DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
PANAMA CITY, FLORIDA 32407

IN REPLY REFER TO:

NAVY EXPERIMENTAL DIVING UNIT REPORT

ER 8-57

Project NS185-005 Subtask 4 Test 36

NORTHILL AIR LUNG FOURTH FIELD TEST

C. J. Leyden

19 August 1956

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ABSTRACT

This report covers the evalution of the Northill Air-Lung Regulator to determine the suitability of the apparatus for use in the Naval Service to depths of 200 feet at work rates equivalent to 0.85 knot swimming.

For the descritpion of the demand regulator in detail, see Evaluation Report 3-57. The regulator was tested objectively by breathing machine runs and subjectively by depth swimming runs, with instrumentation for respiratory pressure, respiratory minute volume, and breathing rate. Subjective swimming pool tests covered in Evaluation Report 3-57 were not repeated here. Breathing machine runs are summarized as recording tape excerpts of peak respiratory pressure versus depth and cylinder pressure. The subjective depth swimming runs are summarized as graphs of peak respiratory pressure, respiratory minute volume, and respiratory rate against time, cylinder pressure, and depth.

The results are discussed constructively and lead to specific conclusions about the apparatus and its suitability for use in the Naval Service.

SUMMARY

PROBLEM

Is the Northill Air-Lung Regulator suitable for use in the Naval Service to depths of 200 feet at work rates equivalent to 0.85 knot swimming?

FINDINGS

The general findings of Evaluation Report 3-57 remain unchanged except for satisfactory performance and suitability. The following specific findings apply to this evaluation.

(1) The regulator is satisfactory for depths of 200 feet at work rates equivalent to 0.85 knot swimming.

(2) The regulator meets NEDU Laboratory criteria of suitability for use in the Naval Service.

ADMINISTRATIVE INFORMATION

Ref: (a) BuShips - NEDU monthly conference, 4 May 1956
(b) Evaluation Report 3-57

Reference (a) established this project. Reference (b) is the first report for the project covering evaluation of the first, second and third field changes installed in Northill Air-Lung Regulator, serial 6-2427. As a result of the report, the regulator was not approved for use in the Naval Service.

The manufacturer requested permission to submit a modified regulator for evaluation. The Bureau of Ships granted permission.

On 23 July 1956, Mr. R. Bicknell delivered by hand Northill Air-Lung Regulator, serial 6-B154, embodying the fourth field change.

C. J. LEYDEN, BM1(DV), USN, was designated project engineer. Work commenced 30 July 1956 and was completed 17 August 1956.

The following breakdown indicates the manpower expended for this project:

DESCRIPTION	MANHOURS
Preparations	10
Breathing machine tests	8
Depth swimming runs	36
Drafting	10
Reporting	20
TOTAL	84

This manuscript was submitted for review on 19 August 1956 and was accepted 27 August 1956.

This report is issued in the Evaluation Report series, distributed only by the Bureau of Ships. It is the second and final report for Project NS185-005, Subtask 4, Test 36.

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1. OBJECT

1.1 Objective

1.1.1 The objective of this evaluation is to determine the suitability of the Northill Air-Lung and its fourth field change for use in the Naval Service to depths of 200 feet at work rates equivalent to 0.85 knot swimming.

1.2 Scope

1.2.1 This report covers the limited evaluation procedure for Class I Open-Circuit Demand Diving Apparatus. This evaluation includes objective breathing machine tests to 132 feet and subjective depth swimming runs to 130, 150, and 220 feet at work rates equivalent to 0.85 and 1.31 knot swimming.

2. DESCRIPTION

2.1 General

2.1.1 The Northill Air-Lung Regulator furnished for this evaluation was a modification of the regulator previously furnished and evaluated in Evaluation Report 3-57. Since the modification resulted in a different of spring tensions only, the description of the Northill Air-Lung Regulator breathing tubes, and mouthpiece may be found in Evaluation Report 3-57 (Section 2).

3. PROCEDURE

3.1 Breathing machine tests

3.1.1 The descent and 132 foot runs were made as follows. The breathing machine was set at 20 breaths per minute and 2 liters per breath.

3.1.2 The 1 psi strain gage was rigged in the recompression chamber. The anlyzer was calibrated and the attenuation was set to give one line of deflection for one centimeter of water pressure. On the recording tape the following was noted: "Northill Air-Lung", date, calibration, attenuation, and the direction of deflection for inhalation and exhalation.

3.1.3 For these runs the Northill Air-Lung Regulator was mounted on a two-cylinder Aqua-Lung manifold. The cylinders were charged to 1800 psi cool; the valves were opened and the apparatus was placed in the chamber. The air reservice device on the Northill Regulator was cut into the system; the air reserve on the cylinders was cut out of the system.

3.1.4 A 3000 psi mechanical gage was rigged to the apparatus manifold. It was placed in the chamber port so as to be visible from the outside.

3.1.5 The mouthpiece connector was inserted into the mouthpiece and taped securely. The pressure tap on the mouthpiece was connected to the signal side of the 1 psi strain gage. The reference side of the strain gage was opened to the chamber and the chamber door was then closed.

3.1.6 The breathing machine was started and the breathing pressure recorder was turned on. The chamber was taken down to 132 feet at a rate of 20 feet per minute, marking every ten feet and each atmospheric increment on the recording tape. Each 100 psig decrement of falling cylinder pressure was also marked on the recording tape. Upon reaching 132 feet the breathing machine was stopped and the breathing pressure analyzer was checked for balance.

3.1.7 The breathing machine was restarted. The chamber was kept at 132 feet and the breathing machine was run until the inhalation pressure reached 40 centimeters of water pressure. At this point the run was terminated, the breathing pressure analyzer was checked for balance and calibration, and the chamber was then returned to the surface.

3.1.8 The cylinders were recharged to 1800 psi cool, the valves were opened, and teh apparatus was replaced in the chamber. The air reserve device on the apparatus was cut out of the system and a second run was made following the same procedure.

3.1.9 The ascent and surface runs were made as follows. Steps 3.1.1 through 3.1.5 were repeated. The chamber was taken down to 132 feet. At 132 feet the breathing pressure analyzer was rebalanced and the breathing machine was turned on. At a rate of 20 feet per minute the chamber was returned to the surface, marking every ten feet and each atmospheric increment on the recording tape. Every 100 psig of falling cylinder pressure was also marked on the recording tape. Upon reaching the surface, the breathing machine was stopped and the breathing pressure analyzer was checked for balance.

3.1.10 The breathing machine was restarted. The chamber was kept at the surface and the breathing machine was run until the inhalation pressure reached 40 centimeters of water pressure. At this point, the run was terminated and the breathing pressure analyzer was checked for balance and calibration.

3.1.11 The cylinders were recharged to 1800 psi cool. The air reserve device on the regulator was cut out of the system and a second run was made following the same procedure.

3.1.12 The surface supplied run made in the Evaluation Report 3-57 was not duplicated for this evaluation.

3.2 Subjective depth swimming runs

3.2.1 For these runs the Northill Regulator was mounted on the two-cylinder Aqua-Lung, charged to 1800 psi cool. During the descent the apparatus was not used by the subject. Upon reaching the bottom the subject donned the apparatus, and assumed his position on the swimming trapeze. The remainder of the first five minutes was used to adjust the instruments. At 5 minutes the subject started to swim on the trapeze against the designated force for his particular run.

3.2.2 Due to a conficting schedule, the depth swimming runs were made at varying depths. Two runs were made at 130 feet, two runs were made at 150 feet, and two runs were made at 220 feet. Four runs were made at the standard swim rate of 0.85 knots. Two runs were made at the spurt swim rate of 1.3 knots.

