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Pumping power requirements for de-icing of shipping lanes

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NATIONAL RESEARCH COUNCIL
DIVISION OF MECHANICAL ENGINEERING
OTTAWA, CANADA
LABORATORY MEMORANDUM

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SUBJECT Pumping Power Requirements for De-icing of Shipping Lanes

PREPARED BY G.G. Levy and G. Faucher

ISSUED TO

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SUMMARY

A preliminary assessment of the power required to pump warm substratum water to the surface from depths between zero and 600 ft. is made.

The bubbler system shows an appreciable reduction in power requirements compared to the pump system; but uncertainties in the analyses suggest that experimental verification of the results should be made.

LIST OF SYMBOLS

- V_a - Volume of free air, cu.ft./sec.
 V_w - Volume of water, cu.ft./sec.
 h_f - Head lost in friction, ft.
 h_k - Velocity head, ft.
 P_s - Absolute pressure of air leaving foot piece, psi
 P_a - Atmospheric pressure, psia

1. INTRODUCTION

De-icing of harbours and docking facilities by pumping relatively warm substratum water to the surface by means of an air bubbler system has been tried with some success. It is proposed to use the same technique to provide ice-free shipping lanes, possibly by pumping the warm water through a large tube that may either be anchored or moved by a ship.

A preliminary assessment of the power required to lift the water from various depths by means of a mechanical pump is given in this memorandum. Power requirements for a bubbler system are presented for comparison.

2. PUMP SYSTEM

In the case under consideration, no lift above the surface of the water was required, hence the pump delivery head was small and equivalent to the specified flow velocities of 5 ft/sec. and 10 ft/sec. plus wall friction losses in the tube.

Because of the small head, particularly at a flow velocity of 5 ft/sec. an air turbine driven pump was not very suitable, hence an electric motor drive was selected. Constant efficiencies of 85 percent for the motor and 80 percent for the pump were used.

Horsepower requirements are shown in Figures 1 and 2 for submergences between zero and 600 ft. and tube diameters of 2, 4, 8 and 16 ft.

3. BUBBLER SYSTEM (FIGURE 3)

Air requirements for the bubbler system were computed by the method outlined in Reference 1 for air lift pumps.

In this analysis it was assumed that the head maintaining steady flow was due to the difference in specific gravity between the mixture in the tube and the water surrounding it. This head was absorbed in overcoming friction and providing kinetic energy of efflux from the pipe.

Since zero lift was required, the air/water ratio may be expressed as:

(see Appendix)

$$\frac{V_a}{V_w} = \frac{h_f + h_k}{34 \ln \left(\frac{B}{P_a} \right)}$$

Air requirements in cubic feet of free air per cubic foot of water are plotted in Figures 4 and 5.

Horsepower requirements at the air injection point were computed on the assumption that the air followed an isothermal expansion process in the tube from the submergence pressure to atmospheric pressure.

The results are also plotted in Figures 1 and 2.

4. DISCUSSION OF RESULTS

For the purpose of this memorandum, line losses and tube entry losses were neglected. Figures 1 and 2 thus show the power required to drive the electric motor in the pump system and the power required at the foot-piece in the bubbler system, both with zero entry losses.

It should be noted that friction factors appropriate to water were used for both systems in this analysis. It would appear that a mixture of air bubbles and water would, in fact, give a larger friction factor than water alone. Although the air/water ratio for the bubbler system is small compared to a conventional air lift pump, where large lifts are normally required, it is possible that the bubbler horsepower requirements shown in Figures 1 and 2 are somewhat optimistic.

With these qualifications, the bubbler system shows a considerable advantage in power input compared to the pump system, particularly with the larger tube diameters.

5. CONCLUSIONS

5.1 At the flow velocities under consideration, the bubbler system appears to require appreciably less power than a mechanical pump system. The apparent simplicity of the bubbler system would seem to be an added advantage.

5.2 Increasing the flow velocity from 5 to 10 ft/sec. in a 16 ft. diameter tube at a submergence of 600 ft. raises the horsepower requirement from 86.5 to 690 hp. for the pump system and from 59 to 464 hp. for the bubbler system.

5.3 The crudity of the bubbler pumping theory and the lack of applicable friction data introduces considerable uncertainties into the analysis. Accordingly, experimental verification should be sought before accepting the above conclusions.

