The Agricultural and Mechanical College of Texas
Department of Oceanography
College Station, Texas

Texas A & M Research Foundation
Project 59

PROGRESS REPORT FOR

QUARTER ENDING MARCH 31, 1953

Project 59 has as its objective the measurement of heat, momentum, and water flux from the sea surface. It is sponsored by the Office of Naval Research (Project NR 083-084, Contract N7onr-487, Task Order 5). The work reported herein is of a preliminary nature.

Report prepared April 24, 1953
by
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I. Aims:

The general aims of the project are:

A. To develop instrumentation suitable for the measurement of the flux of heat, momentum, and water vapor from the sea surface, if possible by more than one method.

B. To obtain a sufficient number of measurements of these fluxes to draw quantitative conclusions about the factors involved.

II. Instrumentation.

A. Fluxmeter. The complete instrument to measure fluxes of heat, water vapor, and momentum simultaneously has been dubbed the fluxmeter. It will be composed of a number of units, which may be described as the anemometer head, temperature and humidity units, and computer-recorders. These all present separate problems and will be discussed separately.

1. Anemometer. The anemometer system described in the first quarterly Progress Report of this project is being developed. Actual construction has been delayed by slow delivery of necessary components, but is now commencing.

2. Temperature Unit. A temperature unit is being constructed using a Western Electric type D-176980 thermistor, linearized according to the scheme given by Beakley.* This temperature unit is designed to work in conjunction with the humidity unit, acting as the dry bulb of a self-computing psychrometer as well as a thermometer. The use of a thermistor rather than a thermocouple permits easy multiplication of the vertical velocity by temperature or specific humidity without the necessity of a complex electronic multiplier.

The instability of the thermistor is of little moment in this application, as variations of temperature are to be measured, rather than the absolute temperature. It is characteristic of the thermistor that while the actual value of its resistance is subject to considerable fluctuation at a given temperature, the slope, or the rate of change of resistance with temperature, remains quite constant, being a function only of the nature of the thermistor material. It is only the slope property that will be used in this application.

* Beakley, W. R., The design of thermistor thermometers with linear calibration, J. Sci. Inst. 28, 176-179, June 1951.

Inasmuch as the thermistors are to be supplied with alternating current, it will not be feasible to speed the response by the scheme recommended by Doyle. However, if it appears necessary, circuitry to accomplish the same end may be developed. At present, it seems that the D-176980 thermistor will have a sufficiently rapid response even as a wet bulb.

3. Humidity Unit. A simple analog computer for the psychrometric equation has been worked out, using thermistors as dry and wet bulbs. The same thermistor used in the temperature unit also serves as the dry bulb for the humidity unit. The analog used is somewhat simpler than that devised by Swinbank, and has the added advantage that the computer can multiply the vertical velocity by the specific humidity without complex multiplier circuitry.

Some thought has been devoted to the development of a wickless wet bulb, which would be almost a necessity with the extremely fine thermistor to be used. The success of such a wet bulb hinges upon the finding of an appropriate hydrophilic material with which to coat the wet bulb. Little success has been achieved so far.

4. Computer Units. Two different types of computer units have been projected, each of which fulfills the same function, probably with comparable accuracy, but which are quite different in detail. Figures I and II give block diagrams of the two schemes.

In computer I, the two induction resolvers are driven from the shaft of the rotating arm anemometer (see first quarterly report), one at the speed of the shaft, and the other at twice the speed. The resolvers multiply the input by $\sin \omega t$, $\cos \omega t$ and $\sin 2\omega t$ at the respective outputs.

In order to use the resolvers, the transducer must produce its output as modulation on a 400-cycle carrier. This can easily be done with a strain gauge bridge type transducer. After passing through the resolvers, this carrier must be removed by rectification. The difficult step occurs in integration, where a rate-servo type integrator must be used to maintain the desired accuracy. The servo motor would be connected to a cyclometer counter for final registration.

For obtaining heat and moisture fluxes, the output from the resolver corresponding to the vertical velocity would be used to drive the bridges for temperature and humidity, followed by amplification, rectification, and integration as before. Separate constant-voltage d.c. supplies to the bridges, followed by amplification and integration, permit the accumulation of integrals of the temperature and specific humidity independent of the fluctuations of vertical velocity. A contactor and magnetic counter keep track of the number of revolutions made by the arm.

