12

Copy 93

NASA Project Apollo Working Paper No. **1035**

PROJECT APOLLO

THE EFFECT OF THE SELECTION OF THE CABIN PRESSURE ON THE ENVIRONMENTAL CONTROL SYSTEM

[redacted]

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

Langley Air Force Base, Va.

December 19, 1961

NASA PROJECT APOLLO WORKING PAPER NO. 1035

PROJECT APOLLO

THE EFFECT OF THE SELECTION OF THE CABIN PRESSURE ON THE ENVIRONMENTAL CONTROL SYSTEM

Prepared by: James F. Saunders Jr.
James F. Saunders, Jr.
AST, Flight Systems

Authorized for Distribution:

Paul E. Purser
for Robert R. Gilruth, Director

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
Langley Air Force Base, Va.
December 19, 1961

TABLE OF CONTENTS

Section Page

LIST OF FIGURES

THE EFFECT OF THE SELECTION OF THE CABIN PRESSURE ON THE ENVIRONMENTAL CONTROL SYSTEM

SUMMARY

This paper reviews the factors used in evaluating the effect of a cabin pressure of 7 psia on the Environmental Control System for the 14-day Apollo mission. The results show that the system operating at 7 psia will supply sufficient air to meet the metabolic and cooling requirements without a significant system weight penalty.

INTRODUCTION

In view of the desire of the NASA Manned Spacecraft Center (MSC) Life Systems Division to utilize a total cabin pressure of 7 psia, a study was made to evaluate the parameters involved in the selection of this pressure. A cabin pressure of 7 psia was found to be desirable by the Life Systems Division as a result of consideration of:

(a) Decompression

(b) Dysbarism

(c) Hypoxia

(d) Fire hazard

(e) Two-gas atmosphere

(f) Other physiological factors

The other primary factors which influence the selection of pressure are:

(a) Cabin leakage

(b) Power requirements

(c) Atmospheric-circulating-loop weight

(d) Structural

The NASA-MSC Structures Branch personnel have indicated that for a cabin pressure below 11 psia, the cabin structural weight will not vary.

This study was made without selecting and sizing actual components in the regenerative atmospheric-circulating loop. The effects of pressure on the cabin fan power and heat exchanger weight were not considered. Several system proposals by industry were used to establish variable system weights versus flow resistance and power in this preliminary study. The investigation of an optimum cabin pressure, from a physiological consideration, required an air-circulating loop which is defined as one which would cool, purify and filter the cabin-gas mixture and make it available to the cabin and/or the astronauts in pressure suits. Power for the Environmental Control System's electrical equipment was assumed to be furnished by a Bacon-type fuel cell and the power-weight penalty used was that of the above fuel-cell system. A range of cabin leak rates was considered where the lower value was chosen as the minimum expected rate and the higher value as a maximum permissible rate. A pressure range of 5 to 11 psia was considered.

DISCUSSION

Basic gas curves.- For ease of calculating, gas weights and densities were plotted in figure 1 for pressures from 0 to 11 psia. Densities were based on the perfect gas formula and a temperature of 70° F. This temperature is used throughout this analysis.

Similarly, the total gas constant for a mixture of oxygen and nitrogen is shown in figure 2, for oxygen partial pressures from 160 to 260 millimeters of Hg and for total cabin pressures from 5 to 11 psia.

Utilizing the individual gas densities from figure 1, the gas constant from figure 2 and Dalton's law for partial pressures, the total weight of the cabin atmosphere versus cabin volume was calculated and is shown in figure 3 for total cabin pressures between 5 and 11 psia. It should be noted that the weight of gas increases with an increased oxygen partial pressure from 160 to 260 millimeters of Hg. However, due to the similar molecular weights of the two gases, it can be seen that there is little variation in the total weight over the range of oxygen partial pressures considered. For this reason, the average weight was used in subsequent calculations and the resulting density versus total pressure is shown in figure 4.

Conversion curves.- Figure 5 was prepared as a convenient method of graphically converting leak rates from volumetric to gravimetric quantities for various cabin total pressures.

The relationship of mass flow to volume flow at various cabin pressures is shown in figure 6.

Analysis.- For this analysis, the following assumptions were made: An airflow of 2.05 pounds per minute was used to satisfy the sensible cooling requirements for the crew plus 0.2 kilowatt fan power and the heat of reaction from the lithium hydroxide (LiOH).

Fan-power requirements.- In computing the weight penalty for fan power, the electrical source chosen was the fuel cell, which was assumed to have a fixed weight of 100 pounds per kilowatt and a variable weight of 1.15 pounds per kilowatt-hour including tankage. These assumptions result in a power weight penalty of 486 pounds per kilowatt for the 14-day mission. The required fan power, at an assumed efficiency of 60 percent to supply various flow rates and system resistance levels, is shown in figure 7. Note that the power required is independent of total pressure at any fixed volumetric flow and pressure rise conditions. Figures 6 and 7 are combined in figure 8 to obtain a plot of fan power versus cabin pressure for the parameters of volume flow and pressure loss for the design condition of 2.05 pounds of gas per minute.

Cabin leakage.- The total weight of gas to offset leakage for the 14-day mission is shown in figure 9. These weights include the supercritical storage tankage for leakage rates of 0.50, 0.35, and 0.20 pound per hour, at a reference cabin pressure of 11 psia. As previously stated, the lower value was chosen as the minimum expected and the higher value is hopefully on the high side of the expected range.

Variable system weight.- The effects of a range of cabin total pressures and system pressure losses on variable air-loop components and their corresponding weights are shown in figure 10. Data on system weights were extrapolated from several industrial sources (refs. 1, 2, and 3).

Combined effects.- The summation of the variable weights shown in figures 8 to 10 is shown in figures 11 to 13 for fixed reference leak rates of 0.50, 0.35, and 0.20 pound per hour respectively. Below 11 psia, cabin pressure does not affect the weight of the cabin structure, at the present status of the structure, so this factor was not taken into consideration in this analysis.

From figure 11 it can be seen that for a leak rate of 0.50 pound per hour, the optimum cabin total pressure is less than 5 psia. Similarly, from figure 12, the optimum pressure for a leak rate of 0.35 pound per hour is approximately 5 psia, and when the leak rate is 0.20 pound per hour (fig. 13), the optimum cabin pressure is approximately 8 psia.

The weight penalty suffered in selecting 7 psia as a total cabin pressure as opposed to the optimum is as follows:

Leak rate (lb/hr)	0.50	0.35	0.20
Approximate optimum pressure – psia	< 5	5	8
Approximate weight penalty – pounds	20	5	2

CONCLUSION

This study shows that with a cabin total pressure of 7 psia, the variable Environmental Control System weight is not excessive regardless of the leak rate allowance.

REFERENCES

1. Lee, R. H., Merrill, L. E., and Nonoshita, R. A.: Engineering Proposal Orbital Bio-Medical Capsule. AiResearch Mfg. Co., Rep. No. AAC-3767-R, Jun. 8, 1960.

2. Olling, E., Sawamura, L., and Nonoshita, G.: Environmental Control System for a Three-Man, Two-Week Orbital Vehicle. AiResearch Mfg. Co., Rep. No. SS-521-R, Sept. 20, 1960.

3. Advanced Design Group, Shaffer, A., ed.: Analytical Methods Applied to Space Vehicle Atmospheric Control Processes, AiResearch Mfg. Co., Rep. No. SS-572-R, May 5, 1961.

