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PART I. UNMANNED EVALUATION OF THE USN MK 1 MOD 0 MASK IN UMBIL--ETC(U)

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Navy Experimental Diving Unit

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NAVY EXPERIMENTAL DIVING UNIT
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PART I. UNMANNED EVALUATION OF THE USN MK 1 MOD 0 MASK IN UMBILICAL AND EMERGENCY MODES

JAMES R. MIDDLETON

PART II. MANNED HUMAN ENGINEERING EVALUATION OF USN MK 1 MOD 0 MASK IN TETHERED SCUBA CONFIGURATION

LT JOHN I. BRADY, JR., MSC, USNR

MAY 1978

Approved for public release; distribution unlimited

Submitted:

J.R. Middleton

J.R. MIDDLETON
Test Engineer

Reviewed:

J.G. MALEC
LCDR, RN
T&E Department Head

Approved:

C.A. BARTHOLOMEW
CDR, USN
Commanding Officer

John I. Brady Jr

J.I. BRADY, JR.
LT, MSC, USNR
Experimental Psychologist

W.H. SPAUR
CAPT, MC, USN
Senior Medical Officer

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Ditching
Integrated Divers Vest
Umbilical Mode
Sideblock
Work of breathing

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

PART I. NEDU conducted a series of unmanned comparative tests using the USN MK 1 MOD O mask in various bailout mode configurations. The purpose of these was to determine if the MK 1 Mod O mask could be used safely with a diver carried scuba air supply. This mode of operation would potentially be used only by activities not having a sufficient air source to maintain 135 psig over bottom pressures during diving operations. In this configuration the tether would be retained for communications. The mask was first tested in the normal umbilical supplied mode to provide a basis for comparison.

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The mask was first tested in the normal umbilical supplied mode to provide a basis for comparison. The MK 1 Mod O was then set up in bailout or emergency mode using first a Scubapro MK V first stage and second a U.S. Divers Conshelf XII first stage. Both first stage regulators were set to factory specifications for intermediate pressure. The standard MK 1 Mod O second stage was used throughout the test series.

Results of the Scubapro MK V and U.S. Divers conshelf XII comparison showed that the Conshelf XII significantly outperformed the MK V. Further tests were conducted using the Conshelf XII at varying intermediate pressures and bailout configurations.

Tests were run with the Conshelf XII supplying pressure to the sideblock emergency port at pressures varying from 135 to 180 psig O/B. A special adapter was constructed and the same tests were run with the first stage supplying the umbilical port.

Test results showed that mask performance in the bailout mode was comparable to that achieved in normal umbilical mode at depths over 60 FSW only when intermediate pressures to the bailout port approached 180 psig O/B. When the first stage regulator was attached to the umbilical port with a special adapter, mask performance was almost indentical to that of normal umbilical mode at supply pressures of only 135 psig O/B. However, because of the additional expense and logistic requirements of using a special adapter for connecting the first stage hose to the umbilical port, it is recommended that the USN MK 1 Mod O mask be used with scuba in the bailout supply mode. Further, it should be used only in conjunction with a U.S. Divers Conshelf XII regulator with an intermediate pressure setting of 180 psig O/B. If diving depths are limited to a maximum of 66 FSW, the 135 psig O/B intermediate supply pressure from the first stage to the bailout port is adequate.

PART II. A human engineering and safety evaluation of the MK 1 Mod O in tethered SCUBA configuration was undertaken at NEDU. The philosophy underlying this evaluation was that this configuration was, for practical purposes, only an extension of normal SCUBA diving. Thus a determination was sought as to whether the MK 1 Mod O or any associated equipment would conflict with the necessary safety procedures involved in the use of SCUBA. The compatibility of the MK 1 Mod O in tethered SCUBA configuration with a variety of diving suits (i.e. swimsuit, wetsuit, drysuit (Unisuit), and MK 16 hot water suit) was also investigated. The observed findings are described and discussed. It was concluded that MK 1 Mod O tethered SCUBA is a viable, safe diving configuration with demonstrated flexibility regarding the diving suits with which it can be used.

Glossary

Abbreviation	Definition
BPM	breaths per minute
cm H_2O	centimeters of water pressure (differential)
fsw	feet of seawater
HeO_2	helium-oxygen breathing gas
I.D.	inside diameter
kg.m/l	breathing work in kilogram meters per liter ventilation
LPM	liters per minute (flow rate)
mil spec	military specification MIL-R-24169A
NEDU	Navy Experimental Diving Unit
O/B	over bottom pressure
ΔP	pressure differential
psig	pounds per square inch gauge
RMV	respiratory minute volume in liters per minute
USN	United States Navy

Abstract

PART I

NEDU conducted a series of unmanned comparative tests using the USN MK 1 Mod 0 mask in various bailout mode configurations. The purpose of these tests was to determine if the MK 1 Mod 0 mask could be used safely with a diver carried scuba air supply. This mode of operation would potentially be used only by activities not having a sufficient air source to maintain 135 psig over bottom pressures during diving operations. In this configuration the tether would be retained for communications. The mask was first tested in the normal umbilical supplied mode to provide a basis for comparison. The MK 1 Mod 0 was then set up in bailout or emergency mode using first a Scubapro MK V first stage and second a U.S. Divers Conshelf XII first stage. Both first stage regulators were set to factory specifications for intermediate pressure. The standard MK 1 Mod 0 second stage was used throughout the test series.

Results of the Scubapro MK V and U.S. Divers Conshelf XII comparison showed that the Conshelf XII significantly outperformed the MK V. Further tests were conducted using the Conshelf XII at varying intermediate pressures and bailout configurations.

Tests were run with the Conshelf XII supplying pressure to the sideblock emergency port at pressures varying from 135 to 180 psig O/B. A special adapter was constructed and the same tests were run with the first stage supplying the umbilical port.

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PART II

A human engineering and safety evaluation of the MK 1 Mod 0 in tethered SCUBA configuration was undertaken at NEDU. The philosophy

underlying this evaluation was that this configuration was, for practical purposes, only an extension of normal SCUBA diving. Thus a determination was sought as to whether the MK 1 Mod 0 or any associated equipment would conflict with the necessary safety procedures involved in the use of SCUBA. The compatibility of the MK 1 Mod 0 in tethered SCUBA configuration with a variety of diving suits (i.e. swimsuit, wetsuit, drysuit (Unisuit), and MK 16 hot water suit) was also investigated. The observed findings are described and discussed. It was concluded that MK 1 Mod 0 tethered SCUBA is a viable, safe diving configuration with demonstrated flexibility regarding the diving suits with which it can be used.

PART I

UNMANNED EVALUATION OF THE USN MK 1 MOD 0
MASK IN UMBILICAL AND EMERGENCY MODES

I. INTRODUCTION

In July 1977 NEDU conducted a series of tests using the USN MK 1 Mod 0 mask in various "bailout" or emergency configurations. These unmanned tests were conducted to determine if the MK 1 Mod 0 mask could safely be used with scuba tanks as a primary operating mode. This mode would potentially be used only by activities not having a sufficient air source to maintain 135 psig over bottom pressures during diving operations. In this configuration the tether would be retained for communications.

A complete series of tests was done initially using the mask in the umbilical mode. This is the normal operating mode and was used to give base data for comparison purposes. Tests included monitoring breathing resistance at RMV's simulating light to extreme diver work rates, measuring sideblock pressure drop and measuring umbilical pressure drop.

The mask was then tested in the emergency mode using two different first stage regulators, firstly with a Scubapro MK V balanced piston first stage, manufactured by Undersea Industries, Inc., 3105 E. Harcourt Street, Compton, California 90221, and secondly a U.S. Divers Conshelf XII balanced diaphram first stage, manufactured by U.S. Divers Company, 3323 W. Warner Avenue, Santa Ana, California 92702.

Both regulators were set to factory specifications of 135 psig O/B intermediate pressure. Each was tested under the same conditions described above for the umbilical mode except that instead of monitoring umbilical pressure drop, first stage intermediate pressure loss at the various RMV's was measured.

Results showed that the Conshelf XII significantly outperformed the MK V. Consequently, testing of the mask in conjunction with the Scubapro MK V was discontinued.

The mask was further tested using the Conshelf XII at higher intermediate supply pressures to the emergency port and the umbilical port (using a special adapter). Test conditions remained identical to those previously described.

II. TEST PROCEDURE

A. Test Plan

NEDU test equipment was set up as shown in Figures 1a and 1b and all testing was done in accordance with applicable mil specs. The actual test plan is given in Appendix A. A breathing machine simulated

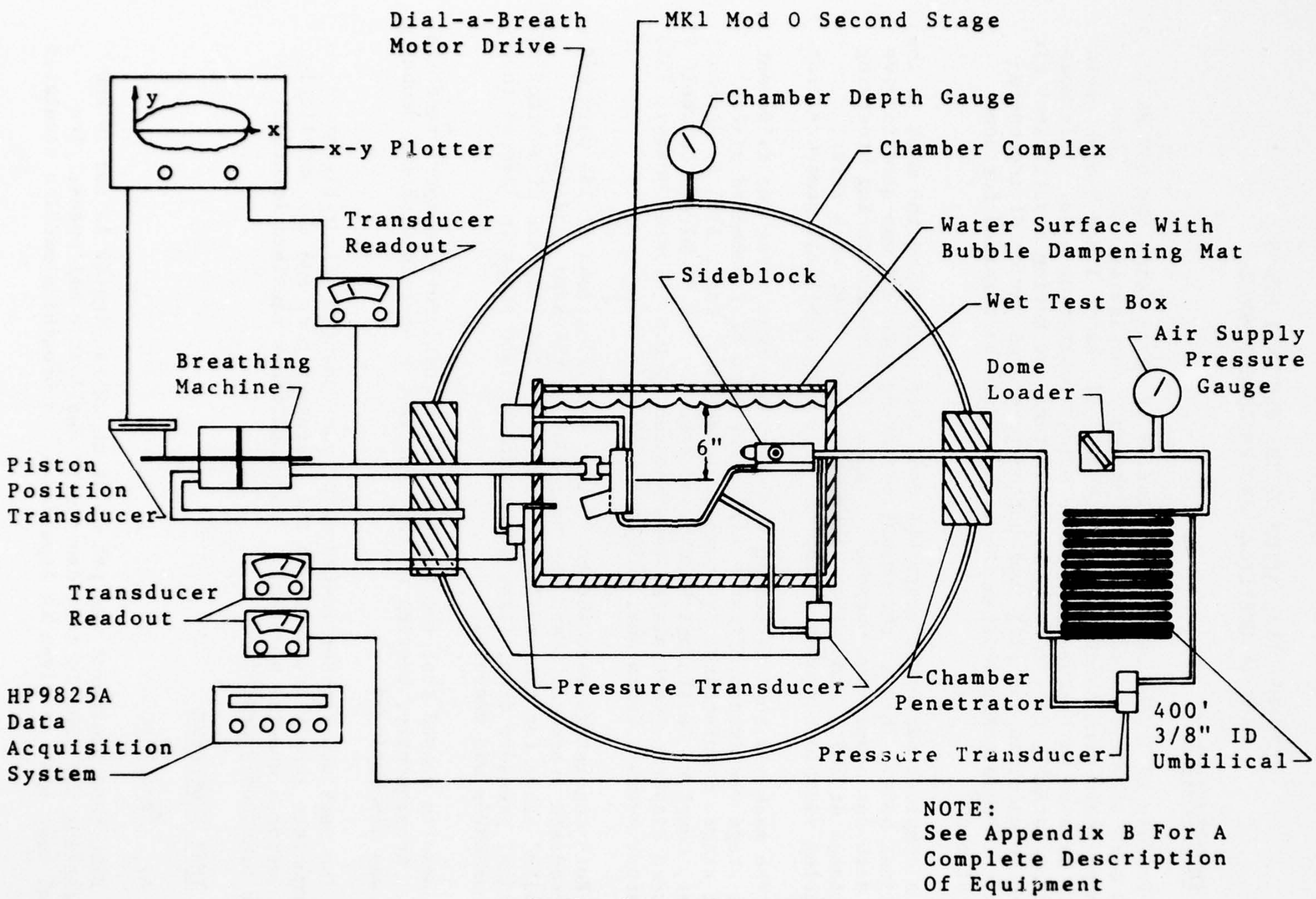


FIGURE 1a TEST SETUP

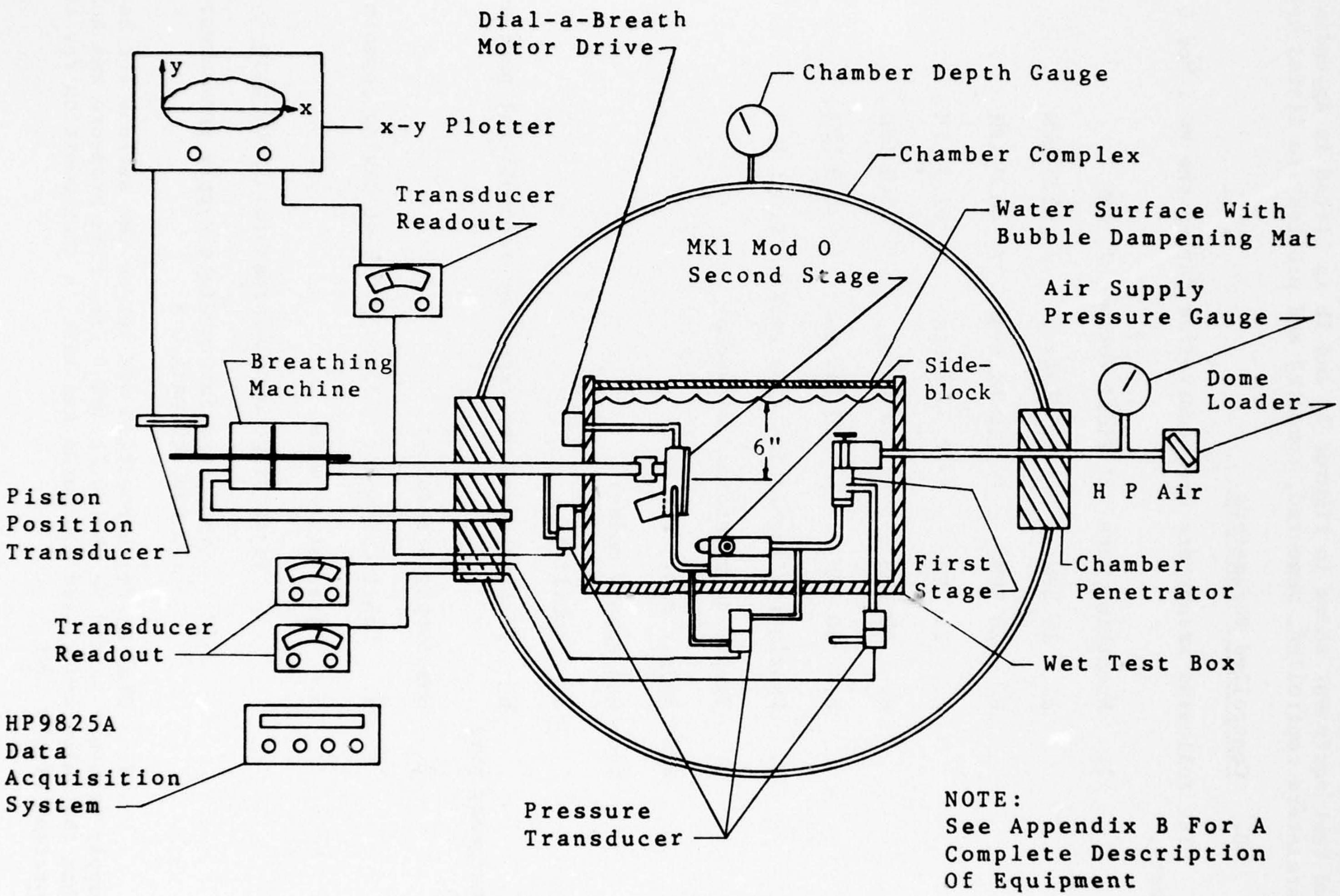


FIGURE 1b TEST SETUP

diver inhalation and exhalation at various depths. The instrumentation and test equipment shown in Figures 1a and 1b is listed in Appendix B. Parameters controlled, measured, computed and plotted are listed below.

B. Controlled Parameters

The following parameters were controlled during the MK 1 Mod 0 tests.

1. Breathing Rate / Tidal Volume / RMV

   a. 15 BPM / 1.5 Liters / 22.5 LPM

   b. 20 BPM / 2.0 Liters / 40.0 LPM

   c. 25 BPM / 2.5 Liters / 62.5 LPM

   d. 30 BPM / 2.5 Liters / 75.0 LPM

   e. 30 BPM / 3.0 Liters / 90.0 LPM

2. Exhalation/Inhalation time ratio: 1.0/1.0

3. Breathing waveform: sinusoid

4. Supply gas: air

5. Gas supply modes:

   a. Umbilical

   b. First stage scuba regulator to umbilical port and emergency port

6. Gas supply pressures:

   a. Umbilical mode: 135 psig O/B at diving console

   b. First stage mode:

      (1) First stage supply pressure: 1000 psig

      (2) First stage intermediate supply pressures: 135 and 180 psig O/B

7. Dial-A-Breath position was set on the surface for each supply pressure tested so that 0.15 cmH_2O free flow pressure was achieved. Then the valve was closed 1.5 turns and left in that position for the duration of the test.

C. <u>Measured Parameters</u>

The following parameters were measured during the tests:

1. Inhalation maximum ΔP

2. Exhalation maximum ΔP

3. ΔP vs. tidal volume plots

4. Dynamic pressure drop across sideblock

5. Dynamic pressure drop across umbilical (umbilical mode test only)

6. Dynamic pressure drop at first stage regulator outlet (emergency mode tests only)

D. <u>Computed Parameters</u>

Respiratory work is computed from ΔP vs. tidal volume plots for selected test conditions.

E. <u>Data Plotted</u>

The following data are plotted.

1. Inhalation maximum ΔP vs. depth at each RMV and supply pressure tested

2. Exhalation maximum ΔP vs. depth at each RMV and supply pressure tested

3. Respiratory work vs. depth at selected RMV and supply pressures

4. Dynamic pressure drop across mask sideblock vs. depth at each RMV and supply pressure tested

5. Dynamic pressure drop across umbilical vs. depth at each RMV tested (umbilical mode only)

6. Dynamic pressure drop at first stage outlet vs. depth at each RMV and supply pressure tested (emergency mode tests only)

III. RESULTS AND DISCUSSION

A. Description

The USN MK 1 Mod 0 is an open circuit full face mask with oral-nasal cavity which is designed for surface supplied or saturation umbilical diving. The mask has the capability of operating in either the demand or free flow mode. The demand mode incorporates a "Dial-A-Breath" valve which allows a diver to maintain low breathing resistance regardless of gas supply pressure. The "Dial-A-Breath" valve is also used to create a free flow mode through the demand regulator. The divers exhaled gas is vented through the exhaust valve in the demand regulator assembly or through a supplemental exhaust valve located beneath the demand regulator housing.

A gas supply umbilical connects to the sideblock assembly on the right side of the mask. The sideblock houses a non-return valve in the umbilical supply port and also incorporates a separate gas supply valve and connector for an emergency gas supply. The emergency supply normally consists of a standard scuba tank and first stage regulator assembly which is worn on the divers back. The intermediate pressure hose from the first stage regulator connects to the emergency supply port on the sideblock. In addition, for test purposes a special adapter was constructed which allowed the first stage intermediate pressure hose to also be connected to the umbilical supply port. This was done to determine if the larger porting in the sideblock umbilical flow path would result in less pressure loss and lower breathing resistance.

B. MK 1 Mod 0 Umbilical Mode Tests Results

1. Breathing Resistance Tests. Breathing resistance was measured at 5 RMV's to simulate light through extreme diver work rates. Light work was simulated at 22.5 RMV, moderate work at 40.0 RMV, moderately heavy work at 62.5 RMV, heavy work at 75.0 RMV and extreme work at 90.0 RMV. The mil spec (reference 1) calls for 40 RMV only. The other RMV's were measured, however, to indicate the full range of mask performance.

The breathing resistances plotted in the figures are the maximum values measured, excluding cracking pressures, during a complete inhalation-exhalation cycle at a given depth and RMV. Umbilical supply pressure was maintained at 135 psig O/B. On plots where the data is incomplete, the test was terminated due to excessive breathing resistance.

a. Inhalation Characteristics. The inhalation resistances plotted are the maximum pressures recorded, except for cracking pressures, at all RMV's. Maximum resistance always occurred at the point of peak flow rate during inhalation and exhalation cycles. It was observed that breathing resistance was very sensitive to "Dial-A-Breath" position. Consequently, the valve was set as previously described for minimum breathing resistance at a specific overbottom pressure and left for the duration of the test. This is true for all modes tested in this report.

The cracking pressure of the MK 1 Mod 0 mask was low and generally was accompanied by smooth flow and no pressure fluctuations on inhalation. The initial pressure spike represents very little breathing work and is ignored when it exceeds peak flow differential pressures. High differential pressures to initiate flow in a demand regulator usually result from an incorrectly adjusted diaphram/linkage assembly. This represents no threat to the divers life support system or its overall performance. A typical pressure volume-loop is represented in Figures 2 and 3. This also applies to all modes tested in this report.

Inhalation resistance remained almost constant at 22.5 (Figure 4) and 40 RMV (Figure 5) reaching a peak of 12 cmH_2O. This is also true of 62.5 RMV (Figure 6) until 198 FSW is reached and breathing resistance increases from 15 to 40 cmH_2O.

At 75 RMV (Figure 7) breathing resistance is very low until depth approaches 165 FSW exceeds 50 cmH_2O. This represents heavy diver work and mask performance under these conditions is exceptionally good.

The extreme work rate of 90 RMV (Figure 8) produced acceptable resistance levels to depths of only 99 FSW. This work rate can be sustained only for very short periods of time and is an extreme performance level for any type of diving equipment.

b. Exhalation Characteristics. Exhalation resistance at 22.5 RMV (Figure 4) and 40.0 RMV (Figure 5) was within mil spec limits. At 62.5 RMV (Figure 6) and 75.0 RMV (Figure 7) exhalation pressures were outside mil spec limits but posed no hindrance to diver performance. Ninety RMV (Figure 8) produced exhalation pressures which are prohibitive at depths over 99 FSW.

2. Work of Breathing Results. The specification governing testing of all breathing apparatus cites peak inhalation and peak exhalation pressures as the standard for evaluation (reference 1). However, recent research (reference 2) has shown that measurements of diver's external respiration work in operating his breathing apparatus yield useful data for evaluating equipment performance. In breathing apparatus other than open circuit demand, breathing work is probably the most valid measurement of equipment performance. With open-circuit demand UBA's, breathing work is supplementary indicator of equipment

