MULTIDISCIPLINARY RESEARCH IN THE GREAT LAKES BASIN

U of M
Sea Grant Program
NOAA

SURFACE METEOROLOGICAL AND OCEANOGRAPHIC PLATFORM

by
Gary C. Goldman

Department of Meteorology and Oceanography
The University of Michigan

A COOPERATIVE RESEARCH PROGRAM SPONSORED BY THE UNIVERSITY OF MICHIGAN AND THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION: U.S. DEPARTMENT OF COMMERCE

SURFACE METEOROLOGICAL AND OCEANOGRAPHIC PLATFORM

by

Gary C. Goldman

Edward C. Monahan
Project Director

Local Meteorology Project

Department of Meteorology and Oceanography
College of Engineering
The University of Michigan

The University of Michigan Sea Grant Program
NOAA, U. S. Department of Commerce

August 1971

PREFACE

The following report, prepared by Mr. Goldman, describes the design, construction, and initial use of a unique buoy designed specifically for the measurements required in our study of the physical behavior of Grand Traverse Bay. Those who read his report, and have some personal experience with such instrument systems, will recognize the magnitude of the task which he has brought to a successful conclusion. He was ably assisted through much of this project by Mr. Louis P. Pocalujka. Mr. Eduardo D. Michelena and Mr. Richard G. Johnson assisted in the installation of the buoy and its anchor, and in the attachment of the sensors.

Professor Gerald C. Gill provided advice on the design of the thermistor shields. Dr. Lee Somers and the other members of the University of Michigan's Sea Grant sponsored Underwater Operations Project provided invaluable assistance during the installation and inspection of the buoy. Mr. Charles D. Craw operated the R/V SEA GRANT I during the initial tow of the buoy, and on numerous occasions since. The assistance of these men is gratefully acknowledged.

The advice of Professor Finn C. Michelsen of the Department of Naval Architecture and Marine Engineering, and the participation of N. A. & M. E. students, Mr. Robert M. Seeger, Mr. Edward N. Comstock, and Mr. Robert A. Pittaway in the design and model testing of the buoy is recognized with thanks.

We wish to thank the personnel of the R/V MYSIS, of the University of Michigan's Great Lakes Research Division, for their aid in the setting of the buoy anchor.

We are most grateful for the aid and facilities provided us in Traverse City by Northwestern Michigan College. We could not have successfully launched the buoy without the assistance of Captain M. Hemmick and the services of N. M. C.'s Great Lakes Maritime Academy. The use of their power barge DRAGON during the setting of the buoy is gratefully acknowledged.

We wish also to thank Mr. Robert W. Severance of Florida State University for provided data on F. S. V.'s TRITON buoy.

It should be noted that prior to installation of the buoy we obtained the required "letters of no objection" from the Chicago District, Corps of Engineers, Department of the Army (16 October 1970) and from the Department of Natural Resources, State of Michigan (5 March 1971). The United States Coast Guard, Ninth Coast Guard District, approved our "Private Aids to Navigation Application" in a letter dated 25 March 1971.

We look forward to the continued use of S. M. O. P. in our study of Grand Traverse Bay.

Edward C. Monahan
Associate Professor
of Oceanography
Ann Arbor, Michigan
August 1971

The University of Michigan is currently participating in the Sea Grant Program, sponsored by the National Oceanic and Atmospheric Administration. The present area of study is the development of the methods of applying the systems analysis approach on Lake Michigan and its environs, and the production of modeling techniques applicable to the Great Lakes. The methods are being formulated, evaluated, and analyzed on Grand Traverse Bay, which closely approximates Lake Michigan in both geographical layout and population density.

The systems analysis approach involves coordinating many disciplines such as law, economics, oceanography, meteorology, biology and other related fields. In an effort to correlate the many variables, it is necessary to accumulate data depicting the natural variables, such as air and water temperature, wind speed and direction and water current speed and direction and the relationship of the water movement to the wind.

It was with this desire in mind that the Surface Meteorological and Oceanographic Platform (SMOP) was built.

DESIGN CRITERIA

Ships are the primary method of collecting oceanographic and meteorological data at sea. However, it is prohibitively expensive to use them as platforms to collect data over long periods of time.

An alternative to using a ship is to use a moored platform which could support the required instruments and allow simultaneous measurements of the desired variables over long periods of time. These measurements would have to be recorded for subsequent retrieval and analysis.

The requirement for this project is to build a moored floating platform that is capable of supporting the required instrumentation, durable enough to stand up to the rigors of Great Lakes conditions, sturdy and stable enough to allow maintenance to be performed on the deck and tower of the platform, and inexpensive to build and maintain.

As the wind data is to be used in conjunction with the heat budget model of Grand Traverse Bay, it is also necessary that the platform remain approximately level and follow the water level.

The platform must meet the following instrumentation requirements as well. Meteorological measurements include air temperature at two different heights, and wind speed and direction. Subsurface measurements include near surface and 20 meter depth water temperature as well as water current speed and direction at the 20 meter depth.

SMOP is moored in the north central portion of Grand Traverse Bay (Figure 1). This location is greater than 4 miles from any significant land mass so as to produce as little obstruction from land as possible for wind and water measurements. In this way, a more appropriate value of the measured parameters can be obtained.

BACKGROUND

Upon determining the requirements for the buoy, a literature search was undertaken to make use of the best available information and designs that fit our purpose.

Most buoys in use today are torroidal or disc shaped with a metal structural framework above the float for meteorological instruments or telemetry equipment, signal lights, and lifting eyes. Below the water there is usually a triangular attachment for the mooring line and instruments (Verber [1967], Farlow [1967], Daubin [1967], Seelinger et al [1967]). This type of float design lacks the roll and yaw stability we need. However, this design is basically simple, and the float would ride well in the water if properly ballasted.

Another type of float is the boat hull design, with an instrument mast vertically upward from the hull (Hakkarinen [1967]). To stabilize this design, Badgley et al [1967] constructed a ballast capable of being lowered while at sea. The added expense of purchasing or building a suitable boat hull eliminated this type of structure.

The most successful design used to obtain air-sea data is the spar buoy (Rudnick [1967], Black [1967], Garstang [1967]). These buoys seemed to offer the most desirable characteristics such as stability and instrumentation supports, however the lack of sufficient heave to follow the sea, and the great cost tended to eliminate our using this design.

What we finally decide upon is in fact a combination of the three types. We used the large surface area and symmetric shape of the disc or torroidal buoys, the deeper draft and triangular shape implied by the boat hull type, and the deep ballast and large central supporting structure indicated in the spar buoys.

In summary, it appears that we used the most favorable characteristics of all available types to develop a buoy most suitable to our needs.

GENERAL DESIGN

The design of SMOP is shown schematically in Figure 2. The buoy consists of a supporting tower (A) with an attached floatation collar (B). Above the water surface is a large fin (C) or wind vane, and a mast (D). Connected to the floatation collar, on elevated platforms, are the wind direction indicator and recording equipment for the wind data (E), and the power supply for the wind recorder (F). A ballast weight (G) is connected to the bottom of the tower, and the water current meter (H) is in the mooring line from the ballast to the anchor (I).

Main Supporting Structure

The main supporting structure for the buoy consists of two open sections of communication tower bolted together near the water line. Each tower section is 3.05 m (10 ft.) long and weighs 78.5 kg (170 lbs.) in air. The tower sections are triangular in horizontal cross section, with each side of the triangle being .61 m (2 ft.).

The tower is used to support the meteorological instrumentation and mast, provide a structure to which the floatation collar is bolted, supply an underwater support for the ballast, and lastly to serve as a ladder during installation and servicing of the meteorolocial instruments.