Computer II is somewhat simpler in form, although considerably more complex in concept. Here multiplication by $\sin \omega t$, $\cos \omega t$ and $\sin 2\omega t$ is combined with integration by the use of the common household

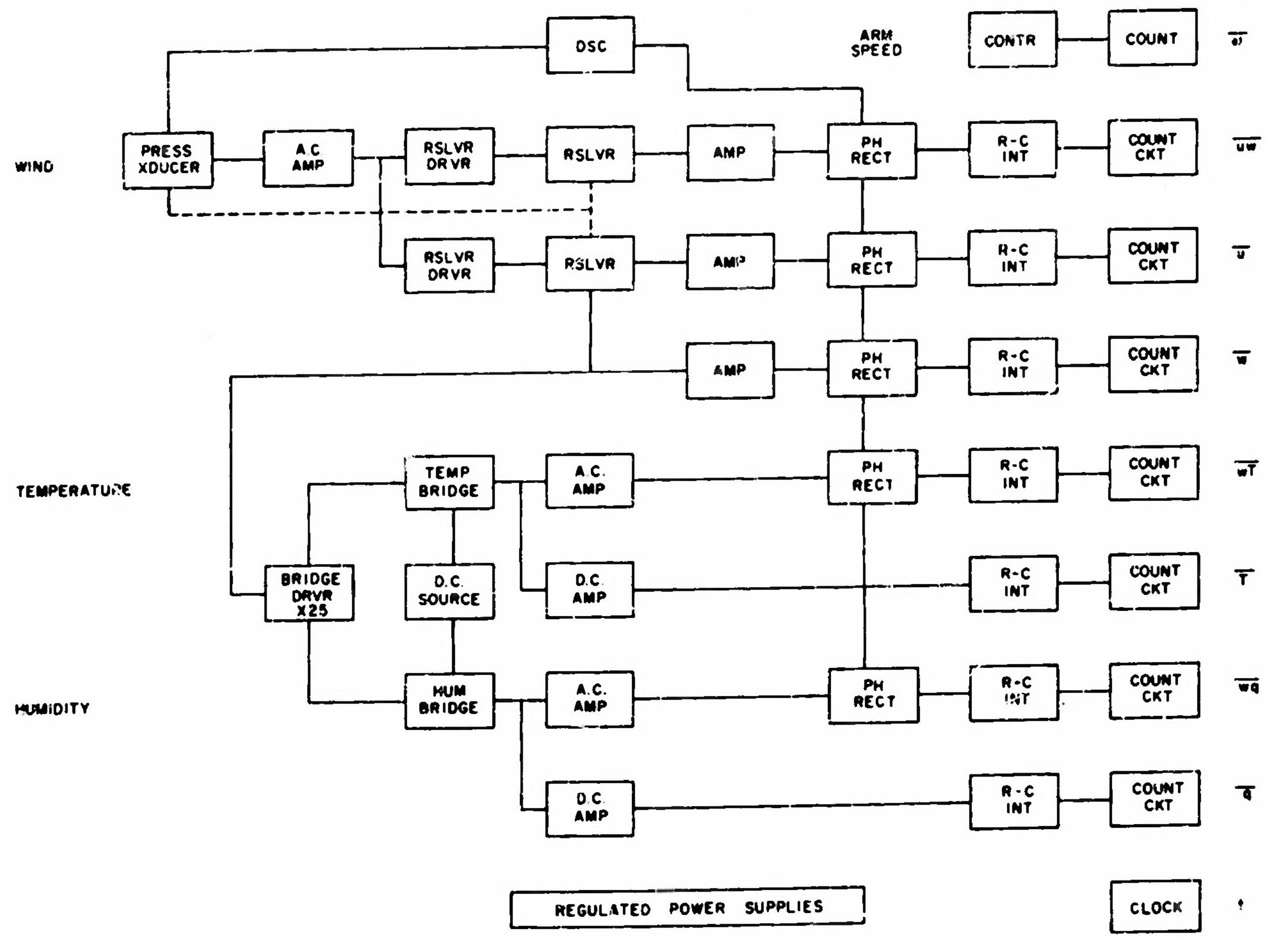

Fig. I.