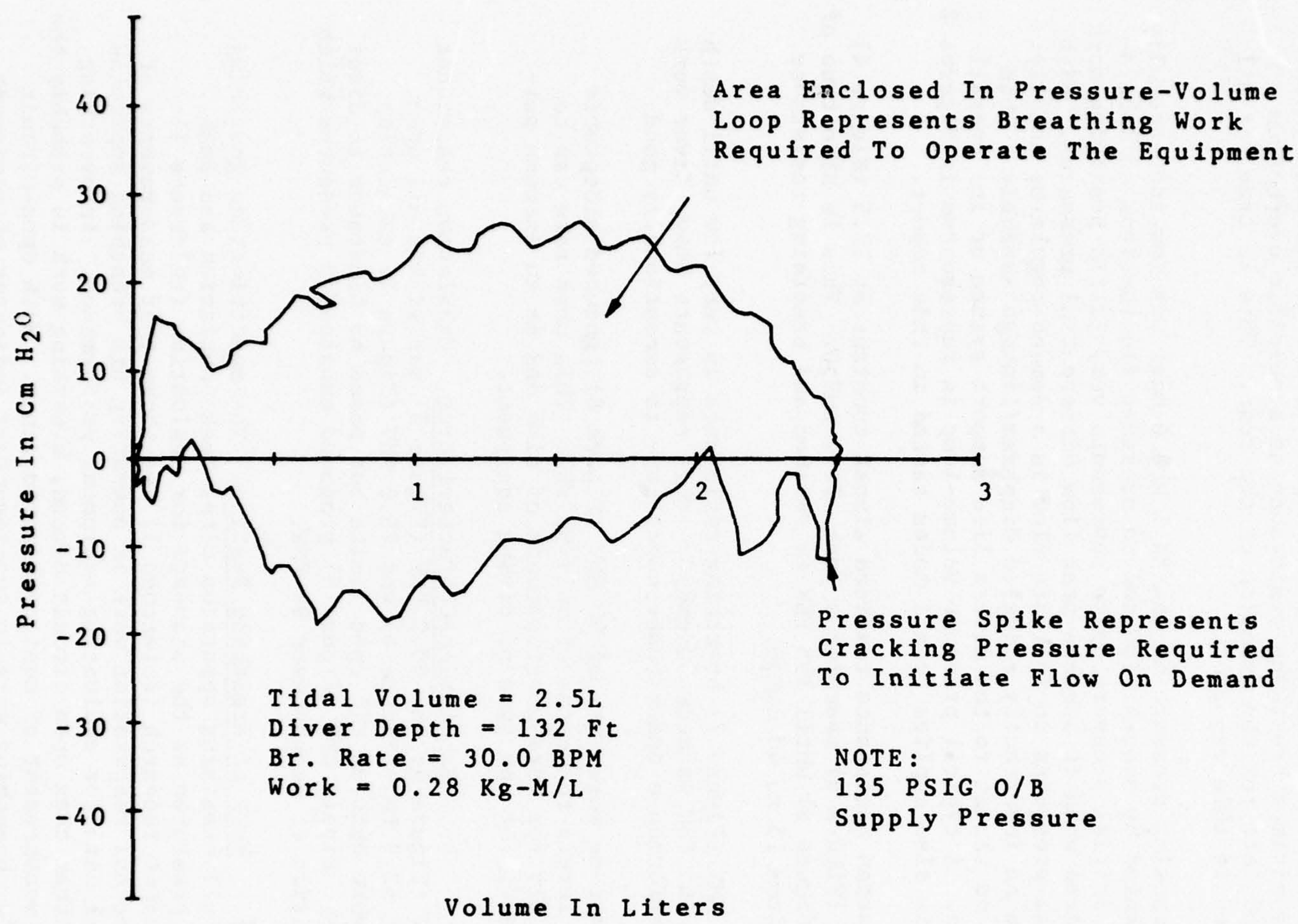


FIGURE 2. MK1 MOD 0 UMBILICAL MODE TEST

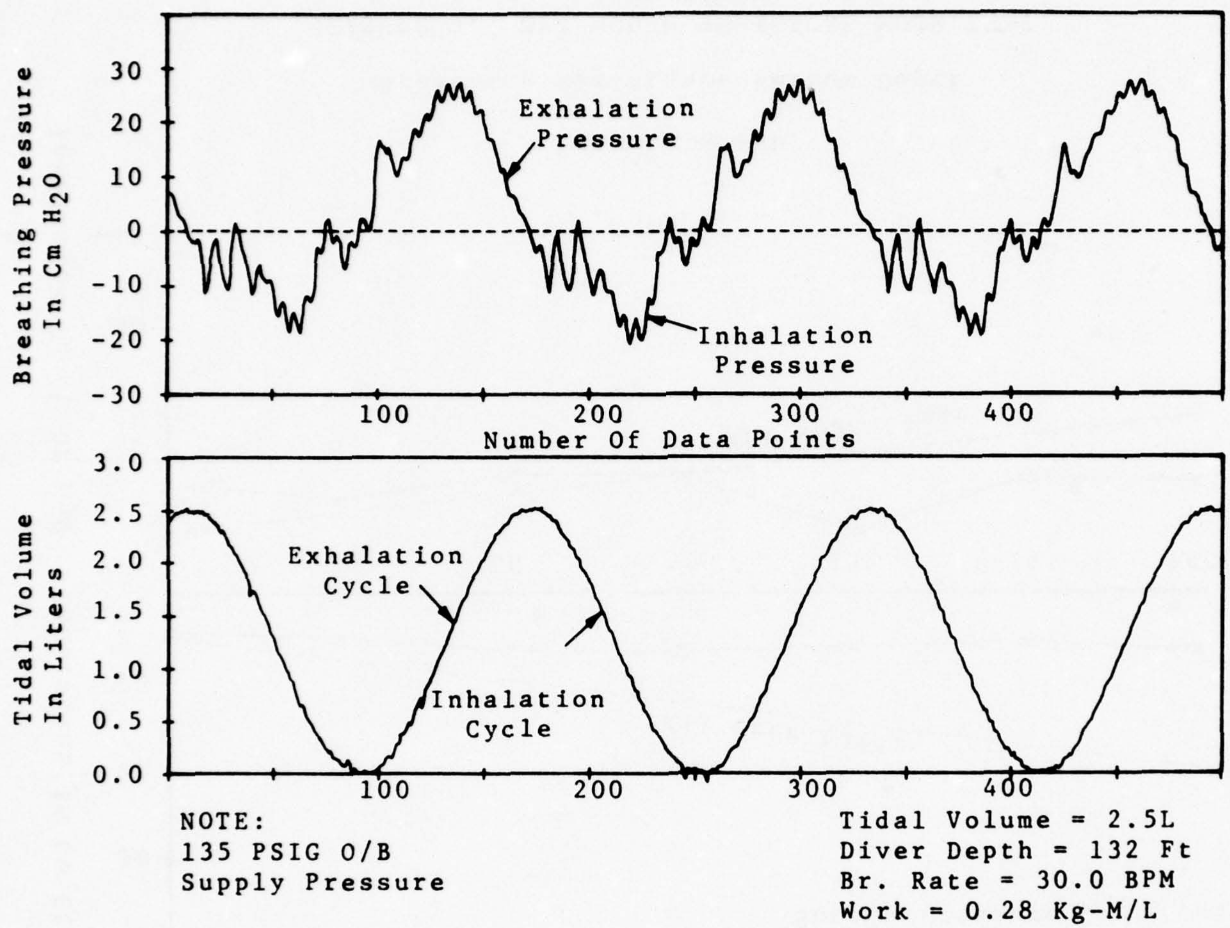
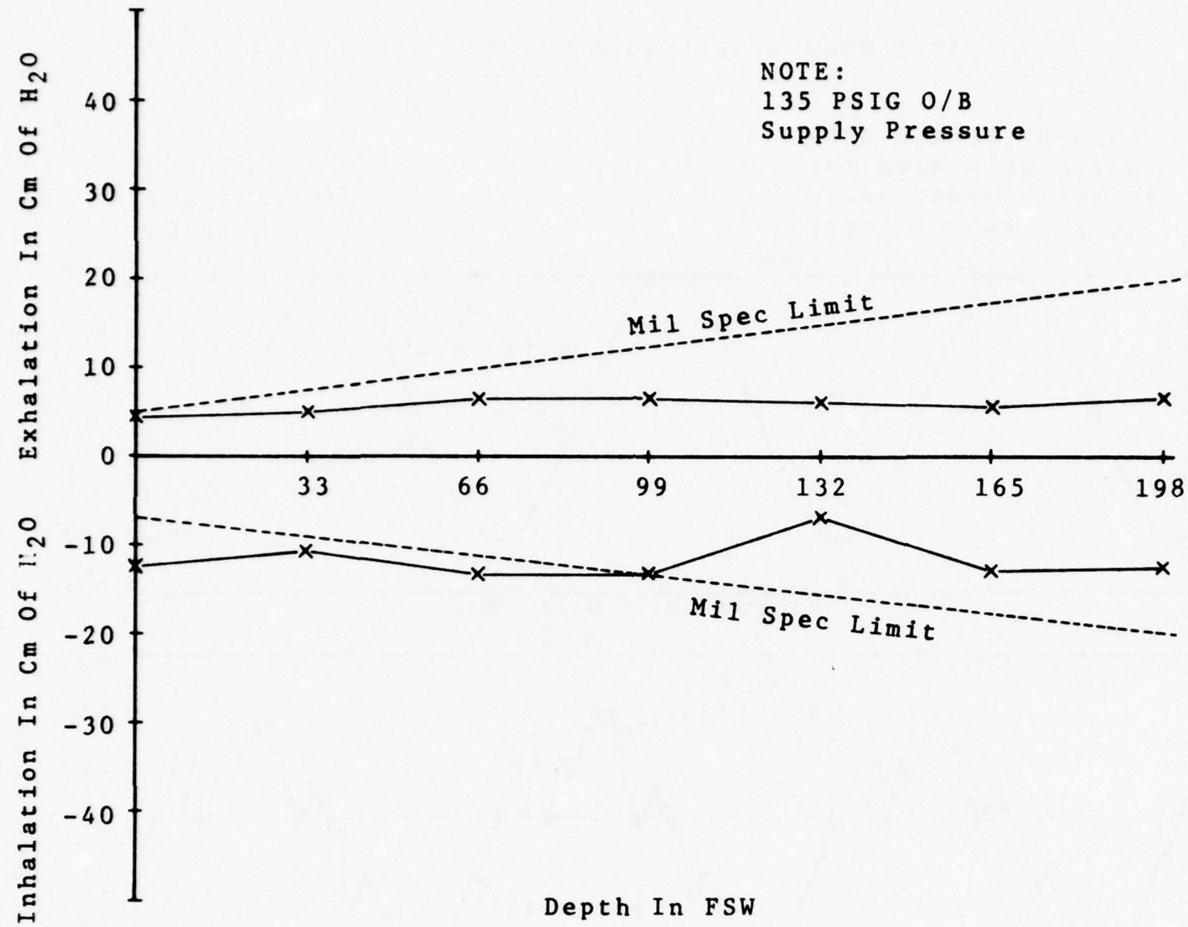
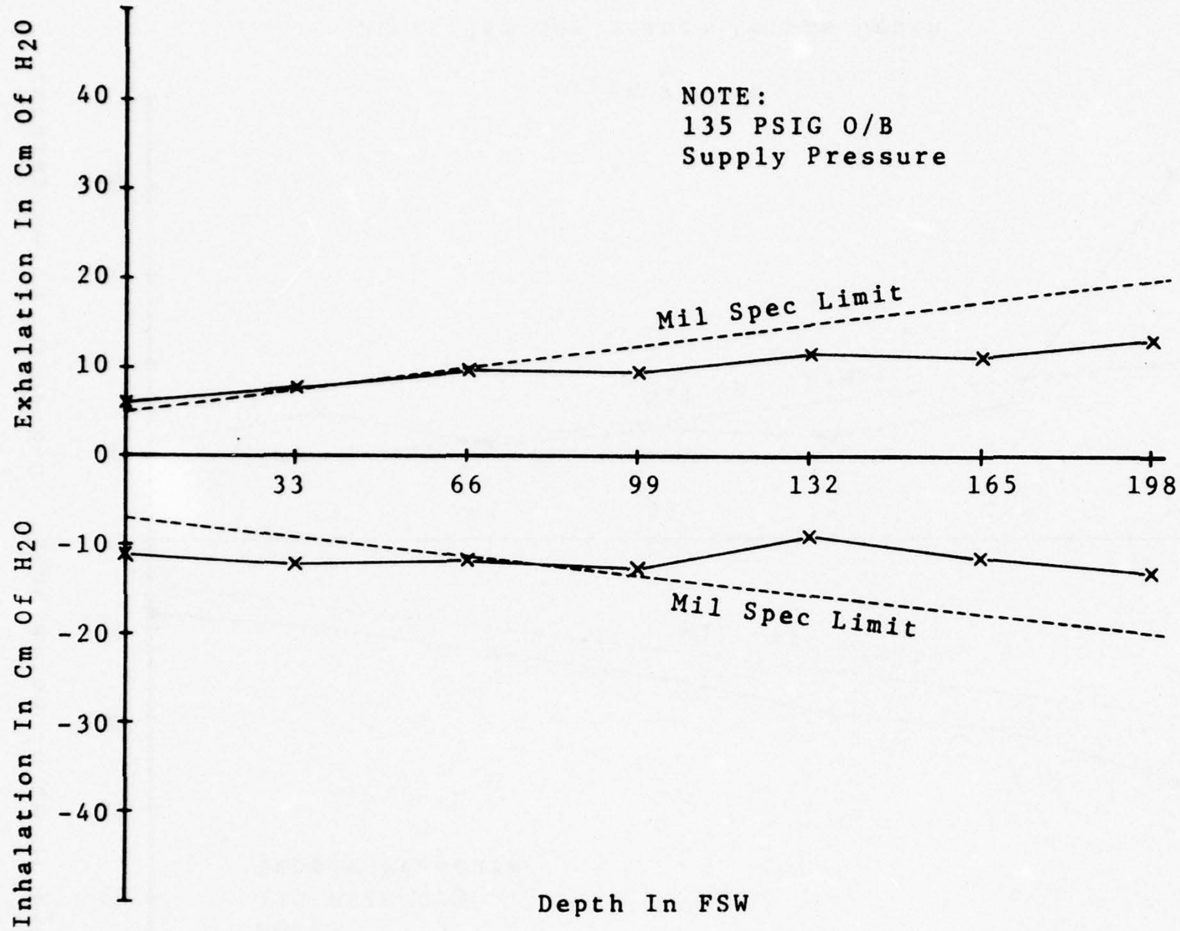


FIGURE 3. MK1 MOD O UMBILICAL MODE TEST



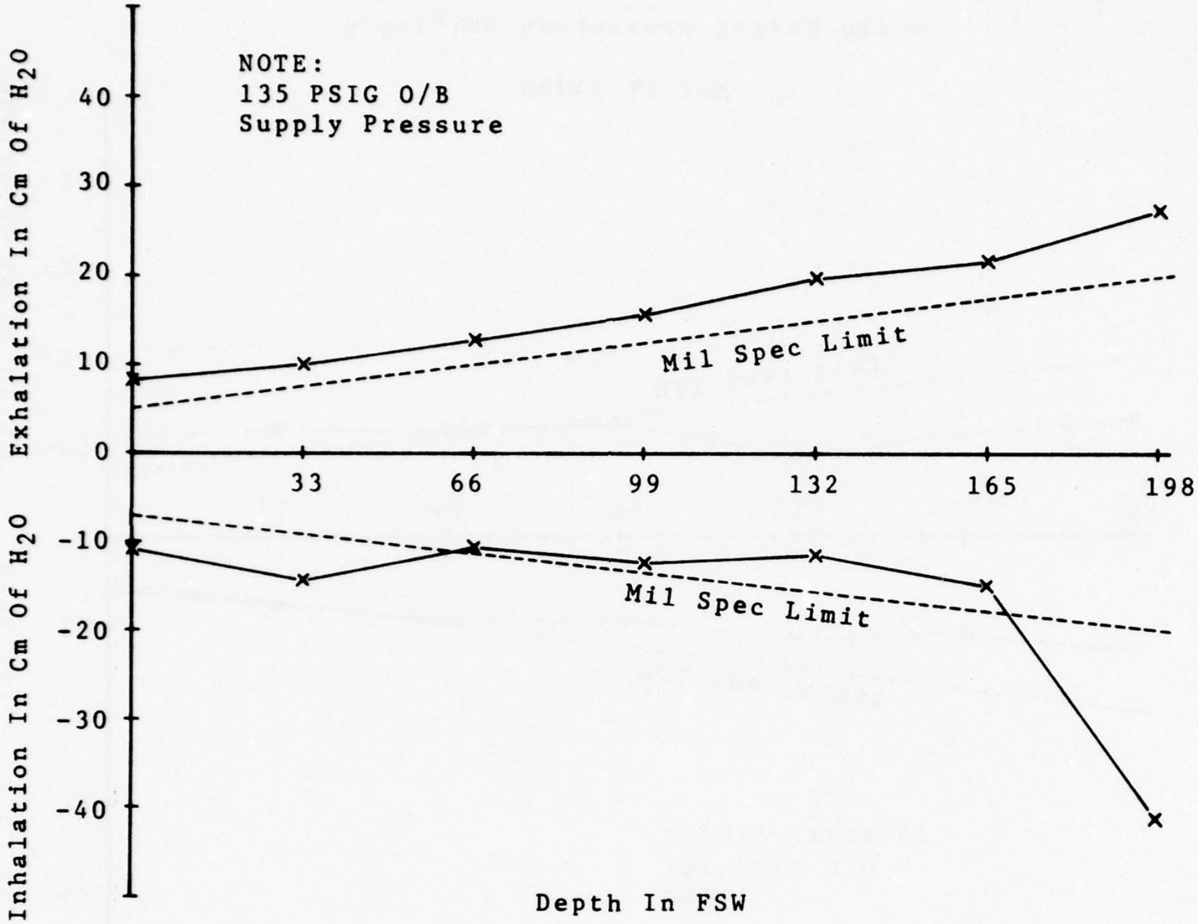
Breathing Resistance Versus Depth

FIGURE 4. MK1 MOD O UMBILICAL MODE TEST
22.5 R/M/V



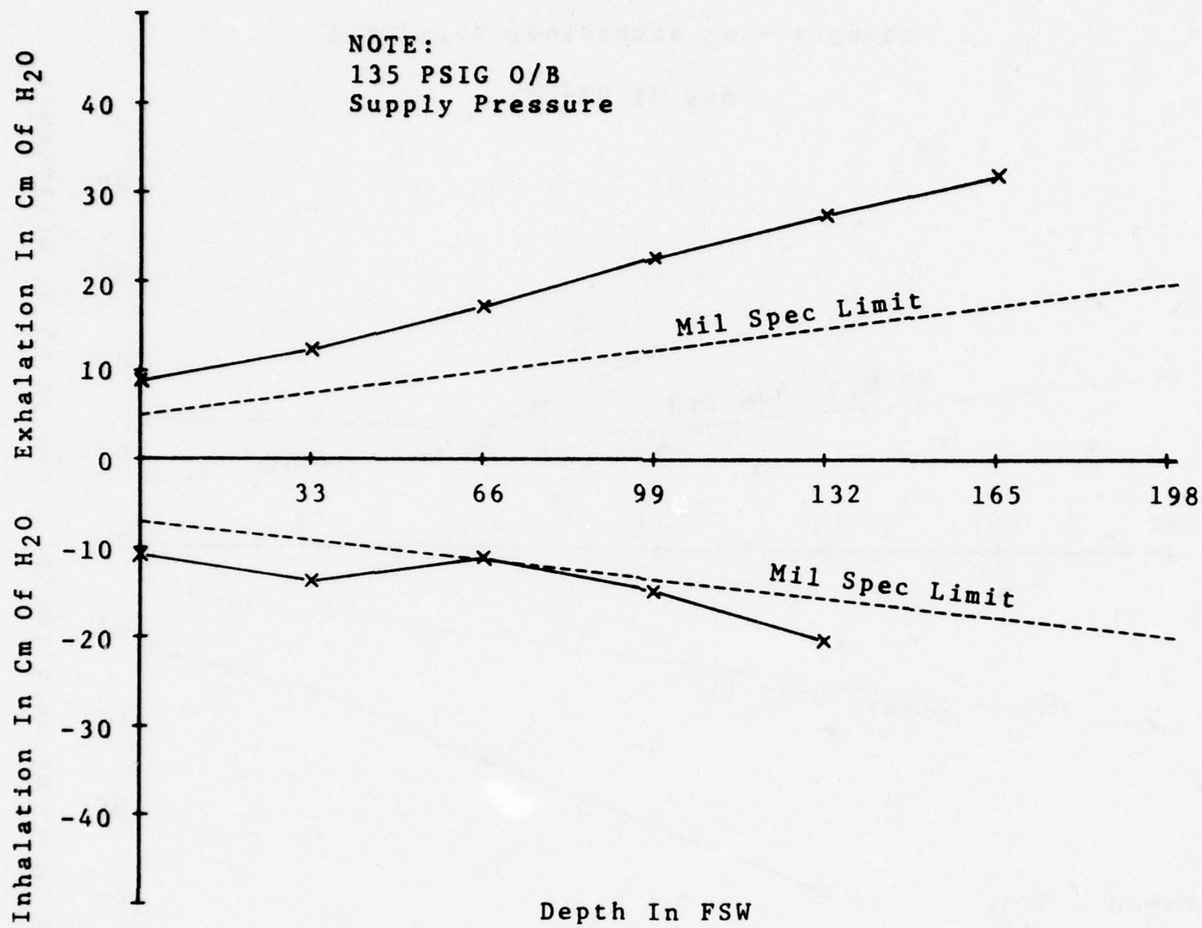
Breathing Resistance Versus Depth

FIGURE 5. MK1 MOD 0 UMBILICAL MODE TEST
40.0 R/M/V



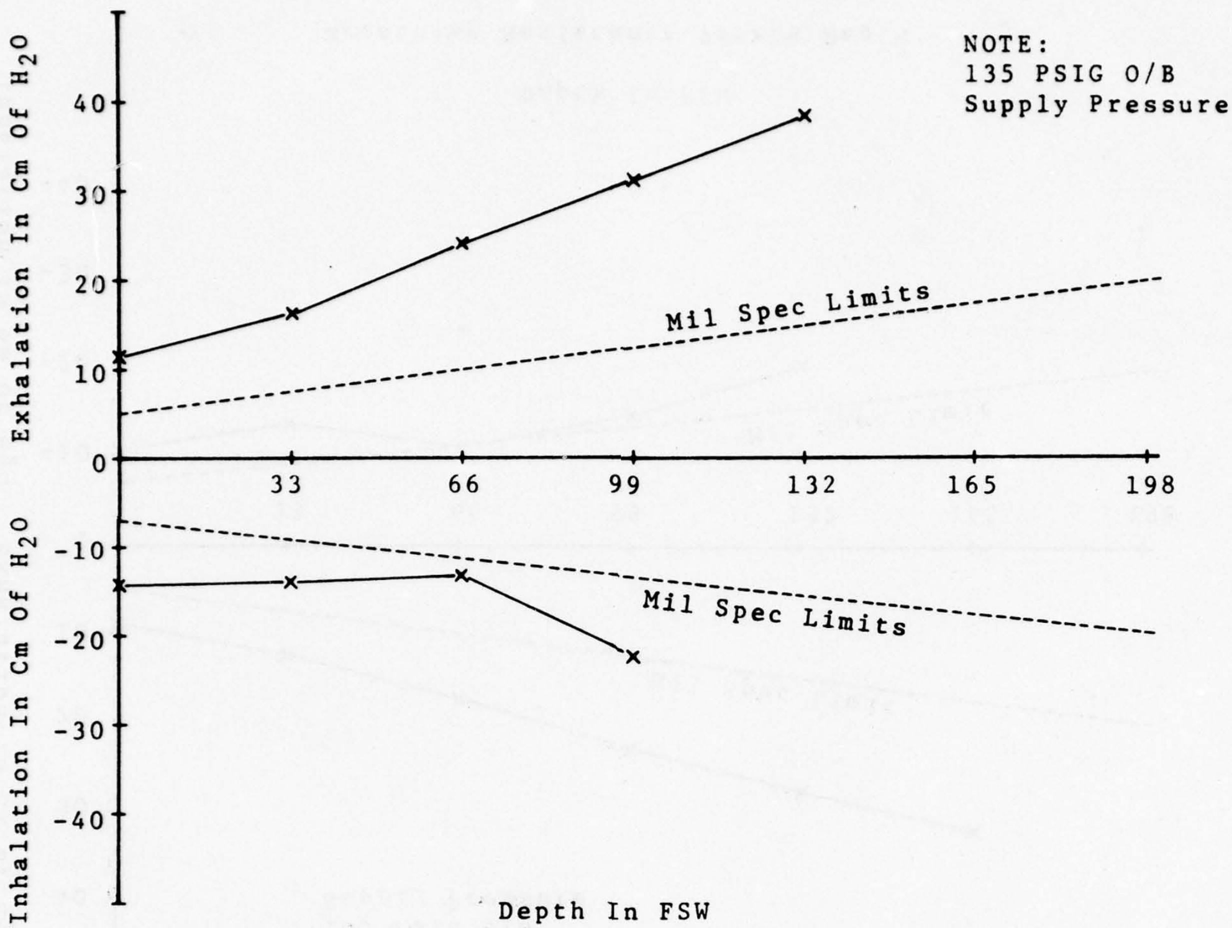
Breathing Resistance Versus Depth

FIGURE 6. MK1 MOD O UMBILICAL MODE TEST
62.5 R/M/V



Breathing Resistance Versus Depth

FIGURE 7. MK1 MOD 0 UMBILICAL MODE TEST
75.0 R/M/V



Breathing Resistance Versus Depth

FIGURE 8. MK1 MOD 0 UMBILICAL MODE TEST
90.0 R/M/V

performance. Reference 3 proposes a standard of 0.170 kilogram-meter per liter ventilation (kg.m/l; liter ventilation is defined as tidal volume at a given RMV) as the maximum allowable external respiratory work. This figure is used in this report for comparative purposes only. Breathing work is defined as the area enclosed by a typical pressure-volume loop generated during one complete breathing cycle (Figure 2). This applies to all modes tested in this report.

Breathing work (Figure 9) required for the MK 1 Mod 0 remained low at 22.5 and 40 RMV reached a maximum of .15 kg.m/l. At 62.5 RMV breathing work reached the NEDU proposed limit of 0.17 kg.m/l at 132 FSW. Work rates at 75 RMV exceeded the proposed standard at 99 FSW and approached .50 kg.m/l at 198 FSW. Beyond 99 FSW at 90.0 RMV, breathing work exceeded levels that would be considered safe in other than emergency conditions.

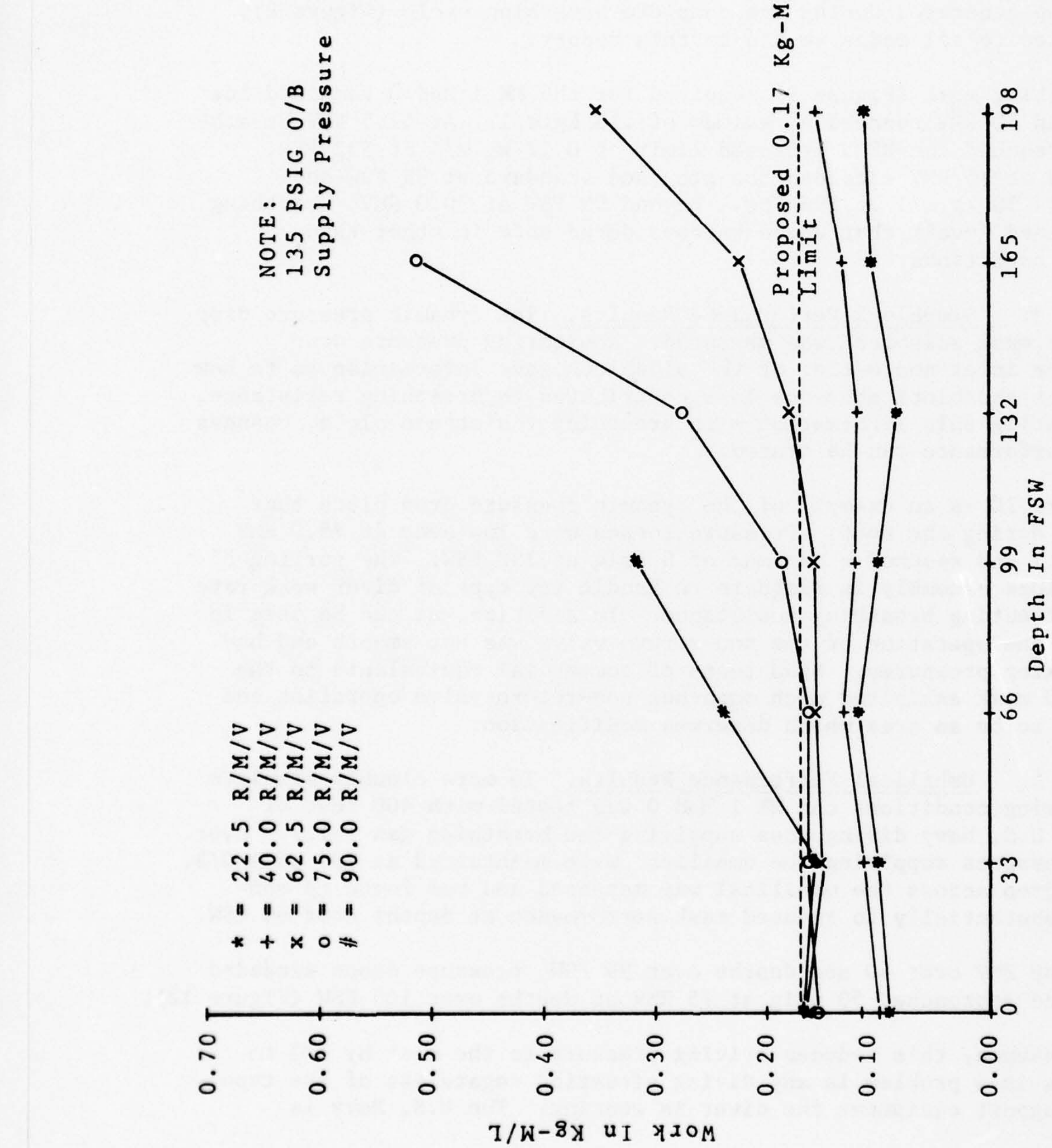
3. Sideblock Performance Results. The dynamic pressure drop across the mask sideblock was measured. Monitoring pressure drop between the inlet and outlet of the sideblock gave information as to how much affect sideblock pressure loss contributed to breathing resistance. By correlating this information with breathing resistance plots, changes in mask performance can be traced.

Figure 10 is an example of the dynamic pressure drop plots that were made during the test. Pressure losses were low even at 75.0 RMV (Figure 11) and reached a maximum of 8 psig at 198 FSW. The porting of the sideblock assembly is adequate to handle any type of diver work rate without affecting breathing resistance. In addition, as can be seen in Figure 10 the operation of the non-return valve was not smooth and had high cracking pressures. NEDU tests of commercial equivalents to the MK 1 Mod 0 mask exhibited much smoother non-return valve operation and show this to be an area which deserves modification.

4. Umbilical Performance Results. To more closely simulate actual diving conditions the MK 1 Mod 0 was tested with 400 feet of 3/8" I.D. U.S. Navy diving hose supplying the breathing gas (air). Over bottom pressures supplying the umbilical were maintained at 135 psig O/B. Pressure drop across the umbilical was measured and was found to contribute substantially to reduced mask performance at depths over 66 FSW.

