THE EFFECT OF FRONTAL PASSAGES ON FLIGHT RESTRICTIONS AT THE CHICAGO, OMAHA, AND KANSAS CITY TERMINALS

Thesis by

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I. Introduction

This study has for its primary purpose the provision of a means for assisting a forecaster in predicting the extent and duration of bad weather during frontal passages. It is particularly intended that the results presented be used to determine how poor flying conditions will get, when the worst conditions will occur, and how long they will persist.

The standard weather classifications of Contact, Instrument, and Closed have been used for denoting the weather conditions at the air terminals and are as defined by the Civil Aeronautics Authority. These classifications are transmitted on the teletype weather sequences used by the airway forecaster. The final results of this thesis are in the form of curves for the individual stations which show for a certain type of frontal passage at any particular time of year, whether the station can be expected to go to conditions of instrument operation or closed, when the restricted condition is likely to occur, and approximately how long it will last.

The variation of the actual weather from these "probable" curves can be considerable and the skill of the forecaster in recognizing the intensity of an approaching front from his synoptic chart and in making a suitable adjustment to the values read from the curves is required in order to make the best possible use of the results of this study. Important factors influencing the weather, namely local effects caused by topography, lakes, sources of smoke pollution, etcetera are taken into account in the mean curves, as the latter are constructed from a study of the actual weather in connection with synoptic maps and weather reports. The same frontal passages were studied for Chicago, Omaha, and Kansas City and the relative amount of flight restriction is very apparent and may be of considerable value in picking alternate terminals for flight operations in the vicinity of fronts.

This study is primarily concerned with the weather during and immediately before and after surface frontal passages, so consequently a great deal of bad weather due to systems which pass near to but not thru the stations was necessarily omitted from the data used herein. For the purpose for which this analysis was made, however, it is believed that a forecaster could assist himself to a large extent by careful correlation of these results with the synoptic charts.

In segregating the fronts which passed through the Chicago, Omaha, and Kansas City area into types it was concluded that a system of separation based upon the two air masses forming the surface discontinuity would be the best method. It was found that the fronts passing these three stations could be grouped into four general types. The air mass notation used is that devised by Dr. Krick.

Frontal Type	Air Mass (before front)	Air Mass (behind front)	Front Type Most Frequent
I	Old Polar Continental	Fresh Polar Continental	Cold
II	Old Polar Type	Fresh Polar Pacific	Occl. or cold with waves
III	Polar Type	Tropical Gulf	Warm
IV	Tropical Gulf	Fresh Polar Type	Cold

The fronts of each particular type are all substantially of a uniform nature. The Type I fronts are almost invariably cold fronts while the Type II fronts are either occlusions or slowly moving cold fronts with wave systems moving along the discontinuity. While the latter type includes two kinds of fronts, the minimum conditions produced by the two were not found to be very different, and consequently the pure air mass typing system was used, both of these fronts being considered as Type II. While the occlusions generally move faster than do the cold front wave systems, the time of flight restriction was very similar in both except in the cases when some warm moist air entered the cyclone structure aloft. Types III and IV are always found to be warm and cold fronts respectively. It is seen from the synoptic charts that the types adopted include practically all fronts which pass these three stations. Like any other statistical weather study, it is believed that the value to be derived from these results lies in the recognition of the differences between any particular frontal passage and the usual or mean passage of the type during the season under consideration.

It is intended that this study of frontal weather be used in connection with the thesis of Dahl and Hills* written at the California Institute of Technology in 1939 which covers substantially the same area (Chicago to Omaha air route) in relation to purely air mass weather. By a use of both papers it is hoped that a forecaster may accelerate his recognition of the weather which he may expect in this region from almost any type situtation.

To agree with the method of seasonal segregation used in the Dahl and Hills thesis*, the year is divided as follows:

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* The Technique of the Development of Dynamic Climatological Information by Dahl (U.S.A.) and Hills (U.S.A.) California Institute of Technology, 1939.

WINTER: December, January, February.

SPRING: March, April, May.

SUMMER: June, July, August.

AUTUMN: September, October, November.

These seasons are more or less standard and were found to be satisfactory for this investigation.

II. Procedure in obtaining data

In order to get a general concept of the problem, and provide data for the classification of the fronts affecting the area, a tabulation was made of the frontal passages at Chicago for the years of 1936 to 1940 inclusive. This tabulation was made from the 6 and 12 hourly synoptic charts analyzed by Dr. I.P. Krick and filed at the California Institute of Technology. The weather produced by all frontal passages within the five year period was tabulated. This data was used in the separation of the frontal types and also to compare the general intensity of the weather produced. Figures IX to XII show portions of the synoptic chart during typical passages of the four general frontal types.

To obtain accurate data concerning the minimum conditions resulting from a frontal passage and an accurate record of the time of instrument and closed conditions, the hourly airway teletype sequences were examined and the weather recorded for each of the three stations during any flight restricting conditions. The synoptic charts were used as a guide in reading the hourly reports. The time of the passage of the surface front was determined by the sequences (to the nearest hourly report). As the hourly sequences for the stations examined were available only from January 1, 1940, to March, 1941, only two winters and one each of the other seasons were covered in this manner. The conditions existing during the passages were, however, compared with the five year map record when the mean time curves of instrument and closed were computed, in an attempt to eliminate the long period displacements of the streamline flow. The existing north-south and east-west displacements of the streamline flow must also be borne in mind by the forecaster when considering the mean time studies.

One difficulty encountered in studying and recording data from the hourly sequences was the determination of the boundary of influence between one front and the next. This difficulty was found only during the most intense portions of the winter seasons. Other conditions giving difficulty were: air mass fogs, air mass thunderstorms, and long periods of visibility-reducing smoke conditions requiring instrument operation. Careful consideration was, however, given each case in an endeavor to eliminate restrictions which were not in some manner dependent upon frontal activity.

III. Analysis of data

The first step in the analysis of the data obtained from the hourly sequences and the synoptic charts was the establishment of the values used in the mean curves. In order to do this histograms were drawn for the following occurrences for each type of front at each station.

1. Hours Instrument plus hours Closed before frontal passage.
2. Hours Closed before frontal passage.
3. Hours Instrument plus hours Closed after frontal passage.
4. Hours Closed after frontal passage.

In any one histogram the values recorded from the individual cases were plotted against convenient hour ranges in order to find the most probable number of hours for the particular case. Histograms were plotted for each frontal type at each station in each of the seasons for the occurrences recorded above. From a consideration of the most probable values in each histogram and of the individual values involved, mean values were obtained for each of the four groups noted above at each station for each season for each of the four frontal types. These means are plotted in figures I through VIII. In order to use these mean curves the factors of the individual case must be forecast in order to determine it variation from the mean.

Some of these factors will be considered in a later part.

