NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 8-87

EVALUATION OF COMMERCIALLY AVAILABLE OPEN CIRCUIT SCUBA REGULATORS

PAUL D. MORSON

AUGUST 1987

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DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
PANAMA CITY, FLORIDA 32407-5001

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NAVSEA Task 85-08

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SCUBA Regulators	Human Factors	NEDU Test Plan 86-13
Breathing Resistance	Unmanned Testing	NEDU Test Plan 86-18
Breathing Work	Manned Testing	NAVSEA Task 85-08

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

From August 1985 through September 1986 NEDU conducted a three phase evaluation of commercially available open circuit SCUBA regulators. Phase one consisted of unmanned testing of 51 SCUBA regulator models or systems commercially available in the United States. Breathing resistance, work of breathing, and first stage performance was evaluated. Phase two consisted of unmanned tests of selected open circuit SCUBA regulators, equipped with low temperature conversion kits. Breathing resistance, work of breathing, first stage performance and performance in cold water was evaluated. Phase three consisted of an open water human factors evaluation of the regulators tested in phase two. As a result of phase one testing a new (Continued on reverse)

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20. ABSTRACT (Continued)

NEDU open circuit SCUBA regulator performance criterion was developed to supersede the 1981 NEDU performance standard for 132 FSW. The new standard is work of breathing not to exceed .14 kg•m/ℓ (1.4 j/ℓ) at all depths and RMV up to 62.5 RMV at 198 FSW. From the field of 51 regulator models and systems tested, 8 met or exceeded the upgraded performance standard at 198 FSW, 17 met or exceeded the 1981 NEDU standard at 132 FSW, 43 met or exceeded the military standard of respiratory pressures (Mil-R-24169B), 6 failed to meet the military standard. Additionally, two regulators were unable to undergo objective analysis of breathing resistance and work due to second stage inhalation pressure incompatibility with the test analysis systems. Results of phase two testing indicated that low temperature conversion modifications frequently increased the work of breathing. In cold water five regulators were considered to have superior performance, one considered moderate, and four unacceptable. Phase three testing rated regulators from adequate to good, with the exception of one regulator that was rated unsafe.

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NOTE: Graphs for the SEA SPORT ZEPHER ZR-01 and TEKNA 2100 BX are not presented.

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Abbreviations

ANU	Authorized for Navy Use
BPM	breaths per minute
cmH_2O	centimeters of water (pressure)
cu ft	cubic feet
°F	degree Fahrenheit
°C	degree Celsius
CF	Canadian Forces
EDF	Experimental Diving Facility (NEDU unmanned test facility)
FSW	feet of seawater
ft	foot
HP	high pressure
IDI	International Divers Inc.
in	inches
J/ℓ	joules per liter (unit respiratory work)
KPa	Kilopascals
LP	low pressure
ℓpm	liters per minute (flow rate)
mg/ℓ	milligrams per liter (water vapor content)
NAVSEA	Naval Sea Systems Command
NEDU	Navy Experimental Diving Unit
O/B	over bottom pressure
PD	POS DIVE
PKS	Parkways
ΔP	pressure differential
ppm	parts per million

psi	pounds per square inch
psig	pounds per square inch gauge
RMV	respiratory-minute-volume in liters per minute
SCUBA	self contained underwater breathing apparatus
TV	tidal volume in liters of air breathed in and out of the lungs during normal respiration
UBA	underwater breathing apparatus
USN	United States Navy

To Convert From	To	Multiply By
kg·m/ℓ	joules per liter (j/ℓ)	9.807
psi	Kilopascals (KPa)	6.845
feet	meters (m)	0.305
FSW	meters of seawater (MSW)	0.305
FSW	Kilopascals (KPa)	3.065
cmH_2O	Kilopascals (KPa)	0.098

Abstract

From August 1985 through September 1986 NEDU conducted a three phase evaluation of commercially available open circuit SCUBA regulators. Phase one consisted of unmanned testing of 51 SCUBA regulator models or systems commercially available in the United States. Breathing resistance, work of breathing, and first stage performance was evaluated. Phase two consisted of unmanned tests of selected open circuit SCUBA regulators, equipped with low temperature conversion kits. Breathing resistance, work of breathing, first stage performance and performance in cold water was evaluated. Phase three consisted of an open water human factors evaluation of the regulators tested in phase two. As a result of phase one testing a new NEDU open circuit SCUBA regulator performance criterion was developed to supersede the 1981 NEDU performance standard for 132 FSW. The new standard is work of breathing not to exceed .14 kg·m/ℓ (1.4 j/ℓ) at all depths and RMV up to 62.5 RMV at 198 FSW. From the field of 51 regulator models and systems tested, 8 met or exceeded the upgraded performance standard at 198 FSW, 17 met or exceeded the 1981 NEDU standard at 132 FSW, 43 met or exceeded the military standard of respiratory pressures (Mil-R-24169B), 6 failed to meet the military standard. Additionally, two regulators were unable to undergo objective analysis of breathing resistance and work due to second stage inhalation pressure incompatibility with the test analysis systems. Results of phase two testing indicated that low temperature conversion modifications frequently increased the work of breathing. In cold water five regulators were considered to have superior performance, one considered moderate, and four unacceptable. Phase three testing rated regulators from adequate to good, with the exception of one regulator that was rated unsafe.

KEY WORDS:

Commercially Available
Open Circuit Demand
SCUBA Regulators
Breathing Resistance
Breathing Work
First Stage Pressure Drop
Cold Water Function
Human Factors
Unmanned Testing
Manned Testing
Open Water Evaluation
NEDU Test Plan 85-21
NEDU Test Plan 86-13
NEDU Test Plan 86-18
NAVSEA Task 85-08

General Introduction

In June 1985 the U.S. Navy Diving Manual, Volume I was revised to permit no-decompression open circuit SCUBA diving with air to a maximum depth of 190 FSW. U.S. Navy uses commercially available SCUBA regulators, as authorized and appearing on the Authorized for Navy Use Listing, reference (a) (ANNEX A).

Of those regulators originally listed for use to 130 FSW, and tested in 1979, only a limited number were identified as being suitable to 190 FSW. Many of those original regulators are now out-of-production and an updated ANU list of commercially available SCUBA regulators was necessary.

In June 1985, NAVSEA Task 85-08, reference (b), directed the Navy Experimental Diving Unit (NEDU) to conduct a survey of commercially available open circuit SCUBA regulators, then perform unmanned testing to determine those regulators whose performance would remain satisfactory to a depth of 190 FSW. The tasking included the test and evaluation of low temperature conversion kits.

In August 1985, NEDU commenced an initial two phase evaluation of breathing resistance, work of breathing and cold water studies of certain selected regulators. Later the evaluation was modified to include a third phase "human factors open water study" to complement the first two phases. The complete evaluation concluded in September 1986.

This report summarizes the test results of all phases of the evaluation and provides full technical information requested by reference (b).

PART I - UNMANNED TESTING: BREATHING RESISTANCE, WORK OF BREATHING AND FIRST STAGE INTERMEDIATE PRESSURE DROP

I. INTRODUCTION

NEDU initially conducted a survey of commercially available open circuit SCUBA regulators manufactured or distributed in the United States. Specific models, representing a broad spectrum of different functional design, were selected for evaluation.

From August through October 1985 NEDU's Experimental Diving Facility conducted unmanned breathing resistance and work of breathing studies on 51 SCUBA regulator models and systems produced by 19 manufacturers. (NOTE: The term system describes a combination of first and second stage regulators produced by different manufacturers.) Evaluated regulator models and systems are listed in Table 1. A list of manufacturers is contained in ANNEX B.

Regulators were purchased from various commercial distributors (SCUBA shops, diving warehouses). Only one complete regulator of each model was purchased.

NOTE: The AGA DIVATOR MK II full face mask, presently utilized by the U.S. Navy when through water communications are required, was evaluated combined with another manufacturer's first stage regulators as a system. Additionally, the MK II breathing valve (positive pressure) with AGA mouthpiece was evaluated. AGA does manufacture a non-positive pressure breathing valve for use with the mouthpiece. The non-positive pressure unit was evaluated by NEDU, however specific results are not included in this report.

Each regulator was calibrated to manufacturers' specifications for first stage static intermediate and second stage cracking pressures. The calibration of each unit followed the standard practices utilized in SCUBA regulator planned maintenance routines conducted by all USN diving activities. Manufacturer's technical representatives, having been invited to observe the unmanned breathing resistance testing of their respective regulators monitored and assisted in calibrations held immediately prior to testing.

The last major evaluation of commercial SCUBA regulators was conducted in June 1979. The result of that evaluation, NEDU Report 2-80 [reference (c)] was the basis for the establishment of performance standards of open circuit demand SCUBA regulator set forth in Standardized NEDU Unmanned UBA Test Procedure, NEDU Report 3-81 [reference (d)]. This standard being, maximum respiratory work level is not to exceed 0.14 kg·m/ℓ or 1.4 j/ℓ at all depths and RMV up to and including 132 FSW and 62.5 RMV with 1000 psig supply pressure to the regulator first stage. This standard coincided with the superior performance regulator group that were later Authorized for Navy Use to a maximum depth of 130 FSW.

TABLE 1

REGULATOR MODELS AND SYSTEMS EVALUATED FOR
BREATHING RESISTANCE/WORK OF BREATHING

1. AGA DIVATOR MK II (full face mask) complete first and second stage with AGA cylinder.
2. AGA DIVATOR MK II (full face mask) used with U.S. DIVERS CONSHELF XIV first stage (system).
3. AGA DIVATOR MK II (full face mask) used with U.S. DIVERS ROYAL SL first stage (system).
4. AGA DIVATOR MK II breathing valve equipped with AGA mouthpiece used with U.S. DIVERS ROYAL SL first stage (system).
5. CRESSI SUB GALAXIE 105
6. CRESSI SUB POLARIS IV
7. DACOR PACER AERO 950A
8. DACOR PACER XL 950
9. DACOR PACER XLE 360
10. INTERNATIONAL DIVERS INC. STAR II
11. INTERNATIONAL DIVERS INC. SUPER STAR II
12. NEMROD SATURN 300
13. NEMROD SATURN 300 PRO
14. OCEAN DYNAMICS RB-5000
15. OCEANIC OMEGA II
16. OCEANIC OMEGA II MAX FLOW
17. PARKWAYS ATLAS
18. CYKLON 300 distributed by PARKWAYS - POSEIDON Systems Pre 1986 model
19. CYKLON MAX II distributed by PARKWAYS - POSEIDON Systems Pre 1986 model
20. POSEIDON CYKLON 300 distributed by POS DIVE - POSEIDON Systems 1986 model
21. POSEIDON CYKLON 5000 distributed by POS DIVE - POSEIDON Systems 1986 model

22. POSEIDON ODIN distributed by POS DIVE - POSEIDON Systems 1986 model

23. POSEIDON THOR distributed by POS DIVE - POSEIDON Systems 1986 model

24. PRO SUB MAXAIR I

25. PRO SUB PROAIR I

26 SCUBAPRO MK III/High Performance

27. SCUBAPRO MK IX/Air I

28. SCUBAPRO MK IX/Balanced Adjustable

29. SCUBAPRO MK IX/High Performance

30. SCUBAPRO MK X/D 300

31. SCUBAPRO MK X/G-250

32. SCUBAPRO MK X/Adjustable

33. SCUBAPRO MK X/Air I

34. SCUBAPRO MK X/Air II

35. SCUBAPRO MK X/Balance Adjustable

36. SCUBAPRO MK X/High Performance

37. SEA PRO FSDS-10

38. SEA PRO FSDS-50

39. SEA QUEST AMF MARES MR 12 - III

40. SEA SPORT ZEPHER ZR-01

41. SHERWOOD BRUT SRB 2100

42. SHERWOOD MAGNUM BLIZZARD SRB-3200

43. SHERWOOD MAGNUM II SRB-3300

44. SPORTSWAYS X-2

45. SPORTSWAYS X-3

46. TABATA TR-100

47. TEKNA 2100 BX

48. U.S. DIVERS CONSHELF XIV

49. U.S. DIVERS CONSHELF 21

50. U.S. DIVERS CONSHELF SE2

51. U.S. DIVERS PRO DIVER

In view of the excellent historical record of the operational performance of the 1979 superior group regulators, the new Navy requirement of diving no-decompression SCUBA to 190 FSW and dramatic improvements in regulator performance since 1979, it was logical to project the established performance standard to 198 FSW vice 132 FSW as an attainable criteria.

Evaluation data analyzed clearly indicated the existence of a group of regulators that meet the evaluation criteria for work of breathing not to exceed 0.14 Kg·m/ℓ (1.4 j/ℓ) at all depths and RMV up to and including 198 FSW and 62.5 RMV with 1000 psig supply pressure to the first stage regulator.

Other standards of performance, NEDU Report 3-81, reference (c), standard at 132 FSW and the USN Military Specification revised, reference (e), (see Figure 1) were additionally applied to further select the best performing regulators in this significantly large test field.

II. FUNCTIONAL DESCRIPTION OF SCUBA REGULATOR MODELS/SYSTEMS

Basic functional descriptions of SCUBA regulator models and systems, consist of a picture and short narrative description (Figures 2 through 52); input was provided by the manufacture and his on-site representative. Descriptions are provided in Alpha numerical sequence.

NOTE: By circumstance POSEIDON regulators pre 1986 models and 1986 models were provided by two separate distributors. Identifying nomenclature on graph and narratives have been purposely modified to avoid confusion between model years and regulator performance.

III. TEST PROCEDURES

A. General. Regulators were scheduled for testing based on the receipt of units and the availability of manufacturers representatives. A reasonable attempt was made to allow a manufacturers representative to be on site to observe the test set up, regulator calibration and subsequent evaluation of respective models.

All test regulators were calibrated to manufacturers specification, obtained from the manufacturers in advance of testing. Unmanned test equipment systems were set and evaluation conducted in accordance with the NEDU test plan, reference (f). Prior to each days testing and between each individual evaluation of a regulator model the breathing machine and test analysis system undervent calibration check.

Upon completion of testing of all models, six regulators from the group were selected at random for separate evaluations to confirm repeatability of data. These regulators were bench tested and recalibrated as necessary to identical specifications of the original evaluation. From these six regulators, 10 separate and complete breathing resistance evaluations were conducted.

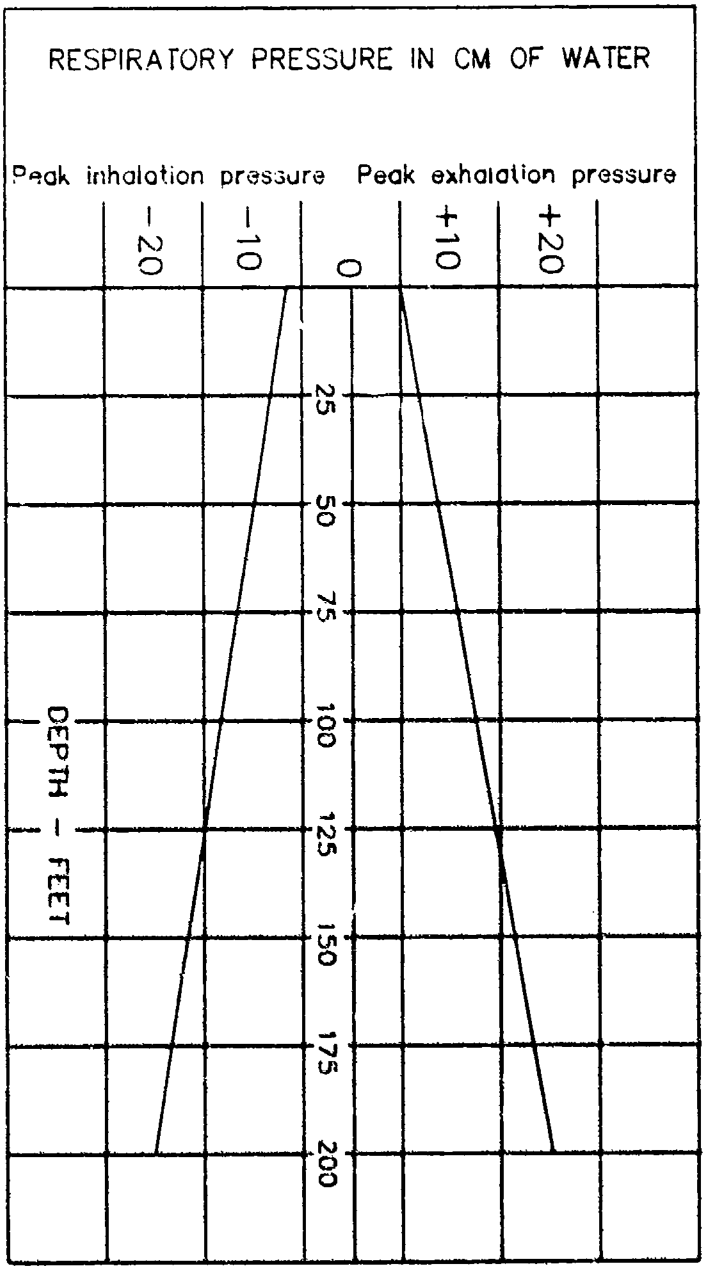


Figure 1 Respiratory Pressure

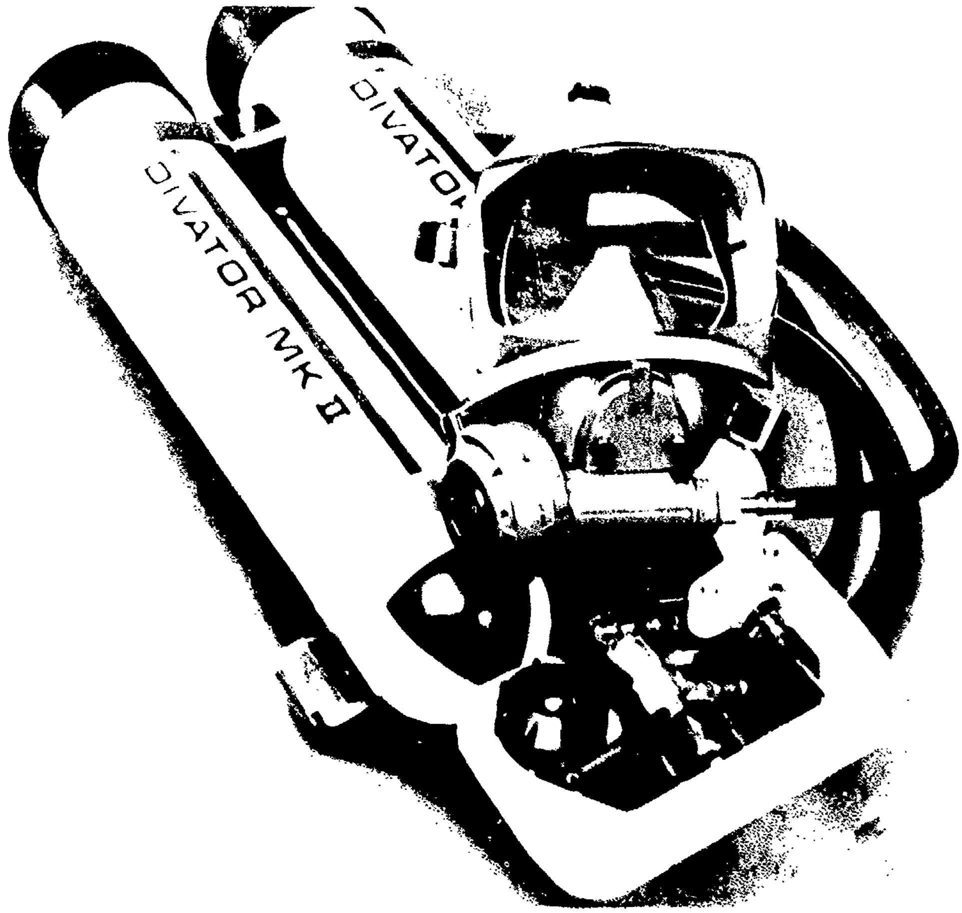


Figure 2. AGA DIVATOR MK II (FULL FACE MASK) COMPLETE WITH AGA CYLINDERS

The AGA DIVATOR II first stage, constructed of chrome plated brass, is a balanced piston regulator that provides three low pressure ports and one high pressure port.

The second stage (breathing valve), balanced pilot type, is made of vestamid and mates to a rubber full face mask. The second stage is designed to maintain a slight positive pressure (2 cm of water column). The positive pressure is automatically actioned when the individual inhales and may be switched off, when not in use, via a lever located on the second stage.

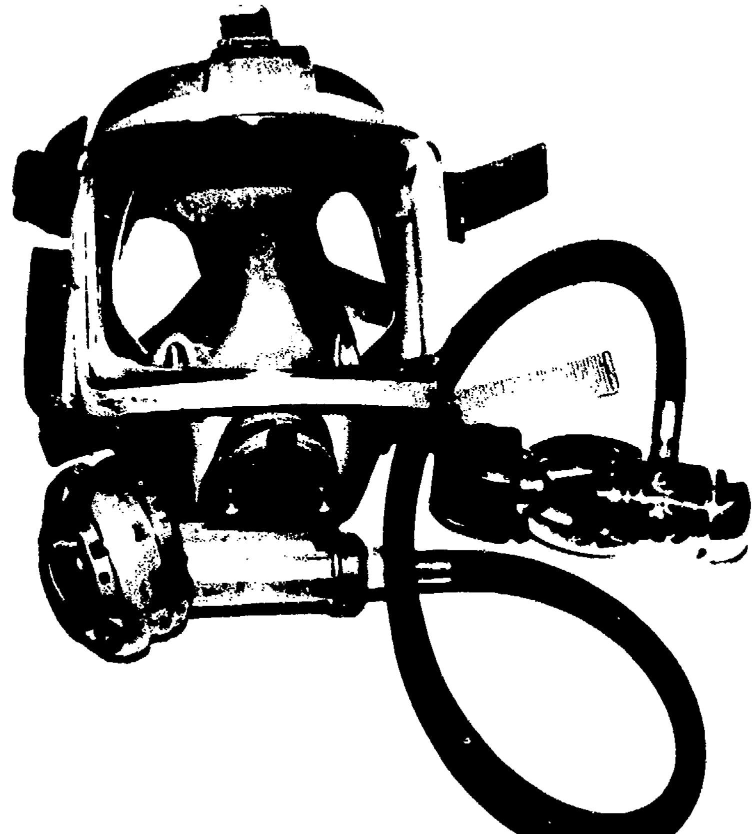


Figure 3. AGA DIVATOR MK II (FULL FACE MASK)/USD CONSHELF XIV FIRST STAGE

The AGA DIVATOR II full face mask with AGA intermediate pressure hose (mates with North American standard thread first stage fittings). The U.S. Divers Conshelf XIV first stage, constructed of chrome plated brass, is a balanced piston regulator that provides three low pressure ports and one high pressure port.

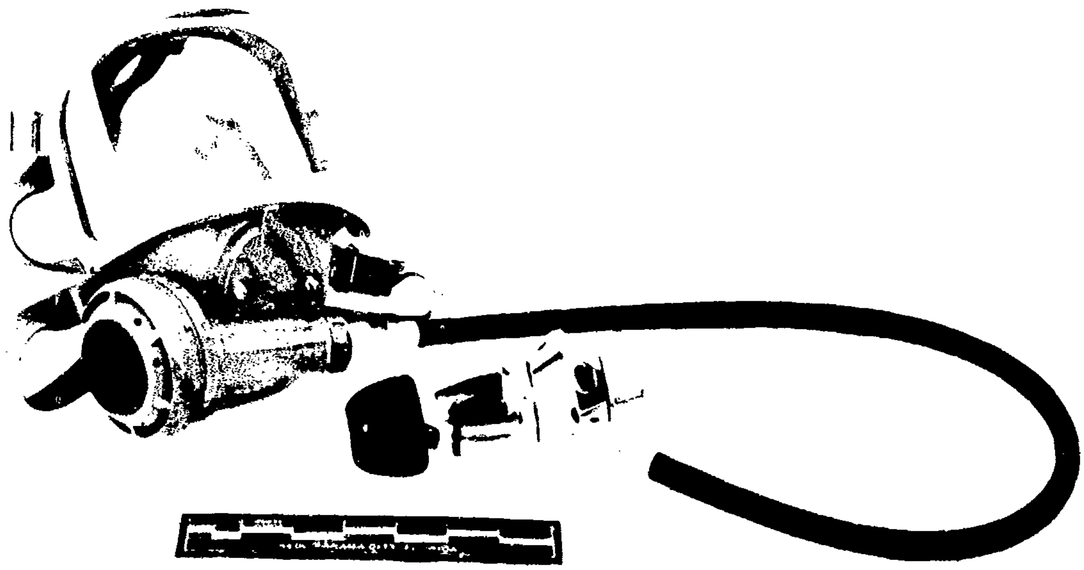


Figure 4. AGA DIVATOR MK II (FULL FACE MASK)/USD ROYAL SL FIRST STAGE

The AGA DIVATOR MK II FFM with AGA intermediate pressure hose for mating with standard thread first stage fittings. The U.S. Divers Royal SL first stage, constructed of chrome plated brass, is a balanced piston regulator that provides four low pressure ports and one high pressure port.

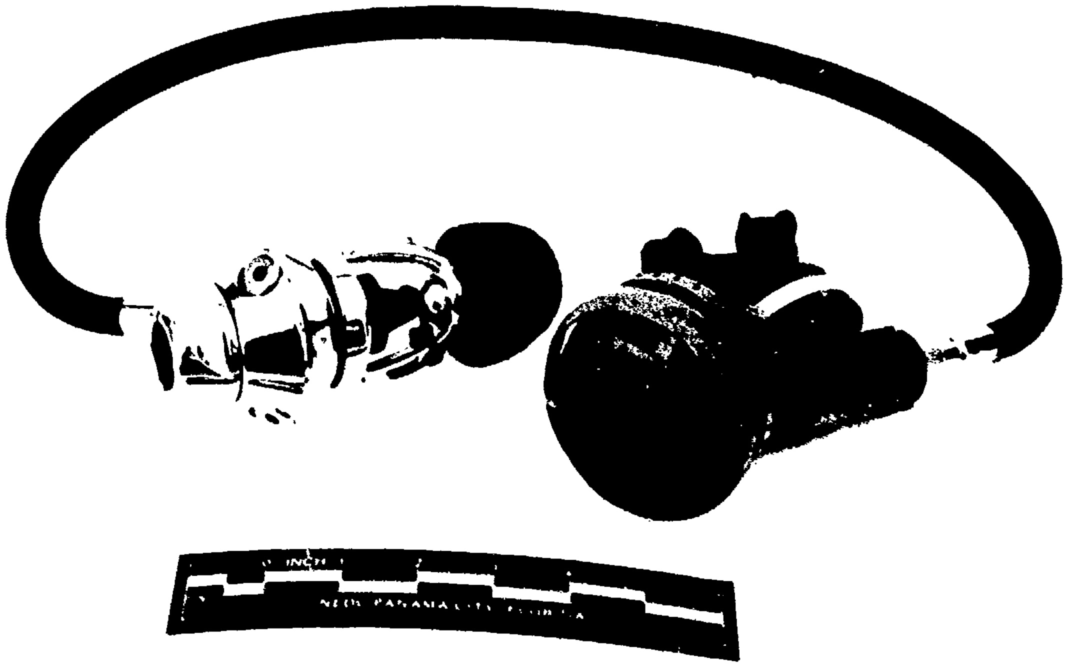


Figure 5. AGA DIVATOR MK II BREATHING VALVE WITH AGA MOUTHPIECE/USD ROYAL SL FIRST STAGE

The AGA DIVATOR MK II breathing valve adapted with AGA mouthpiece vice full face mask utilizes the AGA intermediate pressure hose for mating to standard thread first stage fittings, combined with the U.S. Divers Royal SL first stage. The MK II breathing valve utilized was the same as that tested with the full face mask providing positive pressure on inhalation. AGA additionally manufactures a non-positive pressure breathing valve.

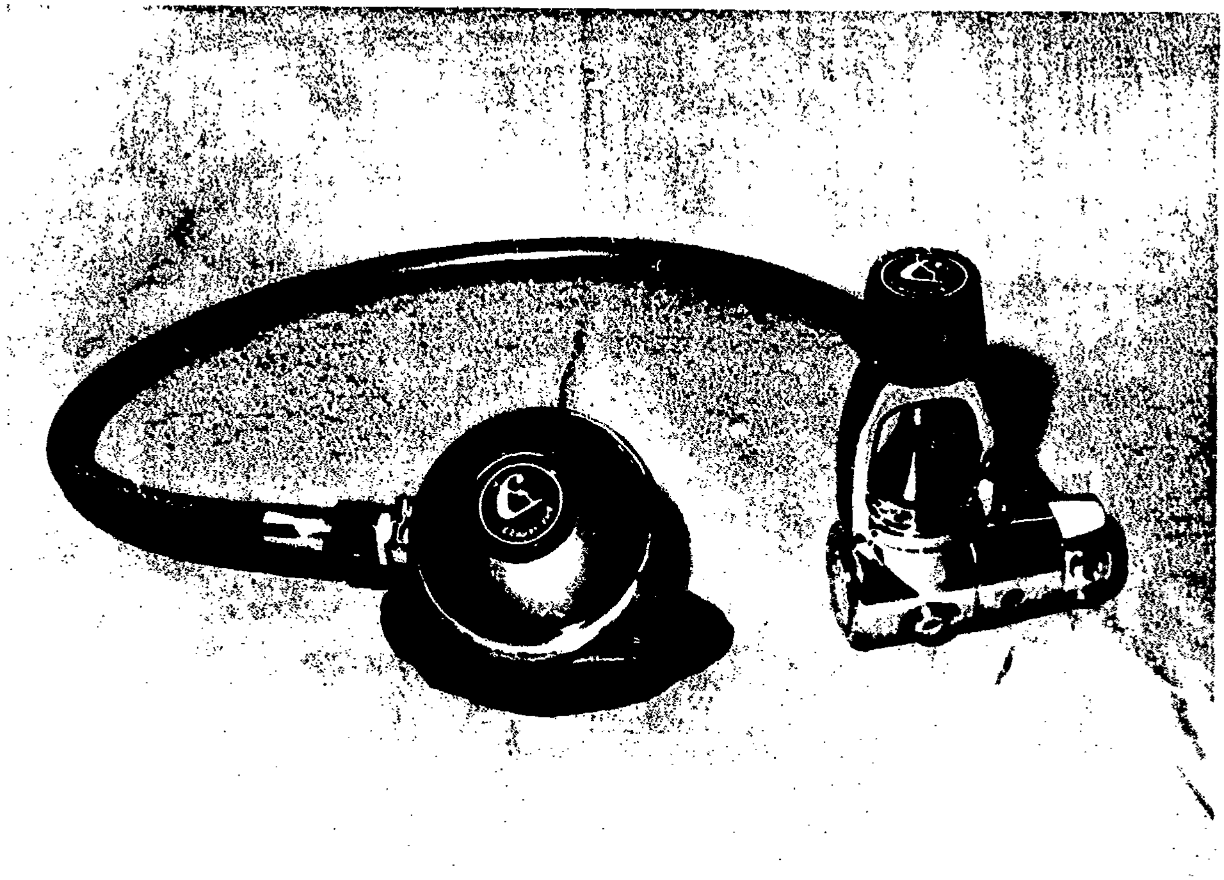


Figure 6. CRESSI-SUB GALAXIE 105

The CRESSI-SUB GALAXIE 105 first stage, constructed of chrome plated brass, is a balanced piston regulator that features three low pressure ports and one high pressure port.

The second stage, constructed of chrome plated brass and AbS plastic, utilizes a Venturi assist.

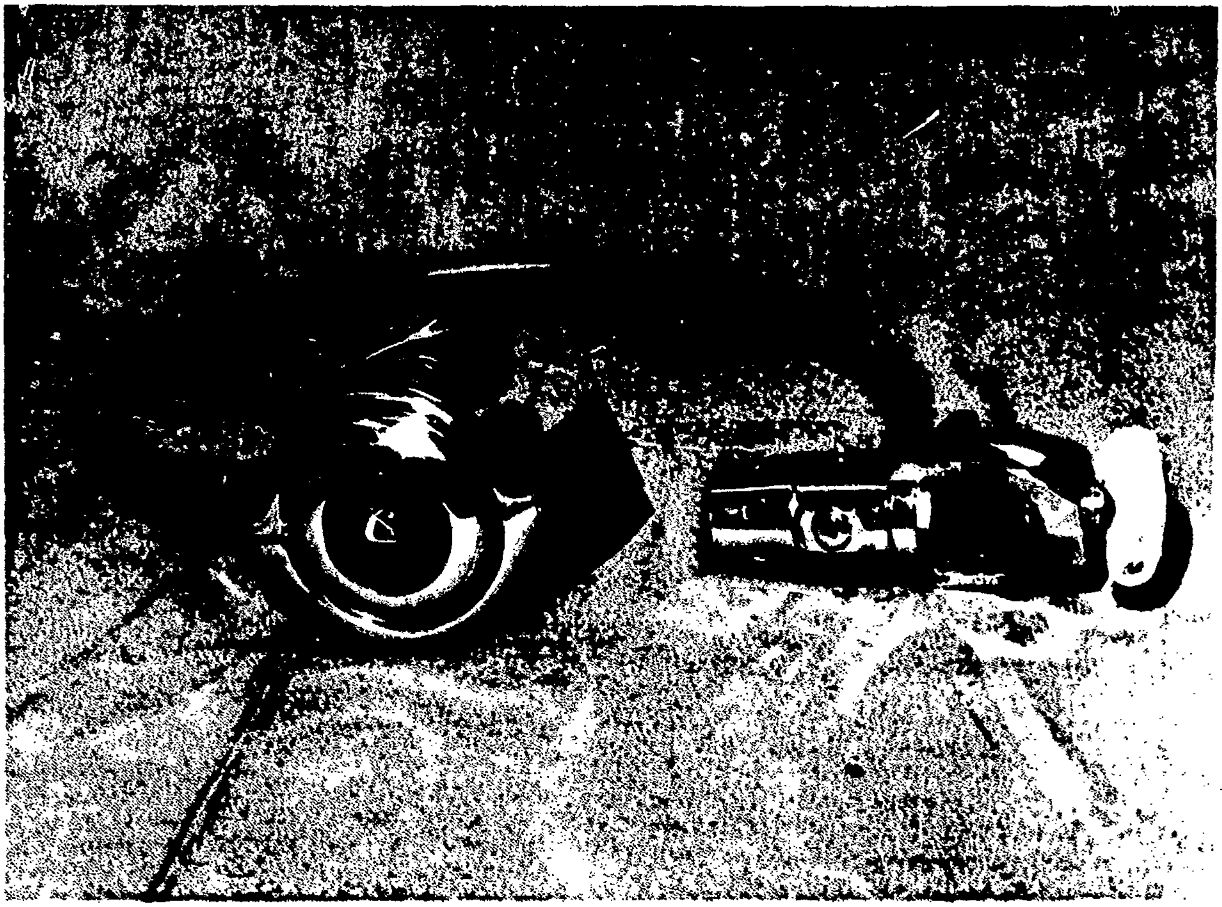


Figure 7. CRESSI-SUB POLARIS IV

The CRESSI-SUB POLARIS IV first stage, constructed of chrome plated brass, is a unbalanced piston regulator that provides three low pressure ports and one high pressure port.

The second stage, constructed of chrome plated brass, utilizes a Vortex assist.

Figure 8. DACOR PACER AERO 950A

The DACOR PACER AERO 950A first stage, constructed of chrome plated brass, is a balanced diaphragm regulator that provides four low pressure ports located on the swivel and two high pressure ports located on the main body. Regulator can be adapted to DIN regulator/tank valve connection.

The second stage, constructed of valox plastic, utilizes a Venturi assist and double exhaust valves.

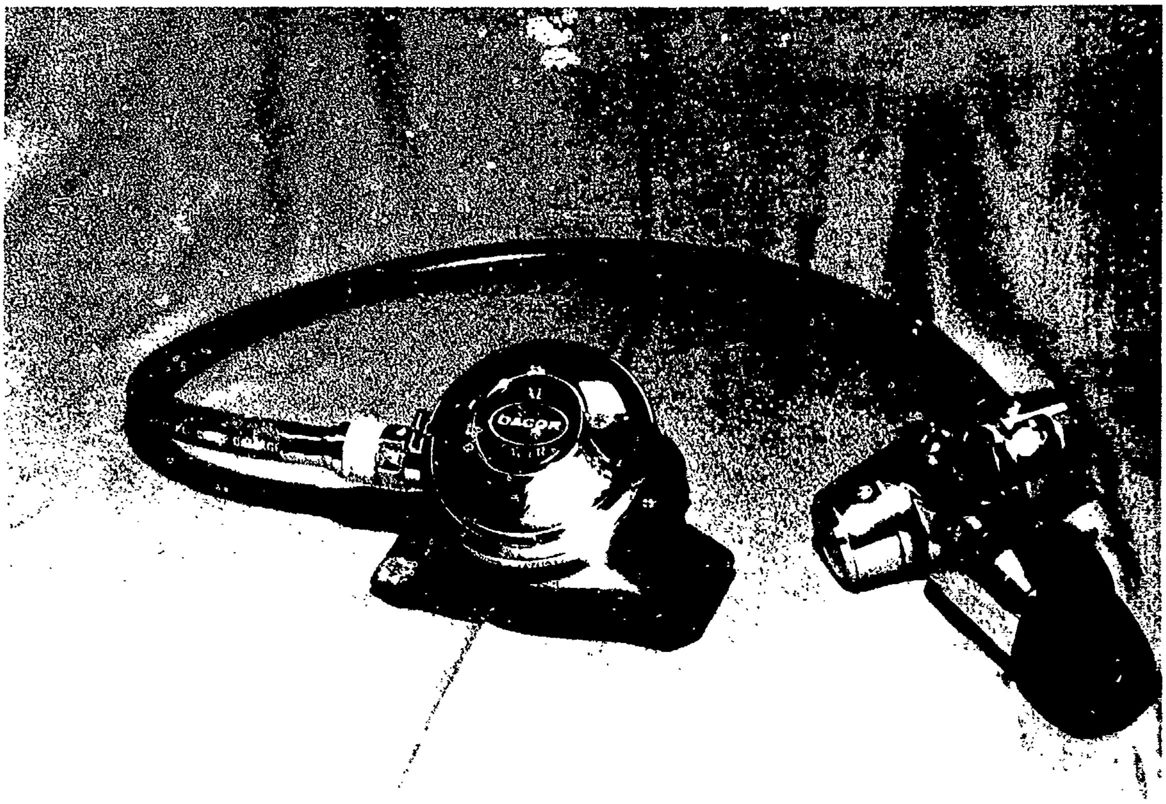
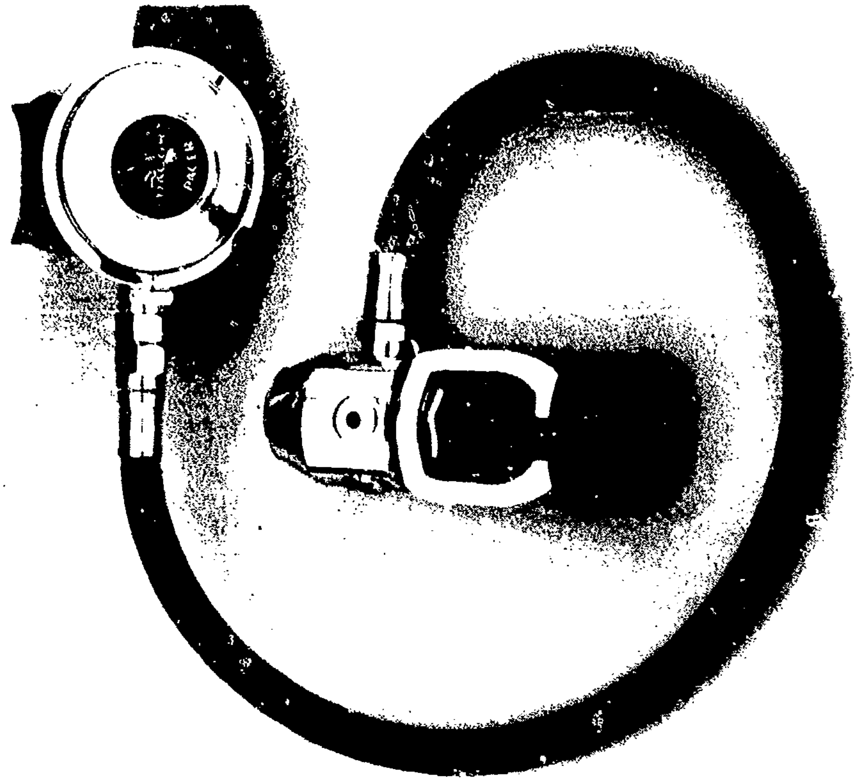


Figure 9. DACOR PACER XL950

The DACOR PACER XL950 first stage, constructed of chrome plated brass, is a balanced diaphragm regulator that provides four low pressure on the swivel and two high pressure ports located on the main body. Regulator can be adapted to DIN regulator/tank valve connection.

The second stage, constructed of chrome plated brass, utilizes a Venturi assist and double exhaust valves. The unit is also provided with an external fine adjustment.



[illegible] PACER [illegible]

[illegible] plated brass, in [illegible] provides three [illegible] ports and one [illegible]

Figure 11. INTERNATIONAL DIVERS, INC. (IDI) STAR II

The IDI STAR II first stage, constructed of chrome plated brass, is a balanced flow through piston regulator that provides four low pressure ports, one large bore low pressure port (not utilized in this configuration) and two high pressure ports.

The second stage, constructed of chrome plated brass and compound rubber, operates via a Vortex assist. Additionally, the exhaust valve operates with a counter weight for use in an inverted position to combat water leakage.

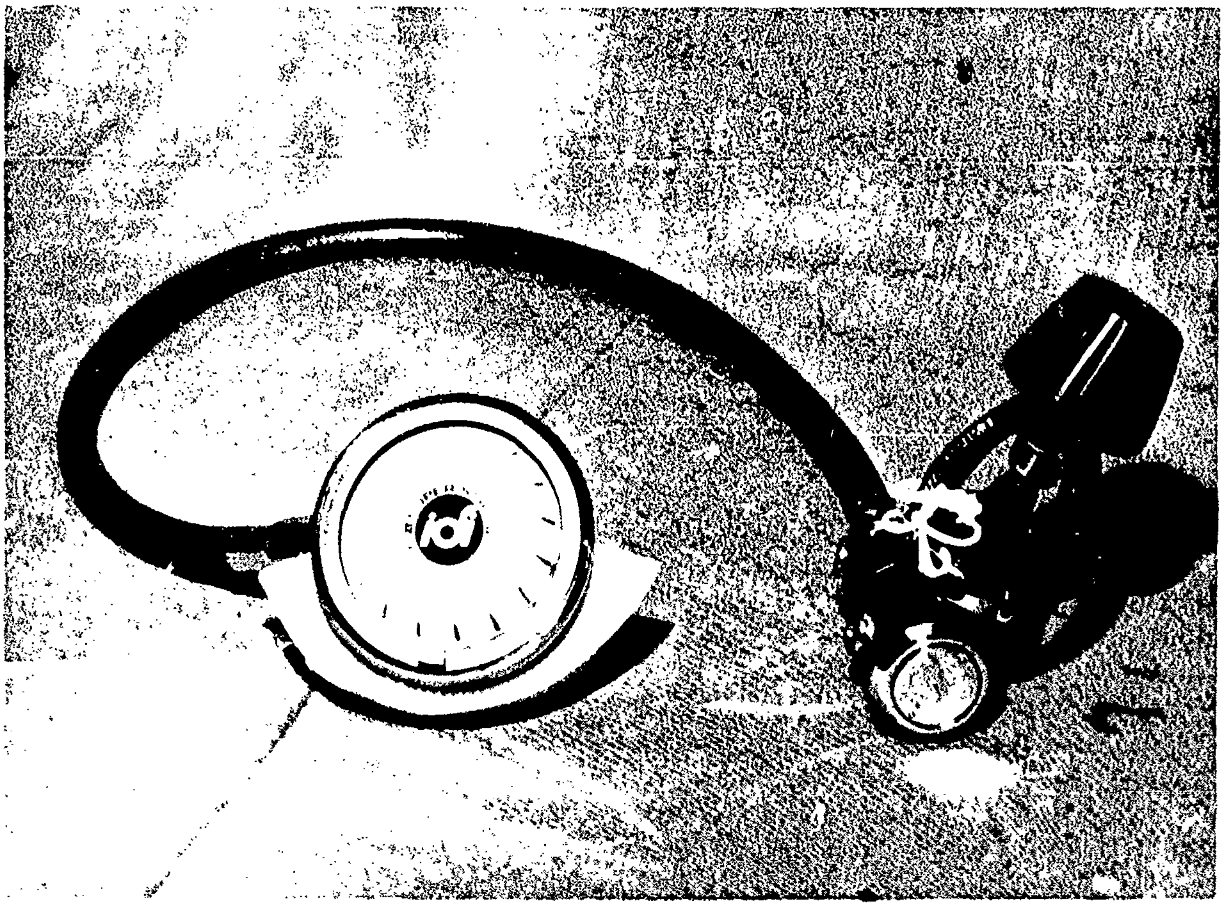


Figure 12. INTERNATIONAL DIVERS, INC. (IDI) SUPER STAR II

The IDI SUPER STAR II first stage is the same as that used by the IDI STAR II with the exception that the one large bore low pressure port is utilized along with a larger bore intermediate pressure hose.

The second stage is slightly modified from the STAR II. It contains an internal aspirator tube for smooth air injection and silicone rubber parts.

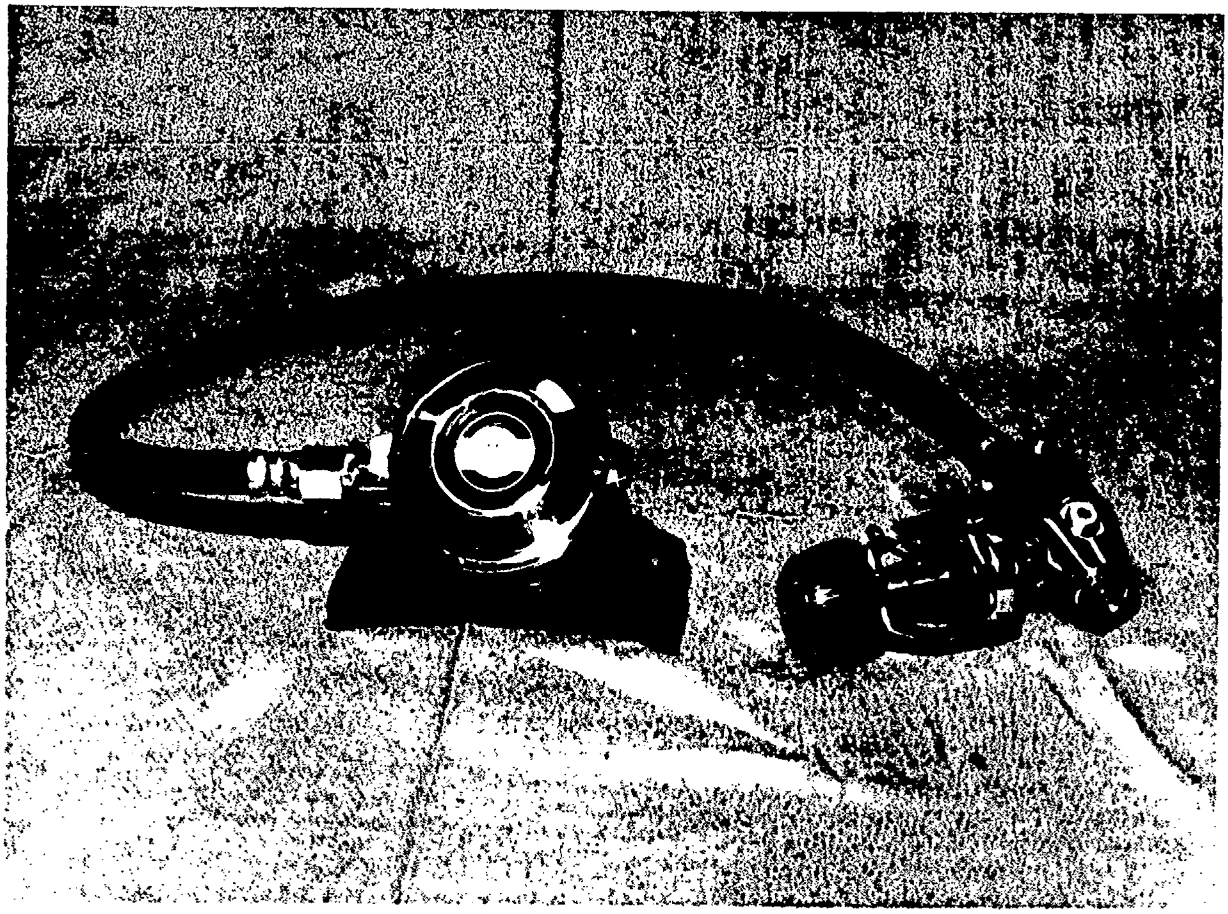


Figure 13. NEMROD SATURN 300

The NEMROD SATURN 300 first stage, constructed of chrome plated brass, is a balanced flow through piston regulator that is teflon coated for cold water environmental protection. It provides five low pressure ports and one high pressure port.

The second stage, constructed of chrome plated brass, utilizes a conventional downstream demand valve with Venturi assist. Rubber components are made of ozone and ultraviolet resistance rubber. Silicone rubber is used for the mouthpiece and exhaust valve.

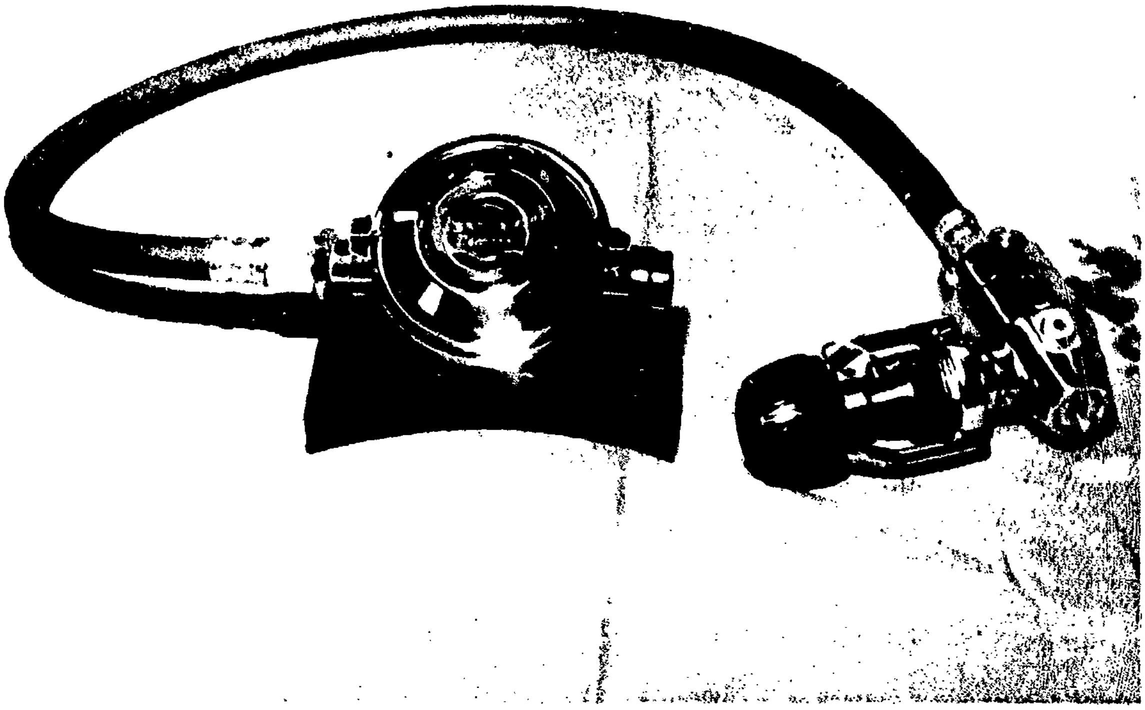


Figure [illegible]. NEMROD SATURN 300 PRO

The NEMROD [illegible] first stage and second stages are the same configuration as the Saturn [illegible] with the exception that second stage [illegible] adjust for inhalation resistance.

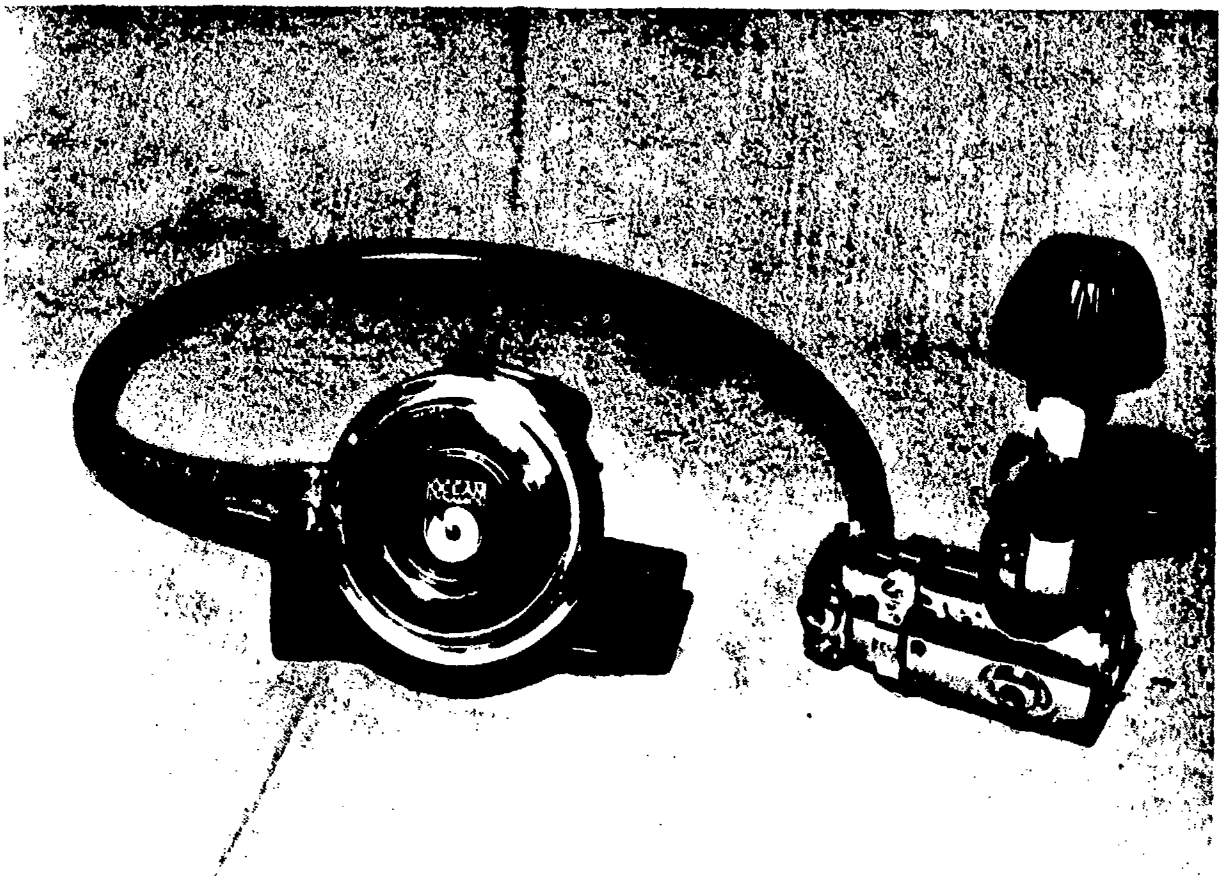


Figure 15. OCEAN DYNAMICS RB-3000

The OCEAN DYNAMICS RB-3000 first stage, constructed of chrome plated brass, is a balanced piston regulator that provides four low pressure ports and two high pressure ports. The yoke assembly is rated at 4,000 psi.

The second stage, constructed of chrome plated brass and ABS plastic, utilizes a Venturi assist.

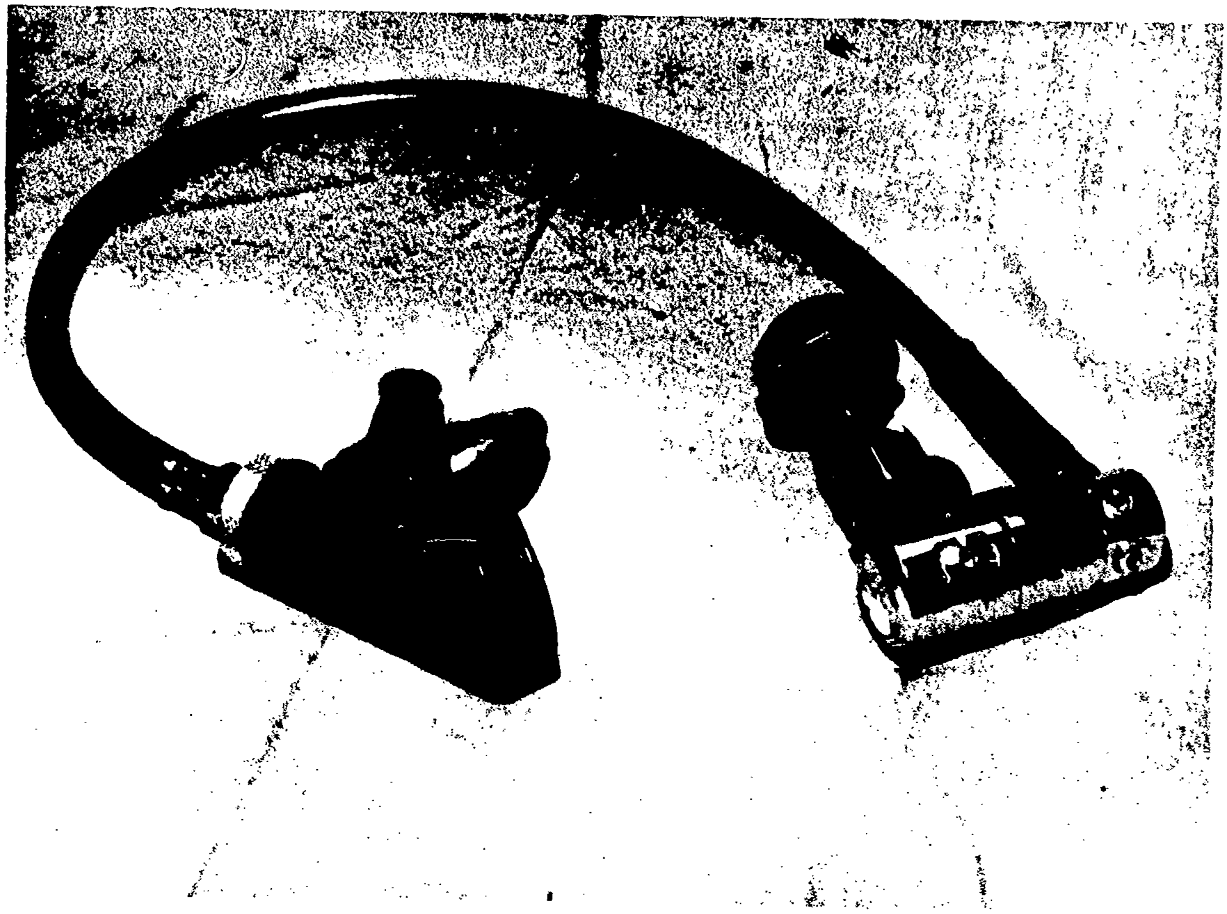


Figure 16. OCEANIC OMEGA II

The OCEANIC OMEGA II first stage, constructed of triple chrome plated brass, is a balanced piston regulator that provides five low pressure ports and two high pressure ports.

The second stage, constructed of noryl plastic utilizes a pilot (servo-controlled valve) assist.

Figure 17. OCEANIC OMEGA II MAXFLO

The OCEANIC OMEGA II MAXFLO first stage is the same as that of the OMEGA II, except that the fifth low pressure port (large bore) and a large bore intermediate pressure hose are utilized.

The second stage remains the same as the OMEGA II.

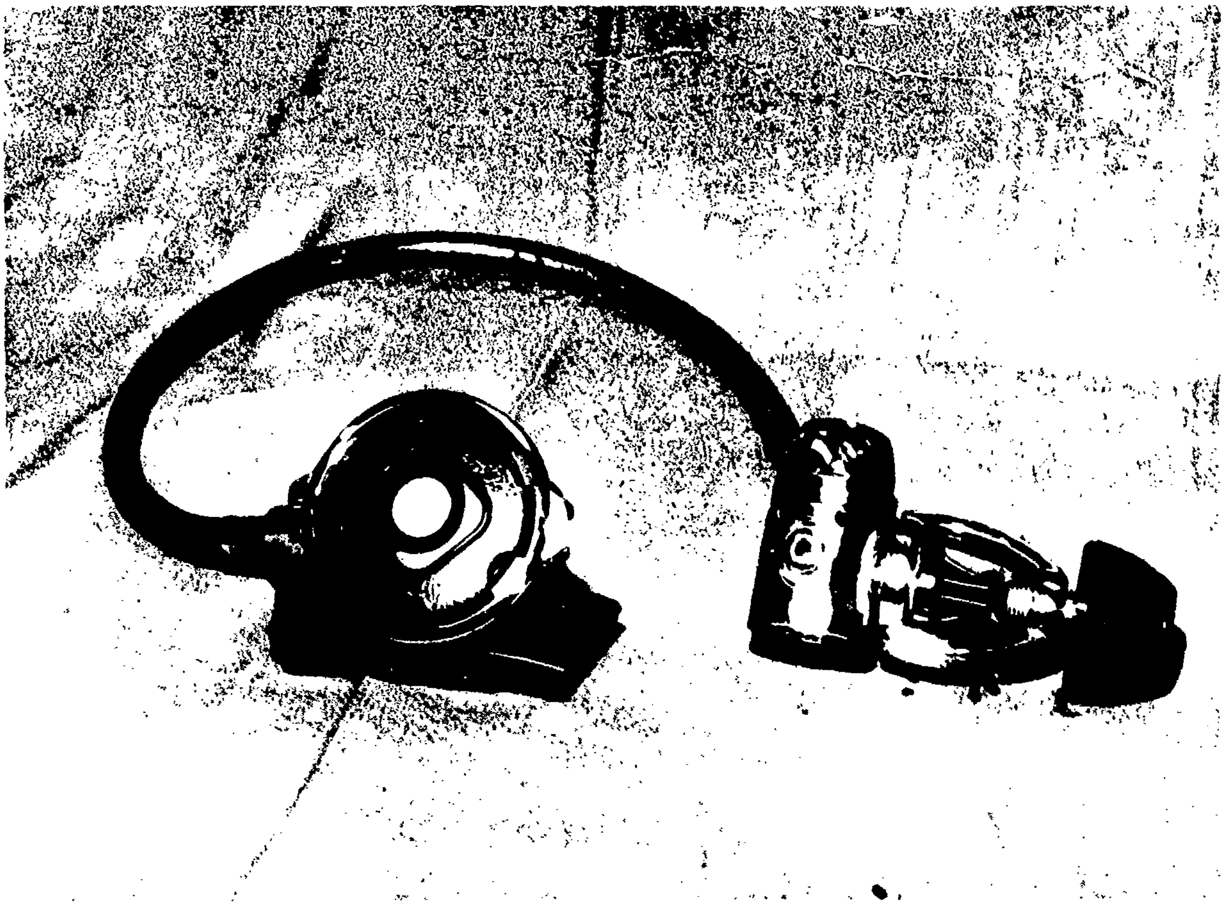


Figure 18. PARKWAYS ATLAS

The PARKWAYS ATLAS first stage, constructed of chrome plated brass, is a balanced flow through piston regulator that provides four low pressure ports and two high pressure ports.

The second stage, constructed of cycolac, utilizes a downstream piston and Vortex assist.

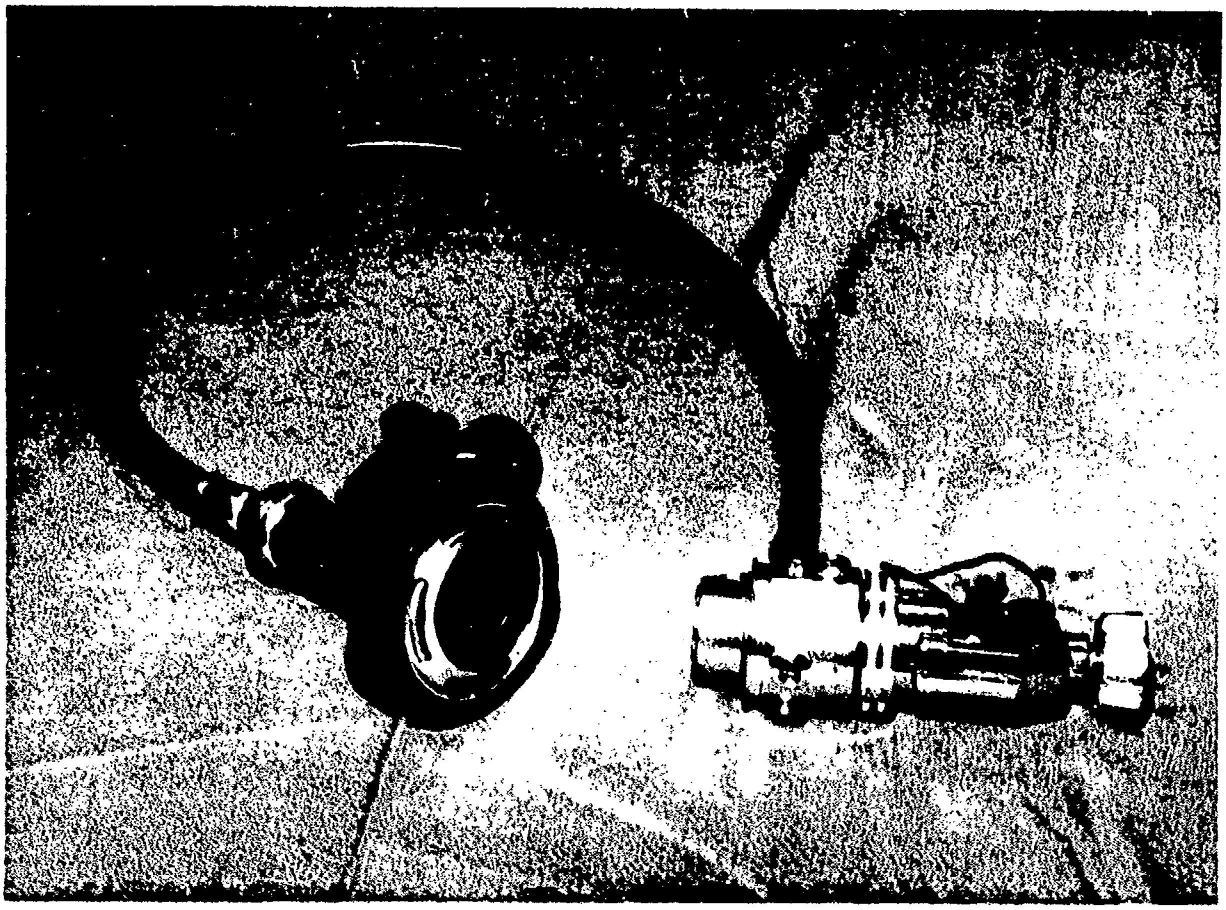


Figure 19. CYKLON 300
(DISTRIBUTED BY PARKWAYS AND MANUFACTURED BY POSEIDON)

The CYKLON 300 first stage, constructed of chrome plated brass, is a unbalanced diaphragm regulator that provides three low pressure ports and one high pressure port. The first stage rated to 4,267 psi is adaptable to U.S./European tanks.

The second stage, constructed of chrome brass utilizes an ejector (for air flow direction) assist.

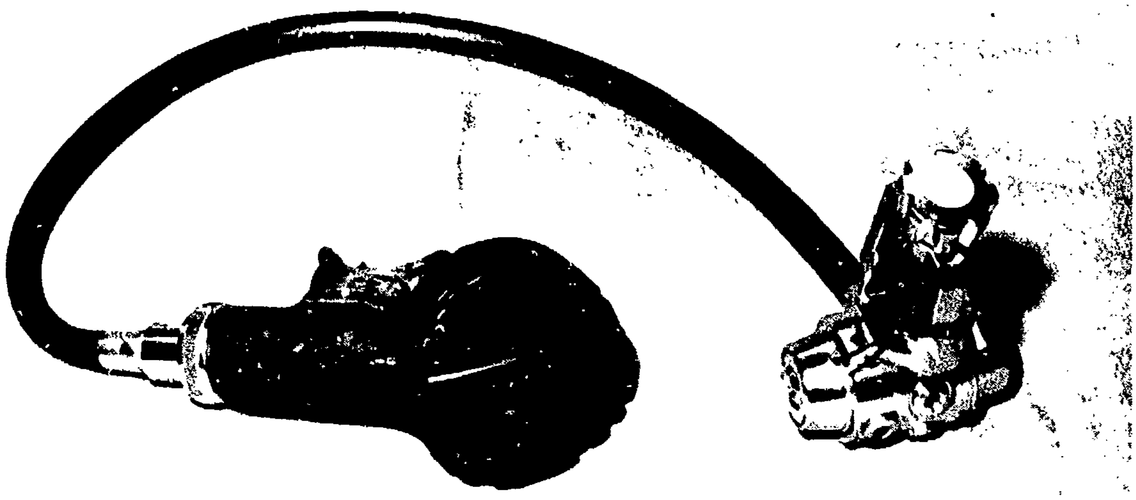


Figure 20. CYKLON MAXIMUM II
(DISTRIBUTED BY PARKWAYS AND MANUFACTURED BY POSEIDON)

The CYKLON MAXIMUM II first stage, constructed of chrome plated brass, is a balanced diaphragm regulator that provides four low pressure ports and one high pressure port. The first stage rated to 4,300 psi is adaptable to U.S./European tanks.

The second stage, constructed from cycolac, utilizes a pilot assist. It also features a +- switch for diver control over the second stage diaphragm (diving/non diving position).

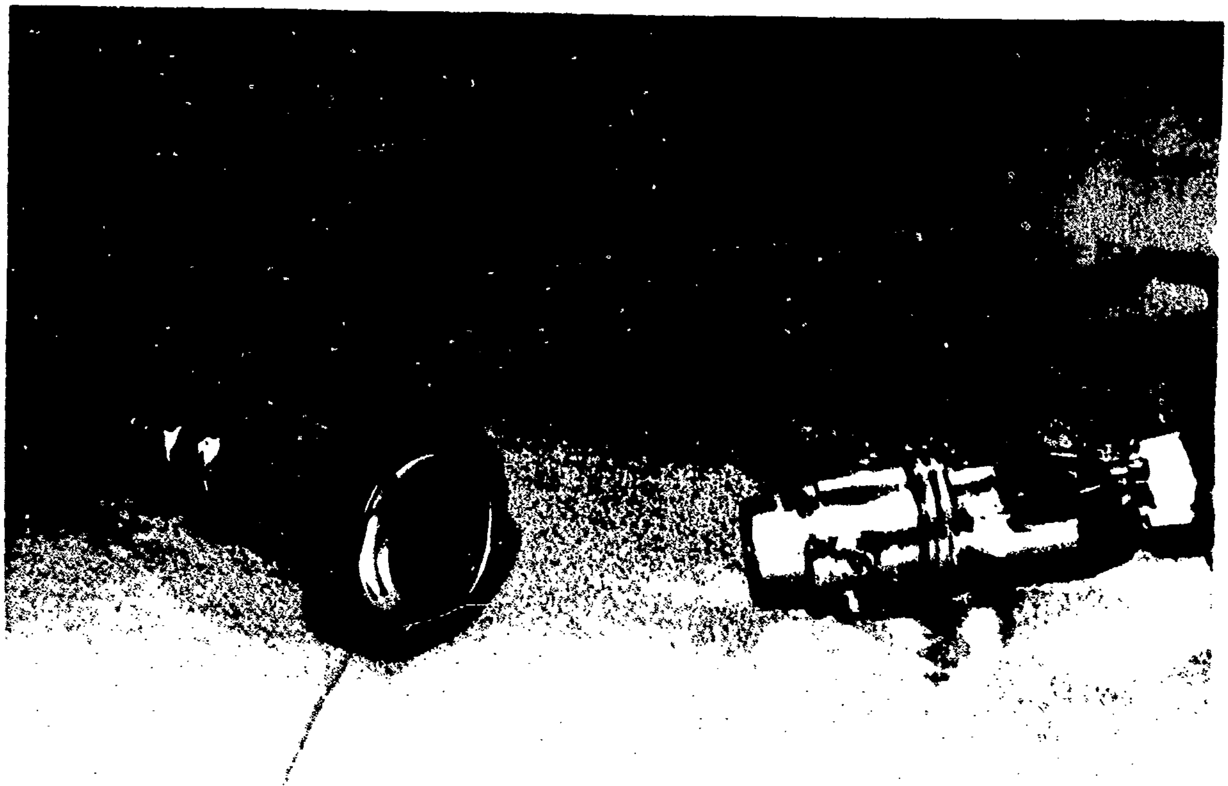


Figure 21. POSEIDON CYKLON 300
(DISTRIBUTED BY POSDIVE)

The POSEIDON CYKLON 300 first stage, constructed of chrome plated brass, is an unbalanced diaphragm regulator that provides three pressure ports and one high pressure port. The First stage, equipped with a newly designed first stage teflon valve seat is rated at 4,400 psi and is adaptable to U.S./European tanks.

The second stage, constructed of chrome plated brass, utilizes a ejector assist, and is equipped with new silicone inhalation and exhalation diaphragms.

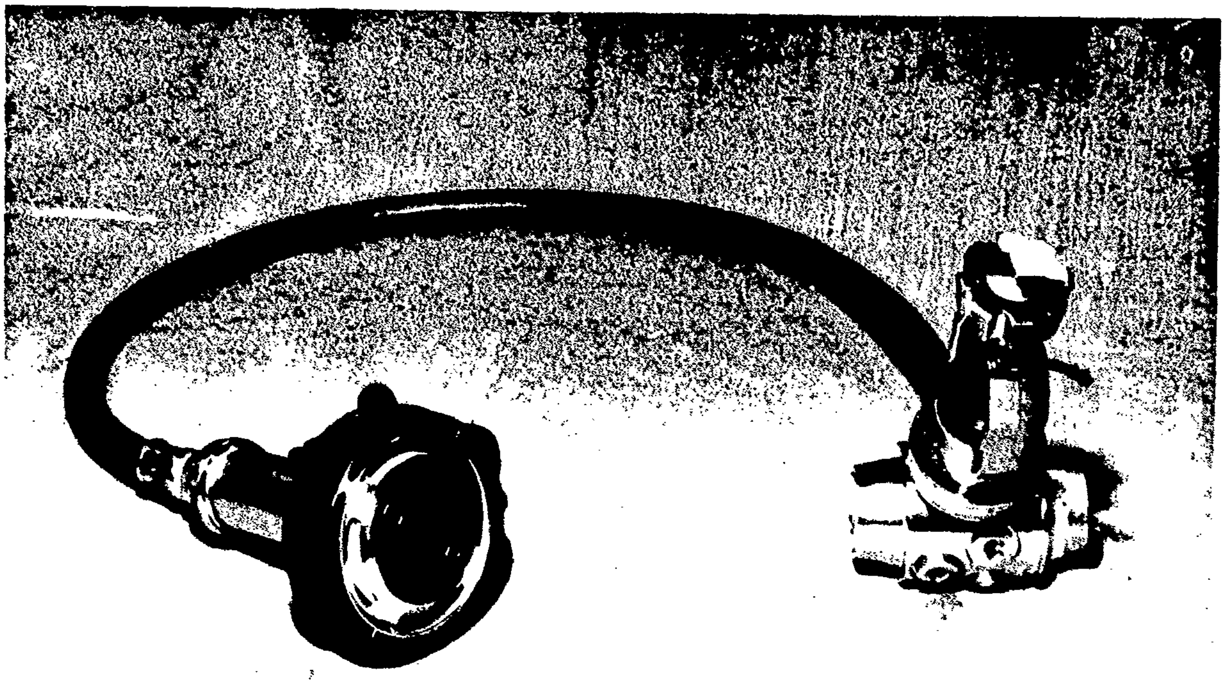


Figure 22. POSEIDON CYKLON 5000
(DISTRIBUTED BY POSDIVE)

The POSEIDON CYKLON 5000 first stage, constructed of chrome plated brass, is a balanced diaphragm regulator that provides four low pressure ports and one high pressure port. The first stage equipped with newly designed first stage teflon valve seat and heavier duty diaphragm spring is rated to 4,400 psi and is adaptable to U.S./European tanks.

The second stage is the same as the Poseidon CYKLON 300.

Figure 23. POSEIDON ODIN
(DISTRIBUTED BY POSDIVE)

The POSEIDON ODIN first stage is the same as the POSEIDON CYKLON 5000.

The second stage, constructed of cyclolac, utilizes a balanced (upstream/downstream) servo assist and is equipped with a new combined silicon inhalation-exhalation diaphragm, new silicon mouthpiece and stainless steel retainer clamp. The second stage also incorporates a "desensitizing" switch employed for "safety second" and buddy breathing.

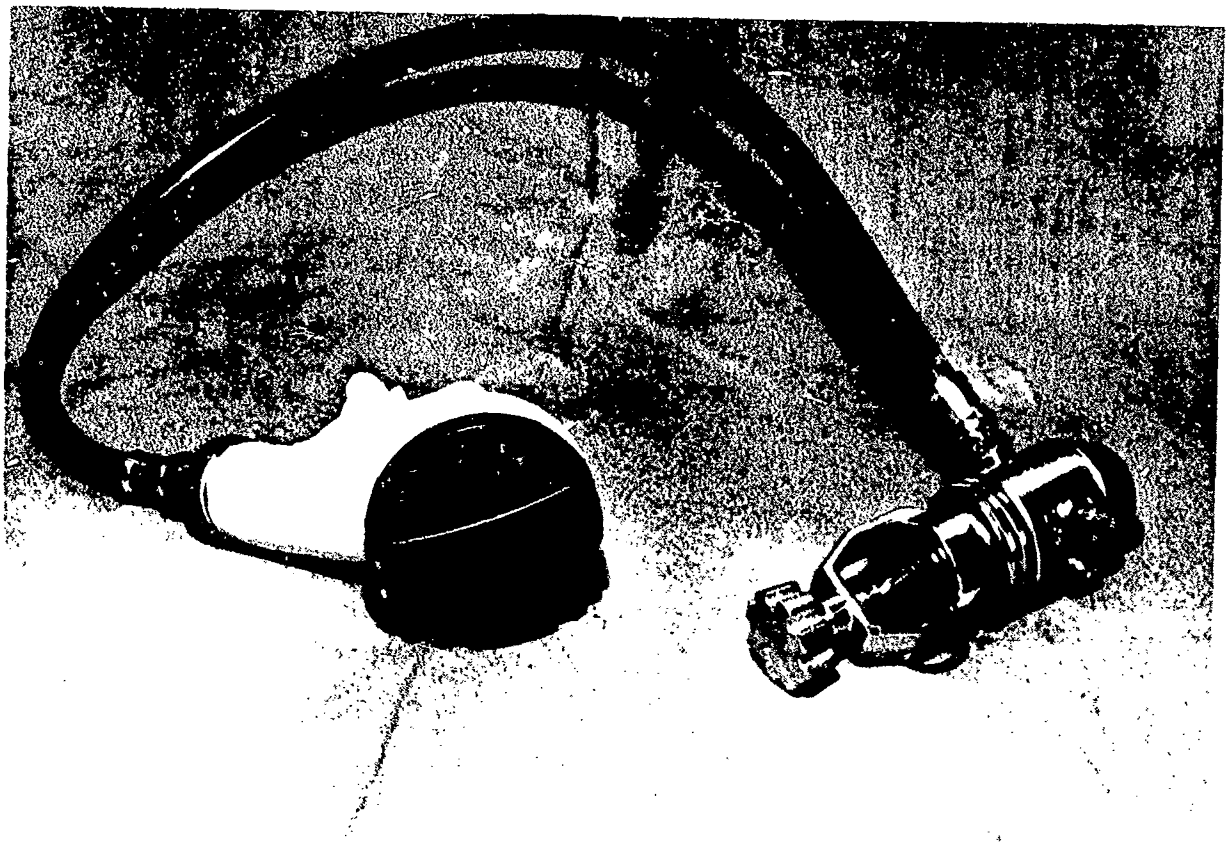


Figure 24. POSEIDON THOR
(DISTRIBUTED BY POSDIVE)

The POSEIDON THOR first stage is the same as the CYKLON 300.

The second stage is the same as the POSEIDON ODIN.

Figure 25. PRO SUB MAXAIR I

The PRO SUB MAXAIR I first stage, constructed of chrome plated brass, is a balanced piston regulator that provides four low pressure ports, two high pressure ports (7/16" thread), a 360° swivel yoke and 360° swivel low pressure manifold head.

The second stage, constructed plated brass and delrin plastic, is a balanced system that utilizes a Venturi assist. The inlet hose swivel can also be rotated away from the diving position to a safety restricted position which eliminates free flow during water entry or other unattended occasions.

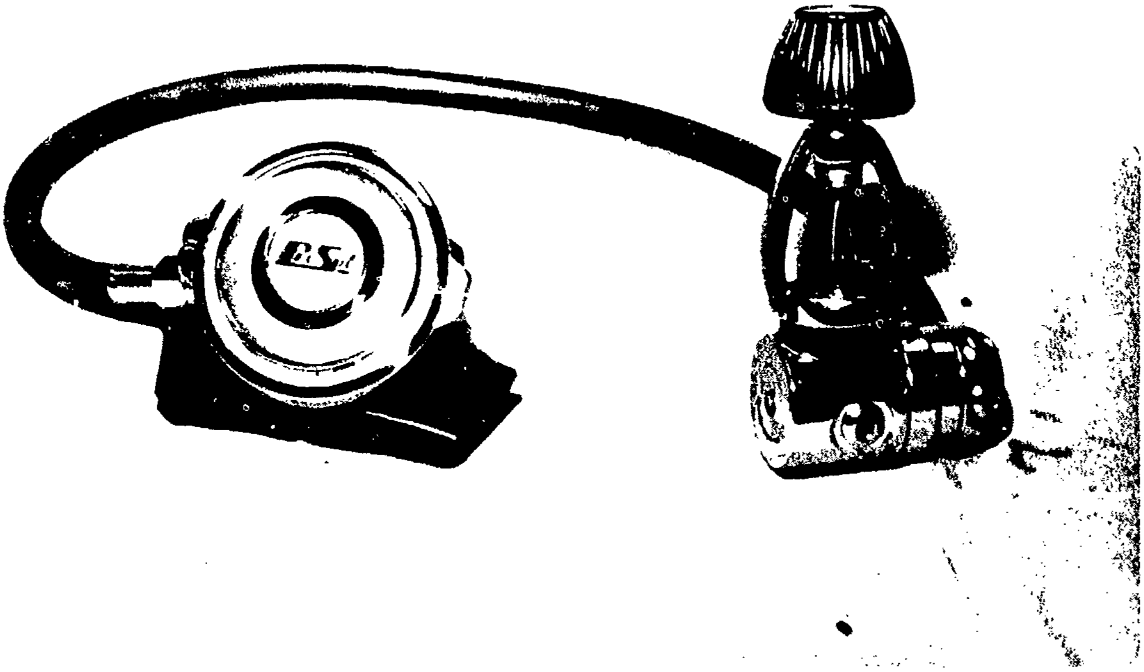


Figure 26. PRO SUB PROAIR I

The PRO SUB PROAIR I first stage, is the same as that used on the PRO SUB MAXAIR I.

The second stage, constructed of chrome plated brass and plastic, utilizes a standard down stream valve with Venturi assist.

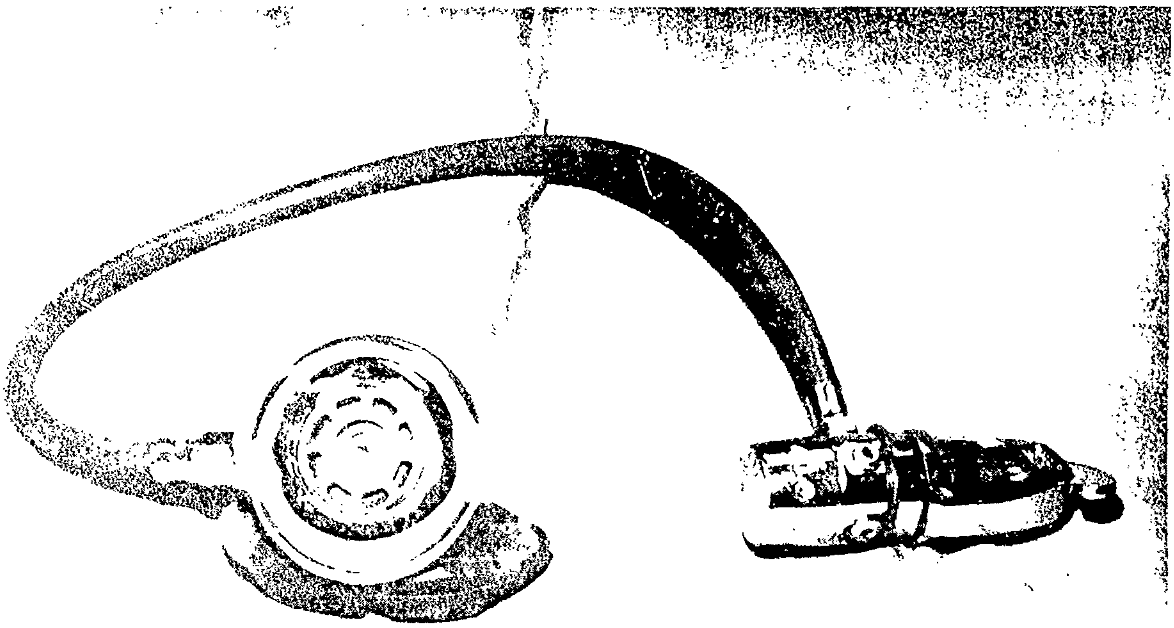


Figure 27. SCUBAPRO MK III HIGH PERFORMANCE

[illegible] first stage, constructed of chrome plated brass, is a [illegible] regulator that provides three low pressure ports, one high [illegible] port, and [illegible] silicon protection environmental cap.

[illegible] High Performance), constructed of chrome [illegible] newly redesigned downstream valve (poppet and lever) [illegible].

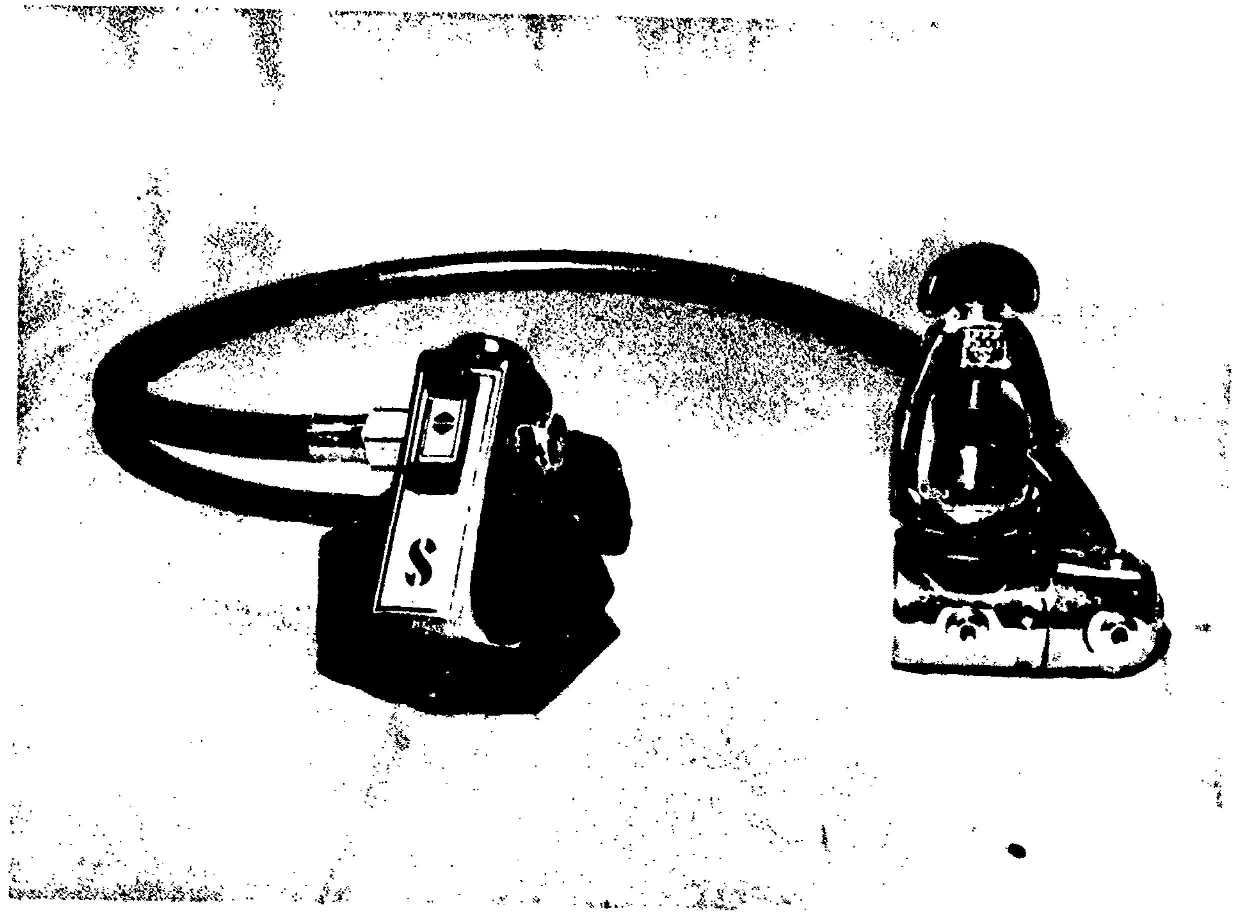


Figure 28. SCUBAPRO MK IX/AIR I

The SCUBAPRO MK IX first stage, constructed of chrome plated brass, is a balanced piston regulator that provides five low pressure ports (in stationary head), two high pressure ports and standard silicon protection environmental cap.

The second stage (SCUBAPRO's AIR I), constructed of fiberglass filled polyester, utilizes a balanced coaxial flow demand valve with Venturi assist. Additionally it provides a dive predive switch.

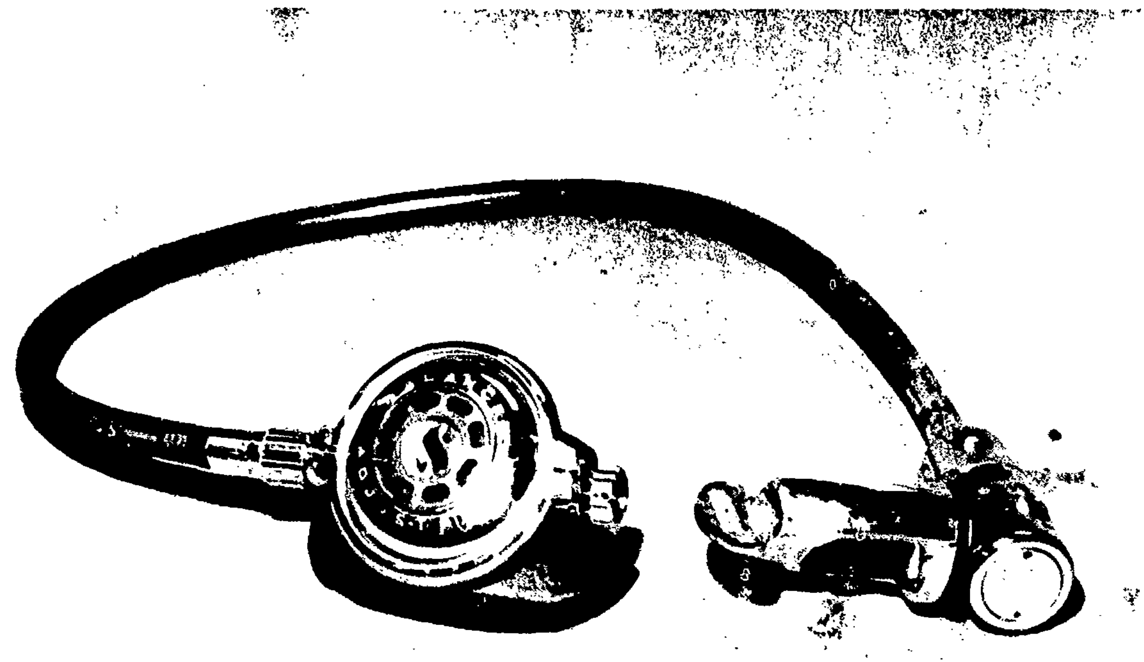


Figure 29. SCUBAPRO MK IX/BALANCED ADJUSTABLE

The SCUBAPRO MK IX/Balanced Adjustable utilizes the MK IX first stage. The second stage "balanced adjustable", constructed of chrome plated brass is a balanced downstream poppet valve system which operates with moderate Venturi assist. Additionally, a diver's adjust for inhalation resistance is provided.

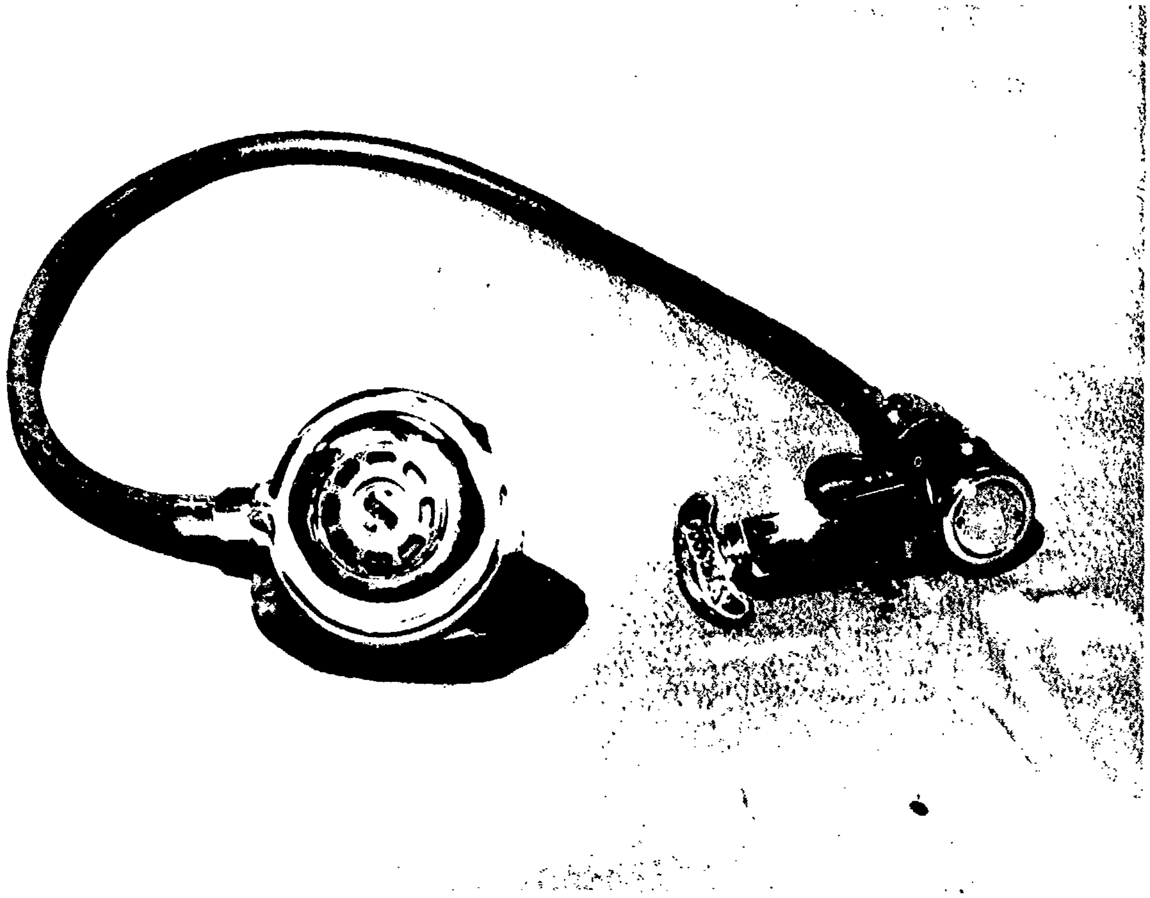


Figure 30. SCUBAPRO MK IX/HIGH PERFORMANCE

The SCUBAPRO MK IX/High Performance utilizes SCUBAPRO's MK IX first stage and high performance second stage.

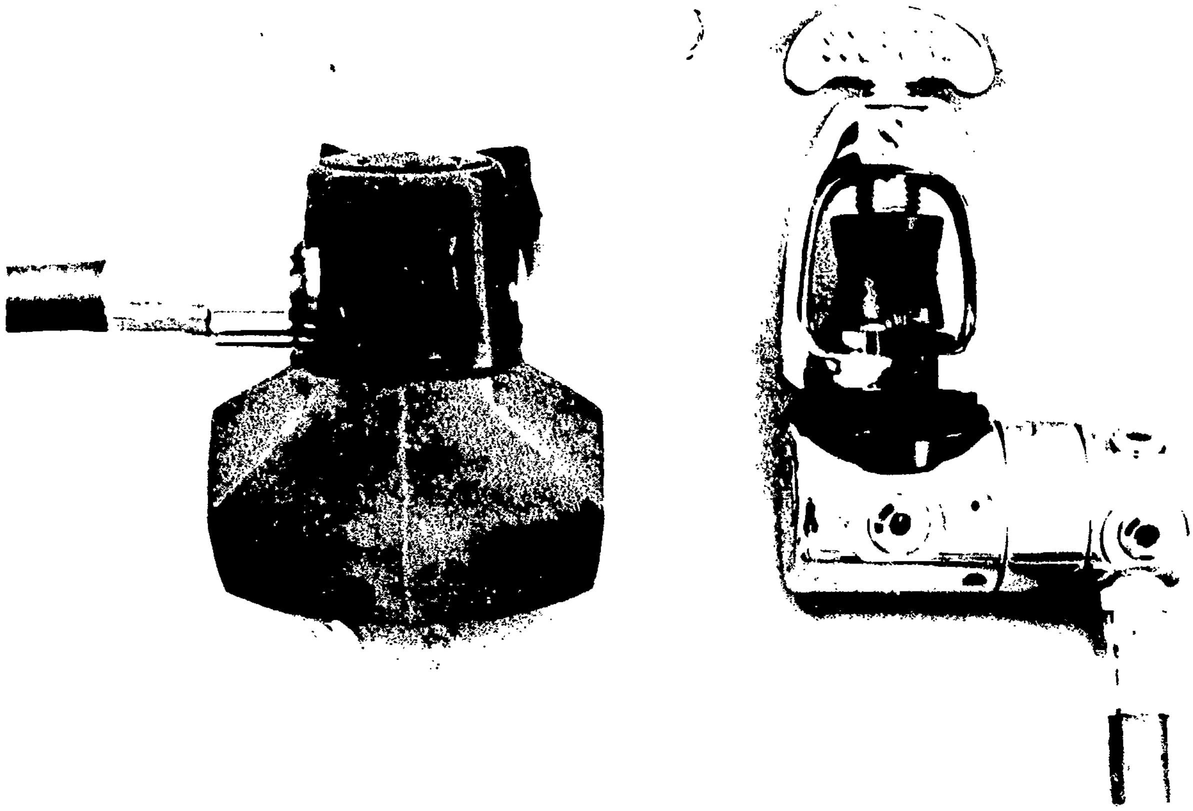


Figure 31. SCUBAPRO MK X/D300

The SCUBAPRO MK X first stage, constructed of chrome plated brass, is a balanced piston regulator that provides five low pressure ports on a 360° swiveling manifold head, two high pressure ports and standard silicon protection environmental cap.

The second stage (SCUBAPRO's D300) is a newly design version of the AIR I, having the same functional mechanisms as the AIR I but is lighter and has higher flow capacity.

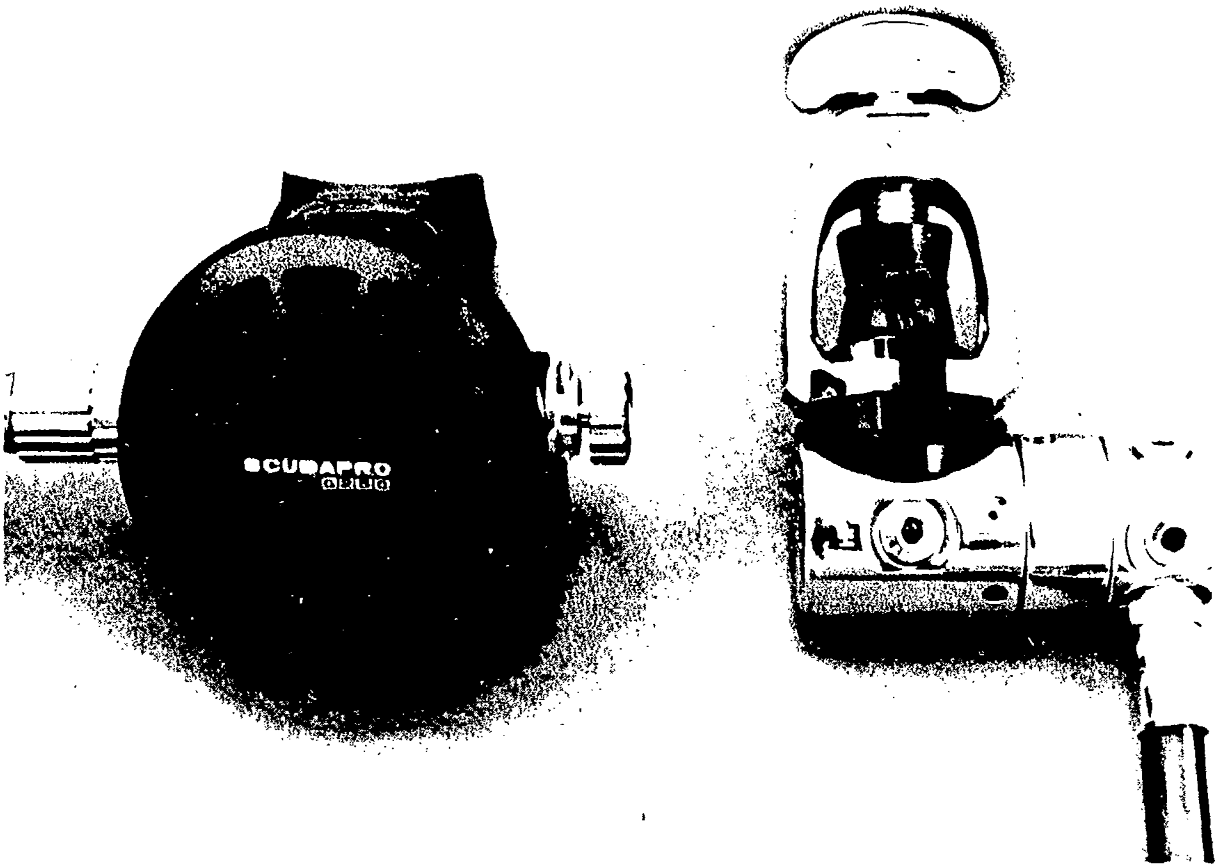


Figure 32. SCUBAPRO MK X/G250

The SCUBAPRO MK X/G250 utilizes the MK X first stage. The second stage (SCUBAPRO's G250), constructed of graphite reinforced nylon, is a pneumatically balanced poppet valve system that utilizes Venturi assist and flow vain. Additionally, a diver's adjust for inhalation resistance is provided.

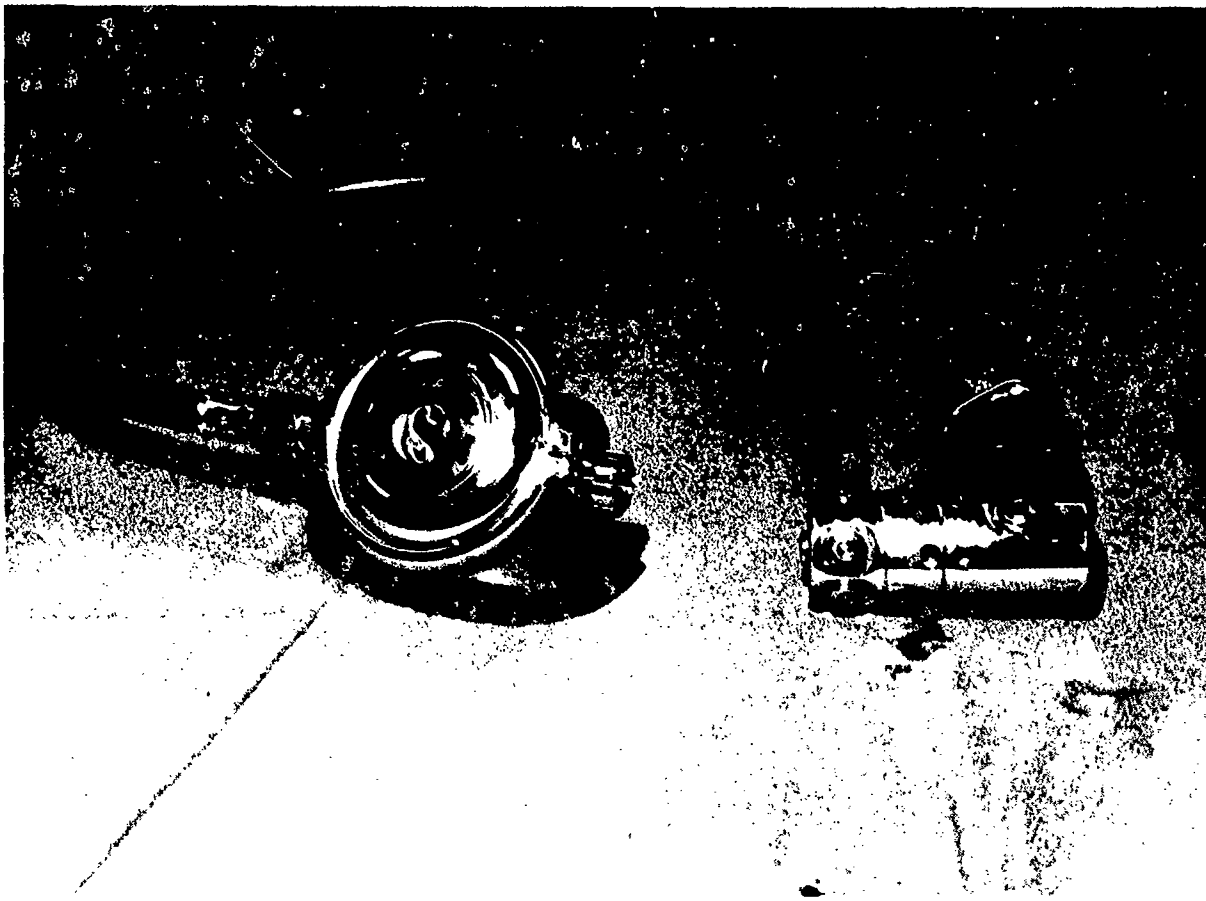


Figure 33. SCUBAPRO MK X/ADJUSTABLE

The SCUBAPRO MK X/Adjustable utilizes the MK X first stage.

The second stage (SCUBAPRO's Adjustable), constructed of chrome plated brass, is a unbalanced downstream poppet valve system which operates with moderate Venturi assist. Additionally, a divers adjust for inhalation resistance is provided.

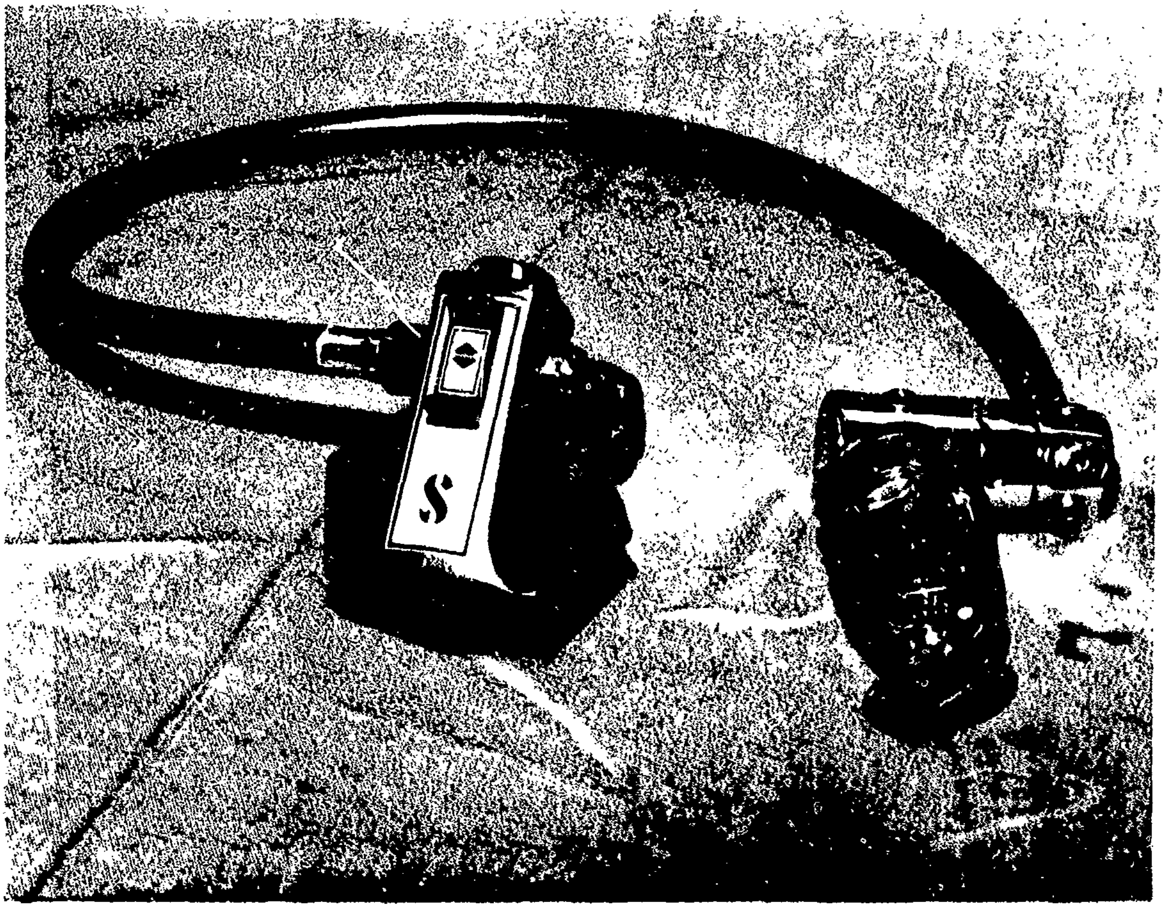


Figure 34. SCUBAPRO MK X/AIR I

The SCUBAPRO MK X/AIR I utilizes the MK X first stage and AIR I second stage.

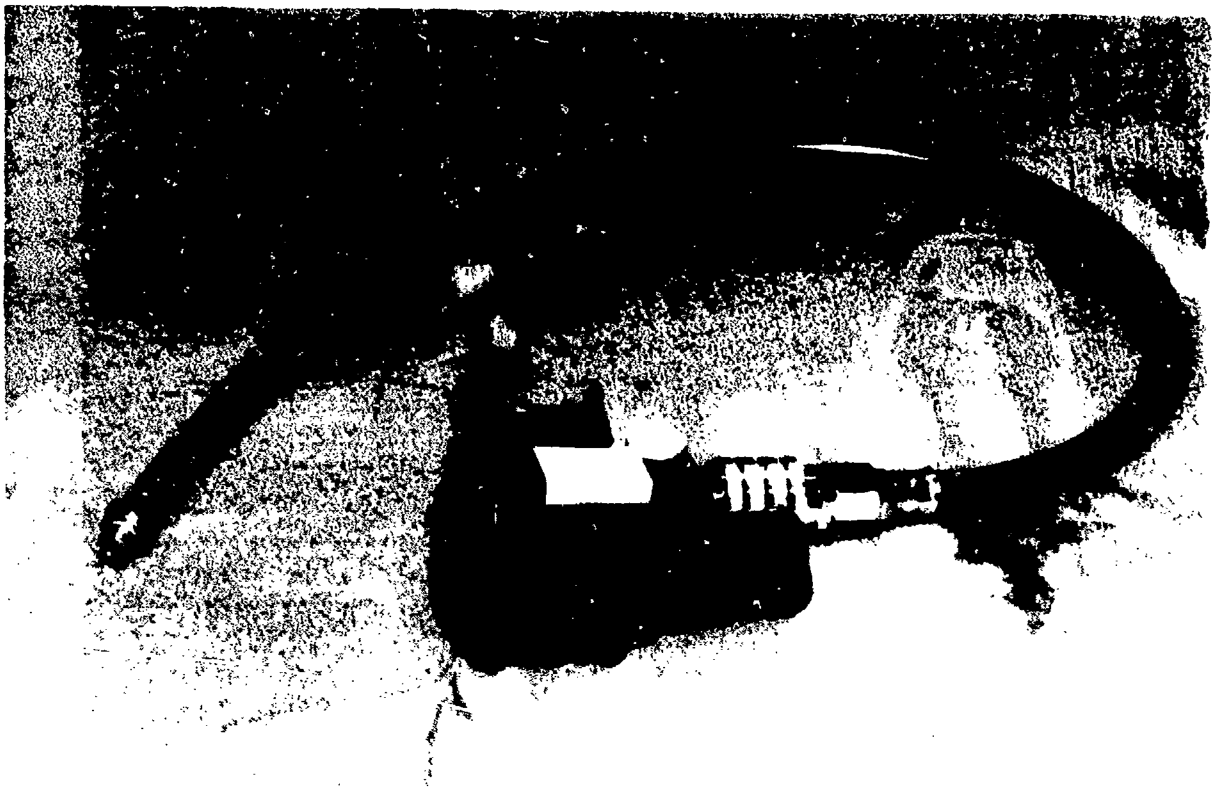


Figure 35. SCUBAPRO MK X/AIR II

The SCUBAPRO MK X/AIR II utilizes the MK X first stage.

The second stage (SCUBAPRO's AIR II) is a combination backup of regulator/power inflator. It is not a primary diver life support regulator system. The AIR II, constructed of fiberglass reinforced polyester, utilizes an unbalanced downstream poppet valve system and moderate Venturi assist.

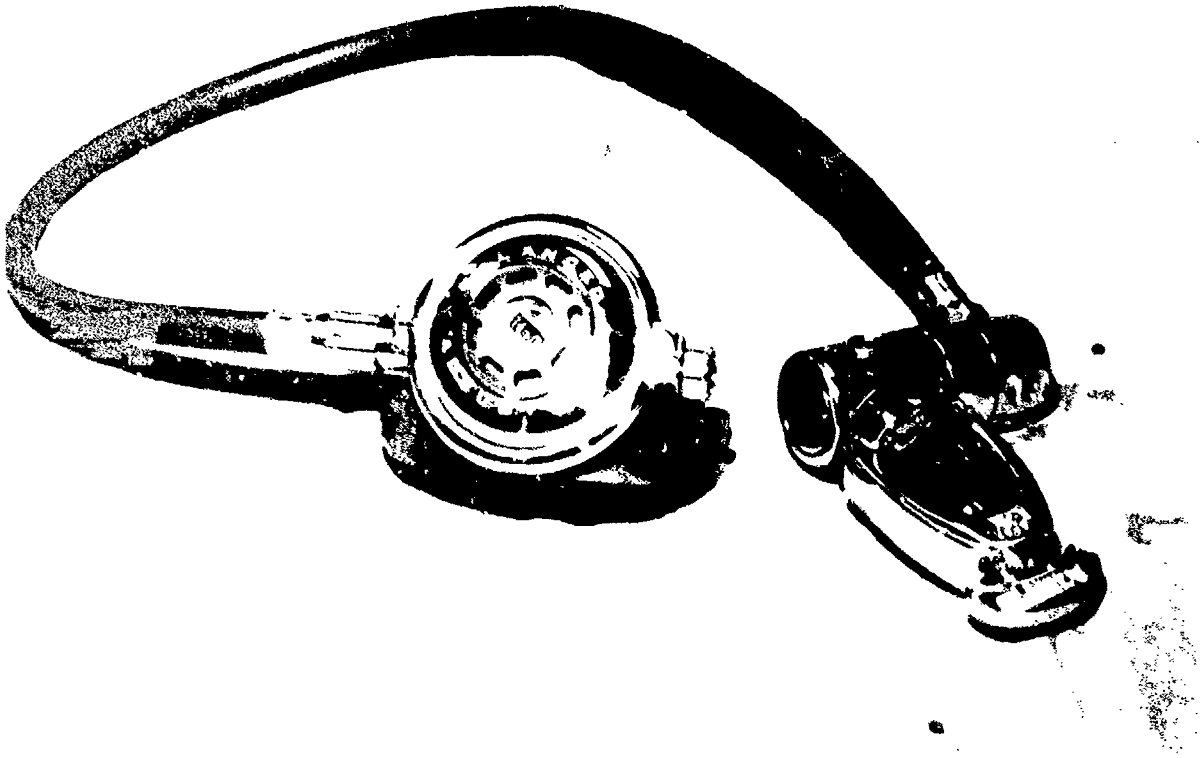


Figure [illegible]. SCUBAPRO MK X/BAL ADJ

The SCUBAPRO MK X BAL ADJ utilizes the MK X first stage and balanced adjust second stage.

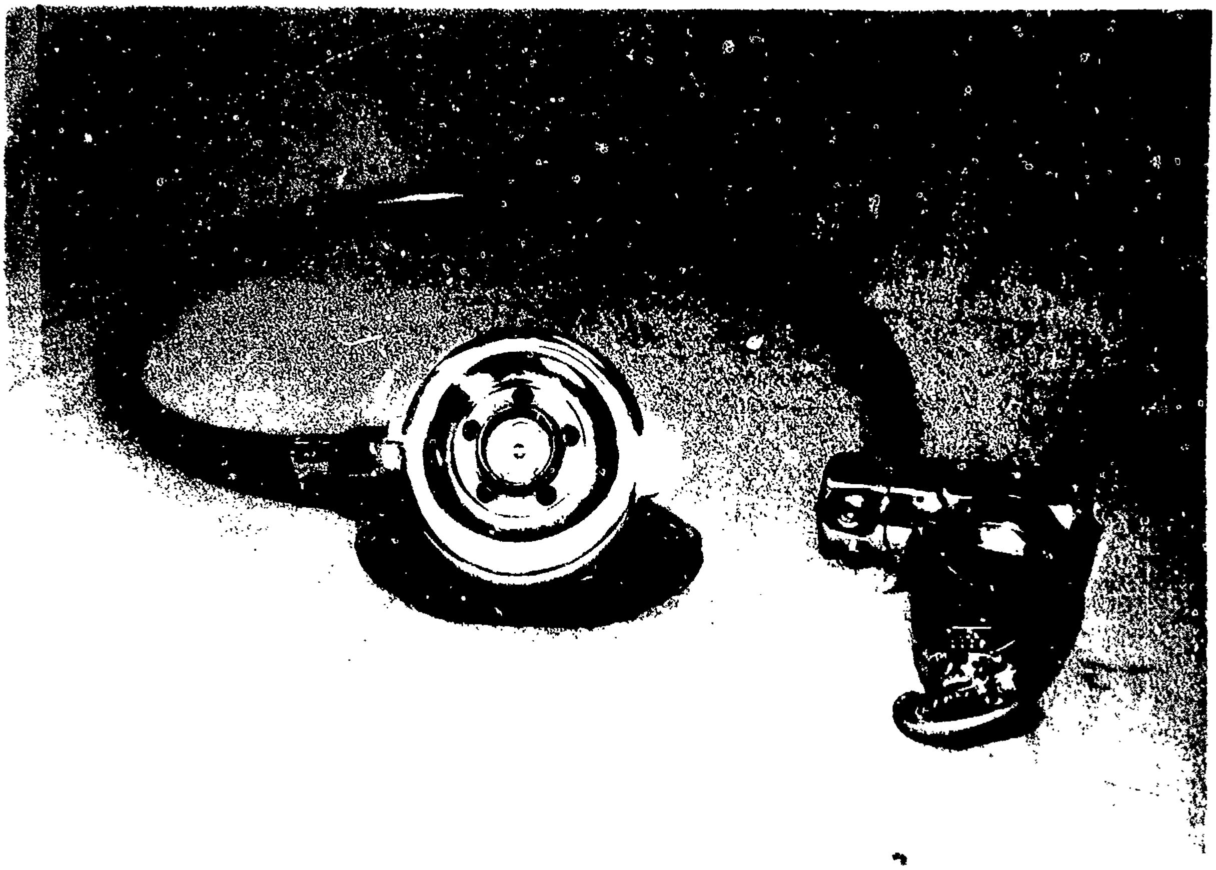


Figure 37. SCUBAPRO MK X/HIGH PERFORMANCE

The SCUBAPRO MK X/High Performance utilizes the MK X first stage and high performance second stage.