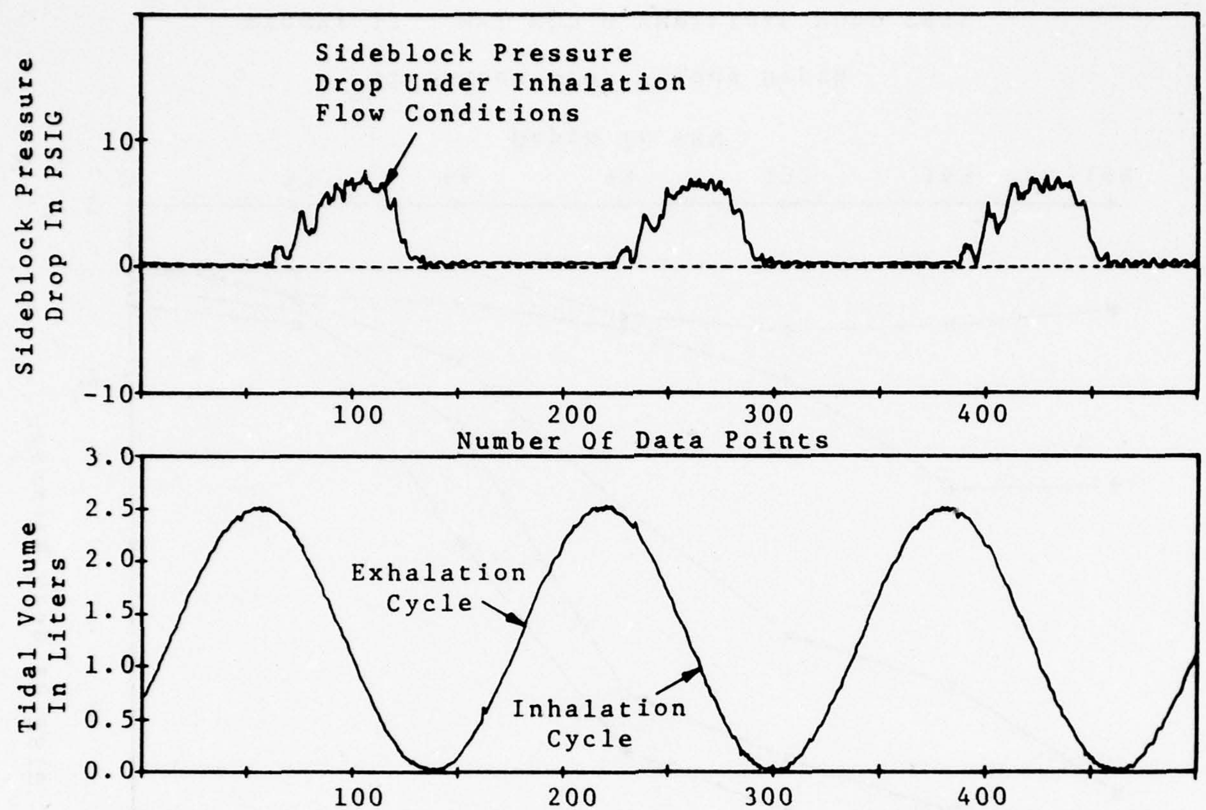
At any RMV over 40 and depths over 99 FSW, pressure drops exceeded 20 psig and approached 50 psig at 75 RMV at depths over 165 FSW (Figure 12).

In essence, this reduces driving pressure to the mask by 10% to 30%. This is a problem in any diving situation regardless of the type of life support equipment the diver is wearing. The U.S. Navy is



Breathing Work Versus Depth

FIGURE 9. MK1 MOD O UMBILICAL MODE TEST

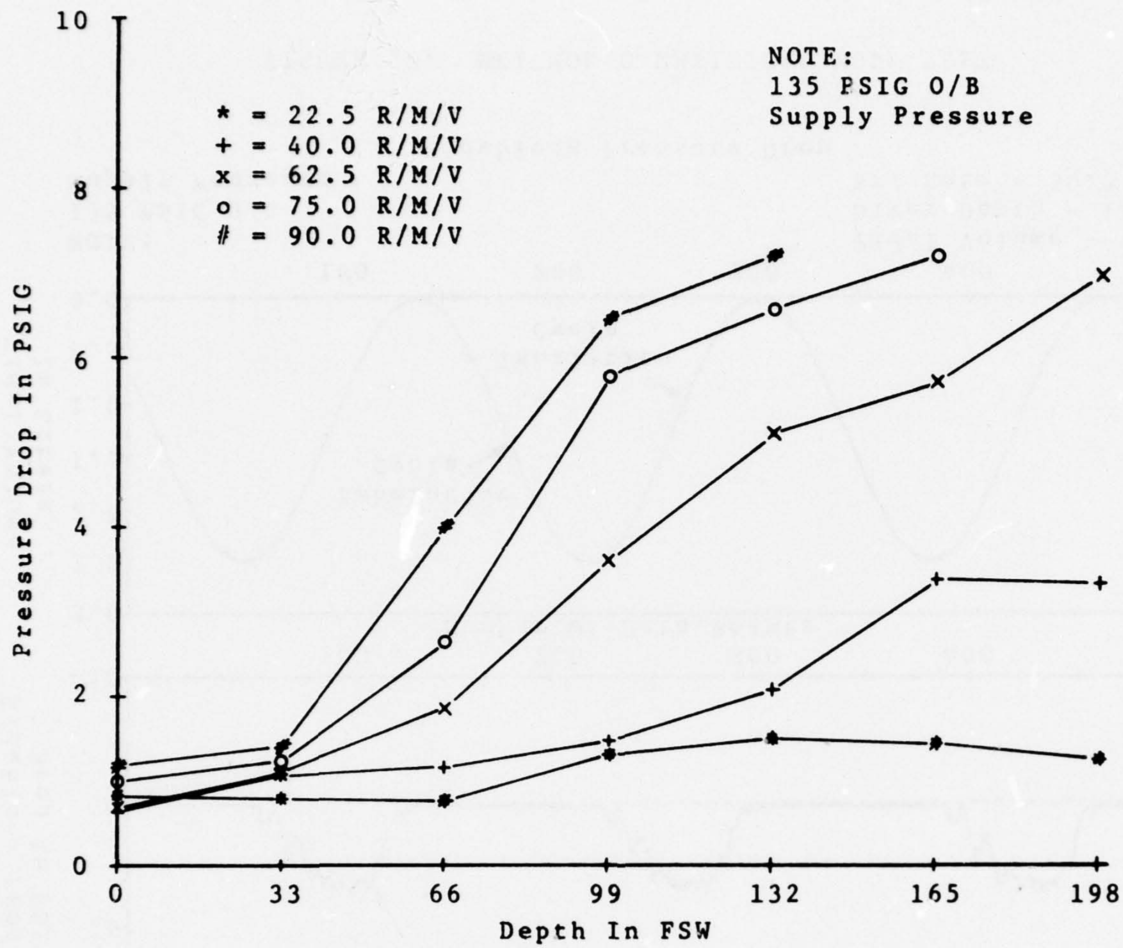


NOTE:
135 PSIG O/B
Supply Pressure

Tidal Volume = 2.5 L
Diver Depth = 132 Ft
Br. Rate = 30.0 BPM

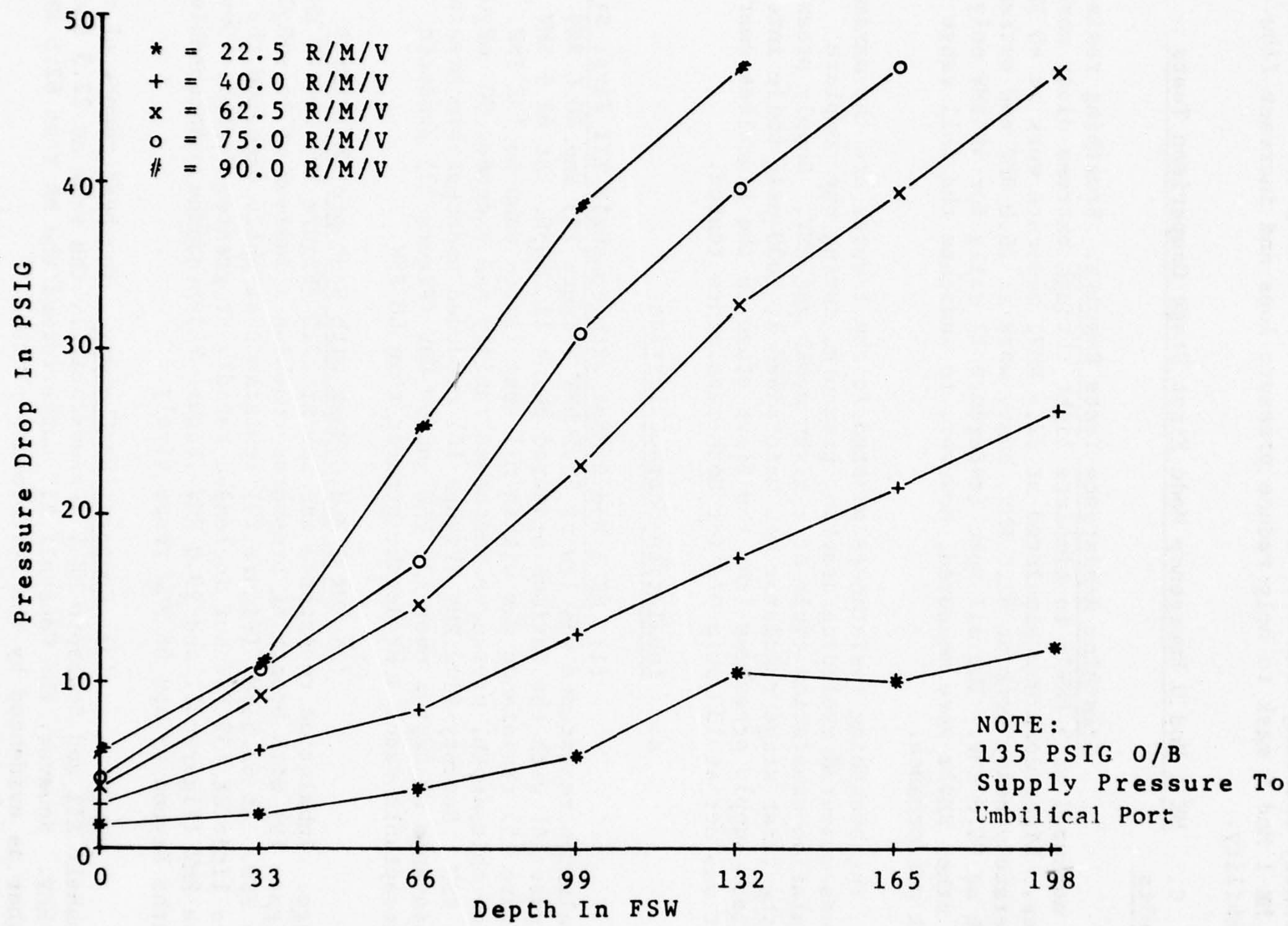
Sideblock Pressure Drop

FIGURE 10. MK1 MOD 0 UMBILICAL MODE TEST



Sideblock Drop Versus Depth

FIGURE 11. MK1 MOD O UMBILICAL MODE TEST



Umbilical Pressure Drop Versus Depth

FIGURE 12. MK1 MOD O UMBILICAL MODE TEST

currently shifting from 3/8" I.D. to 1/2" I.D. diving hose when using the MK 1 Mod 0 mask to help reduce pressure loss and increase flow capability.

C. MK 1 Mod 0 Emergency Mode First Stage Comparison Tests Results

1. Breathing Resistance Tests Results. Breathing resistance was measured at 5 RMV's to simulate light through extreme diver work rates. Light work was simulated at 22.5 RMV, moderate work at 40 RMV, moderately heavy work at 62.5 RMV, heavy work at 75.0 RMV and extreme work at 90.0 RMV. The mil spec (reference 1) calls for 40 RMV only. The other RMV's were measured, however, to indicate the full range of mask performance.

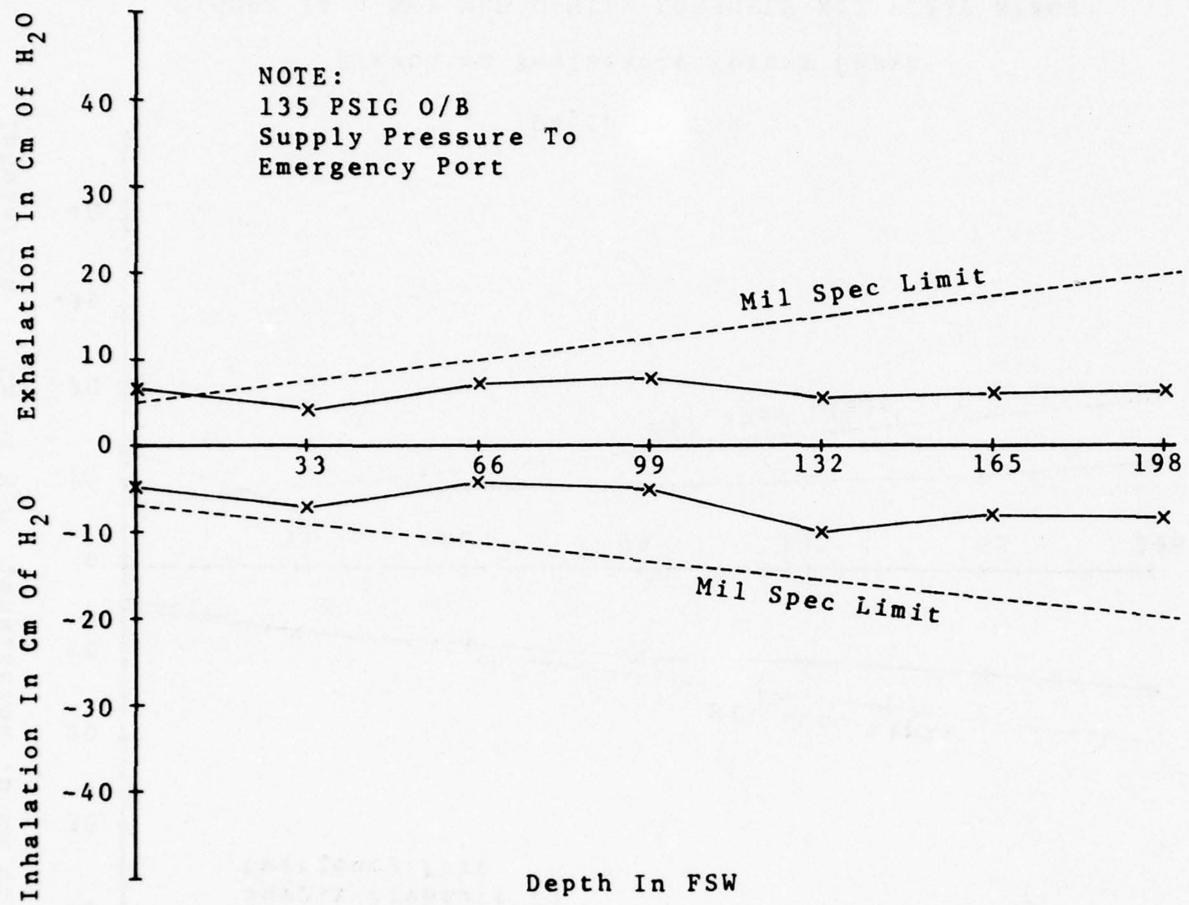
The breathing resistances plotted in the figures are the maximum values measured excluding cracking pressure, during one complete inhalation-exhalation cycle at a given depth and RMV. Supply pressure to the first stage regulator was maintained at 1000 psig while intermediate supply pressures from the first stage to the sideblock emergency port was set at 135 psig O/B for both regulators tested.

a. Inhalation Characteristics

(1) MK 1 Mod 0 Mask with Conshelf XII First Stage. Inhalation resistance was low at 22.5 RMV (Figure 13) and 40.0 RMV (Figure 14) with the maximum measured being 11 cmH_2O. At 62.5 RMV (Figure 15) resistance was within mil spec limits down to 132 FSW. Below this depth, pressures increased rapidly and exceeded 90 cmH_2O at 198 FSW. Seventy-five RMV (Figure 16) produced unacceptable breathing resistance at depths over 132 FSW and 90 RMV (Figure 17) produced unacceptable results at depths greater than 66 FSW.

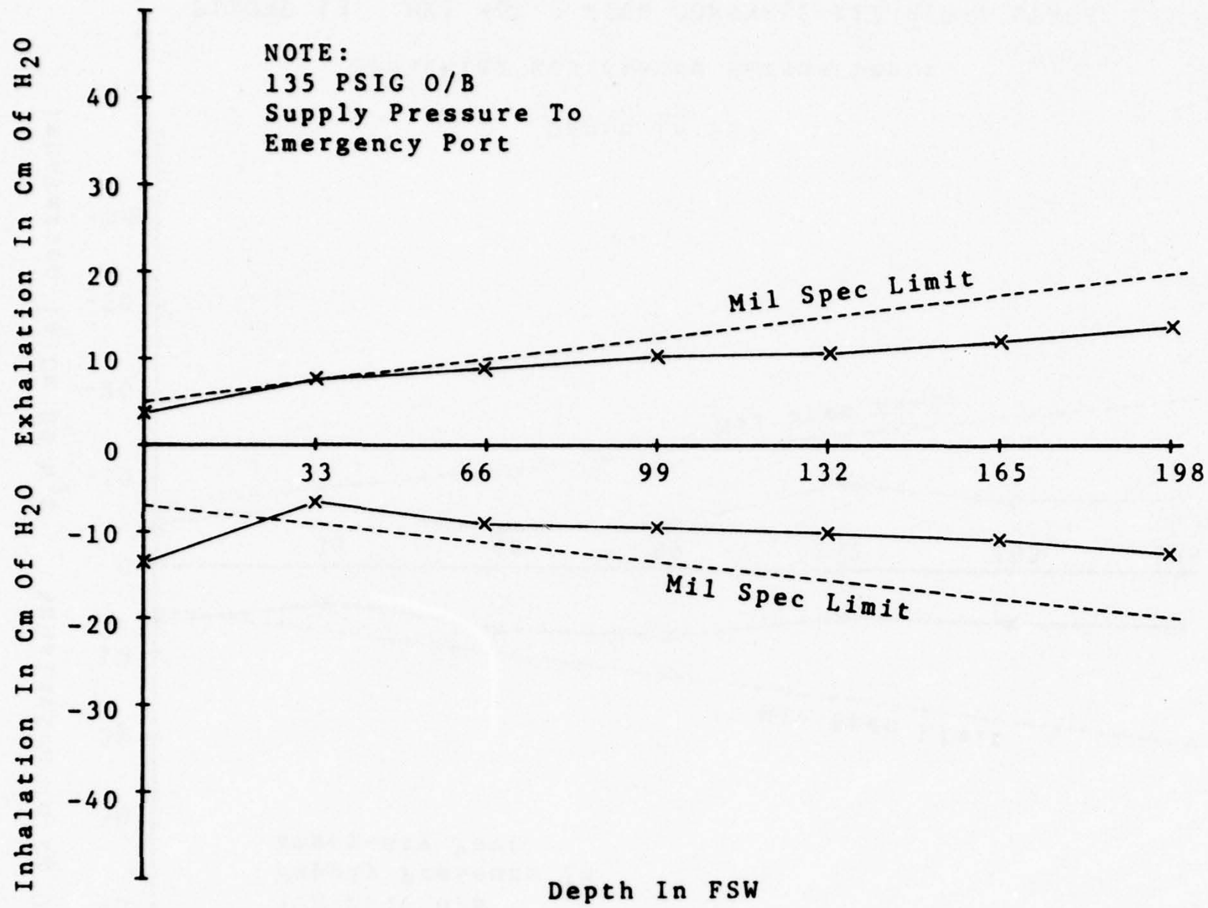
(2) MK 1 Mod 0 Mask with Scubapro MK V First Stage. Inhalation resistance was low at 22.5 (Figure 18) and 40 RMV (Figure 19) with breathing pressures reaching a maximum of 15 cmH_2O at 198 FSW. At 62.5 RMV (Figure 20) resistance slightly exceeded the mil spec limit at 132 FSW but increased rapidly at greater depths. Seventy-five RMV (Figure 21) and 90.0 RMV (Figure 22) produced unacceptable at depths beyond 99 and 66 FSW respectively.

(3) Comparative Summary. The performance of the Conshelf XII and Scubapro MK V was essentially the same at 22.5 and 40 RMV. However, the Conshelf XII outperformed the MK V at 62.5 RMV and higher as evidenced by the performance plots.