The smoke pollution quadrant diagrams (figures XIII, XIV, and XV) were constructed in order to show the directions of the surface wind (on a sixteen point compass) at each station which give smoke pollution at the time of a frontal passage. In obtaining the values plotted it was necessary to make corrections for the differences in the total number of cases of smoke pollution occurring in each of the sixteen compass directions. For each case less than the maximum number of cases occurring, a value of five miles was added in before the average was taken. For example, if the maximum number of cases were 20 and they fell in the south-east wind sector and only 14 cases fell in the east-north-east wind sector, then 6 additional values of five miles would be added to the 14 recorded cases in the east-north-east wind sector before the average for this sector was taken. In this way it is believed that a more representative value for each wind direction sector may be obtained.

IV. Results and Conclusions

The adherence of actual conditions to those represented by the Instrument plus Closed and Closed curves (figures I through VIII) is relative to the unique peculiarities of the individual situation. As these curves represent only the mean conditions of a number of similar type frontal passages in each case, the importance of the deviations from these values cannot be overlooked in the successful use of the curves in the forecasting of operating conditions. It may be stated that the maximum deviation in any case can amount to 100% or greater. Because of the importance of the variations, some of the more prominent factors as observed in the course of this research will be noted.

The most important factor in the intensity of a Type I frontal passage seems to be the temperature difference across the front. From a deductive consideration of this point, such an opinion appears logical, since some of the other important factors in frontal intensity, i.e. specific humidity, frontal slope, and upper air structure are more or less constant within a given season for this type of front. The second most important factor in Type I frontal intensity is probably the orientation of the front with respect to the station. The orientation of the front determines to a large degree the direction of both the pre-frontal and post-frontal surface winds, as well as the trajectory of the air in both air masses. The surface wind directions are important since the terminals considered are associated with large metropolitan and manufacturing areas and show the effects of smoke pollution from these sources. The subject of smoke pollution will be treated in a later portion of this report. The trajectory of the air is important since it determines the latter's stability. This is most important in the case of the air behind the Type I fronts in winter since it determines the distance that the air travels over the water surfaces of the Great Lakes, which in turn is a measure of the amount of snow flurries in the convectively unstable Polar Continental air. As is indicated from figures I and II, the effect of the Lakes is relatively much more noticeable at Chicago because of its position. The trajectory of the air also determines the extent to which local terrain will affect weather conditions. Since all three of the stations under discussion are located in a part of the country which has little or no topographic relief, the orographical effect is in this case practically negligible. The only role of any importance played by the terrain is in its relation to air drainage and smoke pollution at Kansas City.

Since Type II fronts pass through the area under consideration as either occlusions as slowly moving cold fronts along which waves form, the frontal intensity is best judged by the contrast between the two air masses involved, as well as the stage of development of the cyclone formed along the front. The maximum intensity of a Type II front is reached when Tropical Gulf air is drawn aloft into the upper air trough. It can be seen from an inspection of figure III that conditions both before and after a Type II frontal passage are relatively worse than those brought about by a Type I frontal passage. This may be explained in part by the fact that the area involved is usually affected by warm front type precipitation with a Type II frontal passage in contrast to the usual cold front precipitation of Type I. The warm front precipitation area by its very nature may produce longer flight restrictions than that of Type I, since it usually affects the station for a relatively longer period. Low stratus decks with their accompanying drizzle and fog are a common Type II phenomenon. It is to be noted that Type II post-frontal conditions are far worse at Chicago than at either Omaha or Kansas City. This is usually due to the fact that the cyclone center passes much nearer to Chicago than to the other two stations. The usual extension of the precipitation area to the rear of the front in the vicinity of the cyclone center may produce restricted conditions at Chicago for a longer period than at Omaha or Kansas City. A second reason why chicago is more affected by Type II fronts than are the other terminals is that often by the time the upper trough has reached

Chicago, the Tropical Gulf air has had sufficient time to enter the upper structure of the cyclone.

The chief factor in the estimation of the individual Type III front is the intensity of the cyclone with which the front is connected. The intensity of the cyclone determines the extent to which the Tropical Gulf air overruns the warm front surface, which in turn determines to a large extent the pre-frontal restrictions of aircraft operations. It can be stated that possibly the worst weather of all occurs in the area concerned when cyclones involving Type III fronts pass well to the south, since in the majority of cases these cyclones are more intense than those which travel on a more northerly path. There are exceptions to this however, a notable one being the storm which passed through the central part of the country on November 11, 1940.

The criteria which affect the Type IV fronts are much the same as those affecting the Type I fronts, since both are essentially cold front types. Since no closed conditions were observed with Type IV fronts this curve was omitted. It must be stated that the number of Type III and IV fronts passing through the area concerned is much less than the number of Types I and II, and the results in the cases of the former two are therefore less conclusive. In figures V and VI the curves for Omaha and Kansas City are omitted due to a lack of sufficient frontal passages to indicate a curve. This is especially true of the winter seasons.

The correct estimation of the amount of restricted visibility conditions due to smoke pollution from metropolitan and manufacturing sources is also of much importance in determining the deviations of any particular case from the mean curves of figures I through VIII. For this reason the smoke pollution quadrant diagrams were constructed. The data used in the construction of these diagrams was taken only at times near frontal passage and is only valid under these conditions. It is obvious that if much turbulence is present because of strong surface winds, this will substantially reduce the possibilities of smoke restricting the visibility. Optimum conditions for this type of flow are found in the air in back of Type I and IV fronts. Subsidence in the air in advance of the front produce conditions which increase the possibility of smoke pollution.

It has been observed that the time of day of the frontal passage is a factor which can be used in the estimation of the intensity of pre-frontal smoke conditions. Pre-frontal smoke conditions were found to reach a maximum when the surface frontal passage was in the early morning hours.

