be remembered can be found in a book. In this scientific era our store of knowledge is growing so fast that we shall soon need new ways to keep it available. Books have done duty for a thousand years and we should be sorry to lose them, but we can change our habits rapidly and it is already old-fashioned to write a letter with a pen.

This increasing background of experience has meant that we are constantly acquiring new habits and new ways of thought. It does not take us very long to see the way round old quarrels. Darwin and Freud no longer trouble us. We are no doubt born with brains like those of our remote ancestors and when we are grown up we have no more native intelligence than they had, but our brains must have been so modified by what we have learned that they are physically and chemically different, better adapted for the complex social life of our time. We have more knowledge at our disposal. If all goes well with our training, the brains we have ought to be more civilized than those of our fathers and those of the next generation more civilized than ours.

I have claimed that the scientific investigation of mankind can help the process of civilization by finding the weak points in our equipment and suggesting remedies, but these scientific activities will play only a limited part in the development of human society in the scientific age. The power we have acquired over the forces of nature has made it possible to increase our mental training as well as our standard of comfort. Of the two or three thousand million people in the world perhaps not more than five million are receiving a full university training though no doubt more are trained in a narrow technology. Yet the number has risen steeply in spite of wars, perhaps even because of them, and it continues to rise. In the United Kingdom we have 85,000 students at our universities, about 1 in 30 of the whole age group, and that may be all we should contemplate with our present system. A few years ago, however, it was only 1 in 60, and there must be many parts of the world where the university, as we know it, is only now beginning to play its part in civilizing the most intelligent citizens. This could never have happened without all the scientific inventions which have been blamed for our troubles, the improved transport, the cheap printing, the electricity, and the internal-combustion engine. And a university training would have been far less civilizing if it had never left the old authoritarian pattern which roused Huxley to speak in Oxford nearly 100 years ago.

University students, however intelligent, are not usually considered to be the most peaceful members of the community. They have been more welcome in small country towns than in the capitals where they can join revolts against the government of the day, and they tend wherever they are to be critical of those in authority. Long may students remain so. If they were not, if they believed all they read in an officially inspired press, or even what they were taught by unrestrained professors of the greatest integrity, there would be little chance of their learning how to use their knowledge for solving the new problems of our time. The plodding methods of the laboratory and the card index must be there to check their enthusiasm and to show them how the problems have come about. Even if they get no help from that it is something to know that there are many more people in the world today with brains trained better to deal with their environment by learning how its problems have been dealt with in the past.

Our Association is concerned with the advance of natural science. It began when we had little control over the forces of nature and we have now so much control that we might soon become able to destroy two-thirds of the world by pressing a button. Yet the control which has been achieved by science has made it possible for us to improve our own natures by more education in the arts of civilized life. We may perhaps improve ourselves more rapidly if we can gain more insight into human behavior. That is something which the Association can encourage, but it is only a small part of what it must do. It must not cease to encourage every kind of scientific inquiry, for it is human nature to inquire, to learn by experience, and to profit by what it finds out.

An Explanation of the Lake Michigan Wave of 26 June 1954

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THIS paper (*1*) proposes that the unusually high velocity of about 66 mi/hr with which an atmospheric disturbance crossed Lake Michigan on 26 June 1954 was responsible for the disastrous wave that occurred.

On the morning of 26 June about 9:30 CDT an abrupt increase in the level of Lake Michigan occurred along the water front in the vicinity of Chicago, at the southwestern corner of the lake. At least seven lives were lost in the Chicago area as a

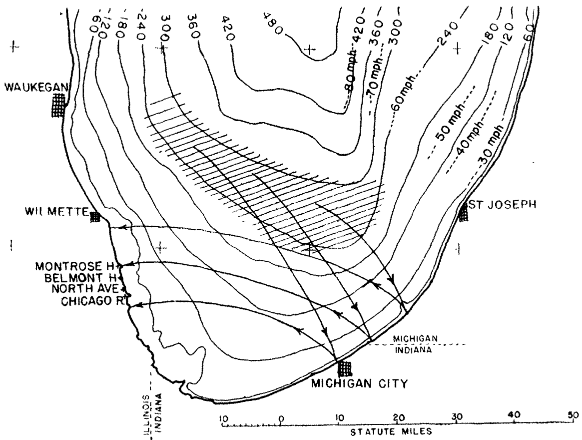

Fig. 1. Lake Michigan depth contours; area of generation and paths of the 26 June 1954 wave.