3.3 Depth run instrumentation

3.3.1 A 1 psi differential strain gage, with the signal side tapped into the mouthpiece tee, was used to measure breathing pressures. The reference side was connected to a bubbler terminating at the demand regulator, with the open end down. Bubbling was kept at a minimum. The analyzer was calibrated before the run, and calibration was rechecked after the run. The analyzer was balanced before the run, on starting the swim, and whenever the center appeared to be drifting. Breathing pressures were recorded from the start of the swim until the run was terminated.

3.3.2 A mechanical pressure gage was used for measuring cylinder pressure. Falling cylinder pressures were noted every 100 psig nad marked on the recording tape.

3.3.3 On all subjective depth swimming runs, the exhaled gas was trapped and led through a gas meter for measurement. The exhaled volume was recorded automatically.

3.3.4 The following information was recorded at the beginning and end of each recording tape: subject, equipment, date, calibration, attenuation, and direction of deflection for inhalation.

3.4 Pool tests

3.4.1 Pool test results for the previous evaluation are recorded in the Evaluation Report 3-57. As no pertinent data would have been added, pool tests for the regulator with the fourth field change installed were not made.

4. RESULTS

4.1 Breathing machine tests

4.1.1 Figure T-1 is the recording tape of run 1 on the breathing machine.

4.1.2 Figure T-2 is the recording tape of run 2 on the breathing machine.

4.1.3 Figure T-3 is the recording tape of run 3 on the breathing machine.

4.1.4 Figure T-4 is the recording tape of run 4 on the breathing machine.

4.1.5 The recording tapes show inhalation pressure, exhalation pressure, and cylinder pressure against depth.

4.2 Subjective depth runs

4.2.1 Figures D-1 and D-2 are graphs of the two subjective depth runs made to a depth of 130 feet at the standard swim rate.

4.2.2 Figure D-3 is a graph of the subjective depth run to a depth of 150 feet at the standard swim rate.

4.2.3 Figure D-4 is a graph of the subjective depth run to a depth of 220 feet at the standard swim rate.

4.2.5 Figure D-6 is a graph of the subjective depth run to a depth of 220 feet at the spurt swim rate.

4.2.6 The graphs show inhalation pressure, exhalation pressure, respiratory minute volume, and respiratory rate against depth and time.

5. DISCUSSION

5.1 Breathing machine tests

5.1.1 Figures T-1, T-2, T-3, and T-4 indicate that the Northill Air-Lung demand regulator embodying its fourth field change, satisfactorily meets the criteria for laboratory evaluation standards at the Navy Experimental Diving Unit. Inhalation and exhalation pressures did not exceed 10 cm of water at the surface or 20 cm of water at 132 feet with cylinder pressures of above 500 psi.

5.1.2 Comparison of Figures T-1, T-2, T-3, and T-4 indicates that the reserve device does not materially affect breathing pressures.

5.2 Subjective depth runs

5.2.1 Table 5-1 on the next page is a comparative summary of the important data appearing in Figures D-1 through D-6.

5.2.2 Runs 1 and 2 were made at 130 feet at the standard swim rate. Both runs remained within acceptable inhalation pressure limits. These results indicate that the Northill Air-Lung Regulator is satisfactory for 0.85 knot swimming at 130 feet.

5.2.3 Run 3 was made at 150 feet at the standard swim rate. Inhalation pressures remained within acceptable limits. The results indicate that the Northill Air-Lung Regulator is satisfactory for 0.85 knot swimming at 150 feet.

5.2.4 Run 4 was made at 150 feet at the spurt swim rate. Inhalation pressures remained within acceptable limits. The results indicate that the Northill Air-Lung Regulator is satisfactory for 1.3 knot swimming at 150 feet.

5.2.5 Run 5 was made at 220 feet at the standard swim rate. A look at the graph of the run shows inhalation reaching 40 cm of water and exhalation 80 cm. There is reasonable doubt that these figures are incorrect due to a mechanical defect on the attenuation setting knob. If this is the case, the values of inhalation and exhalation pressures are in excess by approximately 2 1/2 times. A look at the record for run 6 which was a heavier swim rate would seem to bear out the belief that the values as presented for run 5 are in error. In view of these facts the Northill Air-Lung Regulator is considered to be satisfactory for 0.85 knot swimming at 220 feet.

5.2.6 Run 6 was made at 220 feet at the spurt swim rate. Inhalation pressures remained within acceptable limits. The results indicate that the Northill Air-Lung Regulator is satisfactory for 1.3 knot swimming at 220 feet.

5.2.7 A fluttering noise was encountered on run 1, on exhalation. A wheezing noise was encountered on runs 2, 5, and 6 on inhalation. No noise was encountered on runs 3 and 4. The same subject that made run 1 also made run 4. The same subject that made run 2 also made run 3.

5.2.8 The reason for the noises encountered was not determined. As it seems to be an engineering problem. The determination and elimination of the problem is left to the manufacturer.

6. CONCLUSIONS

6.1 Characteristics

6.1.1 The conclusions of Evaluation Report 3-57 concerning the Northill Air-Lung demand regulator (6.1.1(1) through (4) 6.1.3) remain unchanged.

TABLE 5-1

COMPARATIVE SUMMARY OF INDIVIDUAL RESULTS

RUN NO.	TOTAL TIME OF RUN	CYLINDER PRESSURE		AVERAGE INHALA. PRESSURE IN cm PERIOD		MAXIMUM INHALATION PRESSURE cm*		MAXIMUM EXHALATION PRESSURE cm*		RESPIRATORY MINUTE VOL. IN LITERS*		RESPIRATORY RATE	
	MINUTES	Start psig	Stop psig	5-15 min.	20-30 min.	PEAK cm	TIME* min.	PEAK cm	TIME min.	PEAK lit.	TIME* min.	PEAK bpm	TIM min
1	30	1600	350	8.5	14.0	30	26	20	28	**		8	12
2	31***	1820	320	9.6	10.8	18	31	32	31	23	15	8	15
3	36	1700	200	13.6	18.8	40**	36	34	19	20	12	8	11
4	15	1700	1000	16.3	****	18	12	30	11	24	11	9	11
5	18	1850	700	33.5*********		40	17	80	17	28	18	11	18
6	14	1640	180	19.6+	+	45++	14	50	14	**		23	12

* First time only

** No record, machine failure

*** Cylinder pressure manually bled off for time periods 29 through 31 minutes

**** Valid only for period 5-15 minutes

***** Valid only for period 10-18 minutes

\+ Valid only for period 5-14 minutes

++ Out of gas

6.2 Suitability

6.2.1 The Northill Air-Lung Regulator is satisfactory for 0.85 knot and 1.3 knot swimming to depths of 220 feet. (5.2.2 through 5.2.6)

6.2.2 The Northill Air-Lung Regulator meets NEDU Laboratory criteria of suitability for use in the Naval Service.

7. FIGURES

7.1 Breathing machine runs

7.1.1 Figure T-1 shows breathing pressures and cylinder pressure against depth to 132 feet. The reserve device was cut into the circuit.

7.1.2 Figure T-2 shows breathing pressures and cylinder pressure against depth to 132 feet. The reserve device was cut out of the circuit.

7.1.3 Figure T-3 shows breathing pressures and cylinder pressure against depth from 132 feet back to the surface. The reserve device was cut into the circuit.

