where

*condition* (*1*) applies to some known condition of weight, fuel flow, and specific range at some original basic altitude during cruise climb.

*condition* (2) applies to some new values of weight, fuel flow, and specific range at some different altitude along a particular cruise path.

and

$V$ = velocity, knots
$M$ = Mach number
$W$ = gross weight, lbs.
$FF$ = fuel flow, lbs./hr.
$SR$ = specific range, nmi./lb.
$\sigma$ = altitude density ratio

Thus, during a cruise-climb flight, a 10 percent decrease in gross weight from the consumption of fuel would create:

- no change in Mach number or *TAS*
- a 5 percent decrease in *EAS*
- a 10 percent decrease in $\sigma$, i.e., higher altitude
- a 10 percent decrease in fuel flow
- an 11 percent increase in specific range

An important comparison can be made between the constant altitude cruise and the cruise-climb with respect to the variation of specific range. From the previous relationships, a 2 percent reduction in gross weight during

$$\frac{SR_2}{SR_1}=\sqrt{\frac{W_1}{W_2}} \qquad \textit{constant altitude}$$

$$\frac{SR_2}{SR_1}=\frac{W_1}{W_2} \qquad \textit{cruise-climb}$$

cruise would create a 1 percent increase in specific range in a constant altitude cruise but a 2 percent increase in specific range in a cruise-climb at constant Mach number. Thus, a higher average specific range can be maintained during the expenditure of a given increment of fuel. If an airplane begins a cruise at optimum conditions at or above the tropopause with a given weight of fuel, the following data provide a comparison of the total range available from a constant altitude or cruise-climb flight path.

| *Ratio of cruise fuel weight to airplane gross weight at beginning of cruise* | *Ratio of cruise-climb range to constant altitude cruise range* |
|---|---|
| 0.0 | 1.000 |
| .1 | 1.026 |
| .2 | 1.057 |
| .3 | 1.092 |
| .4 | 1.136 |
| .5 | 1.182 |
| .6 | 1.248 |
| .7 | 1.331 |

For example, if the cruise fuel weight is 50 percent of the gross weight, the climbing cruise flight path will provide a range 18.2 percent greater than cruise at constant altitude. This comparison does not include consideration of any variation of specific fuel consumption during cruise or the effects of compressibility in defining the optimum aerodynamic conditions for cruising flight. However, the comparison is generally applicable for aircraft which have subsonic cruise.

When the airplane has a supersonic cruise for maximum range, the optimum flight path is generally one of a constant Mach number. The optimum flight path is generally—but not necessarily—a climbing cruise. In this case of subsonic or supersonic cruise, a Machmeter is of principal importance in cruise control of the jet airplane.

The *effect of wind on range* is of considerable importance in flying operations. Of course, a headwind will always reduce range and a tailwind will always increase range. The selection of a cruise altitude with the most favorable (or least unfavorable) winds is a relatively simple matter for the case of the propeller powered airplane. Since the range of the propeller powered airplane is relatively unaffected by altitude, the altitude with the most favorable winds is selected for range. However, the range of the turbojet airplane is greatly affected by altitude so the selection of an optimum altitude will involve considering the wind profile with the variation of range with altitude. Since the turbojet range increases