SCIENCE

VOL. LXIX MARCH 8, 1929 No. 1784

CONTENTS

SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. McKeen Cattell and published every Friday by

THE SCIENCE PRESS

New York City: Grand Central Terminal.

Lancaster, Pa. Garrison, N. Y.

Annual Subscription, $6.00. Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the Association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

METEOROLOGY'S FROZEN ASSETS[1]

IN the business and financial world frozen, or unavailable and unsalable, assets are almost as bad as no assets at all. A bank, for instance, may be forced to buy in a large amount of real estate at a foreclosure to avoid losing wholly loans that appeared entirely conservative when made. But by so doing its liquid or cash assets, without which it can not do business, are to that extent rendered unavailable; and its troubles might become serious if too many depositors asked for cash—for cash is what they want and not a vacant lot, perhaps, or other piece of stagnant property. Similarly, the farmer may have tobacco, cotton or grain in a warehouse but be quite unable promptly to sell it. His capital is frozen, and if, as often happens, he borrowed on it, his creditor has a frozen debt and may, therefore, be unable to meet on time obligations that he in turn had assumed; nor indeed does trouble usually end with the third or even fourth removal from the first cause. In short, frozen assets are of no value except when, and to the extent that, they are readily convertible into liquid assets; rather are they liabilities, for they all cost something to keep—taxes at least.

Unfortunately, knowing the pinch of poverty in the midst of plenty—of possessing frozen capital that does no one any good—is not confined to the business world. Science, too, and every branch of it, is far less productive of the good it could do because so many of its valuable assets are rigidly frozen—so many investigations that deal directly with each particular science, and especially so many more that deal with it indirectly, are lost for years, if not forever, in the jungle of journals and tangle of tongues. In this sense meteorology, to be specific and to come at once to the subject under consideration, is actually one of the poorest of all sciences. Its assets, indeed, are amazingly great and rapidly accumulating, but they are frozen to such a depth and breadth that only a Hercules could make them liquid—available for power and light, and able, besides, to change the forlorn desert of our ignorance to an inspiring field of knowledge.

Of course, it occurs to every one that the thousands of observations of temperature, pressure, humidity, wind velocity, and other weather elements, made every

[1] Address of the president of the American Meteorological Society, New York City, December 27, 1928.

day and the world over, are quickly submerged by the new thousands of the next day, and the next and the next, month after month, and year after year, without end.

On first thought it might seem that such a mass of details is both useless and self-destructive, like the giant that grew so big (not so very big either, a height of thirty feet would do the trick) that when down he couldn't get up, but it is neither the one nor the other, neither useless nor unmanageably vast. Just as tens of thousands of telegrams are sent daily, merely to give information as to where certain trains happen to be at the moment and when they may be expected to arrive at particular stations, so, too, many thousands of weather observations are made every day for the express and sufficient purpose of locating storms and other atmospheric states and conditions, to the end that everywhere, within the region served, the coming weather may be foreseen, for at least a day or two, with a fair approach to certainty. And let me say, parenthetically, that fortunately this approach can be, and is, closer and closer to perfection almost in proportion to the severity of the storm and consequent importance of the forecasts; save alone, to be frank, in the case of that erratic weather demon, the tornado. This temporary need is more than sufficient to justify the taking of continuous automatic registrations of the weather elements and of numerous eye observations. But why then store away the records thus obtained, we may be asked, in ever-increasing numbers? Because an urgent need may arise at any time to know exactly what the weather was at a particular time and place; information that such records alone can supply so clearly and so definitely as to preclude all questions and every quibble. But this is not all. From time to time some one needs the detailed weather data of a particular place or of several, or even many, places for a special study he is making of a local climate or the relation, it may be, of that climate to something else, and nothing but the original records will serve his purpose.

As these data are accumulated they also are summarized in such manner as to meet all the more common needs for them. But other needs, and there are many such, are apt to require a different grouping of the data or even to require the data themselves in greater detail. Here again the student can only be referred to the original records. His special needs can not be anticipated—he could not have anticipated them himself—and indeed they often change even during the progress of his work. And the probability that the next student of these data will want them grouped in still another way is so great as to be well-nigh a certainty. Hence it is that in spite of the fact that the millions upon millions of weather data are classified and expressed in terms of averages, extremes, and otherwise, so as to meet most ordinary needs, the complete original records are, and must be, kept for the endless varieties of occasional uses they alone can serve.

All this applies fully only to observations at fixed stations and to those countries that have well-established weather services. These meteorological assets, vast and ever increasing, are fairly liquid—moderately available to every one. They would be distinctly more limpid, however, if all were directly intercomparable, all expressed in the same units, assembled in the same manner and covered the same periods of time.