Bibliography

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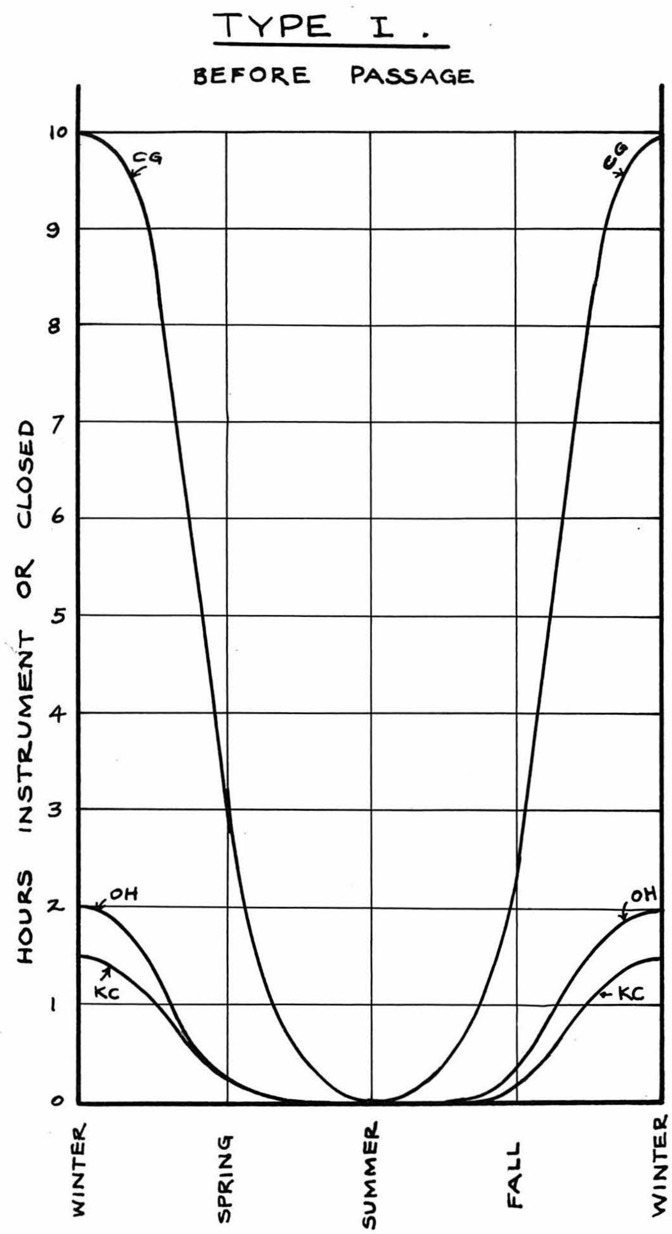
3. Dahl and Hills: The Technique of the Development of Dynamic Climatological Information (Thesis written at the Calif. Inst. Tech. in 1939)
4. Civil Air Regulations - Part 60. - Air Traffic Rules


TYPE I.
BEFORE PASSAGE
HOURS INSTRUMENT OR CLOSED
10
9
8
7
6
5
4
3
2
1
0
CG
CG
OH
OH
KC
KC
WINTER
SPRING
SUMMER
FALL
WINTER

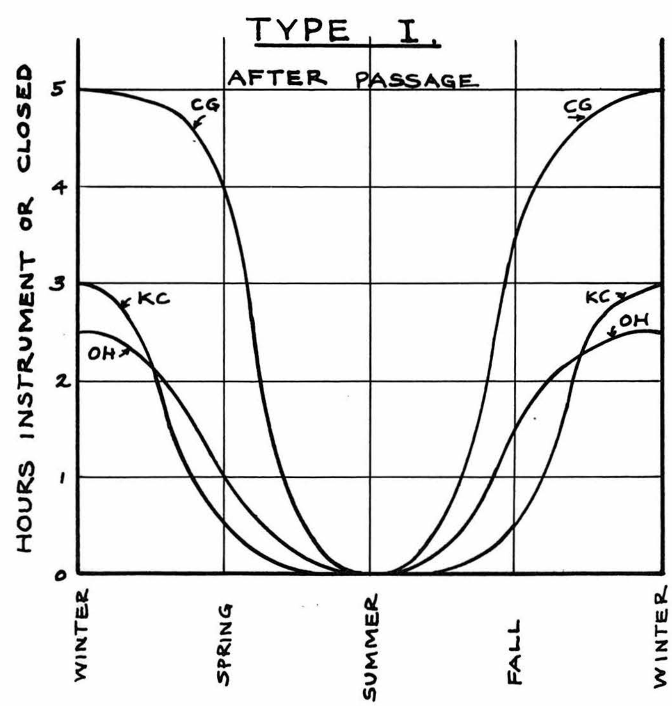

TYPE I.
AFTER PASSAGE
HOURS INSTRUMENT OR CLOSED
5
4
3
2
1
0
CG
CG
KC
KC
OH
OH
WINTER
SPRING
SUMMER
FALL
WINTER

FIG I.

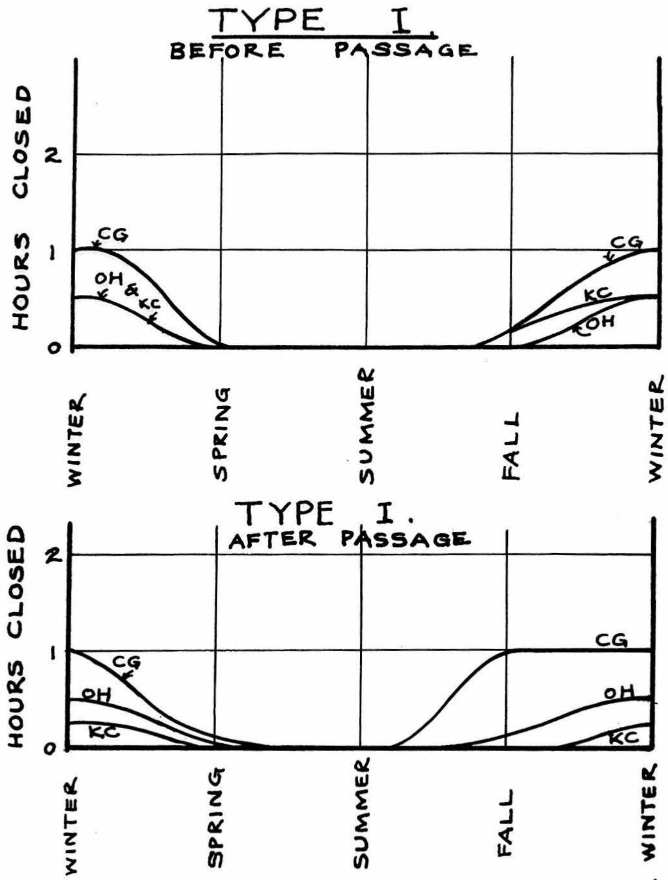
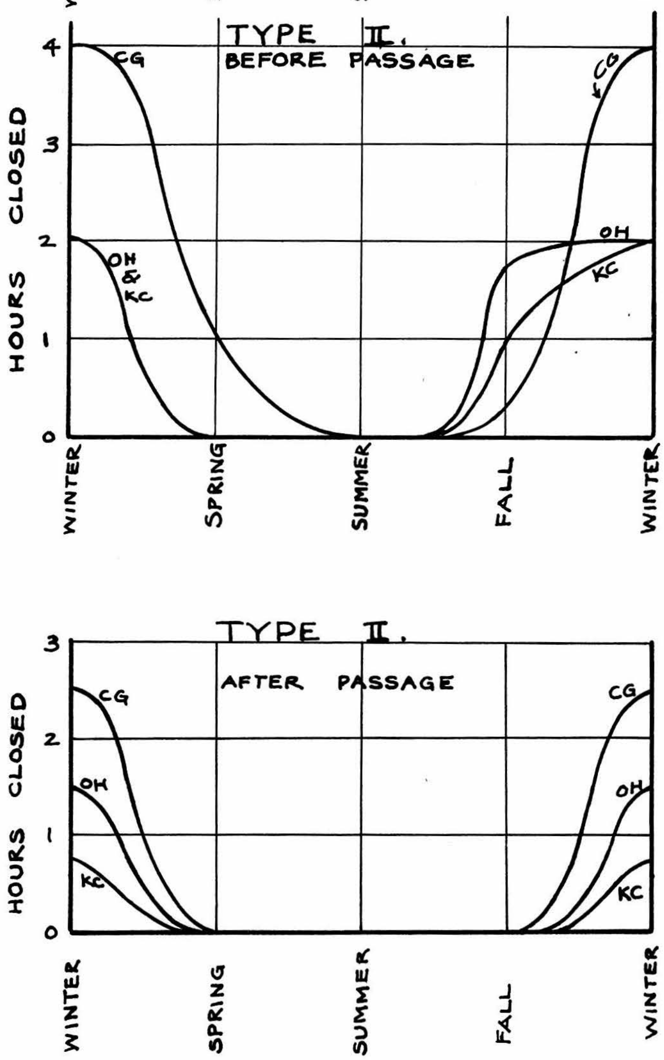