7.1.4 Figure T-4 shows breathing pressures and cylinder pressure against depth from 132 feet back to the surface.

7.2 Subjective depth swimming runs

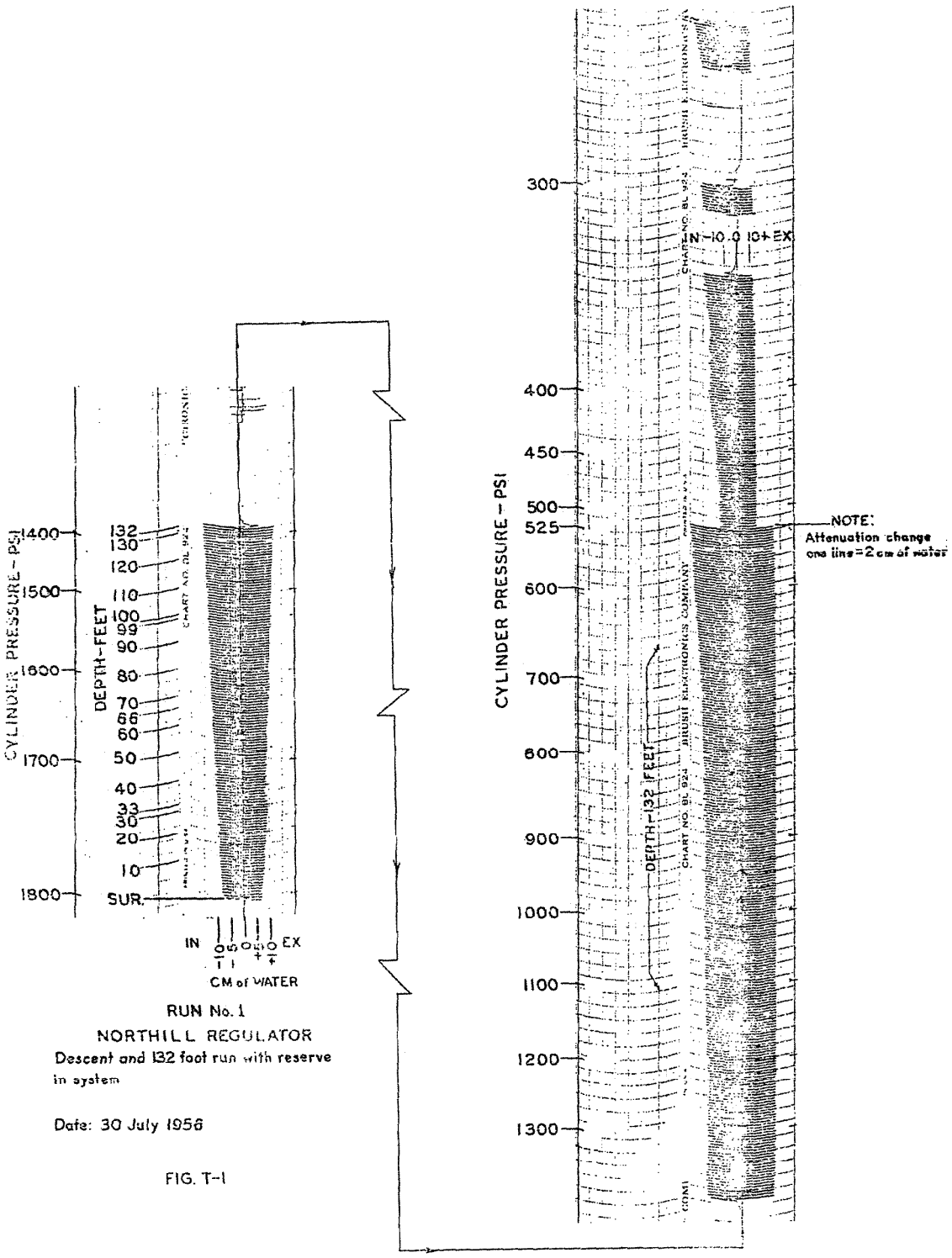
7.2.1 Figures D-1 and D-2 show the data for the standard (0.85 knot) swimming runs made at a depth of 130 feet.