In respect to all other land areas, however, and they are many and vast, the situation is radically different, as it also is for any time more than a few decades back in even those countries that now collect abundant weather data and prepare lengthy climatological tables and digests. Nevertheless, great quantities of widely scattered meteorological data recently have been recorded in regions that even yet make no official weather reports, and other large amounts were recorded in the more fortunate countries before their present services were established, all of which, the recent and the older, and from whatever country, would be very valuable if readily obtainable. But they are not readily obtainable by any one, and by the great majority of those who presumably would make good use of them practically not obtainable at all. They are scattered through many thousands of books, reports, journals and casual publications, in a maze of tongues and a jumble of units. Furthermore, they exist collectively in very few libraries, perhaps half a dozen, at most, in the entire world. Essentially, these assets are rigidly frozen. Little streams trickle from them now and then as from a glacier, but it would take great ardor and many a hot summer to liquefy the whole mass and so warm the soil as to prevent further accumulation in the frozen form.

Again, marine meteorology has furnished, and is furnishing, oceans, if one may use that word in this connection, of data—Arctic oceans, for in great measure they are all frozen. These data are unsatisfactory in many respects. They are obtained here, there and yonder and not, like land data, at fixed places; they consist mainly of eye readings made at certain intervals, with nothing between, and with instruments that seldom, if ever, are, or can be, as satisfactorily installed as land instruments. Finally, vast areas of the oceans are so little traversed as to be practically

unknown meteorologically. It therefore is uncertain how much labor should be spent in so assembling and publishing this material as to render it readily available to all who may need it. At present these assets also are in great measure frozen. A portion of the mass easily could be made liquid, but some of it is so difficult of access that it probably is not worth the fuel it would take to melt it out. But this is no excuse for leaving it all frozen. As much of it as practicable should speedily be rendered liquid, and then the necessary precautions taken to prevent any future freezing over.

The foregoing is, perhaps, too general to excite enough interest to get results of any kind beyond a sleepy nod of assent, like the generalized confession of doing things we ought not to do and leaving undone those we should do. Particulars arouse more concern on the one hand, and curiosity on the other, and stand a better chance of having something done about them. Hence, a few specific examples of meteorology's frozen assets will be cited, assets that it would be eminently practicable to liquidate, and exceedingly worth while.

Every native of the temperate and higher latitudes is familiar with the snowflake. Occasionally, too, some one discovers for himself the snow crystal, especially when the temperature happens to be so low that the crystals remain separate and distinct and not stuck together in tufts of varying sizes as usually is the case when the temperature is but little below the freezing point. But when this observing individual does discover the snow crystal he seldom gives to it more than a passing admiration. Once in a long while some unusually inquisitive person, trained to "see" the things he looks at, examines the snow crystals closely enough to become convinced that while their general pattern appears to be the same, there seem to be two or three different varieties, maybe more. Among these few, in turn, of the more closely observant, there is but one who became so fascinated with the beauties of the snow crystal that he gave to it the ardor of the lover and the patience of the scientist. And so it has come about that his careful search of snow after snow, winter after winter, for a generation or more, among the northernmost of our New England mountains, has revealed not just three or four crystal varieties, but many hundreds of forms, all based on the one fundamental hexagonal pattern. Not only did he find this great multiplicity of kinds, but also he skilfully obtained beautiful microphotographs of them, and thereby made it possible for others to share at leisure and by the comfortable fireside the joys that hour after hour bound him to his microscope and his camera in an ice-cold shed. Of course some of these pictures have been reproduced in journals and some have been used as art patterns and suggestions, but there are, roughly, 4,000 of them in all, and the knowledge they contain and the art inspiration they possess both are, in the main, only frozen assets. This great wealth of material lies unused in the keeping of the patient genius who accumulated it. On any day so simple and so common a thing as a carelessly discarded cigarette or so inevitable an event as the snapping of the thread of a single life may indeed destroy utterly or scatter to the winds this unique collection of a lifetime.

Here is a rare opportunity for some one who wishes to contribute to uplift and progress. It would cost no more than a single stylish limousine, and much—perhaps even all, or more—would be returned in dollars and cents, and a thousandfold returned in the consciousness of well-doing. It would not be an expensive proposition at all, only a few thousand dollars, to reproduce in half-tone, several to the page, every one adjudged sufficiently distinctive of these snow crystal pictures. The accompanying text need not be long; twenty-five pages at most. The whole should be put together in one book of convenient size and pleasing appearance, and sold at a reasonable cost. Thus would be made liquid—readily available to the scientist, the artist and the layman—the meteorological assets, now mostly frozen, and in danger of being forever lost, patiently accumulated over many years by that rare and kindly genius, W. A. Bentley, of Jericho, Vermont.

