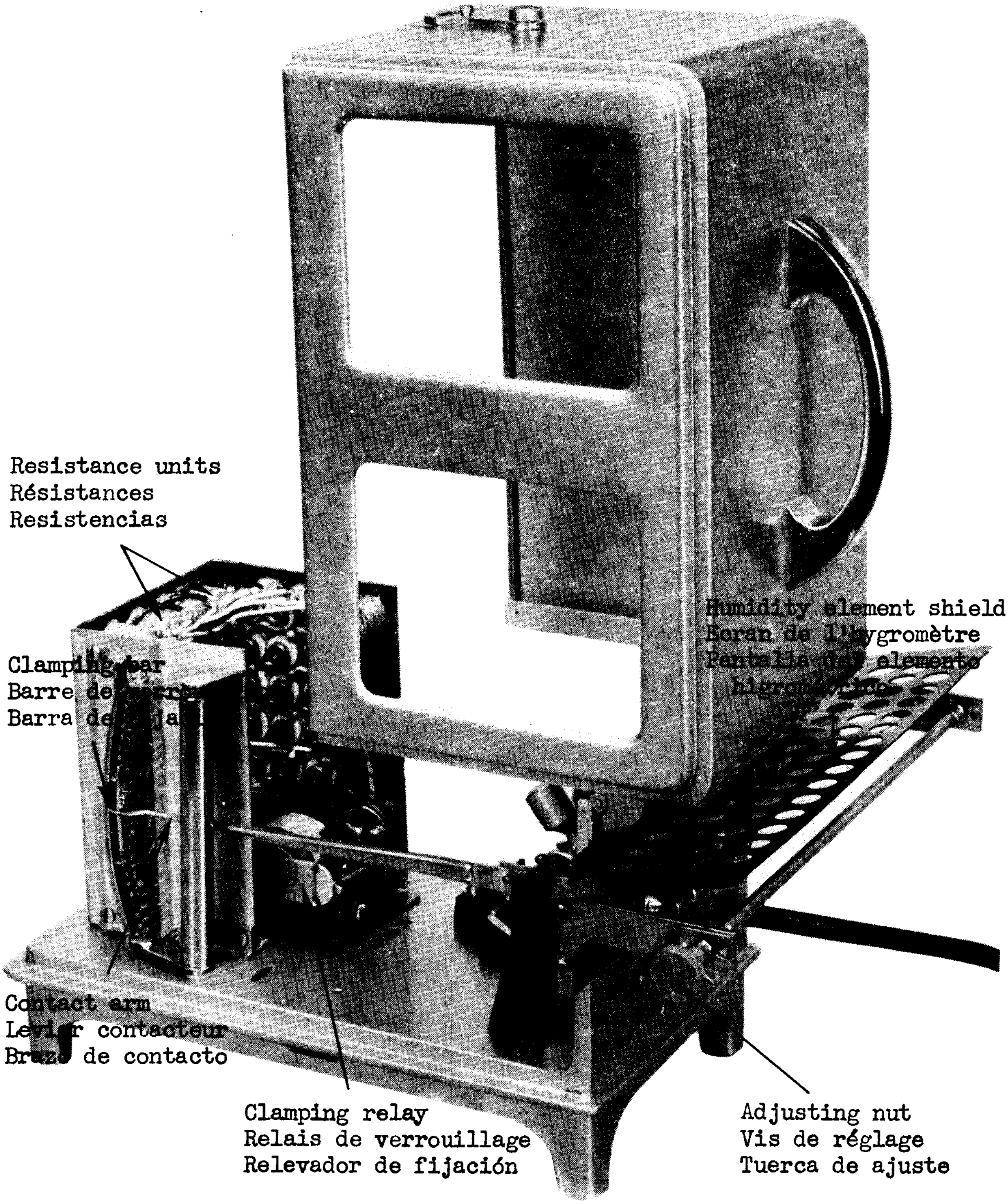

Fig. VI

Humidity Unit
Elément hygrométrique
Elemento higrométrico

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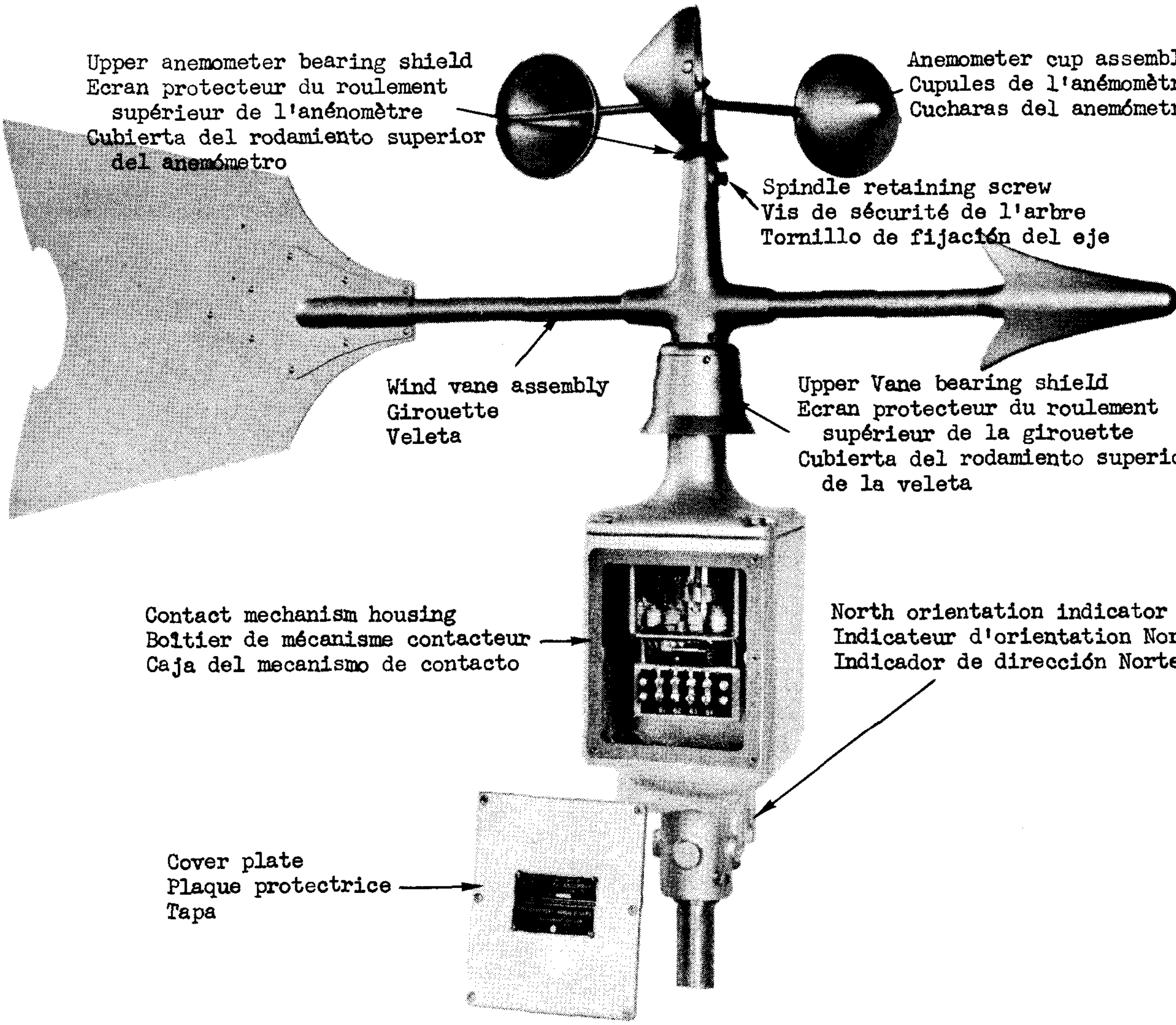