7.2.2 Figure D-3 shows the data for the standard (0.85 knot) swimming run made at a depth of 150 feet.

7.2.3 Figure D-4 shows the data for the spurt (1.3 knot) swimming run made at a depth of 150 feet.

7.2.4 Figure D-5 shows the data for the standard (0.85 knot) swimming run made at a depth of 220 feet.

7.2.5 Figure D-6 shows the data for the spurt (1.3 knot) swimming run made at a depth of 220 feet.



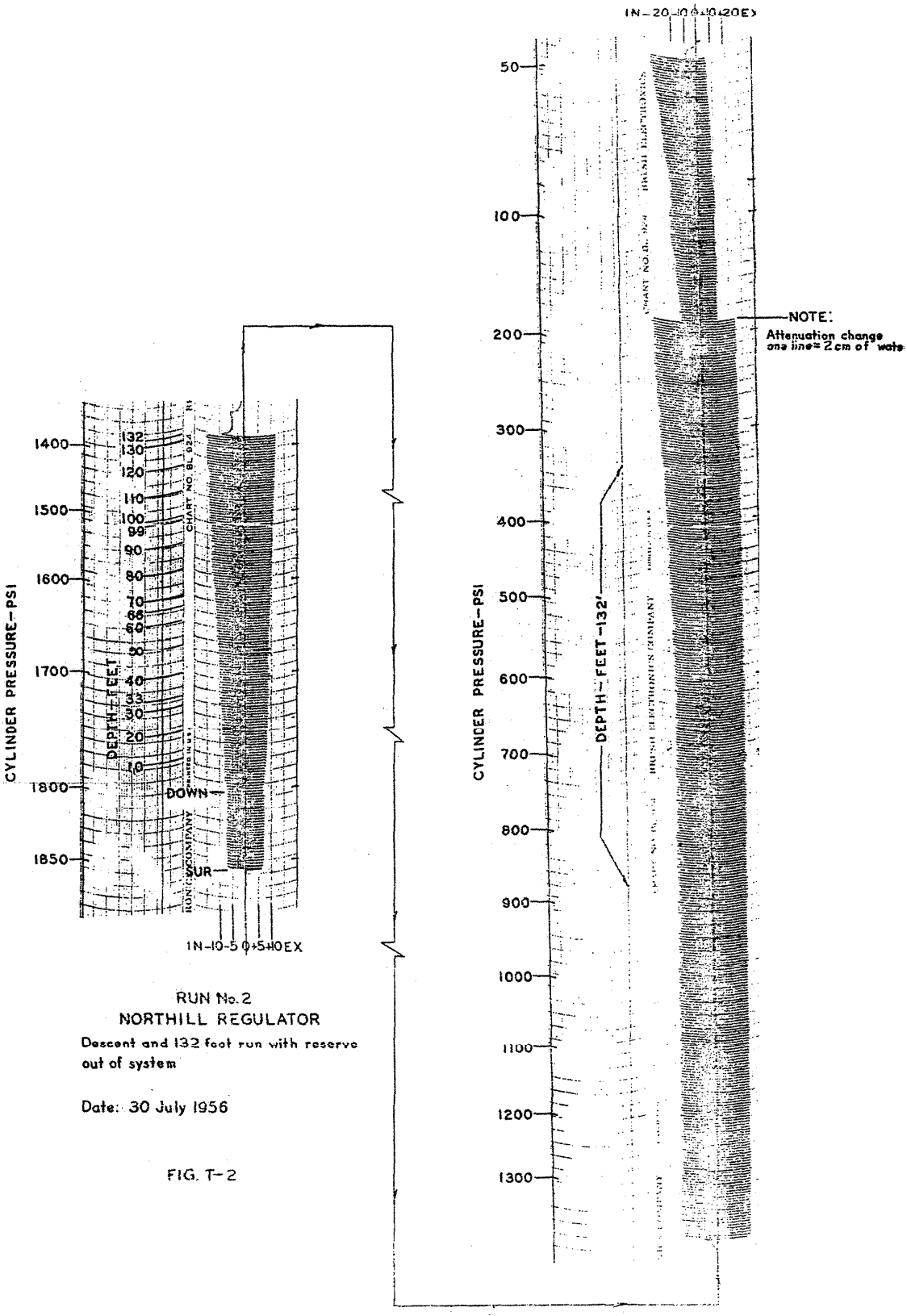
RUN No. 1

NORTHILL REGULATOR

Descent and 132 foot run with reserve in system

Date: 30 July 1956

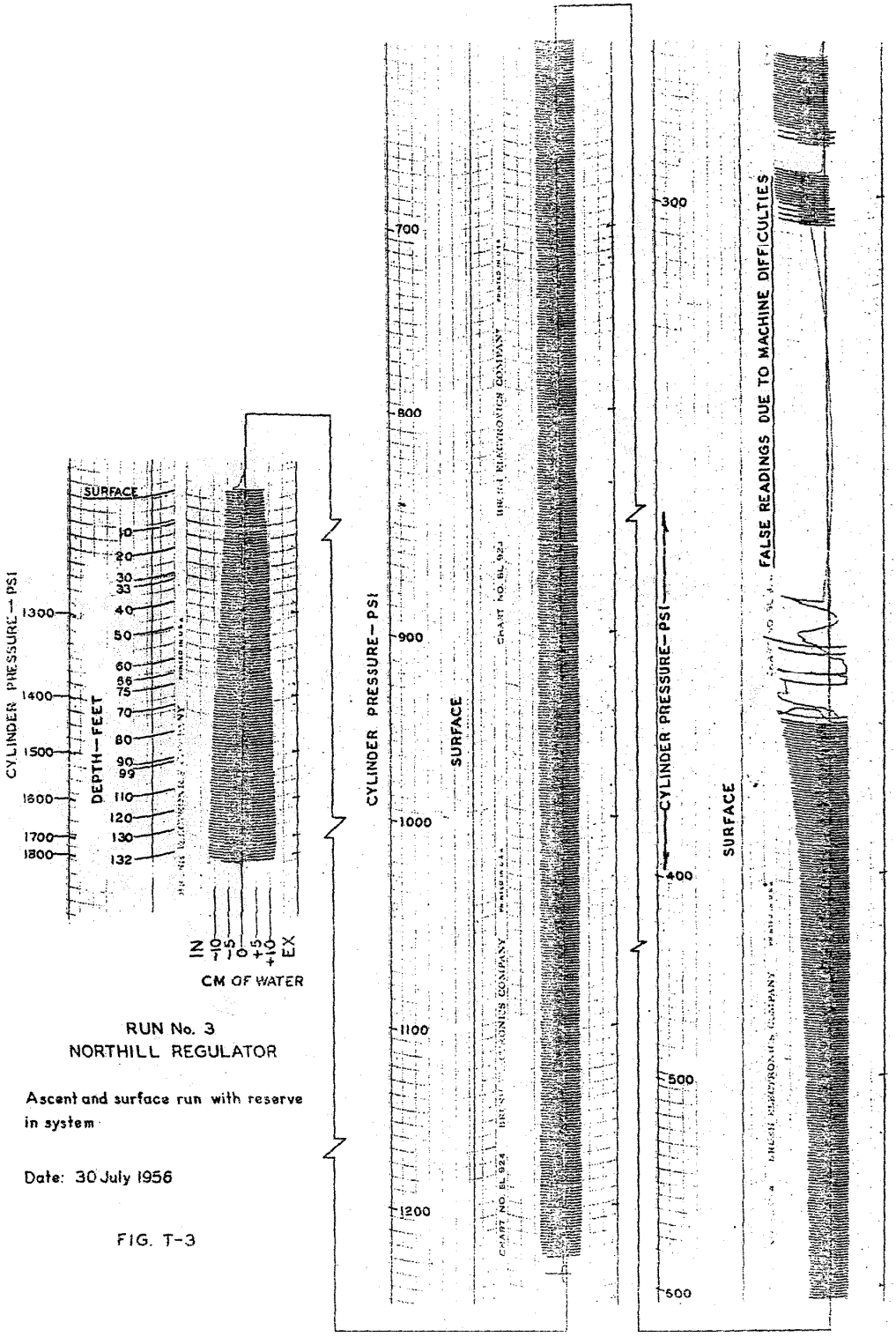
FIG. T-1



RUN No. 2
NORTHILL REGULATOR
Descent and 132 foot run with reserve out of system

Date: 30 July 1956

FIG. T-2

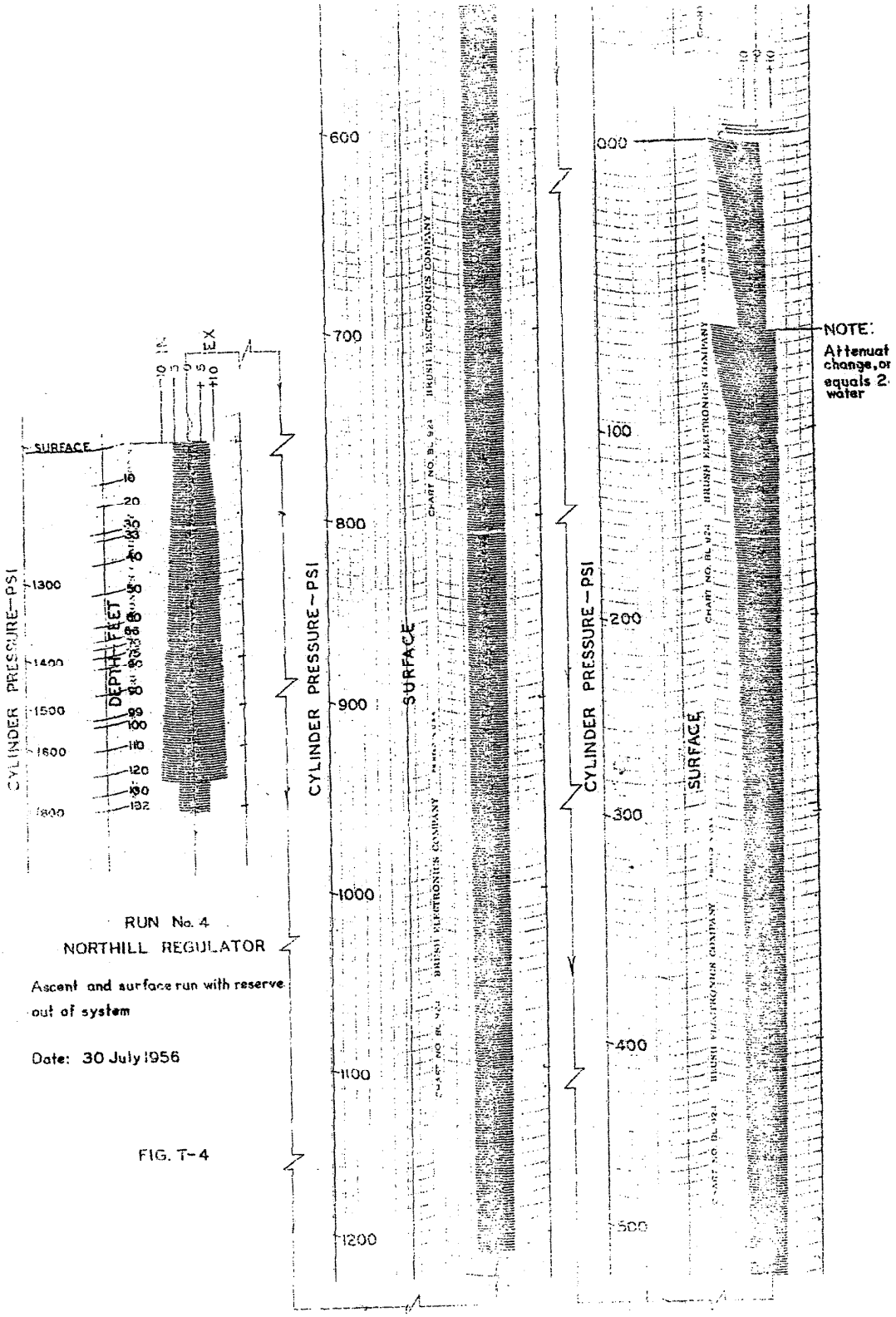


RUN No. 3
NORTHILL REGULATOR

Ascent and surface run with reserve in system

Date: 30 July 1956