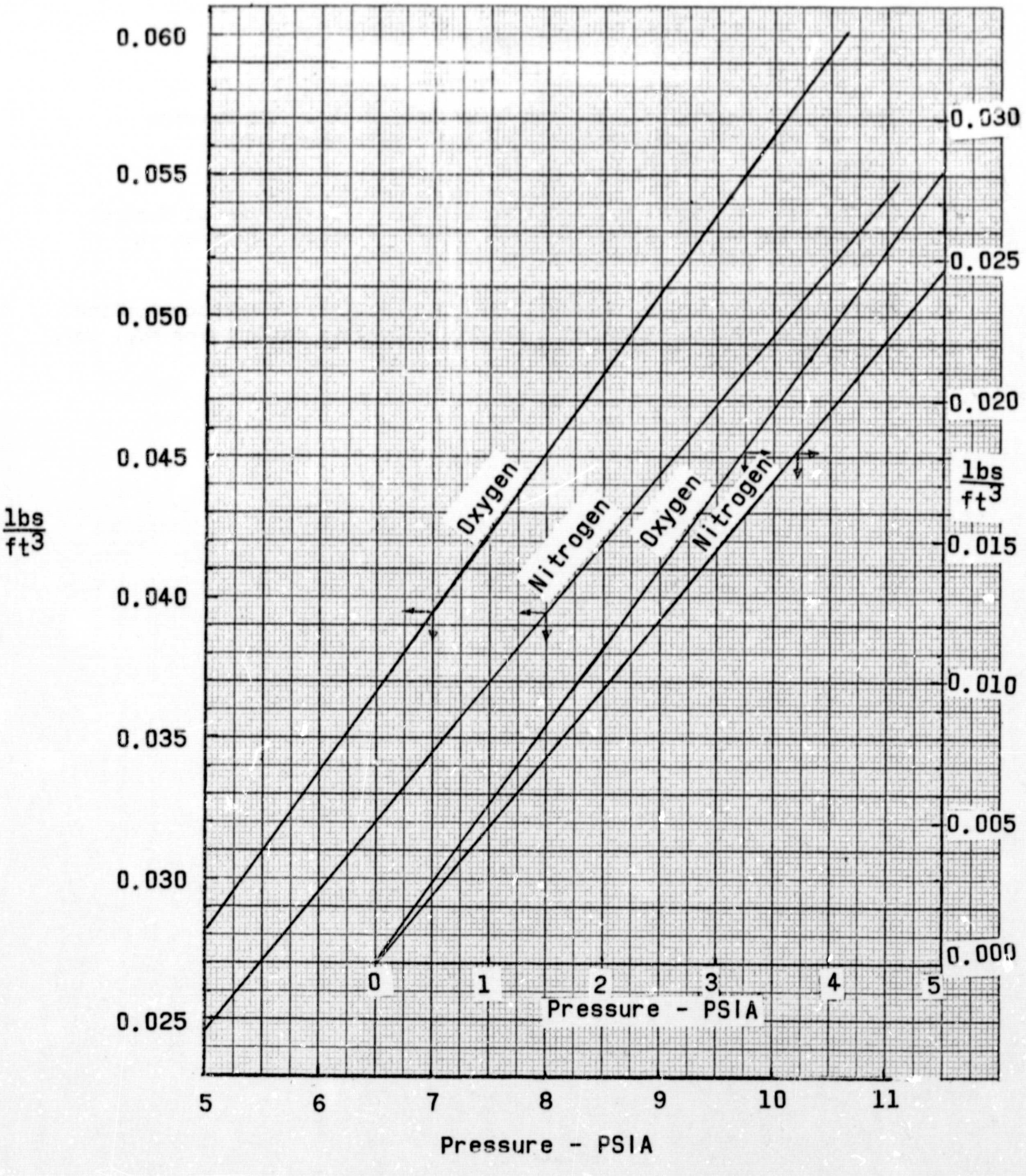

Figure 1. - O_2 and N_2 density versus pressure, temperature = 70° F.

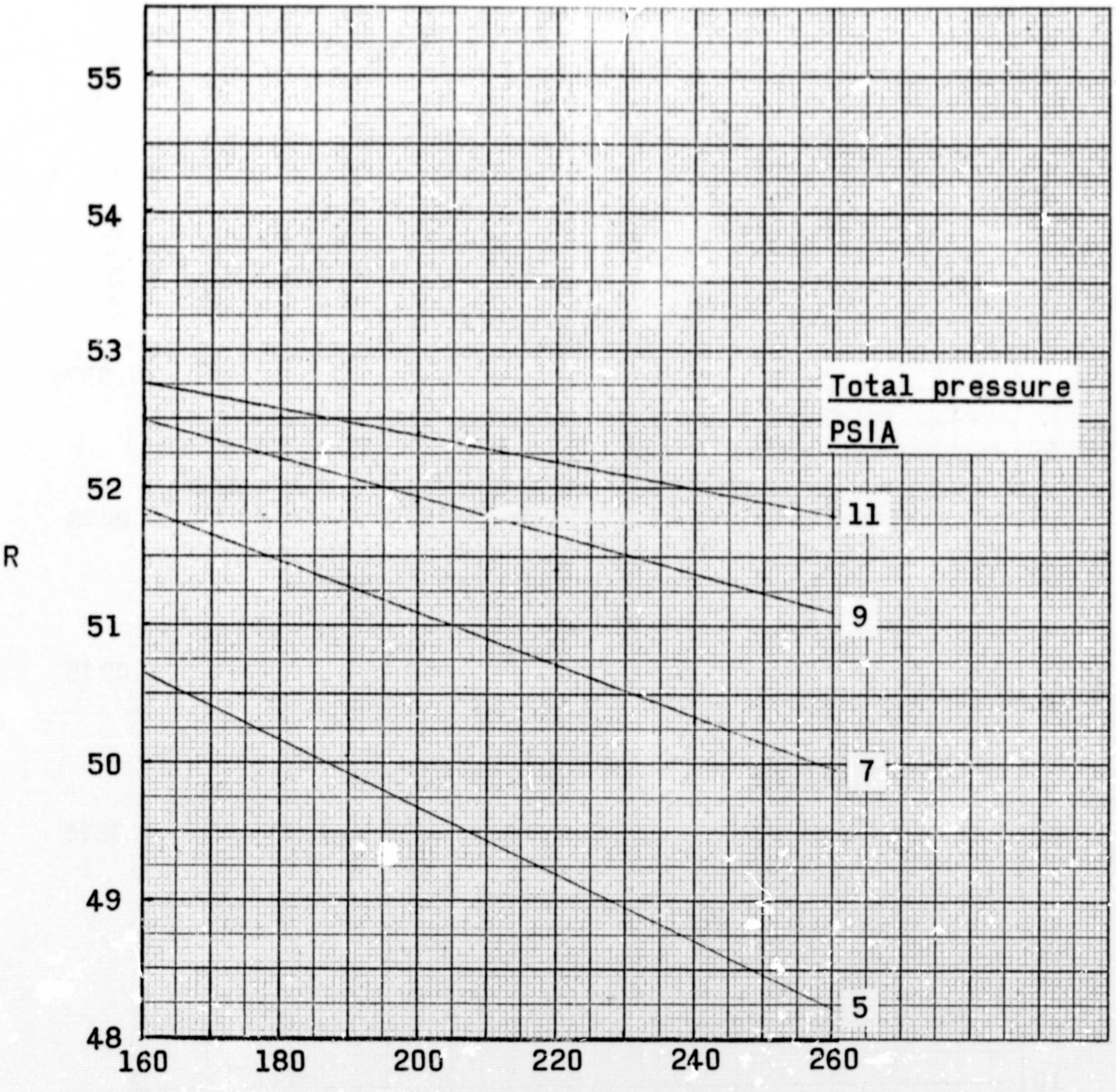

Figure 2. - Gas constant (R) versus pressure. ($T = 70^{\circ}$ F).