Fig. VII

Wind Unit, Masthead Assembly
Elément anémométrique, assemblage placé en haut du mât
Elemento anemométrico, conjunto colocado en la parte superior del poste

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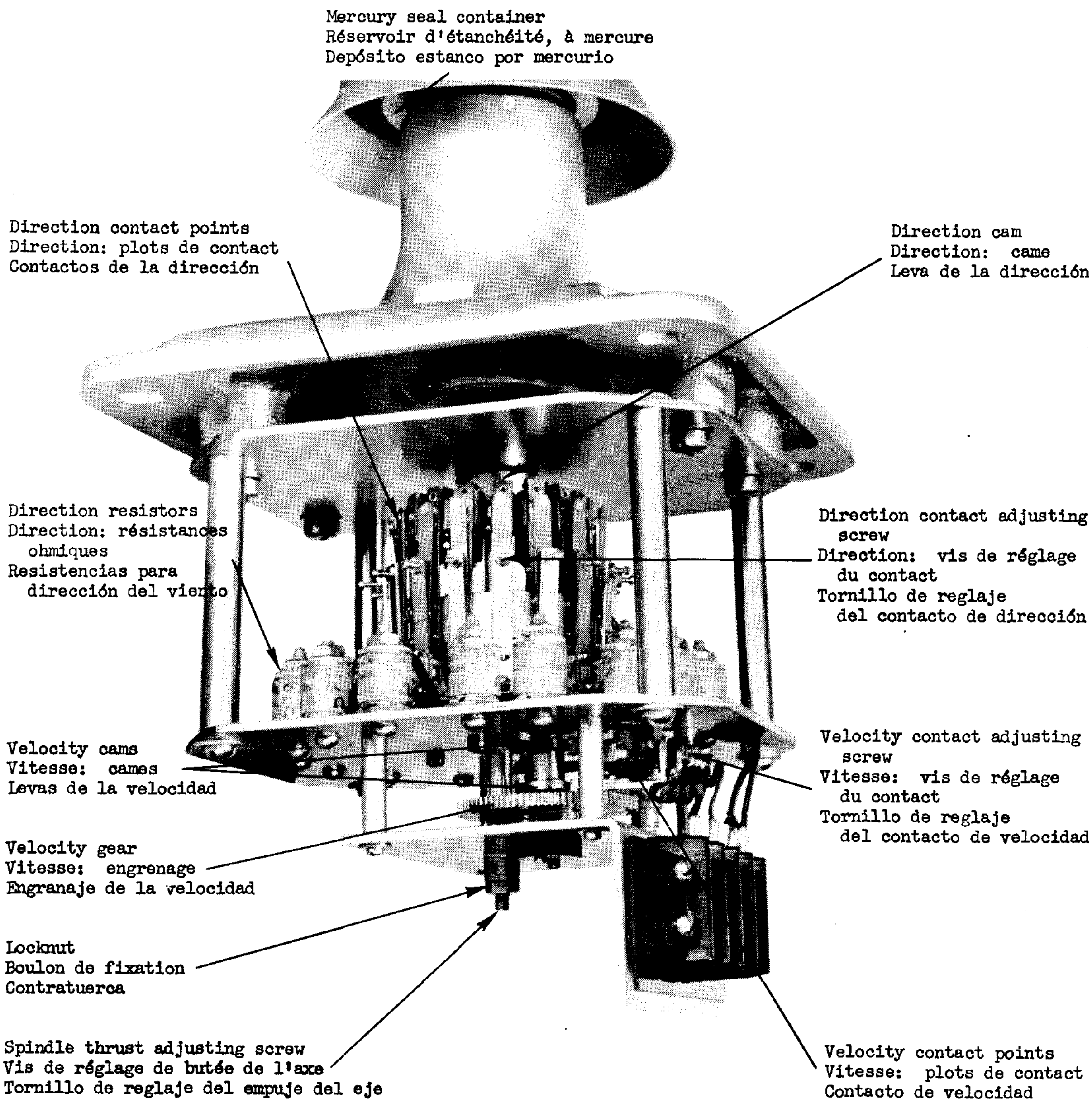

Fig. VIII

Wind Unit - Recording Mechanism
Elément anémométrique - Mécanisme enregistreur
Elemento anemométrico - Mecanismo registrador

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made and a radio signal transmitted. Rainfall can be measured from 0 to 12 inches. A photograph of the precipitation unit is shown in Figure IX.

