

INVESTIGATION OF PRESSURE  
AND TEMPERATURE CHANGES  
AT THE BASE OF THE STRATOSPHERE

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TABLE OF CONTENTS

	Page
I. Introduction .....	1-2
II. Resume of Investigations by W.H.Dines, F.R.S.	3-5
III. Resume of Investigations by E. Palmen .....	6-13
IV. Analysis of Conditions over Stations in the United States .....	14-30
V. Summary .....	31-34
VI. Bibliography .....	35-36

TABLE OF CONTENTS

Page

I. Introduction ..... 1-2

II. Review of Investigation by U.S. Bureau, W.S.A. 2-3

III. Review of Investigation by U.S. Bureau ..... 6-13

IV. Analysis of Conditions over Stations  
in the United States ..... 14-30

V. Summary ..... 31-34

VI. Bibliography ..... 35-36

INVESTIGATION OF PRESSURE AND TEMPERATURE CHANGES AT THE

BASE OF THE STRATOSPHERE

I. Introduction

The object of this study is to investigate the pressure and temperature changes in the region of the Tropopause over stations in the United States and to attempt to seek relationships which might clarify or explain the reason for those phenomena that we know to exist in the upper Troposphere. We are particularly interested in those phenomena which give a variation of Tropopause height with a corresponding change of pressure at the nine kilometer level, and the temperature-height curves associated with such changes of atmospheric conditions.

Inasmuch as this investigation parallels closely those of W.H.Dines, Meteorologist in charge of Investigation of the Upper Air for the London Meteorological Office, and E. Palmén, Professor of the Meteorological Institute of the University of Helsingfors, in relation to the subject matter at hand, a brief resume will be given in order to explain the methods used and the results obtained by these two eminent meteorologists.

INVESTIGATION ON PRESSURE AND TEMPERATURE CHANGES AT THE

BASE OF THE THERMISTOR

1. Introduction

The object of this study is to investigate the pressure and temperature changes in the region of the thermistor over a period in the order of minutes. It is desired to establish the relationship which exists between the pressure and temperature changes in the region of the thermistor and the changes in the electrical resistance of the thermistor. It is also desired to explain the reason for those phenomena that are observed in the order of minutes, and to establish the relationship between the pressure and temperature changes in the region of the thermistor and the changes in the electrical resistance of the thermistor. It is also desired to explain the reason for those phenomena that are observed in the order of minutes, and to establish the relationship between the pressure and temperature changes in the region of the thermistor and the changes in the electrical resistance of the thermistor.

Research in this investigation remains largely those of A. S. Jones, developed in terms of investigation of the types of the thermistor. Jones, and J. Jones, treatment of the thermistor. Institute of the University of Delaware, in relation to the subject matter at hand, a brief review will be given in order to explain the methods used and the results obtained by these two authors.

Special thanks are due Professor C.G. Rossby of the Massachusetts Institute of Technology for his helpful advice in the preparation of this paper.

Special Agent in Charge J. Edgar Hoover

of the Commission on the History of Technology for his  
helpful advice in the preparation of this paper.

The Commission on the History of Technology was organized in 1956 by the National Academy of Sciences and the National Academy of Arts and Humanities. Its purpose was to study the history of technology and to report on its significance to the nation. The Commission was composed of members from various fields, including engineering, history, and the social sciences. It held numerous public hearings and received many suggestions from the public. Its final report, "The History of Technology: A Report to the National Academy of Sciences and the National Academy of Arts and Humanities," was published in 1962. This report emphasized the importance of the history of technology to the nation's future and recommended that the history of technology be included in the curriculum of schools and colleges. It also recommended that the National Academy of Sciences and the National Academy of Arts and Humanities continue to study the history of technology and to report on its progress.

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II. Investigations and Results of W.H.Dines.

The material upon which Dines based his investigations and conclusions consisted of upper air soundings over the British Isles and the Continent of Europe. He took departures from the mean of his sets of soundings and computed total and partial correlation coefficients and regression coefficients between sundry variables of the upper air. His variables were:

1. Pressure in millimeters at sea level.
2. Mean temperature of air column from the 1 to the 9 kilometer level.
3. The pressure at the 9 kilometer level.
4. The height of the Tropopause.
5. The temperature at the Tropopause.

He defined the Tropopause height as that point where the decrease of temperature becomes 1 degree Centigrade or less per kilometer. The formula for obtaining his correlation coefficient was

$$r_{a,b} = \frac{\sum (\delta_a \delta_b)}{n \sigma_a \sigma_b}$$

where

$$\sigma_a = \frac{\sqrt{\sum (\delta_a)^2}}{n}$$

and "a" and "b" represent the variables being correlated, " " the standard deviation, and "n" the number of ascents.

Dines has listed five sets of correlation coefficients obtained from a similar number of groups and

II. Investigation and Results of A. H. Jones

The material used in this investigation and comparison consisted of upper air recordings over the British Isles and the continent of Europe. The work originates from the work of his staff of recording and recording data and partial correlation coefficients and regression coefficients between many variables of the upper air. His variables were I. Pressure in millibars at sea level. II. Sea level temperature of air column from sea to 5 kilometers level. III. The pressure at sea level. IV. The pressure at the height of the tropopause. V. The pressure at the tropopause. He defined the tropopause level as that point where the degree of temperature decrease is greater than that of sea level. The formula for defining the correlation coefficient was

$$r = \frac{\sum (x - \bar{x})(y - \bar{y})}{\sqrt{\sum (x - \bar{x})^2 \sum (y - \bar{y})^2}}$$

$$r = \frac{\sum xy - n\bar{x}\bar{y}}{\sqrt{(\sum x^2 - n\bar{x}^2)(\sum y^2 - n\bar{y}^2)}}$$

and the correlation coefficient was calculated by the method of least squares. The correlation coefficient was calculated by the method of least squares.

There are listed five sets of correlation coefficients between the variables of the upper air.



the British Isles. The correlation coefficients were obtained for all groupings by taking departures from the mean. The mean of the correlation coefficients for the entire five groups were computed and are as follows:

Surface pressure versus mean temperature	0.46
" " " pressure 9 km. level	0.66
" " " Tropopause height	0.69
" " " " temp.	-0.59
Mean temp. versus Pressure 9 km. level	0.92
" " " Tropopause height	0.78
" " " " temp.	-0.39
Press. 9 km. level versus Tropopause height	0.83
" " " " " temp.	-0.49
Tropopause height vs. Tropopause temperature	-0.65

We computed the standard deviations for his various sets of soundings and arrived at the following values for the mean of these standard deviations:

Surface pressure	9.4
Mean temperature	7.0
Pressure at the 9 km. level	9.2
Tropopause height	14.8
Tropopause Temperature	6.6

The units for these values are degrees Centigrade for the temperature, millimeters of mercury for the pressures,

The British Isles. The correlation coefficients were obtained for all groups by using Spearman's rho as the mean of the correlation coefficients for the entire five groups were compared and are as follows:

0.40	British Isles vs. other groups
0.00	Pressure 2 vs. level 1
0.00	Temperature height
-0.10	Temp.
0.00	Level 2 vs. level 1
0.10	Temperature height
-0.10	Temp.
0.00	Level 3 vs. level 1
-0.10	Temp.
0.00	Temperature height vs. Temperature height

We repeated the analysis for the British Isles and other groups and the results are as follows:

0.10	British Isles vs. other groups
0.00	Temperature height
0.00	Pressure at the 2nd level
0.10	Temperature height
0.00	Temperature height

The mean for each group and the correlation coefficients for the temperature, altitude of survey for the pressure,

and 100 meters for the tropopause height.

On the basis of the values of the correlation coefficients coupled with results obtained from partial correlation and regression coefficients, Dines arrived at the following conclusions:

1. The pressure at the 9 kilometer level has a positive effect on the surface pressure and the mean temperature. It is very closely and positively correlated with tropopause height, but he is not certain whether it is as cause or effect. It has a negative effect upon Tropopause temperature.

2. The temperature of the air column from 1 to 9 kilometers has a negative effect upon surface pressure, a large positive effect upon the pressure at the 9 kilometer level, no direct effect upon Tropopause height and a moderate positive effect upon Tropopause temperature.

3. Tropopause height has a positive effect upon surface pressure, no direct effect upon the mean temperature, it is closely correlated with the pressure at the 9 kilometer level, and has a very distinct negative effect upon Tropopause temperature.

4. Tropopause temperature has little effect upon any of the other variables.

and the values for the proposed values.  
On the basis of the values of the coefficients  
obtained from the regression analysis, the following  
relationships are proposed:

1. The pressure of the air in the vessel has a  
positive effect on the reaction rate and the  
temperature. It is very closely and positively  
correlated with the reaction rate, but it is not certain  
whether it is an cause or effect. It has a negative  
effect upon the reaction rate.

2. The temperature of the air in the vessel has a  
positive effect upon the reaction rate, but it is not  
certain whether it is a cause or effect. It has a  
negative effect upon the reaction rate.

3. The reaction rate has a positive effect upon  
the temperature, but it is not certain whether it is  
a cause or effect. It has a negative effect upon  
the reaction rate.

4. The reaction rate has a positive effect upon  
the reaction rate.

### III. Investigations of E. Palmen

The object of this study was to attempt to couple the important temperature and pressure variations in the lower stratosphere with the tropospheric distribution of these two variables. In this connection Palmen studied the effect of both thermal-advection and dynamic convection in relation to the coupling sought.

Palmen elected, as a means of investigating the advective process, to study the results of soundings made on both sides of the polar front. On one side he had Polar air, on the other, tropical maritime air. These soundings showed a temperature difference of about 15 degrees C. between the two air masses, this temperature difference attained its maximum value between the 4 and 7 kilometer levels. The tropopause in the polar air mass was around the 8 kilometer level, that in the tropical air around 12 kilometers. The temperature difference again became large in the vicinity of the 12 kilometer level; however, this difference was in a reverse order to the former, i.e., where the temperature of the tropical air had been higher in the troposphere, it was lower than that of the polar air, in

171. Investigation of the Effect of

The object of this study was to study the effect of the temperature and pressure variations in the lower atmosphere with the propagation of sound waves. In this connection, it was found that the effect of both thermal-expansion and dynamic compression is rather in the same way. This effect, as a means of investigating the adiabatic process, is used in the study of sound waves on both sides of the point of view. On one side, the point of view, on the other, physical conditions are taken into account. A temperature difference of about 1 degree is obtained for air waves, this temperature difference obtained is similar to that obtained for a sound wave. The temperature in the air was found to be 1.5 degrees, that in the physical air found is 1.5 degrees. The temperature difference again found in the vicinity of the air difference level, however, this difference was in a reverse order to the above, i.e., that the temperature of the physical air was found to be 1.5 degrees, it was found that of the point of view,

the stratosphere. Having obtained these results Palmén then proceeds to seek a coupling between the Polar front waves at the surface and the tropopause height changes.