A Rohn Manufacturing Company, Model #65A communication tower is used for its durability, strength, and relative light weight.

Floatation Collar

The requirements for the floatation collar were durability, reliability, modular construction, low cost, sufficient buoyancy, and ease of forming.

As scale model tests on cylindrical, triangular, and catamaran hulls indicated, a triangularly shaped hull is the most desirable from a stability and drag standpoint. This is the current shape of SMOP's floatation collar.

The triangular shape of the collar (Figure 3) is produced by bolting three 2.7 m (9ft.) long, 150 kg (310 lbs.) sections together. Each section is composed of three vertically alligned barrels, welded size by side within a matrix of angle iron for strength and rigidity.

To set the floatation collar in place, the tower is slipped through the triangular hole in the collar (Figure 4). The tower is connected to the collar by two U-bolts around the tower leg and through an L-shaped steel plate (Figure 5). The plate is then bolted to the angle iron framework of the collar. A similar plate is located at each vertex of the triangle, both above and below the water--thereby requiring 6 such connecting plates.

The top of the collar is outfitted with a form fitting deck, made of painted plywood. This oft-wetted decking is also covered with a sand-filled paint to minimize slippage while working on SMOP when it is afloat. The decking is bolted to the angle iron frame to avoid damaging the barrels.

There are many vertical .9 m (3 ft.) long 2 x 4's bolted to the frame around the outside of the collar to act as bumpers for the barrels in the event of collision with a small vessel or floating debris. Furthermore, each barrel is filled with a lightweight (specific gravity of .1) form to prevent complete loss of buoyancy should a barrel puncture occur.

Orienting Fin

The purpose of the orienting fin, or wind vane, is to act as an air rudder and turn the entire platform into the wind so that optimum wind and air temperature measurements can be made. This is accomplished by setting the fin to the rear of the platform. As the wind turns the tower upwind of the fin, the small recording wind vane, the anemometer, and the two air temperature sensors are then turned into the wind with no obstructions.

The fin (Figure 6) is made of .005 m (1/8 in.) thick aluminum. It has a trapezoidal shape, being .91 m (3 ft.) in vertical extent nearest the tower and 1.22 m (4 ft.) in vertical extent farthest from the tower. The fin is 1.52 m (5 ft.) long, and is supported by two 2.73 m (9 ft.) long reinforced channel iron pieces. The cross-sectional area is 1.63 m^2 (17.5 $ft.^2$). The weight of the fin and its supports is 25.8 kg (56.7 lbs.). The horizontal centerline is about 1.8 m (6 ft.)

above the water line, and the vertical centerline is about the same from the center of the tower.

In model tests, the fin appeared very responsive to wind direction, and in open water, the actual buoy can be turned by the force on the fin in a wind as small as .5 m /sec (1 mph).

Instrumentation Mast

The single purpose of the mast is to provide an elevated attachment for the highest air temperature sensor and anemometer.

The instrumentation mast is connected by U-bolts to one of the tower legs, and extends up to a height of 4.5 m (15 ft.) above the water level. It is made of .005 m (2 in.) diameter thinwall electrical conduit.

The original design called for a mast in excess of 10 m in height. The top of the mast was to be guyed with steel cable through 4 horizontal booms that extend from the top of the tower out a distance of 2.5 m During the on-site intallation of the buoy, however, instrumentation difficulties caused the lowering of the mast to its present height.

Ballast

A large ballast weight is necessary to lower the center of gravity of the buoy, and to provide a significant restoring forces when the platform tilts from the vertical.

It is desirable, in our case, to keep the horizontal cross-sectional area of the ballast as small as possible to minimize the vertical drag, and thereby allow the platform to heave with the waves. Again we considered expense, ease of construction, durability, and attachment to the tower.

The ballast is triangular in shape, 1.3 m (4 1/4 ft.) on a side, by .9 m (3 ft.) high. It weighs about 1100 kg (2500 lbs.) in air, and 590 kg (1300 lbs.) in water. Poured reinforced concrete is used, and imbedded in the concrete are pipes for electrical throughputs from the air temperature thermistors to the current meter, bolts to connect the ballast to the tower, an anchoring rod to connect the anchoring line to the ballast, and reinforcement rods to increase the strength of the concrete.

The center of mass of the ballast is approximately 3.6 m (12 ft.) below the water line.

Anchor and Mooring System

The type of mooring chosen allows the platform to heave with the waves, gives the buoy enough freedom to turn easily with the wind, and holds the current meter. A short scope mooring is used, with the length of line about 1 1/2 times the depth of 62 m (200 ft.).

The mooring line, extending from the ballast, (Figure 2) has a short length of chain to prevent chaffing, a section of .005 m (1/2 in.) diameter nylon line down to the current meter, and another nylon line of the same diameter running from the current meter to a chain connected to the anchor.

The anchor is poured reinforced concrete, and is about 1 m. by 1 m by 1/3 m high. It weighs 450 kg (1000 lbs.) in air and about one half that in water. Furthermore, it has metal rods extending about 1/4 m out from the sides and bottom to increase its resistance to dragging along the bottom.

Meteorological Instrumentation

The meteorological parameters measured are wind speed and direction, and air temperature.

The wind speed is sensed using a Geodyne heavy duty anemometer, which rotates at a rate of 16.5 rpm/mph of wind. It is set at a height of 4.5 m (15 ft.) above the water surface, and the wind speed data is recorded on a Geodyne, Model 998-0 Wind Recorder.

The data from the anemometer are received as pulses or switch closures (one for each 8 revolutions of the anemometer). This is counted as the number of revolutions in the 60 second recording interval and is displayed as light spots, using a base 8 counting scheme.

The wind direction relative to the Wind Recorder is sensed about 1 1/2 m (5 ft.) above the water surface using a relatively fast response wind vane, mounted in a cage atop, and recorded by, the Wind Recorder (Figure 6, 7).

The wind vane data are read out using a Gray encoding disc (Anon, 1967). The disc, located directly beneath the vane, turns by following a small magnet attached to the vane. A reference to magnetic north is also recorded using a similar directional encoding disc. From these two sets of data, true wind direction can be determined.

The internal parts of the Wind Recorder consist of a clock mechanism, a separate direction-indicating disc for both the wind vane and compass, and a counter for the anemometer.

The data from the above instruments are carried by fiber optics to the plane of focus of a 16 mm movie camera. At the time of recording, the lights flash in the appropriate spots, and the unshuttered camera stores this data on the film.

The clock mechanism for the Wind Recorder is connected by an axle to a cam, located adjacent to a microswitch. Each time a lobe of the cam activates the microswitch, the film in the camera is advanced. During that time the data being sent by the various sensors are recorded once every 5 seconds. The anemometer continues to count throughout the entire 60 seconds, however. At the completion of the recording period, the film ceases to advance and the lights are not flashed until the next lobe of the cam comes into position on the microswitch.

The intervals between the recording periods are mechanically adjustable by placing the desired cam on the timer. The possible recording intervals are once every 5, 10, 15, 20, 30, or 60 minutes. We chose every 10 minutes and thusly have a capability of up to 68 days of recording time.

The power supply for the Wind Recorder is located on an elevated platform, but is situated behind the tower on the rear deck (Figure 8). The power supply is simply a cylindrical tube, containing an Everyready Y993-2 battery package. This battery is used to advance the film in the camera, run the clock mechanism, and to pulse the lights for the encoding disc and counter.