2.1.2.- Automatic Weather Stations Operated on Islands by the United States Weather Bureau

Operation

As an addition to the hurricane observation network, the United States Weather Bureau has had considerable success in the operation of automatic weather stations on small islands off the coast of Florida since 1945. If the addition of a wind-driven generator can extend the length of time between servicings, it would appear that the installation of similar stations could be considered for more remote islands. Each installation is housed in a "hurricane-proof" type of construction and is equipped with a transmitter consisting essentially of two units, each operating on a staggered schedule and producing alternate transmissions. In case of failure of one unit, transmissions will still occur, but at double the regular (3-hourly) time interval. The antenna for the transmitters is of the non-directional shunt fed type, consisting of a 65-foot self-supporting tubular steel mast designed to withstand wind speeds of 130 knots. Each transmission includes the station identification, barometric pressure, wind direction and wind speed. The identifying letters assigned to each station are transmitted in International Morse Code by automatically keying the unmodulated carrier. Transmissions from all the stations are on 3352.5 kc but are scheduled so that the transmissions are not concurrent.

Description of Meteorological Apparatus

Pressure Unit.- Aneroid cells with 100 mb. pressure range from 930 to 1030 mb. indicate the pressure within an accuracy of ± 1 mb. Pressure data are transmitted between two reference pulses which occur approximately 30 seconds apart. For example, if the variable pulse occurs 20 seconds after the first reference pulse and the time between the first and second reference pulse is 30 seconds, the pressure is $20/30 \times 100 + 930$ mb. = 997 mb.

Wind Unit.- The wind direction is ascertained by a similar method. If a pulse is assumed to occur 15 seconds after the first reference pulse and the time between reference pulses is again 30 seconds, the wind direction would be $15/30 \times 360^\circ = 180^\circ$. Wind speed is transmitted by keying the transmitter directly from the 60th mile contact of a standard Weather Bureau anemometer. The speed is then indicated by the number of pulses transmitted per minute.

Power Supply.- Primary power is supplied from storage cells having sufficient capacity to last four months without recharging. Wind generators are now being used experimentally for battery recharging to increase further the length of time between trips for servicing. A power input of 50 watts produces sufficiently high signal strength to give satisfactory recordings at the receiving terminals.

Receiving Equipment.- The main receiver is placed at a beach location favourable for radio reception and its output is carried by land lines to a recorder in the Weather Bureau Office. An auxiliary receiver, located in the Weather Bureau Office, provides a simultaneous recording in the event that the primary fails. The recording equipment is turned on automatically by a time clock and the complete record is made without the presence of an operator. The recorders are of the vibrating stylus type which produce records of the pulsations on a waxed tape moving at constant speed. The record is directly evaluated by measuring the distances between the signal pulse and reference pulses. An auxiliary battery power supply has been provided for operation of the receivers at each terminal in case of power failure.

Effective Range of Transmitters.- The three automatic weather stations are located at Orange Key, Cape Sable and Dog Rock off the south coast of Florida. The broadcasts from the three transmitters are received at Miami and Key West. The greatest distance of transmission is 170 miles and the shortest distance is 62 miles.

Cost.- No information is available concerning the cost of construction, installation and maintenance of this type of automatic weather station.

2.2.- Buoy Type of Automatic Weather Station Operated by the Canadian Meteorological Service on Lake Ontario

In order to obtain more representative information of meteorological elements to facilitate fog forecasting on the north shore of Lake Ontario, an automatic weather station was established on the lake by the Canadian Government in 1942. Since there were upwelling effects near the shore, temperature measurements in this area were unrepresentative and misleading for purposes of fog forecasting. Accordingly, this automatic weather station was constructed and installed in a large navigation buoy and anchored some distance from the shore (see Figure X).

