



A PRELIMINARY STUDY OF

INDUSTRIAL METEOROLOGY

by

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A.B., Emmanuel College
1940

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1946

Signature Redacted

Signature of Author.....
Department of Meteorology, February 11, 1946

Signature Redacted -

Certified by:.....
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594 Huron Avenue
Cambridge, Massachusetts
February 4, 1946

Professor George W. Swett
Secretary of the Faculty
Massachusetts Institute of Technology

Dear Sir:

In accordance with the requirements for a Master of Science degree, I herewith submit a thesis entitled A Preliminary Study of Industrial Meteorology.

I wish to express my appreciation for the invaluable guidance of my advisor, Professor H. G. Houghton, Jr., of the Meteorology Department.

I would like further to thank Mr. Alan Stienert of The Eastern Company for the data which he so kindly permitted me to use.

To Mr. Frank Townsend, Executive Secretary of the Cambridge Chamber of Commerce I am indebted for his assistance in the survey made of Cambridge industry. Last but far from least, I wish to express my deepest appreciation to Miss Hazel Chamberlain, Assistant Secretary of the Cambridge Chamber of Commerce for her invaluable aid and understanding throughout the entire period of this study.

Very truly yours,

Marion G. Hogan

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I. Introduction

The purpose of this paper is to indicate the future possibilities in the now, much talked of, field of industrial meteorology.

The conclusions presented have been made as a result of a three-fold approach to the problem:

- A. A general summary and appraisal of the material already written on this subject.
- B. A survey of the industries of the City of Cambridge ascertaining the ways in which weather influences business and how successful business has been in coping with these problems by means of weather forecasts.
- C. An analysis of weather's effect on a specific industry as an example of a practical application of industrial forecasting.

On the basis of these results and with full consideration of the present limitations in weather forecasting, conclusions have been drawn as to the possible value of specialized meteorological services to industry.

II. Background from Literature

It is immediately apparent from a study of the progress already made in the field of industrial meteorology that those industries most directly affected by the weather have taken the initiative, both in print and in deed, to mitigate the problems created by weather.

This then is probably the reason why literature dealing with industrial meteorology is found almost exclusively in the periodicals edited by business, industry, and commerce. Few books explaining the industrial applications of weather are available.

"Meteorology, Theoretical and Applied," by Hewson and Longley, devotes an entire chapter to the practical use of weather by transportation companies and retail merchandisers. Likewise Eugene Van Cleef in his text, "The Story of Weather," presents similar ideas on the same subject. These are two of the outstanding examples of what can be found in meteorological "texts" dealing with applications of meteorology to industry. For further study of this subject it is now necessary to turn to the various periodicals published by meteorological societies and the business world.

Power companies have made available many comprehensive studies of the problem of maintenance, repair and supply resulting from weather. Experience and investigation have shown these concerns that humidity, temperature, wind, cloudiness, and freezing rain can be quite accurately forecast for a period not exceeding three days.¹ Utilizing this information, power companies anticipate the required power load² and therefore are prepared for any emergency. Thus, although affected by almost every weather element, power companies through intelligent appraisal and use of weather forecasts have shown how the meteorologist can successfully serve this type of industry.

¹Mahaffy, F. J., Meteorology; Aid to Electrical Engineering, Electrical Engineering, August, 1944.

²For example, an increase in power is utilized to melt freezing rain from the wires.

The heat engineering field has been confronted with many weather problems and through scientific study has proved that weather forecasts can be utilized in the proper heating of buildings. An article in the February 1936 issue of "Domestic Engineering Magazine" presented the results of a test made to ascertain the effect of different types of weather on heating of buildings. The results were as follows:

1. Sunshine on a wall raises the temperature of a wall above the outside temperature.
2. From sunrise until 11 a.m. outside wall surface temperature rose from 20°F. to 60°F. while the outside air temperature rose only to 24.5°F. Before sunrise, wall temperature had been two degrees colder than the outside temperature.
3. Bright sunshine on a house with double the wind velocity increases the rate of heating only about 10%, as compared with a much larger percentage when wind velocity is light.
4. Heavy rain increases loss about 10% while snow has no appreciable effect.
5. On a cloudy night, 15% less heat is lost than on a clear night.
6. Relative humidity has no effect on the heating of a building.

With proven facts such as these available, it is not difficult to understand how an accurate weather forecast can be of assistance to all who are responsible for the proper heating of buildings.

Sales and management magazines present many ways in which advertisements and the planning of sales can be adjusted to the expected weather. Cold temperature products should be advertised when warnings of the first frost are issued. These advertisements can be set up in advance, with definite instructions to have them run at the correct time. Rubbers should be advertised just previous to rain, soft drinks when temperature and humidity are expected to be high. Retail stores can adjust the time of "sales" to

the weather. Damp, cool days discourage shopping so that a "sale" should be planned for the type of day which sale statistics have shown to be conducive to volume buying.

Construction companies determine the work of their crews according to the weather forecast. If the meteorologist promises good weather, outside work is planned, such as painting and, more important, the pouring of concrete; while if damp or extremely cold weather is promised, inside work is planned.

Temperature, fog, and road conditions are the elements of interest to transportation companies. The delivery of goods often is the responsibility of the trucking companies so that a warning of too high or low temperature is a "must" in their business. Since delay in delivery is equally important, they must be forewarned of icy roads, heavy snow, or any other condition which would tend to slow or to prevent deliveries.

Because weather has such an obvious effect on the types of business mentioned, these companies have accepted the problems presented to them and have overcome them quite successfully by the proper use of weather forecasts. Their various magazines contain numerous articles explaining the approach and solution to their weather problems.

In many cases a statistical survey of the effect of weather on a particular company is necessary to indicate what elements are important to have forecast. Eugene Van Cleef has probably done more along this line than any other person. For example, in his article entitled "Influence of Weather on Street Car Traffic in Duluth" he determined through an intensive study of the records, just what weather elements affected the number of street car passengers in the city of Duluth. Mr. Van Cleef concluded that the various factors in the order of their effectiveness were:

1. Precipitation accompanied by winds above twelve miles per hour.
2. Precipitation alone except in the case of snow.
3. Drop in temperature with strong winds.
4. Strong winds - most effective in combination with some other weather element.
5. A decided drop in temperature regardless of other elements.

On the basis of these factors, forecasts of the number of passengers were made for 112 days, with the result that 79 cases out of 100 erred by less than 5%. An over-all average of 85% indicated the forecasts would benefit trolley car lines.³ This survey has been cited merely to show how investigation can widen and has widened the field of applied meteorology.

Therefore, from the literature available on industrial meteorology, one can justifiably say that what has been written and accomplished in this field has been done mainly by those companies which weather affects to such a degree that it cannot be overlooked. An awakening likewise is taking place in those businesses which are affected to a lesser degree. Meteorology, a comparatively young field of science, has focused its attention on the development of more accurate methods of weather forecasting. Now, however, attention is being given to its application to industrial forecasting. The results of these efforts have been published in various meteorological magazines. Men in other fields, having first-hand knowledge of their individual weather problems have also contributed articles to this type of periodical.

6 It might therefore be said in conclusion that for the available literature in this field one must resort almost entirely to periodical literature, published by either business, industry, or by the meteorological field itself.

³ Van Cleef, Eugene, Influence of Weather on Street Car Traffic in Duluth, Monthly Review, 1917.

III. A Study of the Influence of Weather on the Industries of the City of Cambridge

Cambridge, Massachusetts, although it occupies only 6.535 square miles is the sixth most important manufacturing city in New England, with over three hundred different types of industry represented. This city, with its diversified industries, is comparable to any highly industrialized city in this portion of the country. Therefore a survey made of the effect of weather on industrial problems in Cambridge could be utilized justifiably as a basis for conclusions concerning industry in general.

An investigation of the problems created by weather in the industries of Cambridge was undertaken. Through the cooperation of the Chamber of Commerce of Cambridge, an article was published in the August edition of its magazine to familiarize industry with the three-fold purpose of the survey:

1. To determine the influence of weather on industry and business.
2. To obtain from industry information pertaining to the utilization of weather forecasts in overcoming weather problems.
3. To ascertain the number of industries which, either knowingly or not, overlook the difficulties created by weather.

A questionnaire was then mailed to each industry in the city with the request that it be filled out and returned. Many of the questions required only a check, making the questionnaire easier to answer due to its simplicity. Naturally not all of the necessary information could be obtained in this manner so space was made available for any additional information which the person might consider helpful to the project. The number of replies far exceeded expectations; they ranged in type from a simple "no effect" to those offering numerous suggestions and extremely helpful information.

From the completed questionnaires, data sheets were compiled of answers given by each industry to each question. The more important

1945

Weather

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Weather in Dollars and Cents

By Marion G. Hogan, Staff Member, Meteorology Dept., M. I. T.

THE financial aspects of weather are fully appreciated in national disasters such as hurricanes, tornadoes, droughts and floods. But do you realize how a rainy day may affect the sales of a bakery, how freezing rain may injure power lines or how a sudden cold spell may destroy a shipment of perishable foods destined for Cambridge food shelves?

A thorough understanding of such effects, if applied by industry to their own particular problems of production, transportation, and sales would result in the saving of millions of dollars annually. Already specific examples of such application are to be found.

Baking companies save hundreds of thousands of dollars yearly by watching the weather conditions. A survey had shown that, in case of bad weather, women remained at home, causing heavy buying near all subway stations and at in-town stores by men. Accordingly, when weather is fine the bakery sends one half of its products to shops in the suburbs: when stormy seventy-five percent is kept in the city, being distributed at points close to subway or railway stations. Such redistribution of goods results in an annual saving of thousands of dollars. A similar idea could be applied in the

case of a door-to-door bakery route. One of the most important elements connected with the weather is temperature, which in general can be satisfactorily forecast. Such information enables Gas Companies to anticipate a sudden drain on their supply lines due to a drop in temperature and prepare for it. Likewise, greenhouse owners, gardeners, farmers, candy or peanut shippers, traders in fruit, vegetables, grain or any perishable products—all are directly dependent on temperature forecasts for the success of their businesses.

It is necessary for electric light companies to know if a day will suddenly become dark due to cloudiness; knowing this they can anticipate all the lights in that district being turned on simultaneously and plan for it.

Power companies require warnings of heavy icing on their lines; by increasing their power the ice can sometimes be lightened, if not, repair crews can be alerted. Transportation companies, while being affected by temperature are also interested in elements of weather which will slow deliveries such as: snow, freezing rain and fog.

