**transition zone (V)** —the zone at a discontinuity wherein the properties are characteristic neither of one air mass nor the other, but lie somewhere between the two. It is now customary to assume that all the air in the transition zone belongs to the colder air mass, the air in warm sectors being considered more nearly homogeneous.

**unstable (I)** —a vertical distribution of temperature such that particles of air, because of their lesser or greater density than the surrounding air, will rise or sink of their own accord once given an initial impetus up or down. For dry air the unstable lapse rate is greater than the dry adiabat; in the case of saturated air, greater than the saturation adiabat.

**vapor pressure (II)** —the partial pressure of the air exerted solely by the water vapor molecules.

**warm front (V)** —the discontinuity at the front of a warmer air mass which is displacing a retreating colder air mass.

**warm sector (VII)** —the air enclosed between the cold and warm fronts of a cyclone.

**wave disturbance (VII)** —a deformation produced along a front. These waves travel along the discontinuity surface producing new disturbances.

THE DRY CHINOOK WIND

By Harley N. Johnson, U. S. Weather Bureau, Rapid City, S. D.

Authorities agree that the name "chinook" came from a tribe of Indians who formerly resided in the vicinity of the mouth of the Columbia River. The name was originally applied to a warm, moist, southwest wind in the north Pacific states, that was supposed to come from the Chinook Indian villages, but in this discussion only the dry chinook of the eastern slope of the Rocky Mountains and the Black Hills is considered, which wind, because of its similarity to the tempering effect of the warm winds of the North Pacific states, was called "chinook" by early settlers of Montana and Alberta.

The frequency and duration of the chinook wind is a factor of great importance as it affects the climate of the region on the eastern slope of the northern and central Rocky Mountains, especially in the winter season when the severe cold of this latitude is materially tempered by this dry, balmy wind. The average annual temperature of this region is increased at least several degrees by the chinooks, which is markedly advantageous for cattle, crops and industries. In the early spring, however, the wind may be detrimental, as several days of warm wind may cause tree buds to open and occasionally blossoms to burst forth, only to be destroyed later by low temperature. Consequently, fruit raising is generally unsuccessful over the eastern slope of the northern Rocky Mountains, and trees are comparatively short lived due to the great fluctuation in temperature in the winter and early spring.

The real home of the chinook wind is in Wyoming, Montana, Alberta, and Saskatchewan, and in winter it is probably the most spectacular weather phenomenon in the region. That the temperature will rise in a few hours from many degrees below zero, on a day when the ground is covered by a foot or more of snow and the air filled with ice needles, to a temperature well above the freezing point, and the snow disappear as if by magic and the water run in the gutters, is hardly believable until one has actually experi-

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1 Paper read at the Minneapolis meeting, June, 1935.
enced a chinook. A notable record, in this connection, was made near Havre, Montana, on January 19, 1892, when the temperature rose 43 degrees in 15 minutes—from severe cold, —6°, to mild, balmy air, 37° above with the arrival of the chinook.

The chinook as applied to the eastern slope of the Rocky Mountains is a warm, dry westerly or southwesterly wind that blows down the mountain side and occasionally far to the eastward over the plains, its velocity ranging from a gentle zephyr to high winds. Its approach and the period of its continuation is uncertain. It may last a few hours or it may last several days, depending on the movements of the pressure areas which are largely responsible for the wind. It may occur at any season of the year, but the occurrence of the well-defined radical-temperature-change-type is largely confined to the winter and spring months, and such seldom last more than a day or two at a time. Contrary to the general assumption, the radical type is seldom followed by either precipitation or a severe cold wave.

The coming of a chinook in the winter season is welcomed by the stockmen, for its remarkable power to melt snow soon cleans the ranges, exposing the short-grass to the benefit of the range cattle. The abnormal evaporation into the very dry air rapidly takes up the moisture from the snow. Seldom is the ground muddy after the disappearance of the snow. In the earlier days cattle roamed at will in this region, both summer and winter, and without doubt it would be practically impossible for unsheltered stock to have subsisted in the winter season, except for the favorable influence exerted by the chinooks. As a range country for wintering stock this section excels the sections in the same latitude unaffected by the chinooks.

The winter temperatures of the region are among the lowest in the United States, and the snow cover occasionally reaches a depth of from 6 to 14 inches on the level and of several feet where it has been blown by the wind into the gulches and canyons. At periods during the winter the extremely frigid air and the snow render it difficult for range stock to get at the short-grass; the cattle drift with the wind, their legs become sore and bleeding from being cut by the crusted snow, and locomotion is difficult; but in general the winter range would be worthless and starvation of cattle would be inevitable were it not that the snow seldom remains on the ground any length of time, despite the severity of the climate, due to the remarkable influence of the chinooks.