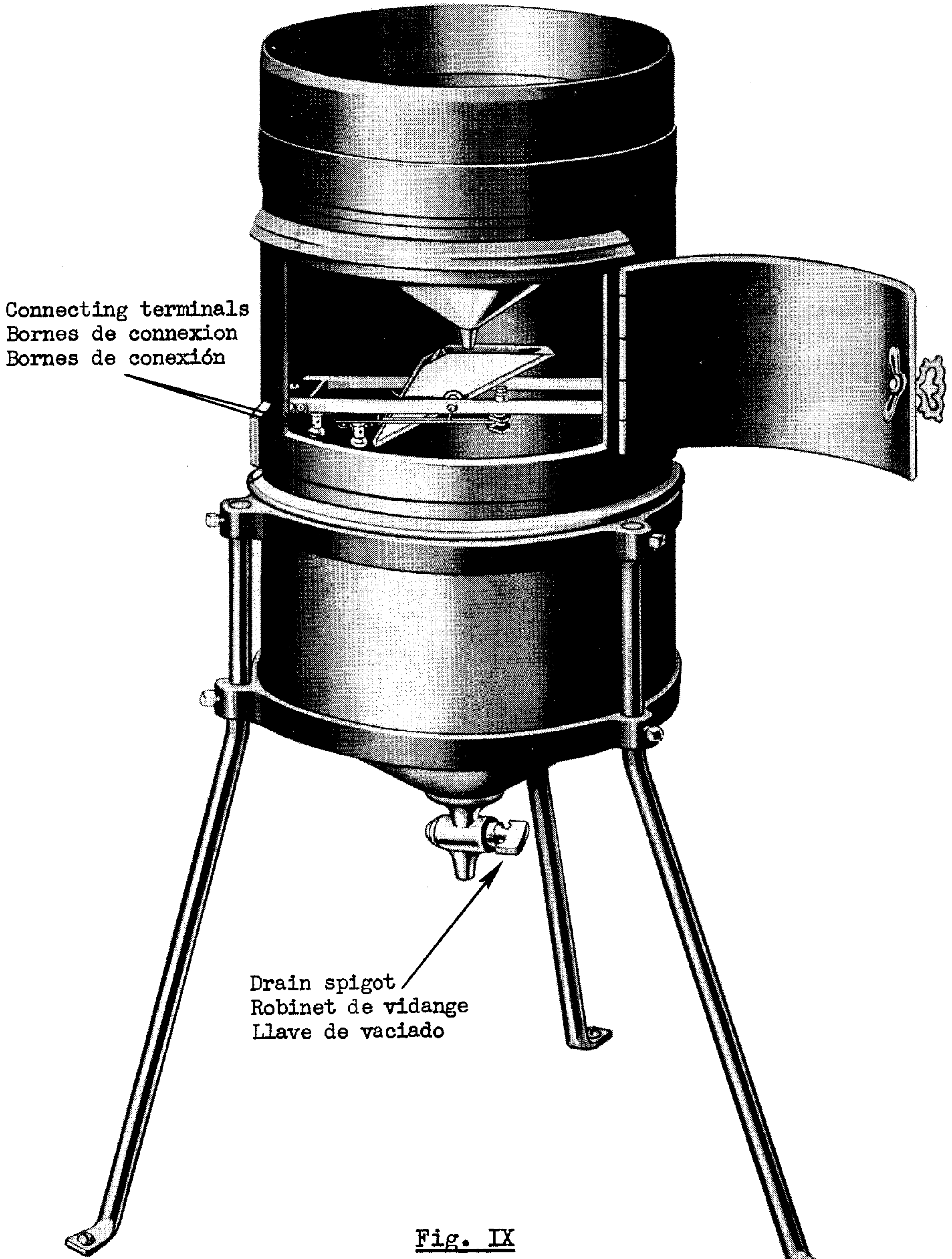

Fig. IX

Precipitation Recorder
Pluviomètre enregistreur
Pluviógrafo

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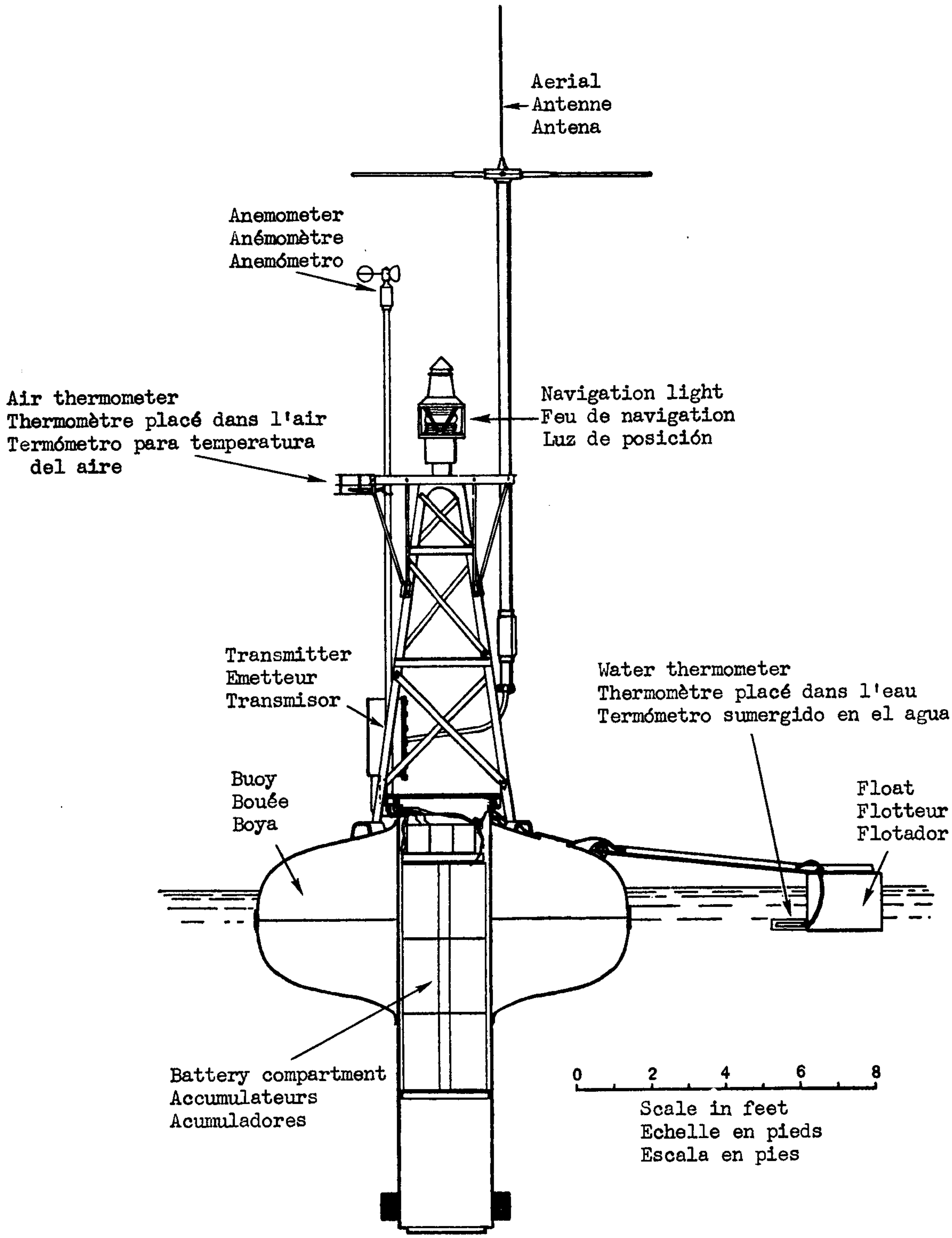

Fig. X

General arrangement of buoy
Disposition d'ensemble de la bouée
Disposición general de la boya

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Meteorological Elements Measured

Indications of air temperature, water temperature and wind speed are transmitted to the meteorological office.

Meteorological Instruments

Air Thermometer.- The thermometer consists of seven resistors in series. These resistors have a negative temperature coefficient. For example they have a resistance of about 70,000 ohms at 86°F and about 154,000 ohms at 32°F. Each resistor is about 3 inches long and about 0.07 inch in diameter so that the several resistors can easily be mounted in a tube of $\frac{1}{4}$ inch diameter. The assembly is properly insulated and enclosed in a thin copper tube. The thermometer is bolted to the safety ring on the tall superstructure of the buoy.