Another field which is and could be further benefited by weather forecasting is the retail dealer. It is a

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The Magazine of Cambridge

AUGUST

known fact, that the number of customers a store has per day is the direct result of the weather. Rain, snow, temperature, humidity, yes, and even Wind Velocity have an effect on the retail store business. If a sale is advertised for a particular day and the day turns out disagreeable, the sale is a failure, the business lost. It may be postponed but the sales never reach the peak which would have been possible had the original day been good. Advertisements, adjusted to weather forecasts can prove a great financial asset to stores. Street car lines can approximate the number of riders per day by means of forecasts. For instance, women will remain home for one or two rainy days but if the rain continues into the third, they will go out regardless and the number of commuters will increase accordingly.

These are but a few of the ways in which weather forecasts are being used by industry to improve their products and increase their sales. The field of industrial weather forecasting is a comparatively new one but its possibilities are unlimited. This fact has been realized by those interested in weather, with the result that Universities, together with Government Agencies are continuing their investigations along these lines and are approaching industry for their necessary assistance.

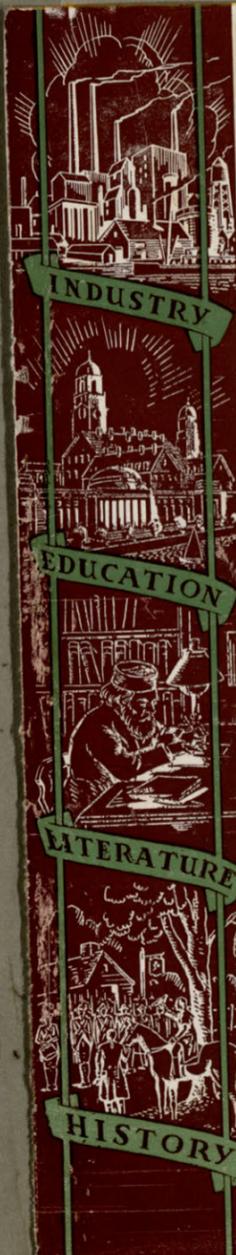
It is necessary for these agencies to be aware of the limitations as well as the advantages of the field

of weather forecasting. It is a fact that weather forecasting on the whole gives a fair degree of satisfaction—actually far beyond a point realized by the general public. Statistics show that eighty percent of all short period forecasts are correct—much better than mere chance or guess work. Nevertheless, the longer the forecast period, the less certain becomes the forecast. For example, weather forecasts for a period up to five days are fairly successful, but forecasts for periods beyond that length of time are almost guesswork. Research is endeavoring to extend the period of successful forecasting, but until that is achieved, weather forecasts for the benefit of industry must be restricted necessarily to short periods.

In order to determine how such short period forecasts can assist industry a preliminary survey is to be carried out in Cambridge and vicinity by a member of the staff of the Department of Meteorology of the Massachusetts Institute of Technology. This survey will attempt first, to find out how the present forecasts are used; second, to determine what added weather information would be of value to industry; and third, to learn how elements such as temperature, humidity, wind velocity, rain and snow affect those concerns not now using weather forecast information. It is not the purpose of this survey to establish any industrial weather service, but rather to study the approach to the vast problem of industrial forecast-

ing. To accumulate the necessary information a questionnaire will be sent to all manufacturers, contractors, industrial and retail men of Cambridge.

Full cooperation of Cambridge industry is of the utmost importance. Industry stands to gain by such a project. Research, combined with the sincere interest on the part of industry can eventually produce a specialized weather service the benefits from which will be as great as those derived by the airlines from their weather service.



The MAGAZINE OF CAMBRIDGE

THE SEWER DEPARTMENT
WEATHER IN DOLLARS
AND CENTS
TAX DOLLAR
GOOD GOVERNMENT IN
CAMBRIDGE

AUGUST - - 1945

WEATHER IN DOLLARS AND CENTS

Gentlemen:

The August edition of the Cambridge Chamber of Magazine carried an article entitled, "Weather in Dollars and Cents", endeavoring to show Cambridge business men how weather forecasting could be of benefit to them.

The enclosed questionnaire is the one referred to in that article. Weather forecasting for industry is an unlimited field but a general survey is absolutely necessary to point the way for future more specific projects. It can not be over emphasized that the success of such a project depends entirely on the whole-hearted support of the Cambridge business man.

It would therefore be appreciated if the enclosed questionnaire were given careful consideration and then answered to the best of your knowledge.

ALL INFORMATION GIVEN IN ANSWER TO THIS QUESTIONNAIRE
WILL BE HELD CONFIDENTIAL.

Sincerely,

-Signature Redacted

Enc.

Marion G. Hogan ✓
Research Assistant

Please return the completed questionnaire to:

Marion G. Hogan, Research Assistant
Department of Meteorology
Rm. 33-418, M. I. T.
Cambridge 39, Massachusetts

WEATHER SURVEY FOR INDUSTRIAL
WEATHER FORECASTING

1. Name of concern _____
Address _____ Telephone No. _____
2. Has the idea of using weather forecasting for industry ever been discussed or considered by you in connection with your business? _____ 2b. Have you read the article referred to in the enclosed letter? YES NO
3. Kind of concern: Manufacturing etc.
4. Kind of business: Retail Wholesale etc.
5. Kind of product: Perishable Non-perishable etc.
6. Extent of deliveries: Local Massachusetts New England Nation
7. At the present time do you make use of any weather forecasts? Yes No
8. If so, from which of the following sources:
Newspaper Radio Telephone (Forecast 4242) Specialized forecast
from Weather Bureau Private forecast
9. Are you interested in a general forecast or in a forecast of some particular element, such as temperature, wind, etc.
10. In what ways do any of the following meteorological elements affect your product or business either in manufacturing or sales as far as you know?
Air pressure
Temperature
Humidity
Wind direction and velocity
Precipitation Rain snow freezing rain sleet
Cloudiness
Visibility
Amount of sunshine
Other elements
(Please check and use reverse side of sheet for remarks)
11. For retail establishments:
Have you ever compared your sales variations with the variations in weather?
If so, with what result?

Do you plan your sales with an eye on the weather?
Would a forecast of rain or snow be of assistance to you?
What is the shortest forecast time which would be of benefit to you?

Do you adjust your advertising to the expected weather?
If so, in what manner?

12. For manufacturing concerns:
 - a. In what way does the temperature affect your production, sales, shipments?
(Considering high temperatures, frost, etc.)
 - b. Does precipitation affect the handling of your product in any way?
 - c. If so, in what manner?

13. For transportation and delivery concerns:
 - a. Do unexpected delays in your deliveries greatly affect your business?
 - b. In what way do temperature, precipitation, etc. affect your business?
 - c. Do you take into consideration the possibilities of fog, heavy snow, icy roads slowing up deliveries?
 - d. Do you receive temperature forecasts when delivering perishable goods?
 - e. For what length of time would precipitation forecasts be necessary?
 - f. Are you held responsible for damage done to products which you deliver?
(Such as high temperatures destroying perishable goods.)

14. For processing and printing concerns:
 - a. Are your work shops so conditioned that the moisture content of the air so necessary for the proper drying of products is controlled?
 - b. In planning your printing jobs, do you consider the likelihood of your inks not drying in time?

15. For advertising concerns:
 - a. Do you consider the effect of weather on the product which you are advertising?
 - b. Do you plan your advertising with an eye on the expected weather?
 - c. Do you plan your advertising in accordance with the natural climate of a particular area?
 - d. Do you vary it in accordance with the locality?

All other information which would indicate if only in a small way the effect of weather on your business may be added in the space below. It is an impossibility to include every type of business in such a short questionnaire, therefore if we have overlooked any questions which you believe would be of importance to us, it would be appreciated if you would include them for our benefit.

statistical results are given below.

The familiarity of industry with the use of weather forecasting had to be determined at the outset. Thirty-three per cent of the industries admitted that the benefits from weather forecasts had been discussed with them, 56% answered in the negative, while the remaining eleven per cent failed to answer this question. Considering the fact that no real effort has been expended to make industry weather conscious, the percentage of affirmative answers was encouraging.

On the whole, a general forecast of weather was of less interest to industry than the forecast of some particular element of weather. Twenty per cent expressed the need for the former, while 50% admitted the necessity for the latter. The complete totals of those interested in a particular element forecast were: 50% yes, 41% no, and 9% no answer.

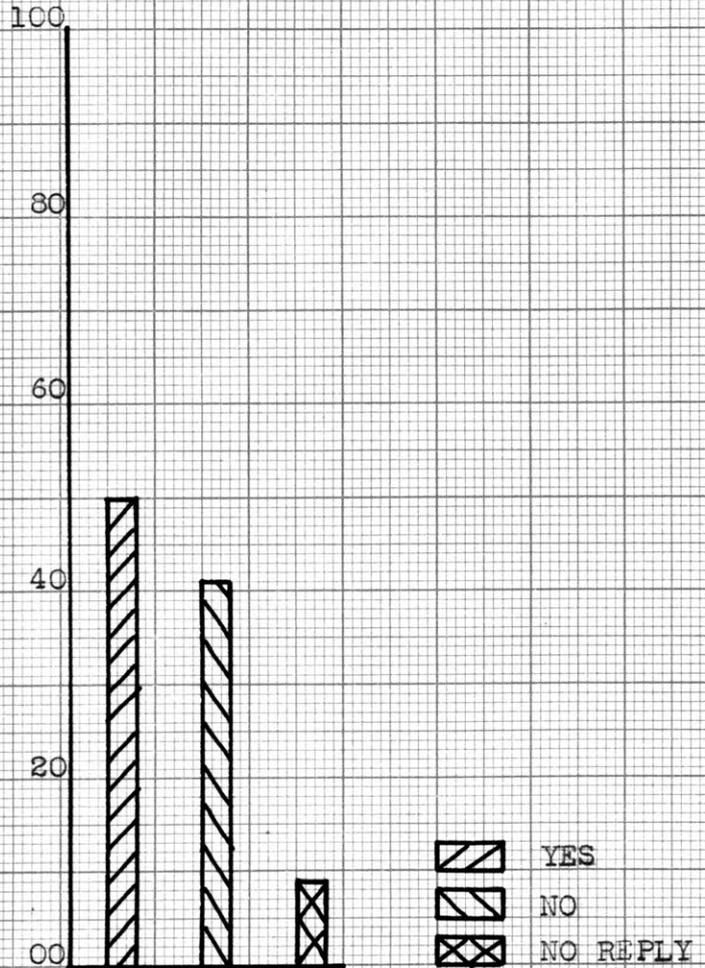
The source of industry's weather information is of the utmost importance. From this, one is able to deduce the extent of its understanding of weather forecasting. Some sources have the latest data available while others give information which has passed its time of usefulness. The replies were as follows:

