When calculating the effect of changing pressure and temperature, it is necessary to multiply the sea level lift by the ratio of pressures and temperatures. For a nonstandard ambient pressure, multiply the lift at the ISA level either by 29.92 "Hg or 1,013.25 millibars (mb).

Temperatures at altitude must also be calculated and compensated for. The factor for temperature is a ratio of absolute temperatures expressed in either degrees Kelvin or Rankine. To get temperature in degrees Rankine, simply add 459 to the normal Fahrenheit temperature. For a new temperature, multiply the lift calculated at the ISA by the factor: (59 °F+ 459)/(new temperature + 459). When using temperature in degrees Centigrade (°C), add 273 to convert to absolute temperature (i.e., Kelvin). This is: (15 °C + 273)/(new temperature + 273). Various lift factors at differing altitudes, comparing helium and hydrogen, are illustrated in Appendix F.

Pressure Ceiling

The pressure ceiling is the altitude at which the lifting gas inside the envelope would expand to just completely fill the envelope, assuming the balloon rose to that altitude. Rising above the pressure ceiling causes lifting gas to be expelled from the appendix and establishes a new, higher pressure ceiling. Exceeding the current pressure ceiling causes loss of lifting gas, reduces gross lift, and typically causes the balloon to eventually begin to descend. Ballast must be expended to maintain the new higher altitude. However, maneuvers that result in altitude changes below the pressure ceiling, do not result in loss of lifting gas or gross lift. Very little ballast is required to ascend while below the pressure ceiling. For these reasons, the gas pilot should always be aware of what the approximate current pressure ceiling is and should consider the consequences of penetrating that ceiling.

The following approximations generally apply to a balloon below 18,000 mean seal level (MSL).

1. For a 1,000 cubic meter balloon at its pressure ceiling, an ambient pressure decrease of 1 "Hg causes a decrease in gross lift of about 80 pounds.
2. For a 1,000 cubic meter balloon at its pressure ceiling, an ambient and gas temperature decrease of 3.3 ºF causes a lift increase of about 16 pounds.
3. For a 1,000 cubic meter balloon at its pressure ceiling, a discharge of about 64 pounds of ballast results in approximately a 1,000 foot increase in altitude.

Additional Factors That Affect Lift

1. A balloon flying below its pressure ceiling (i.e., a flaccid balloon) responds differently from one flying at its pressure ceiling.
2. When the lifting gas inside the balloon is warmer (i.e., super heating) than the ambient air, additional lift is generated. The reverse happens when the lifting gas is colder than the ambient air.
3. Nonstandard atmospheric conditions, such as inversions, affect a balloon's stability.
4. The atmospheric humidity has a small effect on lift with more humidity resulting in slightly less lift.
5. The purity of the lifting gas directly affects lift. Most commercially produced gas is assumed to be greater than 99 percent pure, but purity can be reduced as a result of improper filling technique.

For further discussion of gas balloon calculations, the book *A Short Course on the Theory and Operation of the Free Balloon*, by C. H. Roth, Goodyear Tire and Rubber Company, is recommended reading. This manual provides a good overview of the physics and operation of gas ballooning as of 1917. It is long out of print, but photocopies are readily available.

Weather Considerations for Gas Ballooning

When studying weather for gas ballooning, one must look for trends both further into the future and higher above the ground. The best weather for any flight is determined by the flight's objectives. A flight to set a duration record (maximum time aloft) benefits from light winds and clear skies while a distance competition requires high winds aloft with lighter winds in the landing zone. A competitor in a long competition is likely to encounter several different weather patterns during flight simply due to the length of the flight. Examples of these include precipitation, snow, icing, thunderstorms, lightning, high winds, mountain winds, unstable air, or convective currents.

This discussion again focuses on the most common type of competitive flight, a Gordon Bennett type, with the objective to maximize great circle distance covered. Since winning distances can be well over a thousand miles at altitudes of up to 18,000 feet MSL with times aloft possibly exceeding seventy hours, a much larger area of the weather map must be studied than for a typical hot air flight.

Meteorological Differences From Hot Air Ballooning

In contrast to hot air flights, landing conditions are most likely to be different from those at launch and several weather patterns may be encountered during the flight. Freezing levels and the moisture content of the air should be checked to predict the possibility of icing. Any icing that occurs has multiple negative impacts on the flight. It adds weight to