Meteorology for Engineers

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AS the meteorologist is well aware, the day of the "weather engineer" has not yet arrived. Not today or even tomorrow will a trip to the Weather Bureau reveal a complicated set of lighted maps with levers labeled "fair and warmer," "light rain," etc. In contrast to the profession of engineer, which is one of doing, building, designing, stands that of the meteorologist, whose main function is to predict.

That these predictions are recognized by the public as lacking in complete perfection is evidenced by the large number of jokes, cartoons, and radio programs of which we increasingly defensive weathermen have become the butt. Still, this motley humor reveals something more than the imperfections of the well-meaning civil servants in the weather station. It reveals the fact that the celebrated man in the street, despite his acquaintance with nuclear fission and relativity, is still unaware of how the weather really works. And for this, the meteorologist can hardly blame him, knowing that for sheer complexity, atmospheric problems are at least as difficult of solution as those of the atomic nucleus or of the stellar universe.

And yet, the atmosphere is the medium in which man carries on his daily life. It is as much his element as the sea is that of fish. Adverse weather may mean only a ruined vacation to the city-dweller, but it may spell flood or dustbowl to the farmer, and life or death to the air passenger. The famous Armistice Day Storm of 1940 brought broken signs and show windows to Chicagoans, but outside the city, 150,000 turkeys, thousands of cattle and livestock, three large lake steamers and 157 human lives were lost.

Just as the atmosphere is the medium in which man lives, it is the medium in which the engineer works, and with whose behavior symptoms, the weather, he must continually contend. A man building a dam must know how much water the structure will be called upon to handle, an amount that is determined to a large extent by the rainfall characteristics of the watershed. The pattern in the central Mississippi Valley, where the greatest rain is felt in May, is quite different from that of New England where each month sees almost the same amount of precipitation, although the total yearly rainfalls of the two regions are nearly equal.

An engineer envisioning the growth of a great air terminal with day and night passenger service to far-flung points must know well the wind and weather characteristics of the site. He must know how to avoid the lee-side of smoke-stacks, the fog-covered valley bottom and ocean promontory. He must be aware of the wind structure in the first 50 feet above the ground, because all take-offs and landings are made in that region.

A man designing an airplane must know what stresses may act on its wings. He must realize that the greatest structural damage to aircraft occurs in thunderstorms, where, due to updrafts and downdrafts side-by-side, relative vertical velocities often exceed 100 miles per hour, and where ascending currents can support hailstones the size of eggs. The engineering student is surprised to learn that these same conditions give rise to severe icing, and that the presence of liquid water cooled below its freezing point is vital in the growth of the great cloud-factory, cumulonimbus. Yet these facts are essential knowledge in building carburetor and wing de-icers, designing aircraft windshields, and nearly all of the routine tasks of the aeronautical engineer. Indeed, the opportunities for use of weather knowledge in all phases of engineering are far more extensive than can be indicated here, and every meteorologist can suggest several more from his own experience.

So, while it is true that the engineer cannot as yet design and build his own weather (perhaps it is just as well, since it is hard to foresee general agreement on this topic), he can make use to a far higher extent than the layman of what is already known about weather processes, and he can do this in two ways: First, he can gain an understanding of the basic physics of the atmosphere; with his technical training and background in physics and mathematics, he is in an enviable position to do so. Second, he can learn to make use of existing weather services. He can learn enough of the language of the weatherman to call upon the vast stores of knowledge and information accumulated by the United States Weather Bureau and the university meteorology departments.

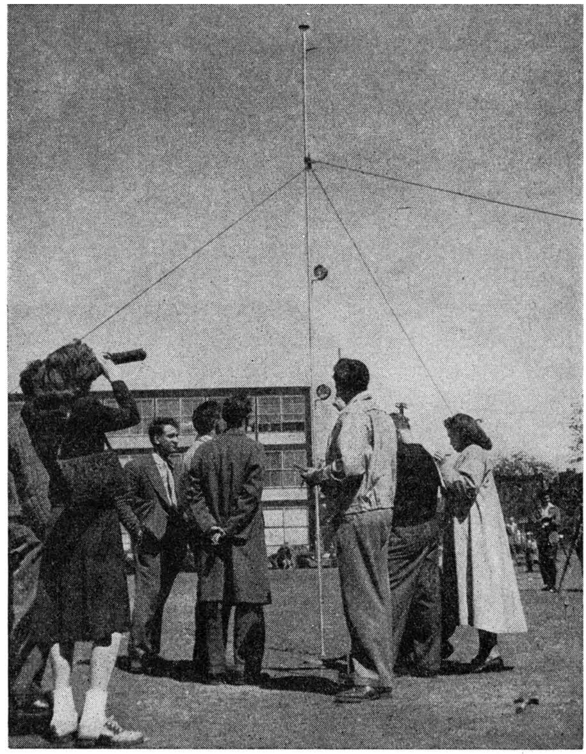
This has been the twofold purpose of those of us in the Physics Department at Illinois Institute of Technology who have had the privilege of organizing a course in meteorology, primarily for some of the junior and senior engineering students. We have not attempted to make forecasters of these students. They have not been required to spend long hours plotting winds and drawing isobars. Neither has it been our goal to make research meteorologists out of them, nor to enable them to fill blackboards with solutions to the equations of motion. During the years in which this course has been developing, the amount of mathematics has indeed been cut down and the emphasis on physical principles increased. The postgraduate engineer cannot be expected to recall what the thermal wind equation is, but he can and should remember that over North America west winds generally increase with height and this occurs because temperatures are higher toward the South.