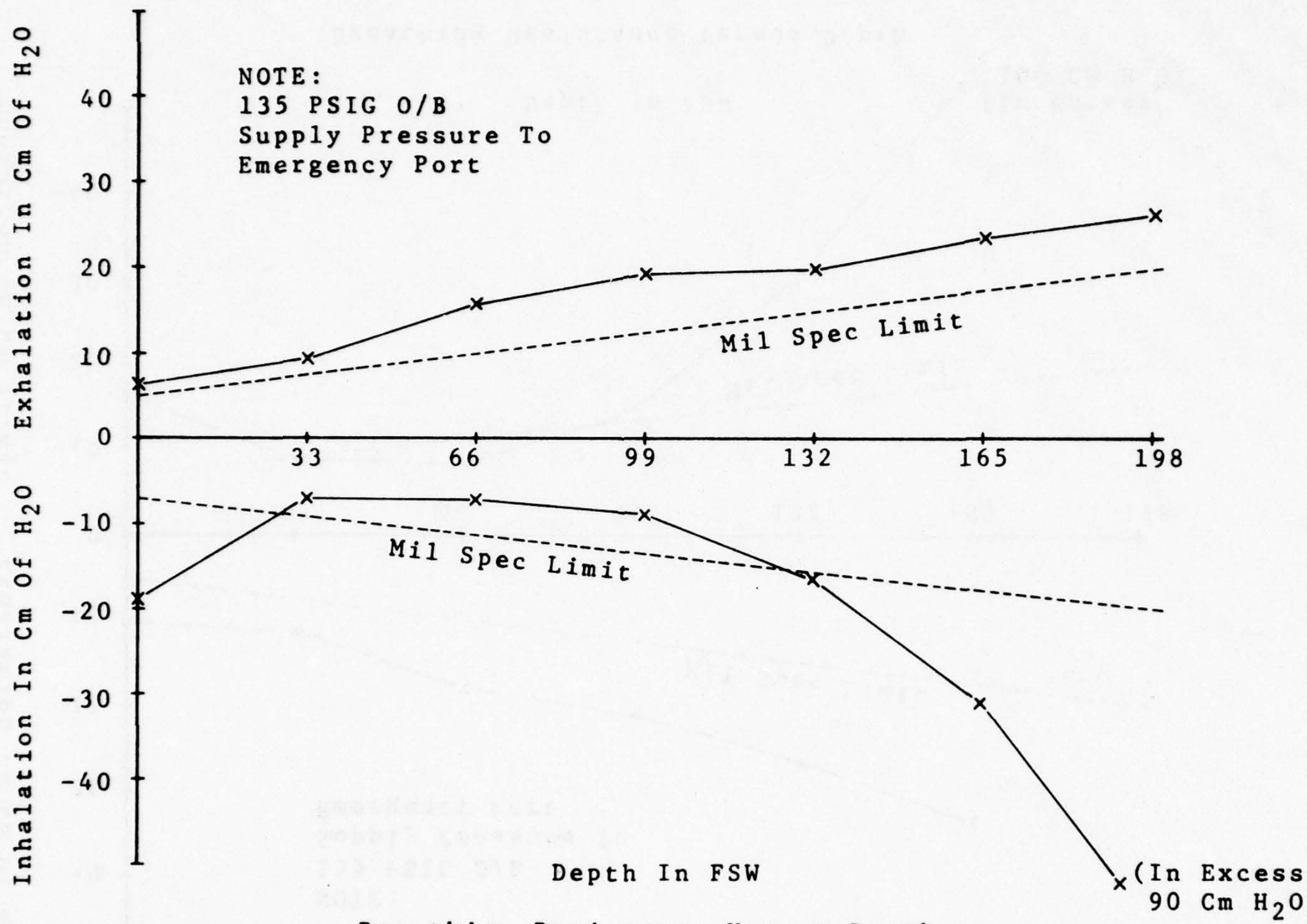
Breathing Resistance Versus Depth

FIGURE 13. MK1 MOD O WITH CONSHELF XII FIRST STAGE
22.5 R/M/V



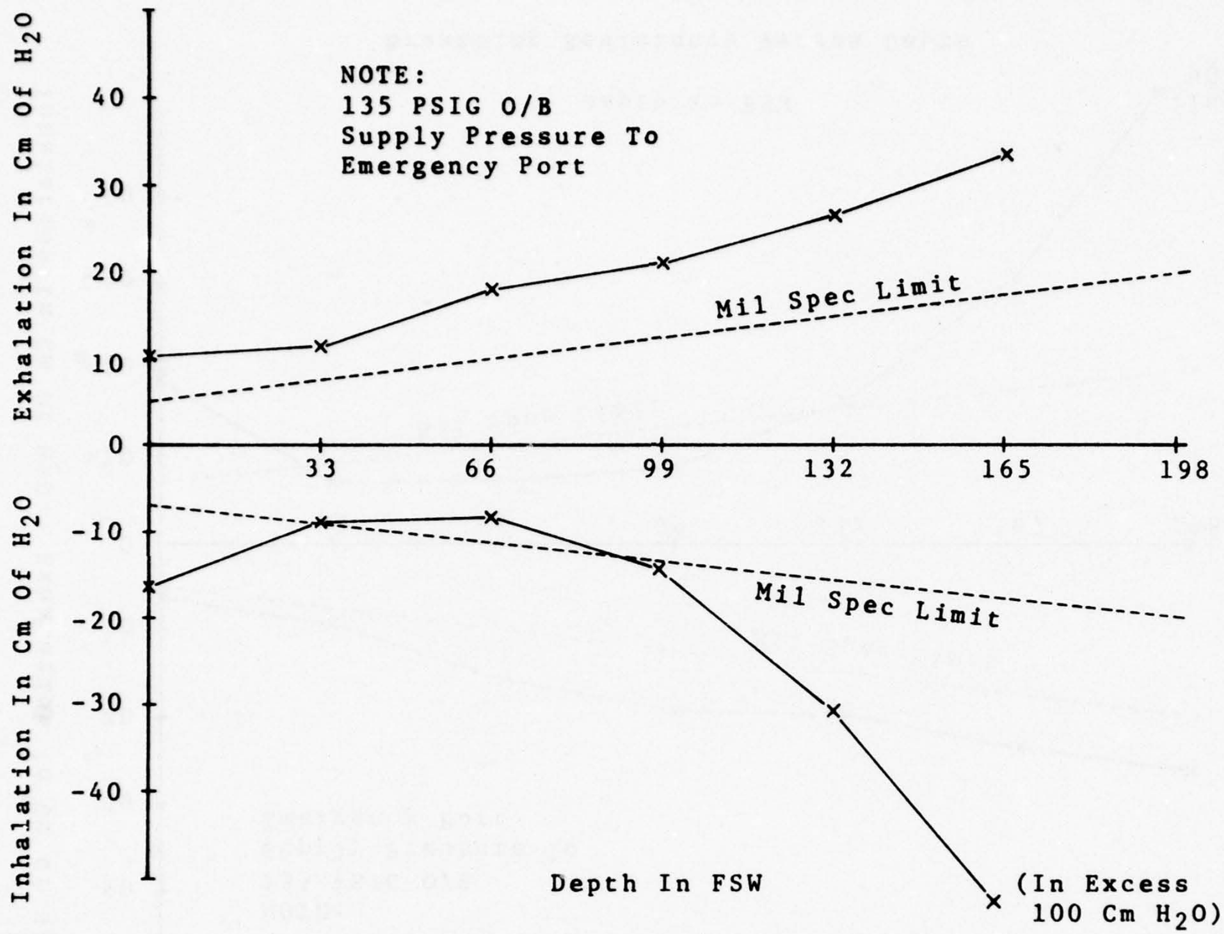
Breathing Resistance Versus Depth

FIGURE 14. MK1 MOD 0 WITH CONSHELF XII FIRST STAGE
40.0 R/M/V



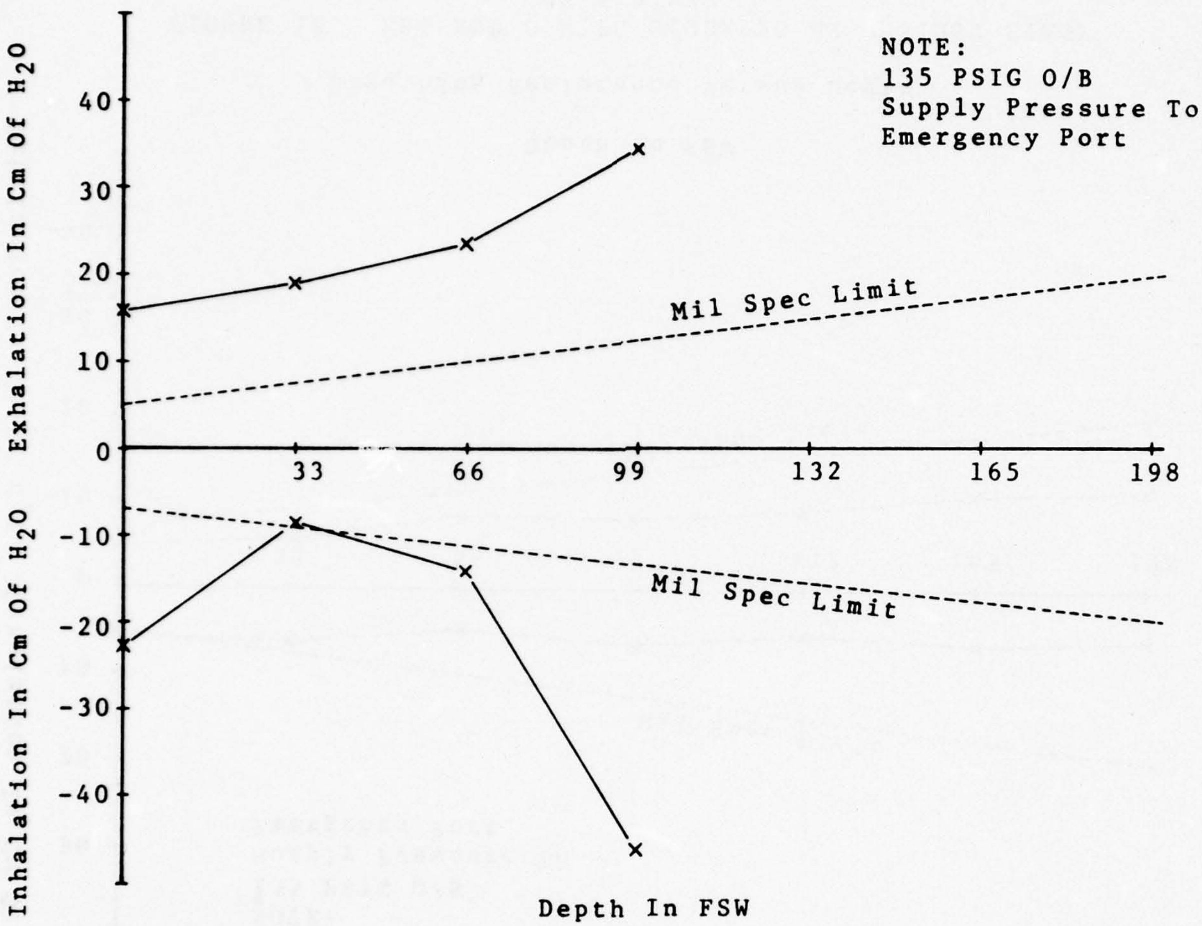
Breathing Resistance Versus Depth

FIGURE 15. MK1 MOD 0 WITH CONSHELF XII FIRST STAGE
62.5 R/M/V



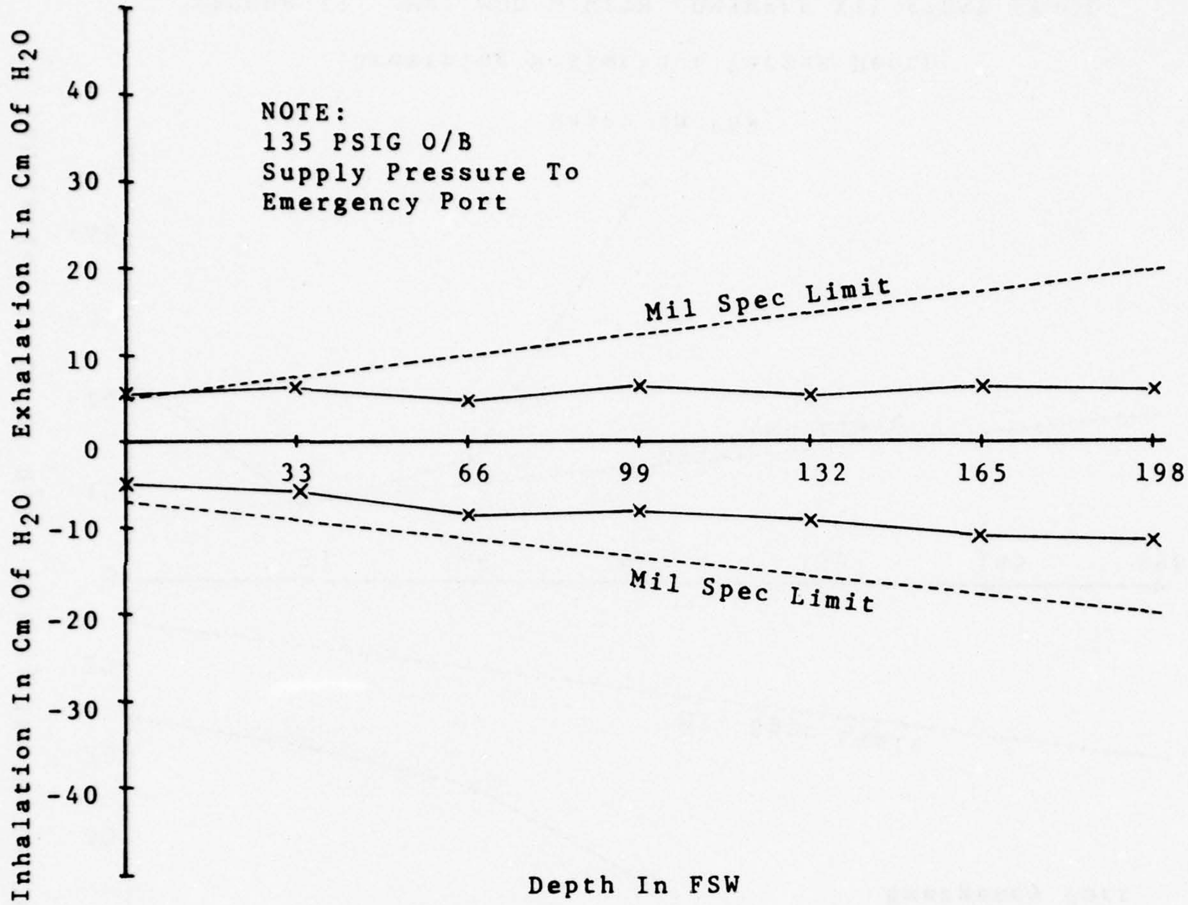
Breathing Resistance Versus Depth

FIGURE 16. MK1 MOD 0 WITH CONSHELF XII FIRST STAGE
75.0 R/M/V



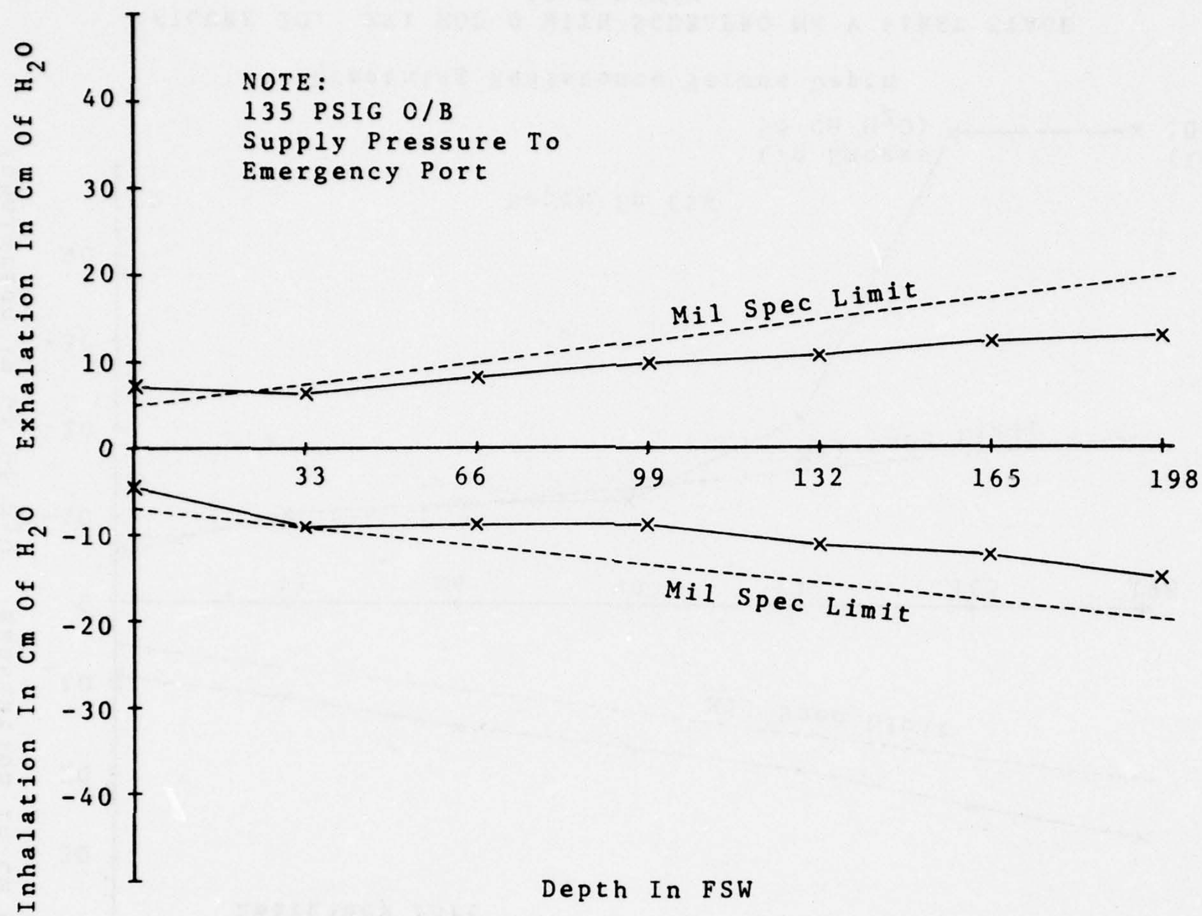
Breathing Resistance Versus Depth

FIGURE 17. MK1 MOD O WITH CONSHELF XII FIRST STAGE
90.0 R/M/V



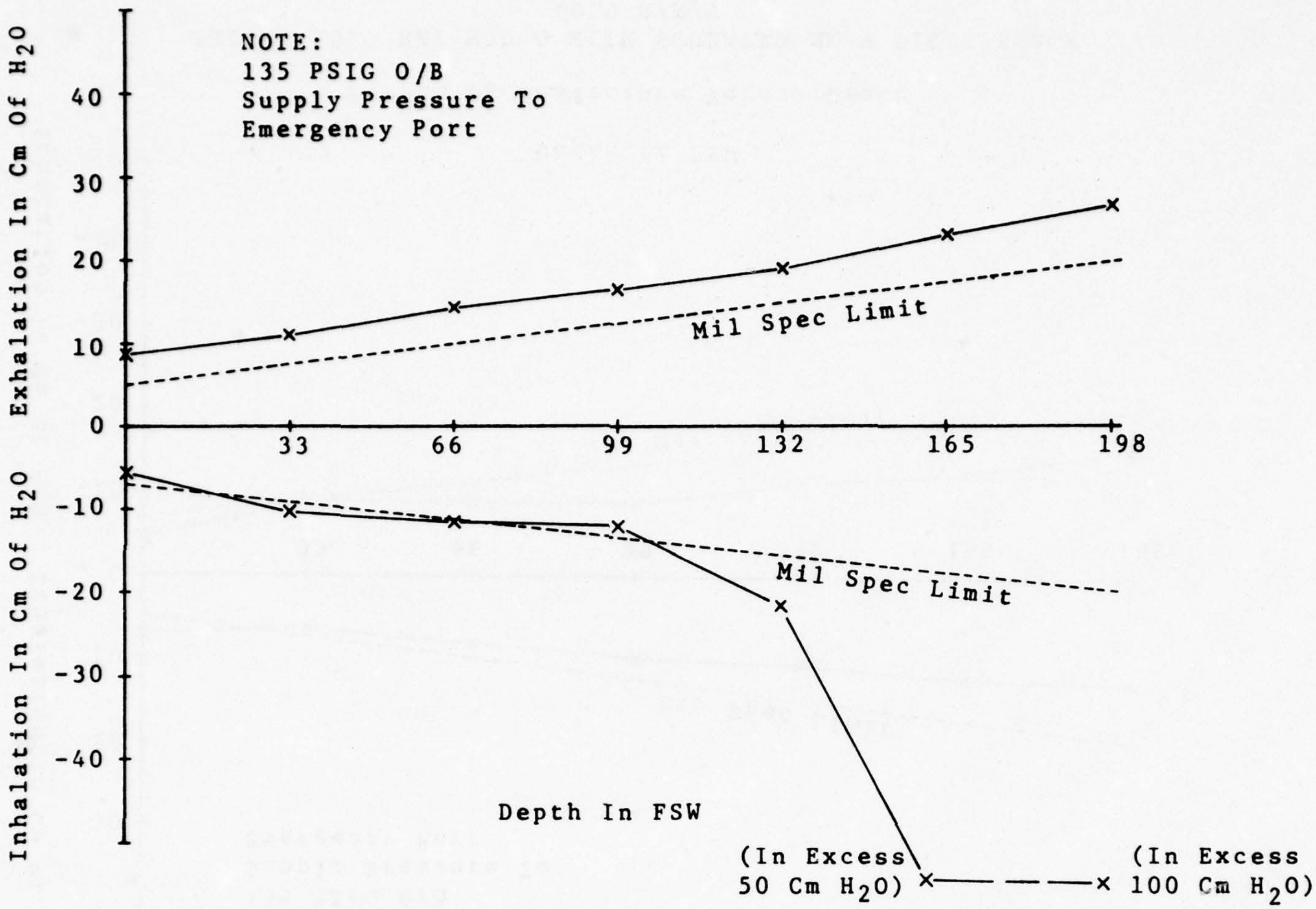
Breathing Resistance Versus Depth

FIGURE 18. MK1 MOD O WITH SCUBAPRO MK V FIRST STAGE
22.5 R/M/V



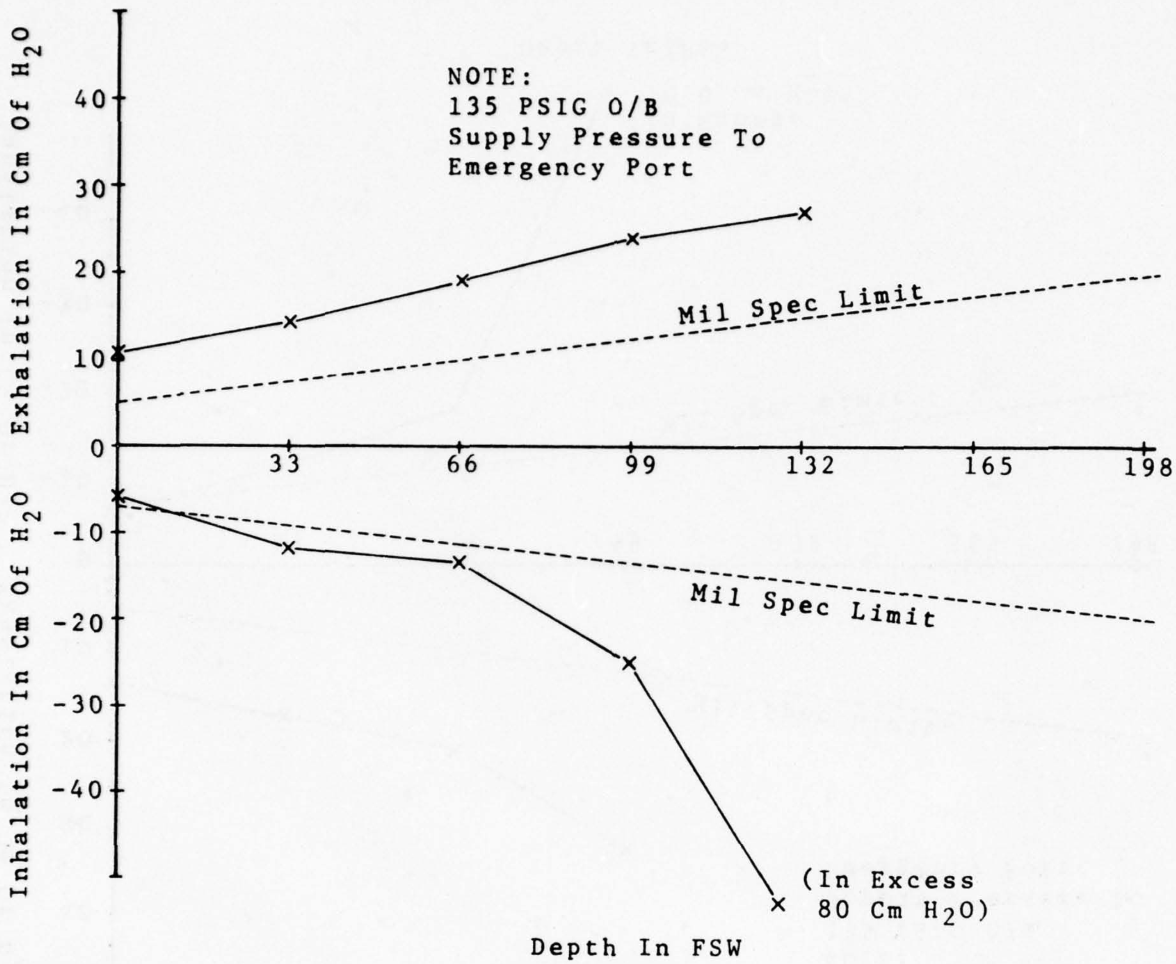
Breathing Resistance Versus Depth

FIGURE 19. MK1 MOD O WITH SCUBAPRO MK V FIRST STAGE
40.0 R/M/V



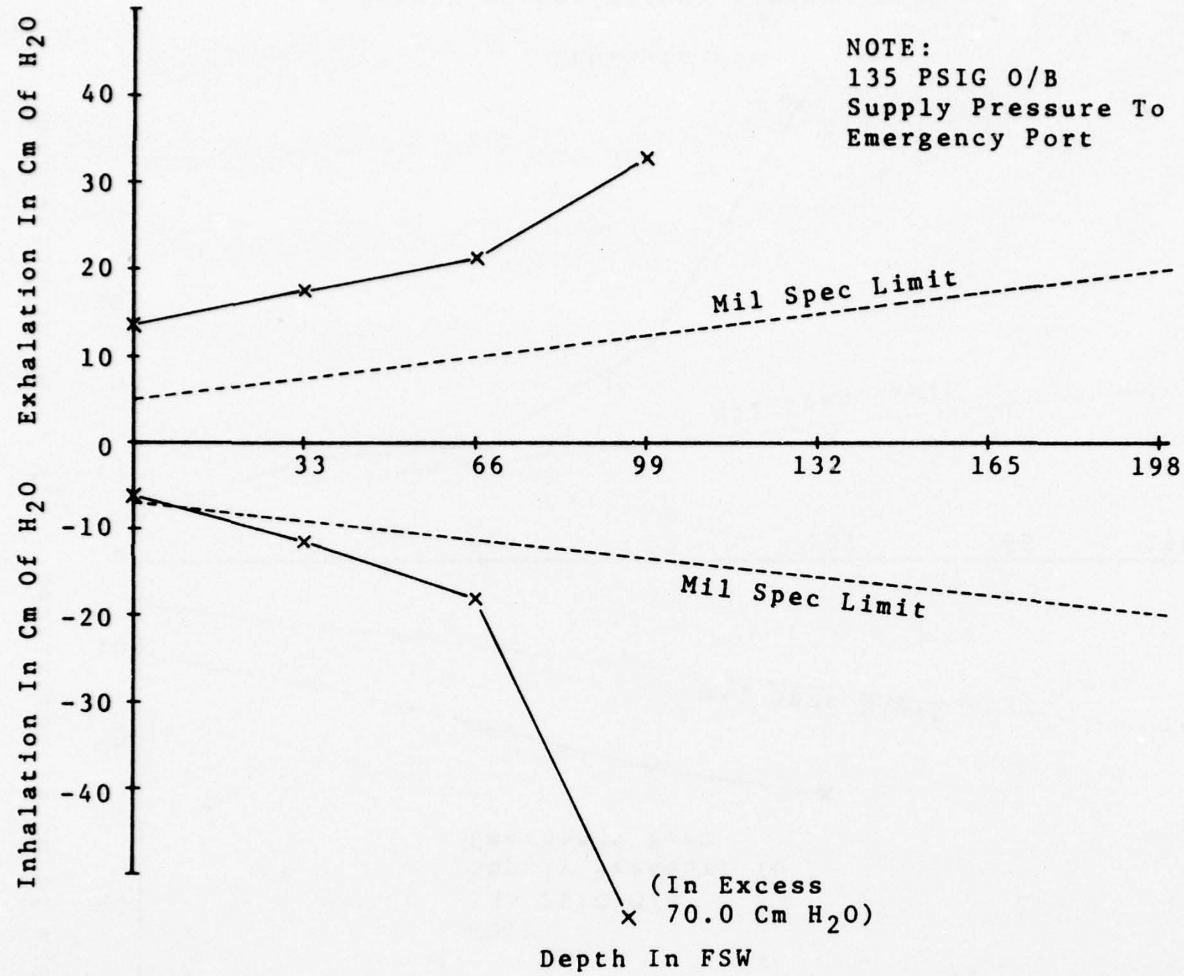
Breathing Resistance Versus Depth

FIGURE 20. MK1 MOD O WITH SCUBAPRO MK V FIRST STAGE 62.5 R/M/V



Breathing Resistance Versus Depth

FIGURE 21. MK1 MOD O WITH SCUBAPRO MK V FIRST STAGE
75.0 R/M/V



Breathing Resistance Versus Depth

FIGURE 22. MK1 MOD O WITH SCUBAPRO MK V FIRST STAGE
90.0 R/M/V

Neither regulator matched mask performance in the umbilical mode. Definite reductions in mask performance are evident at all RMV's over 40.0 when comparing the normal to emergency umbilical modes.

b. Exhalation Resistance (Figures 13 through 22). Exhalation resistance was of course not affected by switching from umbilical to emergency mode. For complete information on exhalation performance refer to the discussion given in the section on umbilical mode tests.

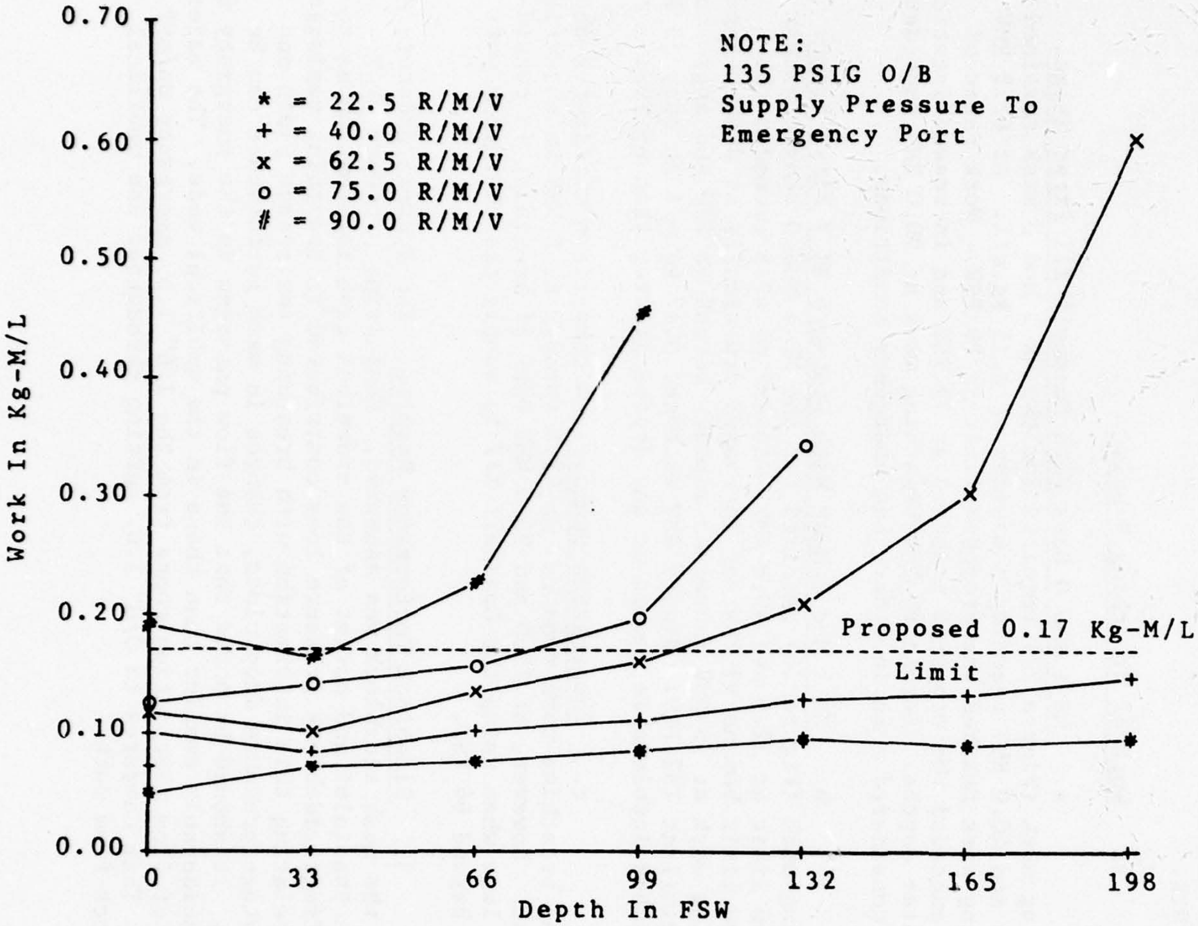
2. Work of Breathing Results

a. MK 1 Mod 0 Mask With Conshelf XII First Stage. Breathing work (Figure 23) required for the MK 1 Mod 0 mask remained low at 22.5 and 40.0 RMV reaching a maximum of 0.15 kg.m/1. At 62.5 RMV breathing work reached the proposed limit at 99 FSW. Work rates of 75 RMV exceeded the proposed standard at 99 FSW and increased drastically at greater depths. Beyond 66 FSW breathing work at 90.0 RMV exceeded levels considered safe in other than emergency conditions.

b. MK 1 Mod 0 Mask With Scubapro MK V First Stage. Breathing work (Figure 24) required for the MK 1 Mod 0 stayed within the proposed limit at 22.5 and 40.0 RMV. An RMV of 62.5 exceeded the proposed limit beyond 99 FSW and increased drastically at deeper depths. Breathing work at 75 RMV increased rapidly beyond 66 FSW and approached 0.60 kg.m/1 at 132 FSW. Ninety RMV exceeded 0.17 kg.m/1 at only 33 FSW and reached intolerable levels at any depths greater than 66 FSW.

