

U. S. NAVY EXPERIMENTAL DIVING UNIT
U. S. NAVAL WEAPONS PLANT
WASHINGTON 25, D. C.

EVALUATION REPORT 9-60

EVALUATION OF DACOR DIVING LUNG
WITH DIAL-A-BREATH FEATURE

PROJECT 185-005 SUBTASK 4 TEST 61

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21 DECEMBER 1959

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ABSTRACT

An open circuit, self contained underwater breathing apparatus was given the standard evaluation for equipment of this type. The apparatus did not meet the criteria for breathing resistance.

SUMMARY

PROBLEM:

Does the new Dacor Diving Lung with the Dial-A-Breath feature meet the criteria for acceptance for use in the U.S.Navy?

FINDINGS:

The new Dacor Diving Lung with the Dial-A-Breath features does not meet the criteria in the following respects:

- (1) The breathing resistance is too high.
- (2) The cylinders are not non-magnetic.
- (3) The cylinders do not meet the 3000 psi working pressure requirement.

RECOMMENDATIONS:

It is recommended that the new Dacor Diving Lung with the Dial-A-Breath feature not be accepted for use in the U.S. Navy. It is further recommended that the manufacturer reduce the breathing resistance of the regulator before resubmitting it for evaluation.

ADMINISTRATIVE INFORMATION

- Ref: (a) EDU Evaluation Report 11-56 "Dacor Diving Lung" 19 March 1956
(b) EDU Evaluation Report 5-57 "Dacor Diving Lung-Second Evaluation" 1 August 1956
(c) BuShips ltr Ser 6380-1222 dtd 24 Jun 1956
(d) Dacor Corporation ltr to EDU dtd 28 July 1959

Reference (a) reference (b) are the reports of evaluation of the "Dacor Diving Lung" conducted at the Experimental Diving Unit in 1956. Reference (c) authorized the Dacor Corporation, Evanston, Ill. to submit the new "Dacor Diving Lung" with a Dial-A-Breath feature with the Experimental Diving Unit for evaluation

Reference (d) stated that the Dacor Corporation had shipped two complete diving lungs to the Experimental Diving Unit. Reference (d) further stated that the primary difference between the new Dacor Diving Lung and the one evaluated previously was the addition of the "Dial-A-Breath" feature.

R.L. Gwinn, MM1(DV), USN was designated project engineer, Work commenced on 5 August 1959 and was completed on 3 September 1959. The following breakdown indicated the estimated manpower expended for this project:

<u>DESCRIPTION</u>	<u>MANHOURS</u>
Mechanical Respirator Tests	36
Human subject tests	75
Subjective tests	15
Drafting	10
Report Preparation	12
Clerical	6
TOTAL	<u>154</u>

Charges incurred in the execution of the project were lodged against allotment 70102/60.

This is the first report under this project number. The report is issued in the Experimental Diving Unit Report series and is distributed only to the Bureau of Ships.

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1. INTRODUCTION

1.1 Background

1.1.1 The "Dacor Diving Lung" is an open-circuit self-contained underwater breathing apparatus. The Dacor apparatus was evaluated at the Experimental Diving Unit in 1956. It was found to be not suitable for use in the U.S. Navy in EDU Evaluation Report 11-56, "Dacor Diving Lung", 19 March 1956. After modifications, made by the manufacturer, the Dacor Diving Lung was found to be suitable for use in the Naval Service in EDU Evaluation Report 5-57, "Dacor Diving Lung - Second Evaluation", 1 August 1956.

1.1.2 Two new Dacor Diving Lungs with a "Dial-A-Breath" feature were submitted to the Experimental Diving Unit for evaluation in July 1956. In his letter dated 28 July 1959, the manufacturer stated that the only change of consequence in the design of the demand regulators is the new Dial-A-Breath feature.

1.2 Objective

1.2.1 The objective of this evaluation is to determine whether the new Dacor Diving Lung with the Dial-A-Breath feature is suitable for use in the U.S. Navy.

1.3 Scope

1.3.1 This evaluation consisted of the standard evaluation procedure for open circuit scuba. This procedure deals primarily with the breathing characteristics of the demand regulator.

2. DESCRIPTION

2.1 General

2.1.1 The Dacor Diving Lung is an open circuit self contained underwater breathing apparatus consisting of one or two compressed air cylinders, harness, regulator assembly (which is mounted on the cylinder manifold), corrugated breathing hoses, and a mouthpiece. The units submitted for this evaluation each have only one compressed air cylinder.

2.1.2 The overall length of the apparatus from the bottom of the cylinder to the top of the valve is 29 inches. The diameter of the cylinder is 6 3/4 inches.

2.1.3 The overall weight of the apparatus when empty is 34 lbs. When charged to 2150 psi the weight is 37 1/2 lbs.

2.1.4 The buoyancy of the apparatus when empty is 1 lb. 13 oz. negative; when the cylinder is charged to 2150 psi it is 5 lb. 4 oz. negative.

2.2 Regulator Assembly

2.2.1 The regulator assembly consists of the following major components:

- (1) Coupling yoke
- (2) High pressure body and first stage regulator
- (3) Low pressure body and demand regulator
- (4) Regulator cover

The regulator is described as a two stage, double diaphragm, demand regulator.

2.2.2 The coupling yoke is a modified medical yoke similar to other yokes used in self contained underwater breathing apparatus.

2.2.3 The high pressure body fits directly to the manifold of the compressed air cylinder and contains the first stage regulator. The first stage regulator reduces the high pressure air from the cylinders to approximately 100 psi over the ambient pressure.

2.2.4 The low pressure body contains the mechanism of the demand system. The demand system consists of a double diaphragm which operates a low pressure valve, allowing air to flow to the breathing hoses whenever the pressure in the inhalation hose is reduced sufficiently below the ambient pressure. The lower half of the double diaphragm normally operates the demand valve. The upper diaphragm contains a one way exhaust valve and will operate the demand valve if the lower diaphragm is punctured. Figure 1 is a simplified cut-away diagram of the regulator assembly.