It is at this point, with the basic circulation principle, that the course begins. Starting with simple convective circulations, like the sea-breeze, through a qualitative discussion of the effects of the earth's rotation and continents, the student is led to a description of the principal observed features of the general circulation as seen by meteorologists today, including such recent advances as the jet stream. Two goals are kept in mind throughout this introductory discussion. The first is a goal of all teachers: to fasten the new material firmly to facts rooted in each student's own observations. In meteorology, this is easy, because the weather and its vagaries have been a major topic of human conversation ever since the first caveman grunted his dissatisfaction with Pleistocene glaciation. For example, to the middle-latitude inhabitant accustomed to wearing a sunsuit one day and a fur coat the next, the battle of the airmasses, polar vs. tropical, can be easily transformed from a textbook discussion of occlusions and isobars to his own very recent memories of frozen cattle, blocked highways and snowbound trains. The second goal is perhaps peculiar to the teaching of meteorology, and is far more difficult to achieve. One must point out that while weather proverbs, such as "red sky at night . . ." are as old as navigation, meteorology as a science is nearly as new as the atomic age; its problems are complex, and no magic set of formulas for quick slide-rule pushing are available. Lest this be too discouraging to the budding engineer, one must simultaneously demonstrate how existing weather knowledge and weather services can be of very great use to him in carrying on his work. For this reason, after the introduction outlined, the course proceeds to a more detailed treatment of those topics of greatest interest to the engineering professions (which turn out, strangely enough, to be nearly identical to the material covered in beginning physical meteorology, and follow closely the sequence presented in Willett's "Descriptive Meteorology"). These lectures are supplemented by laboratory work.

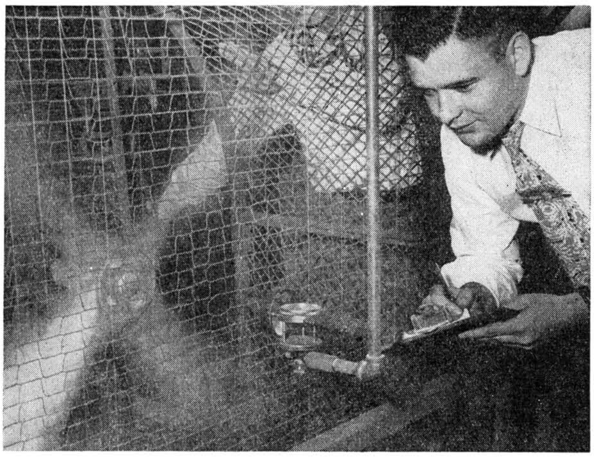
In addition to the free laboratory of nature whose experiments are put on before our eyes all the time, and whose "data and results" consist of the desert, the towering thunderhead, and the blizzard, a man-made laboratory has recently been added to Illinois Tech's meteorology course. By actually swinging a psychrometer, counting the revolutions of a wind-meter, or locating airmass boundaries on a real weather map, the student learns the use and limitations of the common meteorological tools. He sees the actual operation of many of the principles he heard in the lecture-room. A large section of the lectures, for example, are concerned with the relation between atmospheric pressure and height above the ground. This problem is studied not only because it is fundamental to "why the weather," but because of its basic relation to aircraft altimetry, a topic discussed at some length.

What could be a better demonstration of the fact that the pressure decreases upward than the gradual expansion and final bursting of the huge balloon that carries with it the radiosonde trans-

FIG. 1. The engineer studies the effects of wind on bridges and buildings. In this picture, an engineering student explains the disastrous result of a windstorm on the ill-fated Tacoma Narrows suspension bridge.

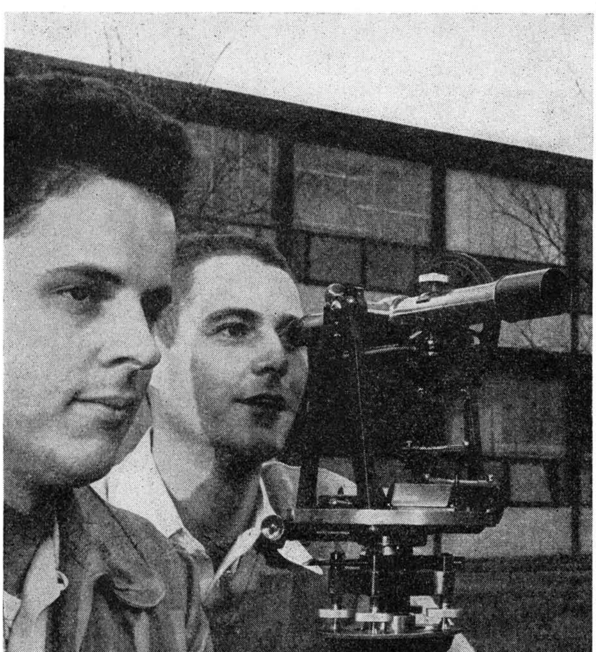


b. In his meteorology course, he uses the same anemometer to study the winds just above the ground.