FIG. T-3



RUN No. 4
NORTHILL REGULATOR

Ascent and surface run with reserve out of system

Date: 30 July 1956

FIG. T-4

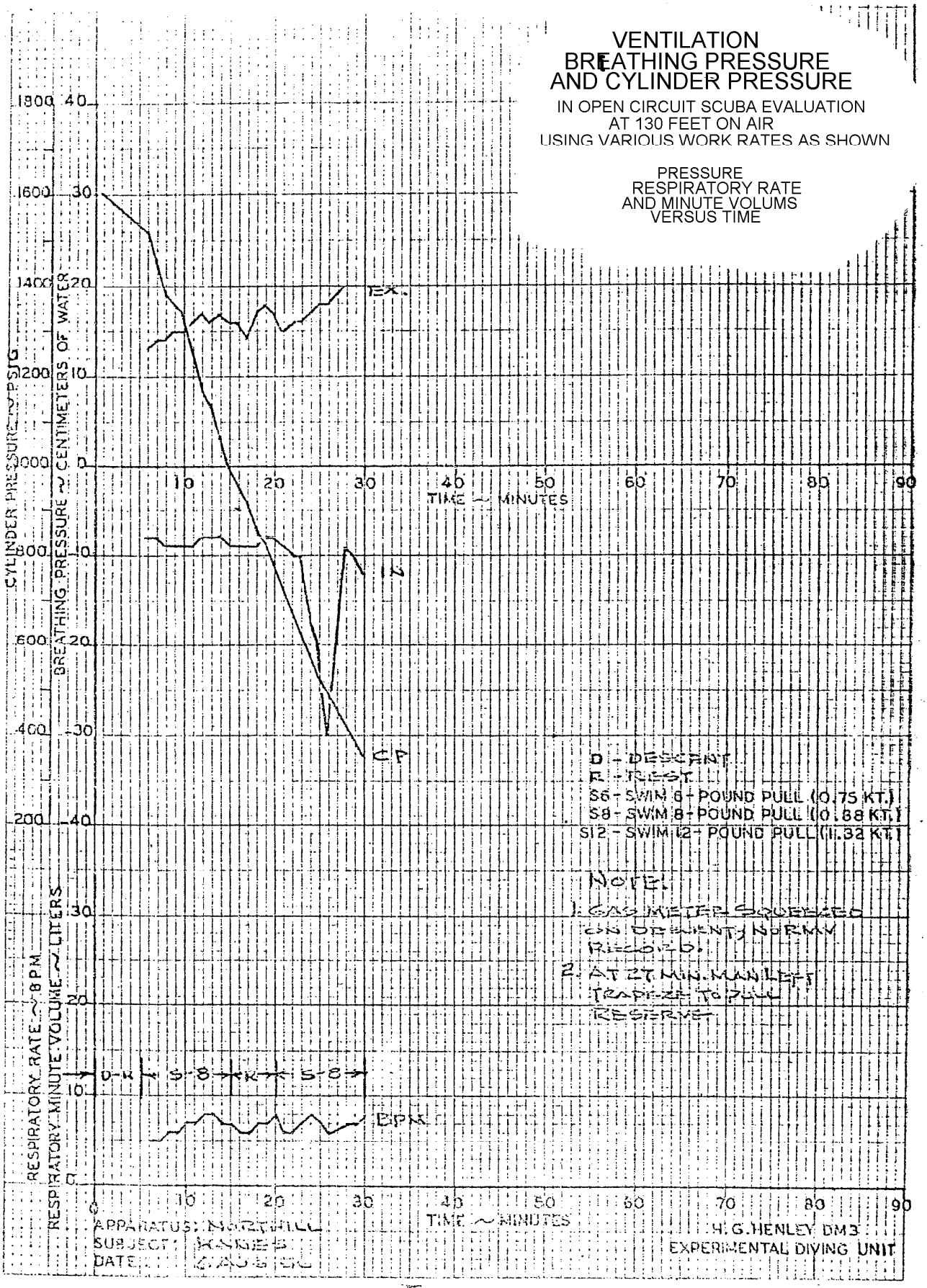

VENTILATION
BREATHING PRESSURE
AND CYLINDER PRESSURE
IN OPEN CIRCUIT SCUBA EVALUATION
AT 130 FEET ON AIR
USING VARIOUS WORK RATES AS SHOWN
PRESSURE
RESPIRATORY RATE
AND MINUTE VOLUMS
VERSUS TIME
CYLINDER PRESSURE ~ PSIG
BREATHING PRESSURE ~ CENTIMETERS OF WATER
RESPIRATORY RATE ~ BPM
RESPIRATORY MINUTE VOLUME ~ LITERS
TIME ~ MINUTES
EX.
IN
CP
BPM
D - DESCENT
R - REST
S6 - SWIM 6 - POUND PULL (0.75 KT.)
S8 - SWIM 8 - POUND PULL (0.88 KT.)
S12 - SWIM 12 - POUND PULL (1.32 KT.)
NOTE:
1. GAS METER SQUEEZED ON DESCENT, NORMV RECORD.
2. AT 27 MIN. MAN LEFT TRAPEZE TO PULL RESERVE
D-R
S-8
R
S-8
APPARATUS: NORTHILL
SUBJECT: KANES
DATE: 6 AUG 56
H. G. HENLEY DM3
EXPERIMENTAL DIVING UNIT