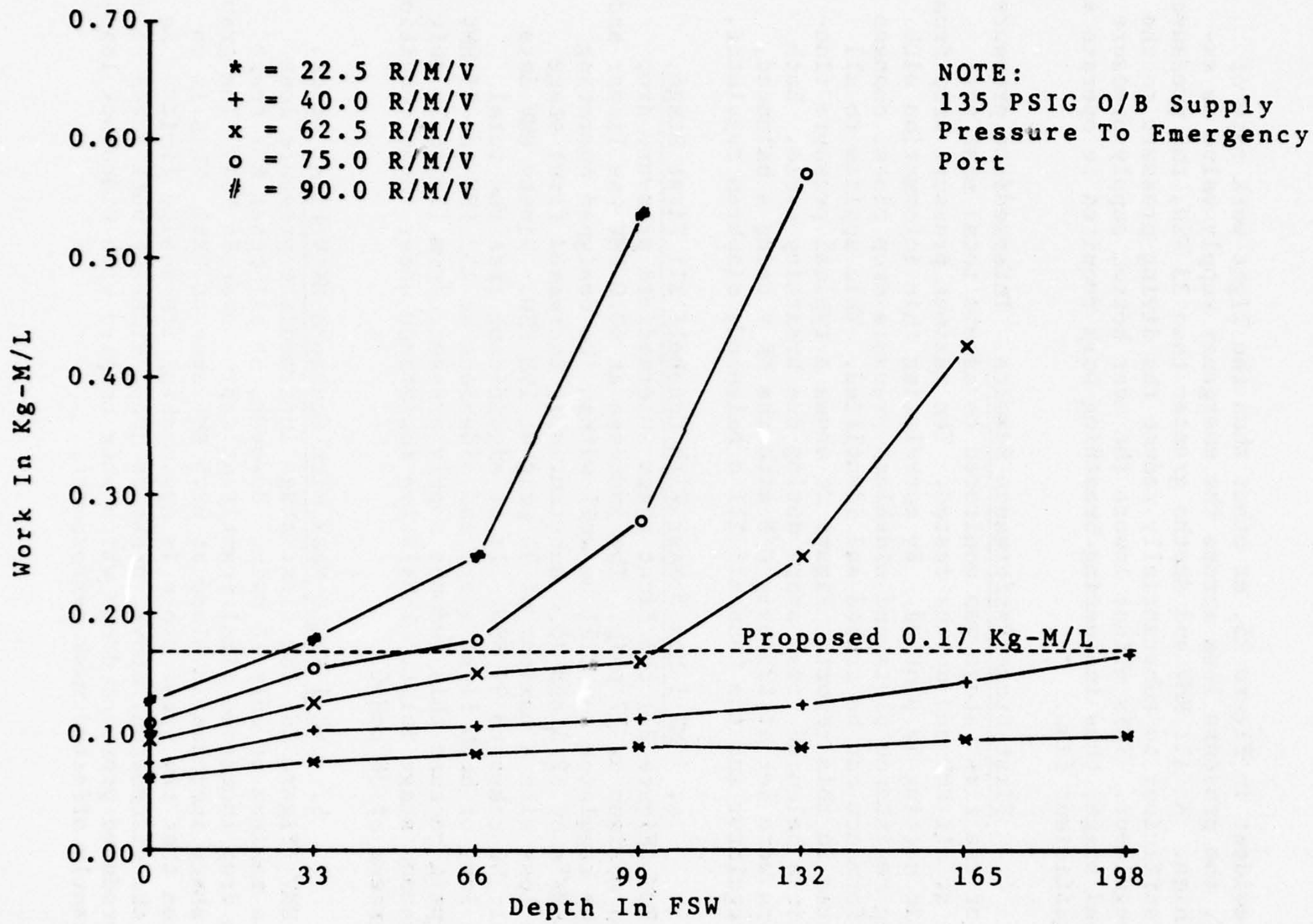
c. Comparative Summary. A comparison of figures shows that the breathing work required at 22.5 through 62.5 RMV is essentially the same. However, at 75.0 and 90.0 RMV work of breathing is considerably less when using the Conshelf XII to supply the emergency port at depths beyond 66 FSW.

3. Sideblock Performance Results. The dynamic pressure drop across the mask sideblock was measured. Monitoring pressure drop between the inlet and outlet of the sideblock gave information as to how much affect sideblock pressure loss contributed to breathing resistance. By correlating this information with breathing resistance plots and first stage pressure drop plots, changes in mask performance can be traced. It should be noted that the flow passages in the emergency mode are considerably smaller than those in the umbilical mode. The major source of flow restriction comes from the 1/8" I.D. emergency on/off valve. This compares to 3/8" I.D. porting throughout the umbilical sideblock flow path.



Breathing Work Versus Depth

FIGURE 23. MK1 MOD 0 WITH CONSHELF XII FIRST STAGE



Breathing Work Versus Depth

FIGURE 24. MK1 MOD O WITH SCUBAPRO MKV FIRST STAGE

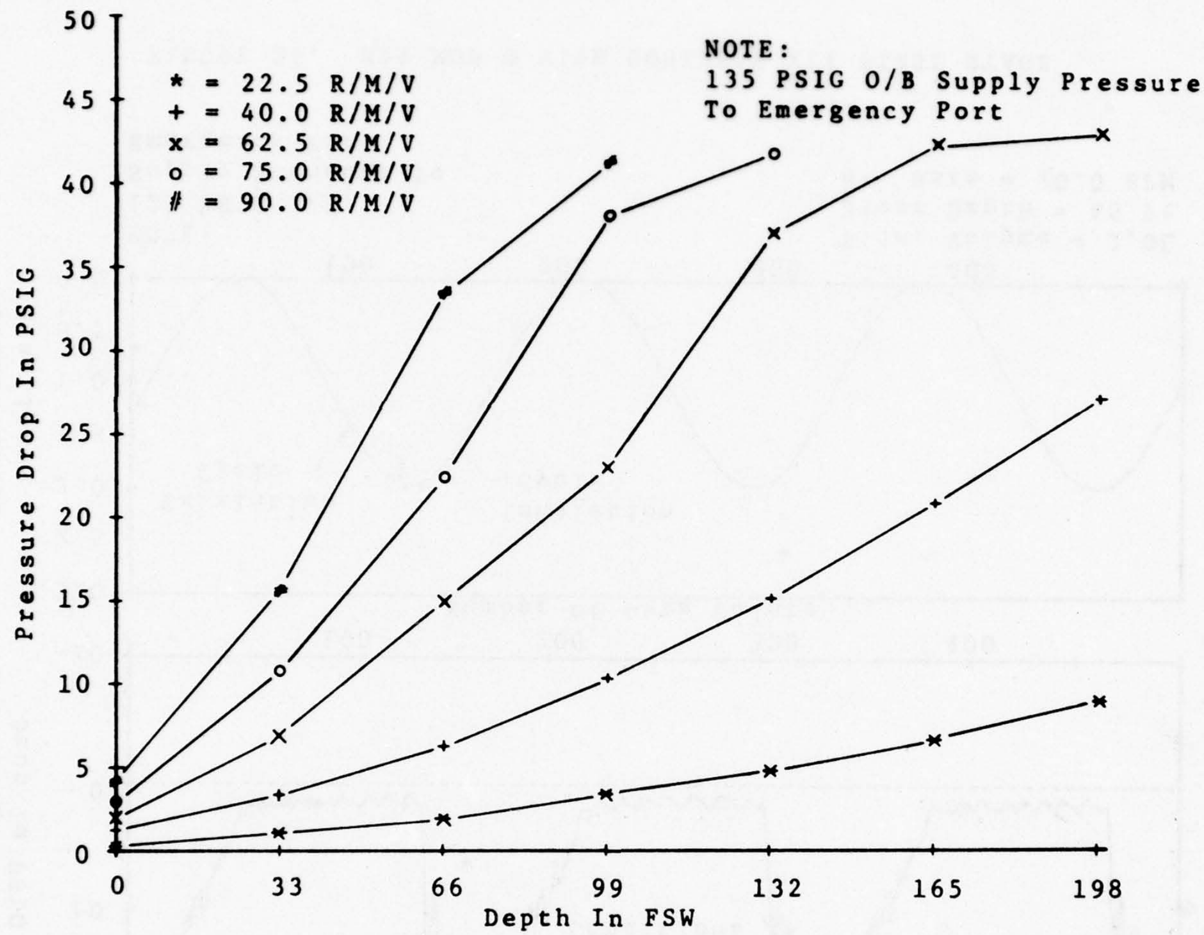
Sideblock performance in the emergency mode was virtually identical for both first stages tested. Consequently, one plot (Figure 25) supplies typical sideblock performance data when used in the emergency mode.

As evident in Figure 25, at other than the light work rate of 22.5 RMV, the pressure loss across the emergency supply valve is extremely high. At all RMV and depths greater than 33 FSW, the pressure loss is sufficient to substantially reduce the diving pressure to the demand regulator. This effect lowers the over bottom supply pressure to the second stage, thus increasing breathing work required to operate and attain sufficient flow.

4. First Stage Performance Results. Intermediate pressure dropout of the first stage was monitored to assess total mask performance at all RMV and depths tested. The maximum pressure drop from the static setting is plotted. By correlating this information with breathing resistance plots and sideblock pressure drop plots, changes in mask performance can be traced and identified. This applies to all tests cited in this report. Figure 26 shows a typical pressure fluctuation in a balanced first stage during one breathing cycle. Both regulators were set at 135 psig O/B with the MK V being a balanced, piston regulator and the Conshelf XII a balanced, diaphram regulator.

a. MK 1 Mod 0 Mask With Conshelf XII First Stage. At 22.5 RMV (Figure 27) the first stage intermediate pressure drop reached a maximum of 17 psig. The increase at 40.0 RMV was linear and showed the regulator to still be well within its designed operating range. RMV's of 62.5 and 75.0 substantially increased first stage pressure loss with a maximum of 34 psig at 198 FSW. Ninety RMV data could only be taken to 99 FSW. It is significant that the total pressure loss of both first stage and sideblock at 132 FSW and 75 RMV is over 60 psig because this reduces supply pressure from 135 to 75 psig O/B at the second stage inlet. Inhalation resistance under these conditions was in excess of 30 cmH_2O.

b. MK 1 Mod 0 Mask With Scubapro MK V First Stage. At 22.5 RMV (Figure 28) the first stage intermediate pressure loss reached a maximum of only 16 psig. However, at all other RMV tested, pressure drop increased significantly at depths over 66 FSW. The graph shows a sharp increase in slope at 62.5 RMV over 40 RMV. This is an indication that the first stage is approaching its design limits. As seen in the discussion, above, pressure drops at heavy work rates below 33 FSW produced pressure drops which when coupled with sideblock losses significantly affected mask performance.



Sideblock Drop Versus Depth

FIGURE 25. MK1 MOD O WITH CONSHELF XII AND SCUBAPRO MK V FIRST STAGE

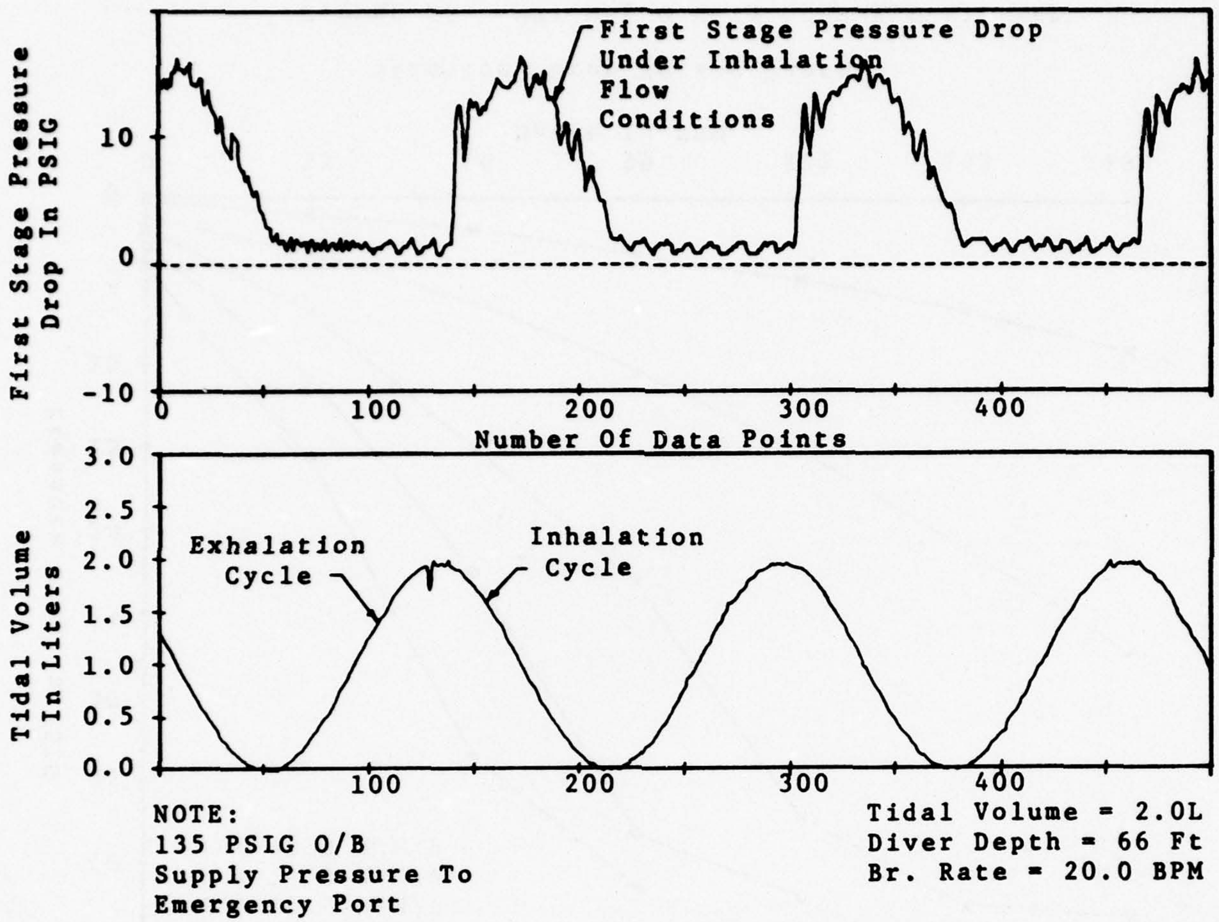
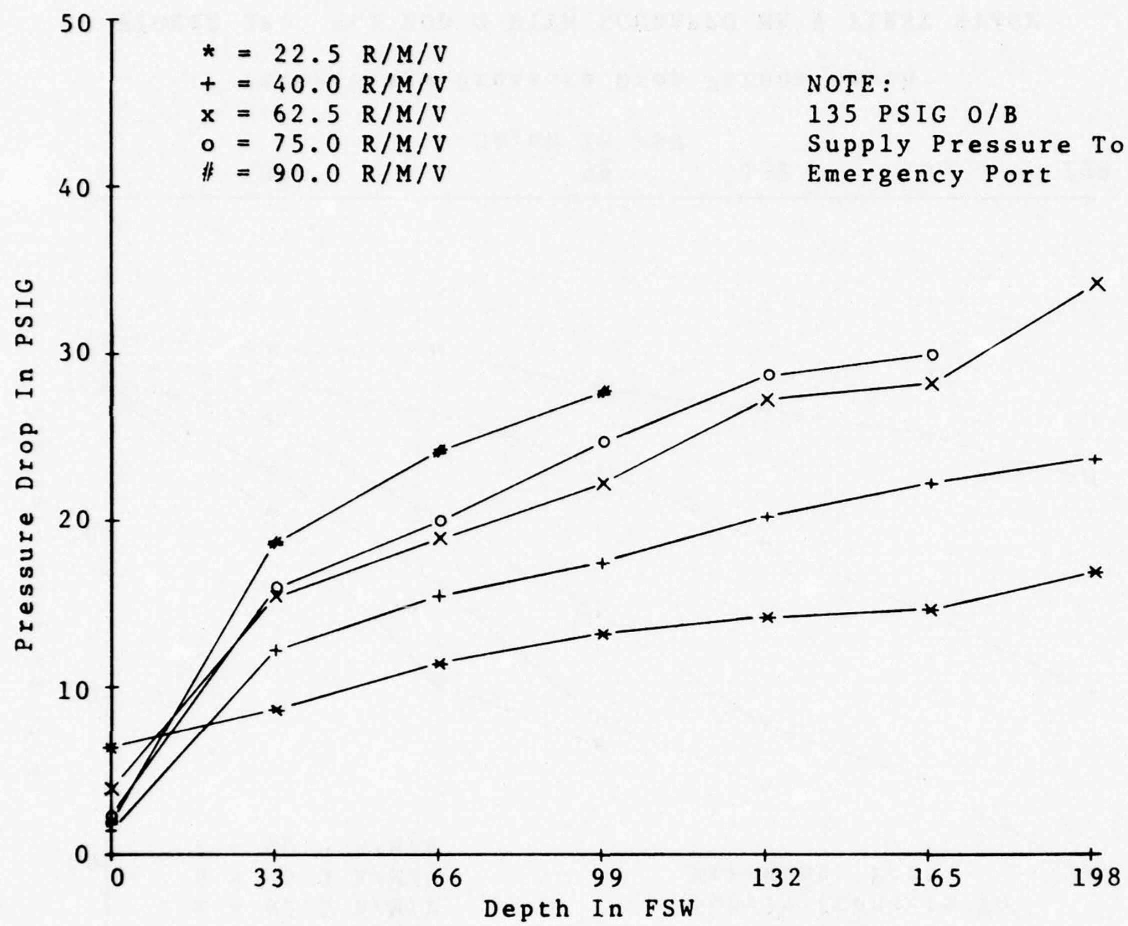
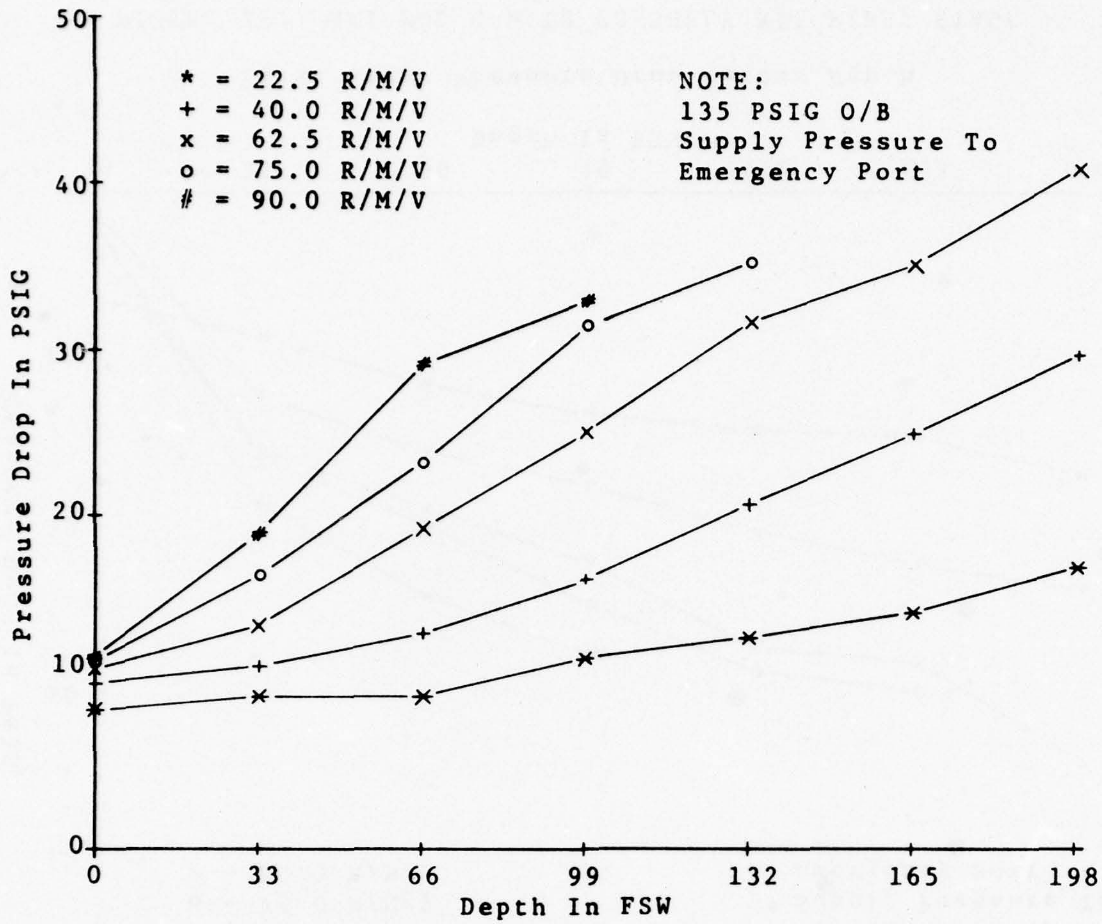


FIGURE 26. MK1 MOD 0 WITH CONSHELF XII FIRST STAGE



First Stage Pressure Drop Versus Depth

FIGURE 27. MK1 MOD O WITH CONSHELF XII FIRST STAGE



First Stage Pressure Drop Versus Depth

FIGURE 28. MK1 MOD O WITH SCUBAPRO MK V FIRST STAGE

c. Comparative Summary. The Conshelf XII exhibited less intermediate pressure loss at the high RMV's than did the Scubapro MK V. In addition, the slope of the graphs indicate that the MK V approaches its design limit at lower work rates and shallower depths than did the Conshelf XII.

Another important aspect is that the Conshelf XII first stage is easily adjustable with a large screwdriver. The Scubapro MK V is preset at the factory and requires that the regulator be completely disassembled and shims added internally to boost the intermediate pressure output. For these reasons, the Scubapro MK V will not be considered further as a possible supply regulator for the USN MK 1 Mod 0 mask in emergency mode.

However, the next section of this report deals with further tests conducted with the MK 1 Mod 0 mask in conjunction with the U.S. Divers Conshelf XII first stage regulator.

D. MK 1 Mod 0 Mask Supplied by Conshelf XII First Stage Regulator at Varying Over Bottom Pressure Tests Results

Once identified as the most suitable regulator for this application, additional tests were conducted using the U.S. Divers Conshelf XII to supply the MK 1 Mod 0 mask. These tests involved two phases:

Phase I - Supplying the sideblock emergency port with the Conshelf XII set at 180 psig O/B.

Phase II - Supplying the sideblock umbilical port with the Conshelf XII (a special adapter was fabricated for these tests) set at 135 and 180 psig O/B.

The purpose of the two fold test series was to determine if higher over bottom supply pressures would result in less inhalation resistance. In addition using a special adapter to supply gas to the umbilical port with the Conshelf XII would determine if the lower pressure drop in the sideblock umbilical flow path substantially reduces breathing resistance.

1. Phase I Tests Results

a. Phase I Breathing Resistance Tests Results. Breathing resistance was measured at five RMV's to simulate light through extreme diver work rates. Light work was simulated at 22.5 RMV, moderate work at 40 RMV, moderately heavy work at 62.5 RMV, heavy work at 75.0 RMV and extreme work at 90.0 RMV. The mil spec (reference 1) call for 40 RMV only. The other RMV's were measured, however, to indicate the full range of mask performance.

The breathing resistances plotted in the figures are the maximum values measured, excluding cracking pressure, during one complete inhalation-exhalation cycle at a given depth and RMV.

Air supply pressure to the first stage was maintained at 1000 psig O/B. This applies to both Phase I and Phase II tests.

(1) Inhalation Characteristics. Inhalation resistance remained constant at both 22.5 (Figure 29) and 40 RMV (Figure 30), with peak pressures of 14 cmH_2O. The situation remained constant at 62.5 RMV (Figure 31) until 198 FSW where resistance jumped to 24 cmH_2O. An RMV of 75 (Figure 32) produced excessive breathing pressures at 165 FSW. Ninety RMV (Figure 33) resulted in inhalation resistance in excess of 80 cmH_2O at 132 FSW.

(2) Exhalation Characteristics. Exhalation resistance was identical to results achieved in the normal umbilical supply mode test. (See "MK 1 Mod 0 umbilical mode test" for complete discussion, Figures 29 through 33.)

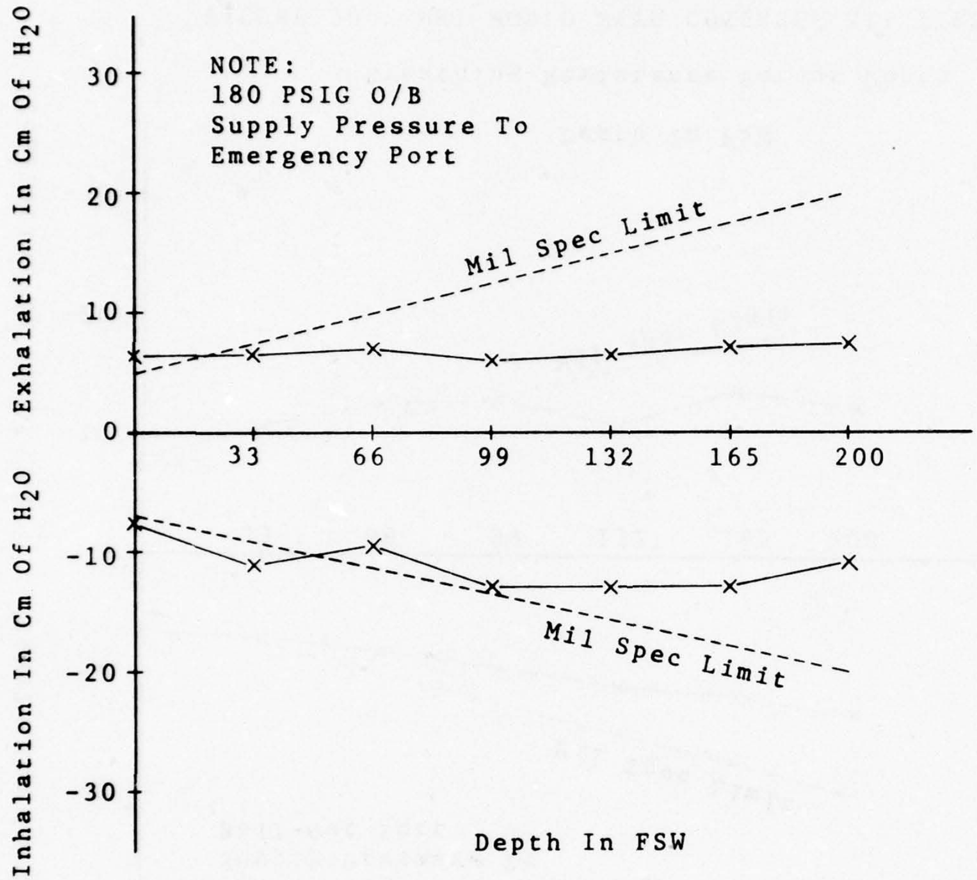
(3) Comparative Summary. Breathing resistances compared favorably with those achieved in the normal umbilical mode tests. No significant degradation was observed at any depth or RMV.

A significant improvement was seen, however, in comparison to the Conshelf XII supplying the sideblock emergency port at 135 psig O/B at depths beyond 99 FSW. Above this depth, mask performance is almost identical at 135 and 180 psig O/B.

b. Phase I Work of Breathing Results. Breathing work results were identical to those achieved in normal umbilical supply mode (see Figure 9).