2.2.5 The Dial-A-Breath feature consists of a small fist "butterfly" or choke valve installed near the outlet from the intake chamber of the regulator. This valve can be rotated by means of a knurled knob on the outside of the regulator. Rotation of the butterfly valve varies the amount of obstructing area in the air flow path and therefore varies the flow resistance in the inhalation circuit of the apparatus.

2.3 Mouthpiece and Breathing Hoses

2.3.1 The mouthbit and tee connector are molded in one piece of soft, black, rubber. The mouthpiece is of a different shape than most mouthpieces, having an indentation in the center of both the top and bottom lip flanges. The mouthpiece contains inhalation and exhalation check valves mounted in nylon housings. The center of the tee connector or valve chamber is set slightly below the mouthbit, providing a water trap. Figure 2 contains diagrams of the mouthpiece.

2.3.2 The breathing hoses are molded of black rubber. The minimum internal diameter of the hoses is 1 1/2 inches.

2.4 Cylinder and Harness

2.4.1 The compressed air supply cylinder is a nominal 70 cubic foot cylinder with an ICC working pressure of 2150 psi. The cylinder is made of steel and is galvanized. The top of the cylinder is fitted with a shut off valve, a seat for the yoke connector, and a reserve valve. The reserve valve is a restricted orifice type.

2.4.2 The cylinder mounting consists of two metal bands. A cotton web harness is attached to the two bands. The harness consists of two straps rigged to provide two shoulder straps, a waist strap and a jock strap. The straps are fitted with metal tips and D-rings.

3. PROCEDURE

3.1 Mechanical Respirator

3.1.1 Standard mechanical respirator tests were made using the MSA rubber bellows mechanical respirator. The respirator was set for a tidal volume of two liters per breath and a respiratory rate of twenty breaths per minute.

3.1.2 Two series of mechanical respirator measurements were made as follows:

- (1) Breathing pressure vs. depth
- (2) Breathing pressure vs. cylinder pressure

Each series was conducted with the Dial-A-Breath valve wide open and again with the Dial-A-Breath closed.

3.1.3 The details of the instrumentation and test procedure are described in Experimental Diving Unit Research Report 6-58, "Mechanical Respirator Techniques in the Evaluation of Scuba", dated 30 June 1958.

3.2 Depth Tests Using Human Subjects

3.2.1 Three subjects each made three swims at surface pressure and at a pressure equivalent to 200 feet of sea water, using the Dacor Diving Lung regulator and mouthpiece assembly. During each swim the exhalation and inhalation pressure in the mouthpiece, the respiratory minute volume (average volume of air inspired per minute), and the respiratory rate were measured. The subjects were swimming against a constant force of 12 pounds during each swim.

3.2.2 Instrumentation for the swims consisted of the following:

(1) A ± 1 psid pressure transducer was connected to a tap in the mouthpiece with the reference side at the hydrostatic pressure adjacent to the demand regulator. The signal from the pressure transducer was amplified and recorded continuously throughout each swim.

(2) A "bubble-catcher" and gas meter arrangement was used which collected all of the exhaled gas and measured the volume throughout each swim.

(3) The subjects swam on a "trapeze swim exgometer" which is a device which permits a swimmer to exert a constant, known force, while remaining stationary in a pressure tank. The force used for all of the swims in this evaluation was 12 pounds.

(4) A pressure gage was attached to the compressed air supply cylinders so that the supply pressure could be measured throughout the swim. The cylinder pressure was recorded at the end of each minute.

3.3.3 Using the instrumentation described above, the subject swam against the trapeze, using the Dacor Diving Lung regulator with the Dial-A-Matic feature for ten minutes in the pressure tank at surface pressure. The diver was approximately three feet below the surface of the water. The pressure in the pressure tank was then increased to the equivalent of 200 feet of sea water and the subject again swam for ten minutes.

3.2.4 The Dial-A-Matic feature was adjusted by the individual subject before each swim. Adjustment was usually accomplished by opening the Dial-A-Breath all the way and then make a sharp inhalation. This caused the regulator to give a continuous flow if the mouthpiece was immediately removed from the subjects mouth. The Dial-A-Breath knob was then turned until the continuous flow stopped. The position of the knob was approximately centered between the two extreme positions after such an adjustment. The knob was not adjusted again during either the surface or the depth swim.

3.3 Subjective Tests

3.3.1 Four subjects used the Dacor Diving Lung in a swimming pool. Each subject used the apparatus in various positions observing the buoyancy, torque, breathing resistance and flooding and clearing characteristics. The Dial-A-Breath knob was adjusted to various positions. After completing his swim, each subject submitted his comments on the apparatus.

3.3.2 Since the reserve valve is designed to warn the diver when he has only 300 psi left in his cylinders by an increase in breathing resistance, the reserve valve was evaluated subjectively. Two divers used the Dacor Diving Lung with the reserve valve up until an increase in breathing resistance was noticed. The pressure in the supply cylinders was then measured. This procedure was conducted at the surface and again at a pressure equivalent to 100 feet of sea water.

3.4 Maintenance

3.4.1 The evaluation of the Dacor Diving Lung from the point of view of maintenance was made by the Scuba maintenance technician at the Experimental Diving Unit. The conclusions pertaining to the maintenance characteristics of this apparatus are primarily the opinions of this technician based on his previous experience with this type of equipment.

4. RESULTS

4.1 Mechanical Respirator Test

4.1.1 The data from the mechanical respirator tests are plotted as follows:

- (1) Figure 3 Breathing Pressure vs. Supply Pressure
- (2) Figure 4 Breathing Pressure vs. Depth

Plots of the data obtained from a competitive regulator and the mechanical respirator criteria for acceptance are also plotted on figure 4 for comparison. The mechanical respirator data which are plotted are the peak inhalation and exhalation pressures expressed in cm. of water.

4.2 Depth Tests Using Human Subjects

4.2.1 The data obtained from the depth tests are peak breathing pressures, respiratory minute volume, and respiratory rate. Figures 5,6, and 7 are plots of this data. A separate plot is made for each subject. The numbers beside the data points refer to the number of the dive for that subject using the Dacor Diving Lung.