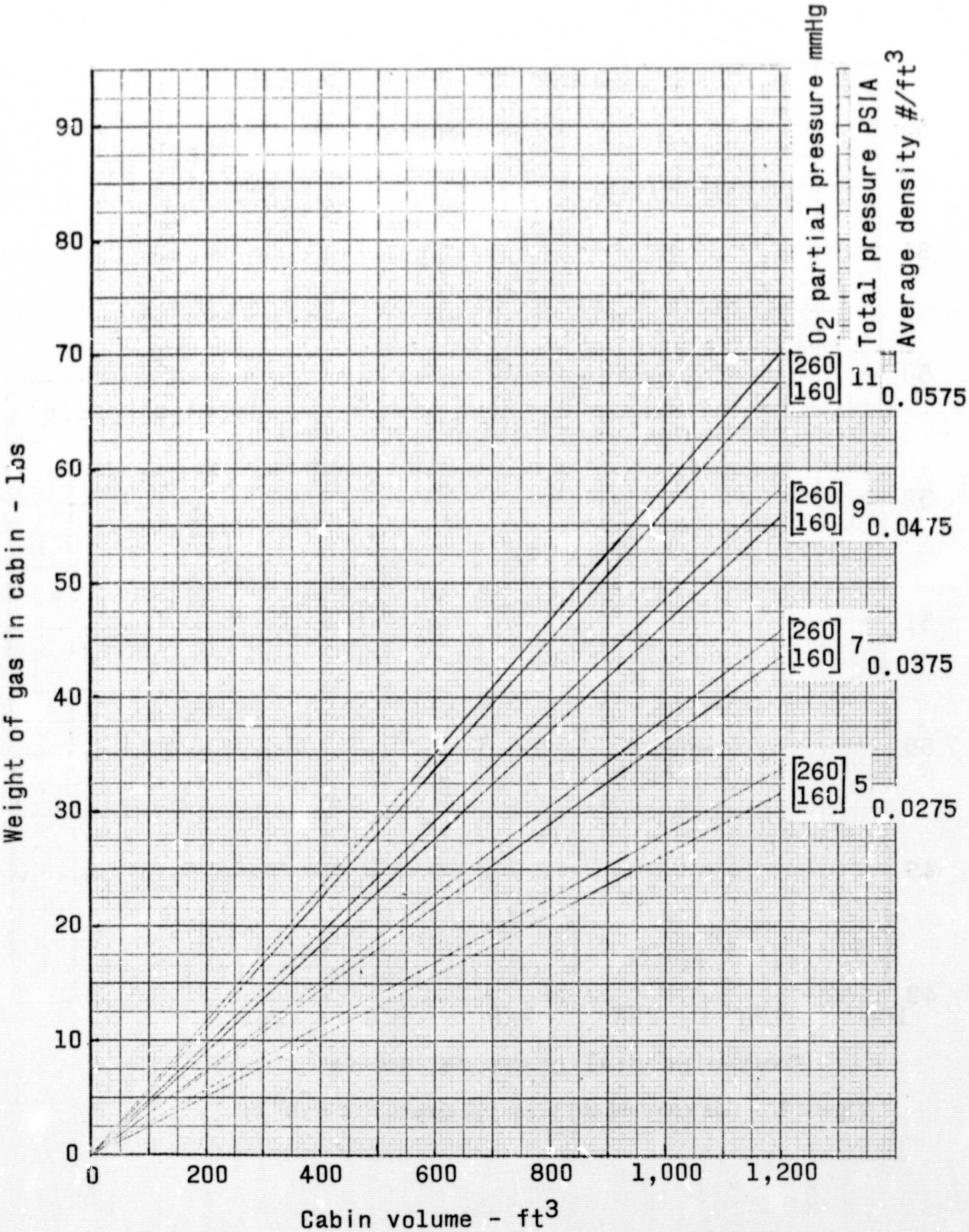

Figure 3. - Cabin gas weight versus cabin volume. (T=70° F)

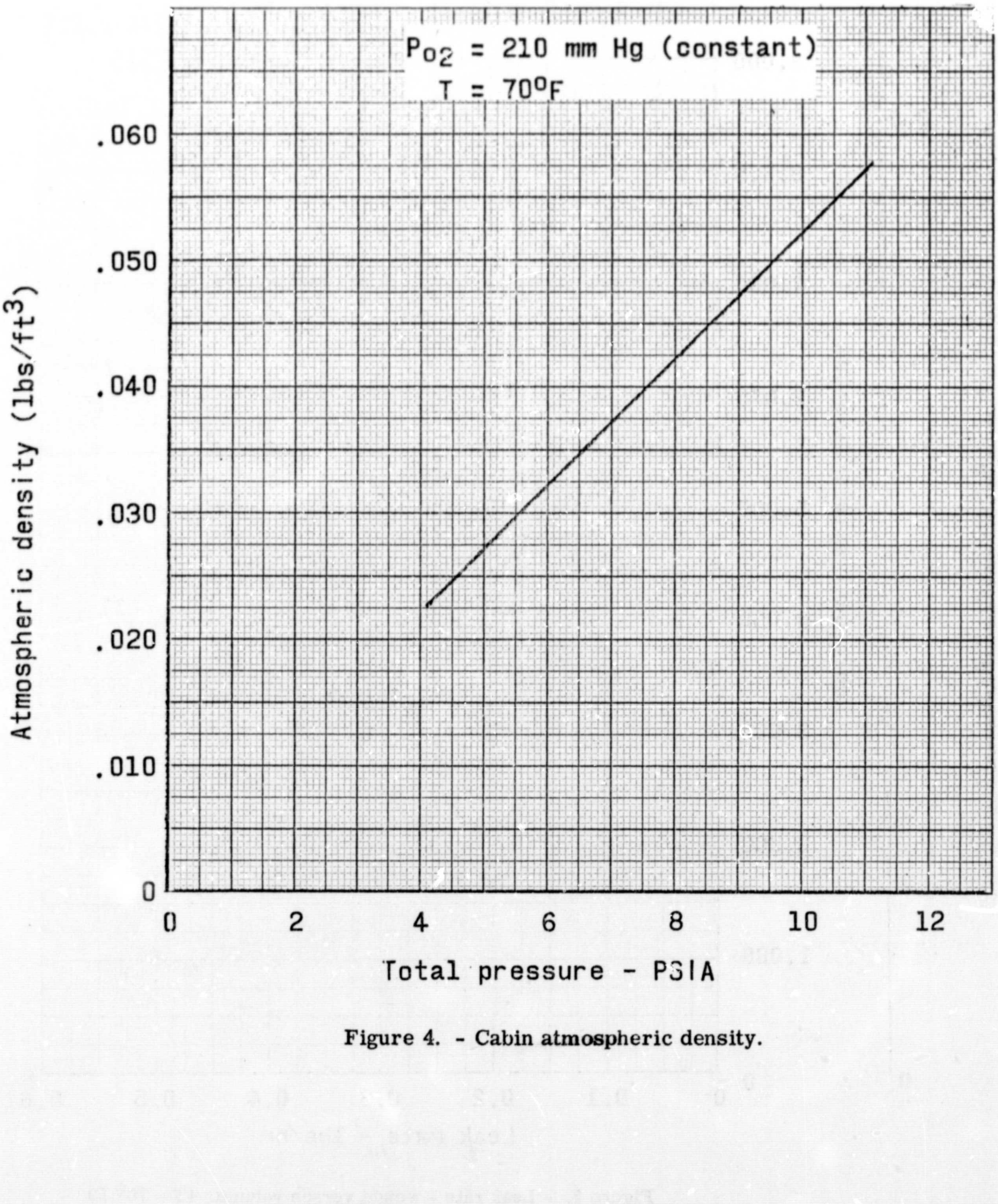

Figure 4. - Cabin atmospheric density.