a. An engineering student uses a windmill anemometer to study **prop-wash.**

d. The short step from transit to pilot-balloon theodolite is eagerly made by these students.



c. The transit is a universal tool in engineering.

FIG. 2. **The engineering student is well-equipped to learn the use and meaning of meteorological instruments, having employed many of the same tools and techniques in his engineering training.**

mitter? What could be a better indication of the three-dimensional character of our ocean of air than the radiosonde itself, which ascending to heights of 50,000 feet and more, sends back to the ground the temperature and humidity at intervals right up into the stratosphere?

What could be a more tangible contact with atmospheric wind-structure than watching radiosonde and balloon ascend, perhaps first toward the south, then reversing, then at greater elevations almost always veering off toward the east, and finally falling to the fishes of Lake Michigan, or upon the cornfield of a baffled Indiana farmer?

Indeed, the changes of wind with height, the relation between winds and pressure, and the turbulent wind structure in the lowest levels above the airfield are the meteorological matters of perhaps the most vital concern to aeronautics. It is for this reason that at least one-half of the course is concerned with many aspects of the subject "wind."

While the wind can often be made to serve the aviator, the meteorologist sees the thunderstorm, freezing rain, sleet and fog, as his greatest enemies. It is important for the student to grasp the connection between instability, rising air, cooling, and condensation, and to recognize that every cloud, nearly every fog, and every thunderhead is a sign of cooling, just as every footprint is a sign that a living creature has passed.

Yet every cloud does not rain. The student knows as well as the weatherman that a gray day is not necessarily synonymous with umbrella carrying. He is therefore ready to accept the fact that to cause a cloud to fall to the ground as rain or snow, something must be added—not just dry-ice, but supercooling as well! This principle is brought home to the engineering student when in his classroom laboratory he takes on himself the role of snow-maker. With deep-freeze and dry-ice, he reënacts this drama of nature, only too often a murder-mystery, that has as its by-products hail, turbulence, icing, thunder and lightning.

As the final phase of their meteorological journey, the Illinois Tech engineers visit the weathermen at work. They invade, for a day, the ivied towers of the University of Chicago, where front-line investigation of instrumentation, theory, and weather forecasting are going on. They help to send up a radiosonde, and listen at the ground receiver to the putts and hums telling of cloud and temperature aloft. They climb around the radio direction-finding equipment (Rawin) which, even through rain and overcast, follows the balloon drifting with high-level winds. They visit the hydrodynamics laboratory to see the tiny model of the rotating earth, and how it begins to reproduce, on a small scale, the circulation of the mighty atmosphere.

And during the last week, as a final integration of what they have learned, they see the United States Weather Bureau in operation. They visit the regional forecast center where amid the clacking of teletypes and clanging of telephones, the real, bona-fide weatherman, the forecaster, does his work, day and night, Sundays and holidays, around the clock. They learn how the data is gathered and watch the decoding of the strange weather-hieroglyphs and the plotting and drawing of weather charts. These are now no longer conglomerates of unfamiliar, mysterious lines and colors, but fog in Omaha, heat wave in Detroit, and rain right outside the window, this minute, with clearing tomorrow night.

For the student who wrote on his final exam paper "From what I have learned here about meteorological problems, I can easily see why the Weather Bureau is proud of its 85 percent forecast record," the purposes of the course have been achieved to a large degree. Although this student, as a graduate engineer, will not thereby achieve a record in forecasting, he will be able to make use of the existing meteorological services. He will have some knowledge of what information is available and how to use it in doing his own job. While the weatherman cannot yet be engineer in his profession, the engineer is more fortunate, for his opportunities to be weatherwise are unlimited.

ANNOUNCEMENT

New Editor for the Journal of Meteorology

The Council of the American Meteorological Society has appointed Dr. Werner A. Baum, Department of Physics-Meteorology, Florida State University, Tallahassee, Florida, as Editor of the *Journal of Meteorology*, beginning with the February, 1950 issue. Effective immediately, all correspondence concerning manuscripts and editorial matters should be addressed to Dr. Baum.

Dr. George W. Platzman completed his second successful year as Editor on September 30, 1949. Under the editorship of Dr. Platzman, the *Journal of Meteorology* has reached an eminent position among the scientific journals of the world. Much credit is due Dr. Platzman and his staff in maintaining the high standards in spite of increased publication costs. More than double was the amount of pages published over the preceding two years.