The air temperature is sensed using a thermistor housed in a set of concentric cylinders (Figure 9). The largest cylinder is .2 m (8 in.) in diameter and is .46 m (18 in.) long. The middle cylinder is .15 m (6 in.) in diameter, and .38 m (15 in.) long. Both of these cylinders are painted white, and are designed to minimize direct or reflected sunlight from hitting the sensing surfaced. Within the smaller cylinder is a .025 m (1 in.) diameter silvered glass cylinder to hold the thermistor and reflect any stray radiation that entered the larger cylinders.

The signal from the thermistors is carried through an electrical cable from the sensor, down the tower, through the hole in the ballast and down to the Braincon current meter, where it is recorded.

The air temperature sensors are located at 4 1/4 m (14 ft.) and 2 m (6 ft.) above the water surface (Figure 10).

Underwater Instrumentation

The underwater parameters being measured are water speed, direction, and temperature. The instrument used is a modified water current meter by Braincon, Model 573 (Figure 11). This instrument uses a savonious rotor to determine the water speed, an externally mounted fin to indicate the water direction (with respect to an internal magnetic compass indicating north), and thermistors to sense water temperature.

The current meter is located at a nominal depth of 20 m (65 ft.). One of the thermistors is mounted in the casing of the current meter to sense the temperature at this depth. Another thermistor is set about

1/2 m (1 1/2 ft.) below the water surface. The other two thermistors are used for air temperature and were discussed in a previous section.

These parameters are recorded on magnetic tape every five minutes. At the end of each 5 minute interval there is a 60 second recording time during which the temperatures and direction are recorded every 5 seconds, and the counts on the savonious rotor are totaled throughout the 60 second interval. The total time the instrument can record in the water is 62.5 days.

MODEL TESTS

Model tests were performed in a wave tank to optimize the hull design of the platform. The models used were 1/20 scale with similar scaling of the waves. A fan supplied the scaled wind conditions on the models.

The shapes considered were cylindrical, catamaran, and triangular (Figure 12). These shapes were chosen because they were easy to form from 55 gallon drums, and could be made to mate easily to the tower.

Motion pictures were taken during the tests to record the angular variations from the vertical with respect to time for different wave heights, however, poor quality of the pictures yielded only qualitative comparisons of the 3 models. The cylindrical shape was much too unstable in rough seas, and the catamaran shape did not orient itself properly into the wind. The best configuration of those tested was the triangular shape. This hull indicated a strongly preferred orientation with respect to the wind direction, and it seemed to ride the waves quite well.

Qualitatively, these results have been upheld by the full size buoy.

COST ESTIMATE

In estimating the total cost of the buoy, the costs that must be considered are.the designing, constructing, assembling, and implanting. This price will not include the price of the Wind Recorder and the current meter, as these items are not directly part of the buoy and can be used elsewhere.

The classification for expenditures are as follows. Purchased Hardware consists of small items such as nuts and bolts, lumber, and the like that are readily available. Manufactured Items are those items purchased directly from a manufacturer or his representative. Fabricated Items are those items that were made up to specific drawings for this project. Manpower includes the time for two part-time employees over an 8 month period.

The breakdown of costs are:

Purchased Hardware	$ 400
Manufactured Items	1200
Fabricated Items	700
Total	$2300

To this total of $2300 we must add the 830 man-hours spent in designing, assembling, and implanting the buoy.

All things considered, this does amount to a relatively inexpensive platform from which sophisticated measurements can and are being made.

SERVICING SMOP

The instrumentation used in collecting data on SMOP was chosen to allow the maximum time between servicing. Both the Wind Recorder and the current meter have self-contained power systems. These instruments require servicing only about once every two months.

For the Wind Recorder, this servicing requires opening the power supply and replacing the battery package. The film in the recorder must also be replaced at this time. The total time required for this procedure is about one hour.

The current meter uses a rechargeable battery pack. There are three batteries that must be recharged for 24 hours each. To cut down on lost data time, three charging units were purchased so the total charging time is only 24 hours. The on-site time for meter removal and replacement is about 1 1/2 hours each. The magnetic tape is also changed at this time.

A navigation beacon light was also chosen so that its life exceeds the 2 month interval between servicings. In this way all the instruments are taken care of at the same time, which greatly reduces manpower requirements. Servicing is accomplished from a 26 ft. work boat, thus eliminating the need for a large expensive research vessel.

Of course, if the data were taken at more frequent intervals than indicated, the frequency of servicing would have a corresponding increase.

SUMMARY

The goal of this project was to design a stable, rugged, inexpensive platform to support meteorological and oceanographic instruments.

The stability was achieved by using scale models to determine the most stable hull design from those considered. A large ballast weight is then used to minimize pitch and roll.

Ruggedness was accomplished by using heavy duty materials such as a sturdy tower, angle iron framework, and a nearly indestructable concrete ballast.

Low cost was adhered to by using readily available, low cost parts and keeping the design as simple as possible.

It is felt that these goals were indeed met, and the field tests have helped to confirm this.

REFERENCES

Anon., Operators Manual for 998 Wind Recorder, Geodyne, 1967.

Badgley, F. I., R. G. Fleagle, L. D. Lang, and M. Miyake. A Meterological Research Buoy, Trans. of 1964 Buoy Tech. Symposium, 205-222, 1967.

Black, D. L. A Stabilized Buoy for Oceanographic and Meteorological Instrumentation, Trans. of 1964 Buoy Tech. Symposium, 603-618, 1967.

Daubin, S. C. Mooring Design and Performance of Oceanographic Buoys, Trans. of 1964 Buoy Tech. Symposium, 91-106, 1967.

Farlow, F. S. A Great Lakes Unmanned Weather Buoy and Current Meter Mooring System, Trans. of 1964 Buoy Tech. Symposium, 619-628, 1967.

Garstang, M., P. F. Smith, and K. E. Perry. An Unattended Buoy System for Digital Recording of Air-Sea Energy Exchange Parameters, Trans. of Second International Buoy Tech. Symposium, 193-200, 1967.

Hakkarinen, W. The World of Nomad I, Trans. of 1964 Buoy Tech. Symposium, 587-600, 1967.

Rudnick, P. FLIP (Floating Instrumentation Platform), Trans. of 1964 Buoy Tech. Symposium, 649-651, 1967.

Seelinger, P. E., R. A. Wallston, B. H. Erickson, J. E. Masterson, and W. E. Hoehne. An Oceanographic Data Collection System, Trans. of Second International Buoy Tech. Symposium, 311-334, 1967.

Verber, J. L. The Use of Unmanned Fixed Buoys for the Collection of Temperature and Current Data, Trans. of 1964 Buoy Tech. Symposium, 183-196, 1967.