Water Thermometer.- The water thermometer is of the same type as the air thermometer except for heavier insulation to prevent short circuiting. It is mounted on a separate buoy 2 feet in diameter and 18 inches high connected to the main buoy by a hinged frame. This arrangement keeps the thermometer at approximately constant depth below the surface. If it were mounted on the buoy the rolling of the latter would often submerge it deeply or raise it out of the water.

Anemometer.- The anemometer is an ordinary three-cup instrument making 150 contacts for a run of one mile of wind. It is mounted on the uppermost part of the buoy.

Transmitter.- A five tube transmitter with an output of about 3 watts, transmitting at a frequency of 62.4 megacycles, is mounted in a watertight compartment on the superstructure of the buoy. The antenna extends to a height of about 24 ft. above the waterline.

Receiver.- The transmissions from the buoy are received by a communications receiver with its output fed to an electronic frequency meter, which indicates directly on a meter dial the frequency of the pulses received from the buoy (100 to 500 cycles per second).

Power Supply.- The entire apparatus, including a flashing red navigation light, is powered by 3 low discharge type DHB-5-1 cells for the filament power and five Layerbilt "B" batteries in series for the plate supply. The life of the batteries is ten to twelve months, without recharging or replacement. If the cup anemometer could be used to recharge the batteries, the period of time between servicings could be extended to well over a year.

Operation.- Every 3 hours an electrically wound clock makes contact, starting a motor which drives 5 timing cams and turning on the filaments and heaters of the transmitter. The relays to the various resistance elements are completed in turn which thus alter the frequency of the broadcast signal in relation to the value of the element being measured.

Accuracy.- After two seasons of operation, the instruments were recalibrated. The air thermometer still had its original relationship between resistance and temperature. However, the water thermometer was reading 3.5°F too high at 72°F and 2.5°F too high at 32°F. This indicated a lowering of resistance, suggesting the entry of water. However, this discrepancy has been corrected. The anemometer showed no variation.

Cost.- No specific information is available concerning actual cost of the instrument or its maintenance. With the exception of the resistors, all the components of the programme circuit are commercial products. It is worthy of note that the entire development was carried out with departmental facilities, including the construction of all apparatus not commercially available.

2.3.- French Stations

2.3.1.- Automatic Weather Station of the French National Meteorological Service

The automatic weather station, of the type developed by the Météorologie nationale, is designed to transmit by radio-telegraphy, over a range of more than 1500 kms, signals corresponding to the values of pressure, temperature, humidity, wind (direction and speed) and amount of precipitation. Provision has been made to add an apparatus which will permit the station to transmit the temperature at the cloud base, which would enable one to make a good approximation of the type of cloud and the height of the base, as well as another apparatus to indicate that a storm occurred in the vicinity of the station at a given hour or during the three hours preceding the time of transmission.

The station includes:

a) A precision clock equipped with electrical rewinding apparatus;

b) Specially equipped meteorological instruments;

c) An apparatus for remote control and for telemetering;

d) A double short-wave pulse transmitter (2 wave lengths);

e) A power supply comprising a bank of accumulators and a wind-driven generator.

General Principles of Operation

The clock mechanism in the station actuates at given hours the closing of a circuit which controls relay of the remote control apparatus which in turn applies voltage to the tube filaments of one of the transmitters.

After a sufficient time interval, high tension is applied to the anodes and to the screen grids of the transmitter which, as from this moment, is ready to function.

The telemetering apparatus controls the successive sending by the transmitter of several series of distinct signals, the number of signals in a series being between 1 and 10:

1) The first series of signals corresponds to the station indicator;

2) Several series of signals correspond to:

the barometer reading - 2 figures (units and tens)

the thermometer " - 2 figures (units and tens)

the rain gauge " - 1 figure (units only)

the hygrometer " - 2 figures (units and tens)

the anemometer " - 1 figure (units only)

the windvane " - 1 figure (units only)

the measurement of cloud base - 2 figures (units and tens)

the storm indicator - 1 figure (units only).

When this cycle has been transmitted three successive times the apparatus reassumes its standby condition after having cut the high and low tension current supplying the transmitter.

A wind-driven generator provides for the charging of the accumulators supplying the transmitter unit. Radio reception is obtained by means of a receiver specially adapted for the reception of the impulses and which controls an oscillograph for registering on a strip of paper the signals sent out by the transmitter.

Description

Electric Clock.- The electric pendulum clock utilized is of the wall type, which has a reserve period of operation ensured by means of a small electric motor for the rewinding of the clock.

Two series of studs arranged on a mobile disc operated by the clock enable two distinct contacts to be established at the proposed hours of transmission, these contacts being related electrically to the remote control set. One of these contacts corresponds to the daytime high frequency, the other to the night-time high frequency, thus permitting transmissions to be made under the most favourable propagation conditions.

Meteorological Instruments.- The sensitive elements of the instruments are identical with those of the recording instruments which are used in meteorological stations. The stylus of each apparatus is provided at its extremity with two contact points and moves without friction in front of a vertical collector carrying two series of contacts, the first corresponding to the units, the second to the tens (the rain gauge, anemometer and the windvane are only provided with a simple collector corresponding to the sending of a signal having only one figure).

The wires for the tens of the same value are all interconnected on the collectors and then led to the tens control jacks of the switchboard; the same applies as regards the units wires.

At the time of the observation, a "feeler" ensures the contact of the stylus on one or more studs corresponding to the value of the reading provided by the sensitive element.

Remote Control and Telemetering Apparatus.- This apparatus controlled by the clock and the meteorological instruments has as its function:

1) Setting the transmitter in operational order after a prearranged time interval;

2) Connecting three times the various meteorological instruments and the station indicator in succession;

3) Ensuring the transmission of a certain number of signals corresponding successively to the figures for tens and units;

4) Cutting the power supply to the transmitter when the third sweep of the instrument contactor has been effected.

Arrangement of the Signals.- The transmission of each figure (unit or tens) corresponds to as many transmissions of four HF pulses of a duration of 40 microseconds - transmitted at a frequency of a hundred per second - as there are units in the figures to be transmitted. These distinct transmissions each being therefore of a duration of 40-milliseconds are separated one from the other by a constant time interval.

The receiver integrates the series of four short pulses (40 microseconds) and the pen of the recording oscillograph marks a tick on each reception of a group of four pulses.