1. Newspaper forecasts - 23%
2. Radio forecasts - 40%
3. Telephone forecasts - 60%
4. Specialized forecasts from the Weather Bureau - 43%
5. Private forecasts - 11%

These percentages were determined from the 50% who indicated the use of forecasts of a particular element. The percentages total greater than 100 due to the use of more than one source by many of the industries. Since the Weather Bureau or a private forecaster is the best source for latest weather information, industries using either of these have given their weather

STATISTICAL RESULTS OF SURVEY

Percentage using
Weather Forecasts



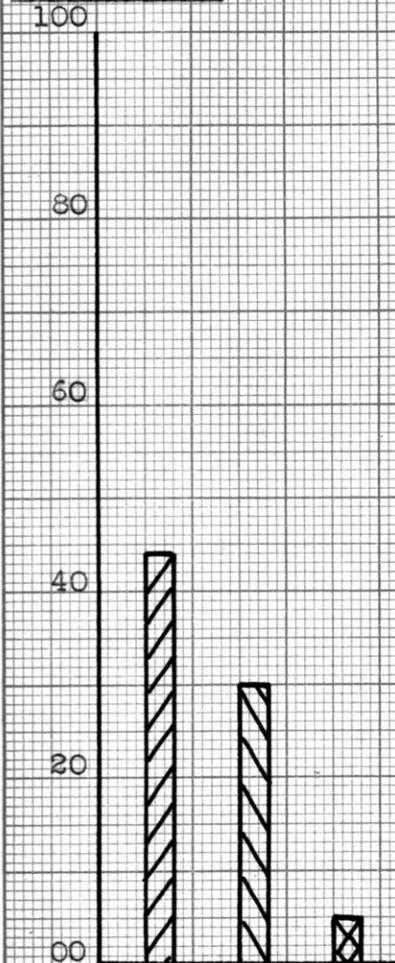
Source, in percentage,
Of Weather Forecasts used.



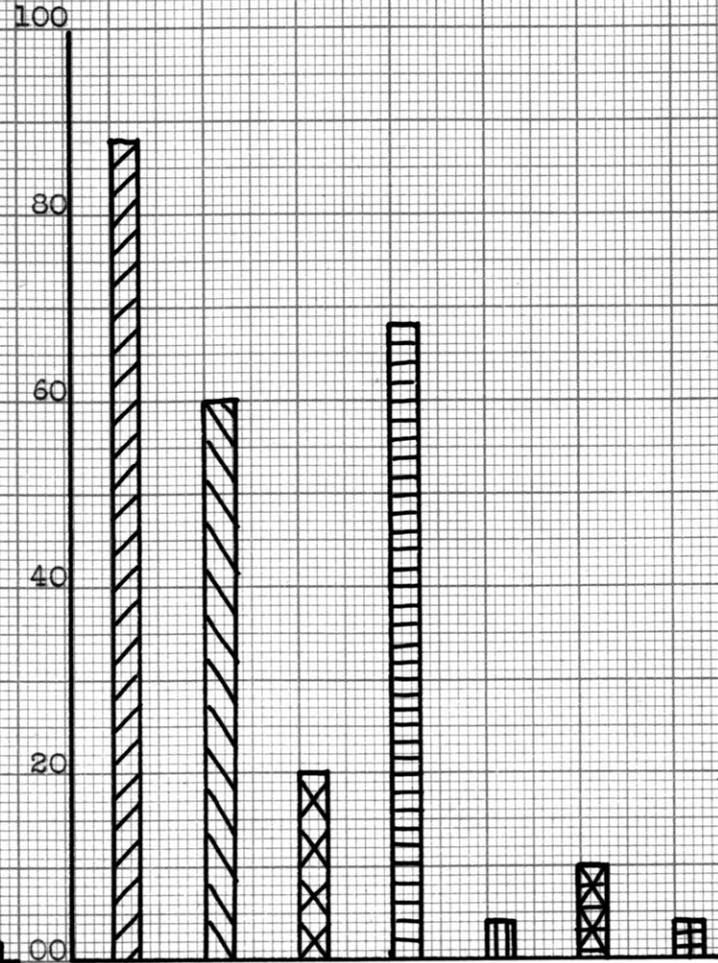
STATISTICAL RESULTS OF SURVEY

Elements required
Based on all replies

Percentages



Elements required based on
Only those who take forecasts

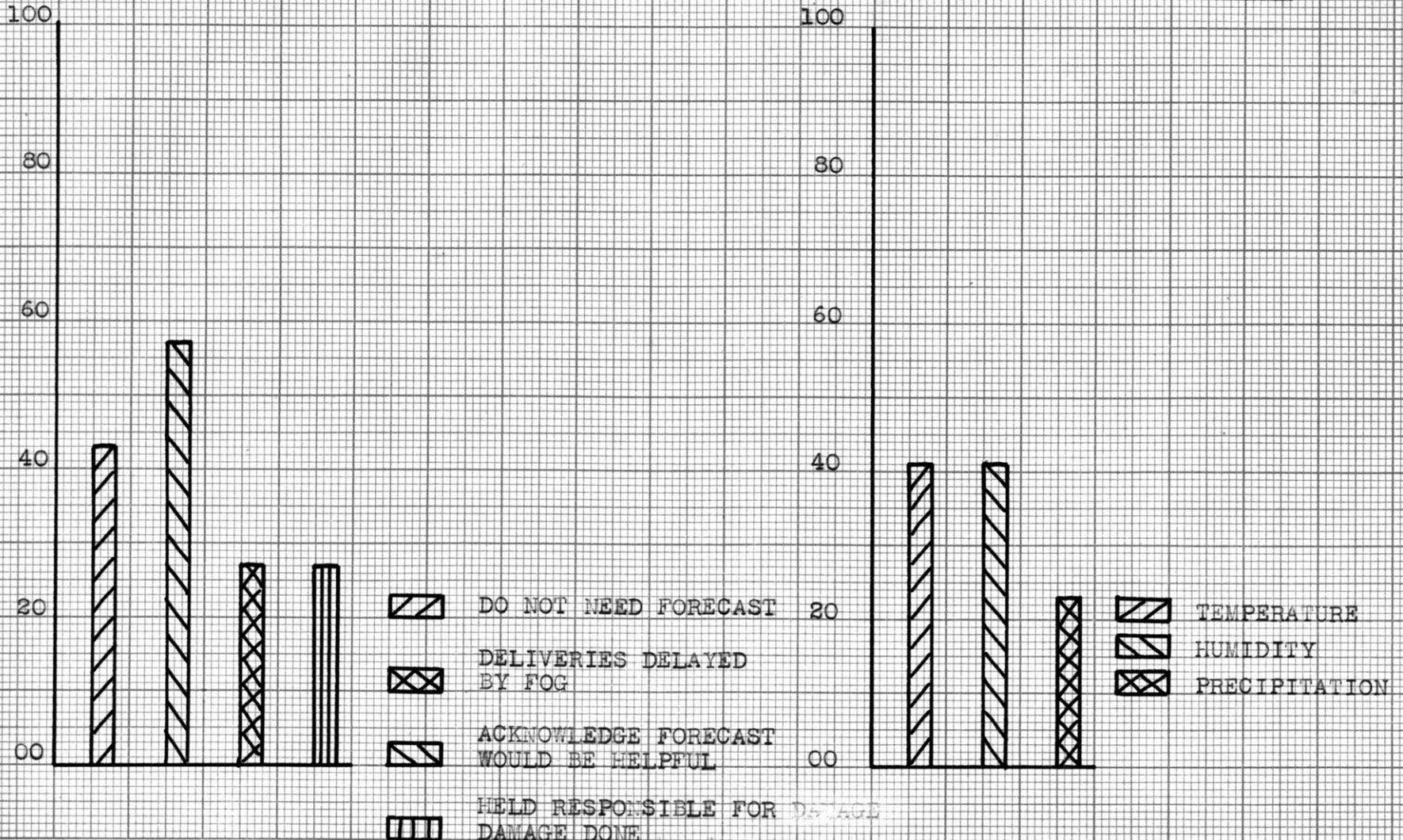


TEMPERATURE	
HUMIDITY	
WIND	
PRECIPITATION	
CLOUDINESS	
VISIBILITY	
SUNSHINE	

STATISTICAL RESULTS OF THOSE
NOT USING WEATHER FORECASTS

Percentages

Elements required by those
Who acknowledge need of forecasts.



problems considerable attention. The companies utilizing the telephone forecast likewise receive comparatively late data but do not avail themselves of the opportunity to discuss their problems with the meteorologist. The least reliable of the five sources mentioned are the radio or newspaper forecasts, not because the forecast is inherently poor, but because it is on the average, twelve hours old.

Extreme temperatures, precipitation of various types, and humidity create the majority of the industrial weather problems. Irrespective of the type of business, one or all of these elements affects either the production, shipment, or sale of the product. These figures substantiate this:

88% acknowledged the need for temperature forecasts.

68% indicated the necessity for a precipitation forecast.

60% showed the need of a humidity forecast.

Fifty-eight per cent pointed out that a forewarning of the type of precipitation was just as essential as the precipitation forecast itself. The effect of other weather elements seems less serious. Wind velocity and direction influenced 20% of the industries while visibility, cloudiness, and sunshine proved of interest to less than 10%.

Companies dealing in the production and transportation of perishable goods are extremely conscious of weather's effect. This is not surprising. However, when percentages indicate that 95% of these companies utilize weather forecasts and the same percentage use warnings of extreme temperature, it is striking evidence of what the future could hold for the industrial meteorologist when all concerns become as conscious of their problems as those dealing in perishables.

The delivery of goods, an important part of any business, is affected greatly by the weather. Moisture or extreme temperatures tend to destroy goods, while fog, icy roads or heavy storms delay deliveries. The wider the sphere of their deliveries, the more weather conscious the company should

be. Although 83% of the industries make deliveries ranging from local to international, only 37% of them make use of the most satisfactory type of forecast. Many are forewarned of temperature, others receive the latest information on road conditions, yet a relatively small percentage receive a complete forecast.