In the explanation of the coupling effect he parallels his ideas with those of Bjerknes. A wave is assumed to have formed on the polar front. The tropical air glides upward on the West side of all wave crests and downward on their East side. This forced vertical motion must die away with elevation, and it is known that it almost disappears at the tropopause. Accordingly, there is vertical shrinking over the West side of the polar front wave crests and corresponding horizontal divergence of the tropical air; on the East side, on the contrary, there is vertical expansion and horizontal convergence. The direct result of horizontal divergence is acceleration of anti-cyclonic circulation and the consequence of convergence is acceleration of cyclonic circulation. The original purely west-east flow of tropical air will therefore assume an anti-cyclonic curvature over the western slopes of the wave crests and a cyclonic curvature over the eastern slopes of the wave crests. The stream lines acquire a sinusoidal like shape in the horizontal - a shape which is also taken up by the isobars. The eventual resultant effect is to have a raising of the tropopause height over the part of the

The atmosphere. Having obtained these results I have  
then proceeded to see a working between the solar light  
waves of the sun and the proposed height of the  
In the explanation of the working effect in  
particular his ideas with those of [?]. I was in  
attempted to have found on his point that the  
his light spread on the west side of all was  
and continued on their east side. This forces vertical  
motion most the way with elevation, and it is  
that is also clear as the proposed. Accordingly,  
there is vertical motion with the west side of the  
waves from west to east and corresponding horizontal  
divergence of the tropical air; on the east side, on  
the contrary, there is vertical - descent and horizontal  
convergence. The direct result of horizontal divergence  
is recession of anti-cyclonic circulation and the  
recession of convergence is acceleration of cyclonic  
circulation. The original purely east-west flow of  
tropical air will therefore become an anti-cyclonic  
flow over the western slope of the wave crests and a  
cyclonic movement over the eastern slope of the wave  
crests. The waves thus acquire a sinusoidal form  
shape in the horizontal - a shape which is also seen in  
of the waves. The essential result effect is to have  
a raising of the proposed height over the part of the



flow with the northerly component, a sinking over that part of the flow with the southerly component. In the stratosphere is found, in turn, a vertical stretching and a vertical shrinking, in conjunction with the shrinking and stretching described above. The tropopause wave was found to be out of phase with the polar front wave, in that its corresponding amplitude points are to the westward of those on the surface.

Having reached this stage by means of thermal advection Palmen then demonstrates how the action of dynamic convection becomes the controlling factor.

The vertical motion is augmented by the increase of vorticity as the cyclone becomes more intense and occludes. The vertical shrinking is accompanied by a convergence of the potential temperature surfaces, the region of vertical stretching is accompanied by a divergence of the potential temperature surfaces with a convergence of these surfaces above the regions of stretching. In the regions of convergence we have a decrease of the temperature gradient. The action of the above is illustrated in the following sketch. (See Page 9). The positions of the points of maximum convergence represent the position of the tropopause in these regions.

Palmen further states that if the convergence of the potential temperature surfaces is super-

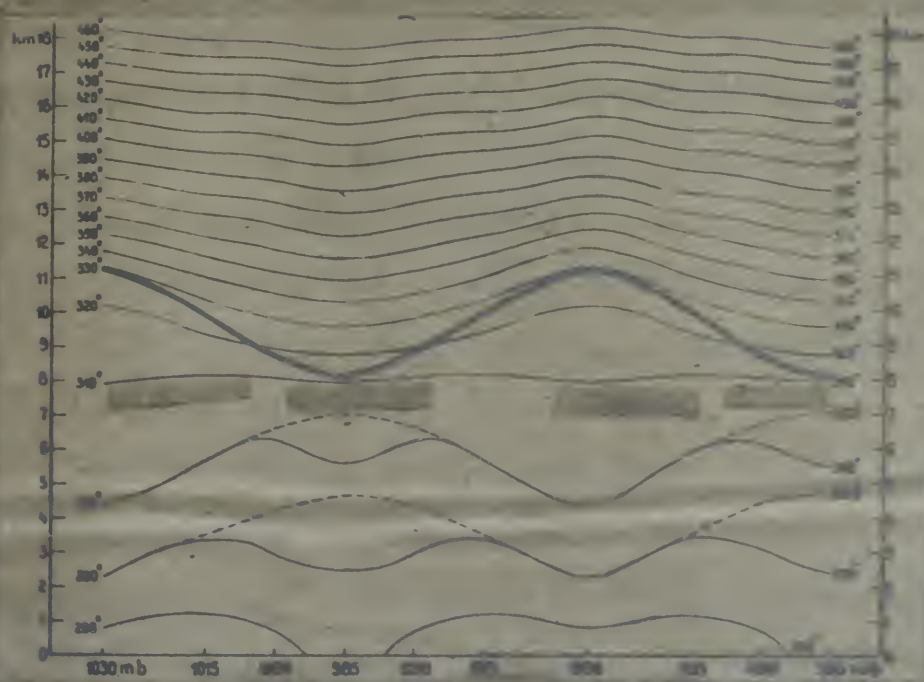
The first step in the analysis is to determine the geometry of the system. This involves identifying the various components and their relative positions. The next step is to establish a coordinate system and define the variables used to describe the system's configuration. This is followed by the derivation of the equations of motion, which are then solved to determine the system's behavior over time. The final step is to analyze the results and compare them with experimental data or theoretical predictions.

The second step is to determine the forces acting on the system. This involves identifying the various forces and their directions. The next step is to establish a coordinate system and define the variables used to describe the system's configuration. This is followed by the derivation of the equations of motion, which are then solved to determine the system's behavior over time. The final step is to analyze the results and compare them with experimental data or theoretical predictions.

The third step is to determine the energy of the system. This involves identifying the various forms of energy and their relative contributions. The next step is to establish a coordinate system and define the variables used to describe the system's configuration. This is followed by the derivation of the equations of motion, which are then solved to determine the system's behavior over time. The final step is to analyze the results and compare them with experimental data or theoretical predictions.

The fourth step is to determine the stability of the system. This involves identifying the various modes of instability and their relative contributions. The next step is to establish a coordinate system and define the variables used to describe the system's configuration. This is followed by the derivation of the equations of motion, which are then solved to determine the system's behavior over time. The final step is to analyze the results and compare them with experimental data or theoretical predictions.

The fifth step is to determine the response of the system to external perturbations. This involves identifying the various sources of perturbation and their relative contributions. The next step is to establish a coordinate system and define the variables used to describe the system's configuration. This is followed by the derivation of the equations of motion, which are then solved to determine the system's behavior over time. The final step is to analyze the results and compare them with experimental data or theoretical predictions.





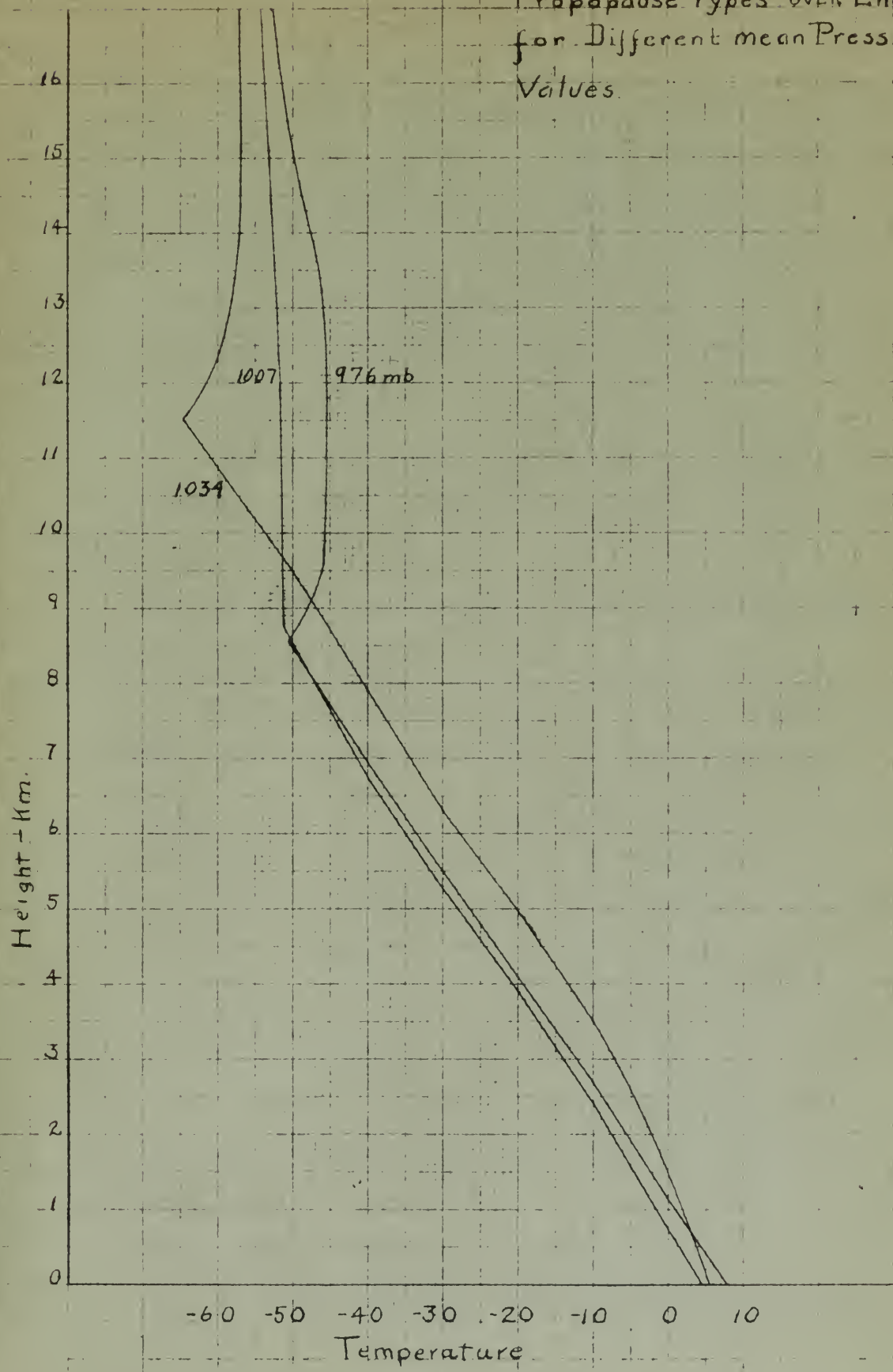
imposed on the existing tropopause, it will cause the normal inversion found in this region to sharpen. He obtains three general types of temperature - height curves extending up into the stratosphere - or "tropopause types" - as are shown on the following sketch. (See page 11). For normal pressure, in this case 1007 millibars, is found an isothermal situation starting at the tropopause; for low pressure at the surface, 976 millibars, is found a sharp inversion of a depth of about 1 kilometer and then a gradual decrease of temperature with height; for high pressures at the surface, 1034 millibars, is found a sharp inversion which extends several kilometers and then becomes practically isothermal.