Pulse Transmitter.- The apparatus used is a pulse transmitter. The transmission can be made on two distinct HF channels, each one connected to two different antennae:

Channel 1. 20 to 11.1 Mc/s. (15-27 metres);

Channel 2. 11.7 to 6.5 Mc/s. (25.6-46 metres).

The pulse transmissions permit one to obtain a peak antenna power greater than 1-Kw since the average power does not exceed 4-watts, whereby an important economy of electrical energy for a given range is obtained.

Two tubes in parallel are in use at each stage of the transmitters, in such a way that the functioning is maintained if a filament is broken. The antennae used are of the Conrad type.

Power Supply Apparatus.- The power consumption of the station (converter, relay, heating of the radio tubes) is 200 watts for the two minutes taken by each transmission. The current necessary is supplied by a converter 24 volts DC/110 volts AC/50 ps. The supply to the converter is assured by a bank of accumulators of 24 volts, the charging of which is obtained by means of a wind-driven generator specially adapted for this purpose.

The accumulators of a special type with a large reserve of electrolyte are equipped with an auxiliary apparatus which ensures a constant level in the cells by means of an automatic supply of distilled water to compensate for the evaporating electrolyte. The capacity of the battery is normally 180 ampere hours.

The wind-driven generator has a nominal power of 150 watts/24 volts, its tapered form and the special arrangement of the propeller permitting it to resist strong gusts of wind. The compactness of the streamlining ensures effective protection for the internal mechanisms against inclement weather. A differential make-break contact permits the use of the apparatus even during periods of light winds and in addition avoids supplying current to the accumulators when the latter are sufficiently charged. The wind generator is fixed at the top of a tubular mast 8 metres in height and is made secure by means of three guy wires.

Installation

The enclosure (See Figure XI) should be selected in a site as open as possible, this preliminary condition being favourable both for the taking of meteorological observations and for the good propagation of radioelectric transmissions.

As far as possible a site immediately adjoining the seacoast should be avoided, since the salt and iodized air causes particularly active chemical corrosion of the different metals which are used in the construction of the automatic station. In the same way one should avoid very humid locations. Whenever possible one should avoid making an installation on a rocky surface which will increase the difficulties of fixing the guy wires and, in addition, presents some difficulty in the earthing of the radio equipment.

The ground necessary for the installation of the station should have the following dimensions: 25 x 35 metres, taking into account the insulated antenna wires and the guying of the pylon for the wind-driven generator.

Weight of the Equipment

All the equipment, meteorological instruments, radio transmitters and accessories weigh 2,500 kilograms. To this total should be added the hut (constructed at the selected location) and the various materials required in the preparation of the concrete used for the mounting of the pylons, for the instrument shelter and for the enclosure.

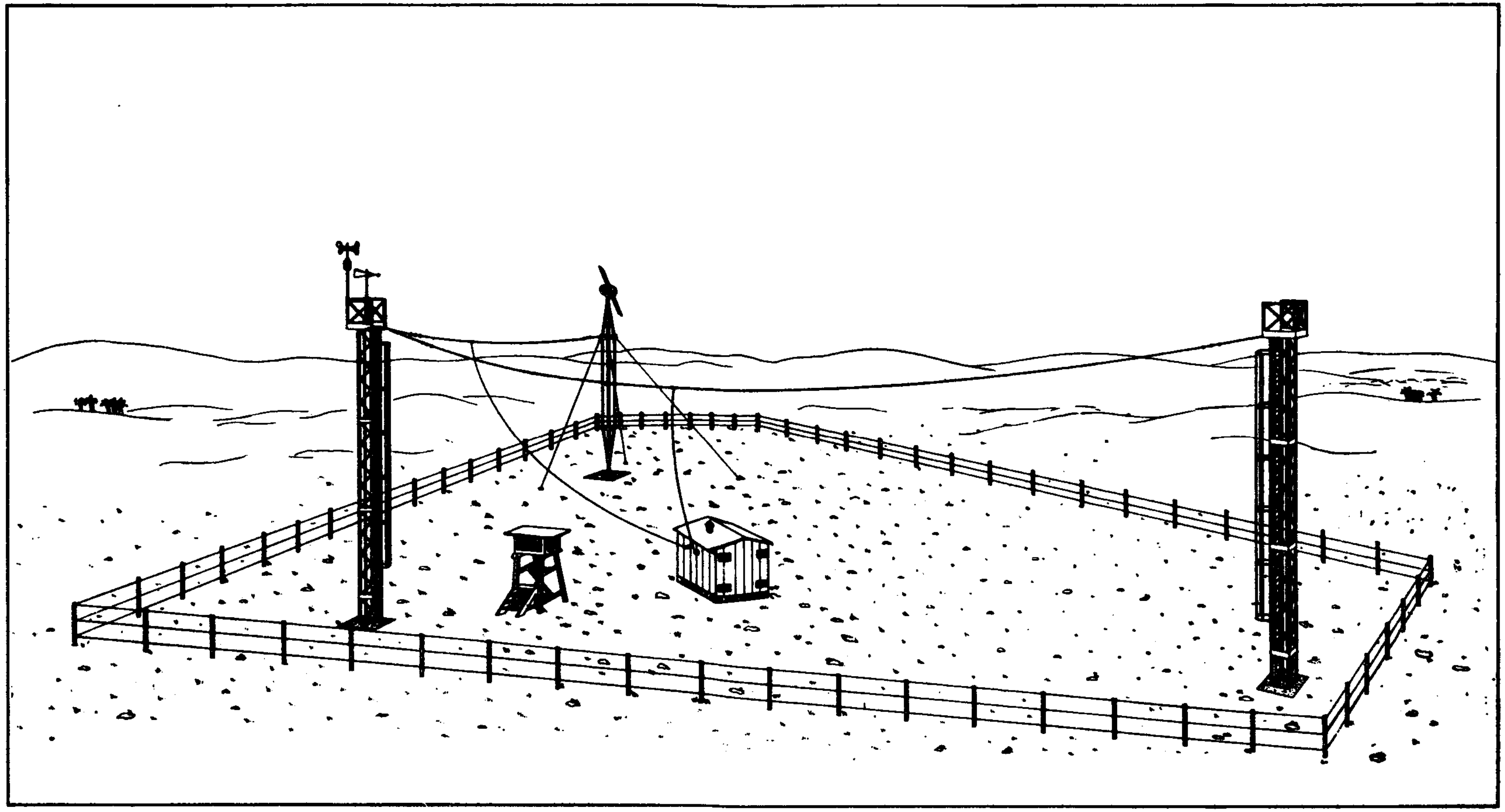

Fig. XI

French automatic weather station - Site
Station météorologique française - Implantation
Estación meteorológica automática francesa - Instalación

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Trials of the Station

Installed at Trappes during the month of December 1948 the automatic weather station has been in continuous operation. Recordings made at Brest and at Annecy have given every satisfaction.