Statistics showed 41% of all of the companies questioned do not make use of forecasts while at the same time 57% of the same group acknowledge that forecasts would be of benefit to them. Once again the elements which affect these companies are temperature, humidity, and precipitation. A forecast of the first two elements could prove helpful to the majority of those companies while a smaller percentage required warning of precipitation. The 57% group is very definitely the field of opportunity for the industrial meteorologist. Industries admitting the existence of weather problems, once convinced of the possibility of solution, will of their own accord turn to the meteorologist.

Use of Forecast by Specific Industries

Many types of industries were represented in the response to the survey. For the purpose of clarity and simplicity, the answers have been divided into fourteen general classifications. The manner in which weather affects each is presented together with the statistics on the use of forecast by those companies.

Construction and Repair Companies

Precipitation affects this type of work most vitally. Except for emergency repairs, all outside construction and repair work is terminated by precipitation of any kind. Likewise, it is necessary to safeguard concrete and lumber against deterioration by rain; the former while in the process of being laid, the latter while being delivered or stored. High wind velocities will prevent any work being done above ground where scaffolds

are required. Weather conditions which stop outside work in turn affect the demand on the supply companies. The longer the period of poor weather, the less the demand for materials from the supply depots, hence a surplus accumulates. All of the companies admit weather cannot be ignored in their businesses; 66% determine the type of work possible through intelligent use of weather forecasts. The difficulties admittedly facing the remaining 33% of the companies could be solved in the same manner.

Chemical Companies and Supplies

Chemical companies have perfected protective measures for their products against extreme temperatures. However, these are so very expensive when utilized that the large companies receive Weather Bureau warnings and use such protective measures only when absolutely necessary, thus effecting large financial savings. Humidity has a decided effect on the drying of adhesives, freezing weather imperils water latices; therefore a forecast of both elements is required by these companies. Whenever possible, concerns producing perishable items plan to sell and transport them prior to the first real frost. This is not always accomplished, in which case they are advised by the Weather Bureau as to the expected temperature. Temperature and humidity are of the utmost importance to these chemical companies yet statistics show that only 42% use weather forecasts while the remaining 58% simply overlook such possible benefits.

Auto Renting Services

Included under this classification are all companies operating taxis, and those renting cars and trucks either to private persons or to large concerns. The hiring of passenger cars by private individuals is 50% transient business. An approximation to the number of cars needed can be made by means of a weather forecast. If pleasant weather is expected, a large volume of business may be anticipated; if disagreeable weather is forecast, a smaller volume may be planned for with an expected increase

in the number of accidents. Sleet, snow, or icy road conditions lead to the latter, as well as to a delay in the time of delivery. Weather warnings keep taxi cab companies on the alert and therefore prepared for all emergencies. Chains and anti-freeze are used on the advice of the meteorologist, while heated cabs are advertised as an added incentive to riders during cold snaps. Forecasts of weather are fully appreciated by persons in charge of this type of automobile renting as shown by 100% subscription to forecasts.

Clay and Brick Companies

In the manufacturing of pottery, clay creates the only difficulty insofar as weather is concerned. It is necessary for clay to be harvested from the pits and then processed. This harvesting usually is done during the summer months, that is, April to September. The first requisite is that the clay be thoroughly dry before it is taken in. The plowing of clay pits must be planned for a period when no precipitation is expected. If it should rain after the pits have been plowed and not harvested, the water stays in the loose clay rather than running off as would be the case if the plowing had not been done. Humidity also affects this process as it enables clay companies to anticipate the length of time which will be required for the clay to dry. A precipitation forecast is an absolute necessity to this type of industry. In the manufacture of bricks, any weather conditions which prevent construction or repair work affect the demand on the brick industry. In this case, the law of supply and demand is governed primarily by the weather. Therefore, any weather information which would be helpful to the contractor should be of assistance to the brick manufacturer. These are the important effects of weather on the pottery and brick industries, as admitted by them. The statistics show 50% of these concerns make use of weather forecasts in planning their activities while the remaining 50% do not.

Retail Stores

Any store which is located at a distance from a general residential area is dependent to a large extent on the weather for its volume of trade. If a day is conducive to remaining in a nice comfortable house while the wind howls outside, then the number of sales in the retail district will decrease regardless of how inviting the previous night's advertising might have been. (omitting such shopping peaks as Easter, Christmas, etc). The money spent for this advertising will not result in the proper volume of sales. The majority of these stores admitted this factor. However, they maintained that in order for a forecast to be of benefit it should be issued at least five days in advance. This might be true but it is also true that the majority of their advertising need not reach the newspaper office until 5 o'clock the night previous to its use. If this be the case, an 18 to 24-hour forecast certainly could be utilized by these concerns. As far as long range planning is concerned, the advertisements could be set up previously and when the forecaster is comparatively certain of a period of good weather, the stores could immediately insert announcements of the sale in the paper. The returns from such planning would pay dividends to the company for the effort expended. The chances are fifty-fifty when guessing at the weather; the store, therefore, stands to lose nothing by adjusting advertisements to weather and does stand to gain whenever the forecast proves correct (which according to Weather Bureau statistics is 80% of the time). The factors which govern the volume of business are temperature, humidity, wind velocity, and precipitation. Full benefits from weather forecasting in this connection can be obtained only after a thorough statistical investigation has been carried out to ascertain the exact effect of weather on the retail business together with its effect on particular items.

Twenty-five per cent of those questioned have compared their sales with the weather and have benefited thereby. If these investigations had been done by one who understands weather elements and the various ways it affects people, the benefits derived would be even greater. All admitted the great influence of weather on business and the statistics show that they have given it some consideration as 75% make use of the forecasts. Many showed a desire for weather forecasts a season or even a year in advance. Although there have been many claims that such forecasts are possible, it is generally accepted that a forecast for a period in excess of three to five days is not significantly better than climatological averages. With weather conditions such as one experiences in Boston, a twenty-four-hour forecast is sometimes very difficult. Therefore the chance for successful forecasting, a season in advance is practically nil. However, the retail dealers might successfully utilize climatological statistics as a substitute for the desired long range forecast. This data has been compiled for a number of years by the Weather Bureau and is available for public use. Business men could anticipate periods of changeable weather such as April, periods of hot sultry weather such as August. These weather statistics will not afford day to day forecasts, but through proper analysis and use will be as satisfactory as any long range forecast which is now available. Long range forecasting still is in the research stage and will be for some time to come. However, the New England business man is noted for using everything available to the best of his ability. He should continue this line of action when he approaches the problems created by weather. The majority of them can be solved by means of a short range forecast. Therefore, he should present his problems to the meteorologist personally, and together they could make forecasting save dollars for the retail stores.

Restaurants

The type of food which appeals to people in warm weather lacks appeal during the cold seasons, a fact to be considered in planning menus. The demand for certain products such as ice cream or soft drinks increases with the increase in temperature and humidity. If a restaurant is so located that it necessitates a person's walking to it, then the amount of business expected also can be determined by the weather. A meteorologist could aid a restaurant manager by supplying necessary weather information.

Transportation Companies

Railroad lines have numerous problems caused by the weather such as:

1. Disruption of traffic due to heavy storms or wash outs.
2. Reduction of passengers due to sudden extreme temperatures.
3. Protection of perishable goods against extreme temperatures.
4. Delays caused by storms resulting in spoilage of perishables unless the possibility of such delays has been anticipated and proper precautions taken.

Confronted with such problems, it is not surprising that railroad companies make use of every available source of weather information.

Street railways are vitally affected by weather conditions. A heavy snow storm not only presents the problem of keeping the cars moving, but also causes the number of passengers to increase due to the unavailability of private cars. An unexpected thunderstorm of rain of any type produces a sudden overloading of the cars if the company is not prepared. Extremely cold temperatures create a difficult problem in generating sufficient electric power in the morning to start cars which have been idle all night in the extreme cold out of doors. Almost every weather element has its effect on the street car lines. They, as well as the railroads, utilize the latest weather information.

Public Utilities

Gas Companies: The manufacture and distribution of gas for use in private homes or business houses is not an instantaneous process. It usually is manufactured forty-eight hours prior to its use, and is transmitted at approximately forty miles per hour. From these two facts the conclusion is drawn that the amount of gas required by certain communities must be anticipated in order to meet the demand. This is done by means of a weather forecast. Experience has proved that low temperatures will increase the amount of gas needed while this same weather element, combined with high winds, increases the amount to an even greater extent.

Electric Power Companies: The use of weather by these companies has been well publicized, therefore a short summary of its uses will suffice:

1. Wind and precipitation forecast for overhead maintenance.
2. Cloudiness, visibility, and temperature determine the load expected. Power companies cannot overlook the effects of weather and, therefore, seek the aid of the meteorologist.

Candy Companies

Numerous candy companies are located in Cambridge and the response to the questionnaire by these concerns was unanimously in favor of using weather forecasts. This is an example of weather having such an effect on a business that it cannot be ignored, and a remedy is absolutely essential. In this case the solution was a special weather forecast issued daily by the United States Weather Bureau, giving the expected temperatures at different destinations designated by the candy companies. This is a specific case of weather forecasting benefiting industry and producing a saving to these concerns which can be counted in dollars and cents.

A few of the effects of weather elements on candy companies are listed:

1. Extreme temperatures while shipping candy.
2. Extreme temperatures while manufacturing candy.
3. High humidity while drying candy.
4. Warm weather causes cocoa butter to rise giving the candy a white appearance.
5. Warm weather also softens goods and causes stickiness.
6. Precipitation effects shipments but does not affect candy.
7. Sales increase in cool weather.

The candy companies plan their production, shipments, and sales with the helpful assistance of the meteorologist, who has proved himself an indispensable asset to this particular type of business.

Printing Companies:

Temperature and humidity are the two elements which cannot be overlooked by printers. Extremely high temperatures cause press rolls to soften and melt while high humidity slows the drying process, causes paper to swell, and glue to become tacky, therefore difficult to use in binding, while low humidity causes static to develop on the paper. All of the companies admitted that these difficulties originate from weather. In view of these facts, it was rather surprising to learn that not one of these companies uses weather forecasting. Perhaps their problems can be remedied by air conditioning. However, as many of these concerns are rather small, the latter would be too great an expense. Therefore, one would think it probable that such a concern would endeavor to find some solution by utilizing weather information. Once again it is a problem for a consulting meteorologist.