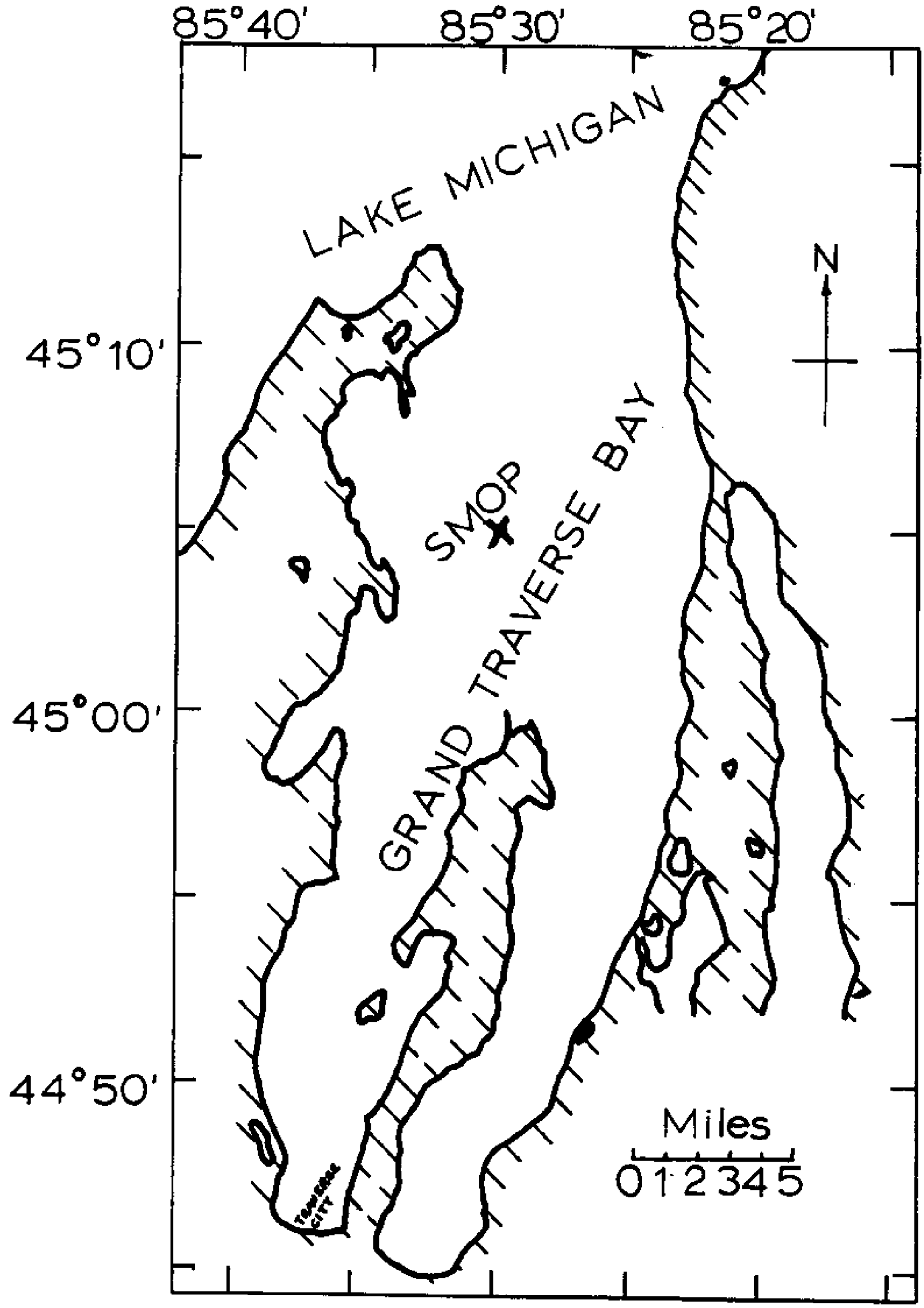

Figure 1 - Location of SMOP in Grand Traverse Bay

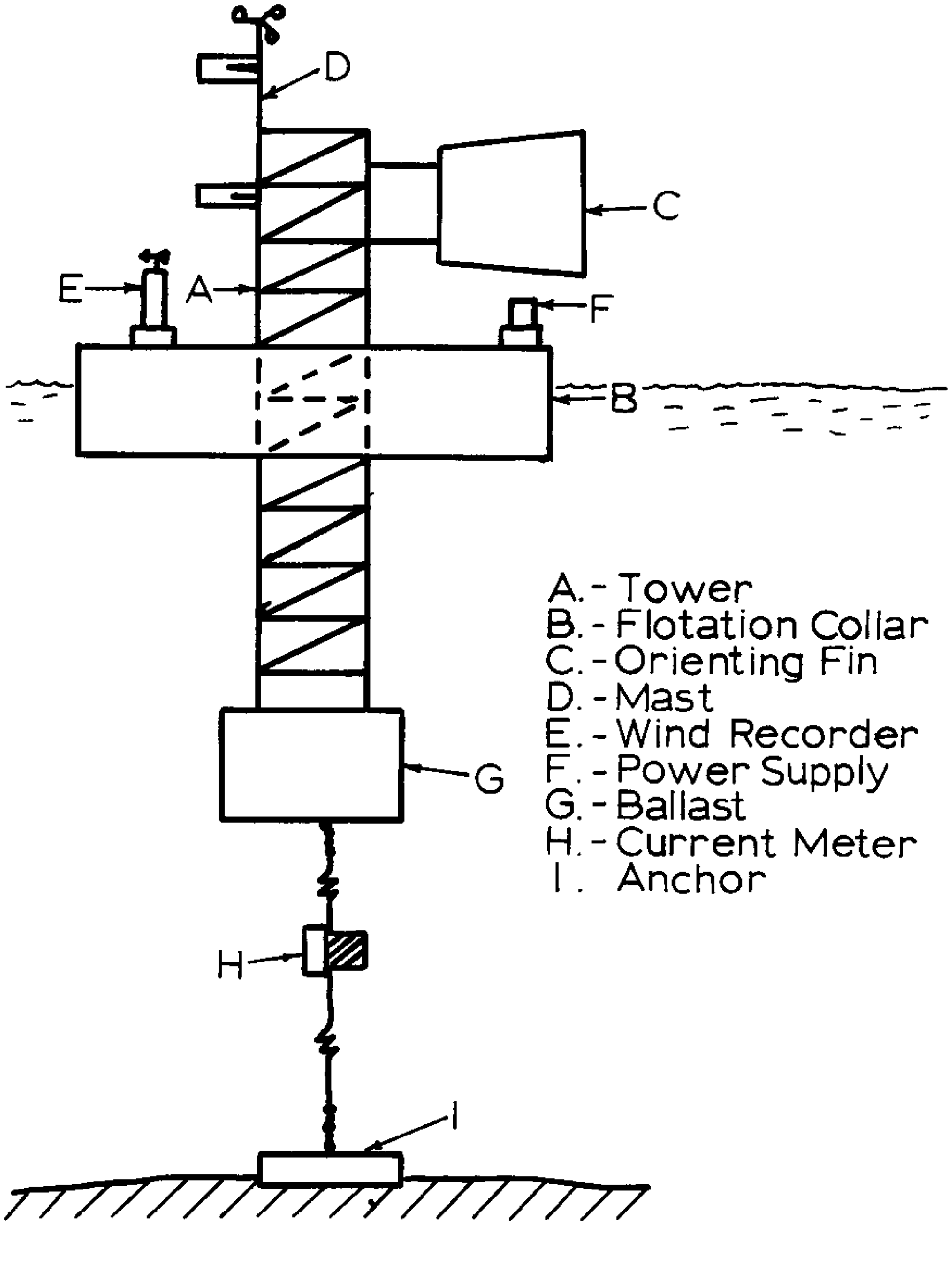

Figure 2-SCHEMATIC OF SMOP

FIGURE 3 Floatation Collar