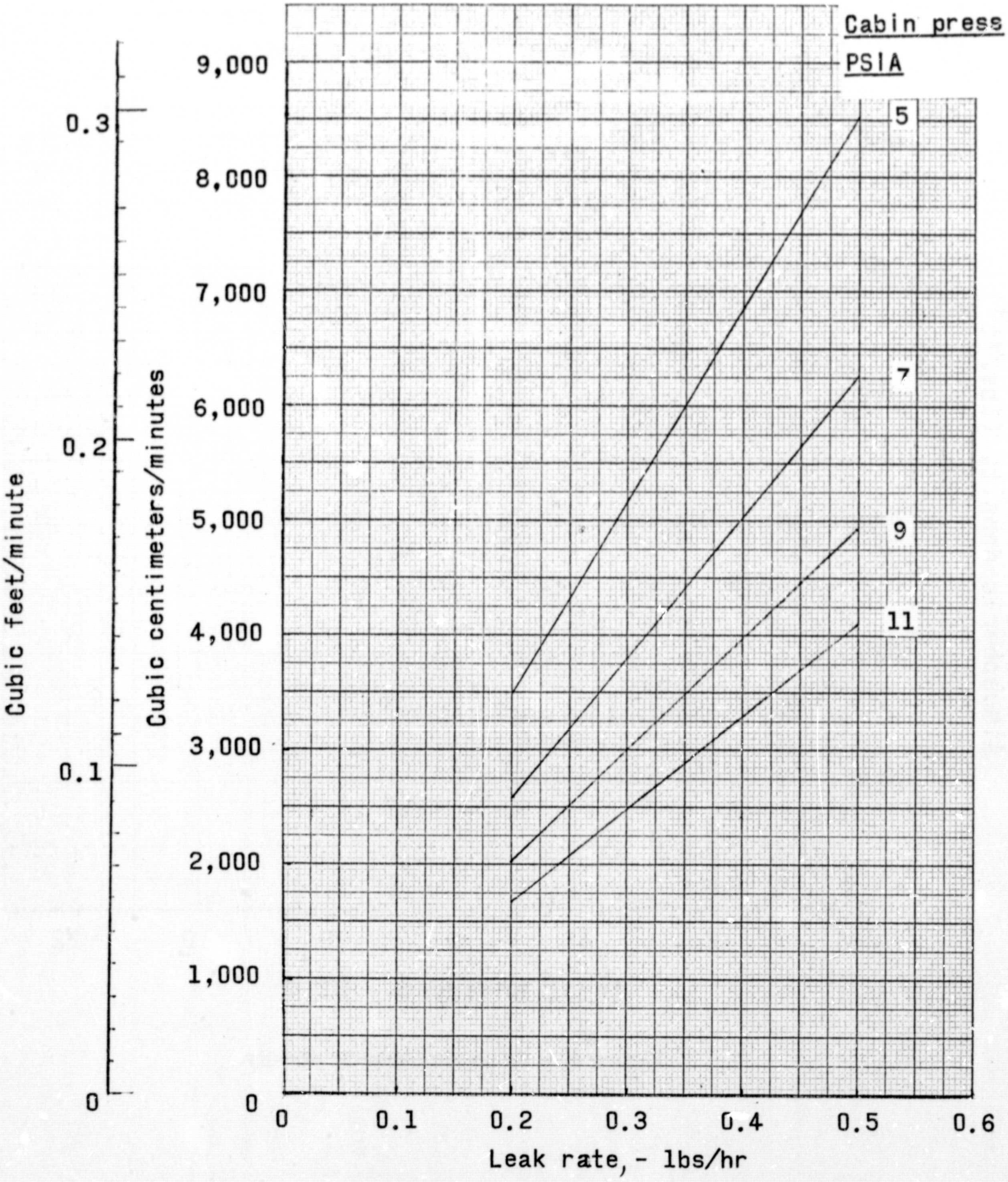

Figure 5. - Leak rate - weight versus volume. (T = 70° F)