Real Estate Maintenance

The proper heating of an apartment house or factory is primarily a problem of anticipating the temperature, wind velocity, cloudiness, precipitation. In short, it is a problem of determining just how much heat will be required, and

how long a time will be needed to bring the temperature to a comfortable level. This is usually accomplished by means of a degree day forecast. (A degree day is the number of degrees the mean temperature is below 65. For example if the mean temperature is 60 then that day is called a 5 degree day.) Upon receipt of the forecast of the degree days for the following days, the superintendent can anticipate the amount of heat required and from this knowledge can determine the time necessary to start the fires. Deciding on the type of repair work, that is inside or outside, is dependent upon the weather. Efficient management of large buildings necessitates the intelligent use of weather warnings.

Distribution Companies

Such companies are charged with the responsibility of keeping agencies well stocked with the required items. Auto supplies, kitchen supplies, dental supplies, beverages, ice cream, etc., all are delivered by distributing companies. These concerns anticipate the demand by studying the influences of weather on the sale of each product and then by means of a forecast they determine which particular item will be in the greatest demand.

Statistical Results from Survey

This survey had a three-fold purpose:

1. To determine the influence of weather on industry and business.
2. To obtain from industry information pertaining to the utilization of weather forecasts in overcoming weather problems.
3. To ascertain the number of industries which, either knowingly or not, overlook the difficulties created by weather.

The feature which becomes immediately evident from this study is that on the word of industry itself, 83% are directly influenced by the weather. This is irrespective of whether industry endeavors to overcome the weather problem.

Our first aim was to establish the premise that weather does create problems for industry. This has been accomplished.

The activities of business and industry may be divided into three main categories: (1) manufacture, (2) shipment, and (3) sale of the product. The use made of this product by the consumer is likewise important. When industrial companies admit that weather does influence their business it must necessarily affect some one or all of the mentioned divisions. Our second aim was to determine just how these concerns, admitting weather problems, cope with them by means of forecasts.

1. 50% of the companies questioned agreed that weather influenced business.
2. Fewer than 5% had made any analysis to determine the exact effect of weather on business.
3. 43% of those making use of weather forecasts named the Weather Bureau specialized service as the source of information.
4. Other sources indicated were
 4. Telephone - 60%
 5. Radio - 40%
 6. Newspaper - 23%
 7. Private forecasters - 11%.

The third aim was to ascertain the number of industries which knowingly, or not, overlook the difficulties created by weather. The figures on this phase are as follows:

1. 41% of the companies questioned do not make use of any weather forecast.
2. Of this number, 57% acknowledge the need for such a service, and stated the elements of interest.
3. Of this same number, 43% could see no need for such a service.

These are the basic statistics resulting from the survey. The conclusions together with general suggestions for the study and future application of industrial meteorology will be presented in a later section.

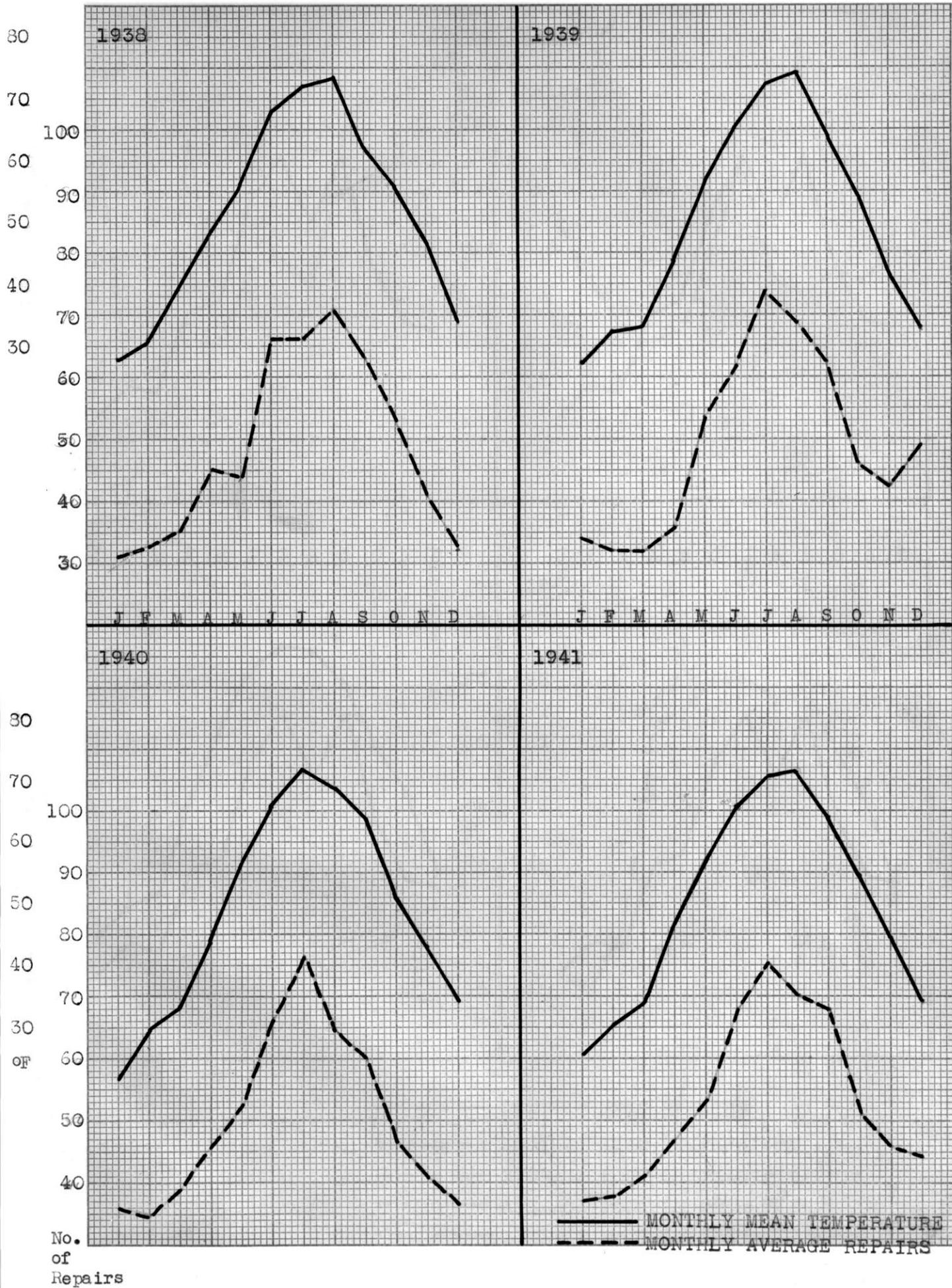
IV. A Practical Application of Industrial Meteorology

A statistical survey to determine the possible correlation between the variability of temperature and the change in the number of repair calls received by a refrigerator company was undertaken.

The data, compiled by the Eastern Company of Cambridge, Massachusetts, gave the number of repairs per day for four years. This data was first broken down into monthly averages and compared with the monthly mean temperature of Boston for a similar period. The resulting graphs showed a definite relation between these two variables: a rise in temperature was usually accompanied by a similar increase in the number of repair calls. In view of this relationship, other elements, namely humidity and precipitation, likewise were plotted against repairs, to investigate the possibility of a similar relationship. No definite correlation was found in either case. For this reason, a more detailed study of the effect of temperature alone was undertaken.

The repair data for the year 1941 was divided into days of the week, making six main divisions, Monday through Saturday inclusive. The mean daily temperature likewise was arranged for the seven days of the week and a simple correlation with no time lag, was run for this year's data. The correlation used was

in which x represents the daily temperature, and y the number of corresponding repairs. The resulting correlations ranged from .64 to .83. These figures would indicate that approximately fifty per cent of the breakdowns in the refrigerators were related to temperature fluctuations. This was substantiated further through similar correlations of daily mean repairs and