FIG. D-1

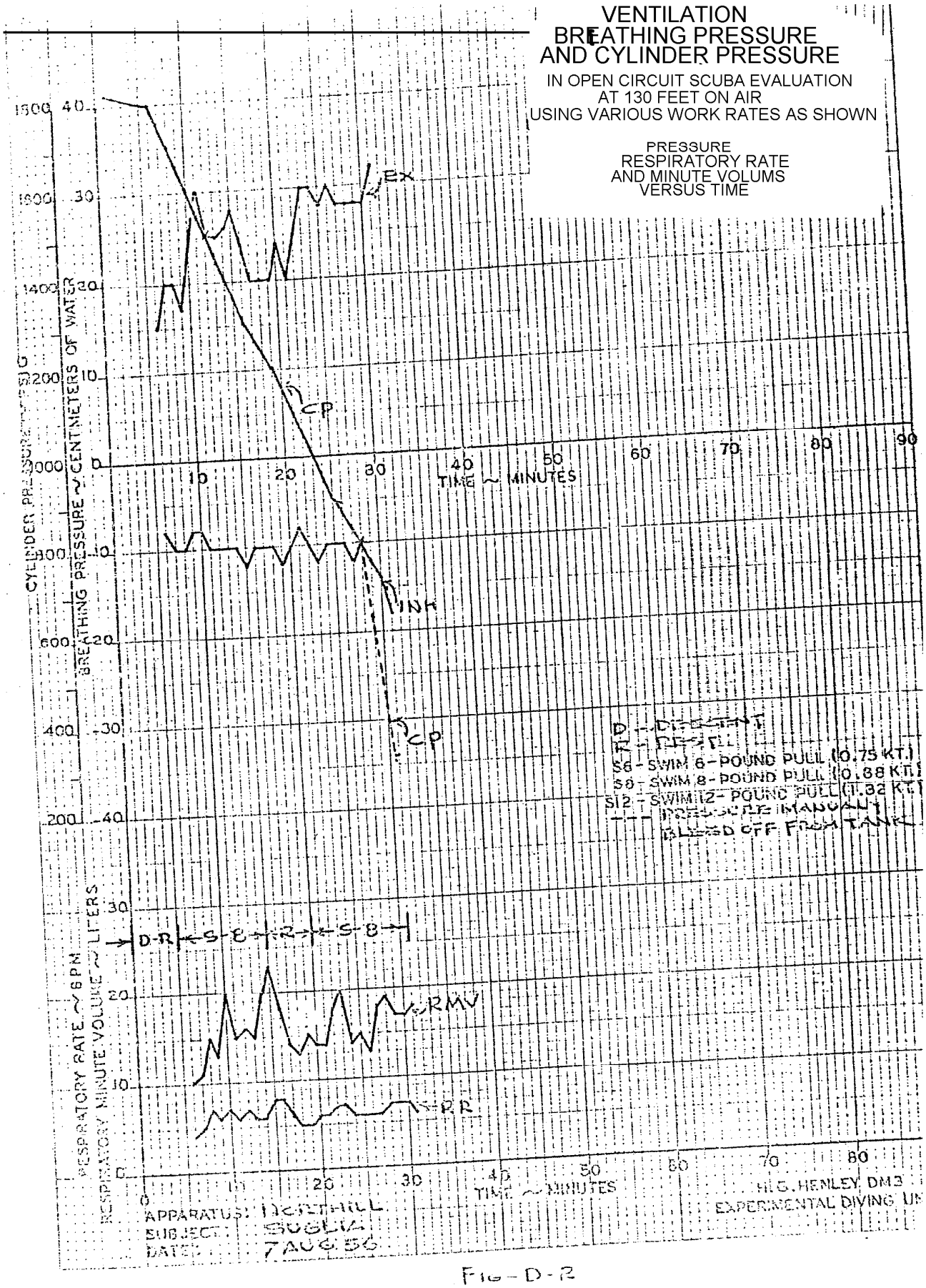
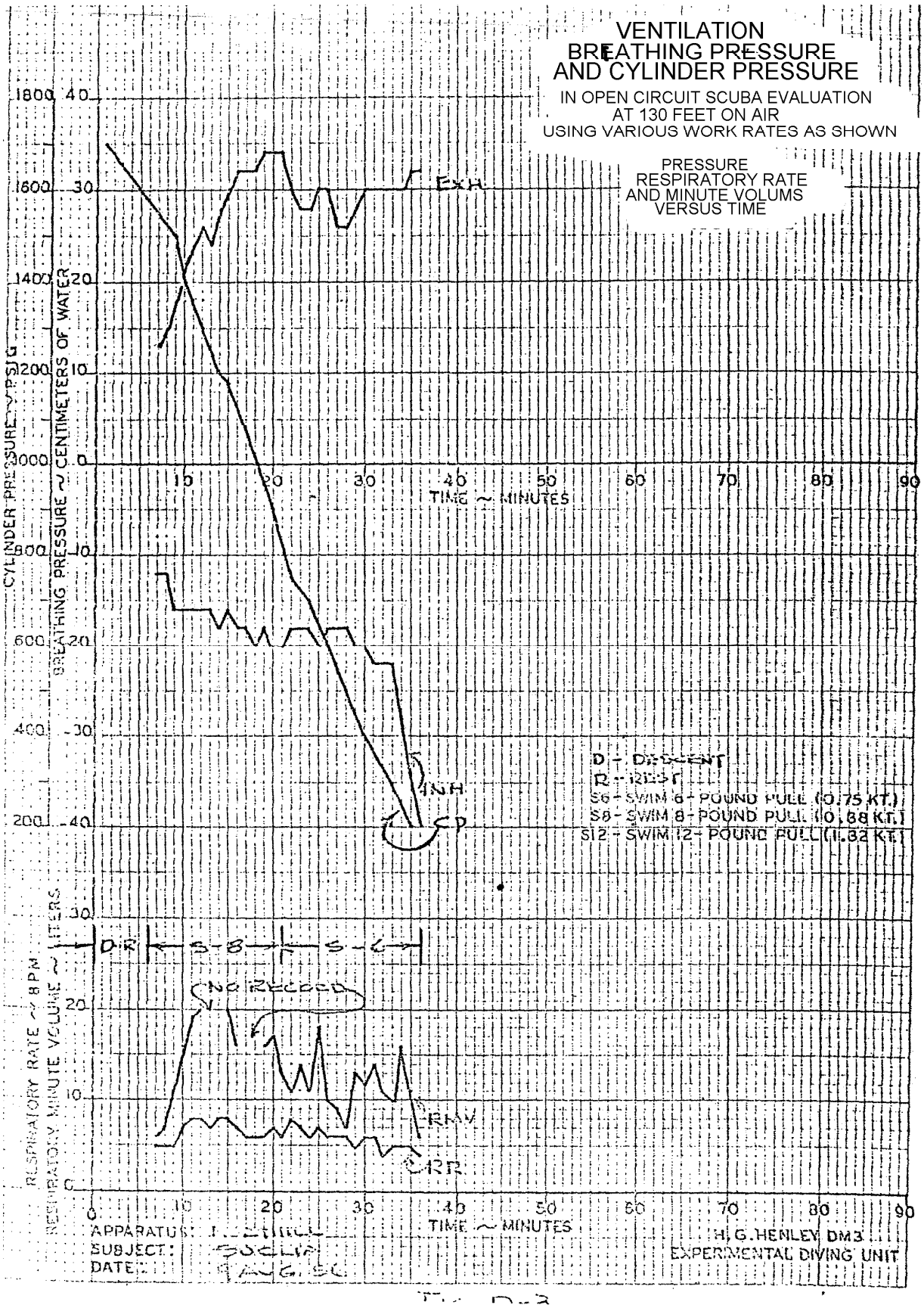

VENTILATION
BREATHING PRESSURE
AND CYLINDER PRESSURE
IN OPEN CIRCUIT SCUBA EVALUATION
AT 130 FEET ON AIR
USING VARIOUS WORK RATES AS SHOWN
PRESSURE
RESPIRATORY RATE
AND MINUTE VOLUMS
VERSUS TIME
CYLINDER PRESSURE ~ PSIG
BREATHING PRESSURE ~ CENTIMETERS OF WATER
TIME ~ MINUTES
EX
CP
INH
CP
D - DESCENT
R - RESTS
S6 - SWIM 6 - POUND PULL (0.75 KT.)
S8 - SWIM 8 - POUND PULL (0.88 KT.)
S12 - SWIM 12 - POUND PULL (1.32 KT.)
--- PRESSURE MANUAL BLEED OFF FROM TANK
RESPIRATORY RATE ~ BPM
RESPIRATORY MINUTE VOLUME ~ LITERS
D-R
S-8
R
S-8
RMV
RR
TIME ~ MINUTES
H.G. HENLEY DM3
EXPERIMENTAL DIVING UN
APPARATUS: NORTHILL
SUBJECT: SUGLIA
DATE: 7 AUG 56