4.2.2 Each data point represents the average of the data obtained during the second five minutes of each 10 minute swim. Previous experience has indicated that the subjects settle down by the time they have been swimming for five minutes. The data obtained during the second five minutes are normally quite consistent; whereas the data obtained during the first five minutes are constantly changing. Therefore, the first five minutes is considered as "warm-up time" and the data obtained during that time is not included in the average.

4.3 Subjective Tests

4.3.1 After using the Dacor Diving Lung in the swimming pool and the pressure tank, the following conclusions were reached:

- (1) The general comfort of the apparatus is good. The mouthpiece is comfortable.
- (2) The harness straps are too long for most subjects. The harness is fairly easy to adjust.
- (3) The apparatus does not restrict the maneuverability of a swimmer.
- (4) The apparatus is very easy to clear. Almost no flooding occurs when the mouthpiece is removed from the mouth underwater.
- (5) The apparatus seemed to be approximately neutrally buoyant in the water.
- (6) No appreciable torque was noticed in any position.
- (7) The breathing resistance at the bottom of the swimming pool did not seem very high. When lying on the back, a slight positive pressure is noticeable in the mouthpiece. If the mouthpiece is removed from the mouth while lying on the back, a continuous flow of air results.

4.3.2 When divers performing light work used the Dacor Diving Lung, it was found that a definitely noticeable increase in breathing resistance did not occur until the cylinder pressure had dropped to approximately 75 psi at the surface and 125 to 175 psi at a depth of 100 feet. After pulling the reserve valve to the down position, the breathing resistance was reduced until the cylinders were nearly empty. When breathing at a rate corresponding to hard work, a noticeable increase in breathing resistance occurred at approximately 300 psi at the surface. This test was not conducted at depth.

4.3.3 After using the Dacor Diving Lung with the Dial-A-Matic in various positions, most of the subjects preferred to set the knob so that maximum breathing resistance without continuous flow was obtained. This adjustment is made as described in 3.2.4. Adjustment of the knob with wet hands is sometimes difficult due to small diameter of the adjusting knob.

4.4 Maintenance

4.4.1 No maintenance problems were encountered during the tests of the Dacor Diving Lung. It is the opinion of the Scuba maintenance technician that the maintenance required for the Dacor Diving Lung would be comparable to other similar regulators. No special problems are anticipated.

5. DISCUSSION

5.1 Mechanical Respirator Tests

5.1.1 Figure 4 shows that the breathing pressures of the new Dacor Diving Lung

with the Dial-A-Breath exceeds the criteria of the military specifications for divers demand regulators even with the Dial-A-Breath all the way open. The breathing pressures of the new regulator are slightly higher than the breathing pressures which were measured for the Dacor Diving Lung in 1956. The current specifications for demand regulators MIL-R-19558 (SHIPS) is dated 14 August 1956. The breathing resistance criteria in this specification are more severe than the criteria upon which the previous evaluation of the Dacor Diving Lung was based. However, a comparison of the breathing pressures obtained in 1956 (EDU Evaluation Report 11-56) with the criteria shows that the breathing pressures of that regulator also exceed the criteria of the new specification.

5.1.2 A plot of the breathing resistance of a recently evaluated demand regulator is also contained in figure 4 for comparison with the criteria and with the breathing resistance of the Dacor Diving Lung. This regulator was within the criteria at all points.

5.1.3 Figure 3 shows that the effect of decreasing cylinder pressure on the breathing resistance of the Dacor Diving Lung regulator is small for cylinders pressure from 3000 psi down to 100 psi. This characteristic is desirable and indicates that the first stage regulator of the Dacor Diving Lung is very good.

5.2 Depth Test using Human Subjects

5.2.1 The criteria for the acceptable performance of a demand regulator during the depth tests requires that the breathing pressures produced by a man swimming against an eight pound force at a pressure equivalent to 200 feet of sea water shall not exceed 20 cm. of water. A recommendation was recently submitted to change the force against which the subject must swim, from eight pounds to twelve pounds and the Dacor Diving Lung was tested in accordance with this recommendation. This modification does not effect the determination of the acceptability of the Dacor Diving Lung since it failed to meet the present criteria for the mechanical respirator phase of the evaluation.

5.2.2 Figures 5, 6 and 7 show that the exhalation pressure exceeded the 20 cm. criteria in six of the nine dives and the inhalation pressure exceeded the criteria in five of the nine dives. The data obtained from identical tests (using the same subject) performed on the recently evaluated demand regulator discussed in 5.1.2 are plotted on figure 7 for comparison. It is seen that this regulator easily met the inhalation criteria, but slightly exceeded the exhalation criteria on two of the dives. It can also be seen that the respiratory minute volume was higher during the tests of this regulator than the respiratory minute volume during the tests of the Dacor Diving Lungs even though the respiratory rate was essentially the same. This indicates that lower flow rates were obtained with higher inspiratory pressure when using the Dacor Diving Lung.

5.3 Subjective Tests and Comparison of Results

5.3.1 The results of the subjective phase of the evaluations were essentially favorable. The inhalation resistance encountered during normal use of the Dacor Diving Lung seems very low subjectively, although the exhalation resistance is noticeably a little higher. With the Dial-A-Breath valve all the way open, air can be obtained with almost no effort once inhalation has been

This would seem to contradict the objective findings of the mechanical respirator and depth test phase of the evaluation. The reason for this apparent contradiction is the fact that during the usual use of breathing apparatus, the high flow rates encountered during the objective test are not required. The criteria for the regulator are based on the maximum anticipated requirements of a diver or swimmer. This is necessary to provide for heavy work or an emergency situation during which the diver would need very high flow rates with a minimum of breathing effort.

5.3.2 The Dacor Diving Lung regulator requires excessive breathing pressures to deliver the required flows of air. This is probably due to the following:

(1) Inhalation - either the reduced pressure is too low or the orifice through which the air must pass is too small.