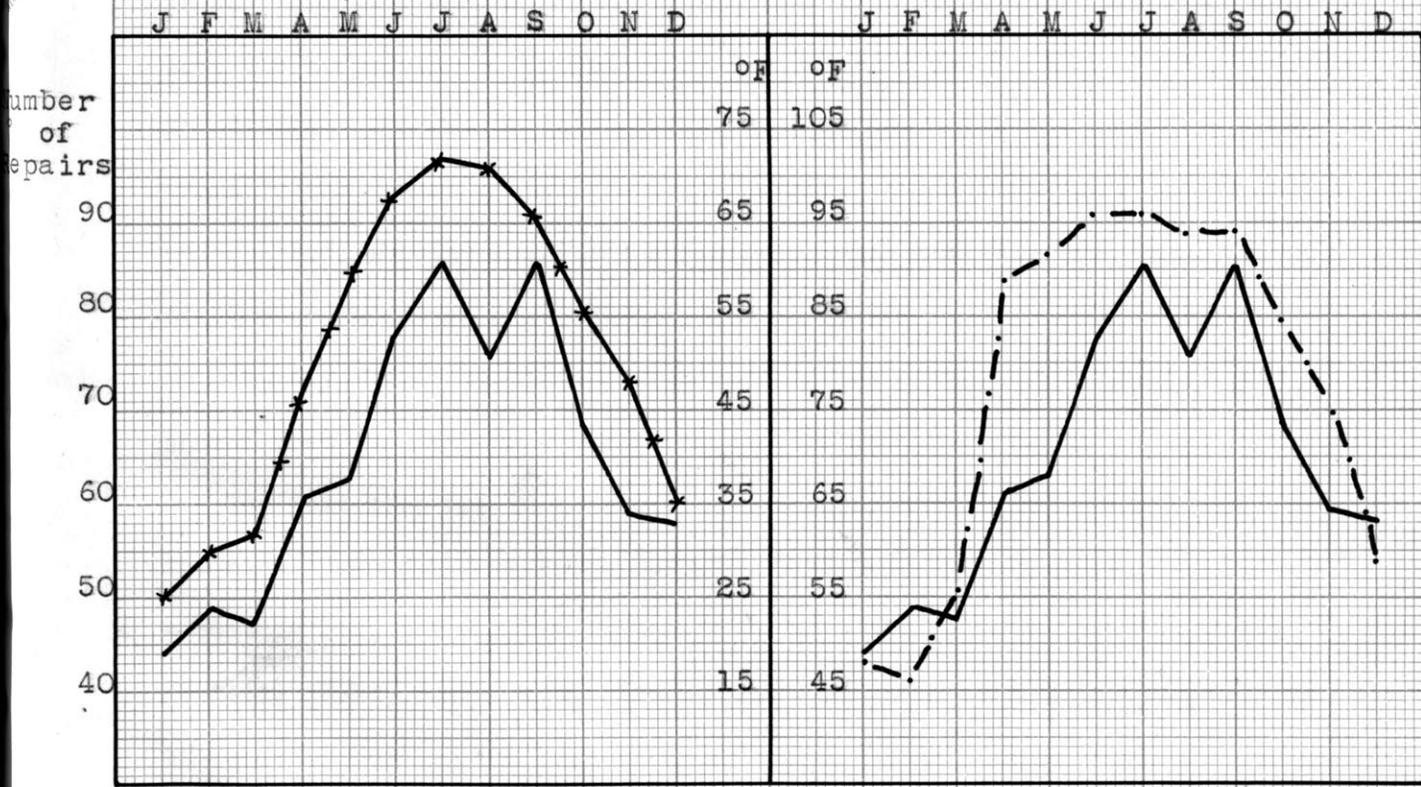
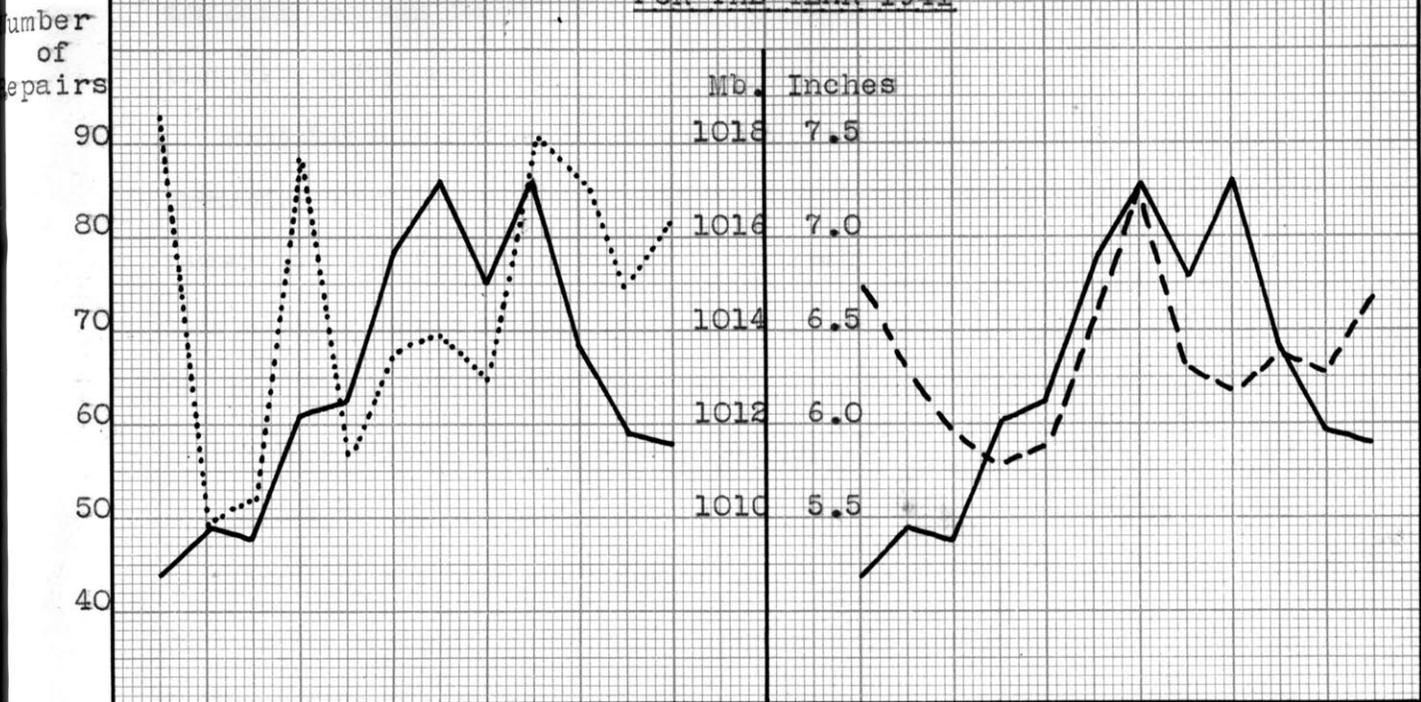


No. of Repairs

— MONTHLY MEAN TEMPERATURE
 - - - MONTHLY AVERAGE REPAIRS

COMPARISON OF THE NUMBER OF REPAIRS WITH WEATHER ELEMENTS

FOR THE YEAR 1941



- MONTHLY MEAN REPAIRS
- × × × × MONTHLY MEAN TEMPERATURE
- - - - AVERAGE MONTHLY PRECIPITATION
- AVERAGE MONTHLY PRESSURE
- · - · AVERAGE MONTHLY MAXIMUM TEMPERATURE

the daily maximum temperature. The result was very similar to the correlation with daily mean temperature averaging about .02 lower.

Realizing that the number of calls per day might be the result of the preceding day's temperature, another correlation between the daily mean temperature and the following day's calls was carried out. As was expected, this process showed a larger correlation. It ranged from .73 to a maximum of .83. The lower limit of this one-day lag correlation was higher in the latter case while the maximum remained practically stationary.

Having determined that a one-day lag was more significant, it then was necessary to ascertain which temperature was the more effective, the daily mean or the maximum. A correlation between the number of repairs and the daily maximum temperature, one-day lag, produced a striking irregularity in the resulting correlations. While Tuesday's correlation was comparatively low, the correlations for Wednesday and Saturday for exceptionally high. To eliminate the possibility of this fluctuation being due to the ordinary trend in the number of average daily repairs, these averages were calculated and graphed, showing a regular curve decreasing steadily from Monday to a minimum on Thursday, a slight increase on Friday, and a definite decrease on Saturday. The correlation with maximum temperature with one-day lag showed that the maximum temperature was the more effective.

The next step was to determine the maximum temperature above which the repair man could expect a definite number of calls per degree. Using a one-day lag, the maximum temperatures were broken into brackets of ten degrees, 50-60, 60-70, etc. The correlations increased as the temperature increased. However the highest correlation, which occurred when the maximum temperature rose above 80°, accounted for approximately one-third of the variability in the number of repair calls. This suggested that the high