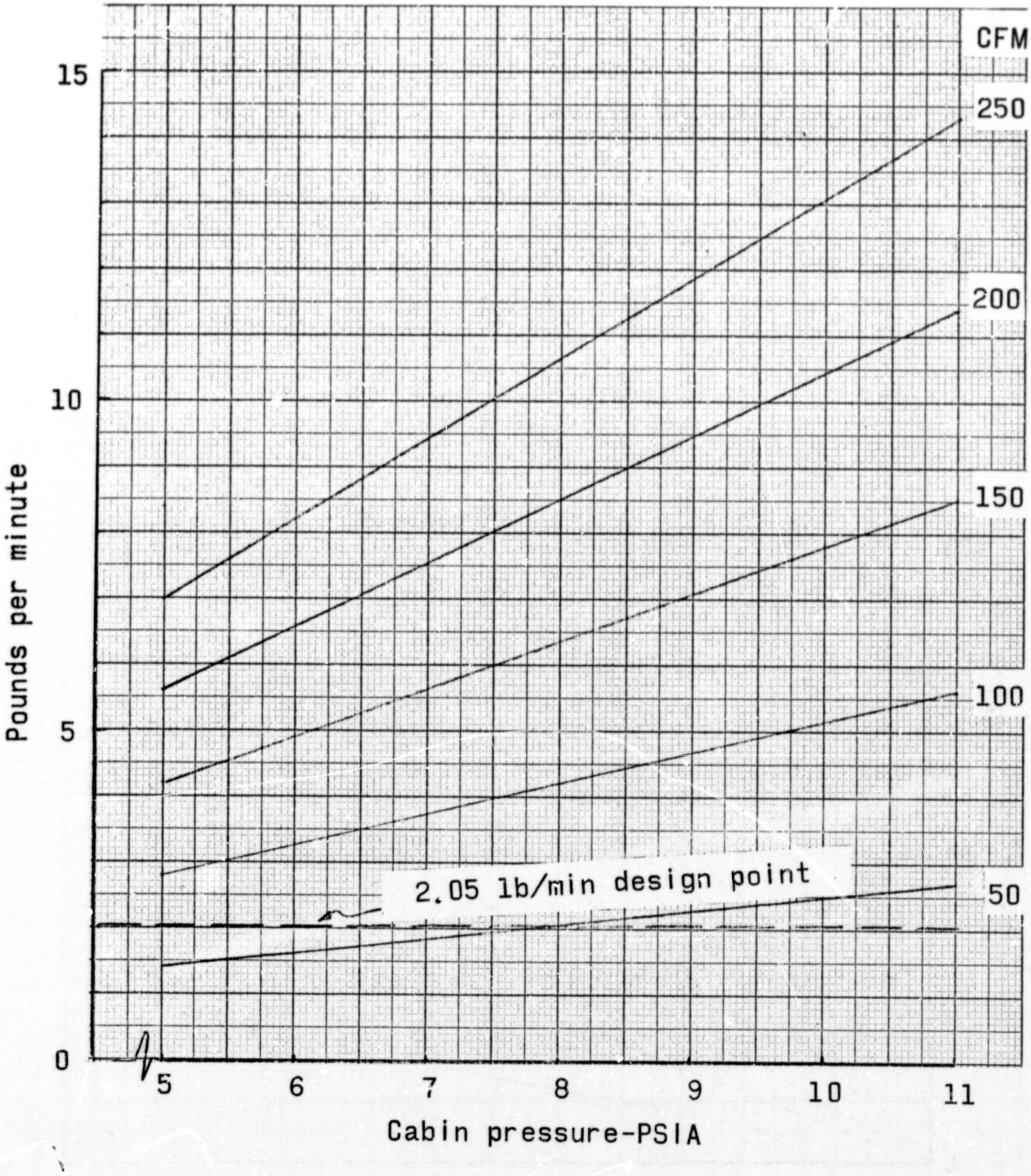

Figure 6. - Mass flow versus cabin pressure for various flow rates at 70° F and the average gas density developed in curve 3.

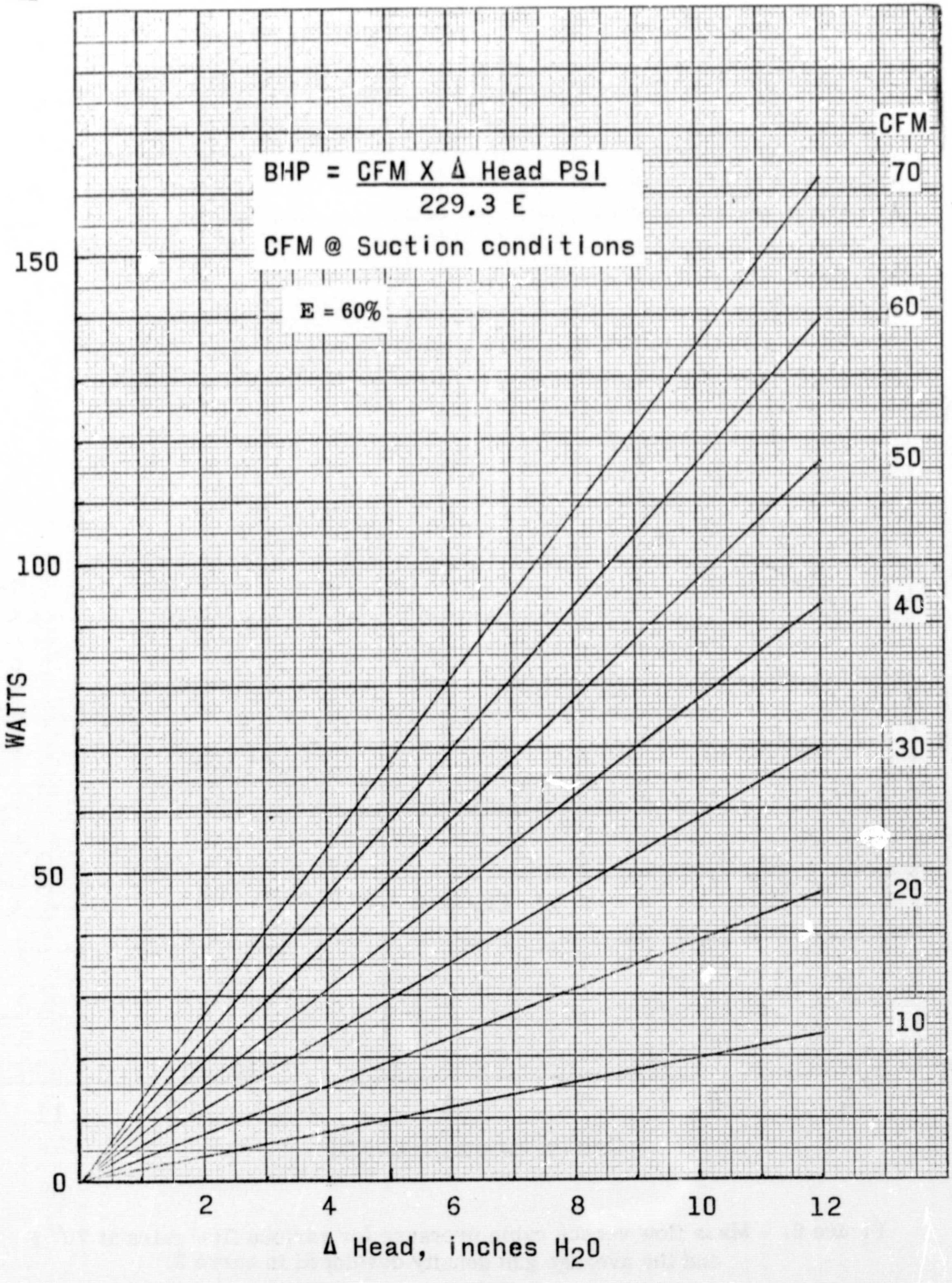

Figure 7. - Fan power for the air loop versus Δ head for various flow rates at 70° F.