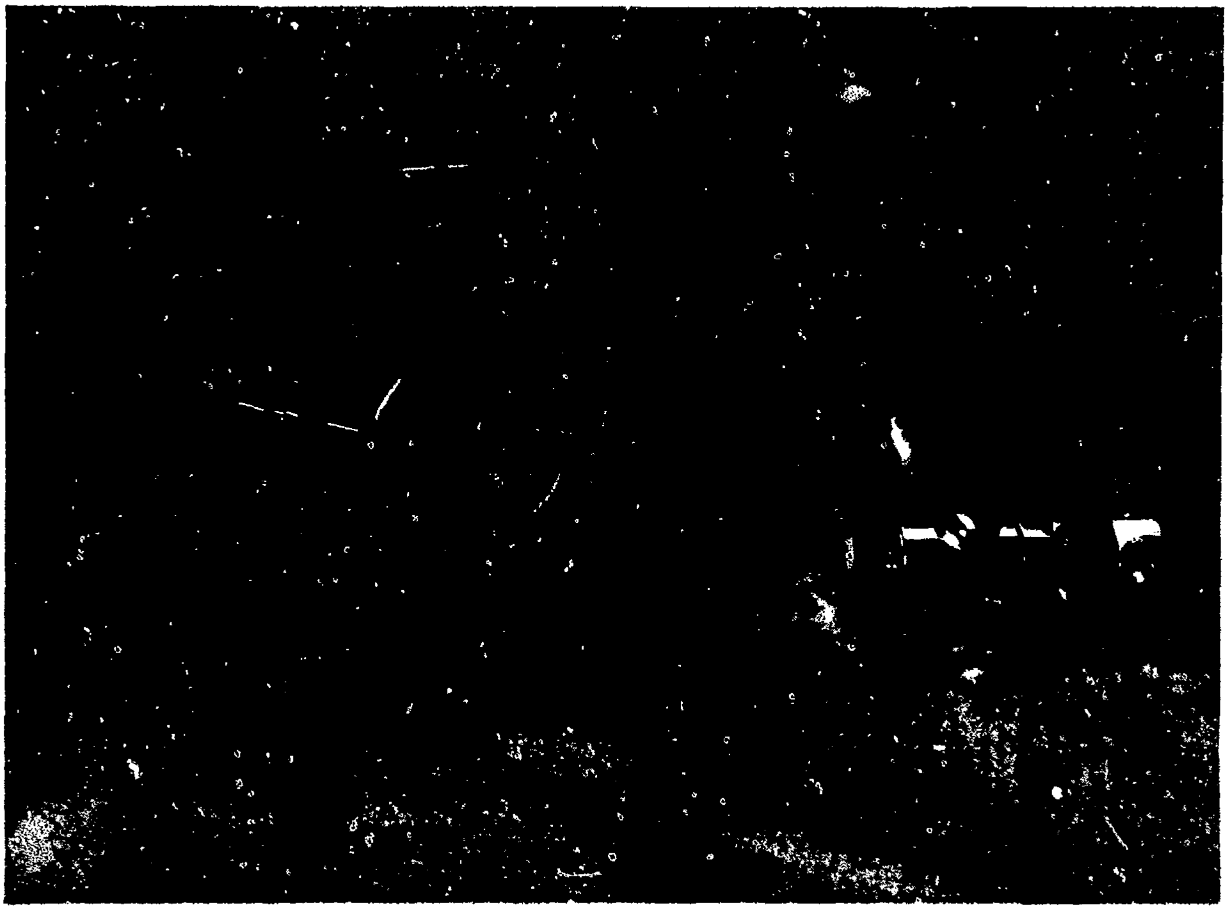


Figure 38. SEA PRO FSDS-10

The SEA PRO FSDS-10 first stage, constructed of chrome plated brass, is a balanced piston regulator that provides four low pressure ports on a swiveling low pressure manifold head, two high pressure ports, the yoke is rated at 4000 psi.

The second stage, constructed of ABS plastic and chrome plated brass, utilizes a downstream poppet valve with Venturi assist.

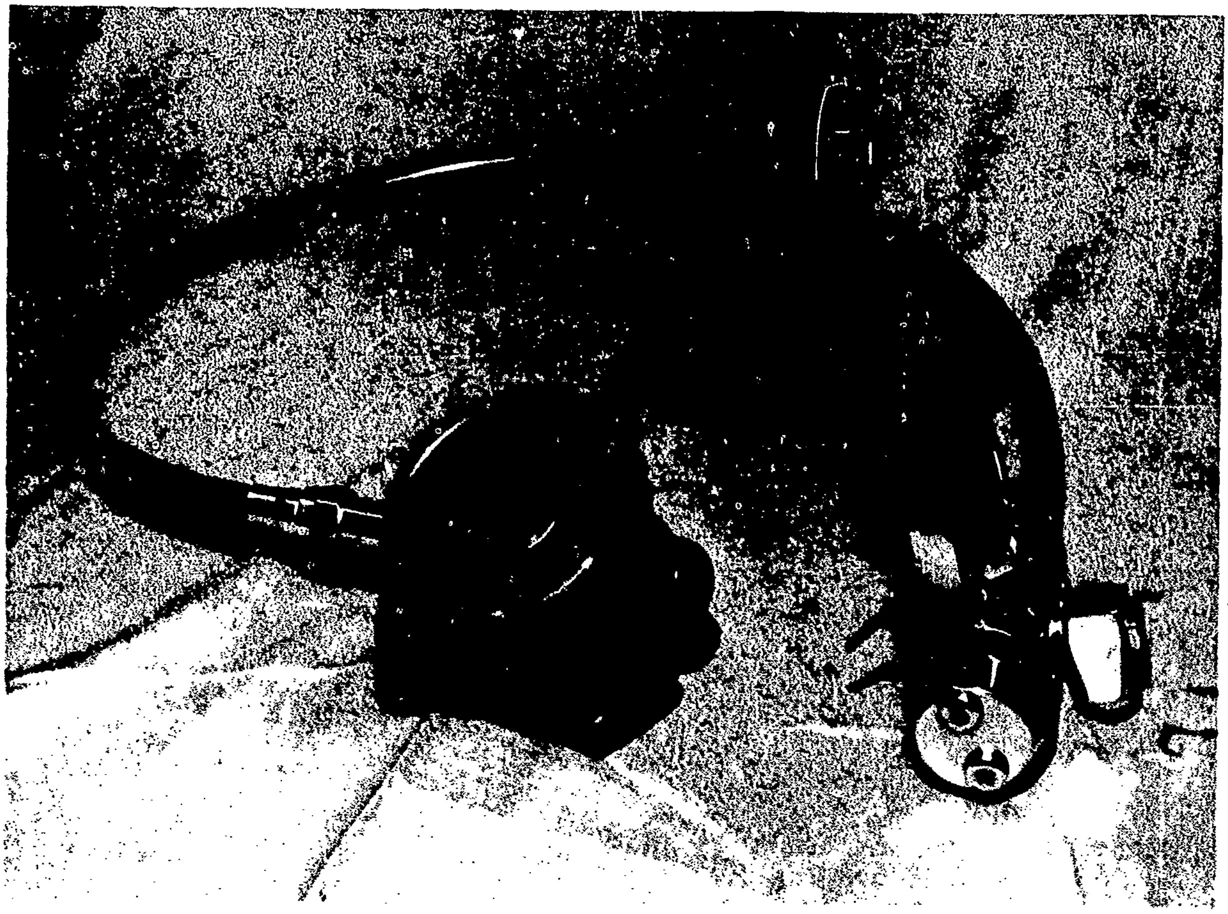


Figure 39. SEA PRO FSDS-50

The SEA PRO FSDS-50 first stage, constructed of chrome plated brass, is a balanced piston regulator with two complete piston assemblies, one large (primary) and one small (secondary). The secondary piston provides air flow to "safe second"/special SEA PRO inflation system. The unit has four low pressure ports and one high pressure port on a 360° swivel.

The second stage is the same as that of the FDS-10.

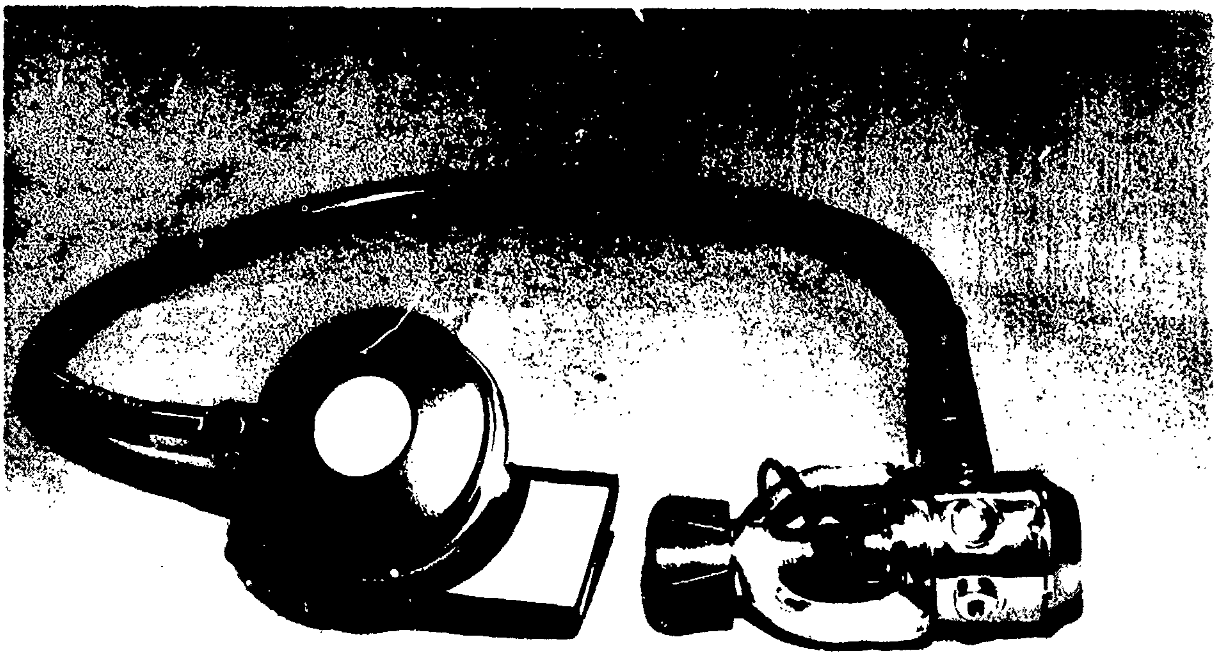


Figure 40. SEA QUEST AMF MARES MR 12 III

The SEA QUEST AMF MARES MR-12 III first stage, constructed of chrome plated brass, is a balanced diaphragm regulator that provides one primary, three secondary low pressure ports and one high pressure port.

The second stage, constructed of chrome plated brass and thermal plastic resin, utilizes a downstream valve system with "AMF" Inc. patented vortex assist.

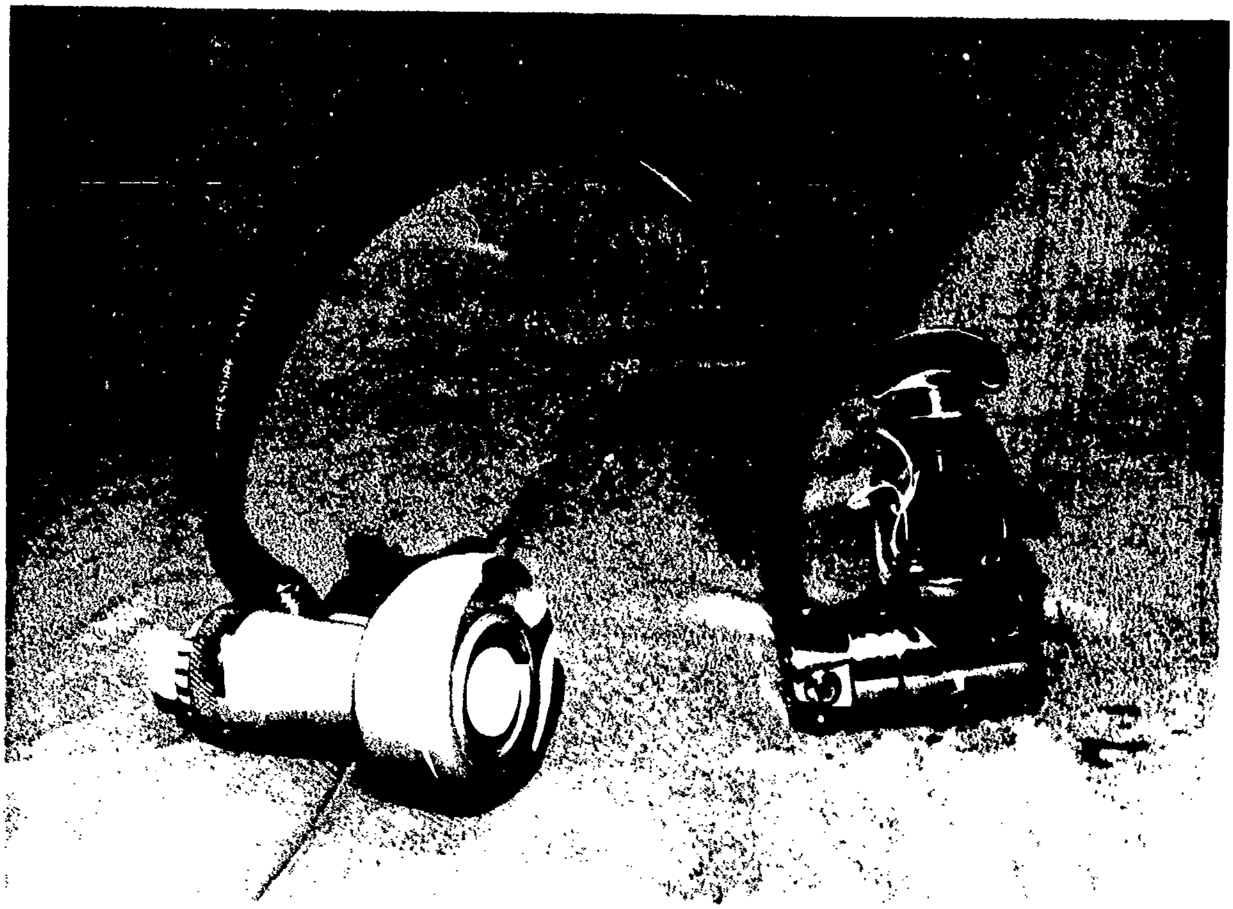


Figure 41. SEASPORT ZEPHER ZR-01

The SEASPORT ZEPHER ZR-01 first stage, constructed of chrome plated brass, is a standard piston regulator with adjustable valve seat to alter intermediate pressure setting. It provides four low pressure ports and two high pressure ports. The unit is adaptable to U.S./European tanks.

The second stage, constructed of impact resistant plastic, utilizes a Servo-controlled (pilot), pressure activated flow valve. Additionally, a "lock-out" button is provided to present inadvertent air flow when the regulator is not in use.

Figure 42. SHERWOOD BRUT SRB 2100

The SHERWOOD BRUT SRB 2100 first stage, constructed of chrome plated brass, is a unbalanced piston regulator that provides three low pressure ports, one high pressure port, a 360° swivel yoke and is designed for service pressure of 3,500 psi. The high pressure port is orificed to provide hosewhip. A dry air-bleed system is utilized, designed to keep the interior of the first stage, including the main spring chamber dry and free of contamination, eliminating the requirement to use silicon grease.

The second stage, constructed of lexan plastic utilizes a downstream valve and Venturi assist.

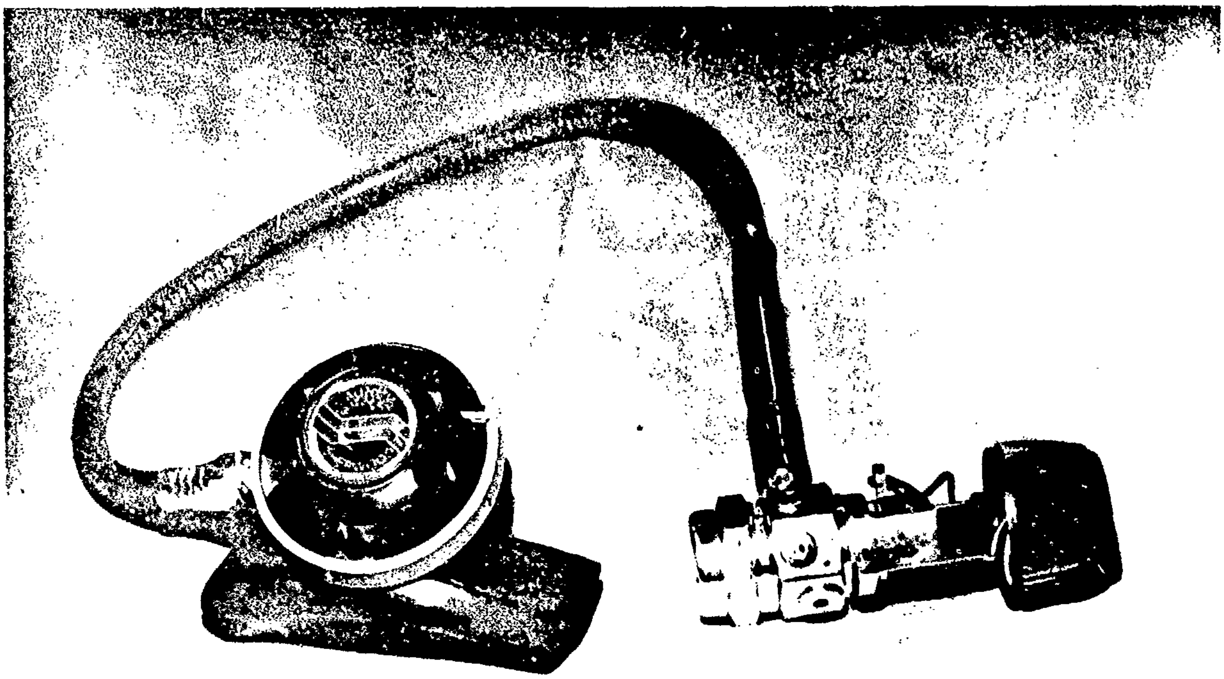


Figure 43. SHERWOOD MAGNUM BLIZZARD SRB 3200

The SHERWOOD MAGNUM BLIZZARD SRB 3200 first stage, constructed of chrome plated brass, is a balanced piston regulator with teflon coated components, 360° swivel yoke, four low pressure ports, one high pressure port and is designed for service pressure of 3,500 psi. The high pressure port is orificed to prevent hose whip. A "dry air-bleed system" is utilized, designed to keep the interior of the first stage, including the main spring chamber, dry and free of contamination eliminating the use of silicon grease.

The second stage, constructed of lexan plastic, has teflon coated components and a unique heat retention system directing heat from exhaled gas to the downstream demand valve body. The unit operates with Venturi assist.

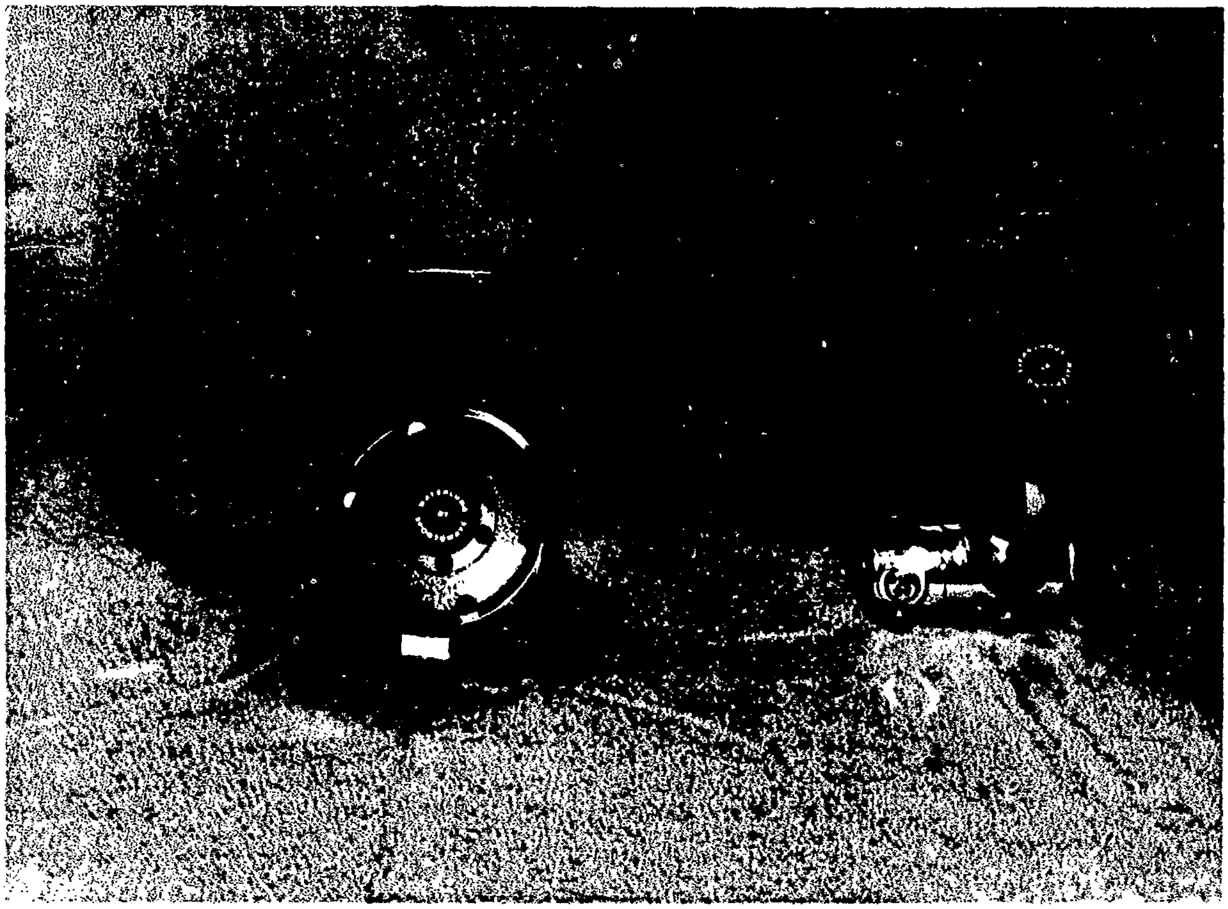


Figure 45. SPORTSWAYS X-2

The SPORTSWAYS X-2 first stage, constructed of chrome plated brass, is a balanced large bore piston regulator that provides five low pressure ports and two high pressure ports.

The second stage, constructed of ABS plastic, utilizes a downstream poppet valve with Venturi assist.

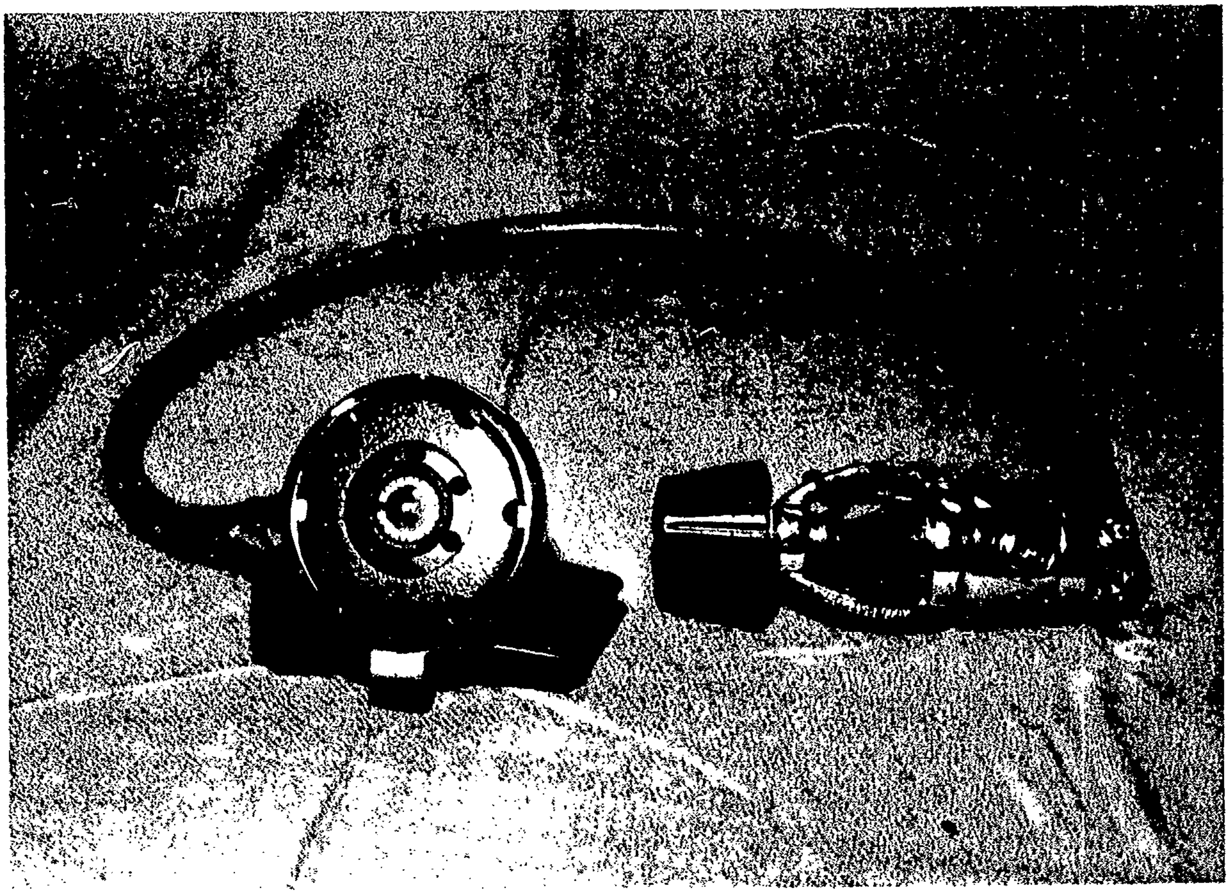


Figure 46. SPORTSWAYS X-3

The SPORTSWAYS X-3 first stage, constructed of chrome plated brass, is a balanced piston regulator that provides four low pressure ports and one high pressure port.

The second stage is the same as that used on the X-2.

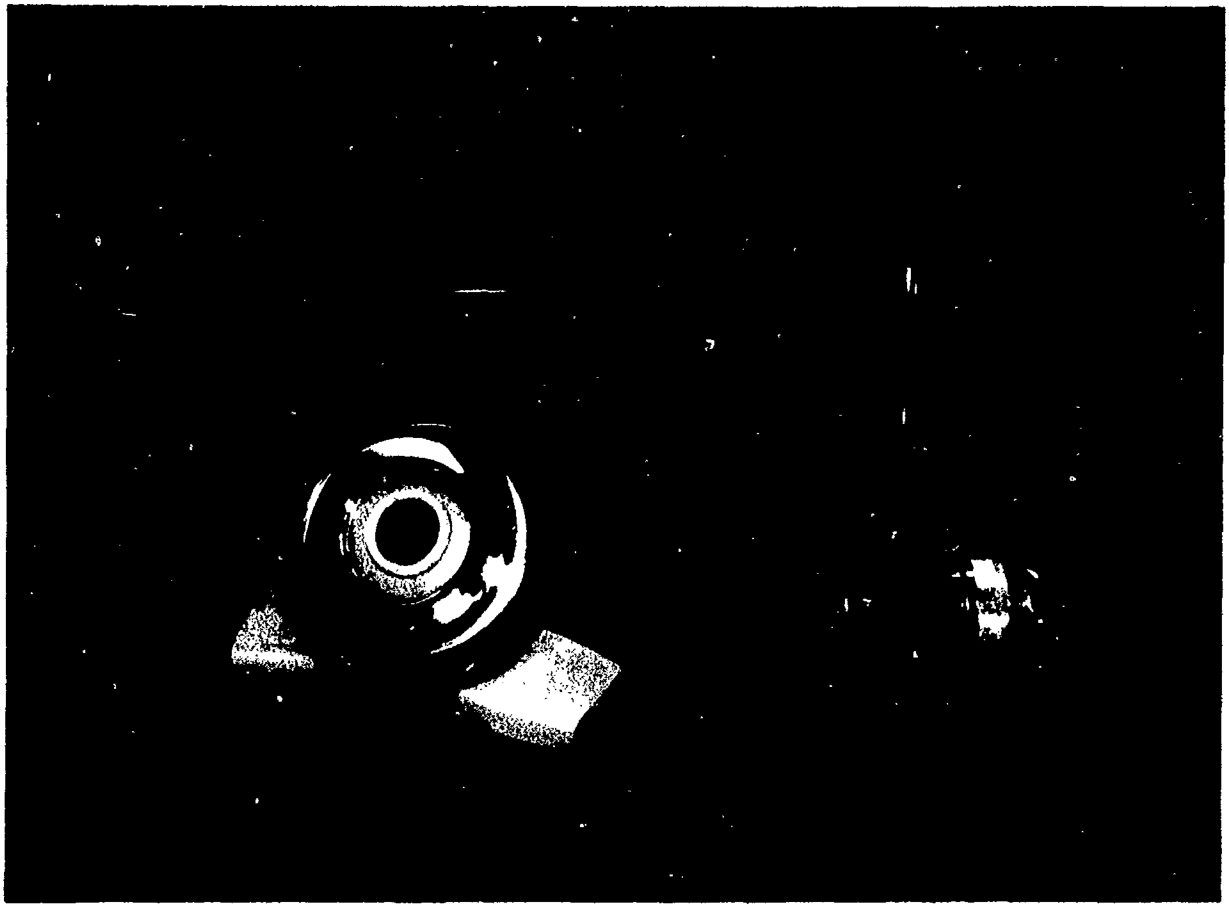


Figure 47. TABATA TR-100

The TABATA TR-100 first stage, constructed of chrome plated brass, is a balanced piston regulator that provides four low pressure ports on a swivel manifold head and two high pressure ports and is designed for a maximum of 4,000 psi service supply.

The second stage, constructed of derlin plastic and chrome plated brass, utilizes a downstream poppet valve with Venturi assist.

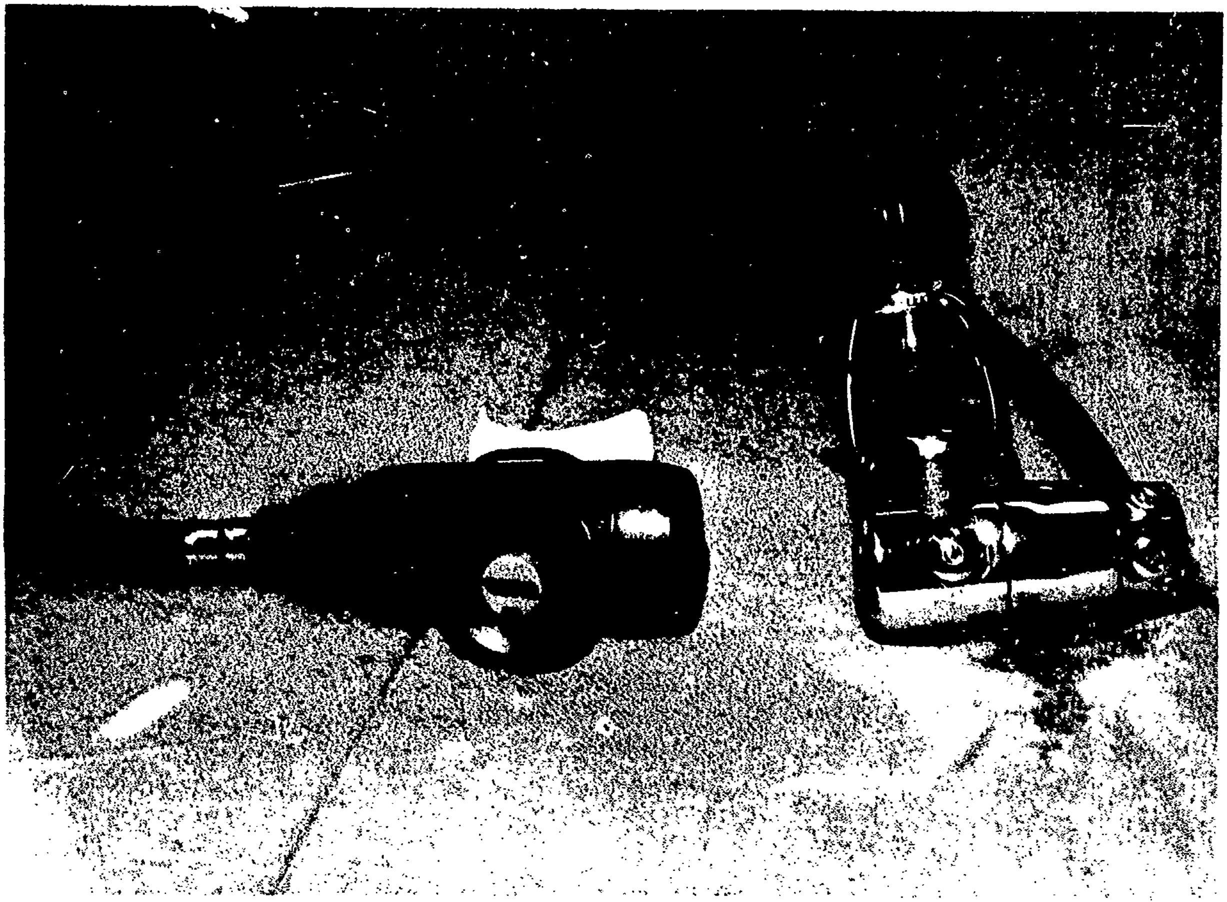


Figure 48. TEKNA T-2100BX

The TEKNA T-2100BX first stage, constructed of nickel plated brass, is a balanced piston regulator that provides four low pressure ports and two high pressure ports.

The second stage, constructed of thermo plastic, is a self tuning, corrosion resistant and utilizes a pilot demand system.

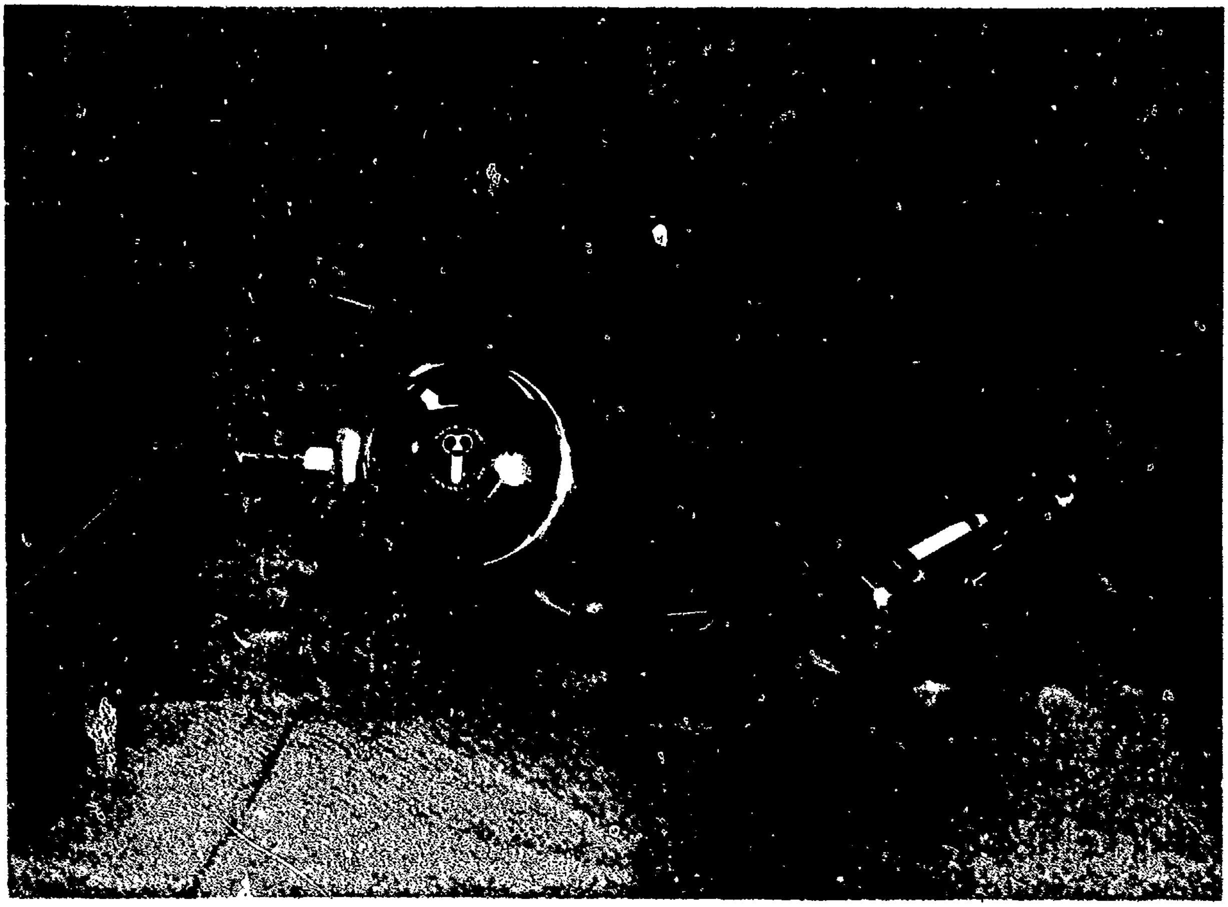


Figure 49. U.S. DIVERS CONSHELF XIV

The USD CONSHELF XIV first stage, constructed of chrome plated brass, is a balanced diaphragm regulator that provides three low pressure ports and one high pressure port.

The second stage, constructed of chrome plated brass, utilizes a downstream [illegible] valve with Venturi assist.

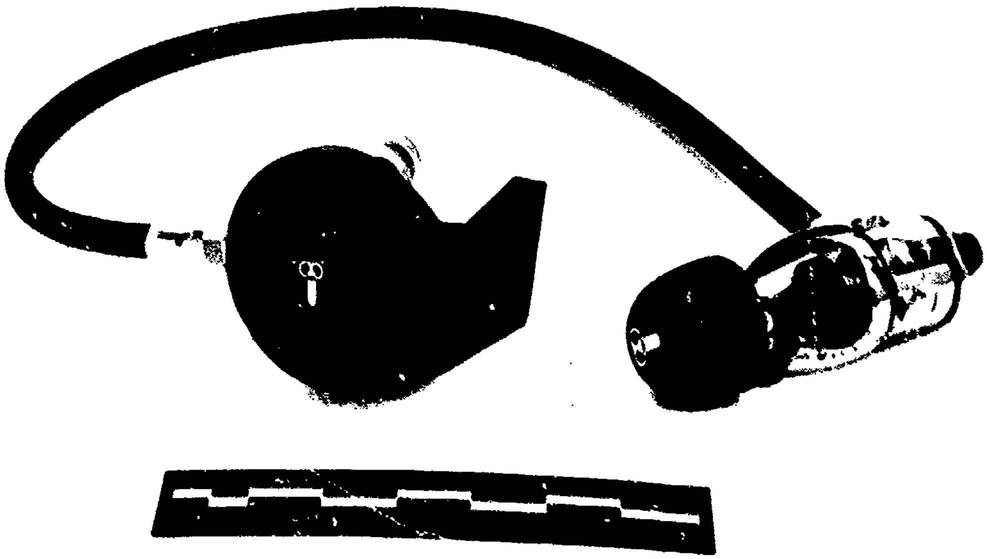


Figure 50. U.S. DIVERS CONSHELF 21

The USD CONSHELF 21 utilizes the CONSHELF XIV first stage.

The second stage, constructed of norel plastic, functions via a dynamically balanced downstream poppet valve with Venturi assist. It features an easy access port for adjustment of the second stage.

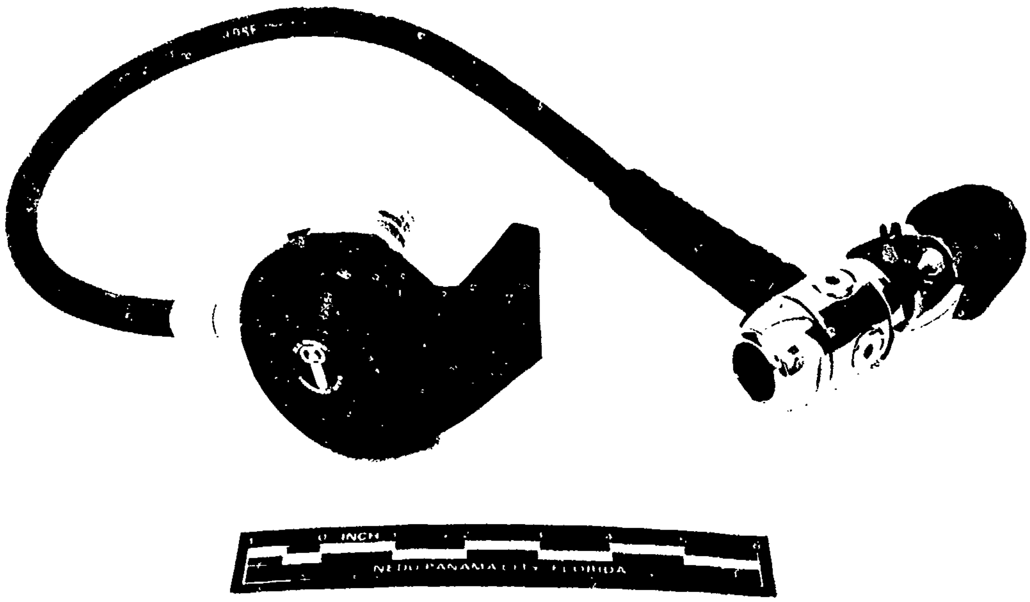


Figure 51. U.S. DIVERS CONSHELF SE2

The USD CONSHELF SE2 utilizes the CONSHELF XIV first stage.

The second stage, constructed of norel plastic, is equipped with large bore intermediate pressure hose and fittings. It functions via a dynamically balanced downstream poppet valve with Venturi assist. Additionally it features an easy access port for adjustment of the second stage.

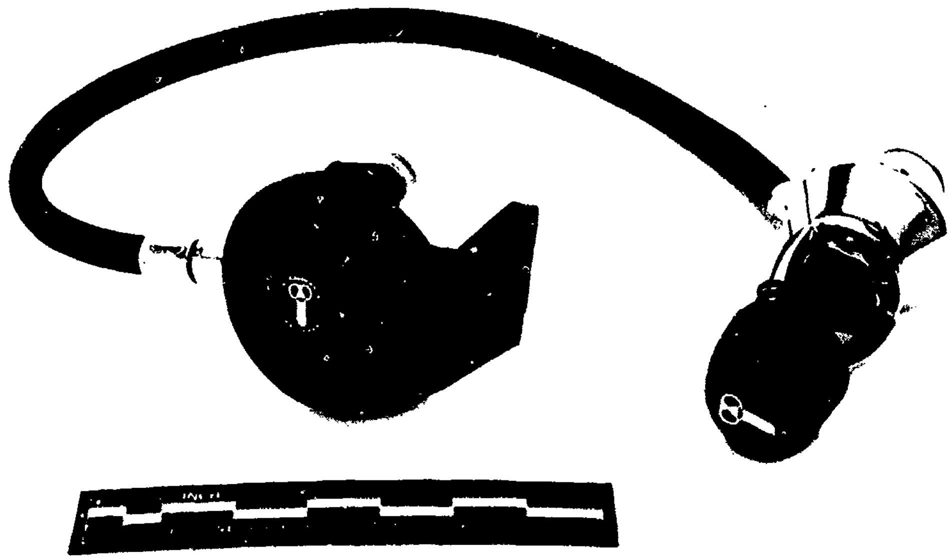


Figure 52. U.S. DIVERS PRO DIVER

The USD PRO DIVER first stage utilizes the USD "ROYAL SL" first stage. Constructed of chrome plated brass, it is a balanced diaphragm regulator that provides four low pressure ports and one high pressure port.

The second stage, supplied via large bore intermediate pressure hose and fittings, is the same as that used on the CONSHELF SE2.

B. Parameters Controlled. The following parameters were controlled:

1. Breathing Rate /	Tidal Volume /	RMV /	Simulated Diver's Work Rate
a. 15 BPM	1.5 Liters	22.50	Light
b. 20 BPM	2.0 Liters	40.0	Moderate
c. 25 BPM	2.5 Liters	62.5	Moderately Heavy
d. 30 BPM	2.5 Liters	75.0	Heavy
e. 30 BPM	3.0 Liters	90.0	Extreme

2. Exhalation/inhalation time ratio: 1.00/1.00

3. Breathing wave form: sinusoid

4. Arc water temperature: ambient

5. Air supply pressure: 1000 psig at all depths except 0, 99 and 198 FSW where data was taken at 1000, 500, and 300 psig supply pressure.

6. Incremental descent stops: 0 to 198 FSW in 33 FSW increment and 300 FSW.

C. Parameters Measured

1. Inhalation peak in cm H_2O

2. Exhalation peak in ΔP in cm H_2O

3. ΔP vs volume plots

4. Change in dynamic overbottom pressure at first stage outlets

D. Parameters Computed. Respiratory work from ΔP vs volume plots (Kg·m/ℓ)

E. Data Plotted

1. Inhalation and exhalation breathing resistance vs depth for each RMV in cm H_2O and KPa at 1000, 500 and 300 psig.

2. Breathing work vs depth for each RMV at 1000 psig supply in (Kg·m/ℓ) and (j/ℓ).

3. Change in dynamic overbottom pressure at the first stage for each RMV at 1000 psig supply in psig and KPa.

IV. TEST RESULTS

Detailed test results are shown in ANNEX C. Graphs are presented in alpha numerical sequence based on manufacturers name and model number.

NOTE: POSEIDON systems pre 1986 models supplied by PARKWAY Distributorship are listed as model no. distributed by Parkway; while POSEIDON systems 1986 model supplied by POS DIVE are listed as POSEIDON model number distributed by POS DIVE.

Regulator performance was analyzed and data obtained at all supply pressures, RMVs and depths up to the point at which breathing resistance (inhalation/exhalation ΔP factor) became excessive, greater than 40 cm H_2 (+ 40 cmH_2O - 40 cmH_2O) of the calibrated range scale. Graphs which are not fully complete indicate this occurrence.

Two regulator models, the SEA SPORT ZEPHER ZR-01 and the TEKNA 2100BX displayed specific inhalation characteristics that prohibit the objective analysis and accurate data reduction of breathing pressure and work of breathing. Therefore, rather than to publish suspect, inaccurate or faulty data, applicable graphs for these models will not be displayed. To maintain an unbiased position these regulators continued to be evaluated through phases two and three.

Analysis of the 10 random evaluation conducted to evaluate repeatability of data was consistent with the mechanical repeatability of data established in reference (d) of ± 10% stated value.

The tolerance of ± 10% of the 1.4 Kg•m/ℓ value was applied in finalization of performance categories.

V. DISCUSSION

From the analysis of data and subsequent grouping of performance levels in relation to established criteria, five performance/group levels were identified.

Group A. Regulators which met or exceeded the upgraded performance requirement of .14 kg•m/ℓ (1.4 j/ℓ) at all depths and RMV up to and including 198 FSW and 62.5 RMV with 1000 psig supply pressure to the regulator first stage (± 10% tolerance/mechanical repeatability).

Group B. Regulators which met or exceeded the 1981 performance requirement of .14 kg•m/ℓ (1.4 j/ℓ) at all depths and RMV up to and including 132 FSW and 62.5 RMV with 1000 psig supply pressure to the regulator first stage (± 10% tolerance/mechanical repeatability).

Group C. Regulators which met or exceeded Mil Spec MIL-R-24169-B (SH) dated 22 Feb 1982 based on established breathing resistance inhalation/exhalation maximum values at 40 RMV, 1000 psig and stated depths.

Group D. Regulators which did not meet Mil Spec MIL-R-24169-B (SH) dated 22 Feb 1982 based on established breathing resistance inhalation/exhalation maximum values at 40 RMV, 1000 psig and stated depths.

Group E. Regulators that could not be objectively evaluated by breathing resistance vs depth and work of breathing vs depth due to second stage inhalation pressure patterns incompatible with data analysis systems.

The 51 regulator models and systems are subsequently placed by group performance levels and presented in Alpha Numerical Sequence within those performance levels.

Group A

1. AGA DIVATOR MK II FFM with U.S. DIVERS ROYAL SL first stage regulator
2. AGA DIVATOR MK II breathing valve with AGA mouthpiece and U.S. DIVERS ROYAL SL first stage
3. POSEIDON CYKLON 5000 (distributed by POS DIVE, POSEIDON 1986 model)
4. POSEIDON ODIN (distributed by POS DIVE, POSEIDON 1986 model)
5. POSEIDON THOR (distributed by POS DIVE, POSEIDON 1986 model)
6. SCUBAPRO MK X/G-250
7. U.S. DIVERS CONSHELF SE-2
8. U.S. DIVERS PRO DIVER

Group B

1. AGA DIVATOR MK II (FFM) complete first and second stages with AGA cylinders
2. AGA DIVATOR MK II (FFM) used with U.S. DIVERS CONSHELF XIV first stage
3. AGA DIVATOR MK II (FFM) used with U.S. DIVERS ROYAL SL first stage
4. AGA DIVATOR MK II breathing valve equipped with AGA mouthpiece used with U.S. DIVERS ROYAL SL first stage
5. DACOR PACER XL 950
6. DACOR PACER XLE 360
7. OCEANIC OMEGA II Max Flow

8. POSEIDON CYKLON 300 (distributed by POS DIVE, POSEIDON 1986 model)

9. POSEIDON CYKLON 5000 (distributed by POS DIVE, POSEIDON 1986 model)

10. POSEIDON ODIN (distributed by POS DIVE, POSEIDON 1986 model)

11. POSEIDON THOR (distributed by POS DIVE, POSEIDON 1986 model)

12. SCUBAPRO MK X/D-300

13. SCUBAPRO MK X/G-250

14. SHERWOOD MAGNUM II SRB-3300

15. U.S. DIVERS CONSHELF 21

16. U.S. DIVERS CONSHELF SE-2

17. U.S. DIVERS PRO DIVER

Group C

1. AGA DIVATOR MK II (FFM) complete first and second stages with AGA cylinders

2. AGA DIVATOR MK II (FFM) used with U.S. DIVERS CONSHELF XIV first stage

3. AGA DIVATOR MK II (FFM) used with U.S. DIVERS ROYAL SL first stage

4. AGA DIVATOR MK II breathing valve equipped with AGA mouthpiece used with U.S. DIVERS ROYAL SL first stage

5. DACOR PACER AERO 950 A

6. DACOR PACER XL 950

7. DACOR PACER XLE 360

8. INTERNATIONAL DIVERS INC SUPER STAR II

9. NEMROD SATURN 300 PRO

10. OCEAN DYNAMICS RB-3000

11. OCEANIC OMEGA II

12. OCEANIC OMEGA II Max Flow

13. PARKWAYS ATLAS

14. CYKLON 300 (distributed by PARKWAYS, POSEIDON pre 1986 model)

15. CYKLON MAXIMUM II (distributed by PARKWAYS, POSEIDON pre 1986 model)

16. POSEIDON CYKLON 300 (distributed by POS DIVE, POSEIDON 1986 model)

17. POSEIDON CYKLON 5000 (distributed by POS DIVE, POSEIDON 1986 model)

18. POSEIDON ODIN (distributed by POS DIVE, POSEIDON 1986 model)

19. POSEIDON THOR (distributed by POS DIVE, POSEIDON 1986 model)

20. PRO SUB MAX AIR I

21. PRO SUB PRO AIR I

22. SCUBAPRO MK III/High Performance

23. SCUBAPRO MK IX/Air I

24. SCUBAPRO MK IX/Balanced Adjustable

25. SCUBAPRO MK IX/High Performance

26. SCUBAPRO MK X/D 300

27. SCUBAPRO MK X/G-250

28. SCUBAPRO MK X/Adjustable

29. SCUBAPRO MK X/Air I

30. SCUBAPRO MK X/Balanced Adjustable

31. SCUBAPRO MK X/High Performance

32. SEA PRO FSDS-50

33. SEA QUEST AMF MARES MR 12-111

34. SHERWOOD BRUT SRB-2100

35. SHERWOOD MAGNUM BLIZZARD SRB-3200

36. SHERWOOD MAGNUM II SRB-3300

37. SPORTSWAYS X-2

38. SPORTSWAYS X-3

39. TABATA TR-100

40. U.S. DIVERS CONSHELF XIV

41. U.S. DIVERS CONSHELF 21

42. U.S. DIVERS CONSHELF SE 2

43. U.S. DIVERS PRO DIVER

Group D

1. CRESSI SUB GALAXIE 105

2. CRESSI SUB POLARIS IV

3. INTERNATIONAL DIVERS INC. STAR II

4. NEMROD SATURN 300

5. SCUBAPRO MK X/Air II (NOTE: A buoyancy compensator inflator/mouthpiece not a primary regulator.)

6. SEA PRO FSDS-10

Group E

1. SEA SPORT ZEPHER ZR-01

2. TEKNA 2100 BX

VI. CONCLUSIONS

A. Unmanned breathing resistance and work of breathing evaluations have identified reliable open circuit demand SCUBA regulators for operational use to 198 FSW. The new performance criteria is a natural progression of the 1981 standards from 132 FSW to 198 FSW based on new USN operational requirements. These performance achievements are directly attributable to manufacturer's improvements in the design and operation of commercially available open circuit SCUBA regulators.

B. From the field of 51 regulators/systems, eight were found capable of meeting or exceeding a new performance criteria at 198 FSW; 17 were found capable of meeting or exceeding the 1981 performance goals; 43 were found capable of meeting or exceeding the military standard; six were found not capable of meeting the military standard; and finally two could not be objectively evaluated from the stand point of unmanned evaluation, due to incompatibility with the data analysis systems.

In comparison to the March 1980 report, reference (b), significant achievements have been made.

C. Additionally it is reminded that:

1. The establishment of performance criteria at 198 FSW is solely a Navy requirement and is not an endorsement that casual/standard SCUBA air diving operations be conducted to such depths.

2. It is important to understand that while eight regulator models/systems met the upgraded 1987 NEDU performance requirement, regulators that meet or exceed the Mil Standard [MIL-R-24169B (SH)], reference (e), are considered to be safe and effective. The 1987 NEDU performance criteria at 198 FSW was specifically designed to identify the highest performance equipment available.

3. Unmanned breathing resistance and work of breathing evaluations, although considered to be a severe test of regulator performance, is not a lifecycle/mechanical failure study.

PART II - UNMANNED TESTING: BREATHING RESISTANCE/WORK OF BREATHING AND COLD WATER FUNCTION EVALUATION OF SELECTED OPEN CIRCUIT SCUBA REGULATORS EQUIPPED WITH LOW TEMPERATURE CONVERSION KITS

I. INTRODUCTION

From April through May 1986, NEDU conducted unmanned breathing resistance and cold water function evaluations of selected open circuit SCUBA regulators equipped with low temperature conversion kits or standard first stage environmental silicon grease injection. A total of 10 regulator models/systems were evaluated under laboratory conditions. Units were selected primarily on their ability to meet NEDU performance criteria at 198 FSW (Group A performance regulators - able to support USN diving operations to 190 FSW). Additional regulators were added to the evaluation study; those of Group E not having been objectively evaluated for breathing resistance/work, therefore included to maintain an unbiased evaluation; and the SHERWOOD MAGNUM BLIZZARD SRB 3200, although not of Group A its reputation of performance as a cold water regulator, in the civilian diving community, warranted evaluation.

NOTE: The AGA DIVATOR MK II breathing valve with mouthpiece was selected for the evaluation, vice the full face mask configuration, in order to parallel the physical characteristics of all other second stage regulators in the study, (i.e. breathing box and oral mouthpiece configuration). Also the use of a full face mask would have unnecessarily complicated the evaluation.

Those regulators selected for the purpose of this study are listed in Table 2.

Also during this period a comparative evaluation of U.S. DIVERS cotton backed vs nylon backed main first stage diaphragms used in the "USD CONSHELF XIV" first stage regulator was conducted. The purpose of the evaluation was to examine the effects that these diaphragms had on first stage regulator static overbottom pressures once exposed to freezing conditions.

Breathing resistance evaluations were conducted on regulators equipped with cold water conversion kits and standard first stage environmental silicon grease injection to ascertain whether such configurations negatively effected the work of breathing. The SHERWOOD MAGNUM BLIZZARD was not evaluated as it underwent no modifications. The SEA SPORT ZEPHER ZR01 and TEKNA 2100BX were not evaluated due to incompatibility with test analysis systems and resultant absence of a baseline comparison.

II. FUNCTIONAL DESCRIPTIONS OF COLD WATER PROTECTION/CONVERSION KITS ON TESTED REGULATORS

A. <u>AGA DIVATOR MK II Breathing Valve with AGA Mouthpiece/U.S. DIVERS ROYAL SL First Stage (see Part I, Figure 5)</u>. The AGA MK II breathing valve (second stage) undergoes no modifications for cold water conditioning. The

TABLE 2

REGULATOR MODELS AND SYSTEMS SELECTED FOR COLD WATER EVALUATION

1. AGA DIVATOR MK II, Breathing Valve with AGA Mouthpiece/U.S. DIVERS ROYAL SL First Stage (System)
2. POSEIDON CYKLON 5000
3. POSEIDON ODIN
4. POSEIDON THOR
5. SCUBAPRO MK X/G-250
6. SEA SPORT ZEPHER ZR-01
7. SHERWOOD MAGNUM BLIZZARD
8. TEKNA 2100 BX
9. U.S. DIVERS CONSHELF SE2
10. U.S. DIVERS PRO DIVER

second stage incorporates a split inhalation/exhalation breathing box with a one way check valve located on the inhalation side. The check valve allows the passing of inhaled air into the mouthpiece (or full face mask if fitted), but prohibits exhaled gas from passing over the pilot valve assembly.

The U.S. DIVERS ROYAL SL first stage is modified to a "supreme" configuration with emplacement of a low temperature conversion kit, U.S. DIVERS part no. 1022-75. The kit consists of a cotton backed diaphragm and generic first stage fittings including: a modified spring retainer (threaded for spring adjusting screw and outer diagram packing ring), modified first stage spring, an outer rubber diaphragm, a diaphragm packing ring, adjusting wrench and silicon liquid. Following a supplied instruction sheet the first stage is modified, overbottom static pressure set to approximately 135 psig vice 145 psig. The spring cavity is then filled with silicon liquid, the outer diaphragm emplaced and secured via the packing ring and seals the silicon liquid within the spring cavity. As the outer diaphragm is secured it slightly compresses the silicon liquid, providing back pressure to the spring and raises the same pressure setting to approximately 145 psig. The inner spring cavity is now environmentally sealed from the ambient environment.

B. POSEIDON: CYKLON 5000, ODIN and THOR (see Part I, Figures 22, 23, 24 respectively). The CYKLON 5000, ODIN and THOR's second stages undergo no modification for cold water conditioning. The first stage is modified only by the emplacement of a standard conversion kit part number POSEIDON 1286 consisting of rubber anti freeze cap and two plastic locking straps (1 spare). The first stage spring cavity is filled with a non-toxic anti freeze liquid, i.e. silicon liquid, etheyl alcohol, etc. The anti freeze cap is then placed over the first stage body and secured in position with a locking strap. The spring cavity is then environmentally sealed.

C. SCUBAPRO MK X/G-250 (see Part I, Figure 32). The SCUBAPRO MK X/G-250 first and second stages undergo no modification for cold water conditioning, except for the injection of environmental silicon SCUBAPRO part number 41-035-000, into the standard silicon protection environmental cap. The silicon grease incases the first stage piston and spring assembly, fills the void of the spring cavity and ultimately displaces all water.

D. SEA SPORT ZEPHER-ZR01 (See Part I, Figure 41). The SEA SPORT ZEPHER-ZR01 first and second stages undergo no modification for cold water conditioning, except for the injection of environmental silicon in the first stage piston/spring cavity.

E. SHERWOOD MAGNUM BLIZZARD SRB 3200 (See Part I, Figure 43). The SHERWOOD MAGNUM BLIZZARD first and second stages are specifically designed for cold water use and undergo no modification nor silicon injection.

F. TEKNA 2100 BX (See Part I, Figure 48). The TEKNA 2100 BX first and second stages undergo no modifications for cold water conditioning, except for the injection of environmental silicon into the first stage piston/spring cavity.

G. U.S. DIVERS CONSHELF SE-2 (See Part I, Figure 51). The U.S. DIVERS CONSHELF SE-2 second stage undergoes no modification for cold water conditioning. The first stage is modified to a "supreme" configuration with the emplacement of a low temperature conversion kit, U.S. DIVERS Part No. 1076-75. The kit consists of generic fittings for the "CONSHELF XIV" first stage. Inventory and instructions remain the same as that described with the "USD ROYAL SL" first stage utilized with the AGA DIVATOR MK II breathing valve and AGA mouth piece.

H. U.S. DIVERS PRO DIVER (See Part I, Figure 52). The U.S. DIVERS PRO DIVER second stage undergoes no modification for cold water conditioning. The first stage a "Royal SL" is modified to a "supreme" configuration in identical manner as described under the AGA DIVATOR MK II breathing valve with AGA mouth piece equipped with U.S. DIVERS ROYAL SL first stage.

III. TEST PROCEDURE

A. Comparison Evaluation U.S. DIVERS Cotton Backed and Nylon Backed Main First Stage Diaphragms

1. Subjective flexibility study: Comparison

a. Three of each diaphragm types were separately sealed in plastic bags, placed in a freezer and frozen for a minimum of 12 hours at 0°F/-17.7 °C.

b. On completion of the 12 hour freeze the diaphragms were immediately analysed for flexibility. Each diaphragm was placed edgewise on a counter top and compressed by index finger pressure to the point of flexing. Subjective evaluation of index finger pressure required to flex the diaphragms was noted.

2. Objective first stage static intermediate pressure study after in freezing conditions: Comparison

a. Four U.S. DIVERS CONSHELF XIV first stages were prepared with cold water conversion kits, set to manufactures specification, and instrumented to monitor first stage intermediate pressure. Two first stages contained cotton backed diaphragms and two nylon backed. Each regulator was appropriately marked; all four were then frozen for a minimum of 12 hours at 0°F/-17.7°C.

b. On completion of the 12 hour exposure each first stage was removed and immediately connected to a H.P. air source. The intermediate static pressure was recorded.

c. On completion of monitoring all regulators were allowed to re-warm to room temperature, over bottom specifications were rechecked and the procedure in b. was repeated.

B. Breathing Resistance and Work of Breathing Evaluation of Selected SCUBA Regulators Equipped with Low Temperature Conversion Kits or Standard First Stage Environmental Silicon Grease Injection. As previously described all regulators except the SHERWOOD MAGNUM BLIZZARD, SEA SPORT ZEPHER ZR-01 and TEKNA 2100 BX were modified and evaluated for breathing performance. Test procedures and parameters were as stated in Part I Section III Paragraph B or as contained in reference (g).

C. Cold Water Function Evaluations of Selected SCUBA Regulators Equipped with Low Temperature Conversion Kits or Standard First Stage Environmental Silicon Grease Injection

1. Introduction to test procedures. All open circuit SCUBA regulators, both first and second stages can mechanically malfunction as a result of cold (affecting such things as spring tension, flexibility of O-rings and diaphragms, etc.) or by a combination of moisture and cold were the formation of ice blocks or alters mechanical functions. Such failures occur when regulators are exposed to cold surface environments, or during diving operations where subsurface temperatures are at or below 37°F/2.77°C.

a. Common malfunctions are as follows:

(1) Rise in first stage overbottom pressure. Regulator fails to properly reduce high pressure (HP) air source to nominal operating low pressures: caused by prolonged exposure of regulator to cold surface conditions whereby first stage component spring and diaphragms become more rigid in operation. This generally leads to a pressure increase on the low pressure side in order to balance the effect of the rigidity and close the HP valve seat. Ultimately, static overbottom pressure rises above the specified norm and forces the second stage down stream valve open, driving the regulator into freeflow.

(2) First stage exterior freeze while immersed. First stages freeze in the open or closed position due to ice formation on the regulator spring and within the spring cavity (occurs in both diaphragm and piston types). Water which enters the spring cavity, via the ambient pressure reference ports, is cooled to the freezing point. Sufficiently cold temperature, to freeze the water is created inside the first stage during the reduction of HP air to low pressures. As ice begins to form, intermediate pressures rise or drop, and the diaphragm or piston can ultimately freeze in an open or close position.

(3) First stage interior freeze. HP valve mechanism can freeze in the open or closed position. This is caused by moisture freeze-up inside the first stage. During reduction of air from high to low pressure, temperatures drop and the regulator cools; moisture condenses and freezes on the HP valve, its seat, and other components.

(4) Second stage down stream valve failure. Second stage supply valves freeze in the open or closed position as a result of the cold's

effect upon moisture that has entered the second stage from the following sources:

(a) Water vapor continues to condense from the supply gas, as pressures are reduced.

(b) Moisture from humid exhaled gas.

(c) Residual water left in the breathing box as a result of immersion.

(d) Moisture that has entered the regulator via the exhaust valve on exhalation (splash back).

b. The probability of a malfunction occurring increases as surface/subsurface environmental conditions increase in severity. Certain standard operating procedures can be adopted to lessen the chance of malfunctions, these include:

(1) Prior to cold water diving operations, regulators are fully serviced and checked for proper function. First stages are modified with cold water conversion kits or silicon grease injection.

NOTE: Cold water conversion kits and use of silicon grease on first stage are designed specifically to prevent first stage exterior freeze while immersed.

(2) Supply air should be as dry as possible [low dew point (low water vapor content)] to prevent internal first stage freeze up and to reduce the probability of the second stage valve of other low pressure action devices (i.e. dry suit inflator, bouyancy compensation inflators) from freezing.

(3) Regulators should be dry, especially second stages; kept warm as long as possible prior to diving, and have as little exposure as possible to harsh cold surface environments. If snowing, (blowing snow etc.) second stages should be covered to prevent entrance of moisture.

(4) Once exposed to cold surface conditions regulators should not be breathed or exhaled into; nor should they be purged for more than one second while on the surface.

(5) If possible, make water entrance by taking a deep breath, place regulator in the mouth, enter the water, after entrance exhale and breathe normally with the regulator, keeping it submerged at all times. This is important where surface temperatures are lower than the ambient water. (This method keeps the regulator from flooding during entrance and prohibits excess water moisture entering the second stage).

(6) While submerged breath normally, avoid extreme work conditions which demand high gas flows through the regulator. High gas flows

will produce a cooling effect on valve mechanisms and produce condensation. Again avoid prolonged purging of the second stage; if equipped with d suit inflation or bouyancy compensation devices inflate them with short bursts of air.

(7) If the regulator is removed and flooded, attempt to clear the regulator with exhaled gas rather than purging. If purging is necessary, again avoid any prolonged bursts of air.

2. Test procedures, cold water function

a. Based on the common types of malfunction and standard operation procedure, test procedures were developed as contained in unmanned test plan for cold water function, reference (g).

All test regulators were equipped as necessary with applicable cold water conversion or silicon injection. Prior to each evaluation regulators were checked for proper operation, calibrated to manufactures specification, completely dried, and instrumented. Regulators were then frozen for a minimum of 12 hours at temperatures 0°F/-17.77°C. After removal from the freezer they were transported to the test chamber via packed ice chest.

Regulators were immediately placed into the arc, connected to analysis systems, and the first stage HP supply opened. The second stage was then purged for one second, dipped and flooded in salt water brine at below freezing temperature. The regulator was then drained and connected to the breathing machine. The salt water brine arc level was raised to cover the regulator and the breathing machine started. High pressure supply air was cooled to arc temperature and regulators breathed at 40 ℓPM, exhaled gas was heated and a high relative humidity of 90% maintained. Water vapor content of the supply gas was also noted. The evaluations continued for one hour or until malfunction occurred. If malfunction occurred the regulator was removed and inspected. Ten separate evaluations were scheduled to provide a statistical data base. NOTE: The purging of the regulator was conducted to confirm proper mechanical function of first and second stages. The dipping/flooding of the second stage in the below freezing salt water brine, although not recommended as a standard operating procedure was conducted to create a worse case situation of water moisture residue in the second stage.

b. Submergent liquid and control temperature. A salt water brine, with a salinity at 29°/00, was selected as the submerging agent. This salinity was selected as it represent possible polar conditions. Additionally when cooled to a temperature of 29°F/-1.66°C the salt water bath was at the freezing point. Salt water/arc temperatures below 29°F could not be attained due to the limitations of arc conditioning system.

c. Parameters controlled. The following parameters were controlled:

				Simulated Diver's
(1)	Breathing Rate /	Tidal Volume /	RMV /	Work Rate
	(a) 20 BPM	2.0	40.0	Moderate

(2) Exhalation/inhalation time ratio: 1.00/1.00

(3) Breathing wave form: Sinusoid

(4) Arc salt water salinity 29°/00

(5) Arc salt water brine temperature: 29°F ±1°F/-1.66°C

(6) Air supply: 2,250 psig (maximum supply pressure available due to system configuration. Represented worse case pressure ΔP drop possible for first stage reducing regulator)

(7) High pressure air supply temperature: 29°F/-1.66°C

(8) Water vapor content high pressure air supply to the first stage: average mean due point -40°F/-40°C, 120 ppm (v/v), .089 mg/ℓ

(9) Evaluation depth and times: .5 FSW for one hour or until regulator malfunctioned

(10) Exhaled gas temperature: 80°F/26.66°C

(11) Exhaled gas minimum relative humidity: 90%

d. Parameters measured:

(1) Breathing resistance in cmH_2O and work of breathing kg.m/ℓ at 40 RMV

(2) Change in dynamic intermediate over bottom pressure at first stage outlet

(3) Maximum and minimum first stage over bottom pressures controlled during operation

(4) Water arc temperatures

(5) Gas supply temperature

(6) First stage regulator low pressure temperature

(7) Water vapor content/dew point of high pressure air supply to first stage

IV. TEST RESULTS

A. Comparison Evaluation U.S. Divers Cottoned Backed and Nylon Backed Main First Stage Diaphragms

1. Subjective flexibility study: Comparison. Subjective observations indicated nylon backed diaphragms became very rigid and required significant index finger pressure to flex. Cotton backed diaphragms became far less rigid than nylon units, required significantly less index finger pressure to flex.

2. Objective First Stage Static Intermediate Pressure Study After Freezing Conditions. U.S. Diver's Conshelf XIV first stage static pressures of all units equipped with nylon diagrams greatly exceed the preset static pressure of 145 psig. Readings recorded were 187, 197, 220 and 230 psig.

First stage static pressures of units equipped with cotton backed diaphragms although exceeding the preset static pressure of 145 psig remained consistently close to that value. Reading recorded were 147, 150, 150 and 157 psig.

B. Breathing Resistance/Work of Breathing Evaluation of Selected SCUBA Regulators Equipped with Low Temperature Conversion Kits or Standard First Stage Environmental Silicon Grease Injection

1. Test results are presented, Tables 3 through 9, in a format to allow direct comparison of breathing resistance and work of breathing under normal configuration and then with conversion kit. Data displayed is at 1000 psig, at RMV levels of 22.5, 40 and 62.5 and to a depth of 198 FSW. Test results indicated that in all circumstances breathing resistance and work of breathing increased as a result of low temperature conversion kits.

2. Results are indexed as follows:

Table No.	Regulator Name
3	AGA DIVATOR MK II Breathing Valve with AGA Mouthpiece/USD Royal SL first stage
4	POSEIDON CYKLON 5000
5	POSEIDON ODIN
6	POSEIDON THOR
7	SCUBAPRO MK X/G-250
8	U.S. DIVERS CONSHELF SE-2
9	U.S. DIVERS PRO DIVER

TABLE 3

LOW TEMPERATURE CONVERSION: OPEN CIRCUIT BREATHING LOOP ANALYSIS

Equipment Tested: AGA DIVATOR MK II with AGA Mouthpiece/USD ROYAL SL First Stage

Breathing Gas: Air

Console Pressure: 1000 psig

Overbottom First Stage Pressure: 138 psig (N)
: 138 psig (WCK)

		DEPTH FSW													
		0		33		66		99		132		165		198	
RMV	DATA	N	WCK	N	WCK	N	WCK	N	WCK	N	WCK	N	WCK	N	WCK
22.5	EXH	3.74	3.77	5.36	4.13	5.82	5.15	5.40	5.19	5.93	4.88	6.88	4.97	5.96	5.36
	INH	-2.19	-2.39	-1.98	-2.96	-1.80	-3.24	-2.50	-3.28	-2.47	-3.81	-1.38	-4.02	-3.07	-4.09
	FSPD	9.80	6.90	12.00	8.70	10.80	10.50	12.80	11.70	14.00	18.10	15.60	14.90	17.30	16.80
	WORK kg·m.ℓ	.0398	.0300	.0314	.0388	.0378	.0440	.0529	.0409	.0613	.0422	.0458	.0575	.0577	.0630
	WORK j/ℓ	0.39	0.30	0.31	0.38	0.37	0.43	0.52	0.40	0.60	0.41	0.45	0.57	0.57	0.62
40.0	EXH	5.47	3.66	5.86	5.11	6.42	5.99	6.53	6.63	6.85	6.31	6.60	6.56	7.94	5.74
	INH	-2.22	-4.02	-2.75	-4.19	-3.07	-3.77	-3.53	-4.16	-3.70	-4.44	-4.34	-4.66	-3.63	-6.38
	FSPD	11.40	8.80	15.40	10.80	14.60	13.70	17.80	15.90	20.20	18.80	22.70	22.90	26.70	30.17
	WORK kg·m.ℓ	.0422	.0498	.0435	.0476	.0501	.0616	.0543	.0606	.0565	.0786	.0648	.0698	.0681	.0898
	WORK j/ℓ	0.42	0.49	0.43	0.47	0.49	0.61	0.53	0.60	0.56	0.77	0.64	0.68	0.67	0.88
62.5	EXH	6.38	3.81	5.78	7.33	8.50	7.26	7.27	8.92	8.04	7.33	10.19	8.64	9.45	12.59
	INH	-3.10	-5.82	-4.09	-4.26	-3.84	-4.90	-4.55	-4.86	-5.64	-7.83	-5.50	-8.32	-8.68	-8.90
	FSPD	14.80	10.80	16.00	13.90	19.80	18.40	24.70	22.90	28.60	27.90	33.50	30.90	37.70	34.30
	WORK kg·m.ℓ	.0408	.0614	.0458	.0665	.0558	.0771	.0612	.0799	.0711	.0926	.0808	.0990	.0906	.1276
	WORK j/ℓ	0.40	0.60	0.45	0.65	0.54	0.75	0.60	0.79	0.70	0.91	0.80	0.97	0.89	1.26

N = Regulator normal configuration
WCK = Regulator with conversion kit
EXH = Maximum Exhalation effort in centimeters H_2O
INH = Maximum Inhalation effort in centimeters H_2O
FSPD = Maximum First stage pressure drop in psig
WORK kg·m/ℓ = Work of breathing in kilograms per meter/per liter
WORK j/ℓ = Work of breathing in joules per liter

TABLE 4

LOW TEMPERATURE CONVERSION: OPEN CIRCUIT BREATHING LOOP ANALYSIS

Equipment Tested: POSEIDON CYKLON 5000

Breathing Gas: Air

Console Pressure: 1000 psig

Overbottom First Stage Pressure: 165 psig (N)
: 170 psig (WCK)

RMV	DATA	DEPTH FSW 0 N	0 WCK	33 N	33 WCK	66 N	66 WCK	99 N	99 WCK	132 N	132 WCK	165 N	165 WCK	198 N	198 WCK
22.5	EXH	3.62	4.13	5.64	5.74	6.03	5.70	7.06	6.12	6.71	7.10	6.74	7.03	6.67	9.41
	INH	-2.87	-2.90	-2.63	-3.08	-3.16	-3.85	-3.30	-3.85	-2.91	-3.43	-2.95	-4.09	-3.83	-2.97
	FSPD	10.08	15.49	12.98	20.89	18.17	24.59	19.47	27.69	18.87	27.79	20.37	31.08	22.07	33.48
	WORK kg-m.ℓ	.0420	.0428	.0524	.0524	.0562	.0599	.0643	.0668	.0594	.0701	.0624	.0747	.0665	.0829
	WORK j/ℓ	0.42	0.42	0.52	0.52	0.55	0.59	0.63	0.66	0.58	0.69	0.61	0.74	0.65	0.82
40.0	EXH	4.65	6.51	7.24	8.50	8.31	8.78	10.51	10.25	11.04	10.71	8.20	10.95	10.40	11.72
	INH	-3.23	-2.87	-3.19	-5.04	-3.16	-4.23	-2.95	-7.70	-3.23	-6.61	-5.39	-9.69	-3.87	-8.68
	FSPD	11.08	18.49	15.78	25.99	19.07	30.48	20.87	35.58	20.37	37.48	21.37	43.28	23.17	45.28
	WORK kg-m.ℓ	.0538	.0600	.0657	.0782	.0694	.0887	.0844	.1068	.0781	.1135	.0763	.1245	.0837	.1393
	WORK j/ℓ	0.53	0.59	0.64	0.77	0.68	0.87	0.83	1.05	0.77	1.12	0.75	1.23	0.82	1.37
62.5	EXH	6.03	7.35	8.59	11.72	10.68	12.11	16.01	13.33	12.17	16.88	16.89	18.44	16.32	17.95
	INH	-4.65	-4.20	-4.22	-6.58	-4.90	-8.85	-4.97	-9.52	-6.74	-12.35	-4.69	-16.06	-6.28	-22.92
	FSPD	12.78	22.49	18.47	32.08	21.27	37.68	21.97	39.98	20.47	41.08	22.47	48.18	24.16	51.27
	WORK kg-m.ℓ	.0643	.0772	.0706	.1106	.0781	.1340	.1048	.1512	.0841	.1831	.0933	.2068	.0932	.2527
	WORK j/ℓ	0.63	0.76	0.69	1.09	0.77	1.32	1.03	1.49	0.83	1.80	0.92	2.03	0.92	2.49

N = Regulator normal configuration
WCK = Regulator with conversion kit
EXH = Maximum Exhalation effort in centimeters H_2O
INH = Maximum Inhalation effort in centimeters H_2O
FSPD = Maximum First stage pressure drop in psig
WORK kg-m/ℓ = Work of breathing in kilograms per meter/per liter
WORK j/ℓ = Work of breathing in joules per liter

TABLE 5

LOW TEMPERATURE CONVERSION: OPEN CIRCUIT BREATHING LOOP ANALYSIS

Equipment Tested: POSEIDON ODIN

Breathing Gas: Air

Console Pressure: 1000 psig

Overbottom First Stage Pressure: 130 psig (N)
: 128 psig (WCK)

RMV	DATA	DEPTH FSW													
		0		33		66		99		132		165		198	
		N	WCK	N	WCK	N	WCK	N	WCK	N	WCK	N	WCK	N	WCK
22.5	EXH	2.80	3.80	3.98	6.18	4.51	5.69	4.44	8.90	5.08	14.45	5.86	8.52	5.47	11.48
	INH	-3.34	-7.50	-3.48	-6.46	-3.51	-7.92	-4.29	-6.63	-3.05	-8.69	-3.41	-7.12	-4.05	-7.78
	FSPD	10.18	26.21	14.28	28.21	15.38	30.62	15.58	34.32	16.38	34.72	17.87	38.12	18.57	38.32
	WORK kg-m.ℓ	.0307	.0504	.0271	.0453	.0325	.0449	.0354	.0507	.0369	.0525	.0394	.0584	.0421	.0608
	WORK j/ℓ	0.30	0.50	0.27	0.45	0.32	0.44	0.35	0.50	0.36	0.52	0.39	0.57	0.41	0.60
40.0	EXH	4.40	5.83	4.83	7.47	6.28	8.27	8.41	8.17	8.02	10.44	9.26	10.05	9.41	10.92
	INH	-4.01	-7.75	-4.69	-8.17	-5.08	-9.77	-4.83	-7.85	-3.55	-6.21	-3.66	-8.06	-4.93	-8.41
	FSPD	11.88	27.41	14.78	32.12	15.48	33.92	17.87	36.52	17.07	36.92	20.37	38.92	21.47	43.82
	WORK kg-m.ℓ	.0349	.0642	.0465	.0586	.0574	.0672	.0639	.0736	.0598	.0745	.0649	.0853	.0661	.0909
	WORK j/ℓ	0.34	0.63	0.46	0.58	0.56	0.66	0.63	0.72	0.59	0.73	0.64	0.84	0.65	0.89
62.5	EXH	6.71	6.81	9.48	11.41	7.91	11.87	11.39	20.24	12.74	17.80	15.01	16.93	16.08	21.33
	INH	-3.55	-8.24	-4.51	-8.97	-5.57	-7.99	-6.53	-9.11	-3.80	-7.54	-7.13	-10.12	-5.86	-11.66
	FSPD	13.28	29.11	15.78	31.72	17.87	35.72	17.47	38.62	18.4	42.02	20.17	43.42	21.67	41.02
	WORK kg-m.ℓ	.0497	.0662	.0711	.0816	.0675	.0963	.1012	.1076	.0945	.1217	.1172	.1431	.1240	.1655
	WORK j/ℓ	0.49	0.65	0.69	0.80	0.66	0.95	1.00	1.06	0.93	1.20	1.15	1.41	1.22	1.63

N = Regulator normal configuration
WCK = Regulator with conversion kit
EXH = Maximum Exhalation effort in centimeters H_2O
INH = Maximum Inhalation effort in centimeters H_2O
FSPD = Maximum First stage pressure drop in psig
WORK kg-m/ℓ = Work of breathing in kilograms per meter/per liter
WORK j/ℓ = Work of breathing in joules per liter

TABLE 6

LOW TEMPERATURE CONVERSION: OPEN CIRCUIT BREATHING LOOP ANALYSIS

Equipment Tested: POSEIDON THOR

Breathing Gas: Air

Console Pressure: 1000 psig

Overbottom First Stage Pressure: 170 psig (N)
: 167 psig (WCK)

RMV	DATA	DEPTH FSW 0 N	0 WCK	33 N	33 WCK	66 N	66 WCK	99 N	99 WCK	132 N	132 WCK	165 N	165 WCK	198 N	198 WCK
22.5	EXH	3.02	3.64	4.44	5.00	4.58	5.03	3.66	5.70	4.61	6.71	5.04	10.07	4.37	8.85
	INH	-2.34	-6.05	-3.34	-7.87	-3.51	-8.25	-3.55	-8.88	-3.73	-8.60	-3.05	-8.57	-4.01	-11.19
	FSPD	12.28	14.29	21.77	21.49	29.26	26.69	29.76	30.28	36.05	35.38	39.74	43.38	41.84	51.17
	WORK kg-m.ℓ	.0186	.0444	.0212	.0549	.0273	.0561	.0264	.0635	.0337	.0675	.0301	.0724	.0304	.0862
	WORK j/ℓ	0.18	0.44	0.21	0.54	0.27	0.55	0.26	0.62	0.33	0.66	0.30	0.71	0.30	0.85
40.0	EXH	4.90	5.84	6.21	7.06	8.09	12.17	8.55	10.24	9.55	10.31	7.28	10.98	8.16	14.23
	INH	-3.16	-7.48	-4.01	-9.30	-3.69	-9.93	-3.62	-9.69	-4.29	-11.12	-4.05	-9.93	-4.05	-10.77
	FSPD	15.98	19.39	28.36	26.39	32.15	33.18	38.24	40.08	46.93	46.48	51.12	51.17	58.11	76.36
	WORK kg-m.ℓ	.0289	.0568	.0338	.0724	.0468	.0758	.0558	.0911	.0603	.0960	.0479	.1054	.0490	.1421
	WORK j/ℓ	0.28	0.56	0.33	0.71	0.46	0.75	0.55	0.90	0.59	0.94	0.47	1.04	0.48	1.40
62.5	EXH	4.65	6.12	6.42	9.72	12.28	11.89	13.42	15.63	10.26	16.96	12.81	17.25	15.47	18.44
	INH	-4.47	-9.93	-5.47	-9.51	-3.73	-11.29	-4.19	-10.17	-4.54	-12.59	-4.29	-14.29	-4.44	-16.00
	FSPD	20.67	23.09	34.35	35.28	40.84	42.18	49.23	51.07	60.31	59.37	69.99	68.99	108.64	70.52
	WORK kg-m.ℓ	.0407	.0716	.0491	.0931	.0810	.1168	.0922	.1397	.0616	.1677	.0737	.1850	.0621	.2030
	WORK j/ℓ	0.40	0.70	0.48	0.92	0.80	1.15	0.91	1.37	0.61	1.65	0.73	1.82	0.61	2.00

N = Regulator normal configuration
WCK = Regulator with conversion kit
EXH = Maximum Exhalation effort in centimeters H_2O
INH = Maximum Inhalation effort in centimeters H_2O
FSPD = Maximum First stage pressure drop in psig
WORK kg-m/ℓ = Work of breathing in kilograms per meter/per liter
WORK j/ℓ = Work of breathing in joules per liter

TABLE 7

LOW TEMPERATURE CONVERSION: OPEN CIRCUIT BREATHING LOOP ANALYSIS

Equipment Tested: SCUBAPRO MKX/G-250

Breathing Gas: Air

Console Pressure: 1000 psig

Overbottom First Stage Pressure: 132 psig (N)
: 130 psig (WCK)

		DEPTH FSW													
		0		33		66		99		132		165		198	
RMV	DATA	N	WCK	N	WCK	N	WCK	N	WCK	N	WCK	N	WCK	N	WCK
22.5	EXH	3.49	4.37	4.19	5.28	7.43	4.96	4.33	5.00	4.51	5.48	4.23	4.82	5.25	5.24
	INH	-4.04	-6.15	-4.26	-6.85	-2.64	-6.43	-5.77	-6.25	-4.86	-6.95	-5.46	-7.09	-4.86	-6.32
	FSPD	19.59	18.39	19.59	19.59	20.49	17.99	19.79	18.79	22.49	21.09	22.19	21.09	23.29	21.29
	WORK kg-m.ℓ	.0508	.0680	.0557	.0737	.0624	.0756	.0643	.0726	.0602	.0730	.0609	.0655	.0598	.0631
	WORK j/ℓ	0.50	0.67	0.54	0.72	0.61	0.74	0.63	0.71	0.59	0.71	0.59	0.64	0.59	0.62
40.0	EXH	5.49	6.46	5.35	5.73	6.62	6.92	6.02	6.36	5.21	8.56	7.36	7.02	7.89	7.09
	INH	-4.54	-5.87	-4.79	-8.59	-5.28	-7.97	-6.09	-6.64	-5.53	-6.53	-5.11	-7.55	-5.18	-7.65
	FSPD	20.79	18.59	20.69	19.89	22.59	21.99	22.39	20.79	24.99	26.29	25.89	30.28	27.89	28.09
	WORK kg-m.ℓ	.0570	.0707	.0629	.0720	.0559	.0627	.0568	.0598	.0447	.0580	.0492	.0526	.0473	.0507
	WORK j/ℓ	0.56	0.69	0.62	0.71	0.55	0.62	0.56	0.58	0.44	0.57	0.48	0.52	0.47	0.50
62.5	EXH	5.70	6.36	6.97	7.79	7.85	10.41	8.56	12.68	10.74	12.54	12.57	13.00	13.13	13.59
	INH	-5.21	-6.81	-5.35	-6.81	-5.35	-7.30	-6.34	-5.38	-6.13	-6.85	-6.13	-6.81	-6.30	-6.90
	FSPD	20.79	19.89	22.09	23.89	24.99	28.39	26.09	24.39	28.59	33.88	31.18	30.38	31.28	33.78
	WORK kg-m.ℓ	.0574	.0657	.0487	.0569	.0511	.0507	.0463	.0400	.0440	.0430	.0412	.0463	.0519	.0776
	WORK j/ℓ	0.56	0.65	0.48	0.56	0.50	0.50	0.46	0.39	0.43	0.42	0.41	0.46	0.51	0.76

N = Regulator normal configuration
WCK = Regulator with conversion kit
EXH = Maximum Exhalation effort in centimeters H_2O
INH = Maximum Inhalation effort in centimeters H_2O
FSPD = Maximum First stage pressure drop in psig
WORK kg-m/ℓ = Work of breathing in kilograms per meter/per liter

TABLE 8

LOW TEMPERATURE CONVERSION: OPEN CIRCUIT BREATHING LOOP ANALYSIS

Equipment Tested: US DIVERS CONSHELF SE2

Breathing Gas: Air

Console Pressure: 1000 psig

Overbottom First Stage Pressure: 144 psig (N)
: 150 psig (WCK)

RMV	DATA	DEPTH FSW 0		33		66		99		132		165		198	
		N	WCK	N	WCK	N	WCK	N	WCK	N	WCK	N	WCK	N	WCK
22.5	EXH	5.32	5.28	6.73	8.36	7.68	8.43	7.75	9.20	9.69	10.43	7.79	9.87	6.13	8.57
	INH	-6.98	-6.23	-8.00	-7.17	-7.15	-7.31	-7.82	-8.43	-7.51	-7.07	-8.07	-6.30	-9.09	-9.20
	FSPD	8.51	9.40	14.72	16.69	16.22	18.29	15.02	19.09	15.62	18.19	17.23	20.69	18.93	22.29
	WORK kg-m.ℓ	.0898	.0838	.0993	.1061	.1039	.1110	.1090	.1165	.1108	.1160	.1093	.1126	.1093	.1208
	WORK j/ℓ	0.88	0.82	0.97	1.00	1.02	1.09	1.07	1.14	1.09	1.14	1.07	1.11	1.08	1.19
40.0	EXH	6.06	6.93	9.80	9.55	11.03	12.46	11.35	10.78	12.76	13.96	13.50	12.88	13.85	15.36
	INH	-8.11	-6.51	-7.75	-8.64	-6.66	-7.31	-7.33	-10.22	-6.63	-6.72	-6.77	-7.38	-7.51	-7.14
	FSPD	11.52	10.99	17.03	19.49	17.73	23.59	19.33	23.89	21.03	25.69	24.24	30.08	27.74	34.68
	WORK kg-m.ℓ	.1007	.1026	.1182	.1267	.1191	.1304	.1274	.1321	.1317	.1360	.1320	.1396	.1311	.1532
	WORK j/ℓ	0.99	1.01	1.16	1.25	1.17	1.28	1.25	1.30	1.30	1.34	1.30	1.37	1.29	1.51
62.5	EXH	11.0	10.32	10.43	13.82	10.75	12.07	16.21	14.87	20.72	17.74	16.53	18.76	15.01	20.44
	INH	-6.98	-5.81	-9.30	-14.17	-11.95	-12.53	-6.34	-10.25	-5.04	-11.30	-8.35	-10.18	-11.77	-19.91
	FSPD	13.92	13.99	19.53	24.29	23.84	28.69	27.34	33.36	30.35	36.68	32.05	42.28	35.35	47.38
	WORK kg-m.ℓ	.1130	.1194	.1253	.1437	.1315	.1544	.1438	.1588	.1448	.1776	.1367	.1947	.1477	.2467
	WORK j/ℓ	1.16	1.17	1.23	1.41	1.29	1.52	1.41	1.56	1.42	1.75	1.35	1.92	1.45	2.43

N = Regulator normal configuration
WCK = Regulator with conversion kit
EXH = Maximum Exhalation effort in centimeters H_2O
INH = Maximum Inhalation effort in centimeters H_2O
FSPD = Maximum First stage pressure drop in psig
WORK kg-m/ℓ = Work of breathing in kilograms per meter/per liter
WORK j/ℓ = Work of breathing in joules per liter

TABLE 9

LOW TEMPERATURE CONVERSION: OPEN CIRCUIT BREATHING LOOP ANALYSIS

Equipment Tested: US DIVERS PRO DIVER

Breathing Gas: Air

Console Pressure: 1000 psig

Overbottom First Stage Pressure: 145 psig (N)
: 146 psig (WCK)

RMV	DATA	DEPTH FSW													
		0		33		66		99		132		165		198	
		N	WCK	N	WCK	N	WCK	N	WCK	N	WCK	N	WCK	N	WCK
22.5	EXH	4.58	5.98	5.00	8.26	6.38	8.85	6.26	8.71	6.45	10.46	6.77	9.69	7.51	9.76
	INH	-7.01	-4.83	-8.49	-6.23	-6.87	-5.70	-7.01	-5.77	-7.26	-5.98	-8.39	-6.75	-8.25	-6.68
	FSPD	19.13	19.20	22.23	21.59	24.74	22.39	26.94	24.19	26.34	24.89	29.64	27.09	30.45	28.49
	WORK kg-m.ℓ	.0837	.0710	.0914	.0889	.0943	.0986	.0945	.0997	.0974	.1005	.0994	.1051	.1031	.1033
	WORK j/ℓ	0.82	0.70	0.90	0.87	0.93	0.97	0.93	0.98	0.96	0.99	0.98	1.03	1.01	1.07
40.0	EXH	6.52	8.12	9.73	12.67	8.88	12.56	11.59	14.45	11.00	10.95	11.14	13.44	11.14	12.25
	INH	-8.49	-5.56	-6.24	-5.00	-6.80	-4.83	-5.67	-5.49	-6.80	-14.52	-7.01	-5.42	-6.70	-9.03
	FSPD	20.73	20.19	24.04	22.99	26.84	25.69	30.15	28.69	30.05	34.19	33.35	34.09	36.45	37.49
	WORK kg-m.ℓ	.0958	.0864	.1065	.1072	.1084	.1192	.1092	.1173	.1103	.1262	.1105	.1371	.1159	.1458
	WORK j/ℓ	0.94	0.85	1.05	1.05	1.07	1.17	1.07	1.70	1.09	1.24	1.09	1.35	1.14	1.43
62.5	EXH	6.91	11.30	9.90	14.17	12.23	15.92	12.86	18.69	13.46	18.20	14.38	18.16	18.19	21.66
	INH	-9.41	-4.23	-7.72	-4.86	-6.20	-8.82	-5.71	-4.34	-6.13	-8.33	-7.30	-11.76	-8.21	-16.20
	FSPD	21.63	21.19	25.44	25.99	30.15	31.69	34.15	34.99	35.55	38.19	40.26	42.58	43.57	46.38
	WORK kg-m.ℓ	.0934	.1004	.1151	.1235	.1204	.1359	.1142	.1581	.1151	.1801	.1221	.1989	.1482	.2428
	WORK j/ℓ	0.92	0.99	1.13	1.22	1.18	1.34	1.12	1.56	1.13	1.77	1.20	1.96	1.46	2.39

N = Regulator normal configuration
WCK = Regulator with conversion kit
EXH = Maximum Exhalation effort in centimeters H_2O
INH = Maximum Inhalation effort in centimeters H_2O
FSPD = Maximum First stage pressure drop in psig
WORK kg-m/ℓ = Work of breathing in kilograms per meter/per liter
WORK j/ℓ = Work of breathing in joules per liter

C. Cold Water Function Evaluations Selected SCUBA Regulators Equipped with Low Temperature Conversion Kit or Standard First Stage Environmental Silicon Grease Injection.

NOTE: Due to system limitations a statistical data base of 10 runs per regulator could not be achieved. Data obtained during condition where arc temperatures rose out of the prescribed temperature control of 29°F ±1°F was disregarded.

1. AGA DIVATOR MK II, Breathing Valve with AGA Mouthpiece/USD ROYAL SL First Stage (total of 4 separate runs conducted under acceptable test conditions)

a. Successful: 3 runs completed successfully, no malfunctions, regulator operated normally.

b. Minor malfunctions: 1 run completed despite minor malfunction of slight free flow. At 12 minutes into the evaluation a minor free flow from second stage was observed. The free flow continued throughout the evaluation but did not increase in severity.

c. Major malfunction, evaluation stopped: 0 runs

d. Initial first stage overbottom pressure after freezing: preset pressure was 155 psig. Recorded pressures 156, 176, 173, and 180 psig.

e. First stage intermediate pressure control during 1 hour immersion: The first stage intermediate O/B pressures rose from 139 to 153 psig maximum and dropped from 117 to 112 psig minimum.

f. Observation/analysis of malfunction: Despite severe exterior freezing on first stage components, the regulator controlled first stage pressure satisfactorily. Work of breathing did not vary from previous non-freezing analysis. Cause of minor malfunction (second stage free flow) could not be specifically identified.

2. POSEIDON CYKLON 5000 (total of 5 separate runs conducted under acceptable test conditions)

a. Successful: 4 runs completed successfully, no malfunctions, regulators operated normally.

b. Minor malfunction: 0 runs

c. Major malfunction, evaluation stopped: 1 run. Regulator initially free flowed when first stage supplied with high pressure air. Upon dunking, free flow stopped, evaluation was continued. At 30 minutes into the evaluation minor free flow at second stage occurred and increased in severity to point at which evaluation was stopped.

d. Initial first stage overbottom pressure after freezing: Preset pressure was 168 psig. Recorded pressure 160, 161, 172, 174, 183 psig.

e. First stage intermediate pressure control during one hour immersion: The first stage intermediate O/B pressures rose from 156 to 171 psig maximum, and dropped from 135 to 112 psig minimum.

f. Observations/analysis of malfunction: Despite exterior freezing on first and second stages components regulator controlled first stage pressures satisfactorily. Work of breathing did not vary from previous non-freezing analysis. Free flow at second stage was identified as having been caused by ice formation between the interface link/ejector sleeve prohibiting second stage low pressure valve piston from fully seating.

3. POSEIDON ODIN (total of 6 separate runs completed under acceptable test conditions)

a. Successful: 4 runs completed successfully, no malfunctions, regulator operated normally.

b. Minor malfunction: 1 run. Regulator initially free flowed when first stage supplied with high pressure air. Upon dunking, free flow stopped, continued with the evaluation no further malfunction occurred.

c. Major malfunction, evaluation stopped: 1 run. Regulator went into severe free flow when first stage supplied with high pressure air. Free flow would not cease, despite dunking.

d. Initial first stage overbottom pressure after freezing: Preset pressure was 130 psig. Recorded pressures 112, 125, 130, 128, 130 psig.

NOTE: 112 psig reading coincided with regulator that initially free flowed then stopped. Unable to attain accurate first stage reading of regulator that went into severe free flow.

e. First stage intermediate pressure control during 1 hour immersion: The first stage intermediate O/B pressures rose from 118 to 137 psig maximum, and dropped from 98 to 78 psig minimum.

f. Observations/analysis of malfunction: Despite exterior freezing on first stage components, regulator controlled first stage pressure satisfactorily. Work of breathing did not vary from previous non-freezing analysis. Both situations of free flow were attributed to the second stage. Specific identification of malfunctioning component could not be attained.

4. POSEIDON THOR (total of 4 separate runs completed under acceptable test conditions)

a. Successful: 4 runs completed successfully, no malfunctions regulator operated normally

b. Minor malfunction: 0 runs

c. Major malfunction, evaluation stopped: 0 runs

d. Initial first stage overbottom pressure after freezing: Preset pressure was 130 psig. Recorded pressures: 160, 160, 164, 167 psig.

e. First stage intermediate pressure control during one hour immersion: The first stage intermediate O/B pressures rose from 123 to 127 psig maximum, and minimum values held at approximately 103 psig.

f. Observations/analysis of malfunction: Despite severe exterior freezing on first stage components, regulator controlled first stage pressures satisfactorily. Work of breathing did not vary from previous non-freezing analysis. No malfunctions occurred.

5. <u>SCUBAPRO MK X/G-250 (total of 5 separate runs completed under acceptable test conditions)</u>

a. Successful: 3 runs completed successfully. However first stage overbottom pressure consistently increased to high values.

b. Minor malfunction: 1 run completed despite minor malfunctions of slight free flow from second stage noted 12 minutes into the evaluation. Free flow continued throughout the evaluation but did not increase in severity.

c. Major malfunction, evaluation stopped: 1 run. At 3 minutes into the evaluation second stage went into a severe free flow.

d. Initial first stage over bottom pressure after freezing: Preset pressure 118 psig. Recorded pressures 138, 146, 117, 141, 142.

e. First stage intermediate control during one hour immersion: The first stage intermediate O/B pressures rose from 140 to 176 psig maximum, and dropped from 110 to 80 psig minimum.

f. Observations/analysis of malfunctions: Exterior freezing occurred on all regulators which completed one hour of evaluation. First stage O/B bottom pressure consistently increased throughout the period of immersion to pressures well beyond the preset value. Cause of the one minor malfunction was attributed to ice forming over the interface between the demand lever and the poppet valve. Analysis of severe free flow indicated that substantial ice had formed over the interface between the demand lever and poppet valve, keeping the demand lever depressed. Additionally ice had formed on the inhalation diaphragm and the area immediately adjacent to the exhaust valve.

6. <u>SEA SPORT ZEPHER ZR-01 (total of 3 separate runs conducted under acceptable test conditions)</u>

a. Successful: 0 runs

b. Minor malfunction: 0 runs

c. Major malfunction, evaluation stopped: 3 runs. During two runs, the second stage immediately went into free flow when the first stage was supplied with high pressure air. Free flow could not be stopped. During the third run the second stage went into severe free flow after 10 minutes into the evaluation.

d. Initial first stage overbottom pressure after freezing: Preset pressure was 150 psig. Recorded pressures at 160, 164 psig. One pressure reading could not be accurately attained.

e. First stage intermediate pressure control during one hour immersion: Recorded pressures were only attainable during the first 10 minutes of one study. Maximum over bottom pressure rose from 164 to 174 psig, minimum over bottom held at 138 psig prior to entering a free flow condition.

f. Observations/analysis malfunction: On two separate occasions the regulator went into severe free flow condition, very shortly or immediately after opening high pressure air supply, no specific cause could be identified. During the one study that resulted in free flow after 10 minutes of the immersion analysis, ice had formed in the first stage spring cavity and on the first stage piston O ring despite the presence of silicon grease. In the second stage, ice had formed on the defector plate and poppet assembly. The regulator could not be analyzed for relative work of breathing.

7. SHERWOOD MAGNUM BLIZZARD (total of 4 separate runs conducted under acceptable test conditions)

a. Successful: 4 runs completed successfully, no malfunctions, regulator operated normally.

b. Minor Malfunction: 0 runs

c. Major Malfunction; Evaluation Stopped: 0 runs

d. Initial first stage overbottom pressure after freezing: Preset value was 133. Recorded pressure at 130, 130, 133, 133.

e. First stage intermediate pressure control during one hour immersion: Regulators initially began the immersion with maximum O/B pressure of 142, pressures remained relatively constant throughout the period only rising briefly to a maximum 163 psig. Minimum values remained consistent throughout, fluctuating between 120 and 115 psig.

f. Observations/analysis of malfunctions: Despite external freezing on first stage the regulator satisfactorily maintained first stage pressure, work of breathing did not vary from previous non-freezing analysis.

8. TEKNA 2100 BX (total of 3 separate runs conducted under acceptable test conditions)

a. Successful: 1 run completed successfully, however, first stage overbottom pressure increased dramatically from 137 to 185 psig over the one hour period.

b. Minor Malfunction: 1 run. 50 minutes into the evaluation second stage commenced a minor free flow. Again first stage overbottom pressure increased dramatically over the immersion period to 190 psig.

c. Major malfunction, evaluation stopped: 1 run. 12 minutes into the evaluation the second stage went into severe free flow condition.

d. Initial first stage overbottom pressures after freezing: Preset pressure was 118 psig. Recorded pressures were 119, 121, 127 psig.

e. First stage intermediate pressure control during one hour immersion: The first stage intermediate O/B pressure rose from 140 to 190 psig maximum, and minimum values held at approximately 115 psig.

f. Observation/analysis of malfunction: First stage regulator exterior freezing occurred on all completed evaluations. First stage overbottom pressures dramatically increased throughout the period of immersion. Analysis of the second stages showed ice formation about pilot valve stem. Relative breathing work of TEKNA remained consistent throughout the evaluation.

9. U.S DIVER'S CONSHELF SE-2 (total of 4 separate runs conducted under acceptance test conditions)

a. Successful: 1 run completed successfully, no malfunctions, regulator operated normally.

b. Minor Malfunctions: 1 run. Regulator second stage went into slight free flow at 56 minutes into the evaluation. First stage overbottom pressure had consistently risen from 138 psig to maximum of 190 psig then dropped and held at 170 psig.

c. Major malfunctions; evaluation stopped: 2 runs, regulator second stage went into severe free flow at 17 and 22 minutes into the evaluations. On both cases the free flow increased in severity. First stage pressure remained in the window of normal operating pressures.

d. Initial first stage overbottom pressures after freezing: Preset pressure was 138. Recorded pressures were 156, 145, 148, 164 psig.

e. First stage intermediate pressure control during one hour immersion: Regulator initially began the immersion period with a maximum O/B pressure of 140 psig. Pressure varied up to 190 psig but then returned to 170 psig. Minimum values began at 130 psig and a then dropped to 105 psig.

f. Observations/analysis of malfunctions: First stage exterior icing occurred in all cases. First stage pressures were erratic in some cases. Analysis of severe free flow situations indicated the second stage had ice formed about the interface between the horseshoe valve and the poppet valve, on the inhalation diaphragm, also immediately adjacent to and in the exhaust valve. Analysis of the minor free flow incident indicated that small quantities of ice had again formed on the interface between the horseshoe valve and the poppet; free flow was evidentally caused by high overbottom pressure. Work of breathing did not vary from previous non-freezing analysis.

10. U.S. DIVERS PRO DIVER (total of 3 separate runs conducted under acceptable test conditions)

a. Successful: 0 runs

b. Minor malfunction: 0 runs

c. Major malfunction, evaluation stopped: 3 runs . In all three cases regulators went into severe free flow when first stage supplied with high pressure air.

d. Initial first stage overbottom pressure after freezing: Preset pressure was 140 psig. During these three evaluations accurate first stage pressures could not be attained. The regulators were subsequently monitored in a static condition, pressures recorded were at 200, 200, 220 psig.

e. First stage intermediate pressure control during one hour immersion/Analysis of Malfunction: In all three cases first stage overbottom pressure had risen to such an extreme as to immediately over power the dynamically balanced second stage valve.

f. Observation/analysis of malfunction: Regulator malfunction was directly attributed to high first stage intermediate pressures.

V. DISCUSSION

A. Comparison Evaluation U.S. Divers Cotton Backed and Nylon Backed First Stage Diaphragms. Subjective and objective test results clearly indicated that the cotton backed diaphragm became far less rigid than nylon backed units and as such had far less affect in raising USD CONSHELF XIV first stage static overbottom pressure above preset pressures for regulators exposed to cold environments. Pressures recorded from nylon units would have been more than sufficient to immediately over-drive dynamically balanced second stage demand valve into free flow.

B. Breathing Resistance/Work of Breathing. Data indicated that in all cases, whether dealing with conversion kits for diaphragm or silicon injection for piston first stages, that such configuration reduced the performance of the regulator as measured at 70°F. As depth and RMV levels increased, regulators equipped for cold water function had inhalation resistance and work of breathing values higher in comparison to their normal configuration. Analysis of volume vs. ΔP XY loops consistently showed an increase in area on the inhalation side. This larger area directly corresponds to an increase in work of breathing. The SCUBAPRO MK X/G-250, a first stage piston regulator, was the least affected in comparison to the remaining regulators equipped with diaphragm first stages. No further increase in work of breathing was noted when converted regulators were subsequently tested in the freezing environment. The work of breathing goal of .14 kg·m/ℓ (1.4 j/ℓ) at all depths and RMVs up to and including 198 FSW on 62.5 RMV with 1000 psig supply pressure to the first stage regulator could not be attained by POSEIDON CYKLON 5000, POSEIDON ODIN, POSEIDON THOR, U.S. DIVERS CONSHELF SE2 and U.S. DIVER PRO DIVER. The goal was attained by the AGA DIVATOR MK II with AGA mouthpiece/USD ROYAL SL first stages and the SCUBAPRO MK X/G-250. However, in all cases exhalation/ inhalation values were well within the established values of the Mil Spec MIL-R-241698-SH 22 Feb 1982, reference (e).

C. Cold Water Function

1. First stage external spring cavity freeze. Use of environmental cold water conversion kits and silicon grease injection

a. The cold water conversion kits used on the diaphragm first stage regulators proved to be totally effective in preventing first stage exterior freeze of the spring cavity. No exterior freezes of diaphragm first stage regulators were recorded.

b. Environmental silicon grease injection proved to be effective in preventing spring cavity freezing. However, one case of first stage exterior freeze was recorded with SEA SPORT ZEPHER ZR-01. In this case silicon grease had been forced out of spring cavity through the first stage ambient sensing ports by piston action. Water entered the resulting void and a freeze occurred. All piston first stage regulators that used environmental protective silicon grease were checked for extrusion prior to each evaluation and silicon injected as necessary. The extrusion of silicon grease is a common problem with piston regulators. It can be limited, but not prohibited, via the adaptation of smaller ambient sensing ports as found on the SCUBAPRO MKX environmental standard silicon protection environmental cap.

c. The dry air bleed system utilized on the SHERWOOD MAGNUM BLIZZARD also proved totally effective in protecting its first stage from spring cavity freeze.

2. First stage interior freeze. No occurrence of first stage interior freeze was recorded, even though the average water vapor content in the supply air remained relatively high with a mean dew point of -40°F/-40.0°C/moisture content of 120 ppm, .089 mg/ℓ.

3. First stage intermediate pressures

a. First stage intermediate pressure immediately after freezing: Relatively excessive first stage intermediate static pressures were recorded with AGA DIVATOR II with USD ROYAL SL first stage and the US DIVER PRO DIVER also equipped with the ROYAL SL first stage. The AGA breathing valve, a balanced pilot second stage, never went into free flow. However, the U.S. DIVERS PRO DIVER second stage, a dynamically balanced down stream poppet valve went into free flow on every evaluation. The ROYAL SL first stage did have cotton diaphragms installed, but its performance after freezing was not as controlled as the USD CONSHELF (XIV) first stage used with the USD SE2. All other first stage regulators static pressures remained near preset standards.

The most precise intermediate static pressure control consistent to preset pressures was demonstrated by the SHERWOOD MAGNUM BLIZZARD.

b. First stage intermediate pressure control during one hour immersion: Once the breathing machine was started all first stage intermediate pressure returned to optimum, with the exception of the SEA SPORT ZEPHER ZR-01. In this case intermediate pressure increased to 175 psig from a preset value of 150 psig, shortly thereafter the regulator malfunctioned with the first stage freezing and the regulator attained free flow.

The AGA DIVATOR MK II/USD ROYAL SL, POSEIDON CYKLON 5000, ODIN, and THOR; SHERWOOD BLIZZARD, all continued to operate within preset first stage pressure ranges.

The US DIVER SE2 operated normally but on one instance pressures increased to a maximum of 190 psig, then dropped and maintained at 170 psig, this coincided with the occurrence of a slight free flow, but the evaluation was completed. The SCUBAPRO MK X/G-250 and TEKNA 2100 BX both consistently increased their overbottom pressure with MK X/G-250 rising to a maximum of 174 psig and TEKNA to 190 psig. The design characteristics of both second stages (the SCUBAPRO a balanced adjustable, the TEKNA a pilot) prevent the second stages going into free flow as a direct result of excessive first stage overbottom pressures.

4. <u>Second stage failure</u>

a. Second stage failure, due to excessively high first stage overbottom pressure: The U.S. DIVERS PRO DIVER was the only regulator specifically identified as having malfunctioned due to excessive first stage pressure. The US DIVER CONSHELF SE-2 (identical second stage to the PRO DIVER) did attain a slight free flow as previously mentioned where pressure went as high as 190 psig. However pressures returned to 170 psig and the regulator completed the evaluation without attaining a severe free flow.

b. Second stage failure, due to freezing of valve assembly: The POSEIDON 5000 (one occurrence), the SCUBAPRO MK X/G-250 (two occurrences), SEA SPORT ZEPHER ZR-01 (two occurrences), TEKNA 2100 BX (two occurrences) and US DIVER CONSHELF SE-2 (three occurrences) could be identified as having failed due to icing on second stage demand valve mechanisms. Specific cause, whether by condensed water vapor, residual moisture, humidified exhaled gas, etc. could not be precisely determined; however, both the SCUBAPRO MK X/G-250 and U.S. DIVERS SE-2 second stages had ice form on demand diaphragms in the area immediately adjacent to the exhaust valve and in the case of the SE-2 on the interior surface of the exhaust valve. This would tend to suggest some moisture may have entered due to splash back from the exhaust valve.

5. <u>Performance in cold water based on second stage design features</u>

a. Unbalanced/dynamically balanced demand poppet [POSEIDON CYLKON 5000, SHERWOOD MAGNUM BLIZZARD, U.S. DIVERS CONSHELF SE-2 (same as PRO DIVER)]: Comparing the performance of the SHERWOOD MAGNUM BLIZZARD second stage to the U.S. DIVERS CONSHELF SE-2 (both of similar structural design) would indicate the SHERWOOD MAGNUM BLIZZARD to be the superior of the two. The SHERWOOD teflon coated components and heat retention system were effective in preventing second stage malfunction under test conditions. The POSEIDON CYKLON 5000 second stage design (side mount inhalation/exhalation diaphragms, operation device linkage with ejector) was also considered effective.

b. Pneumatically balanced, demand poppet (SCUBAPRO MK X/G-250): The SCUBAPRO G-250 second stage did malfunction due to second stage icing. Its relative performance, being the only second stage in this category, is considered moderate. However, its balanced design was considered to have played an important role in preventing free flow, as first stage pressures rose from a preset value of 118 psig to as high as 176 psig during the immersion study.

c. Pilot/Servo (AGA DIVATOR MK II Breathing Valve with AGA Mouthpiece, POSEIDON ODIN, POSEIDON THOR, SEA SPORT ZEPHER ZR-01, TEKNA 2100BX): The SEA SPORT ZEPHER ZR-01 and TEKNA 2100BX second stages were both identified to have malfunctioned due to icing. The AGA MK II breathing valve, POSEIDON second stage in the POSEIDON ODIN and THOR (both identical second stages) could not be specifically identified as having failed due to icing during the immersion study. In any case these second stages clearly out performed the SEA SPORT ZEPHER and TEKNA and are considered to be effective.

6. <u>Total performance rating in cold water</u>. Based on performance during cold water function evaluations the 10 open circuit SCUBA regulators are grouped in the following performance categories (present in alpha-numerical sequence):

a. Superior Performance:

AGA DIVATOR MK II Breathing Valve with AGA Mouthpiece/U.S. DIVERS ROYAL SL First Stage

POSEIDON CYKLON 5000

POSEIDON ODIN

POSEIDON THOR

SHERWOOD MAGNUM BLIZZARD

b. Moderate Performance:

SCUBAPRO MK X/G-250

c. Unacceptable:

SEA SPORT ZEPHER ZR-01

TEKNA 2100 BX

U.S. DIVERS CONSHELF SE-2

U.S. DIVERS PRO DIVER

VI. CONCLUSIONS

A. U.S. DIVERS Cotton Backed Diaphragms. Results of studies conducted with the U.S. DIVERS CONSHELF XIV, first stage, clearly indicated that cotton backed diaphragms substantially enhanced the control of intermediate pressures after exposure to cold conditions.

B. Breathing Resistance/Work of Breathing. In all cases, breathing resistance and the work of breathing values, of regulators equipped with cold water conversion kits or silicon grease, increased as a direct result of the modifications. Although total effects varied, all units evaluated were considered to be functionally safe at all depths up to 198 FSW.

C. Cold Water Function. Ten regulators were evaluated under laboratory conditions and grouped into three distinct performance categories. The results indicated a strong interdependence between first and second stages performance. In instances where first stage intermediate pressures rose excessively high immediately after freezing or during the immersion exposure, the use of pneumatically balanced second stages prevented total system failure.

During immersion studies, diaphragm first stage regulators provided greater consistency of control on overbottom pressures in comparison to piston regulators that use environmental silicon grease. Additionally, diaphragm units recorded no external freezes while silicon injected units did. Piston regulators required continuous checks and maintenance for extrusion of grease while diaphragm units suffered no extrusions. Materials used in the manufacture of main first stage diaphragms should be specifically selected to provide maximum flexibility and minimum rigidity during exposure to cold.

Second stage regulators of a conventional design (U.S. DIVERS and SCUBAPRO), exempting SHERWOOD, were consistently out performed by regulators of unconventional design (AGA, POSEIDON) that utilized balanced pilot/servo assist mechanisms. These units also incorporated features that lessened the effects of moisture and cold via the use of plastics, rubber valve sleeves, check valves, reduced area of exposed mechanical linkage, and removal of primary second stage actuation devices from the immediate and direct path of exhaled gases and splash back (moisture residue) from exhaust valves.

Overall, five regulators were considered superior performers, one considered moderate, and four unacceptable. It is emphasized that regardless of a regulators superior performance, proper standard operating procedures for cold water operations should always be followed.

PART III - MANNED TESTING: HUMAN FACTORS OPEN WATER STUDIES

I. INTRODUCTION

From August through September 1986, NEDU conducted manned human factor open water studies on selected commercially available open circuit SCUBA regulators. A total of 11 regulator model/systems were evaluated under open water conditions. This was a follow on evaluation, complimenting Phase One and Two. The evaluation was <u>subjective</u> in nature. Those regulator model/systems selected for the study are listed in Table 10.

II. MANNED TEST PROCEDURE

Human evaluation was conducted per NEDU Test Plan 86-18, reference (h). During the evaluation 156 dives were conducted. Maximum depth of dives was to 130 FSW. Diver-subjects completed a regulator questionnaire and entered appropriate remarks on the conclusion of each dive.

III. MANNED TEST RESULTS

Manned test results are contained in table format and classified into three categories. Responses required a numerical score or a YES/NO answer. Tables are as follows:

A. Table 11 - Physical Characteristic - Numerical Rating

B. Table 12 - Breathing Performance - Numerical Rating

C. Table 13 - General Regulator Function - YES/NO Rating

IV. DISCUSSION

A. <u>Physical Characteristics</u>. Subjective responses indicated diver-subjects rated regulators from not quite adequate to good. Total averaging, however, indicated regulators performed at an adequate or good level. Highest scores went to the U.S. DIVERS CONSHELF SE-2 and PRO DIVER with the AGA DIVATOR MK II breathing valve with AGA mouthpiece and U.S. DIVERS ROYAL SL first stage following closely. Lowest marks were assigned to SEA SPORT ZEPHER ZR-01.

B. <u>Breathing Performance</u>. Total average scores of subjective responses indicated the highest rating assigned to the U.S. DIVERS CONSHELF SE-2 and PRO DIVER, followed very closely by the AGA DIVATOR MK II with AGA mouthpiece/U.S. DIVER ROYAL SL first stage and the SCUBAPRO MK X/G-250. Lowest scores were assigned to SEA SPORT ZEPHER ZR-01 at the not quite adequate level.