(2) Exhalation - the cross-sectional area of the minimum restriction in the exhalation circuit is too small; this restriction may be the exhaust valve in the diaphragm.

5.3.3 The mouthpiece of the Dacor Diving Lung was found to be very comfortable. Extensive tests to determine the comfort of this mouthpiece were not conducted, however. The shape of the mouthpiece is different from any previously evaluated mouthpiece. The indentations in the lip flange are considered to be an improvement in the mouthpiece design.

5.4 Reserve Valve and Cylinders

5.4.1 The tests of the reserve valve indicate that the amount of reserve air supply which a diver will have can be considerably less than 300 psi. This is an undesirable feature. The reserve valve does have the advantage of simplicity of design. Another advantageous feature of this type of reserve valve is that the cylinders can be charged with the reserve valve in any position, eliminating the possibility of unknowingly getting only a partial charge in the cylinders.

5.4.2 The air supply cylinders are made of steel which means they would undoubtedly not meet the non-magnetic requirements. The cylinders have a working pressure of only 2150 psi which does not meet the requirement of 3000 psi.

5.4.3 It should be pointed out that the cylinders and reserve valve do not affect the acceptability of the regulator assembly, since the various components are considered separately.

6. CONCLUSION

6.1 CONSLUSIONS

6.1.1 The following conclusions apply to the new Dacor Diving Lung with the Dial-A-Breath feature:

- (1) The regulator does not meet the breathing resistance criteria for acceptance.
- (2) The mouthpiece design is good.
- (3) The air supply cylinders do not meet the pressure and magnetic requirements.

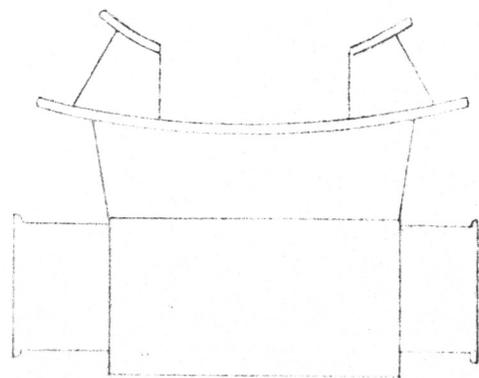
(4) The Dial-A-Breath feature does provide some variation in the breathing resistance.

6.2 Recommendations

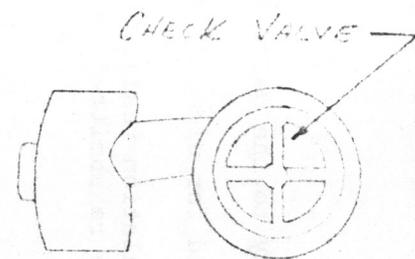
6.2.1 The following are recommendations which apply to the Dacor Diving Lung:

(1) The Dacor Diving Lung should not be accepted for use in the U.S.Navy.

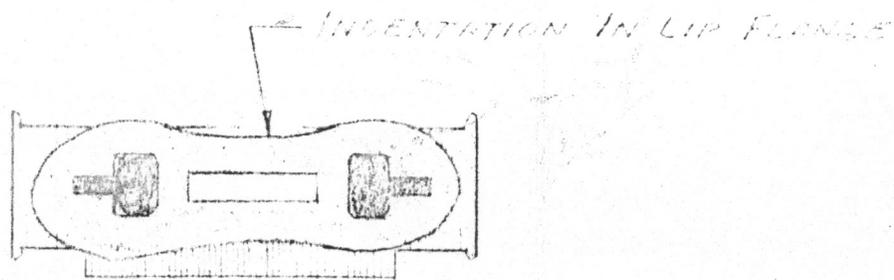
(2) The source of the high inhalation and exhalation resistance should be located and eliminated if the regulator is to be resubmitted for further evaluation.