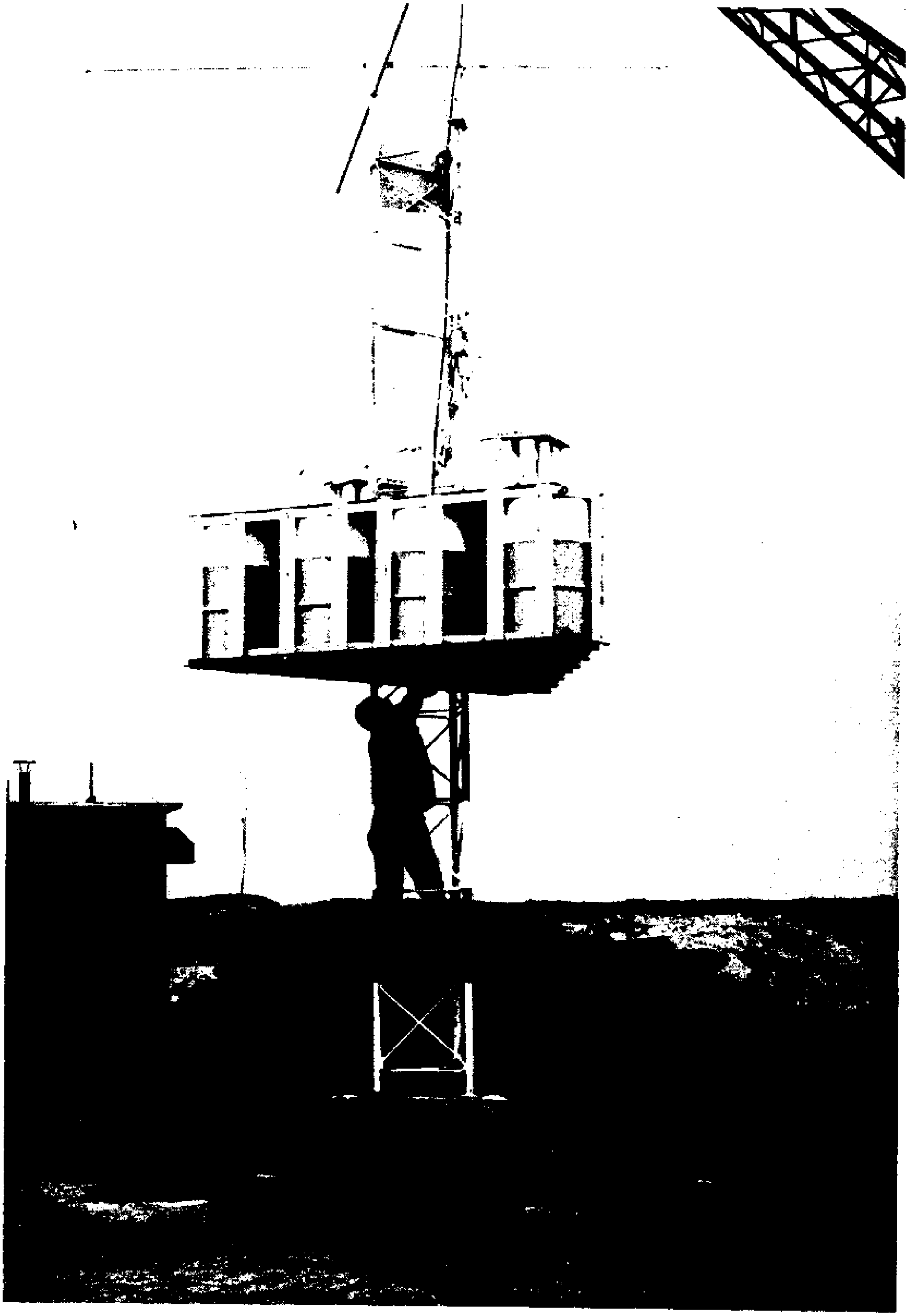

FIGURE 4 Dockside Assembly of SMOP

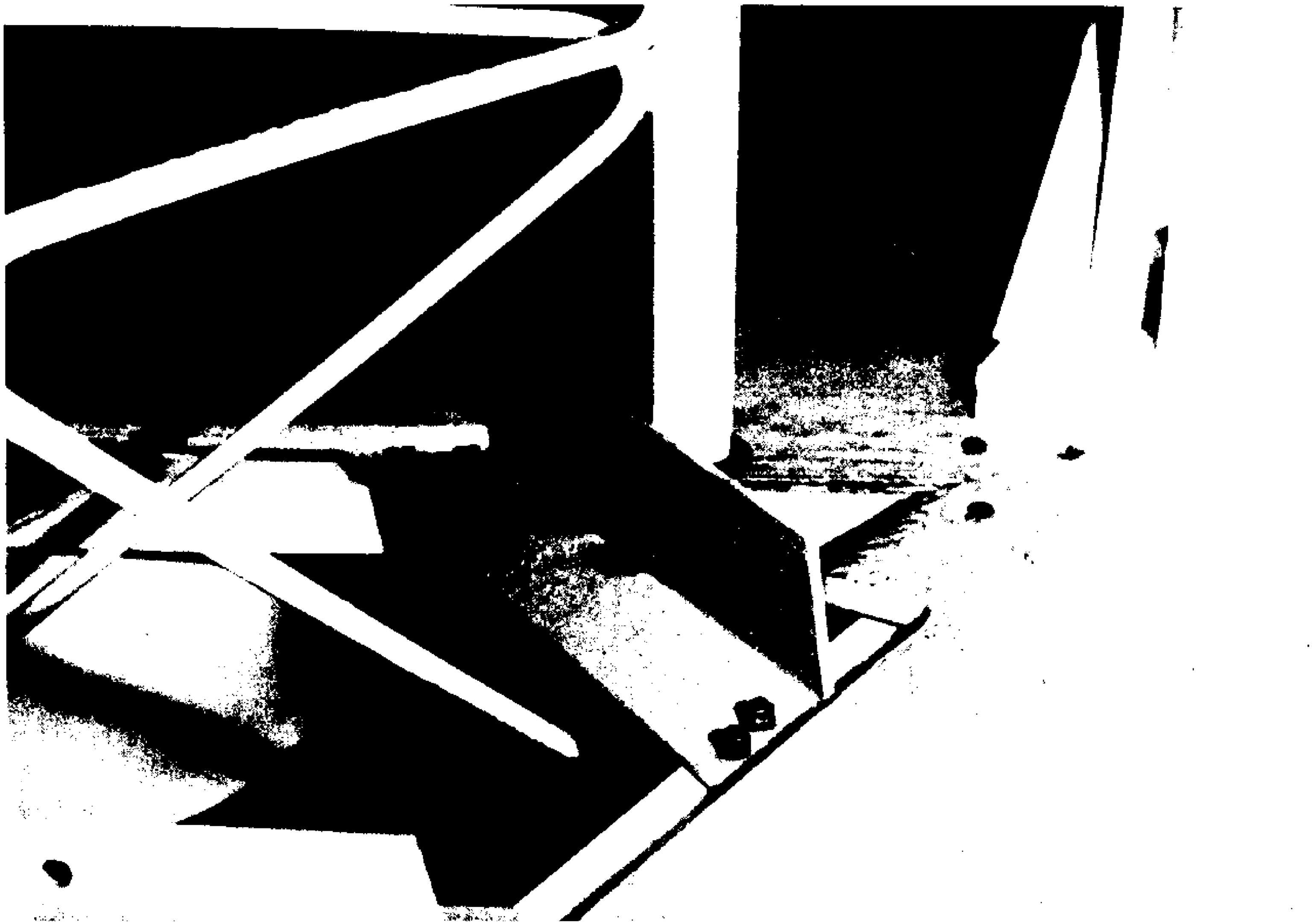

FIGURE 5 Connecting Plate Between Floatation Collar and Tower