2.3.2.- Automatic Weather Station Maintained by the French Meteorological Service on the top of the Eiffel Tower

At the present time there is an automatic weather station installed at the top of the Eiffel Tower in Paris. Since the time of its installation in 1943, the transmissions to the headquarters of the Meteorological Service have been by land-line communications. However, a radio transmitter of low power consumption has recently been utilized. The results of this latest installation have not, as yet, been received.

Meteorological Elements Measured

Continuous observations of temperature, humidity and pressure are made at one minute intervals throughout the 24 hours. The number of records made each day is 1,440 for each element observed, a relatively high figure which permits accurate determination of the mean meteorological data.

Meteorological Instruments

Thermometer.- The sensitive element, based on the Wheatstone bridge system, is contained in an air-tight metal tube, and two wires are used for the transmission. Each increment of 0.2°C is transmitted from the Tower and remotely recorded.

Hygrometer.- A hygrometric instrument is employed. It is exposed to the open air a fair distance from the Tower with very little protection against the weather. Transmissions of relative humidity take place by a succession of discrete steps, each step averaging 3 to 4 percent of saturation.

Barometer.- A Richard shell-type sensitive barometer is used. Information concerning successive increments transmitted is not available.

Transmitter.- An interesting type of transmitter, designed and produced entirely in the workshops of the National Meteorological Office, has proved to be very successful. No failure ascribable to the actual principle of the device has been noted over several years of operation.

Receiver.- A permanent record of all observations is made on a revolving drum-type recorder. Each contact on the rotating disc causes an electro-magnetic armature to operate and the pen attached to the latter marks a dot or pip on the recording drum. Thus, the observer may take frequent readings from the recording device located in the instrument room, a considerable distance from the place of recording.

Maintenance.- The only normal servicing required is a lubrication of the electric motor and other moving parts at intervals of six months.

Power Supply.- The power supply, apparently from the municipal utilities, is an alternating current rectified by copper oxide cells and filtered by a condenser of about 10 microfarads.

Cost.- Since this instrument was produced and is maintained entirely by the National Meteorological Office, no specific information is available concerning actual cost.

Comments.- Continuous observations of lapse rate of temperature, humidity and pressure from the surface to the top of the Eiffel Tower have yielded valuable information for purposes of stratus cloud and temperature forecasting and three-dimensional research.

2.4.- Automatic Weather Stations in the U.S.S.R

It is understood that there is a network of automatic weather stations already established in the U.S.S.R. which transmit observations on the average 4 times a day. The elements measured are pressure, temperature, wind speed and direction and, in some cases, precipitation. Stations have already been established on the Murmansk coast, in the Kara Kum desert and on one of the islands in the Aral Sea. The stations have a range of 375 miles and are designed for a year's operation without any servicing.

2.5.- German Automatic Weather Stations

Two types of automatic stations were developed and utilized in Germany during the 1939-1945 war: a marine type, mounted on a buoy and a type for use on land. The details of these instruments are summarized below.

A) Marine Type

The buoy has more or less the same shape and size as a torpedo. A system of anchorage, made up of a cable and a heavy weight maintains the buoy in a fixed position (experiments have shown that during strong winds and at a depth of 2,000 metres, the stability thus obtained is satisfactory, and the drift does not exceed more than a few nautical miles over a period of several months). Moreover the centre of gravity of the buoy has been placed low enough to make its rolling negligible. The tension plaque battery is of the dry type of 900 volts maximum, mounted in a cylinder in the interior of which slides a second floating cylinder carrying the heating battery adapted for three months operation, the transmitter and the clock mechanism for the purpose of starting the functioning of the station.

The transmitter is a Lorentz with a 100-150 watt antenna, mounted on springs and covering a range of frequencies from 3,800 - 7,000 kcs. (about 79 - 43 metres). The clock mechanism which, four times a day, at the required intervals, provides for the operation of transmitter circuits and the operation of the measuring instruments is a Siemens spring model, having a reserve period of operation of several hours and is rewound at regular intervals by an electric auxiliary motor. A meticulous setting of the frequency of the controlling mechanisms appears to ensure that the clock shall have an adequate operating precision.

The antenna is telescopic and has a vertical extension of 8 metres. At its base are arranged the instruments for measuring the meteorological elements. The telemetering system of this apparatus functions in the following manner:

> A certain number of metallic discs, each one bearing in relief one or more morse code letters in such a way that each disc constitutes a different signal, are set up one above the other, each one of them being separated from its neighbour by a similar disc made of non-conducting material. In this way a revolving cylinder is provided which has a uniform movement. The stylus-arms of the meteorological measuring instruments move over the exterior surface of this cylinder with which they are in contact, one after the other at the time of the observation; when the meteorological element corresponding to one of the stylus recorders varies, this stylus moves along the generatrix of the cylinder

and at the time of the observation makes contact with one or the other of the discs bearing the Morse letters in such a way that the signal corresponds to a value of the element being measured.

Moreover, to distinguish unmistakably to which element the transmitted signal corresponds, the stylus-arms are arranged asymmetrically on the exterior surface of the cylinder. It is simple to transmit a special signal or "pip" at the beginning of each revolution of the cylinder in order to mark the beginning of the measurement.