FLUXMETER COMPUTER I

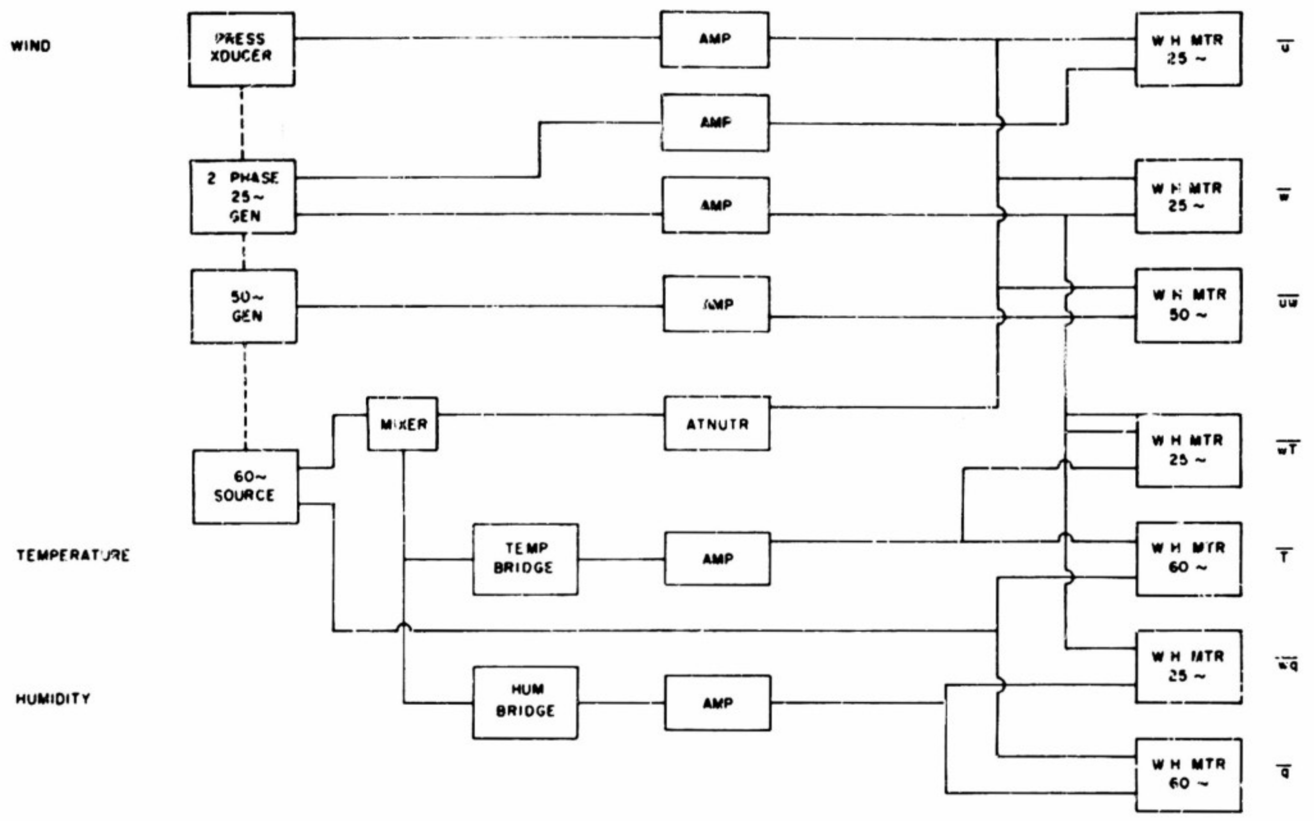

Fig. II.

FLUXMETER COMPUTER II

watt-hour meter. The rotating arm anemometer is driven by a synchronous motor at exactly 1500 r.p.m. (25 cycles). Generators attached to the same drive mechanism produce voltages proportional to sin ωt, cos ωt, and sin $2\omega t$ which are used to drive the potential coil of a watt-hour meter of appropriate characteristics. The current coil is driven by the amplified signal voltage from the pressure transducer, or in the case of the fluxes of heat and water vapor, the output of the pressure transducer is passed through the temperature and humidity bridges, and then, appropriately amplified, passed on to the watt-hour meters. Separate registration of the temperature and humidity integrals is obtained by injecting a voltage of still a different frequency (60 cycles) into the bridges at constant voltage, registering the result on a separate meter.

The rate of rotation of the watt-hour meter is the product of the currents passing through the two coils and the cosine of the phase angle between those currents. Here the phase angle is the angle of the wind, the current through the potential coil is constant, and the amplitude of the current through the current coil is that of the quantity to be integrated.

Watt-hour meters adapted precisely to this application are available complete with contactors for counting individual turns of the disc. Unfortunately, delivery on these items is extremely slow, five months being the present quotation.

It is thus contemplated to proceed with the development of both systems, or possibly an alternative. This, in addition to avoiding possible protracted delays in testing the general scheme, should afford interesting data for the construction of future computing systems of this type.

III. Personnel.

Dr. Arnold H. Glaser went on full time as Chief Scientist on 10 January 1953. Mrs. Jean Hitt has been employed as part-time secretary.