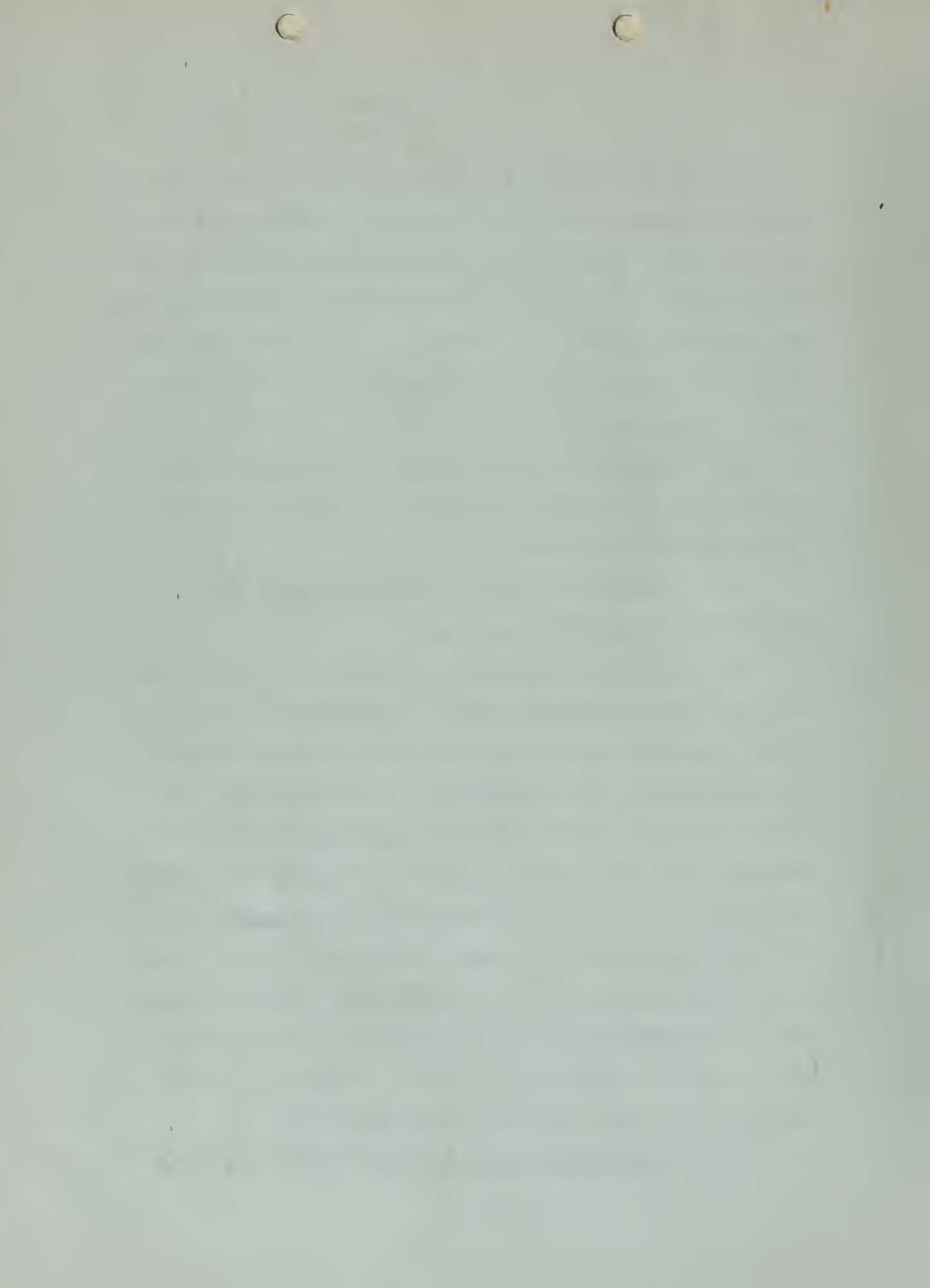
If the action of the deformation field is such that the convergence of the potential temperature surfaces takes place other than at the tropopause itself, then, Palmen asserts, a new tropopause is formed at this region of convergence and the old tropopause is annihilated. The formation of this new tropopause, in sections, at varying heights, gives a leaf-like structure, instead of a continuous smooth boundary surface. Turbulent mixing takes place between the open discontinuities of the new tropopause structure.

From the investigations and results as outlined above, Palmen arrives at the following conclusions:

... on the existing hypothesis, it will remain the  
normal frequency found in this region to observe. In  
obtain three general types of responses - height  
curves extending up into the atmosphere - or "response  
types" - as are shown in the following sketch. (See page 11.)  
The normal pressure, in this case 1000 millibars, is  
found as indicated starting at the tropopause,  
for the pressure at the surface, 970 millibars, is found  
a sharp increase of a depth of about 1 kilometer and  
then a gradual decrease of temperature with height.  
For high pressure at the surface, 1030 millibars, in  
found a sharp increase which extends several kilometers  
and then becomes gradually less steep.  
If the value of the atmospheric ratio is near  
that the temperature of the potential temperature  
surface level gives other than at the tropopause level,  
then, when constant, a new tropopause is found at this  
region of convergence and the old tropopause is eliminated.  
The location of this new tropopause, in looking at very-  
low heights, gives a left-hand structure, instead of a  
continuous smooth boundary surface. This last being  
takes place between the open characteristics of the  
new tropopause structure.  
From the investigation and results an ob-  
tained three, which appear as the following conclusions:

Tropopause Types OVER England  
for Different mean Pressure  
Values.







1. In the primary development of a cyclone, advection dominates, in that the temperature changes in the main can be attributed to meridional advection - in this stage, polar front waves and tropopause waves are coupled in a certain phase displacement. The general tropopause and stratosphere advection represents a unified atmospheric flow pattern.

2. Investigation of temperature contrasts between tropical air and polar air gives the best means of study of meridional advection.

3. At times the frontal surface extends to the upper boundary of the tropopause.

4. As occlusion sets in a cyclone the dynamically vertical displacement dominates, in that, from this stage on, the temperature and pressure changes depend, in the main, on the vortification of the cyclone. A closer analysis of these temperature changes and of the vertical oscillations of the tropopause that one has to deal with, with the attendant deformation fields, show that not only tropopause types may change, but in certain cases the tropopause itself. From this it follows that the actually occurring vertical action in a so-called tropopause front may not always be determined from the oscillation of the apparent tropopause.

6. By investigating typical individual cases as



1. In the primary development of a cyclone, advection dominates, in that the temperature changes in the main can be attributed to meridional advection - in this stage, polar front waves and tropopause waves are coupled in a certain phase displacement. The general tropopause and stratosphere advection represents a unified atmospheric flow pattern.

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6. By investigating typical individual cases as

1. In the primary development of a system, the  
the function, in that the system is not in the  
with can be attributed to mechanical vibration - in this  
stage, both local waves and propagating waves are coupled  
to a certain phase displacement. The general response  
and atmospheric pressure variations in certain cases  
include the system.

2. Investigation of propagating waves in the  
system is not only the first step in the study  
of mechanical vibration.

3. At least for local waves effects in the  
upper boundary of the propagator.

4. In addition to the system the system  
evolution displacement function, in that, from this  
stage on, the response and pressure change depend  
in the main, on the vibration of the system. A  
close study of these responses depend on the  
external conditions of the propagator that can be  
and with, with the external conditions, the  
that are with propagator wave and change, but in certain  
cases the response is not. This is the case that  
the system is not only a system in a co-located  
propagator that are wave in addition from the  
condition of the system propagator.

5. In addition to the system the system

well as through the formation of suitable mean values the influences of the fields of deformation of the temperature distribution in the environment of the tropopause over cyclones and anti-cyclones becomes quite clear. Over strong cyclones and occlusions the tropopause is generally characterized by a sharp inversion. This is also the case over anti-cyclones. There is an important difference in that the tropopause is low over cyclones and high over anti-cyclones. Also the tropopause inversion over cyclones covers about 1 kilometer while the inversion is several kilometers deep over anti-cyclones. At normal pressure the lower stratosphere over Europe is characterized by particularly isothermal stratification.

7. By the distribution of potential temperature one can, by omitting radiation and advection, in certain cases compute the vertical displacements which actually took place in the generation of highs and lows.

8. The question of the seat of atmospheric pressure variations can be answered only on the basis of detailed analysis of the phenomena at different levels. It is true that in general the stratosphere phenomena, on the face of it, have a deciding influence on the pressure variations below. But this fact depends on the general thermal structure of the atmosphere and has nothing to do with the problem of cause and effect.

well as through the formation of multiple cells which  
the influence of the field of definition of the  
immediate situation in the environment of the  
response over systems and anti-systems become clear  
clear. Over strong systems and systems the response  
is generally characterized by a sharp transition.  
This is also the case over anti-systems. It is an  
important difference in that the response is low over  
systems and high over anti-systems. Also the response  
is low over systems and high over anti-systems. It is  
clear with the transition in several different ways  
over anti-systems. It is clear that the response is low  
over systems and high over anti-systems. It is clear that  
the response is low over systems and high over anti-systems.