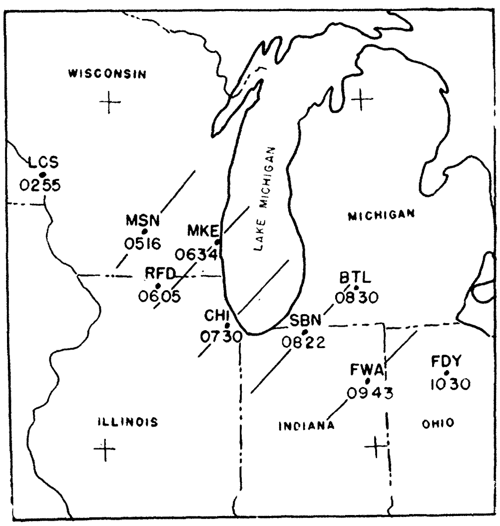

Fig. 2. Arrival times and orientation of the pressure-jump line in the Lake Michigan area. Station notation is: LCS-La Crosse, MSN-Madison, MKE-Milwaukee, RFD-Rockford, CHI-Chicago, SBN-South Bend, BTL-Battle Creek, FWA-Fort Wayne, FDY-Findlay.

Table 1. Wave height and arrival time.

Station	Reported height (ft)	Arrival time (A.M. CDT)
Eastern side of lake		
St. Joseph	No significant change	
Michigan City		
USCGS	6.2	8:12
Breakwater	5.5	8:10
Western side of lake		
Chicago		
Belmont Harbor	6.3	9:30
Montrose Harbor	8.0	9:25
North Ave.	10.0	9:30
River mouth	2.4	9:40
Waukegan	No significant change	

result of the first unexpected increase, which reached 8 ft at Montrose Harbor, Chicago, and 10 ft at North Avenue. Although the lake level generally increased 2 to 4 ft from about the Indiana-Illinois line northward to near Waukegan, the height varied because of local shoaling and funneling conditions (Fig. 1). According to observations, the wave approached Chicago from the east to southeast. It was first observed at Michigan City, Ind. with a height of 5.5 to 6.2 ft at 8:10 A.M. Here the wave approached from the northwest. Table 1 gives lake-height data for significant points for which information is available.

A few hours earlier a severe squall line with winds up to 60 mi/hr had arrived from the northwest and crossed southern Lake Michigan. Its maximum lateral extent was about 150 mi. Associated with the squall line was a very rapid and strong pressure-jump, which for most stations for which records are available amounted to about 0.1 in. in a few minutes. The progress of the pressure-jump line is shown in Fig. 2. It was noted first at La Crosse, Wis. at 2:55 A.M. and crossed Chicago at 7:30, or about 2 hr before the disastrous wave. The squall and pressure-jump crossed the southern portion of the lake and arrived at Michigan City simultaneously with the wave from the northwest.

From early reports of this event we concluded that it probably involved resonant coupling of a traveling atmospheric disturbance to surface waves. Unna (*2*) in 1928 explained certain abnormally high tides in the Thames River by this mechanism. Proudman (*3*) showed theoretically that waves of large amplitude could be expected when the velocity of the air disturbance equaled the velocity of a gravity wave in water. He applied his results to explain the strong surge off the Sussex coast of 20 July 1929. We have investigated coupling from the atmosphere to flexural waves in ice (*4*), seismic ground roll (*5*), and so on. Using these results, one can explain the Lake Michigan wave on the basis of resonant transfer of energy from the traveling pressure-jump and its associated high winds in the air to a gravity wave traveling with equal velocity in the lake. Only for equal velocities can a large wave be generated. It is therefore necessary to show that appropriate velocities occurred and that an appropriate area of generation existed in the lake, for the velocity of a gravity wave in the lake depends only on the depth of water.

On the basis of pressure-jump times for the meteorological stations in Fig. 2, the velocity and orientation of the pressure-jump line have been determined. This line moved with a velocity of about 50 mi/hr west of Lake Michigan and increased to an average of 66 mi/hr while crossing the lake. The velocity east of the lake was about 60 mi/hr. The average velocity across the entire network of stations shown from La Crosse eastward was 57 mi/hr. The usual velocity of a pressure-jump line in this area is 20 to 40 mi/hr. Figure 2 also shows isochrones for the pressure-jump line.