Table 10

REGULATOR MODELS AND SYSTEMS SELECTED FOR MANNED HUMAN FACTORS EVALUATION

1. AGA DIVATOR MK II (Full Face Mask) Used With U.S. DIVERS ROYAL SL First Stage (System)
2. AGA DIVATOR MK II Breathing Valve Equipped With AGA Mouthpiece Used With U.S. DIVERS ROYAL SL First Stage (System)
3. POSEIDON CYKLON 5000
4. POSEIDON ODIN
5. POSEIDON THOR
6. SCUBAPRO MK X/G-250
7. SEA SPORT ZEPHER ZR-01
8. SHERWOOD MAGNUM BLIZZARD
9. TEKNA 2100 BX
10. U.S. DIVERS CONSHELF SE-2
11. U.S. DIVERS PRO DIVER

TABLE 11
PHYSICAL CHARACTERISTICS
(MANNED SCUBA REGULATOR EVALUATION)
NUMERICAL

		NUMBER OF DIVES	MOUTH-PIECE (COMFORT)	2ND STAGE BUOYANCY	2ND STAGE RANGE OF MOTION	BUBBLE DISPER-SION	AIR HOSE LENGTH	1ST STAGE DURA-BILITY	2ND STAGE DURA-BILITY	AIR HOSE DURA-BILITY	PURGE BUTTON OPER-ATION	2ND STAGE ADJUST-MENT	1ST STAGE ADJUST-MENT	DIAL-A-BREATH/ DEFLEC-TOR	REGU-LATOR RATING	TOTAL AVERAGE
I	AGA DIVATOR MK II W/MP USD ROYAL SL 1ST STAGE	15	4.86	5.06	5.2	4.86	4.86	5	4.73	4.93	5.2	N/A	5	N/A	5.1	4.98
II	AGA DIVATOR MK II W/FFM USD ROYAL SL 1ST STAGE	15	N/A	4.06	4.73	4.93	4.73	5	4.65	4.86	4.9	N/A	5	N/A	4.66	4.75
III	POSEIDON CYKLON 5000	16	3.6	4.53	3.93	4.46	3.96	4.6	4.53	4.73	4.93	N/A	5	N/A	3.86	4.38
IV	POSEIDON ODIN	13	4.07	4.38	4.38	4.30	4.53	4.23	4.15	4.53	3.76	N/A	5	N/A	3.5	4.26
V	POSEIDON THOR	12	4.04	4.5	4.25	4.16	4.12	4.29	4	4.33	3.66	N/A	5	N/A	3.8	4.20
VI	SCUBAPRO MK X/G-250	14	4.53	4.64	4.71	4.75	4.78	4.35	4.78	4.78	4.85	4	3	4.53	4.89	4.56
VII	SEA SPORT ZEPHER ZR-01	13	4.03	4.38	4.46	4.61	4.46	4.23	3.76	4.46	4.30	N/A	4	N/A	3.03	4.16
VIII	SHERWOOD MAGNUM BLIZZARD	14	4.07	4.42	4.71	4.82	4.60	4.42	4.14	4.64	4.57	4	3	N/A	4	4.28
IX	TEKNA 2100 BX	12	3.75	4.58	4.5	4.83	4.66	4.58	4.25	4.70	4.62	N/A	4	N/A	3.87	4.39
X	U.S. DIVERS CONSHELF SE-2	15	6.26	5.2	5	4.93	4.8	5.13	5.06	5.26	5.2	5	5	N/A	5.43	5.12
XI	U.S. DIVERS PRO DIVER	17	5.05	4.88	5.05	5	4.94	5.23	5.11	5.11	5.29	5	5	N/A	5.32	5.08

1. EXTREMELY POOR
2. POOR
3. NOT QUITE ADEQUATE
4. ADEQUATE
5. GOOD
6. EXCELLENT

TABLE 12
BREATHING PERFORMANCE RATING
(MANNED SCUBA REGULATOR EVALUATION)
NUMERICAL

		NUMBER OF DIVES	UP-RIGHT POSITION		45° FACE UP POSITION		45° FACE DOWN POSITION		FULL DOWN HEAD POSITION		PRONE POSITION		SUPINE POSITION		135° HEAD DOWN POSITION		135° HEAD UP POSITION		AVERAGE SCORE		TOTAL AVERAGE
			IN	EX	IN	EX	IN	EX	IN	EX	IN	EX	IN	EX	IN	EX	IN	EX	IN	EX	
I	AGA DIVATOR MK II W/HP USD ROYAL SL 1ST STAGE	15	5.13	5.33	5.06	5.33	5.06	5.33	5	5.33	5.13	5.33	5.06	5.33	5.2	5.33	5.2	5.33	5.10	5.33	5.22
II	AGA DIVATOR MK II W/FFM USD ROYAL SL 1ST STAGE	15	4.83	4.83	4.76	4.8	4.96	4.9	5	5	5.06	5	4.93	5	4.93	4.93	4.93	4.93	4.92	4.92	4.92
III	POSEIDON CYKLON 5000	16	4.68	4.81	4.62	4.62	4.5	4.81	4.43	4.68	4.56	4.75	4.37	4.68	4.37	4.68	4.5	4.68	4.5	4.74	4.62
IV	POSEIDON ODIN	13	4.15	4.53	4.15	4.53	4.15	4.53	4	4.53	4.23	4.61	3.92	4.38	3.92	4.38	3.92	4.38	4.05	4.48	4.27
V	POSEIDON THOR	12	4.36	4.63	4.18	4.63	4.36	4.45	4.27	4.63	4.27	4.63	4.09	4.63	4	4.54	4	4.54	4.19	4.59	4.39
VI	SCUBAPRO MK X/G-250	14	5.06	5.06	4.8	5.13	5	5.13	4.8	5.13	5.06	5.06	4.6	5.13	4.73	5.06	4.66	5.06	4.84	5.09	4.97
VII	SEA SPORT ZEPHER ZR-01	13	3.76	4.15	3.38	4.15	3.38	4.07	3.53	3.92	3.69	4.15	3.33	4.07	3.3	4.15	3.33	4.15	3.44	4.12	3.78
VIII	SHERWOOD MAGNUM BLIZZARD	14	4.21	4.57	4	4.57	4.21	4.57	4.14	4.5	4.28	4.5	4.07	4.57	3.92	4.64	3.92	4.64	4.09	4.57	4.33
IX	TEKNA 2100 BX	12	3.91	4.58	3.91	4.66	4.08	4.66	4	4.58	4	4.58	4.08	4.66	4	4.58	4	4.58	3.99	4.61	4.30
X	U.S. DIVERS CONSHELF SE-2	15	5.26	5.4	5.26	5.4	5.26	5.4	5.2	5.4	5.33	5.4	5.2	5.4	5.26	5.33	5.26	5.4	5.25	5.38	5.32
XI	U.S. DIVERS PRO DIVER	17	5.41	5.29	5.23	5.29	5.23	5.29	5.17	5.29	5.41	5.29	5.05	5.29	5.11	5.29	5.05	5.29	5.21	5.29	5.25

1. EXTREMELY POOR
2. POOR
3. NOT QUITE ADEQUATE
4. ADEQUATE
5. GOOD
6. EXCELLENT

TABLE 13
GENERAL REGULATOR FUNCTION
(MANNED SCUBA REGULATOR EVALUATION)
YES AND NO QUESTIONS

		NUMBER OF DIVES	DID THE REGULATOR INGEST WATER AT ANY TIME?		DID YOU EXPERIENCE WATER DRAG WHEN FREE SWIMMING?		DURING TOWED DIVER SCENARIO DID YOU EXPERIENCE EXCESSIVE DRAG?		DID THE REGULATOR FREE FLOW?		DOES THE 2ND STAGE FORCE AIR EXCESSIVELY TO THE DIVER?		DID YOU FEEL COMFORTABLE DIVING WITH THIS REGULATOR?	
			YES	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES	NO
I	AGA DIVATOR MK II W/MP USD ROYAL SL 1ST STAGE	15	0	15	0	15	1	N/A	2	13	1	14	14	1
II	AGA DIVATOR MK II W/FFM USD ROYAL SL 1ST STAGE	15	0	15	5	10	N/A	1	6	9	2	13	11	4
III	POSEIDON CYKLON 5000	16	3	13	1	15	1	N/A	2	14	3	13	9	7
IV	POSEIDON ODIN	13	1	12	4	9	1	N/A	6	7	5	8	9	4
V	POSEIDON THOR	12	3	9	1	11	1	N/A	5	7	4	8	10	2
VI	SCUBAPRO MK X/G-250	14	0	14	0	14	N/A	1	4	10	0	14	14	0
VII	SEA SPORT ZEPHER ZR-01	13	4	9	0	13	N/A	1	1	12	8	5	1	12
VIII	SHERWOOD MAGNUM BLIZZARD	14	3	11	0	14	N/A	1	5	9	2	12	12	2
IX	TEKNA 2100 BX	12	0	12	1	11	N/A	1	0	12	4	8	8	4
X	U.S. DIVERS CONSHELF SE-2	15	1	14	0	15	N/A	1	4	11	1	14	15	0
XI	U.S. DIVERS PRO DIVER	17	0	17	0	17	N/A	1	3	14	0	17	17	0

C. General Regulator Function. Overall favorable responses went with the AGA DIVATOR MK II breathing valve with AGA mouthpiece/U.S. DIVERS ROYAL SL first stage, SCUBAPRO MK X/G-250 and U.S. DIVERS CONSHELF SE-2 and PRO DIVER. The least favorable went to the SEA SPORT ZEPHER ZR-01.

NOTES: (1) Only one mechanical failure was recorded. The piston o-ring on the SCUBAPRO MK X first stage was scored and required replacement.

(2) The SEA SPORT ZEPHER ZR-01 pressed in air channel-way, on the second stage, was removed during the evaluation as it was considered a safety hazard. The channel-way could easily separate from the second stage case and possibly become lodged in the diver's airway.

V. CONCLUSION

The subjective human factors evaluation indicated that relatively, diver-subjects assigned high scores to AGA DIVATOR MK II breathing valve with AGA mouthpiece/U.S. DIVERS ROYAL SL first stage, AGA DIVATOR MK II full face mask/U.S. DIVERS ROYAL SL first stage, SCUBAPRO MK X/G-250, the U.S. DIVERS CONSHELF SE-2 and PRO DIVER.

Moderate scores to the POSEIDON CYKLON 5000, POSEIDON ODIN, POSEIDON THOR, SHERWOOD MAGNUM BLIZZARD and TEKNA 2100 BX.

Low scores to the SEA SPORT ZEPHER ZR-01.

Overall, regulators evaluated in this phase, with the exception of the SEA SPORT ZEPHER ZR-01 were considered to have operated at the adequate or good levels. The ZEPHER was considered to have operated at the not quite adequate level.

Regulators from Group E Performance Category Phase One: By subjective evaluation, the TEKNA 2100 BX is considered an adequate and safe regulator. The SEA SPORT ZEPHER ZR-01 in normal configuration, with air channel-way installed, was considered not quite adequate and unsafe.

ANNEX A

LIST OF REFERENCES

(a) NAVSEAINST 9597.1A, "Promulgation of List of Diving Equipments which are Authorized For Navy Use", Ser 00C31/888 dtd 14 August 1984.

(b) NAVSEA Task 85-08, "Commercial Open Circuit SCUBA Regulator Test & Evaluation" dtd 27 June 1985.

(c) NEDU Report 2-80, "Evaluation of Commercially Available Open Circuit SCUBA Regulators," James R. Middleton, March 1980.

(d) NEDU Report 3-81, "Standardized NEDU Unmanned UBA Test Procedures and Performance Goals," James R. Middleton, Edward D. Thalmann, CDR, MC, USN.

(e) MIL-R-24169B (SH) "Military Specification: Regulator, Air, Demand, Single Hose, Dives," dtd 22 February 1982.

(f) NEDU Test Plan 85-21, "Unmanned Evaluation of Commercially Available Open Circuit SCUBA Regulators," July 1985.

(g) NEDU Test Plan 86-13, "Unmanned Breathing Resistance and Cold Water Function Evaluation of Selected Open Circuit SCUBA Regulators Equipped With Low Temperature Conversion Kits," April 1986.

(h) NEDU Test Plan 86-18, "Manned Evaluation of Selected Commercially Available Open Circuit SCUBA Regulators," July 1986.

ANNEX B

LIST OF MANUFACTURERS

1. AGA/INTERSPIRO
   Intersiro AB
   S-181 81 Lidingo Sweden

   U.S. Distributor
   AGA/INTERSPIRO
   Pistol Shop Road
   Rockfall, Connecticut 06481
   Phone: 203-481-3899

2. CRESSI SUB
   677 S.W. First Street
   Miami, Florida 33130
   Phone: 305-545-9000

3. DACOR
   161 Northfield Road
   Northfield, Illinois 60093
   Phone: 312-446-9555

4. INTERNATIONAL DIVERS INC.
   14747 Artesia Boulevard
   Suite 5-A
   La Mirada, California 90638
   Phone: 714-994-3900

5. NEMROD
   P.O. De La Ribera, S/N
   Apart Ado, 51
   08420, Canovellas
   (Barcelona) Spain

6. OCEAN DYNAMICS
   363 W. Victoria Street
   Gardena, California 90248
   Phone: 213-538-9540

7. OCEANIC
   14275 Catalina Street
   San Leandro, California 94577
   Phone: 415-352-5001

8. PARKWAYS
   241 Raritan Street
   South Amboy, New Jersey 08879
   Phone: 201-721-5301

9. POSEIDON SYSTEMS
POSEIDON, Industri AB
Akeredsvagen 1
Box 850 S-421 08
Vastra Frolunda Sweden
Phone: 031-49 8440

U.S. Distributor
VIKING AMERICA INC.
55 Old South Avenue
Stratford, Connecticut 06497
Phone: 203-377-6974

NOTE: U.S. Distributorship for POSEIDON SYSTEMS shifted from PARKWAYS to POS DIVE to Viking America, Inc.

10. PRO SUB, INC.
341 East Alondra Boulevard
Gardena, California 90248
Phone: 1-800-222-7241

11. SCUBAPRO
3105 E. Harcourt
Rancho Dominguey, California 90221
Phone: 213-639-7850

12. SEA PRO
18030 S. Euclid Street
Fountain Valley, California 92708
Phone: 714-979-6730

13. SEA QUEST
2151-F Las Palmas Drive
Carlsbad, California 92009
Phone: 619-438-1101

14. SEA SPORT/SMY
P.O. Box 58828
Tukwila, Washington 98188
Phone: 206-575-0886

15. SHERWOOD
120 Church Street
P.O. Box 790
Lockport, New York 14094
Phone: 716-433-3891

16. SPORTSWAYS
2050 Laura
Huntington Park, California 90255
Phone: 213-587-4173

17. TABATA
P.O. Box 2429
Huntington Park, California 90255
Phone: 213-587-4173

18. TEKNA
P.O. Box 849
Belmont, California 94002
Phone: 415-592-4070

19. U.S. DIVERS
3323 W. Warner Avenue
Santa Ana, California 92799-5018
Phone: 714-540-8010

ANNEX C

Graphs: Unmanned Evaluation Breathing Resistance, Work of Breathing, and First Stage Pressure Drop

1. AGA DIVATOR MK II (Full Face Mask) Complete First and Second Stage with AGA Cylinder
2. AGA DIVATOR MK II (Full Face Mask) Used with U.S. DIVERS CONSHELF XIV First Stage (System)
3. AGA DIVATOR MK II (Full Face Mask) Used with U.S. DIVERS ROYAL SL First Stage (System)
4. AGA DIVATOR MK II Breathing Valve Equipped with AGA Mouthpiece Used with U.S. DIVERS ROYAL SL First Stage (System)
5. CRESSI SUB GALAXIE 105
6. CRESSI SUB POLARIS IV
7. DACOR PACER AERO 950 A
8. DACOR PACER XL 950
9. DACOR PACER XLE 360
10. INTERNATIONAL DIVERS INC. STAR II
11. INTERNATIONAL DIVERS INC. SUPER STAR II
12. NEMROD SATURN 300
13. NEMROD SATURN 300 PRO
14. OCEAN DYNAMICS RB-3000
15. OCEANIC OMEGA II
16. OCEANIC OMEGA II MAX FLOW
17. PARKWAYS ATLAS
18. CYKLON 300 Distributed by PARKWAYS - POSEIDON Systems Pre 1986 Model
19. CYKLON MAX II Distributed by PARKWAYS - POSEIDON Systems Pre 1986 Model
20. POSEIDON CYKLON 300 Distributed by POS DIVE - POSEIDON Systems 1986 Model

21. POSEIDON CYKLON 5000 Distributed by POS DIVE - POSEIDON Systems 1986 Model

22. POSEIDON ODIN Distributed by POS DIVE - POSEIDON Systems 1986 Model

23. POSEIDON THOR Distributed by POS DIVE - POSEIDON Systems 1986 Model

24. PRO SUB MAXAIR I

25. PRO SUB PROAIR I

26. SCUBAPRO MK III/High Performance

27. SCUBAPRO MK IX/Air I

28. SCUBAPRO MK IX/Balanced Adjustable

29. SCUBAPRO MK IX/High Performance

30. SCUBAPRO MK X/D 300

31. SCUBAPRO MK X/G-250

32. SCUBAPRO MK X/Adjustable

33. SCUBAPRO MK X/Air I

34. SCUBAPRO MK X/Air II

35. SCUBAPRO MK X/Balance Adjustable

36. SCUBAPRO MK X/High Performance

37. SEA PRO FSDS-10

38. SEA PRO FSDS-50

39. SEA QUEST AMF MARES MR 12 - III

40. SHERWOOD BRUT SRB 2100

41. SHERWOOD MAGNUM BLIZZARD SRB-3200

42. SHERWOOD MAGNUM II SRB-3300

43. SPORTSWAYS X-2

44. SPORTSWAYS X-3

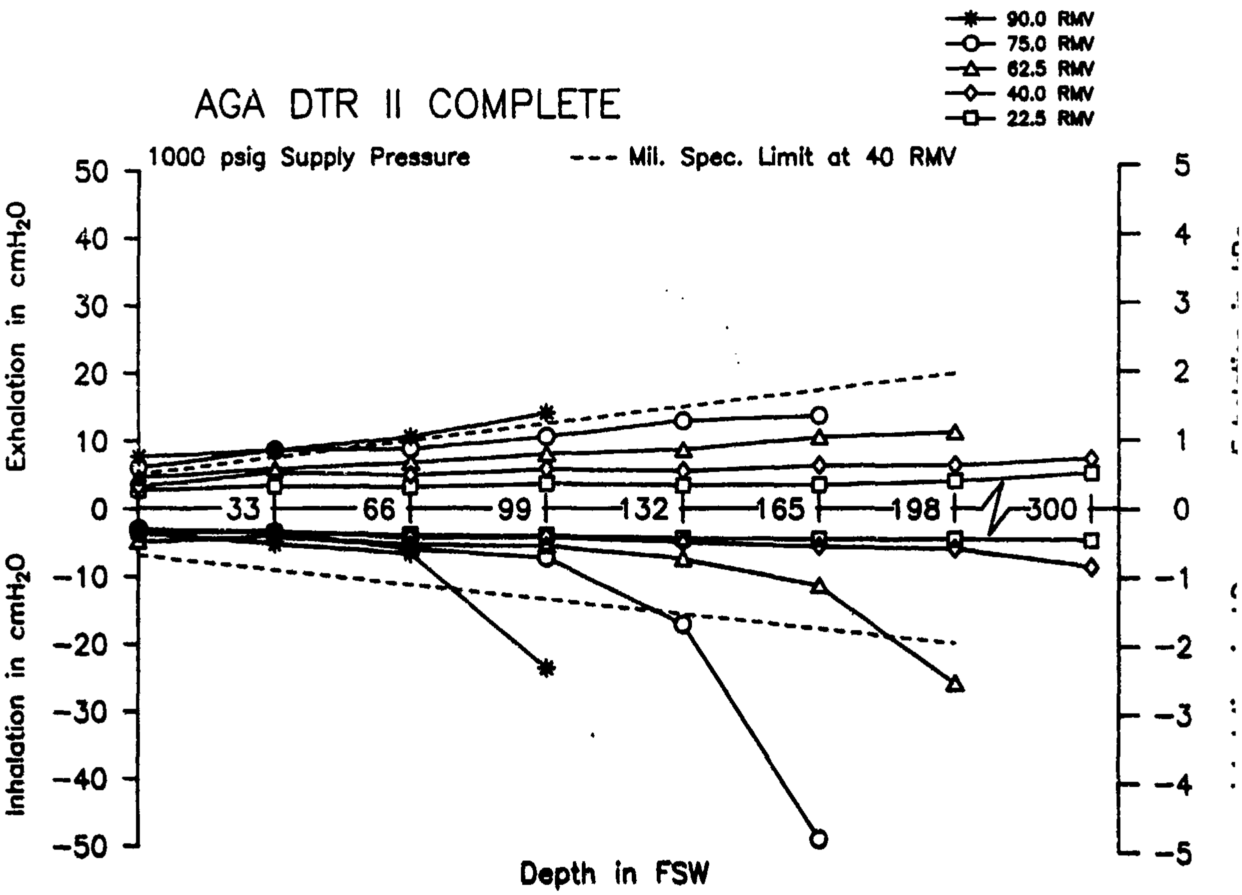
45. TABATA TR-100

46. U.S. DIVERS CONSHELF XIV

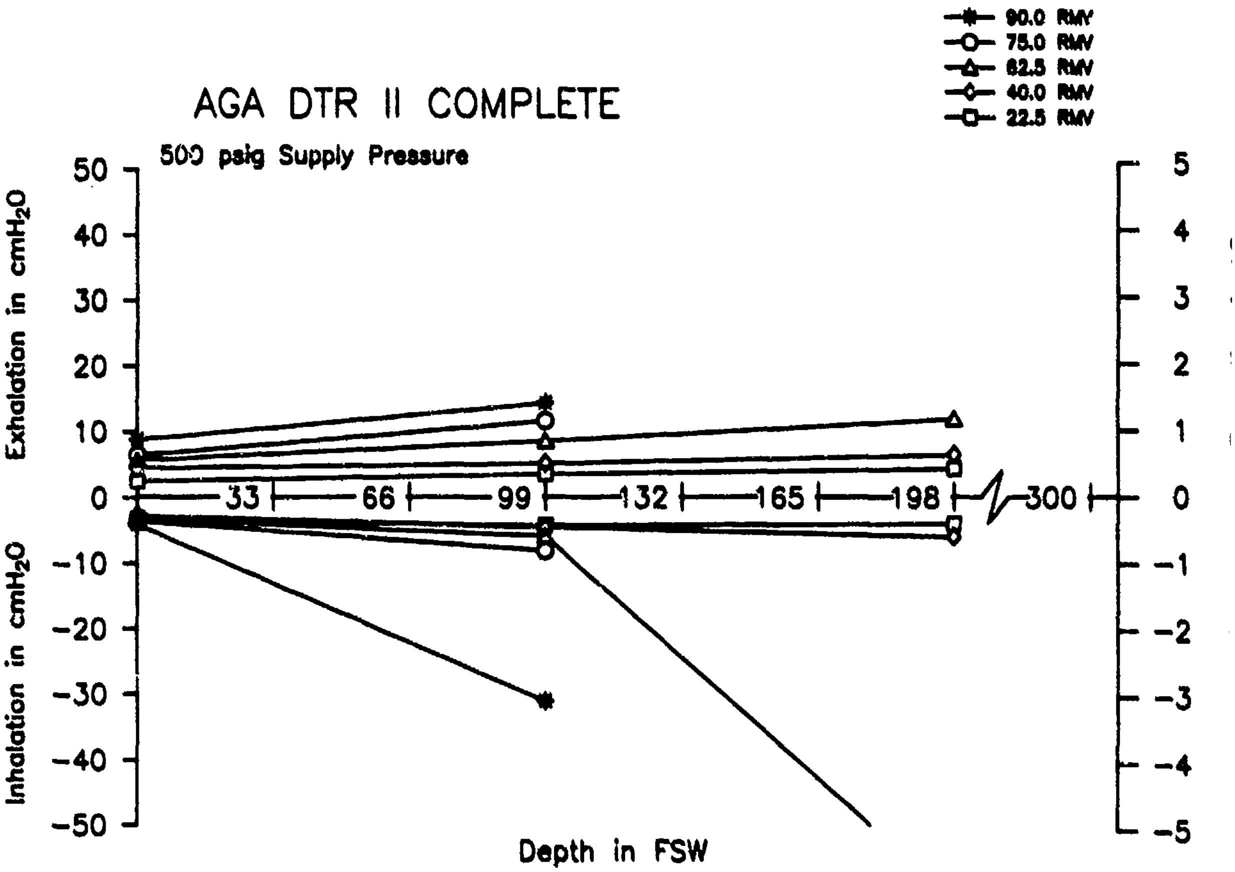
47. U.S. DIVERS CONSHELF 21

48. U.S. DIVERS CONSHELF SE2

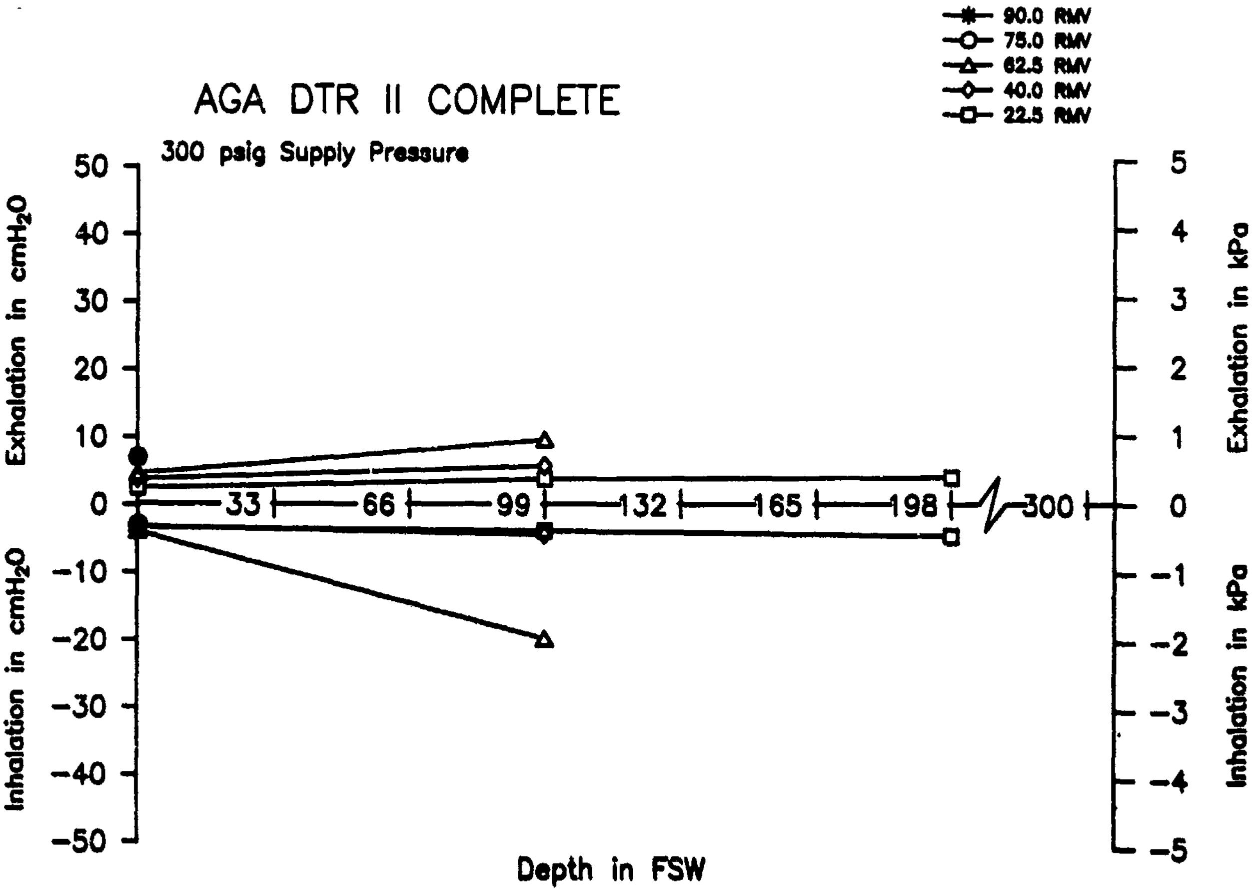
49. U.S. DIVERS PRO DIVER



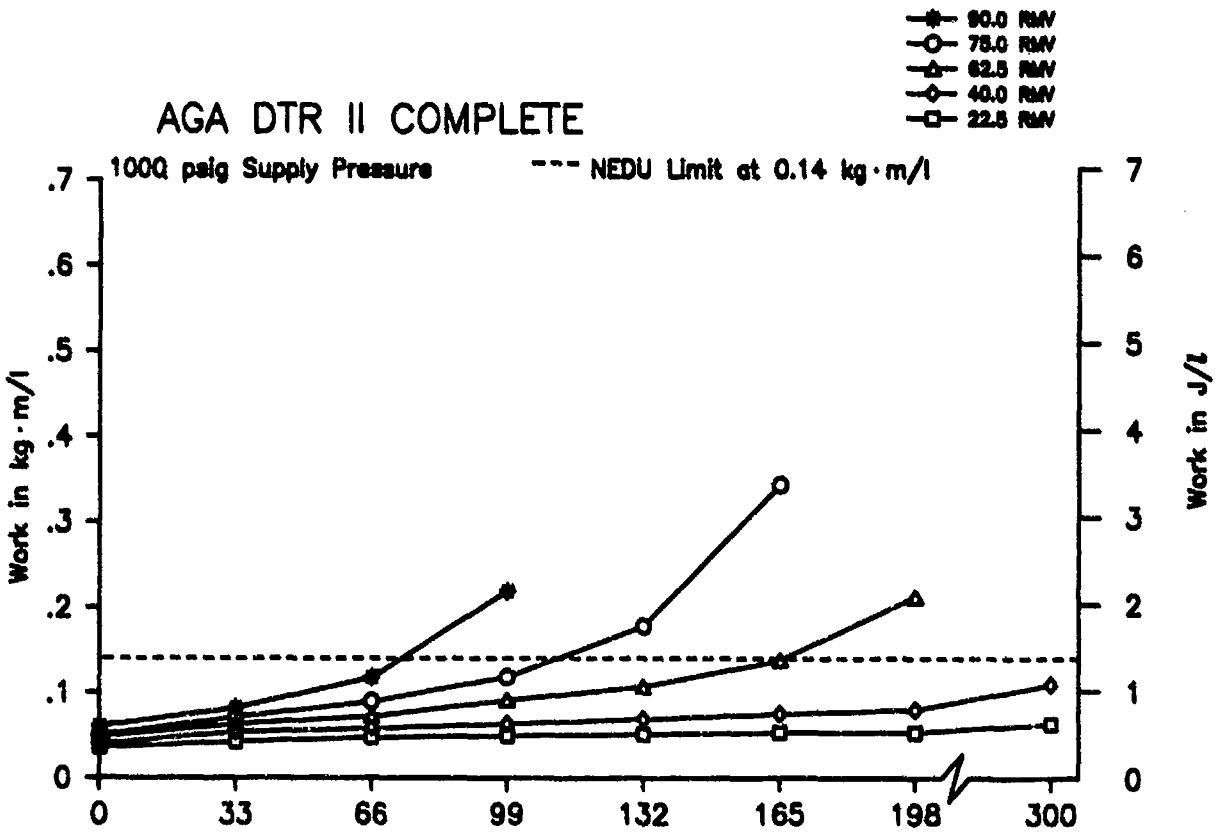
Breathing Resistance vs. Depth



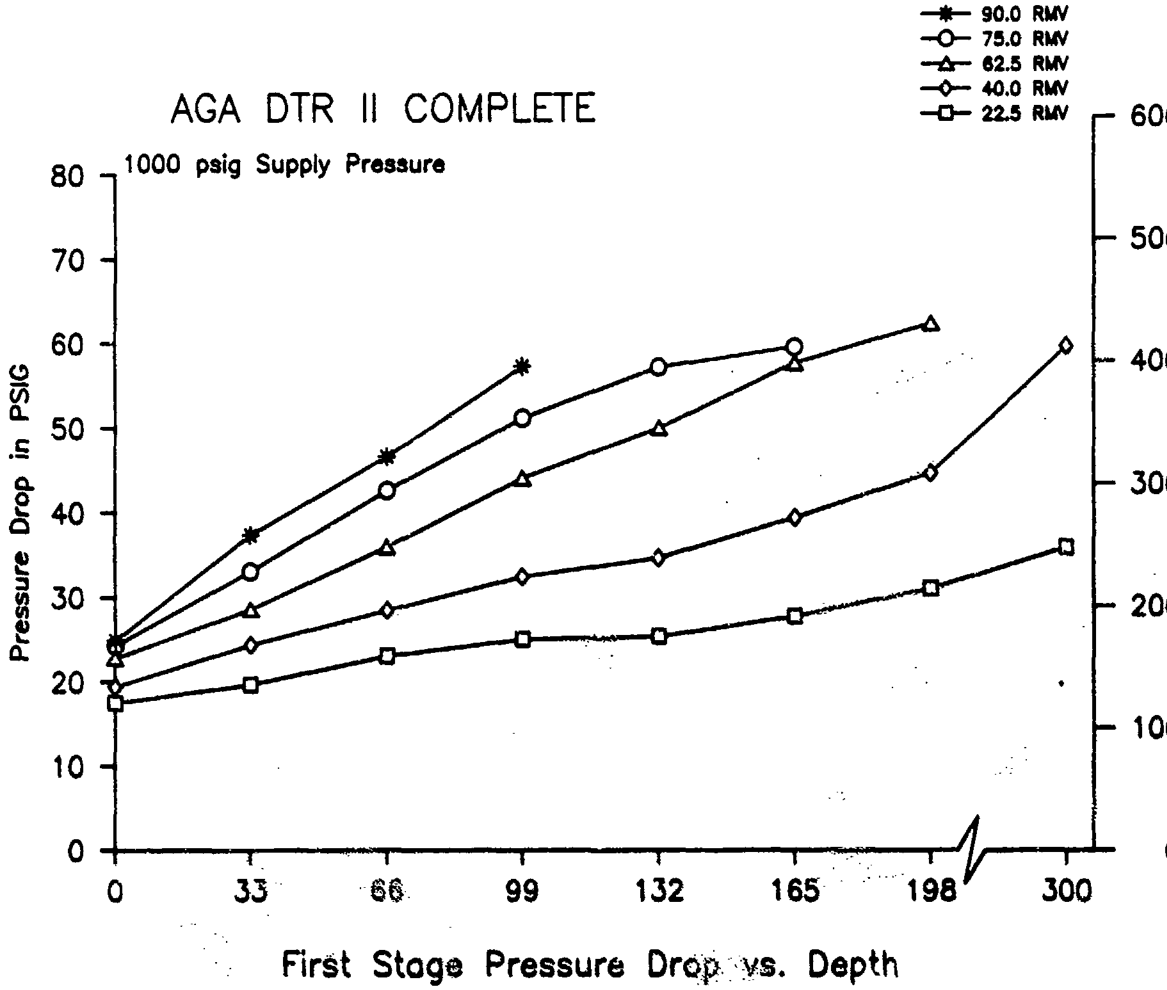
Breathing Resistance vs. Depth



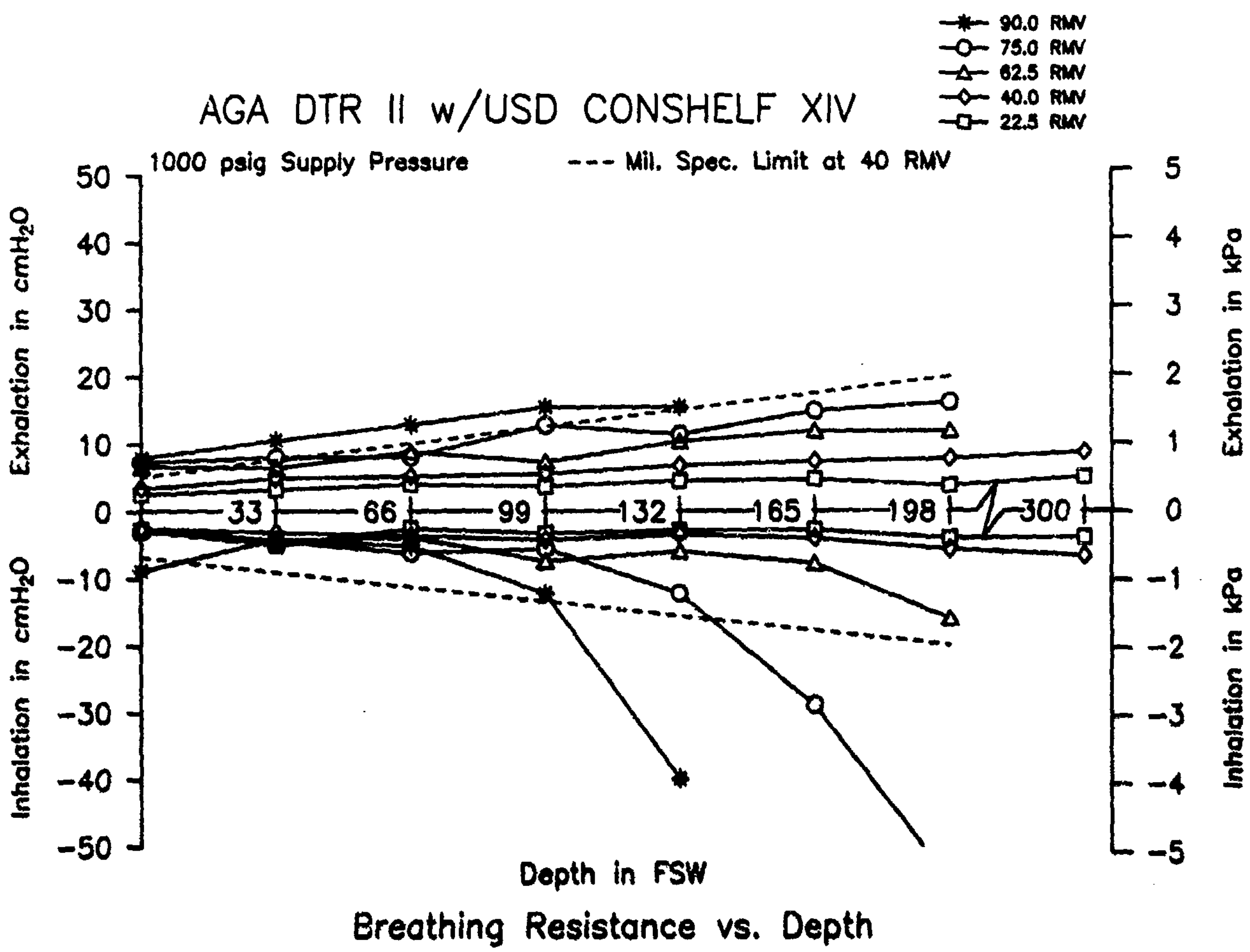
Breathing Resistance vs. Depth



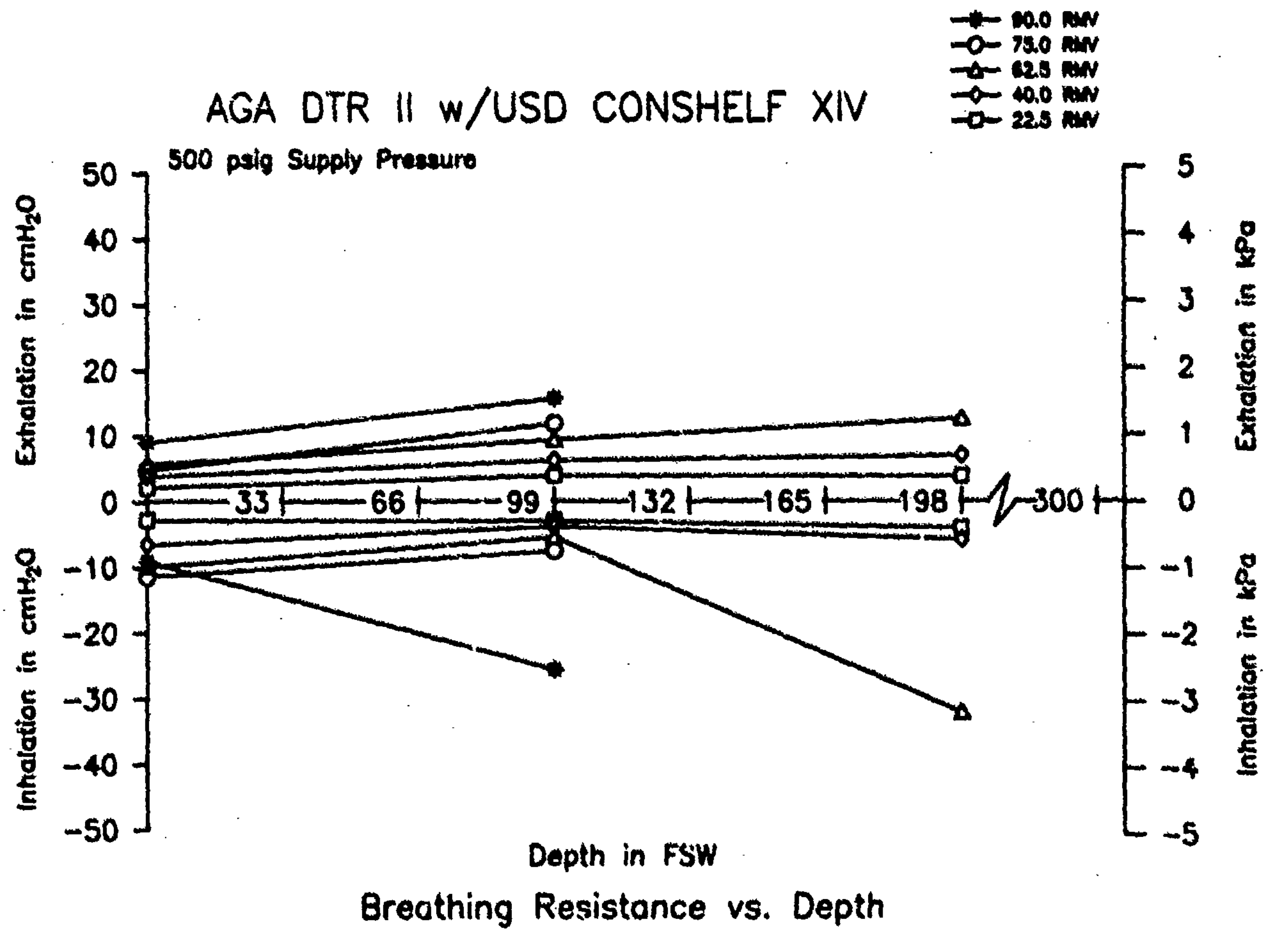
Breathing Work vs. Depth



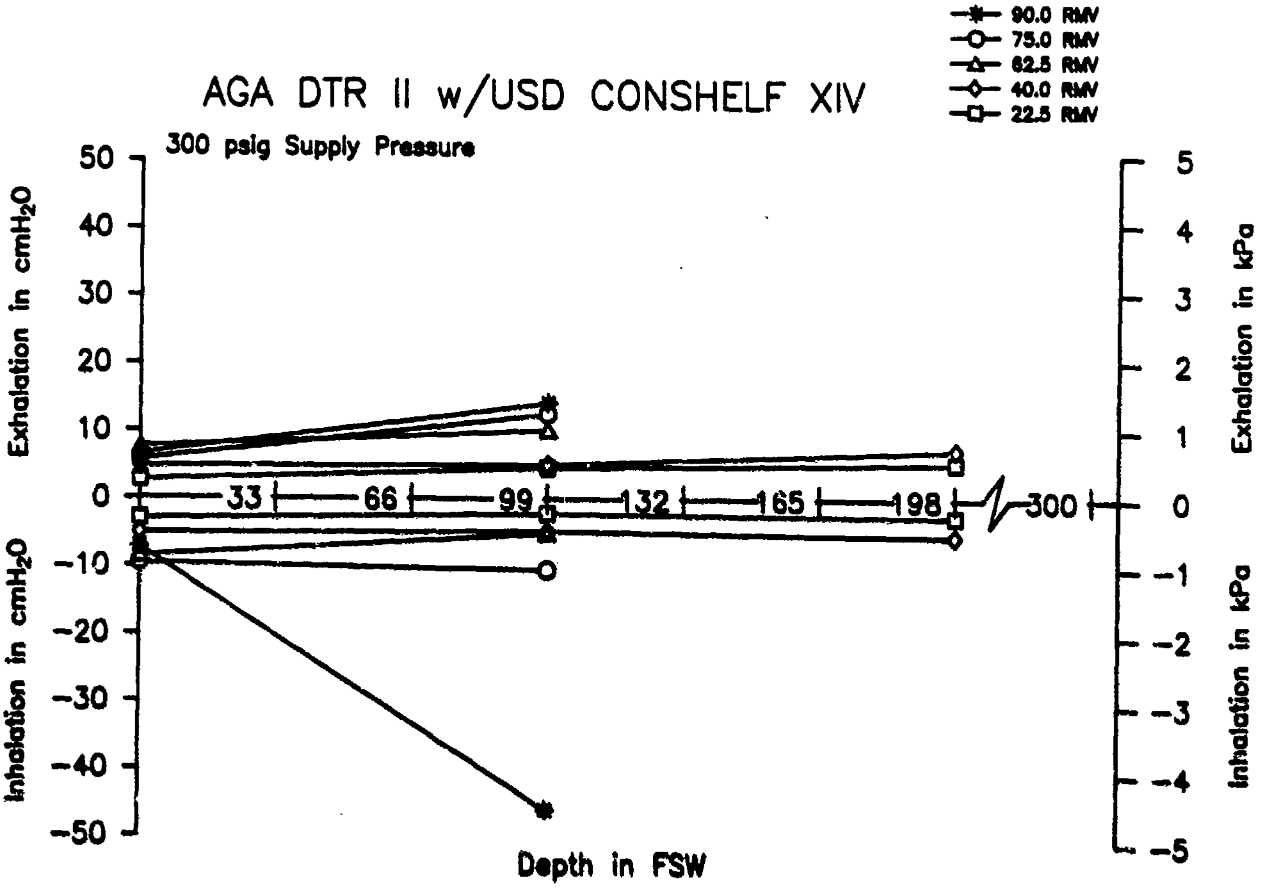
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
AGA DTR II COMPLETE
1000 psig Supply Pressure
Pressure Drop in PSIG
80
70
60
50
40
30
20
10
0
600
500
400
300
200
100
0
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth



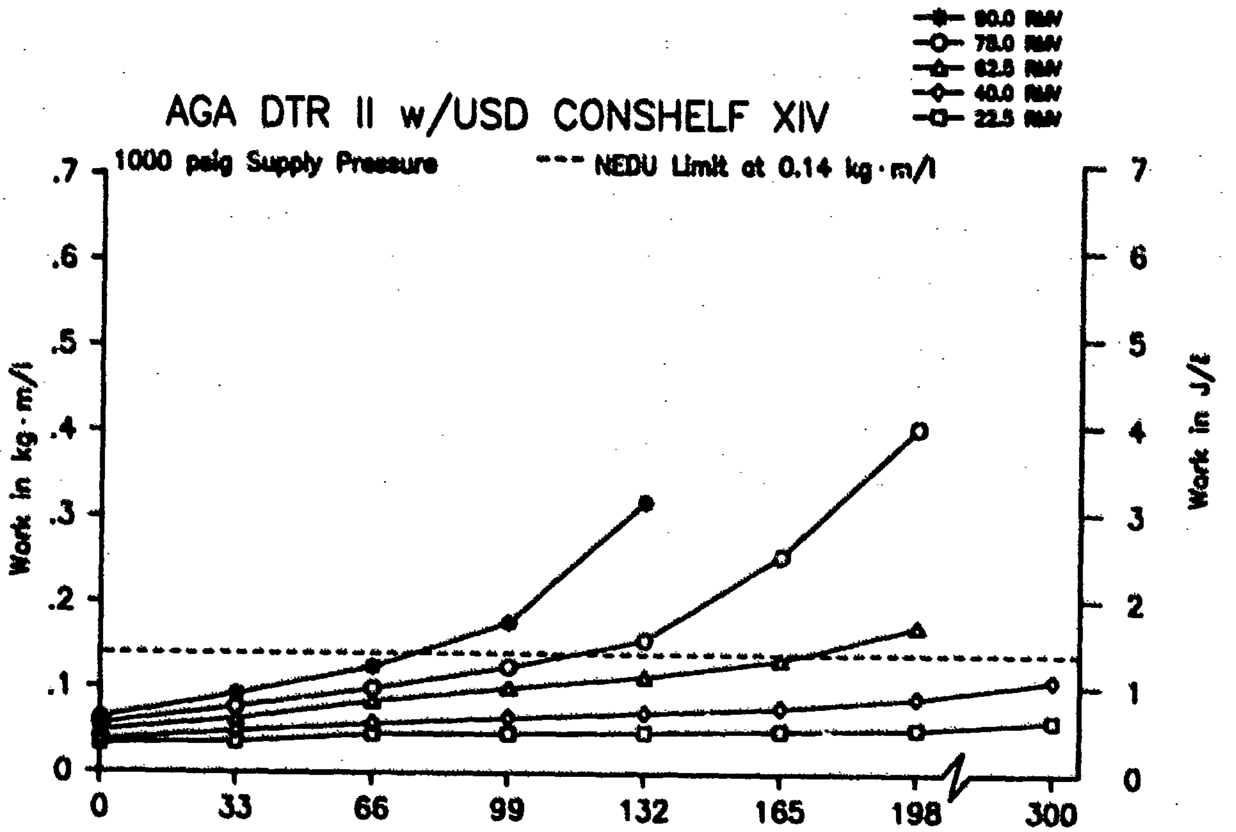
AGA DTR II w/USD CONSHELF XIV
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
-10
-20
-30
-40
-50
5
4
3
2
1
0
-1
-2
-3
-4
-5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



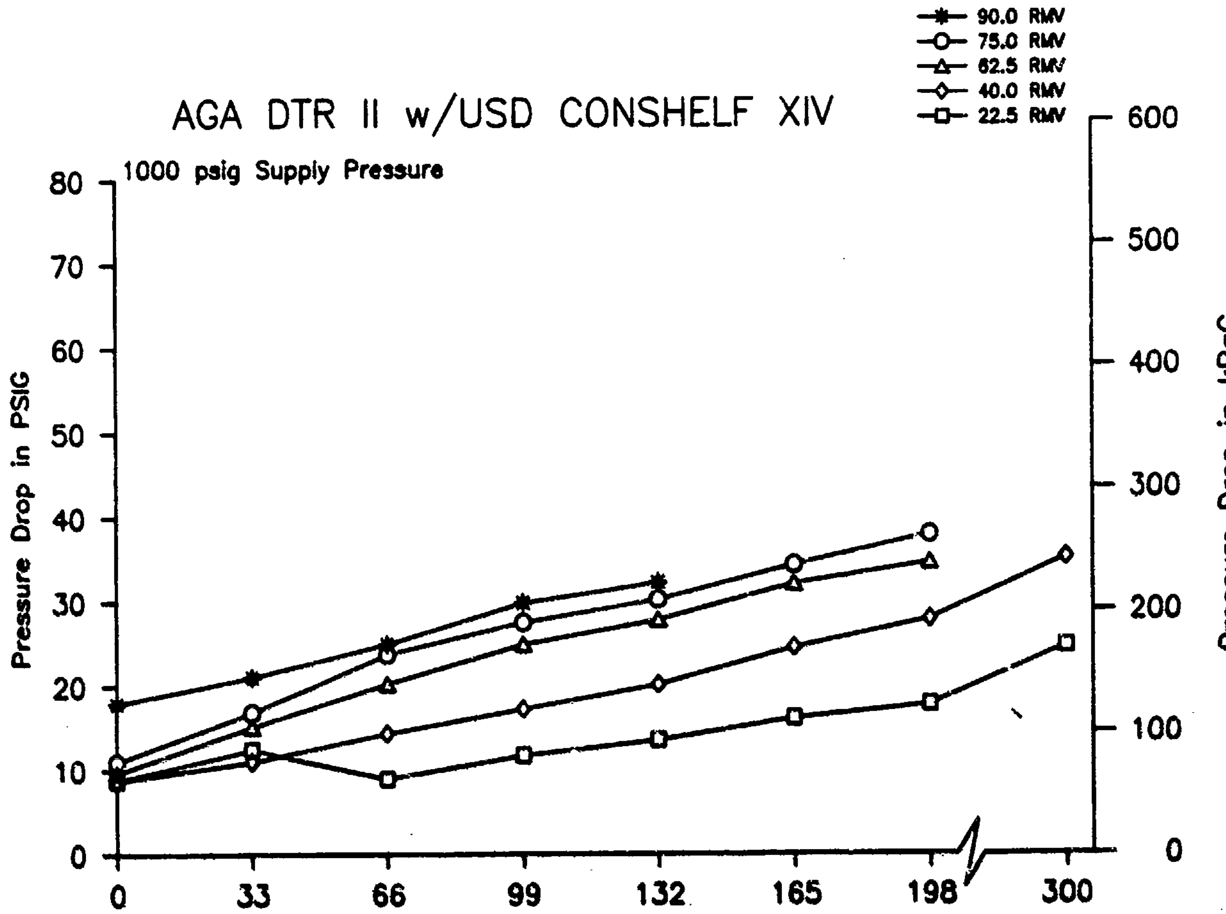
AGA DTR II w/USD CONSHELF XIV
500 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
-10
-20
-30
-40
-50
5
4
3
2
1
0
-1
-2
-3
-4
-5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



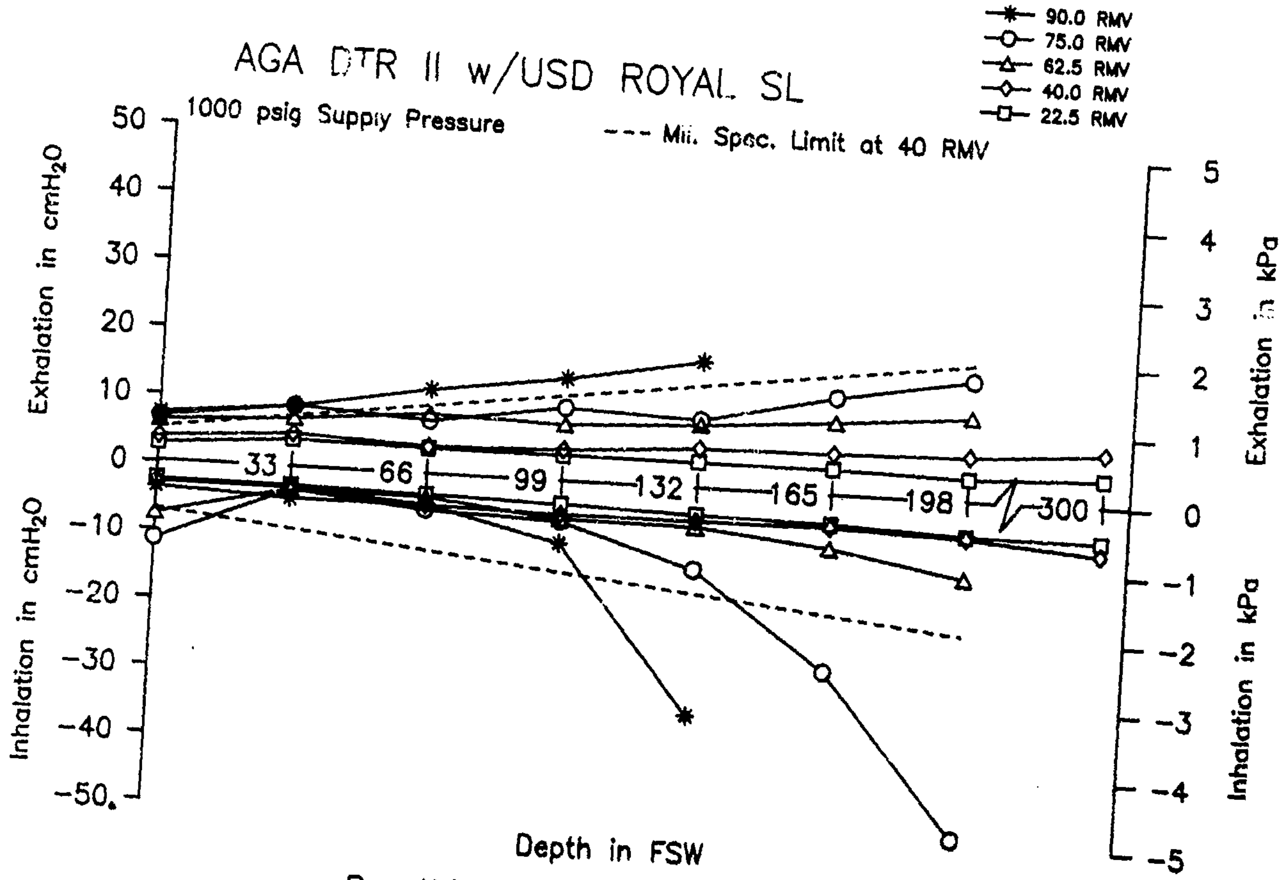
Breathing Resistance vs. Depth



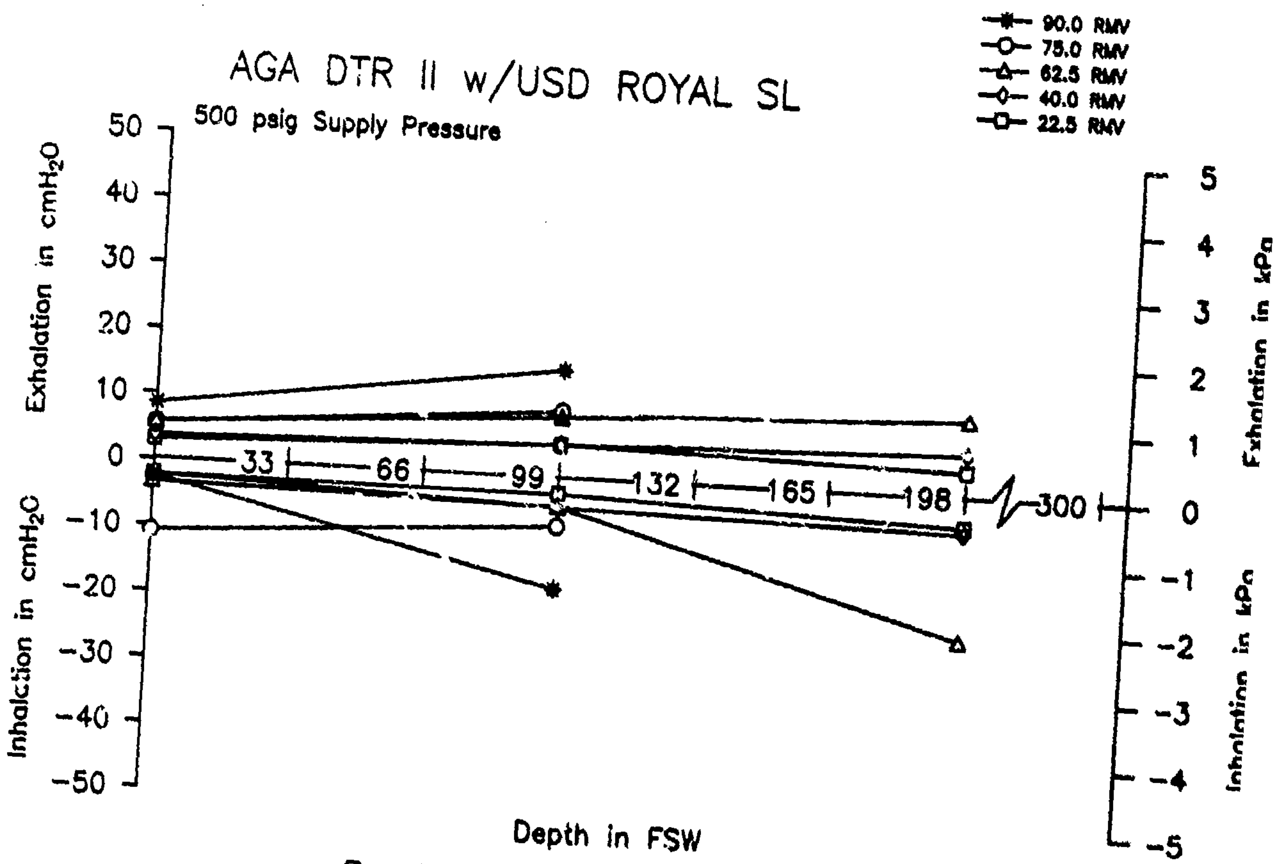
Breathing Work vs. Depth



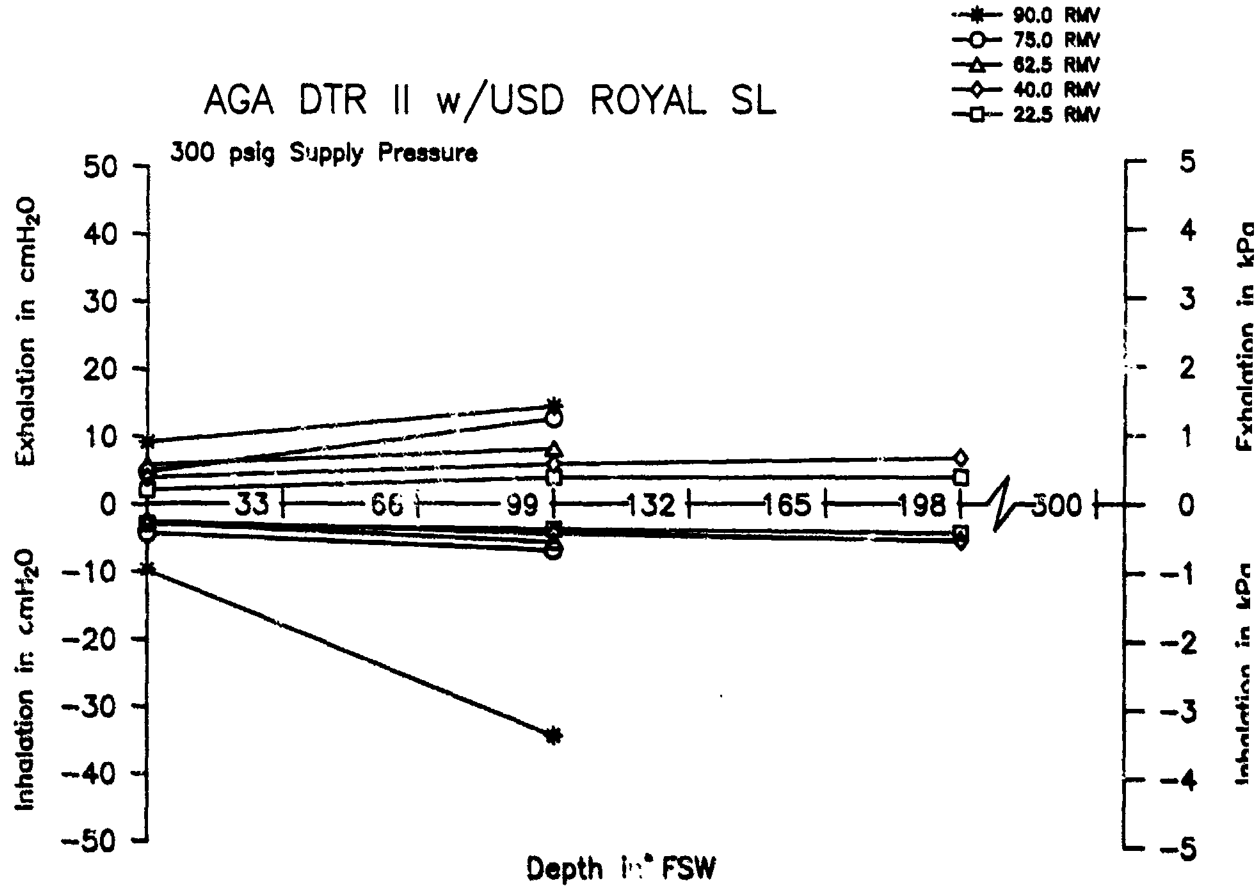
First Stage Pressure Drop vs. Depth



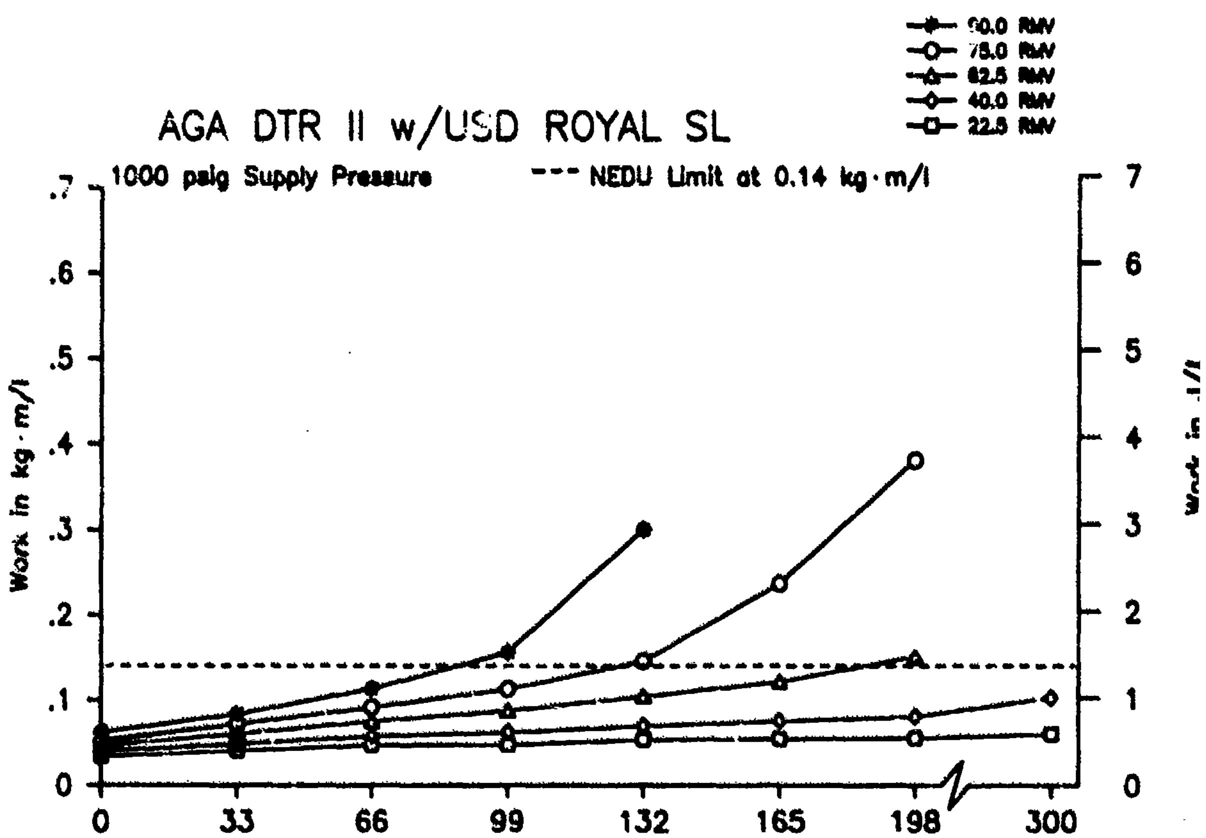
Breathing Resistance vs. Depth



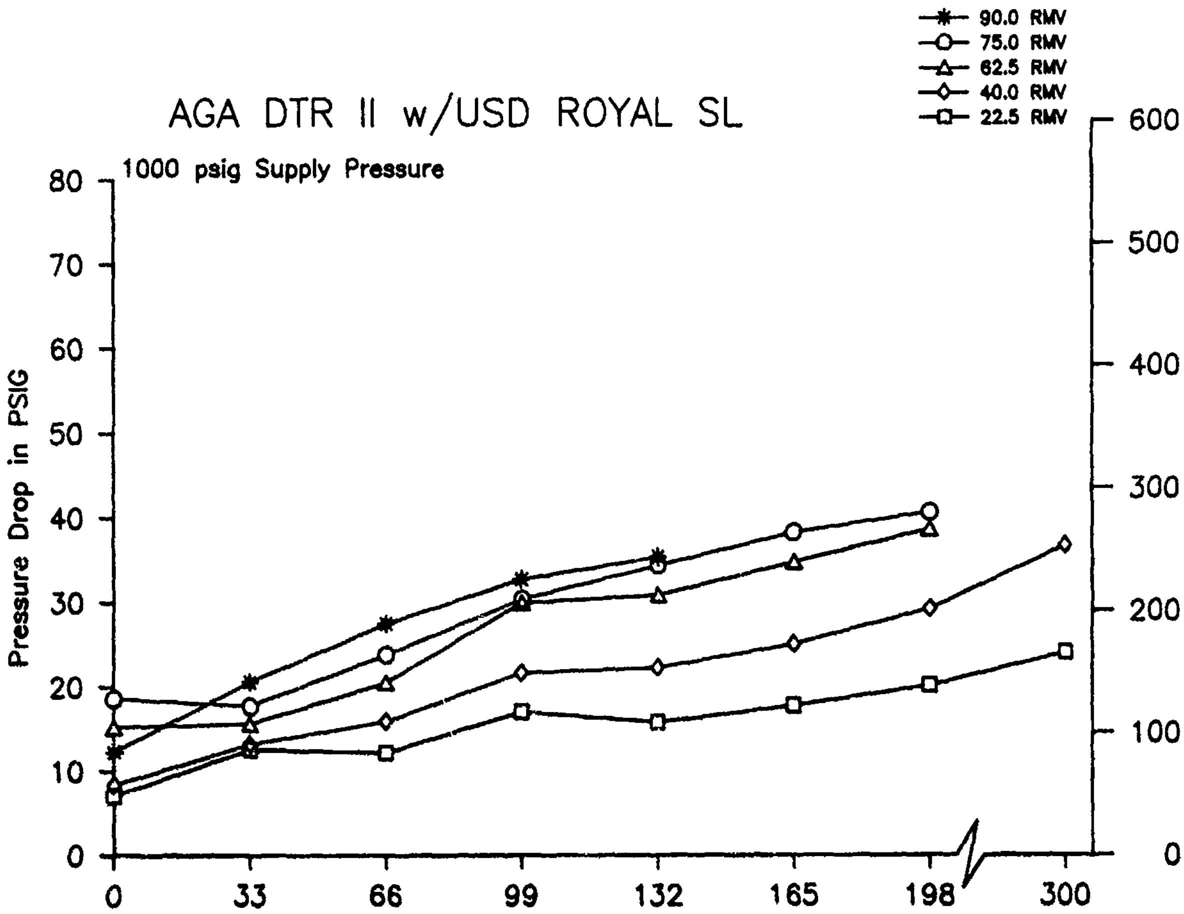
Breathing Resistance vs. Depth



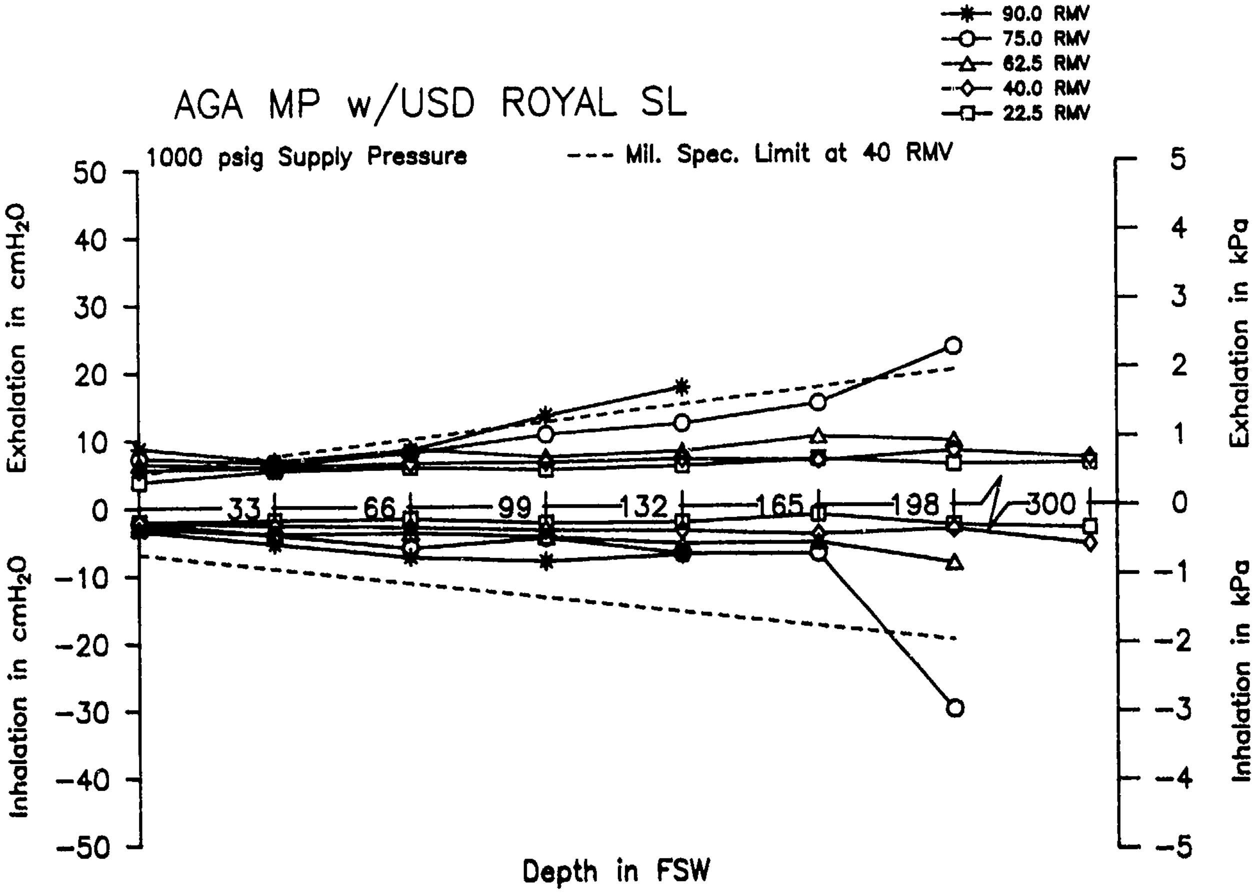
Breathing Resistance vs. Depth



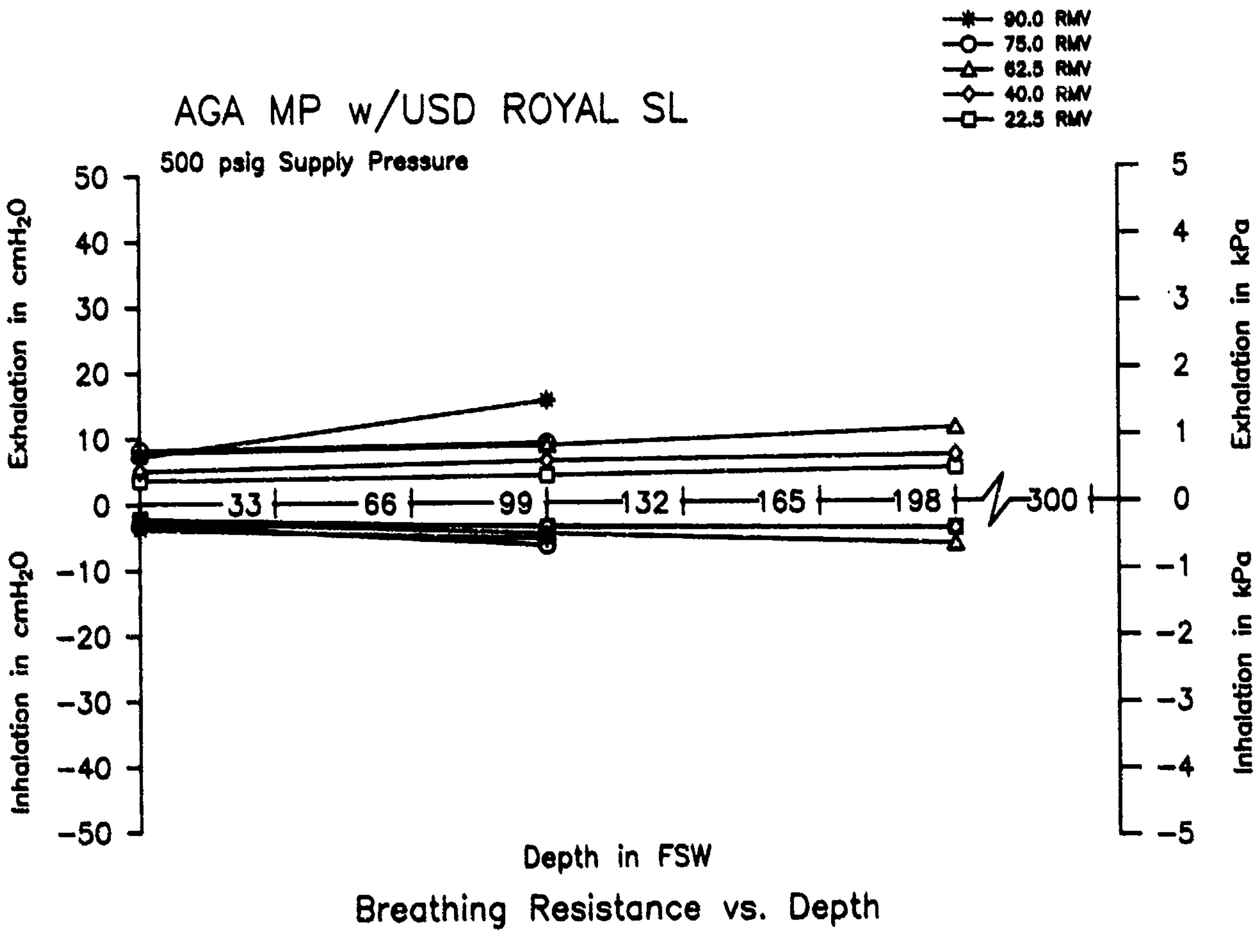
Breathing Work vs. Depth



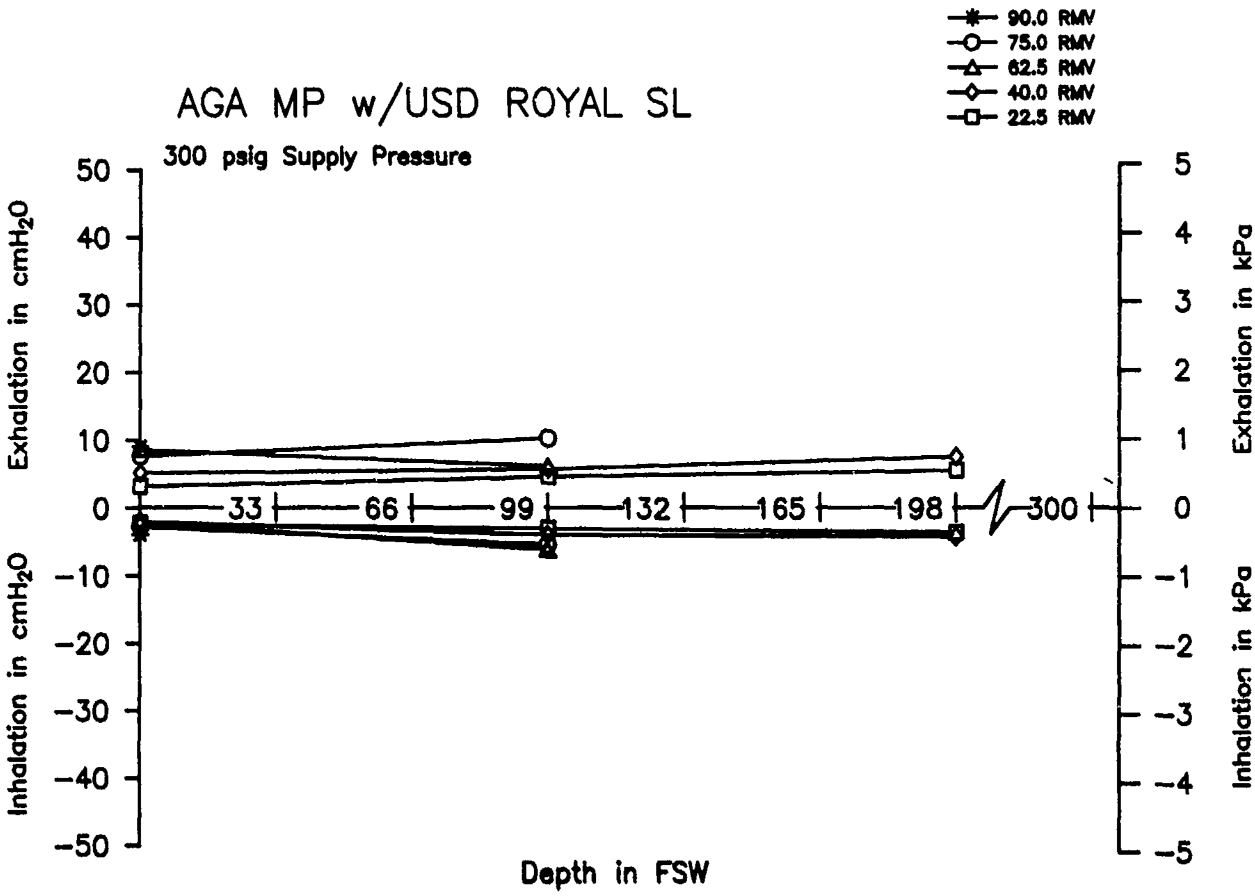
First Stage Pressure Drop vs. Depth



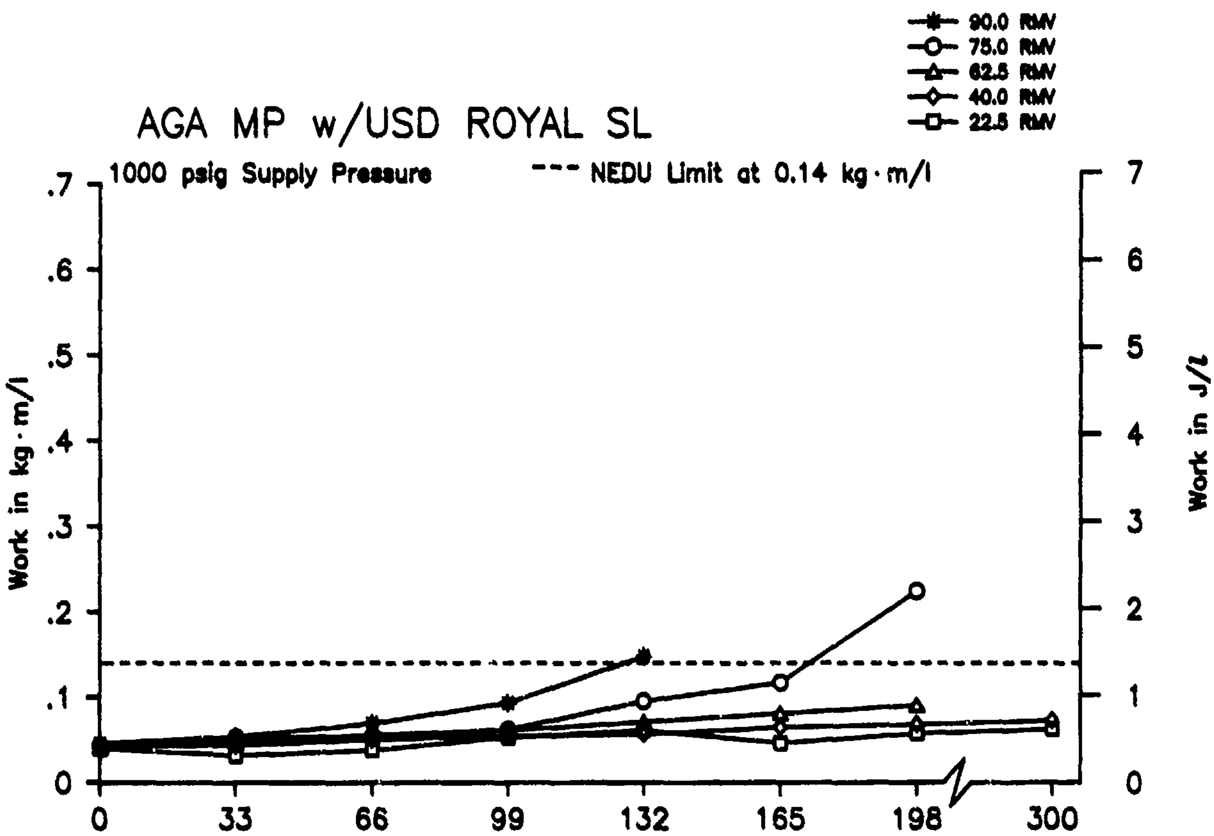
Breathing Resistance vs. Depth



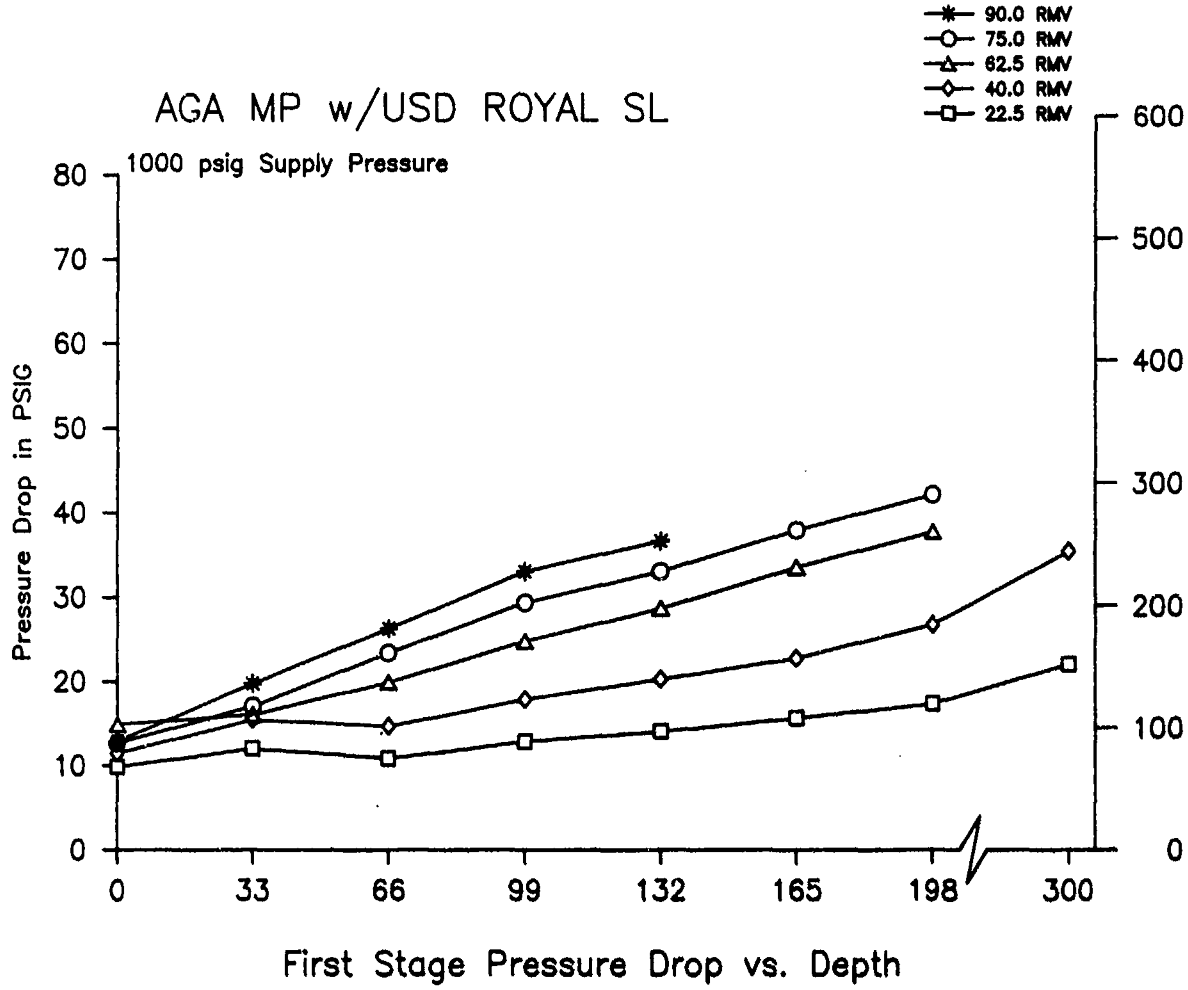
Breathing Resistance vs. Depth

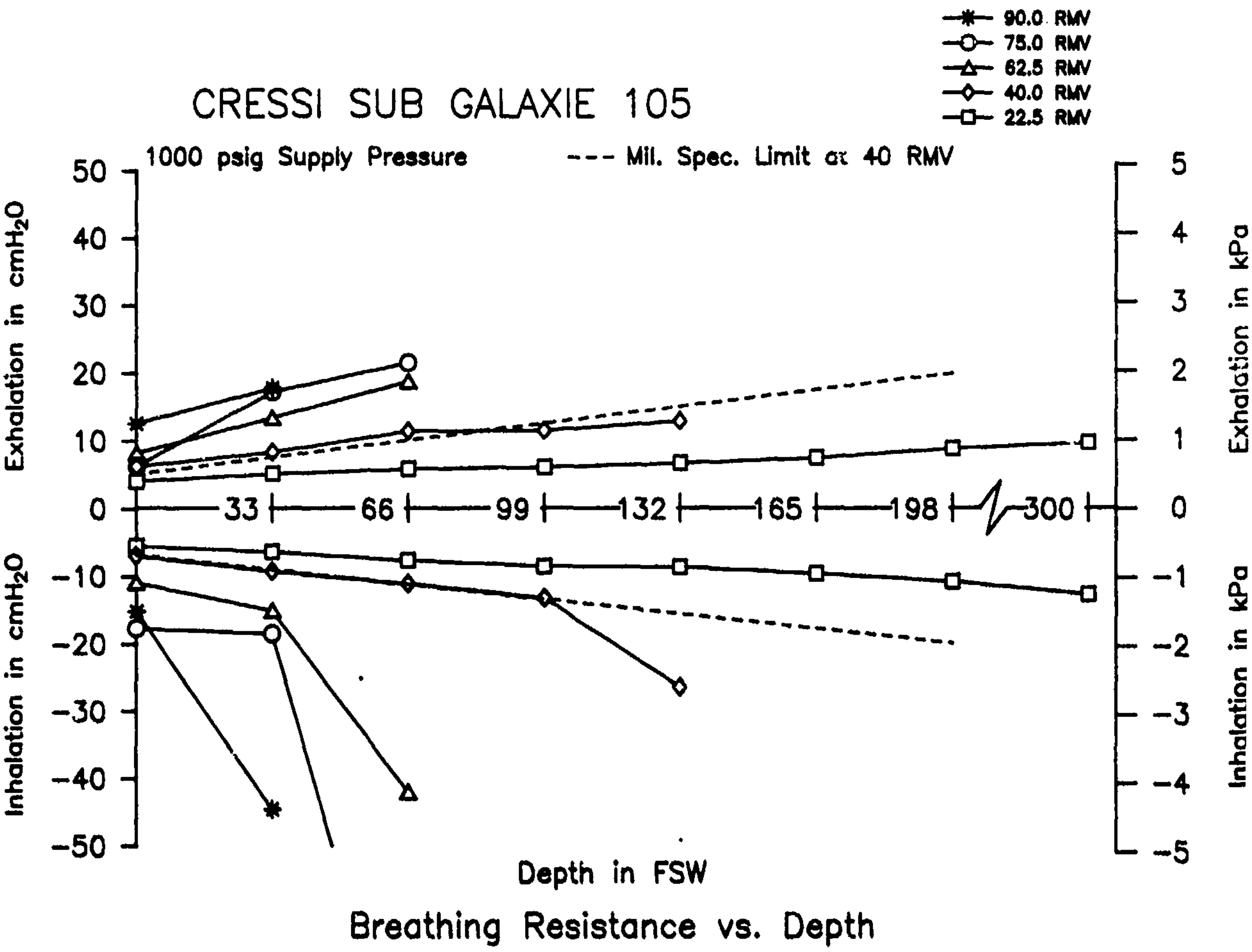


Breathing Resistance vs. Depth

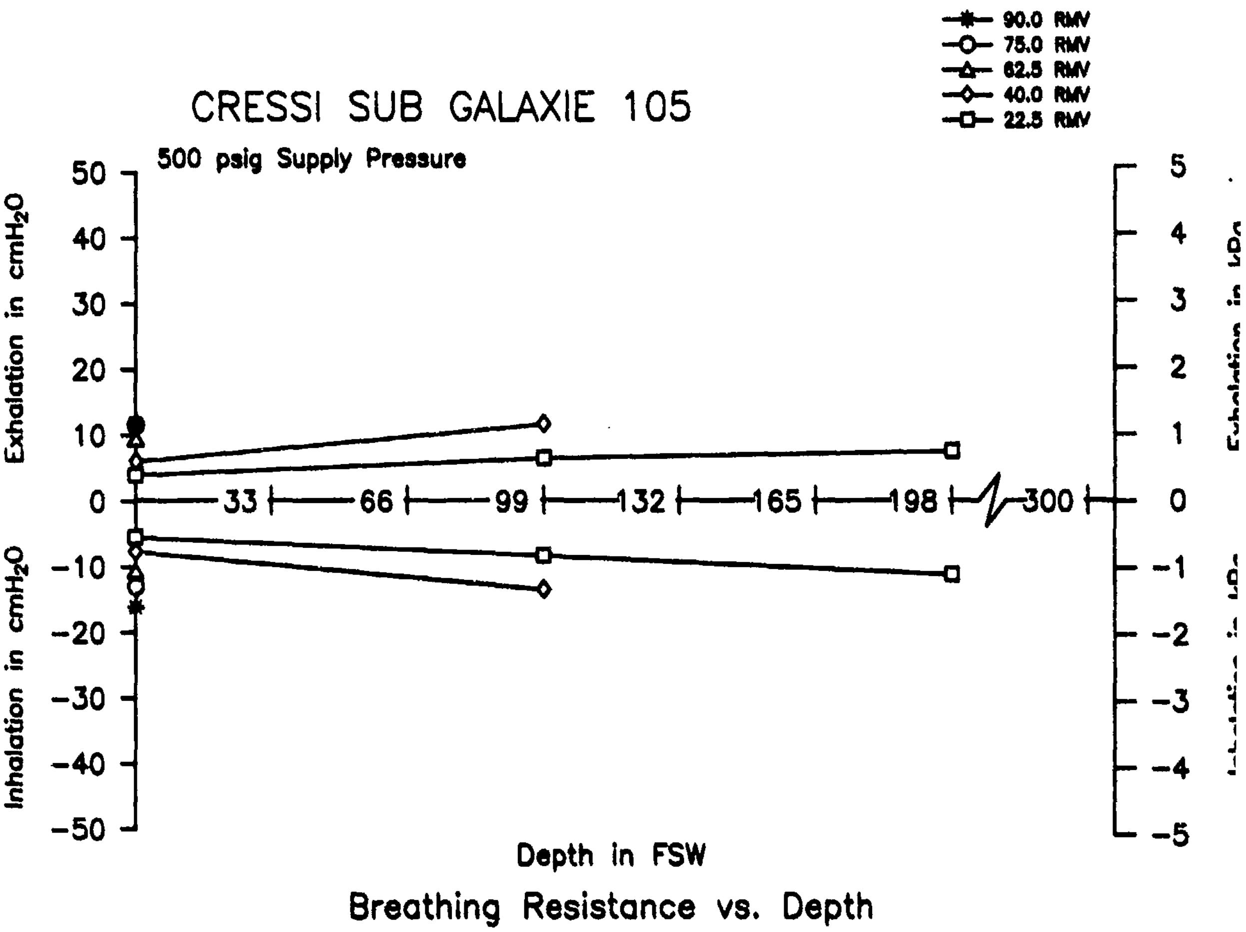


Breathing Work vs. Depth

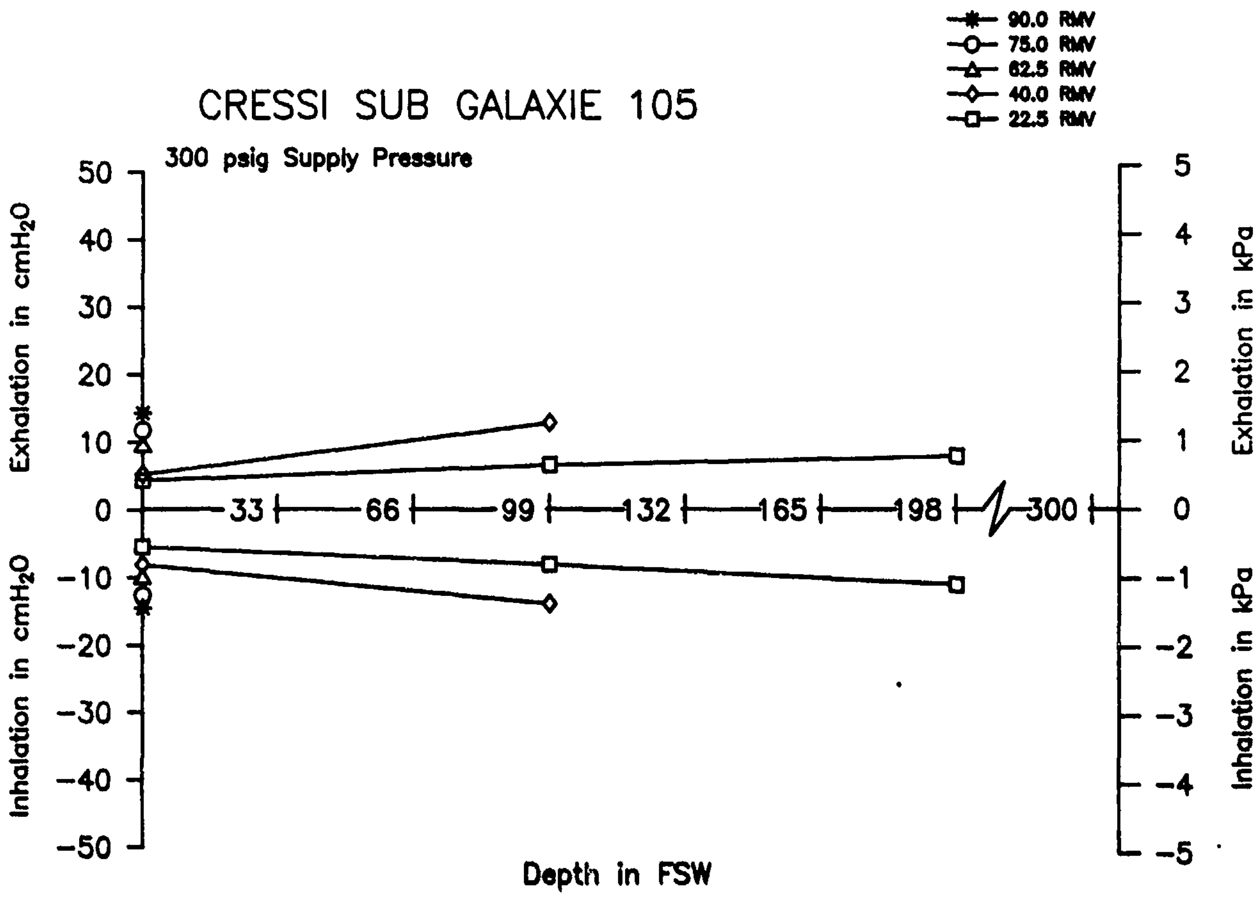

AGA MP w/USD ROYAL SL
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
0
10
20
30
40
50
60
70
80
100
200
300
400
500
600
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth



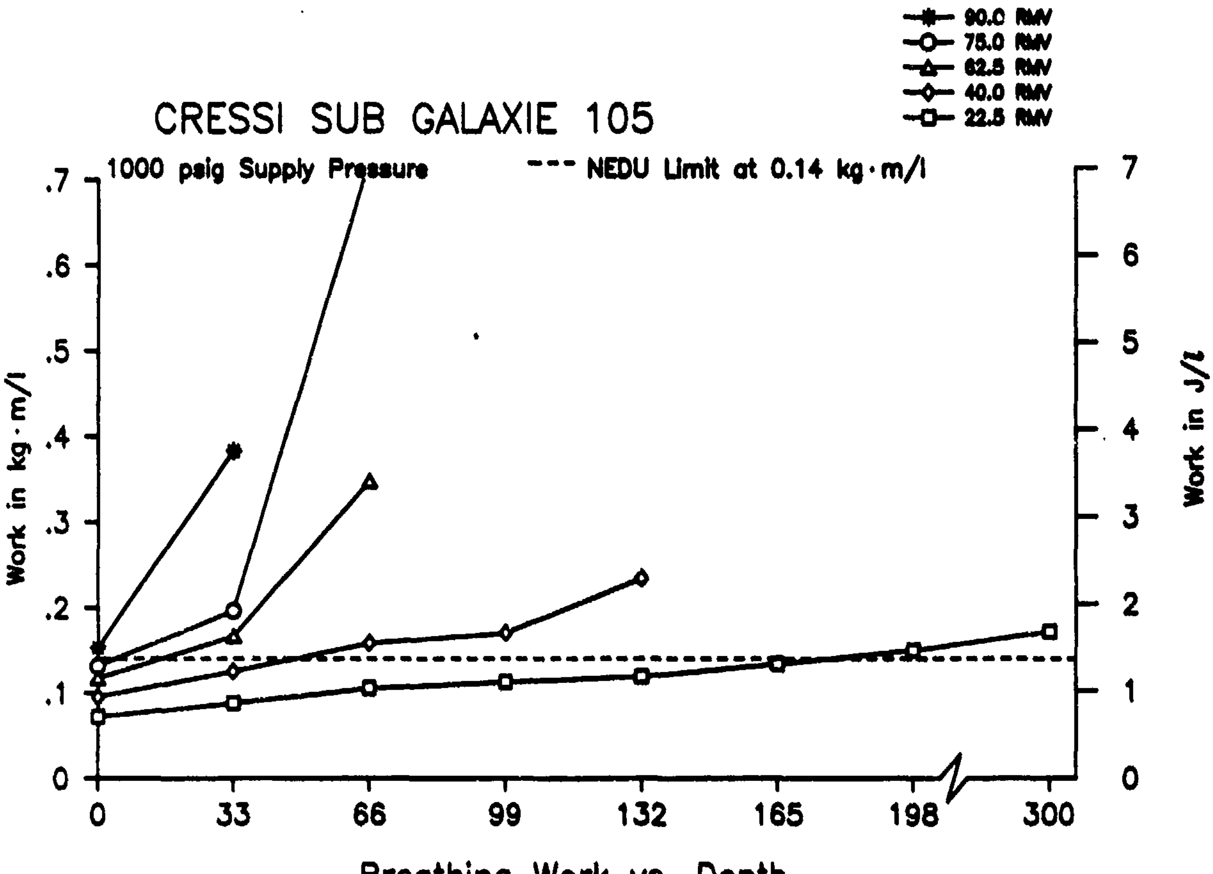
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
CRESSI SUB GALAXIE 105
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
-10
-20
-30
-40
-50
5
4
3
2
1
0
-1
-2
-3
-4
-5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



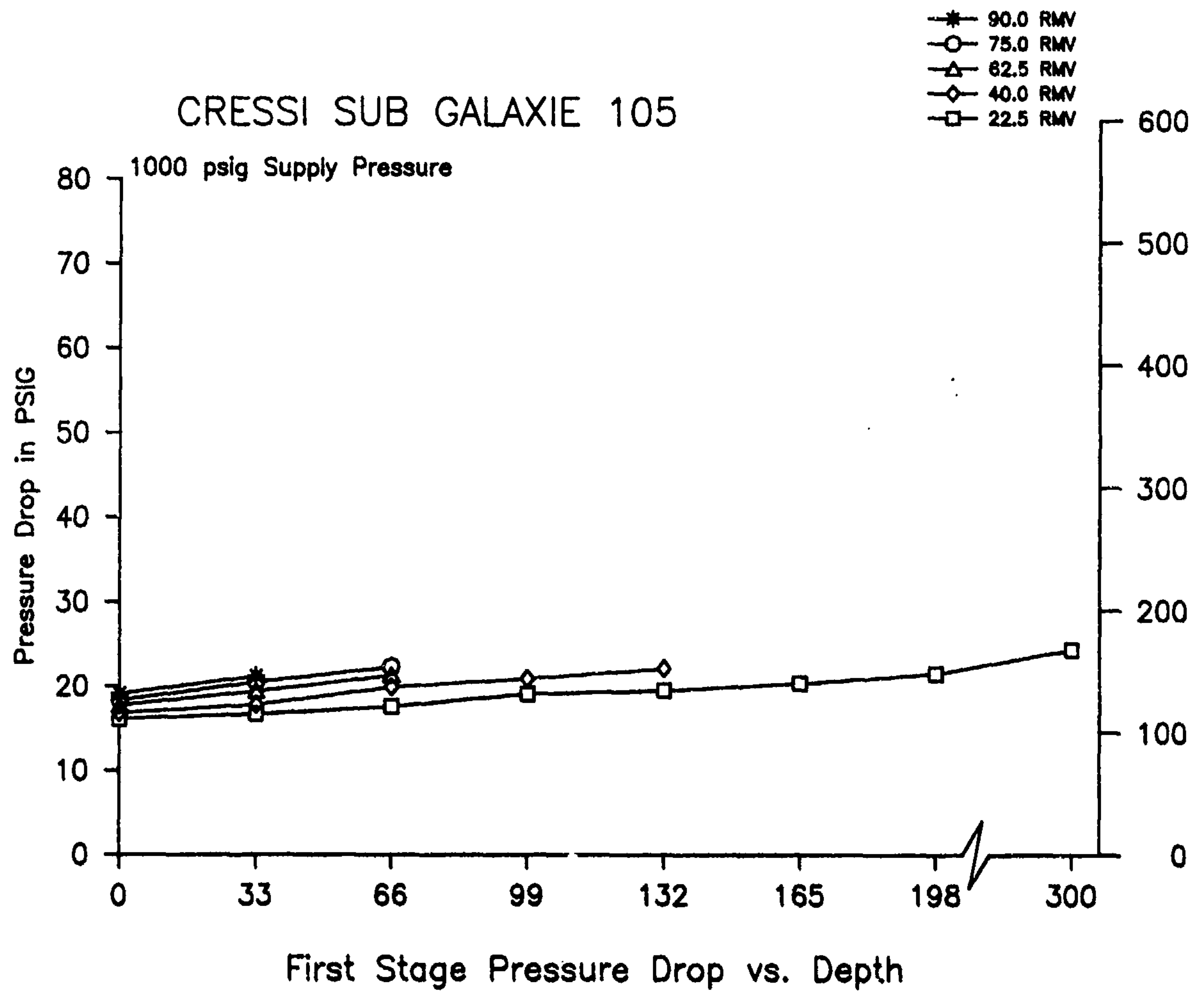
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
CRESSI SUB GALAXIE 105
500 psig Supply Pressure
Exhalation in cmH_2O
Inhalation in cmH_2O
50
40
30
20
10
0
-10
-20
-30
-40
-50
5
4
3
2
1
0
-1
-2
-3
-4
-5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



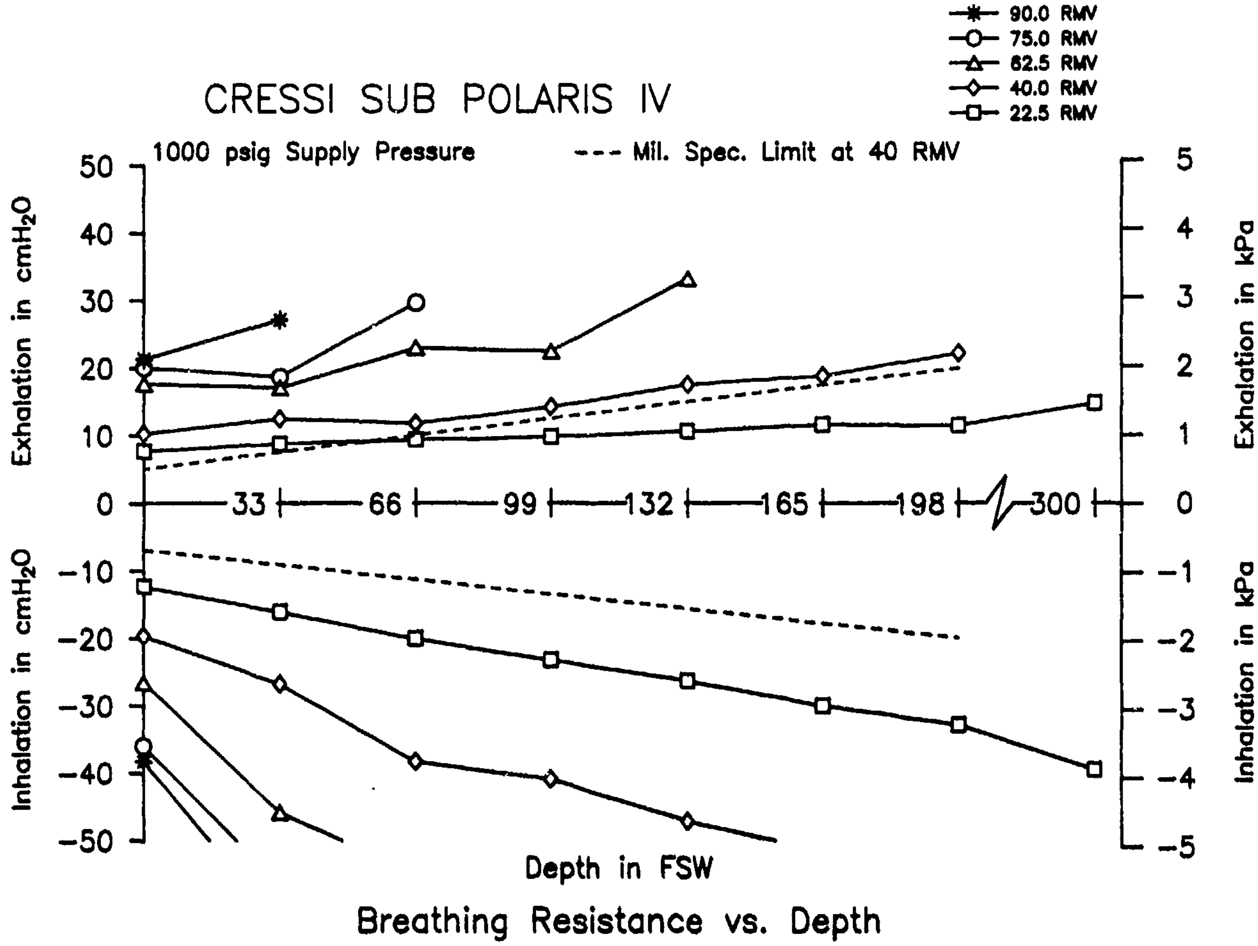
Breathing Resistance vs. Depth



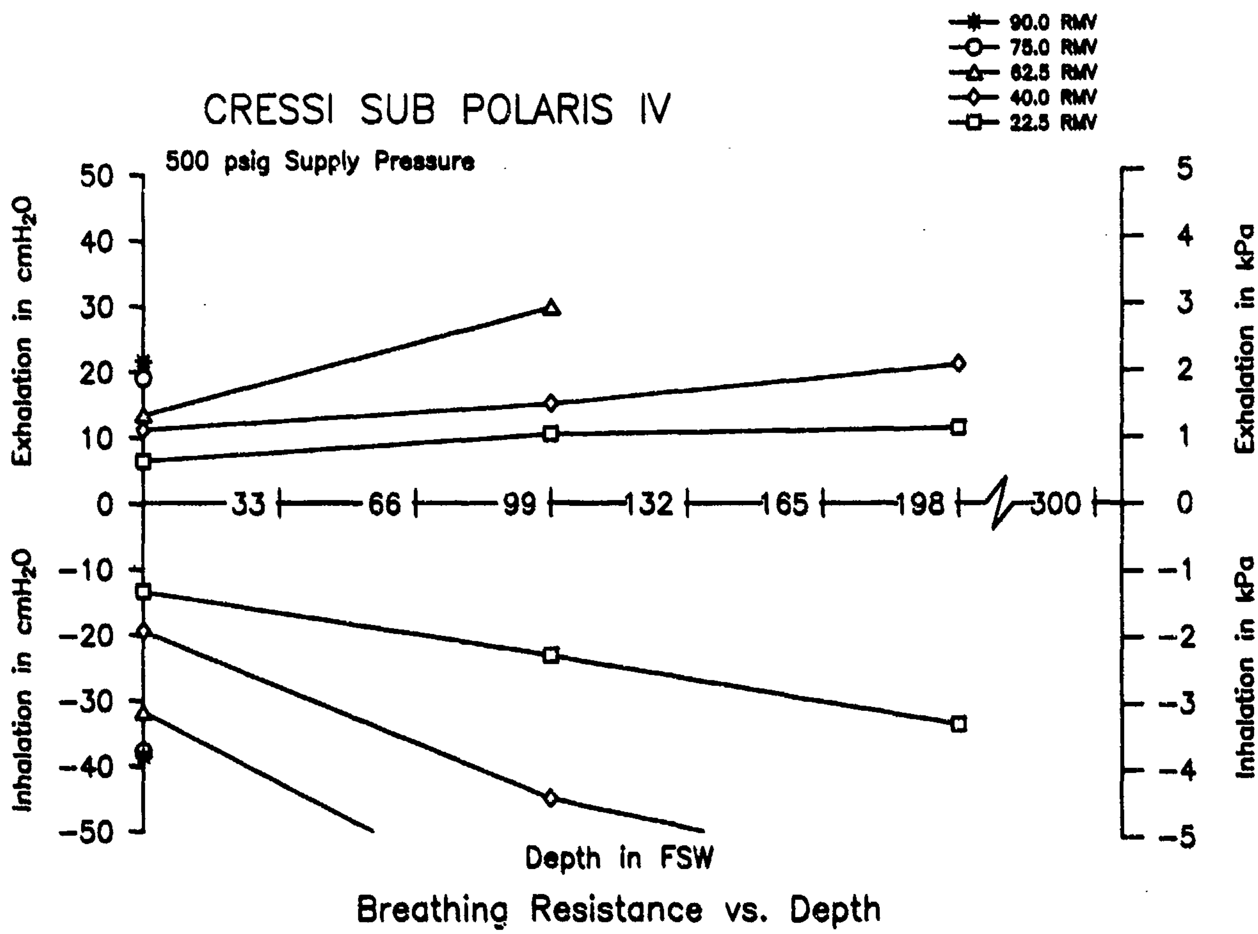
Breathing Work vs. Depth



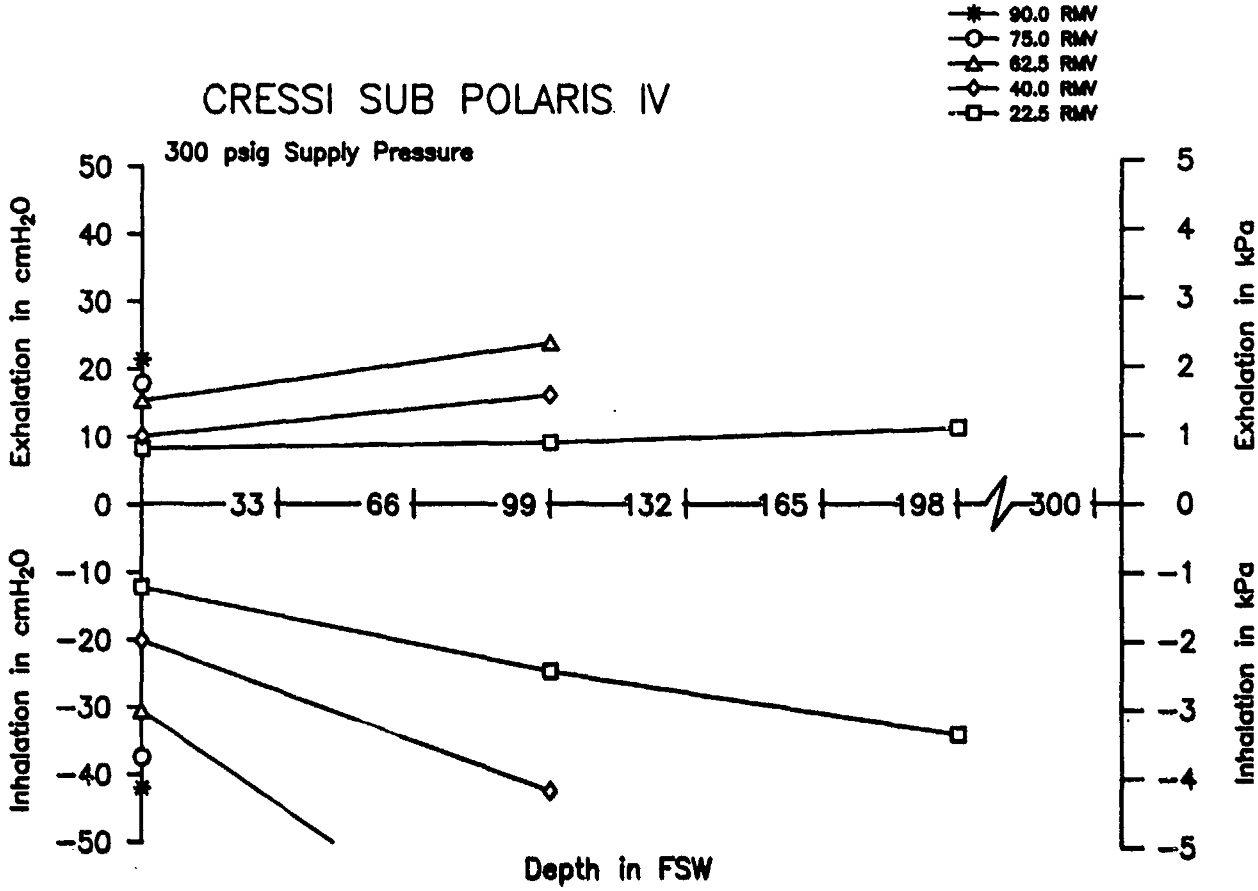
CRESSI SUB GALAXIE 105
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
0
10
20
30
40
50
60
70
80
0
100
200
300
400
500
600
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth



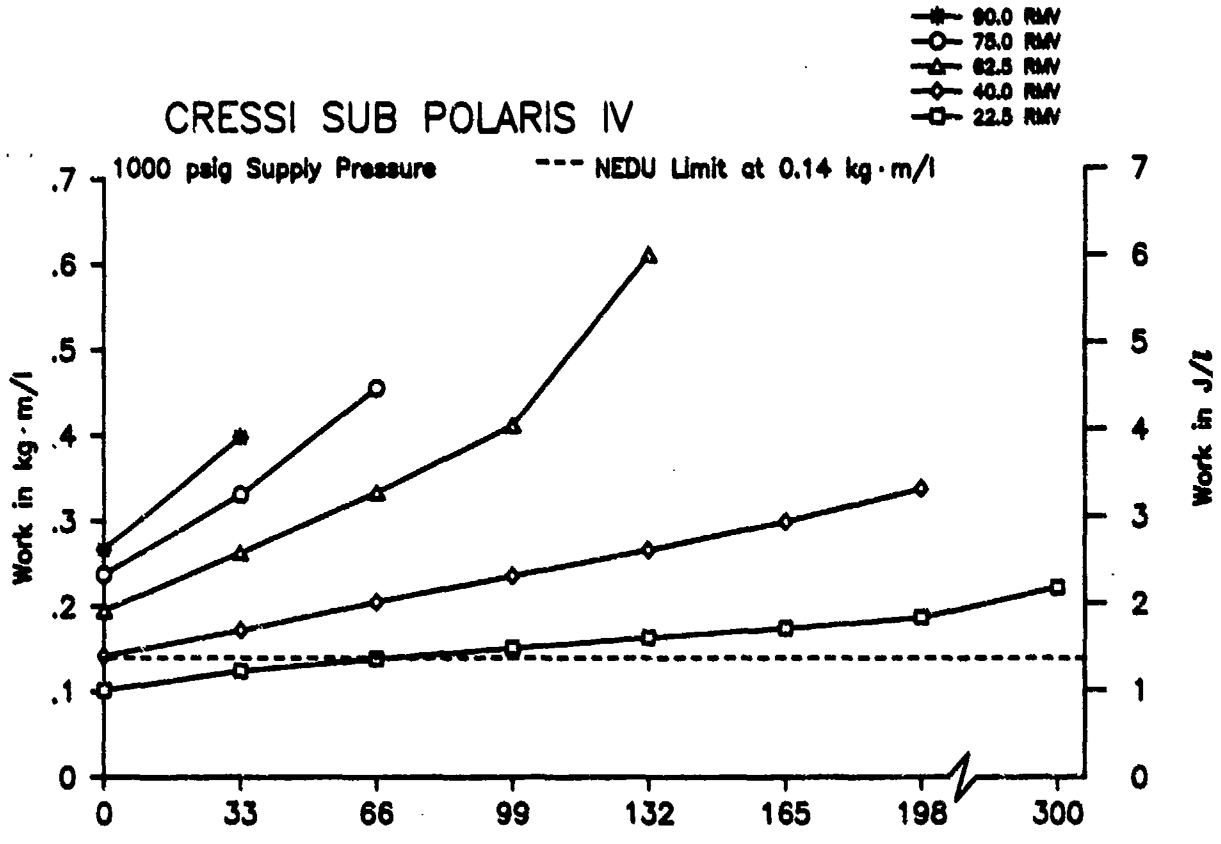
CRESSI SUB POLARIS IV
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
-10
-20
-30
-40
-50
5
4
3
2
1
0
-1
-2
-3
-4
-5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



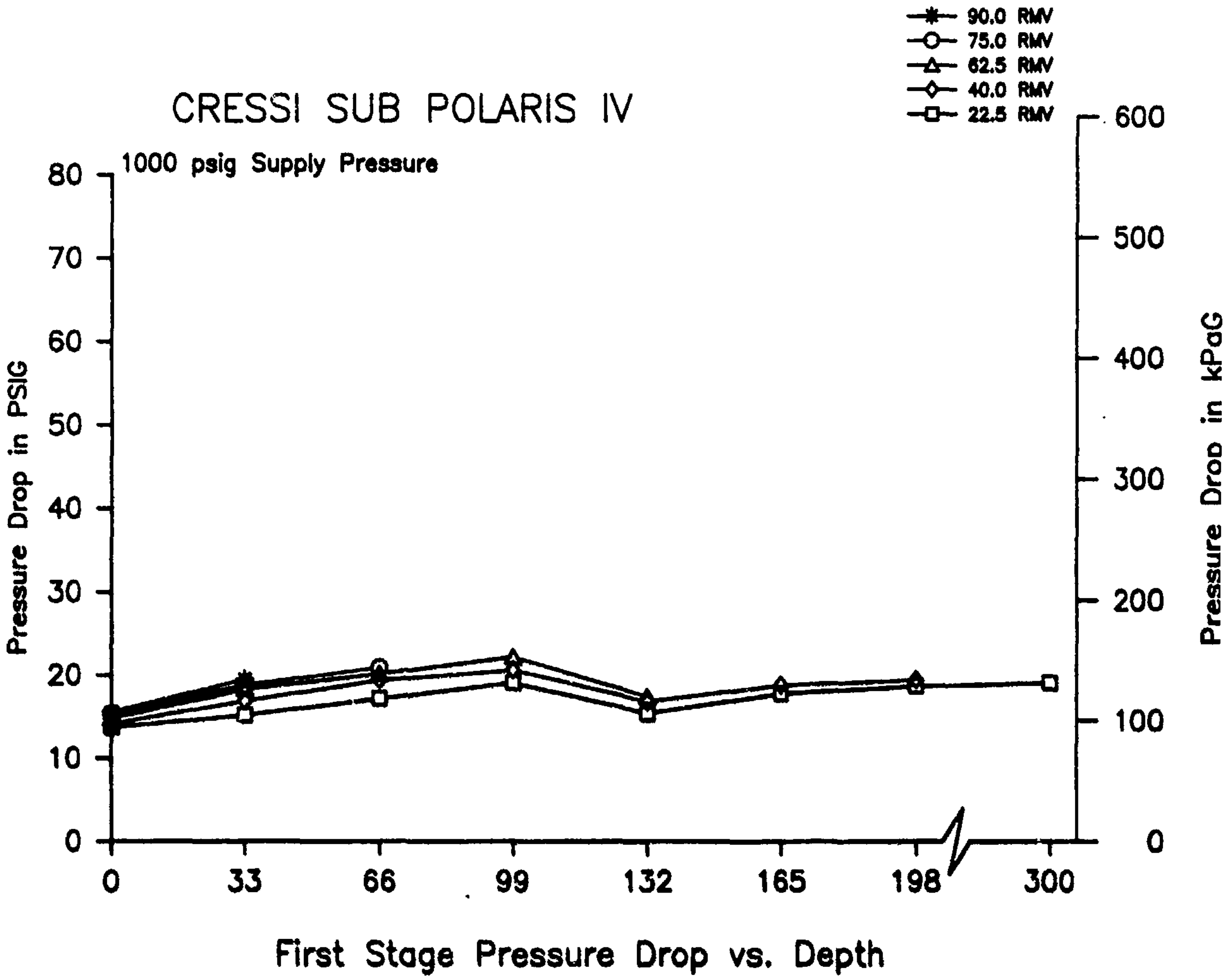
CRESSI SUB POLARIS IV
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
500 psig Supply Pressure
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
-10
-20
-30
-40
-50
5
4
3
2
1
0
-1
-2
-3
-4
-5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