TYPE I.
BEFORE PASSAGE
HOURS CLOSED
0
1
2
CG
OH & KC
CG
KC
OH
WINTER
SPRING
SUMMER
FALL
WINTER
TYPE I.
AFTER PASSAGE
HOURS CLOSED
0
1
2
CG
OH
KC
CG
OH
KC
WINTER
SPRING
SUMMER
FALL
WINTER

FIG. II.


TYPE II.
BEFORE PASSAGE
HOURS CLOSED
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1
2
3
4
CG
OH & KC
CG
OH
KC
WINTER
SPRING
SUMMER
FALL
WINTER
TYPE II.
AFTER PASSAGE
HOURS CLOSED
0
1
2
3
CG
OH
KC
CG
OH
KC
WINTER
SPRING
SUMMER
FALL
WINTER

FIG. IV

TYPE II
BEFORE PASSAGE

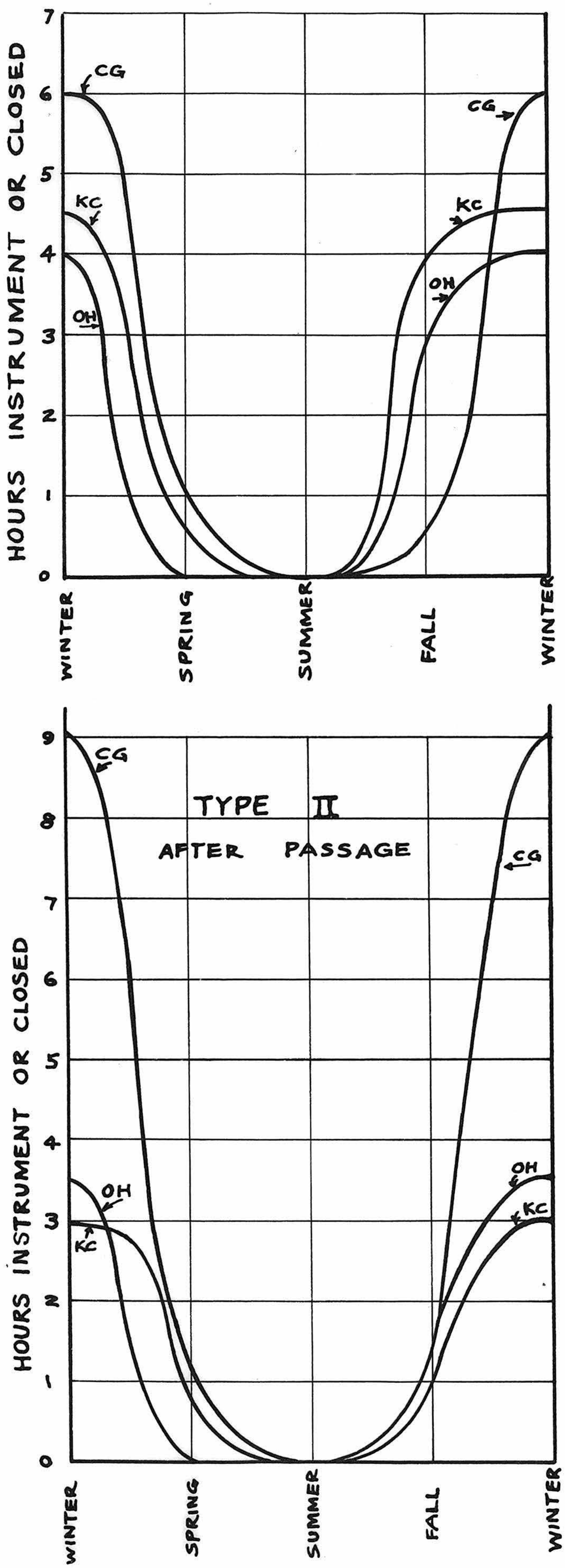


FIG. III.