TOP VIEW



SIDE VIEW



FRONT VIEW

FIGURE - B

DACOR DIVING LUNG MOUTHPIECE ASSEMBLY

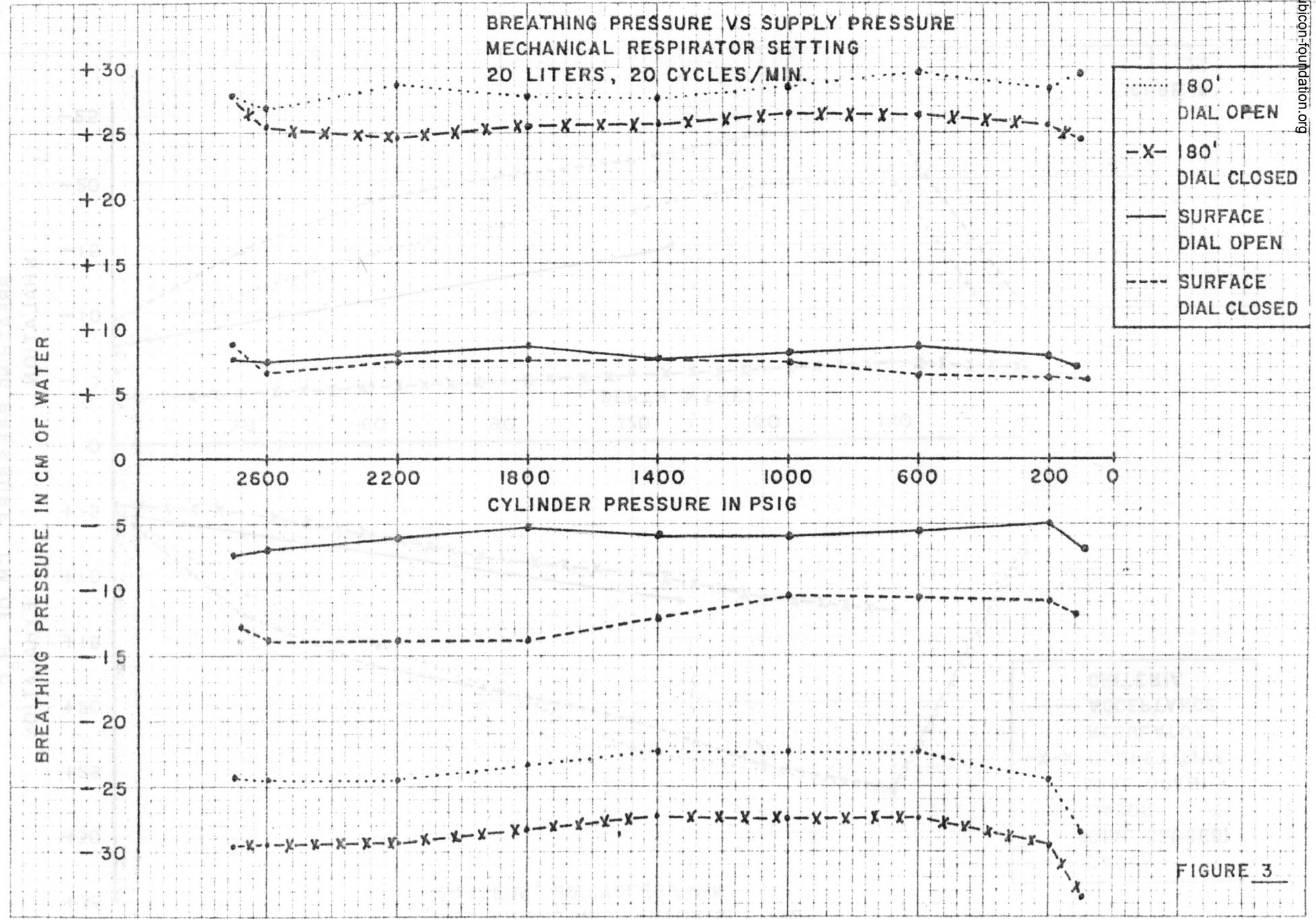


FIGURE 3

BREATHING PRESSURE VS DEPTH