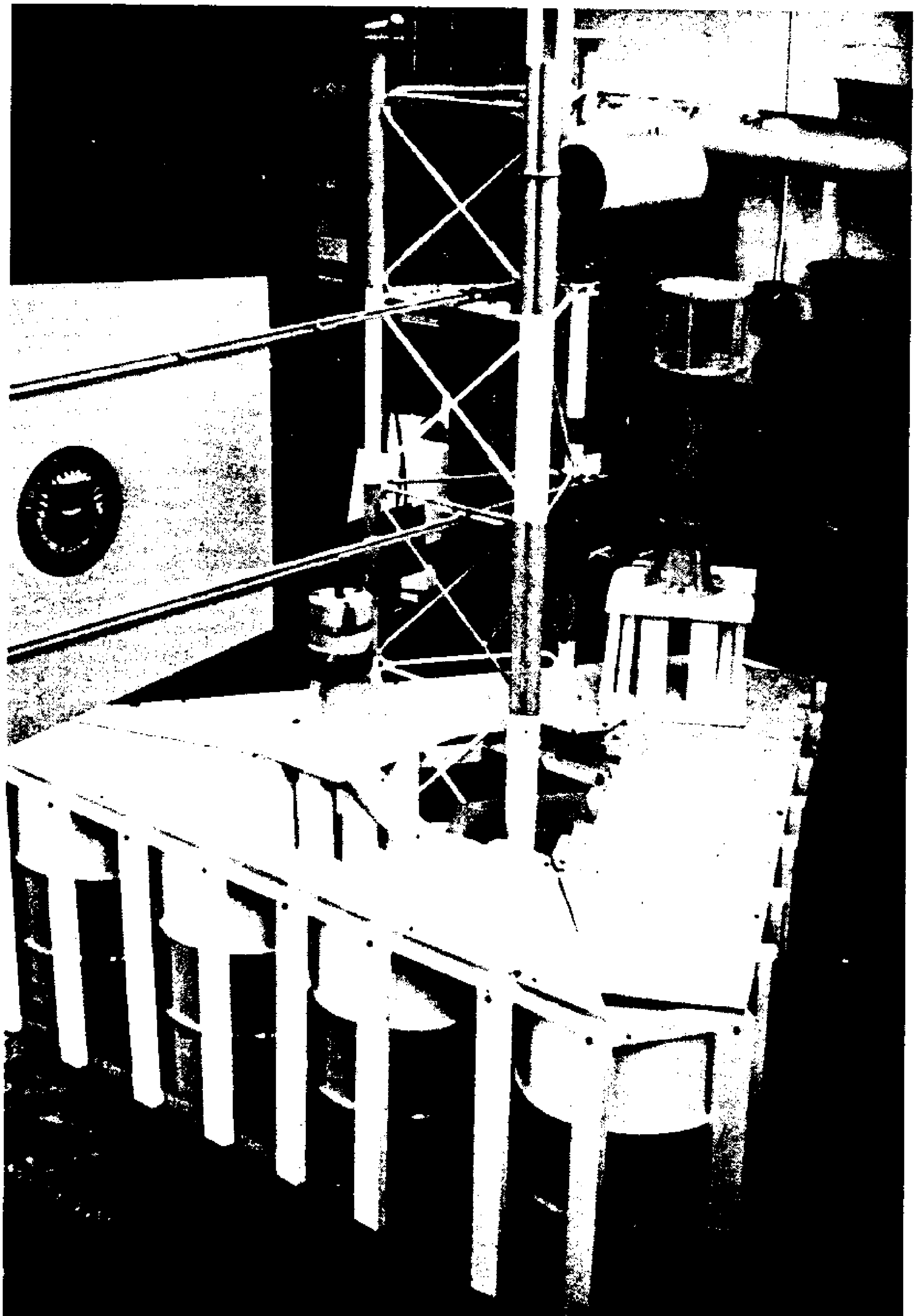

FIGURE 6 Preliminary Lab Assembly of SMOP

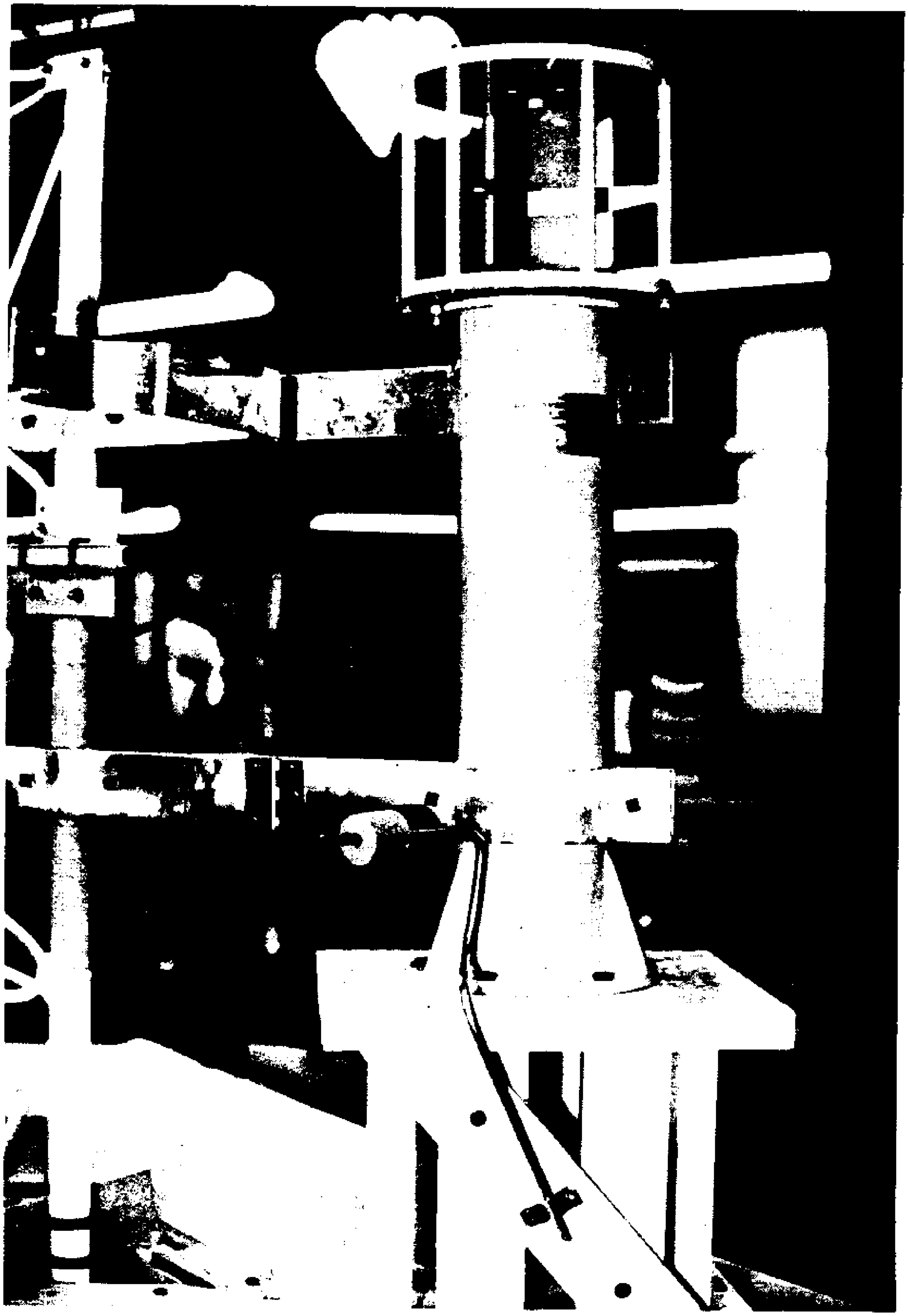

FIGURE 7 Wind Recorder