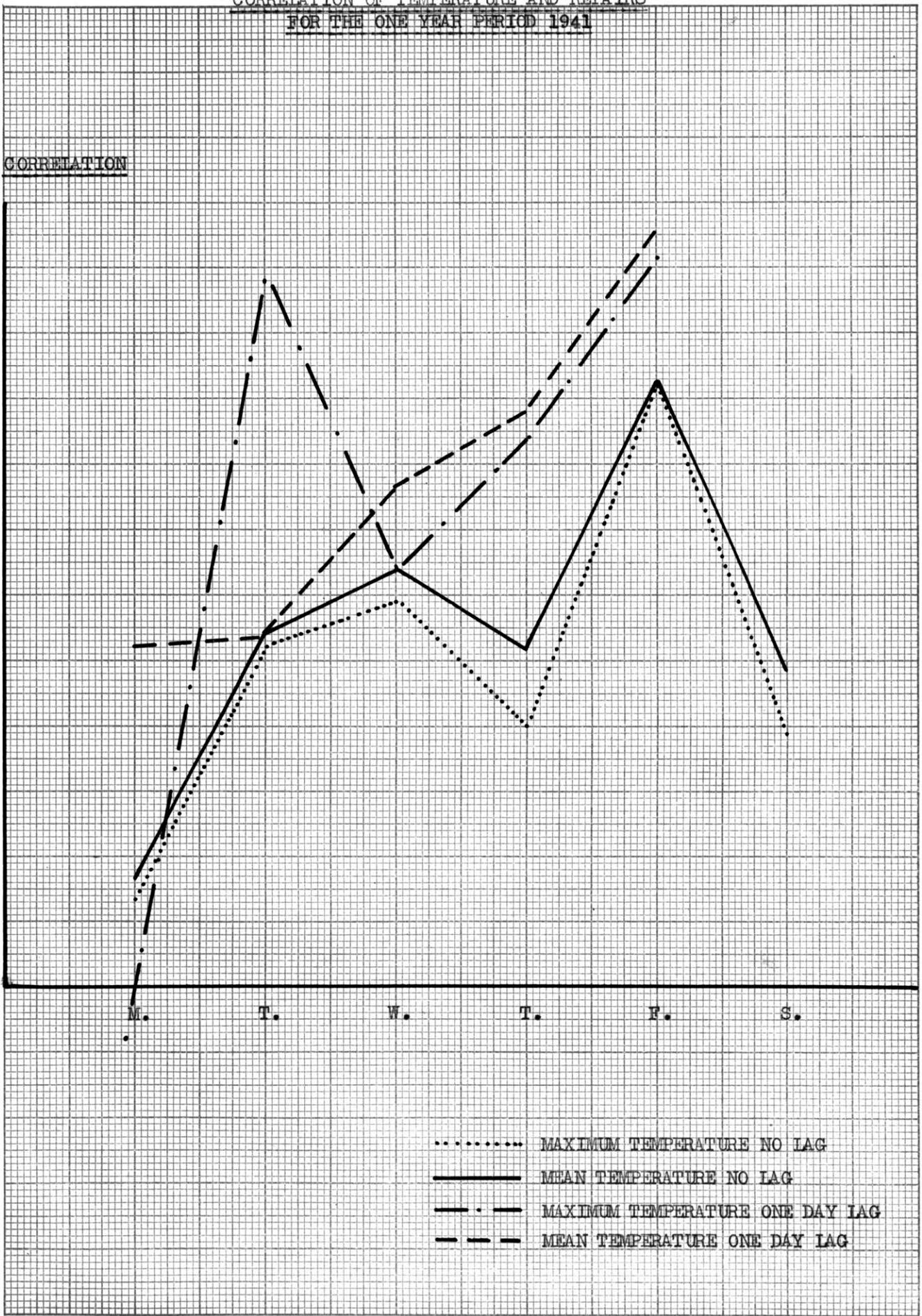
CORRELATION OF TEMPERATURE AND REPAIRS
FOR THE ONE YEAR PERIOD 1941

CORRELATION

0.9
0.8
0.7
0.6

M. T. W. T. F. S.

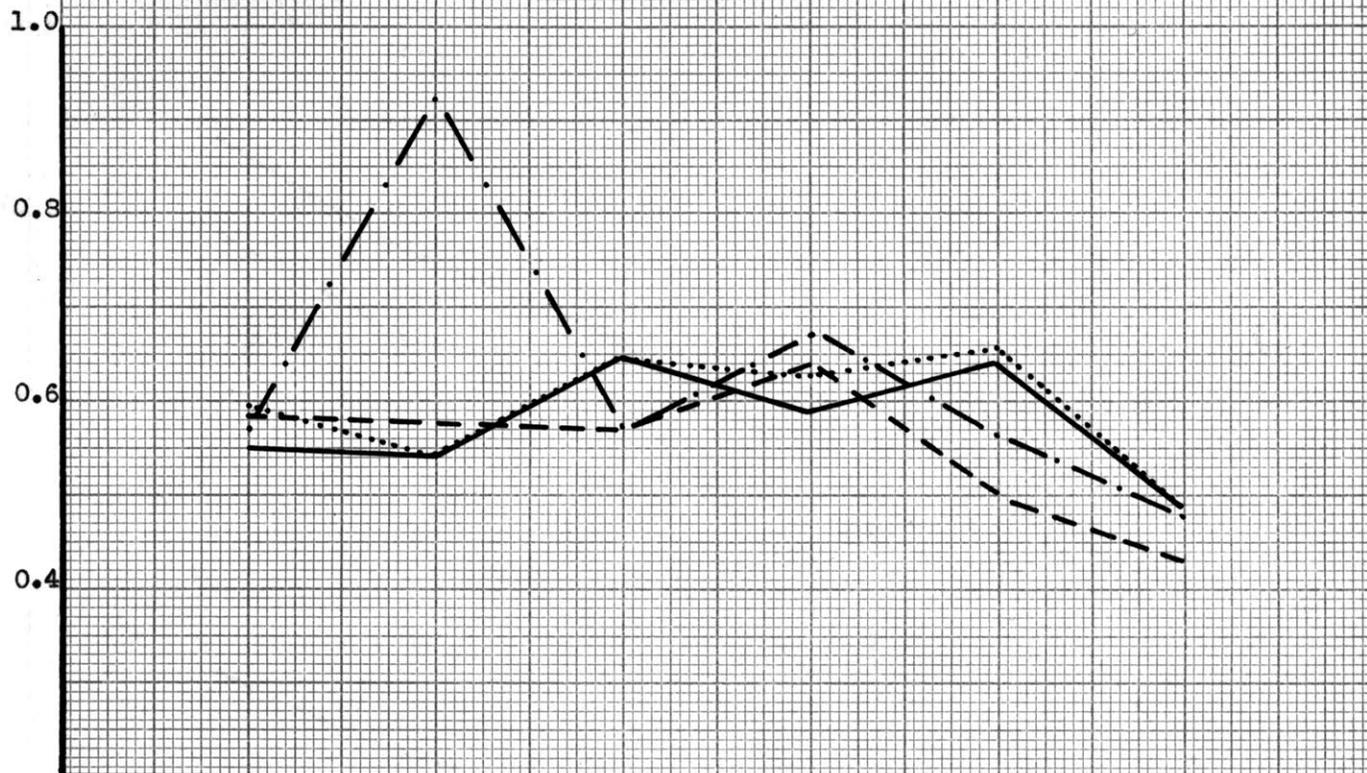
- MAXIMUM TEMPERATURE NO LAG
- MEAN TEMPERATURE NO LAG
- · - · - MAXIMUM TEMPERATURE ONE DAY LAG
- - - - MEAN TEMPERATURE ONE DAY LAG



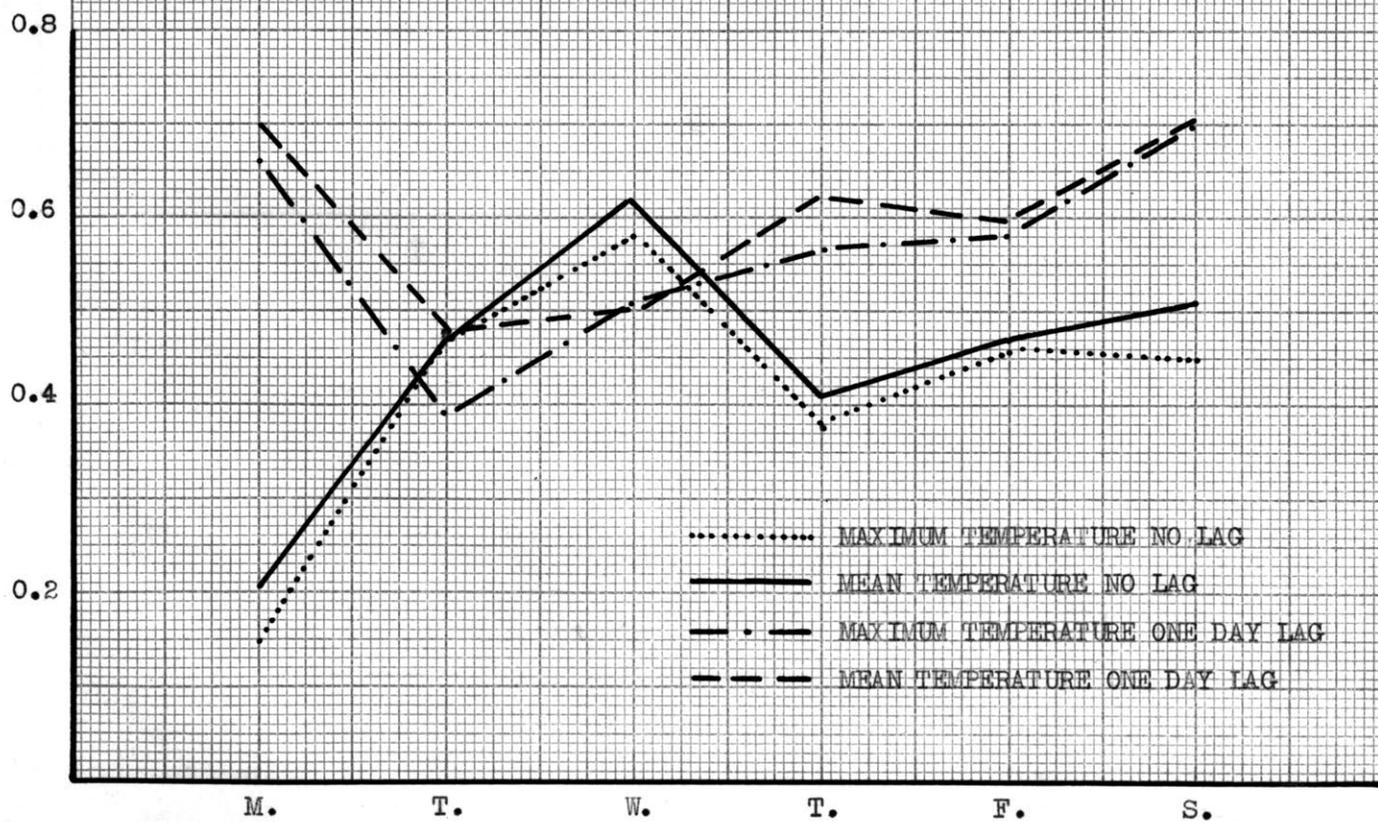
CORRELATION OF TEMPERATURE AND REPAIRS
BY SEASONS
FOR THE TWO YEAR PERIOD 1940-1941

CORRELATION

OCTOBER THROUGH APRIL



MAY THROUGH SEPTEMBER



- MAXIMUM TEMPERATURE NO LAG
- MEAN TEMPERATURE NO LAG
- . - . MAXIMUM TEMPERATURE ONE DAY LAG
- - - - MEAN TEMPERATURE ONE DAY LAG

AVERAGE REPAIRS PER DAY OF WEEK

Number of repairs

100

90

80

70

60

50

40

M

T

W

T

F

S

—————

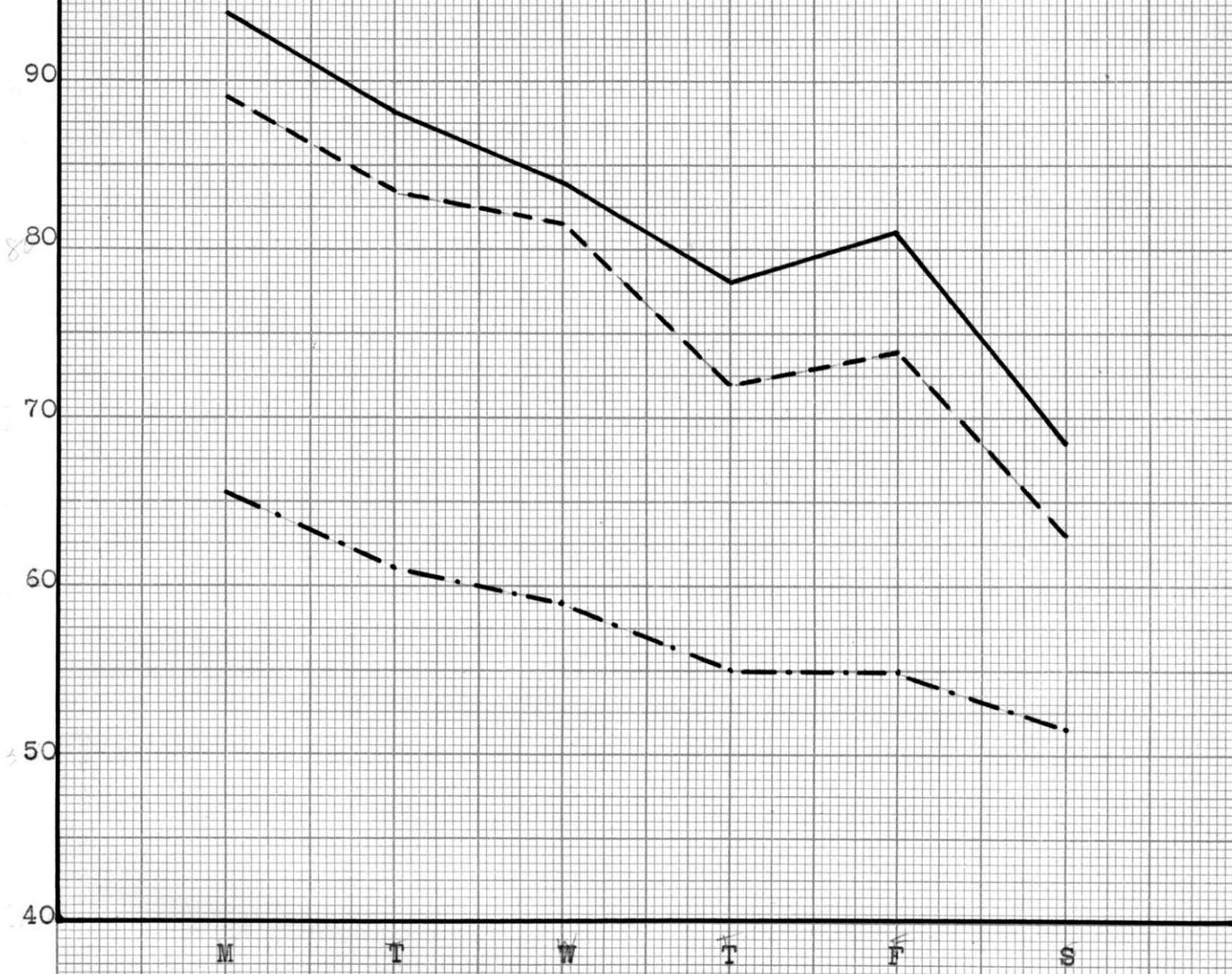
AVERAGE REPAIRS PER DAY OF WEEK FOR SUMMER SEASON FOR PERIOD OF TWO YEARS.