MECHANICAL RESPIRATOR SETTING
2 LITERS, 20 CYCLES / MIN.

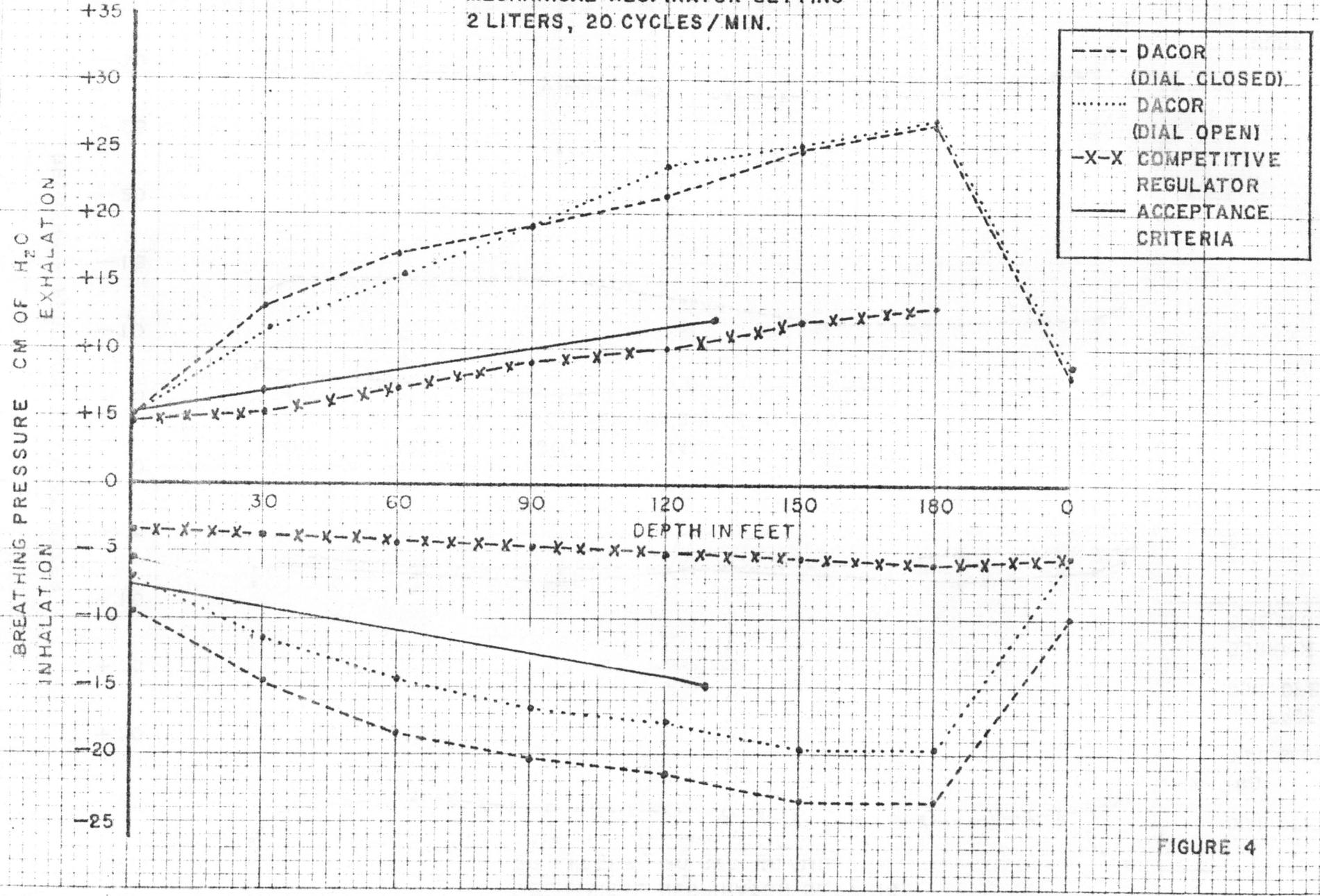
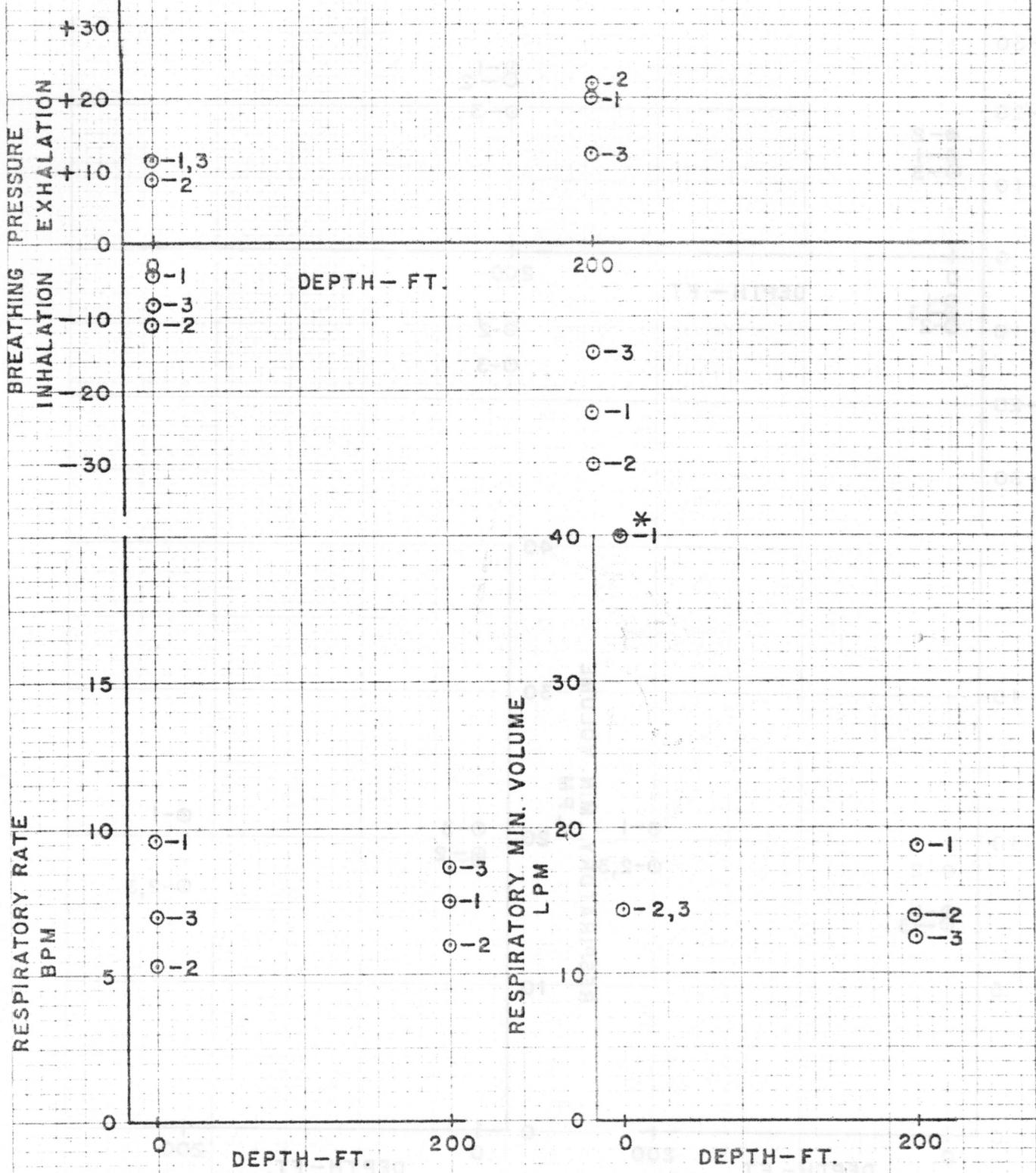