FIGURE 8 Power Supply for Wind Recorder

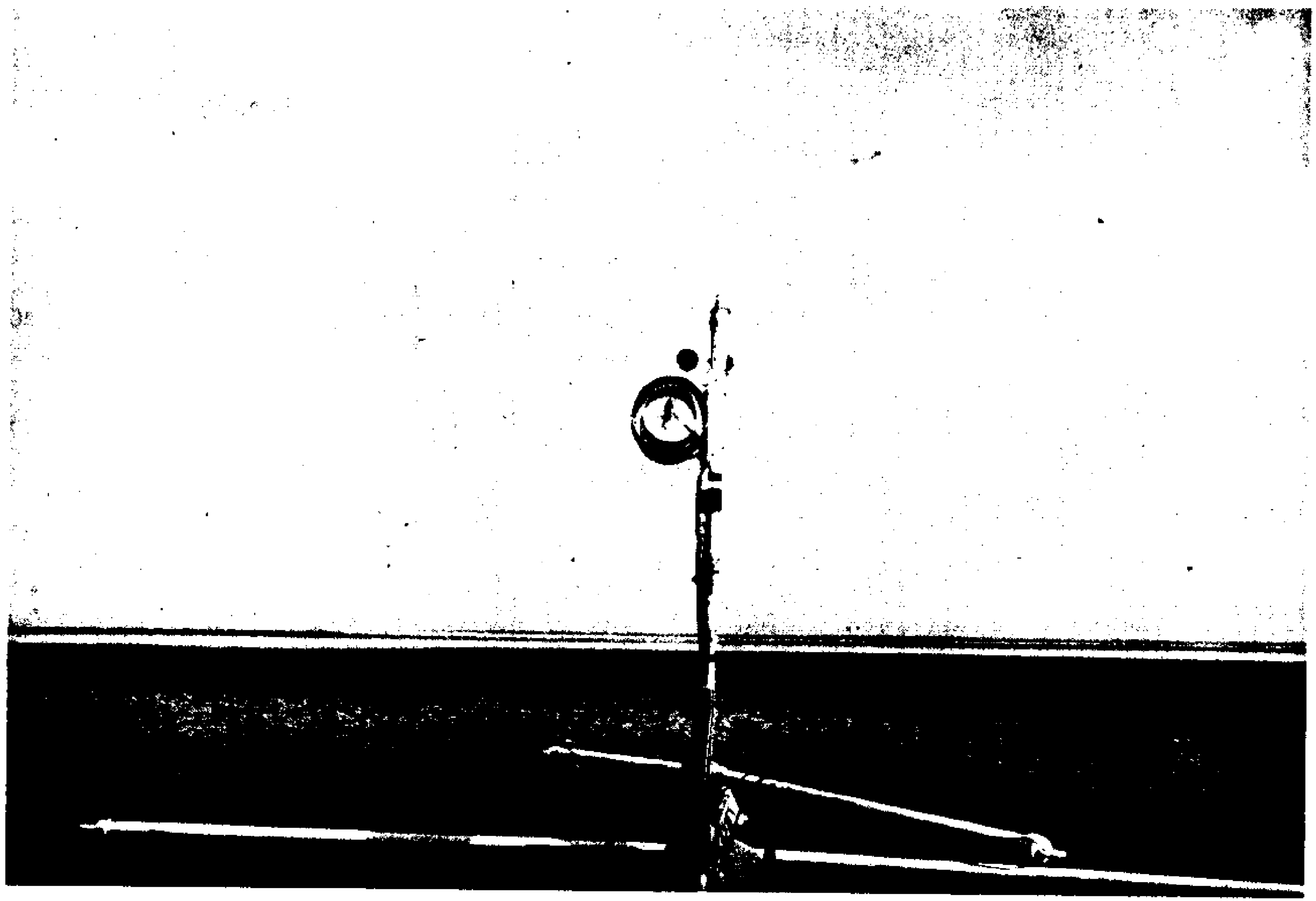

FIGURE 9 Anemometer and Upper Air Temperature Sensor

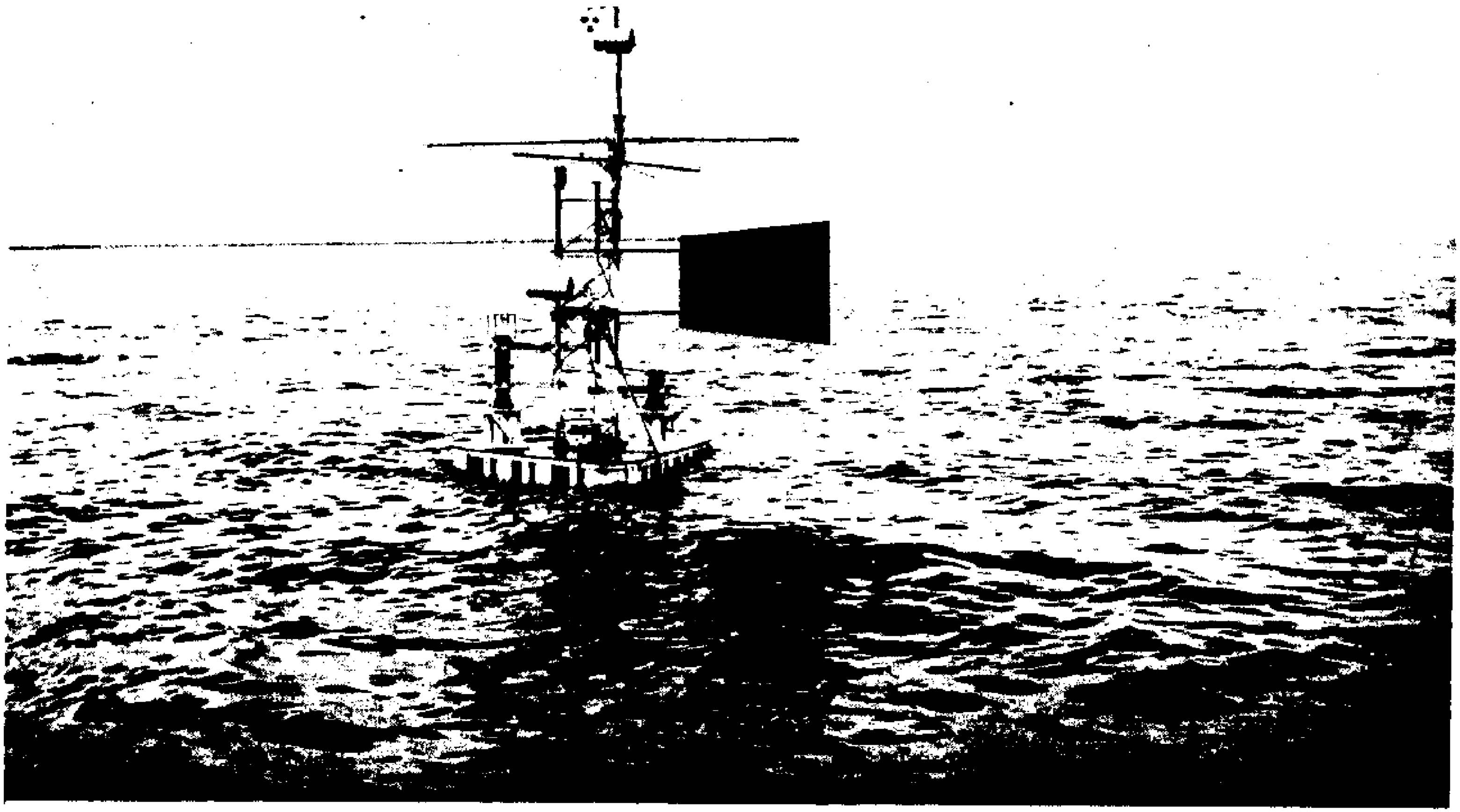