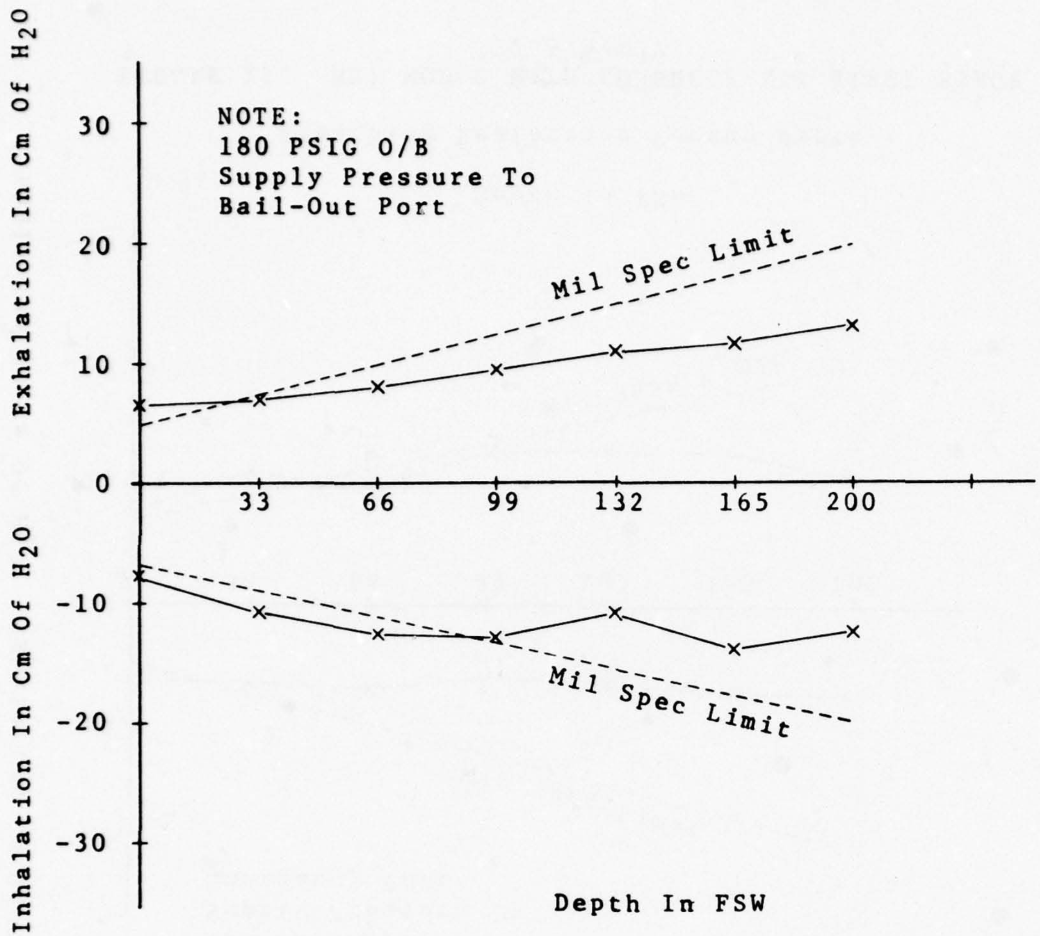
c. Phase I Sideblock Performance Results. Sideblock pressure losses at 180 psig O/B supply were practically identical to those achieved in the "MK 1 Mod 0 emergency mode first stage comparison tests" where the O/B supply pressure was maintained at 135 psig (see Figure 25). It is important to note that while pressure losses were the same, the 180 psig O/B supply pressure resulted in improved mask performance because effective driving pressure to the second stage was increased.

d. Phase I First Stage Performance Results. First stage intermediate pressure losses were comparable to those measured at the 135 psig O/B setting. For a complete description see the "MK 1 Mod 0 emergency mode first stage tests" (Figure 27). Once again,



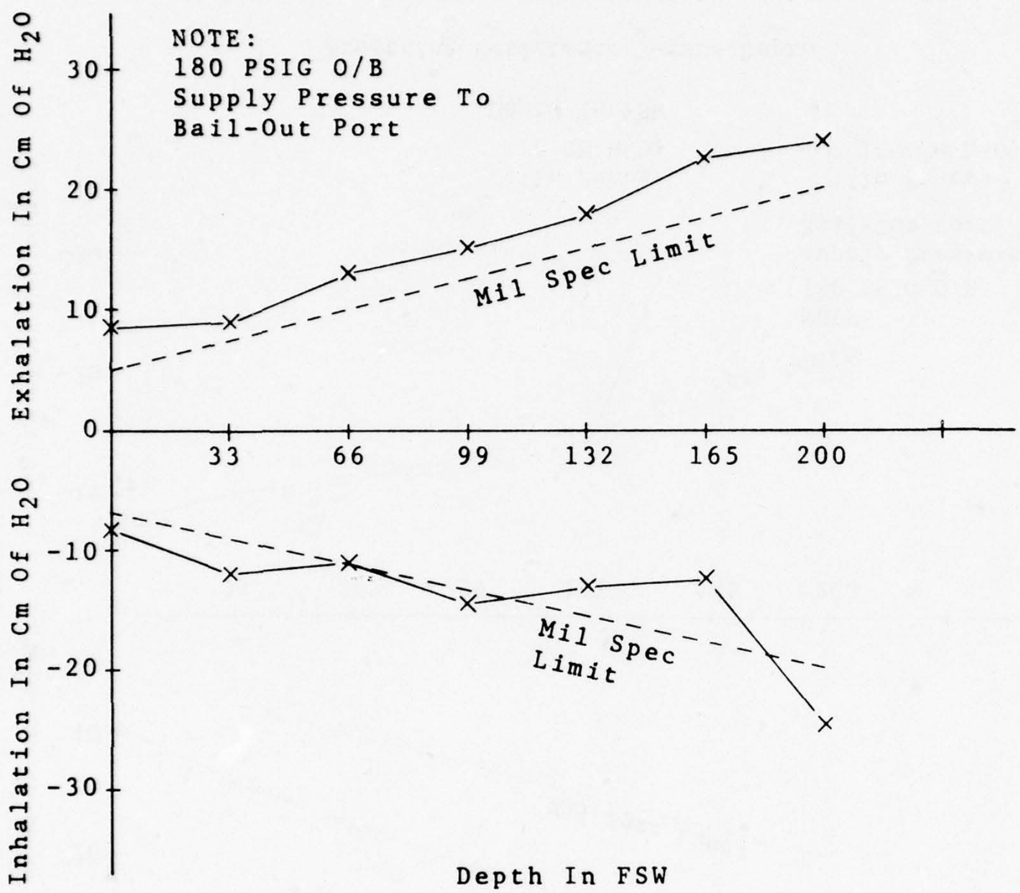
Breathing Resistance Versus Depth

FIGURE 29. MK1 MOD 0 WITH CONSHELF XII FIRST STAGE
22.5 R/M/V



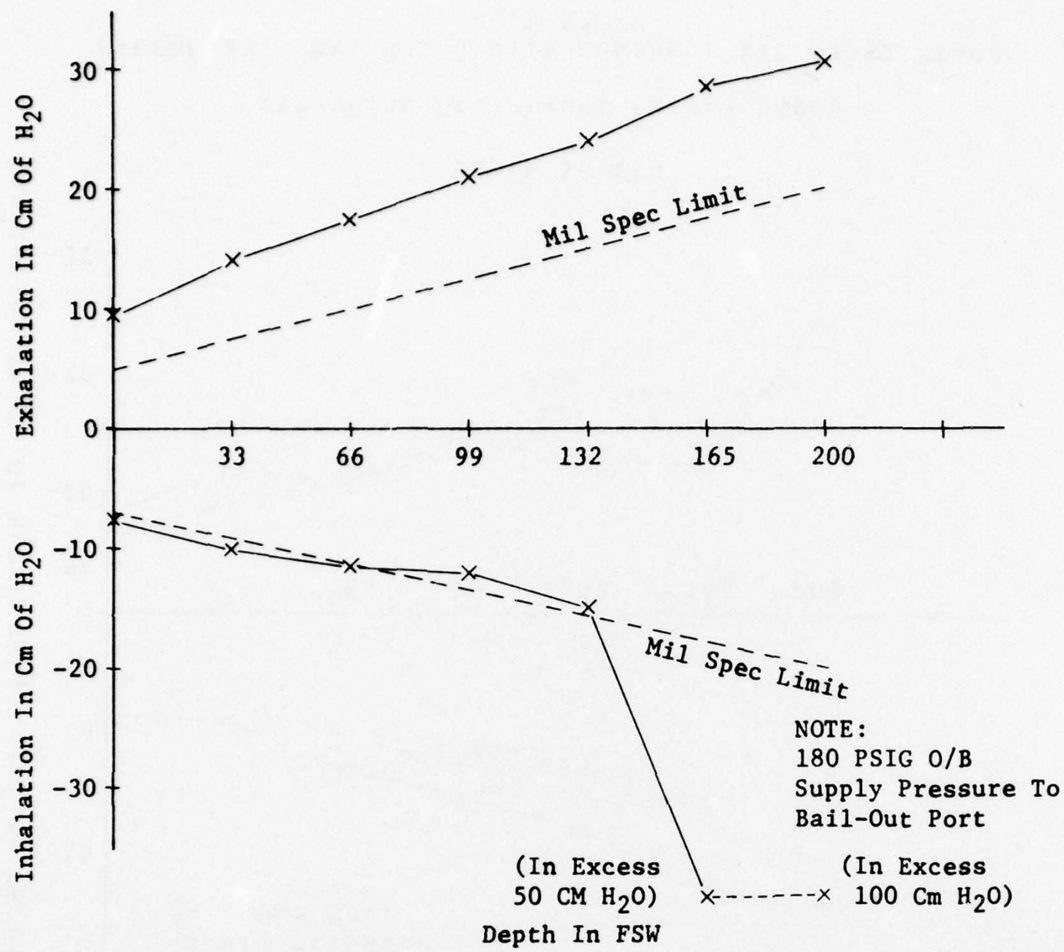
Breathing Resistance Versus Depth

FIGURE 30. MK1 MOD 0 WITH CONSHELF XII FIRST STAGE
40.0 R/M/V



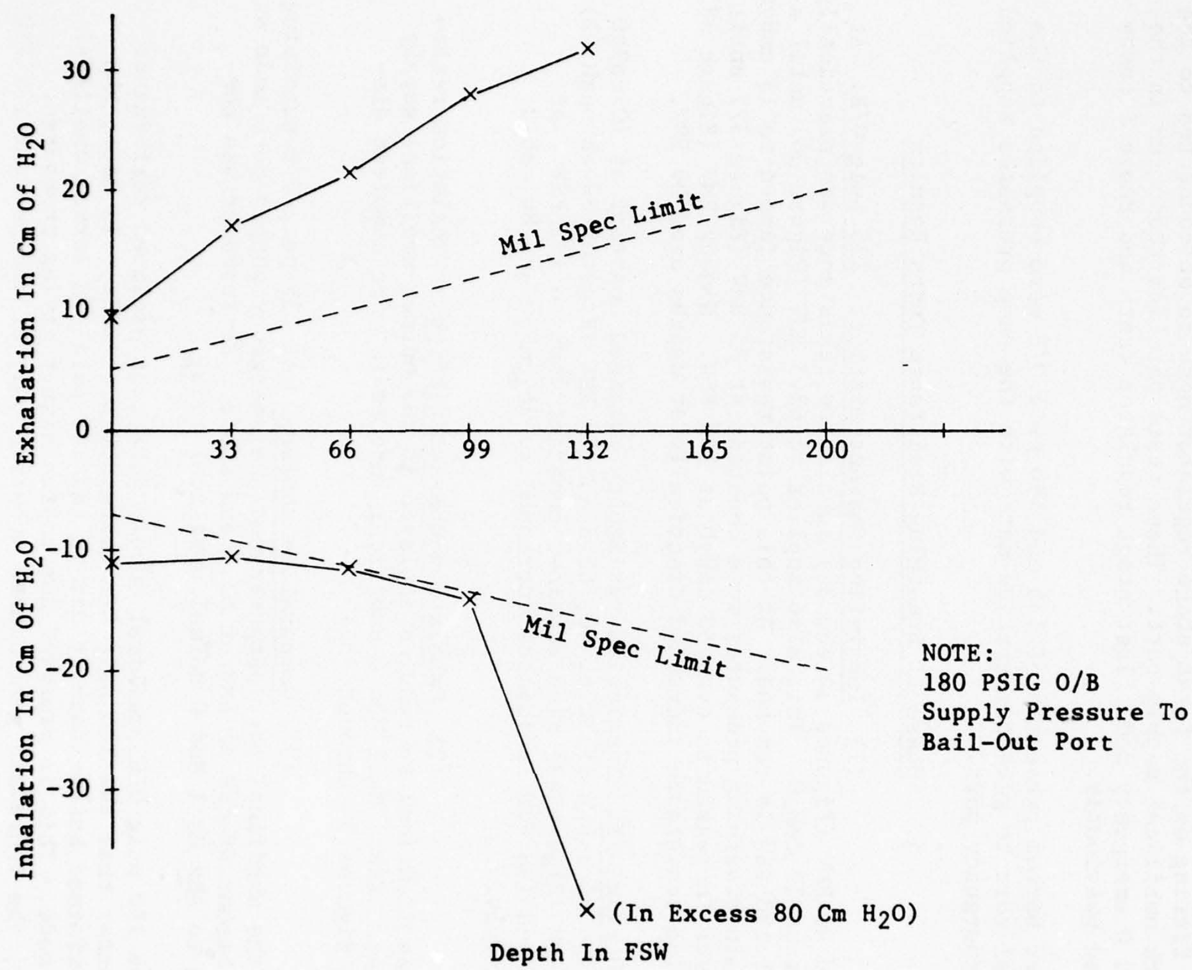
Breathing Resistance Versus Depth

FIGURE 31. MK1 MOD O WITH CONSHELF XII FIRST STAGE
62.5 R/M/V



Breathing Resistance Versus Depth

FIGURE 32. MK1 MOD O WITH CONSHELF XII FIRST STAGE
75.0 R/M/V



Breathing Resistance Versus Depth

FIGURE 33. MK1 MOD 0 WITH CONSHELF XII FIRST STAGE
90.0 R/M/V

however, the higher over bottom supply pressure resulted in a net increase in driving pressure to the demand regulator on the mask.

2. Phase II Tests Results

NOTE: A special adapter was constructed for this test that enabled the end fitting on the first stage regulator hose to be connected to the sideblock umbilical supply port. These tests parallel those run in the MK 1 Mod 0 emergency mode first stage regulator tests and Phase I tests described previously.

Over bottom pressures of 135 and 180 psig O/B were supplied to the umbilical port to give comparative data with the same pressures supplied to the emergency port.

a. Phase II Breathing Resistance Tests Results

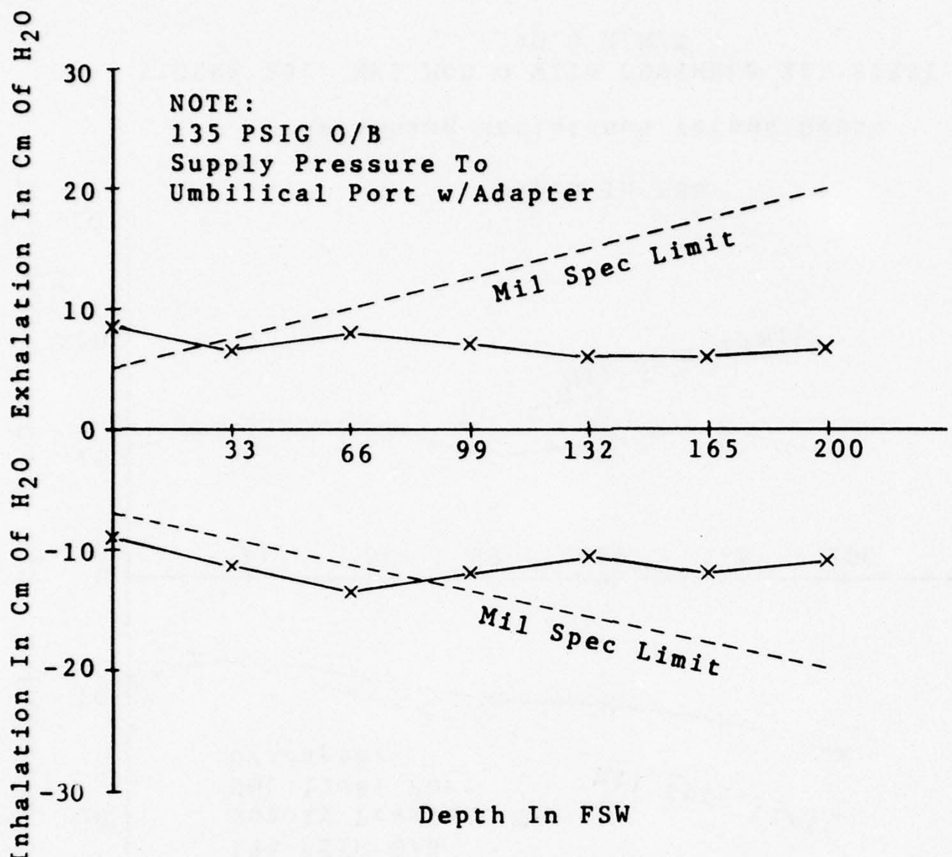
(1) Inhalation Characteristics. 135 psig O/B. At 22.5 and 40 RMV (Figures 34 and 35) inhalation resistance was practically constant at 12 cmH_2O. This also applies to 62.5 RMV (Figure 36) until a depth of 198 FSW is reached. At this point resistance jumped to 18 cmH_2O. Once again breathing pressures were constant at 75 RMV (Figure 37) until resistance increased to over 50 cmH_2O at 165 FSW. Ninety RMV (Figure 38) inhalation resistance increased drastically at depths over 99 FSW.

180 psig O/B. Inhalation resistance remained constant at 10 cmH_2O regardless of depth at 22.5, 40, 62.5 and 75 RMV (Figures 39 through 42). Ninety RMV (Figure 43) also remained constant down to 132 FSW. At 165 FSW and 198 FSW resistance increased to 26 cmH_2O and 86 cmH_2O respectively.

(2) Exhalation Characteristics. Exhalation resistance was identical to results achieved in the normal umbilical supply mode test. (See "MK 1 Mod 0 umbilical mode tests" for complete discussion Figures 34 through 43.)

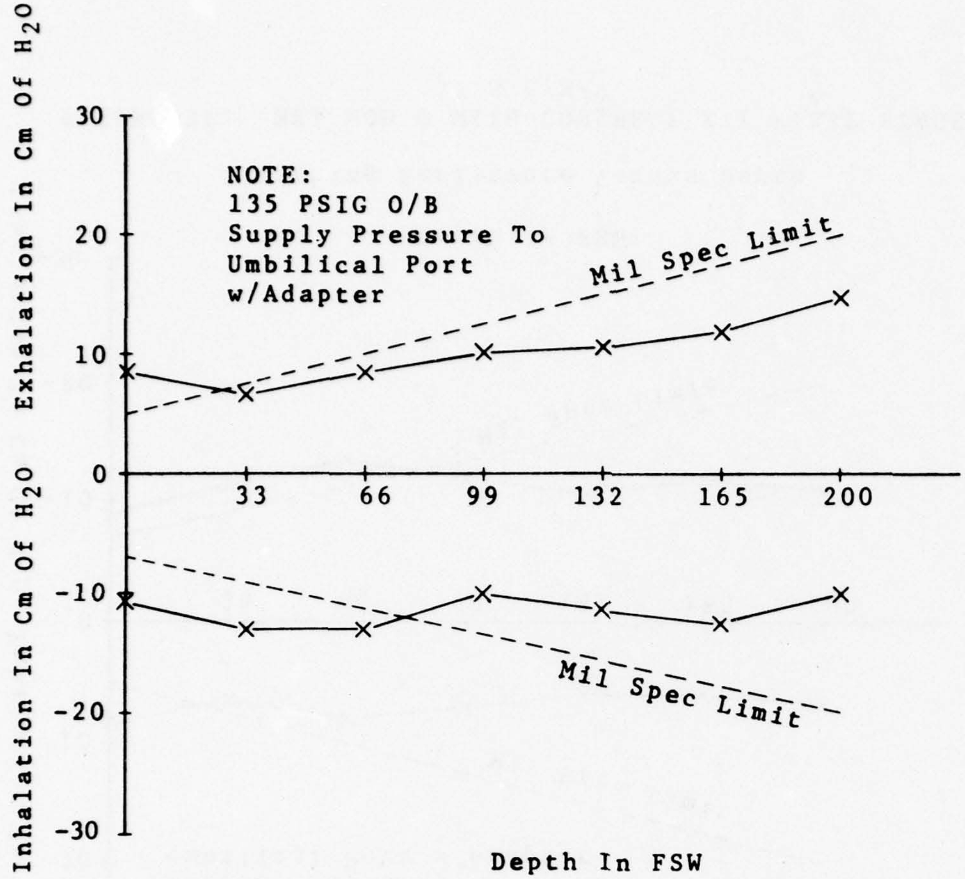
(3) Comparative Summary. At 135 psig O/B supplying gas to the umbilical port outperformed the emergency supply port mode at depths beyond 99 FSW at RMV of 62.5 and above. Performance was comparable to the MK 1 Mod 0 normal umbilical mode.

The 180 psig O/B umbilical supply port test produced performance much better than the 180 psig O/B emergency port mode. In fact, the mask performed better than it did in the 135 psig O/B normal umbilical supply mode. This is expected due to the higher diving pressures. However, the increased performance occurred only at depths over 132 FSW and 75 RMV.