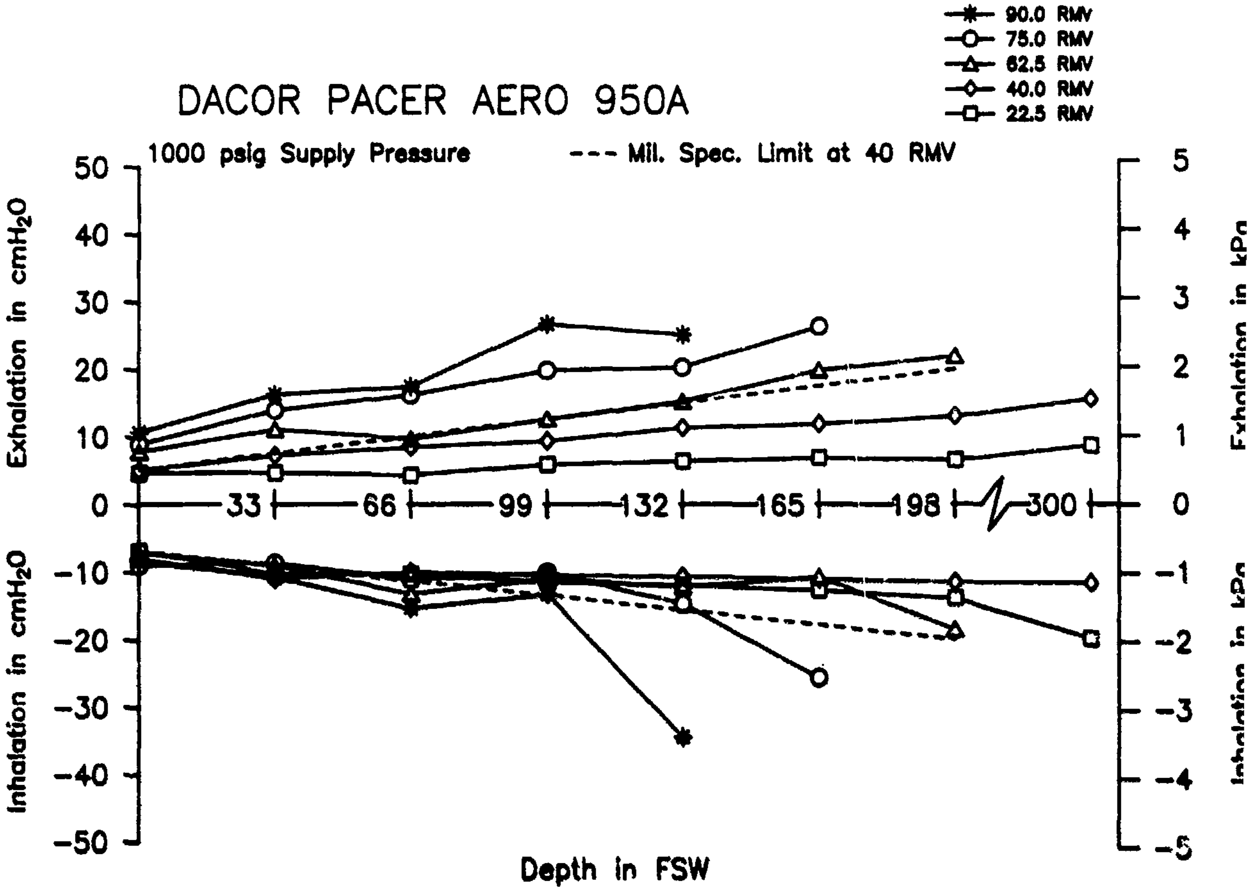
Breathing Resistance vs. Depth



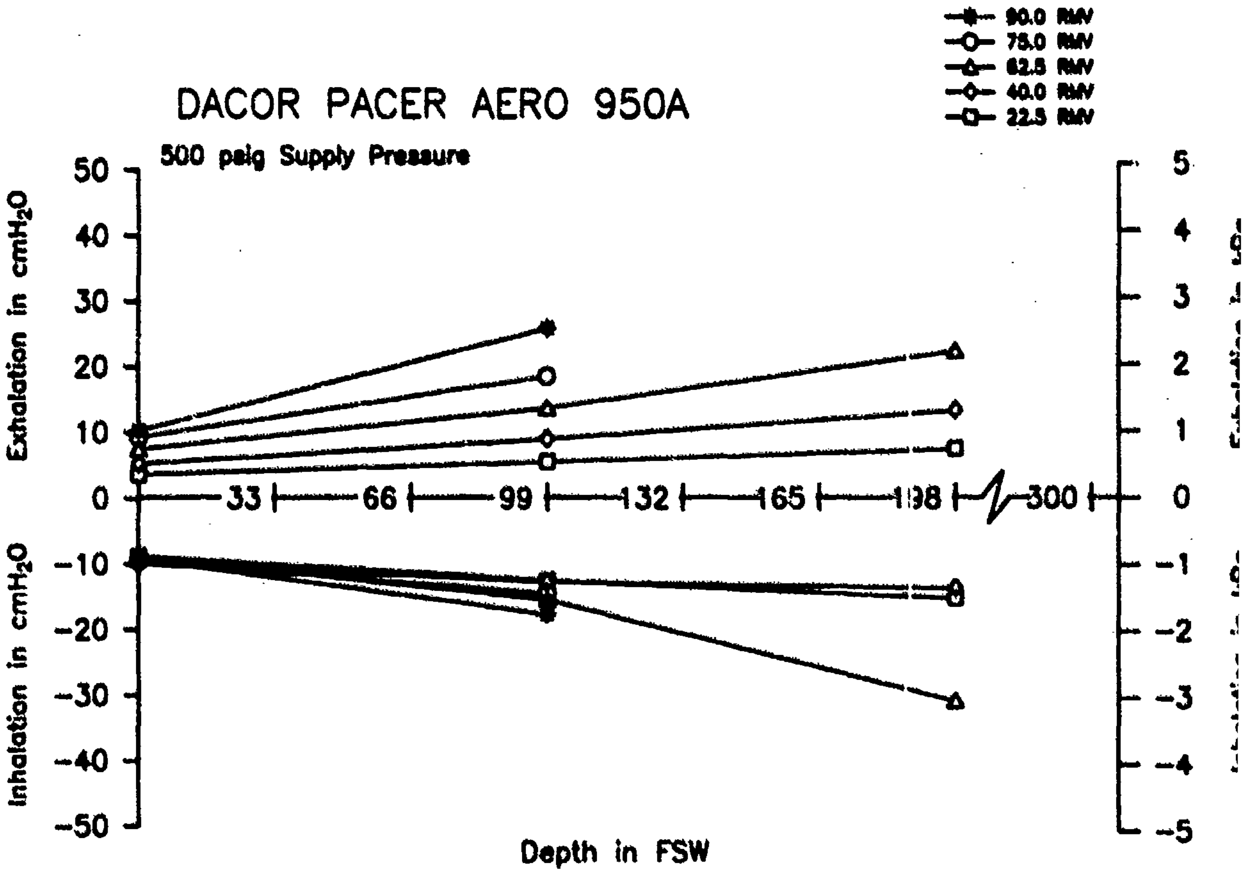
Breathing Work vs. Depth



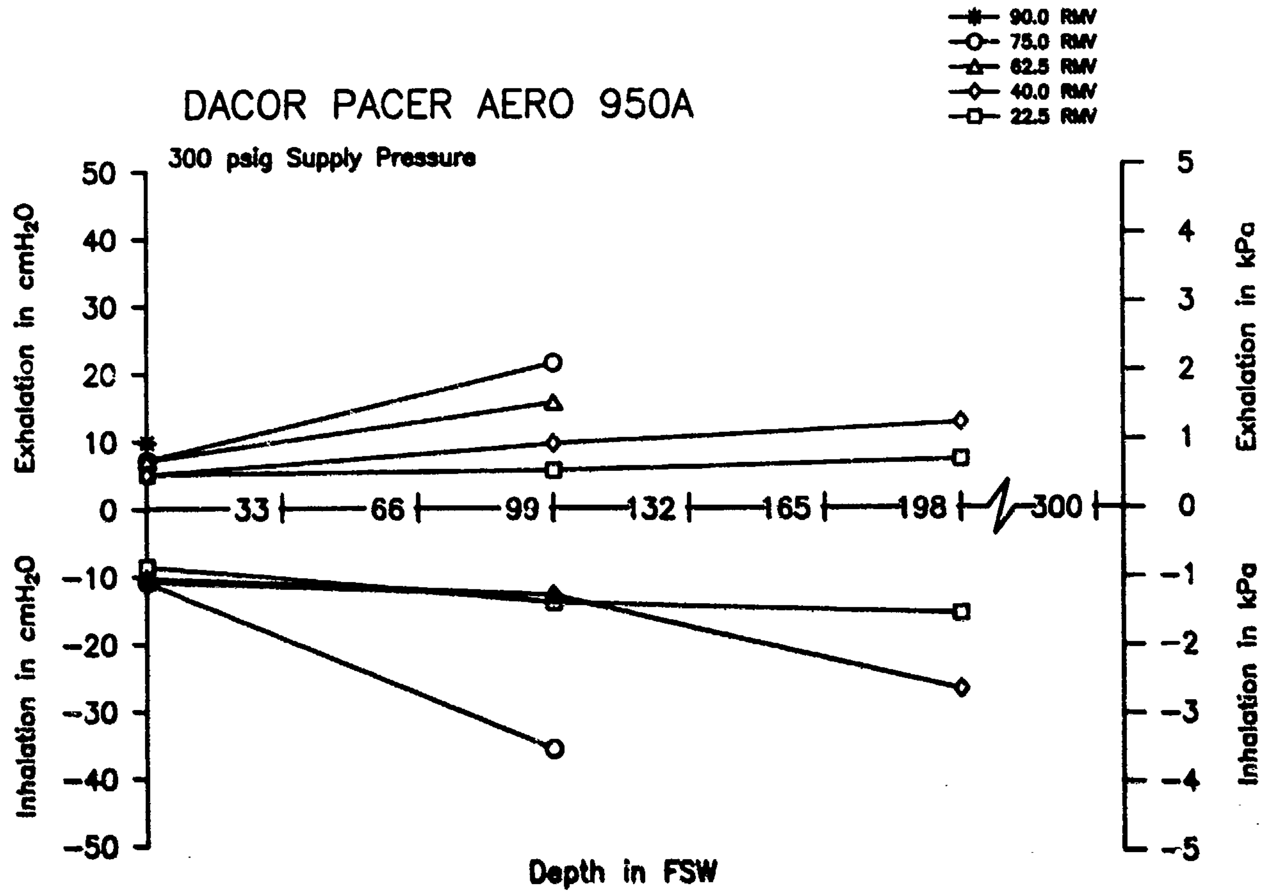
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
CRESSI SUB POLARIS IV
1000 psig Supply Pressure
Pressure Drop in PSIG
Pressure Drop in kPaG
80
70
60
50
40
30
20
10
0
600
500
400
300
200
100
0
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth



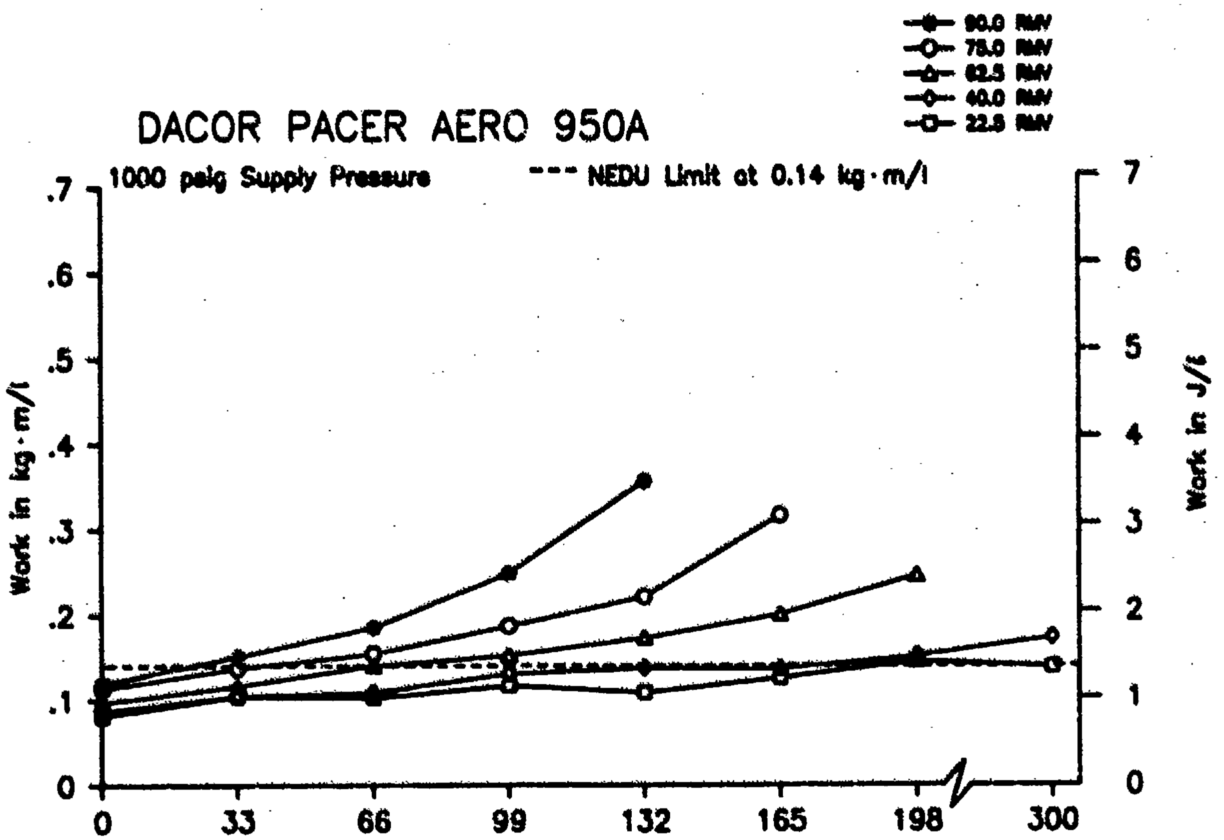
Breathing Resistance vs. Depth



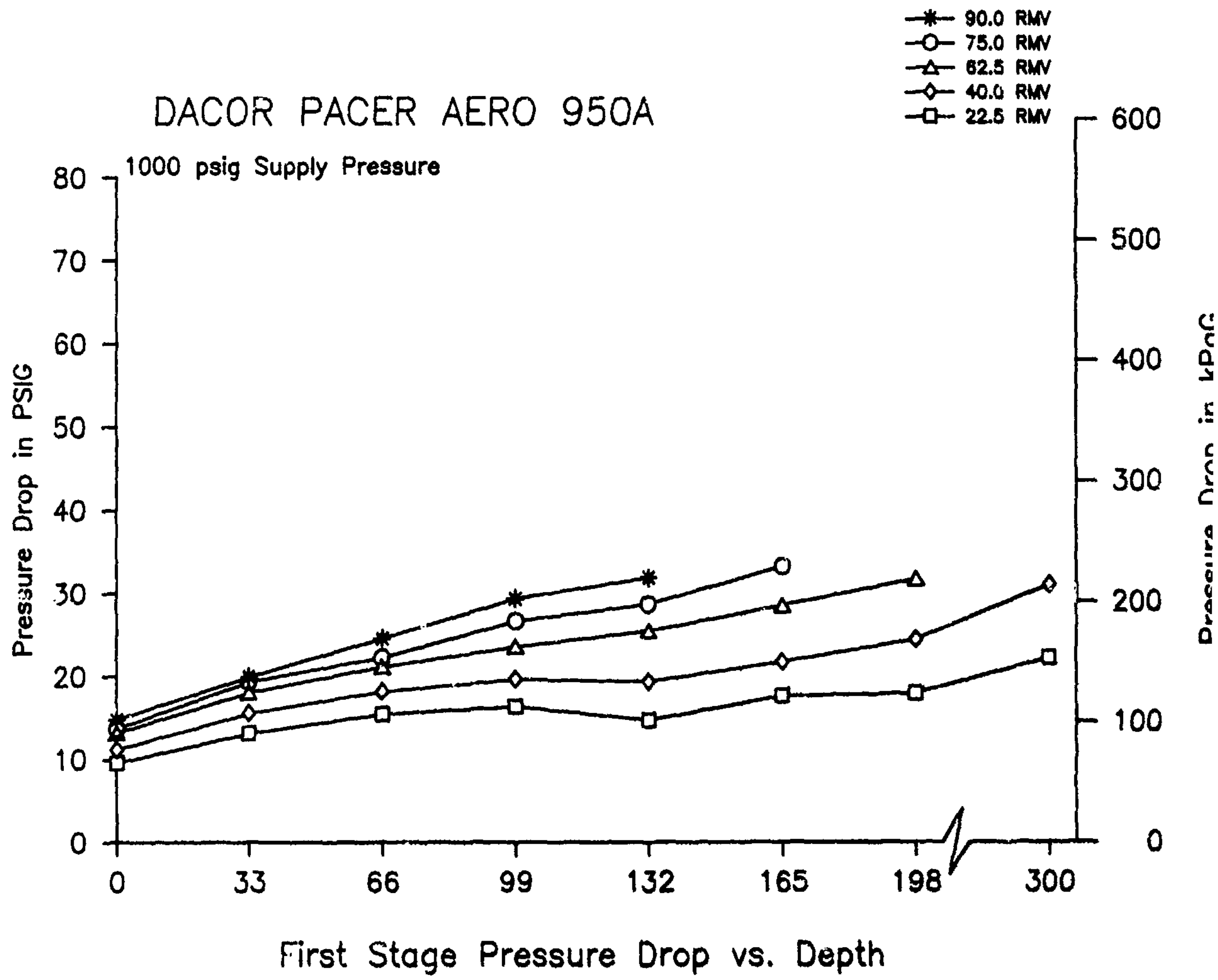
Breathing Resistance vs. Depth



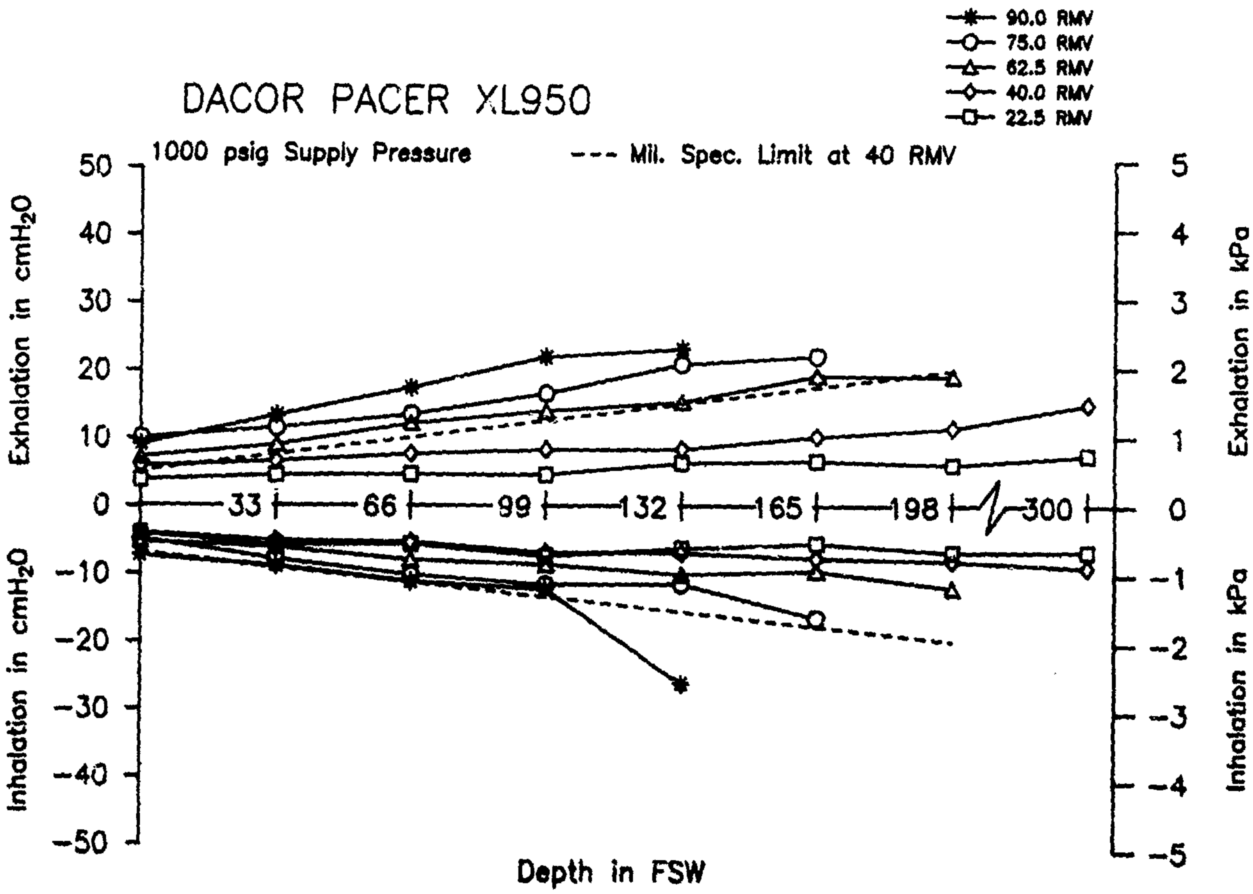
Breathing Resistance vs. Depth



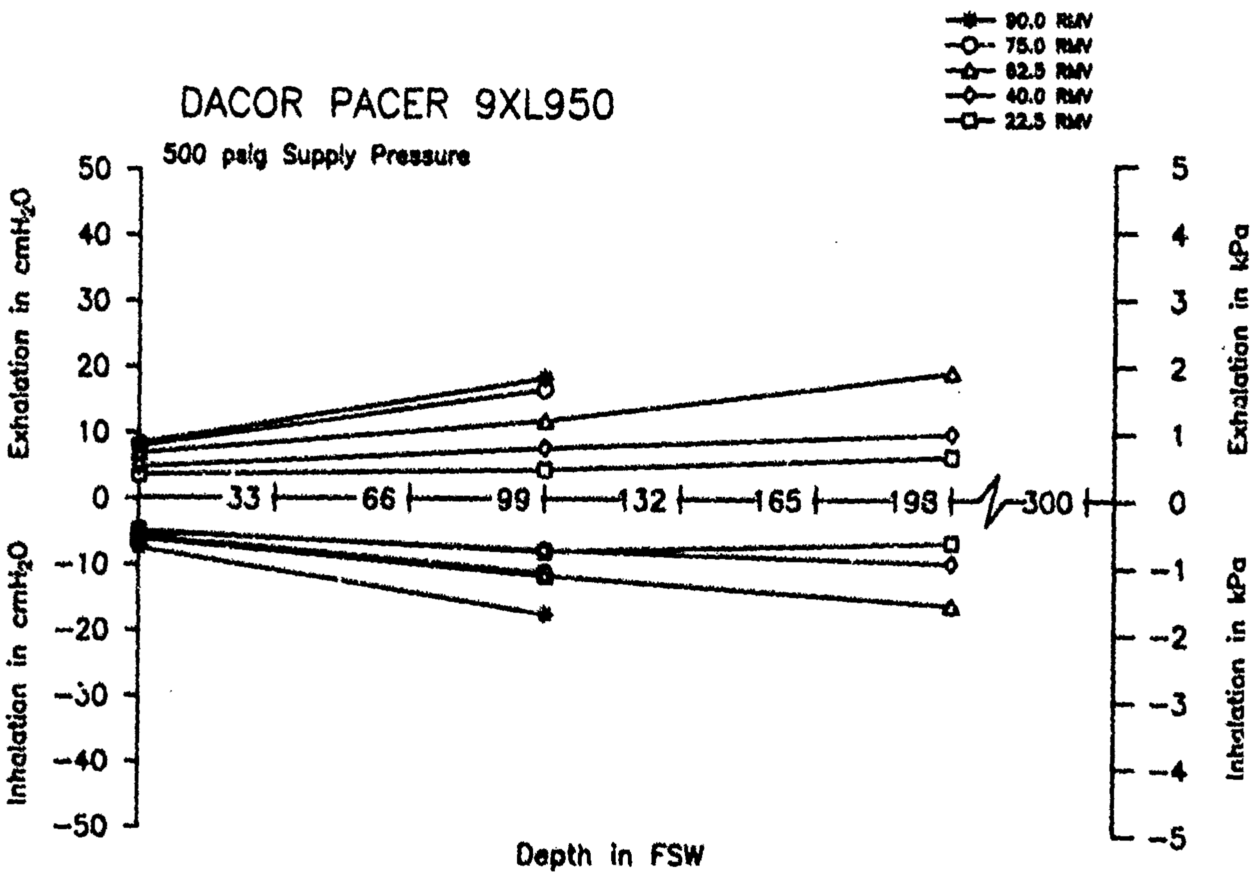
Breathing Work vs. Depth



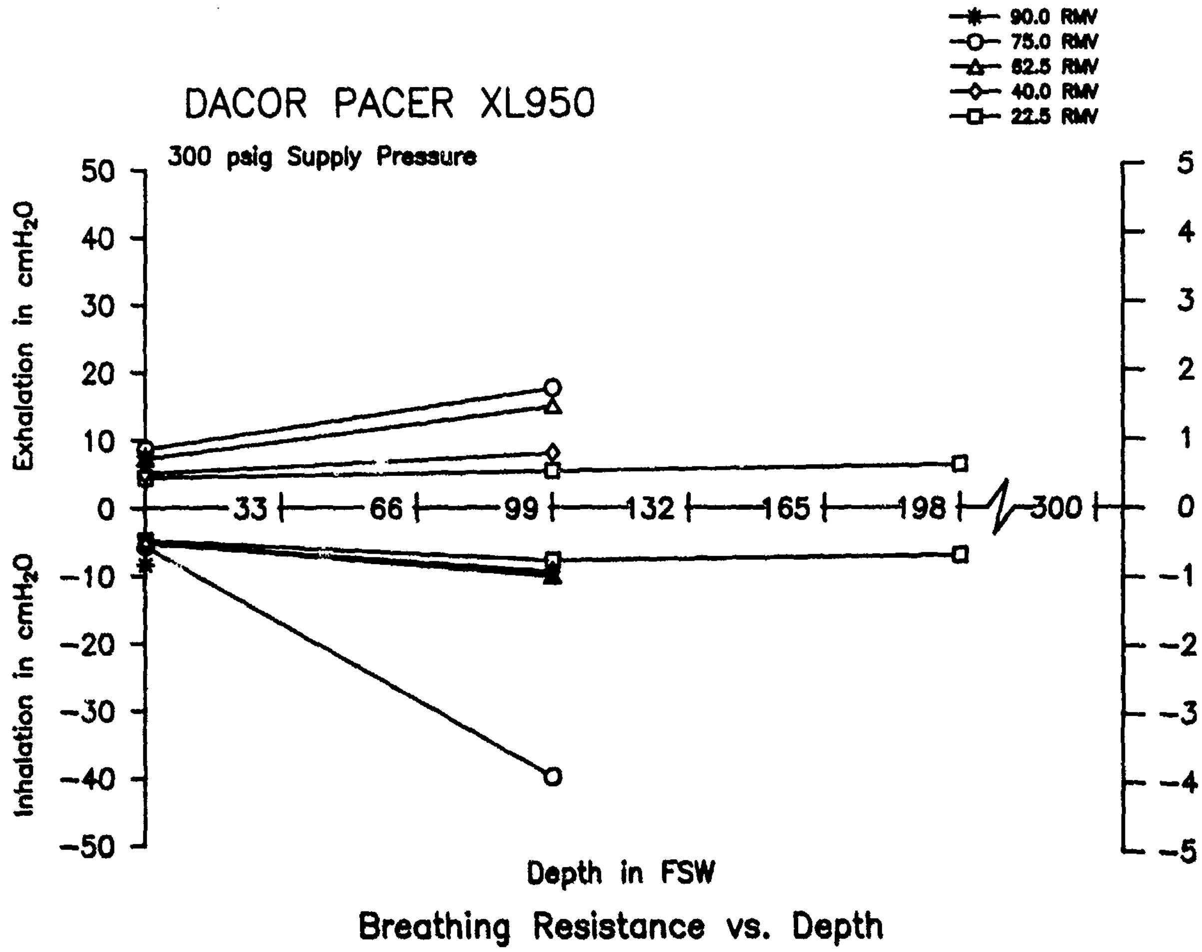
DACOR PACER AERO 950A
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
Pressure Drop in kPaG
0
10
20
30
40
50
60
70
80
100
200
300
400
500
600
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth

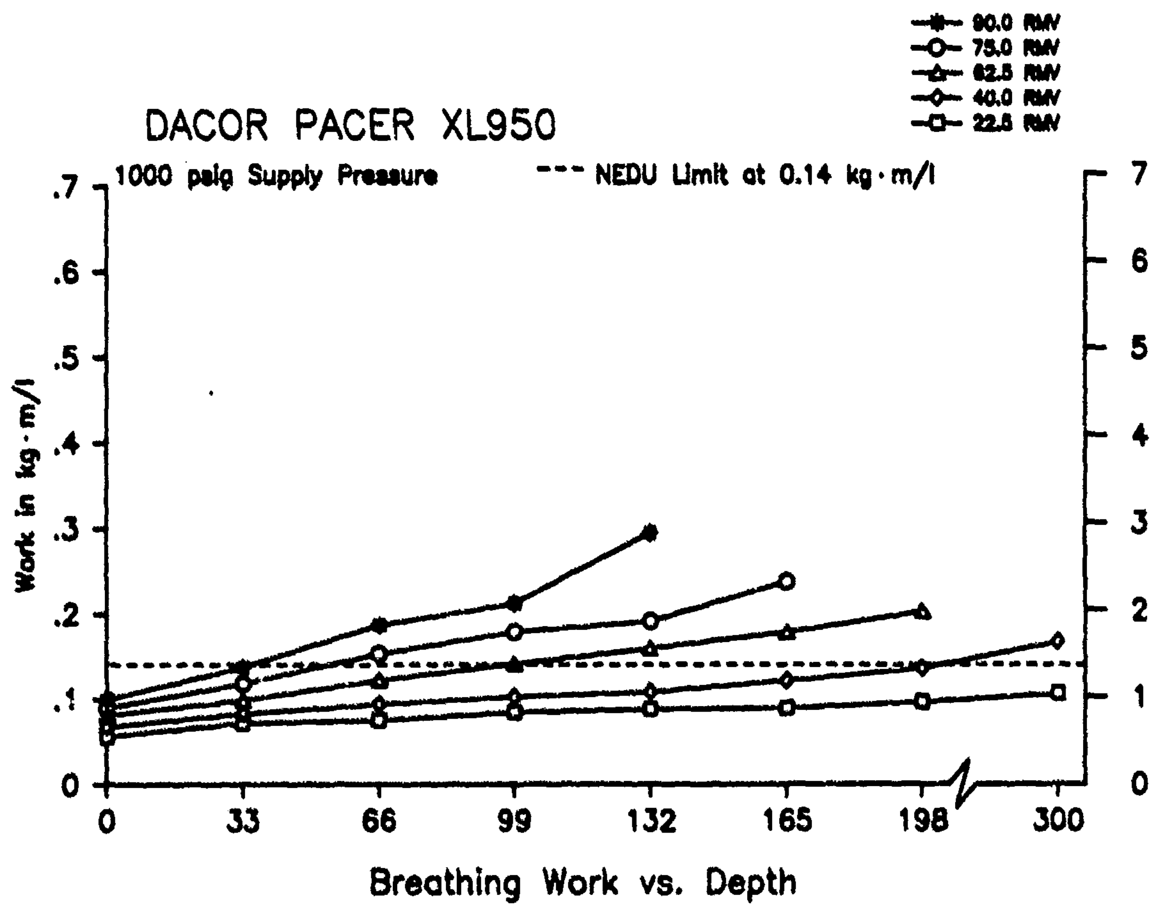


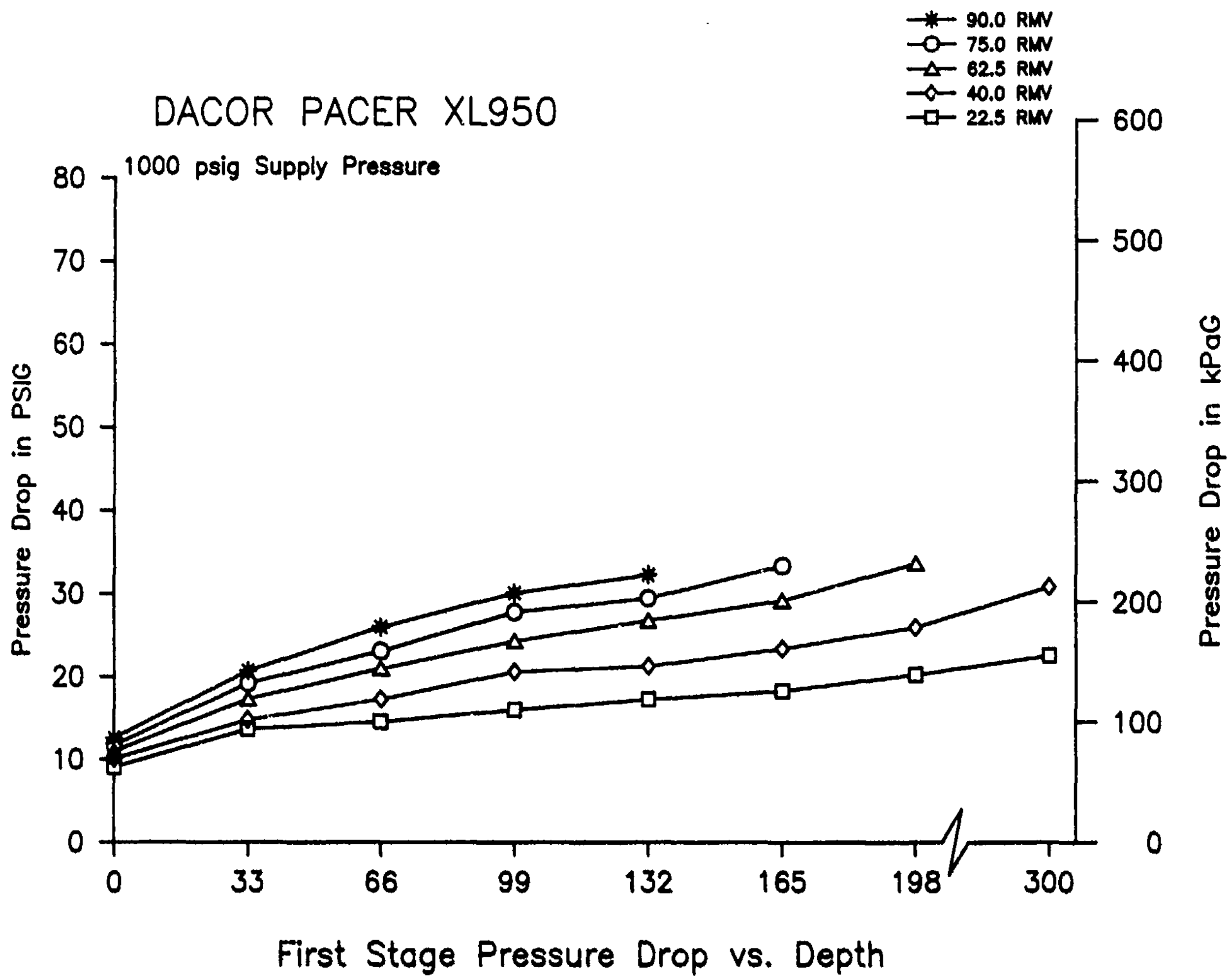
Breathing Resistance vs. Depth

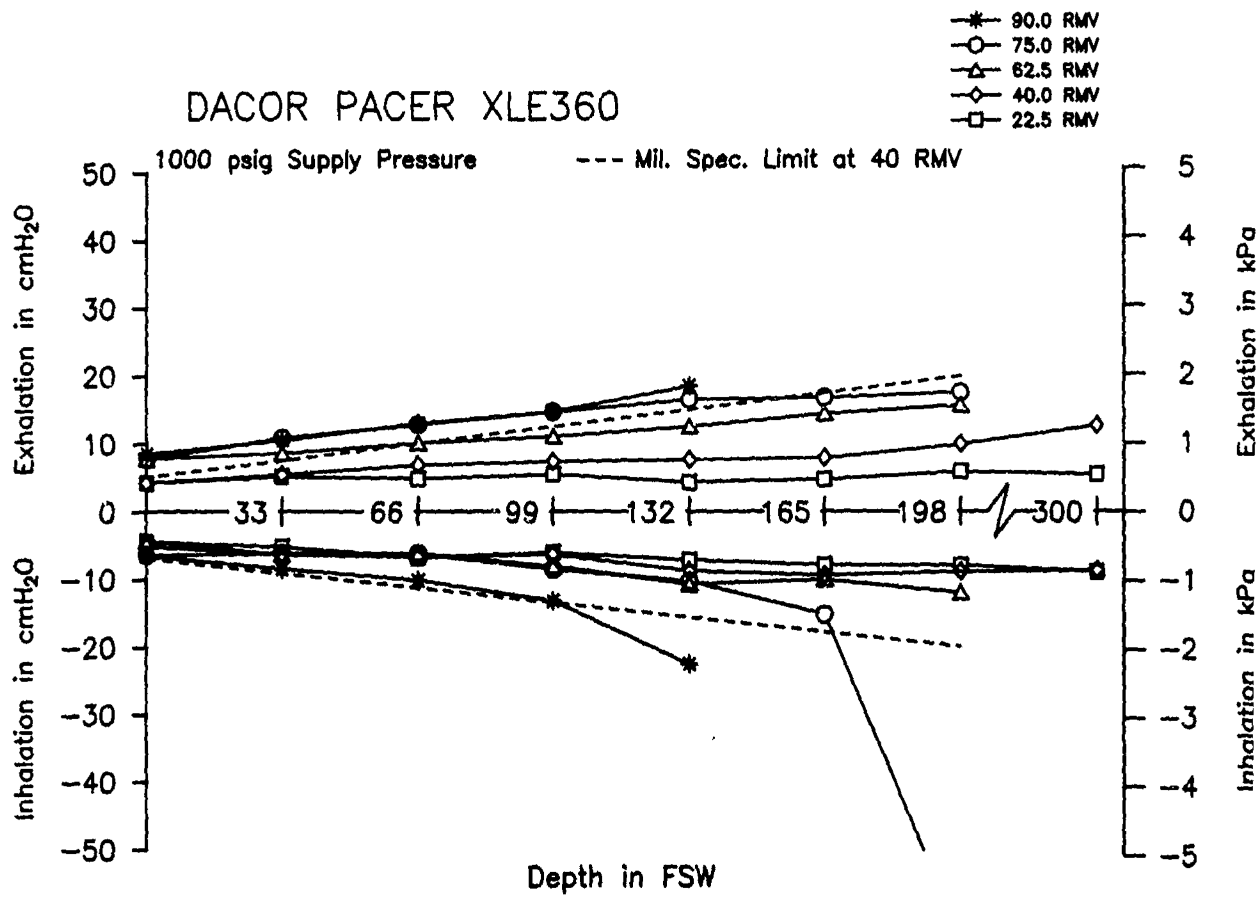


Breathing Resistance vs. Depth

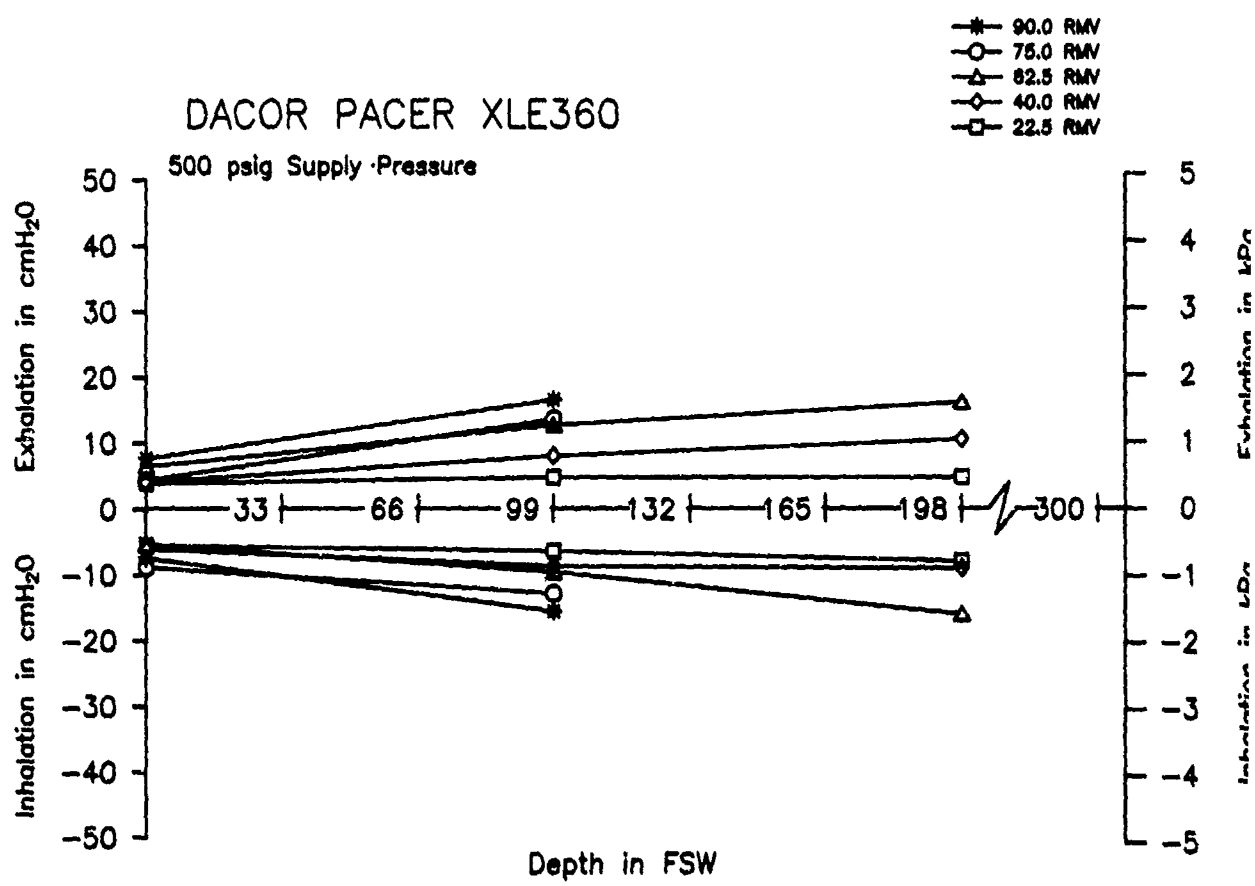

DACOR PACER XL950
300 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH2O
Inhalation in cmH2O
50
40
30
20
10
0
-10
-20
-30
-40
-50
5
4
3
2
1
0
-1
-2
-3
-4
-5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth


DACOR PACER XL950
1000 psig Supply Pressure
--- NEDU Limit at 0.14 kg·m/l
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Work in kg·m/l
.7
.6
.5
.4
.3
.2
.1
0
7
6
5
4
3
2
1
0
0
33
66
99
132
165
198
300
Breathing Work vs. Depth

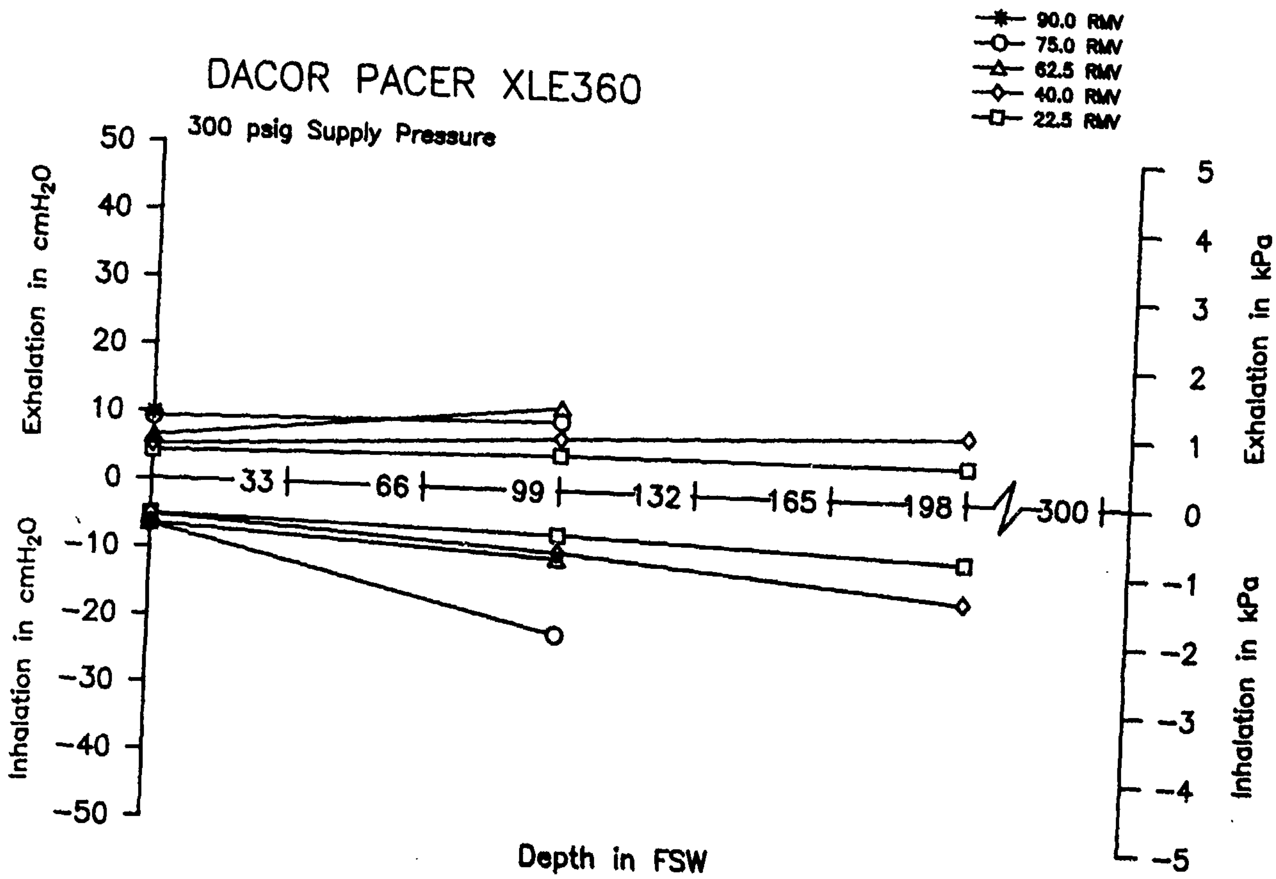

90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
DACOR PACER XL950
1000 psig Supply Pressure
Pressure Drop in PSIG
Pressure Drop in kPaG
80
70
60
50
40
30
20
10
0
600
500
400
300
200
100
0
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth



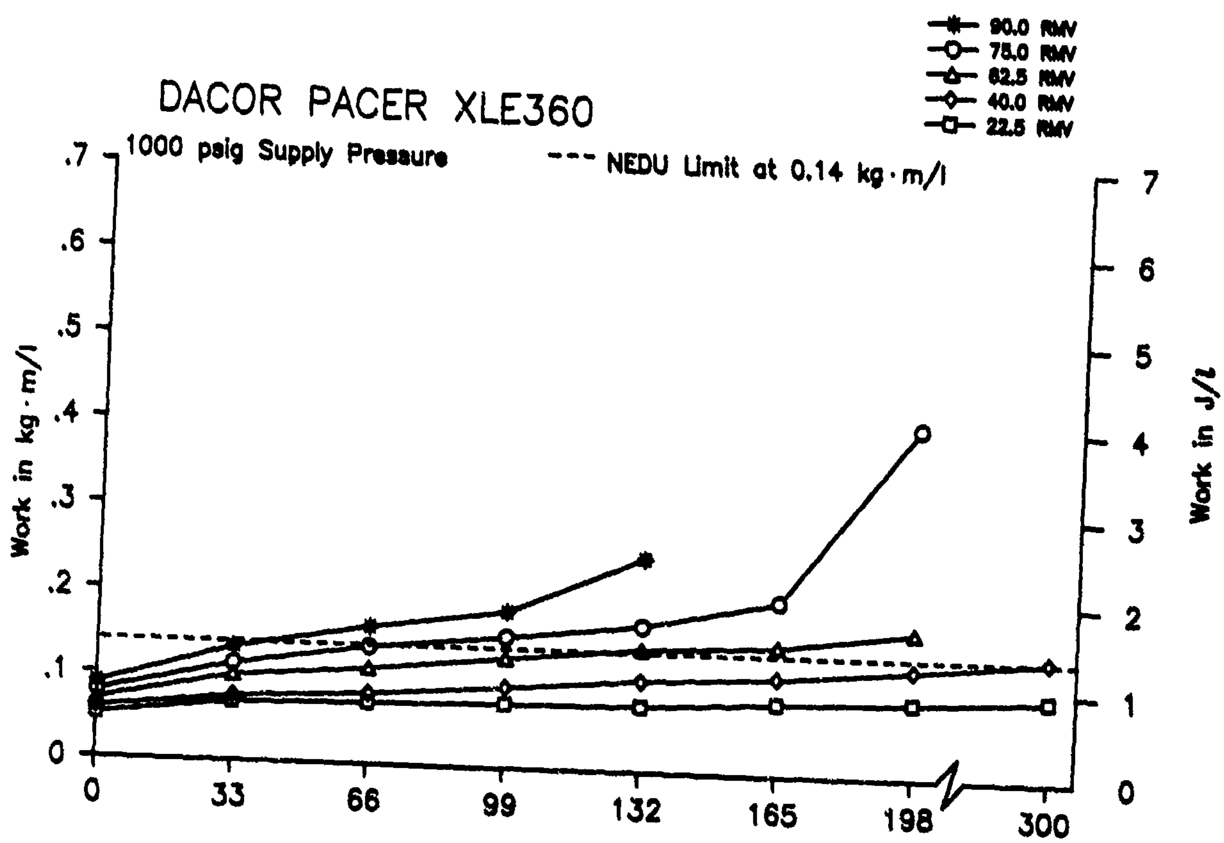
Breathing Resistance vs. Depth



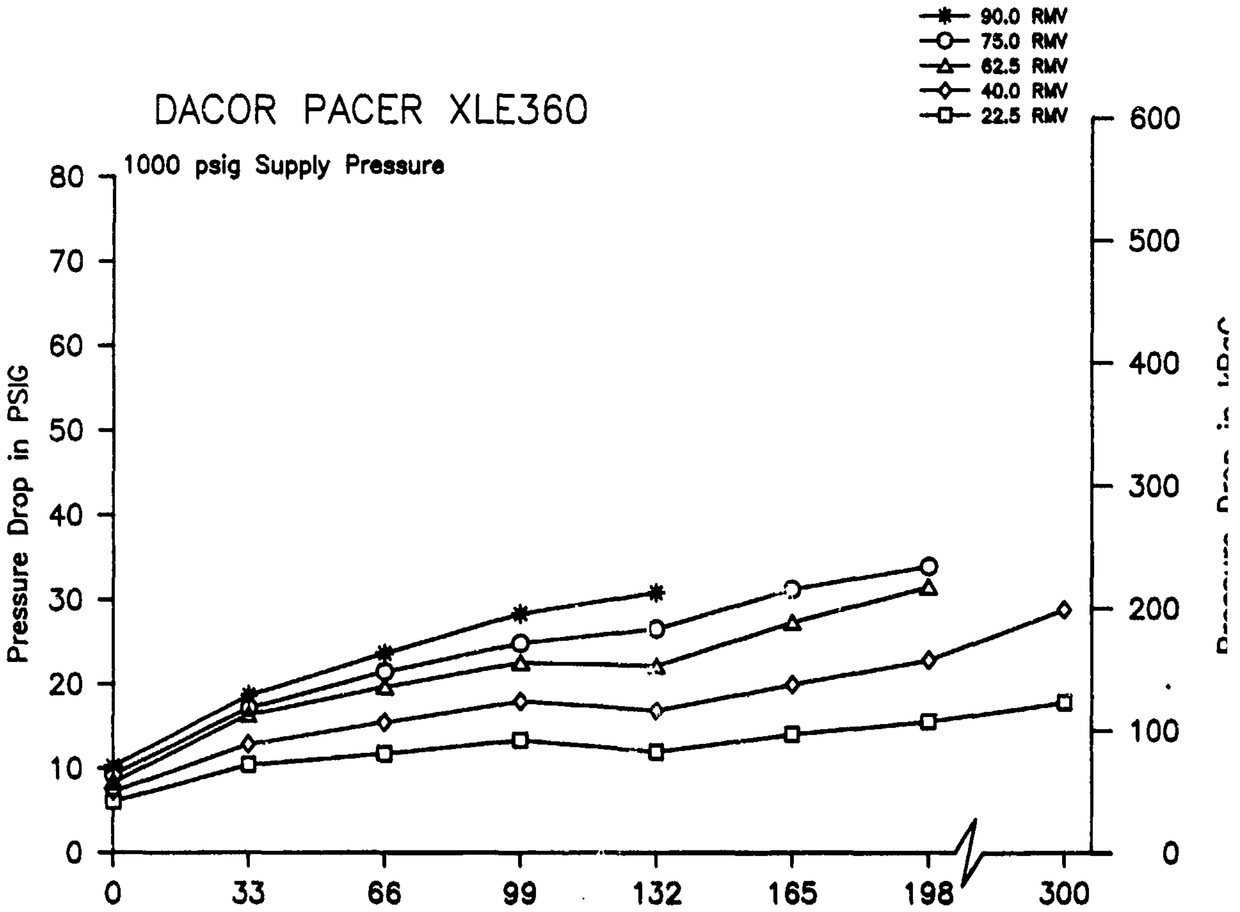
Breathing Resistance vs. Depth



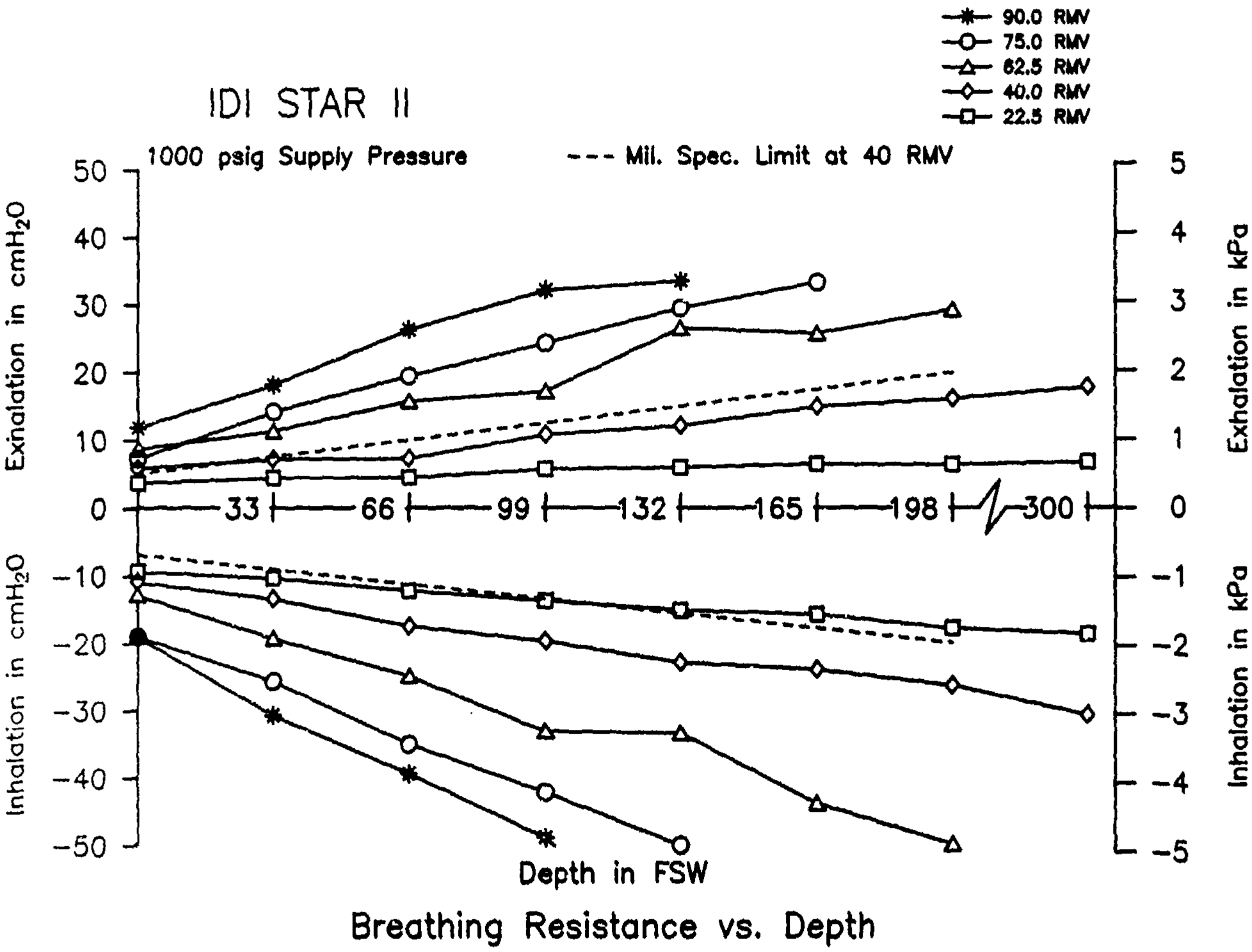
Breathing Resistance vs. Depth



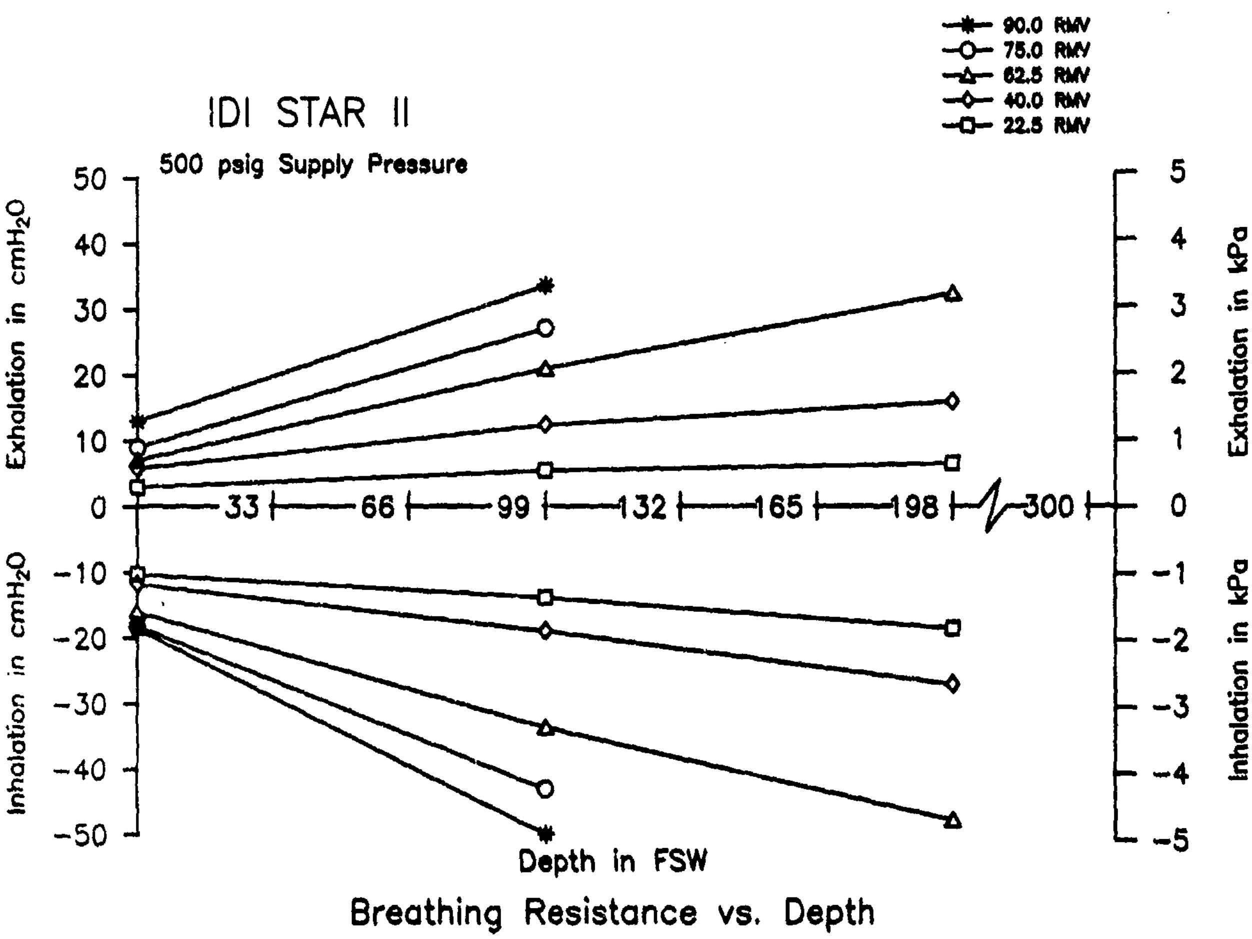
Breathing Work vs. Depth



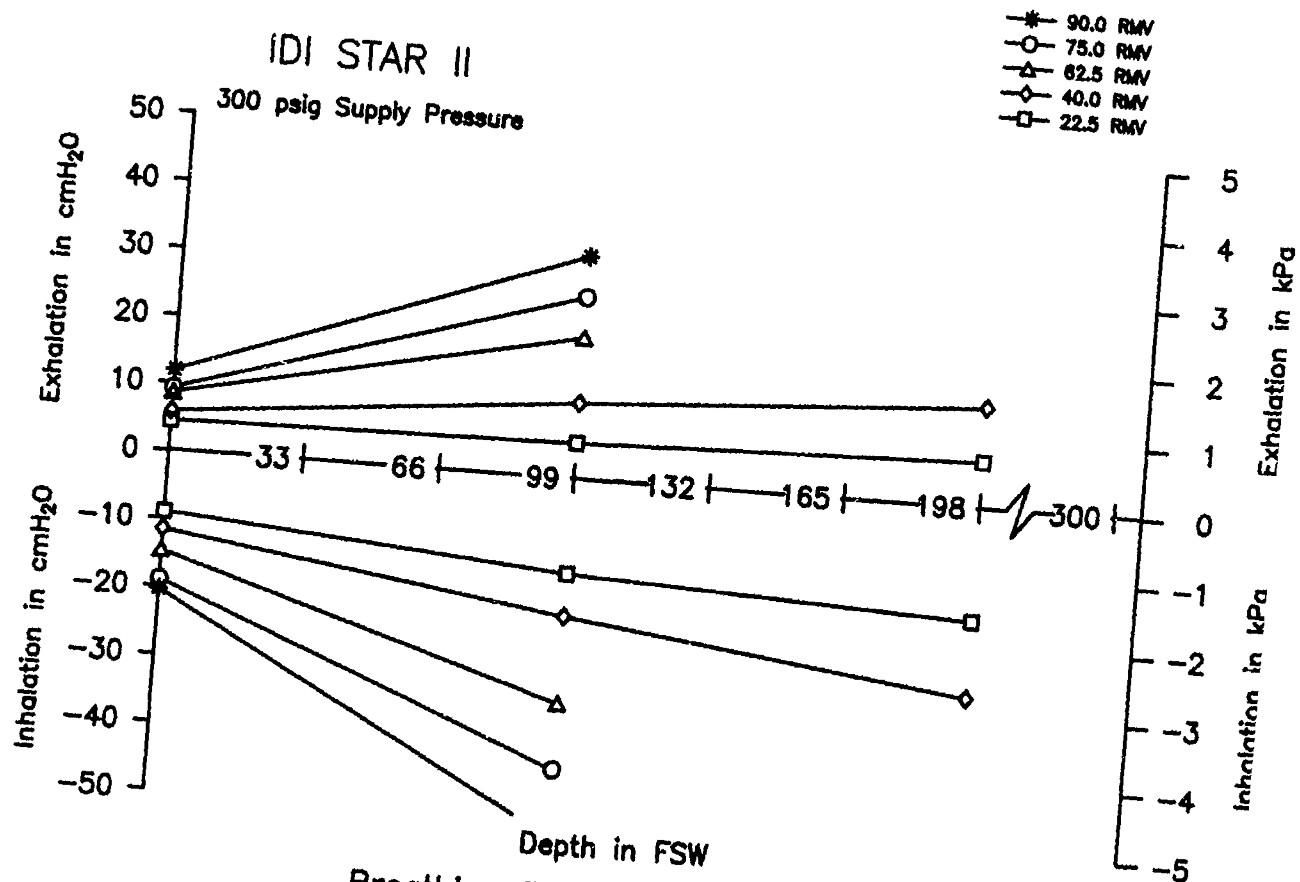
First Stage Pressure Drop vs. Depth



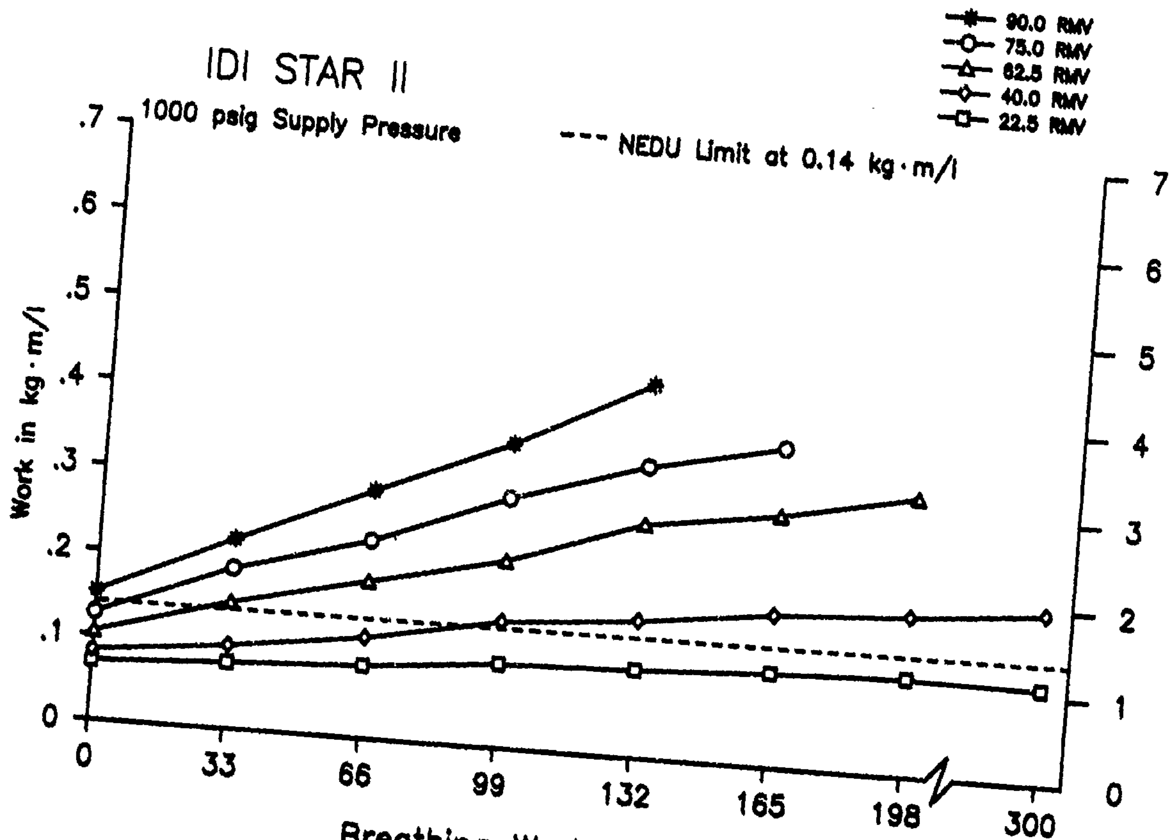
IDI STAR II
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
-10
-20
-30
-40
-50
5
4
3
2
1
0
-1
-2
-3
-4
-5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



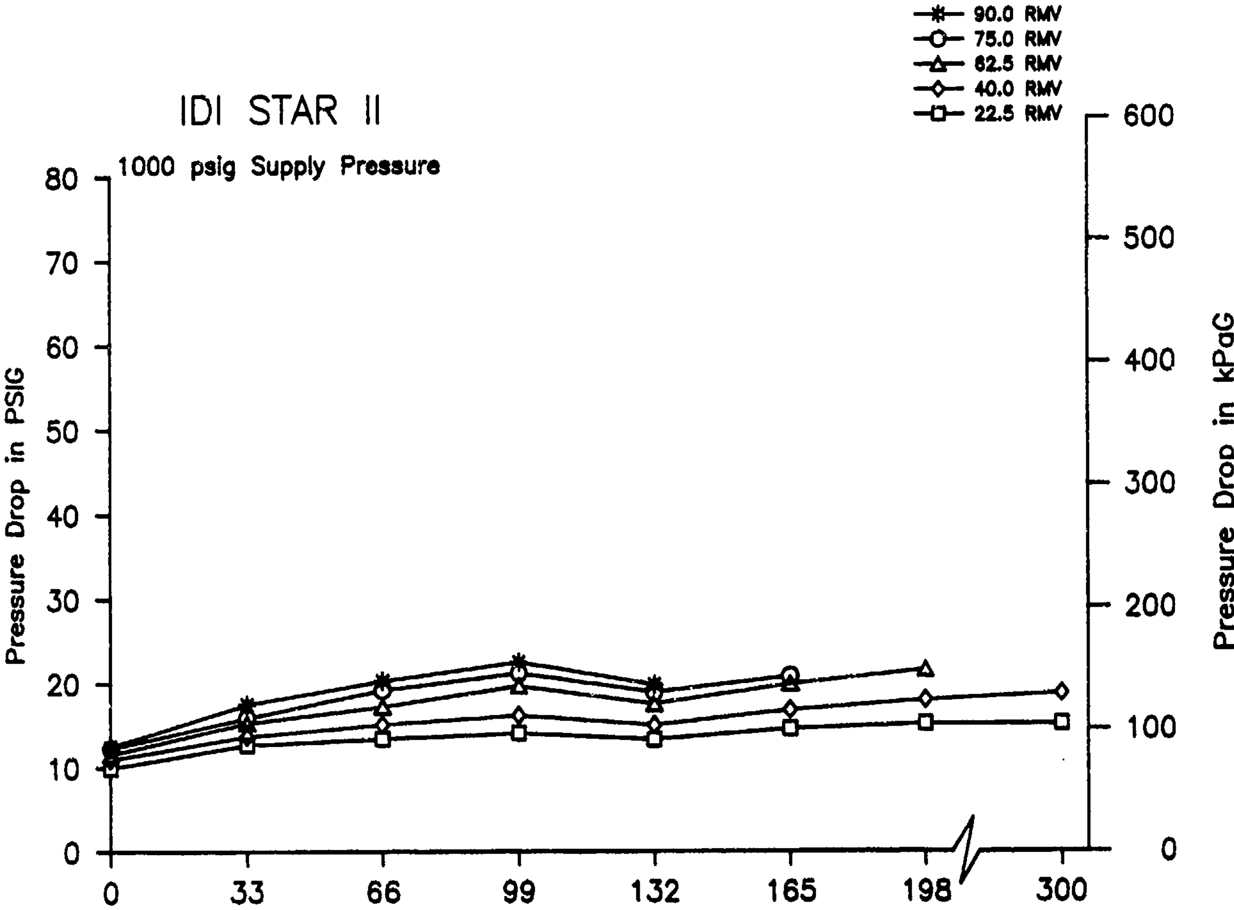
IDI STAR II
500 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
-10
-20
-30
-40
-50
5
4
3
2
1
0
-1
-2
-3
-4
-5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



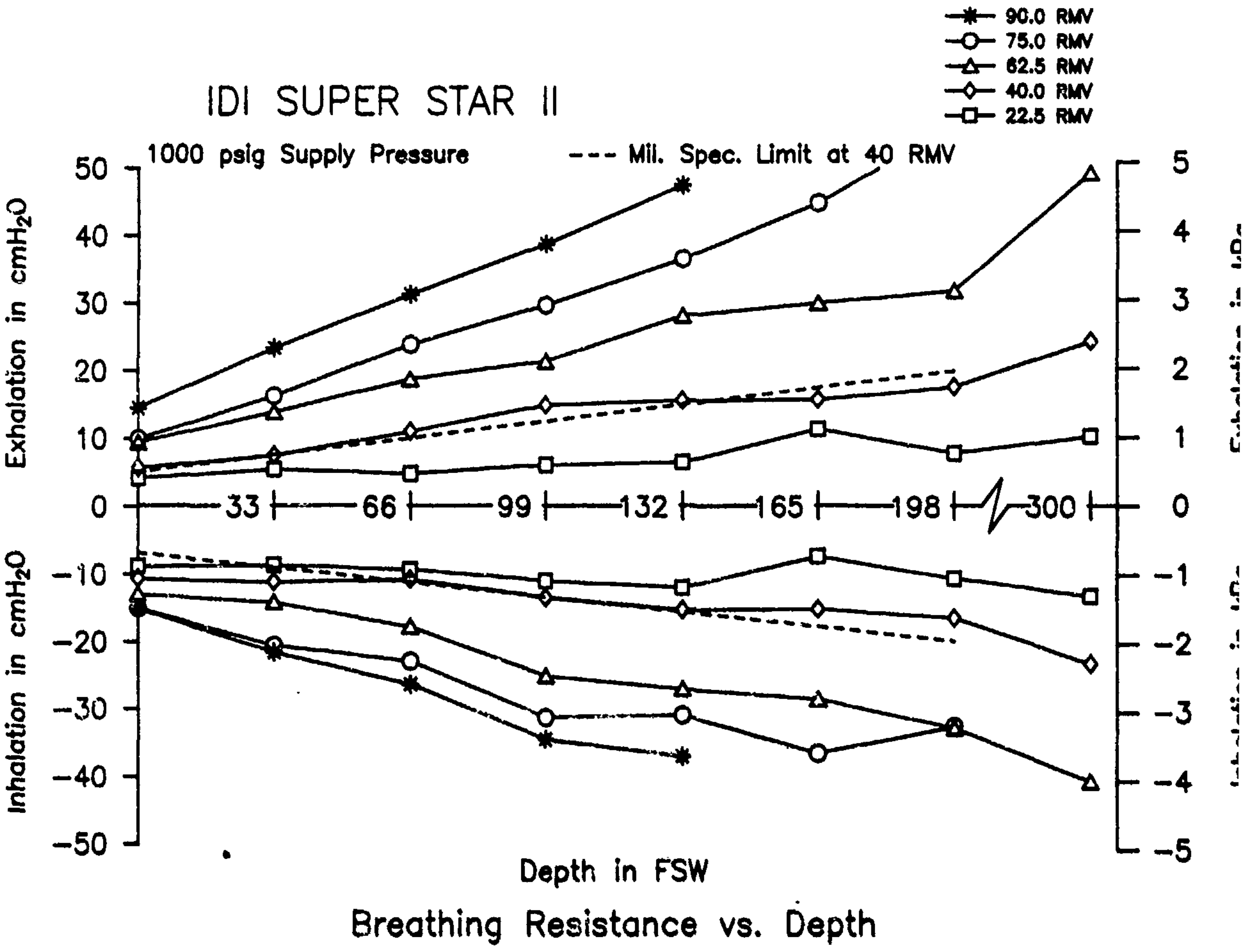
Breathing Resistance vs. Depth

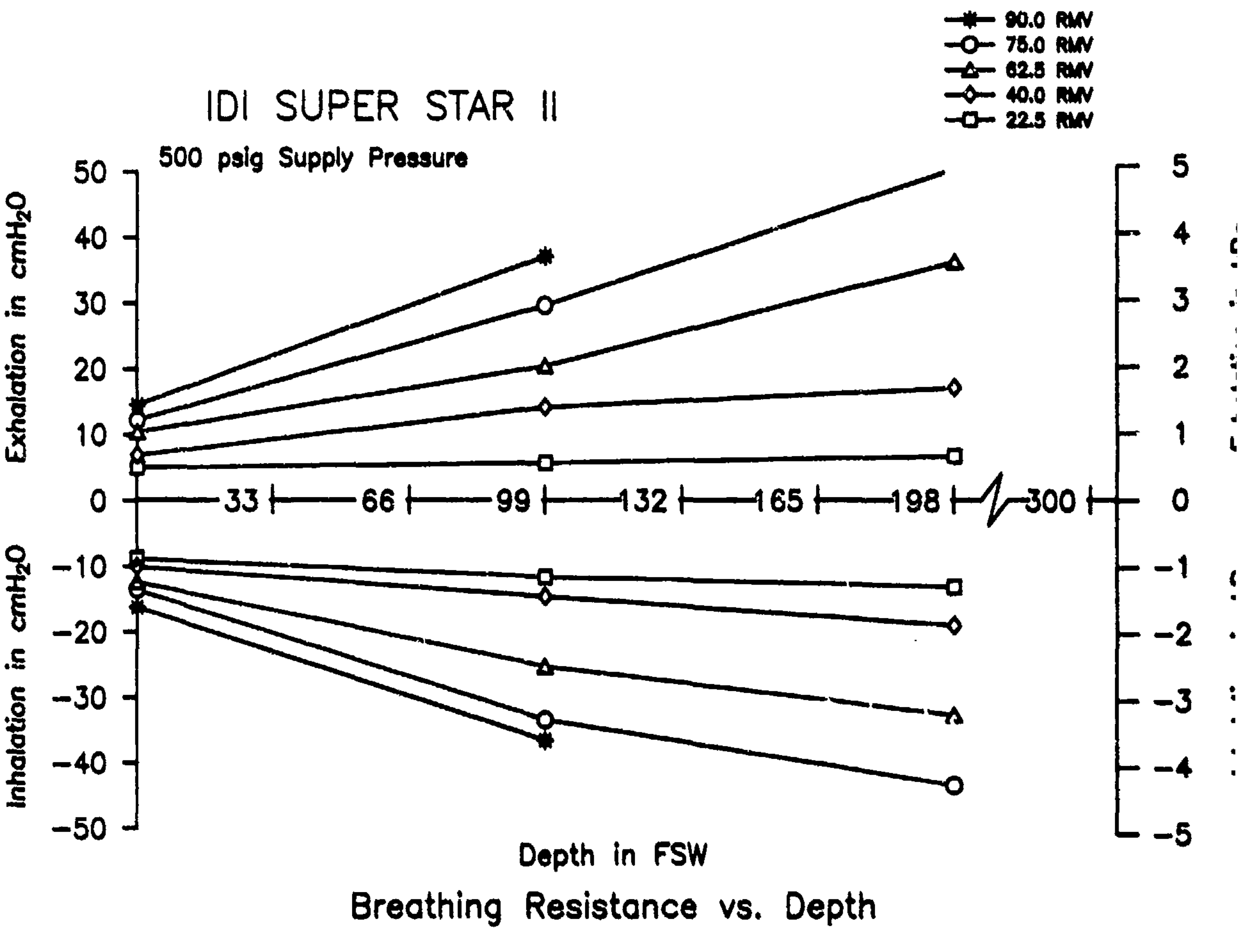


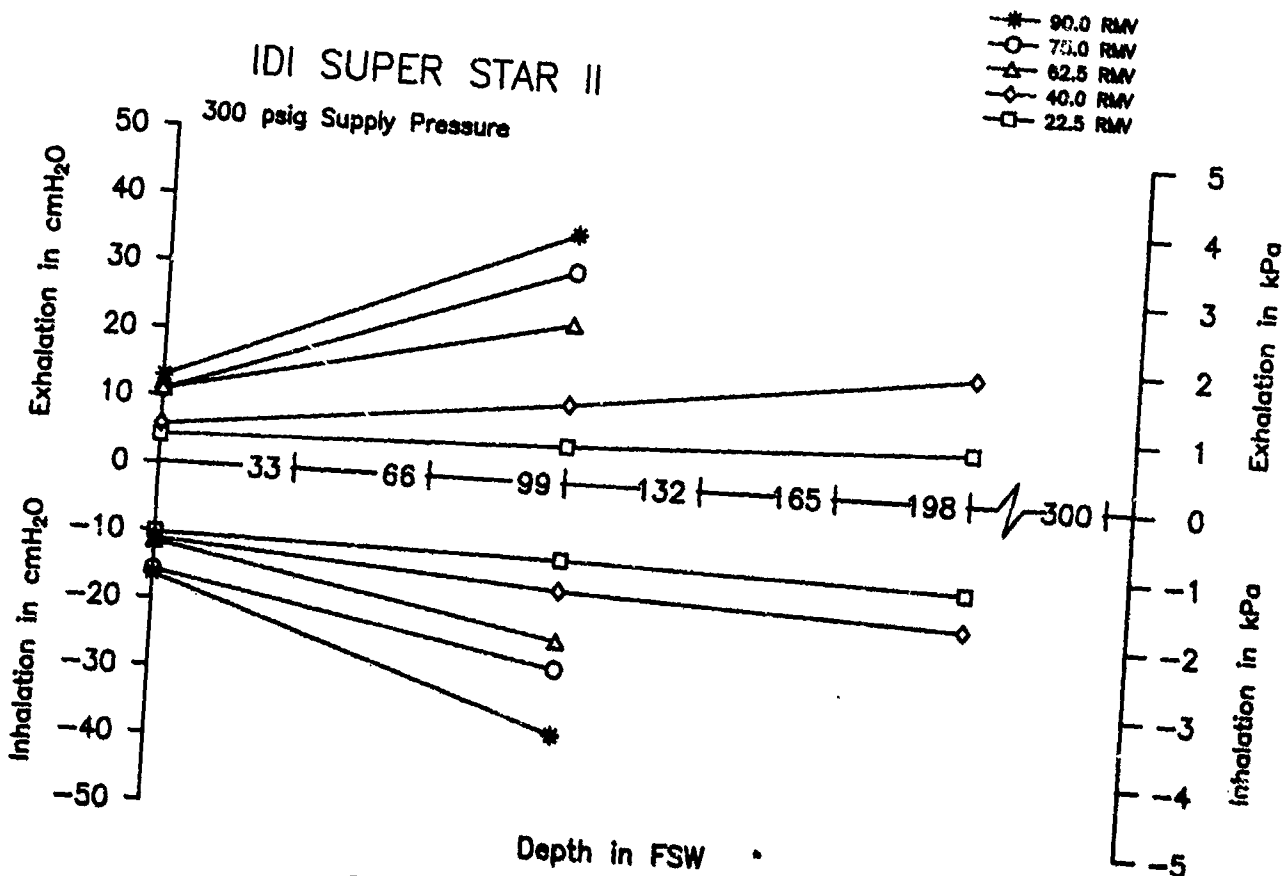
Breathing Work vs. Depth



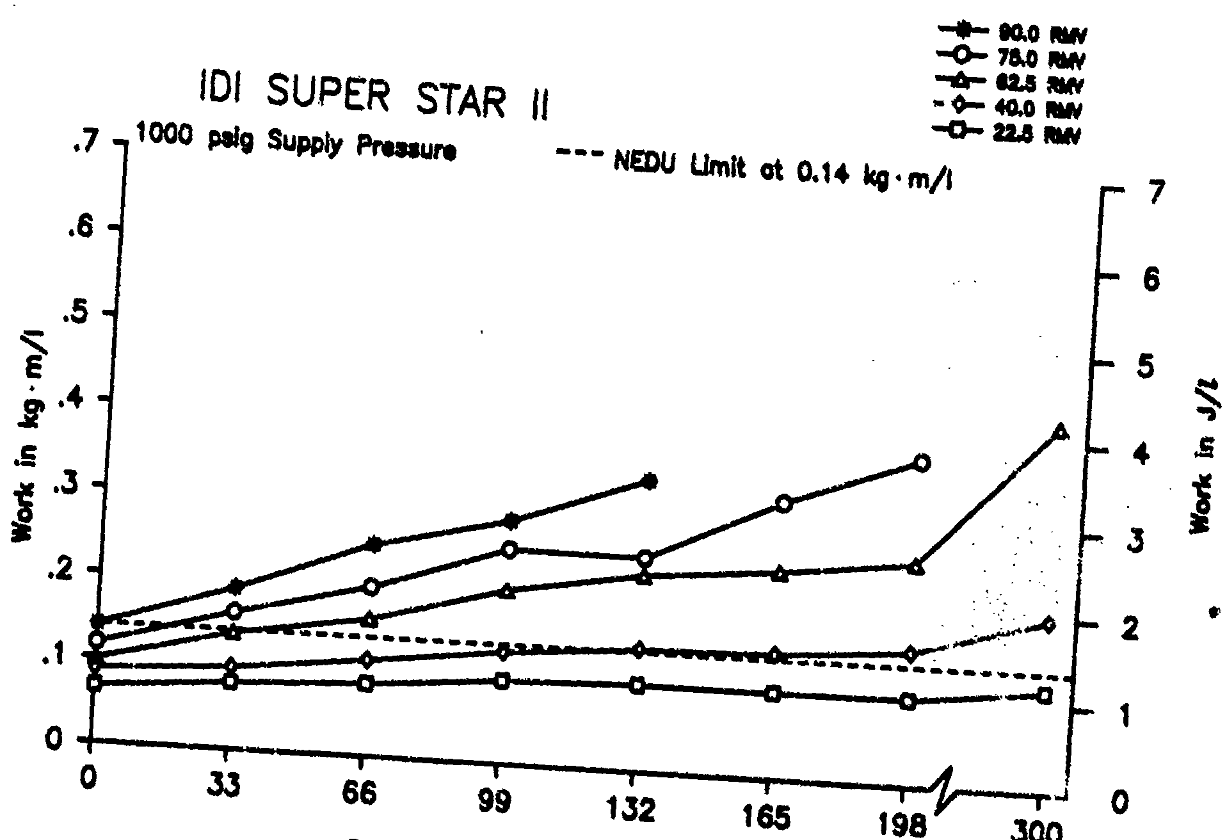
First Stage Pressure Drop vs. Depth


90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
IDI SUPER STAR II
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
50
40
30
20
10
0
−10
−20
−30
−40
−50
33
66
99
132
165
198
300
5
4
3
2
1
0
−1
−2
−3
−4
−5
Depth in FSW
Breathing Resistance vs. Depth

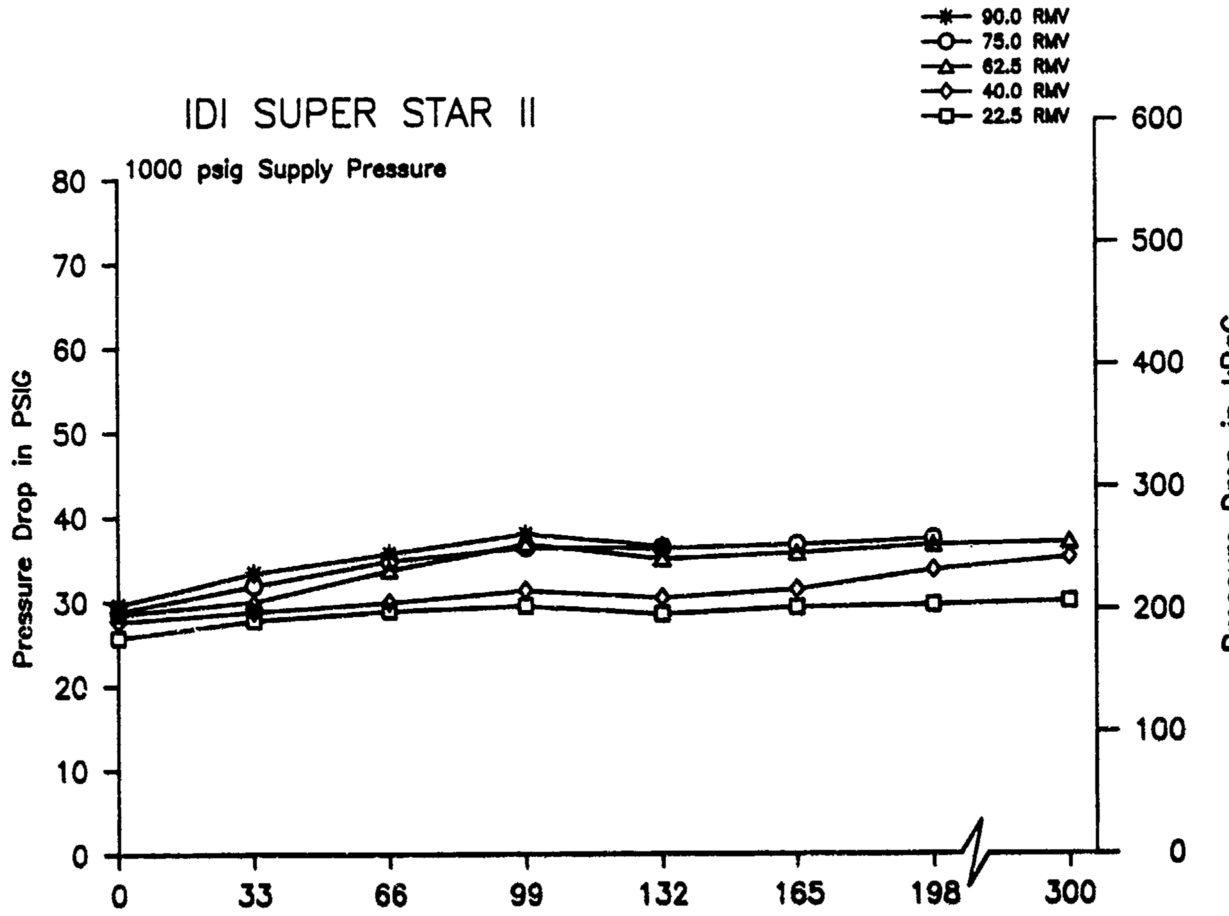

90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
IDI SUPER STAR II
500 psig Supply Pressure
Exhalation in cmH_2O
Inhalation in cmH_2O
50
40
30
20
10
0
−10
−20
−30
−40
−50
33
66
99
132
165
198
300
5
4
3
2
1
0
−1
−2
−3
−4
−5
Depth in FSW
Breathing Resistance vs. Depth