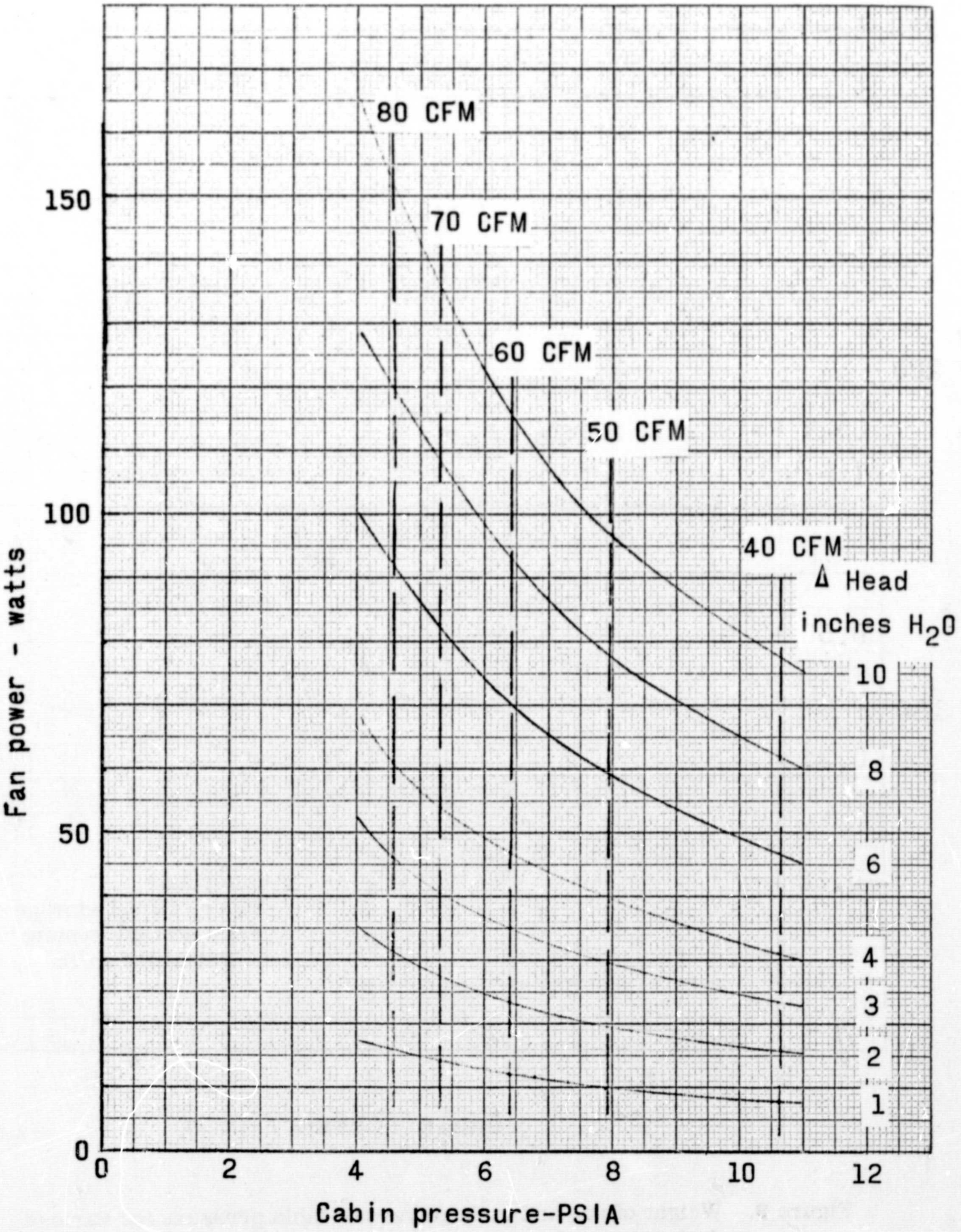

Figure 8. - Fan power, at 60% eff. for the air loop versus cabin pressure. Air flow at 2.05 lb/min and 70° F.

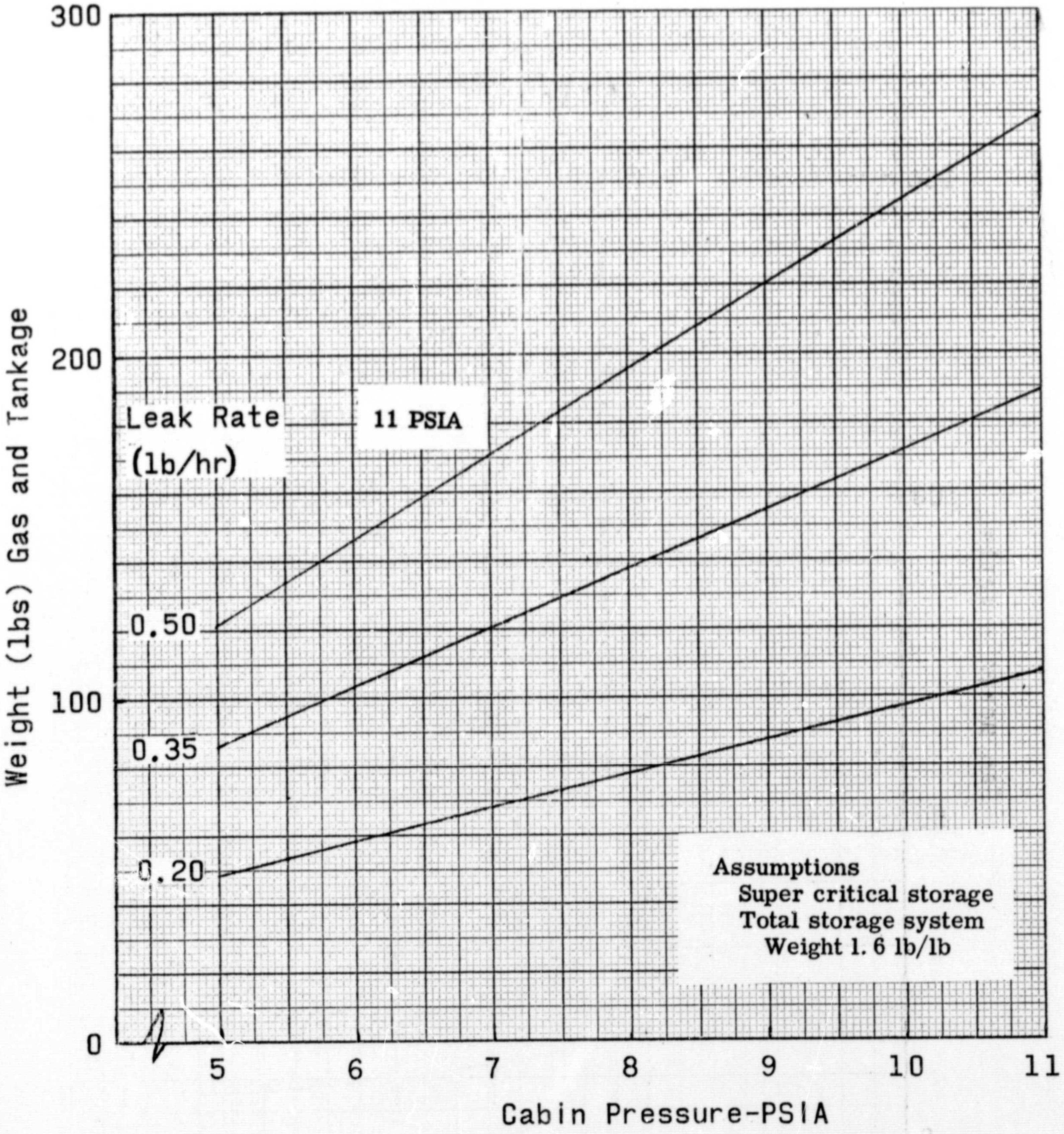

Figure 9. - Weight of gas and tankage versus cabin pressure for various leak rates and a reference pressure of 11 psia.

