United States Department of Agriculture
Soil Conservation Service
Engineering Division

Technical Release No. 4
Design Section
June 20, 1956

# HEIGHT OF WATER COLUMN SUPPORTED BY ATMOSPHERIC PRESSURE[1]

This technical release gives a simplified method of determining the maximum negative head permissible to avoid cavitation in pressure conduits and the maximum permissible suction head for suction lift pumps.

When the air above the surface of a liquid is evacuated, the liquid will evaporate until a saturated vapor exists above the surface of the liquid. The pressure of this vapor depends on the temperature of the liquid. Values of the vapor pressure of water for various temperatures are given in Table I.

The pressure p at a given point in a liquid is equal to the weight of the column of liquid above the point.

$$p = wh \qquad \text{- - - - - - - - -} \qquad (1)$$

and

$$h = \frac{p}{w} \qquad \text{- - - - - - - - - -} \qquad (2)$$

where $p$ = the pressure, $lbs/ft^2$
$w$ = unit weight of the liquid, $lbs/ft^3$
$h$ = height of the column of liquid, ft

The expression h (Eq. 2) is called pressure head. It is the depth in feet of a liquid of specific weight w required to give a pressure p.

Absolute pressure is defined as

$$p_{ab} = p_a + wh \qquad \text{- - - - - - - -} \qquad (3)$$

where $p_a$ = actual atmospheric pressure, $lbs/ft^2$
$wh$ = gage pressure, $lbs/ft^2$
$p_{ab}$ = absolute pressure, $lbs/ft^2$

The values of absolute pressure are always positive. The values of gage pressure may be positive or negative. Gage pressure will be positive if it is greater than atmospheric pressure and negative if it is less than atmospheric. Negative gage pressures vary from zero at atmospheric pressure to a maximum negative value at absolute zero.

[1]This Technical Release was prepared by A. R. Gregory of the Design Section to meet a specific field problem.

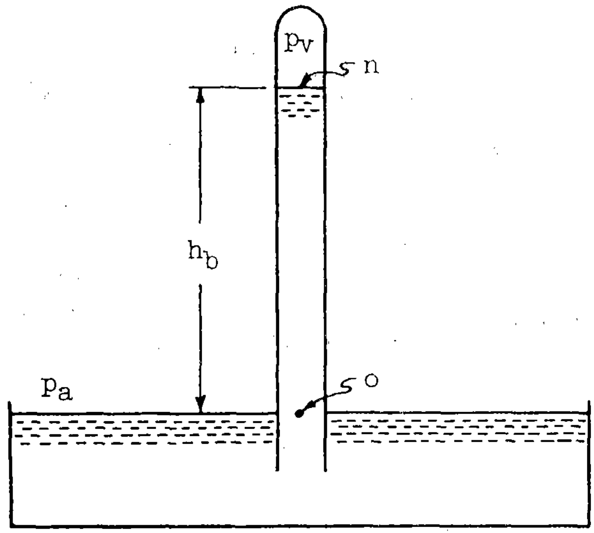



FIGURE I

The pressure of the atmosphere $p_a$ is measured by the use of barometers (see Fig. I). A tube, closed at one end, is filled with a liquid and inverted in a container containing the same liquid. If the tube is long enough, there will be a space at the top of the tube that is empty except for the saturated vapor of the liquid.

The pressure at the surface of the liquid (point n) is equal to the vapor pressure $p_v$. The pressure at point o is $p_v + h_b w$. Since the pressure within a liquid is the same at any given elevation $p_o = p_a$ and

$$p_a = p_v + h_b w$$

or

$$h_b = \frac{p_a}{w} - \frac{p_v}{w} \qquad (4)$$

where $h_b$ = height of the column of liquid supported by atmospheric pressure, ft
$p_a$ = actual atmospheric pressure, $lbs/ft^2$
$p_v$ = vapor pressure of the liquid, $lbs/ft^2$
$w$ = unit weight of the liquid, $lbs/ft^3$

Equation 4 can be used to determine the height of a column of water that will be supported by the atmospheric pressure if the temperature of the water and the actual atmospheric pressure are known.

In Eq. 3, h is the general term for pressure head.

Equations 3 and 4 can be used to determine whether cavitation will occur in a pressure conduit. When $h_b$ is greater than h, the vapor pressure of the liquid is greater than the absolute pressure in the conduit and cavitation will occur.

Equation 4 can be used to determine the allowable suction head for suction lift pumps.

Values of $p_v$ and w may be obtained from Table I.

TABLE I

| Temperature °F | Vapor Pressure, $p_v$ lbs/ft$^2$ | Specific Weight, w lbs/ft$^3$ |
|---|---|---|
| 32 | 12.75 | 62.416 |
| 50 | 25.65 | 62.408 |
| 70 | 52.69 | 62.300 |
| 90 | 100.54 | 62.118 |

Atmospheric pressure not only varies with the altitude and temperature, but also varies with weather conditions. Table II has been prepared from unpublished data obtained from the U. S. Department of Commerce, Weather Bureau. The pressures given in Table II are equal to or less than any recorded atmospheric pressures during the period of record for the corresponding elevations. Therefore Table II gives probable minimum atmospheric pressures for corresponding elevations.