No doubt any one familiar with meteorology can cite specific cases of frozen assets, and it is to be hoped that each will do so on every proper occasion, and himself do what he can to better the unfortunate condition. But let me suggest one thing in this connection that must seem Utopian, and yet a thing which I know to be within comparatively easy reach of realization. The great library at the central office of the U. S. Weather Bureau contains almost 50,000 volumes, and receives every journal, the world over, that deals with meteorology or any kindred subject. Of course an excellent and up-to-date card catalogue of all this material makes it as readily available as are the books and journals of our largest libraries and greatest institutions. But a card catalogue, though indispensable, is for all that a cold and lifeless thing, solitary, bulky and immovable. How exceedingly helpful it would be if in addition to this invaluable library guide we also could have an encyclopedic meteorological dictionary that listed every one of the thousands of words, many of them in no dictionary, that has air, weather or climatic significance; a work that gave the origin of these words,

wherever known, the sense or senses in which they have been and are used, with citations of place and author, and, finally, competent, *critical* references to the best literature in which they occur. As stated above, this seems altogether too good a thing to be realized. Well, it is in the making, and very far along at that. Even in its incomplete form it is extremely valuable, and I base this assertion on the abundant use I have been kindly permitted to make of it. I refer, of course, to that super card-catalogue which the indefatigable, accommodating and scholarly librarian of the U. S. Weather Bureau, Mr. C. F. Talman, has been accumulating for nearly two decades. It is a huge undertaking, but the material already assembled on many thousands of large dictionary cards, and to which additions are made daily, has already proved its worth. It is constantly consulted in the reference work of the library; has often been drawn on in supplying material for dictionaries, handbooks and encyclopedias, and furnished the material for the meteorological glossary in the Weather Bureau's "Instructions to Marine Meteorological Observers"—the best glossary of its kind extant, and yet the merest and most condensed sample of what the complete work would be like.

It would cost a little to liquidate this frozen asset, perhaps $25,000, and it would take at least two or three years, and more likely five, to do it, but it would be money extremely well spent, so far as the benefits to meteorology are concerned, and some of the cost would come back by way of sales of the publication. But such a dictionary would be out of date, some may insist, as soon as published. Certainly it would be out of date to some extent, just as all dictionaries and all other works of reference necessarily are. The logic of that situation is not to do nothing, but to have the material as nearly up to date as practicable at the time of first publication, and then day by day, as occasion may suggest or necessity require, accumulate notes and manuscript for a new edition.

To complete this work would be a big labor, and its publication a little expensive, but I can say with that assurance that comes from experience that few things indeed in the field of meteorology would so multifoldly reward the labor and the cost its completion would require.

The most valuable of meteorology's frozen assets and the part most urgently needed is that which treats the subject as a pure science—the theoretical and, in great measure, highly mathematical books, monographs and innumerable papers that discuss this or that particular phenomenon or group of phenomena. The progress of meteorology as a science depends, in the first place, mainly on the production of such papers, and, in the second place, upon the orderly assemblage in convenient book form of the substance of all these innumerable contributions.

These books—there is material enough for several—should not be mere translations of originals or assemblages of original articles, but treatises on the several branches or phases of meteorology based on a clear understanding of all contributions to it.

A very large percentage of these contributions, especially of the more important ones, necessarily are in the concise language of the mathematician. This makes them difficult and tedious reading, and there is no help for it, for there is no other language by which these ideas can be so tersely expressed and with such exact delimitation as certainly will exclude everything else—no other language by which, concerning such matters, it is possible to tell in terms of the premises, the truth, the whole truth, and nothing but the truth, nor other way rigidly to test the premises themselves, and if they are true to deduce therefrom additional truths often even of a kind totally unsuspected. It is only this type of meteorology, the physical and mathematical discussion of the air and its ways, that can or should command the serious attention and respect of our better educational institutions. Of course there still will be abundant room and necessity for non-mathematical, or common-sense, reasoning, for always there are important phenomena which we can not yet express in terms of precise, inclusive and solvable equations. Nevertheless, mere descriptive meteorology is pretty certain to be regarded as mostly talk, and often mighty loose talk at that. Meteorology, however, has the frozen assets which, if made properly liquid, then would command the highest respect of those who should teach this subject, mainly physicists, especially those that have neither a desire nor the occasion to shun mathematics; but it is obligatory that the meteorologists who have access to this mass of crude material first get it into form for the physicist to use.