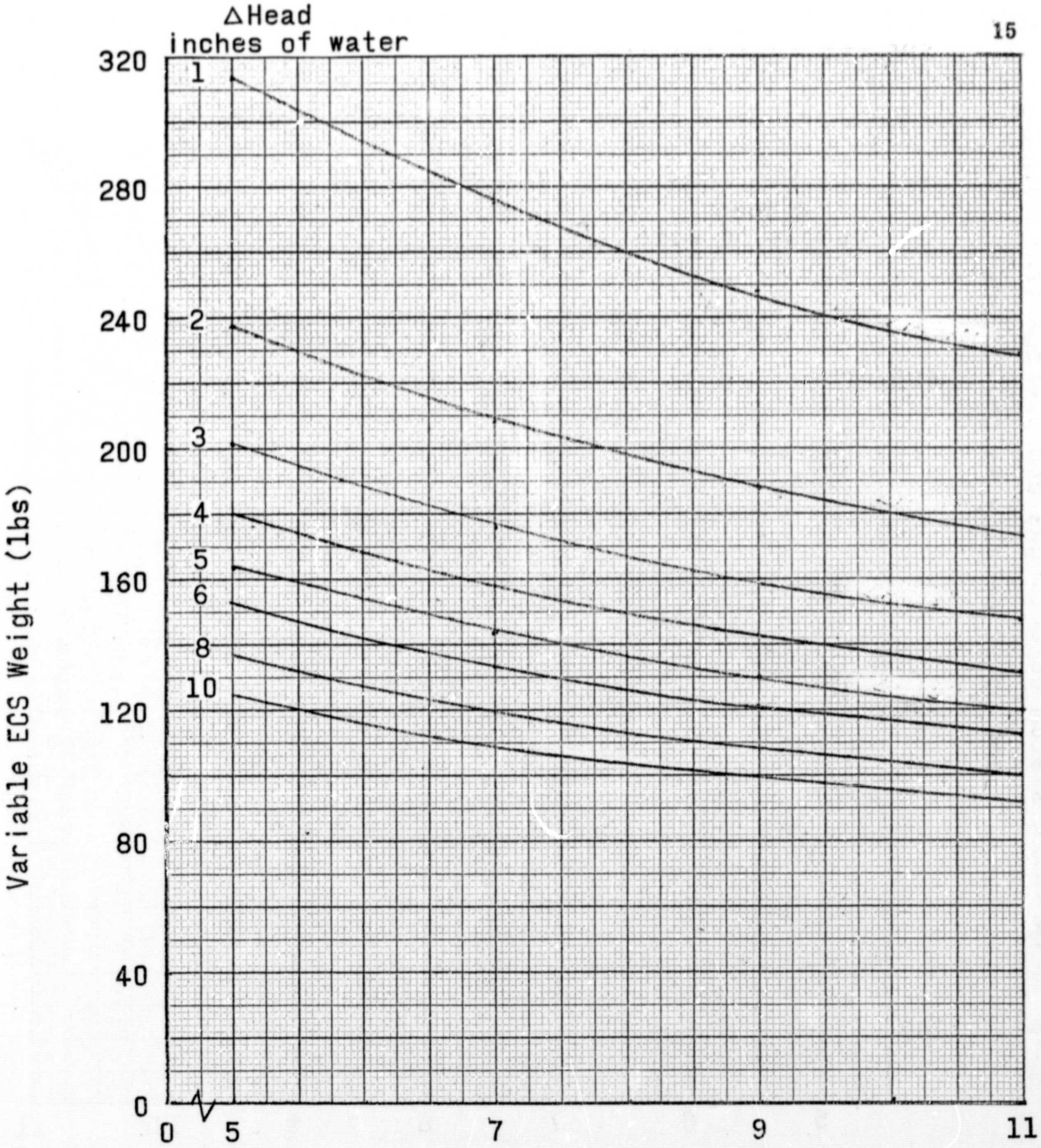

Figure 10. - Variation in ECS weight versus cabin pressure for selected system Δ head.

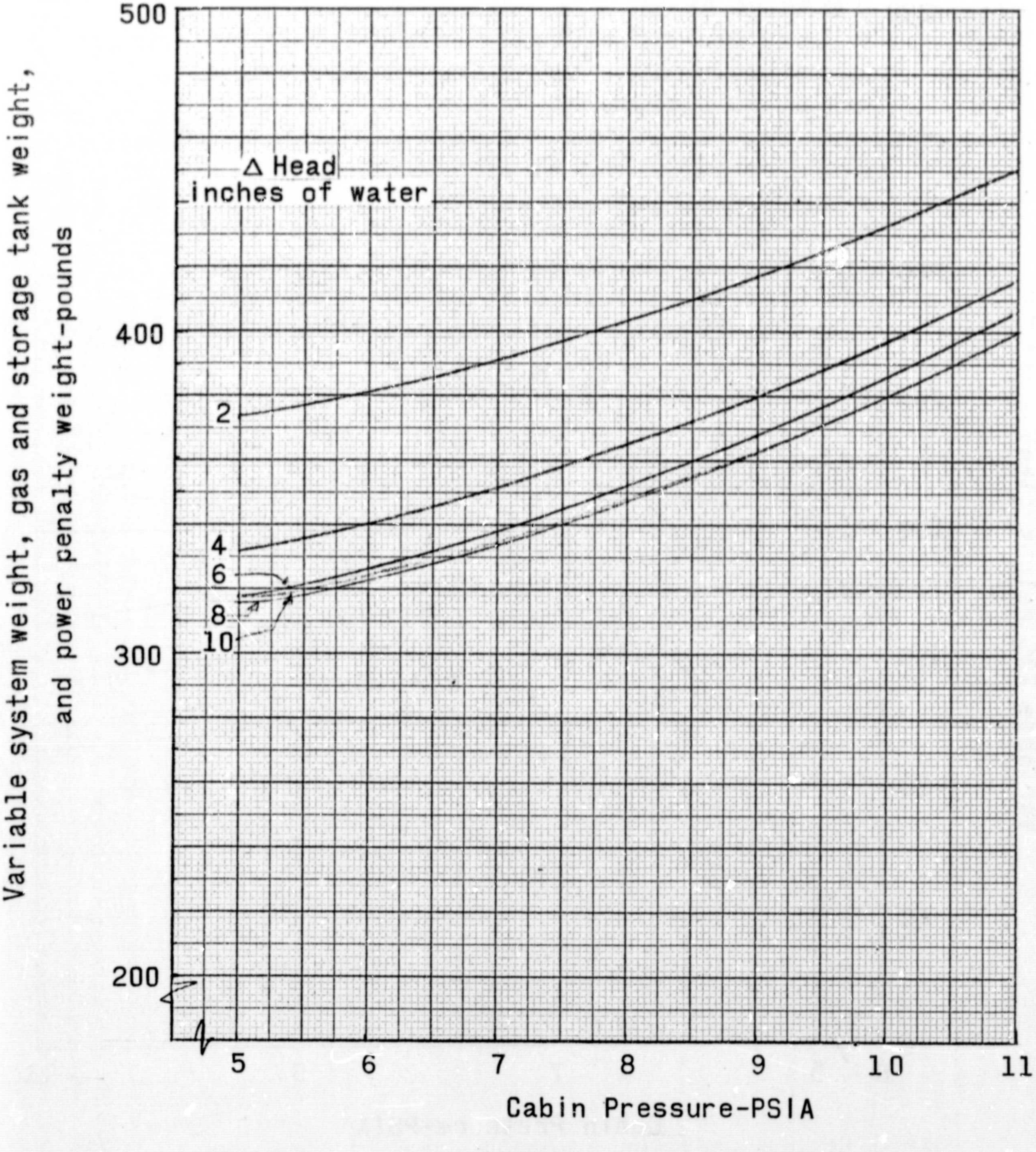

Figure 11. - Total variable ECS weights versus cabin pressure for various system Δ heads with a leakage rate of 0.50 lb/hr at a reference pressure of 11 psia.