7. The transition of potential boundaries  
can be by either vertical and horizontal, in certain  
cases complete and vertical boundaries also entirely  
but there is the transition of high and low.

8. The transition of the level of response systems  
variation can be assumed only on the basis of detailed  
analysis of the response of different levels. It is  
clear that in general the response systems, in  
the face of it, are a double response in the response  
vertical plane. The response systems on the ground  
vertical structure of the response and the response to  
as well as the response of over and under.

#### IV. Analysis of Conditions Over Stations in the U.S.

The greatest obstacle to the proper development of this subject is the lack of sounding balloon ascents, not so much in quantity, but scarcity of soundings made at regular intervals over a period of time when large temperature and pressure variations are to be encountered. Also it was essential to use soundings which had been evaluated in a manner such that temperature, pressure, and elevation could be selected for a great number of points without having to recompute the soundings. The most desirable series of soundings were obtained for the stations listed below:

- |                        |           |
|------------------------|-----------|
| 1. Royal Center, Ind.  | May 1926  |
| 2. Grosbeck, Texas     | Oct. 1927 |
| 3. Broken Arrow, Okla. | Dec. 1929 |
| 4. Royal Center, Ind.  | Sep. 1930 |
| 5. Royal Center, Ind.  | Feb. 1931 |

This information was obtained from the various Monthly Weather Reviews.

All seasons except the summer are represented in this group, in addition there is a variation of latitude between the extreme stations of about ten degrees. Since some of the groups evaluated by Dines consisted of

IV. Analysis of the ...

The present analysis is based on the ... of this subject in the case of ... and to some in quantity, the ... as regular intervals over a ... of ...

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- 1. ...
- 2. ...
- 3. ...
- 4. ...
- 5. ...

The ... and ...

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... and ...



soundings made throughout the year and at various stations in Europe, it is believed that reliable results can be obtained from the above stations.

It was necessary to select a system of grouping the soundings in pairs such that the maximum number could be obtained, since it was believed that satisfactory mean values could not be established accurately for the monthly periods. The groupings consisted in determining the changes between two subsequent soundings where the time interval between the two was not less than eight hours and not more than thirty hours. This irregular time interval was necessary because of the fact that the balloons were not released at constant intervals, a few of the records were lost or destroyed, and some of the soundings extended only a few kilometers above sea level.

In many of the soundings it was extremely difficult to determine the tropopause height, necessitating the formulation of an arbitrary definition for this height. The method used by Dines was selected, in which he defines the tropopause height as the highest point where the temperature decrease is less than one degree per kilometer. By adhering to a rule of this sort there is a tendency to eliminate all low inversions one of which may be the tropopause with a considerable



temperature decrease above the inversion. Therefore the results obtained by using tropopause heights and temperatures, cannot be judged so much by their numerical values but certainly the signs of the correlation coefficients should be correct.

The soundings were grouped for each station into pairs as explained above and the time variation of the various elements obtained. From these differences the standard deviations were computed by the formula

$$\sigma = \sqrt{\frac{\sum (\delta_a)^2}{n}}$$

The values of the standard deviations are listed below:

Ps	4.5 mb.
Tn	3.4°C.
Pg	4.4 mb.
Hc	1370 m.
Tc	6.1°C.

By comparing the standard deviations with the individual differences no ratio of the two was greater than 2.5 which shows that the material selected was very uniform.

The correlation coefficients were calculated from the standard deviations by means of the formula:

temperature decrease above the thermostat. The above the  
results obtained by using independent heights and temper-

atures, cannot be found so easily by their numerical  
values but certainly the sign of the correlation coef-  
ficient should be correct.

The readings were grouped for each station  
into pairs as explained above and the time variation of  
the various elements obtained. From these differences  
the standard deviations were computed by the formula

$$\sigma = \sqrt{\frac{\sum (d)^2}{n}}$$

The values of the standard deviations are listed below

12	0.5
13	0.5
14	0.5
15	0.5
16	0.5
17	0.5

If comparing the standard deviations with the

individual differences in pairs of the two variables  
then it is seen that the standard deviations are very

uniform.

The correlation coefficients were calculated

from the standard deviations in pairs of the variables

and the results are as follows:

$$r_{a,b} = \frac{\sum (\delta_a \delta_b)}{\sqrt{\sum (\delta_a)^2 \sum (\delta_b)^2}}$$
 where a, and b represent the variables being correlated. The correlation coefficients are listed below in addition to those obtained by Dines.

<u>Number of Combinations</u>	<u>Items Correlated</u>	<u>Correlation Coefficients</u>	<u>Mean Correlation Coefficients-Dines</u>
82	r <sub>1,2</sub>	-.30	.46
80	r <sub>1,3</sub>	.12	.66
52	r <sub>1,4</sub>	.14	.69
52	r <sub>1,5</sub>	.11	(-).59
80	r <sub>2,3</sub>	.70	.92
52	r <sub>2,4</sub>	.35	.78
52	r <sub>2,5</sub>	(-).16	(-).39
52	r <sub>3,4</sub>	.25	.83
52	r <sub>3,5</sub>	(-).04	(-).49
52	r <sub>4,5</sub>	(-).67	(-).65

- 1 = Surface Pressure
- 2 = Mean Temperature 1 - 9 km.
- 3 = Pressure 9 km.
- 4 = Height Tropopause
- 5 = Temperature Tropopause.

It will be noted that wherever Hc or Tc is involved as one of the variables, the number of groupings decreases. This is due to the fact that many of the soundings did not extend up to the tropopause.

$$\frac{\sum_{i=1}^n x_i^2}{n} = \frac{10}{10} = 1$$
 where  $x_i$  and  $n$  represent the

variables being correlated. The correlation coefficient
 are listed below in addition to those obtained by hand.

Number of  
 Combinations Represented  
 Term  
 Inverse  
 Correlation Coefficient-Value

10	1	1.00	1.00
10	1	1.00	1.00
10	1	1.00	1.00
10	1	1.00	1.00
10	1	1.00	1.00
10	1	1.00	1.00
10	1	1.00	1.00
10	1	1.00	1.00
10	1	1.00	1.00
10	1	1.00	1.00

1 = Number of combinations  
 2 = Number of combinations  
 3 = Number of combinations  
 4 = Number of combinations  
 5 = Number of combinations  
 6 = Number of combinations  
 7 = Number of combinations  
 8 = Number of combinations  
 9 = Number of combinations  
 10 = Number of combinations

It will be noted that wherever the number of combinations
 involved is one or two, the correlation coefficient is 1.00.
 This is due to the fact that the only way of
 arranging the two items is in the order of

It was believed that the extreme smallness of most of the correlation coefficients might be due to the method of grouping together stations in different latitudes and for different seasons of the year. Several of the individual months were grouped separately but the correlation coefficients obtained from these groups were of about the same magnitude as those found for the entire group, so that the correlation coefficients calculated from the entire group were accepted as being representative of the atmosphere over the United States.

The correlations which are of chief interest to synoptic meteorologists are those which may be deduced from surface observations. From the table it may be seen that surface pressure has a fair negative correlation with the mean temperature but practically no correlation with any of the other elements. This brings out very strikingly the independence of surface pressure. This is in direct opposition to the results obtained by Dines as may be noted from an inspection of the tables above. This difference may be explained by considering the disturbances observed over the United States and Europe. As a general rule cyclones and anticyclones occurring over Europe are very deep, well-developed disturbances, which in many instances are believed to extend well into the stratosphere.

It is believed that the present condition of  
the world is the result of the combination of  
many factors, and that the only way to  
bring about a permanent peace is by  
the cooperation of all nations. It is  
the duty of every nation to contribute  
to the maintenance of world peace,  
and to the promotion of the welfare  
of all mankind. It is the duty of  
every nation to respect the rights  
of other nations, and to refrain  
from the use of force. It is the  
duty of every nation to promote  
the economic and social progress  
of all nations, and to cooperate  
in the solution of the world's  
problems. It is the duty of every  
nation to maintain the highest  
standards of morality and justice,  
and to promote the welfare of all  
mankind. It is the duty of every  
nation to respect the rights of  
other nations, and to refrain from  
the use of force. It is the duty  
of every nation to promote the  
economic and social progress of all  
nations, and to cooperate in the  
solution of the world's problems.



Over the United States most of the surface disturbances are comparatively shallow and move fairly rapidly. This is apparent from the atmospheric cross-sections made at M.I.T. during the past winter.

The only marked agreement between the correlation coefficients of Dines and those obtained for the United States are those between mean temperature and the pressure at the 0 kilometer level, and between the tropopause height and the temperature at the tropopause. It is seen that with a high pressure at the 9 kilometer level there is a corresponding large increase in the mean temperature of the column of air under this level and for a low temperature at the 9 kilometer there exists a low mean temperature of the air column. This warming and cooling is of such a magnitude that it cannot be explained by this change of pressure so that other explanations had to be sought which are incorporated in that part of the investigation following the methods of Palmen. It is also seen that with a high tropopause there exists cold temperatures and with a low tropopause there exists warm temperatures. More detailed discussion of this condition will be given on the following pages.



Potential Temperature Surfaces in the Vicinity of the Tropopause and Tropopause Types Obtained from this Distribution Paralleling the Methods of Falmen.

The first step in the study of the distribution of potential temperature surfaces in the vicinity of the tropopause was to obtain correlation coefficients between the pressure at the 9 kilometer level and the heights of specific potential temperature surfaces. In selecting potential temperature surfaces it was deemed expedient to select surfaces close enough to the tropopause so that the contour of the latter could easily be compared to the contour of the former. At the same time it was necessary to use a range of surfaces which would clearly indicate any convergence or divergence and important temperature variations.