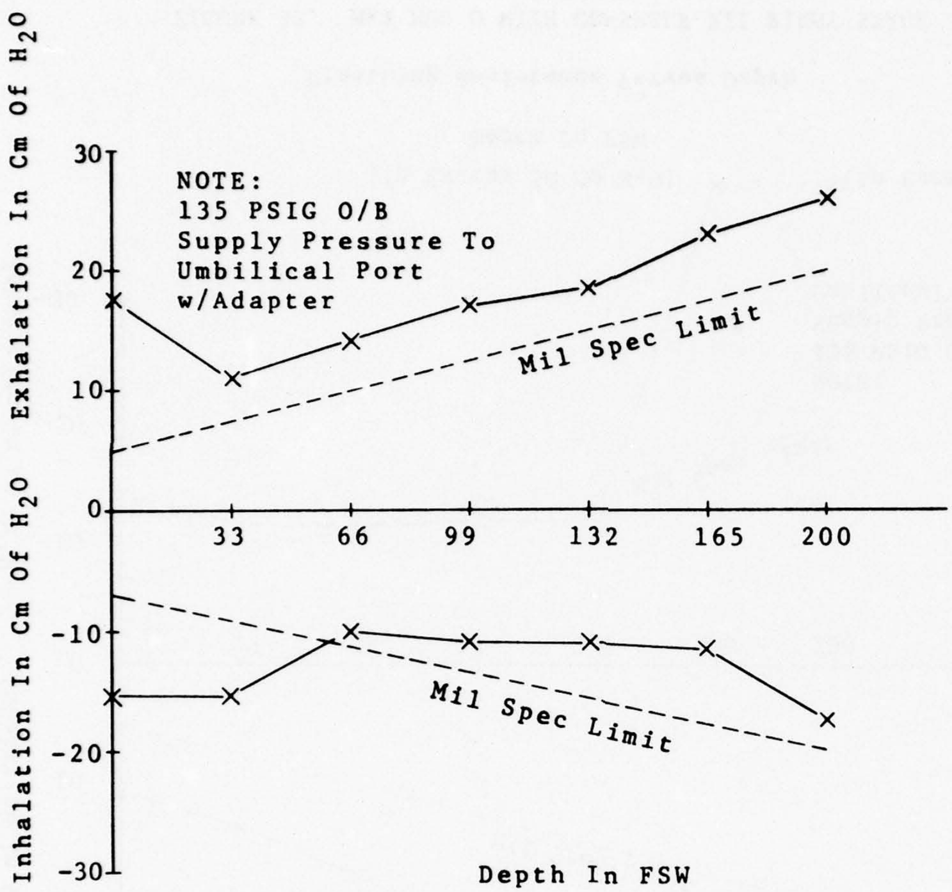
Breathing Resistance Versus Depth

FIGURE 34. MK1 MOD 0 WITH CONSHELF XII FIRST STAGE
22.5 R/M/V



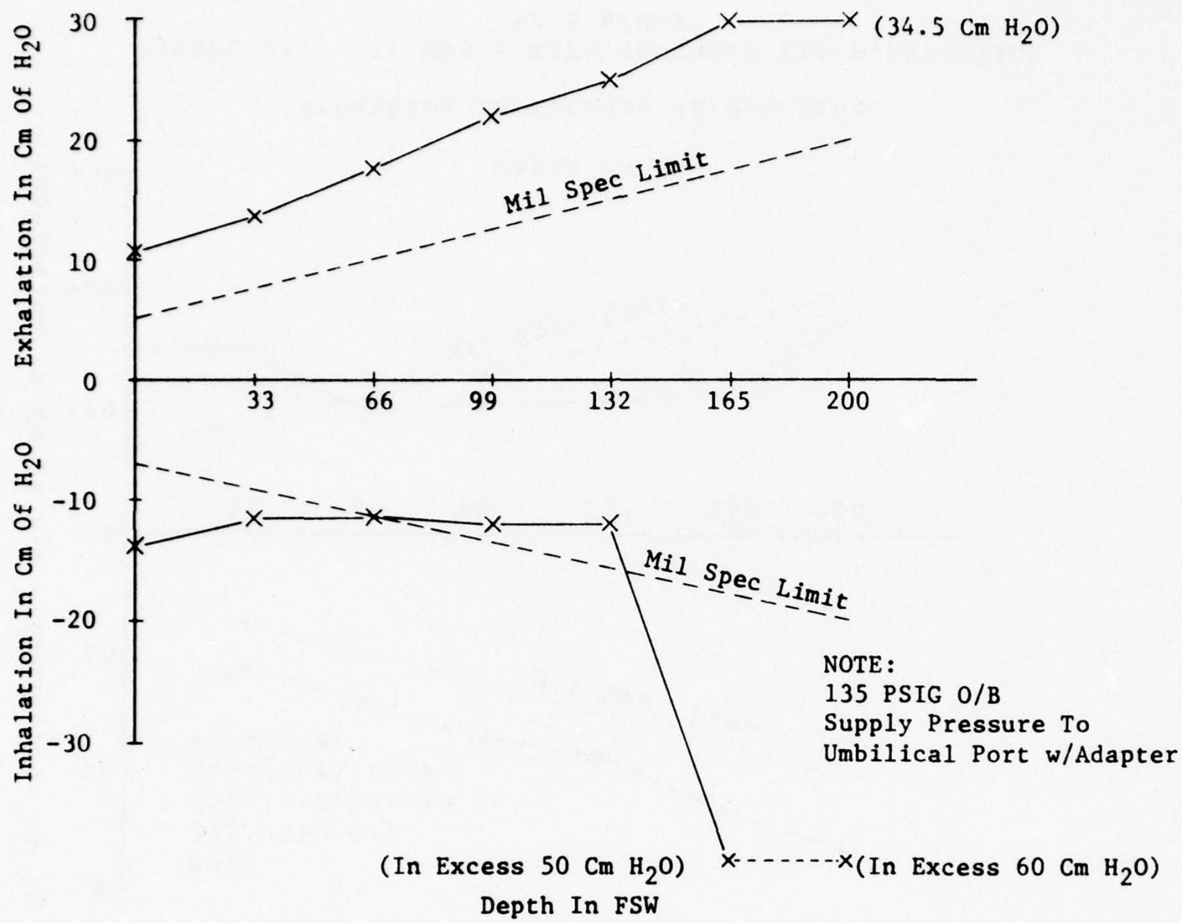
Breathing Resistance Versus Depth

FIGURE 35. MK1 MOD O WITH CONSHELF XII FIRST STAGE
40.0 R/M/V



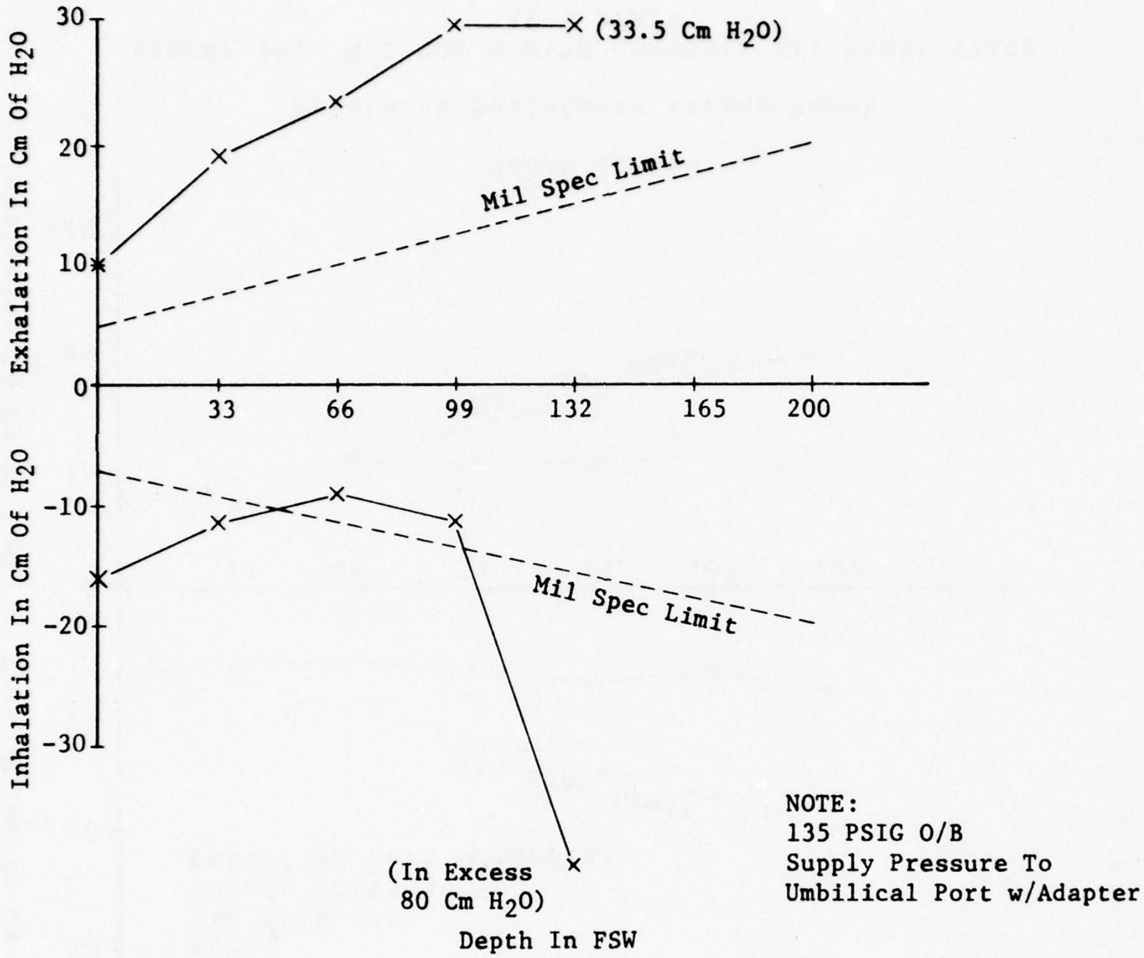
Breathing Resistance Versus Depth

FIGURE 36. MK1 MOD O WITH CONSHELF XII FIRST STAGE
62.5 R/M/V



Breathing Resistance Versus Depth

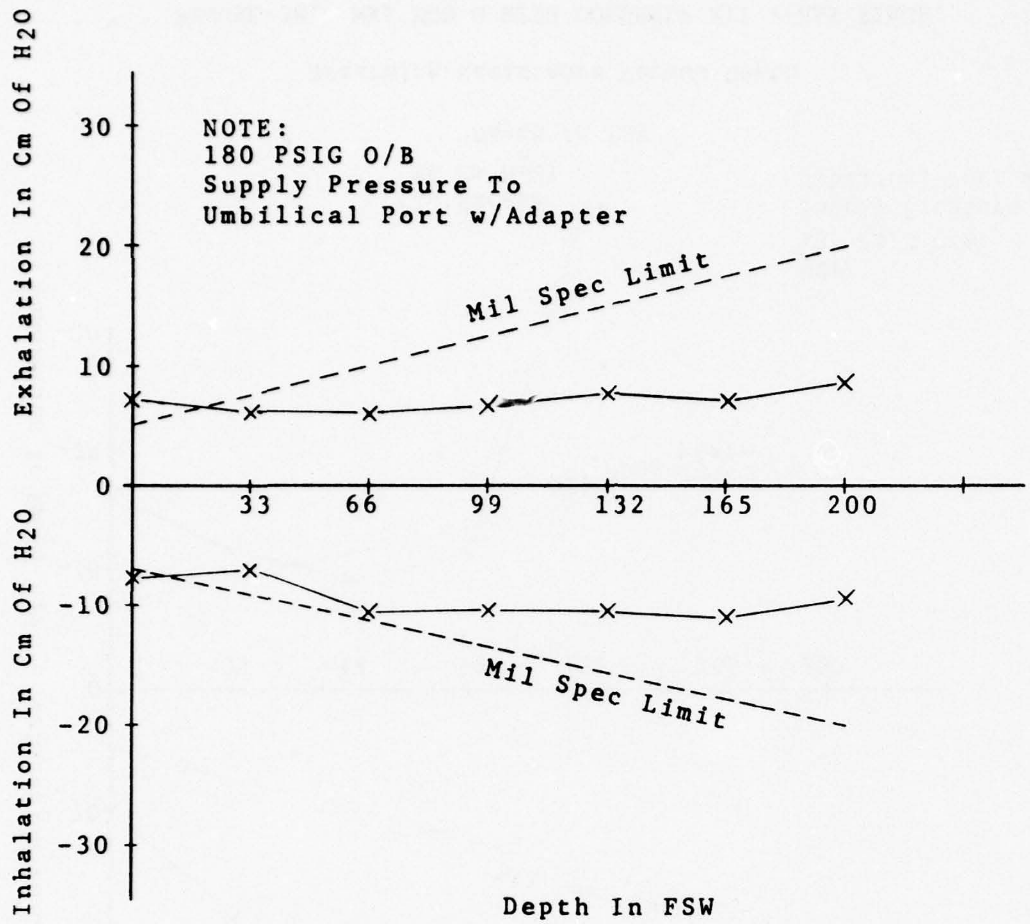
FIGURE 37. MK1 MOD 0 WITH CONSHELF XII FIRST STAGE
75.0 R/M/V



Breathing Resistance Versus Depth

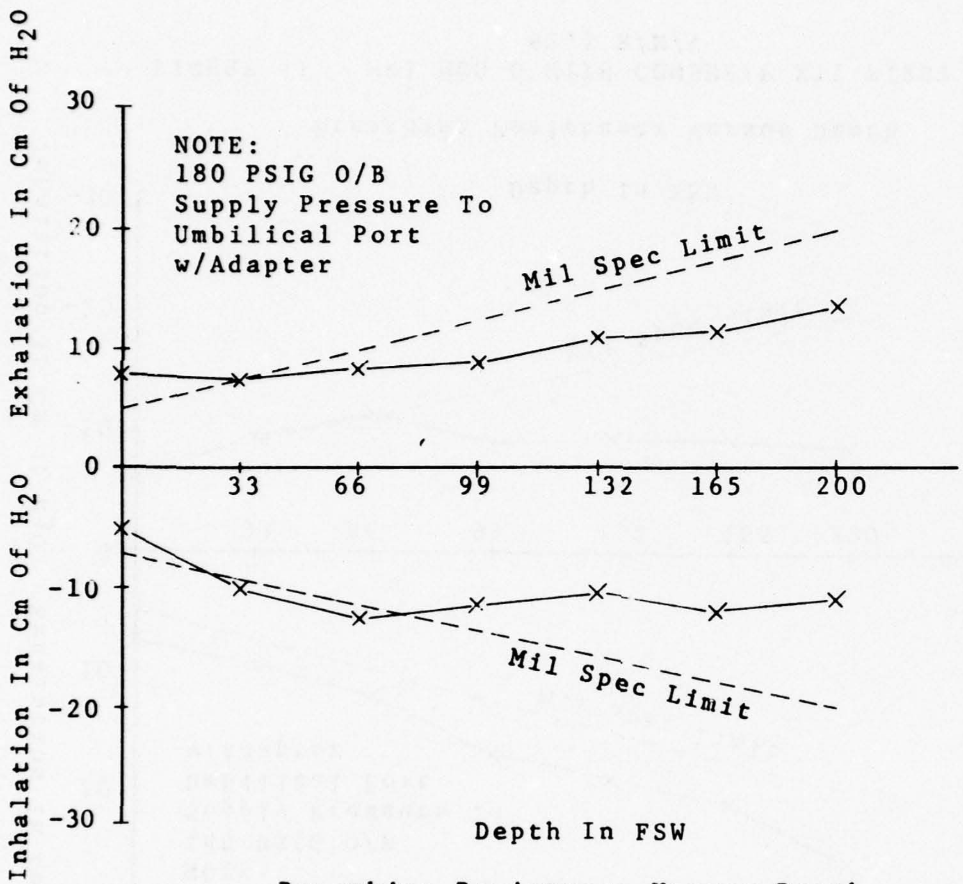
FIGURE 38. MK1 MOD 0 WITH CONSHELF XII FIRST STAGE

90.0 R/M/V



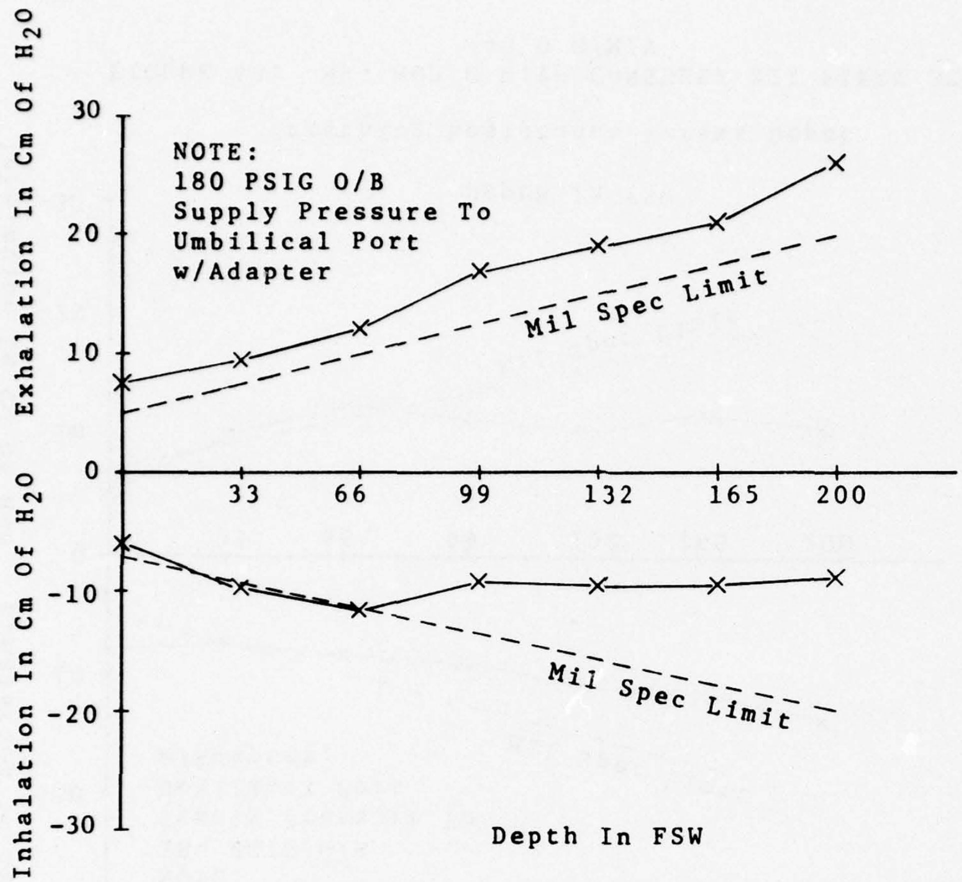
Breathing Resistance Versus Depth

FIGURE 39. MK1 MOD O WITH CONSHELF XII FIRST STAGE
22.5 R/M/V



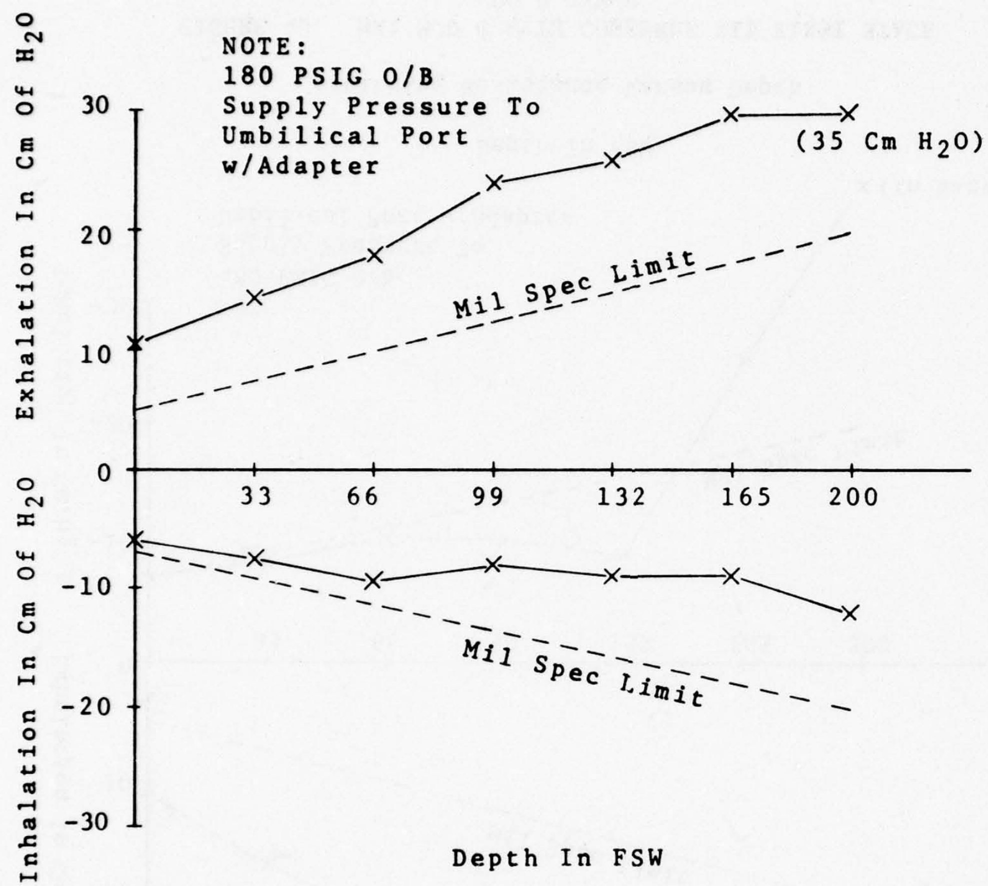
Breathing Resistance Versus Depth

FIGURE 40. MK1 MOD O WITH CONSHELF XII FIRST STAGE
40.0 R/M/V



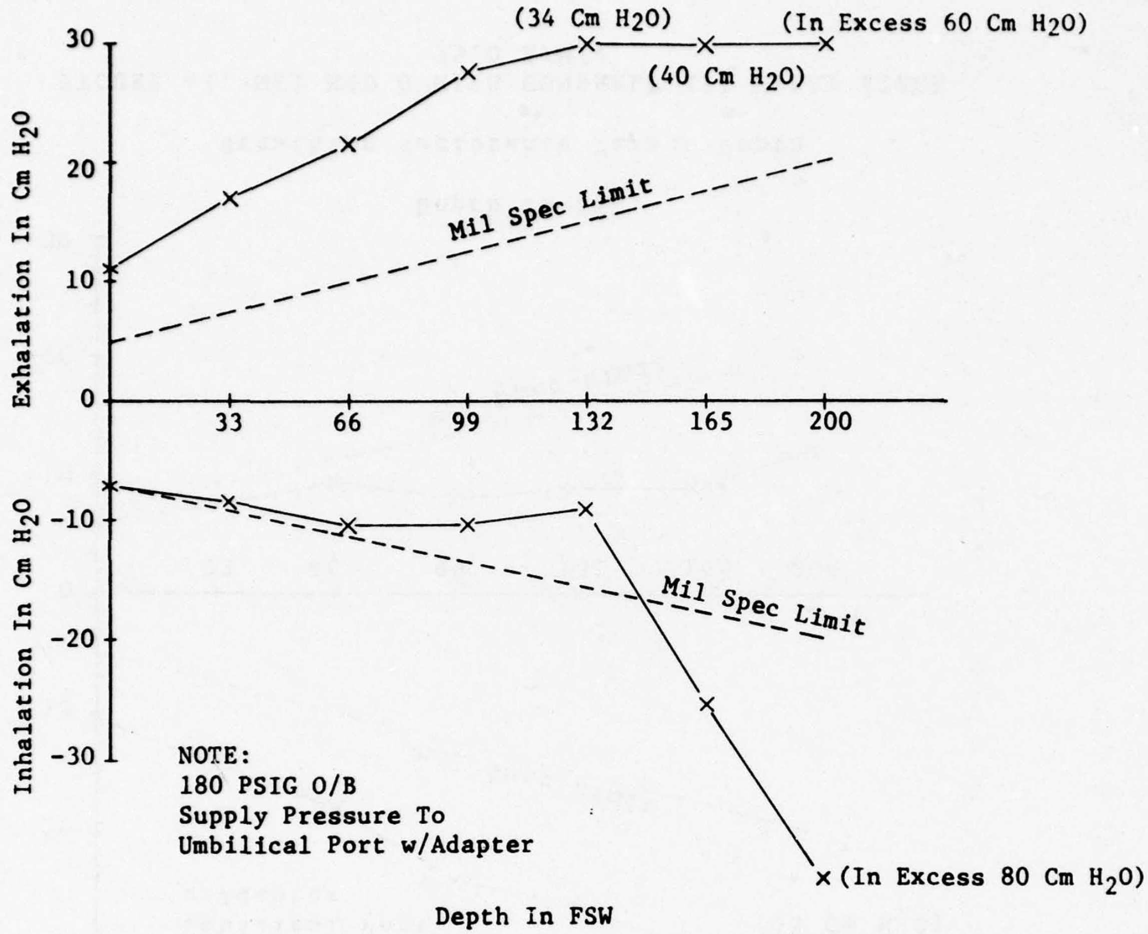
Breathing Resistance Versus Depth

FIGURE 41. MK1 MOD O WITH CONSHELF XII FIRST STAGE
62.5 R/M/V



Breathing Resistance Versus Depth

FIGURE 42. MK1 MOD 0 WITH CONSHELF XII FIRST STAGE
75.0 R/M/V



Breathing Resistance Versus Depth

FIGURE 43. MK1 MOD O WITH CONSHELF XII FIRST STAGE
90.0 R/M/V

b. Phase II Work of Breathing Results

(1) 135 psig O/B Supply Pressure. Breathing work was comparable to that measured in the MK 1 Mod 0 umbilical mode test (see Figure 9).

(2) 180 psig O/B Supply Pressure. Breathing work was similar to that measured in the normal umbilical mode except at depths over 132 FSW and RMV of 75 and over. These conditions required breathing work approximately 20% less than those measured in the normal umbilical mode (See Figure 9).

c. Phase II Sideblock Performance Results. Sideblock pressure losses were almost identical for 135 and 180 psig O/B (Figure 44). It is interesting that the pressure drops were greater than those experienced in the normal umbilical supply mode (Figure 11) and less than those measured in the emergency supply port mode (Figure 26). The reason for this phenomena is due to the special adapter used during the tests. While its flow passages were larger than the emergency port, they were smaller than the normal umbilical port mode due to interfacing requirements.

d. Phase II First Stage Performance Results. First stage intermediate pressure losses were similar to those occurring during Phase I tests (see Figure 27).

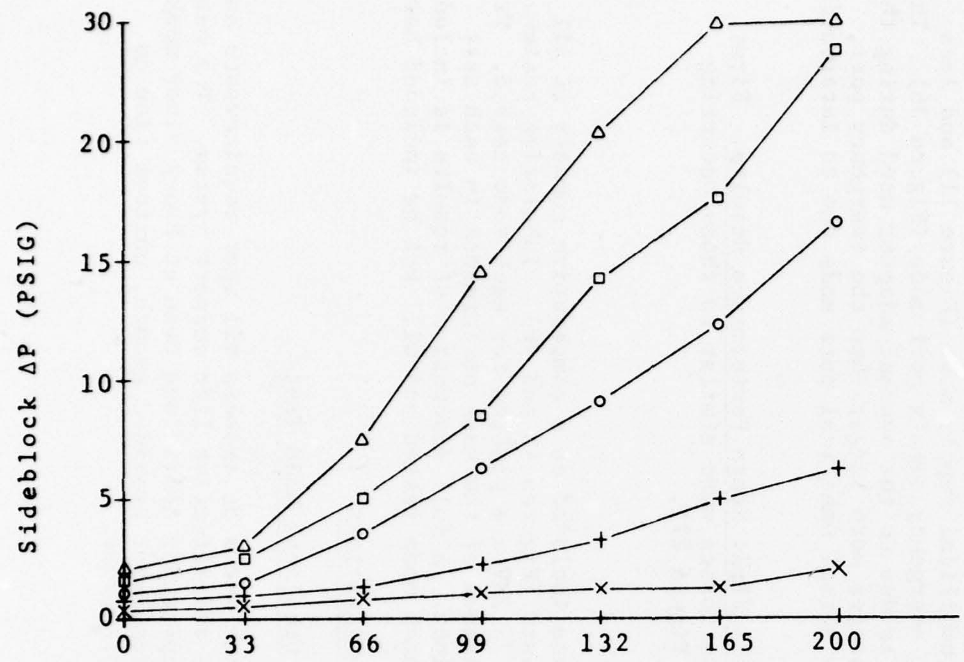
E. Overall Summary

The following plots are included as a comparative summary of all data taken during these tests (Figures 45 and 46). Inhalation resistance vs. depth at 40 and 75 RMV are plotted for each mode tested. From these plots a direct comparison of the mask performance in each test configuration can be obtained. A full discussion of results is included in the sections covering each mode tested and will not be included here.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. MK 1 Mod 0 Mask Umbilical Mode Test

The USN MK 1 Mod 0 mask meets or exceeds mil spec requirements and is considered to be a safe and effective life support system. The mask performed well under all operating conditions even at heavy diver work rates. The second stage regulator provided smooth, uniform flow on demand with low cracking pressures.