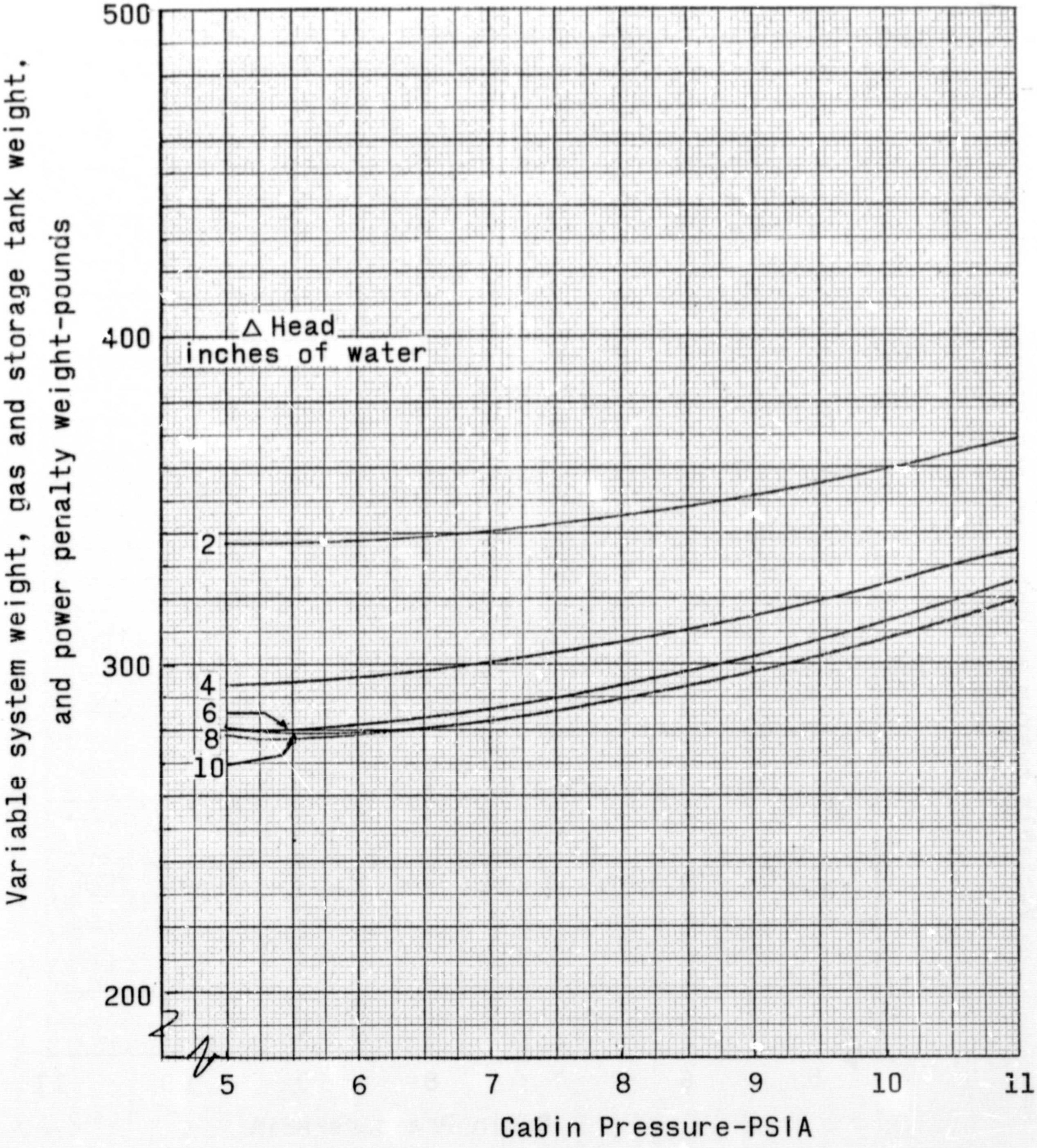

Figure 12. - Total variable ECS weights versus cabin pressure for various system Δ heads with a leakage rate of 0.35 lb/hr at a reference pressure of 11 psia.

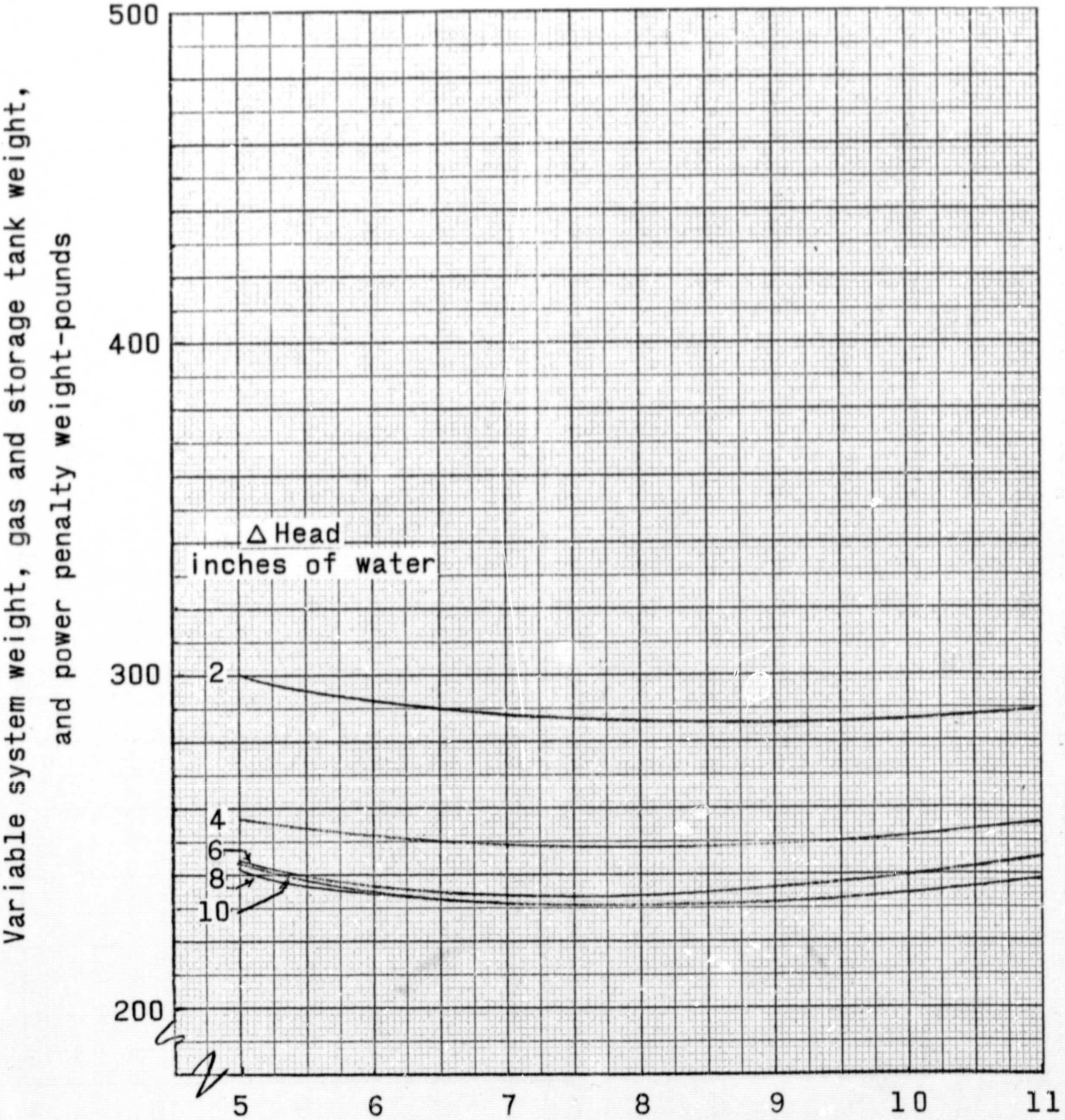

Figure 13. - Total variable ECS weights versus cabin pressure for various system Δ heads with a leakage rate of 0.20 lb/hr at a reference pressure of 11 psia.