FIGURE 4

DEPTH TEST DATA



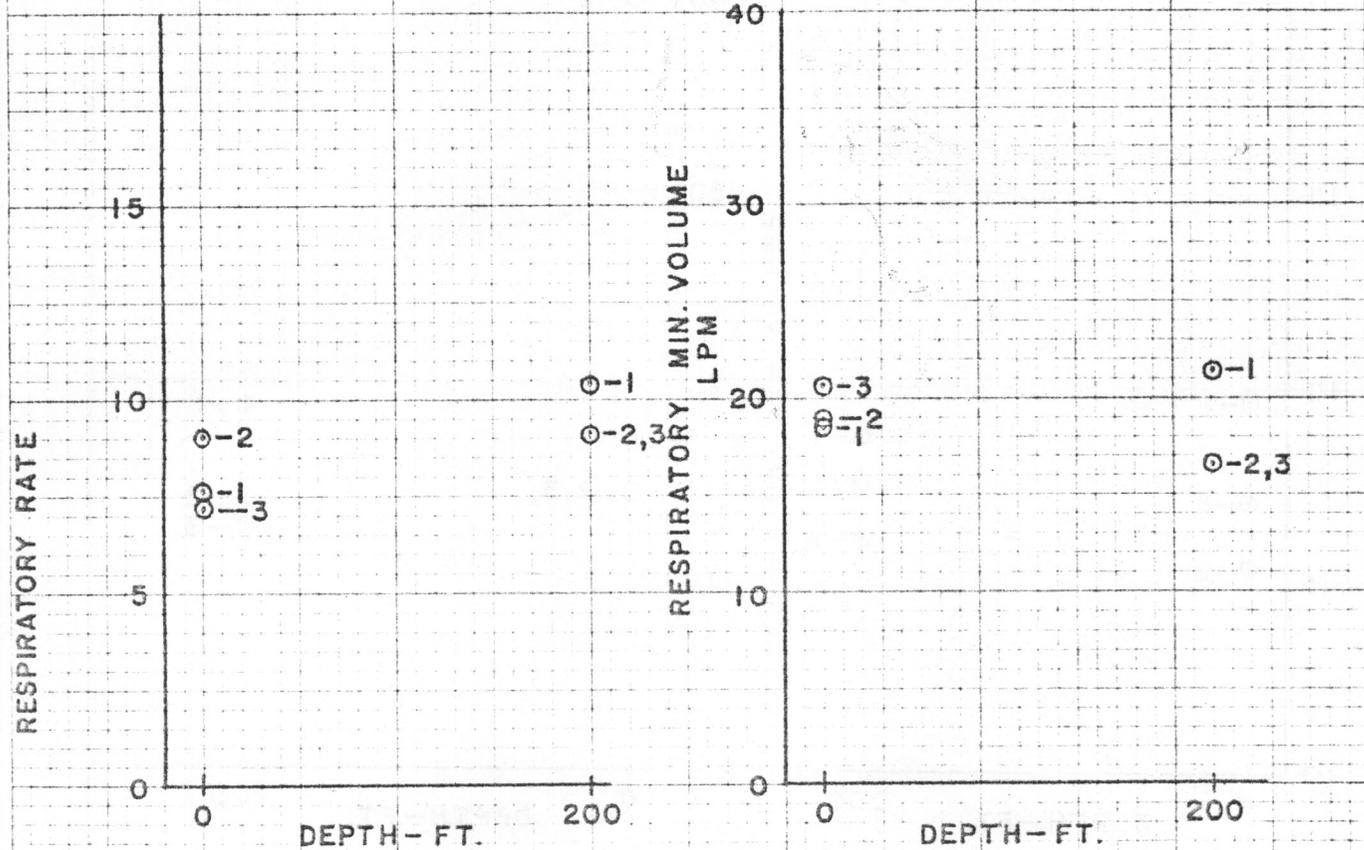
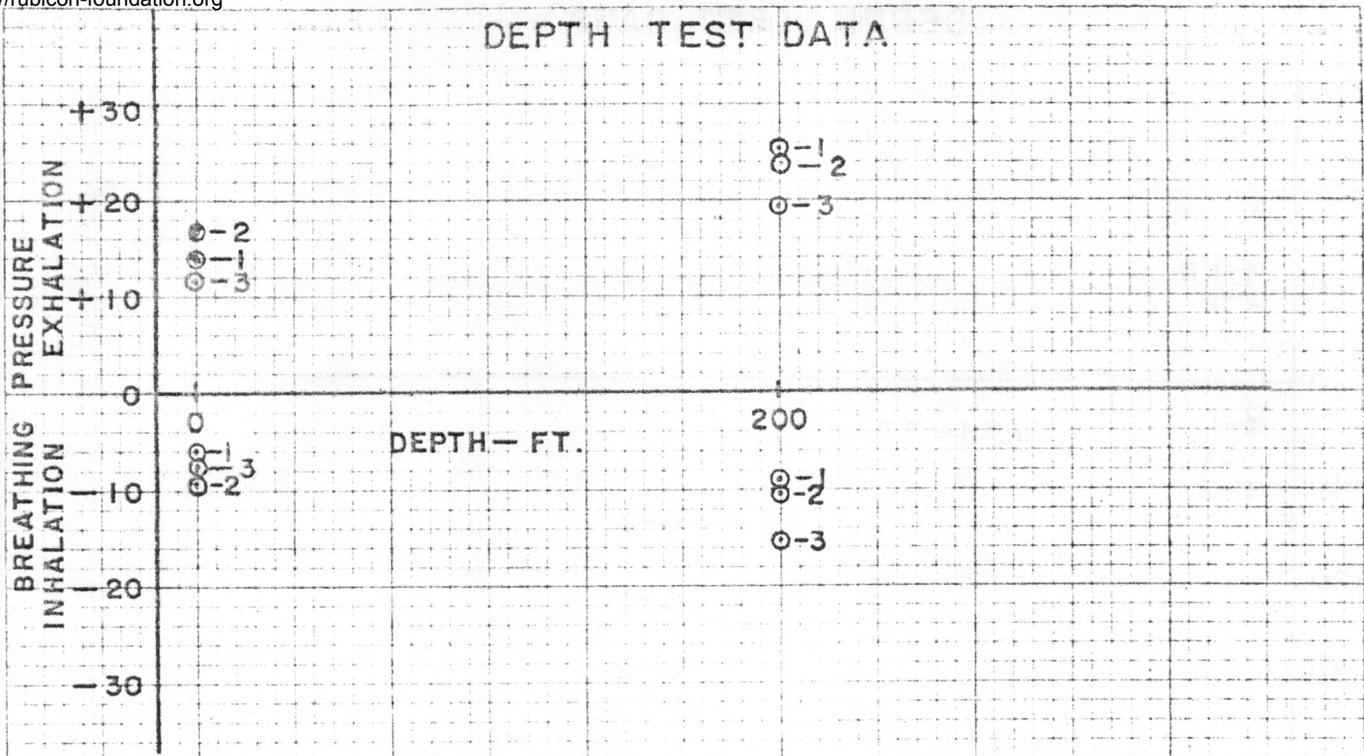
SUBJECT : CARROLL
 REGULATOR : DACOR

*
 REGULATOR FREE-FLOWED

FINS : VOIT VIKINGS
 WORK RATE : 12 LBS
 SCHEDULE : 10 MIN SURFACE 10 MIN 200 FT.