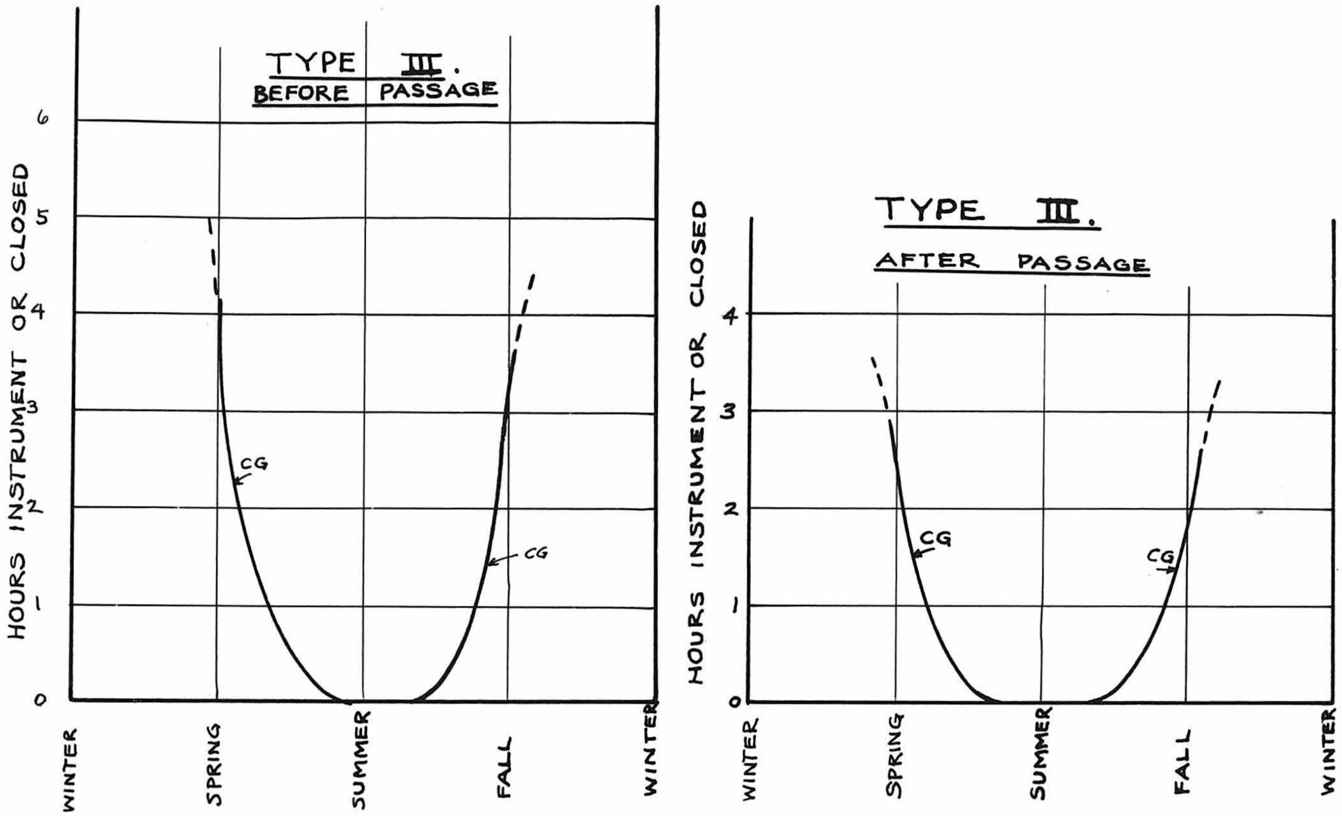

TYPE III.
BEFORE PASSAGE
HOURS INSTRUMENT OR CLOSED
0
1
2
3
4
5
6
CG
CG
WINTER
SPRING
SUMMER
FALL
WINTER
TYPE III.
AFTER PASSAGE
HOURS INSTRUMENT OR CLOSED
0
1
2
3
4
CG
CG
WINTER
SPRING
SUMMER
FALL
WINTER

FIG. V.

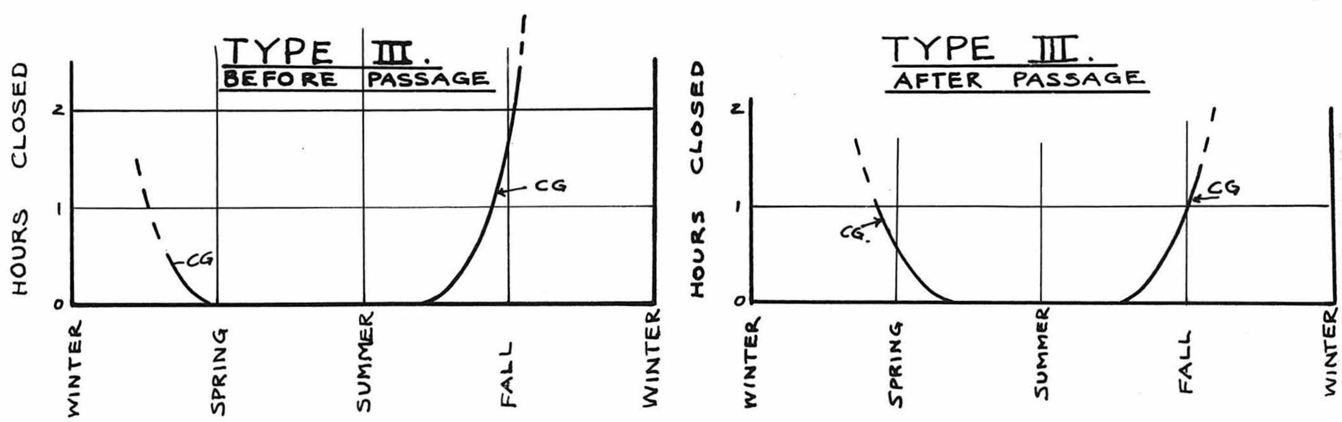
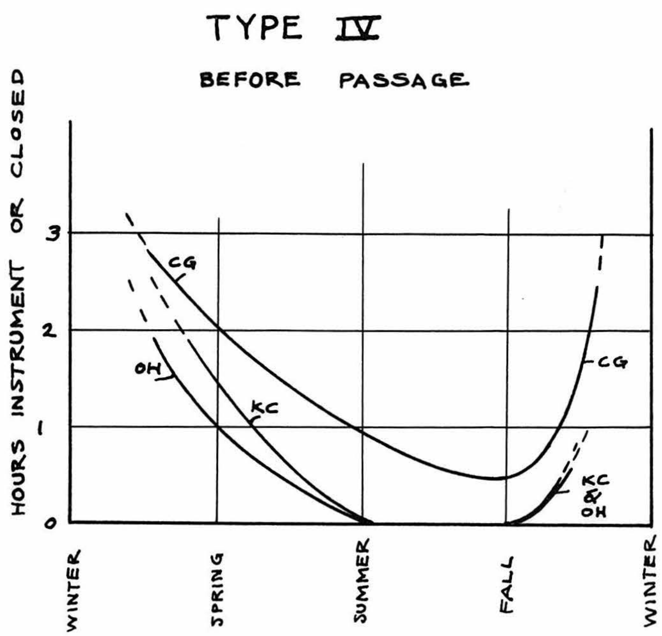

TYPE III.
BEFORE PASSAGE
HOURS CLOSED
0
1
2
CG
CG
WINTER
SPRING
SUMMER
FALL
WINTER
TYPE III.
AFTER PASSAGE
HOURS CLOSED
0
1
2
CG.
CG
WINTER
SPRING
SUMMER
FALL
WINTER

FIG. VI.


TYPE IV
BEFORE PASSAGE
HOURS INSTRUMENT OR CLOSED
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2
1
0
CG
OH
KC
CG
KC
&
OH
WINTER
SPRING
SUMMER
FALL
WINTER