The material used consisted of the records for September 1930 and February 1931 for Royal Center, Indiana and for December 1929 at Broken Arrow, Oklahoma. The values for these correlation coefficients are tabulated on page 21.

potential temperature contours in the vicinity of the  
tropopause and tropopause type changes from this data  
potential temperature contours in the vicinity of the

The first step in the study of the distribu-  
tion of potential temperature contours in the vicinity  
of the tropopause was to obtain correlation coefficients  
between the pressure at the 5 kilometer level and the  
height of specific potential temperature contours. In  
addition potential temperature contours at sea level  
were plotted to show whether there was any correlation  
between the contour of the latter and the  
contour of the former at the latter. It was found  
it was necessary to use a range of contours which would  
directly indicate any correlation of the two  
contour potential temperature contours.

The contour lines plotted of the two  
for December 1951 and February 1951 for that contour,  
January and for December 1951 at these three stations.  
The figure for these correlation coefficients are tabu-  
lated on page 11.

BRZEN ARROW - DECEMBER 1929

$\theta$	$r$	$H_{mean}$	$P_{9mean}$	Number of Pairs
315	(-) .91	6,740	313	21
325	+ .51	9,395	310	16
335	+ .74	11,010	310	14
365	+ .81	13,200	309	13

ROYAL CENTER - SEPTEMBER 1930

320	(-) .53	5,620	323	24
335	(-) .40	9,300	324	17
350	+ .15	12,460	322	18
365	+ .65	13,320	324	15

ROYAL CENTER - FEBRUARY 1931

300	(-) .76	4,540	302	27
310	(-) .25	8,090	302	22
320	+ .23	9,960	302	20
330	+ .59	11,050	302	20
340	+ .74	11,510	302	18
360	+ .67	12,760	302	16

-----

The number of pairs of soundings available for the individual months range from 27 for the lower surface to 13 for the extreme value of potential temperature. It is unfortunate that more soundings in sequence could not have been obtained, however, it is believed that they are adequate for the investigation at hand. A very consistent range of correlation coefficients was obtained for each individual month, being negative for low poten-

C

C

TABLE 1 - 1954 - 1955

Year	Group	Mean	Std. Dev.	n
1954	1	0.07	0.15	15
1955	1	0.15	0.15	15
1954	2	0.12	0.15	15
1955	2	0.15	0.15	15

TABLE 2 - 1954 - 1955

Year	Group	Mean	Std. Dev.	n
1954	1	0.07	0.15	15
1955	1	0.15	0.15	15
1954	2	0.12	0.15	15
1955	2	0.15	0.15	15

TABLE 3 - 1954 - 1955

Year	Group	Mean	Std. Dev.	n
1954	1	0.07	0.15	15
1955	1	0.15	0.15	15
1954	2	0.12	0.15	15
1955	2	0.15	0.15	15

The mean of each of the two variables for the individual units from 1954 and 1955 are shown in Table 1. The mean of each of the two variables for 1954 and 1955 are shown in Table 2. The mean of each of the two variables for 1954 and 1955 are shown in Table 3. The mean of each of the two variables for 1954 and 1955 are shown in Table 4. The mean of each of the two variables for 1954 and 1955 are shown in Table 5.

tial temperature values and positive for high potential temperatures. The magnitude of the correlation coefficients are large for the extreme values of potential temperature.

In order to show graphically the points brought out by the correlation coefficients, a plot of the pressure at the 9 kilometer level was made against the height of potential temperature surfaces. Over the low pressure there is a marked concentration of potential temperature surfaces. Over the high the tropopause is much higher and it has increased its potential temperature by some 20 degrees.

The curves discussed in this paragraph and those that follow will be found grouped by stations on pages 24,25,26,27,28,29,

In order to obtain the best average position for the tropopause, regression equations were deduced and regression lines for the various potential temperatures. These were superimposed on their respective potential temperature curves on the pressure-height plot.

The regression equation used was:

$$h = h_{\text{mean}} + r \sqrt{\frac{\sum (\delta h)^2}{\sum (\delta P_9)^2}} (P_9 - P_{9\text{mean}})$$

Characteristic temperature-height curves were plotted for the distribution of potential temperature regression lines for high, average, and low pressures at

141 experiments were not possible for high potential temperatures. The results of the conventional experiments are given for the various values of potential temperatures.

In order to show graphically the points brought out by the conventional coefficient, a plot of the pressure at the 0 potential level was made against the height of potential temperature surfaces. Over the low pressure there is a marked concentration of potential temperature surfaces. Over the high pressure is much higher and it has increased the potential temperature by 20 degrees.

The curves obtained in this experiment and those for other will be found plotted by stations on page 24, 25, 26, 27, 28, 29.

In order to obtain the best possible results for the procedure, potential surfaces were obtained and potential lines for the various potential surfaces were also obtained as their respective potential surfaces were in the pressure-height plot.

The following equation was used:

$$P = \frac{M}{M_0} \left( \frac{P_0}{P} \right)^{\frac{1}{\gamma}} \left( \frac{T}{T_0} \right)^{\frac{\gamma}{\gamma-1}}$$

Graphical representation of the curves was plotted for the distribution of potential surfaces and potential lines for high, average, and low pressure at



the 2 kilometer level. The equation used to establish the temperature at different levels was formed from Poisson's equation and the hydrostatic equation:

$$T = \theta \left[ \frac{r_0 k}{r_0} - \frac{g}{C_p} \left( \frac{z - z_0}{u_{mean}} \right) \right] \text{ where } \theta = \text{Potential Temperature.}$$

These temperature-height curves show that definite characteristic types of the tropopause inversion exist over high and low pressure areas at the 2 kilometer level. A marked similarity will be noted for the three cases analyzed. The inversions over low pressure are several kilometers lower than the mean height of the tropopause and are marked by fairly steep lapse rates in the troposphere below this inversion. Above the inversion there is a gradual decrease of temperature continuing as far as the sounding was extended. The tropopause over the high was not marked by a large inversion but gave a small rate of increase of temperature in the stratosphere.

It is to be noted that the troposphere is about 6 degrees warmer under the high pressure than under the low. Above the tropopause the temperature over the high is considerably colder than that over the low. This distribution is exactly that found by Valann, which has been accounted for by him through the influence of

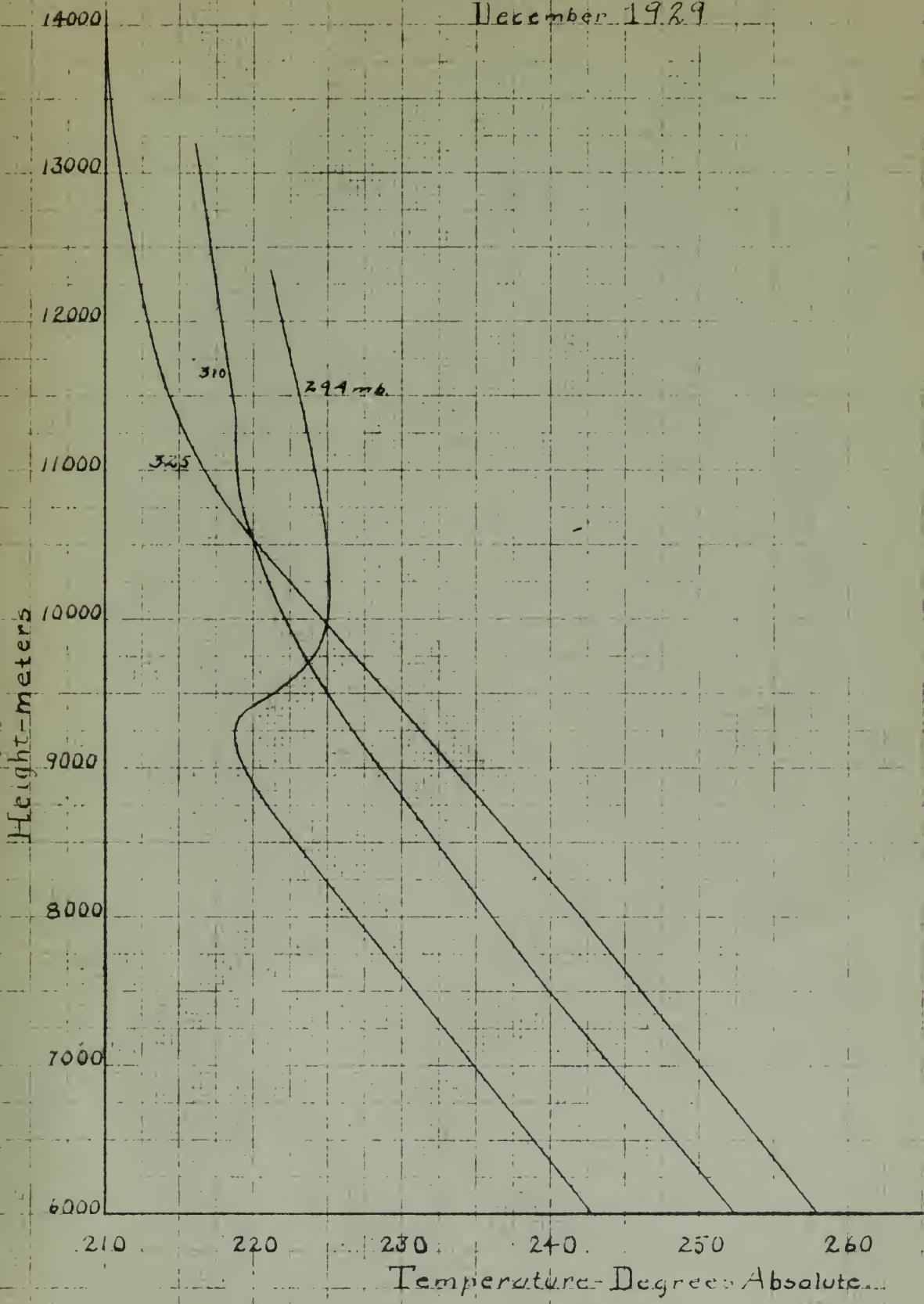
The following table shows the results of the investigation into the effects of the various factors on the rate of reaction. The results are given in the following table.

$$T = \frac{1}{k} \left[ \frac{1}{a-x} - \frac{1}{a} \right] \quad \text{where } a = \text{initial concentration}$$

The results of the investigation into the effects of the various factors on the rate of reaction are given in the following table. The results are given in the following table.