6. REFERENCES

1. Proceedings of the Institute of Mechanical Engineers, 1917.

APPENDIX

Taking $\frac{V_m}{V_w}$ to be the mean ratio of air to water by volume, the mean

specific gravity of the mixture = $\frac{V_w}{V_w + V_m}$

∴ Head maintaining steady flow = $S - \frac{(L + S) V_w}{V_w + V_m}$ ft. of water

= $\frac{V_m}{V_w} S - L$ feet of mixture in the tube (1)

This head was absorbed in overcoming friction in the tube and in giving kinetic energy of efflux from the tube, so that $\frac{V_m}{V_w} S - L = h_f + h_k$

∴ $V_m = V_w \frac{(L + h_f + h_k)}{S}$ (2)

where h_f and h_k were measured in feet of mixture in the tube.

Assuming isothermal expansion of the air in the rising main, a work balance gives:

$$V_m (P_s - P_a) = P_a V_a \ln \frac{P_s}{P_a}$$

∴ $V_m = V_a \left(\frac{P_a}{P_s - P_a} \right) \ln \frac{P_s}{P_a}$ (3)

Substituting for V_m in equation (2) gives:

$$\frac{V_a}{V_w} = \frac{L + h_f + h_k}{S \left(\frac{P_a}{P_s - P_a} \right) \ln \frac{P_s}{P_a}} \quad (4)$$

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Taking P_s as being equal to the absolute pressure at depths S , and P_s and P_a as pressures in feet of water, $\frac{P_a}{P_s - P_a} = \frac{34}{34 + S - 34} = \frac{34}{S}$

$$\therefore \frac{V_a}{V_w} = \frac{L + h_f + h_k}{34 \ln \frac{P_s}{P_a}} \quad (5)$$