· - - - ·

AVERAGE REPAIRS PER DAY OF WEEK FOR WINTER SEASON FOR PERIOD OF TWO YEARS.

- - - - -

AVERAGE REPAIRS PER DAY OF THE WEEK FOR ONE ENTIRE YEAR IRRESPECTIVE OF SEASONS.



general correlations obtained were misleading for, had they been significant, the correlations should be just as high as those obtained from breaking the temperatures into temperature brackets.

If the original correlations were important, then correlations made by seasons should show this very definitely. Considering the fact that refrigerators operate under comparatively steady temperature conditions during winter months, and are exposed to very different conditions in the summer, one might justifiably expect high correlation in the summer and low correlation in the winter. Continuing with this idea, two years' data was divided into seasons, May through September, and October through April. This was then broken into days of the week similar to the other correlations already described. All four correlations were computed for each season, namely maximum and minimum temperatures with no lag and a one-day lag. As opposed to the wide range obtained in the first correlations, the regularity and equality of correlation from the winter data for a period of two years was striking. The daily correlation in all the cases of this bracket fell in the region from .50 to .60. The regularity of this curve substantiates the idea that the variation would be slight in the winter but the magnitude, although small, is still larger than would be expected under winter conditions.

Similar correlations calculated for the summer season produced results more comparable to the original general correlations. One-day lag again proved to give the highest correlation coefficients and although the curve followed a trend similar to the first calculations, the magnitude was not as large. The maximum in the former case was .88 while in the latter it was only .70. The variations in the summer data were much larger than the winter but the average correlations showed very little difference. This dispells the idea that temperature is as effective a factor in determining

the number of repairs as would have been anticipated from the correlations of the average yearly data rather than considering it by seasons.

From the simple statistical correlations carried out in this study, it may be deduced that 33% of the variability in the number of repairs on refrigerators can be accounted for by the variation in temperature. This is far less than was expected when the study was undertaken. The assistance which a temperature forecast could afford the repair man therefore, is not as great as one would anticipate by merely glancing at the original graphs of the mean temperature versus number of repairs. It is possible that a further statistical study would lead to more definitive results; for example, multiple correlations might be of value.

The main difficulties arise from two sources:

1. The number of refrigerators which could require repair on any given day is not definite. Therefore, the basic course in itself is variable.
2. The type of repair done on the refrigerator was not considered. This is of primary importance. For instance, if a repair man is summoned and his work merely entails the adjustment of a handle, the fixing of a loose connection, or more important, merely checking because the lady of a house decides it sounds odd, such repairs cannot possibly be associated with the weather. This is the second variable which must be eliminated before any definite correlation between the weather and the repairs on refrigerators could give useful results.

The first difficulty cannot be overcome readily. The latter can be solved rather simply by merely keeping records of the type of repairs done on each repair call. Through the aid of the refrigerator men themselves, some clue as to the type of trouble most closely associated with temperature variations could be determined. Correlations carried out, using only this type of calls and a one-day lag temperature would be more definitive

of temperature's effect on repairs. In this way average "non-temperature" repair calls for each day could be calculated and then by means of a maximum temperature forecast the repair man could anticipate how many additional repairs might be expected above and beyond the average "non-temperature" repairs.

This study was carried out as an example of a practical application of industrial meteorology. Its aim was to show how a statistical study could indicate to industry just how weather forecasts could be utilized. The following conclusions may be of assistance to any further statistical studies along similar lines:

1. A thorough understanding of the business for which one is to make a study is absolutely essential. In this way many difficulties are avoided or overcome. As in the case cited above, a knowledge of the cause of the refrigerator breakdown would facilitate in the elimination of one of the variables.
2. A thorough knowledge of statistical methods is required. Thus the variability due to other elements could readily be evaluated.
3. Greatest benefits from weather forecasts can be obtained only after thorough statistical studies have been carried out, considering every element which could possibly affect the particular industry, not by mere snap judgment as would have been the case by merely utilizing the original mean graphs in the study above.
4. After the study has been completed and the important elements have been determined the results should be given to the industry. However it should not stop there. A full explanation of what information is essential in a forecast should be explained and the proper interpretation and use of it made evident. For instance, if the element of importance proved to be wind, it is not sufficient to have the man in charge obtain a forecast

such as, "Moderate north winds backing to northwest and becoming fresh," unless that person knows how many miles an hour is meant by the terms "moderate," and "fresh." A good forecast is primary, but proper interpretation and use of it likewise is very important.

From this particular study of the practical side of industrial meteorology it may be concluded that statistical studies, to determine the effect of weather on industry will play a vital part in making industry weather conscious and in advancing the whole field of industrial meteorology.

V. Conclusions

The main conclusions from this threefold study are as follows:

1. The best source of material on industrial meteorology can be found mainly in the periodicals published by business, industry, and meteorological societies.
2. The majority of these articles have been written by men in private industry and business, to whom weather presents such a problem, that it cannot be ignored. The efforts they have expended and the ways in which they have endeavored to mitigate such problems usually appear in the periodical devoted to their major field of interest.
3. Until the present, any use made of weather forecasts by industry has been initiated by industry itself.
4. No determined effort has been made by any prominent agency to further the field of industrial meteorology.
5. Industry as a whole is more conscious of weather's effects than one might expect (considering the comparatively small amount of concentrated effort which has been expended in its direction).
6. Of all the industries surveyed, 85% admit that weather influences their business. An even larger percentage is affected by it although this group does nothing to overcome the problem created.
7. Of all the industries taking weather forecasts, less than 50% use the best source of weather information, namely direct consultation with the Weather Bureau or with a private forecaster.
9. Before industry can obtain the best results from weather forecasting, methods of overcoming their weather problems must be pointed out to them by an agency or an individual whose name carries sufficient prestige to warrant consideration of it by industry.

10. Industries confronted with weather problems should be encouraged to discuss their questions with a meteorologist. The meteorologist must come to be considered as an advisor and not as a scientist who is to be avoided.
11. Companies desiring a long range forecast should be shown that although this is an impossibility, intelligent use of climatological data can suffice in many cases. Further, it should be indicated that their problems can be solved in many instances through discussion with a meteorologist. Retail dealers often overlook the very efficient use which can be made of excellent short range forecasts.
12. Clarification of weather terms is absolutely essential. Forecasts must be worded so that the man in business, with no background in the science of meteorology, can understand a forecast and not be misled by scientific terms. A cold front passage might mean absolutely nothing to a person interested in shipping perishable goods, but a forecast of temperatures between 10 and 15 degrees means that perishable goods should not be shipped except in properly heated cars.
13. A general forecast is not very useful to the industrialist. For this reason it should be explained to him that if he is interested in a particular element he should state that fact and also tell what his specific problem is.
14. The present limitations of weather forecasting should be explained to industry. For instance, although the possibility of a successful long range forecast is slight, a forecaster can tell in August approximately when the first frost is likely to strike. This is not a long range forecast but it can be of benefit to industry.

15. The field of industrial meteorology has had a promising future, but this can be realized only through intensive effort by the private meteorologist, meteorological societies, or the Weather Bureau.
16. A statistical study showing how weather influences a particular business probably is the most important factor in the development of industrial meteorology.
17. A well-organized campaign must be undertaken. Individual companies must be contacted and with their backing the problem and possible solution should be presented to large organizations such as the retail dealers association or the chamber of commerce. A successful statistical study made of a large retail store could be utilized to extend such investigations to large retail dealers' associations. If savings of dollars and cents can be shown, financial backing might well be expected from such organizations.
18. Although this field is unlimited, advances in heating or in air conditioning eliminate the necessity for some specific weather forecasts. However in the latter case, the installation and maintenance costs are prohibitive and far beyond the reach of the small business man. For this reason, he should not be overlooked by the private meteorologist endeavoring to sell weather information.
19. The more weather conscious industry becomes the greater the demand on the Weather Bureau. At present the number of forecasts required from the Bureau is in excess of its ability to serve due to a shortage of manpower. When fully staffed, the Bureau still will be unable to cope with this demand. Industrial meteorology is the field for the private forecaster. This is a service which industry should not expect to obtain free of charge. A good forecast means a saving to industry and industry should be willing to pay.

20. In view of the fact that the Weather Bureau, meteorological societies, and universities are the recognized sources of weather information and carry prestige with industry, these groups can assist materially in indicating to industry the added benefits to be derived from the individual attention of the private meteorologist. After long years of service, a private meteorologist may establish a reputation so that industry will recognize his ability, but this certainly is a long and unrewarding career. Therefore it is my opinion that the future of industrial meteorology, although it appears unlimited, cannot be developed to its utmost in the near future unless some well established agency makes a decided effort in this direction.

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