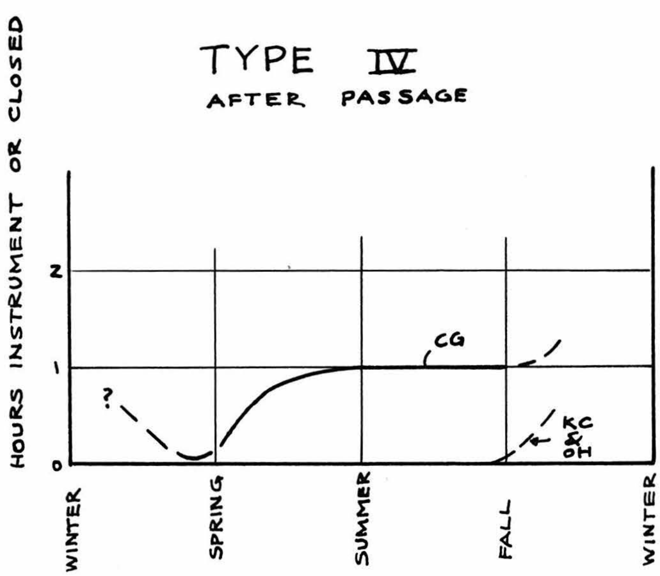
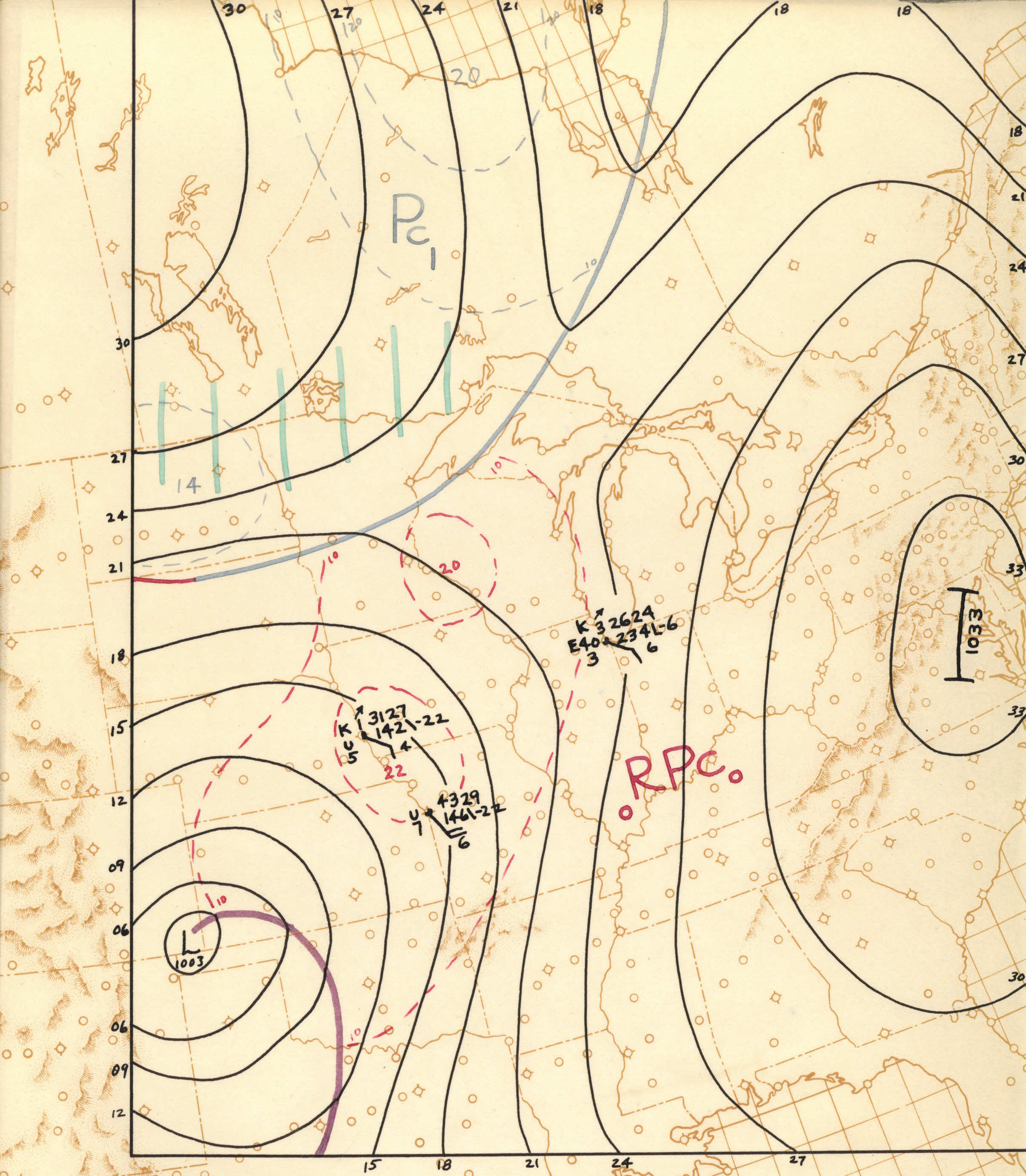

TYPE IV
AFTER PASSAGE
HOURS INSTRUMENT OR CLOSED
2
1
0
?
CG
KC
&
OH
WINTER
SPRING
SUMMER
FALL
WINTER

FIG. VII



Tuesday January 21, 1941 5AM

FIG. IX.

Type I approaching stations from north with typical orientation.