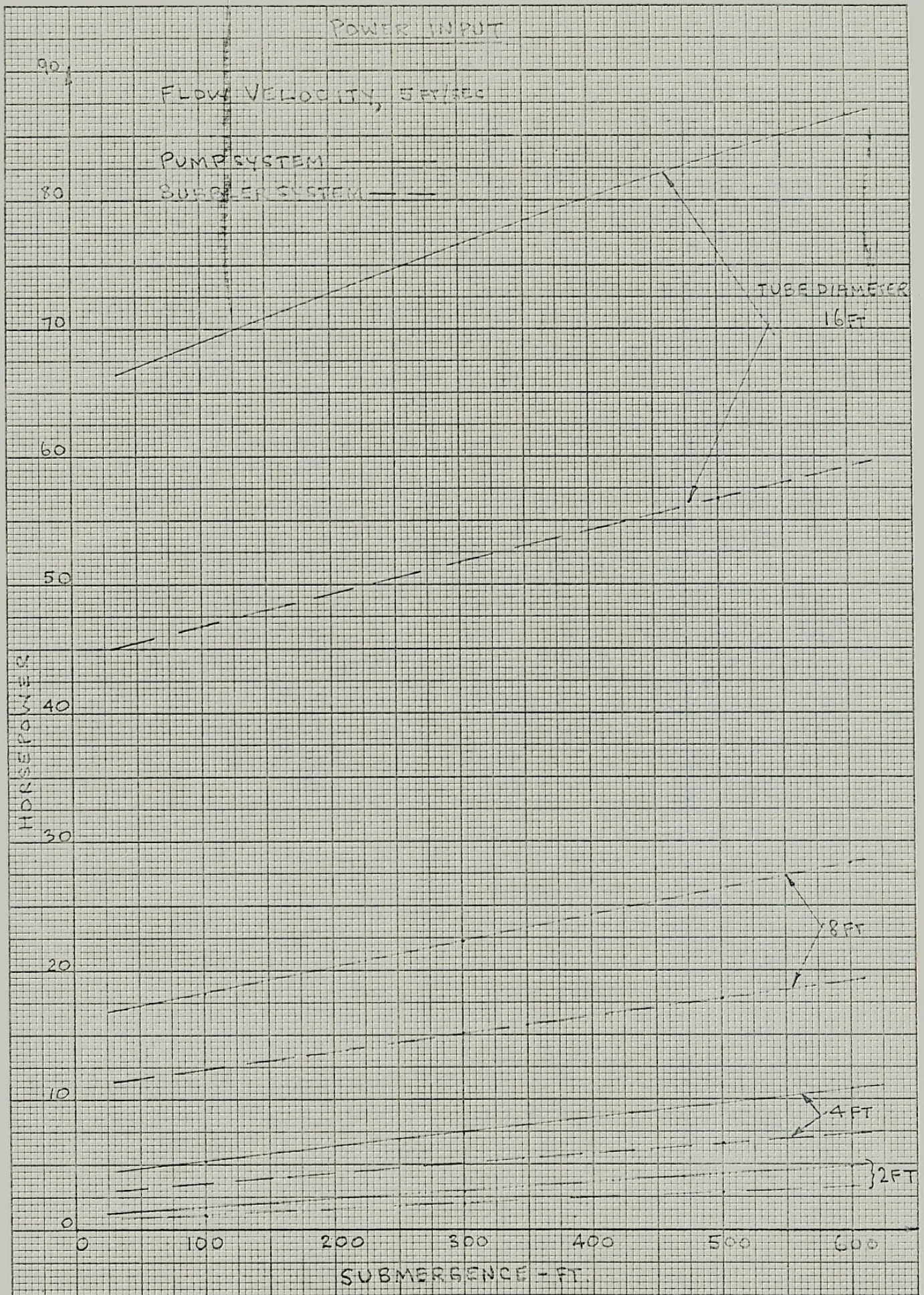


FIG I

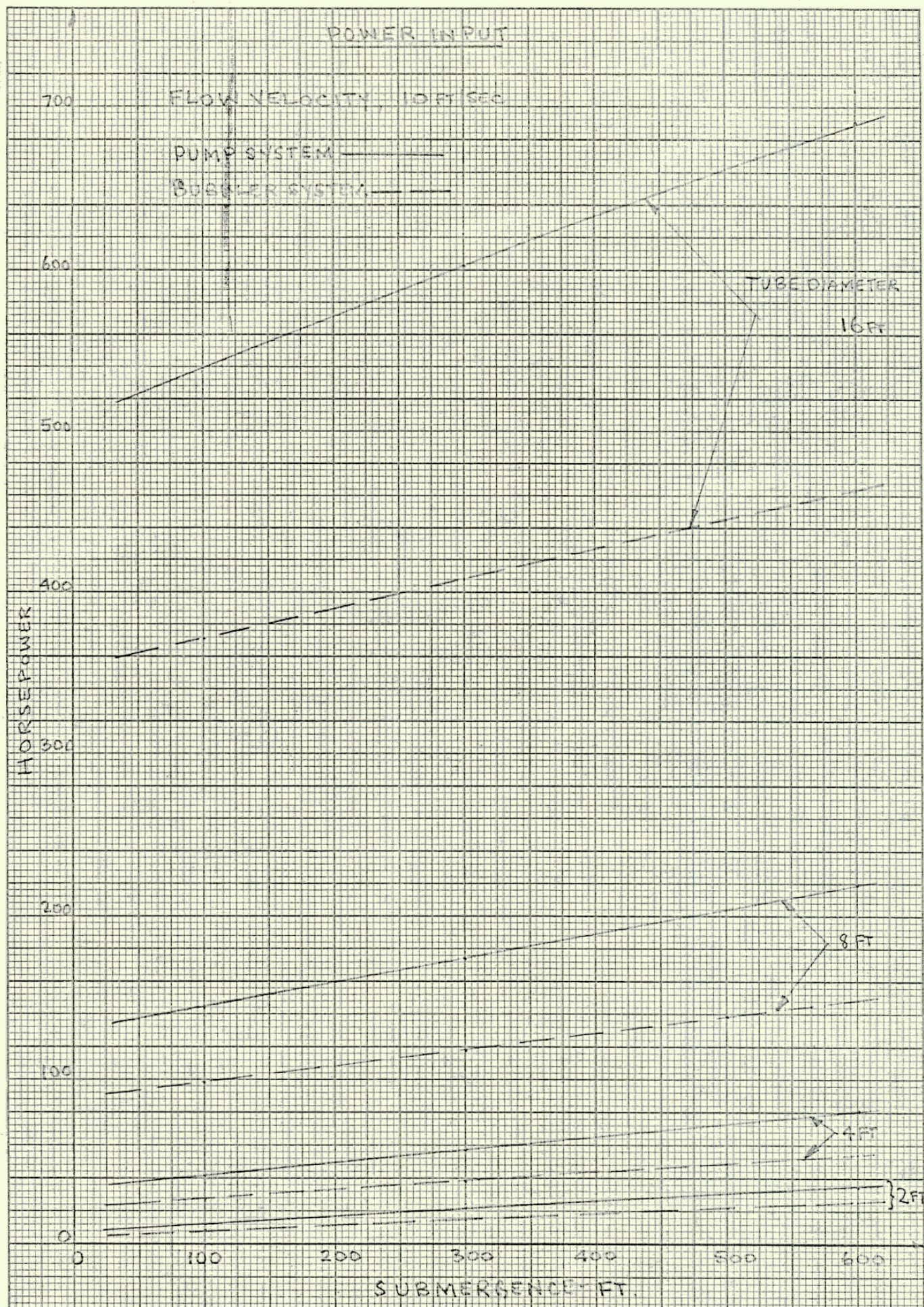


FIG 2

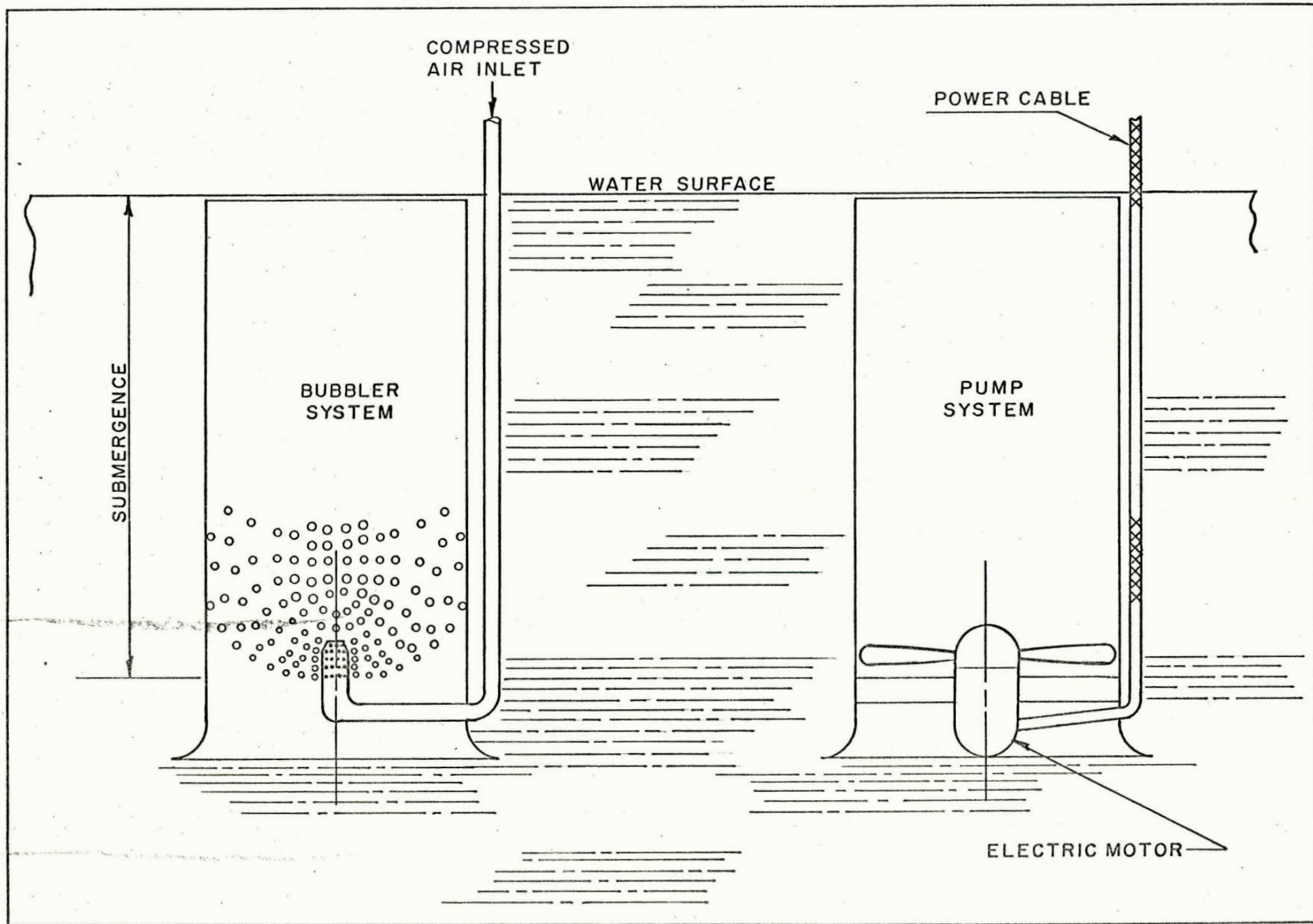


FIG 3