I have tried, as some may know, to practice in this case what I preach. But let me say that keeping in sight, or even wireless range, of the procession is a hopeless task for any one individual. Furthermore, all that has yet been done, both in this country and abroad, falls very far short of presenting the air and its ways in that mathematical elegance and accuracy that even now is possible, and which, if done, would stimulate tremendously further study and research. I, for one, had begun to be hopeful that systematic digests of mathematical meteorology soon would begin to appear, for we had the man, Mr. E. W. Woolard, who had the rare native ability, the

exceptional training and the many years of accumulated acquaintance with that difficult subject absolutely essential even to trying to do anything with it. But, for the present, at least, that most hopeful promise is lost to us, and I see nothing on the horizon just now that offers any real prospect of the early thawing out of these vast, frozen, mathematical assets of meteorology.

Perhaps some one may ask, and it would be a perfectly proper and natural question, what use could be made of this wilderness of symbols if we had it—this strange and difficult language that very few meteorologists can read, or ever, in their daily work, have any occasion to read.

For one thing, and a more than sufficiently important one, it could be presented to our leading educational institutions as convincing proof that meteorology is, indeed, a difficult branch of physics worthy to take rank among the intellectual nobles, instead of being a little kitchen scullion, as so many now seem to regard it, in that most populous household called geography. Having thus established both its respectability as a college subject, and difficulty of mastery, it inevitably would attract some of the better students, who in turn would advance it to still higher stages. Thus the service of meteorology would become recruited, in part, from that hardworking upper 10 per cent., and not, as otherwise necessarily, from those who, in this particular at least, only toy with studying by taking a mere descriptive subject of juvenile grade.

Of course it is not suggested that only such as have had advanced training (whether in college or out makes no difference) be admitted to a meteorological service. Those who are mentally capable of acquiring such training seldom are temperamentally adapted to the necessary task of hewing wood and drawing water; and, besides, whatever their temperament, the training in question would but make them fretful, discontented and inefficient in mentally cramped quarters from which no speedy relief was in sight. But on the other hand knowledge is power, and the adequately trained man, however and wherever he got his training, can make many a position intellectually respectable that to the untrained affords only a daily grind of routine tasks. Furthermore, and this is especially to the point, the chief advances in any subject come almost wholly from the better trained in that subject, just as almost every suggestion during the World War, worthy of trial and adoption, came from a small number of trained scientists, and hardly any from all the other patriots—earnest and anxious, but impotent for lack of knowledge of the principles involved.

In order, then, that the science of the atmosphere may become truly worthy of a respectable place at college, a place that would enable meteorological services, aerodromes, airways and the whole growing field of aeronautics, and other interests besides, to draw from the upper levels of college and not from the lower—or lower still—it is imperative that we somehow make easily accessible meteorology's vast mathematical and physical assets. In great measure they are frozen, terribly frozen, but they must be made liquid. It can be done and must be done. This is meteorology's greatest opportunity and most urgent need.

W. J. HUMPHREYS

U. S. WEATHER BUREAU,
WASHINGTON, D. C.

HIGH FREQUENCY RADIATION OF THE X-RAY TYPE[1]

IN my address last year, I referred to recent advances in the production of very high voltages for technical purposes, and the application of these voltages to highly exhausted tubes in order to obtain a copious supply of high-speed electrons and atoms and high-frequency radiation. It is of interest to note how rapidly in recent years our ideas have widened as to the possibilities of production of very high-frequency radiation of the X-ray type, both by artificial and natural processes.

In my address this afternoon, I shall briefly consider the present state of our experimental knowledge on this subject, and the various directions of attack by which we may hope to get further information. On the quantum theory, the energy associated with a quantum of radiation of frequency ν is given by $h\nu$, where h is the well-known constant of Planck. When swift electrons impinge on matter, radiation of an X-ray type is generated over a wide range of frequencies, and it has been verified experimentally that the maximum frequency of the radiation obtainable in this way is limited by the relation $E = h\nu$, where E is the energy of motion of the electron, a result in accordance with energy considerations.

For purposes of discussion, it is very convenient to express the energy of a quantum not in ergs but in terms of a potential difference in volts, through which an electron must fall to acquire an equal energy. Expressed in this way, the energy of a quantum of green light corresponds to 2 electron-volts or 2 volts

[1]From the address of the president of the Royal Society, London, given at the anniversary meeting, November 30, 1928, and printed in the *Proceedings* of the society.