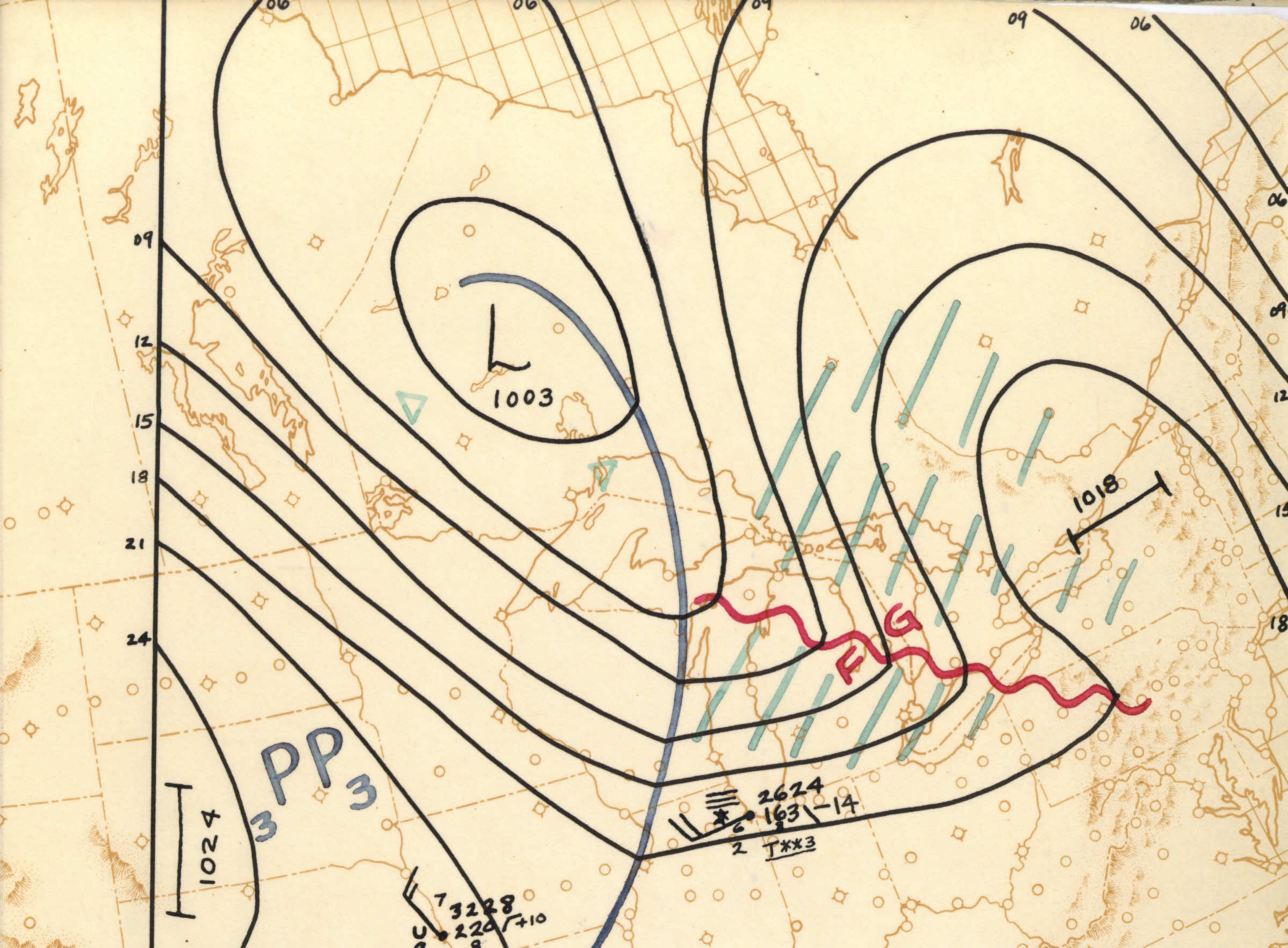
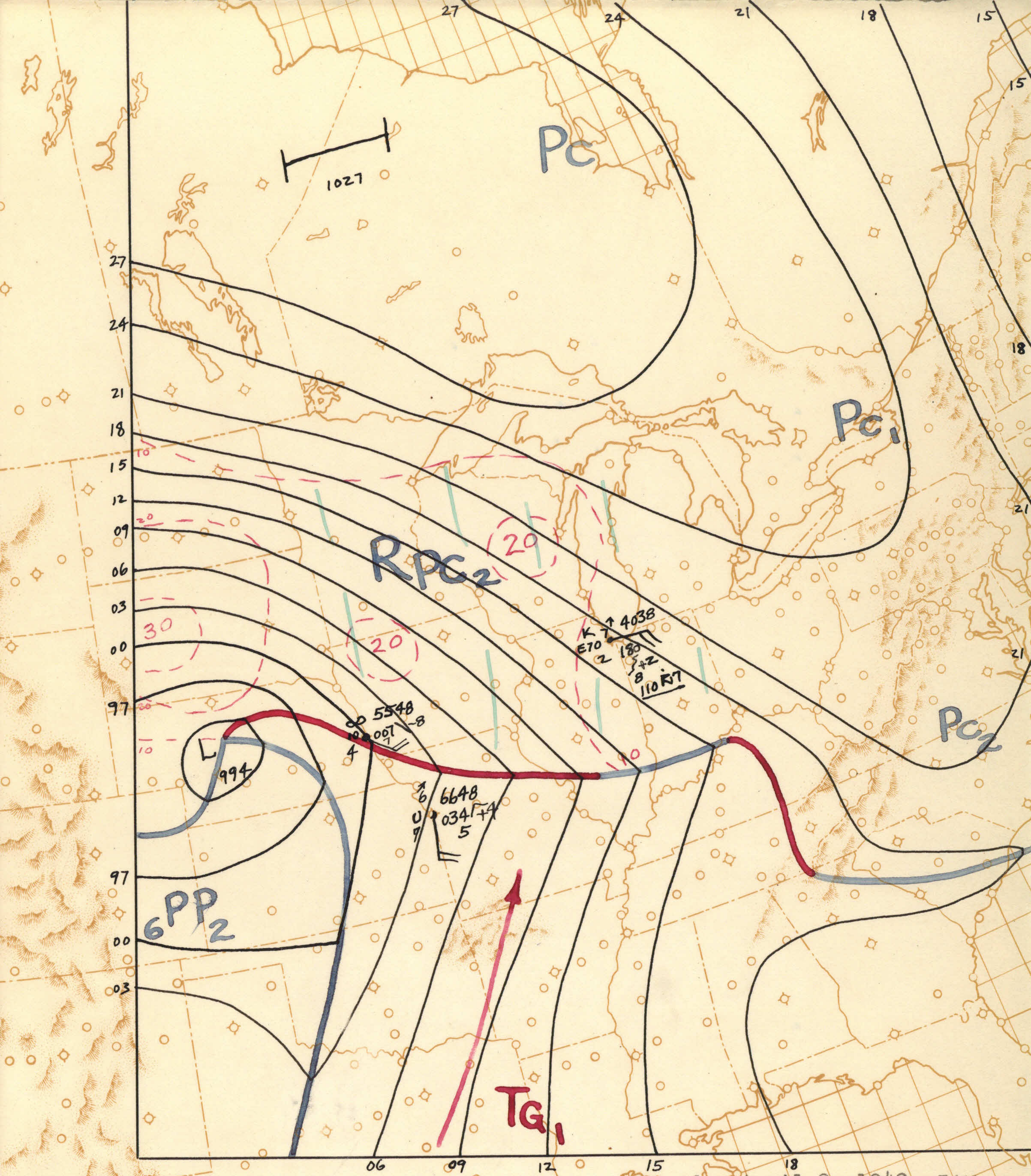


FIG. X.

Wednesday January 29, 1941 11PM

Type II past Omaha and approaching Kansas City and Chicago.



Tuesday April 2, 1940 5AM

FIG. XI.

Type III past Kansas City and at Omaha and approaching Chicago.

Type IV approaching Kansas City.