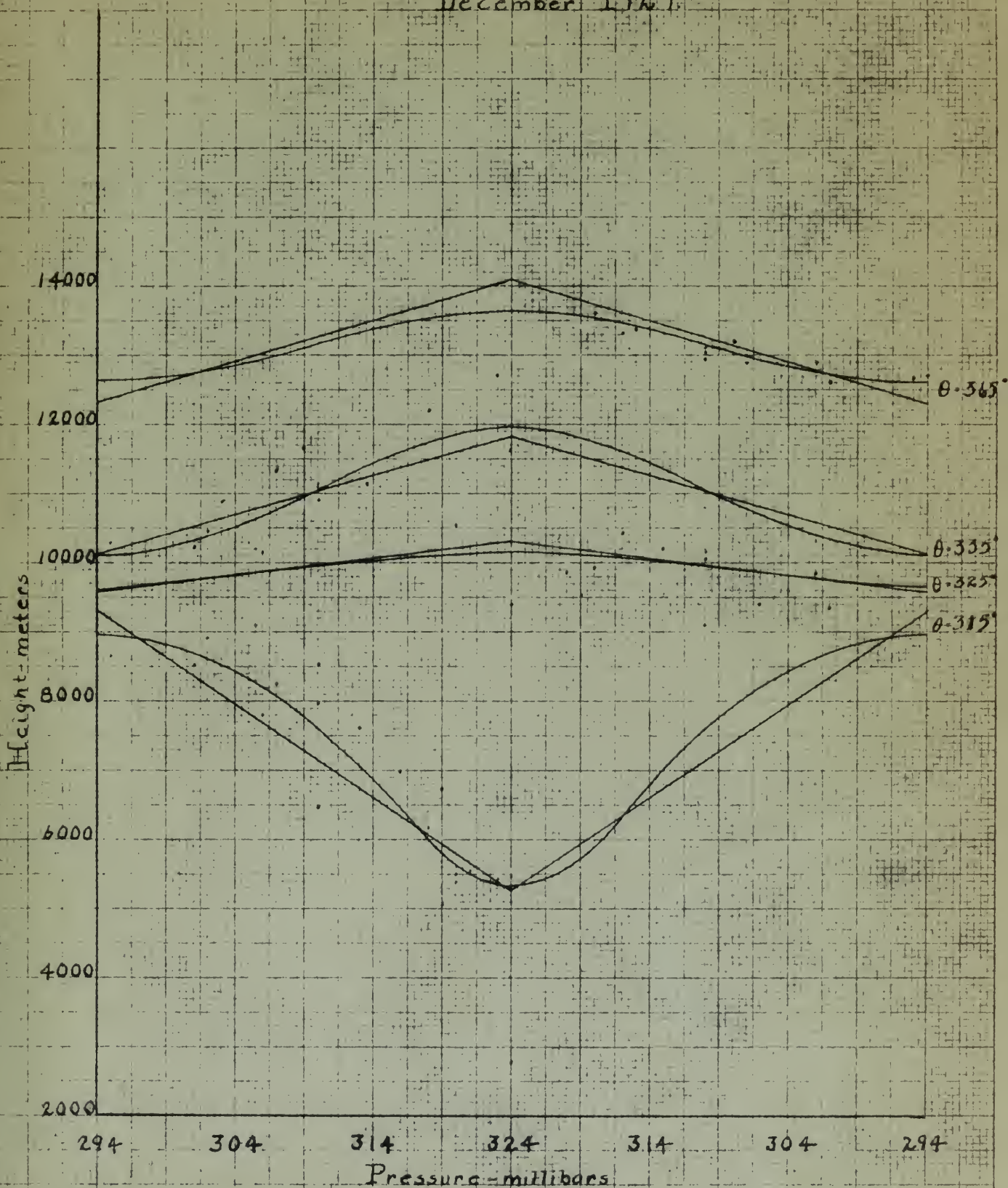
The results of the investigation into the effects of the various factors on the rate of reaction are given in the following table. The results are given in the following table.

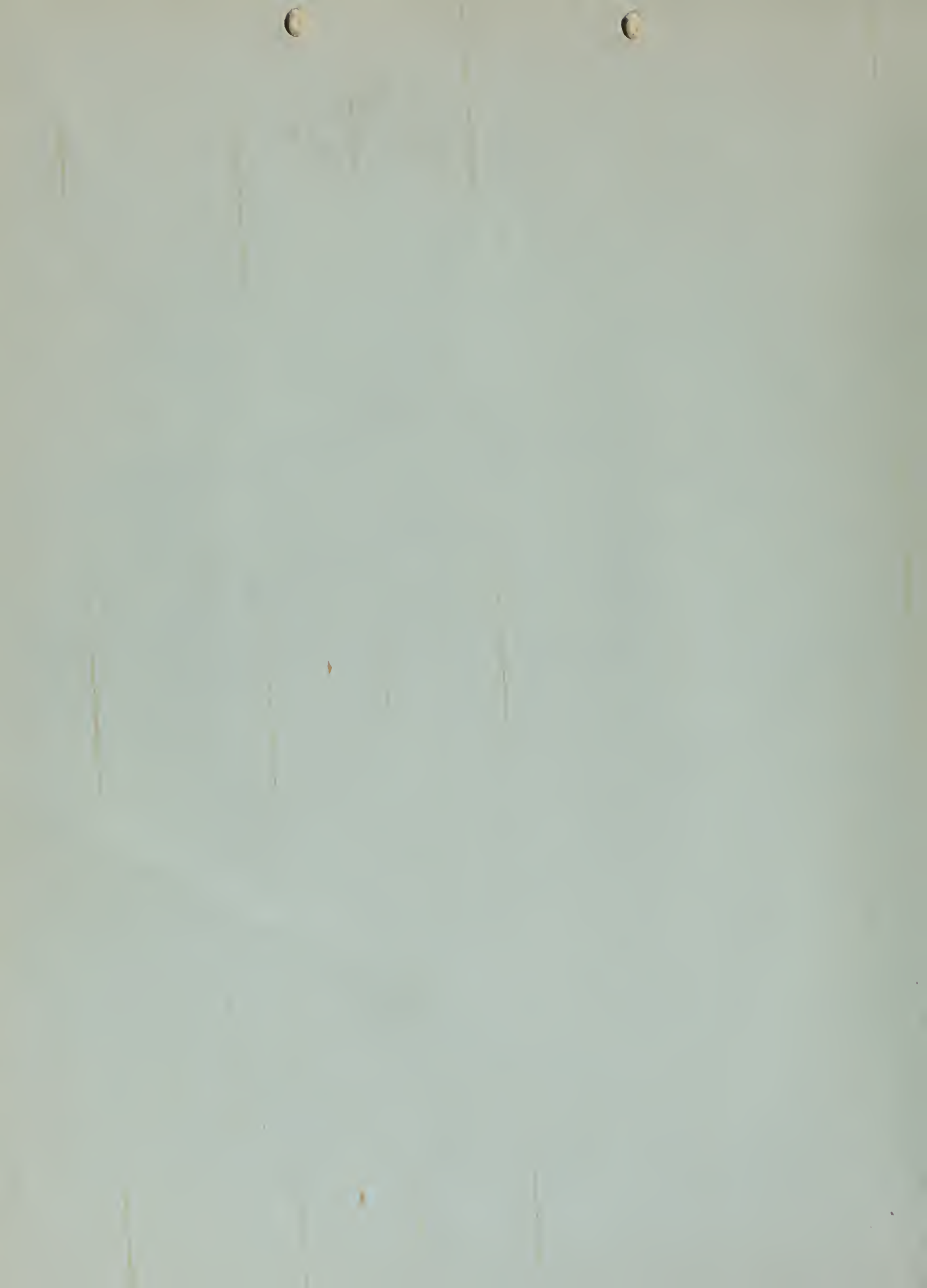
Temperature-Height Curves  
Broken Arrow, Okla.  
December 1929



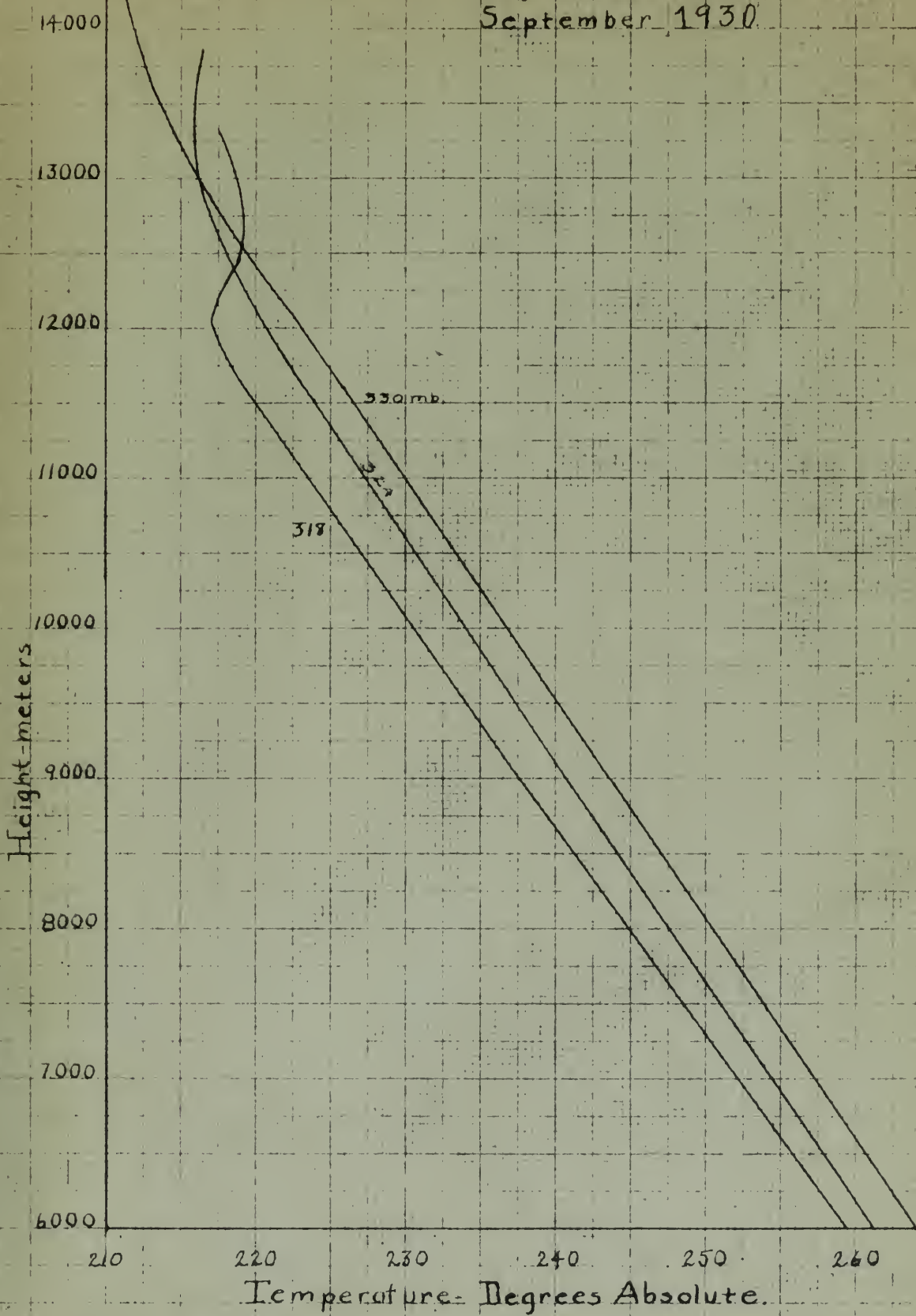


Pressure-Height Curves  
Bronen Arrow, Okla.  
December 1929.