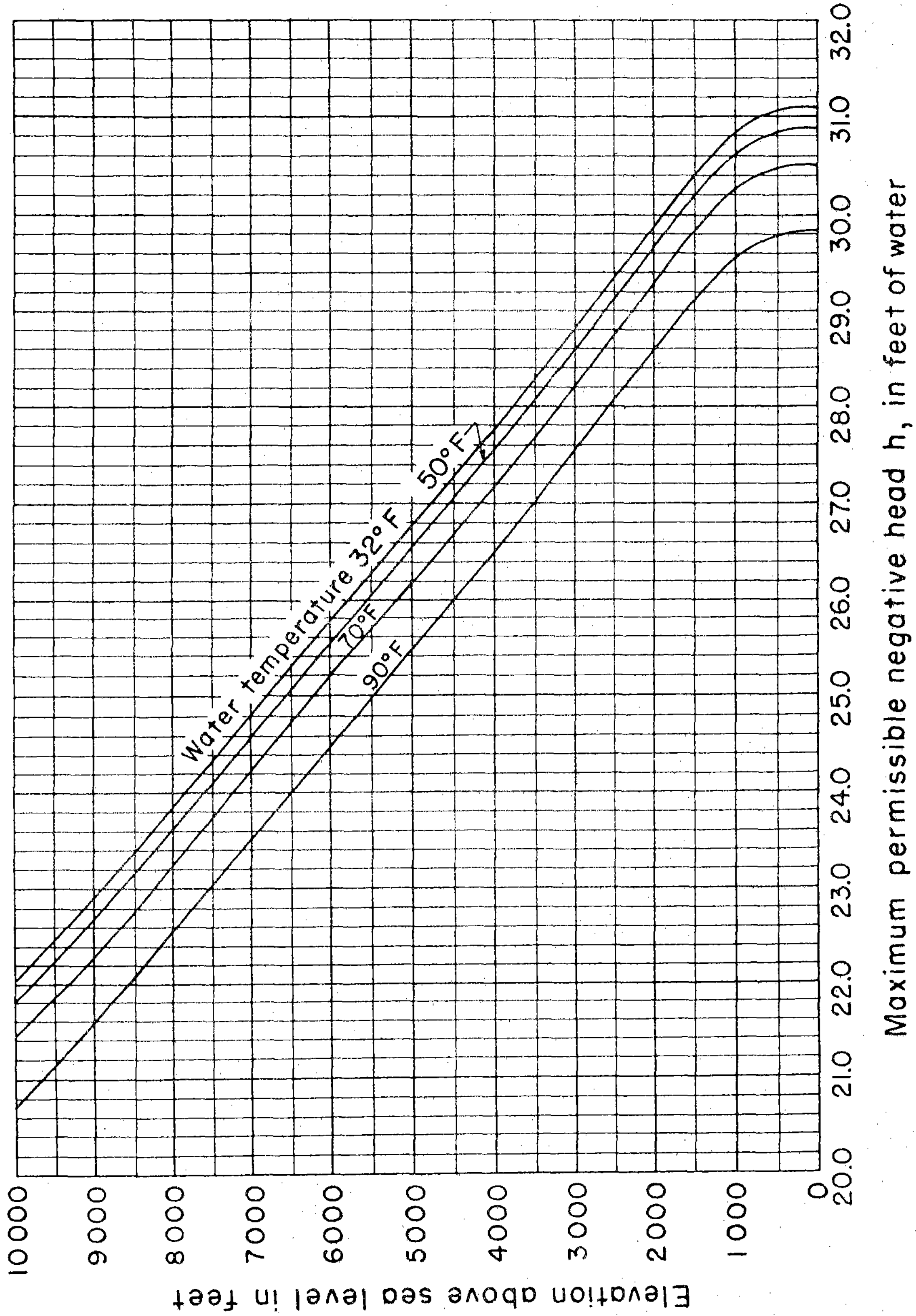
TABLE II

| Elevation ft | Minimum Atmospheric Pressure, $p_a$ lbs/ft$^2$ |
|---|---|
| 0 | 1954 |
| 1000 | 1937 |
| 2000 | 1876 |
| 3000 | 1811 |
| 4000 | 1748 |
| 5000 | 1683 |
| 6000 | 1621 |
| 7000 | 1559 |
| 8000 | 1500 |
| 9000 | 1441 |
| 10000 | 1387 |

Values of $h_b$ can be obtained directly from the curves in ES-112. The minimum atmospheric pressures given in Table II and the values of $p_v$ and w from Table I were used to prepare the curves in ES-112.

Examples of the application of this concept are illustrated in Technical Release No. 3.

Maximum negative head permissible to avoid cavitation in pressure conduits for various elevations and water temperatures




| REFERENCE | U. S. DEPARTMENT OF AGRICULTURE<br>SOIL CONSERVATION SERVICE<br>ENGINEERING DIVISION - DESIGN SECTION | STANDARD DWG. NO.<br>ES-112<br>SHEET 1 OF 1<br>DATE 5-24-56 |
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