FIG - D - 2


VENTILATION
BREATHING PRESSURE
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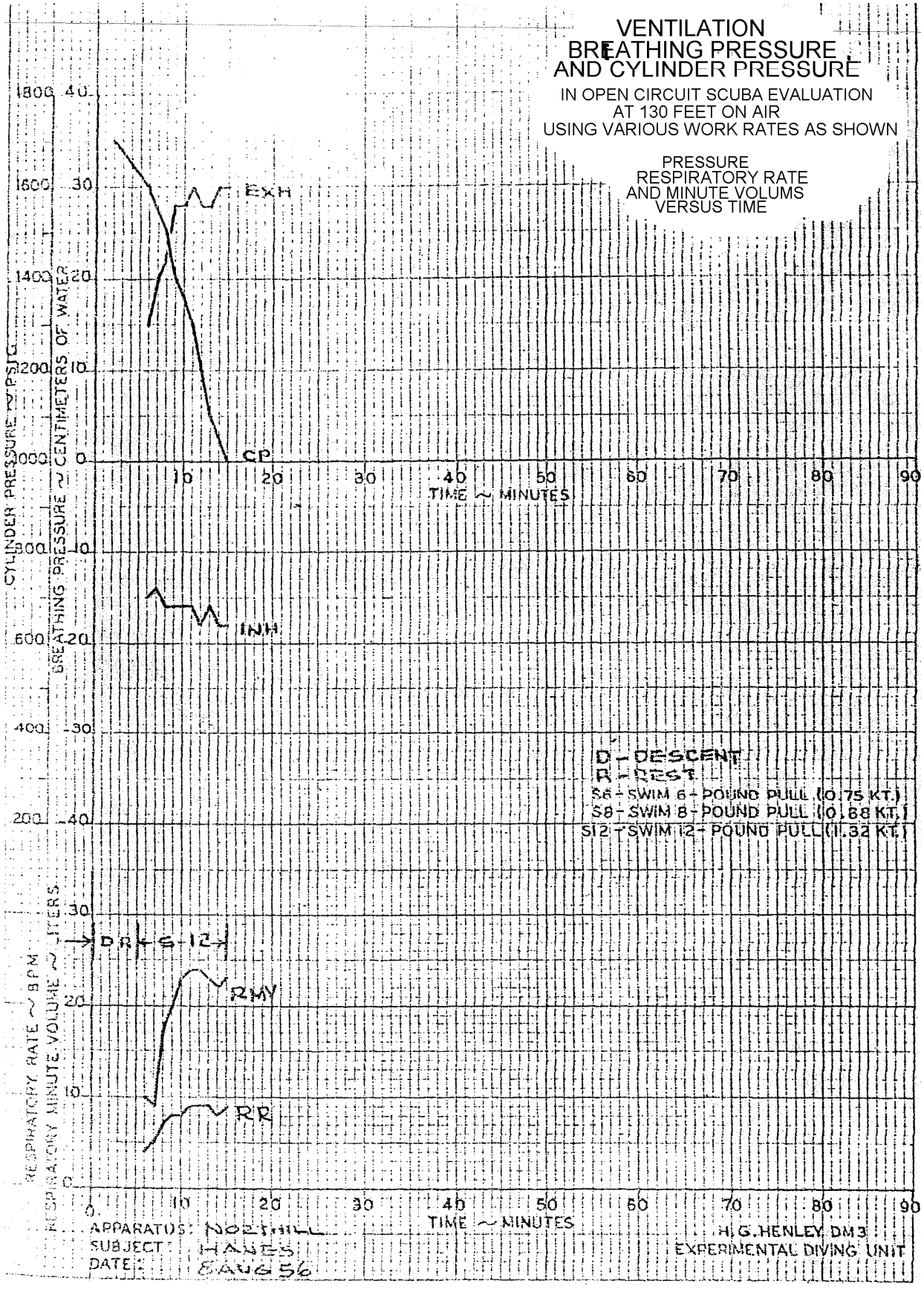
IN OPEN CIRCUIT SCUBA EVALUATION
AT 130 FEET ON AIR
USING VARIOUS WORK RATES AS SHOWN
PRESSURE
RESPIRATORY RATE
AND MINUTE VOLUMS
VERSUS TIME
CYLINDER PRESSURE ~ PSIG
BREATHING PRESSURE ~ CENTIMETERS OF WATER
TIME ~ MINUTES
EXH
INH
CP
D - DESCENT
R - REST
S6 - SWIM 6 - POUND PULL (0.75 KT.)
S8 - SWIM 8 - POUND PULL (0.88 KT.)
S12 - SWIM 12 - POUND PULL (1.32 KT.)
D R
S-8
S-6
NO RECORD
RMV
RR
RESPIRATORY RATE ~ BPM
RESPIRATORY MINUTE VOLUME ~ LITERS
APPARATUS:
SUBJECT:
DATE:
H. G. HENLEY DM3
EXPERIMENTAL DIVING UNIT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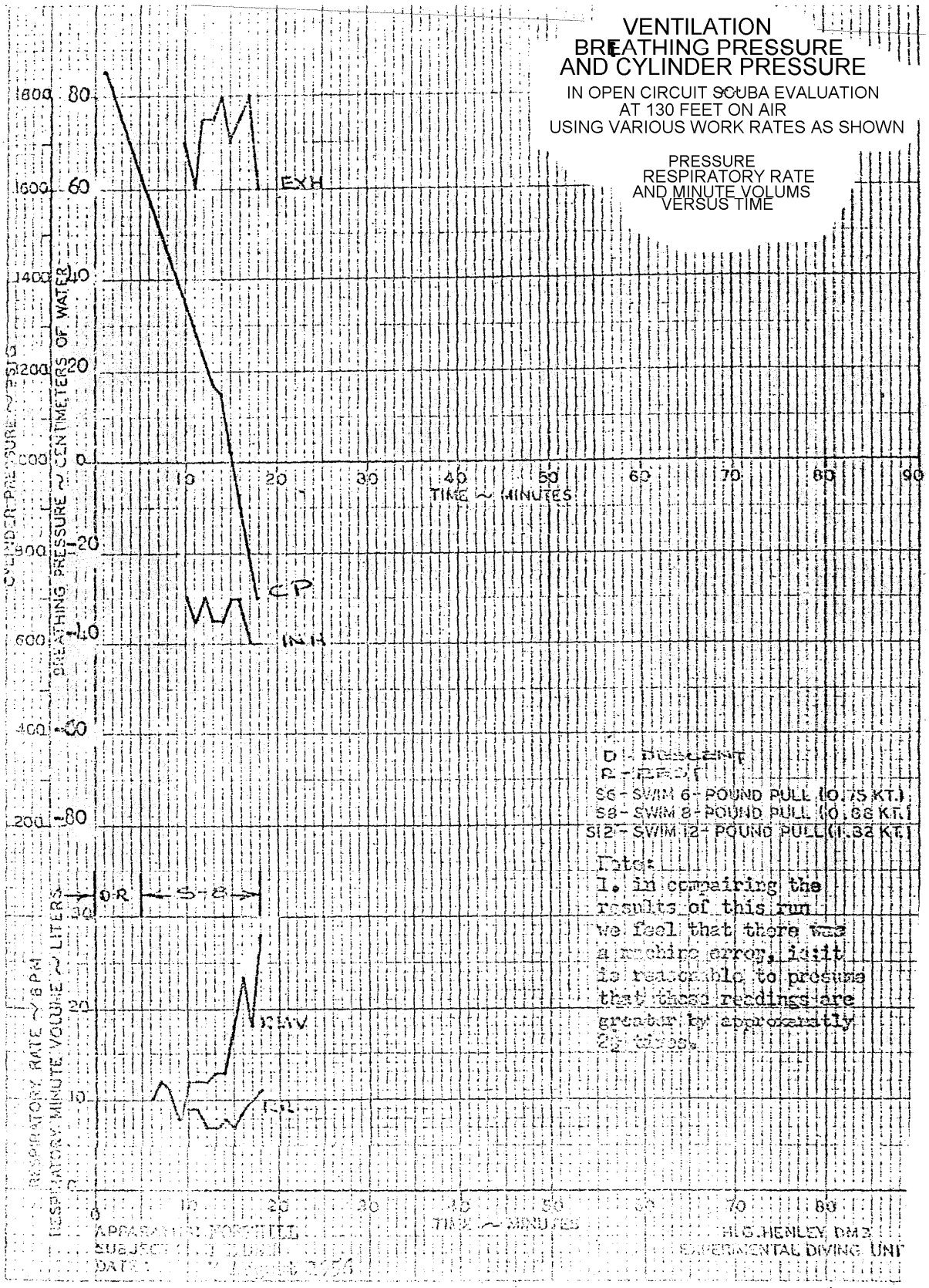
IN OPEN CIRCUIT SCUBA EVALUATION
AT 130 FEET ON AIR
USING VARIOUS WORK RATES AS SHOWN
PRESSURE
RESPIRATORY RATE
AND MINUTE VOLUMS
VERSUS TIME
CYLINDER PRESSURE ~ PSIG
BREATHING PRESSURE ~ CENTIMETERS OF WATER
EXH
CP
INH
TIME ~ MINUTES
D - DESCENT
R - REST
S6 - SWIM 6 - POUND PULL (0.75 KT.)
S8 - SWIM 8 - POUND PULL (0.88 KT.)
S12 - SWIM 12 - POUND PULL (1.32 KT.)
RESPIRATORY RATE ~ BPM
RESPIRATORY MINUTE VOLUME ~ LITERS
D R S-12