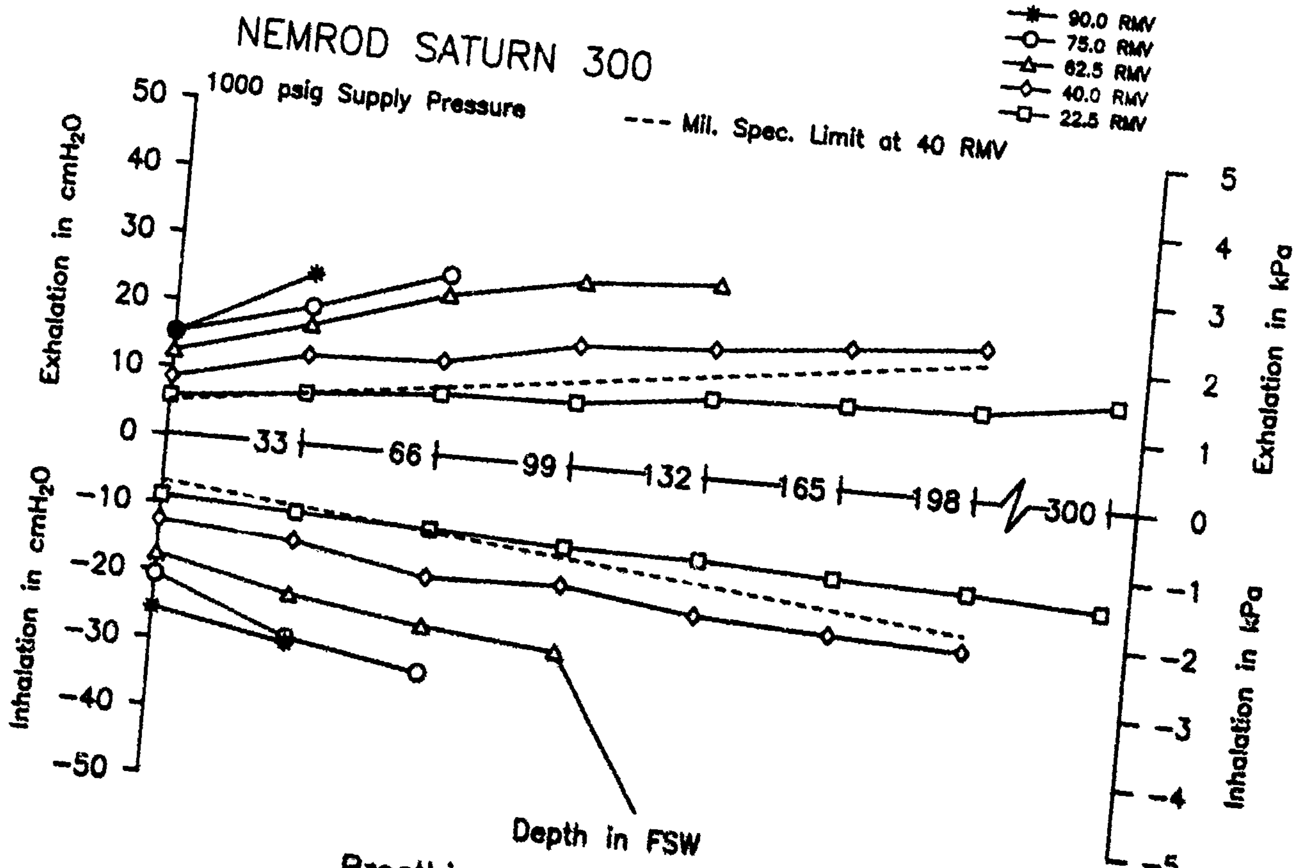
Breathing Resistance vs. Depth



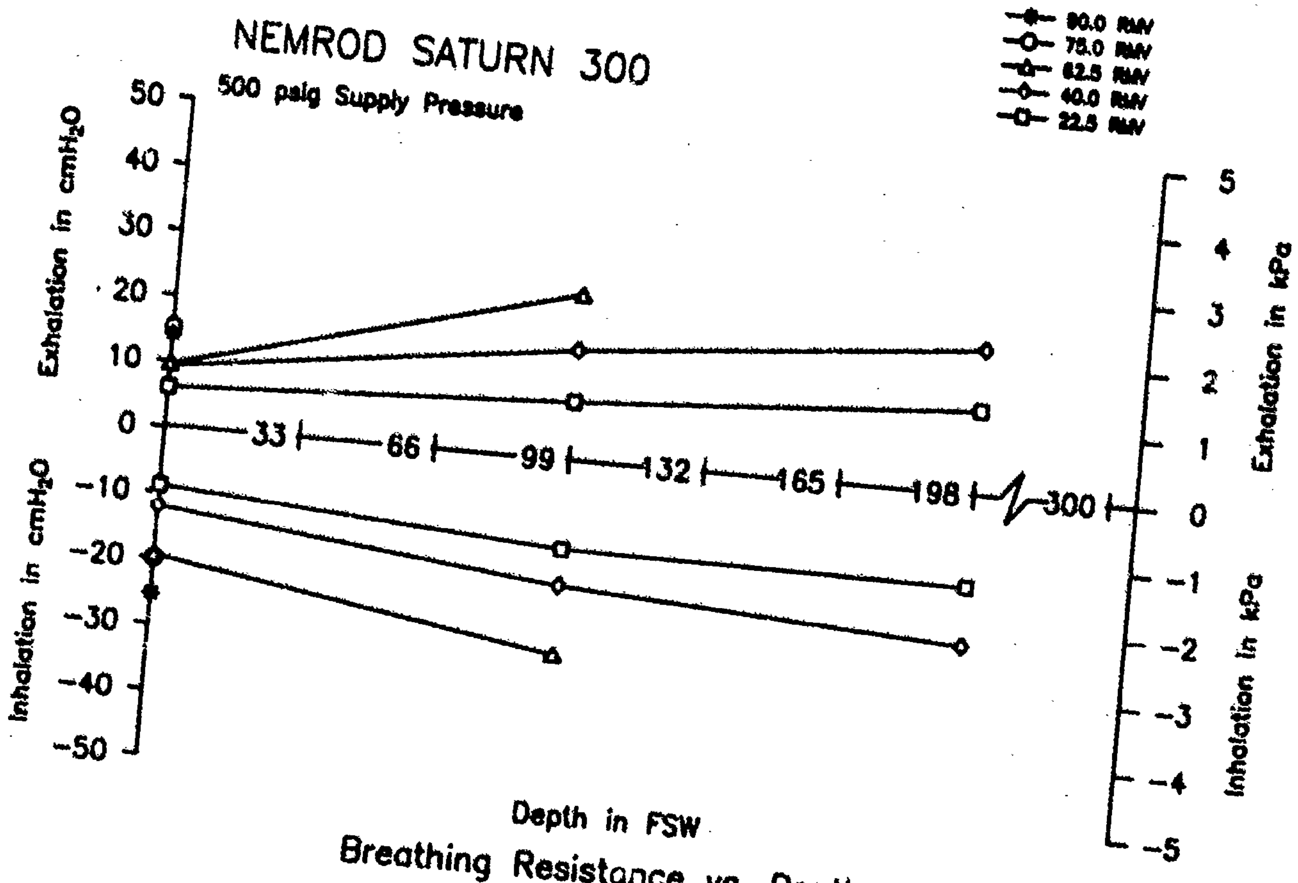
Breathing Work vs. Depth



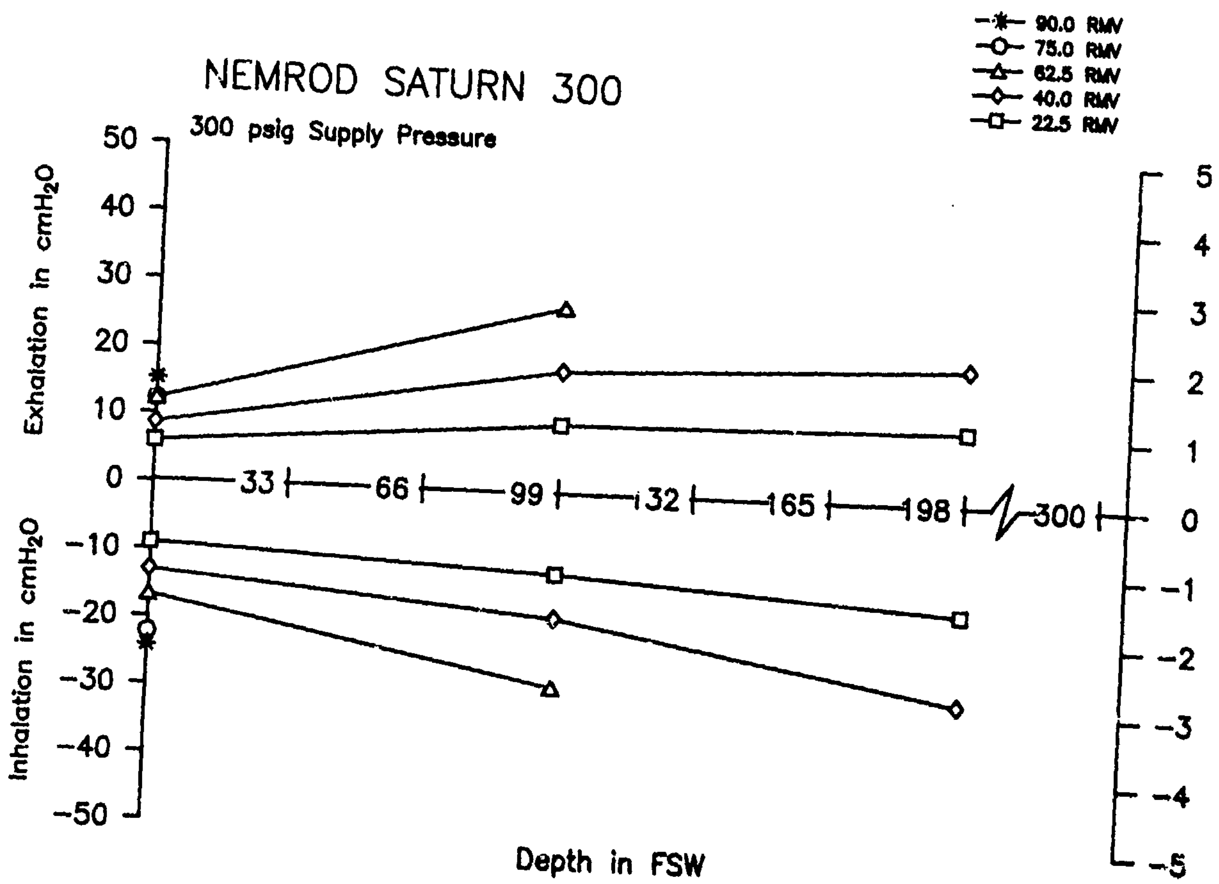
First Stage Pressure Drop vs. Depth



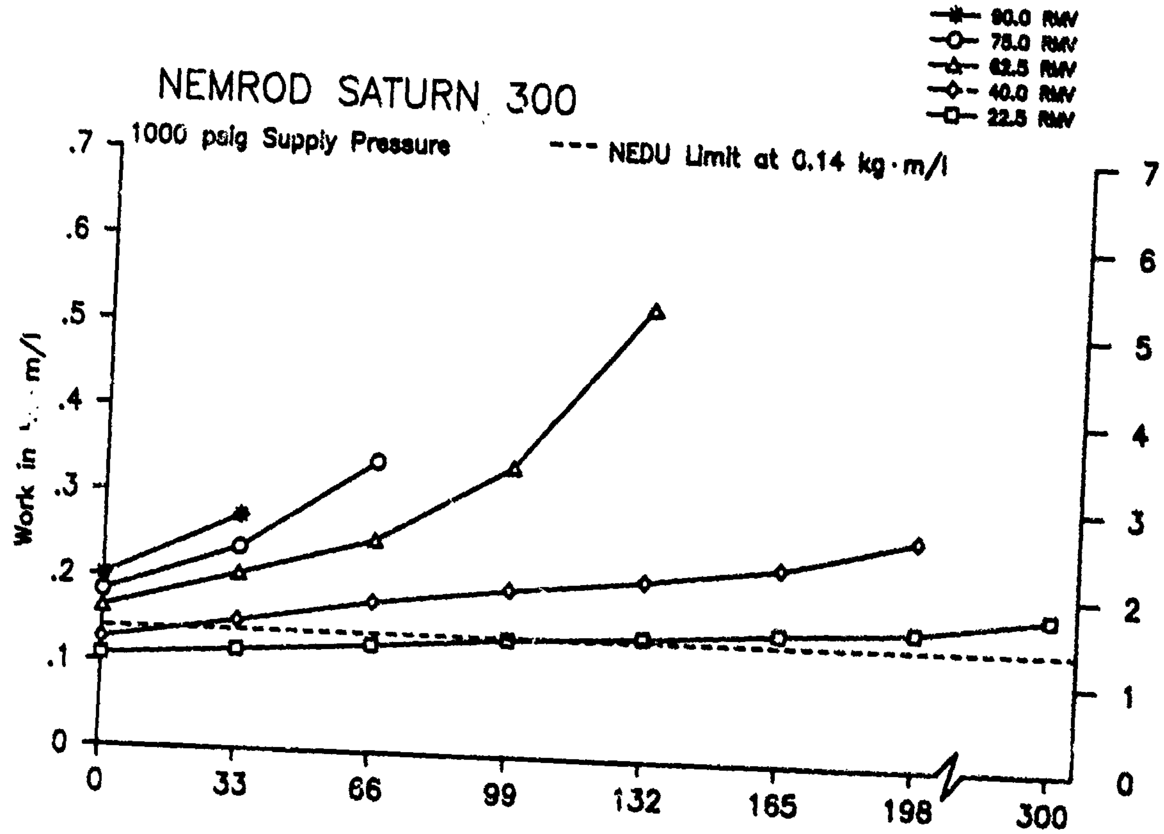
Breathing Resistance vs. Depth



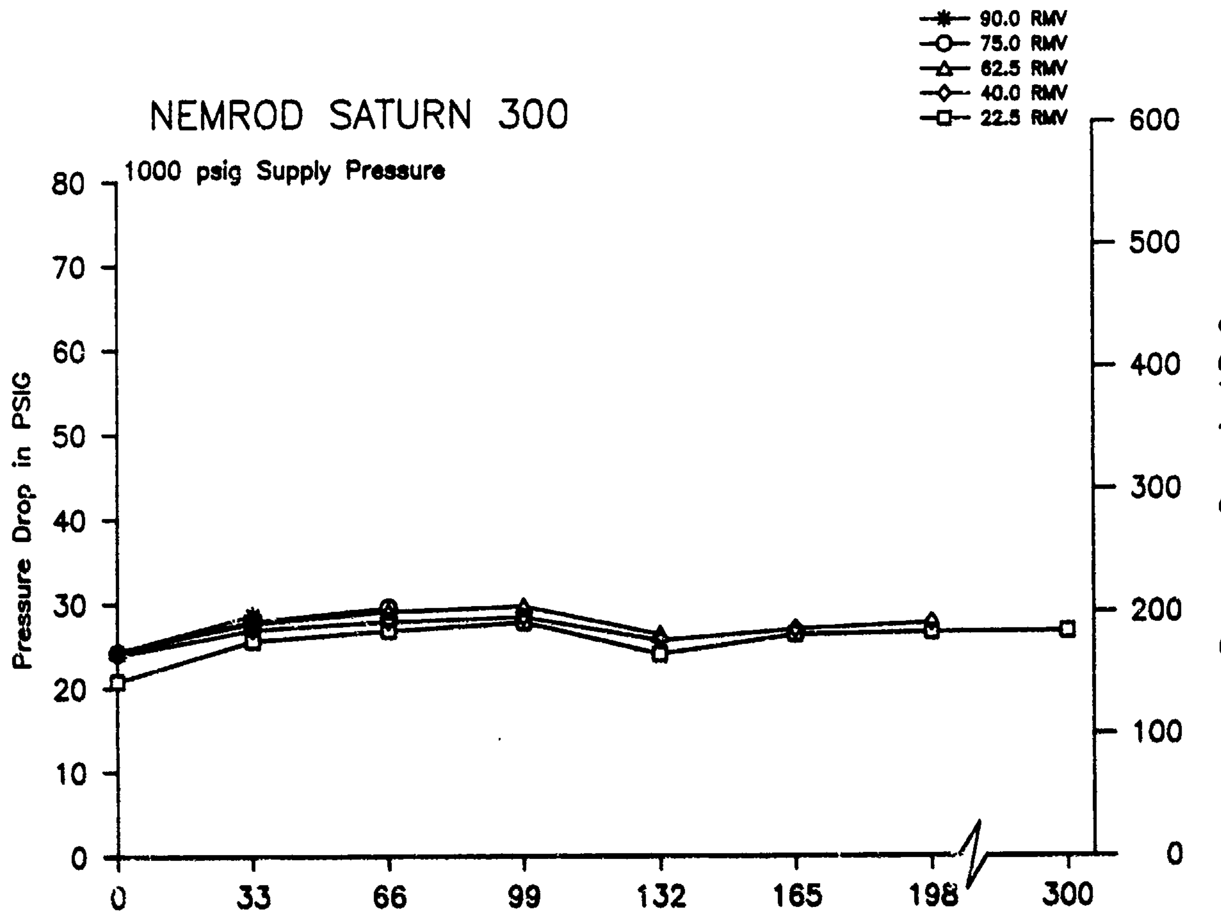
Breathing Resistance vs. Depth



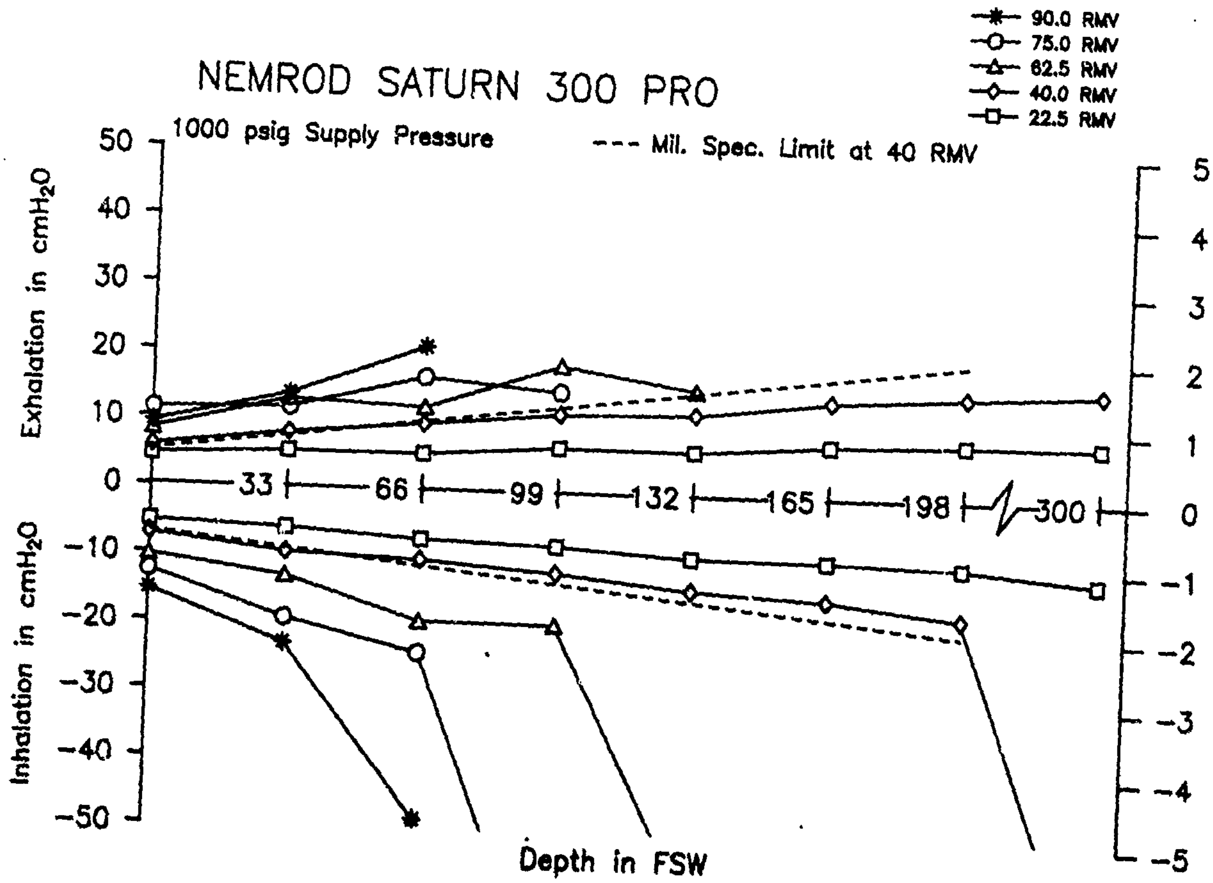
Breathing Resistance vs. Depth



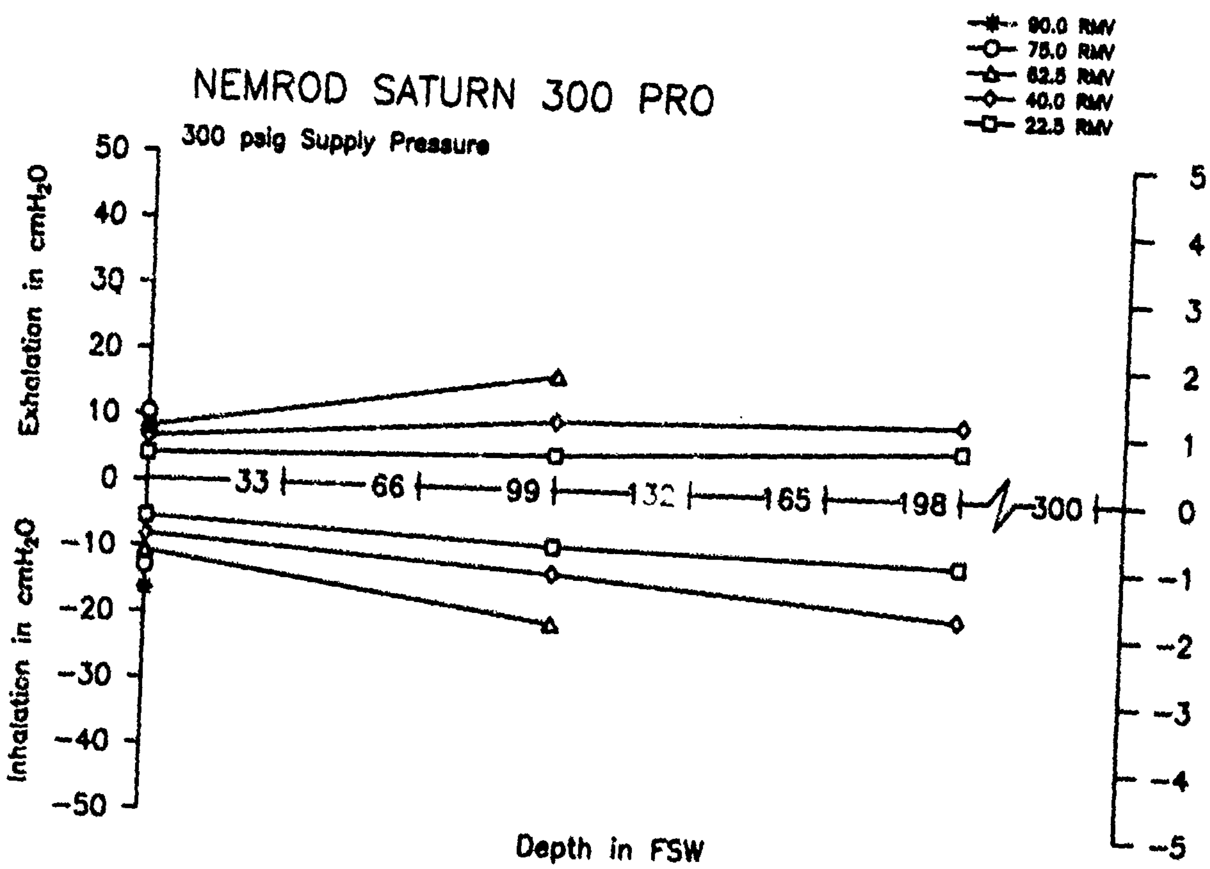
Breathing Work vs. Depth



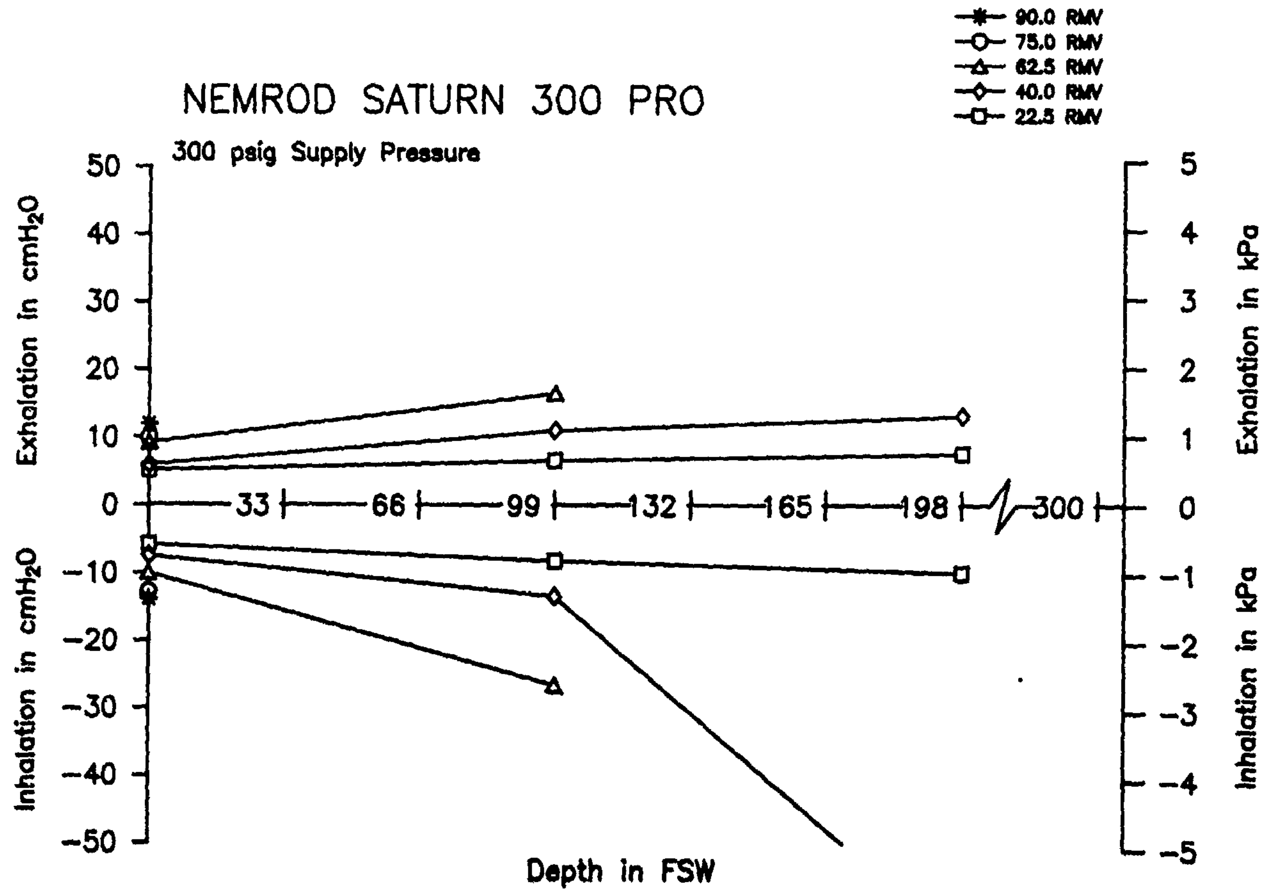
First Stage Pressure Drop vs. Depth



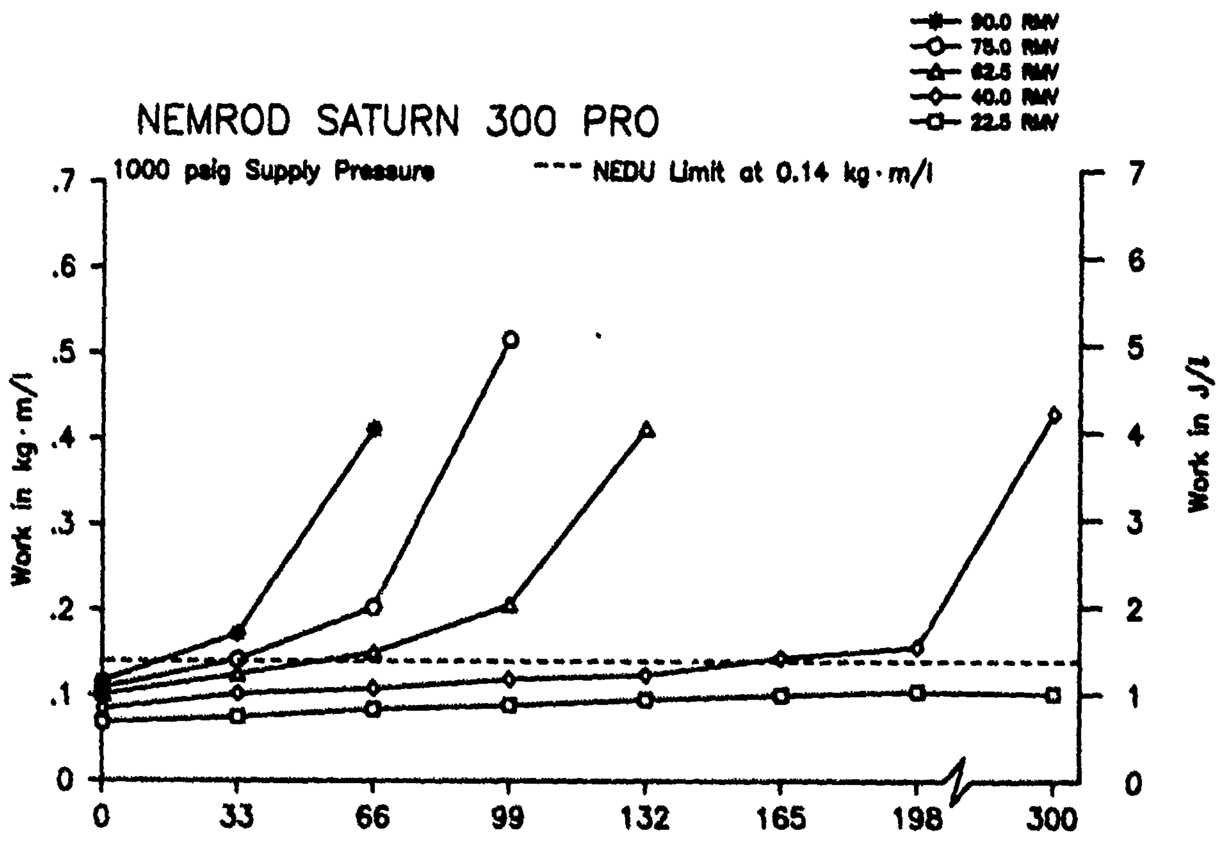
Breathing Resistance vs. Depth



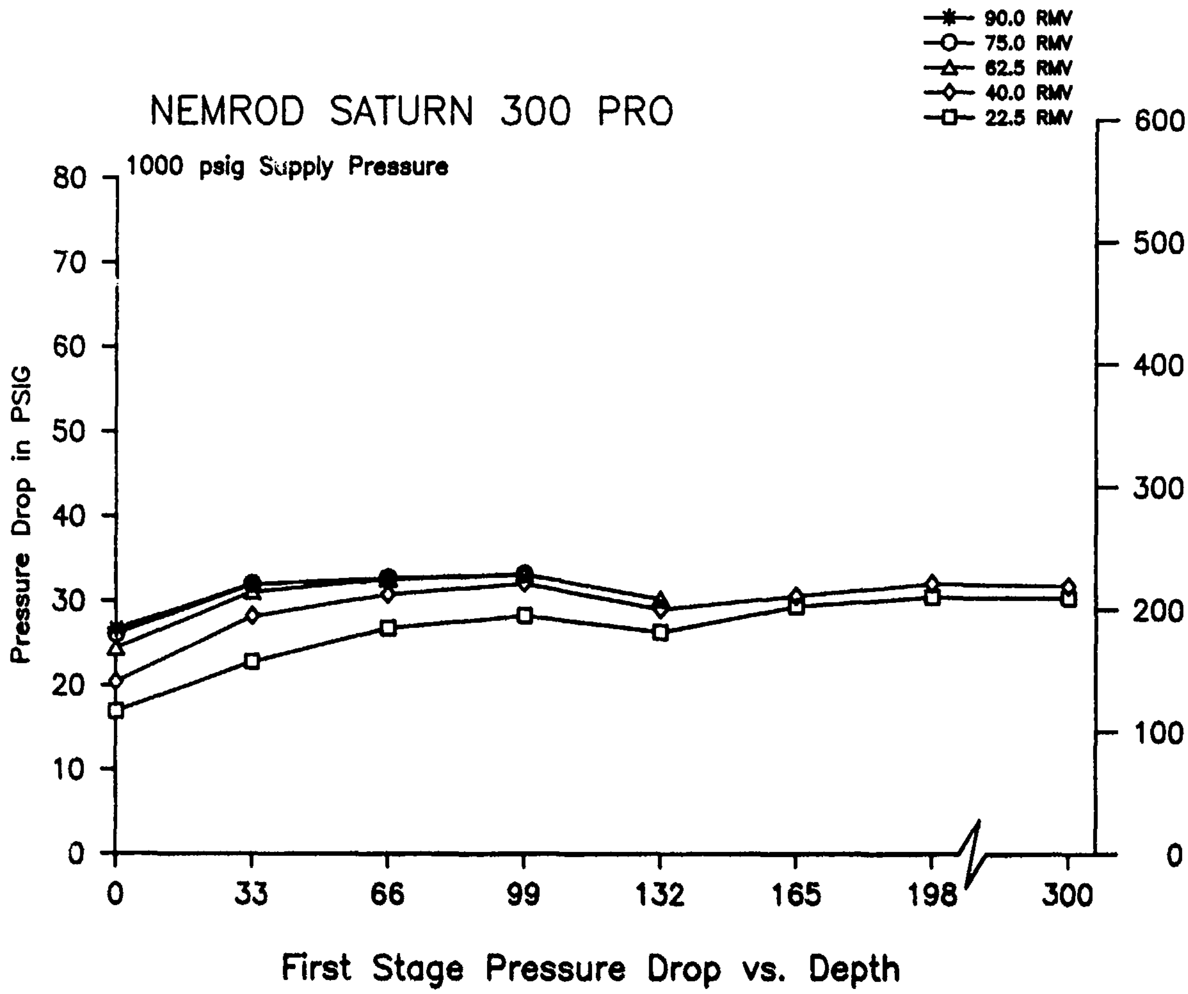
Breathing Resistance vs. Depth

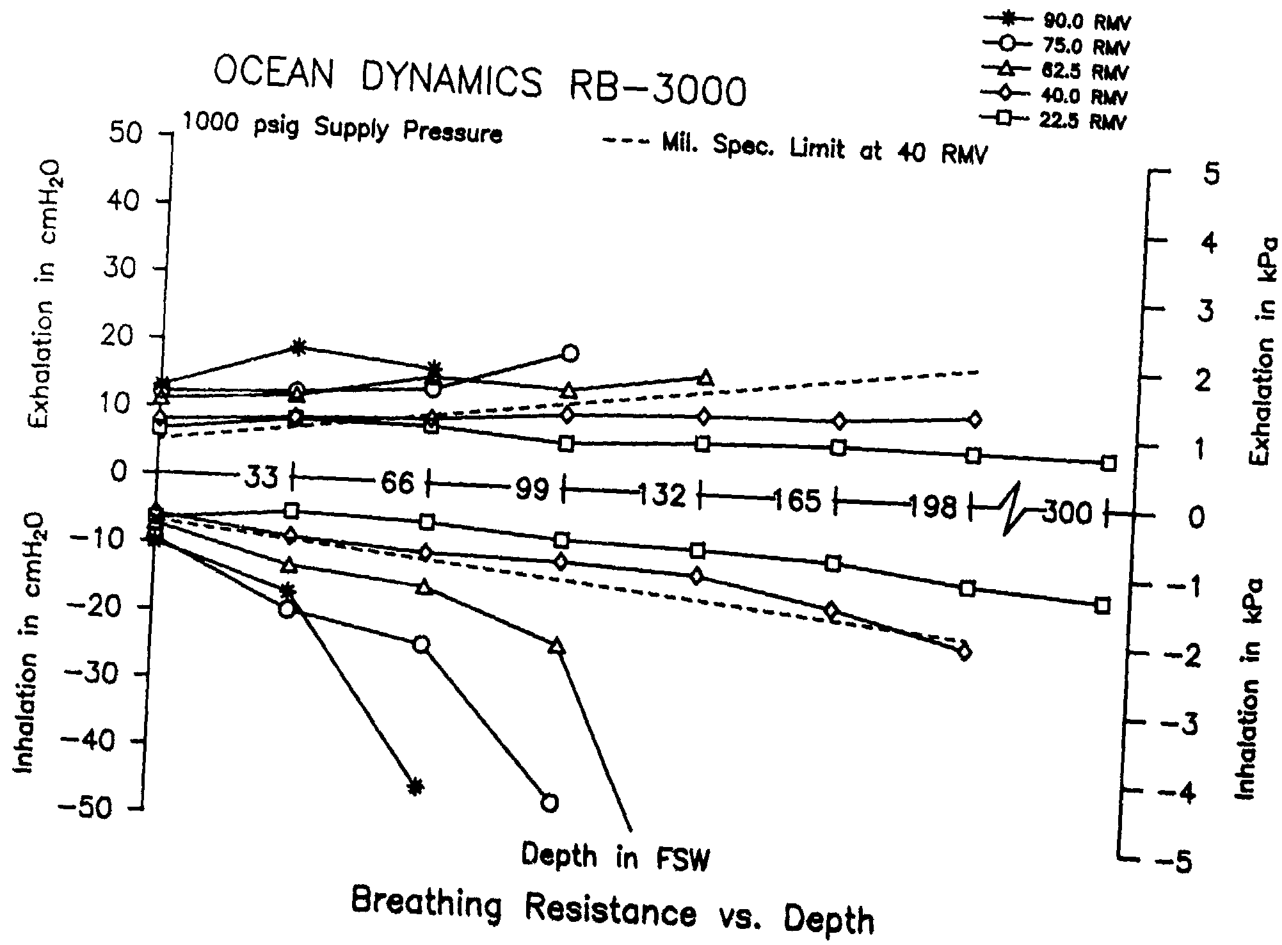


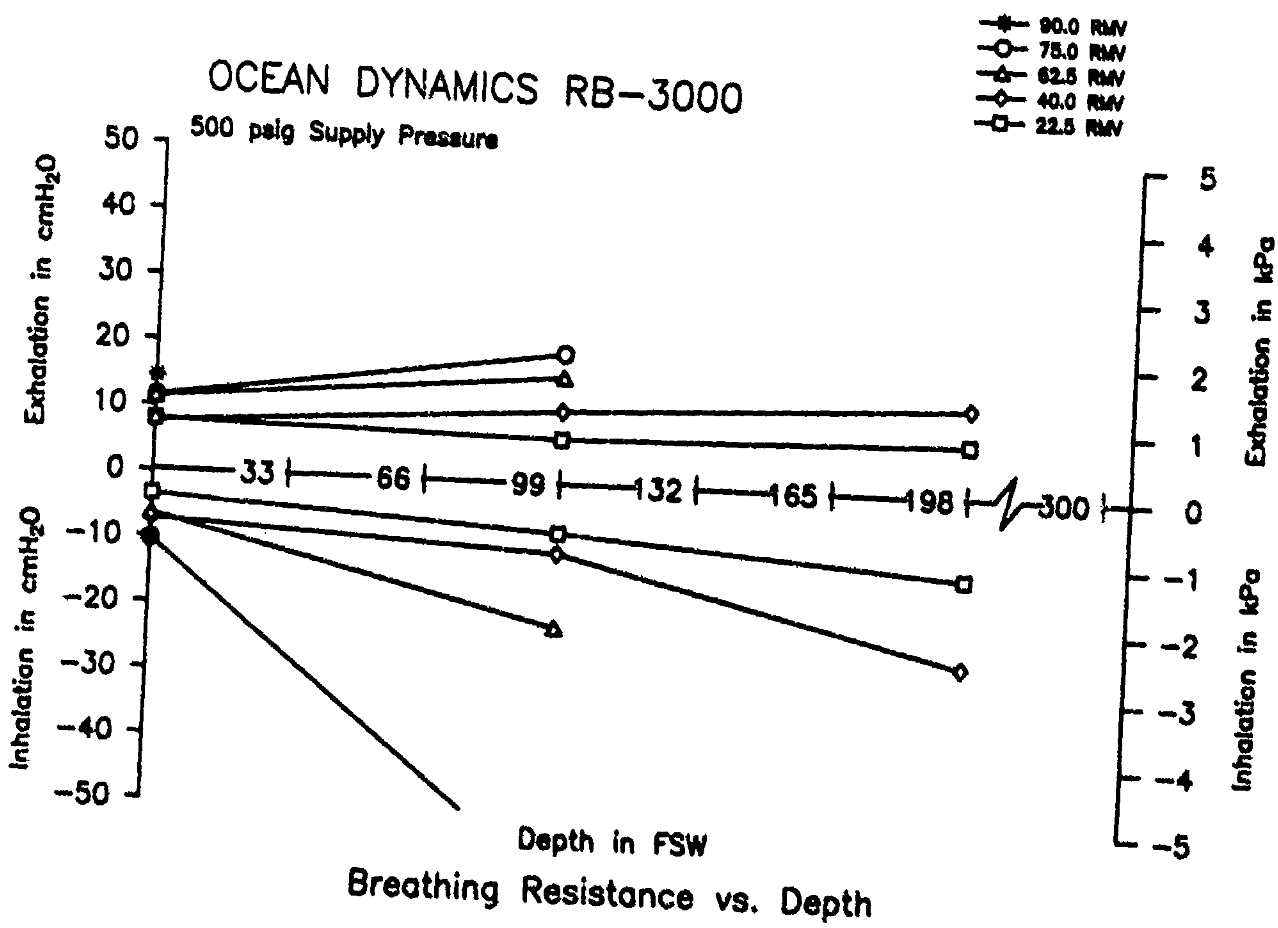
Breathing Resistance vs. Depth

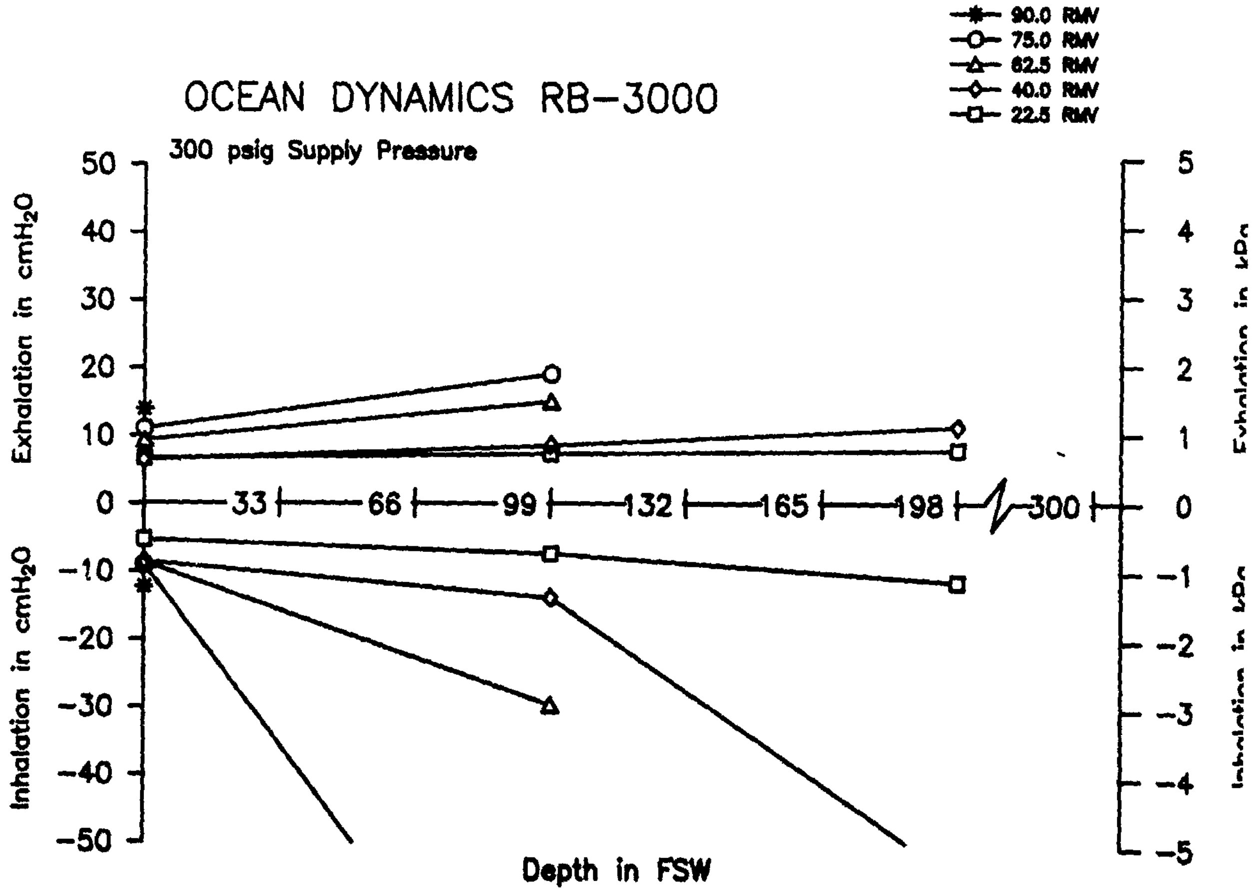


Breathing Work vs. Depth

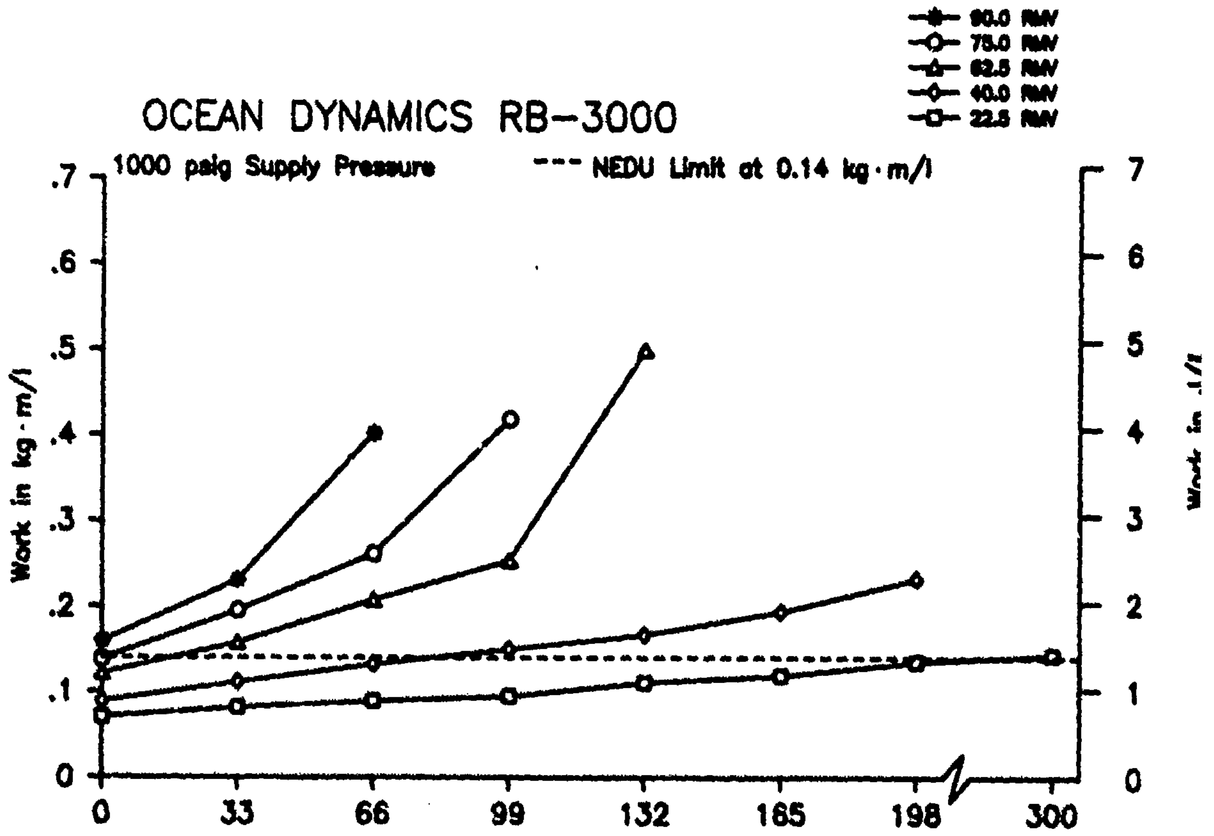

NEMROD SATURN 300 PRO
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
0
10
20
30
40
50
60
70
80
0
100
200
300
400
500
600
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth


OCEAN DYNAMICS RB-3000
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth

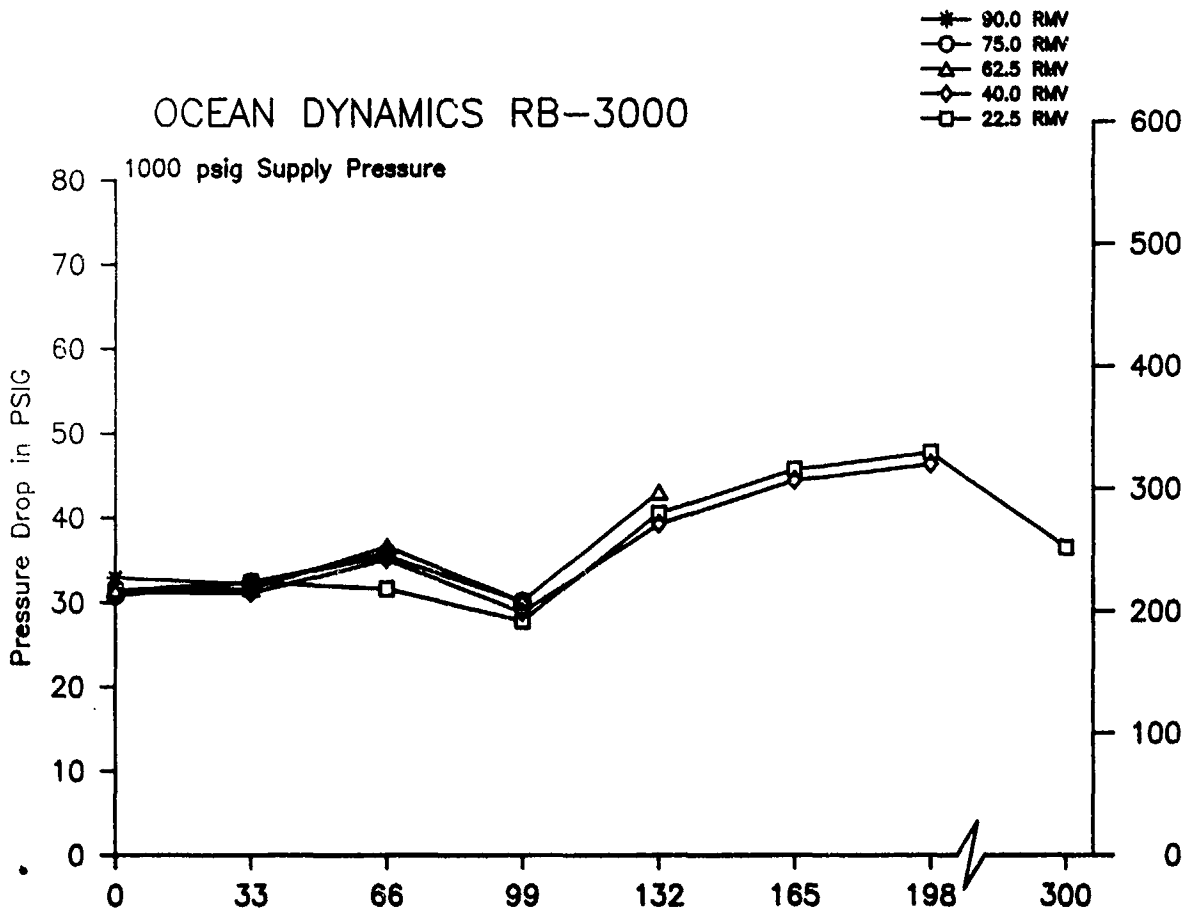

OCEAN DYNAMICS RB-3000
500 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



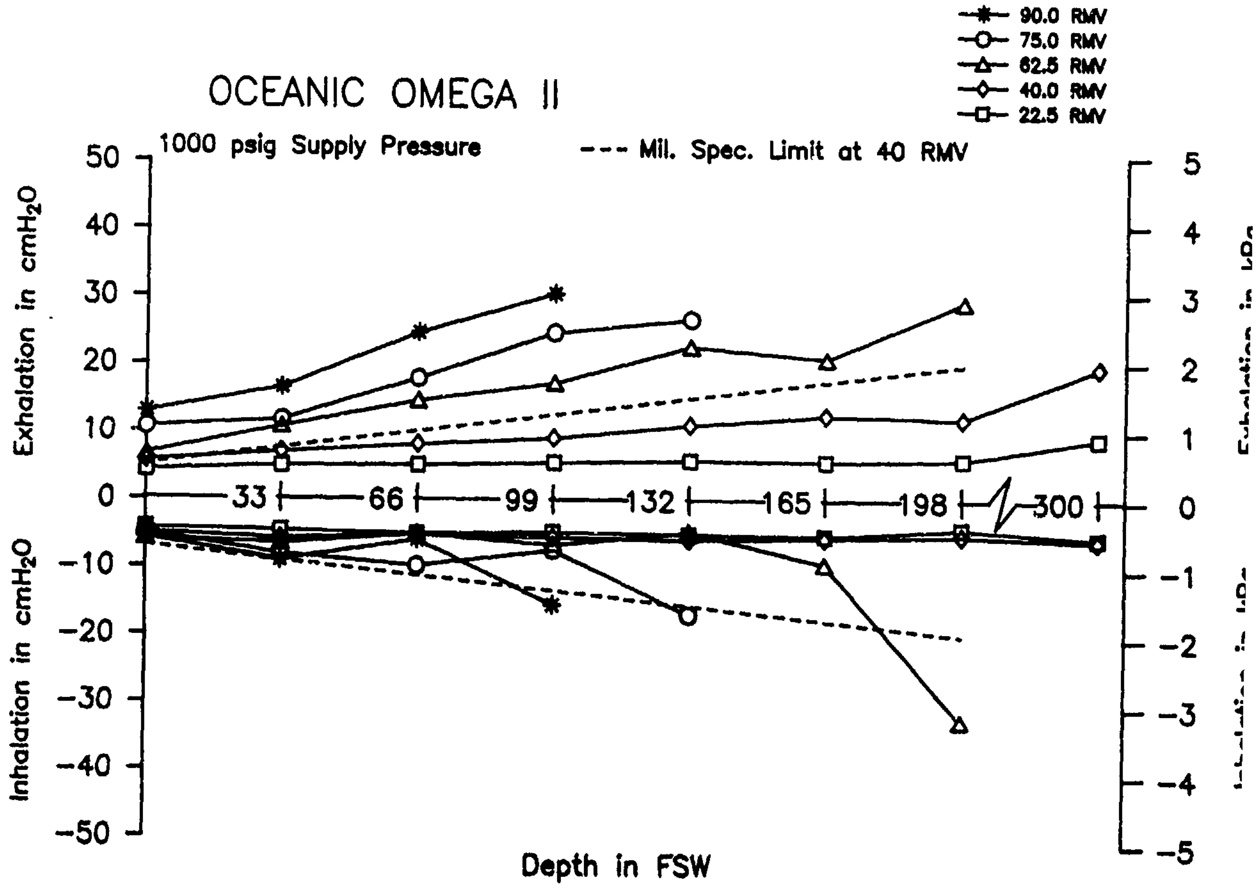
Breathing Resistance vs. Depth



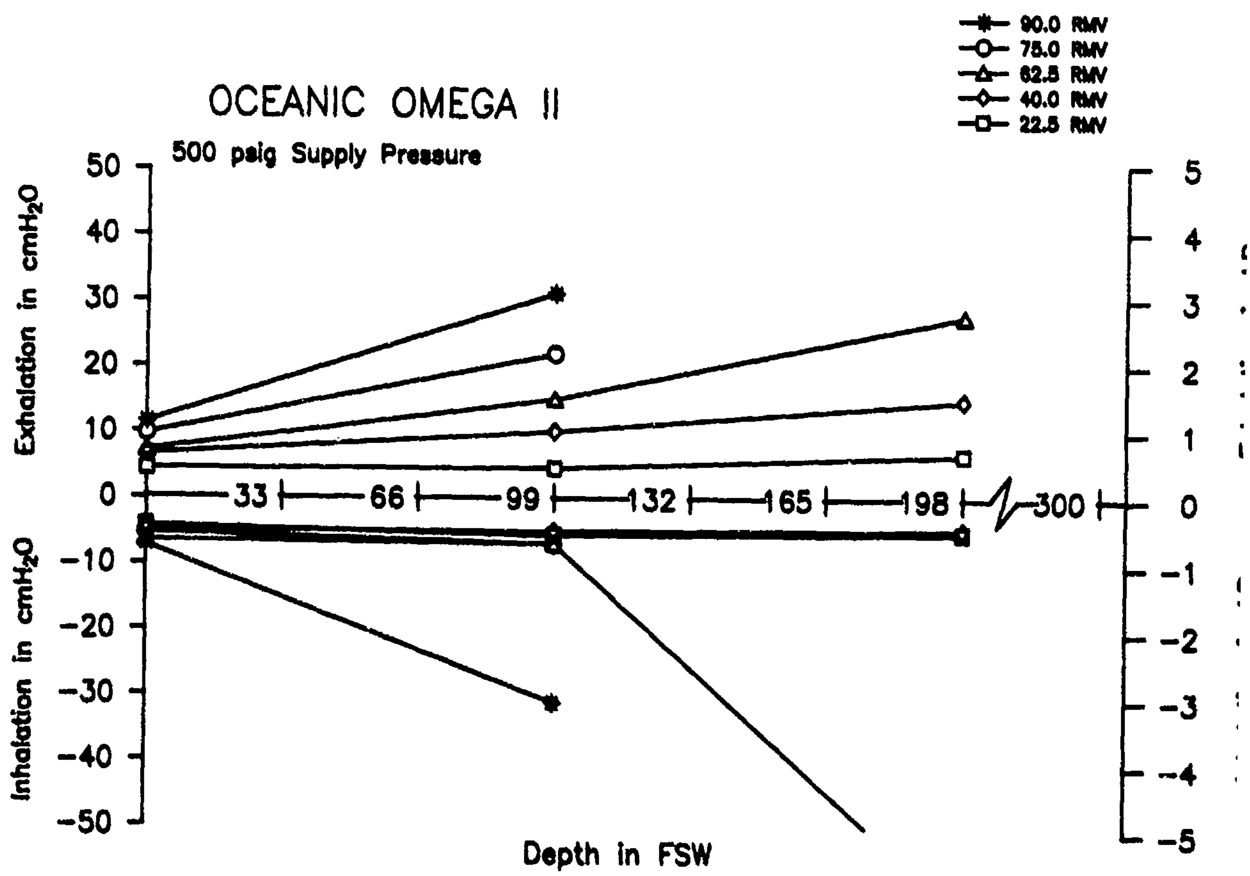
Breathing Work vs. Depth



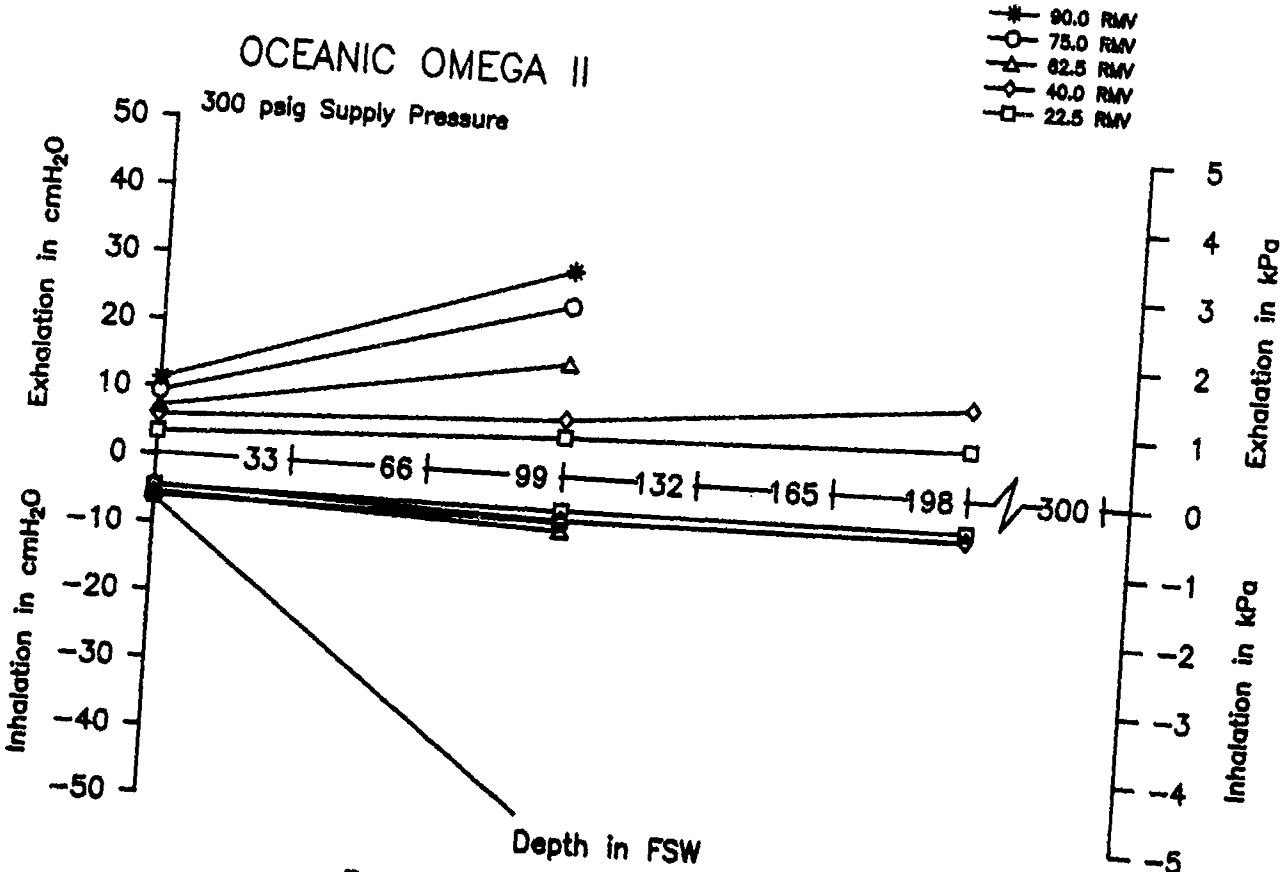
First Stage Pressure Drop vs. Depth



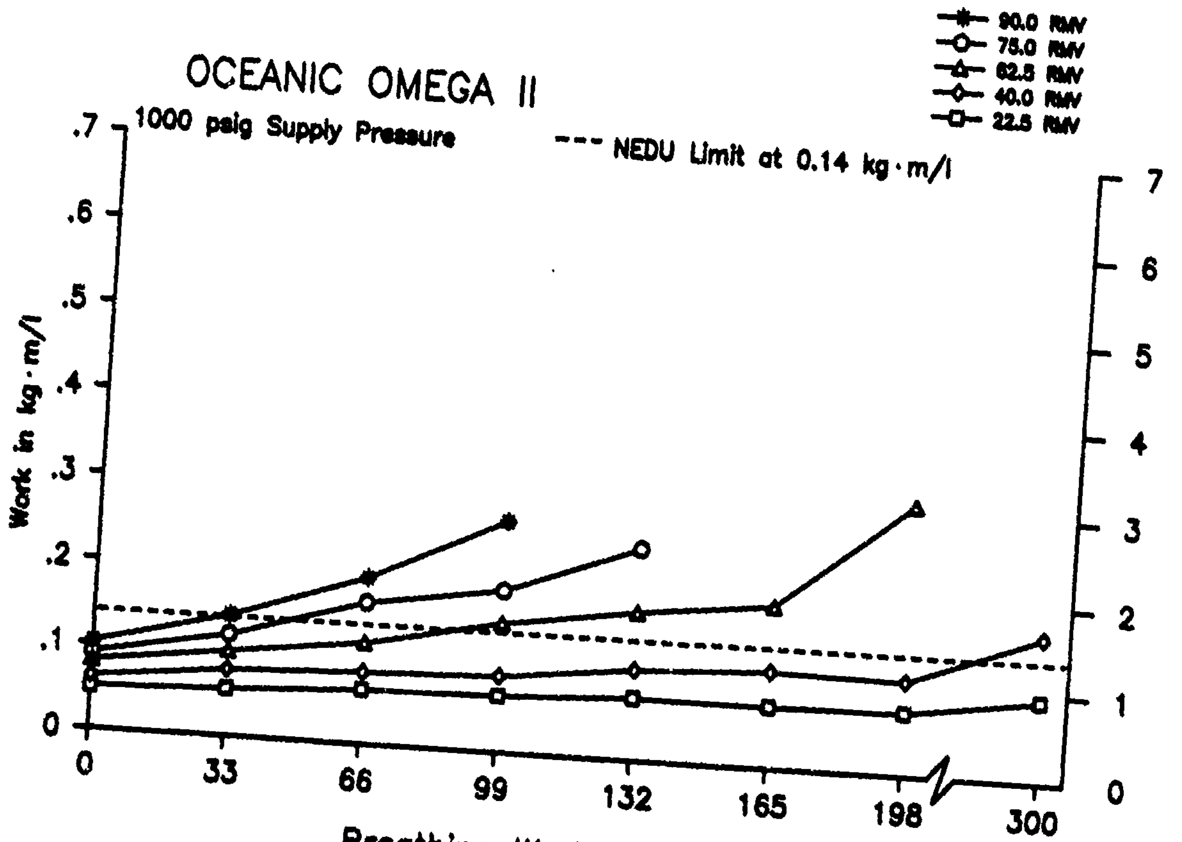
Breathing Resistance vs. Depth



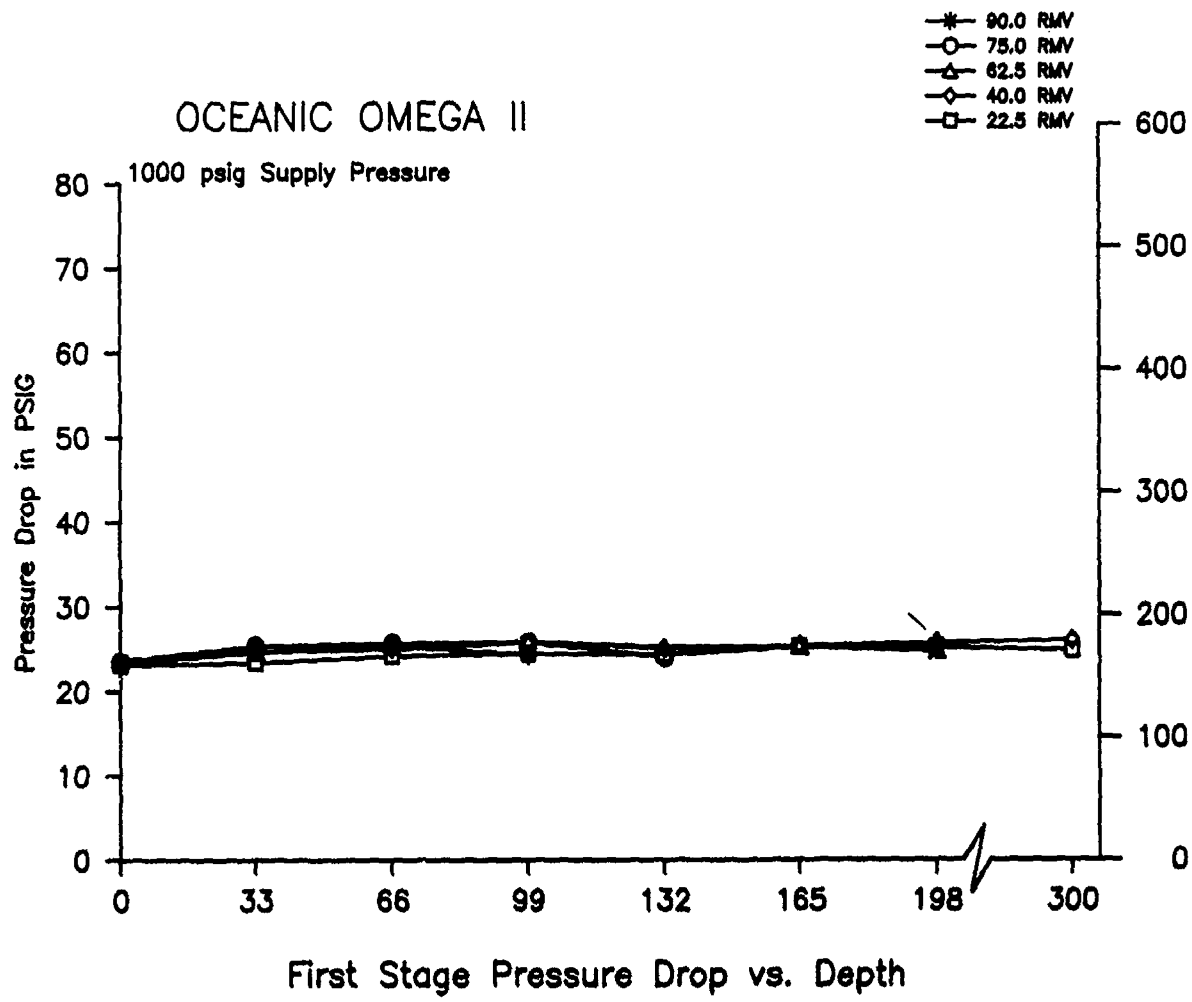
Breathing Resistance vs. Depth



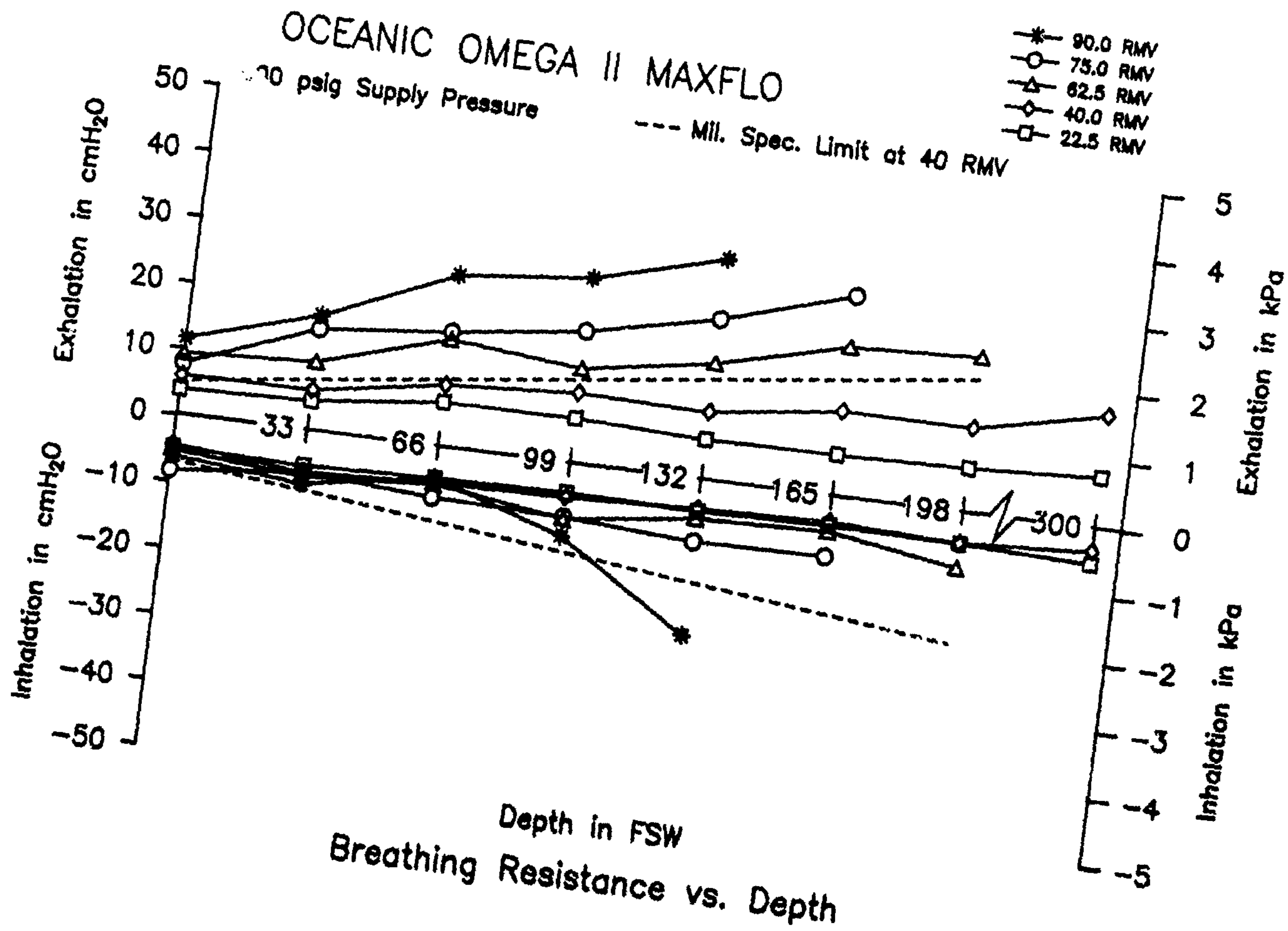
Breathing Resistance vs. Depth

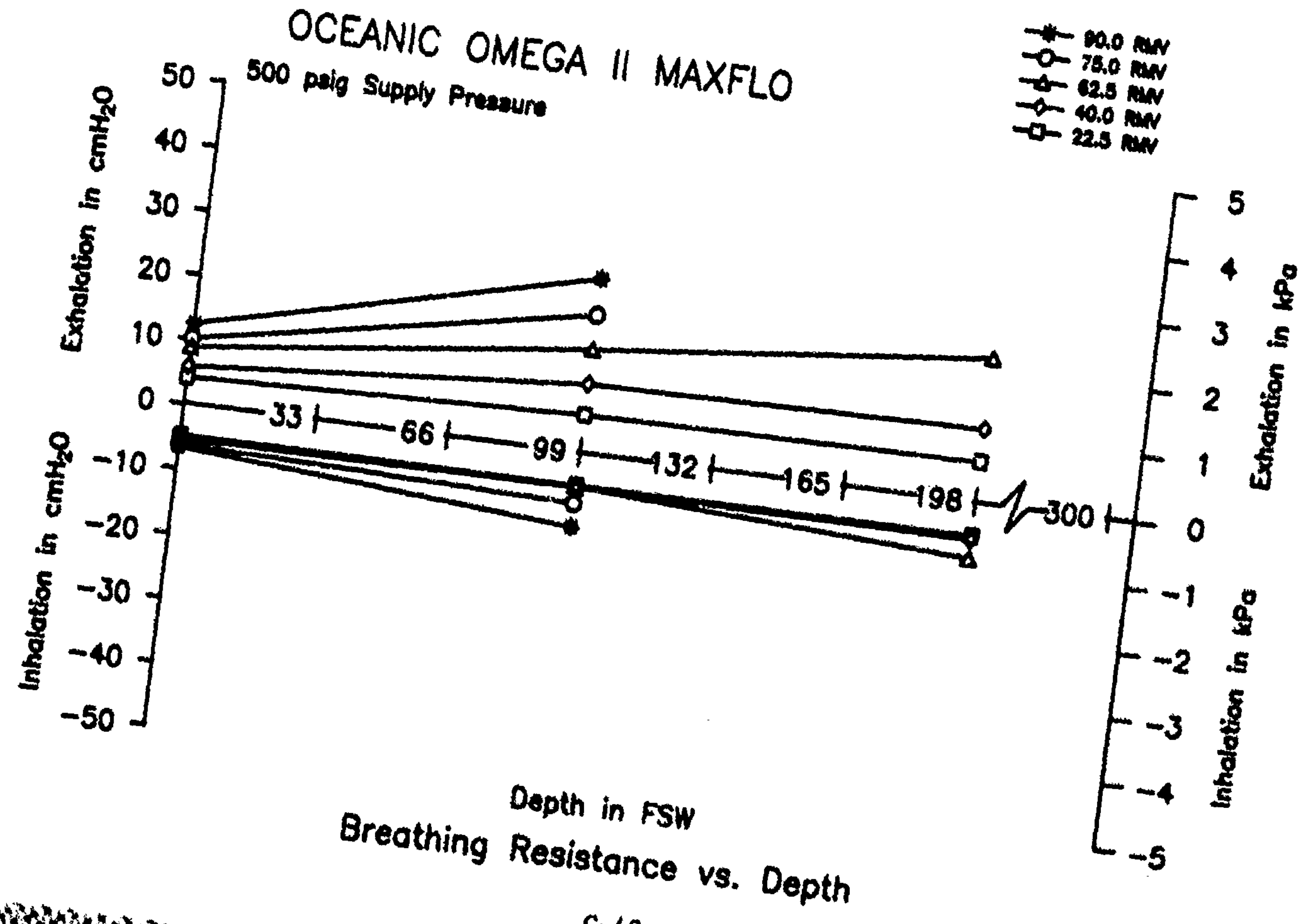


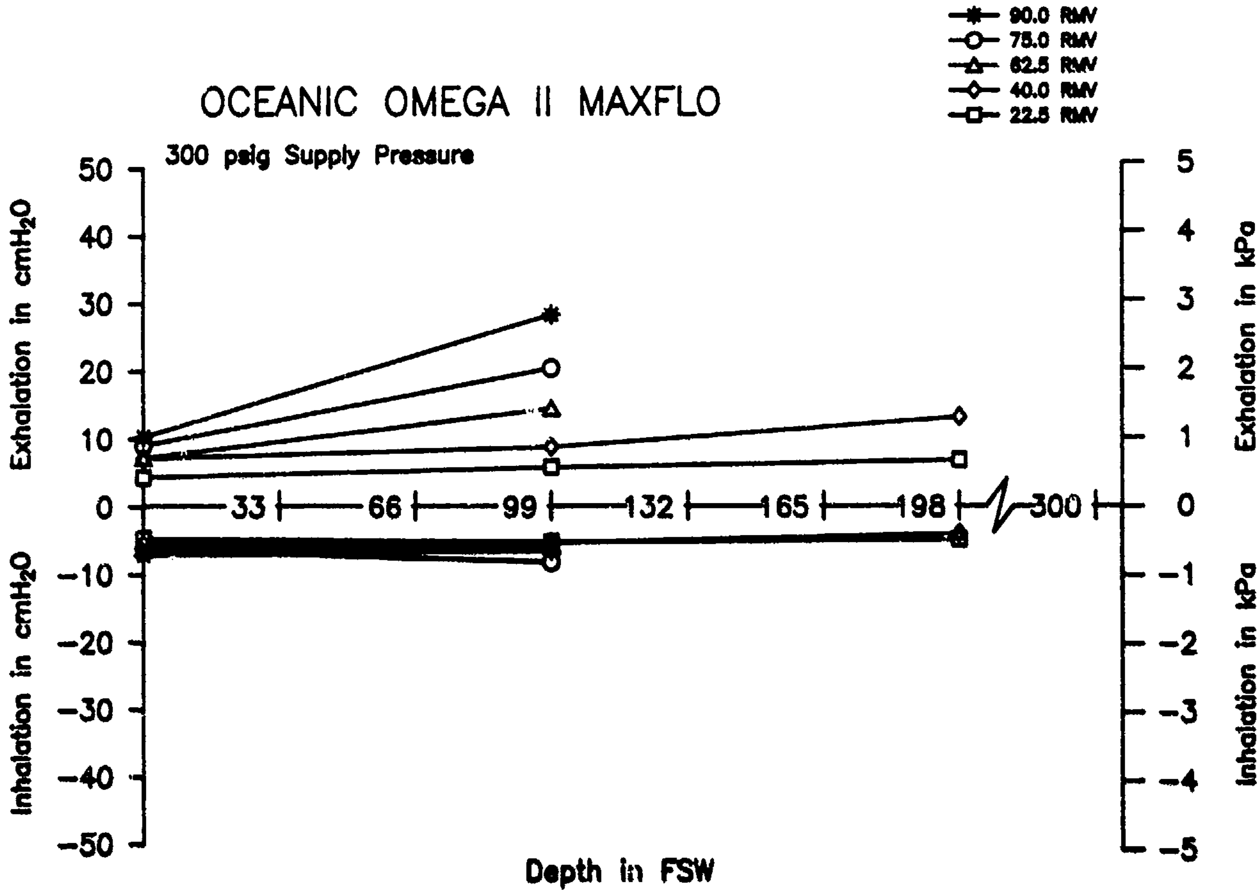
Breathing Work vs. Depth



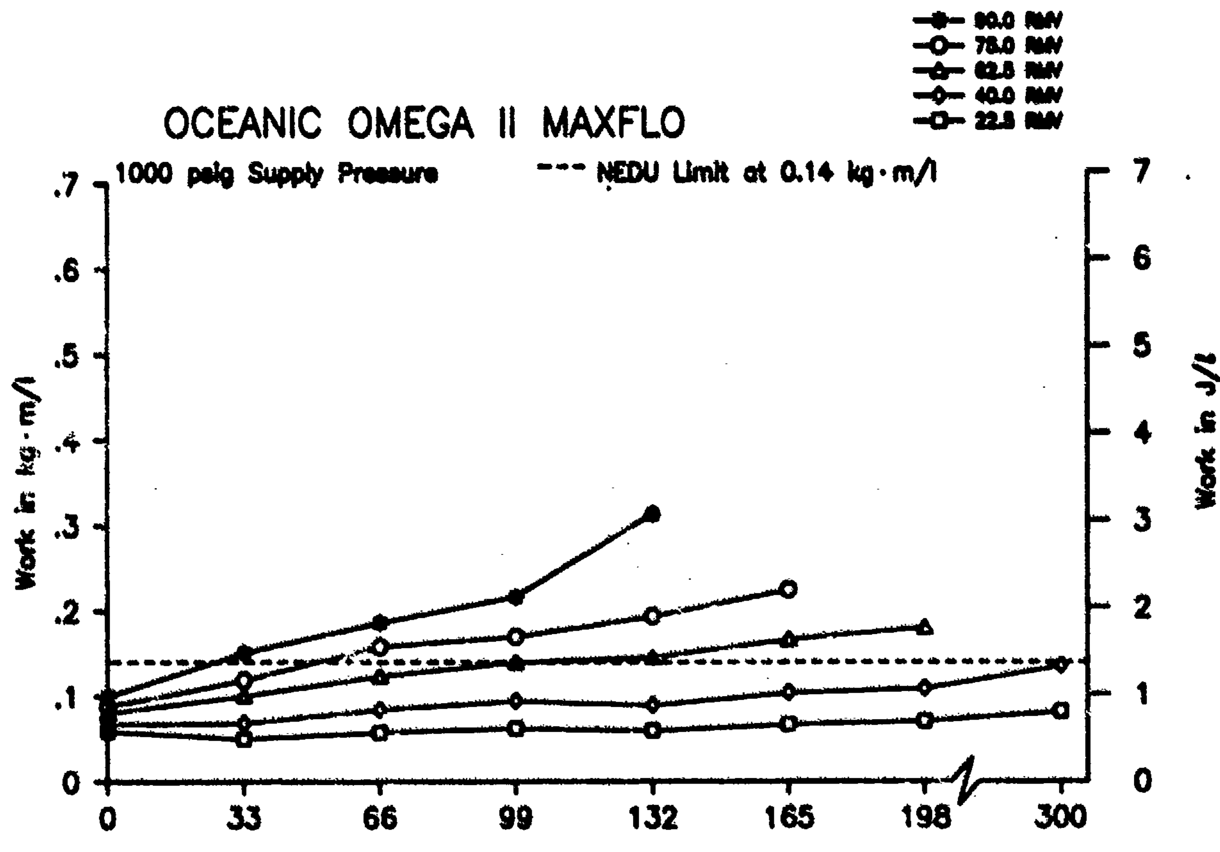
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
OCEANIC OMEGA II
1000 psig Supply Pressure
Pressure Drop in PSIG
80
70
60
50
40
30
20
10
0
600
500
400
300
200
100
0
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth


OCEANIC OMEGA II MAXFLO
0 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
-10
-20
-30
-40
-50
5
4
3
2
1
0
-1
-2
-3
-4
-5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth

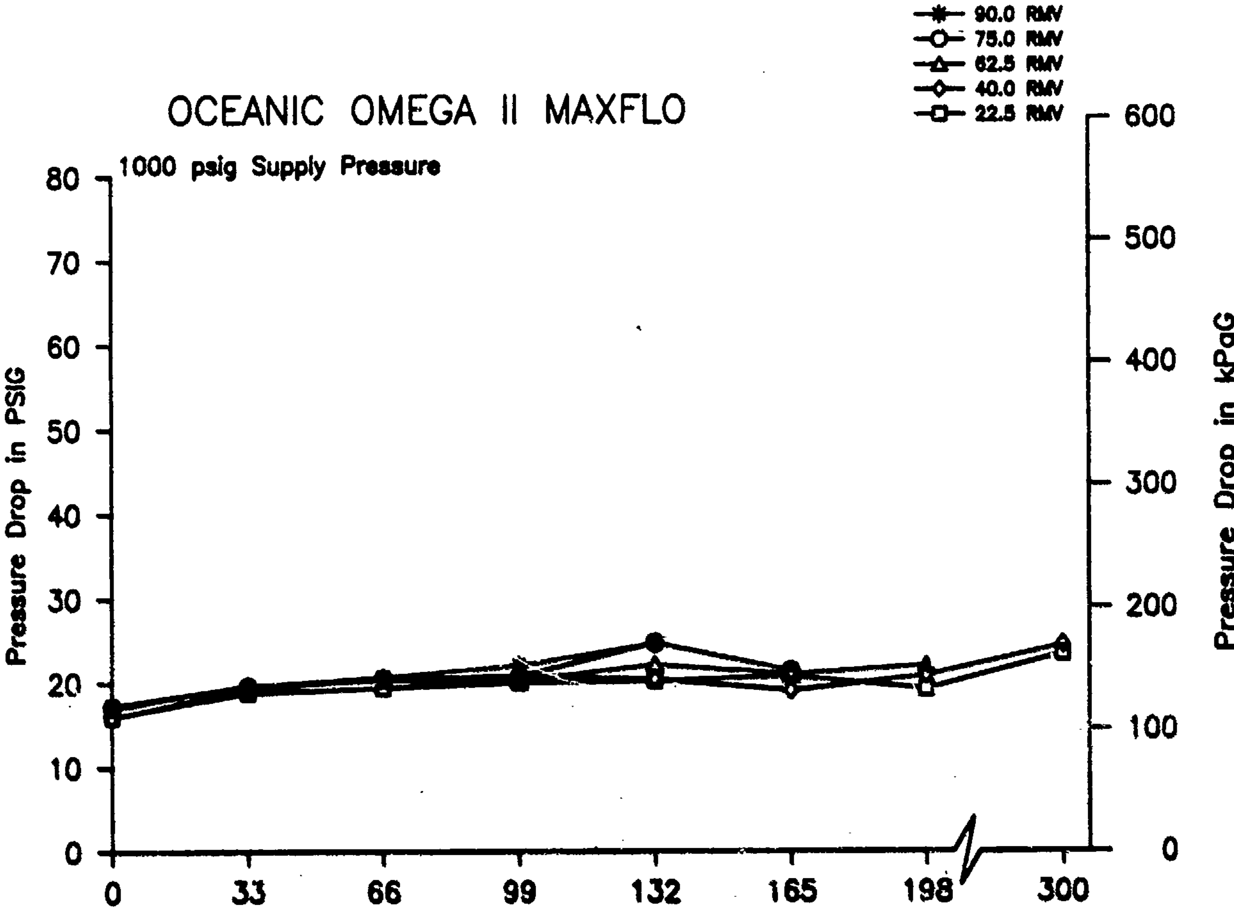

OCEANIC OMEGA II MAXFLO
500 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
-10
-20
-30
-40
-50
5
4
3
2
1
0
-1
-2
-3
-4
-5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



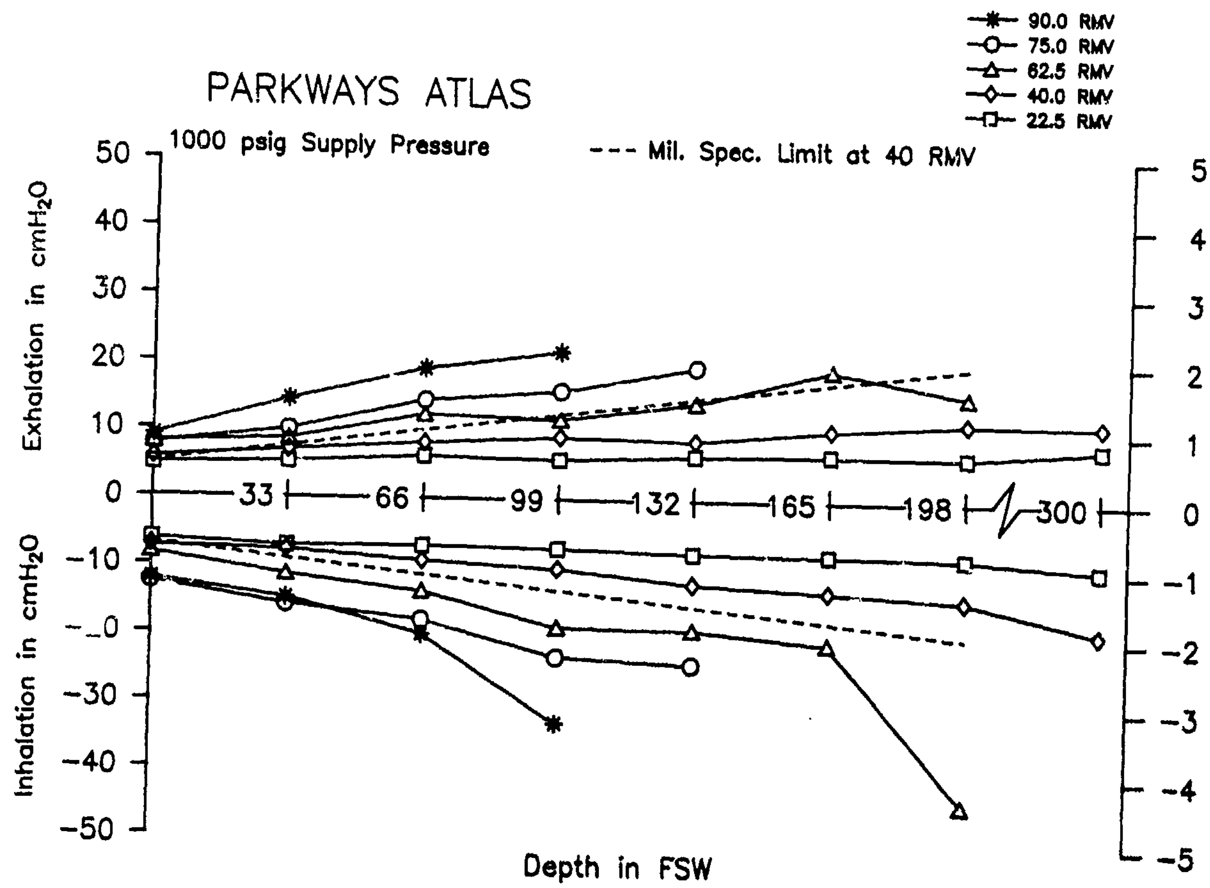
Breathing Resistance vs. Depth



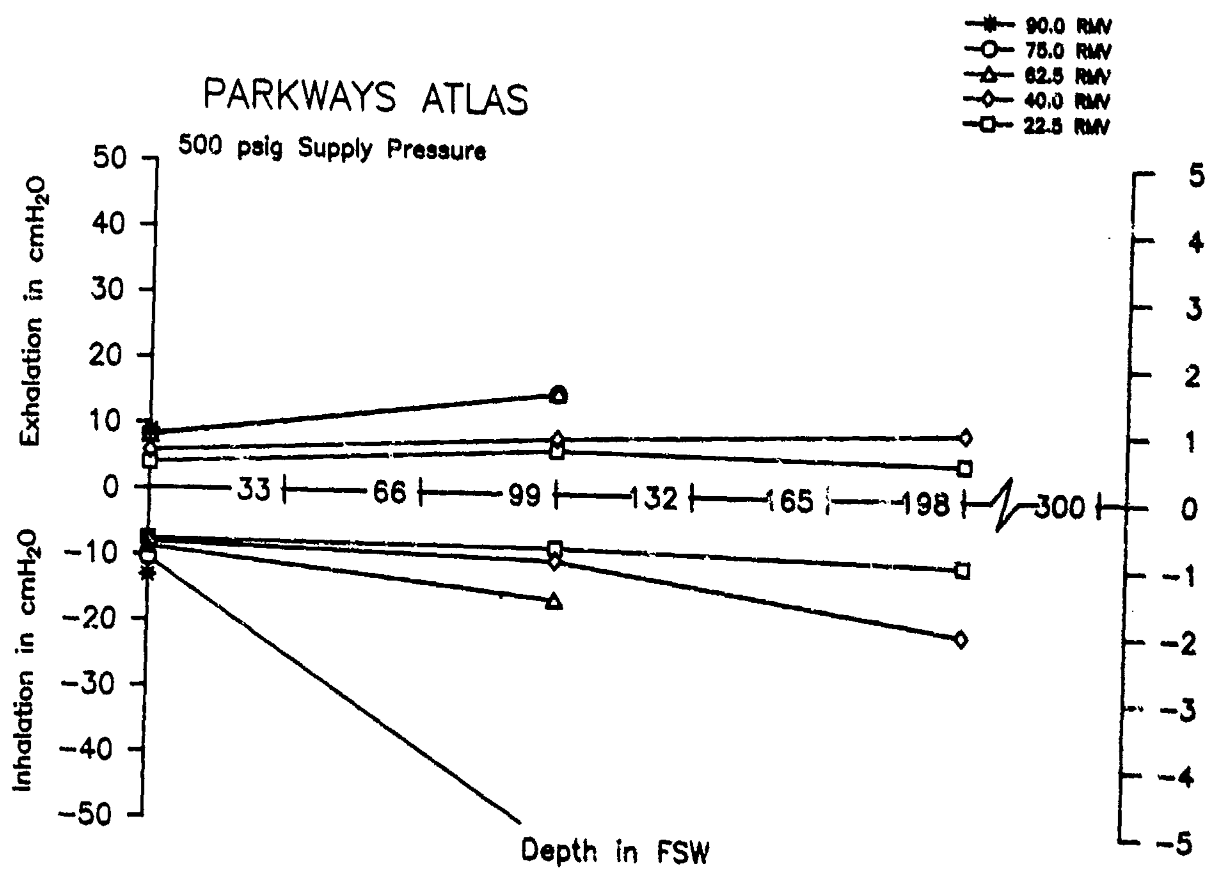
Breathing Work vs. Depth



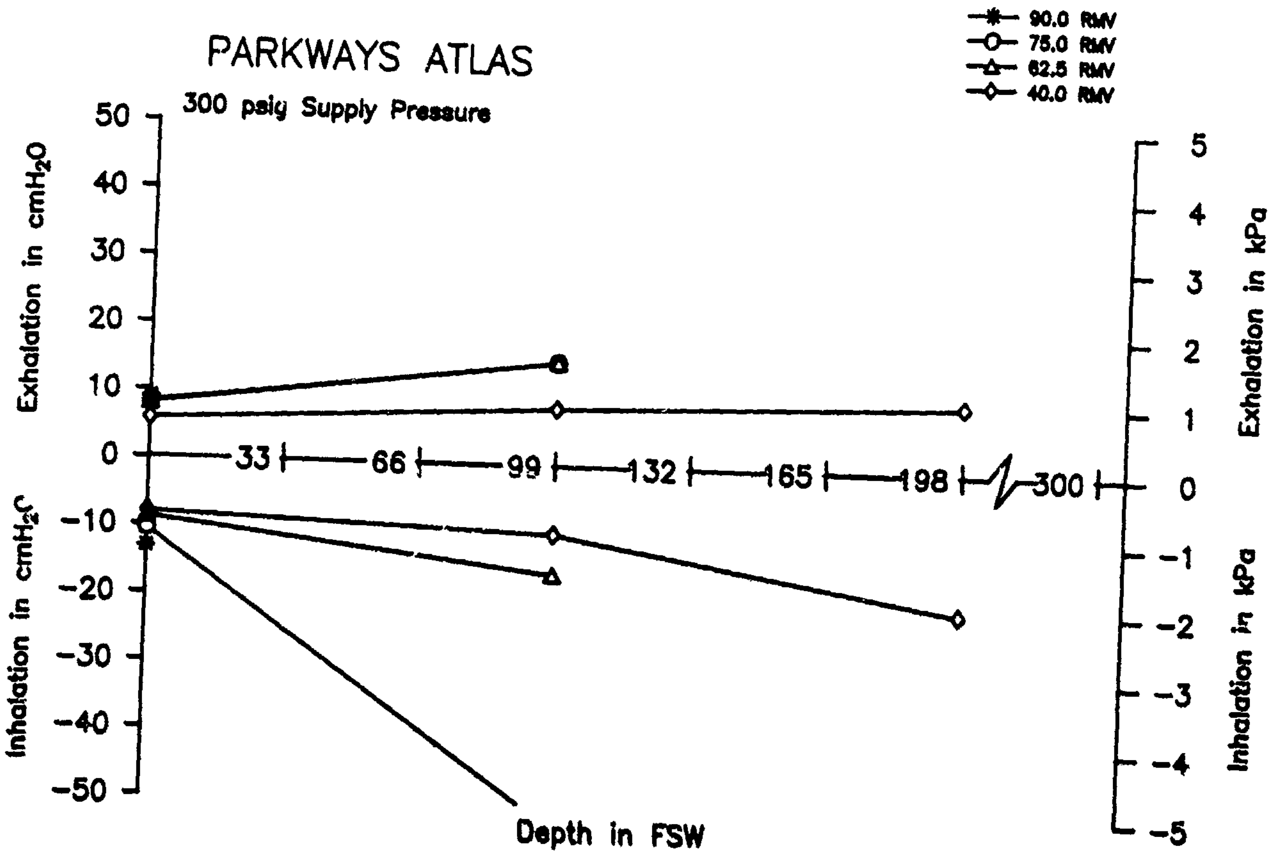
First Stage Pressure Drop vs. Depth



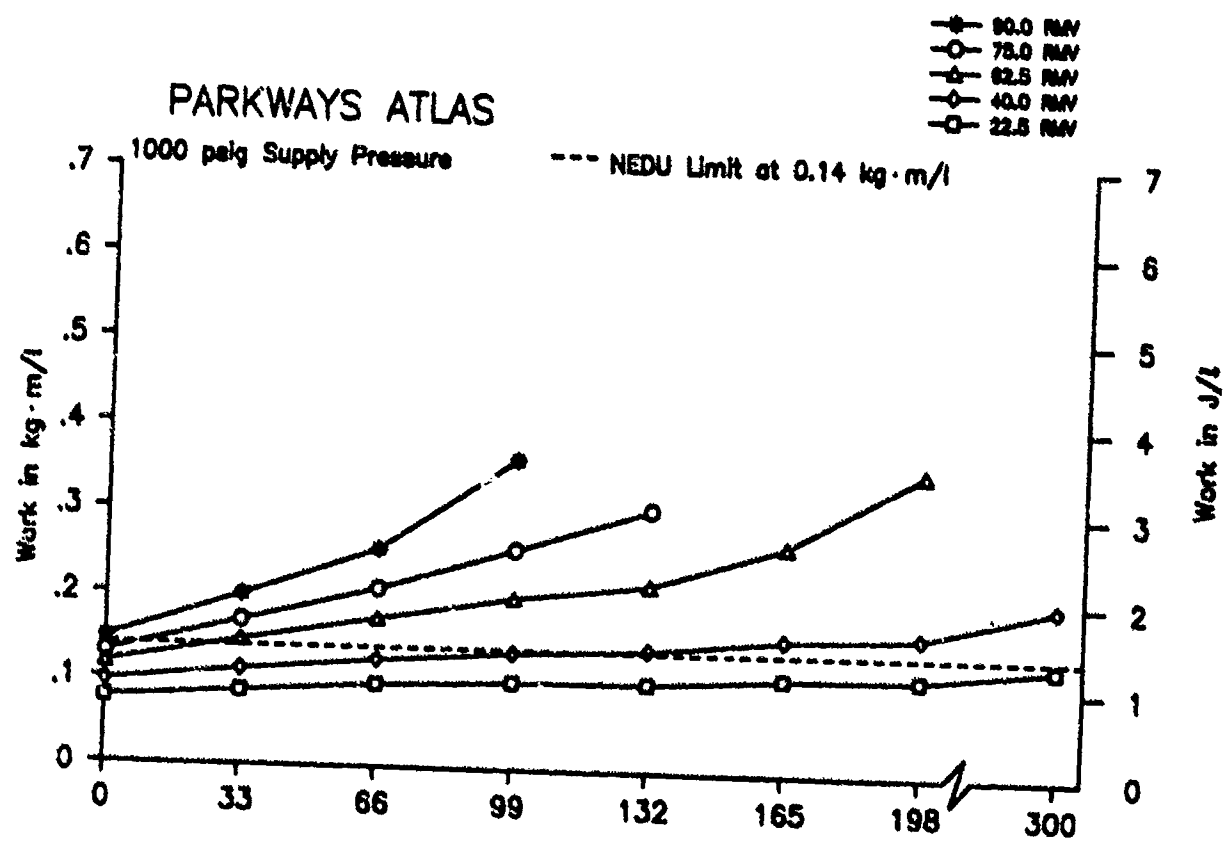
Breathing Resistance vs. Depth



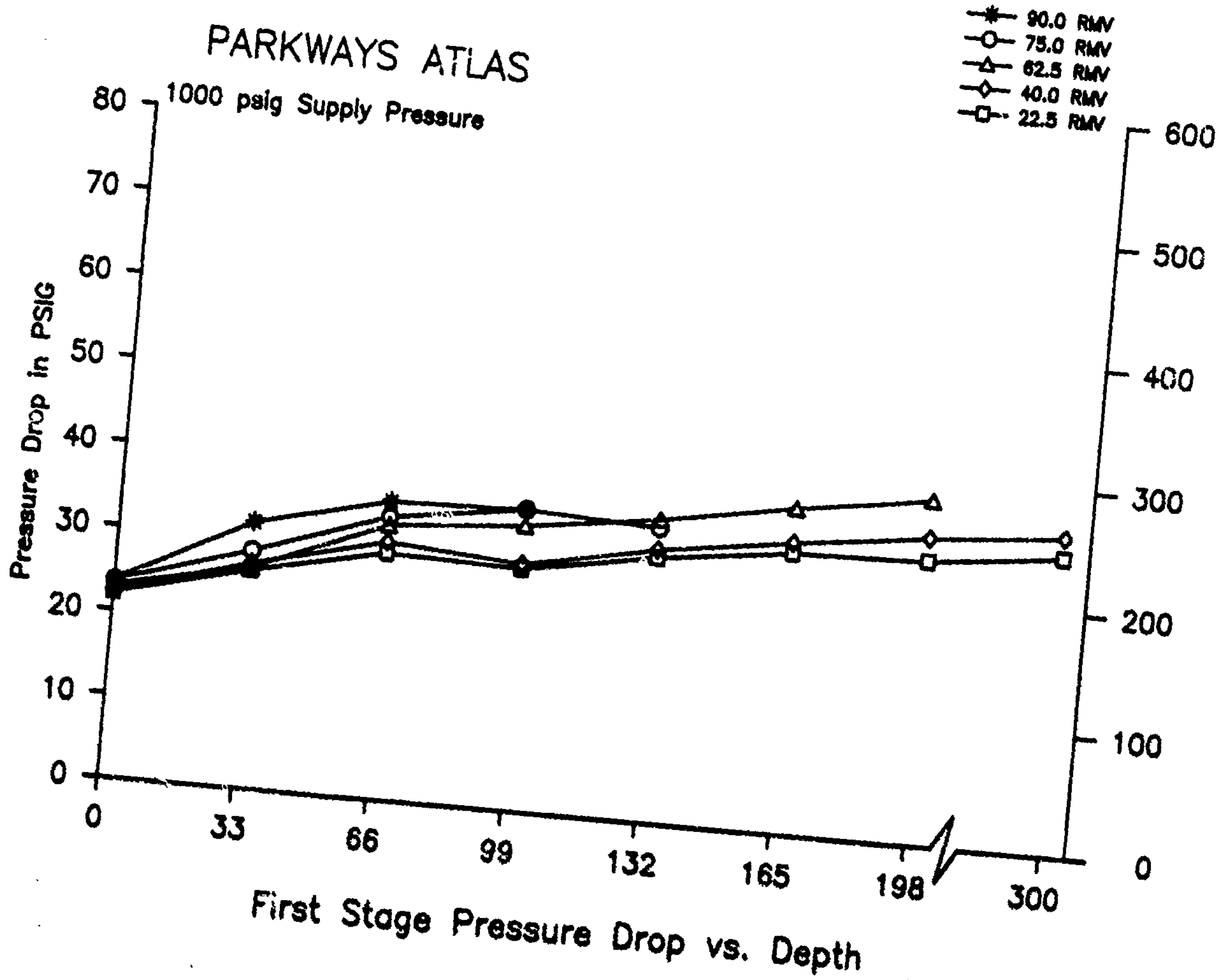
Breathing Resistance vs. Depth

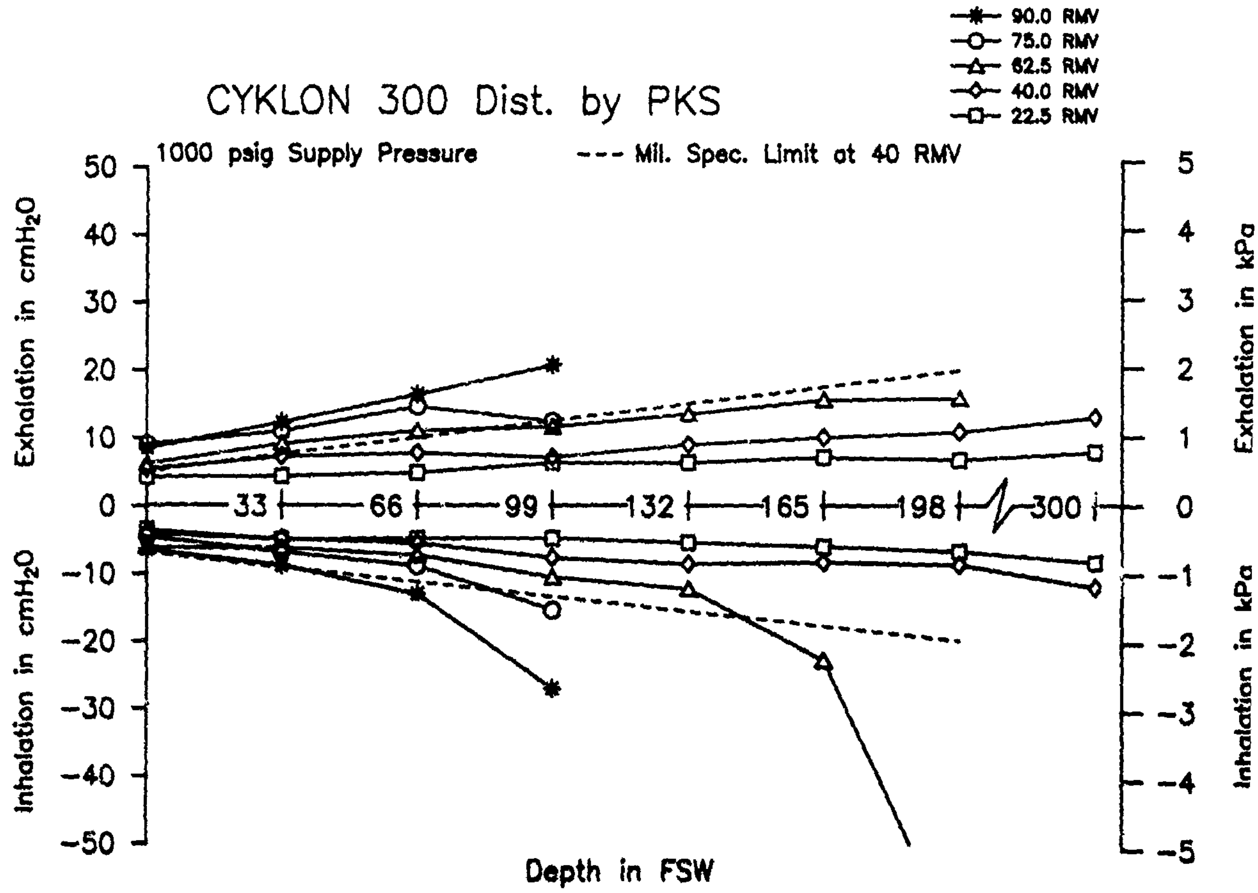


Breathing Resistance vs. Depth

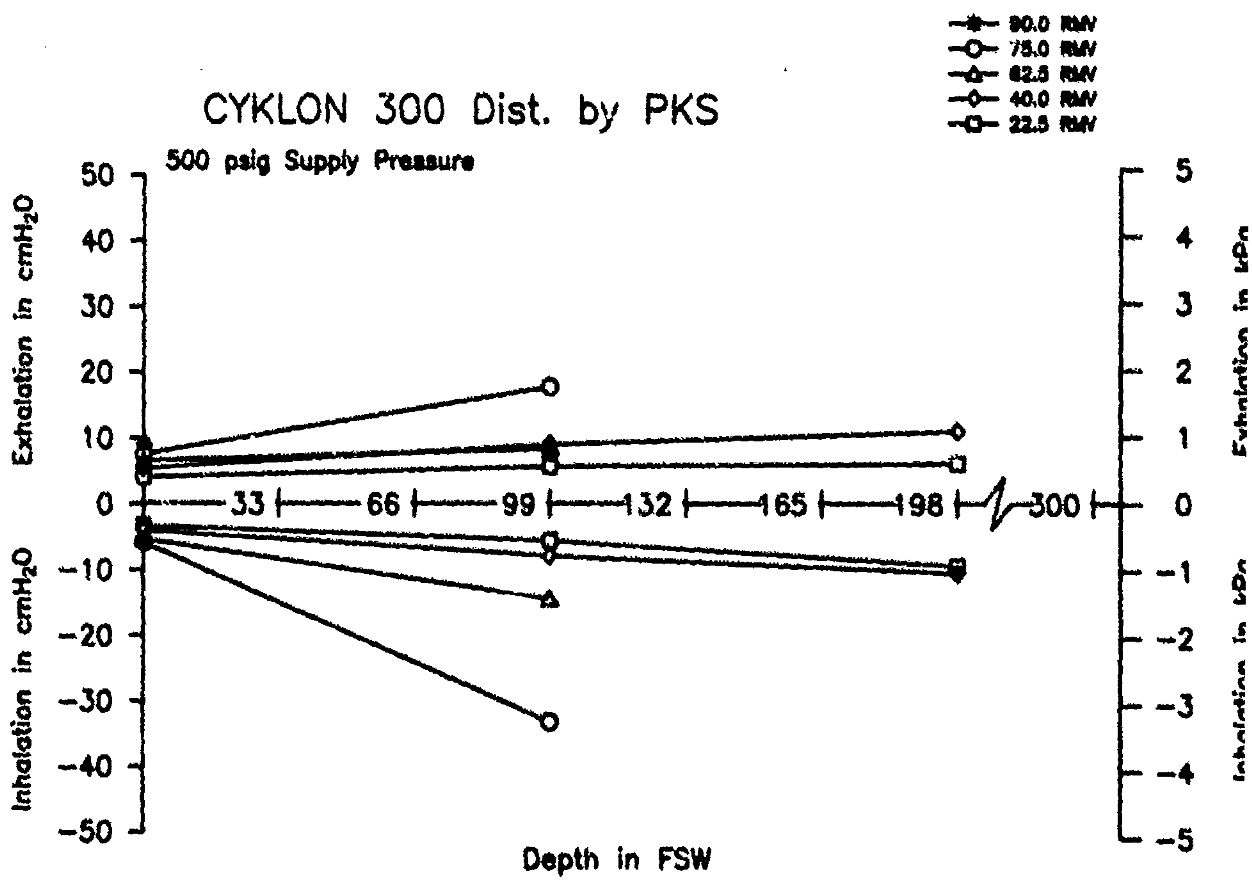


Breathing Work vs. Depth

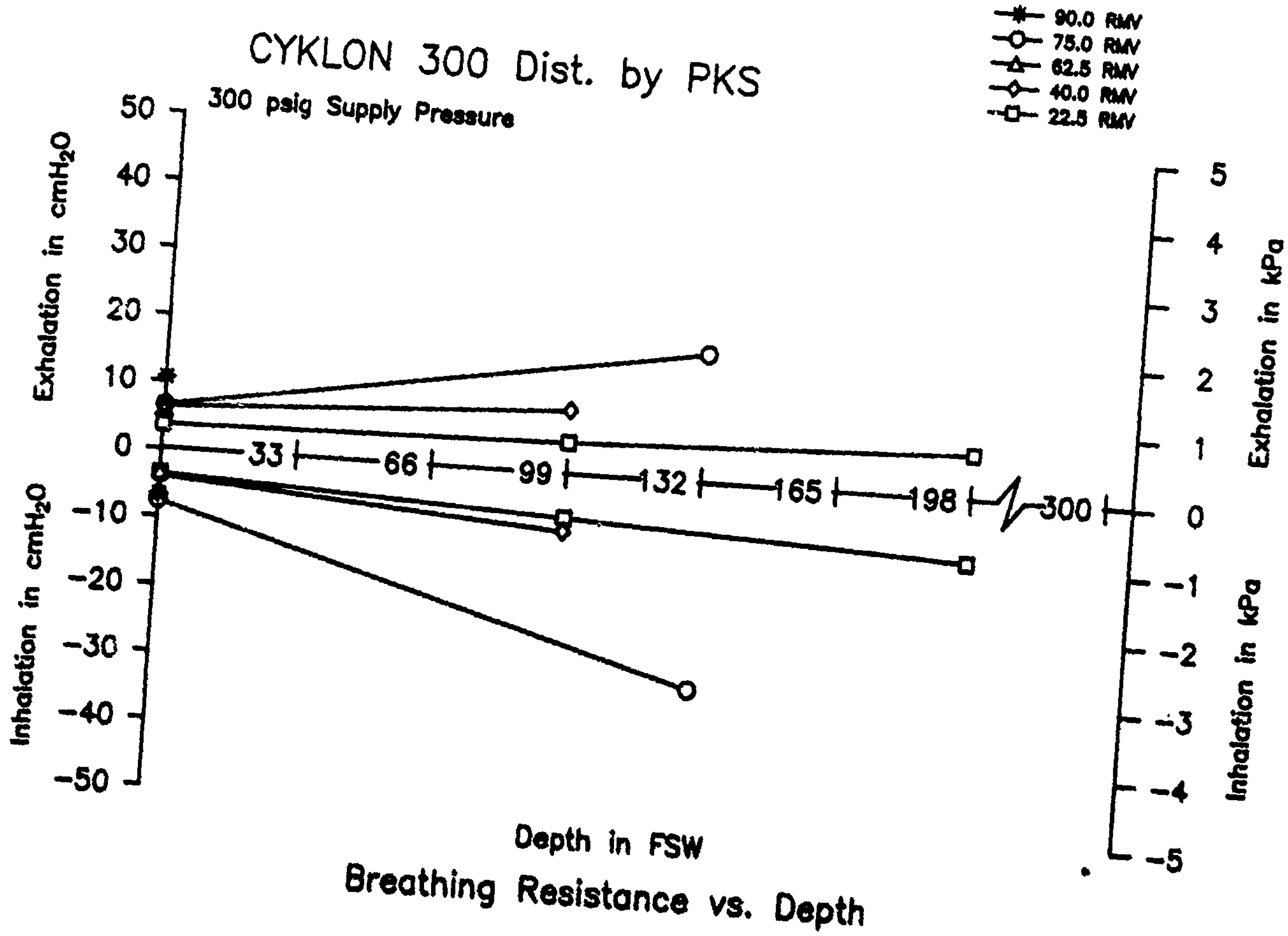

PARKWAYS ATLAS
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
80
70
60
50
40
30
20
10
0
600
500
400
300
200
100
0
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth

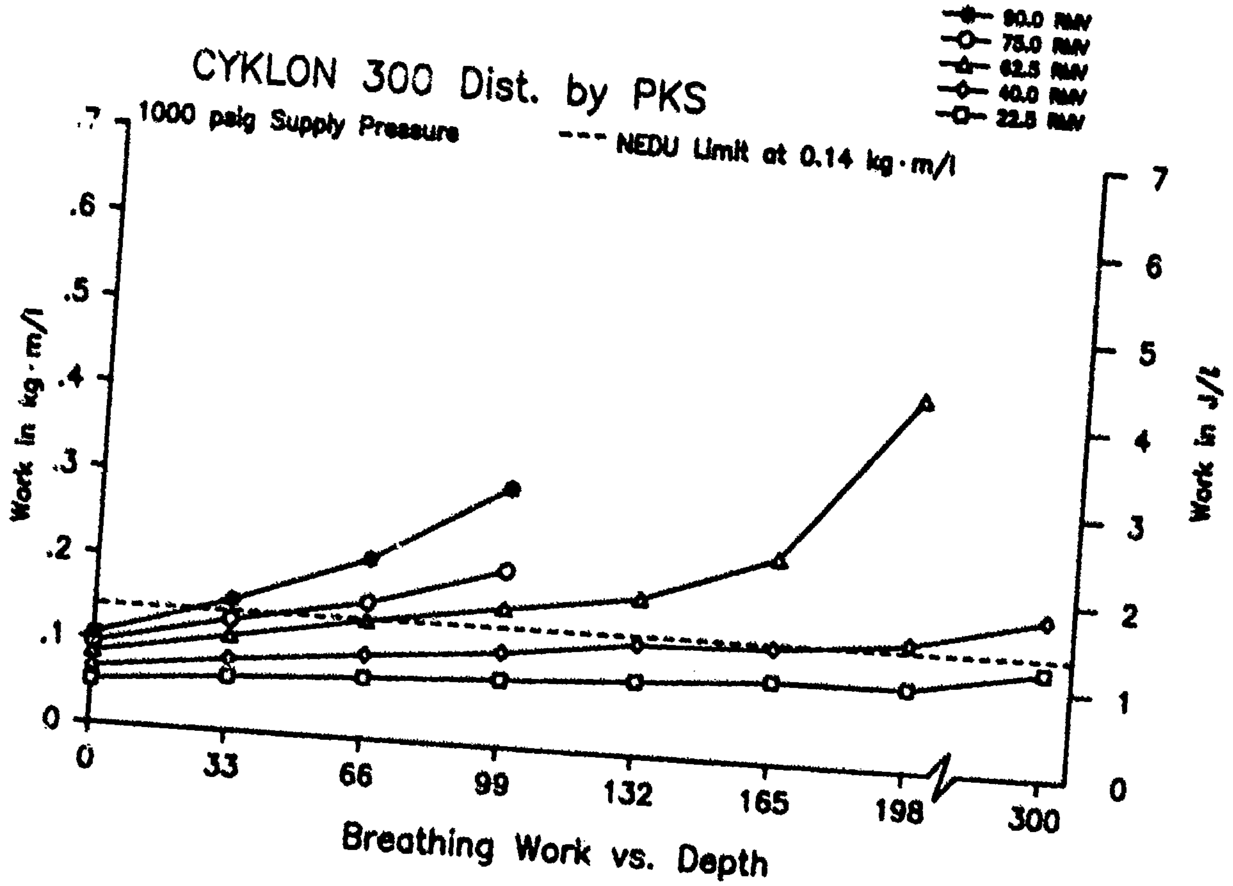


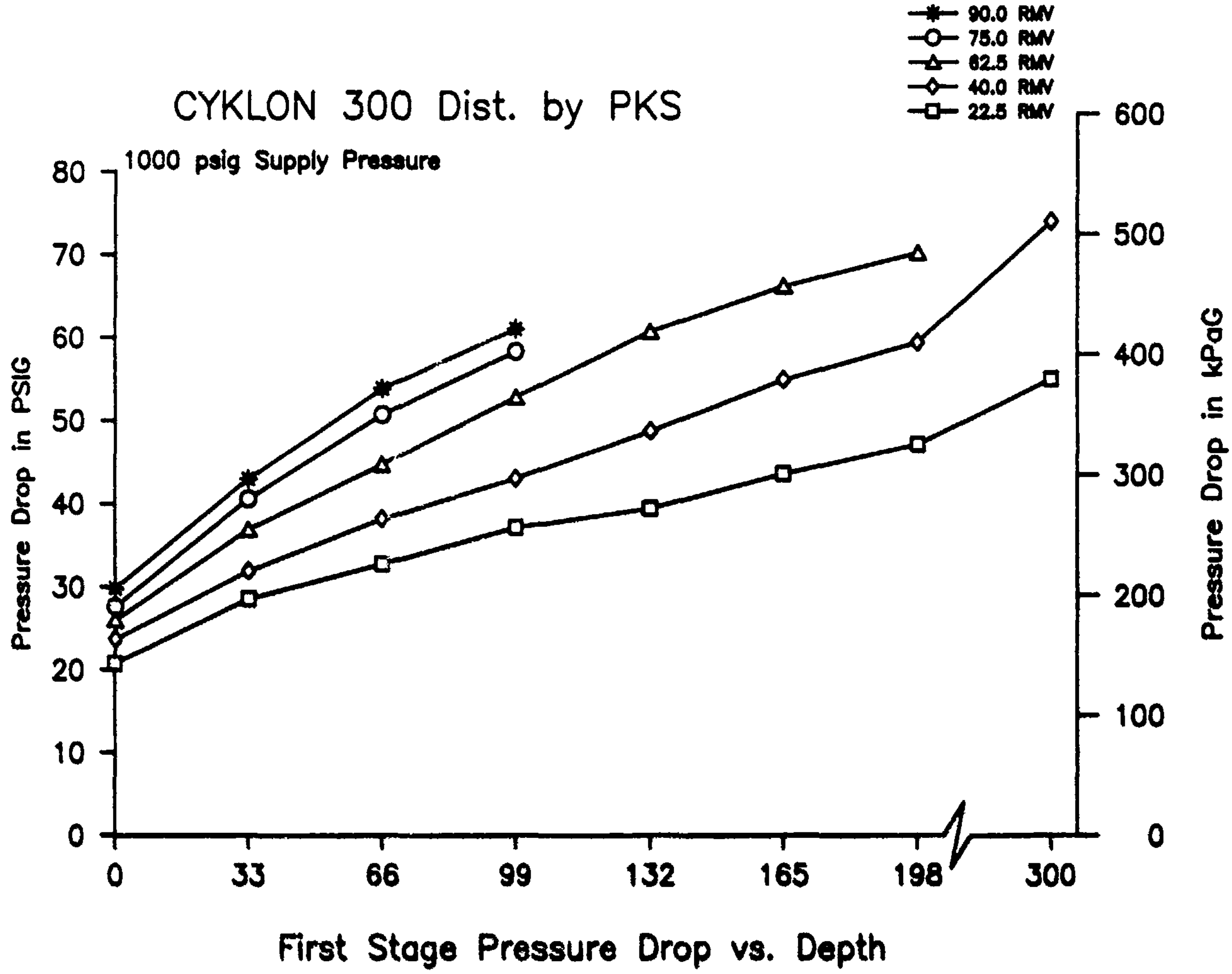
Breathing Resistance vs. Depth



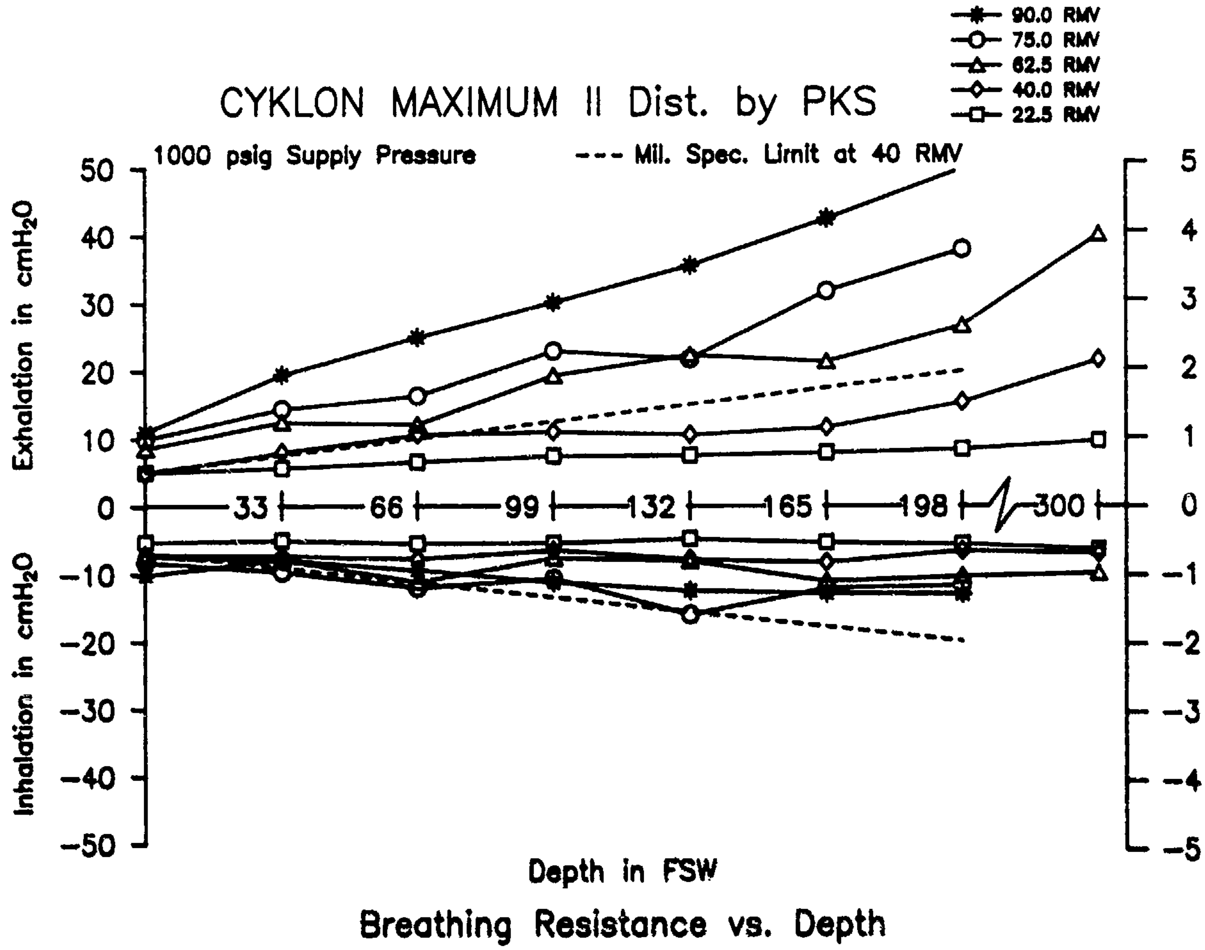
Breathing Resistance vs. Depth

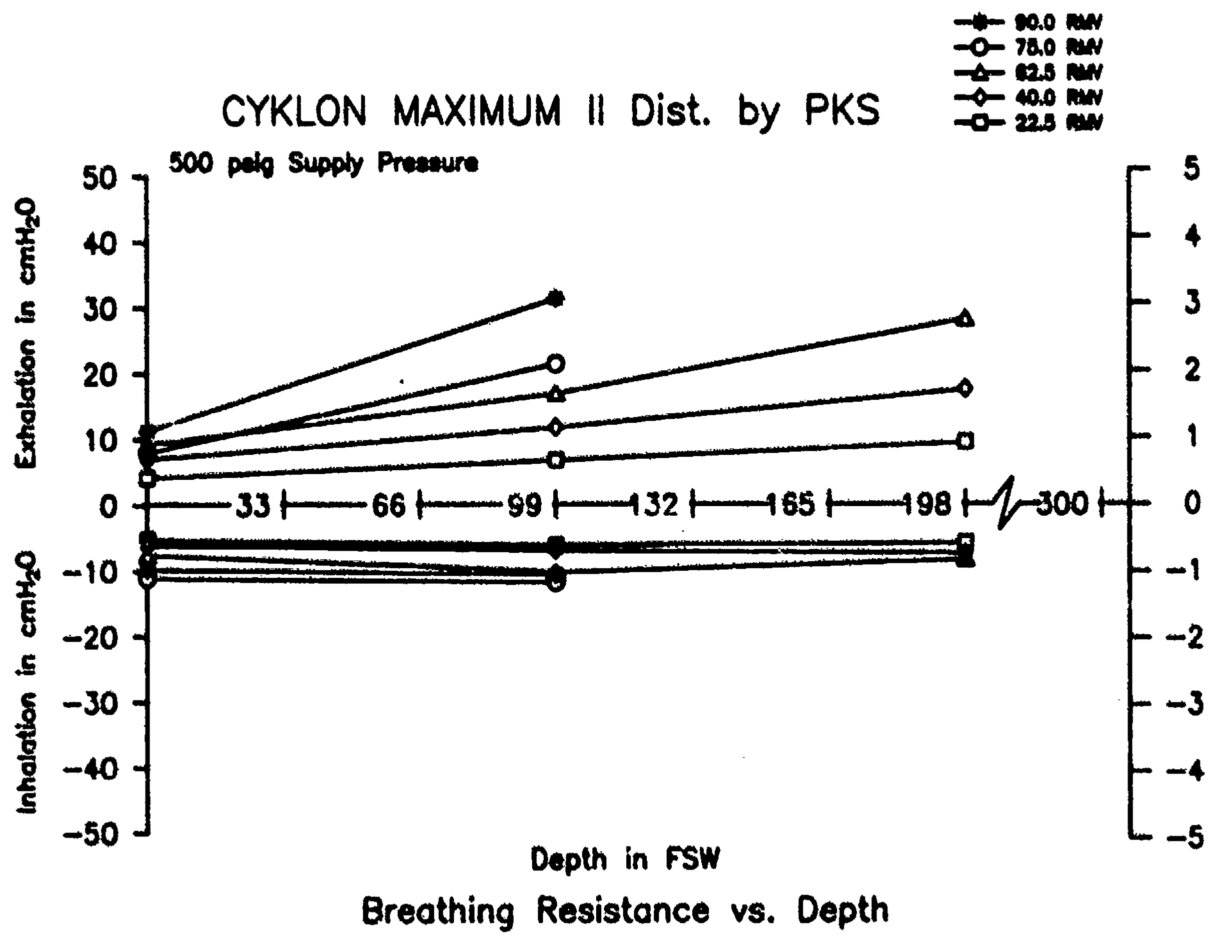

CYKLON 300 Dist. by PKS
300 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth

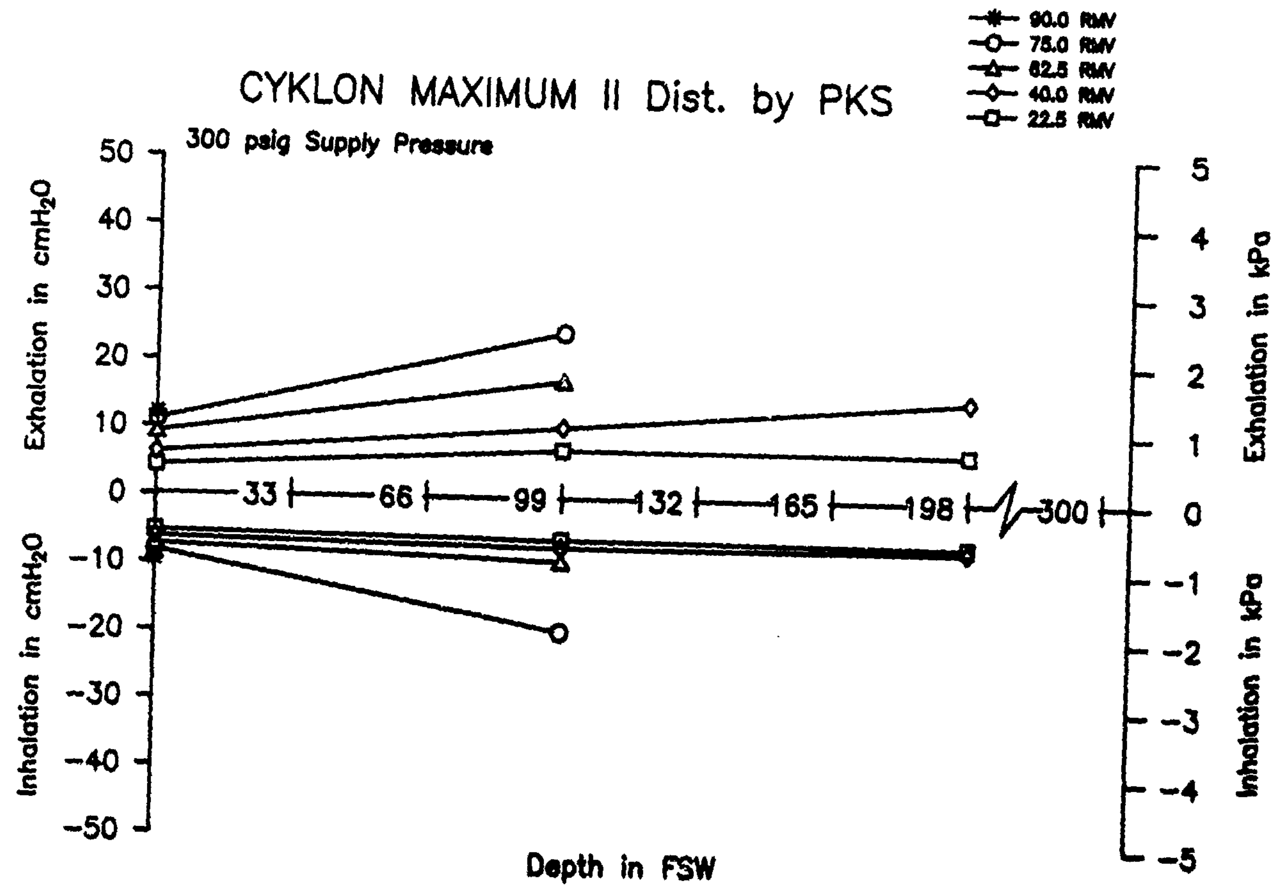

CYKLON 300 Dist. by PKS
1000 psig Supply Pressure
--- NEDU Limit at 0.14 kg·m/l
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Work in kg·m/l
Work in J/l
0
33
66
99
132
165
198
300
Breathing Work vs. Depth



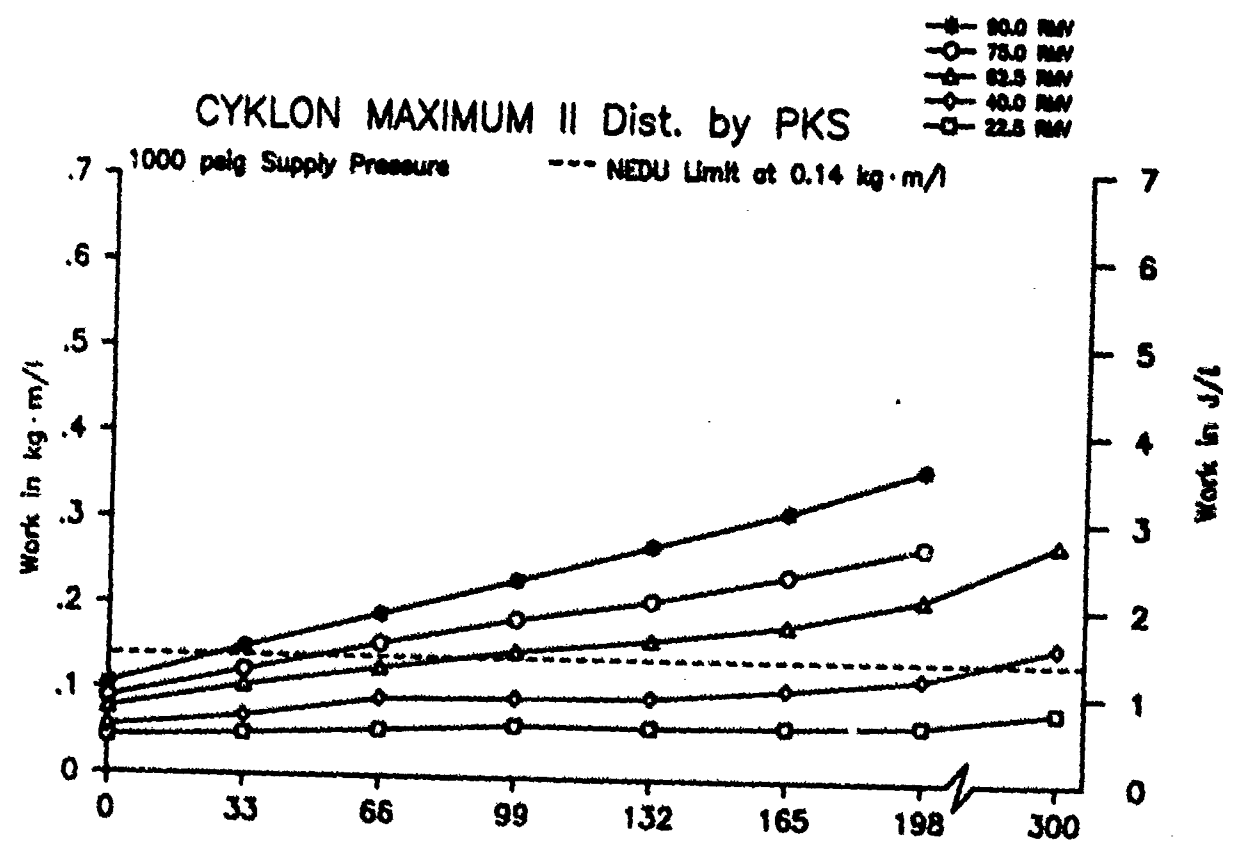
CYKLON 300 Dist. by PKS
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
Pressure Drop in kPaG
0
10
20
30
40
50
60
70
80
100
200
300
400
500
600
33
66
99
132
165
198
First Stage Pressure Drop vs. Depth


90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
CYKLON MAXIMUM II Dist. by PKS
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
50
40
30
20
10
0
−10
−20
−30
−40
−50
33
66
99
132
165
198
300
5
4
3
2
1
0
−1
−2
−3
−4
−5
Depth in FSW
Breathing Resistance vs. Depth

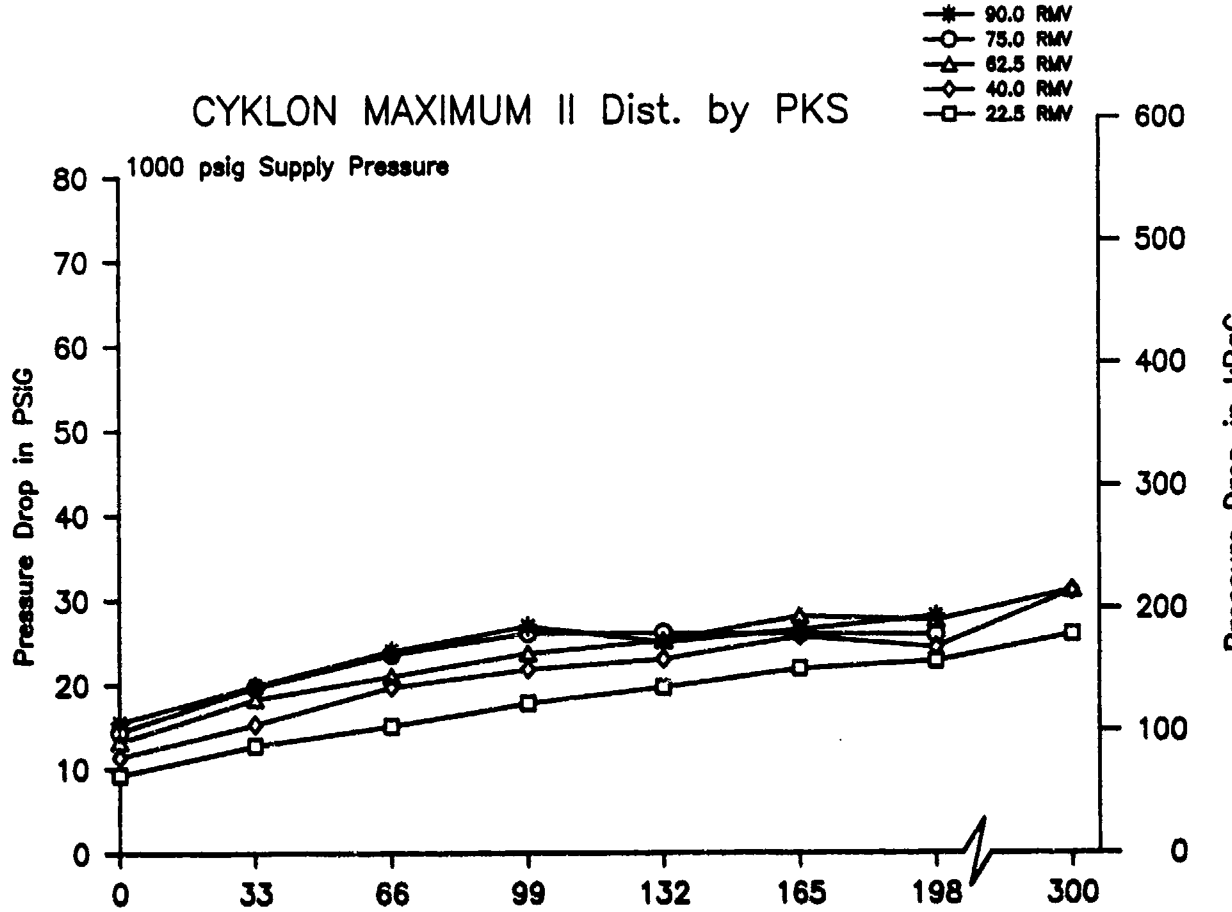

90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
CYKLON MAXIMUM II Dist. by PKS
500 psig Supply Pressure
Exhalation in cmH_2O
Inhalation in cmH_2O
50
40
30
20
10
0
−10
−20
−30
−40
−50
33
66
99
132
165
198
300
5
4
3
2
1
0
−1
−2
−3
−4
−5
Depth in FSW
Breathing Resistance vs. Depth