Finally, the cylinder-stylus mechanism comprises a morse manipulator for the transmitter so that each observation transmitted by the buoy is composed of a certain number of letters (as many letters as the number of elements measured) each group of letters corresponding to the value of one of these elements at the time of observation. The measuring instruments used were two barometers having Vidi capsules, the first giving an approximate value of pressure, the second supplementing the first value to give the exact pressure; a Bourdon tube thermometer for the air temperature and a bi-metallic thermometer for the water temperature.

An apparatus for measuring the direction and speed of the wind has been studied but was not used on the buoys.

The accuracy obtained was within plus or minus one milibar, and within plus or minus one degree centigrade. The messages were given in the following form: A: B: C: D: T: A being the approximate pressure reading, B being the complementary pressure reading in order to obtain the pressure reading to the nearest millibar, C being the water temperature, D the air temperature, and T the station indicator. The duration of the broadcast was one minute, and during this minute the measurement group was repeated twelve times, which represents a very acceptable standard of operation.

Buoys of this type were installed in the following regions:

a)	Atlantic	57°N	14°W
		53°N	14°W
		56°N	34°W
		72°N	12°E
		72°N	40°E
b)	Baltic	Gulf of Bothnia	
c)	Mediterranean	43°N	9°E
d)	Black Sea	44°N	37°E
		42°N	31°E

The broadcast frequencies were selected to secure the best results. the Germans, it seems, received 80 - 90% of the messages at a distance of 1,000 and 2,000 Kilometres in middle latitudes and 50 - 60% in northern latitudes. Several listening stations were responsible for picking up the messages in order to improve the chances of success.

B) Type for Use on Land

The construction of the stations for use on land is of the same type as the buoy and only the antenna is different. It is mounted on a tripod mast, each leg of which houses one of the three main instruments. The total weight of the station is two and a half tons, and the batteries ensure operation for a period of six or nine months. An anemometer and a wind vane could easily be added, the question of weight being quite secondary. Finally, a clock-work operated system permits the station to transmit two series of letters instead of one: the second series giving, firstly, the wind direction in two letters; secondly,the wind speed in two letters; and thirdly, a repetition of the station indicator.

Stations of this type were established principally in the following locations: Bear Island, Spitzbergen, Jan Mayen, Novaja Zemlya, in the Aaland Islands and in Labrador. According to the Germans, the instruments gave satisfactory results even in the extremely severe climatic conditions to which they were subjected.

3.- CONCLUSIONS

After almost 10 years of experiments, the States which have undertaken research on automatic weather stations have modified and improved them to such an extent that a high degree of accuracy and reliability is now obtainable in their operation. Moreover, with the addition of the wind-driven electric generator to charge the lead-acid storage batteries, the length of time between servicings can probably be extended to a year or more.

The examples given above of existing and successfully operating automatic weather stations clearly indicate that they can be used to obtain weather information from isolated places on a routine basis and are adaptable to varying conditions of climate and location. Thus far, no information has been received concerning the performance of automatic weather stations in desert regions although there is no reason to suppose that they cannot readily be adapted for use in such areas.

Practical recognition of the importance of automatic weather stations has been evidenced in the reports of three ICAO Regional Air Navigation Meetings, viz., Middle East, South Pacific and South Atlantic and in the ICAO Mission's technical report on Air Navigation facilities in Iceland.

States, in whose areas sparse and inadequate weather reporting networks exist may, therefore, find in this publication sufficient justification for re-considering the possibility of supplementing such networks by a series of automatic weather stations located at the most significant points.

The establishment of automatic stations is already recommended for the following locations:

1) Jarvis Island - Approximately 1200 miles south of Hawaii, 0.5°S, 160°W.

2) Rochedos Sao Paulo - a reef in the South Atlantic approximately half-way between Dakar, French West Africa and Natal, Brazil.

3) Fjordungsvatn, Iceland - A small lake approximately in the centre of Iceland.

4.- BIBLIOGRAPHY

1) Automatic Weather Station, Navy Model TDM-1, Navships 900,832, Bendix Aviation Corporation, Friez Instrument Division, Baltimore 4, Maryland, U.S.A.

2) A Buoy Automatic Weather Station, W.E. Knowles Middleton, Meteorologist, Department of Transport, Toronto, Ontario and L.E. Coffey, Radio Engineer, Department of Transport, Ottawa, Ontario, P. 122-129, Vol. 2, Number 2, June 1945, "The Journal of Meteorology".

3) Automatic Weather Stations, J.S.F. - Vol. 2, Number 7, July 1947, p. 197-198 "Weather".

4) Télémétéorographe R. Strutz, Modèle O.N.M. et intégraphe météorologique par R. Strutz. E.E.R.M. Service,Instruments,Méthodes d'Observation. Etudes instrumentales.

5) Automatic meteorological station network in the U.S.S.R. Anon. Journal of Scientific Instruments, London 23, 1946, p. 192.

6) C.B. Pear, Radio equipment for an un-manned weather station. B. Amer. Met. S. 21, 1940, pp. 107-110.

7) Diamond & Hinman. An automatic weather station - Washington, J. Res. Bar. Stand. 25, 1940, pp. 113-148. (Sci. Abs. 1882 B, October 1940). See J. Sc. Instru., London, 18, 1941, p. 16; Abs. Sci. & Tech. Press, 25321, November, 1940; Milan, Geof. Pura Appl. 2, 1940, pp. 220-223.

8) Diamond & Hinman. Remote automatic weather observations. B. Amer. Met. S. 21, 1940, pp. 343-349.

9) H. Diamond. Recent application of radio to the remote indication of meteorological elements. Repr. from: New York, N.Y., Elect. Engin. April, 1941, pp. 163-167.

10) Wood. Automatic weather stations. J. met. Amer. Met. Soc. 3, 1946, pp. 115-121.

11) Coates. The Automatic weather station. Washington P.U.S. Naval Inst. 73, 1947, pp. 1096-1103.

12) A. Perlat. Les Stations météorologiques automatiques. La Météorologie, July - September, 1948, p. 196.

13) A. Perlat. La Station météorologique automatique de la Météorologie nationale. "La Météorologie" - Jan-Mars 1949

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Figure X - Journal of Meteorology, American Meteorological Society, Vol. 2, No. 2, June 1945.

Figure XI - La Météorologie, Annuaire de la Société météorologique de France, Janvier - Mars, 1949.

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