NOTE:
135 & 180 PSIG O/B
Supply Pressure To
Umbilical Port

Sideblock Pressure Drop Versus Depth

FIGURE 44. MK1 MOD O WITH CONSHELF XII FIRST STAGE

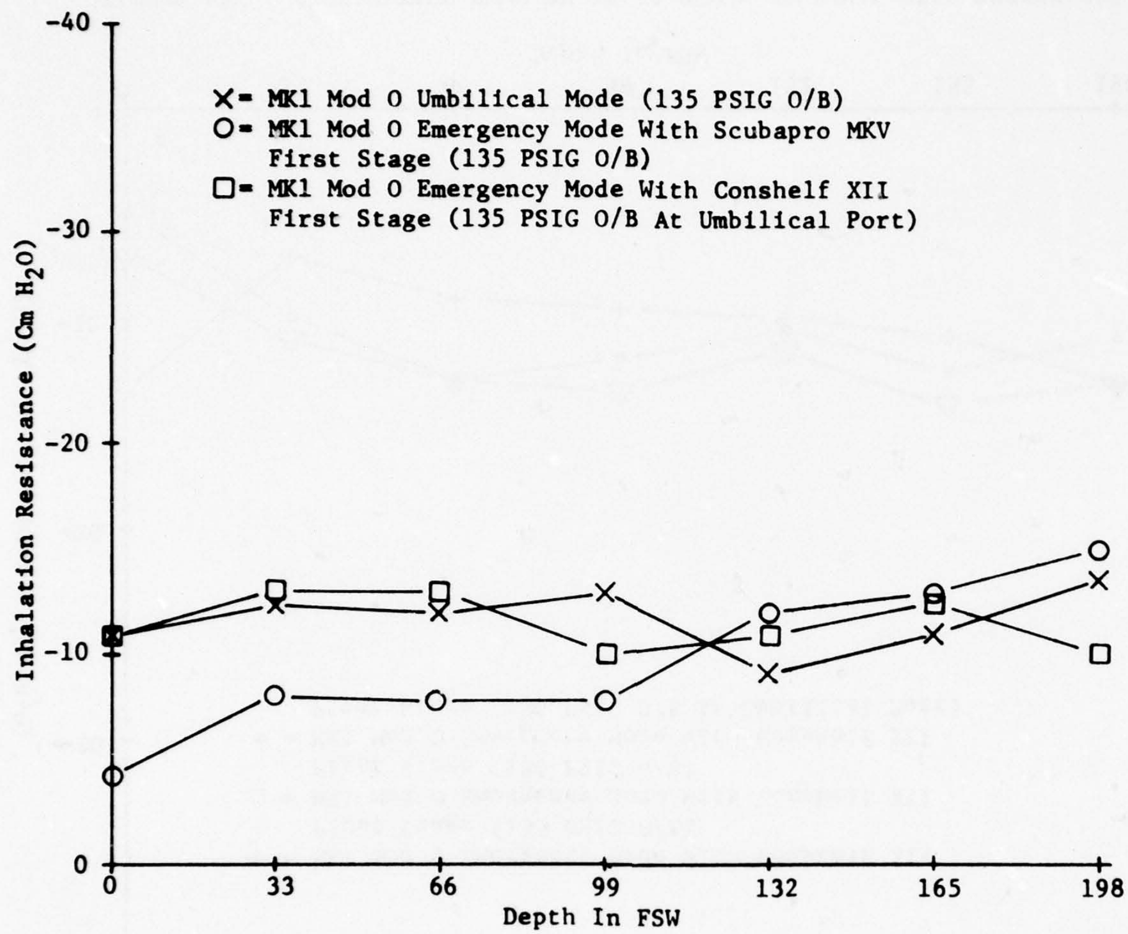


FIGURE 45a. COMPARATIVE SUMMARY AT 40 R/M/V OF INHALATION RESISTANCE

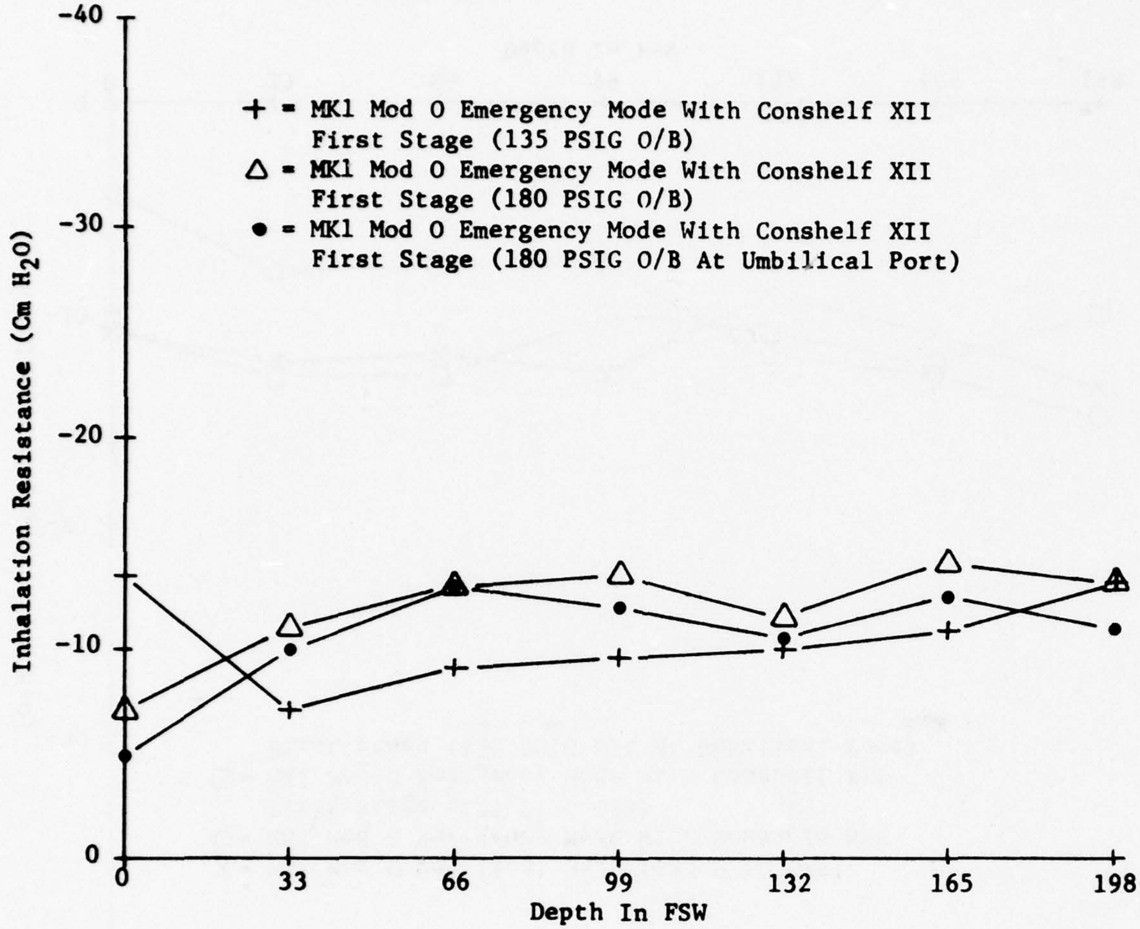


FIGURE 45b. COMPARATIVE SUMMARY AT 40 R/M/V OF INHALATION RESISTANCE

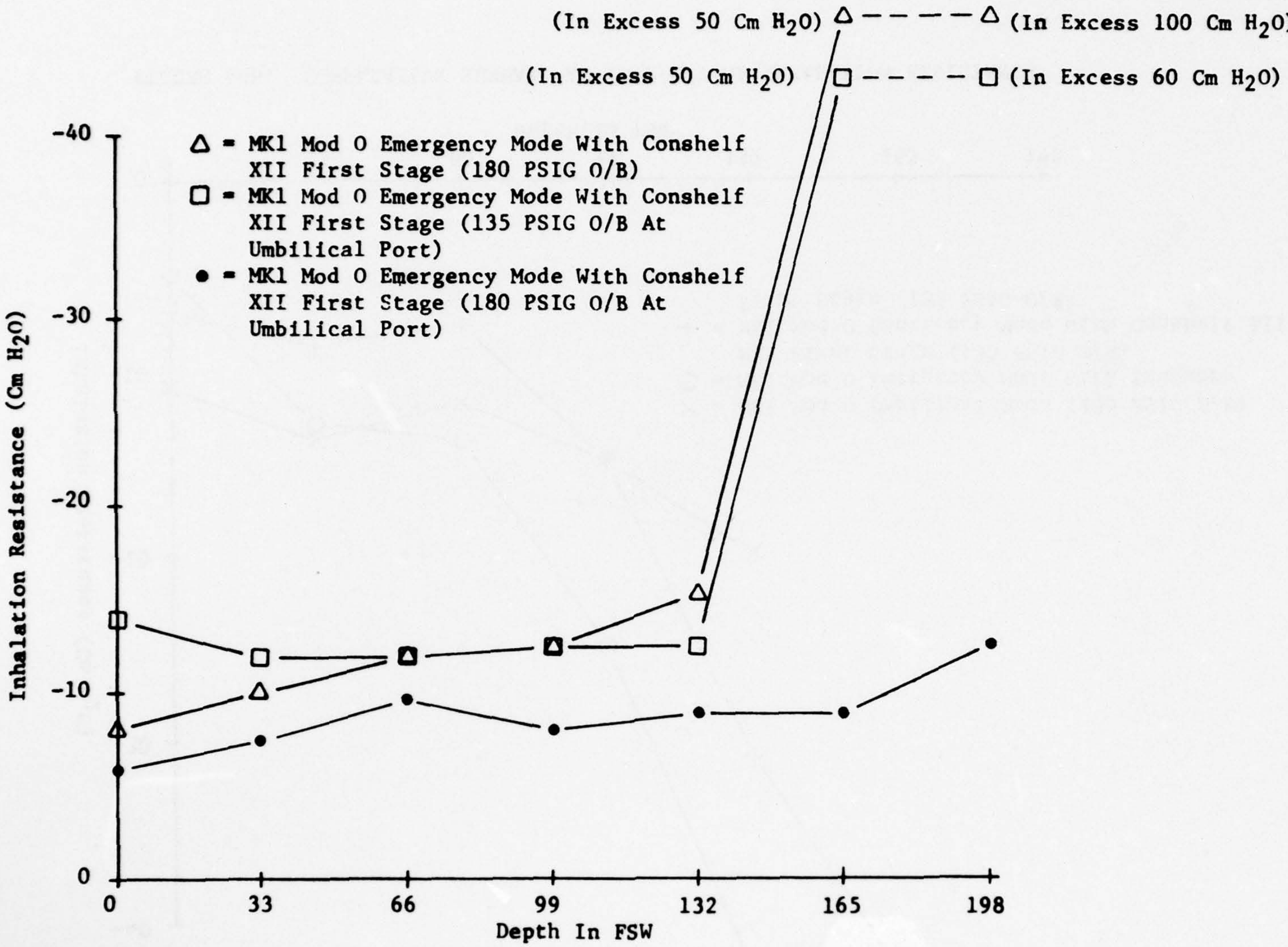


FIGURE 46a. COMPARATIVE SUMMARY AT 75 R/M/V OF INHALATION RESISTANCE

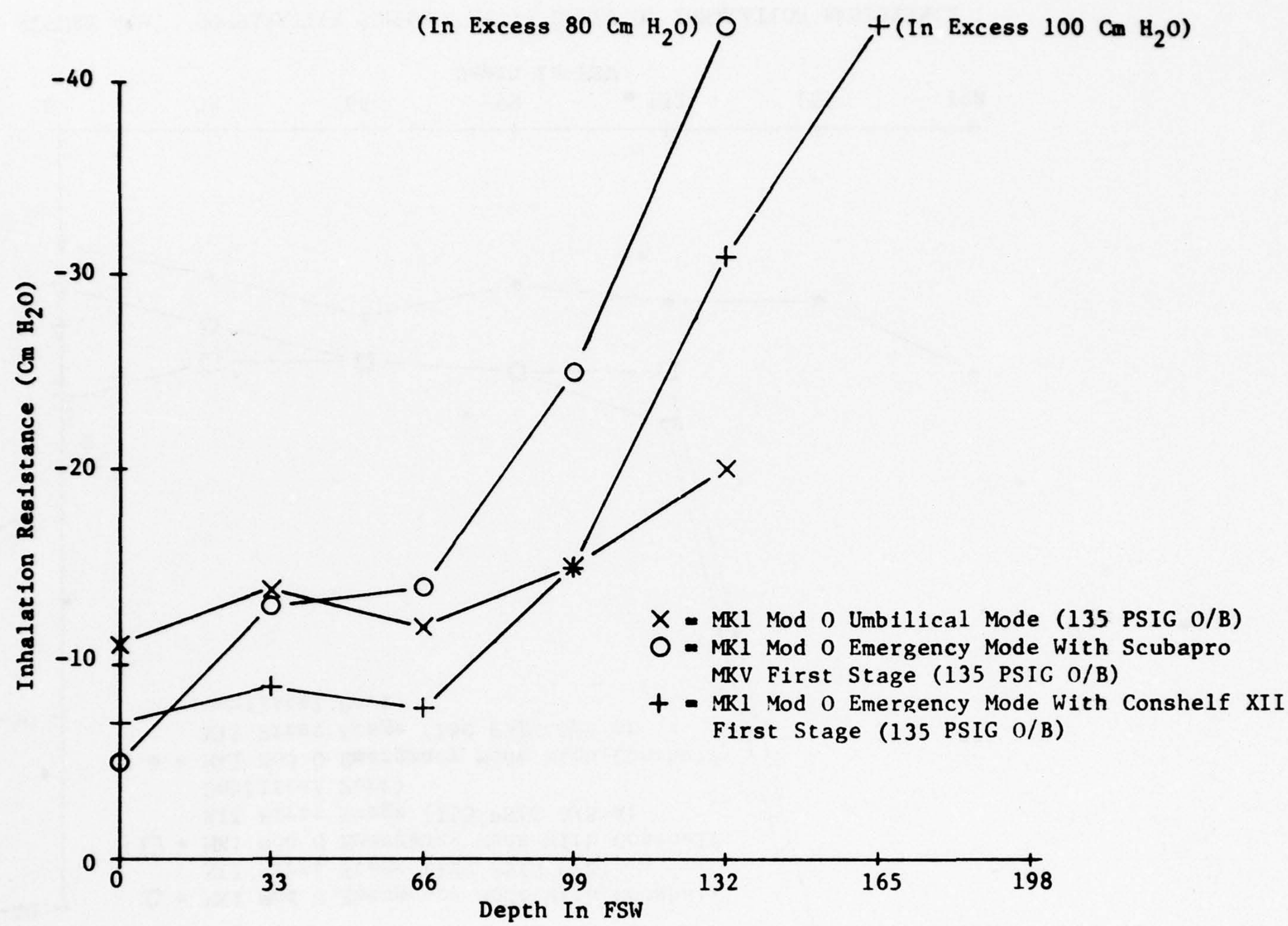


FIGURE 46b. COMPARATIVE SUMMARY AT 75 R/M/V OF INHALATION RESISTANCE

Breathing work required to operate the mask was generally low and would not inhibit a divers ability to perform useful work except in extreme cases.

Pressure drop is low, and flow characteristics of the sideblock in the normal umbilical mode are good. However, non-return valve operation was erratic under flow conditions and required high cracking pressures. While overall mask performance was not affected, this is an area that warrants further consideration.

The 3/8" I.D. umbilical, currently the standard of the commercial and military diving community, exhibits large pressure loss at depths over 99 FSW and high diver work rates. While the mask performed well under all but extreme diver work rates, performance could be improved by the use of 1/2" I.D. umbilical.

B. MK 1 Mod 0 Mask Emergency Mode First Stage Regulator Comparison Tests

The U.S. Divers Conshelf XII first stage regulator was found to outperform the Scubapro MK V first stage at RMV over 40. However, neither regulator matched mask performance in the normal umbilical mode at depths over 99 FSW and the higher RMV.

Sideblock pressure losses through the emergency mode flow path were high and definitely affected mask performance. The high pressure drops were caused by the 1/8" orifice in the emergency on/off valve. It is not recommended that any changes be made to this valve because further testing showed that by increasing the supply pressure from the first stage to 180 psig O/B produced results comparable to the normal umbilical mode tests.

The two first stage regulators tested both exhibited large pressure drops under heavy to extreme work conditions. These losses reduced mask performance when coupled with pressure losses in the sideblock. However, the Conshelf XII has an external adjustment screw which facilitates increasing its intermediate pressure output. The Scubapro MK V has no such capability. Consequently, the MK V was dropped from consideration and the Conshelf XII was further evaluated in the emergency mode using higher intermediate pressure settings.

C. MK 1 Mod 0 Mask Supplied by Conshelf XII First Stage Regulator at Varying Over Bottom Pressure Tests

This test series compared mask performance when supplied by the Conshelf XII first stage at varying over bottom pressure to both the emergency port and the umbilical port. Maximum mask performance was obtained by connecting the Conshelf XII to the umbilical port via a special adapter at 180 psig O/B. Performance under these conditions exceeded even that attained in the normal umbilical supply mode tests.

However the logistics and costs involved in supplying the fleet with special adapters more than offsets any gains from using this configuration.

Mask performance was found to be equal to the normal umbilical mode when the Conshelf XII supplied the emergency port at 180 psig O/B. This configuration is adequate for any normal surface supplied diving situation where the scuba tank and first stage are for emergency situations only.

In addition, for applications where the MK 1 Mod 0 mask may be used with scuba tanks only on a free swimming (or tether for communications only) diver, the Conshelf XII supplying the emergency port at 135 psig O/B was found to be adequate in all work ranges at depths no greater than 66 FSW.

V. REFERENCES

1. Department of the Navy Military Specification MIL-R-24169A, Regulator, Air, Demand, Single Hose, Nonmagnetic, Divers, 22 March 1967.

2. Navy Experimental Diving Unit Report 23-73, U.S.N. Procedures for Testing the Breathing Characteristics of Open-Circuit Scuba Regulators, by S. D. Reimers, p. 5, 11 December 1973.

3. Navy Experimental Diving Unit Report 19-73, Proposed Standards for the Evaluation of the Breathing Resistance of Underwater Breathing Apparatus, by S. D. Reimers, p. 36, 30 January 1974.

PART II

MANNED HUMAN ENGINEERING EVALUATION OF USN MK 1 MOD 0 MASK IN TETHERED SCUBA CONFIGURATION

I. INTRODUCTION

As just described, MK 1 Mod 0 in tethered SCUBA configuration (MK 1 Mod 0/SCUBA (tethered)) underwent extensive unmanned testing. When used with the proper regulator and pressure settings, mask performance with SCUBA was comparable to that achieved in normal umbilical mode at depths of 60 FSW or shallower. Following this analysis, a manned evaluation was undertaken to identify any safety or human engineering inconsistencies which might be present in this diving configuration.

The philosophy underlying this evaluation was that MK 1 Mod 0/SCUBA (Tethered) is, for practical purposes, only an extension of normal SCUBA diving. Thus, a determination was sought as to whether the MK 1 Mod 0 or any associated equipment would conflict with the necessary safety procedures involved in the use of SCUBA. The compatibility of MK 1 Mod 0/SCUBA (Tethered) with a variety of diving suits (i.e. swimsuit, wetsuit, drysuit (Unisuit), and MK 16 hot water suit) was also investigated.

II. TEST PROCEDURE

Specifically, the following rig/suit configurations were examined:

(1) MK 1 Mod 0/SCUBA (Tethered) with Integrated Divers Vest (IDV) and swimsuit

(2) MK 1 Mod 0/SCUBA (Tethered) with standard backpack and harness with swimsuit

(3) MK 1 Mod 0/SCUBA (Tethered)/IDV with wetsuit

(4) MK 1 Mod 0/SCUBA (Tethered)/standard harness with wetsuit

(5) MK 1 Mod 0/SCUBA (Tethered)/IDV with drysuit (Unisuit)

(6) MK 1 Mod 0/SCUBA (Tethered)/standard harness with drysuit (Unisuit)

(7) MK 1 Mod 0/SCUBA (Tethered)/IDV with hot water suit

(8) MK 1 Mod 0/SCUBA (Tethered)/standard harness with hot water suit

Single, as well as, twin SCUBA cylinders were employed.

Using each of these configurations, the following characteristics were assessed and documented photographically:

(1) Could divers operate the reserve air control knob?

(2) By what means can a strain or lift line be attached to the diver?

(3) When hauled to the surface, what was the positional attitude of the diver using various attachment points and which was preferred by the diver?

(4) In the event of umbilical entrapment, can the diver ditch strain and communications umbilicals quickly and efficiently?

(5) In the event of rig entrapment, however remote the possibility, can the diver completely ditch MK 1 Mod 0/SCUBA so a free ascent can be made? If so, what was the exact procedure followed?

(6) Does use of the IDV interfere with control knobs associated with some of the suits?

The bulk of the evaluation occurred in the NCSC Bldg. 319 test pool (depth 20 ft) in which the water was maintained at a temperature of 80-85°F. An acrylic diving bell was positioned on the bottom of the pool to be used by the divers after ditching procedures, thus eliminating the necessity of making free ascents. All divers were first class Navy divers with considerable experience in both the MK 1 Mod 0 and SCUBA. An open water dive was also undertaken in 60 ft of water at the Stage II U.S. Navy platform located 2 miles offshore of Panama City.

III. RESULTS AND DISCUSSION

With regard to the use of MK 1 Mod 0/SCUBA (Tethered) with IDV, the following characteristics were observed:

(1) Regardless of the type of suit being worn, all divers were able to reach and operate the reserve air control knob. They did report, however, that it was more difficult with the IDV than with a standard backpack and harness. This is probably due to the fact that the IDV may tend to reduce the diver's ability to move the tank around on his back when reaching for the valve, particularly when wearing the more movement-restrictive suits such as Unisuit and hot water suits.

(2) The IDV provides four D-ring strain lift points - front upper left, front lower right, front upper right, and upper back (behind the

neck). Divers were able to attach or release the snap shackle life line in all positions. When hauling divers to the surface, all reported the upper back position was most comfortable, but found it to be a little more difficult to attach and release from there than the other three locations. When lifted from upper back position, divers arrived at the surface in a head up vertical position. Lifts from the front tended to pull the vest sideways and upward with the divers arriving at the surface in a head-up, but generally, sideways position.

(3) All divers successfully ditched strain and communication umbilicals quickly (5-10 seconds) and with little difficulty. In the case of the hot water suit, the hot water umbilical was ditched with only a minimum of additional effort. Divers performed the umbilical ditching with gloves appropriate to the suit they were wearing.

(4) Regardless of the suit used, divers were able to completely ditch MK 1 Mod 0/SCUBA (Tethered) with IDV. Ditching completion times seem to be largely dependent on the individual diver and the type of gloves being worn. Times ranged from 18 seconds (swimsuit/no gloves) to 62 seconds (hot water suit/gloves). During all ditching procedures, the two double D-ring restraint straps on the IDV were always placed in the quick-release configuration. Without the quick-release arrangement, ditching of the vest with gloves would be considerably more difficult. In general, the ditching procedure was as follows: (1) Release crotch strap, (2) unfasten quick-release waist strap, (3) release small double D-ring strap located at the top of front zipper, (4) unzip front zipper, (5) slide IDV with SCUBA bottles off and bring around to the front, (6) loosen spider, and (7) pull mask free of face.

(5) When wearing MK 1 Mod 0/SCUBA (Tethered) with IDV, the vest completely covers the two buoyancy control valves located on the upper chest region of the Unisuit. This interference makes the operation of these valves extremely difficult, if not impossible. No interference with hot water control knobs was observed when the IDV was worn with the MK 16 hot water suit.

Use of an inflatable life vest with the Integrated Diver's Vest is generally impractical and not recommended. When the life vest is worn inside the IDV to allow the MK 1 Mod 0/SCUBA (Tethered) to be ditched, the diver is unable to reach the CO_2 cartridge actuator. If the life vest is worn on the outside, it can be operated properly, but prevents the quick removal of the IDV during the ditching procedure. It is generally agreed, however, that the probability of having to ever completely ditch the rig is quite small. Not only would the diver have to have an entangled rig, but he would also have to be out of air and thus "forced" to free ascend.

With regard to the use of MK 1 Mod 0/SCUBA (Tethered) with a standard backpack and harness, the following characteristics were observed:

(1) Regardless of the type of suit being worn, all divers were able to reach and operate the reserve air control knob.

(2) When wearing standard backpack and harness, and while wearing an inflatable life vest (in this case, a Fenzy), locations for attaching a strain lift line were somewhat limited. The lift line can either be attached to the D-ring on the life vest (front lower center) or wrapped around the divers waist. Both means were sufficient to lift the diver to the surface, but were considered generally inferior to the built-in easily accessible lift points on the IDV.

(3) Ditching umbilicals in the MK 1 Mod 0/SCUBA (Tethered) with standard harness did not differ substantially with respect to completion times when compared to the same procedure with IDV.

(4) Regardless of the suit being worn, divers were able to completely ditch MK 1 Mod 0/SCUBA (Tethered) with standard harness. The completion times were consistently faster than those associated with the IDV. Standard harness ditching times ranged from 9 to 33 seconds. Again, completion times appeared to be related to type of glove and suit worn.

(5) Contrary to the IDV, the standard harness did in no way cover or interfere with the buoyancy controls of the Unisuit. Likewise, no interference with the hot water suit was observed.

IV. CONCLUSIONS AND RECOMMENDATIONS

(1) MK 1 Mod 0/SCUBA (Tethered) is a viable, safe diving configuration with demonstrated flexibility regarding the diving suits with which it can be used.

(2) Specific operating procedures should be established for the use of MK 1 Mod 0/SCUBA (Tethered).

APPENDIX A

TEST PLAN

I. <u>MK 1 Mod 0 Umbilical Mode Test</u>

1. Install MK 1 Mod 0 mask in chamber and connect instrumentation as shown in Figure 1.
2. Calibrate all sensors.
3. Fill test box with water until manikin head is submerged.
4. Install wave suppressor in test box.
5. Set umbilical supply pressure at 135 psig over bottom pressure.
6. Record static reading on all transducers.
7. Adjust "Dial-A-Breath" control for proper setting.
8. Record regulator offset.
9. Set breathing machine tidal volume to 1.5 liters.
10. Turn on breathing machine tidal volume to 1.5 liters.
11. Record, plot, print, and store data.
12. Turn off breathing machine.
13. Change tidal volume to 2 liters.
14. Turn on breathing machine at 20 BPM.
15. Repeat steps 12 and 13.
16. Change tidal volume to 2.5 liters.
17. Turn on breathing machine at 25 BPM.
18. Repeat steps 12 and 13.
19. Turn on breathing machine at 30 BPM.
20. Repeat steps 12 and 13.
21. Change tidal volume to 3.0 liters.

22. Turn on breathing machine at 30 BPM.

23. Repeat steps 12 and 13.

24. Close chamber.

25. Open compliance chamber solenoid valve.

26. Compress chamber to 33 Ft. H_2O.

27. Close compliance chamber solenoid valve.

28. Repeat steps 5 through 23.

29. Open compliance chamber solenoid valve.

30. Compress chamber to 66 Ft. H_2O.

31. Close compliance chamber solenoid valve.

32. Repeat steps 5 through 23.

33. Open compliance chamber solenoid valve.

34. Compress chamber to 99 Ft. H_2O.

35. Close compliance chamber solenoid valve.

36. Repeat steps 5 through 23.

37. Open compliance chamber solenoid valve.

38. Compress chamber to 132 Ft. H_2O.

39. Close compliance chamber solenoid valve.

40. Repeat steps 5 through 23.

41. Open compliance chamber solenoid valve.

42. Compress chamber to 165 Ft. H_2O.

43. Close compliance chamber solenoid valve.

44. Repeat steps 5 through 23.

45. Open compliance chamber solenoid valve.

46. Compress chamber to 198 Ft. H_2O.

47. Close compliance chamber solenoid valve.

48. Repeat steps 5 through 23.

49. Open compliance chamber solenoid valve.

50. Close umbilical supply valve.

51. Decompress chamber.

52. Bleed supply regulator dome and umbilical supply hose.

II. <u>MK 1 Mod 0 Mask Emergency Mode Conshelf XII or Scubapro MK V First Stage Regulator Tests</u>

1. Install MK 1 Mod 0 mask in chamber and connect instrumentation as shown in Figure 2.

2. Adjust first stage regulator for 135 psig over bottom pressure.

3. Calibrate all sensors.

4. Fill test box with water until water level is 6 inches above the regulator.

5. Install wave suppressor in test box.

6. Set first stage supply pressure at 1000 psig.

7. Adjust "Dial-A-Breath" control for proper setting.

8. Record static reading on all transducers.

9. Record regulator offset.

10. Set breathing machine tidal volume at 1.5 liters.

11. Turn on breathing machine at 15 BPM.

12. Record, plot, print, and store data.

13. Turn off breathing machine.

14. Change tidal volume to 2.0 liters.

15. Turn on breathing machine at 20 BPM.

16. Repeat step 12.
17. Turn off breathing machine.
18. Change tidal volume to 2.5 liters.
19. Turn on breathing machine at 25 BPM.
20. Repeat step 12.
21. Change breathing machine to 30 BPM.
22. Repeat step 12.
23. Turn off breathing machine.
24. Change tidal volume to 3.0 liters.
25. Turn on breathing machine at 30 BPM.
26. Repeat step 12.
27. Turn off breathing machine.
28. Close chamber.
29. Open compliance chamber solenoid valve.
30. Compress chamber to 33 Ft. H_2O.
31. Close compliance chamber solenoid valve.
32. Repeat steps 7 through 27.
33. Open compliance chamber solenoid valve.
34. Compress chamber to 66 Ft. H_2O.
35. Close compliance chamber solenoid valve.
36. Repeat steps 7 through 27.
37. Open compliance chamber solenoid valve.
38. Compress chamber to 99 Ft. H_2O.
39. Close compliance chamber solenoid valves.

40. Repeat steps 7 through 27.

41. Open compliance chamber solenoid valve.

42. Compress chamber to 132 Ft. H_2O.

43. Close compliance chamber solenoid valve.

44. Repeat steps 7 through 27.

45. Open compliance chamber solenoid valve.

46. Compress chamber to 165 Ft. H_2O.

47. Close compliance chamber solenoid valve.

48. Repeat steps 7 through 27.

49. Open compliance chamber solenoid valve.

50. Compress chamber to 198 Ft. H_2O.

51. Close compliance chamber solenoid valve.

52. Repeat steps 7 through 27.

53. Open compliance chamber solenoid valve.

54. Decompress chamber.

55. Bleed first stage regulator dome and first stage supply lines.

APPENDIX B

TEST EQUIPMENT

1. MK 1 Mod 0 Bandmask Regulator and sideblock
2. Validyne pressure transducer w/50.0 psid diaphram (2 ea)
3. Validyne pressure transducer w/1.00 psid diaphram
4. Validyne CD-19 transducer readout (4 ea)
5. X-Y plotter
6. Hewlette Packard 9825 Data Acquisition System
7. NCSC Hydrospace chamber complex
8. Air pressure gauge (0-3000 psig)
9. Dome loader
10. Breathing machine w/piston position transducer
11. Wet test box
12. Motor drive to adjust Dial-A-Breath knob
13. First stage regulators (Conshelf XII, Scubapro MK V)
14. Validyne pressure transducer w/250 psid diaphram
15. Chamber depth gauge
16. Bubble dampening mat
17. 400' 3/8" I.D. umbilical

APPENDIX C

MAN-HOURS REQUIRED

The man-hours required for the test of the USN MK 1 Mod 0 mask are computed below.

	Men	Hours	Man-Hours
Test set-up	3	12	36
Test operation	3	48	144
Chamber operation	1	48	48
Post-test cleanup	2	3	6
Data reduction/report production	1	200	200
Duplicating	4	25	100
TOTAL			534