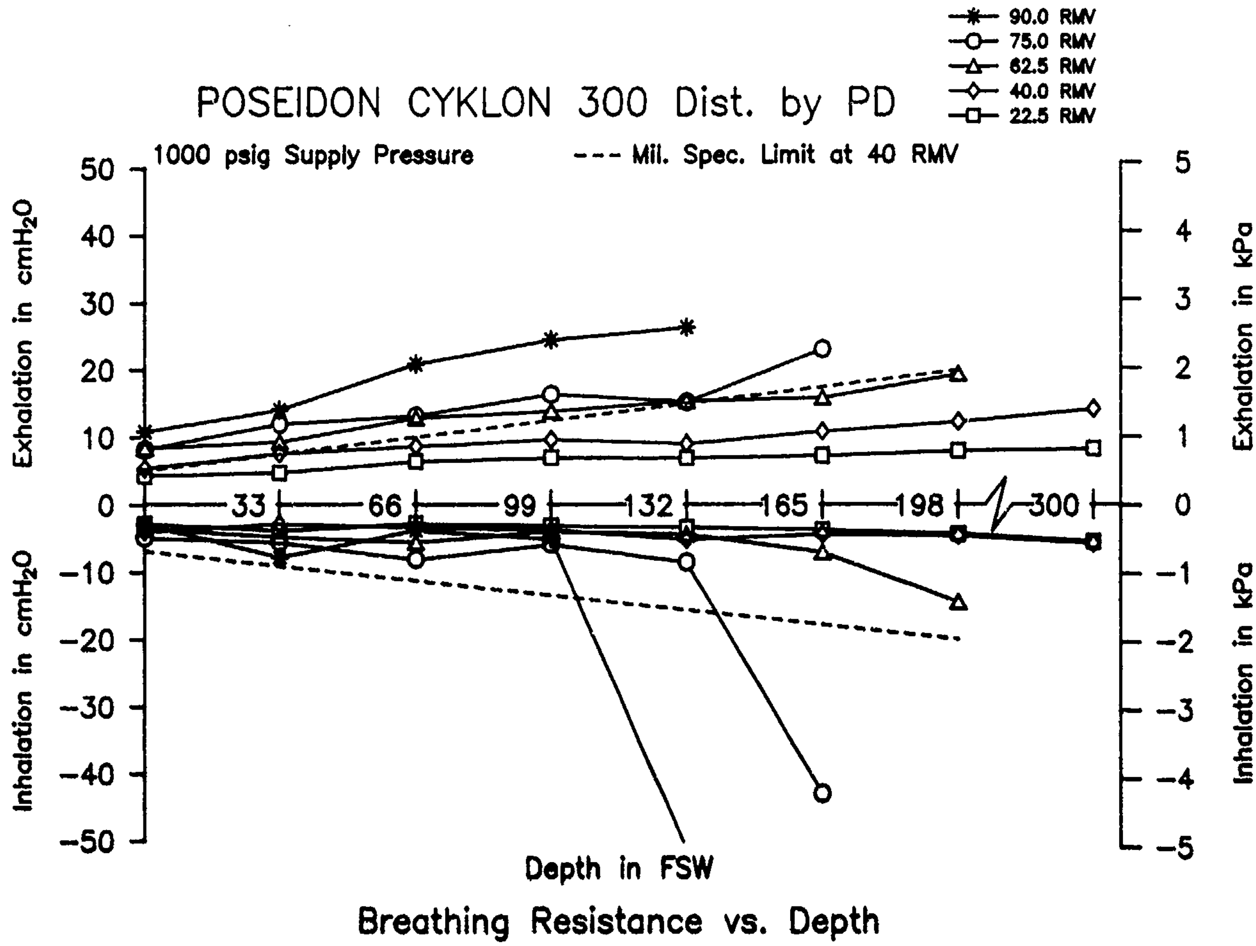
Breathing Resistance vs. Depth



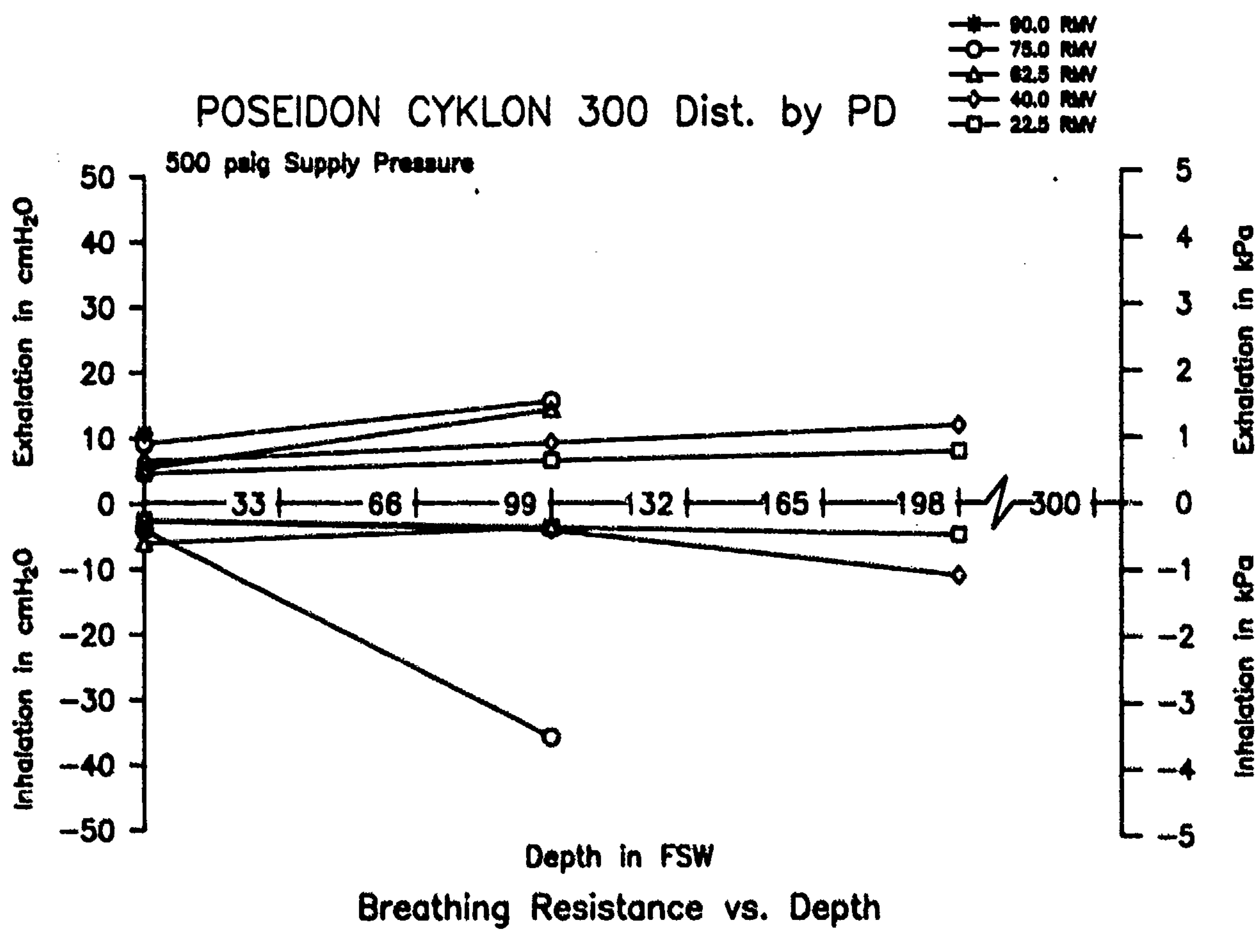
Breathing Work vs. Depth



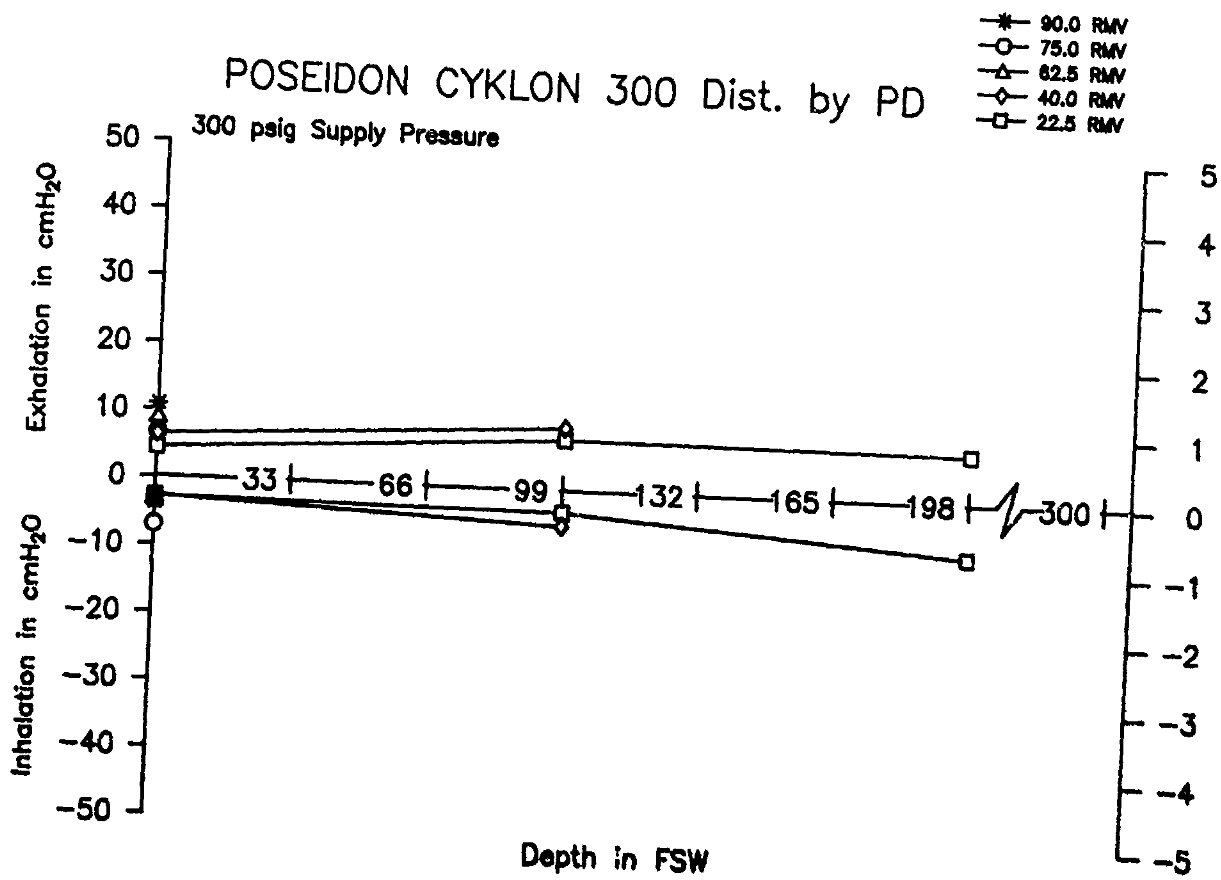
First Stage Pressure Drop vs. Depth



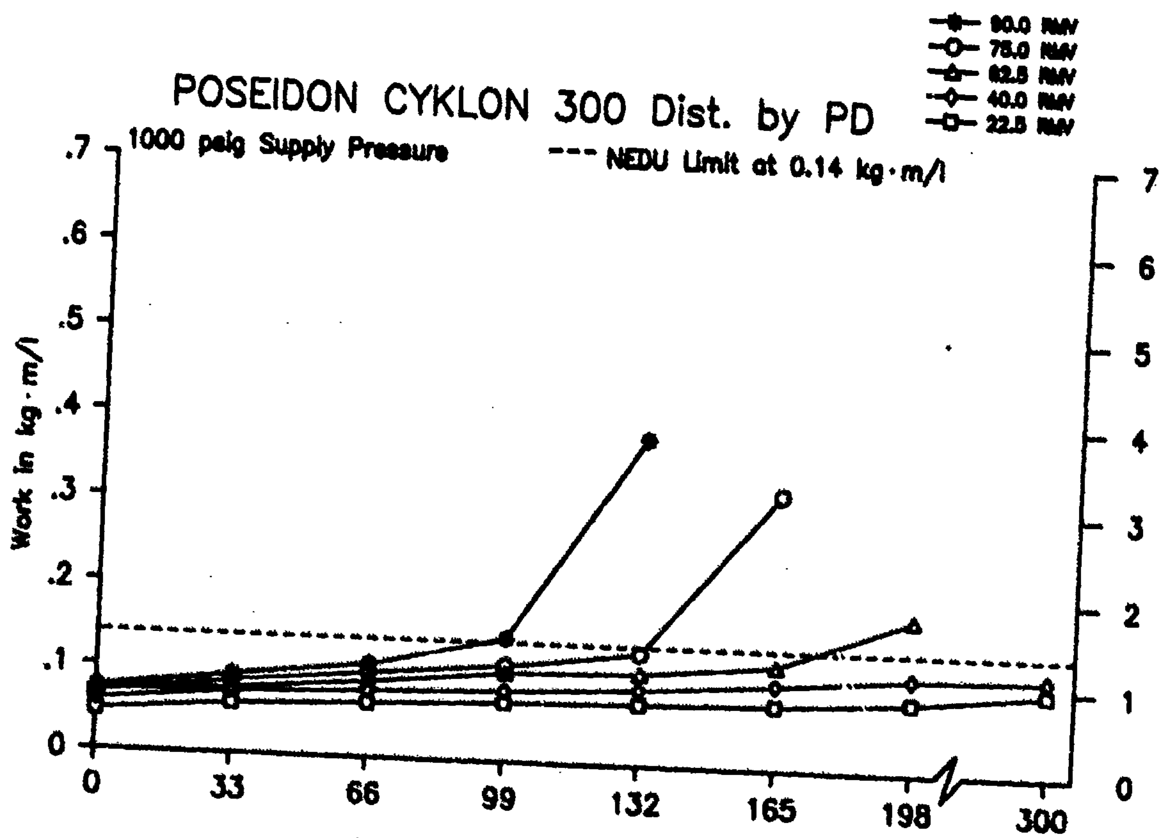
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
POSEIDON CYKLON 300 Dist. by PD
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
−10
−20
−30
−40
−50
33
66
99
132
165
198
300
5
4
3
2
1
0
−1
−2
−3
−4
−5
Depth in FSW
Breathing Resistance vs. Depth



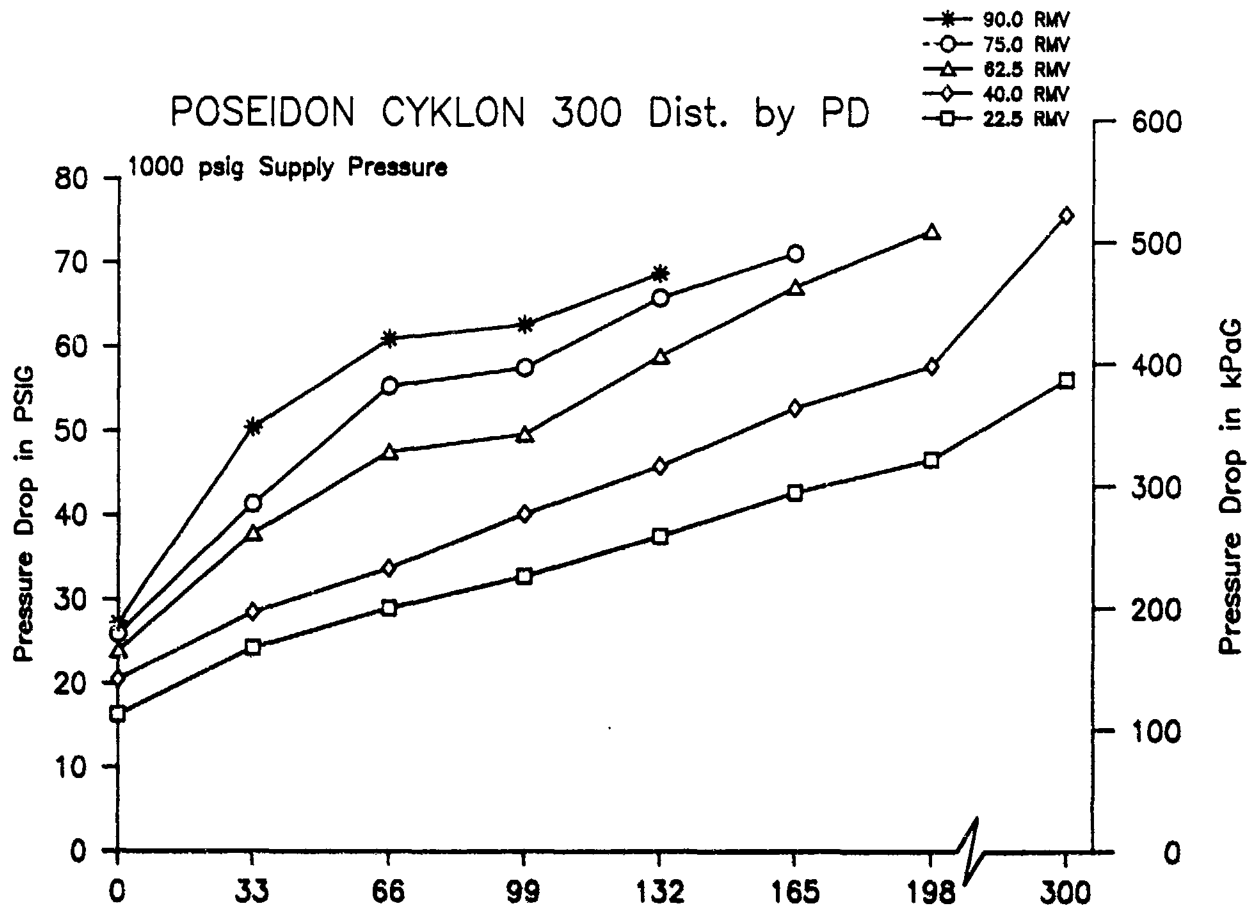
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
POSEIDON CYKLON 300 Dist. by PD
500 psig Supply Pressure
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
−10
−20
−30
−40
−50
33
66
99
132
165
198
300
5
4
3
2
1
0
−1
−2
−3
−4
−5
Depth in FSW
Breathing Resistance vs. Depth



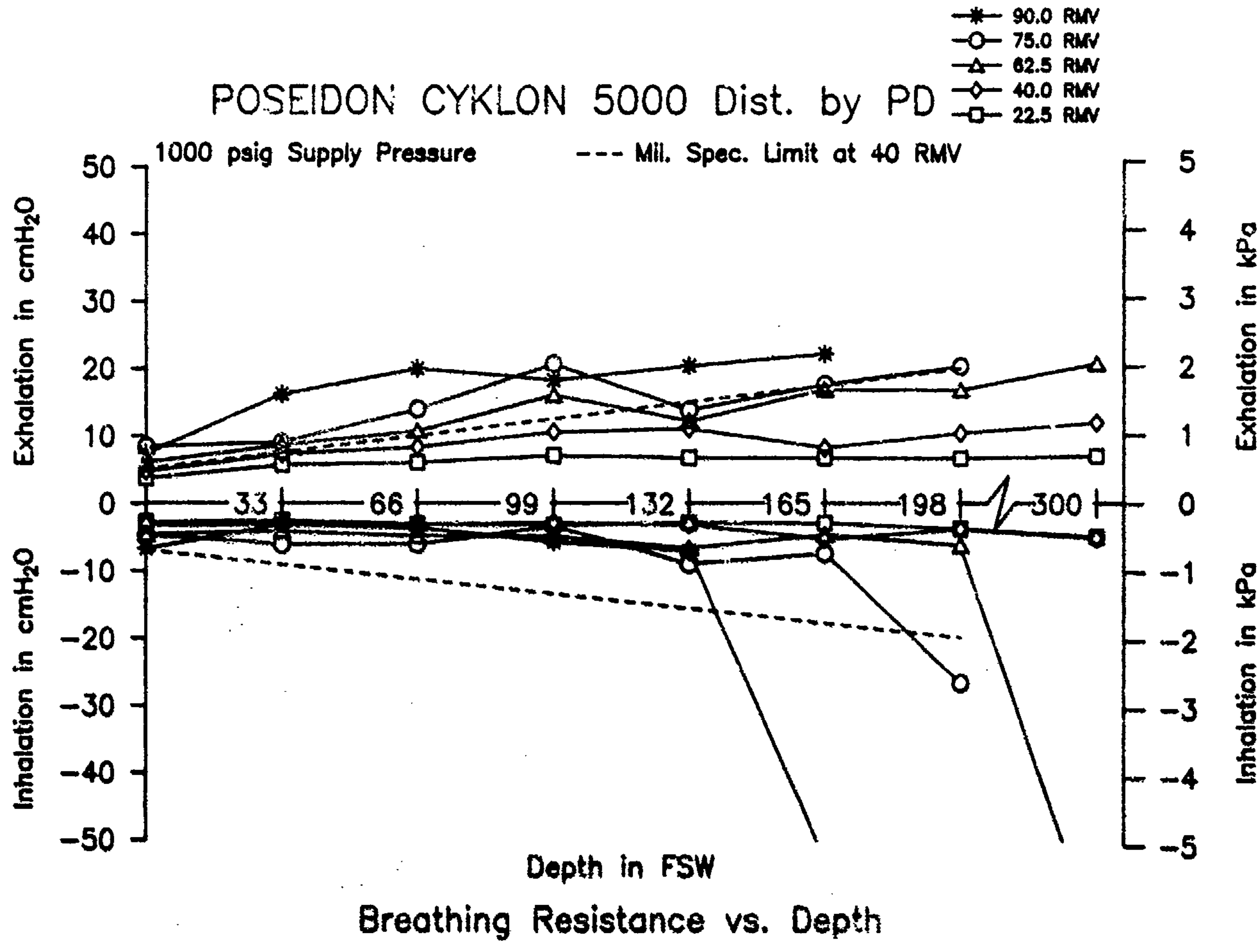
Breathing Resistance vs. Depth



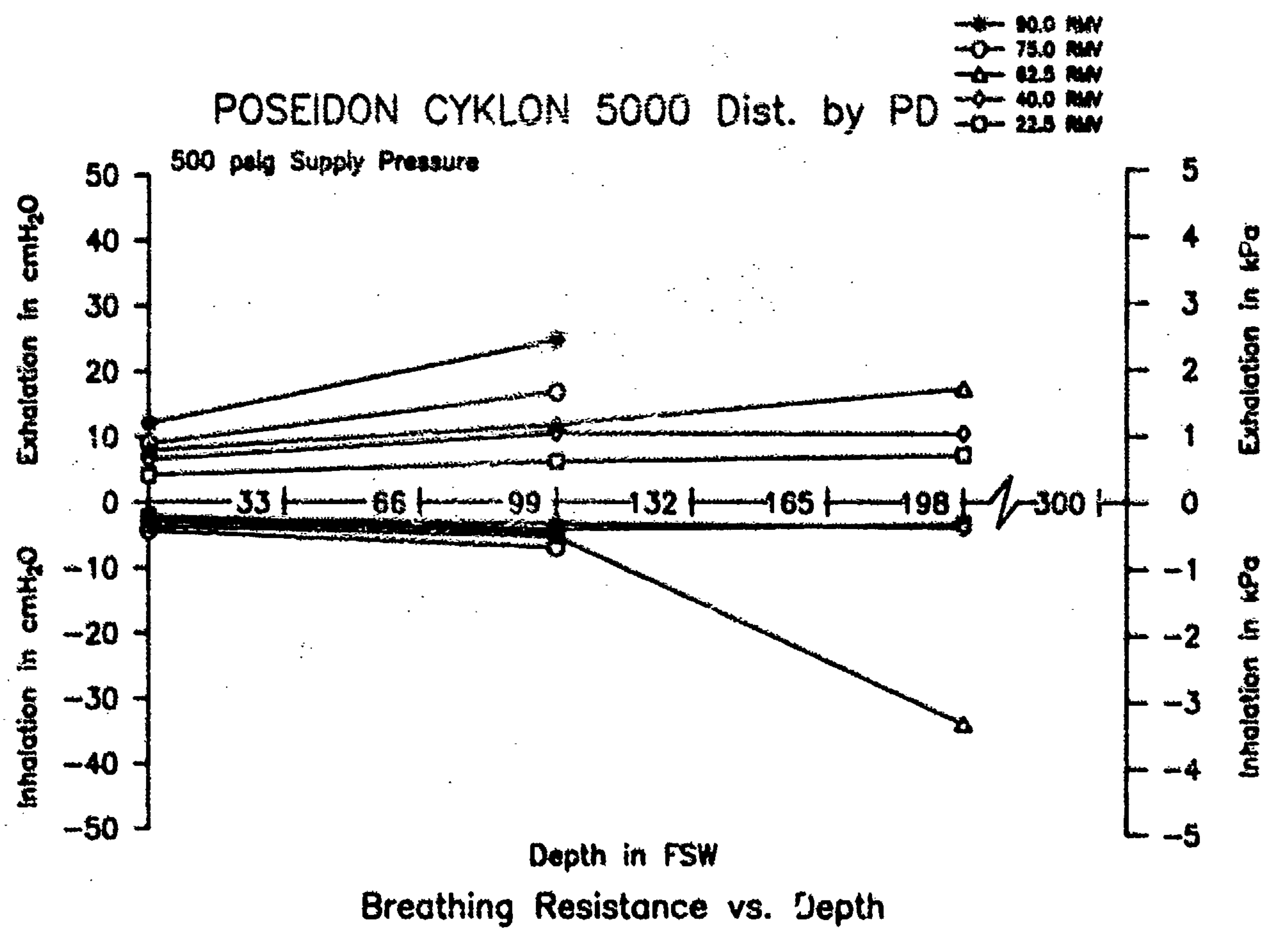
Breathing Work vs. Depth



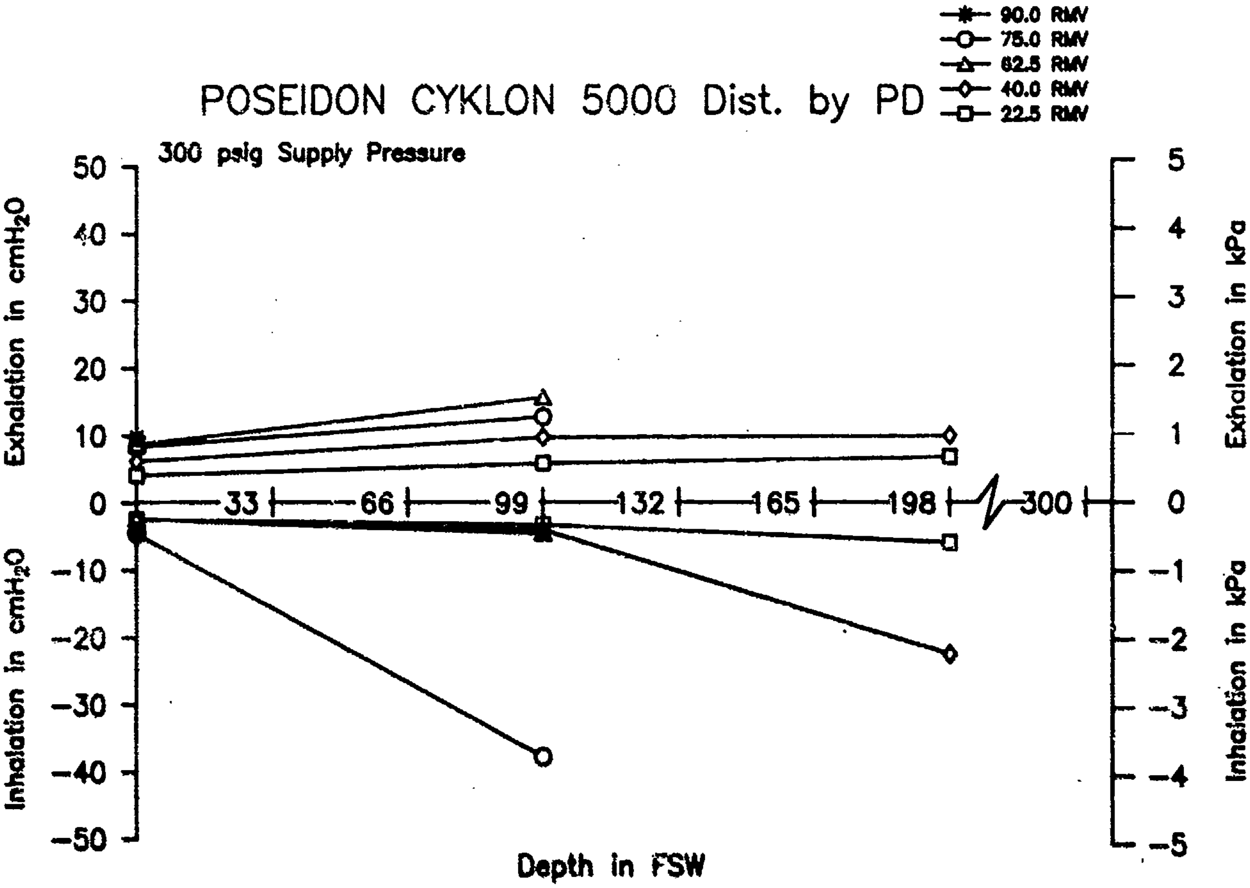
First Stage Pressure Drop vs. Depth



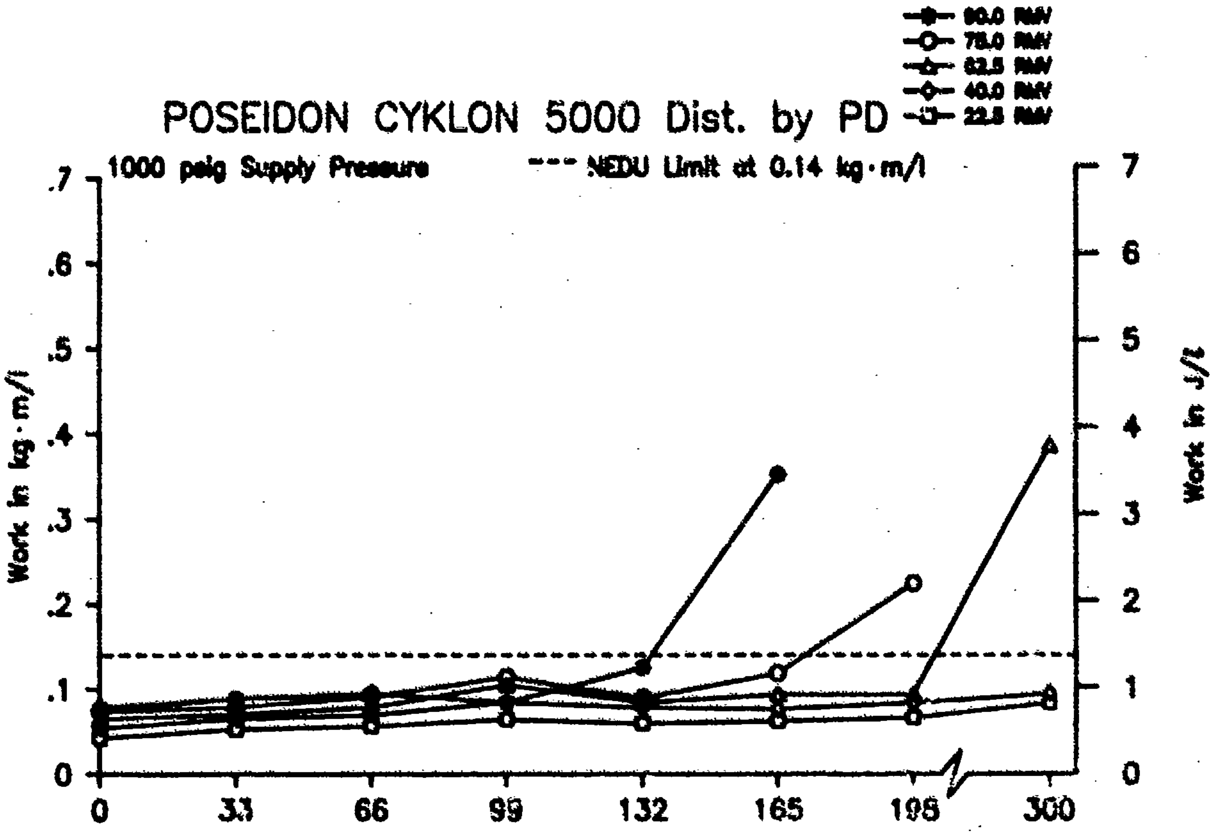
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
POSEIDON CYKLON 5000 Dist. by PD
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



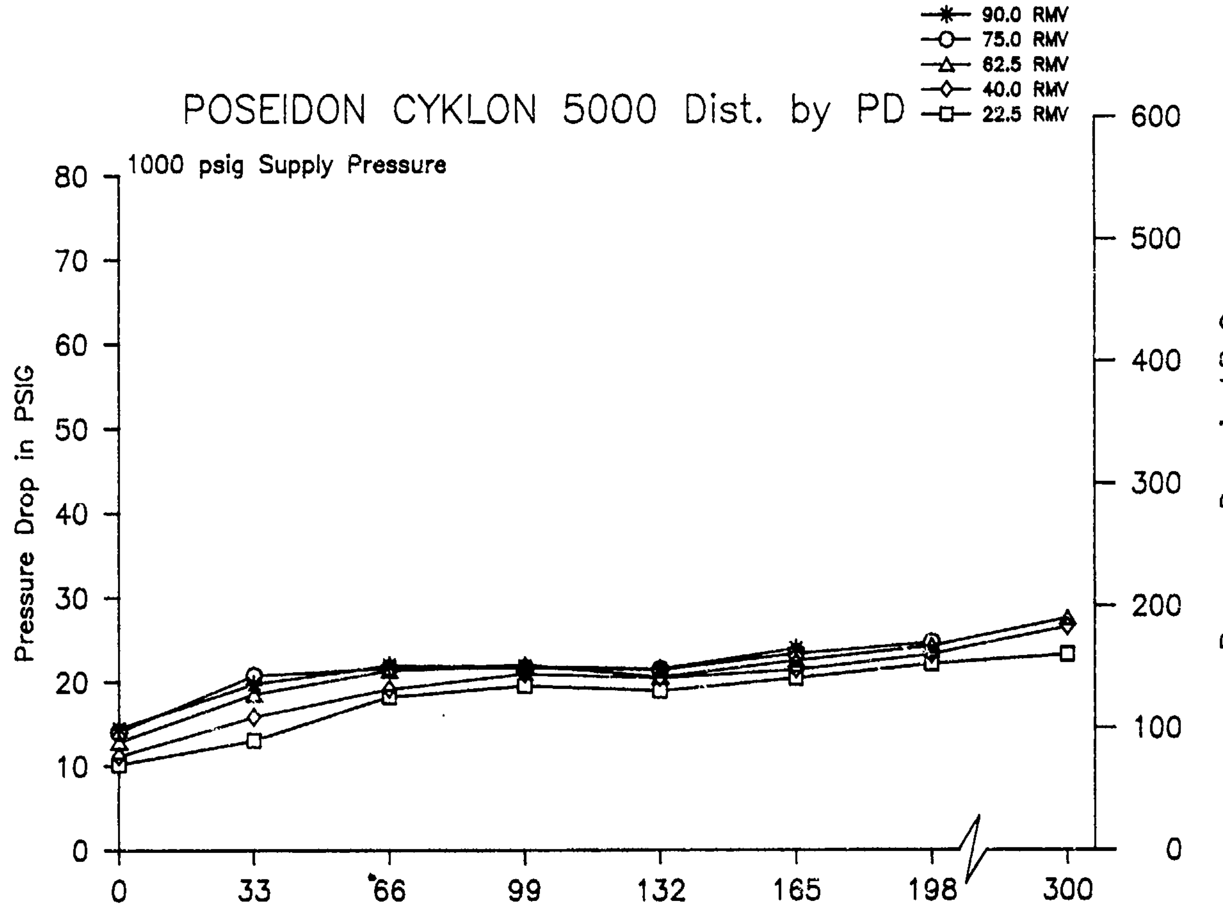
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
POSEIDON CYKLON 5000 Dist. by PD
500 psig Supply Pressure
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



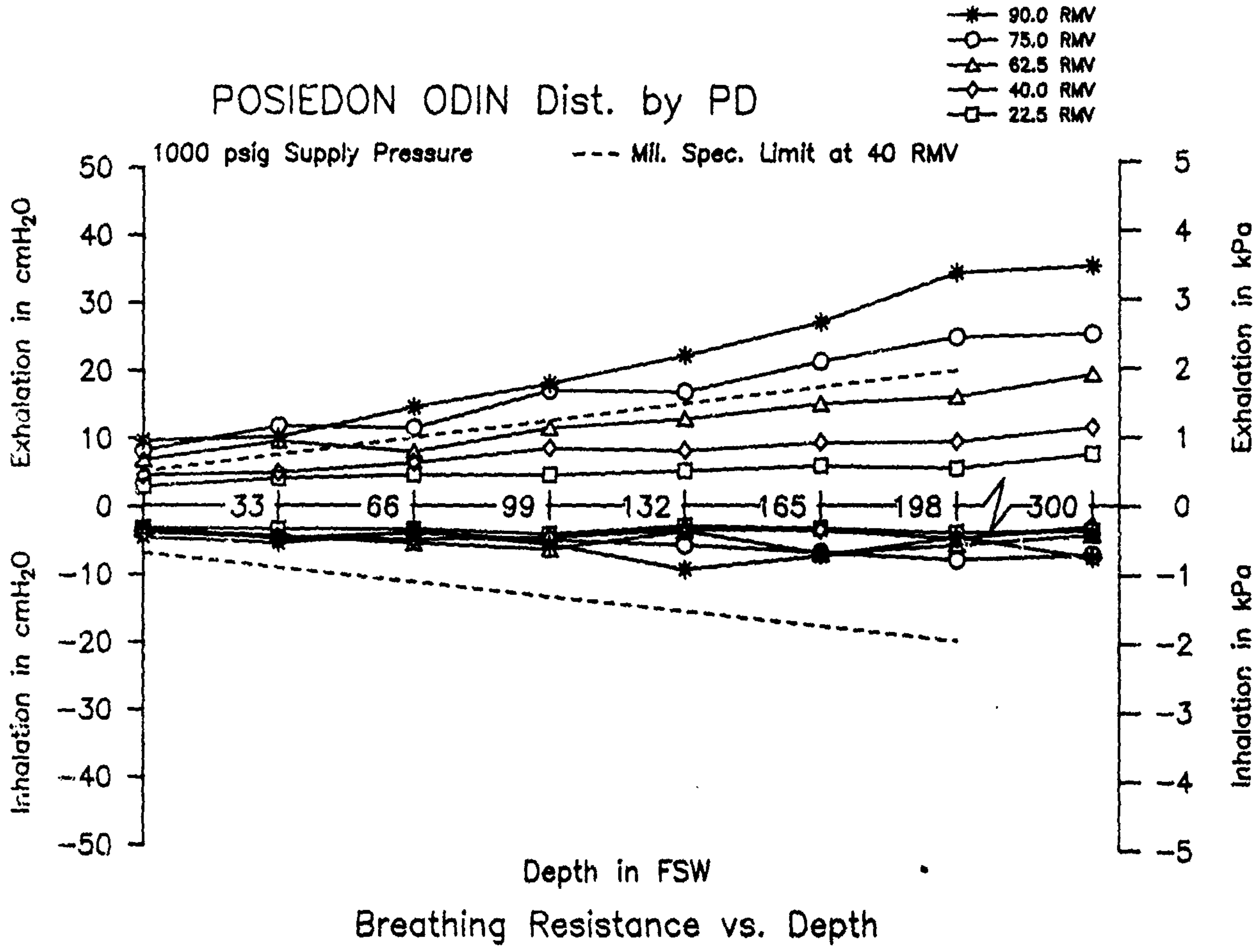
Breathing Resistance vs. Depth

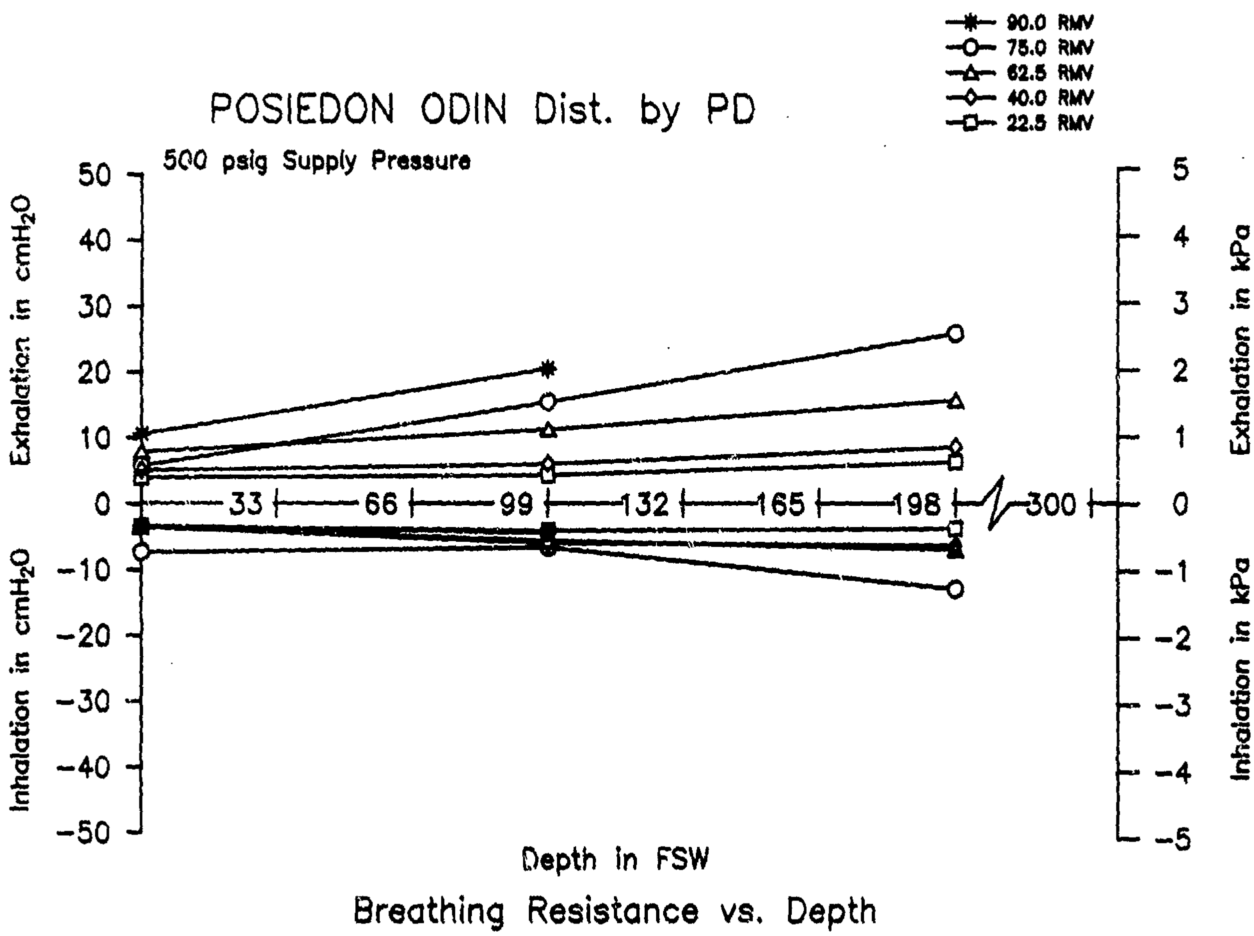


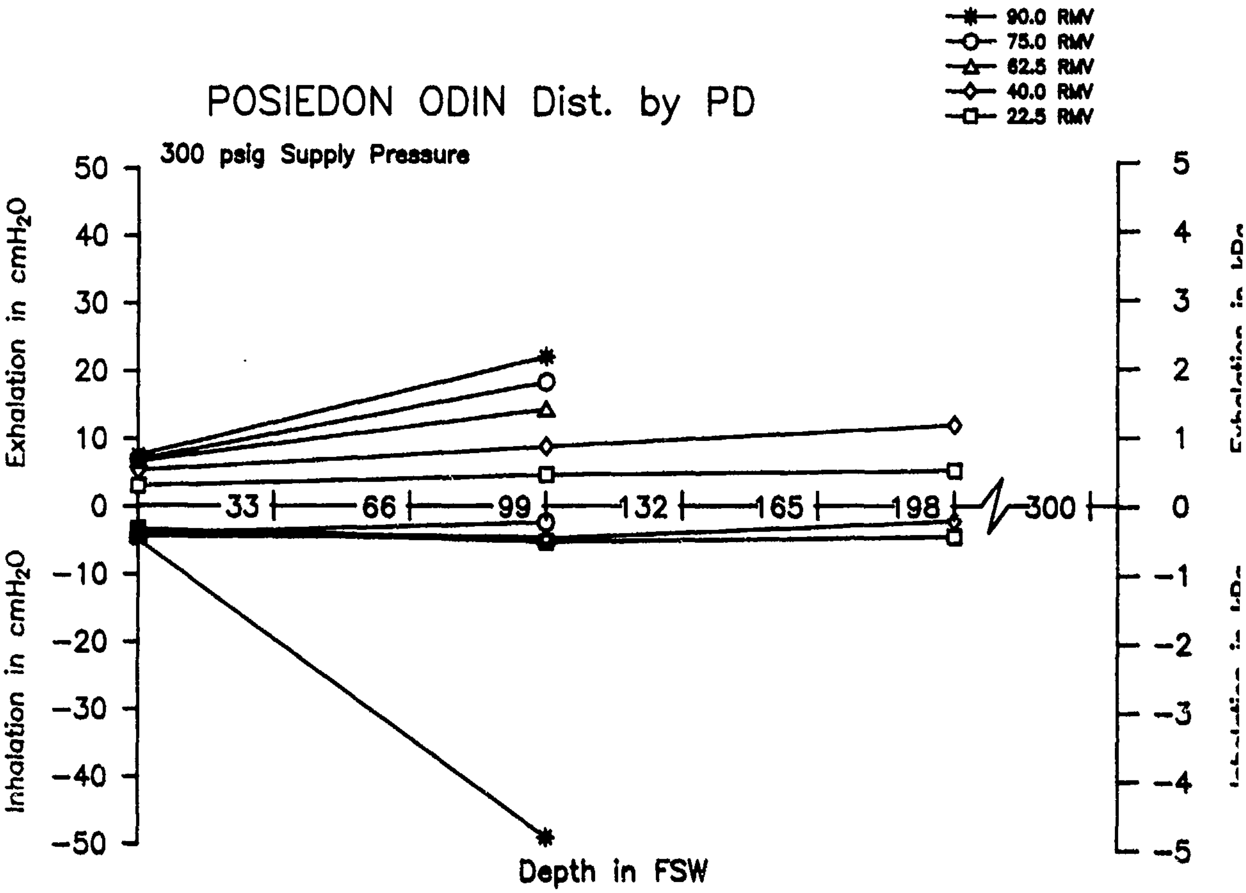
Breathing Work vs. Depth



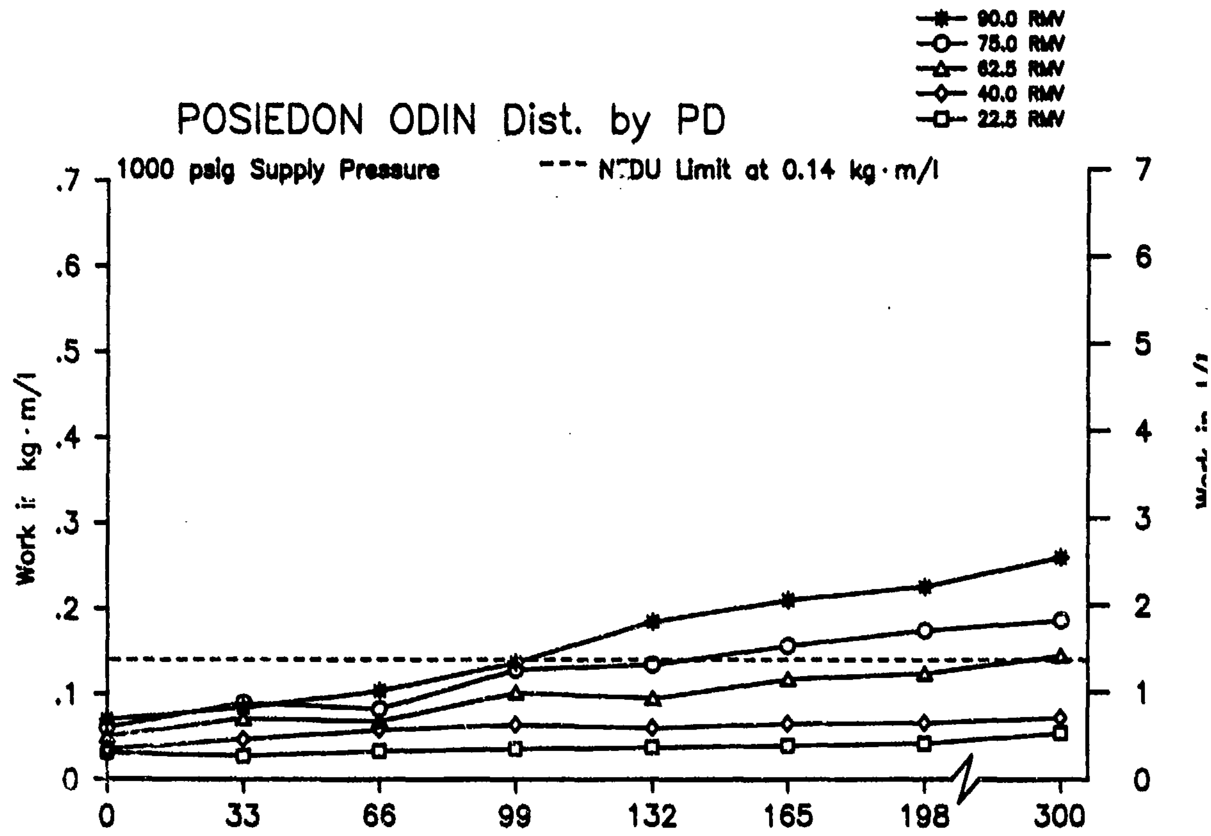
First Stage Pressure Drop vs. Depth


POSIEDON ODIN Dist. by PD
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
−10
−20
−30
−40
−50
5
4
3
2
1
0
−1
−2
−3
−4
−5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth

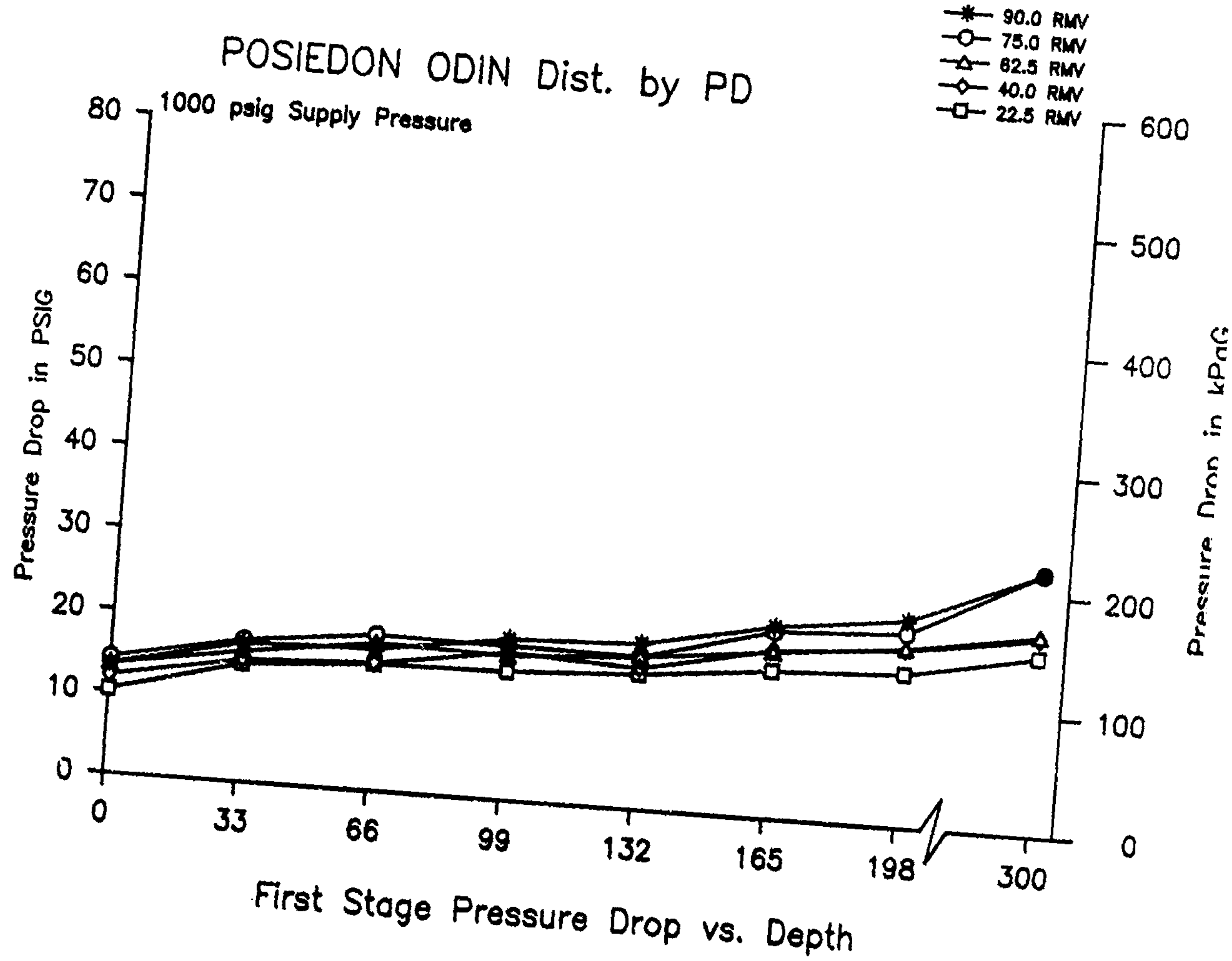

POSIEDON ODIN Dist. by PD
500 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
−10
−20
−30
−40
−50
5
4
3
2
1
0
−1
−2
−3
−4
−5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



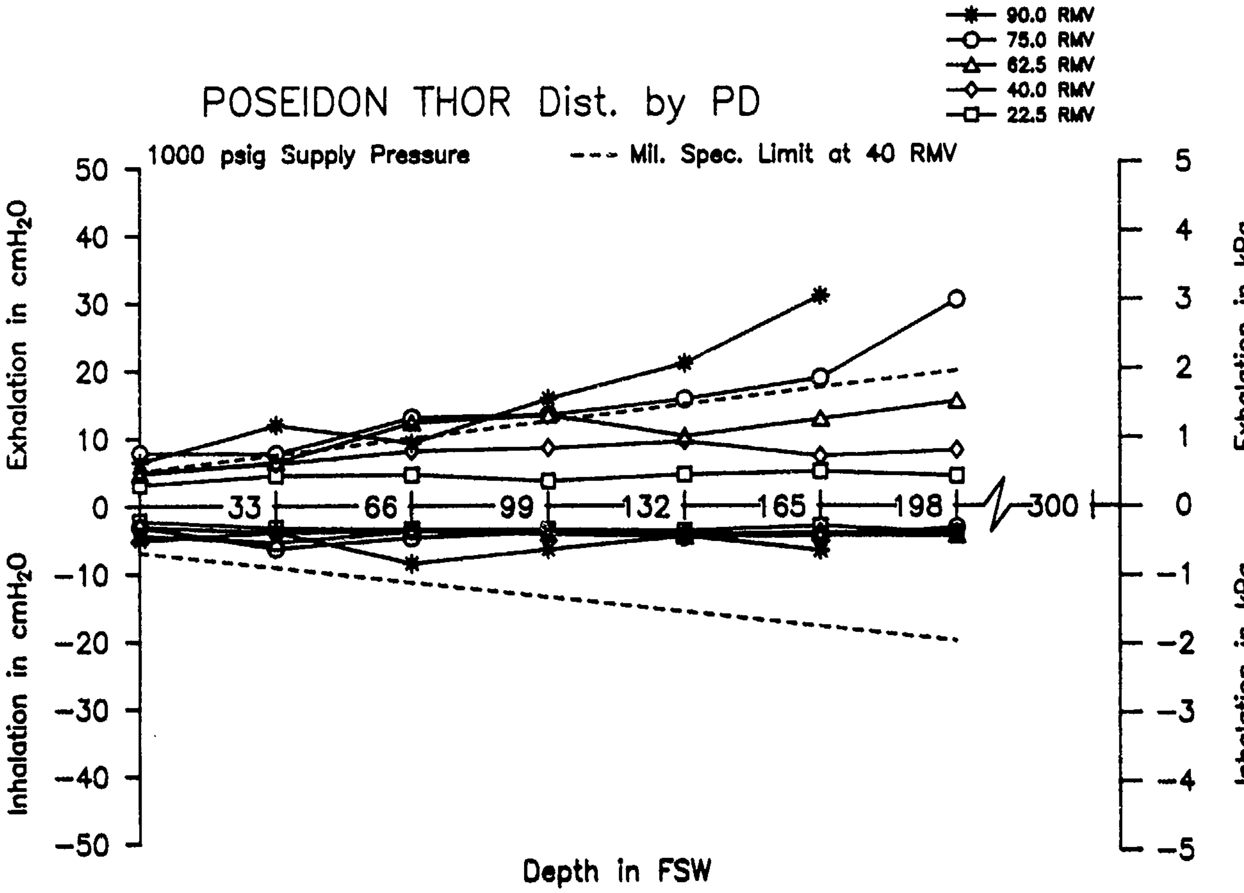
Breathing Resistance vs. Depth



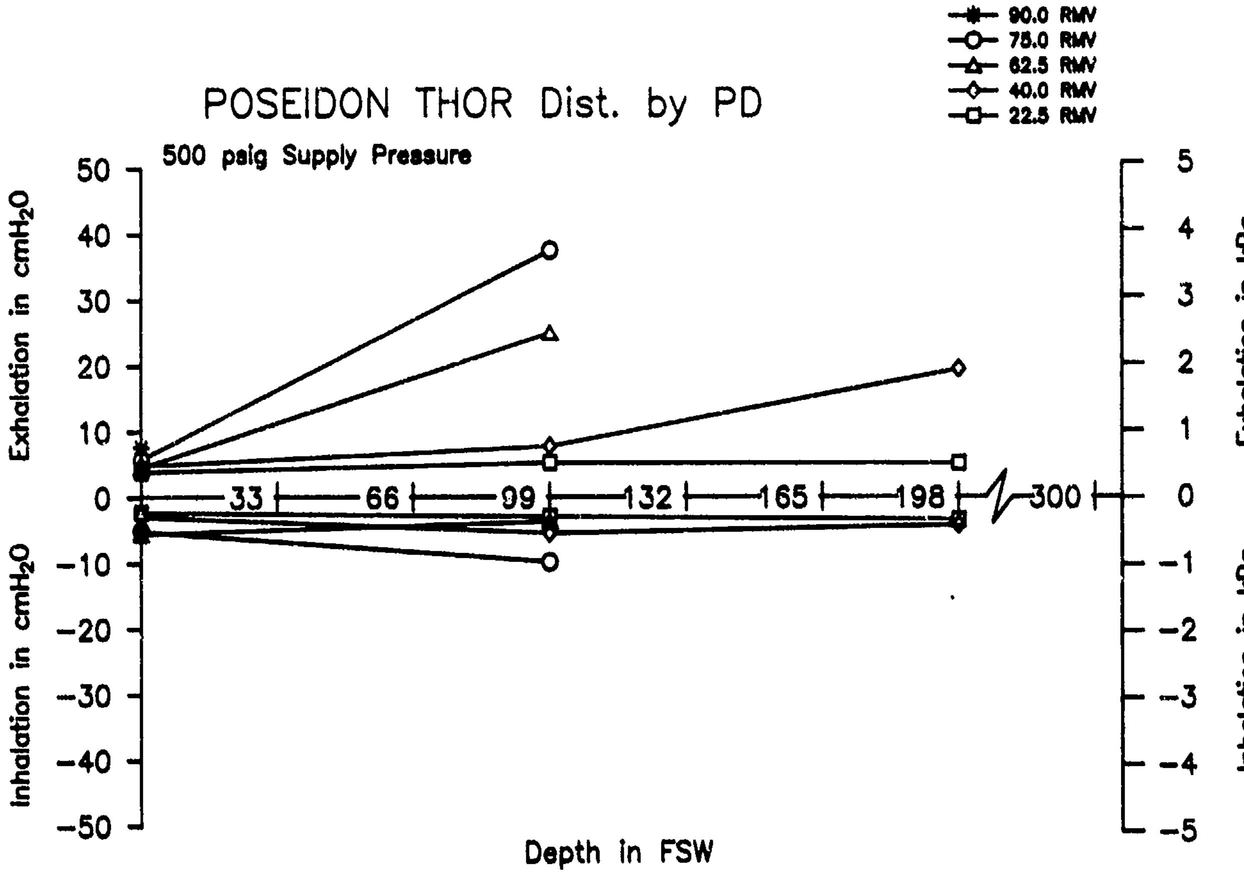
Breathing Work vs. Depth



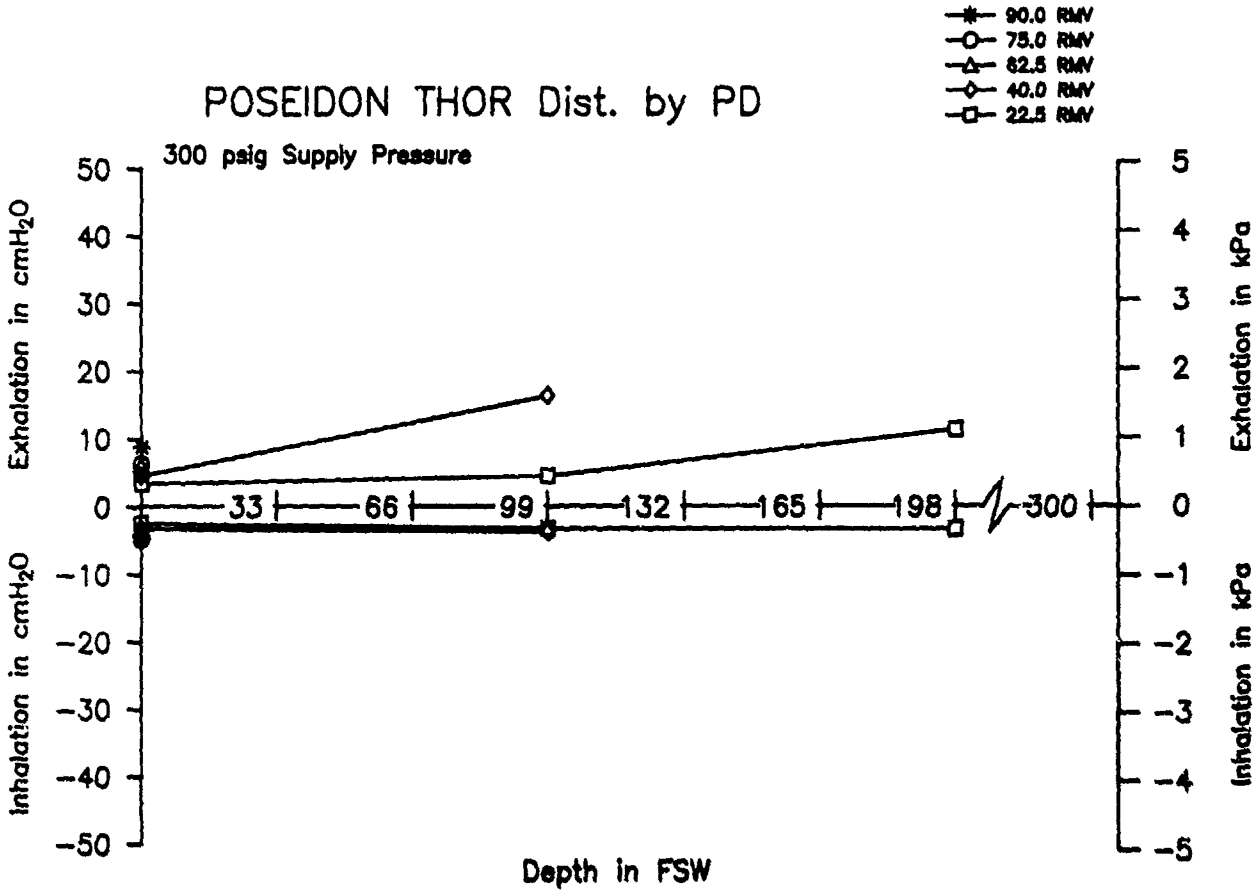
POSIEDON ODIN Dist. by PD
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
Pressure Drop in kPaG
80
70
60
50
40
30
20
10
0
600
500
400
300
200
100
0
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth



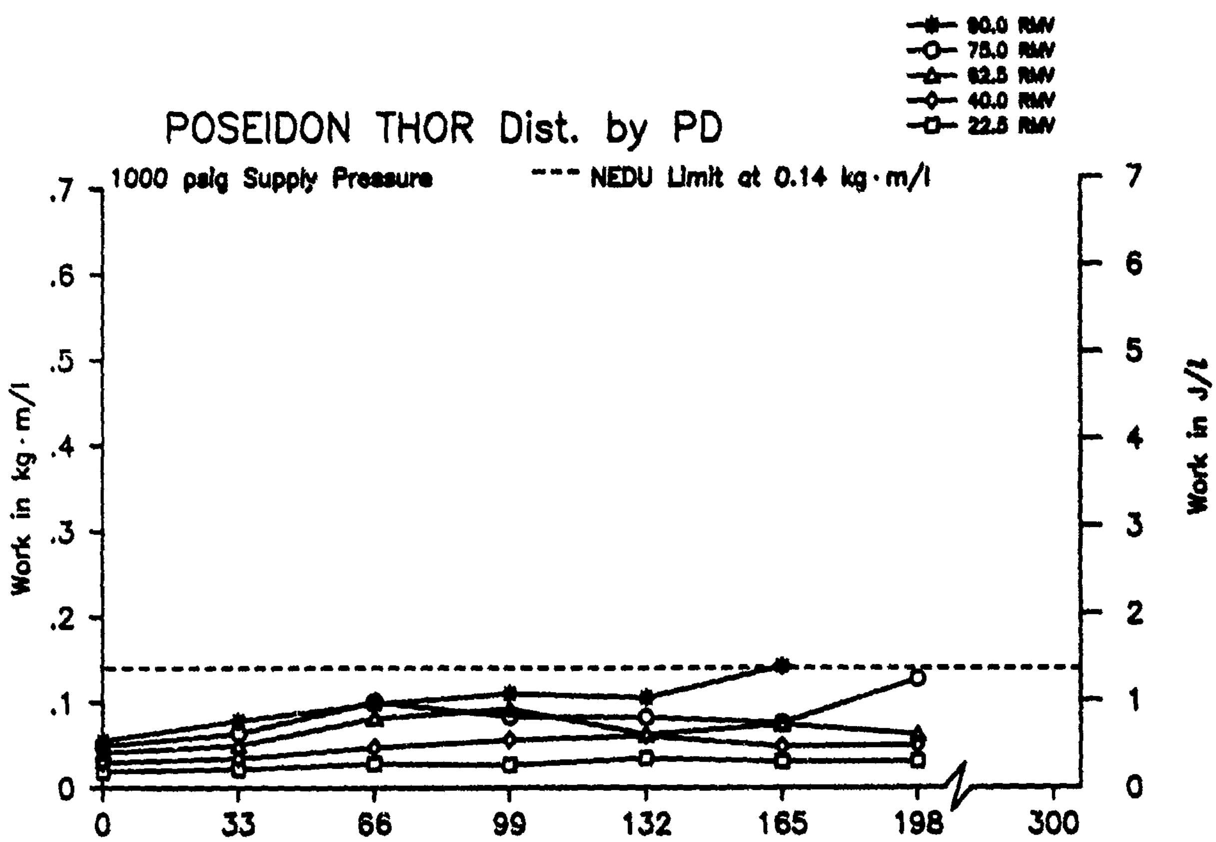
Breathing Resistance vs. Depth



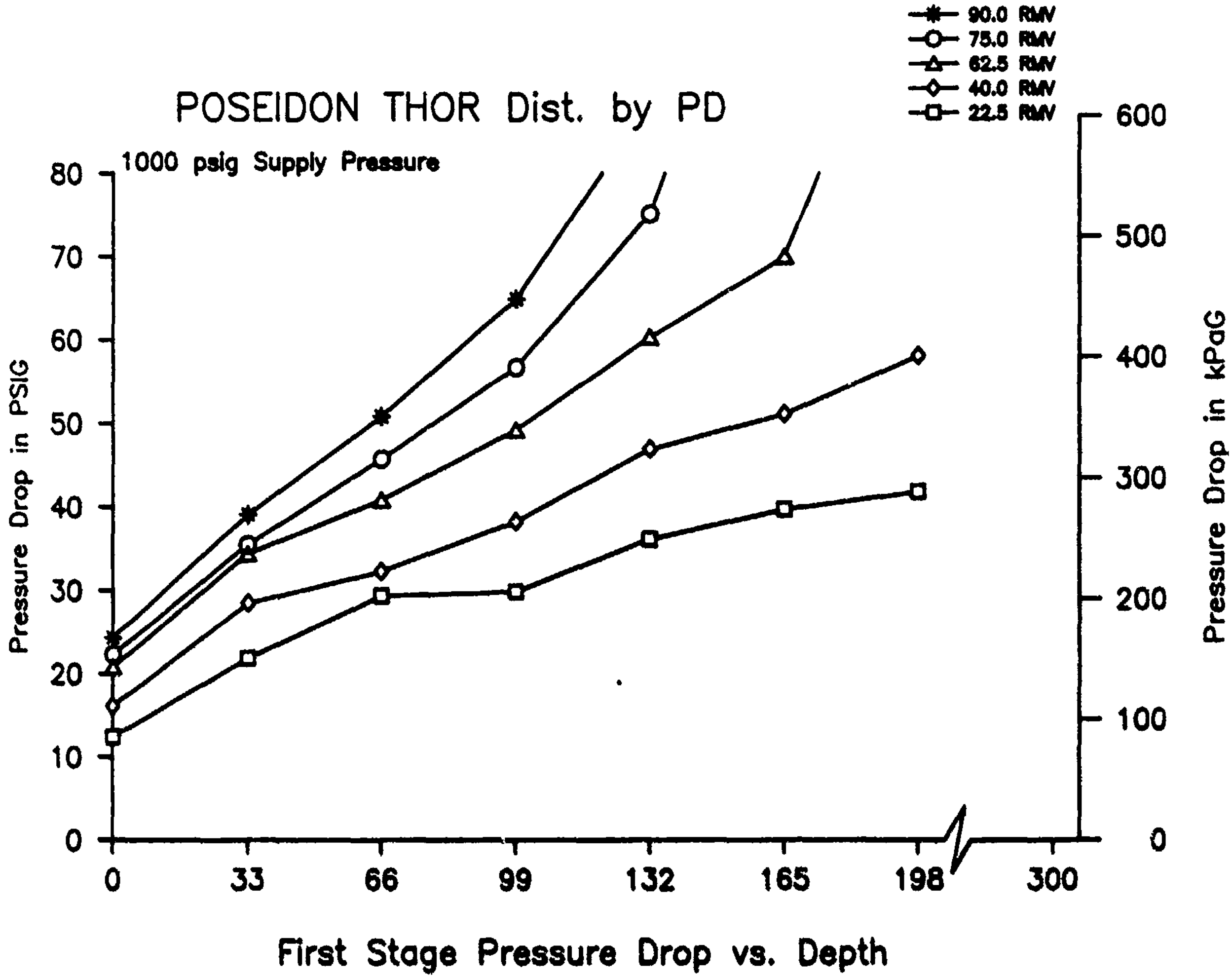
Breathing Resistance vs. Depth

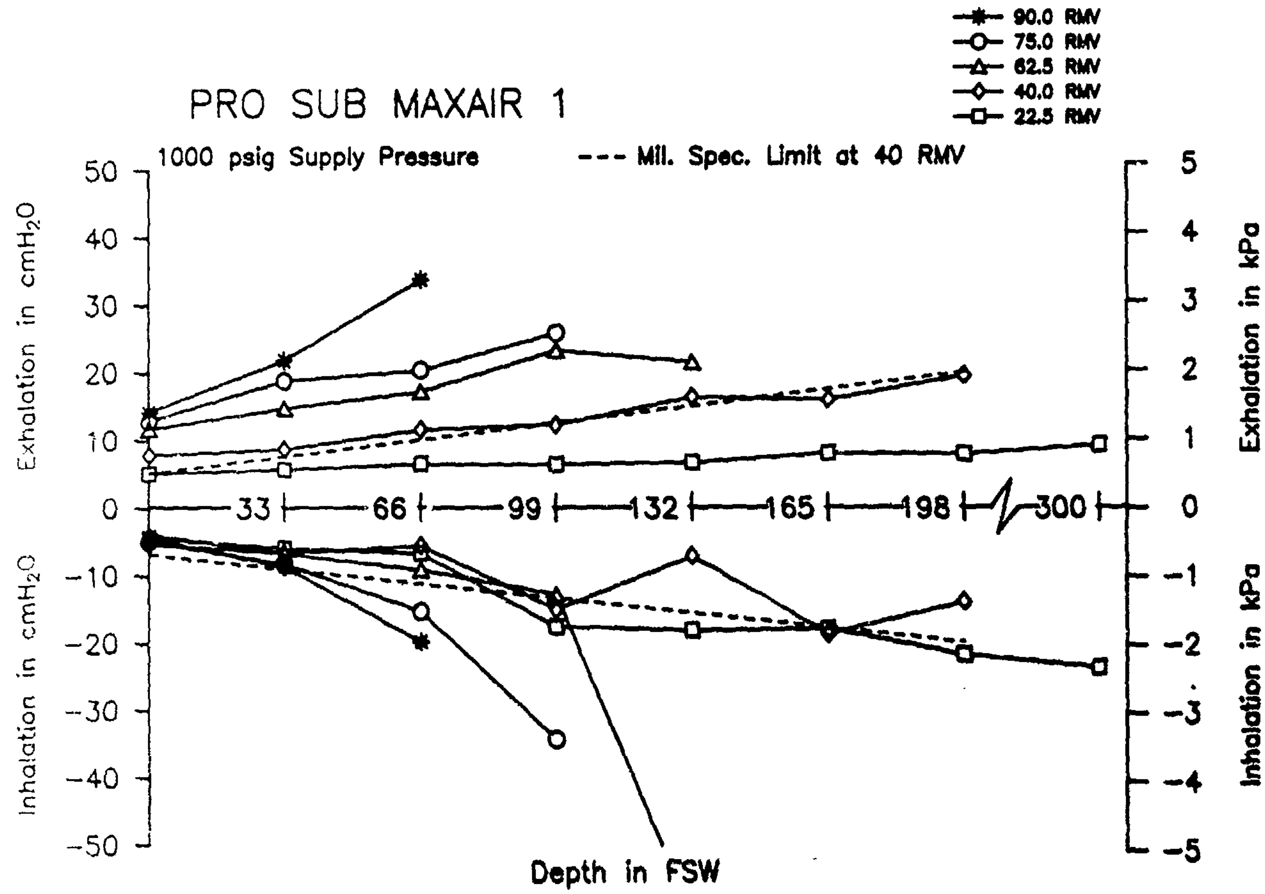


Breathing Resistance vs. Depth

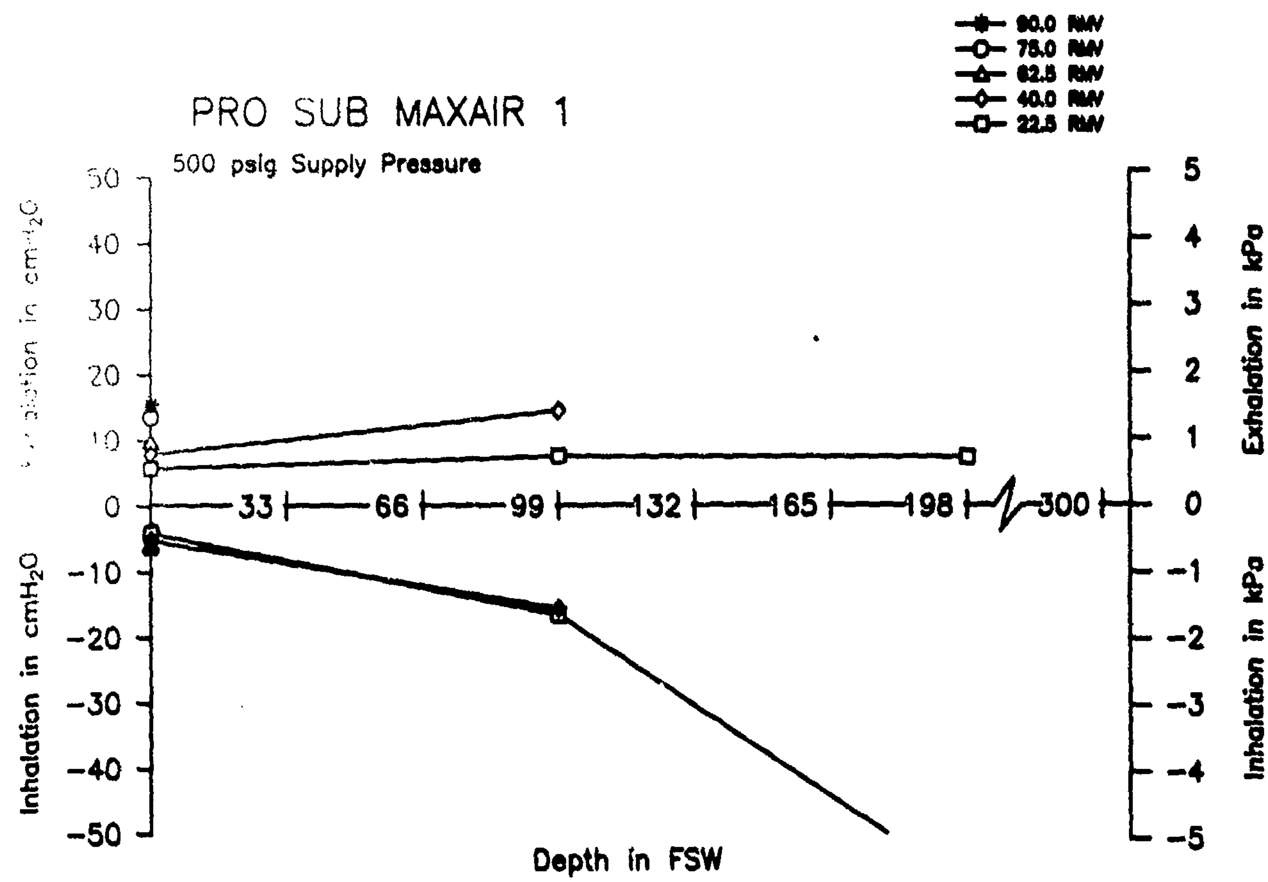


Breathing Work vs. Depth

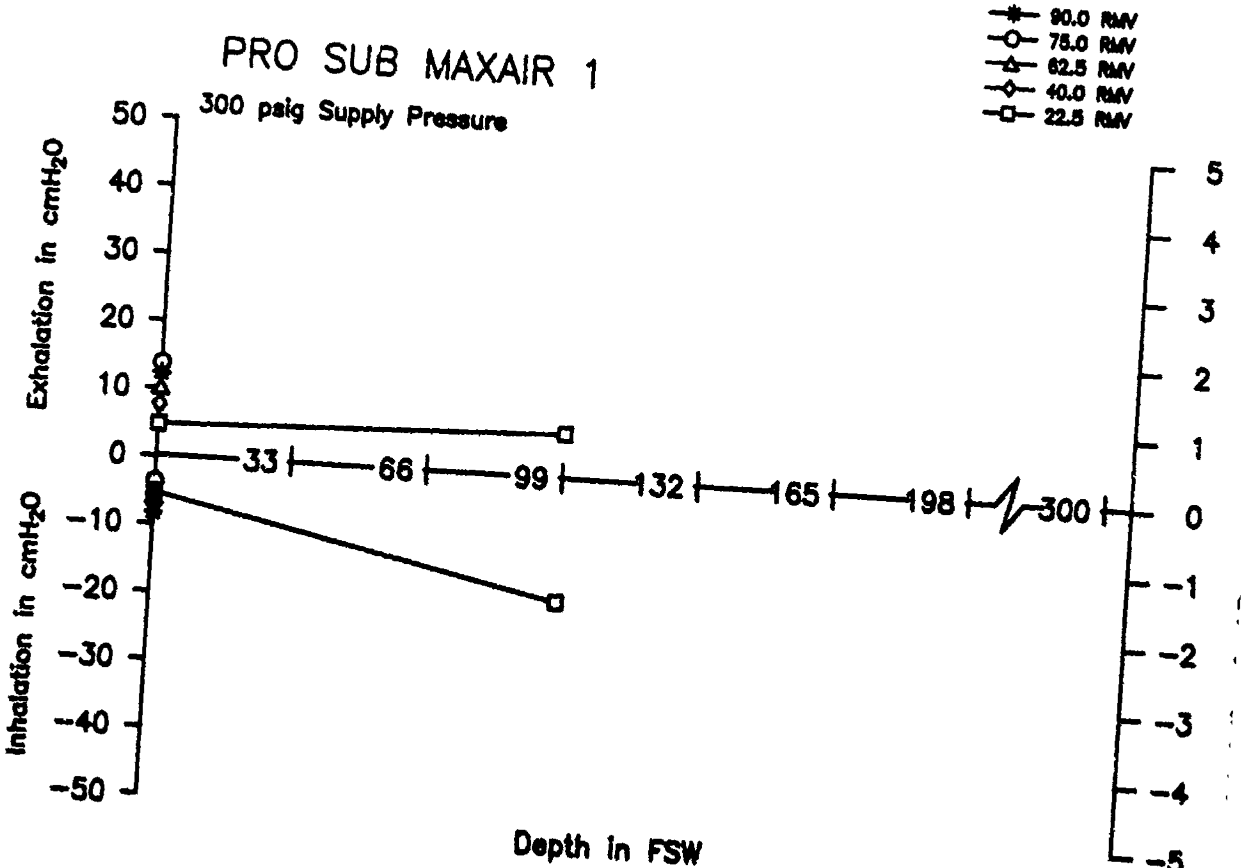

POSEIDON THOR Dist. by PD
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
Pressure Drop in kPaG
0
10
20
30
40
50
60
70
80
100
200
300
400
500
600
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth



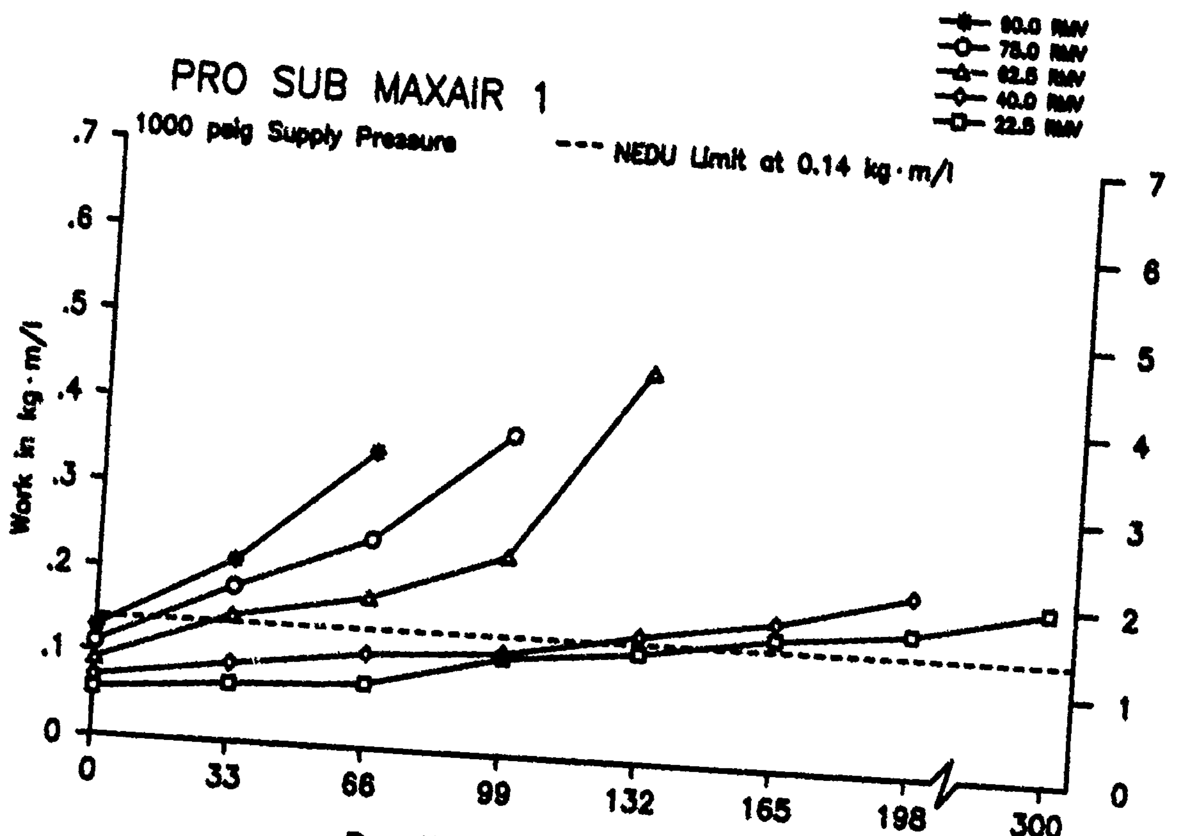
Breathing Resistance vs. Depth



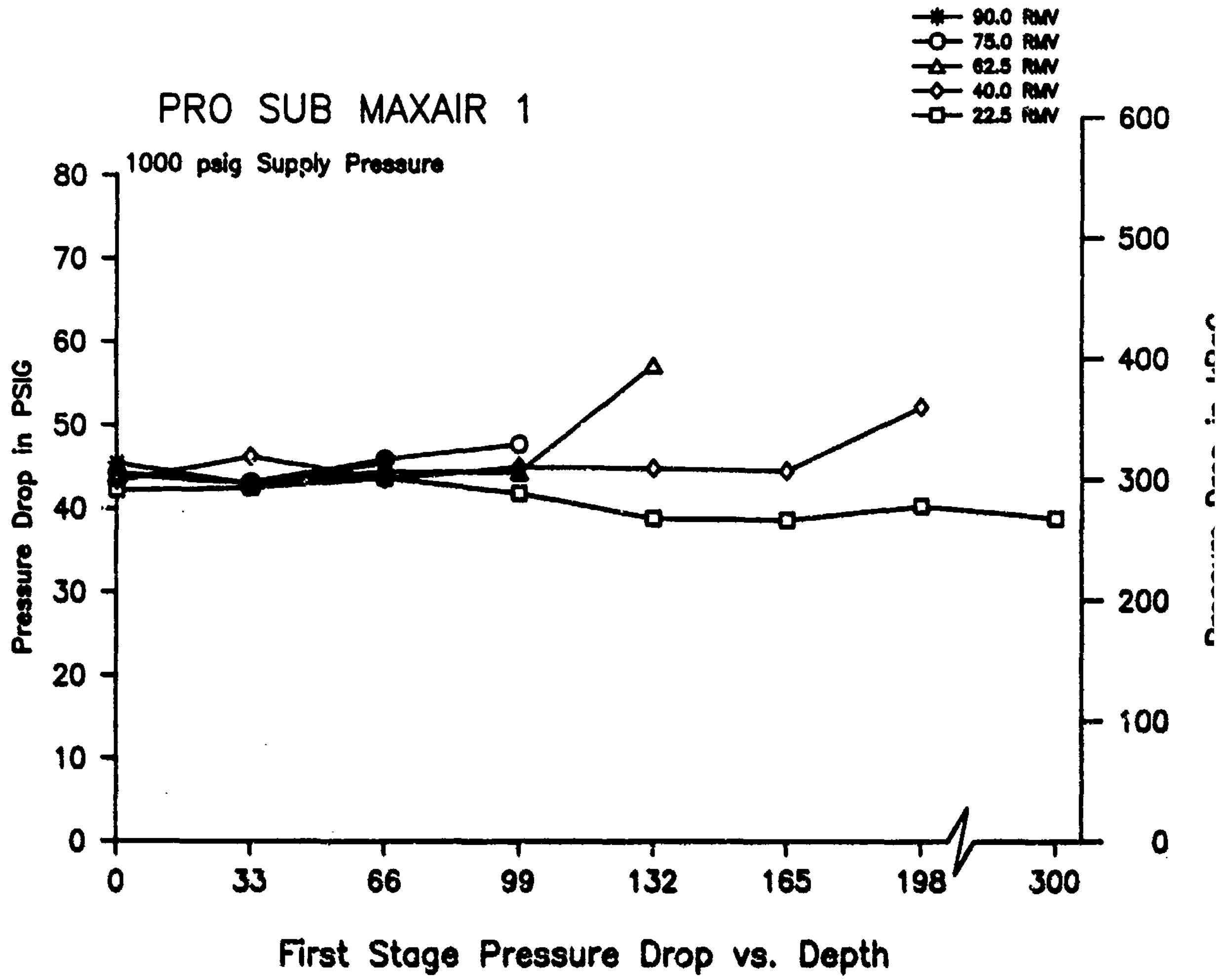
Breathing Resistance vs. Depth



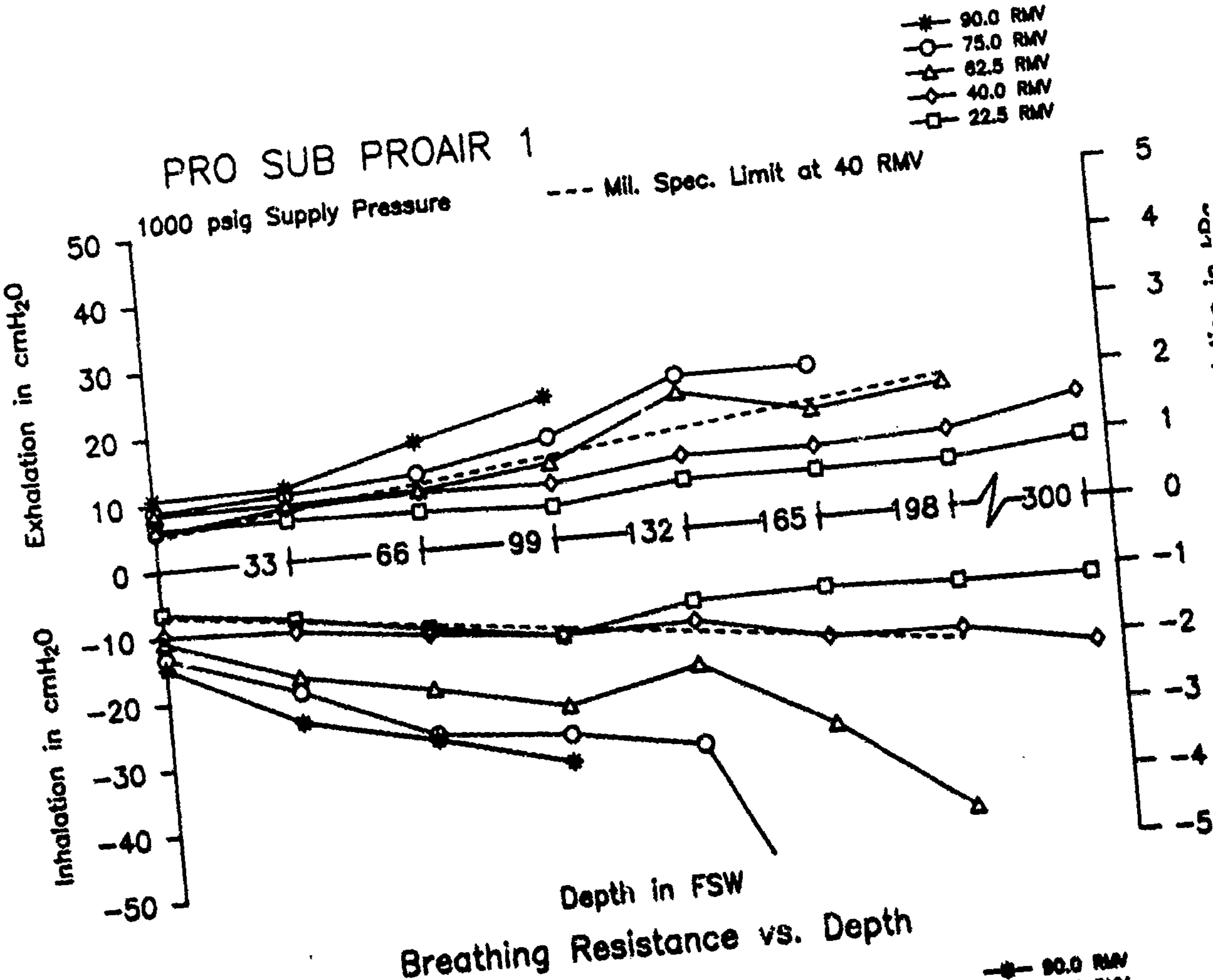
Breathing Resistance vs. Depth

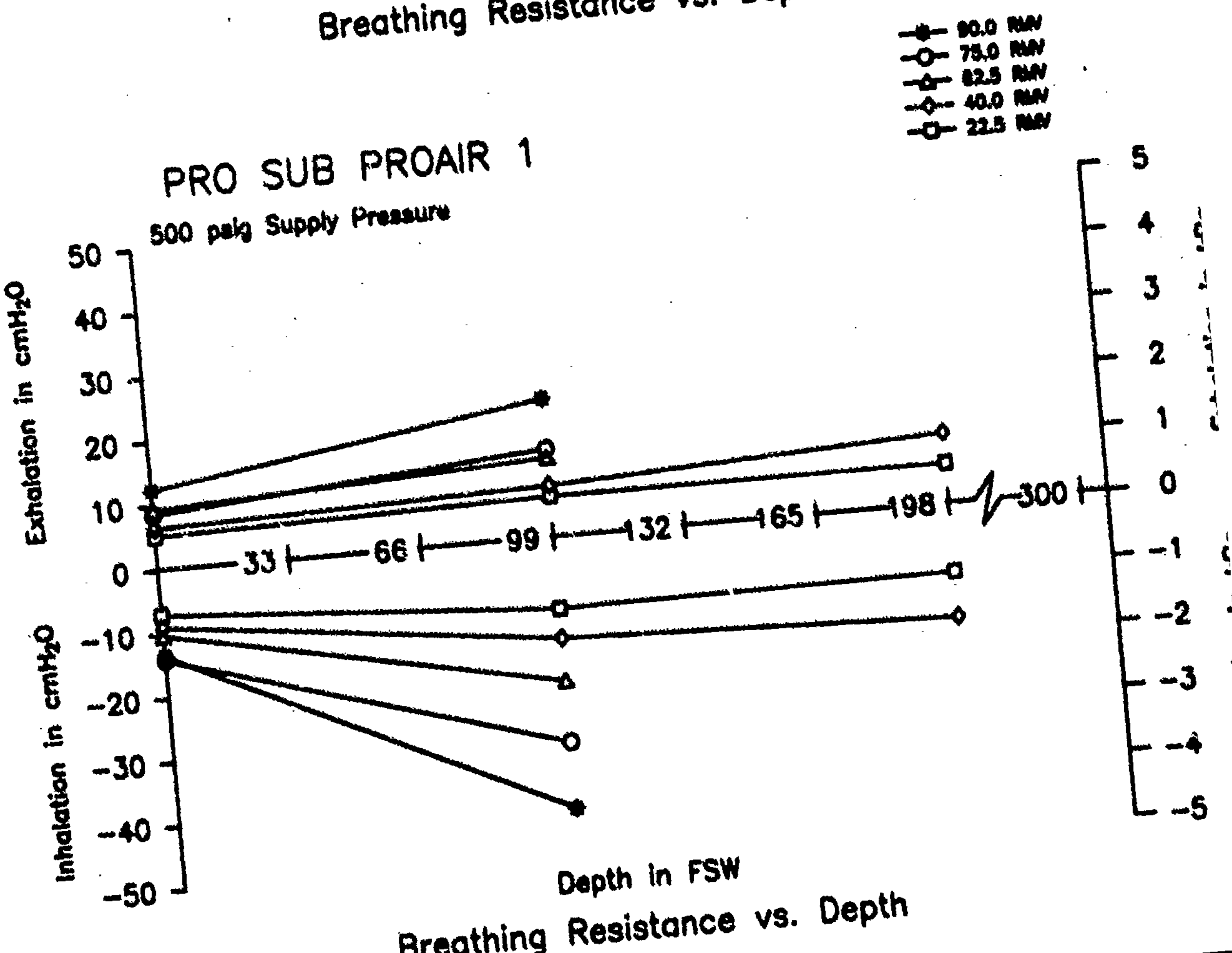


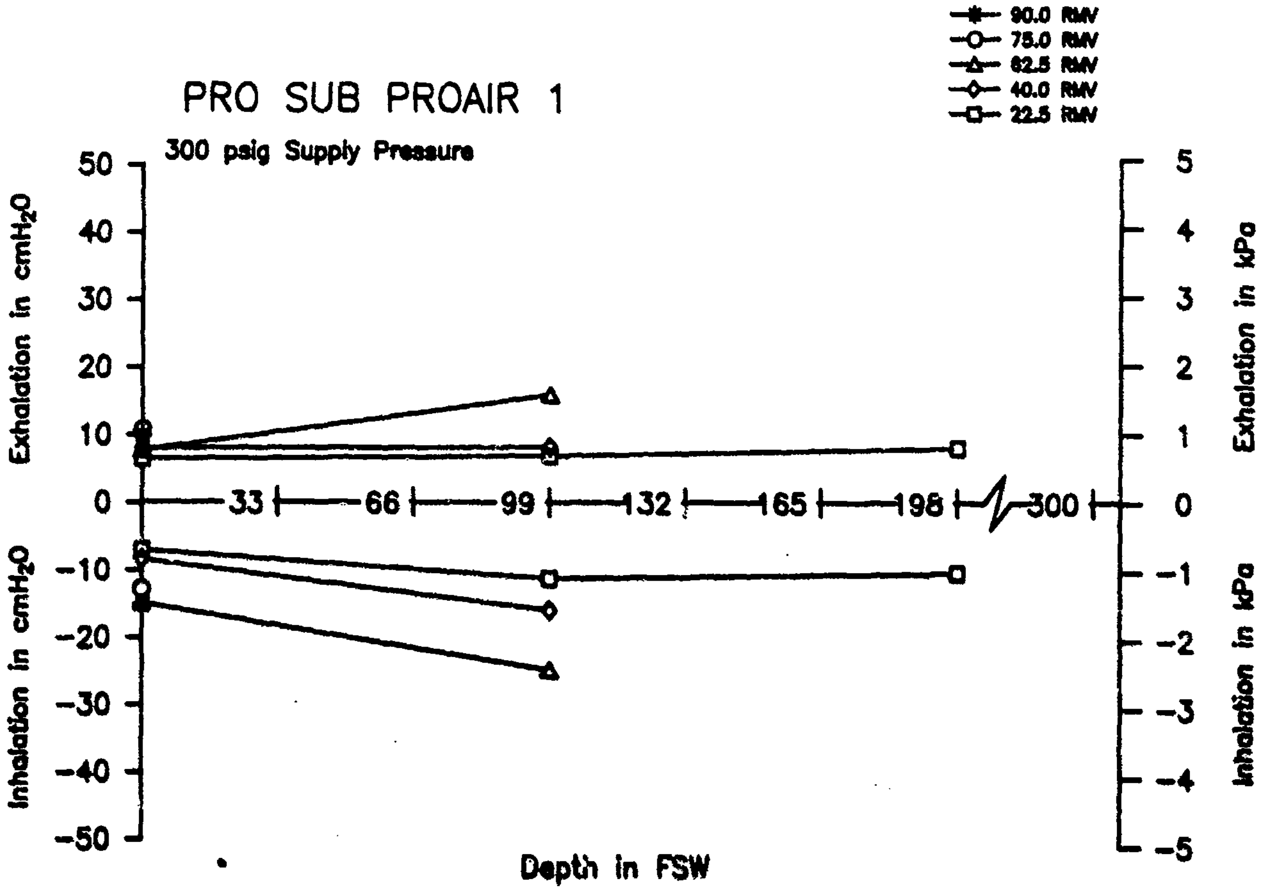
Breathing Work vs. Depth



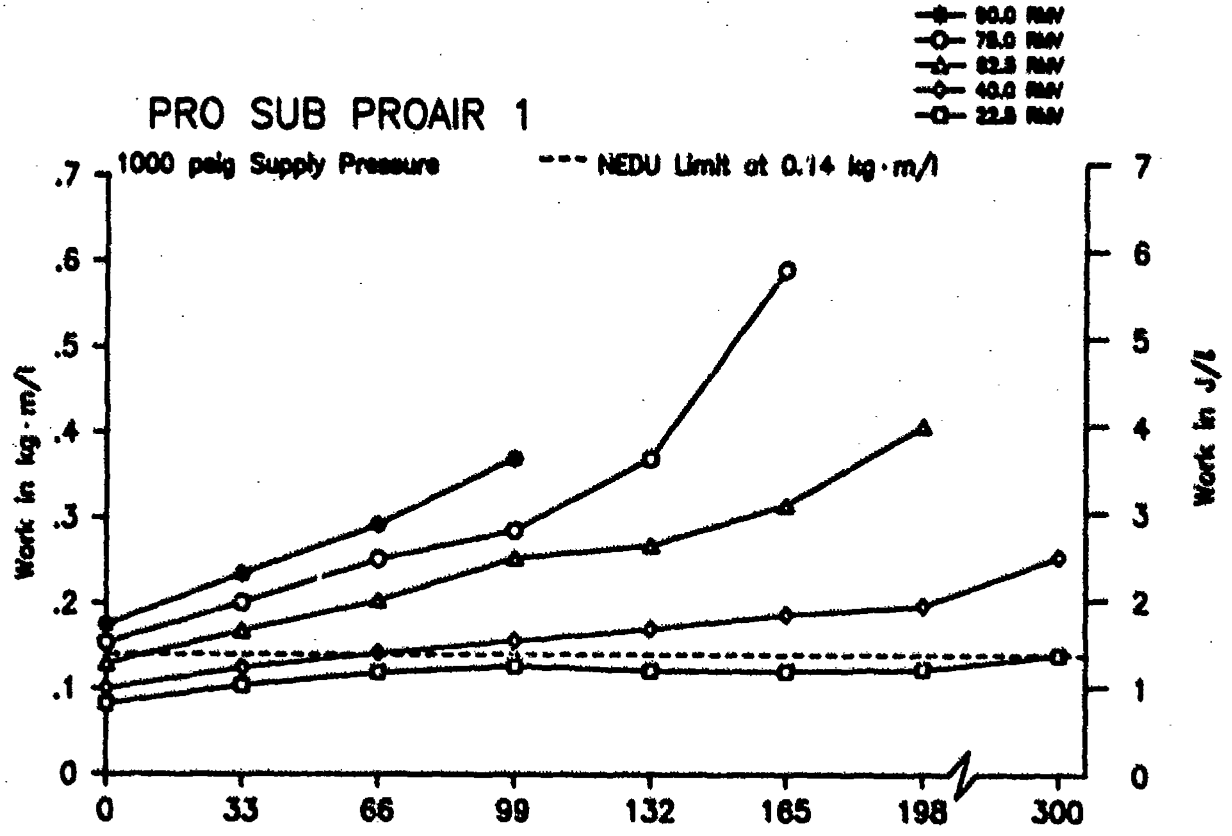
PRO SUB MAXAIR 1
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
80
70
60
50
40
30
20
10
0
600
500
400
300
200
100
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth


90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
PRO SUB PROAIR 1
--- Mil. Spec. Limit at 40 RMV
1000 psig Supply Pressure
Exhalation in cmH_2O
Inhalation in cmH_2O
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth

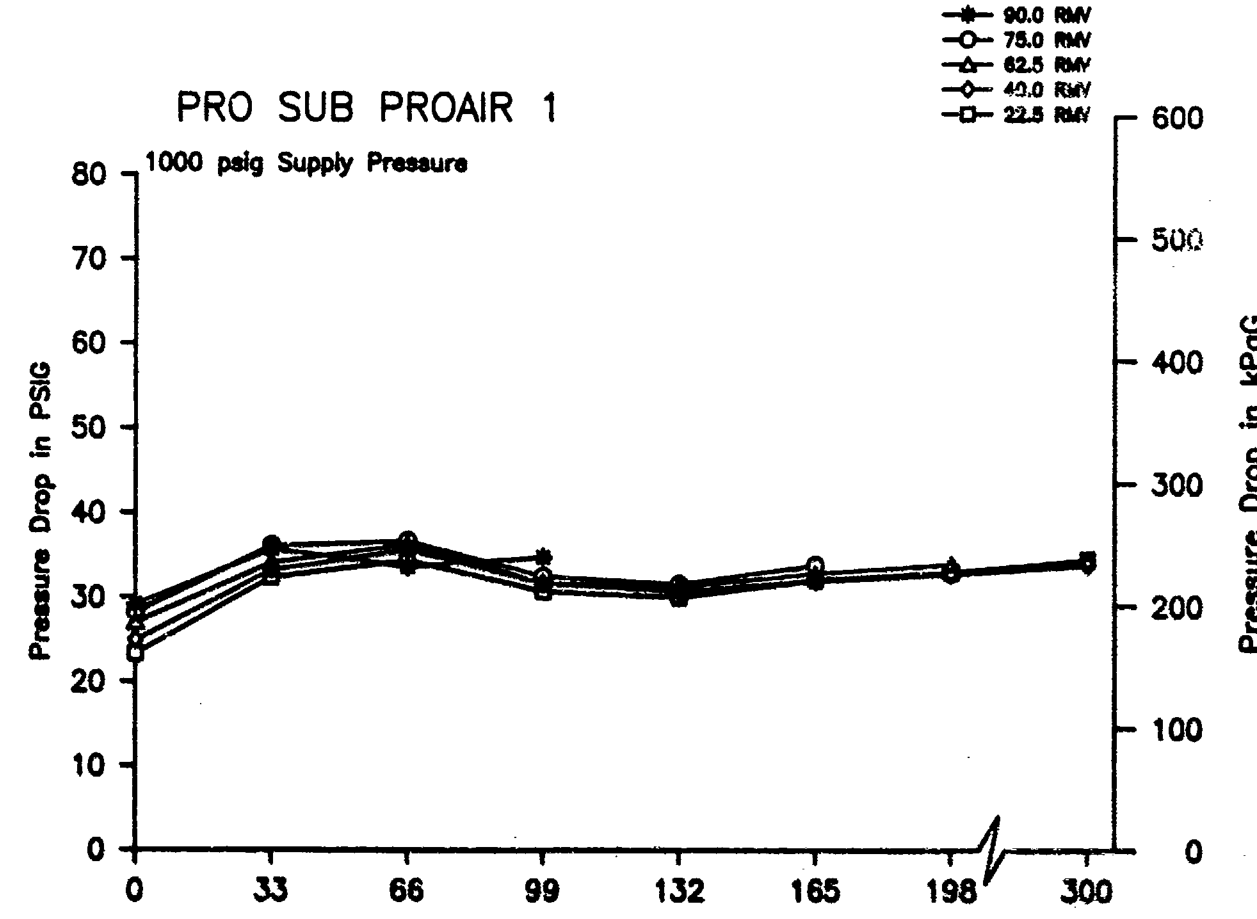

90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
PRO SUB PROAIR 1
500 psig Supply Pressure
Exhalation in cmH_2O
Inhalation in cmH_2O
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



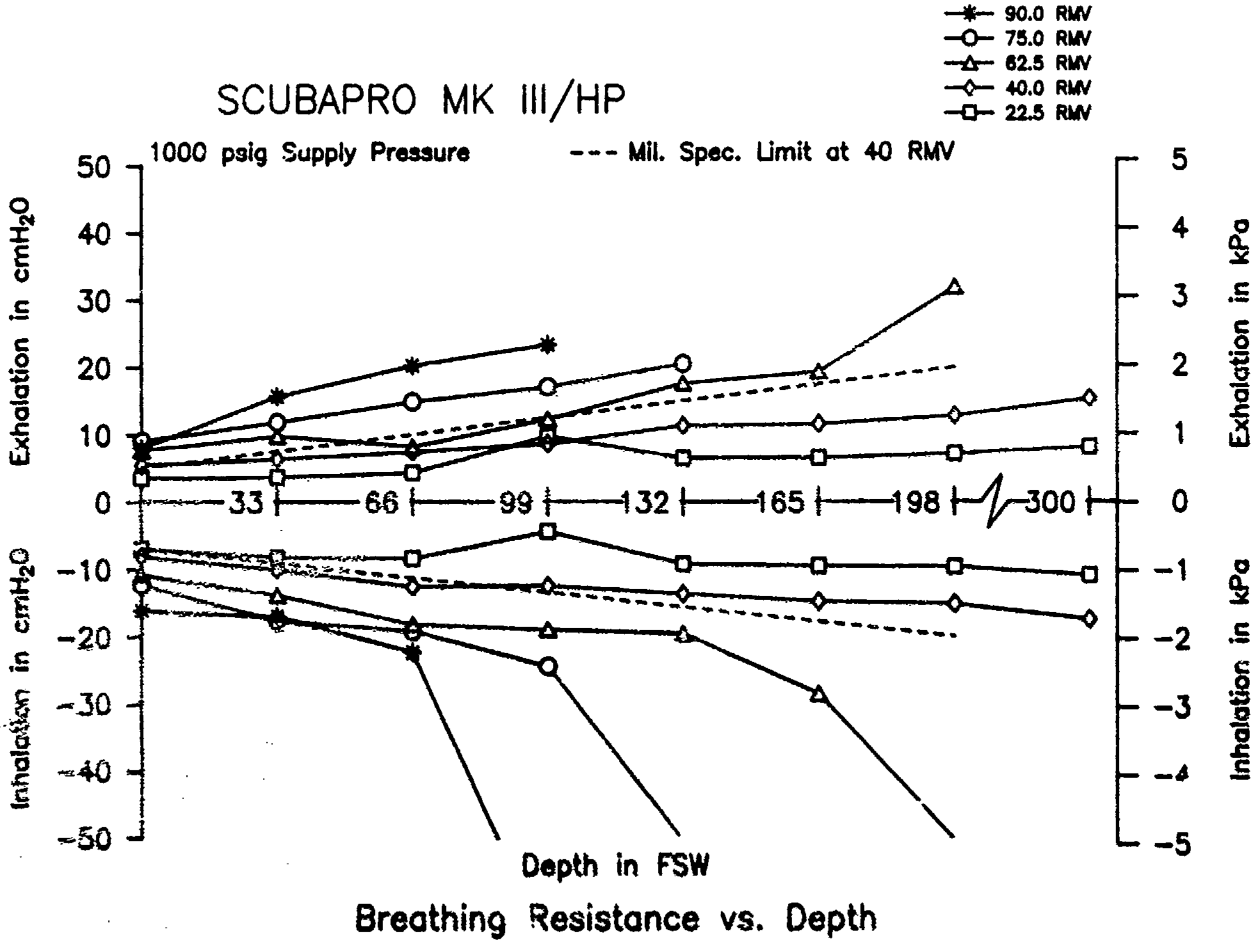
Breathing Resistance vs. Depth

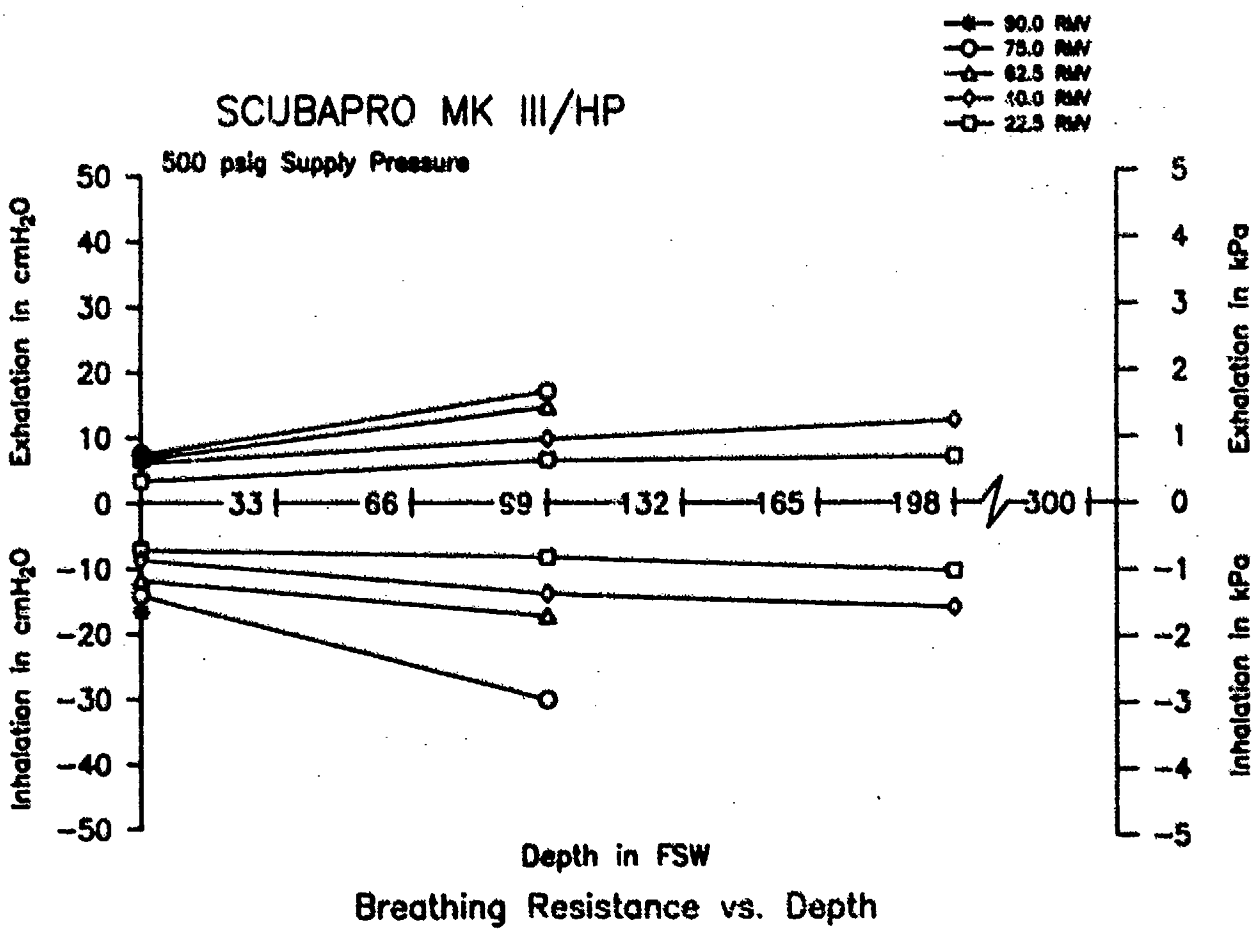


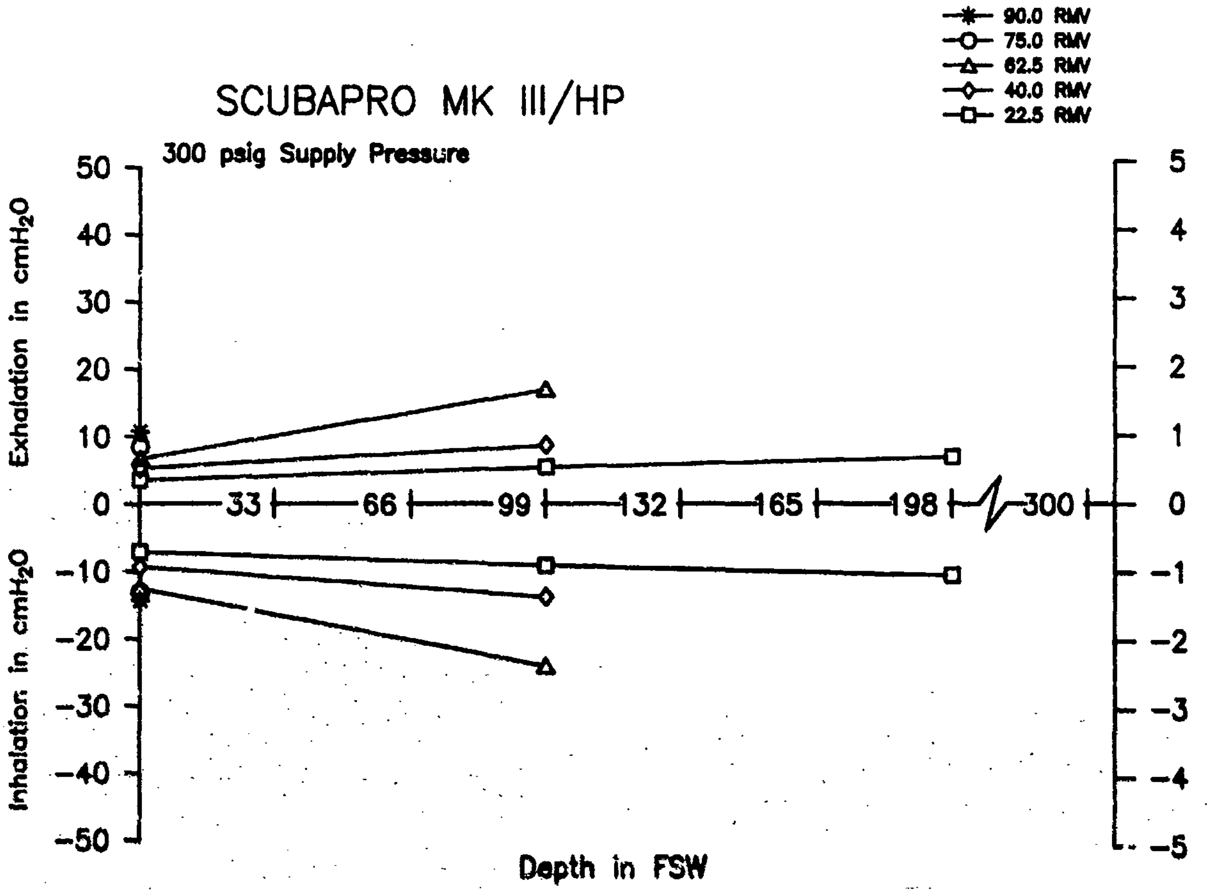
Breathing Work vs. Depth



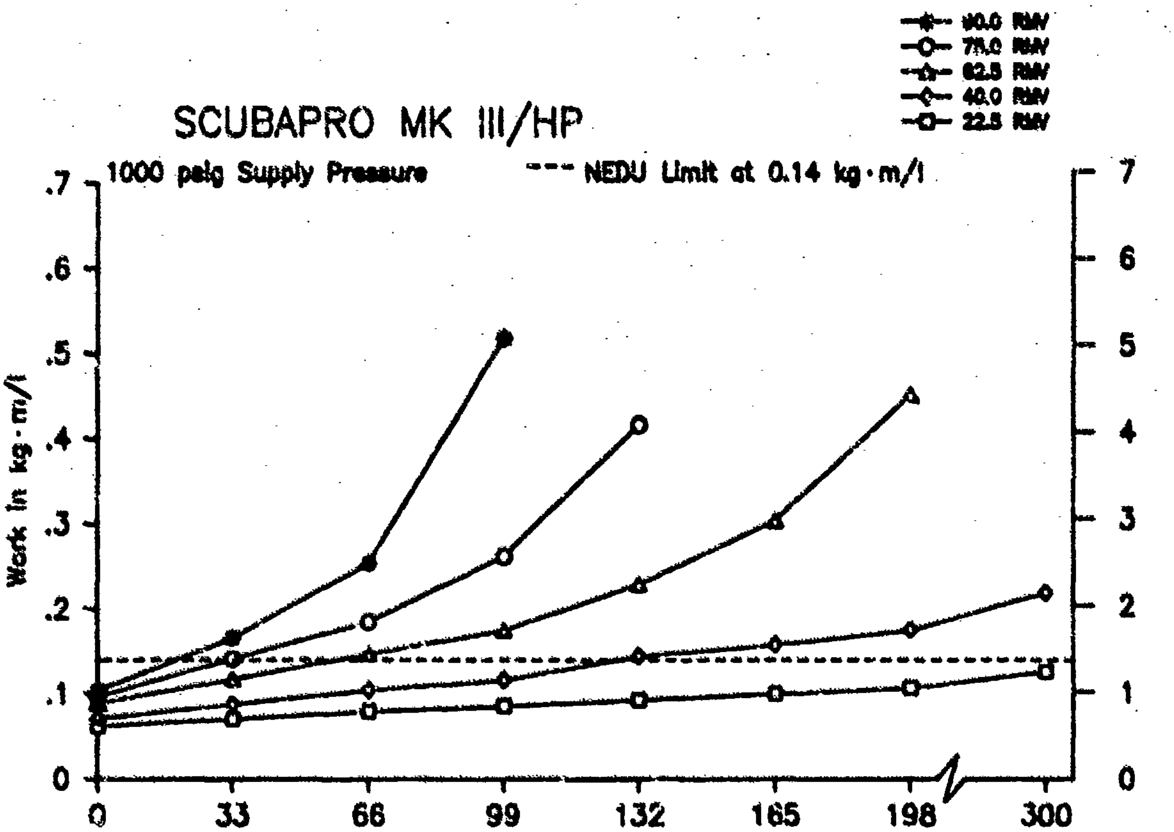
First Stage Pressure Drop vs. Depth


90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
SCUBAPRO MK III/HP
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
-10
-20
-30
-40
-50
5
4
3
2
1
0
-1
-2
-3
-4
-5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth

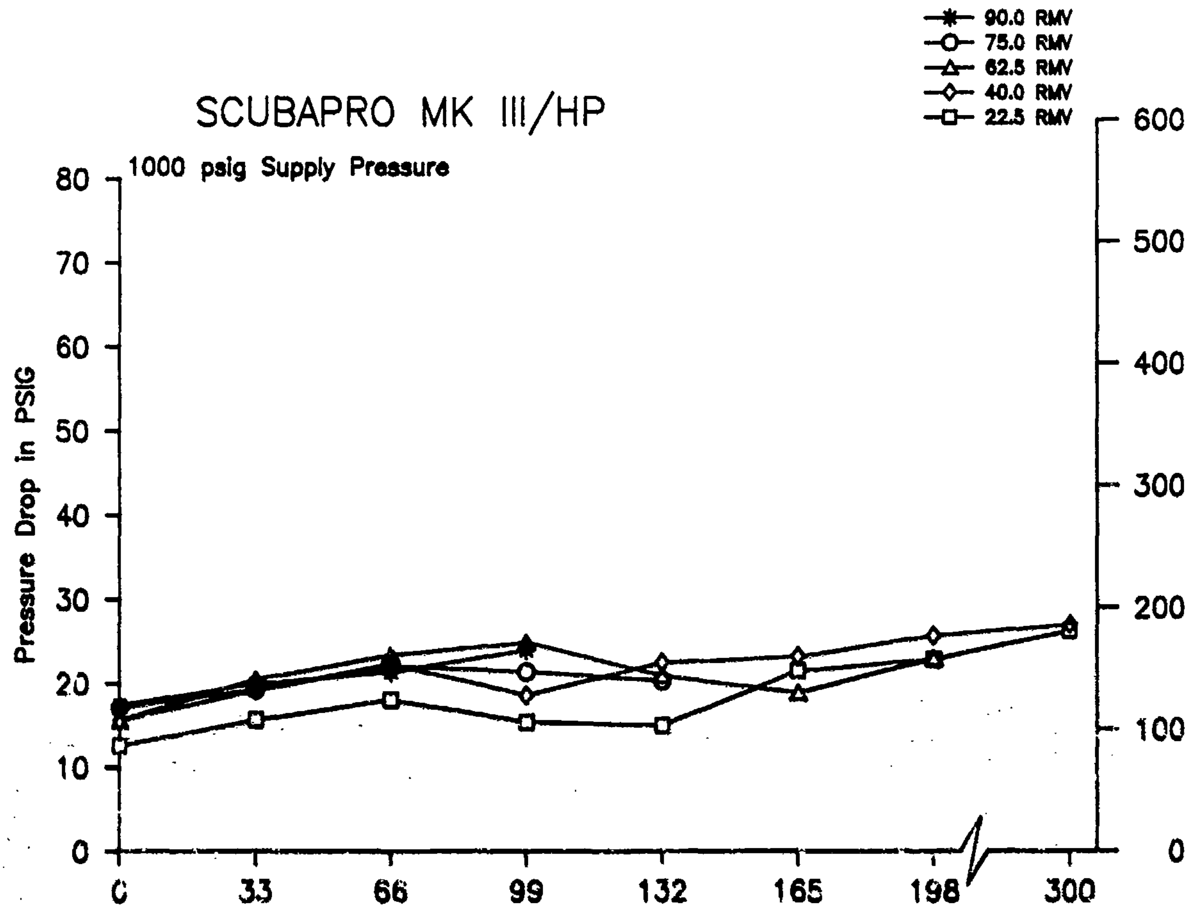

90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
SCUBAPRO MK III/HP
500 psig Supply Pressure
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
-10
-20
-30
-40
-50
5
4
3
2
1
0
-1
-2
-3
-4
-5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