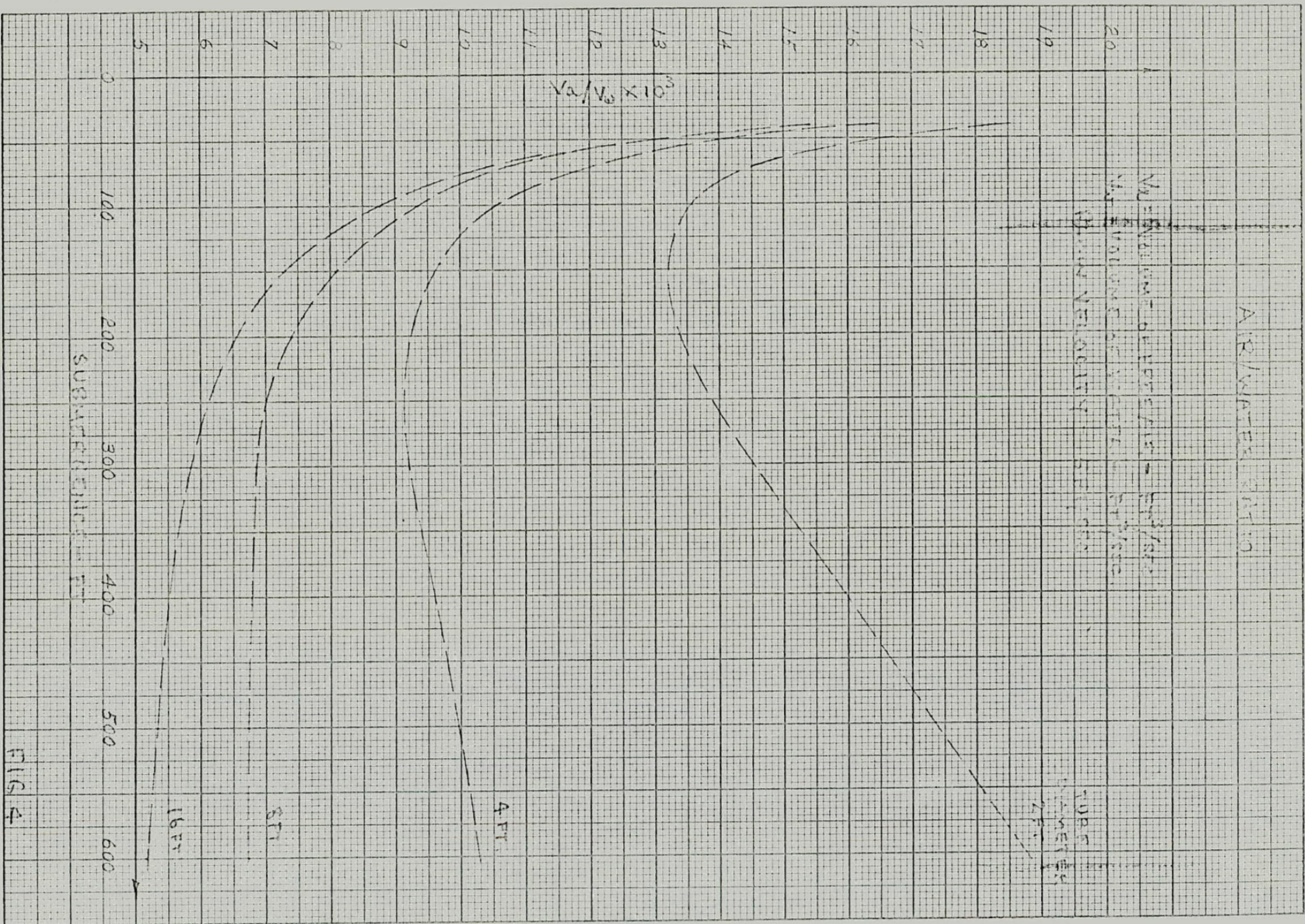


FIG. 4

AIR/WATER RATIO

V_a - VOLUME OF FREE AIR - FT³/SEC

V_w - VOLUME OF WATER - FT³/SEC

V_a/V_w - AIR/WATER RATIO

TUBE
DIAMETER
2 FT

70

50

30

40

30

20

10

0

$V_a/V_w \times 10^3$

4 FT

8 FT

16 FT

0 100 200 300 400 500 600

SUBMERGENCE - FT

FIG. 5