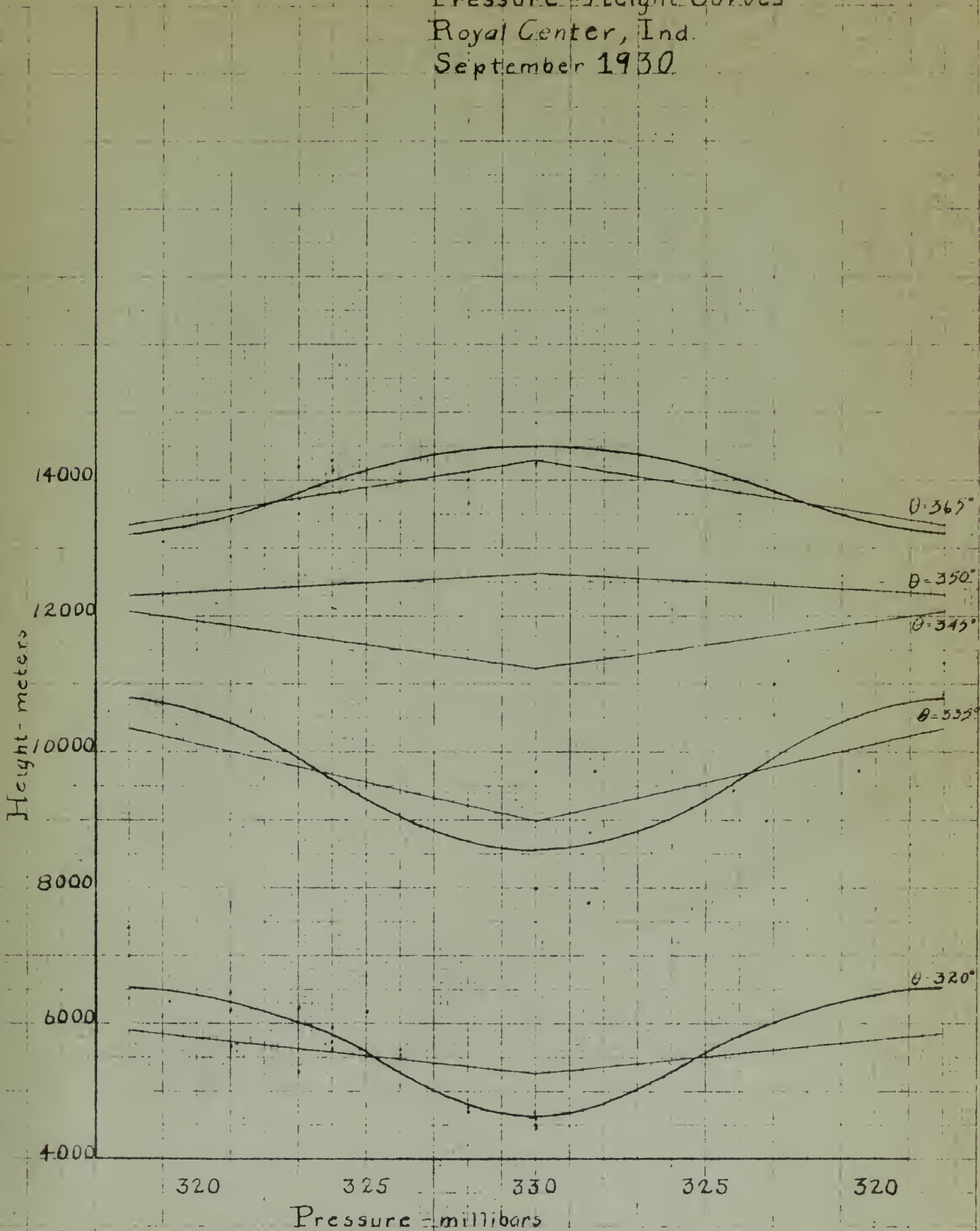
Temperature-Height Curves  
Royal Center, Ind.  
September 1930