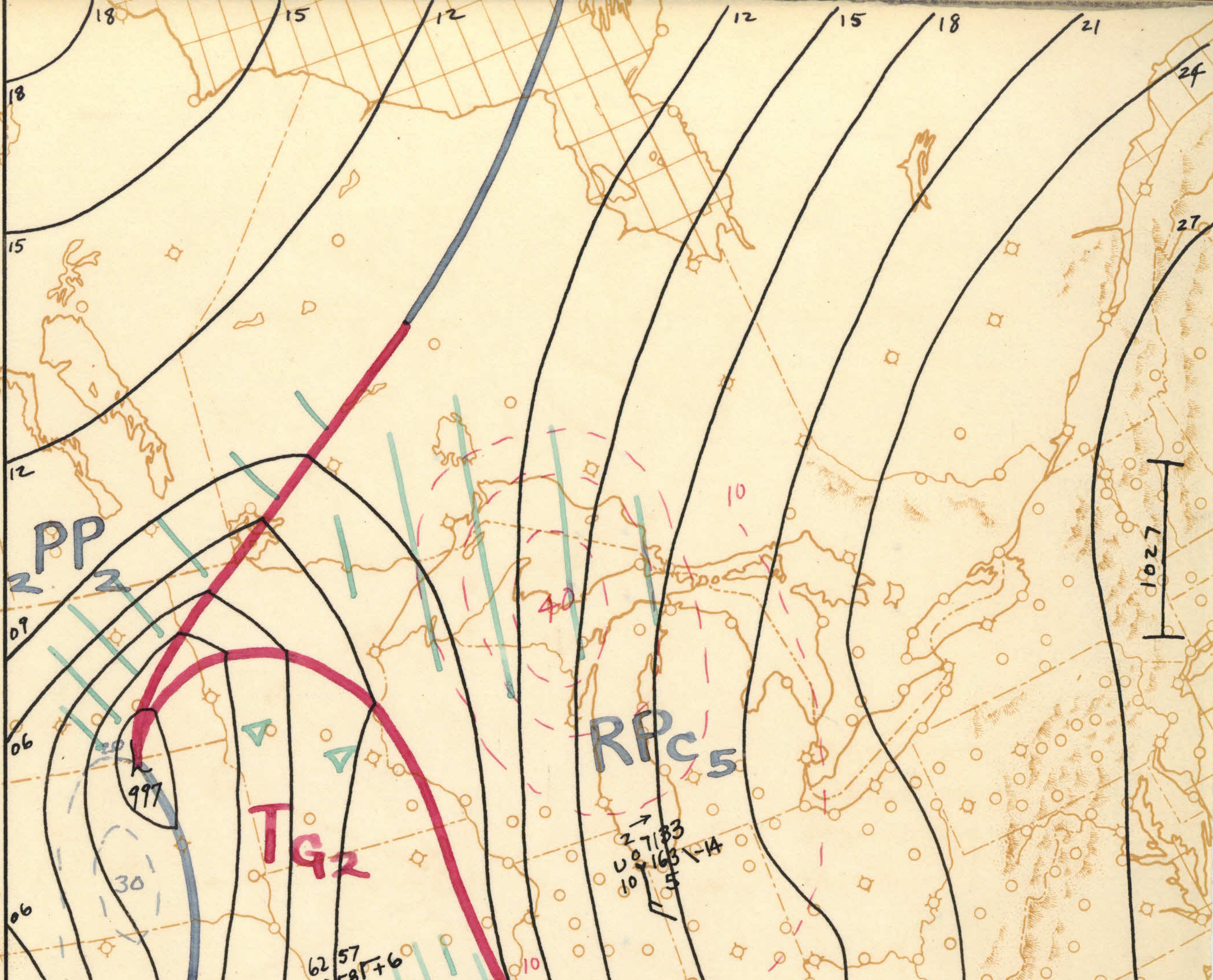


FIG XII. Sunday April 28, 1940 5PM

Type IV approaching Omaha and Kansas City.

Type III past Omaha and Kansas City and approaching Chicago.

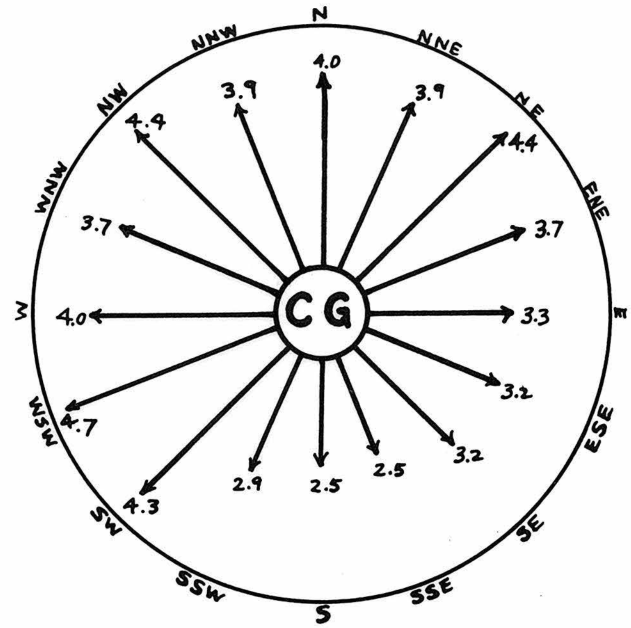


FIG. XIII

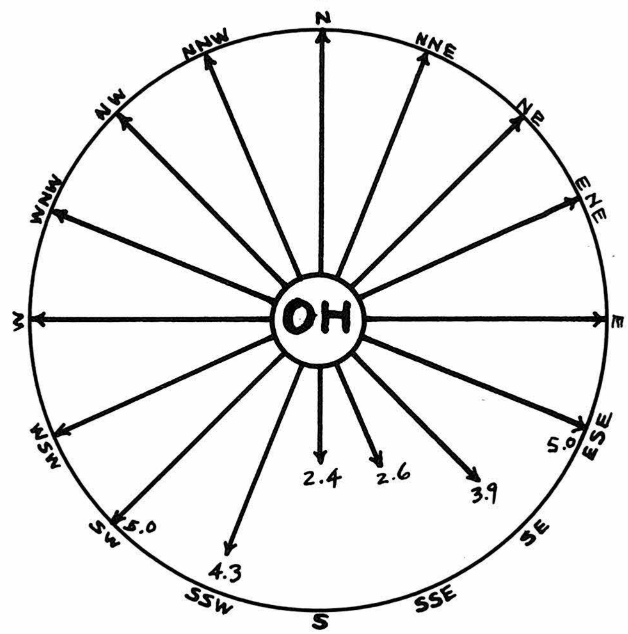


FIG. XIV

MEAN VISIBILITY DURING SMOKE RESTRICTION NEAR FRONTS – (miles)

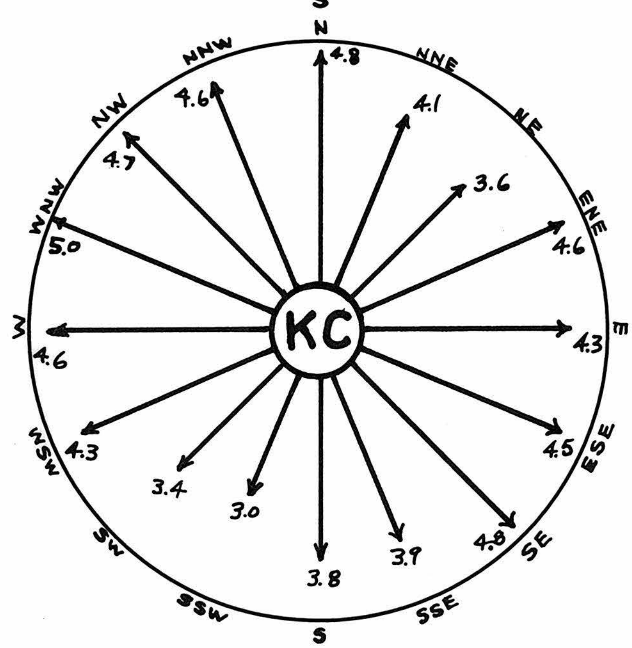


FIG. XV