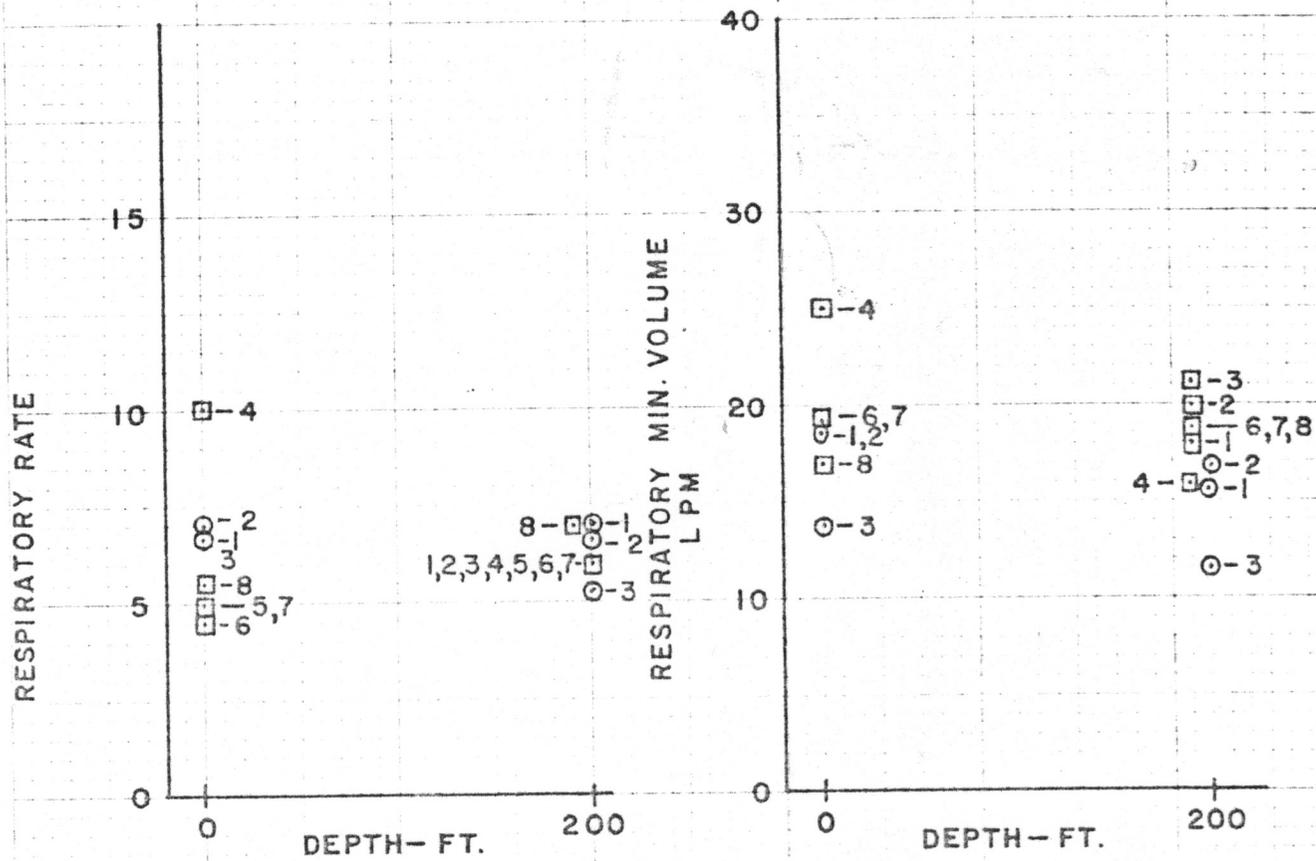
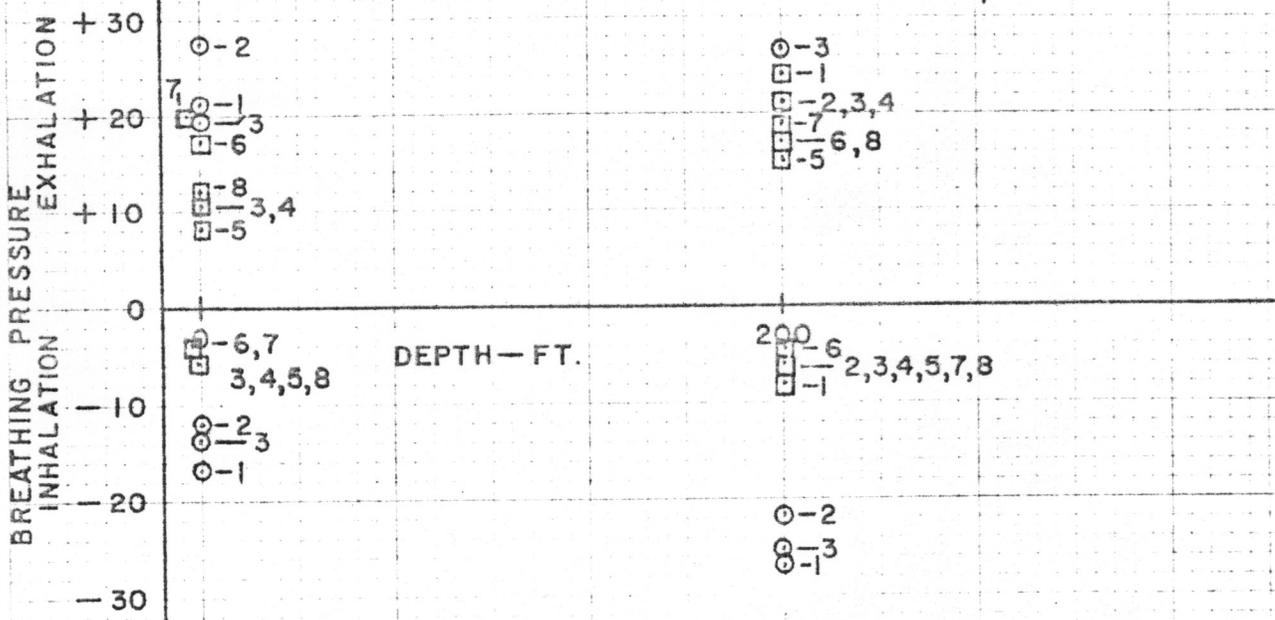
FIGURE 5

DEPTH TEST DATA



SUBJECT: GWINN
REGULATOR: DACOR
FINS: VOIT VIKINGS
WORK RATE: 12 LBS
SCHEDULE: 10 MIN. SURFACE 10 MIN. 200 FT. FIGURE 6

DEPTH TEST DATA



SUBJECT: JANNEY
 REGULATOR: DACOR COMPETITIVE
 FINS: DUCK FEET
 WORK RATE: 12 LBS
 SCHEDULE: 10 MIN SURFACE 10 MIN 200 FT.

FIGURE 7