Figure 1 shows depth contours for the southern portion of Lake Michigan. According to well-known theory a wave of length much greater than the water depth would travel with a velocity c, determined by the relationship $c = \sqrt{gh}$, where g is the acceleration due to gravity and h is the depth of water. According to this formula a depth of 288 ft is required for a wave velocity of 66 mi/hr. Such a depth exists for a relatively long fetch almost exactly in the direction of squall movement between 240- and 300-ft depth contours. Also indicated in Fig. 1 are velocity contours for free gravity waves described by the $\sqrt{gh}$ law. The approximate area of generation is indicated by crosshatching. Since the wave was moving in an area of variable water depth, refraction effects introduced a deflection of the wave path toward shallower water, producing paths approximately like those shown by the heavy arrows, which indicate the incidence of the wave on the east coast and its reflection to the west coast.

The times of occurrence of the various events are compatible with this explanation. Eighty minutes for transit of the reflected wave from the vicinity of Michigan City to the Chicago shore exceeds the transit time of the squall and the associated direct wave westward across the lake, because the reflected wave was traveling in shallower water.

The uniqueness of this pressure-jump lies in its abnormally high velocity of propagation. The amplitude of the jump was not abnormal and was fairly typical of those that occur about 20 times per year in this vicinity.

Several points are suggested by the theory now proposed.

1) If our thesis is confirmed, several hours' advance warning may be possible on the basis of the position and unique velocity of a squall line such as this one.

2) A study based upon the explanation given here together with a history of the occurrence of similar waves in this and other parts of the Great Lakes, could facilitate the forecasting of future occurrences.

3) These results can be applied to continental shelf areas and would probably be of practical value in the North Sea, the Gulf of Mexico, and similar areas.

References and Notes

1. Lamont Geological Observatory Contribution No. 123. This study would have been impossible without the generous cooperation of the U.S. Weather Bureau and the Beach Erosion Board. The opinions expressed are our own.
2. P. Unna, "Thames floods," *Nature* **121**, 942 (1928).
3. J. Proudman, *Dynamical Oceanography* (Wiley, New York, 1953), pp. 295–300.
4. F. Press and M. Ewing, *J. Appl. Phys.* **22**, 892 (1951).
5. ———, *Geophys.* **16**, 416 (1951).

Saul Dushman, Unofficial "Dean of Men" of the General Electric Research Laboratory

THE death of Saul Dushman on 7 July ended a very unusual career. He was one of the most valuable and highly regarded scientists in the General Electric Research Laboratory. Yet he was not a prolific discoverer or inventor—he is credited with eight patents during his 40 years of service. Neither was he an outstanding pioneer in theoretical research, although he was a brilliant analyst and student of science, and his many publications show a remarkable grasp of fundamentals in both physics and chemistry. These publications were of such merit that they earned him a world-wide reputation.

But his greatest contributions, and those most valued in the Research Laboratory, were human ones, the dynamic influence of a sterling character, dedicated to the service of science and of his fellow men.

Dr. Dushman was born in Rostov, Russia, on 12 July 1883. When he was 9 years old his family migrated from West Russia (now Poland) to Canada, and settled in Toronto. Here he attended public schools, graduating from high school with the highest scholastic record ever achieved in the province of Ontario. This won him the Prince of Wales scholarship at the University of Toronto where he graduated in 1904 with an A.B. degree. After several years as lecturer and demonstrator, he received his Ph.D. in physical chemistry in 1912, and later in that year he joined the staff of the General Electric Research Laboratory.

Dr. Dushhman was married in 1907 to Amelia Gurofsky, who died in 1912, leaving a daughter, Beulah, now in government service in Washington, D.C. In 1914 he married Anna Leff, who survives him.

Upon his arrival at the Research Laboratory, Dr. Dushman was invited by Irving Langmuir to join in the study of electron emission and other high-vacuum problems. He continued to work in this field for most of his life, and he made many valuable contributions. It was this research that laid the foundation for the publications for which he is best known.

Perhaps it was his experience as a lecturer that led Dr. Dushman, early in his career, to undertake the task of correlating and interpreting new science in a series of publications. Two qualities made him well fitted for this task. The first was the ability to read and digest scientific literature with great rapidity. He became a compendium of information, to whom his colleagues in the laboratory often turned for help on a wide range of subjects.

The titles of a few of his early papers published in the *General Electric Review* will show the breadth of his interests:

Modern theories of light (1914)
Recent views on matter and energy (1914)
The absolute zero (1915)