46.49 The SR-71 Blackbird aircraft travels at $2193mph$ at an an altitude of $70,000ft$ where the temperature is $-70°F$. What is the Mach number?

A. 2.8

B. 3.3

C. 7.7

D. 18.9

The Mach Number is the ratio of velocity of the air to the speed of sound.

$$M = \frac{V}{c}$$

The Speed of Sound, c, is a function of the ratio of specific heats, k, the Specific Gas Constant, R, and the temperature, T, in absolute terms i.e. Rankine. The gravitational constant, g_c, also needs to be included to make the units work out, which must be inferred since it is not shown in the reference handbook.

Calculate the speed of sound in air at $-70°F$.

$$c = \sqrt{kRT}$$

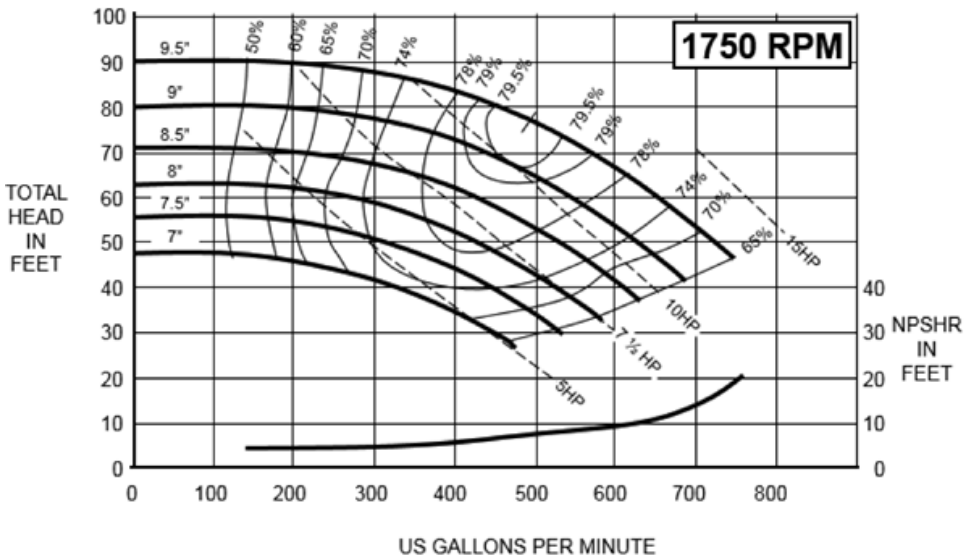
$$c = \sqrt{(1.4)\left(53.3\frac{ft \cdot lb_f}{lb_m \cdot R}\right)(390R)\left(32.2\frac{ft \cdot lb_m}{s^2 \cdot lb_f}\right)} = 968\frac{ft}{s}$$

Determine the Mach number. Convert mph to $\frac{ft}{s}$ such that the final result is unitless.

$$M = \frac{(2193mph)\left(88\frac{ft}{min \cdot mph}\right)\left(\frac{1min}{60s}\right)}{968\frac{ft}{s}} = 3.3$$

Answer B

46.50 The flow rate at the operating point of a $7\frac{1}{2}HP$ pump described by the pump curve below is $300gpm$. What is the amount of pump head needed at the pump shaft?



A. $59ft$

B. $69ft$

C. $74ft$

D. $79ft$

Reading the Pump Performance Curve, follow the $7\frac{1}{2}HP$ curve until it intersects with $300gpm$. This is the operating point. Use the vertical axis to obtain the total head in ft at the operating point. This represents the head added to the fluid by the pump.

$$h_{added} \approx 59ft$$

The head needed *at the shaft* is greater than the head added to the fluid because the pump is not 100% efficient. Read the efficiency at the operating point.

$$\eta_{pump} \approx 75\%$$

Find the amount of head needed at the pump shaft.

$$h_{shaft} = \frac{h_{added}}{\eta_{pump}} = \frac{59ft}{0.75} = 78.7ft$$

Answer D