Any surface winds, regardless of the origin, in passing from an anticyclone towards a cyclone center, are necessarily forced upward over intervening mountains, thereby causing expansion and dynamic cooling. The ascending air soon reaches the dew point, it becomes cloudy, and precipitation occurs on the windward side of the mountain. This cooling proceeds at the approximate rate of 1.6 degrees per each 300 feet of ascent, up to the point where condensation begins, above which the liberated heat of condensation reduces this cooling rate about one-half. Once the rising air reaches the top of the mountain the precipitation ceases, the clouds become less or disappear, and it starts downward on the lee side of the mountain, being adiabatically heated as it descends at approximately the dry rate for the whole of the descent. During the descent the air rapidly becomes very dry. Therefore, upon
reaching the foot of the mountain the air temperature may be 30 or 40° higher and the humidity much lower than it was at the same level on the opposite side of the mountain where the air started its upward movement.

A typical set-up of pressure conditions necessary for the development of and indicative of the occurrence of a chinook wind is as follows: An extensive area of high pressure attended by low temperatures moves from the Canadian Northwest across Alberta to Saskatchewan. In the meantime there is an area of moderately low pressure and high temperatures over the inter-mountain region. This results in an influx of abnormally cold air to the low, attended by much cloudiness and perhaps some snow in Montana and Wyoming. The high area then proceeds from Saskatchewan southeastward to the Central Valleys and an area of low pressure from the north Pacific coast advances eastward over British Columbia and Alberta to Saskatchewan, then southeastward over northeastern Montana, the Dakotas, and to the Missouri River Valley. Meanwhile the low area over the Inter-mountain region has shifted to the southern Plateau and a moderate high area moves in from the middle and north Pacific coast and settles over the Salt Lake basin and intensifies. The pressure areas are now ideally located to produce a chinook wind over the eastern slope of the Rocky Mountains in Wyoming and Montana.

This pressure situation results in a steady flow of air ranging in direction from east through southeast and south to southwest or west. The movement of the cold easterly wind is usually light, while the southwest or west winds may develop a rather strong gale, dependent upon the steepness of the barometric gradient from the high area over the western Plateau to the low centered over Saskatchewan or the Dakotas, and the rapidity with which the low area moves to the eastward.

With the approach of this westerly or chinook wind there is usually a flat layer of cirro-stratus clouds increasing in density to alto-stratus; the wind starts with considerable suddenness and the velocity quickly increases; the temperature rises rapidly, and the humidity falls abruptly. As the chinook progresses there is a tendency for the clouds to disappear, although occasionally the sky remains partly cloudy to cloudy during the period of its duration. If the clouds disappear the sky takes on a deep blue color and the visibility becomes unlimited.

To those who make weather maps daily, it is common knowledge that the temperatures reported from the eastern slope of the Black Hills are often higher and out of agreement with the temperatures reported from the surrounding stations located on the Plains having otherwise apparently the same general weather conditions. To understand these seeming abnormalities of temperature the chinook must be considered, especially during the winter season.

The Black Hills is an elongated anticlinal mass, irregular in outline, in length about 125 miles trending north-northwest and south, by about 65 miles in width, culminating in peaks 7200 feet in elevation above sea-level, being the highest point between the Rocky Mountains proper and the Atlantic seaboard. Evergreen trees, spruce in the gulches and pine on the mountain slopes up to timber line, cover the greater portion of the area, and the elevation is sufficiently great that the westerly winds blowing over it from a high to a low
pressure area develop chinook conditions on the eastern slope.

Since the chinook winds of the Black Hills are often swift and the heating rapid, it follows that the most pronounced of them are quite likely to be accompanied also by frequent strong gusts and general turbulence. Ordinarily the abrupt or sudden rises in the temperature at Rapid City are due to the same general processes involved in the Rocky Mountain chinook, or possibly in some cases a continuation of the Rocky Mountain chinook. In the more decided cases there is precipitation on the western slope of the Black Hills, which would not seem likely if they were but continuations of chinooks from the Rockies, since the air masses would be too dry upon reaching the Black Hills. Practically every winter brings to the Black Hills several of these abnormal temperature rises, many of which are more pronounced than when they made their appearance on the eastern slope of the Rockies, being perhaps accentuated successively upon coming in contact with Big Horn Mountains of Wyoming and later the Black Hills.