IV. Visits.

In accordance with the terms of the contract, Dr. Glaser, upon joining the project, embarked upon an extended tour of institutions conducting research along lines similar to that of this contract. His itinerary and results of conferences follow:

Ames, Iowa, 8 January, conference with Professors A. R. Kassander, Jr. and J. E. McDonald of Physics Department, Iowa State College. The feasibility of this project's utilization of the Iowa State recording and tabulating apparatus was discussed. Some advantages were seen, but it was found that any extended observation program would use tabulator time excessively, resulting in high expense. It was considered indicative that the Round Hill group, after going to the considerable expense of constructing appropriate recording apparatus to work with the Iowa State tabulator, has made no use of it. This was followed by a very enlightening discussion on the use of the Western Electric thermistors and their characteristics. Dr. Glaser had the pleasure of dining with Prof. McDonald.

Madison, Wisconsin, 9 January, conference with Professors Reid Bryson and V. E. Suomi of Meteorology Department, University of Wisconsin. Since Dr. Glaser had recently worked with this group, he is well acquainted with their work. Subjects of discussion included the possibility of purchase of an improved type of net radiometer developed at Wisconsin. (After some correspondence, Prof. Suomi has agreed to construct one for us.) Prof. Bryson was interested in the problem of the measurement of surface stress on the ocean. He expressed some doubt as to the applicability of the simple methods he has found for the measurement of these stresses on lake surfaces.

Washington, D. C., 12-13 January, conference with members of Geophysics Branch, ONR. General discussion of plans for research. Lt. Bodurtha extended the hospitality of his home.

Washington, D. C., 14 January, conference with Dr. Lester Machta on general aspects of turbulence research. Discussion was hampered by classification of his work. Brief conference with Dr. Harry Wexler. Attended seminar by Dr. Charles Gilman of USWB on future direction of forecasting research.

Silver Spring, Maryland, 15 January, conference with Dr. Frenkiel of Johns Hopkins Applied Physics Laboratory. Dr. Frenkiel suggested the use of the anemoclinometer as the anemometer for the fluxmeter; an analysis of the form of presentation of data required would appear to rule out the use of this anemometer in the present instrument. Dr. Frenkiel gave some interesting suggestions on experimental procedures to evaluate a single number index of turbulent diffusion.

Seabrook Farms, New Jersey, 15-16 January, conference with Drs. Thornthwaite and Halstead and other staff of Johns Hopkins Applied Climatology Laboratory. After an inspection of the installation, an interesting discussion of the problems of flux measurement ensued. It was suggested that careful measurements of profile can be of considerable utility in flux measurements. The techniques of obtaining good profiles were discussed. Dr. Thornthwaite pointed out that a fixed marine site offers a unique opportunity for the accumulation of climatic data of value. Dr. Halstead revealed some interesting work on the aerodynamic properties of different types of surface.

Upton, Long Island, 19 January, conference with Messrs. Smith, Mazzarella and Singer of the Meteorology Group of the Brookhaven National Laboratory. Panofsky's flux measurements at Brookhaven were discussed, as well as the problems of corrosion-proofing instruments to be exposed to marine climates for long periods.

Woods Hole, Massachusetts, 21-22 January, conference with Mr. Andrew Bunker on fluxmeter instrumentation. He has a functioning fluxmeter, which he kindly offered to loan us for the period of the Cambridge Research Center GRD Great Plains Field Observation Program in August and September of this year. Steps are being taken to take advantage of this offer. Conference with Mr. J. R. D. Francis of the Imperial College of Science and Technology yielded the information that profiles of wind, temperature, and humidity may be quite misleading in flux computations when applied over a water surface. This is somewhat at variance with the contention of Thornthwaite.

South Dartmouth, Massachusetts, 23 January, conference with Drs. Record and Cramer and Mr. Gill of the MIT Round Hill Field Station. This organization has also been measuring fluxes, but has found that with direct-recording instruments, the calculation problem precludes the taking of extended series of observations. The group must be complimented on having made some good measurements.

New York City, 26-29 January, attended meetings of American Meteorological Society and New York Academy of Sciences. The meetings afforded an opportunity for numerous informal conferences with many workers in the field of turbulence and turbulent diffusion. These contacts have since proved to be of inestimable value.

Boston, Massachusetts, 30 January, attended organizational meeting of GRD Great Plains Micrometeorological Program. One of the impressions carried away from this preliminary meeting was the extreme desirability that this project participate actively.

Boston, Massachusetts, 2 January, conference with Mr. Ben Davidson and Dr. Heinz Lettau of GRD on problems of micrometeorological measurement.

This series of visits can be described as very successful.

On 20 March, Drs. Freeman and Glaser attended a meeting of the Central Texas branch of the American Meteorological Society. Dr. Glaser presented a paper on the "Great Plains Micrometeorological Observation Program".