FIGURE 10 SMOP Anchored and Recording Data

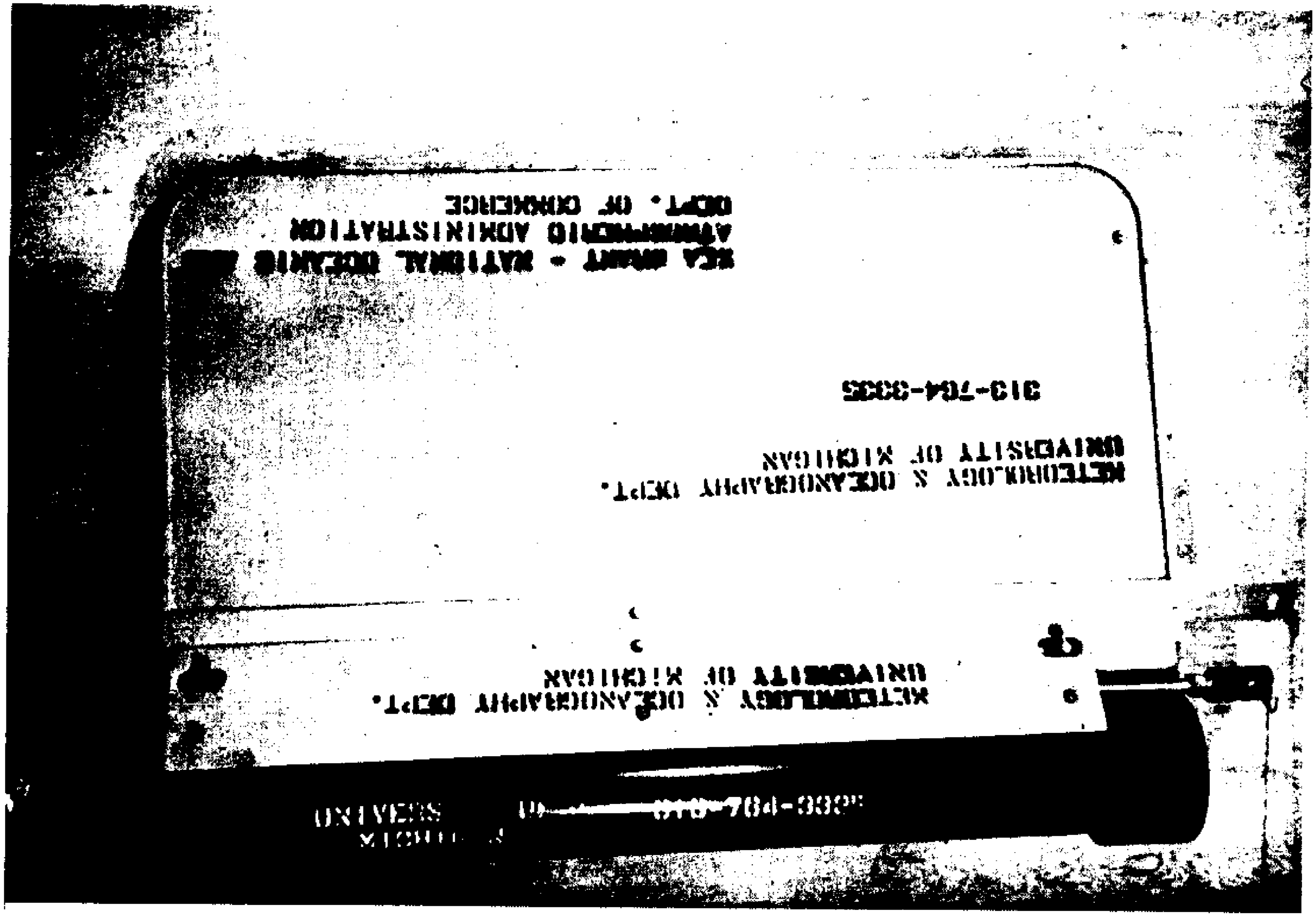

FIGURE 11 Current Meter

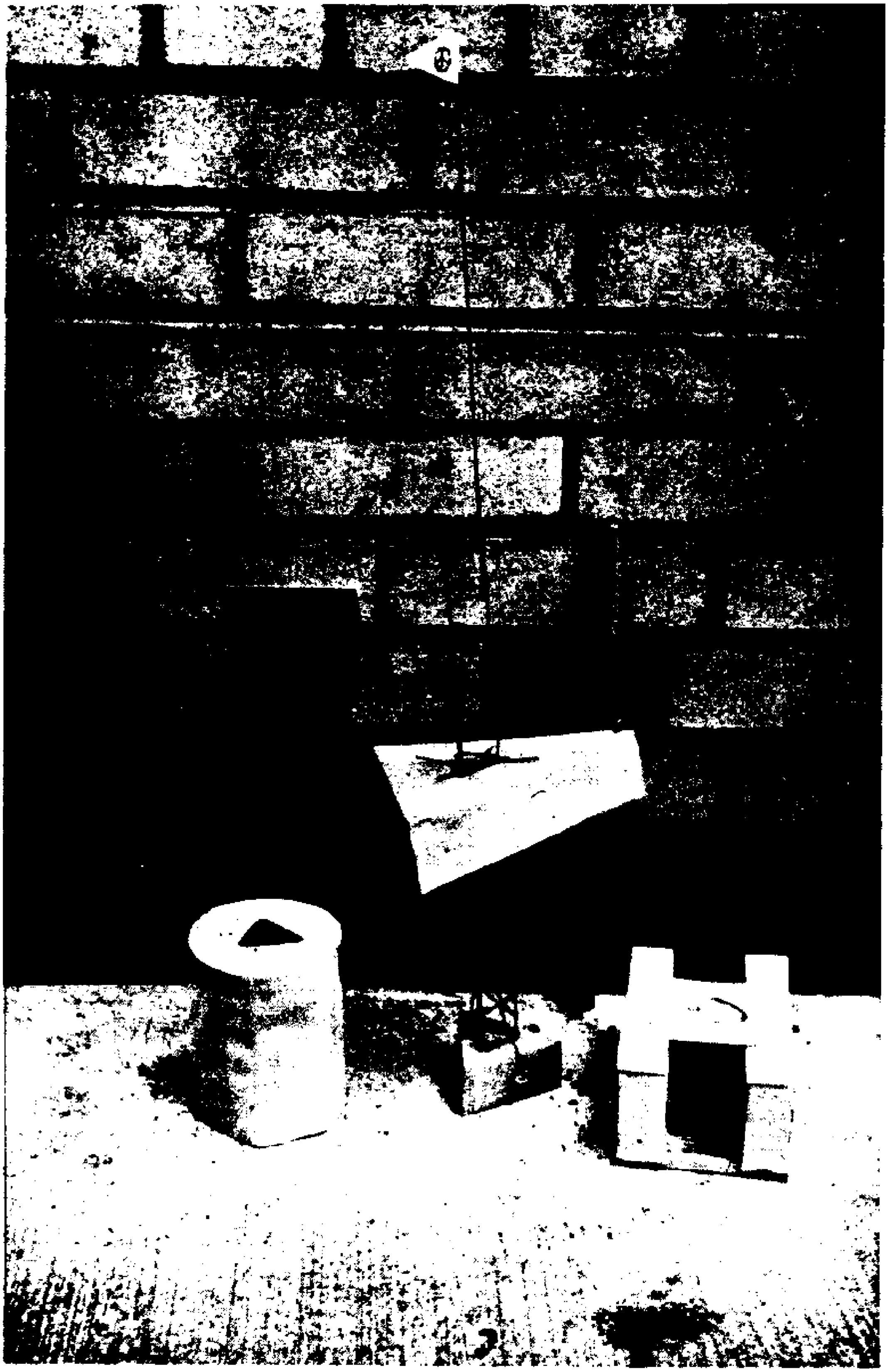

FIGURE 12 1/20 Size Scale Models