RMV
RR
TIME ~ MINUTES
APPARATUS: NORTHILL
SUBJECT: HANES
DATE: 8AUG56
H.G.HENLEY DM3
EXPERIMENTAL DIVING UNIT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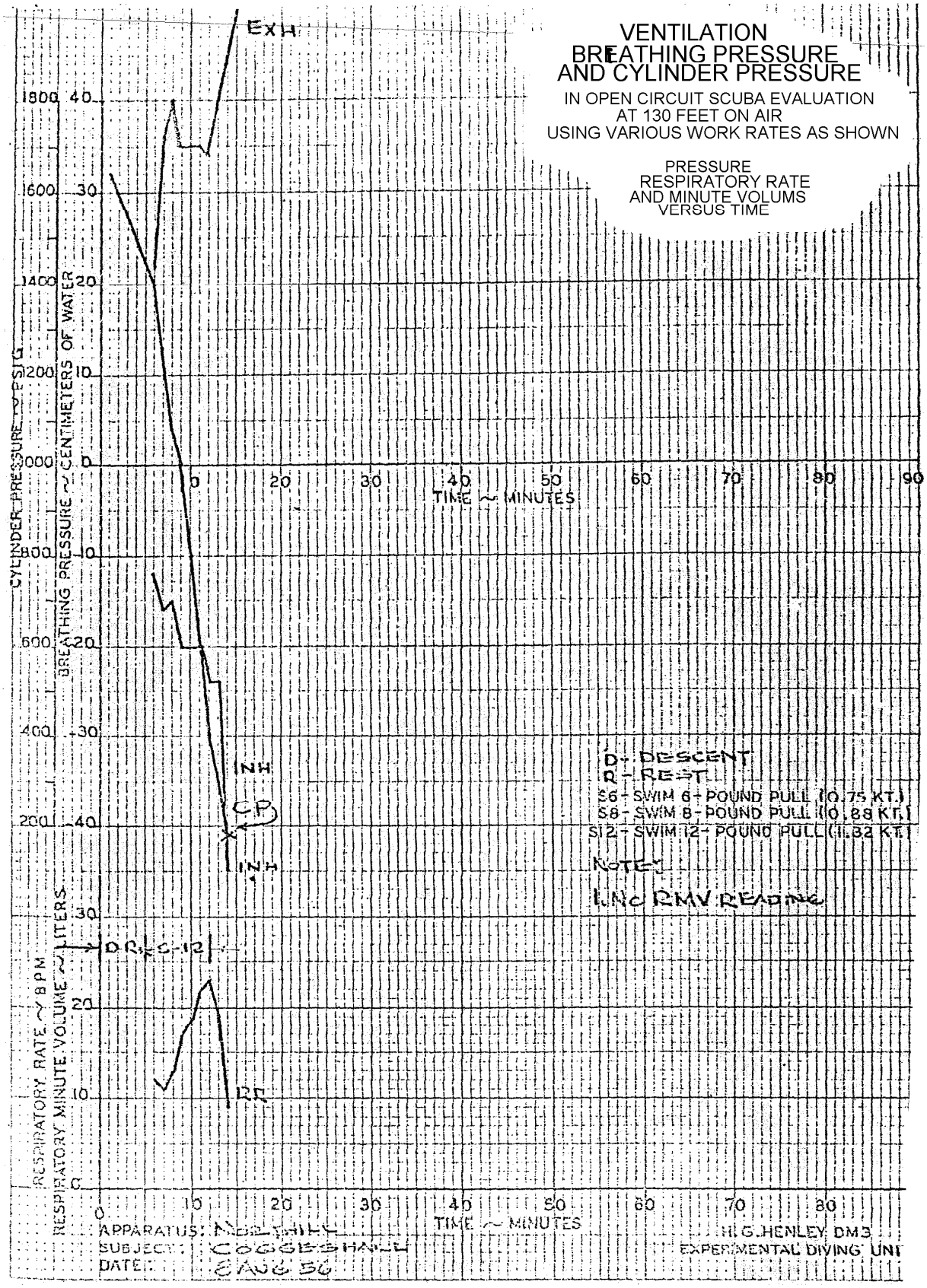
TIME ~ MINUTES
EXH
CP
INH
D - DESCENT
R - REST
S6 - SWIM 6 - POUND PULL (0.75 KT.)
S8 - SWIM 8 - POUND PULL (0.88 KT.)
S12 - SWIM 12 - POUND PULL (1.32 KT.)
Note:
1. in compairing the results of this run we feel that there was a machine error, it is reasonable to presume that these readings are greater by approximately 2½ times.
D R
S-8
RESPIRATORY RATE ~ BPM
MINUTE VOLUME ~ LITERS
MAV
RR
TIME ~ MINUTES
APPARATUS
SUBJECT
DATE
H.G. HENLEY DM3
EXPERIMENTAL DIVING UNIT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RESPIRATORY RATE
AND MINUTE VOLUMS
VERSUS TIME
EXH
INH
CP
INH
DR
S-12
RR
D - DESCENT
R - REST
S6 - SWIM 6 - POUND PULL (0.75 KT.)
S8 - SWIM 8 - POUND PULL (0.88 KT.)
S12 - SWIM 12 - POUND PULL (1.32 KT.)
NOTES
1. NO RMV READING
CYLINDER PRESSURE ~ PSIG
BREATHING PRESSURE ~ CENTIMETERS OF WATER
RESPIRATORY RATE ~ BPM
RESPIRATORY MINUTE VOLUME ~ LITERS
TIME ~ MINUTES
APPARATUS:
SUBJECT: COGGESHALL
DATE: 8 AUG 56
H. G. HENLEY DM3
EXPERIMENTAL DIVING UNIT

FIG D-6