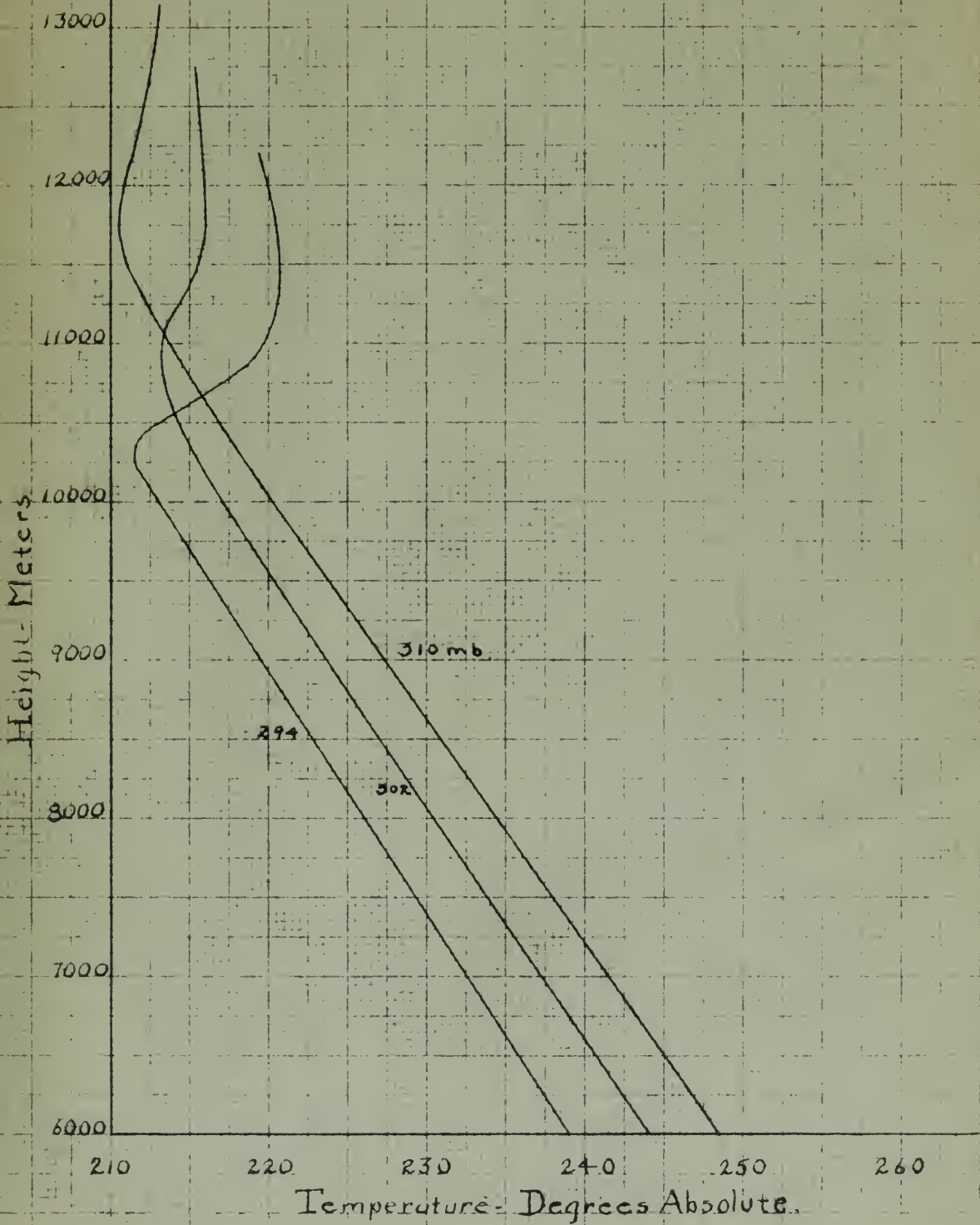


Pressure-Height Curves  
Royal Center, Ind.  
September 1930



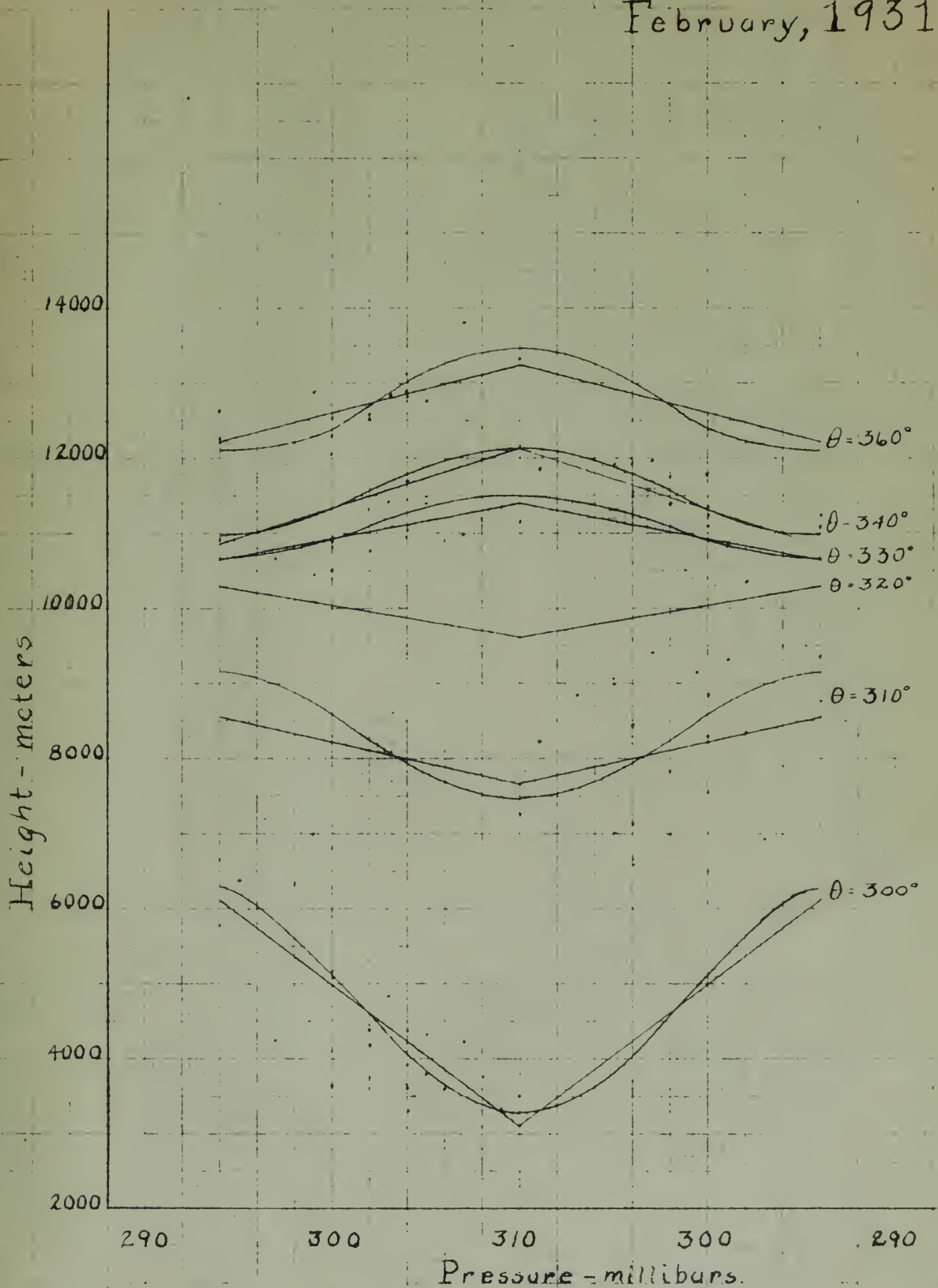


Temperature-Height Curves  
February 1931  
Royal Center, Ind.





Pressure - Height Curves  
Royal Center, Ind.  
February, 1931.





thermal-advective and dynamic processes as explained in the resume of his work.

From the above investigation the following conclusions have been drawn:

...and the ...

...in the ...

...the ...

...and ...



### 7. Summary

1. The contour of the potential temperature surfaces in the vicinity of the tropopause and in the stratosphere are very similar to the contour of the tropopause, while in the troposphere below the 9 kilometer level the slope of the former is opposite to that of the latter.

2. The existence of the tropopause types is substantiated by the distribution of the potential temperature surfaces. Over the low pressure area we have a well defined field of convergence, indicative of a region of great stability - over the high pressure area we find more equal spacing of the surfaces but, however, a gradual decrease in the distances between these surfaces - an indication of stability but to a lesser degree. The translation of the distribution of potential surfaces to a temperature versus height diagram shows in more detail the actual amount of stability represented.

3. The displacement of the concentration of potential temperature surfaces to a different level causes the regeneration of the tropopause at that level. We have a condition where the instantaneous height of the tropopause cannot be defined as existing at one

1.1. INTRODUCTION

1. The purpose of this report is to provide a comprehensive overview of the current state of research in the field of artificial intelligence. This report will focus on the development of machine learning algorithms and their applications in various domains. The report is organized as follows: Section 2 discusses the background and motivation for this research. Section 3 describes the methodology used in this study. Section 4 presents the results of the experiments. Section 5 discusses the implications of the findings and future research directions.

2. The background of this research is rooted in the long history of artificial intelligence. The field has seen significant progress in recent years, particularly in the area of machine learning. This progress has been driven by advances in hardware and software, as well as the availability of large datasets. The current research aims to explore the potential of deep learning architectures in solving complex tasks. The methodology involves training a neural network on a large dataset and evaluating its performance on a set of test cases. The results show that the proposed model achieves state-of-the-art performance on the task. The implications of these findings are significant, as they demonstrate the power of deep learning in solving real-world problems. Future research should focus on improving the efficiency and interpretability of these models.

3. The significance of this research lies in its contribution to the understanding of machine learning. The findings provide valuable insights into the behavior of deep learning models and their ability to learn from data. This research also highlights the importance of data quality and quantity in achieving high performance. The results suggest that further research is needed to address the challenges of model interpretability and generalization. The research has practical implications for the development of intelligent systems in various industries, including healthcare, finance, and education.

height only. The shifting of the tropopause to different levels has its origin in the thermal-advective processes.

4. The tropopause height varies as the pressure at the 9 kilometer level. Little correlation exists between the pressure at the surface and that of the 9 kilometer level, hence there is little correlation between surface pressure and tropopause height. The transitory nature of the shallow-disturbances which traverse the United States would account for this variation from European conditions.

5. The tropopause type curves show definitely that the troposphere temperature for a high pressure at the 9 kilometer level is considerably higher than that for a low pressure at the same level. In the stratosphere the opposite effect is true, i.e., over the high it is colder than over the low. This distribution of temperature is accounted for primarily by advection but intensified in the vicinity of the tropopause by convection especially over a low pressure area.

6. An examination of the zonal distribution of pressure and temperature at different heights indicates that the conditions outlined as existing over the United States could be accounted for primarily by thermal-advective but that convection is required to complete the picture.

... The ... of ... to ...  
 ... has its origin in the ...  
 ...

6. The ... of ... as ...  
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8. The ... of ...  
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 ...

7. The temperature height curves for Royal Center, February 1931 show the temperature at the base of the inversion for the low pressure curve to be low and practically the same as that for the same relative position on the high pressure curve. This phenomenon is difficult to explain, however, the curves in general, demonstrate the existence of strong convection over a cyclone and a resultant cold tropopause temperature.

In connection with this idea, it is known that when polar continental air leaves its source region and crosses an open ocean surface, violent convection ensues. It is probable that, initially, when air temperatures are very low, this convection extends to about 8 or 9 kilometers. When this polar maritime air passes over land the convection phenomenon is diminished and the tendency towards the restoration of radiation equilibrium is strengthened. If in this case, we had a very strong flow of polar pacific air it is probable that the results indicated by the temperature-height curve represents that state where the convection process is still felt giving the extremely low tropopause temperature and a tropopause height slightly higher than normal conditions would warrant.

Reference to the daily sounding-balloon ascents made at Royal Center during the month shows several cases where there exists extremely steep lapse rates below the

7. The proposed change should be made.

It is suggested that the Commission should be asked to

investigate the proposed change so as to

ascertain the effect of the proposed change on the

public interest. This Commission is

difficult to satisfy, however, its duty is to

ascertain the effect of the proposed change on the

public interest and to report thereon.

The Commission should also be asked to

investigate the proposed change so as to

ascertain the effect of the proposed change on the

public interest. This Commission is

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public interest. This Commission is

difficult to satisfy, however, its duty is to

ascertain the effect of the proposed change on the

public interest and to report thereon.

The Commission should also be asked to

level of the tropopause and in the vicinity thereof, with marked inversions present just above the tropopause. A thorough and comprehensive study of this problem necessitates the investigation of the predominant wind direction. For the soundings cited, this essential data was missing in the majority of cases.

level of the program and in the vicinity thereof, with  
certain limitations imposed but these limitations  
through and comprehensive study of this program  
with the investigation of the program and its  
for the existing study, this essential data was missing  
in the vicinity of cases.

The program was designed to provide a comprehensive  
study of the program and its various phases  
and to provide a complete and accurate  
report of the results of the study. The study  
was conducted in accordance with the plan  
and the results of the study were  
presented in a clear and concise  
manner. The study was conducted  
in accordance with the plan and  
the results of the study were  
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CONTENTS

1. The Role of the State in Economic Development - 1-10
2. The Role of the State in Economic Development - 11-20
3. The Role of the State in Economic Development - 21-30
4. The Role of the State in Economic Development - 31-40
5. The Role of the State in Economic Development - 41-50
6. The Role of the State in Economic Development - 51-60
7. The Role of the State in Economic Development - 61-70
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1950-1951

1. The first part of the report deals with the general situation in the country during the year 1950-1951. It is a very interesting and informative study of the economic and social conditions of the country during this period. The author has done a very thorough job of collecting and analyzing the data, and his conclusions are well supported by the facts.

2. The second part of the report deals with the specific aspects of the economy, such as the agricultural sector, the industrial sector, and the services sector. Each of these sections provides a detailed and up-to-date account of the current state of affairs in that sector, and also offers some suggestions for improvement.

3. The third part of the report deals with the social conditions of the country, such as the level of education, the state of health care, and the general standard of living. This part of the report is also very well written and provides a clear and concise summary of the social situation in the country.

4. The fourth part of the report deals with the government's policies and programs during the year 1950-1951. It provides a detailed account of the various initiatives that have been undertaken by the government, and also offers some critical analysis of their effectiveness.

5. The fifth part of the report deals with the future prospects of the country. It provides a clear and concise summary of the author's views on the economic and social challenges that the country will face in the years ahead, and also offers some suggestions for how these challenges can be met.











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D76

Drouilhet

32850

Investigation of pressure  
and temperature changes at  
the base of the strato-  
sphere.

Thesis  
D76

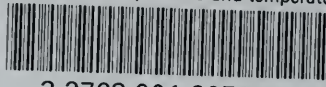
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