During 1915 the several outstanding chinooks in the Black Hills prevented the mean temperature from reaching what otherwise probably would have been the coldest year of record at Rapid City; during January, November and December there were six days upon which the temperature changes were so unusual as to merit mention:

<table>
<thead>
<tr>
<th>Date</th>
<th>Temp. Rise</th>
<th>Max. Wind</th>
<th>Prev. Dir.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan. 4</td>
<td>21° in 2 hrs.</td>
<td>26 miles</td>
<td>SW</td>
</tr>
<tr>
<td>Jan. 12</td>
<td>28° in 30 min.</td>
<td>33</td>
<td>S &amp; SW</td>
</tr>
<tr>
<td>Nov. 18</td>
<td>20° in 1 hr.</td>
<td>44</td>
<td>W</td>
</tr>
<tr>
<td>Nov. 22</td>
<td>22° in 1 hr.</td>
<td>34</td>
<td>W</td>
</tr>
<tr>
<td>Nov. 23</td>
<td>27° in 15 min.</td>
<td>19</td>
<td>W</td>
</tr>
<tr>
<td>Dec. 22</td>
<td>21° in 1½ hrs.</td>
<td>39</td>
<td>W</td>
</tr>
</tbody>
</table>

Probably the most noteworthy records of sudden temperature rises at Rapid City, due to chinook winds, are as follows: January 13, 1913, a rise of 64°, from —17° to 47° in 14 hours; and December 29, 1933, a rise of 67°, from zero at 8 p.m. December 28th to 67° above at 2 p.m. December 29th, an 18-hour period, being the greatest temperature rise in any 24-hour period of record at Rapid City. The humidity readings during the period of this phenomenal temperature rise were as follows: 1:45 a.m., 95%; 6 a.m., 30%; 9:45 a.m., 29%; Noon, 52%; 1:45 p.m., 21%; 6:00 p.m., 33%.

Aside from the direct chinook winds, there are two general causes for temperatures in the Black Hills in the winter season being higher than on the surrounding plains.

Many periods of high temperatures occur on the eastern slope of the Black Hills that are less pronounced in the suddenness of the temperature rise, and more prolonged in duration than those of the typical chinook wind periods. These are caused by a current of warm air overriding a mass of stagnant cold, dense surface air in the basins of Wyoming and adhering to earth upon and after coming in contact with the Black Hills. The air pressure conditions are similar to those of the abrupt temperature change type of winds but the warm air on descending the eastern slopes of the Rocky Mountains comes in contact with the cold mass and glides along its sharp upper surface; con-
Continuing eastward in passing over the Big Horn Mountains the chinook process is repeated with further drying and warming as a result, and in the lee the warm currents again override the cold, dense air in the basins. After passing over the summit of the Black Hills the mechanical turbulence caused by the Hills, wears away by friction the cold land layer on the lee side and here the warm air first reaches the surface east of the Rockies.

In the winter season it is not an unusual condition to have steep inversions in temperature in the general area of country embracing the Black Hills, with the temperatures near the surface decidedly lower than at elevations of 1000 to 6000 feet, especially is this true in the early mornings. It may be inferred that this rather normal winter inversion effect, undoubtedly at times in combination with other effects, plays an important role in causing the occasional rapid rise in temperature at Rapid City, not strictly attributable to chinook effects, nor having all the attributes ordinarily associated with chinook winds. A necessary combination is, of course, a pressure condition such as to cause a strong west-to-east circulation and the attendant mechanical downdraft on the lee side of the Hills. Undoubtedly at times a subsidence effect enters into the general phenomena, the inevitable temperature rise where the air spreads out aloft accentuating the so-called chinook effect.

Therefore, the conclusion is that the dry chinook winds of the pronounced type occur on the eastern slope of the Rocky Mountains and over the Black Hills area under definitely defined meteorological conditions and a forecast of their approach is no more uncertain of verification than the ordinary daily weather forecast; but the sudden local temperature changes in the Black Hills, due to inversions in temperature and subsidence effects, not wholly indicated by the attendant meteorological conditions, are more difficult to foretell with only surface observations available.

ABSTRACTS, MINNEAPOLIS MEETING

Practical Uses of Weather Data in Public Utility Operations

By A. C. Braun, Assistant Engineer, Wisconsin Michigan Power Co., Appleton, Wis.

Actual uses to which weather data has been put, using records obtained from 8 years' operation of an observer's weather station maintained by the Wisconsin Michigan Power Company, are related in this paper. In the operation of an extensive electric distribution system, load dispatchers make use of weather maps supplemented by local anemometer and barometer indications. Kilowatt hour generation is influenced by precipitation and bears a direct relation to the amount of hydro or steam generation. In budget preparation operating costs are affected by both rainfall and temperature trends. Coal storage piles gain in tonnage with heavy precipitation and spontaneous combustion occurs or is absent as a result. Steam boiler operating costs are directly affected to some extent. Gas sales curves are in direct relation to monthly mean temperatures. Soil temperatures affect the accuracy of gas meter measurements.

The number of bus passengers varies directly with good or bad weather.