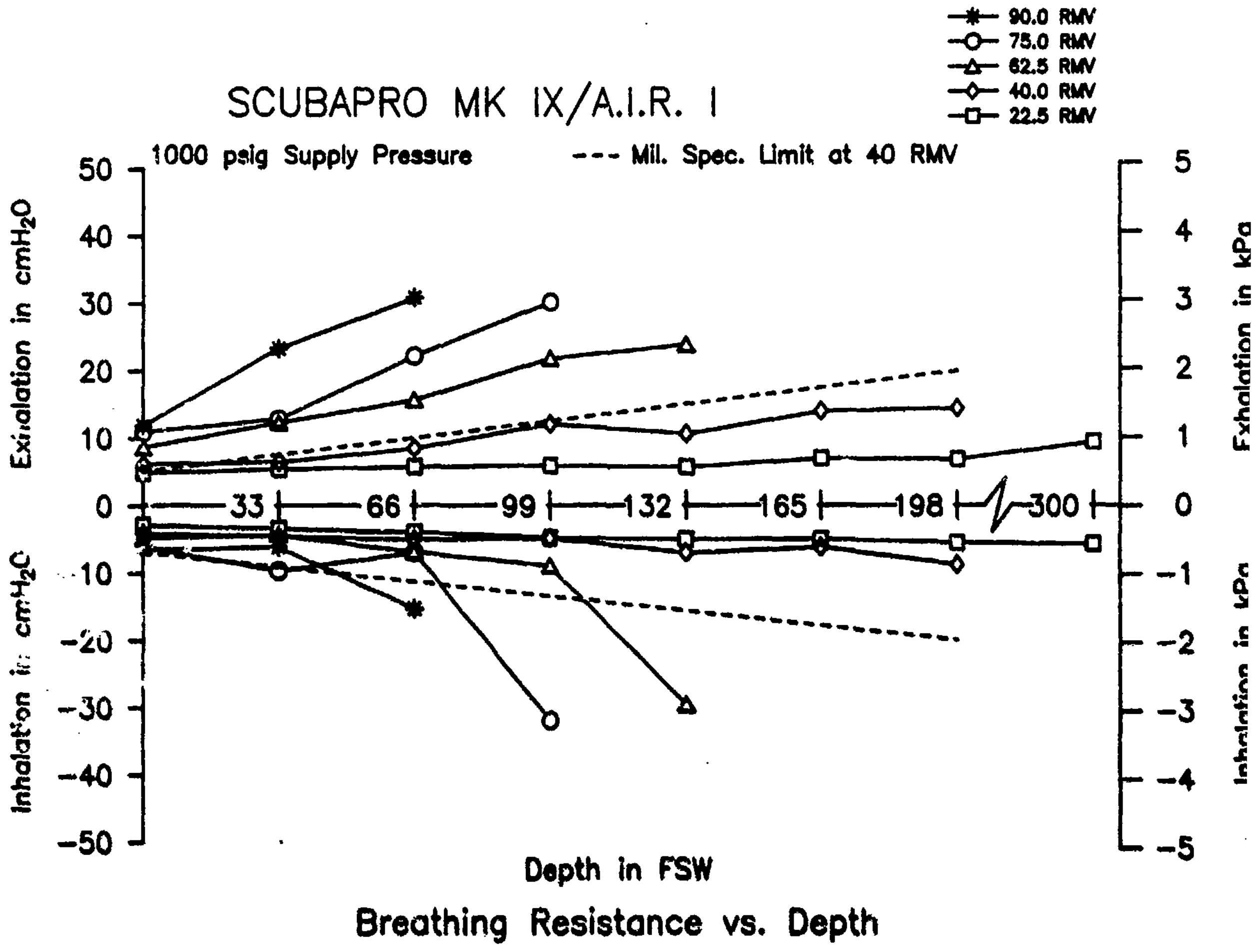
Breathing Resistance vs. Depth

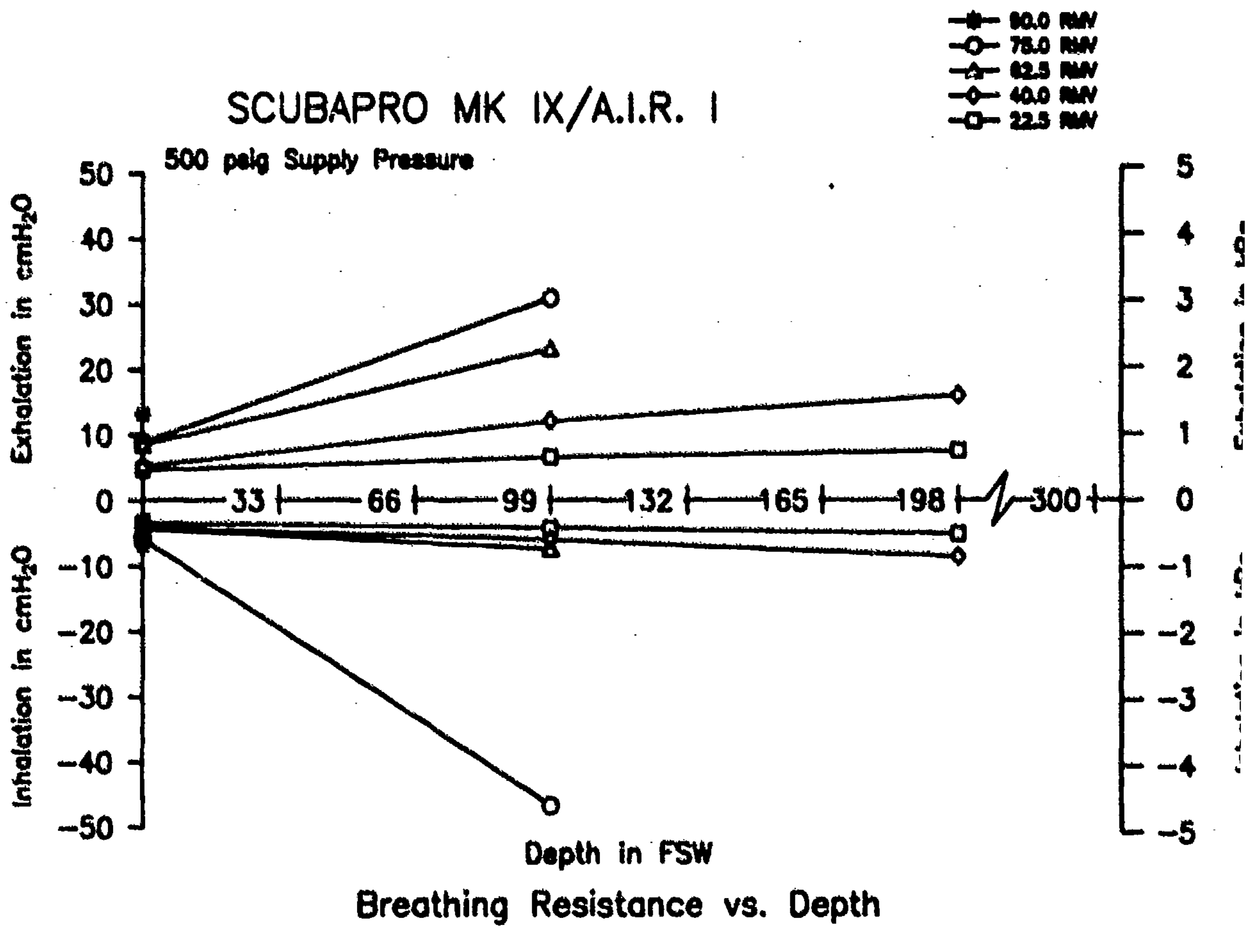


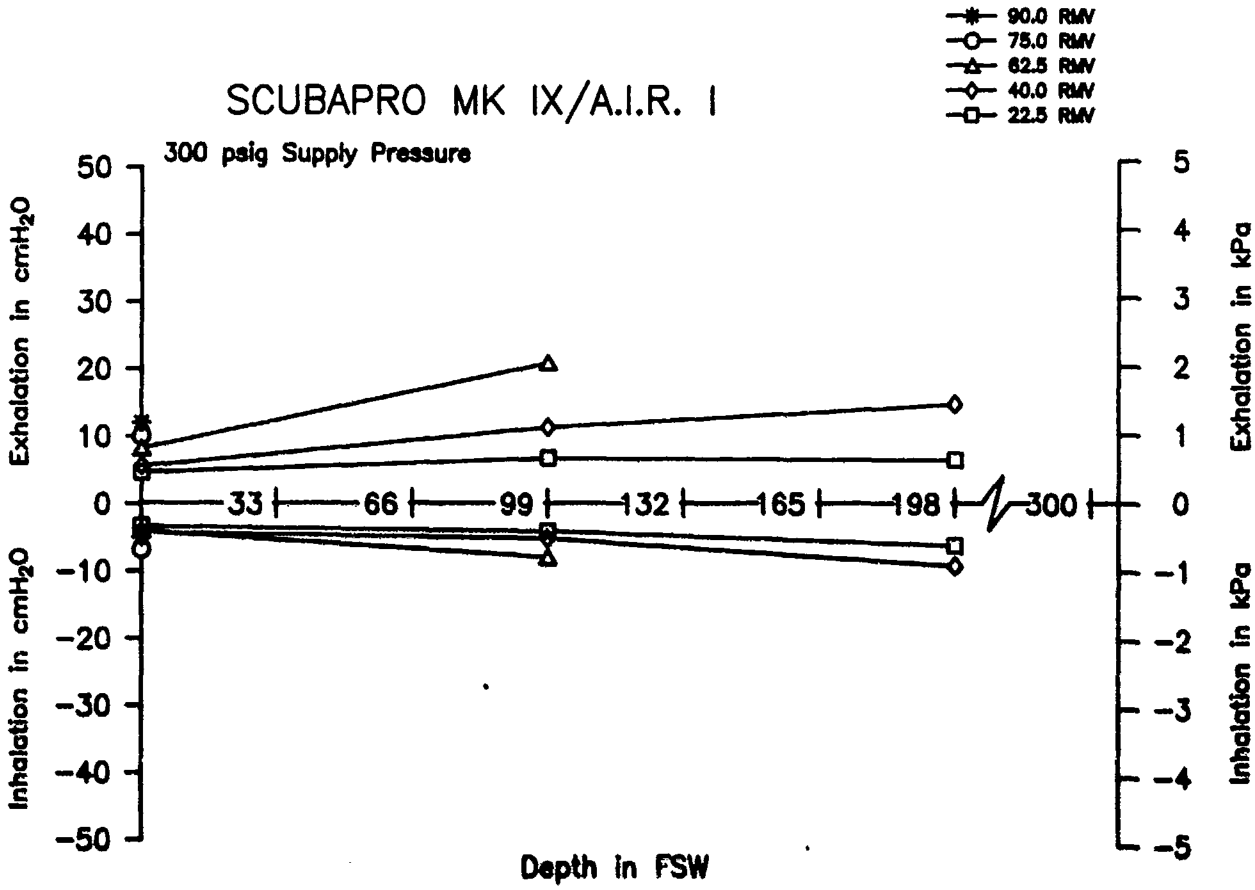
Breathing Work vs. Depth



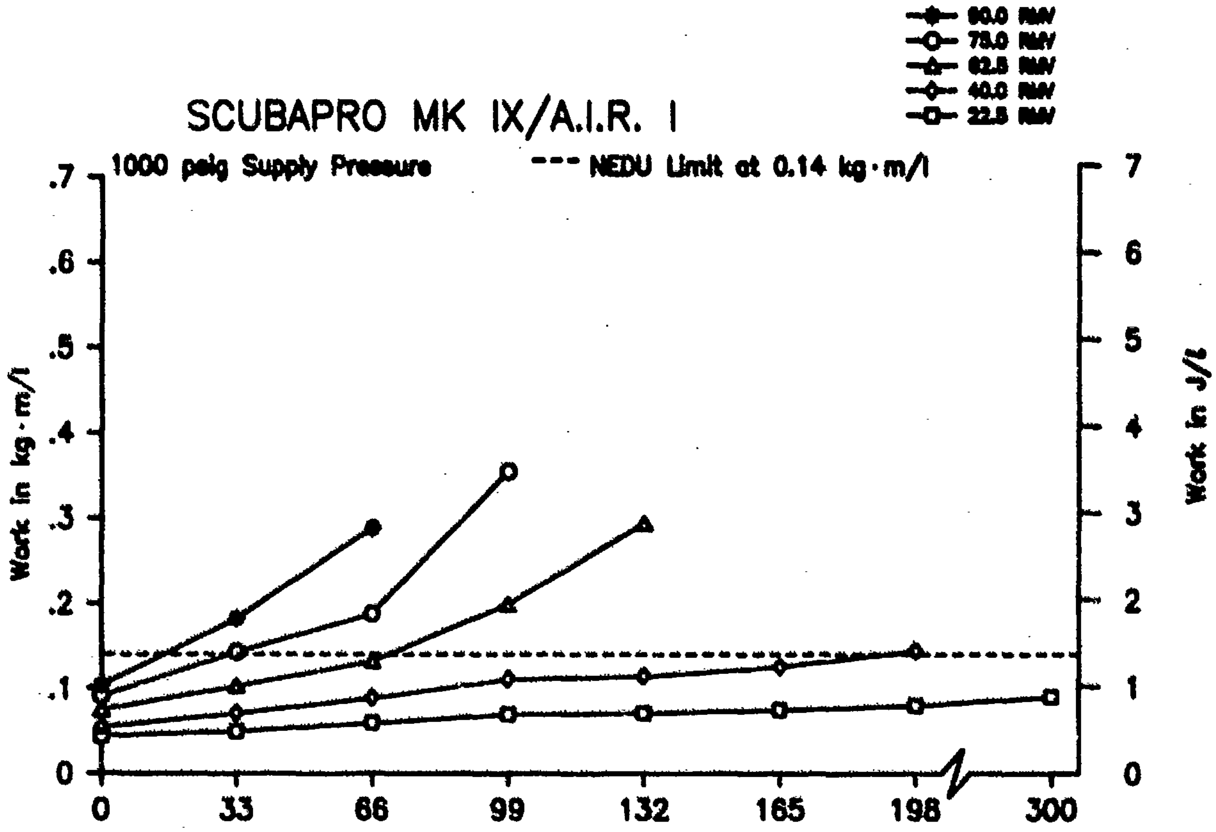
First Stage Pressure Drop vs. Depth


90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
SCUBAPRO MK IX/A.I.R. I
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Depth in FSW
Breathing Resistance vs. Depth

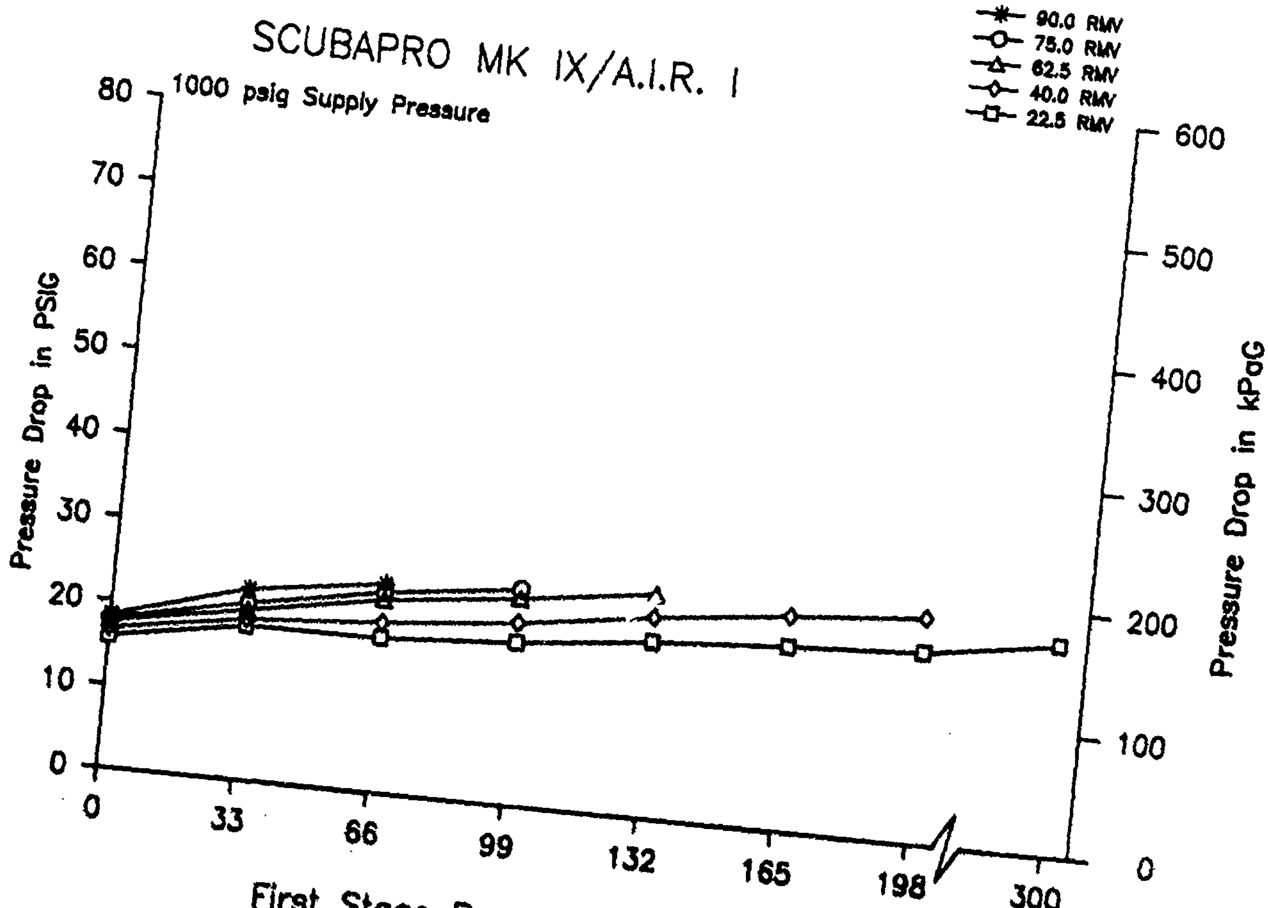

90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
SCUBAPRO MK IX/A.I.R. I
500 psig Supply Pressure
Exhalation in cmH_2O
Inhalation in cmH_2O
Depth in FSW
Breathing Resistance vs. Depth



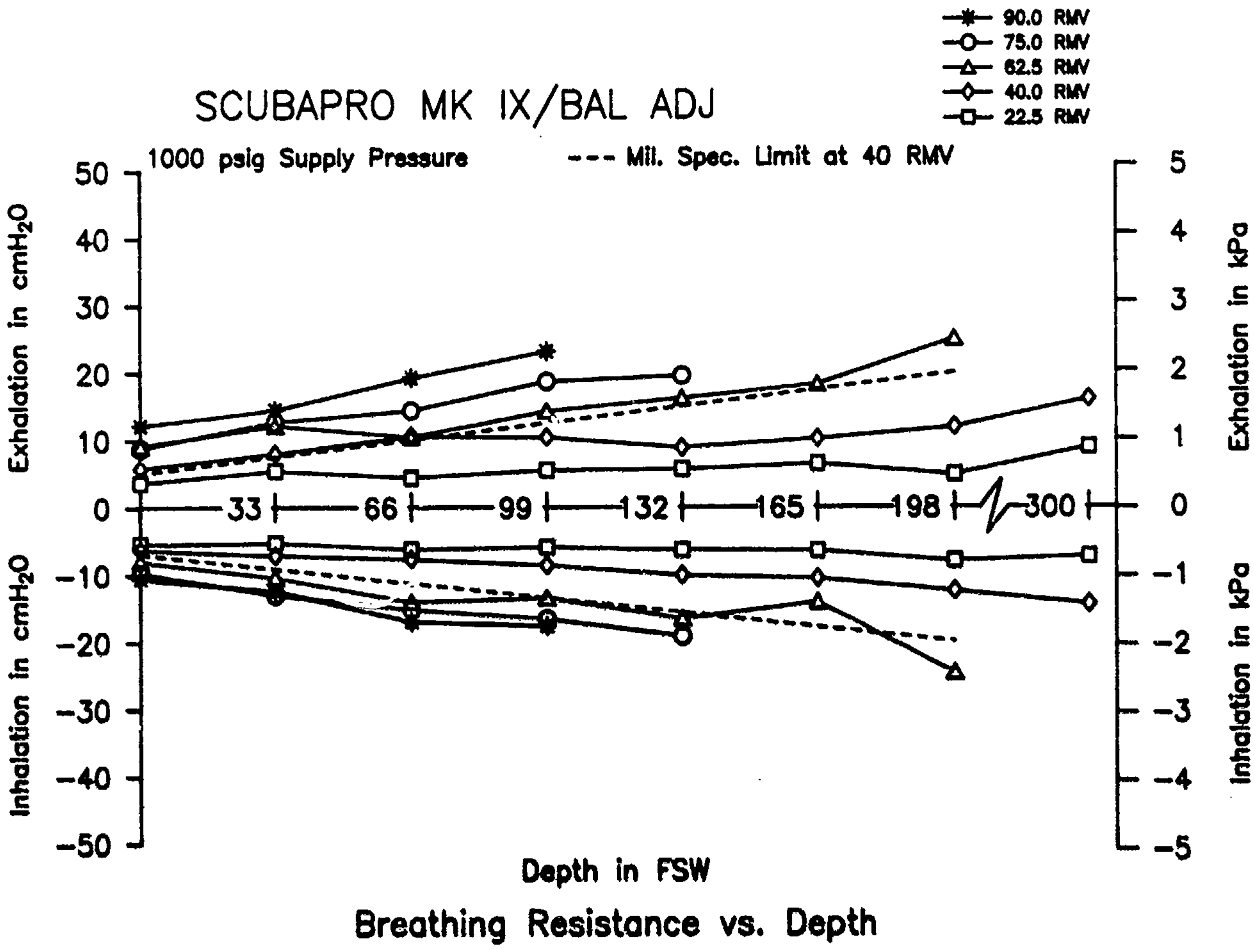
Breathing Resistance vs. Depth



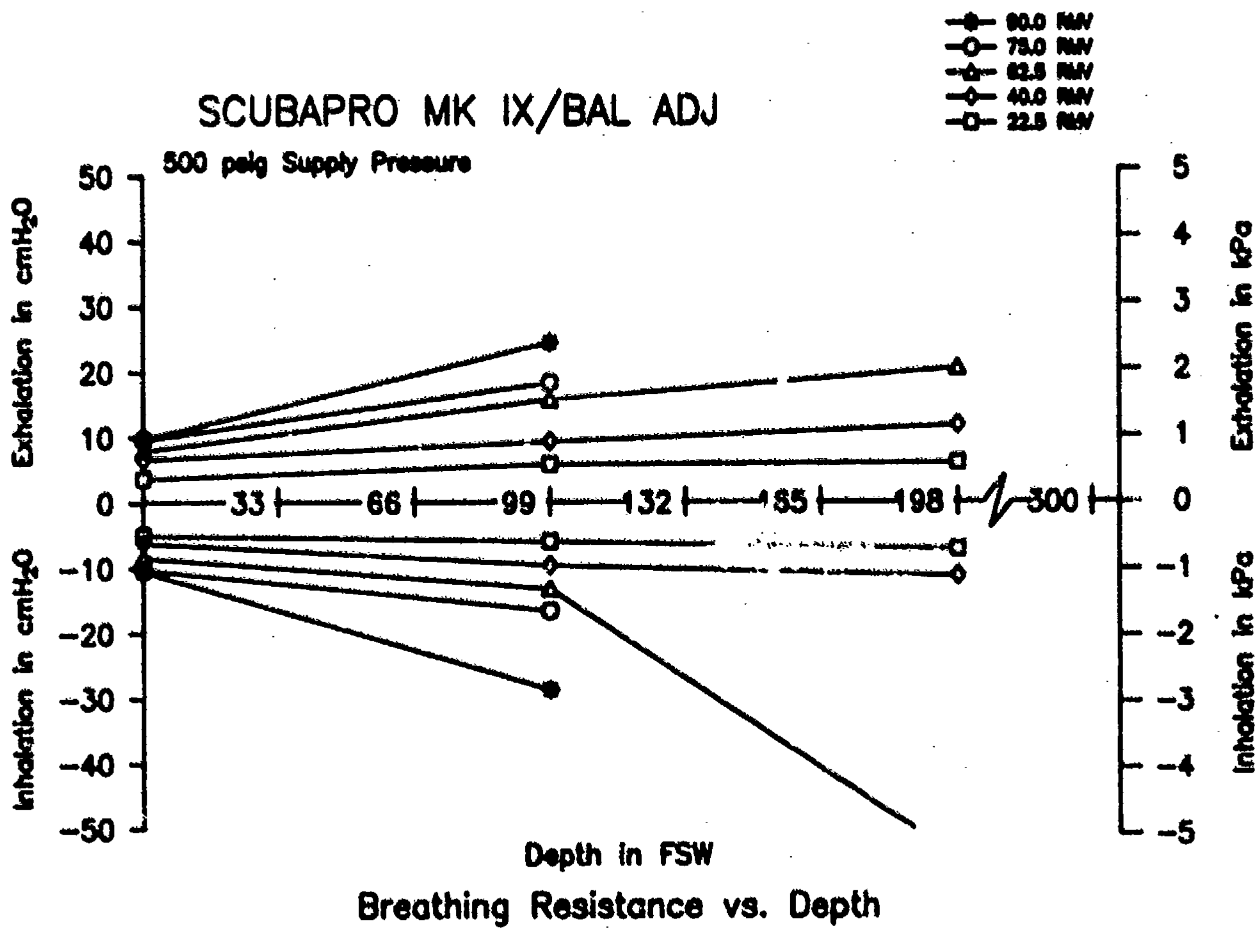
Breathing Work vs. Depth



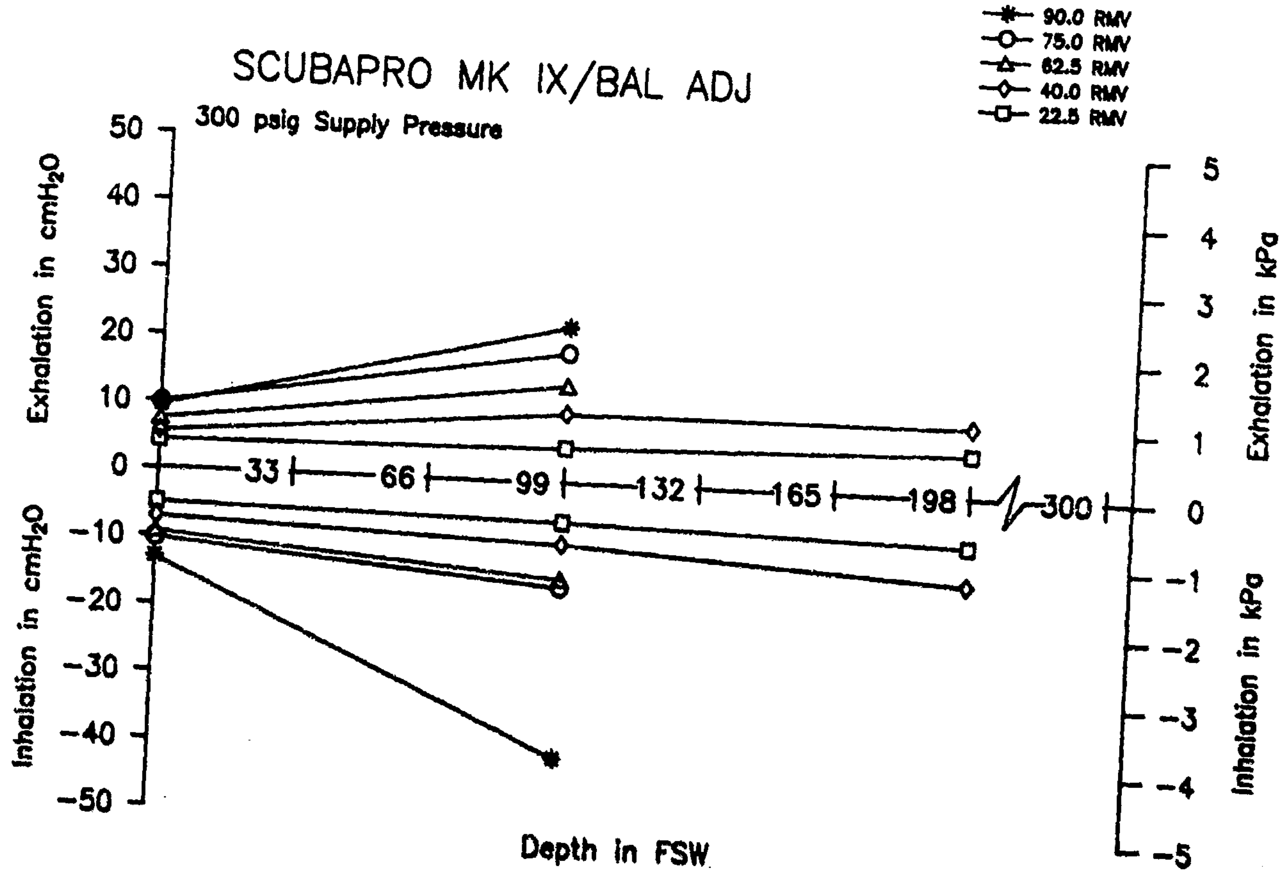
First Stage Pressure Drop vs. Depth



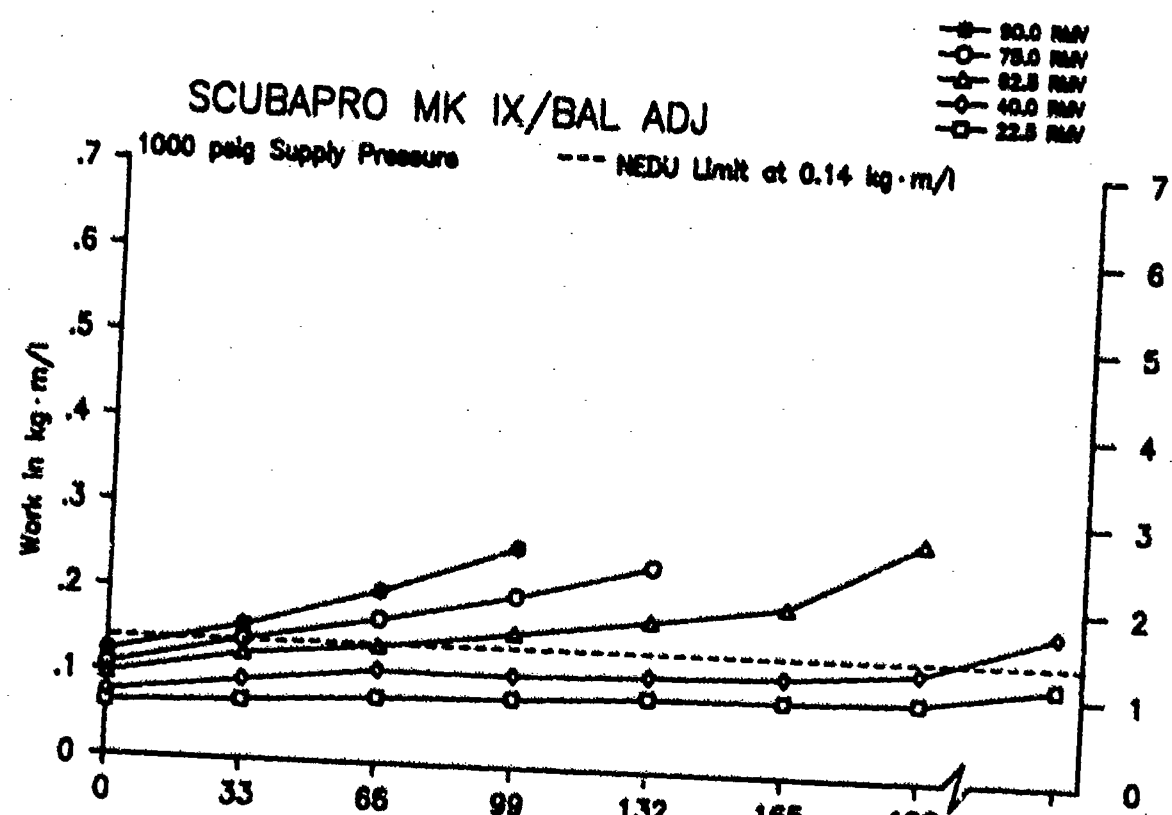
SCUBAPRO MK IX/BAL ADJ
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
−10
−20
−30
−40
−50
5
4
3
2
1
0
−1
−2
−3
−4
−5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



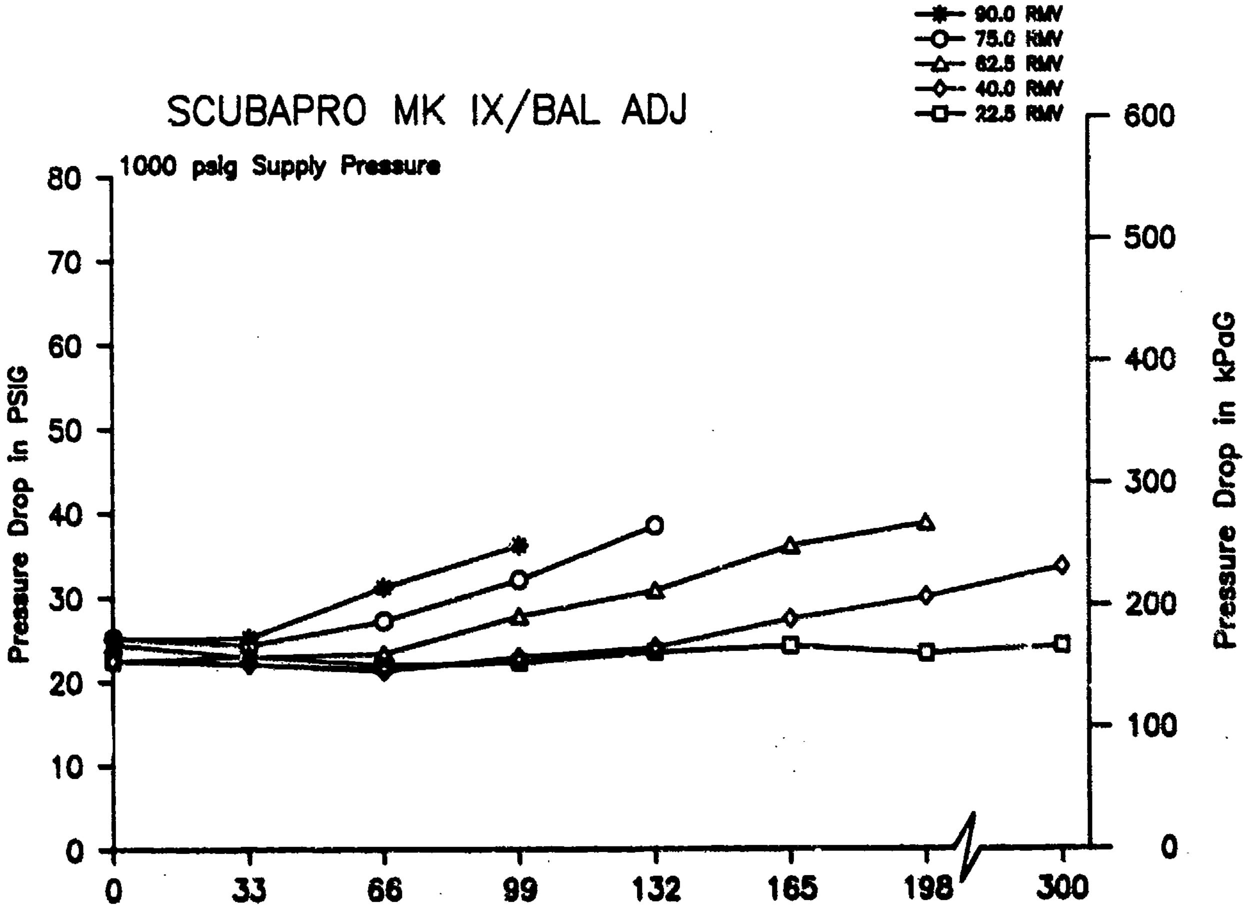
SCUBAPRO MK IX/BAL ADJ
500 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
−10
−20
−30
−40
−50
5
4
3
2
1
0
−1
−2
−3
−4
−5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



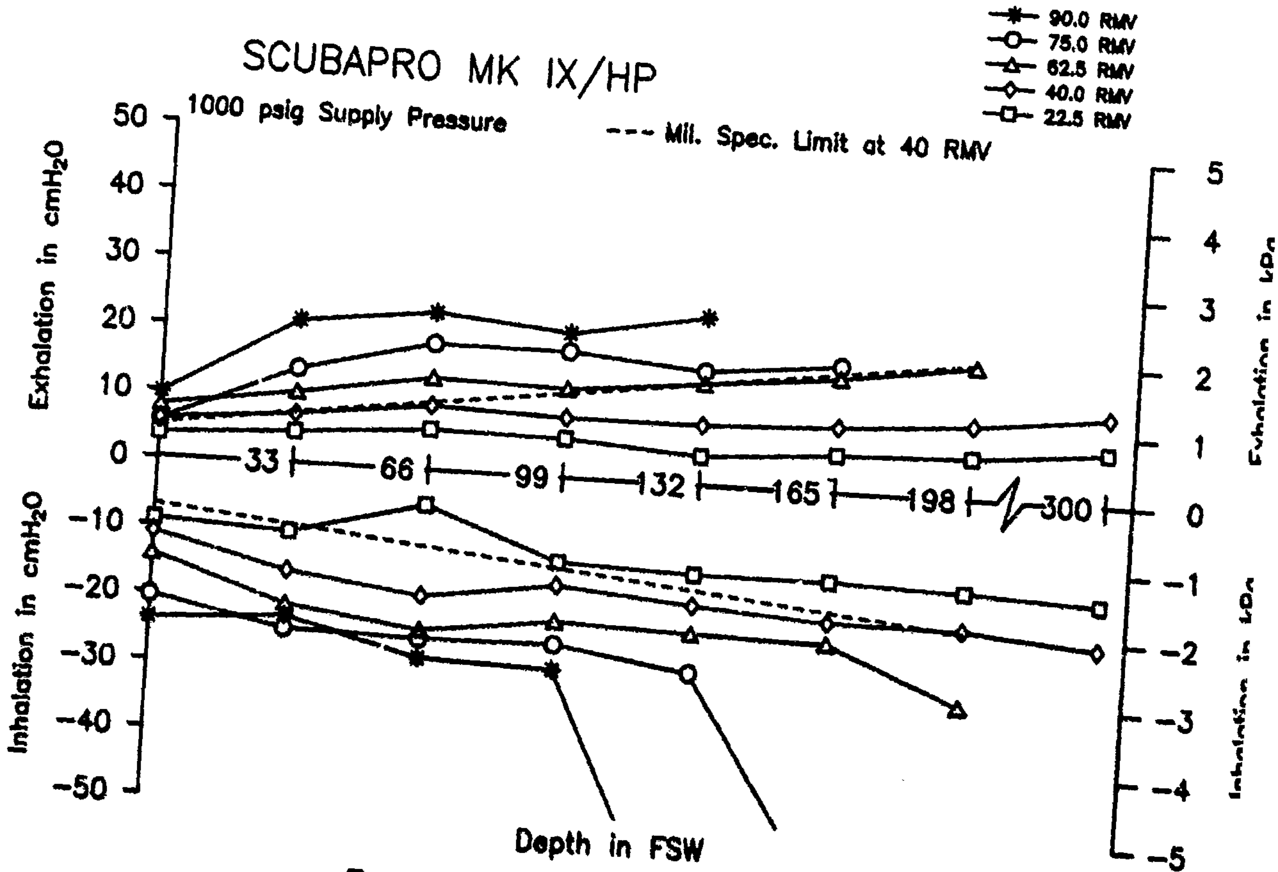
Breathing Resistance vs. Depth



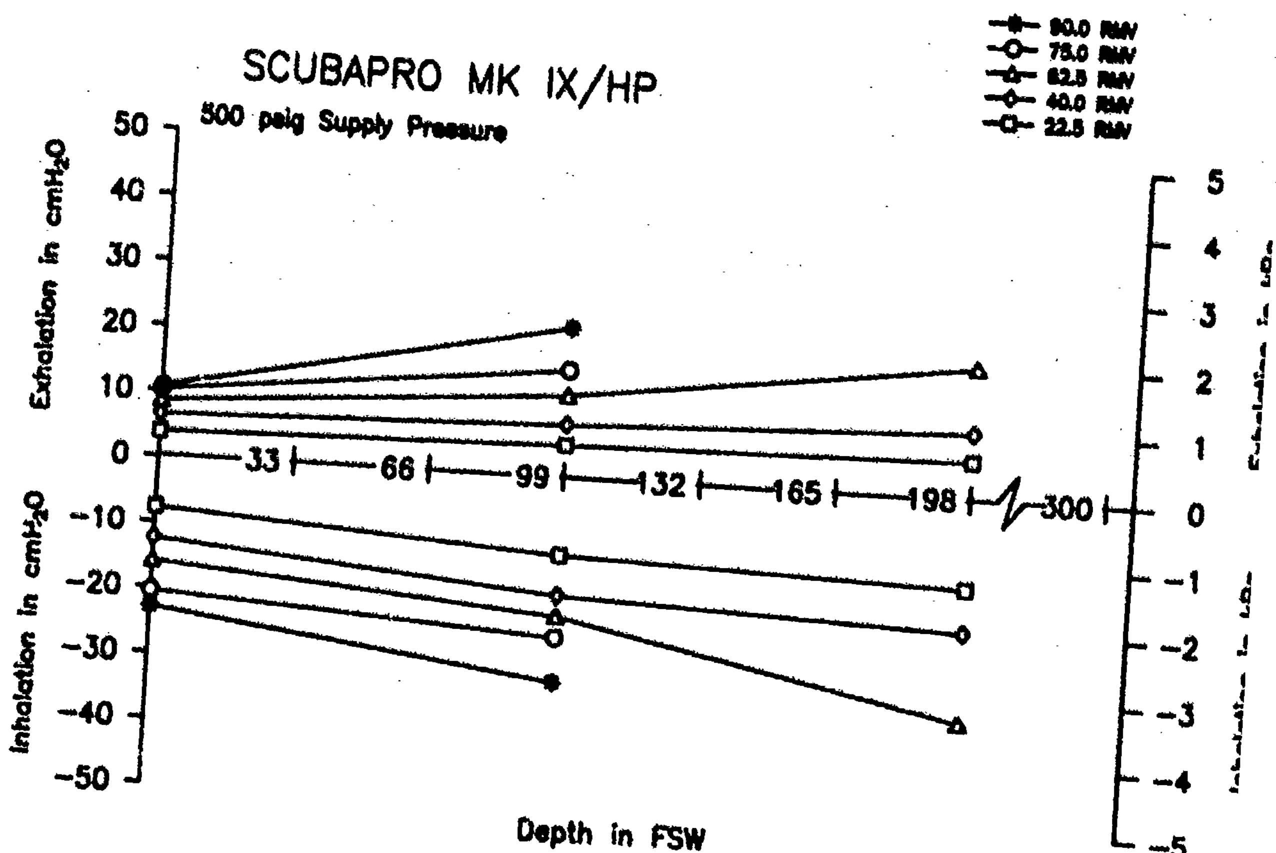
Breathing Work vs. Depth



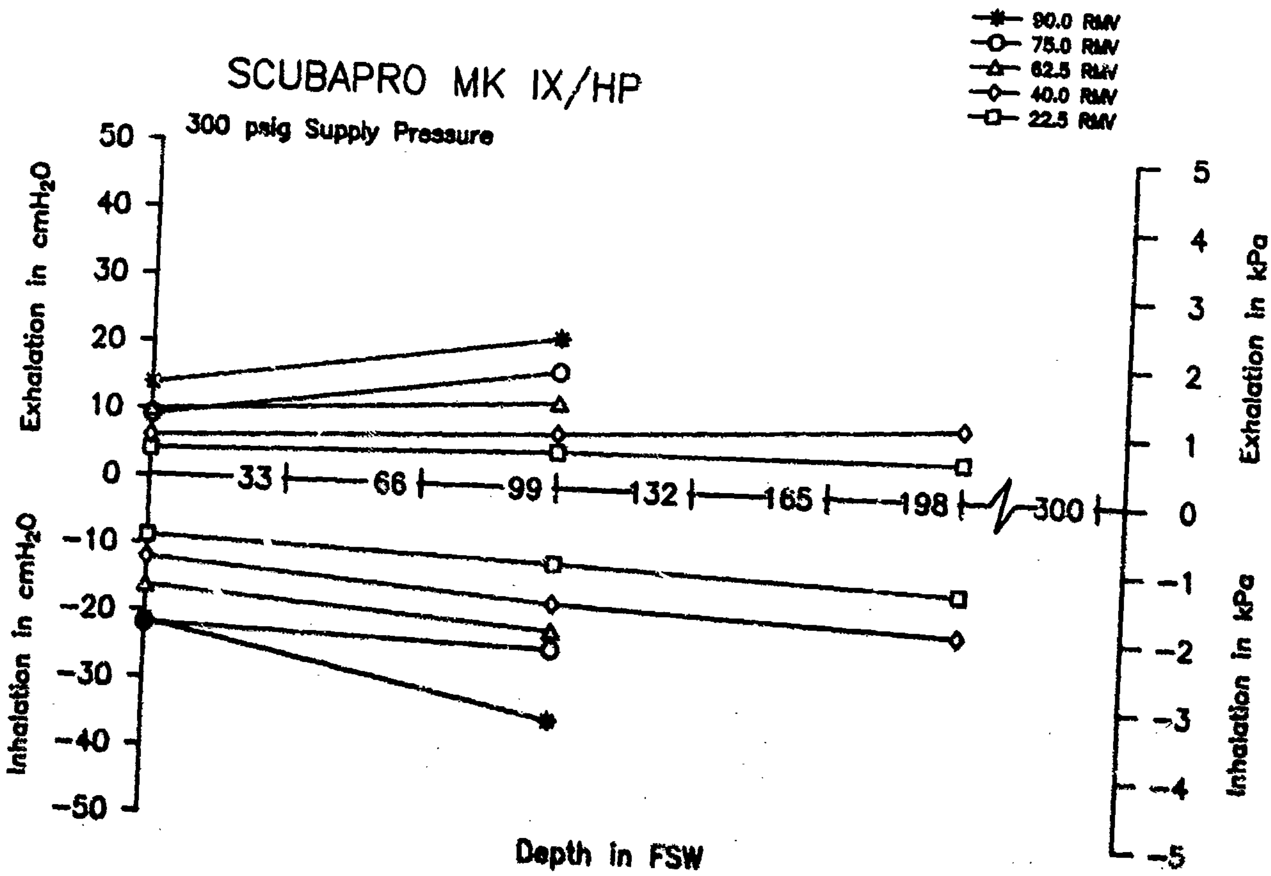
First Stage Pressure Drop vs. Depth



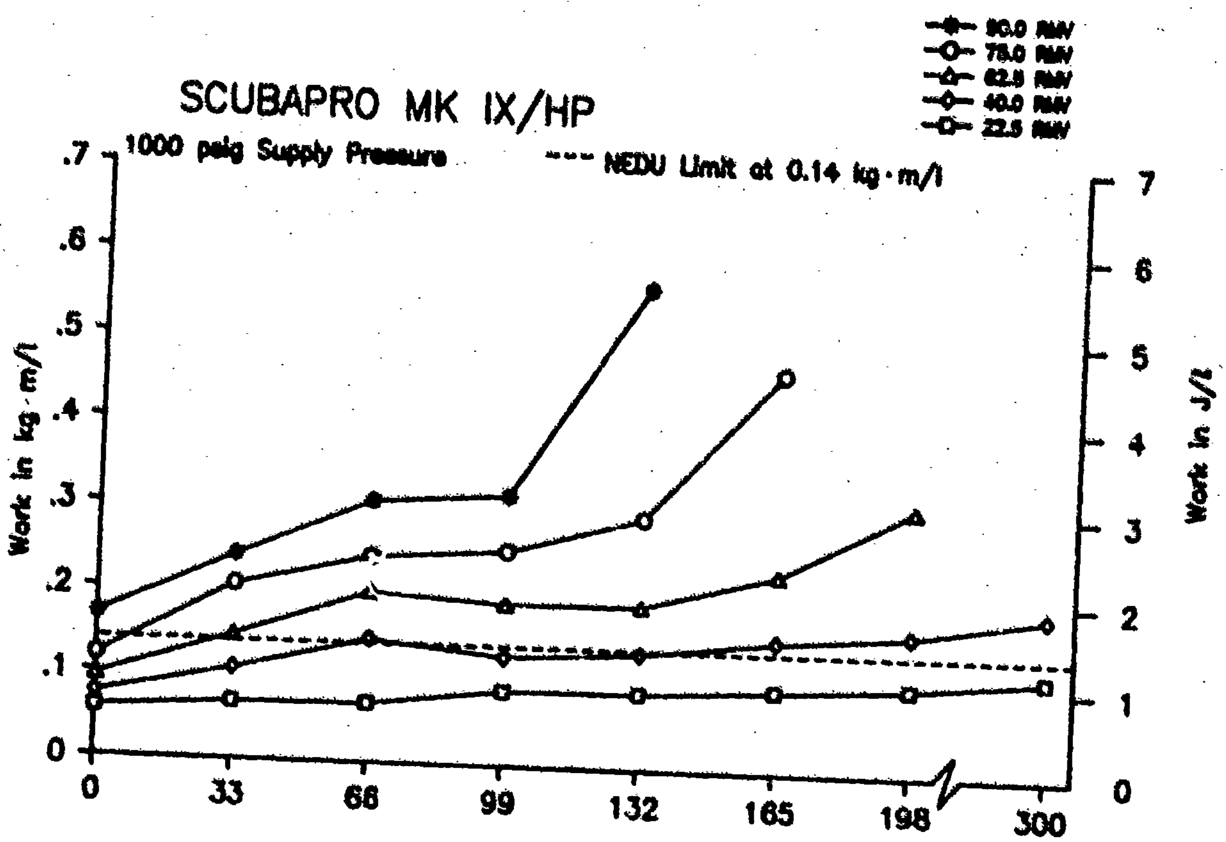
Breathing Resistance vs. Depth



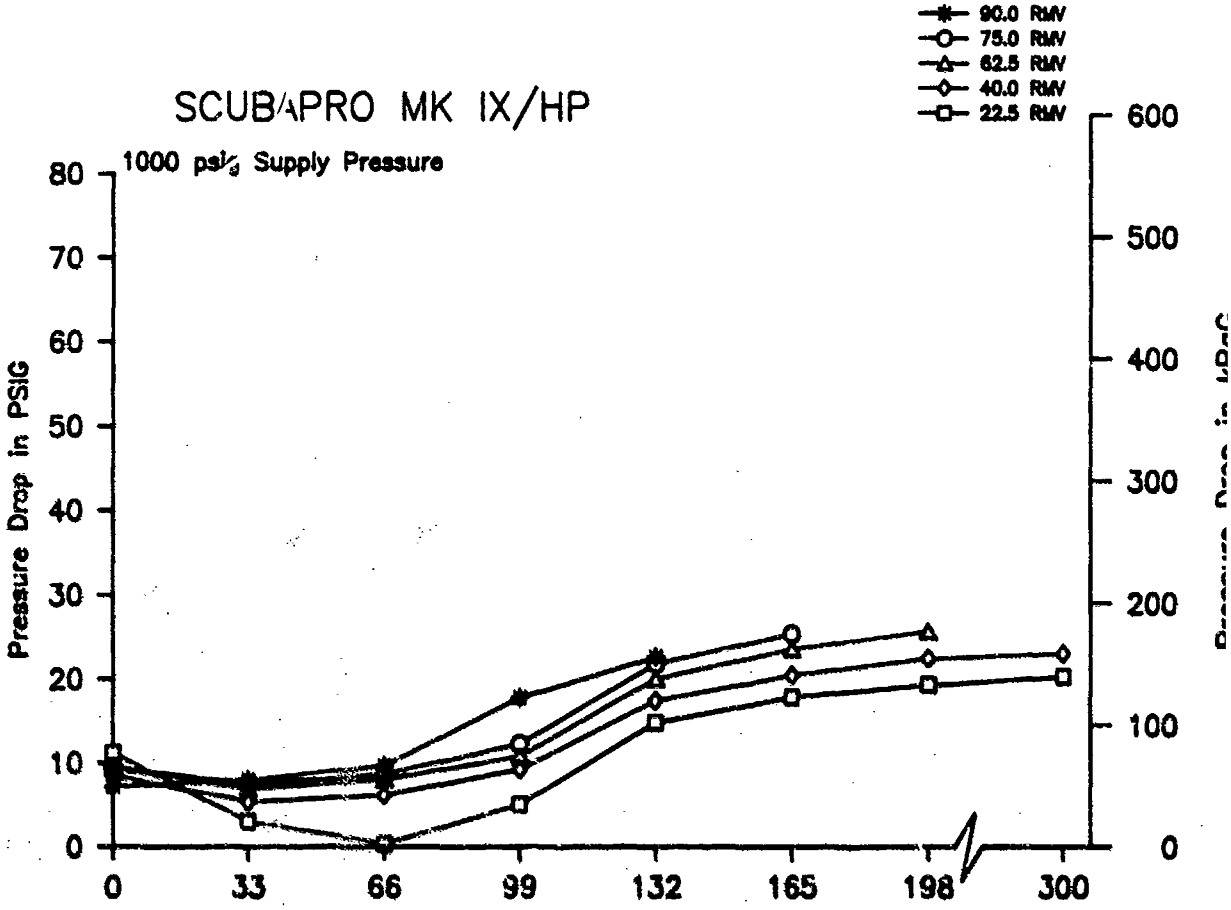
Breathing Resistance vs. Depth



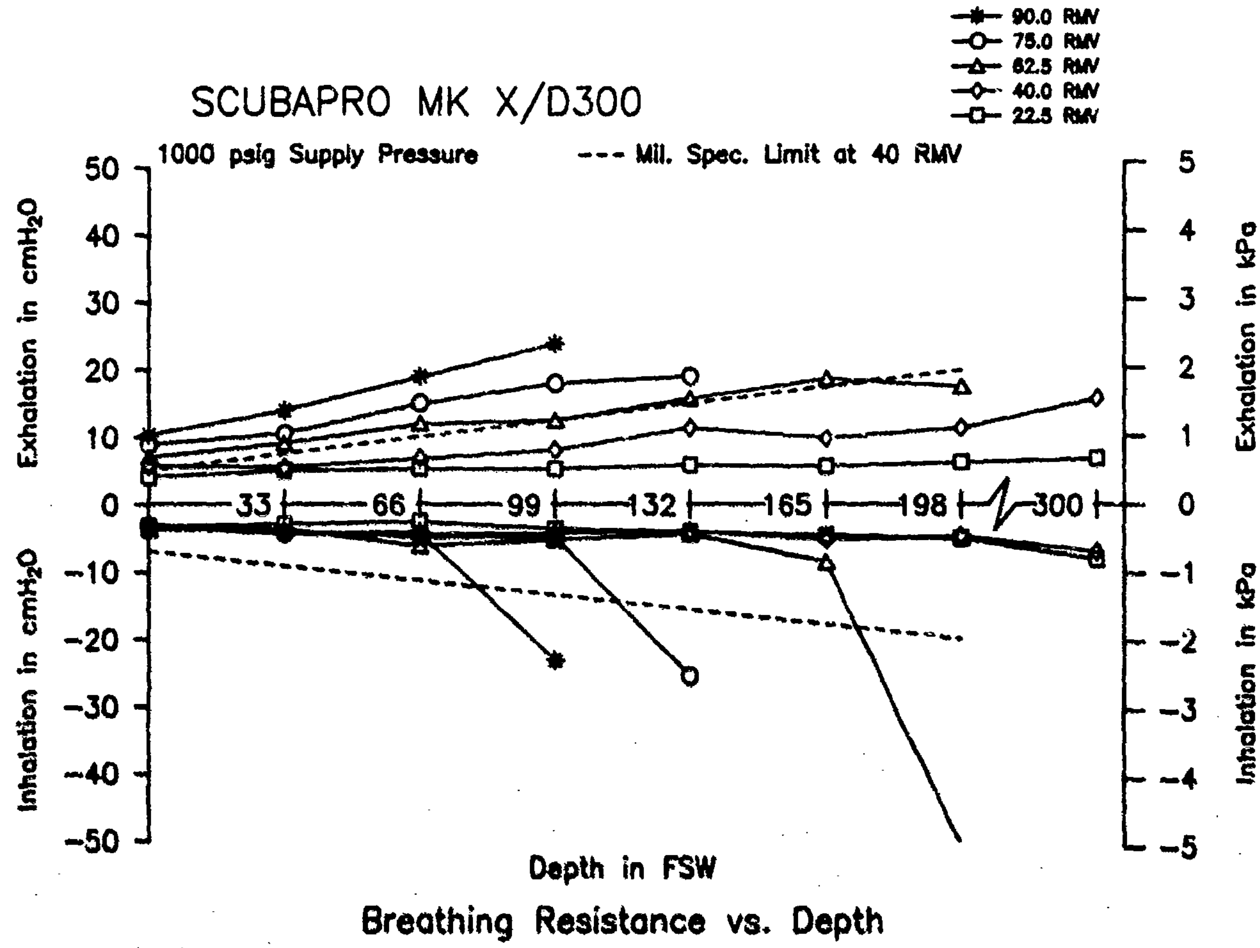
Breathing Resistance vs. Depth

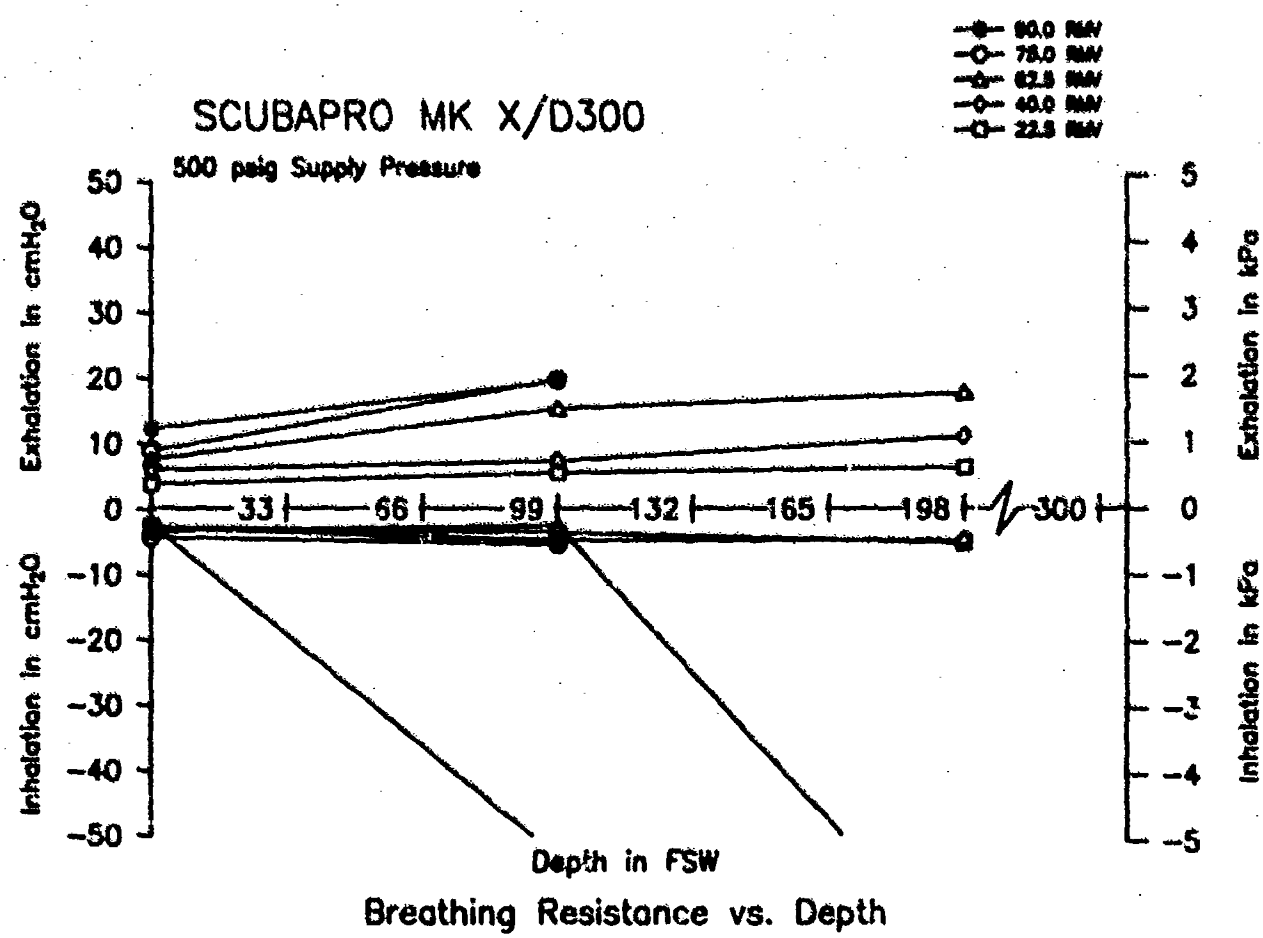


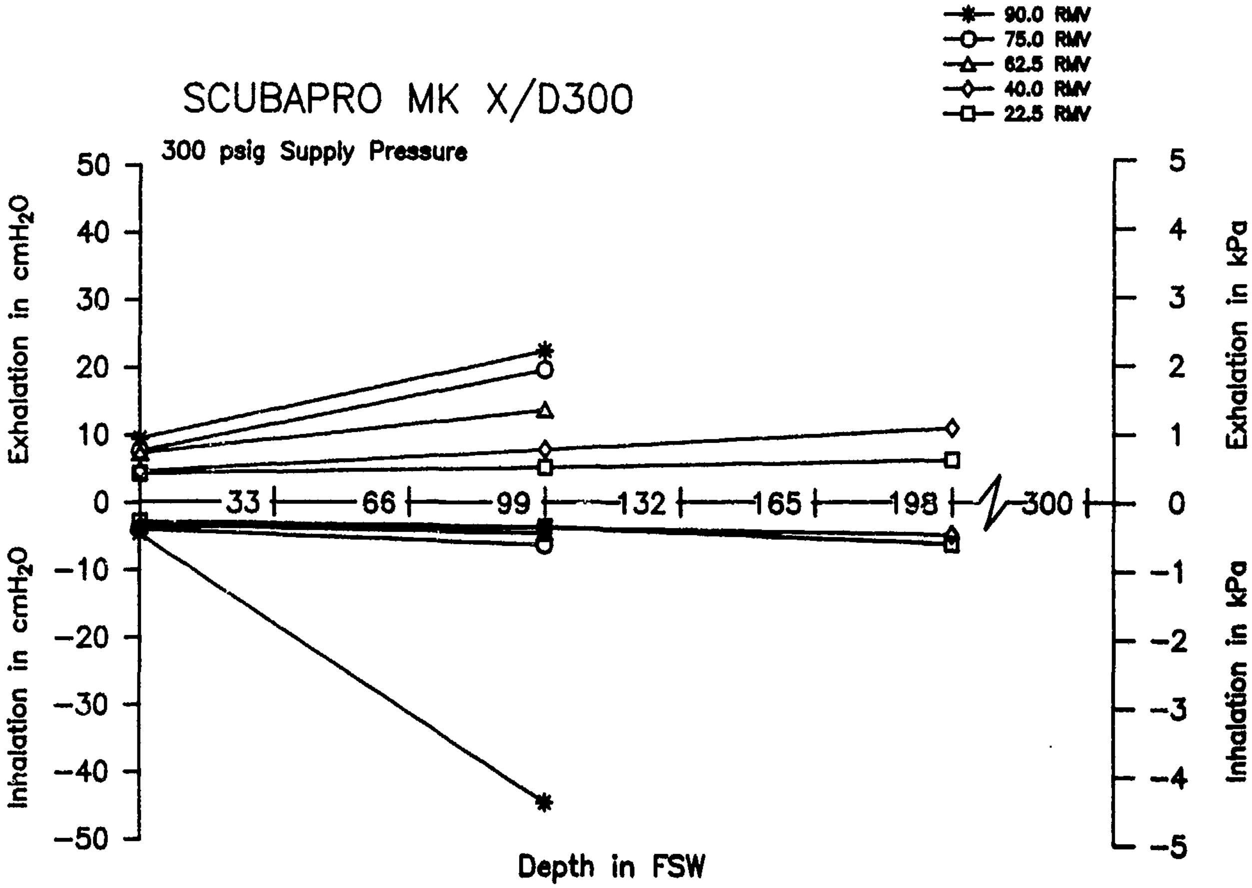
Breathing Work vs. Depth



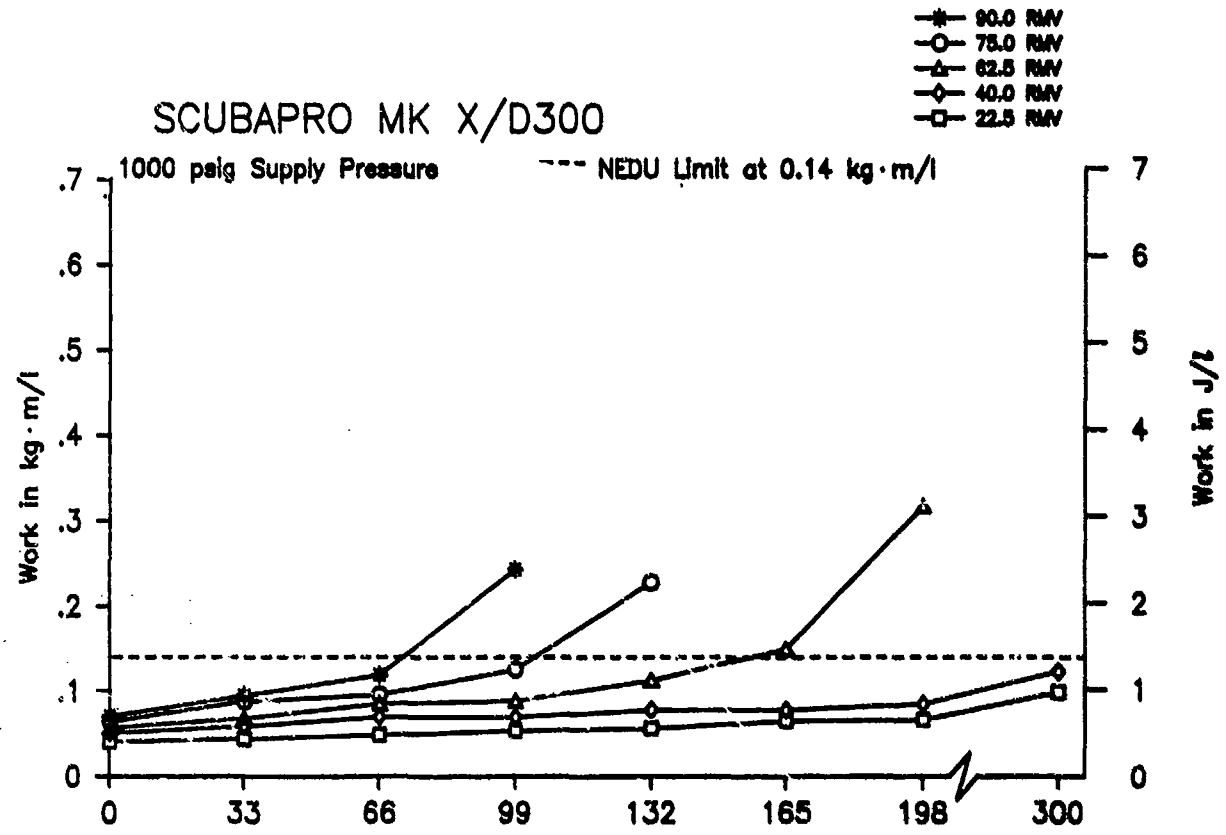
First Stage Pressure Drop vs. Depth


90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
SCUBAPRO MK X/D300
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
Depth in FSW
Breathing Resistance vs. Depth

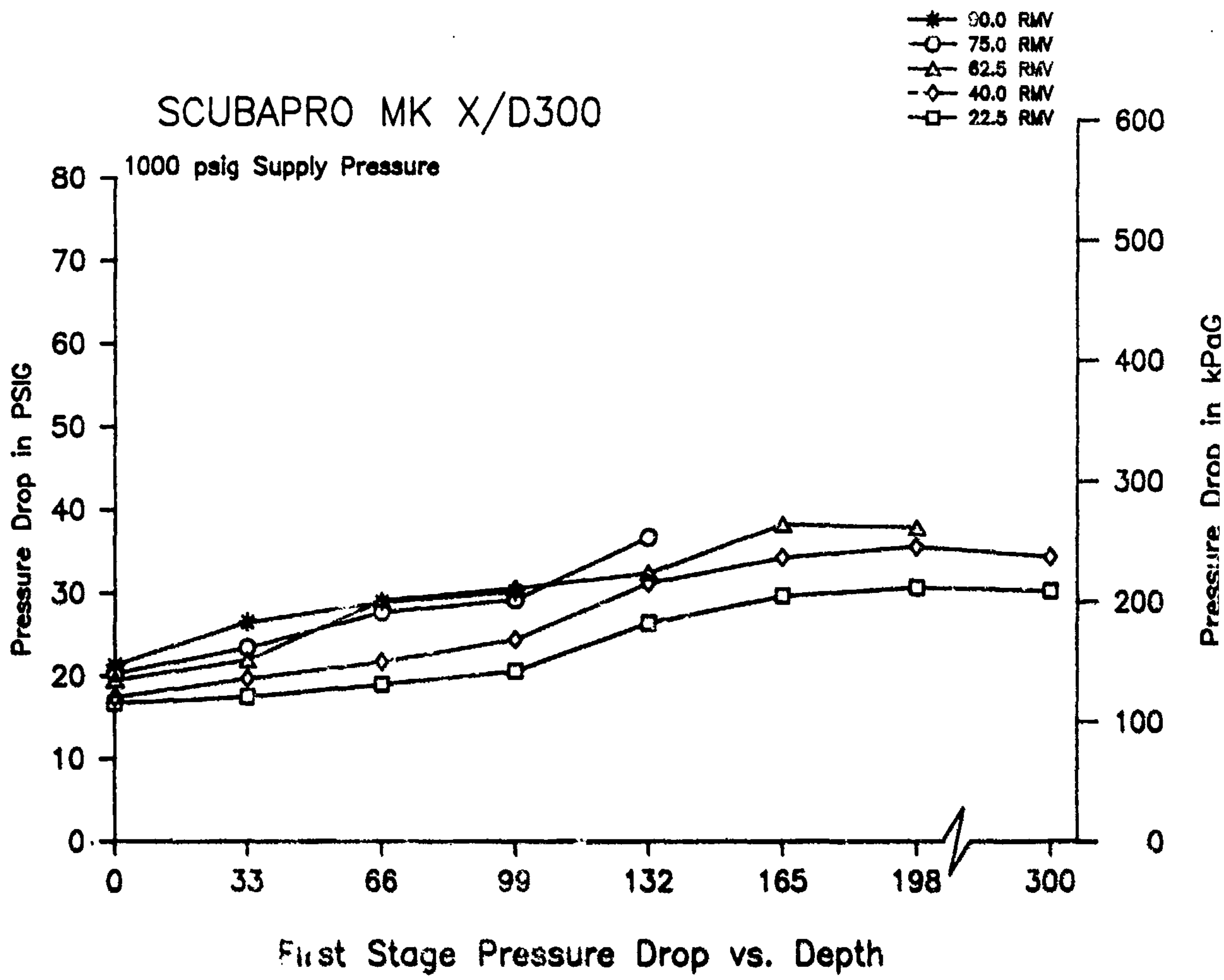

90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
SCUBAPRO MK X/D300
500 psig Supply Pressure
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
Depth in FSW
Breathing Resistance vs. Depth



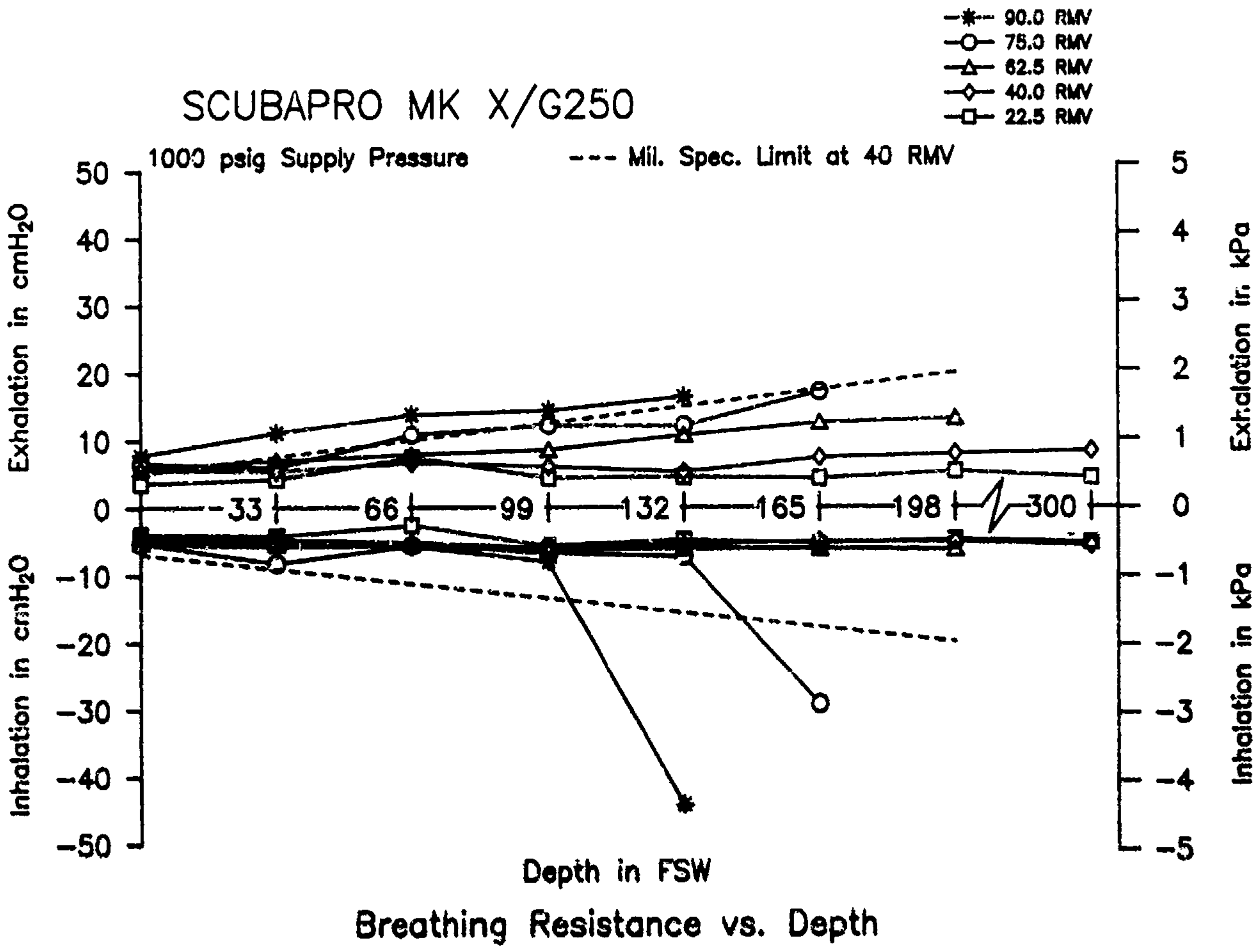
Breathing Resistance vs. Depth

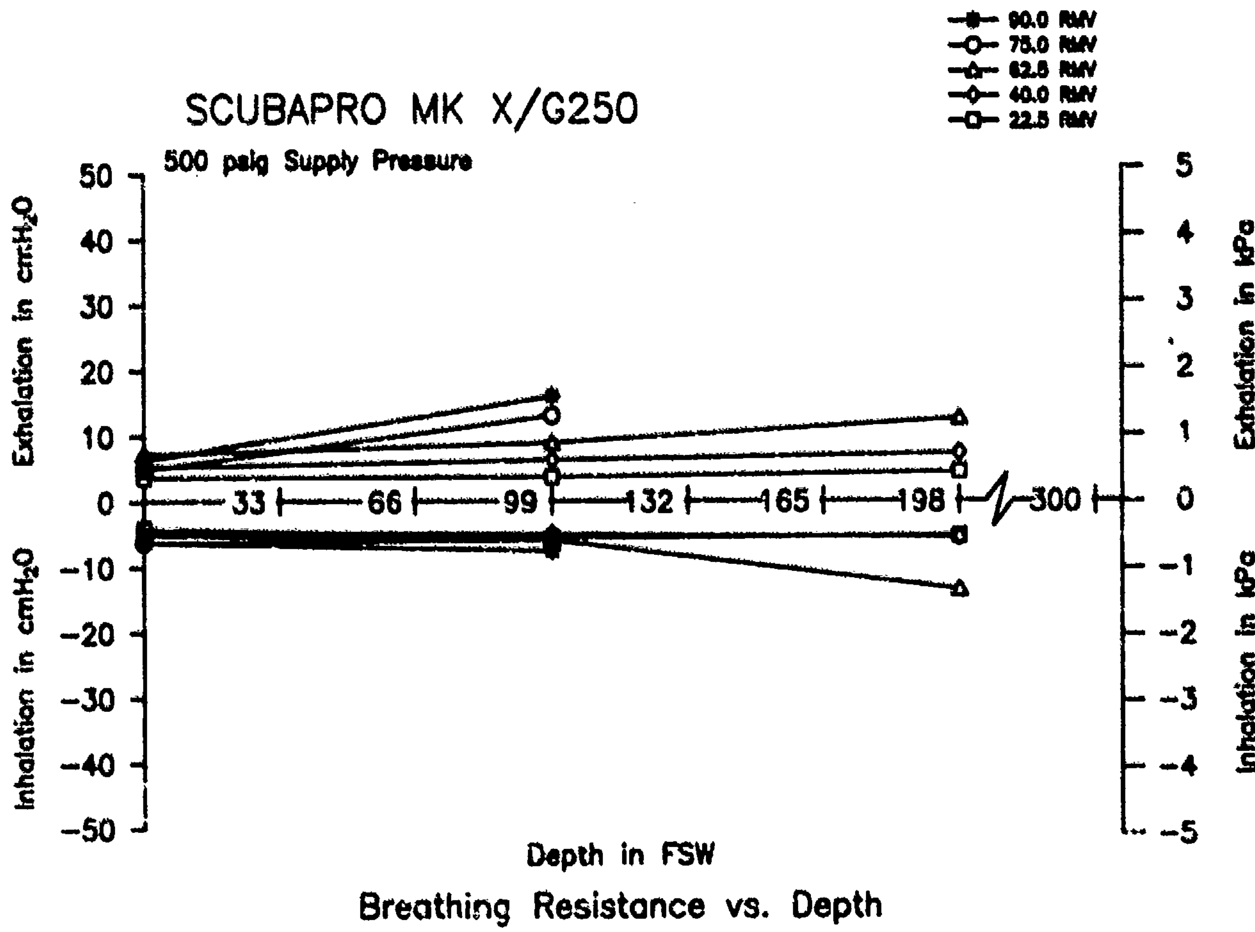


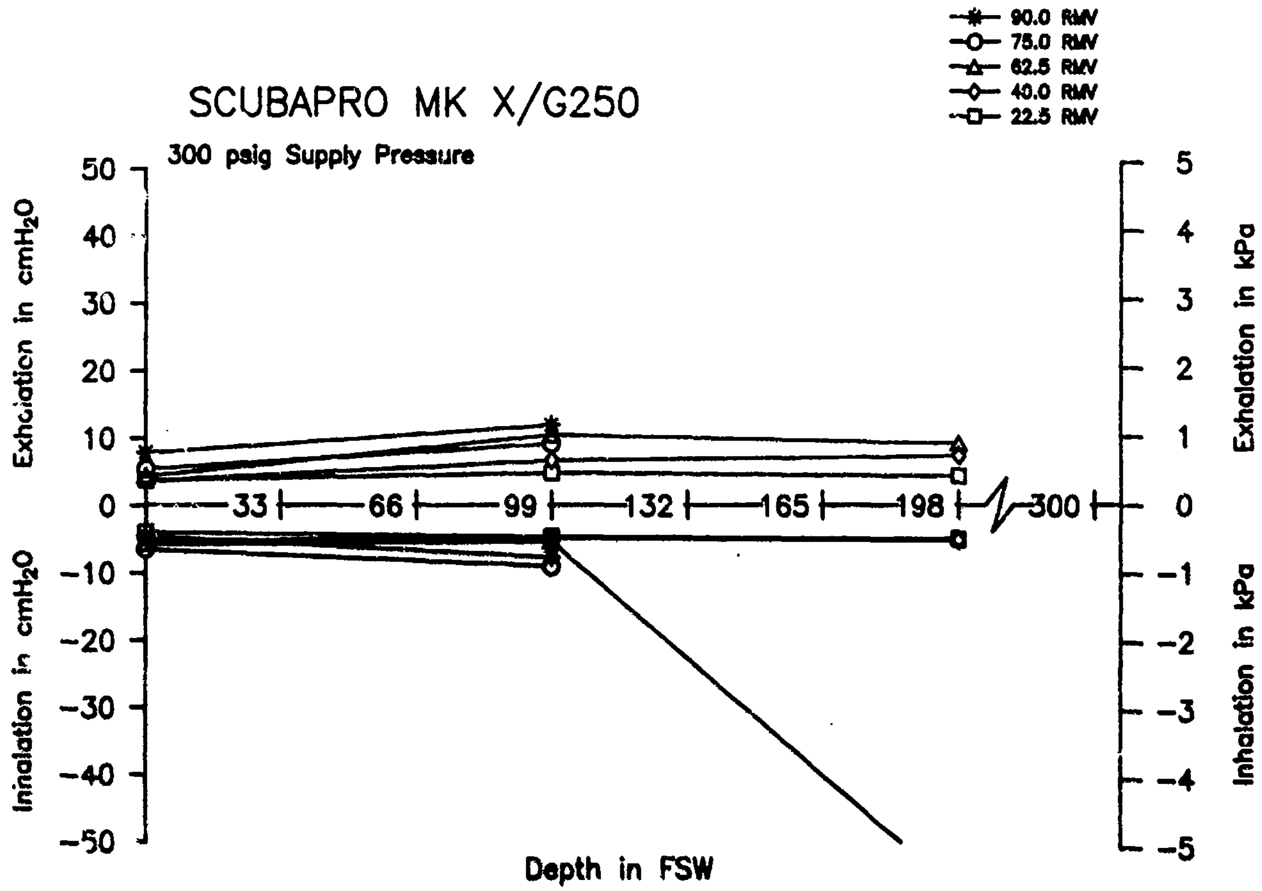
Breathing Work vs. Depth



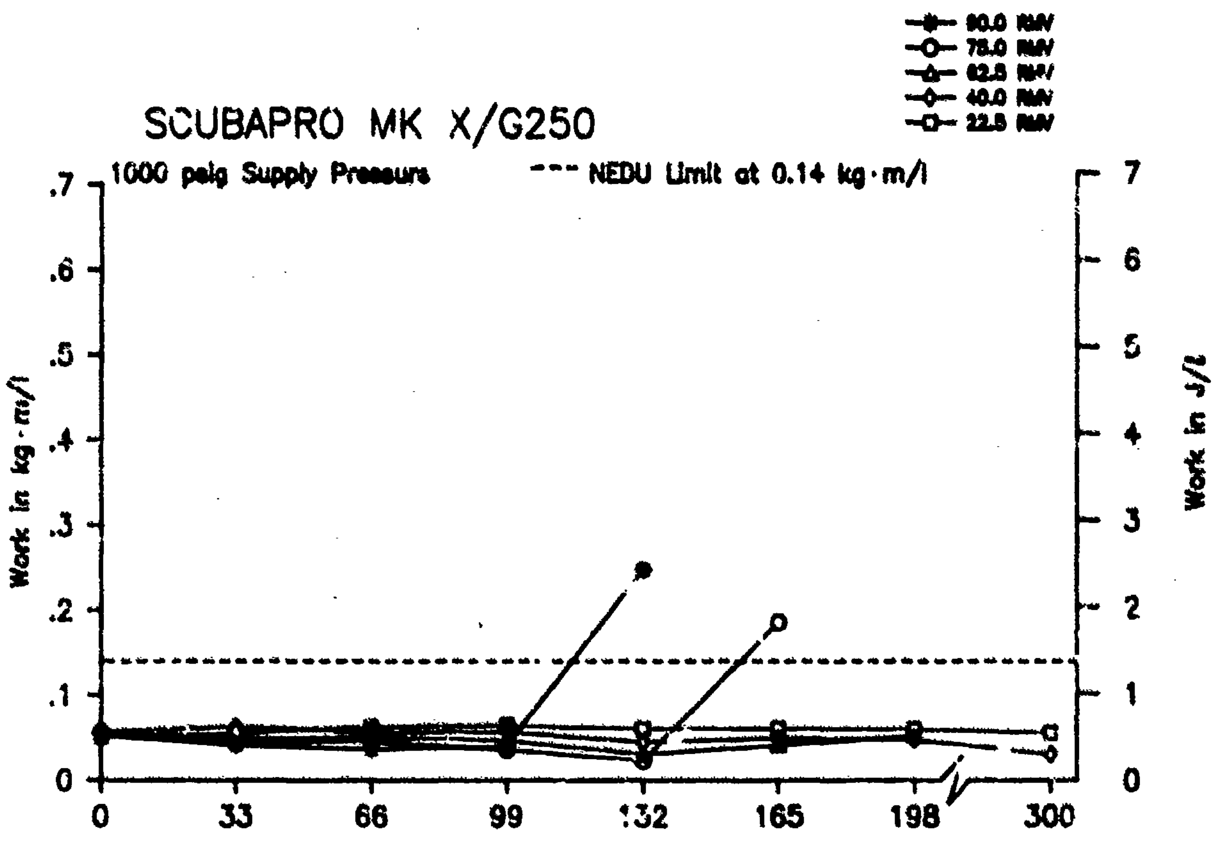
SCUBAPRO MK X/D300
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
Pressure Drop in kPaG
0
10
20
30
40
50
60
70
80
0
100
200
300
400
500
600
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth


90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
SCUBAPRO MK X/G250
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
−10
−20
−30
−40
−50
5
4
3
2
1
0
−1
−2
−3
−4
−5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth

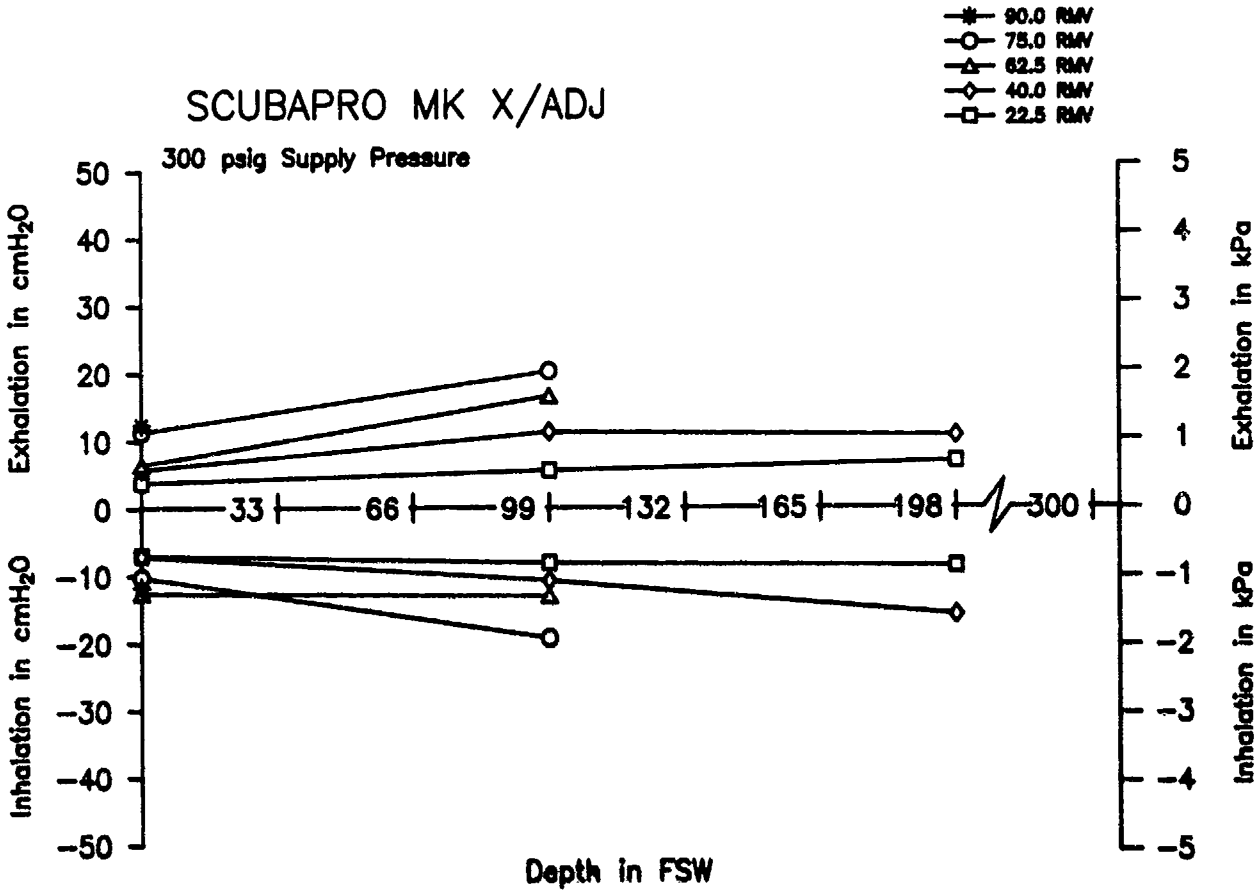

90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
SCUBAPRO MK X/G250
500 psig Supply Pressure
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
−10
−20
−30
−40
−50
5
4
3
2
1
0
−1
−2
−3
−4
−5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



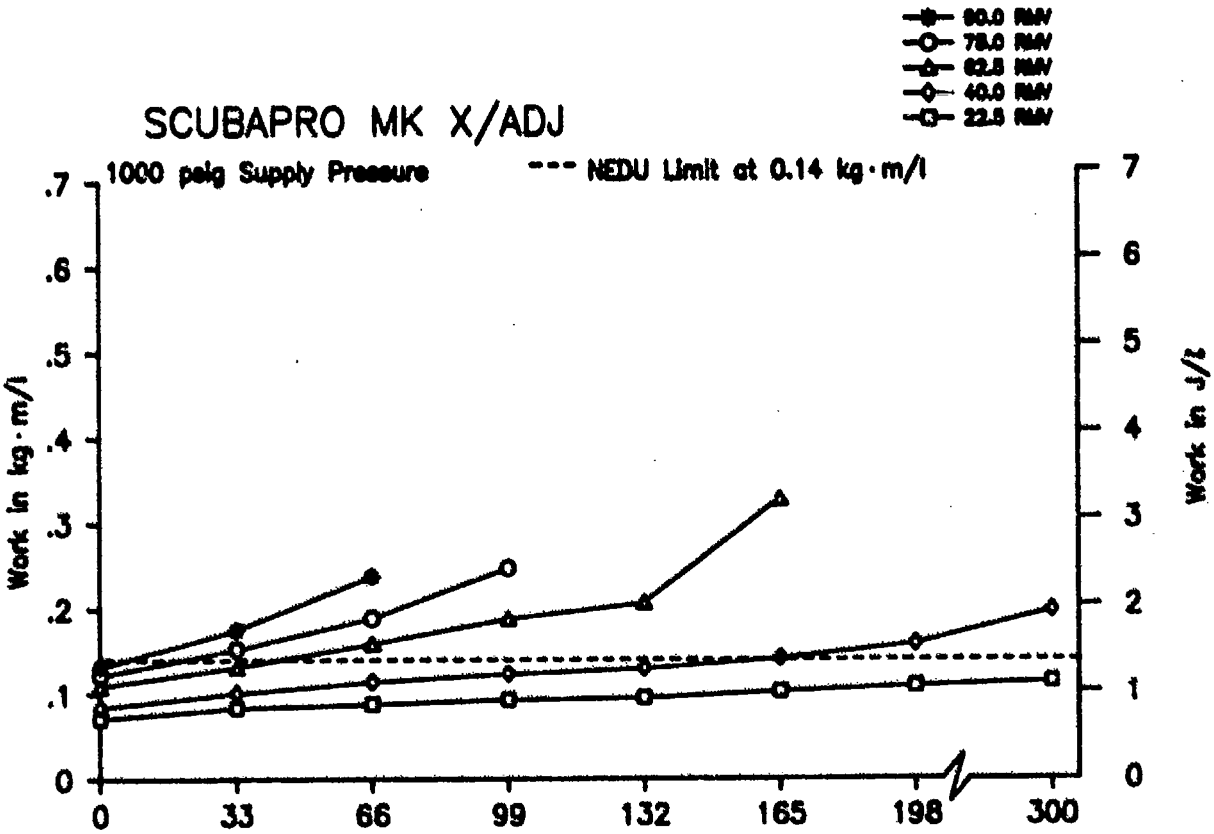
Breathing Resistance vs. Depth



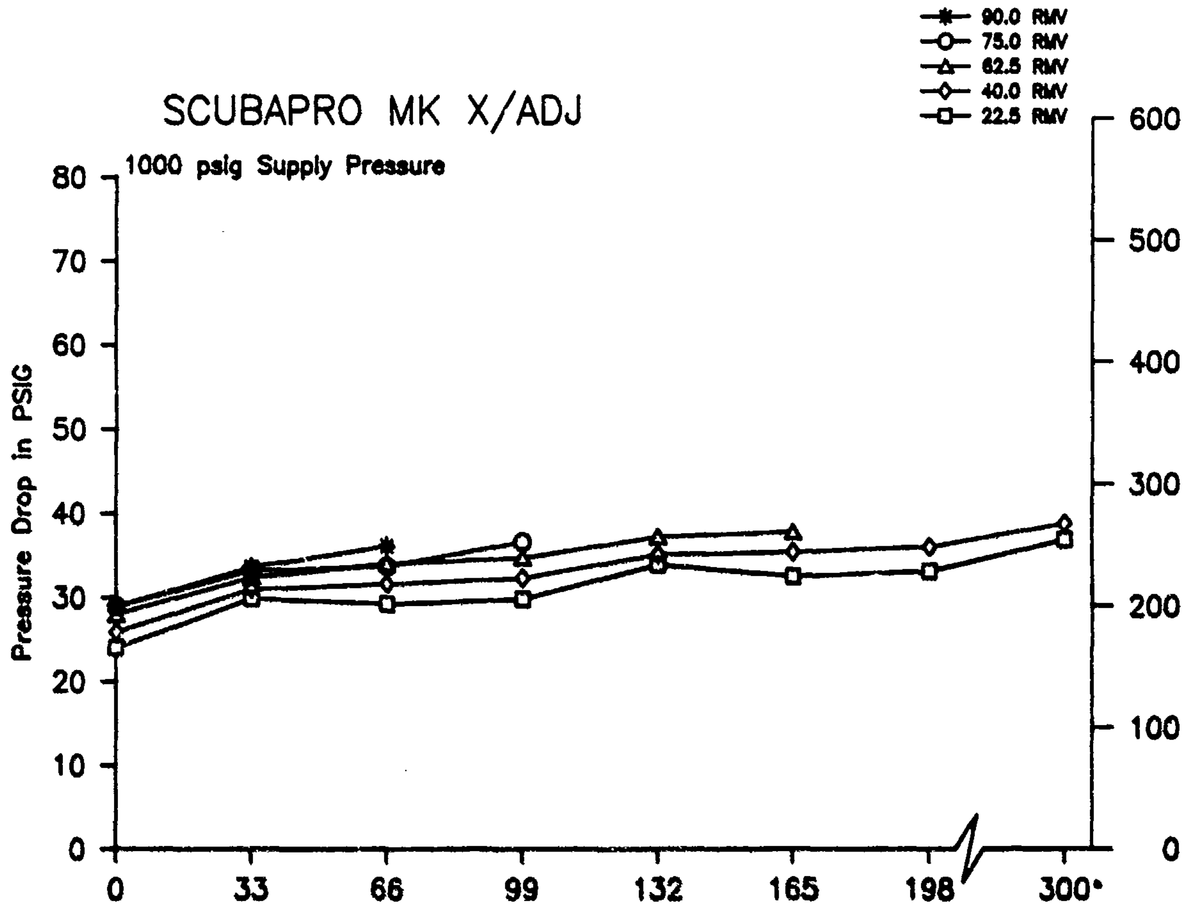
Breathing Work vs. Depth



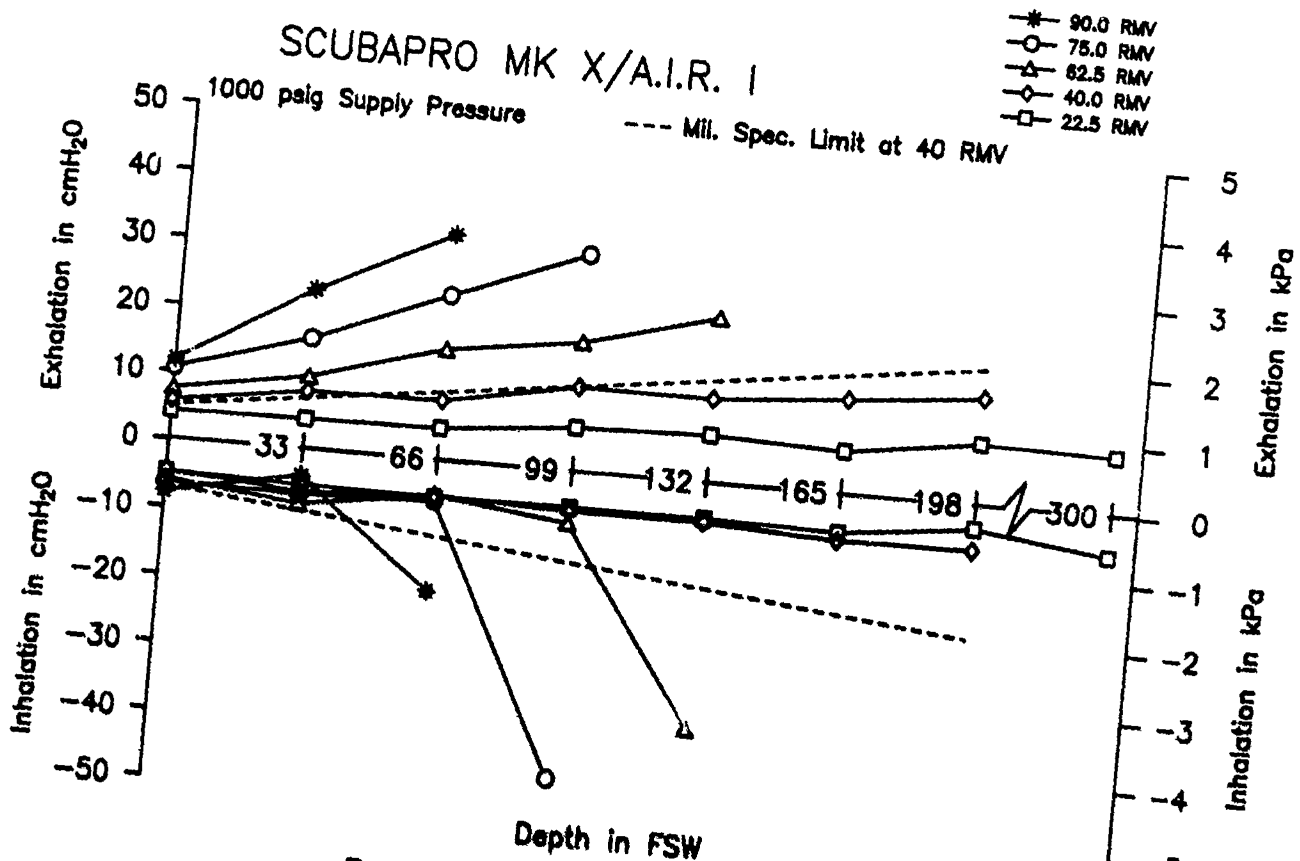
Breathing Resistance vs. Depth



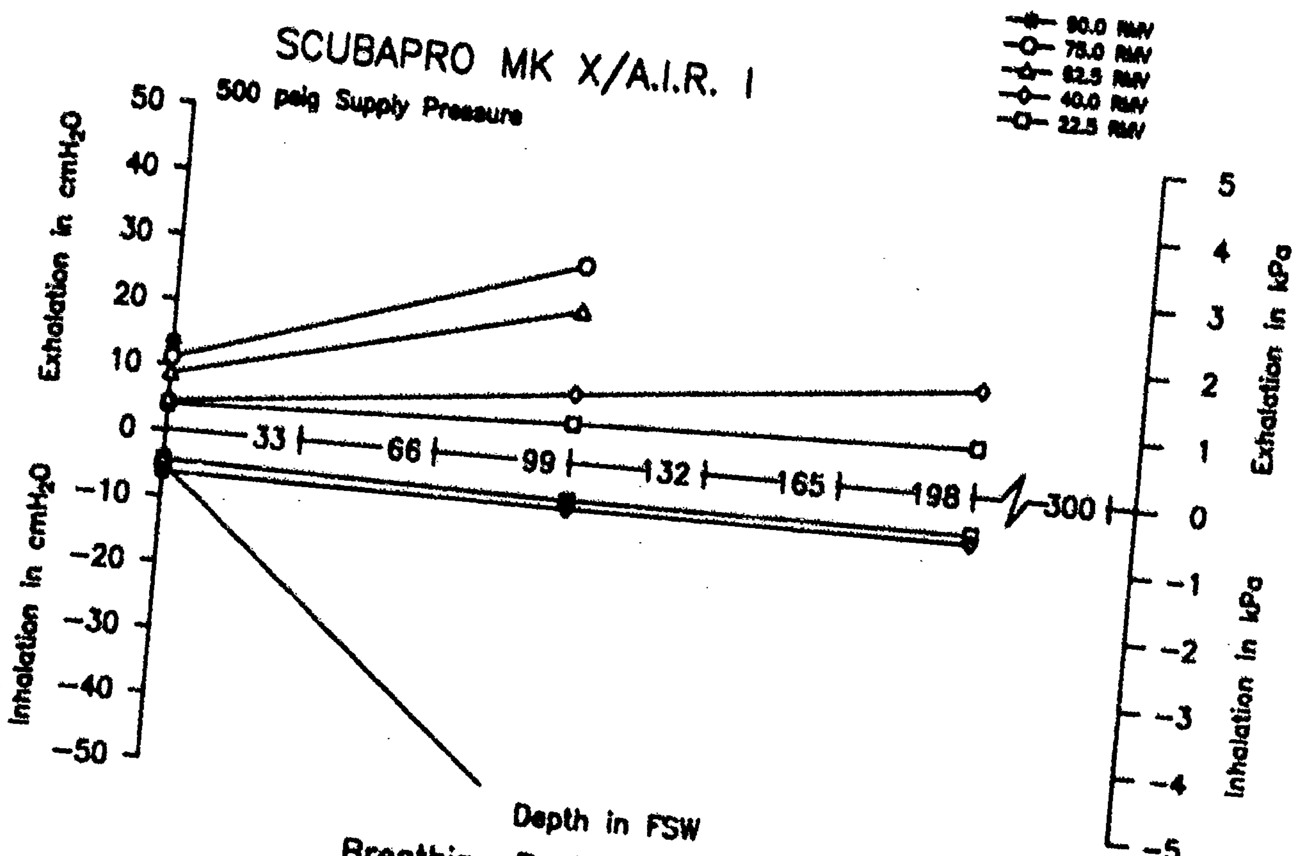
Breathing Work vs. Depth



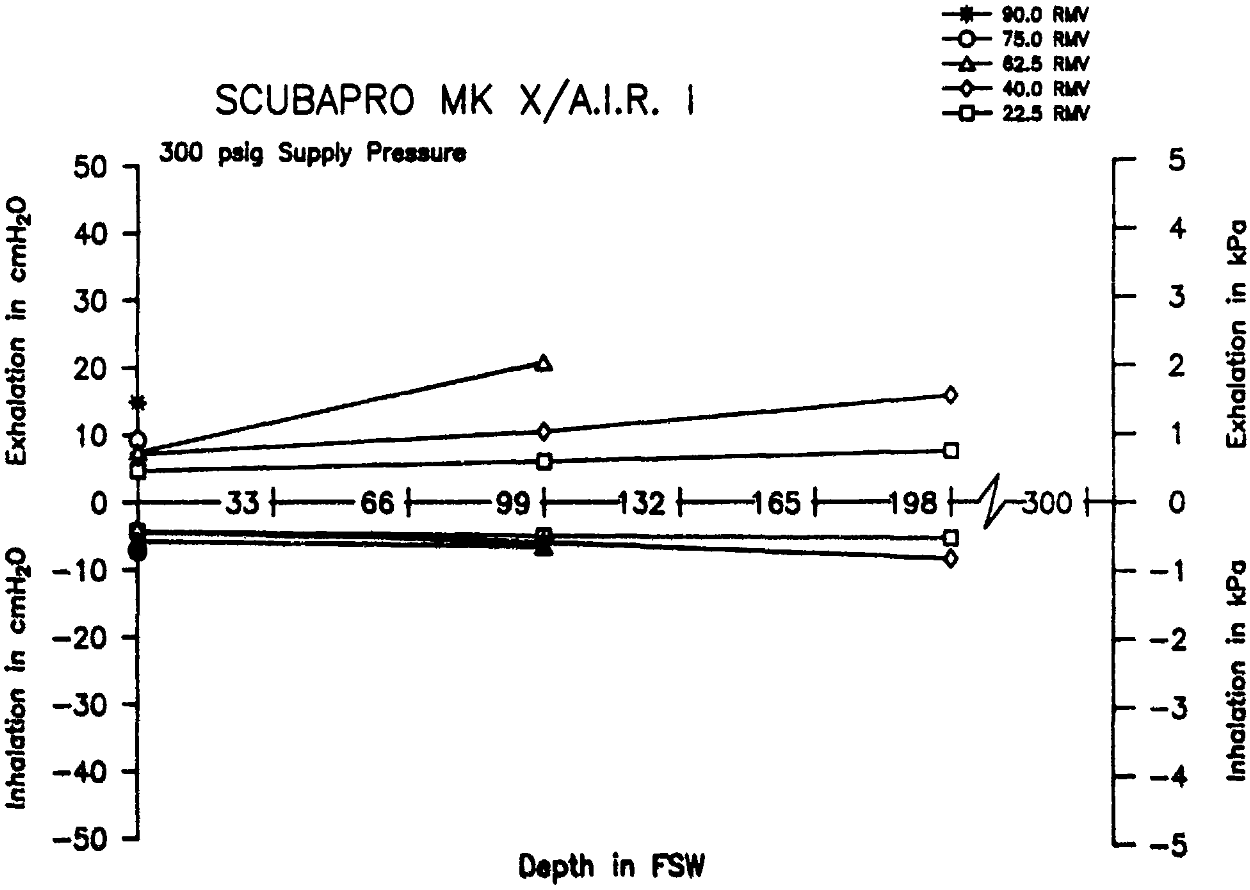
First Stage Pressure Drop vs. Depth



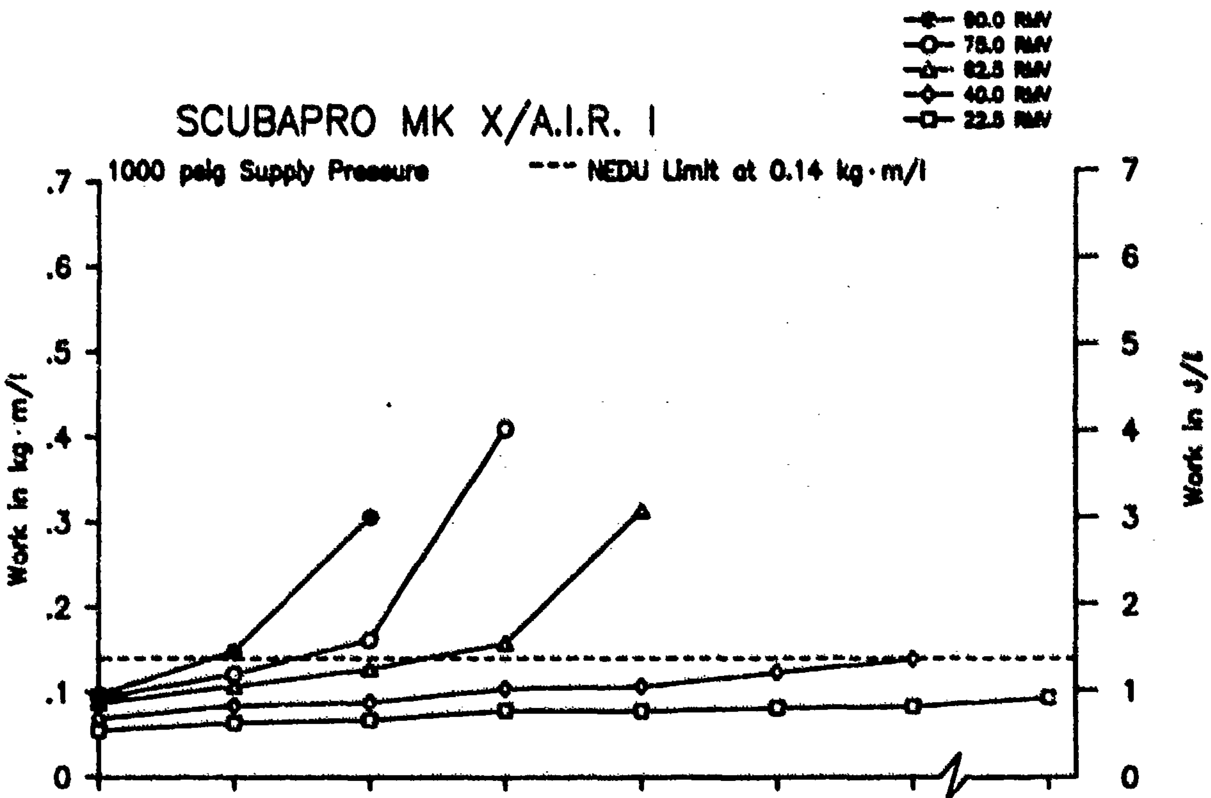
Breathing Resistance vs. Depth



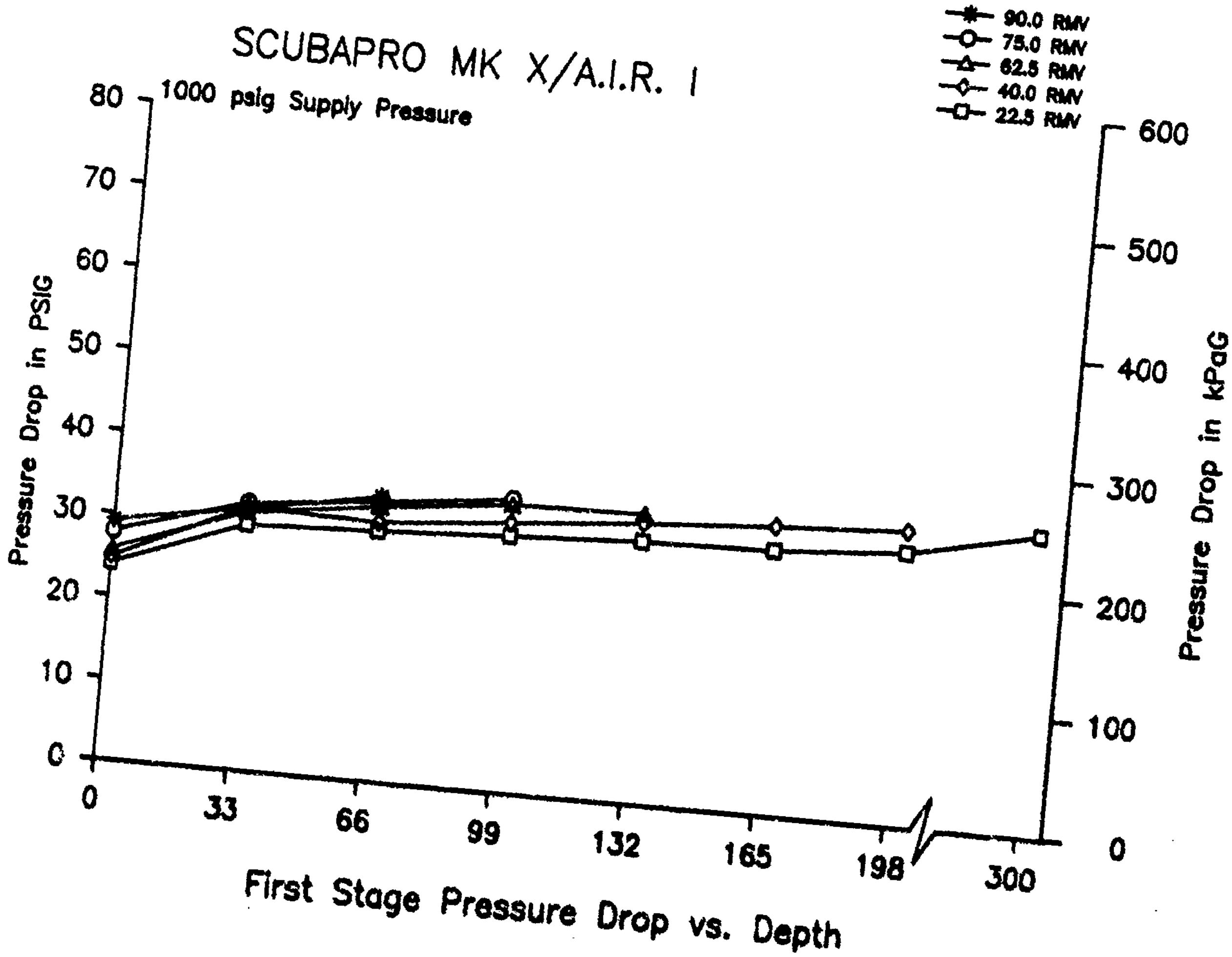
Breathing Resistance vs. Depth



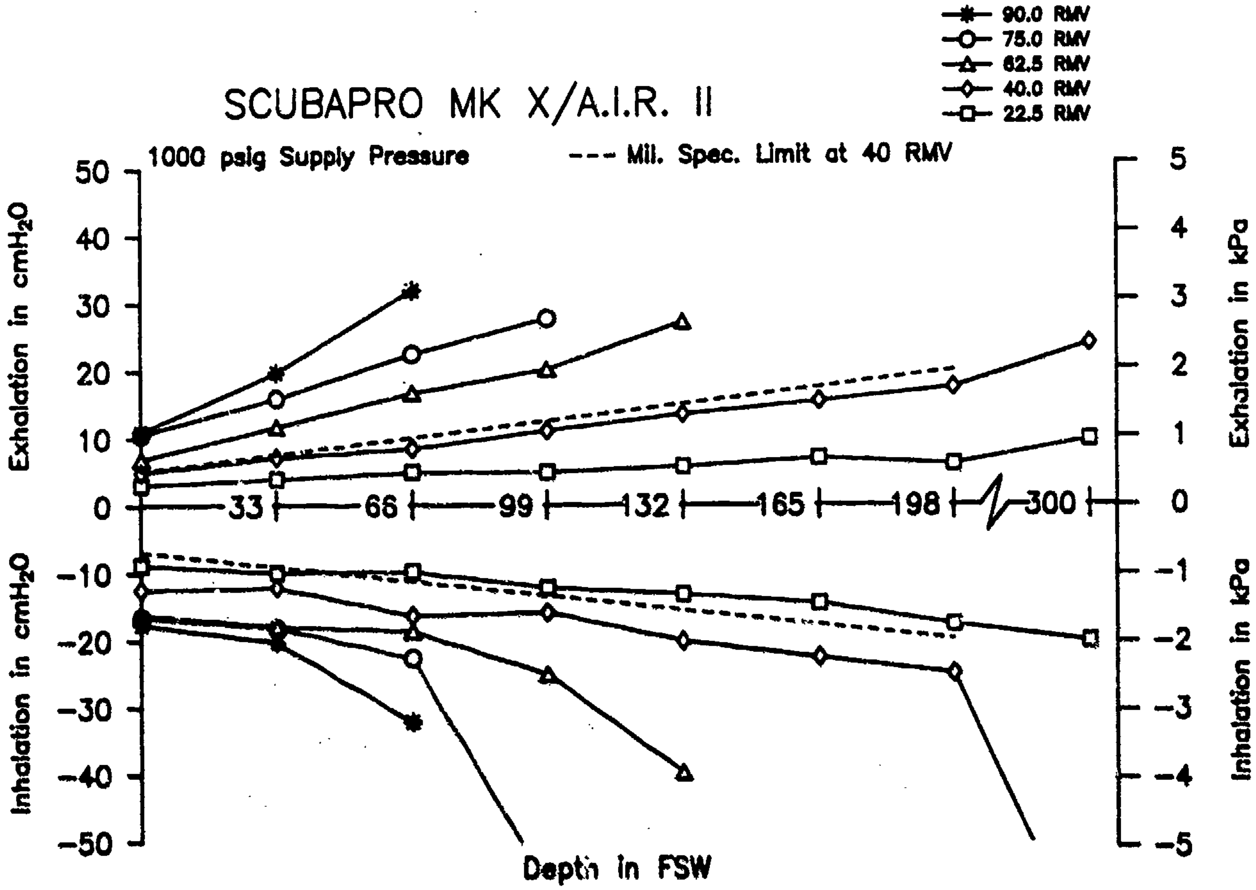
Breathing Resistance vs. Depth



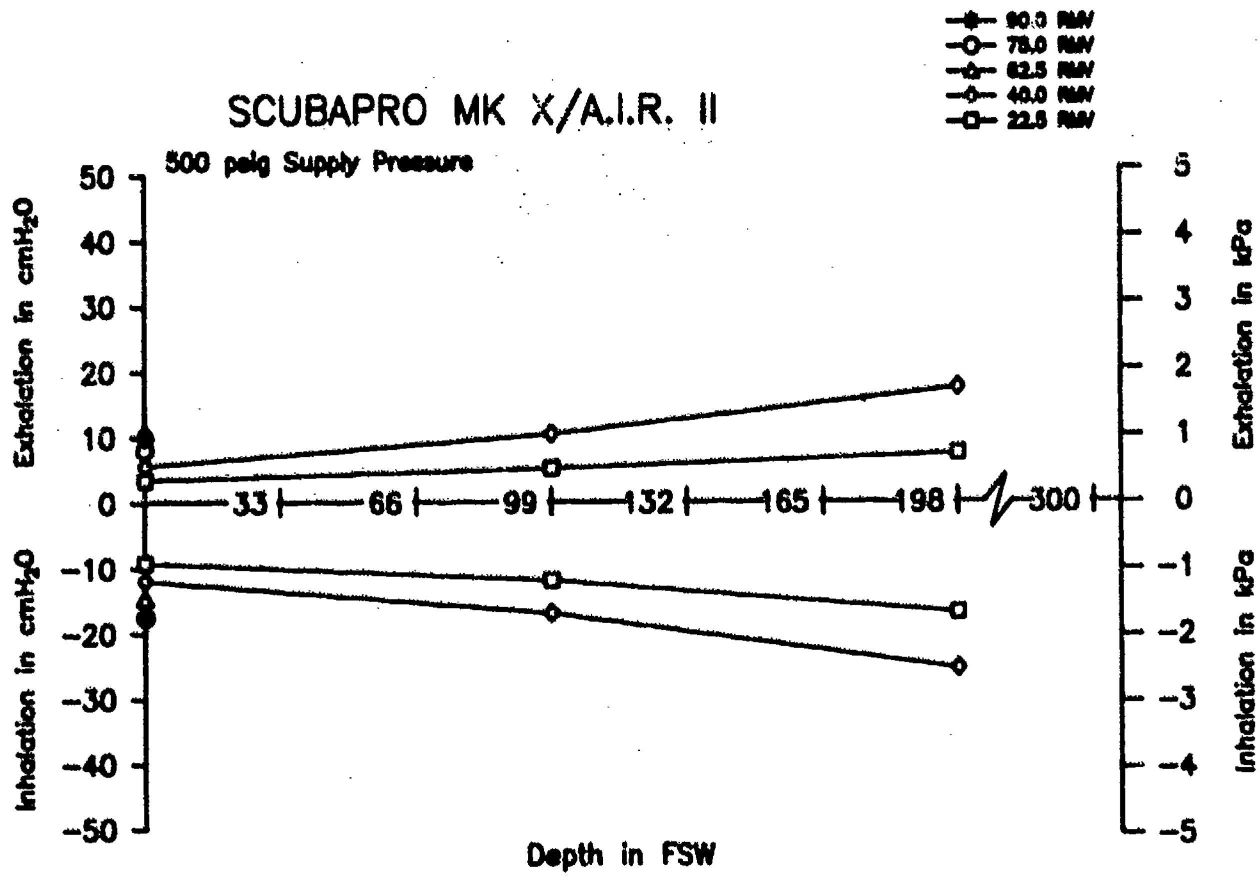
Breathing Work vs. Depth



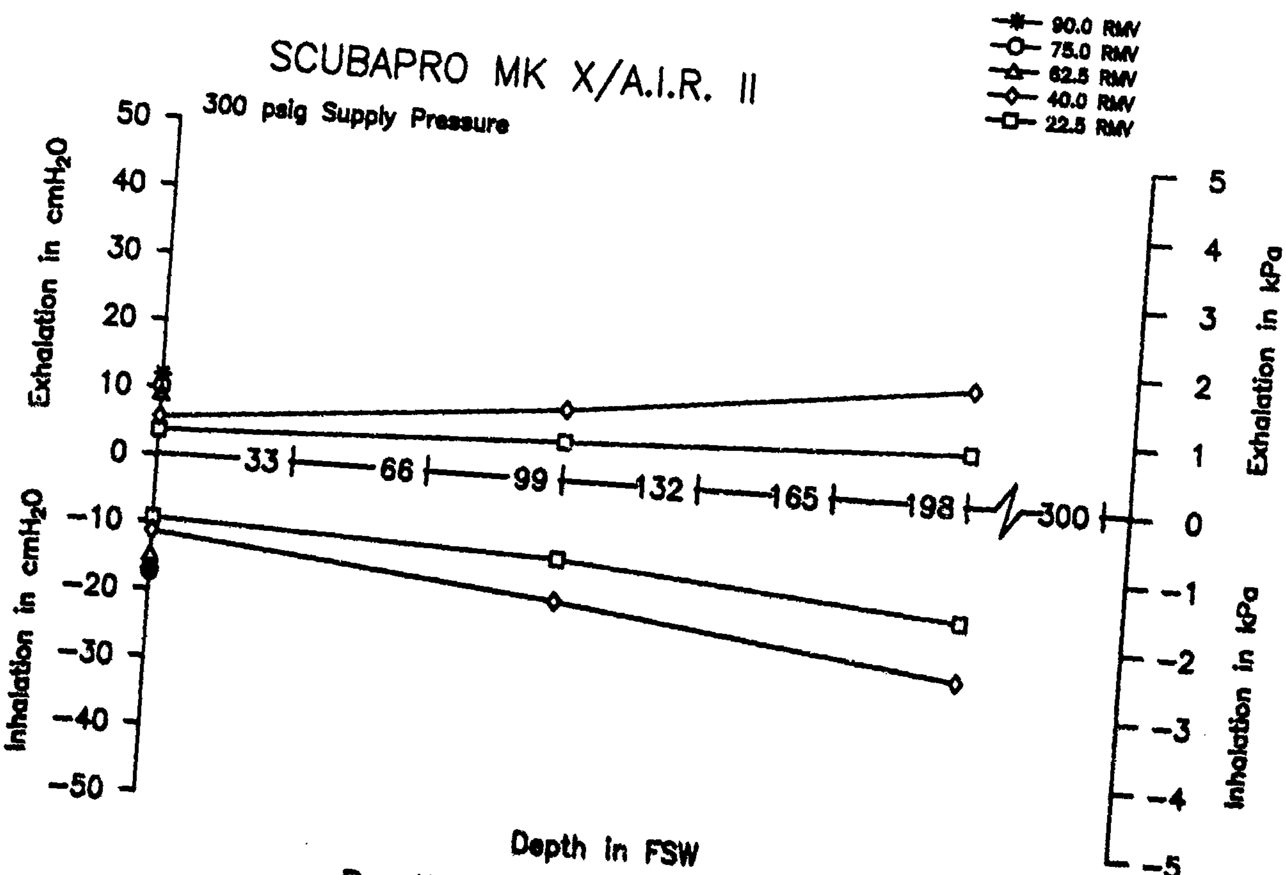
SCUBAPRO MK X/A.I.R. I
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
80
70
60
50
40
30
20
10
0
Pressure Drop in kPaG
600
500
400
300
200
100
0
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth



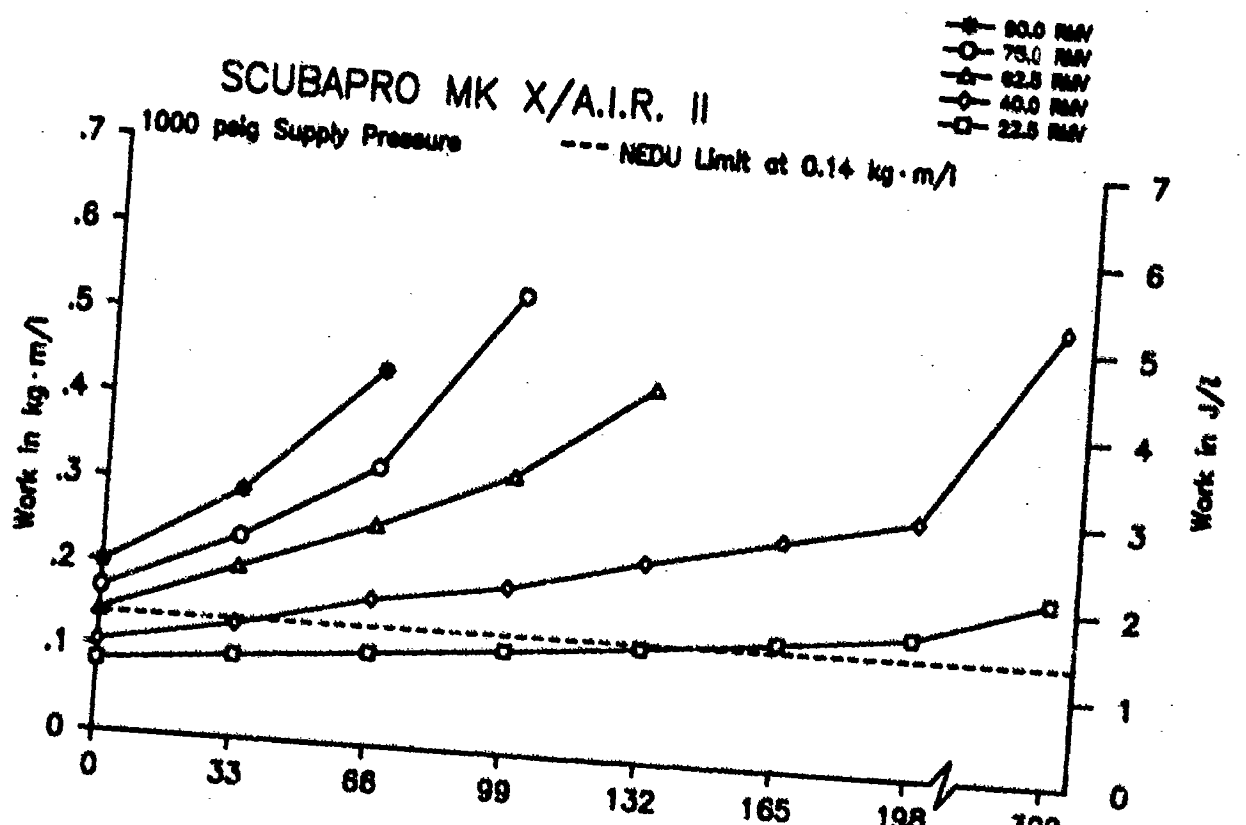
Breathing Resistance vs. Depth



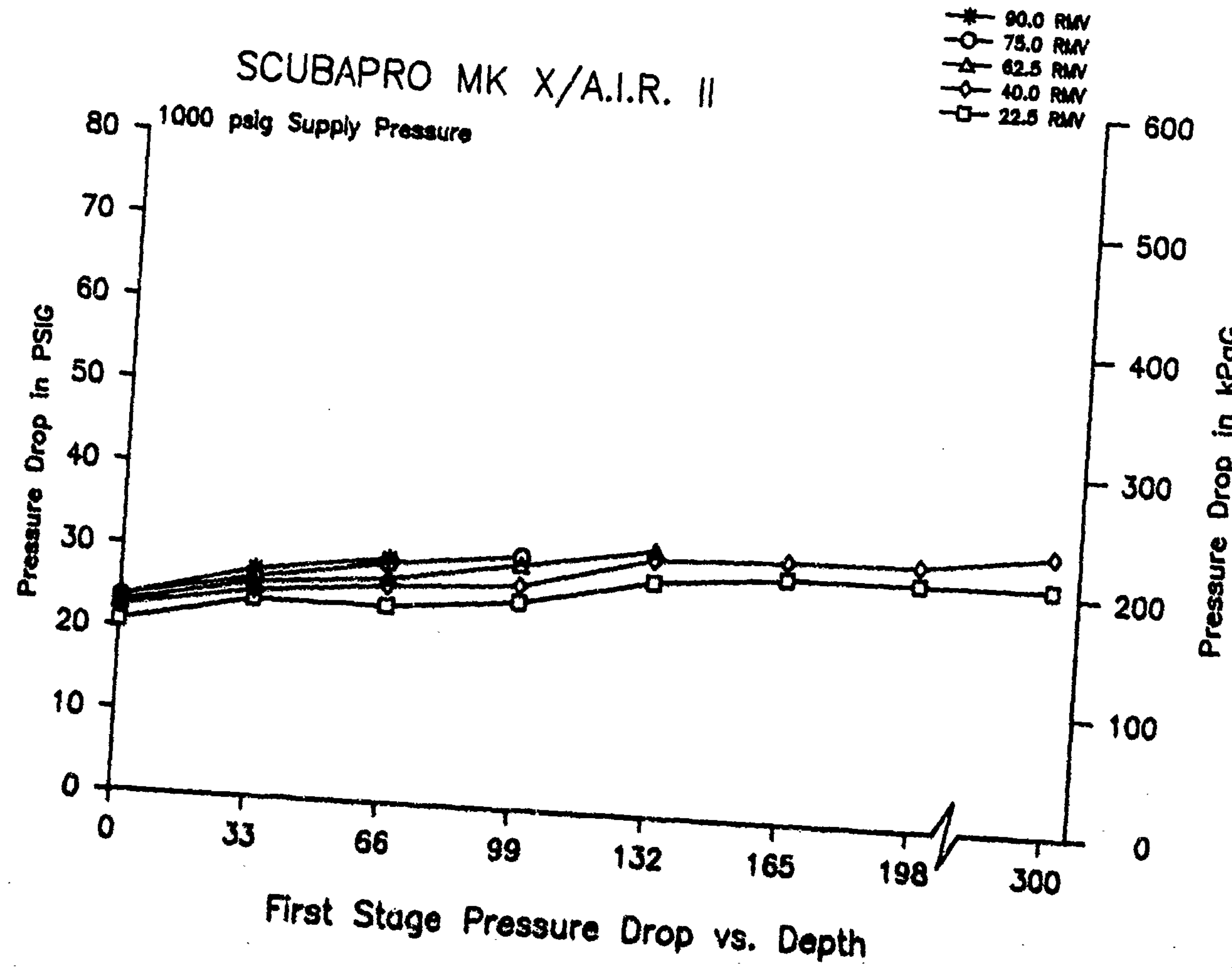
Breathing Resistance vs. Depth



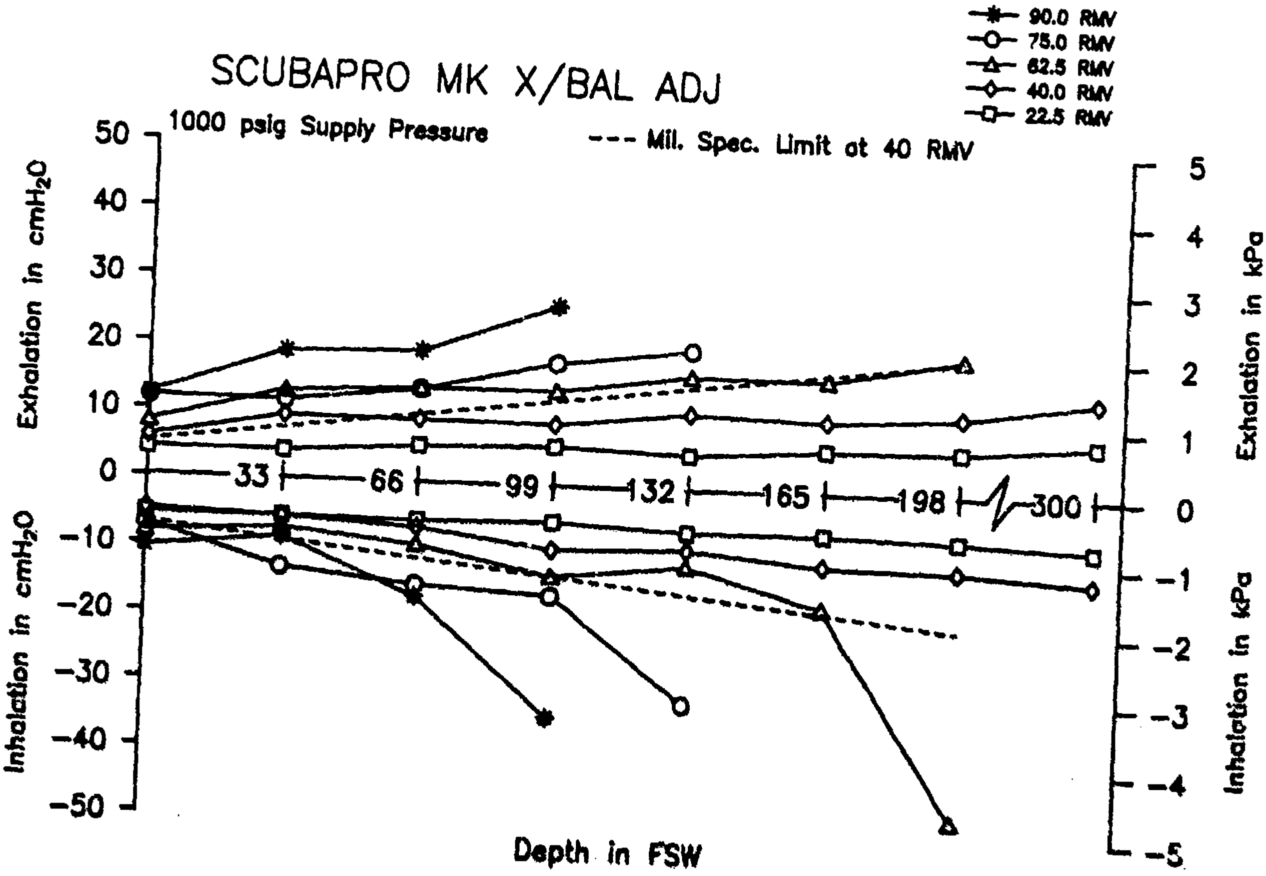
Breathing Resistance vs. Depth



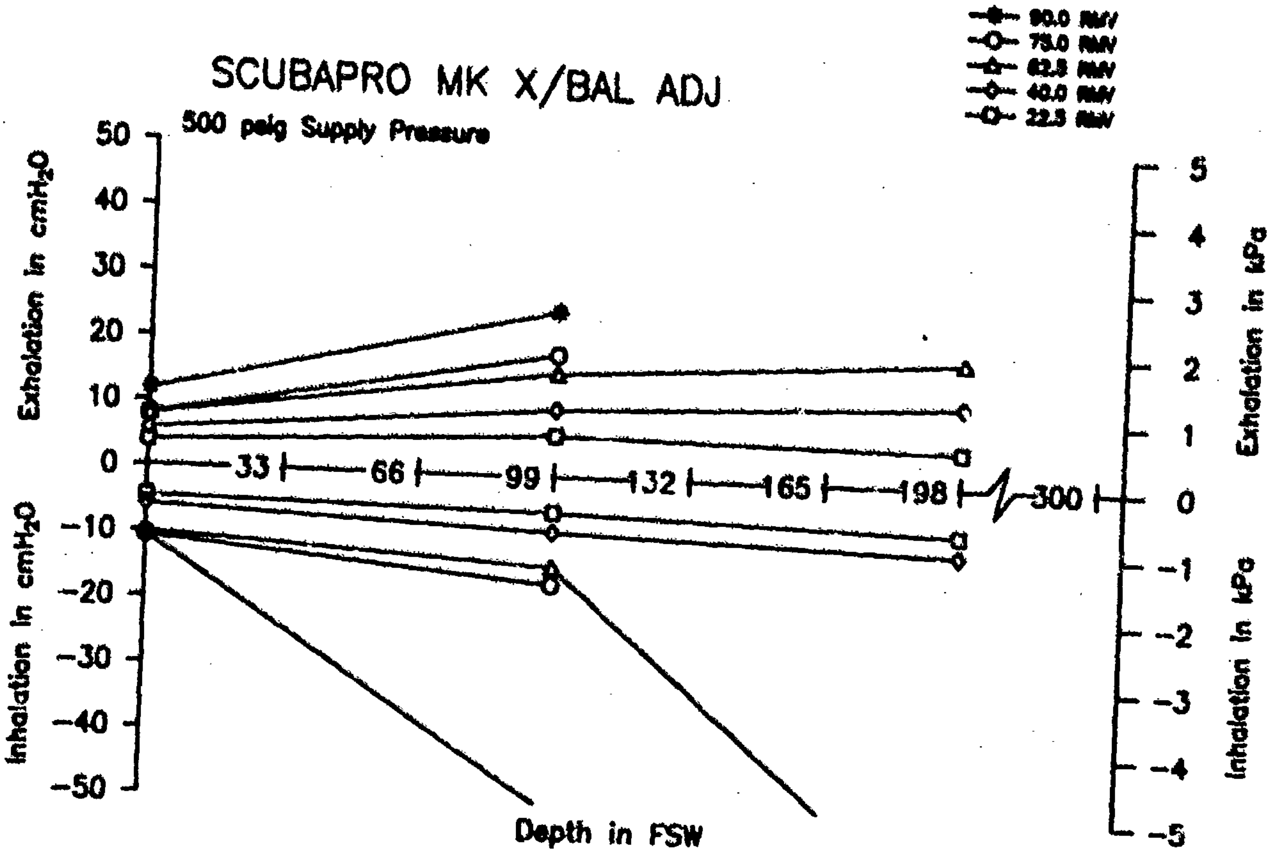
Breathing Work vs. Depth



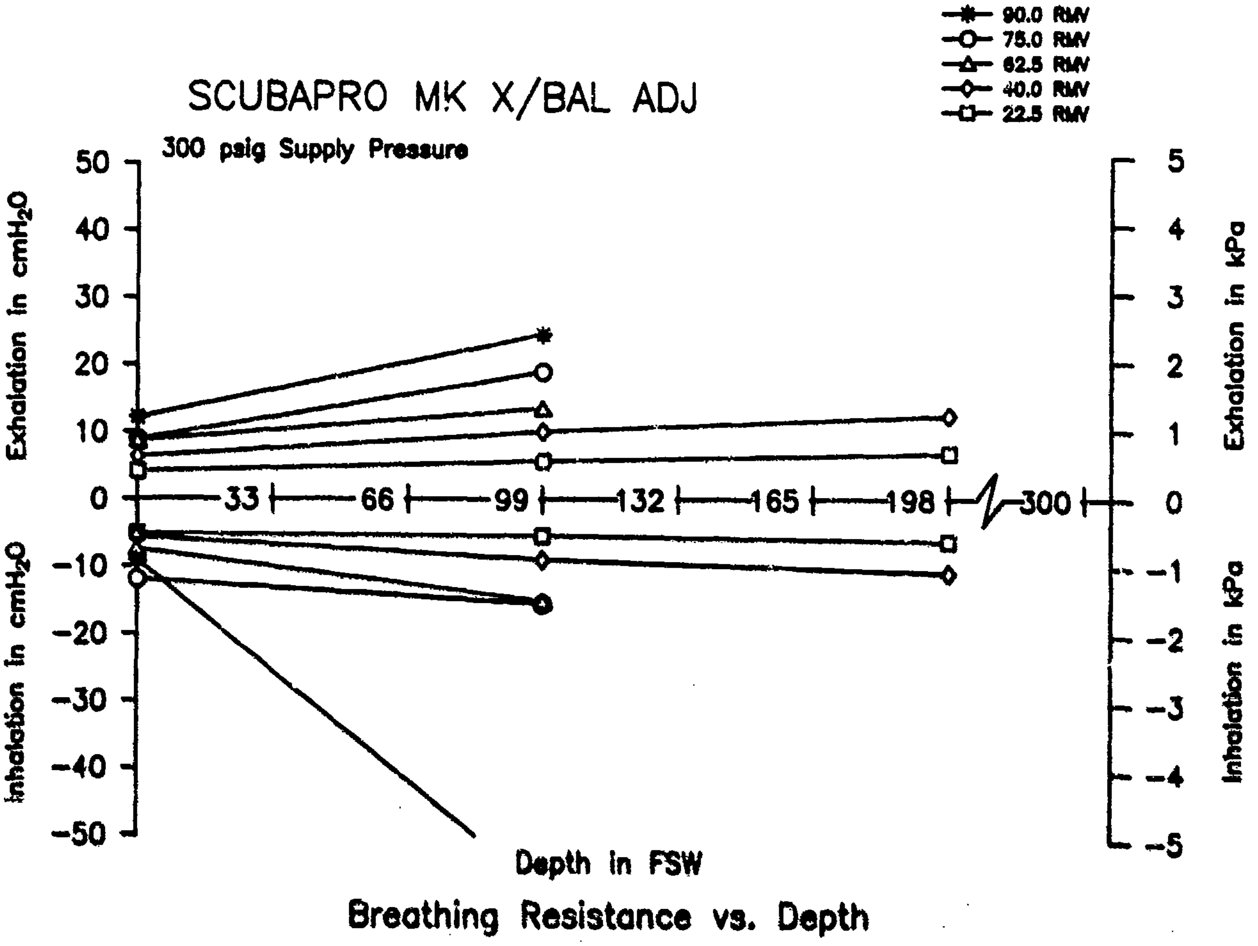
SCUBAPRO MK X/A.I.R. II
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
Pressure Drop in kPaG
80
70
60
50
40
30
20
10
0
600
500
400
300
200
100
0
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth



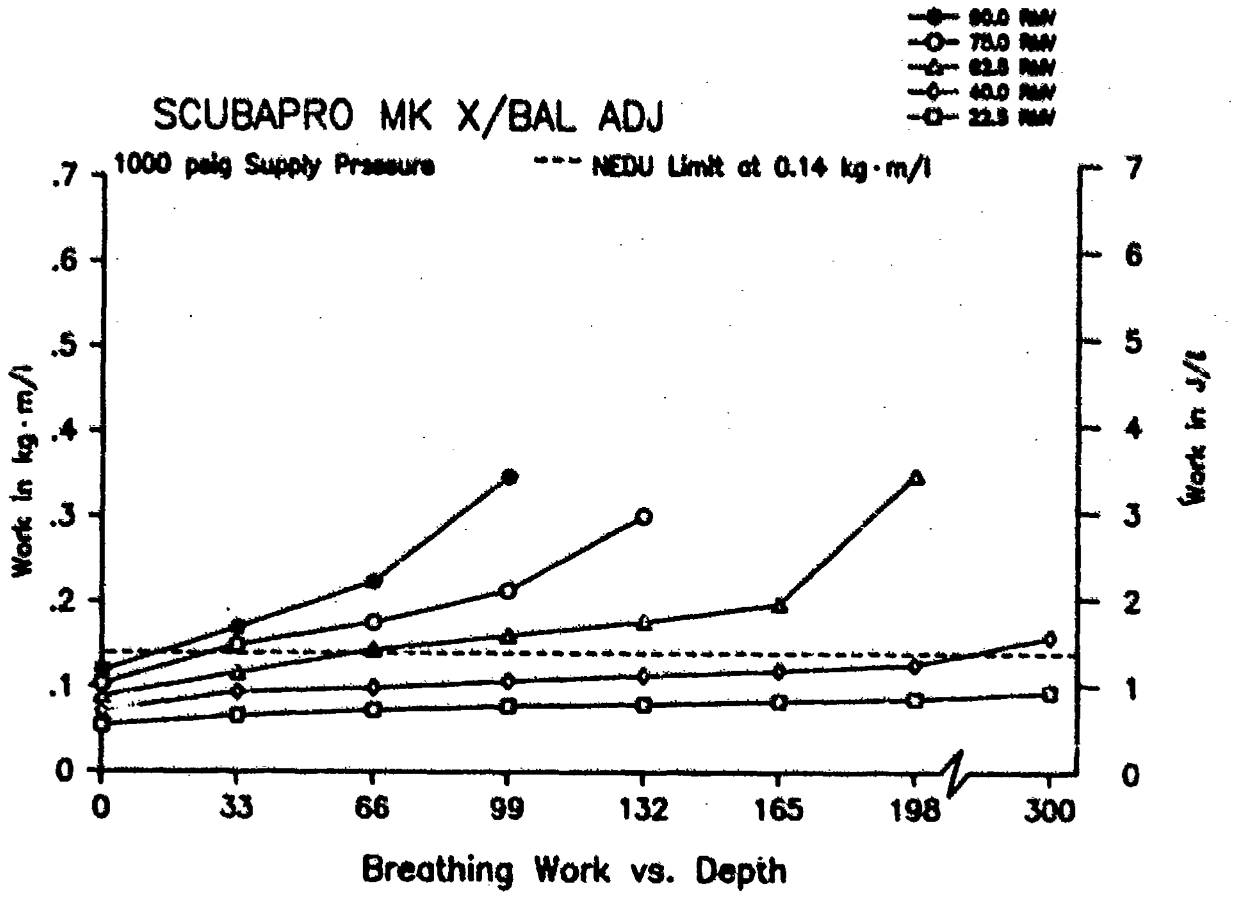
Breathing Resistance vs. Depth



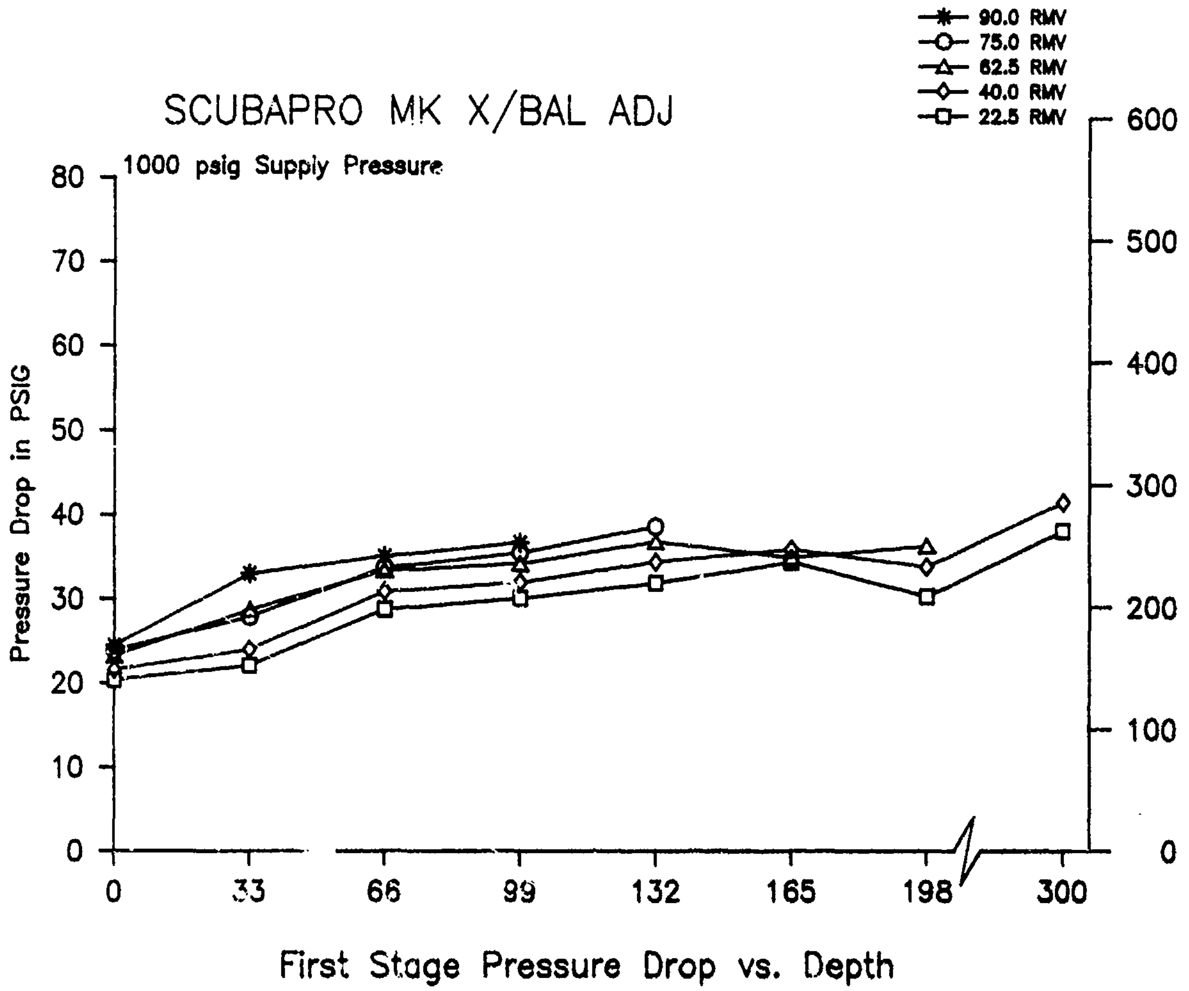
Breathing Resistance vs. Depth



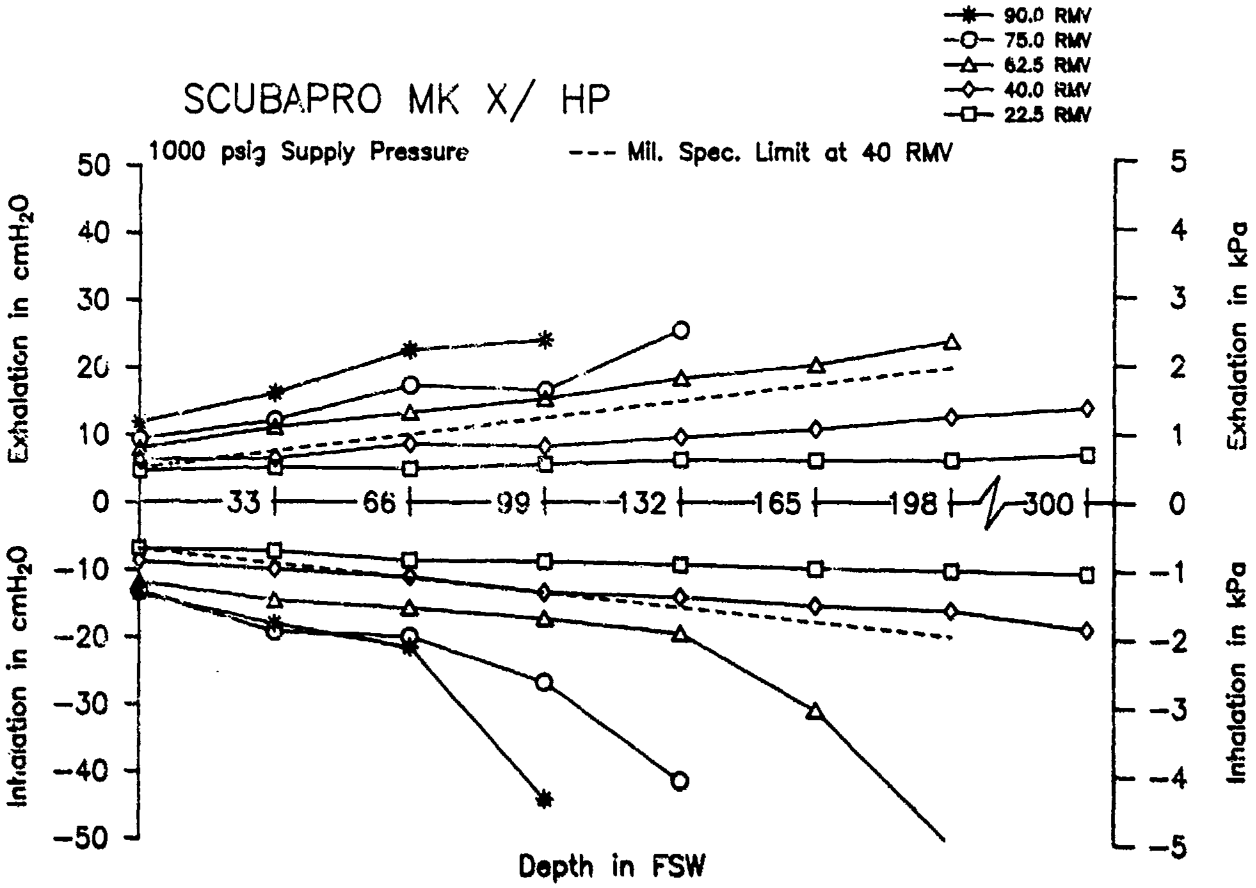
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
SCUBAPRO MK X/BAL ADJ
300 psig Supply Pressure
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
Depth in FSW
Breathing Resistance vs. Depth



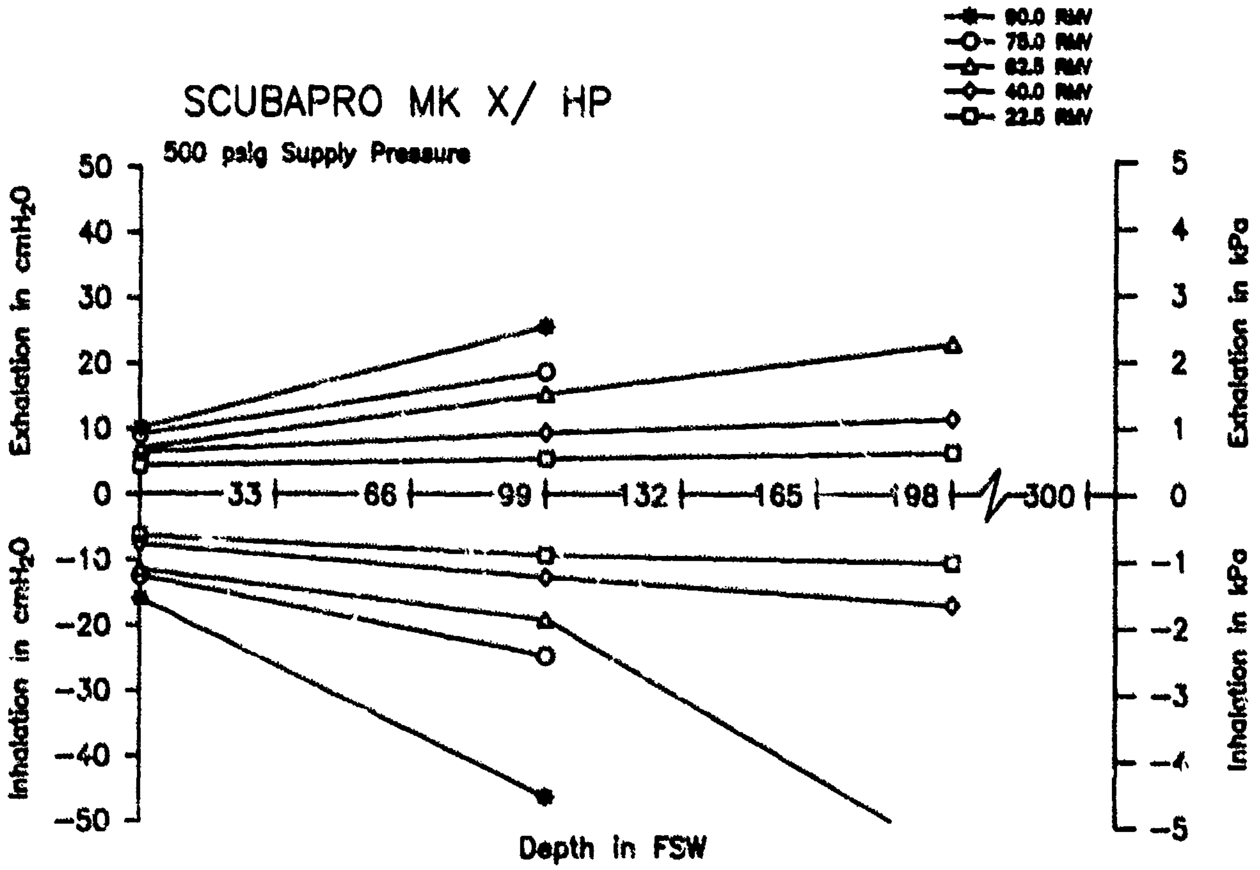
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
SCUBAPRO MK X/BAL ADJ
1000 psig Supply Pressure
NEDU Limit at 0.14 kg·m/l
Work in kg·m/l
Work in J/l
Breathing Work vs. Depth



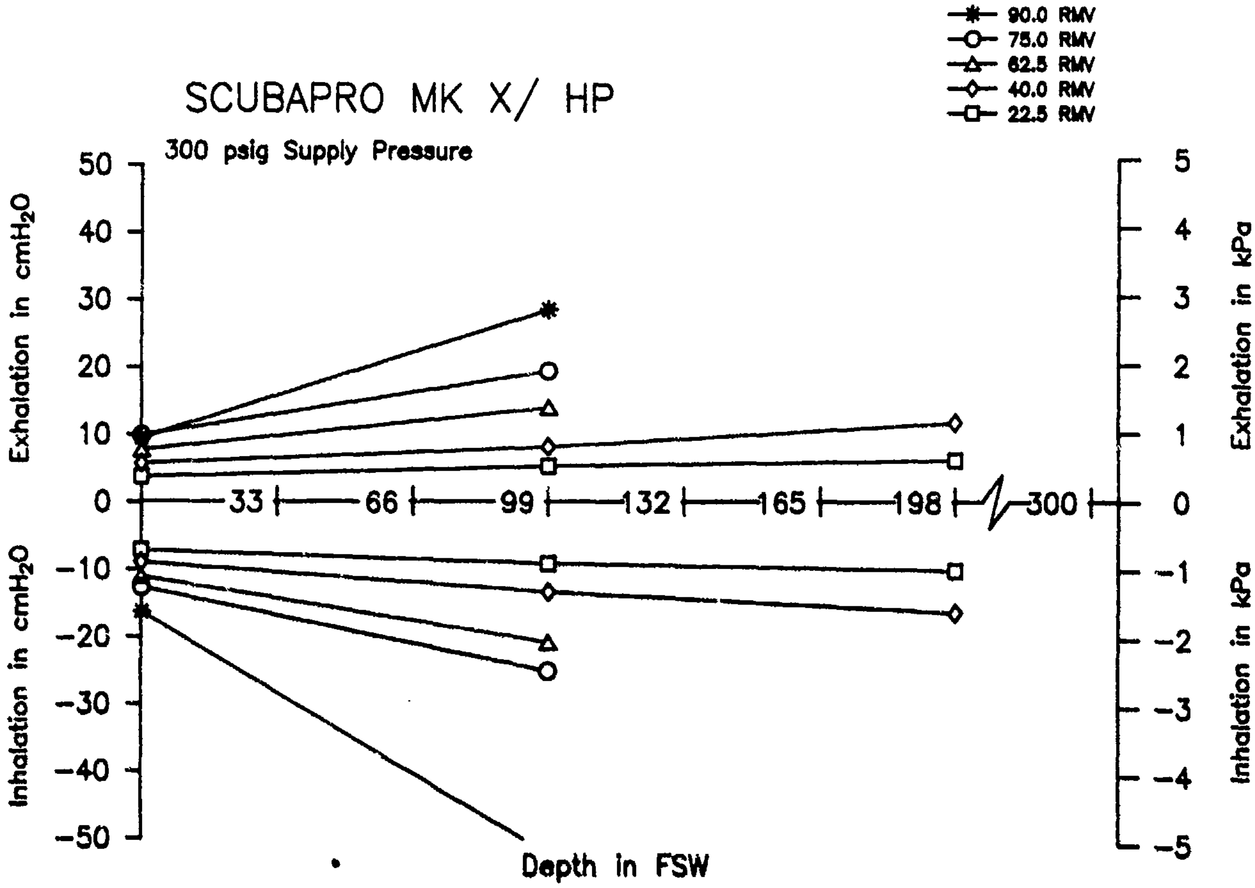
SCUBAPRO MK X/BAL ADJ
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
80
70
60
50
40
30
20
10
0
600
500
400
300
200
100
0
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth



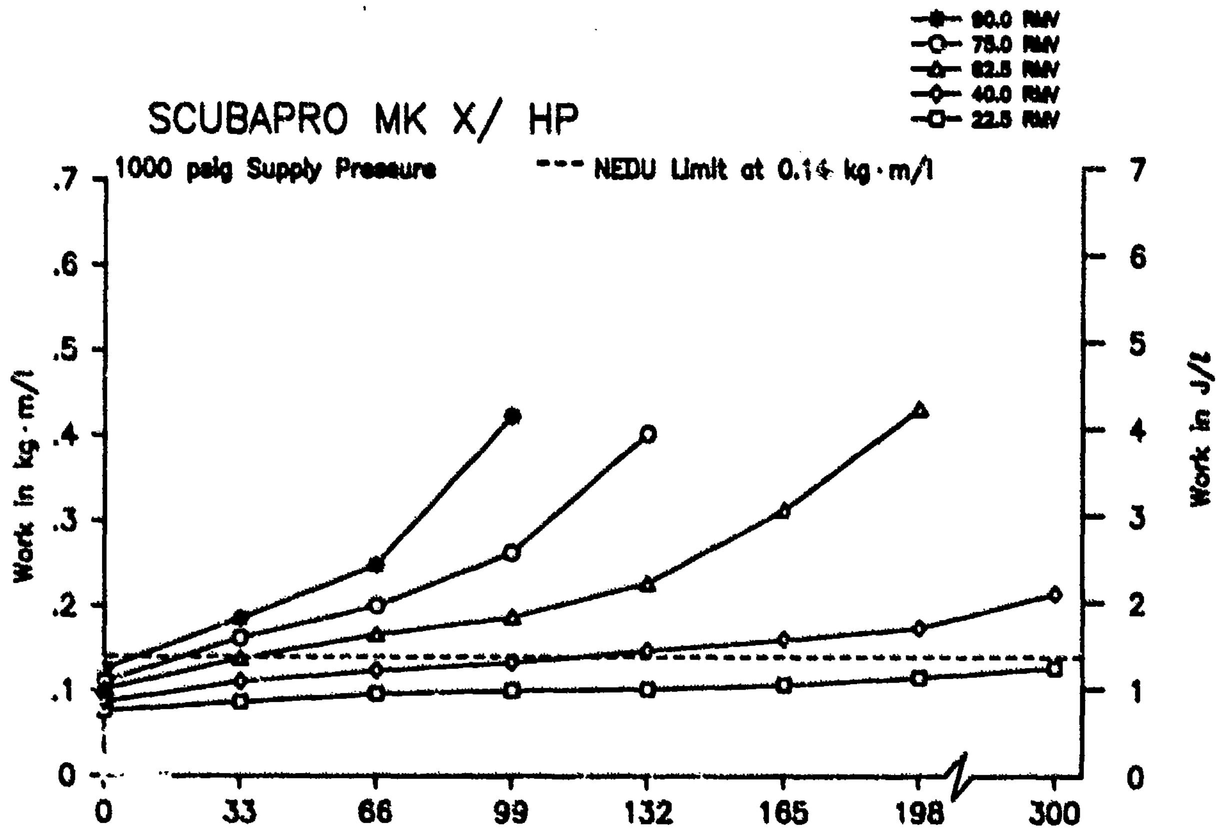
Breathing Resistance vs. Depth



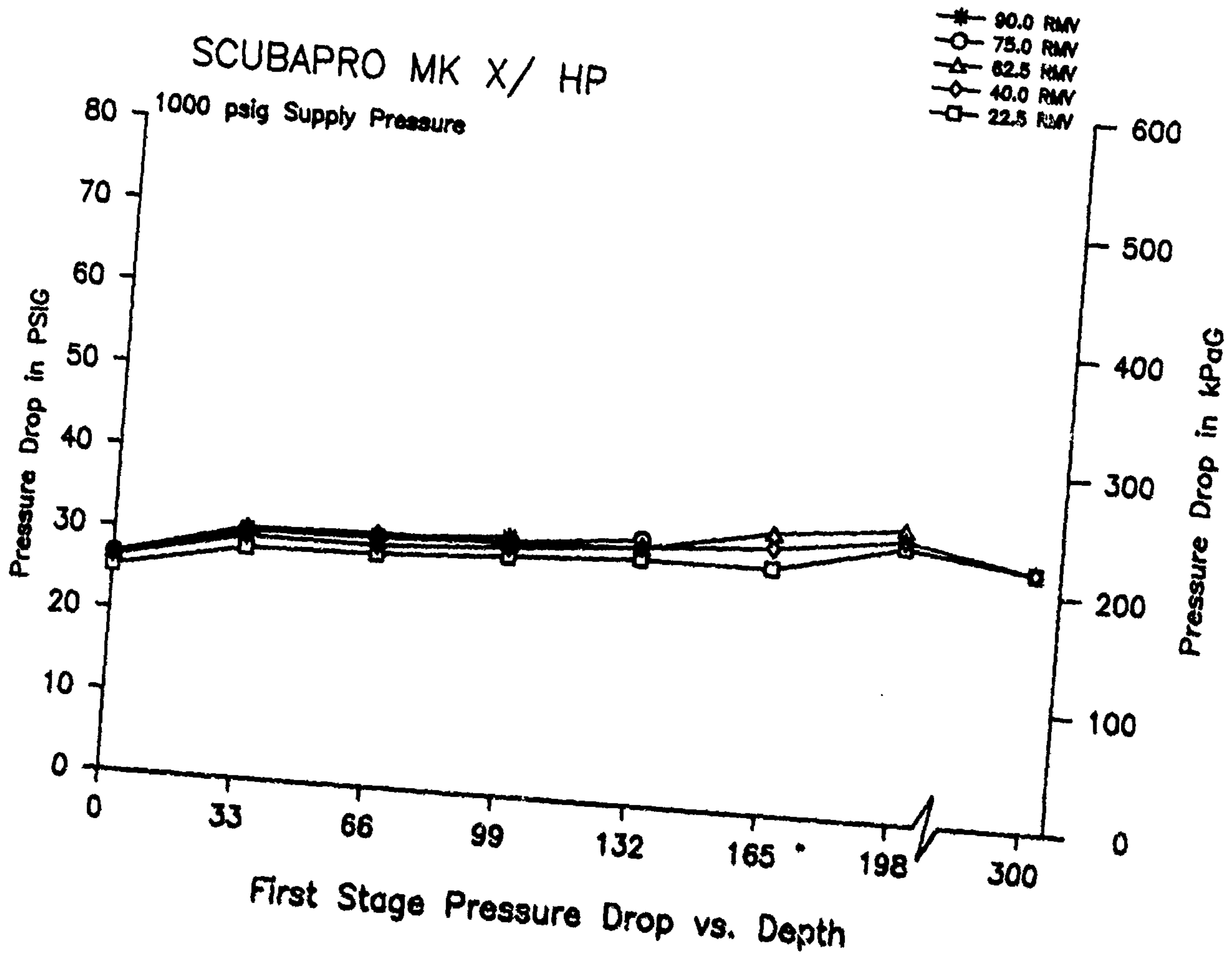
Breathing Resistance vs. Depth

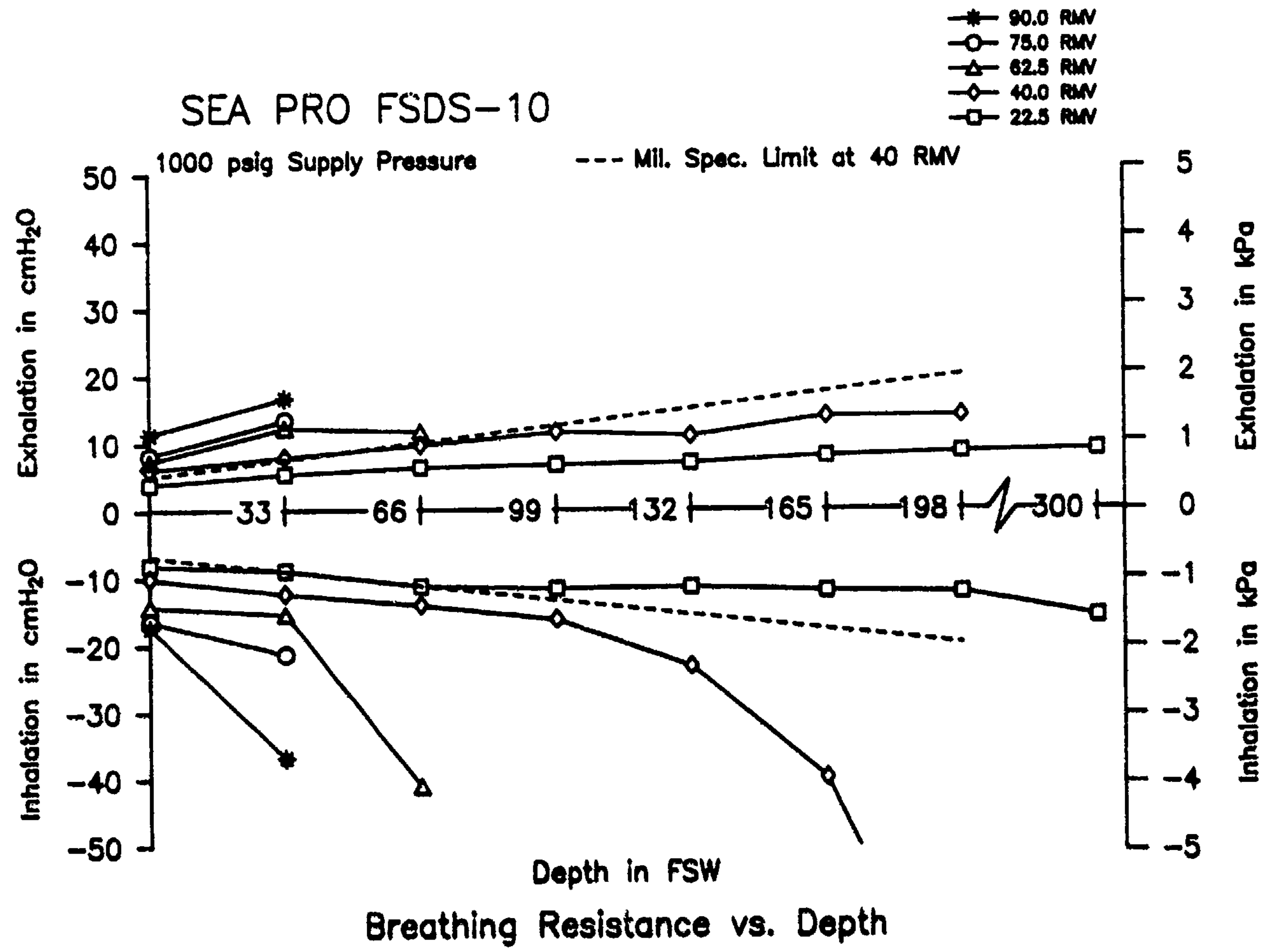


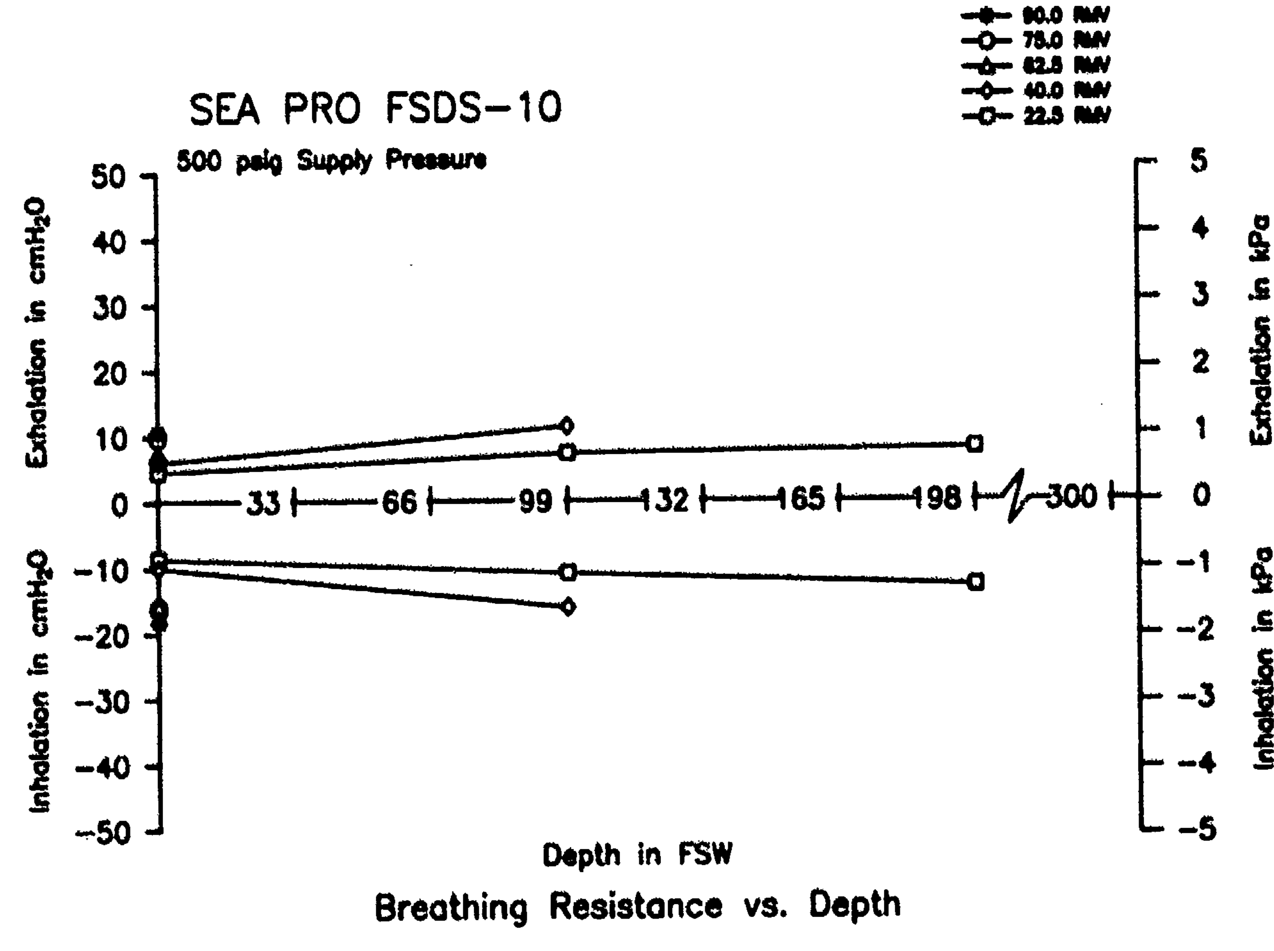
Breathing Resistance vs. Depth

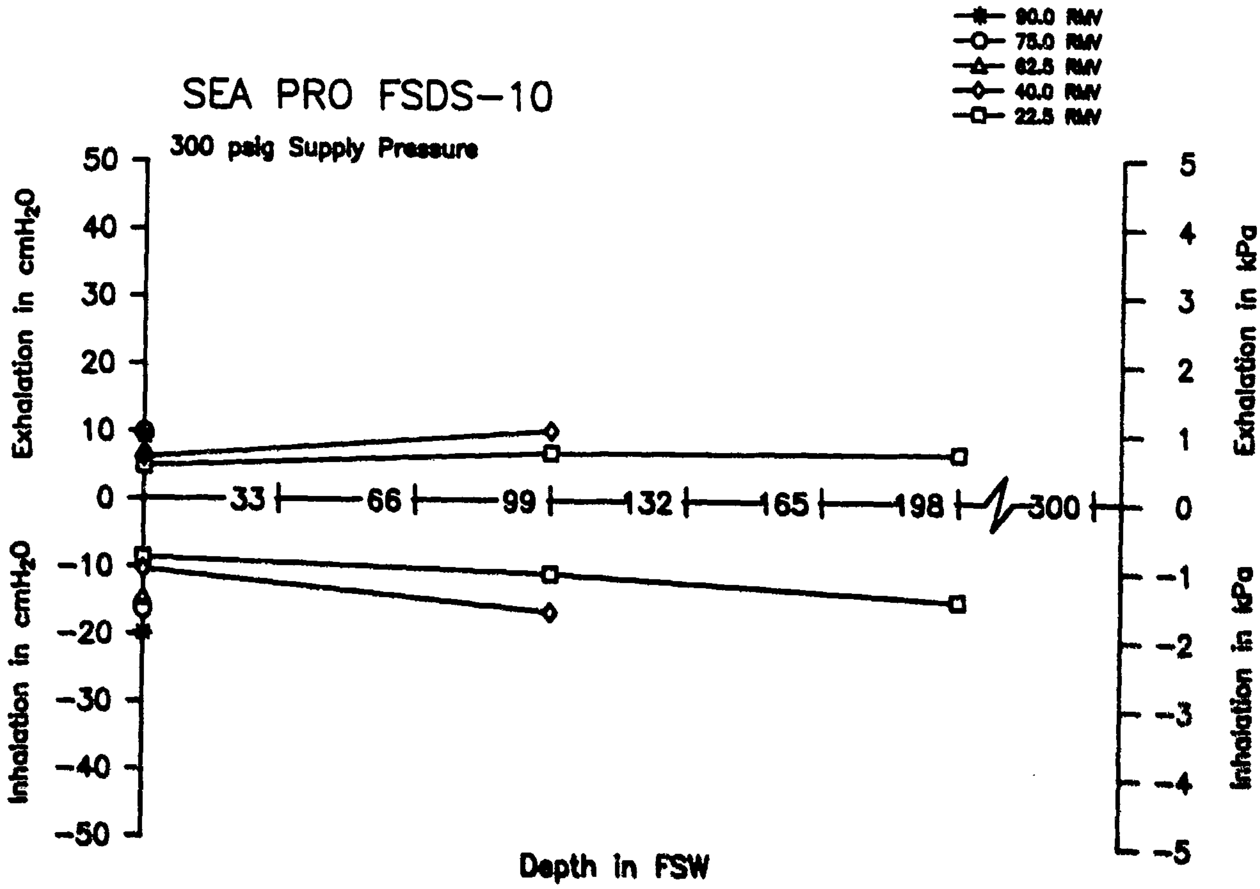


Breathing Work vs. Depth

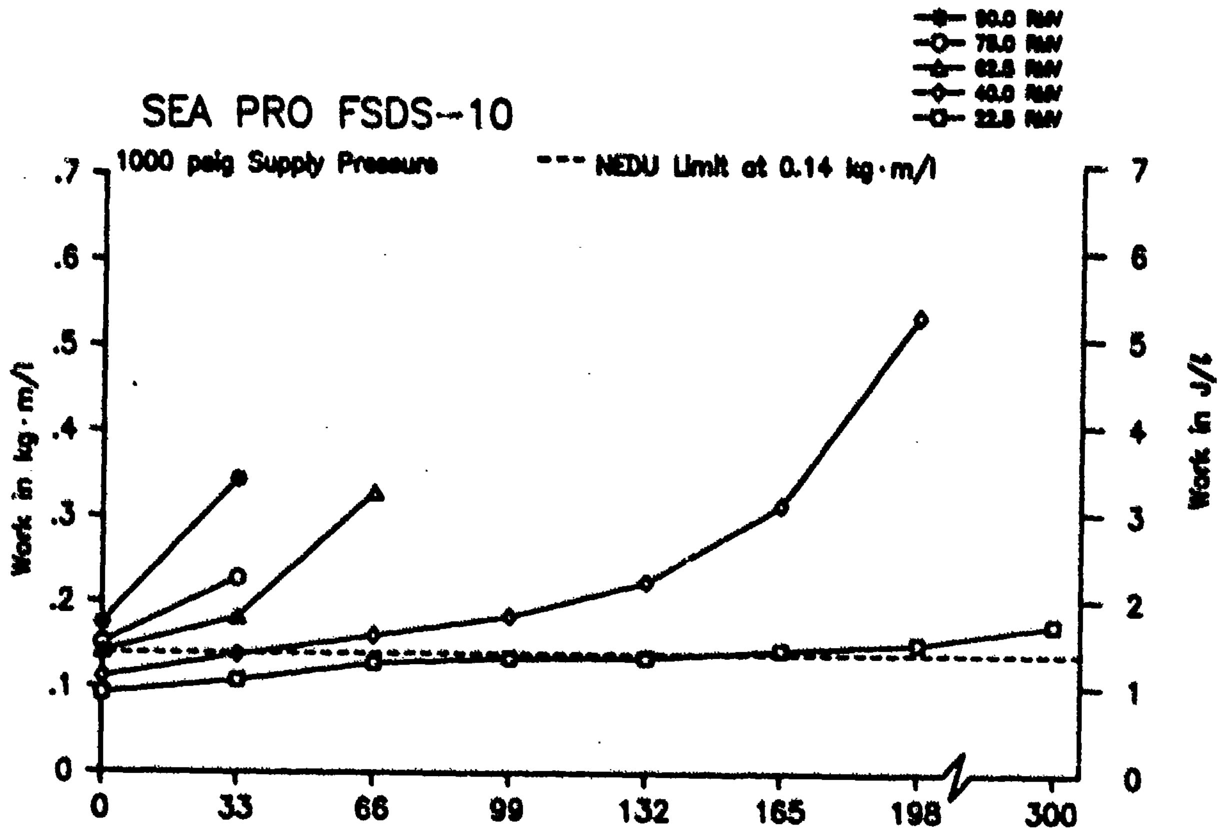

SCUBAPRO MK X/ HP
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
Pressure Drop in kPaG
80
70
60
50
40
30
20
10
0
600
500
400
300
200
100
0
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth


90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
SEA PRO FSDS-10
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth

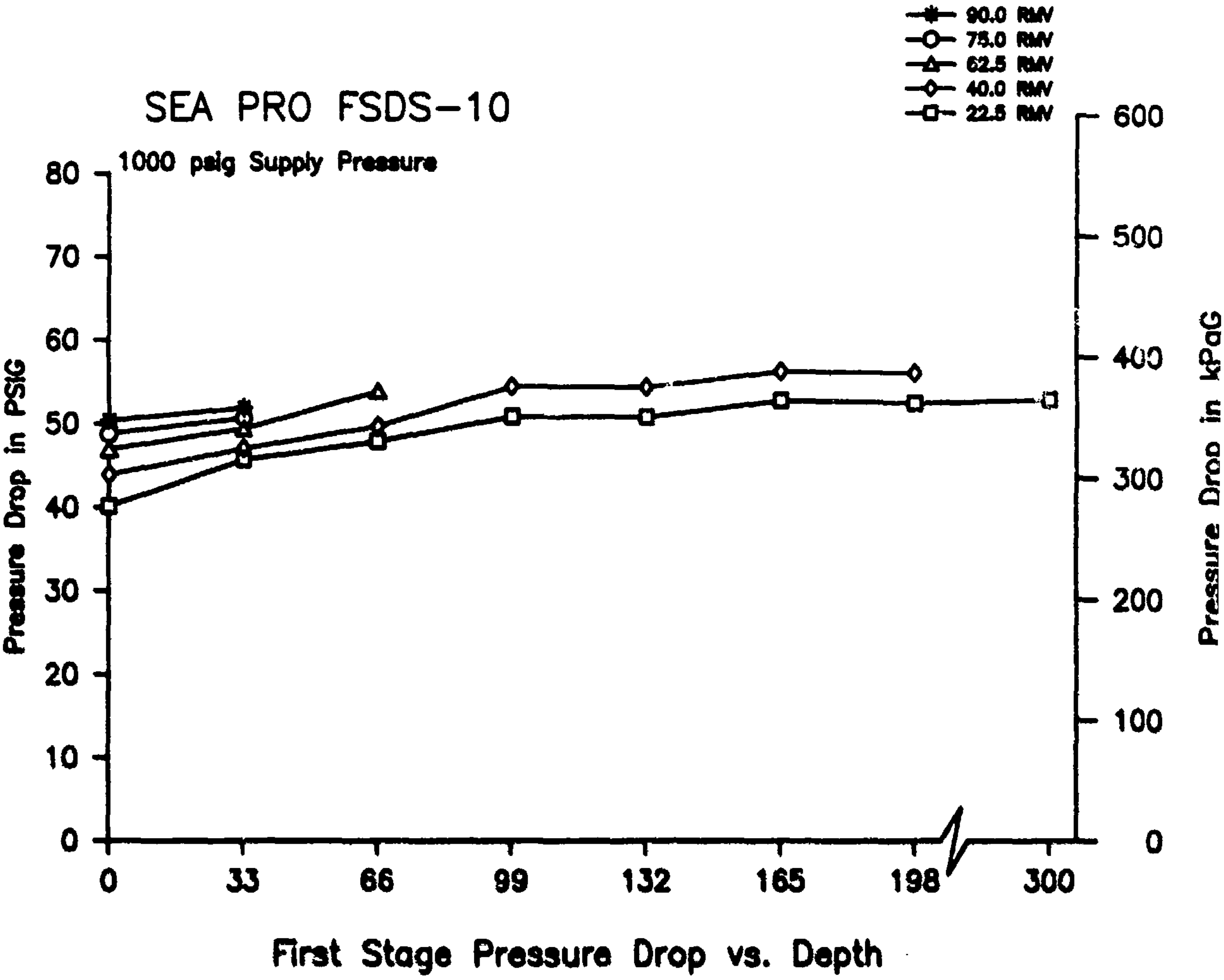

90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
SEA PRO FSDS-10
500 psig Supply Pressure
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



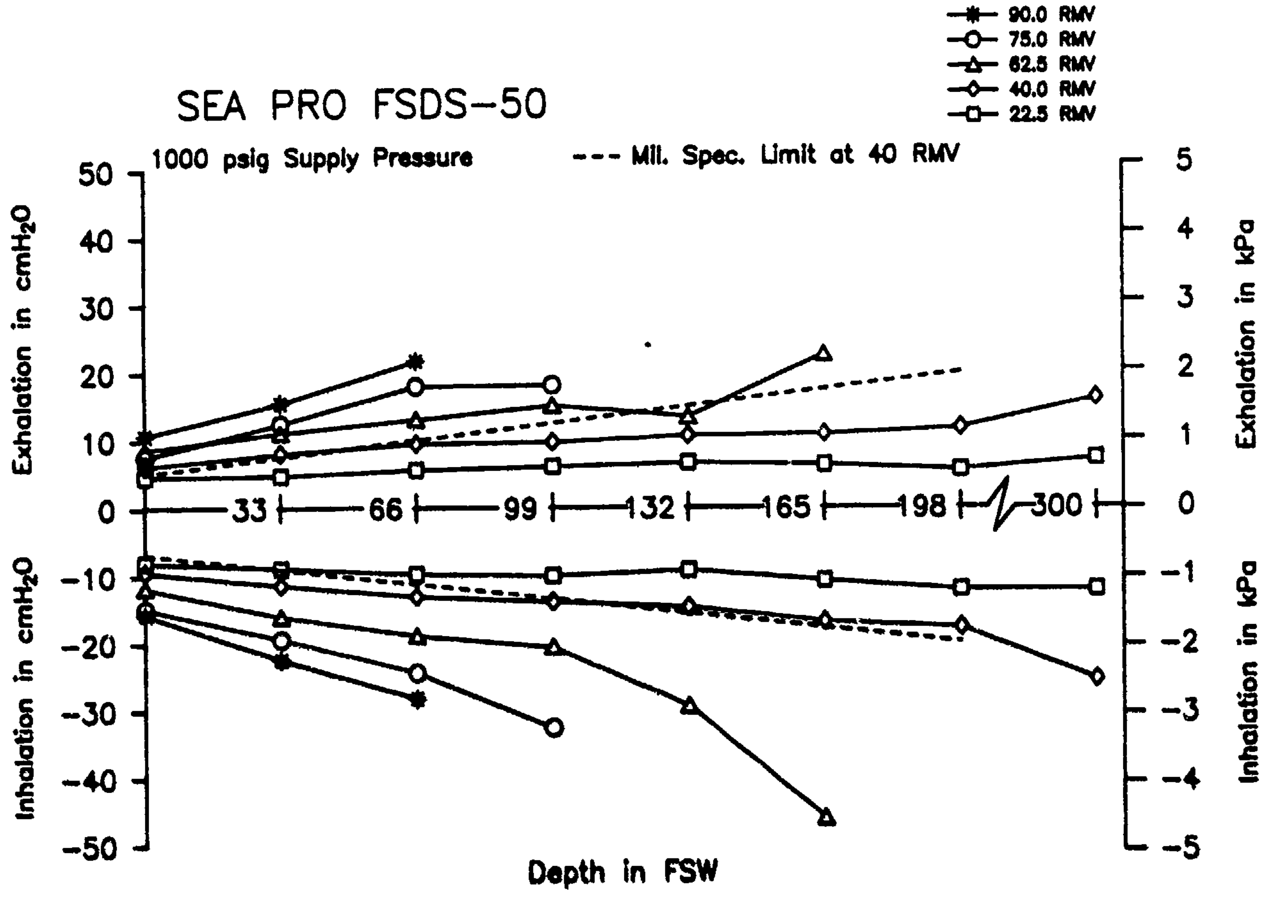
Breathing Resistance vs. Depth



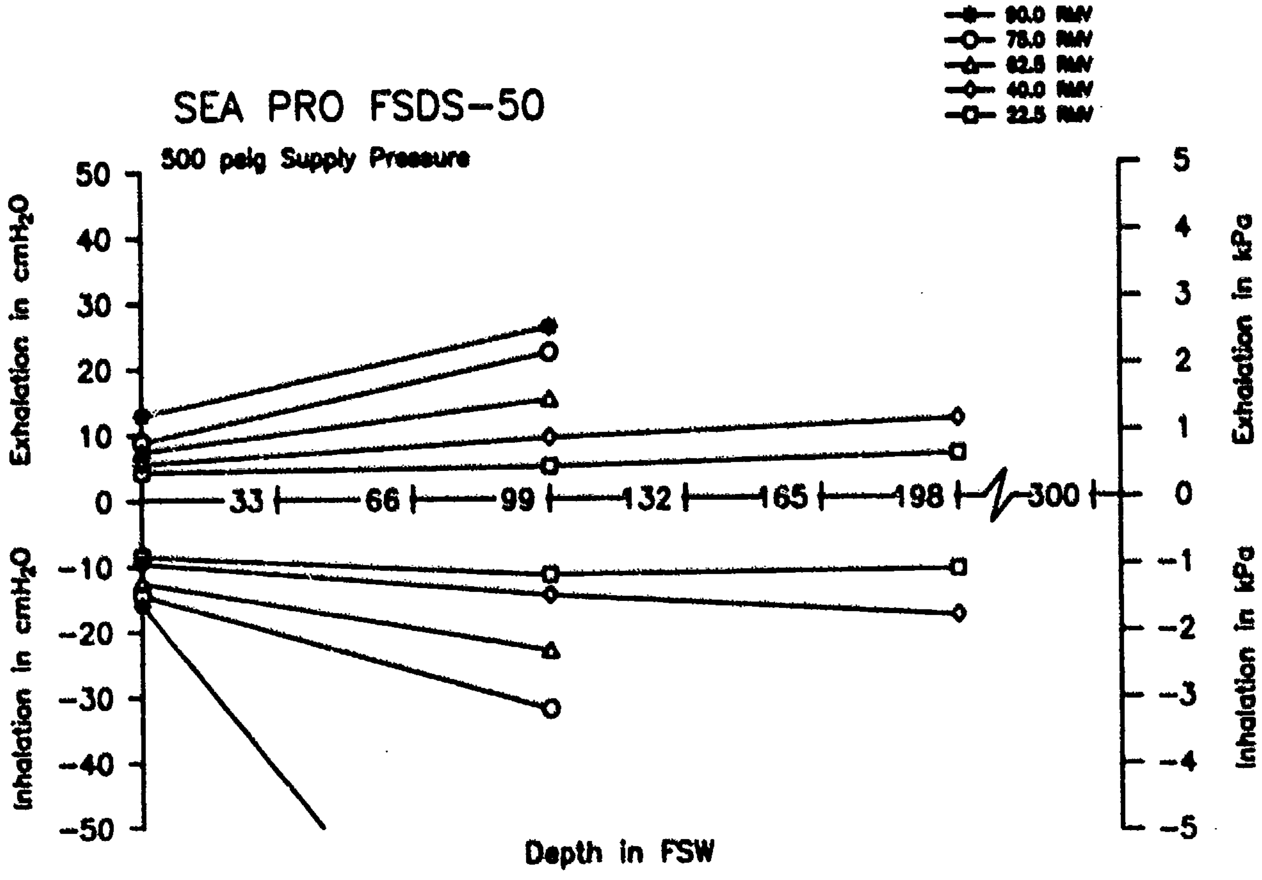
Breathing Work vs. Depth



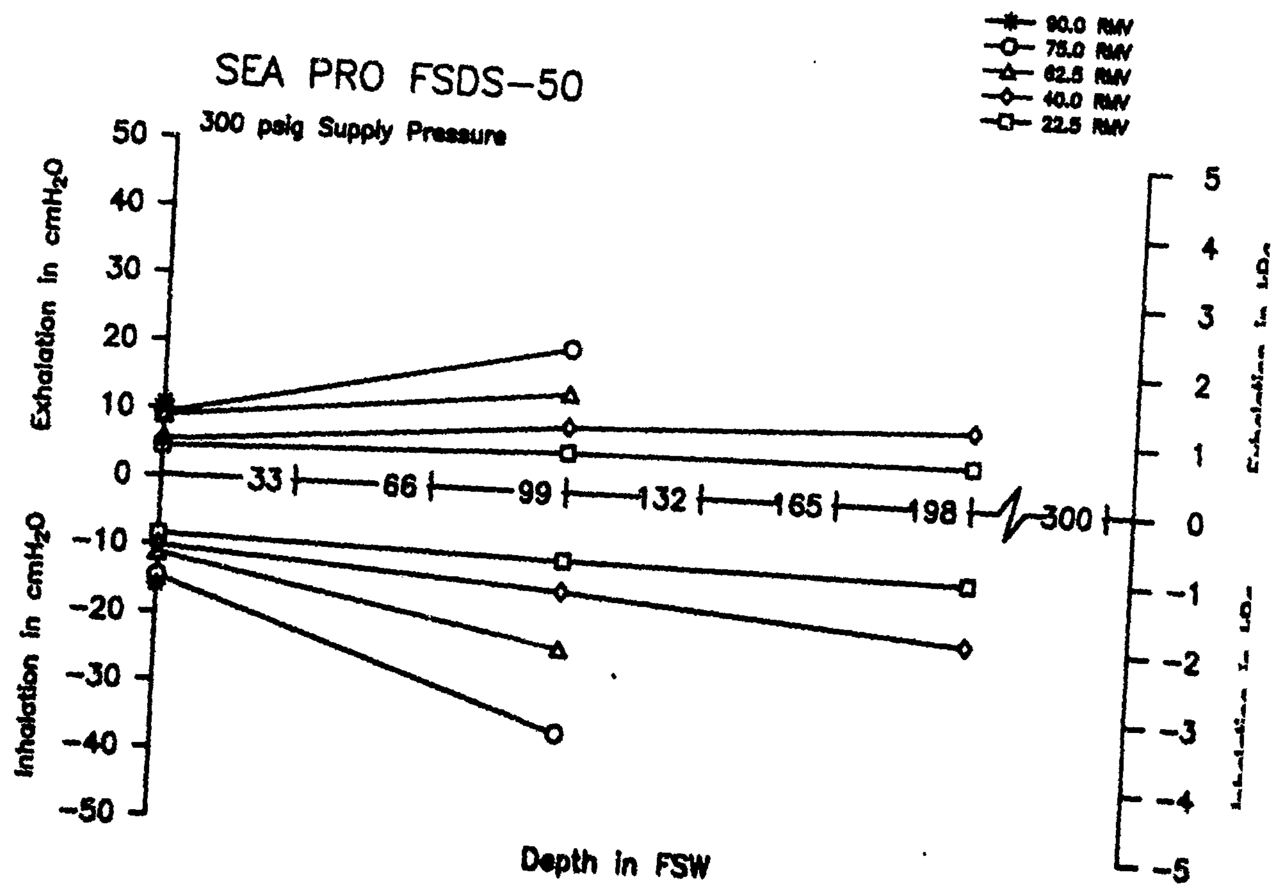
SEA PRO FSDS-10
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
Pressure Drop in kPaG
80
70
60
50
40
30
20
10
0
600
500
400
300
200
100
0
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth



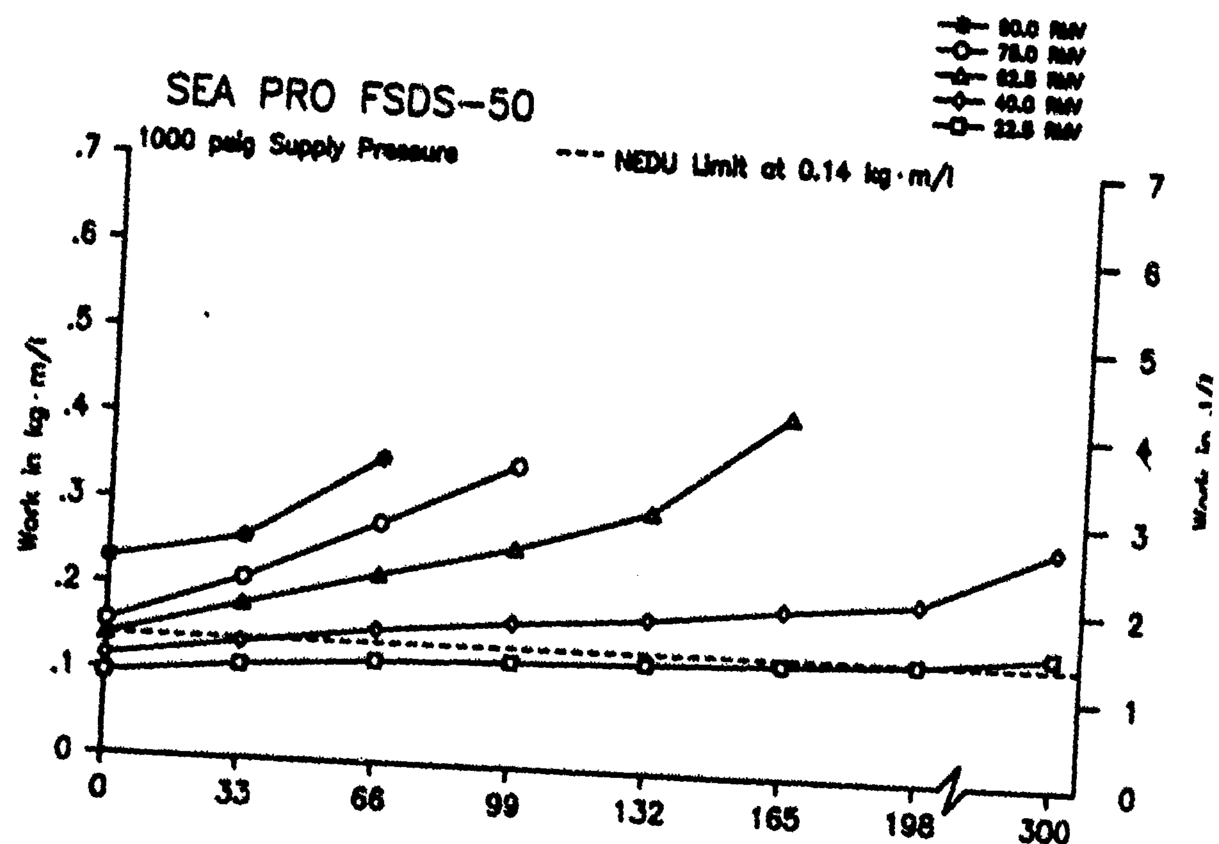
Breathing Resistance vs. Depth



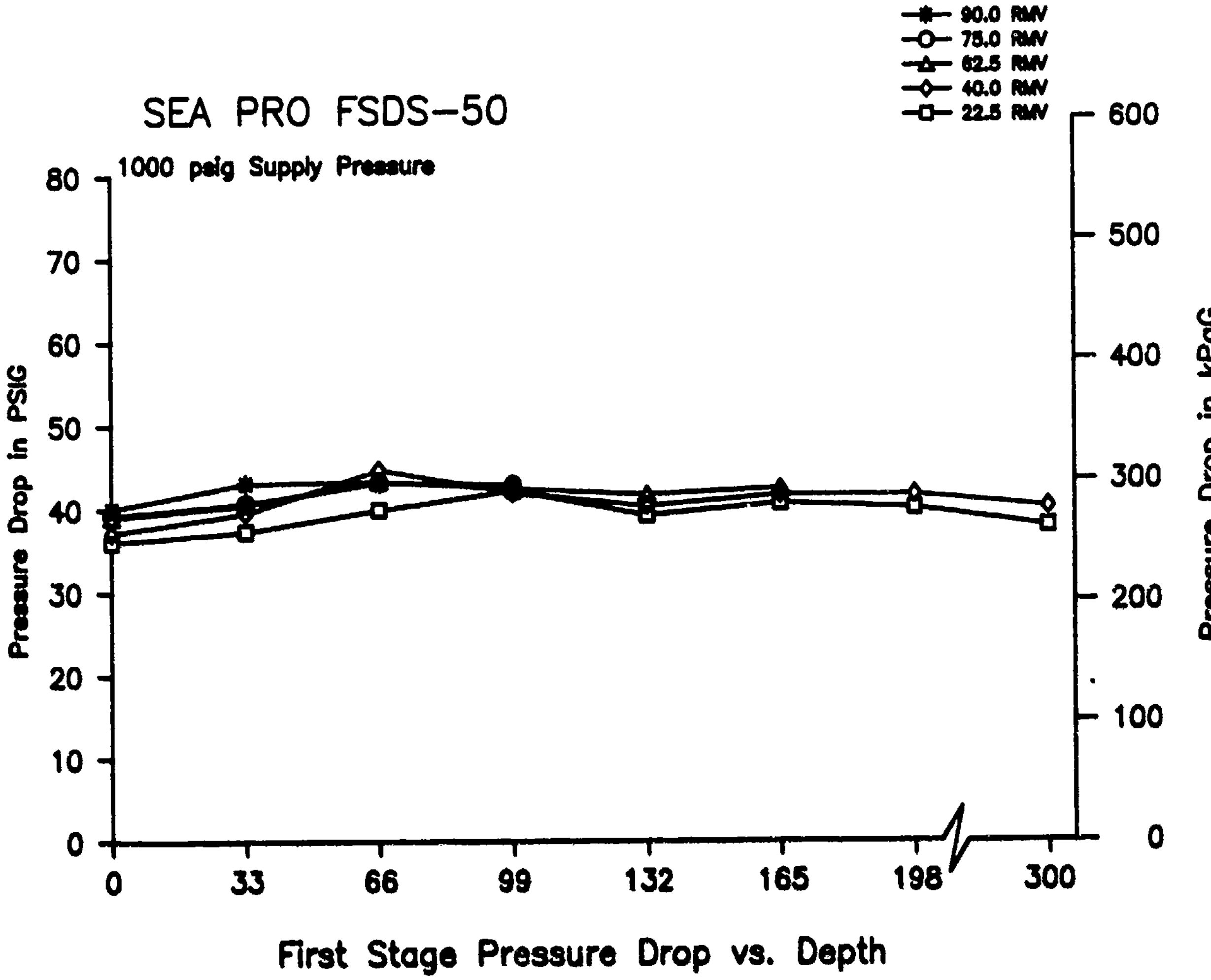
Breathing Resistance vs. Depth

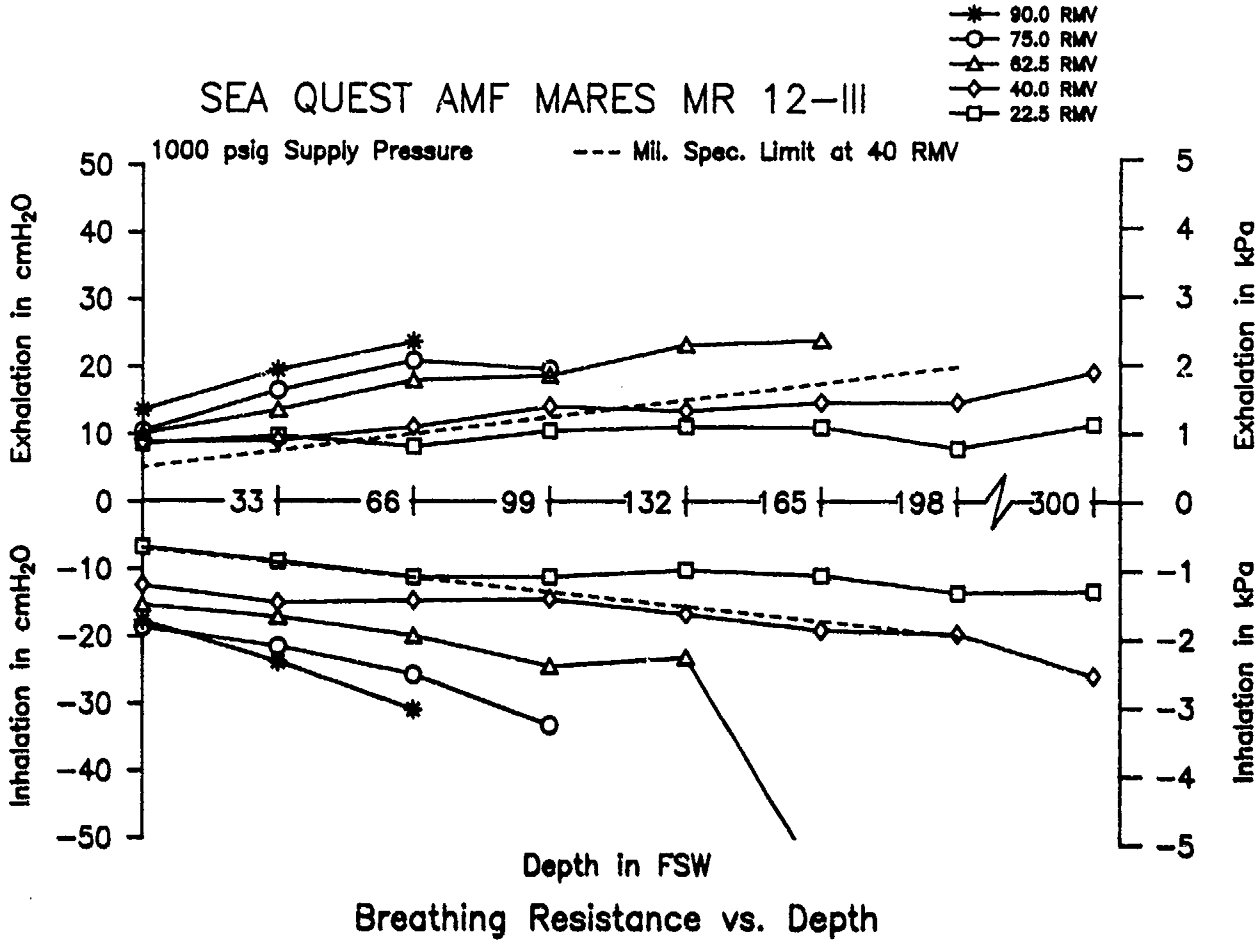


Breathing Resistance vs. Depth

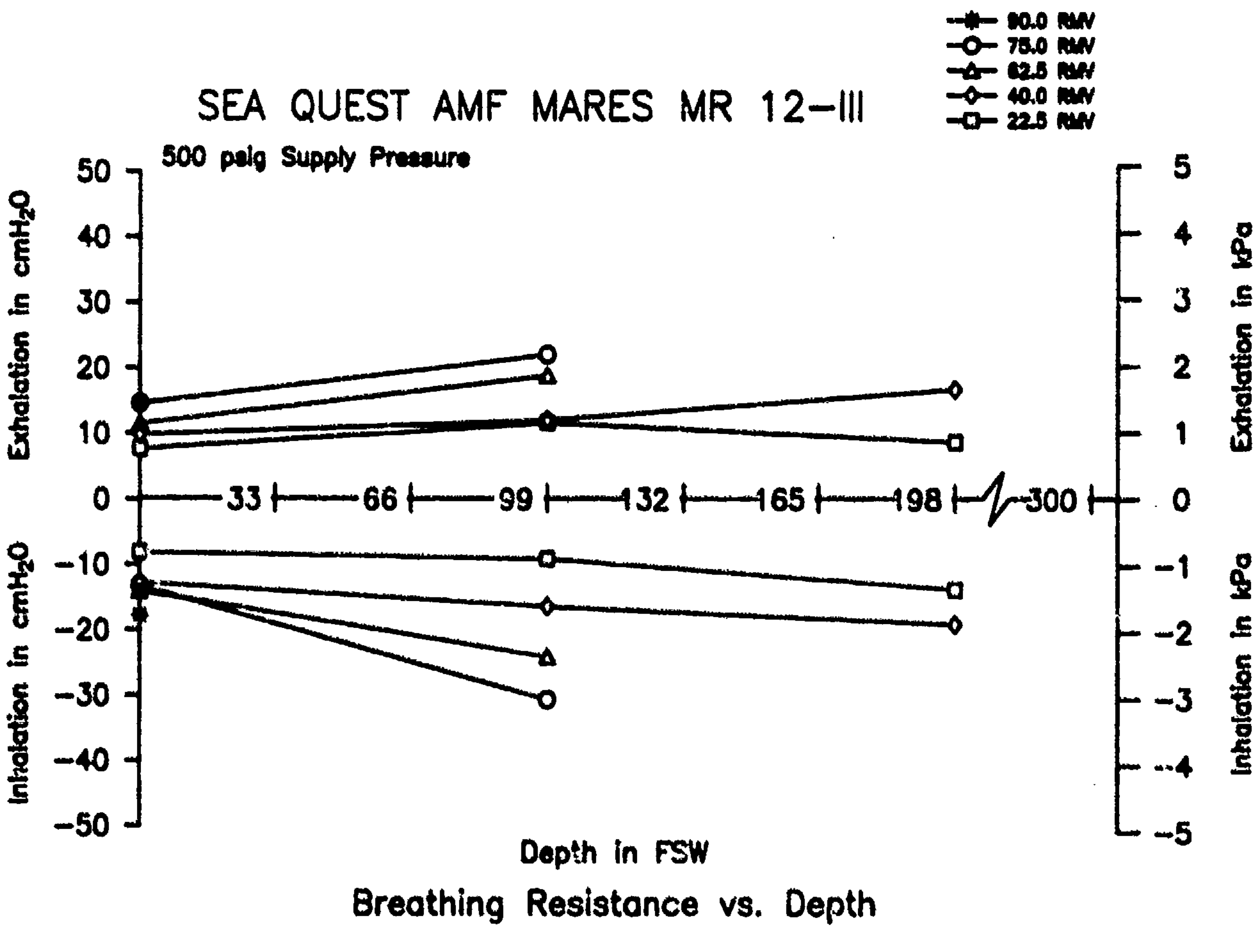


Breathing Work vs. Depth

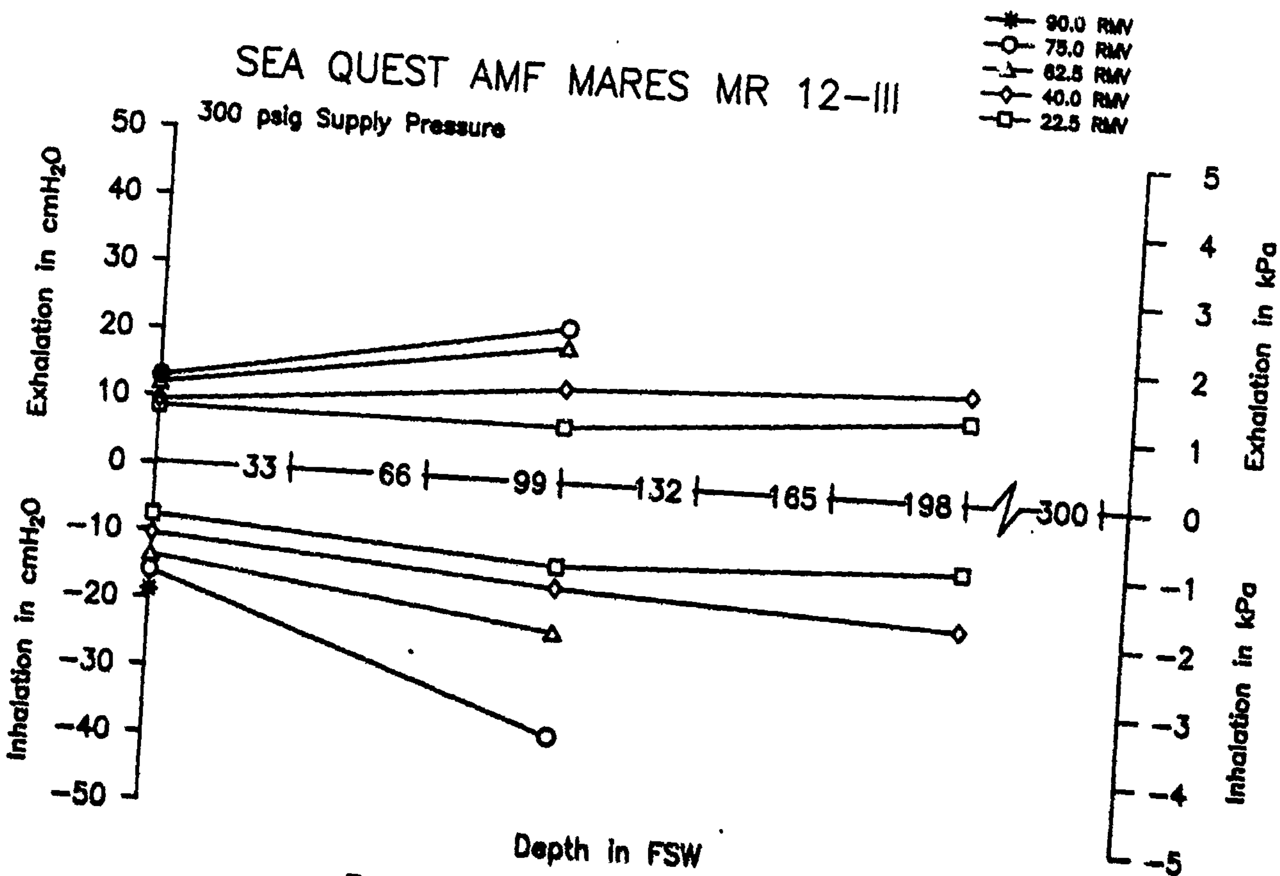

SEA PRO FSDS-50
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
80
70
60
50
40
30
20
10
0
600
500
400
300
200
100
0
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth



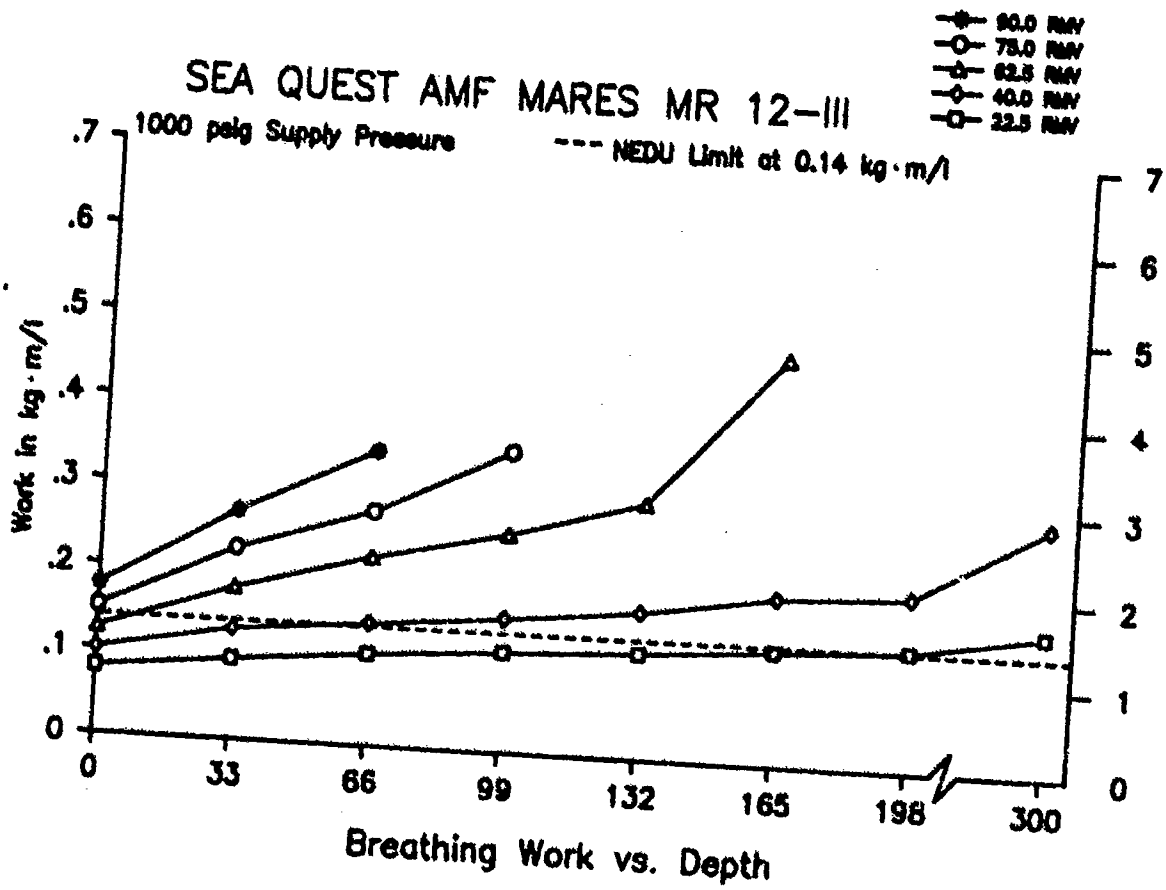
SEA QUEST AMF MARES MR 12-III
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
-10
-20
-30
-40
-50
5
4
3
2
1
0
-1
-2
-3
-4
-5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



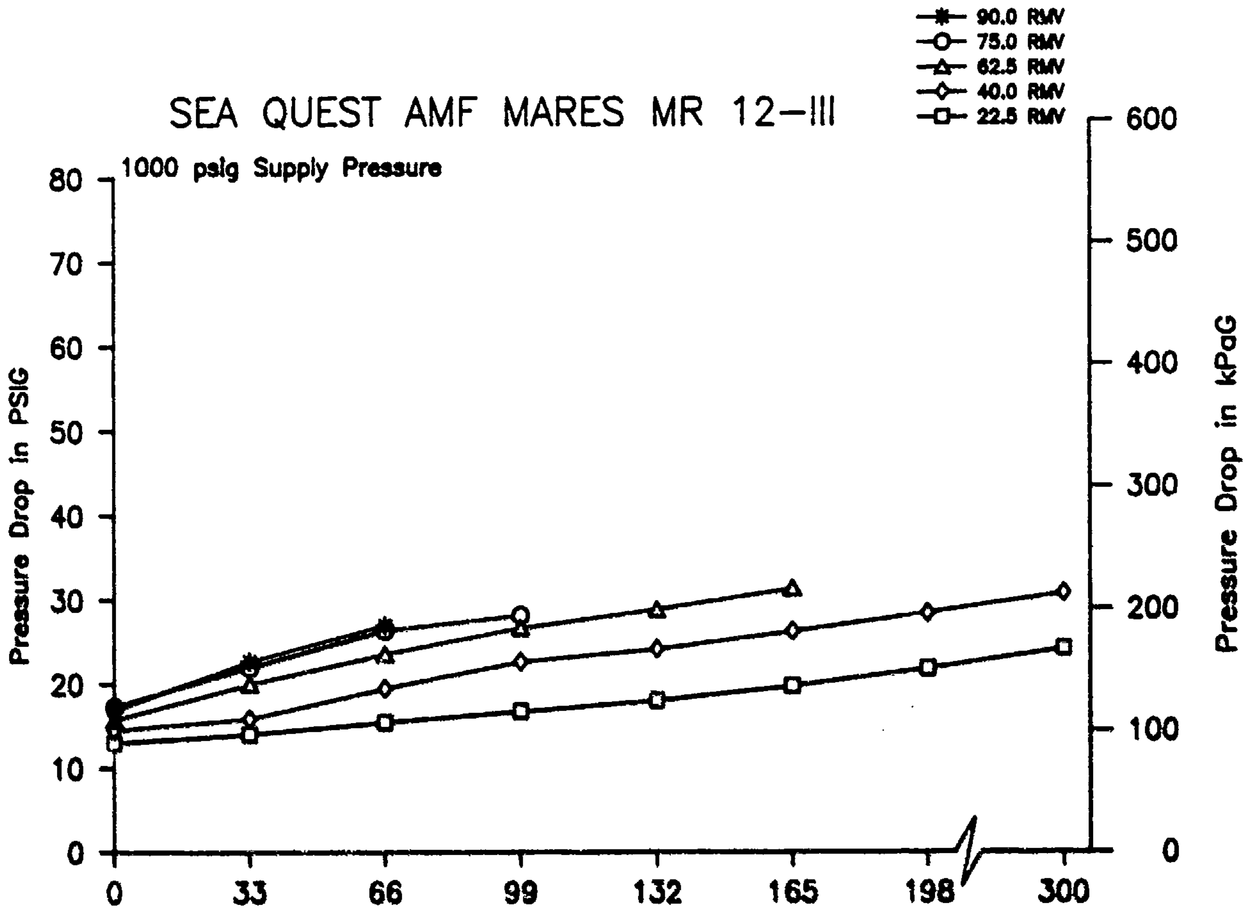
SEA QUEST AMF MARES MR 12-III
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
500 psig Supply Pressure
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
-10
-20
-30
-40
-50
5
4
3
2
1
0
-1
-2
-3
-4
-5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



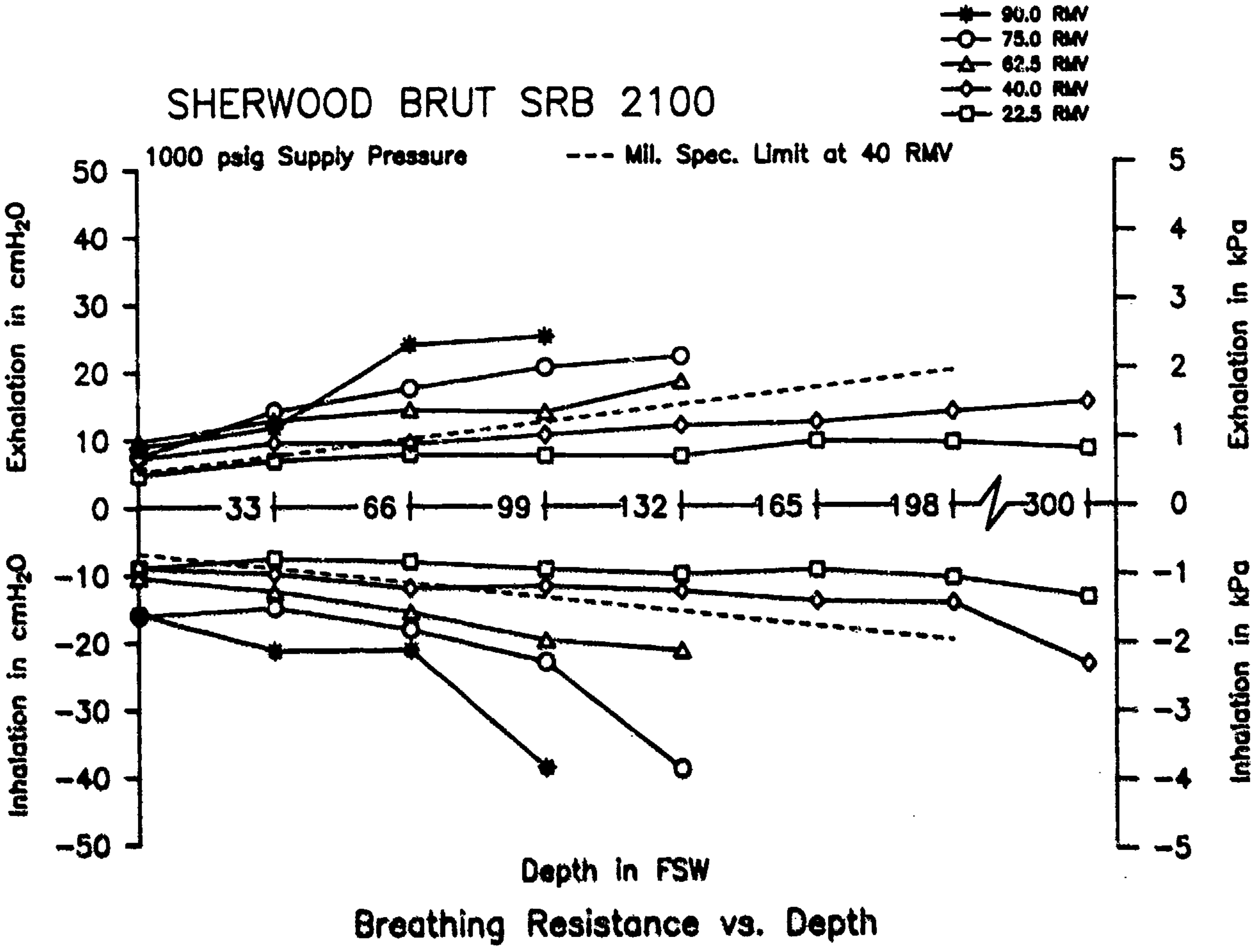
Breathing Resistance vs. Depth

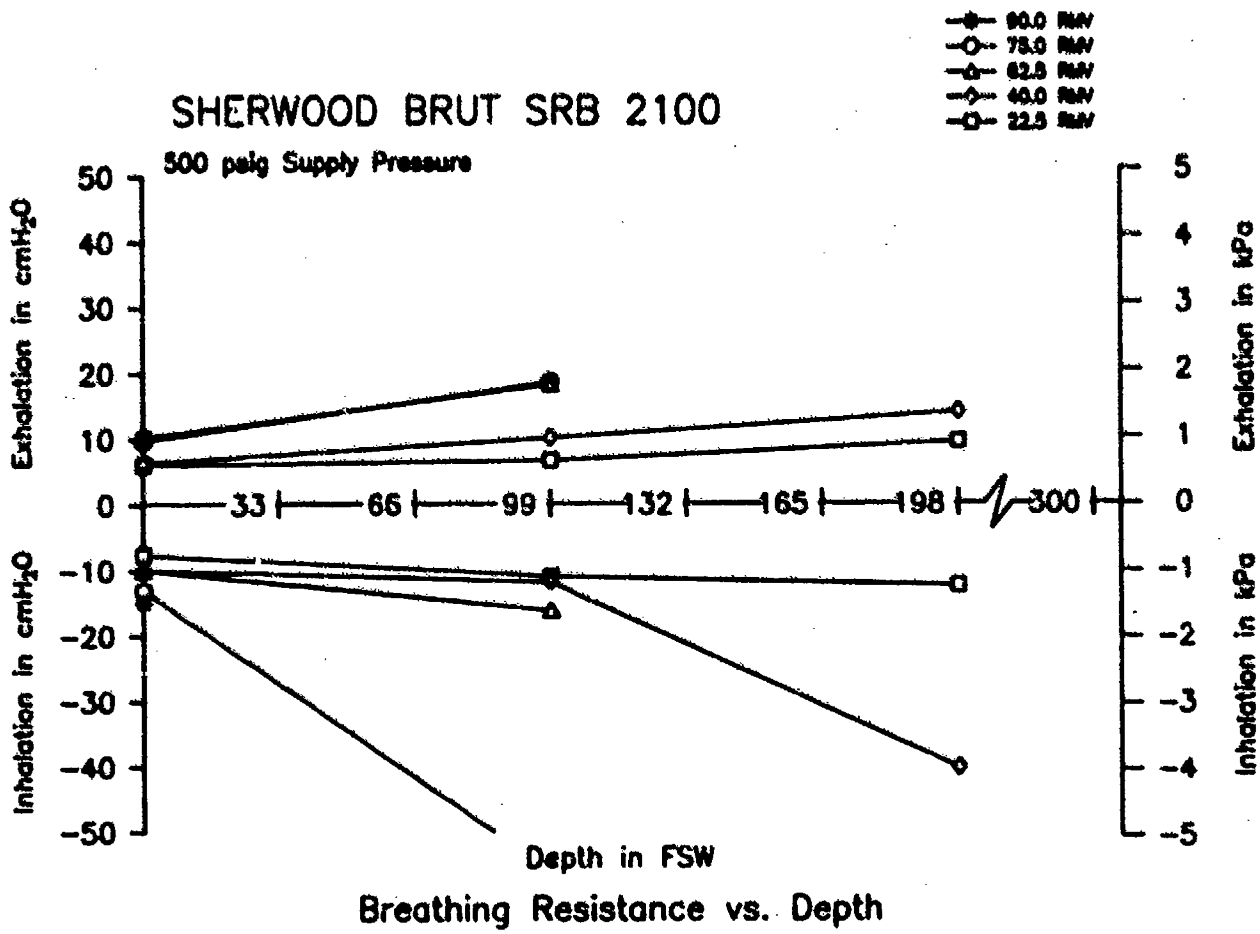


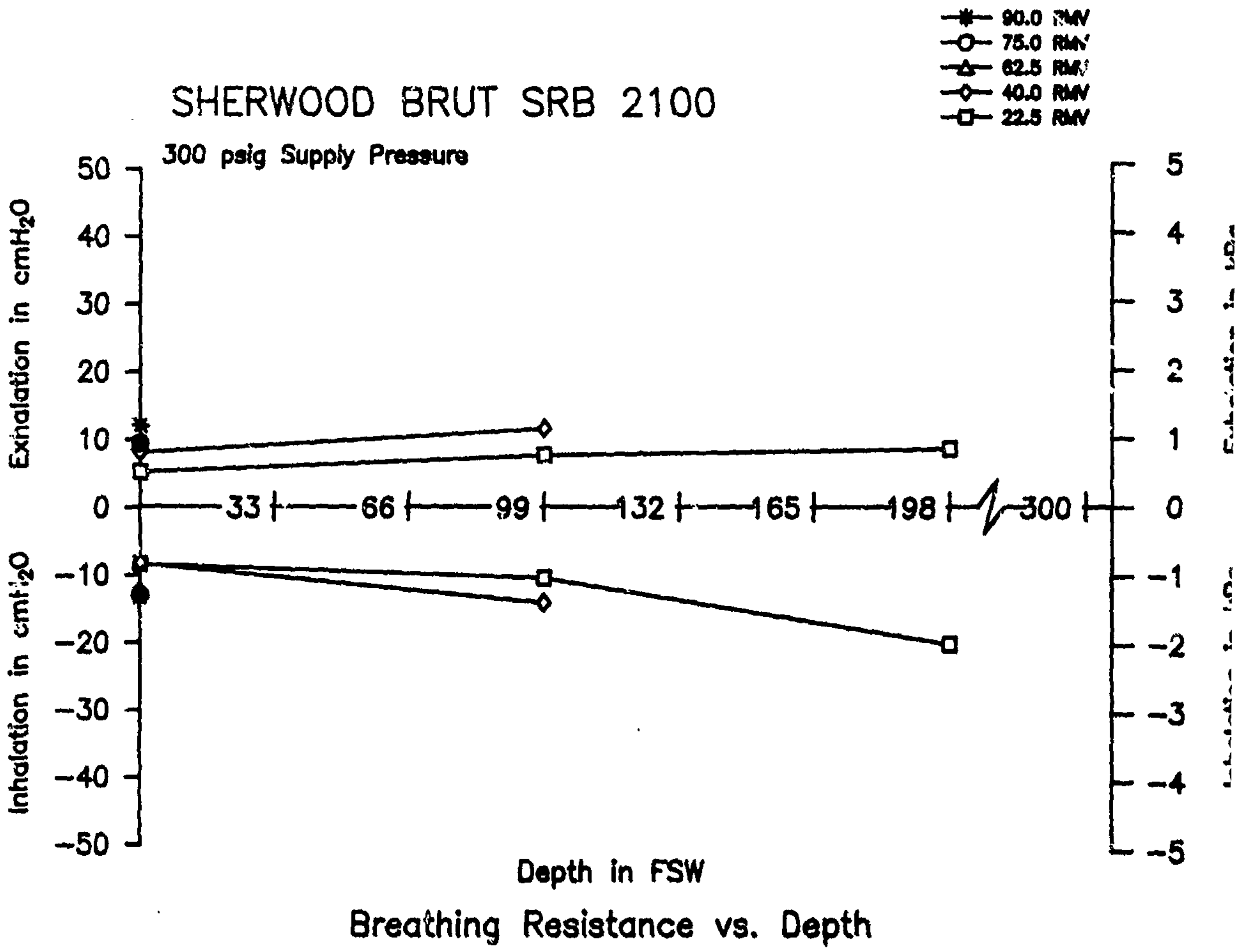
Breathing Work vs. Depth

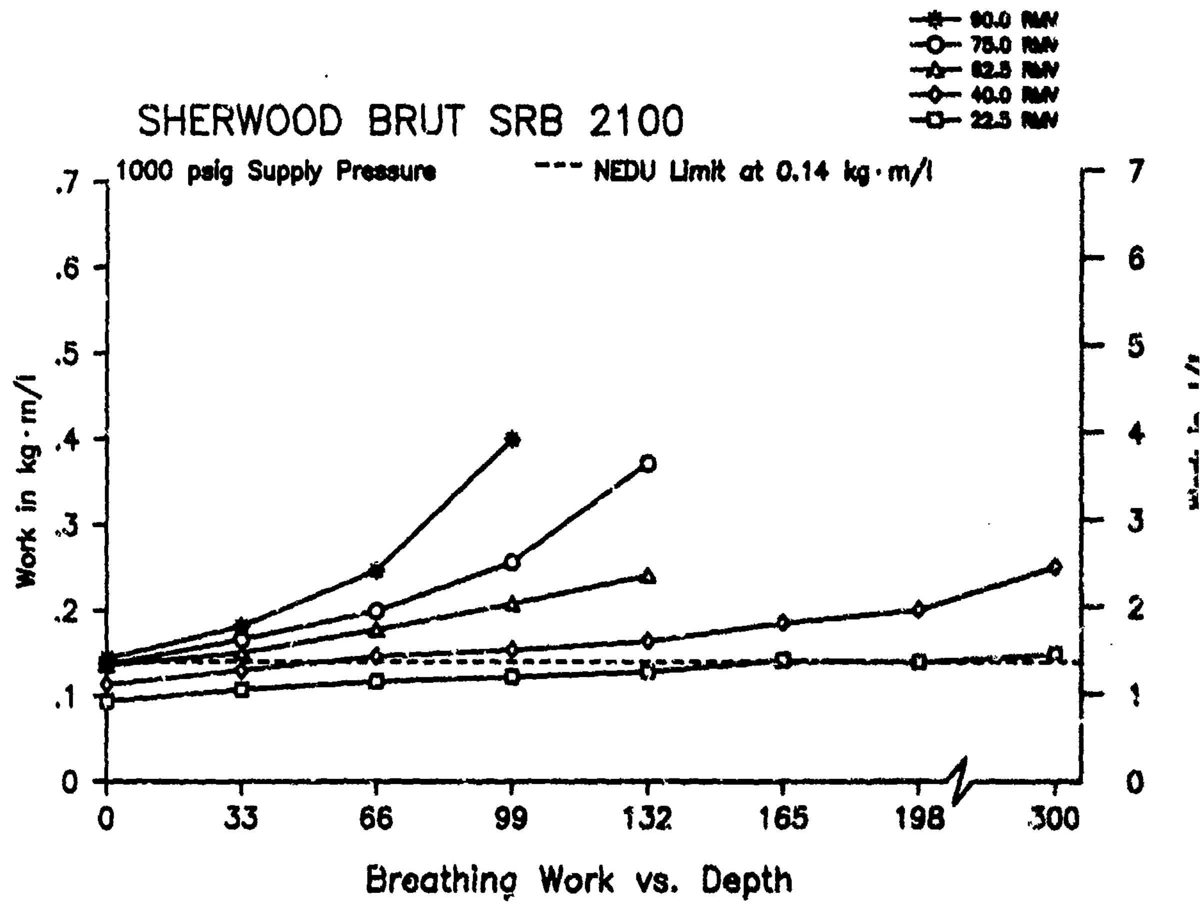


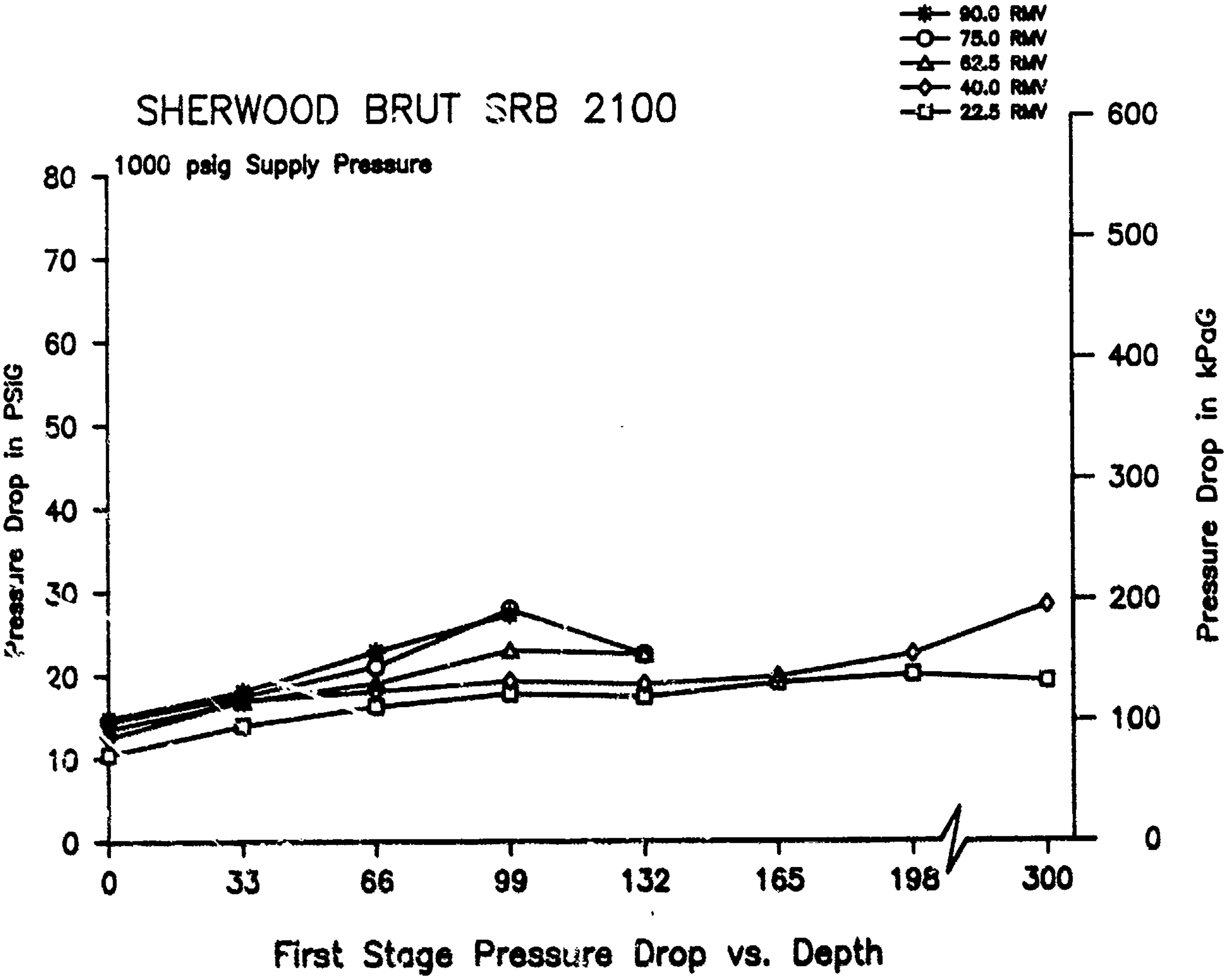
First Stage Pressure Drop vs. Depth


SHERWOOD BRUT SRB 2100
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
Depth in FSW
Breathing Resistance vs. Depth

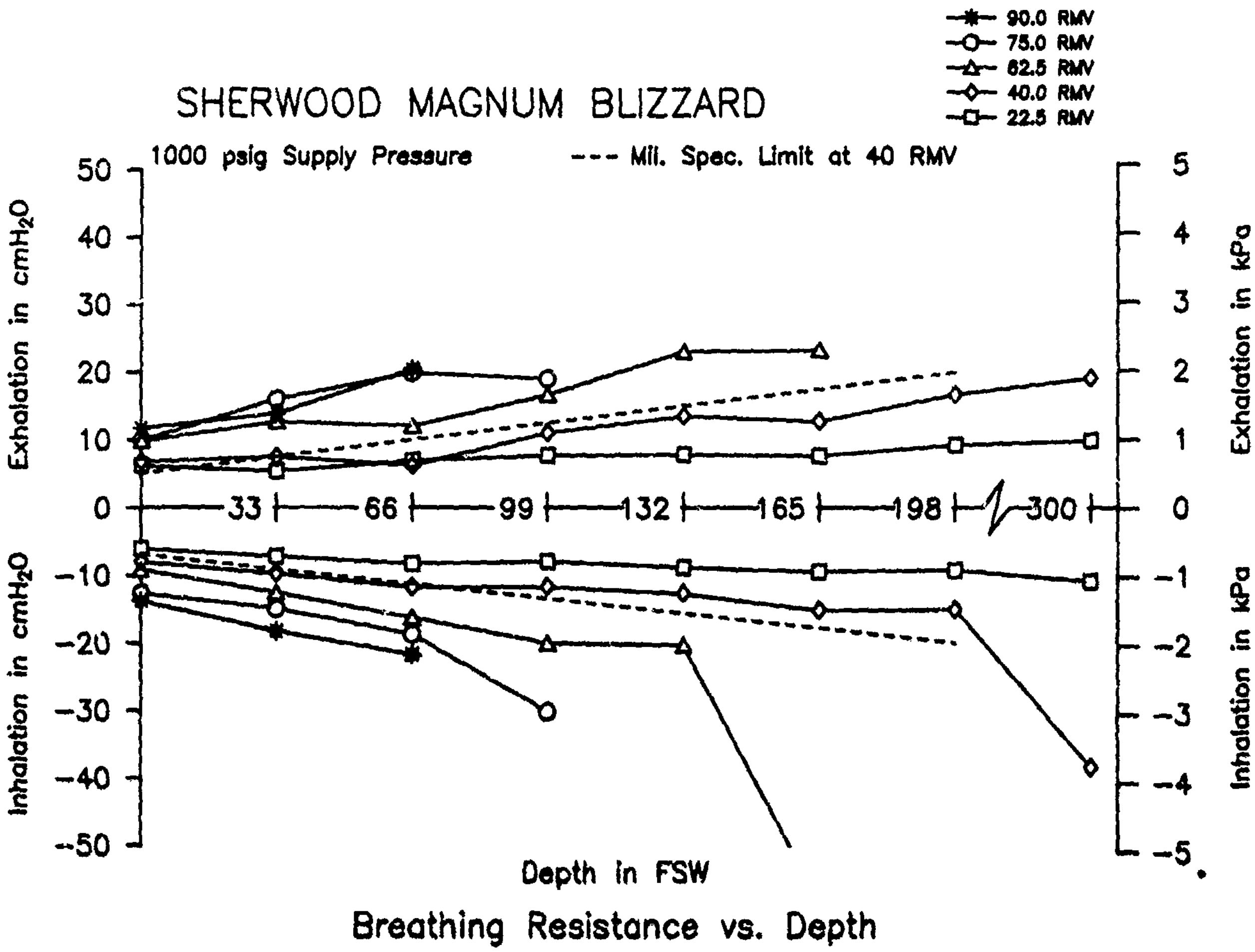

SHERWOOD BRUT SRB 2100
500 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
Depth in FSW
Breathing Resistance vs. Depth


SHERWOOD BRUT SRB 2100
300 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH2O
Inhalation in cmH2O
Depth in FSW
Breathing Resistance vs. Depth

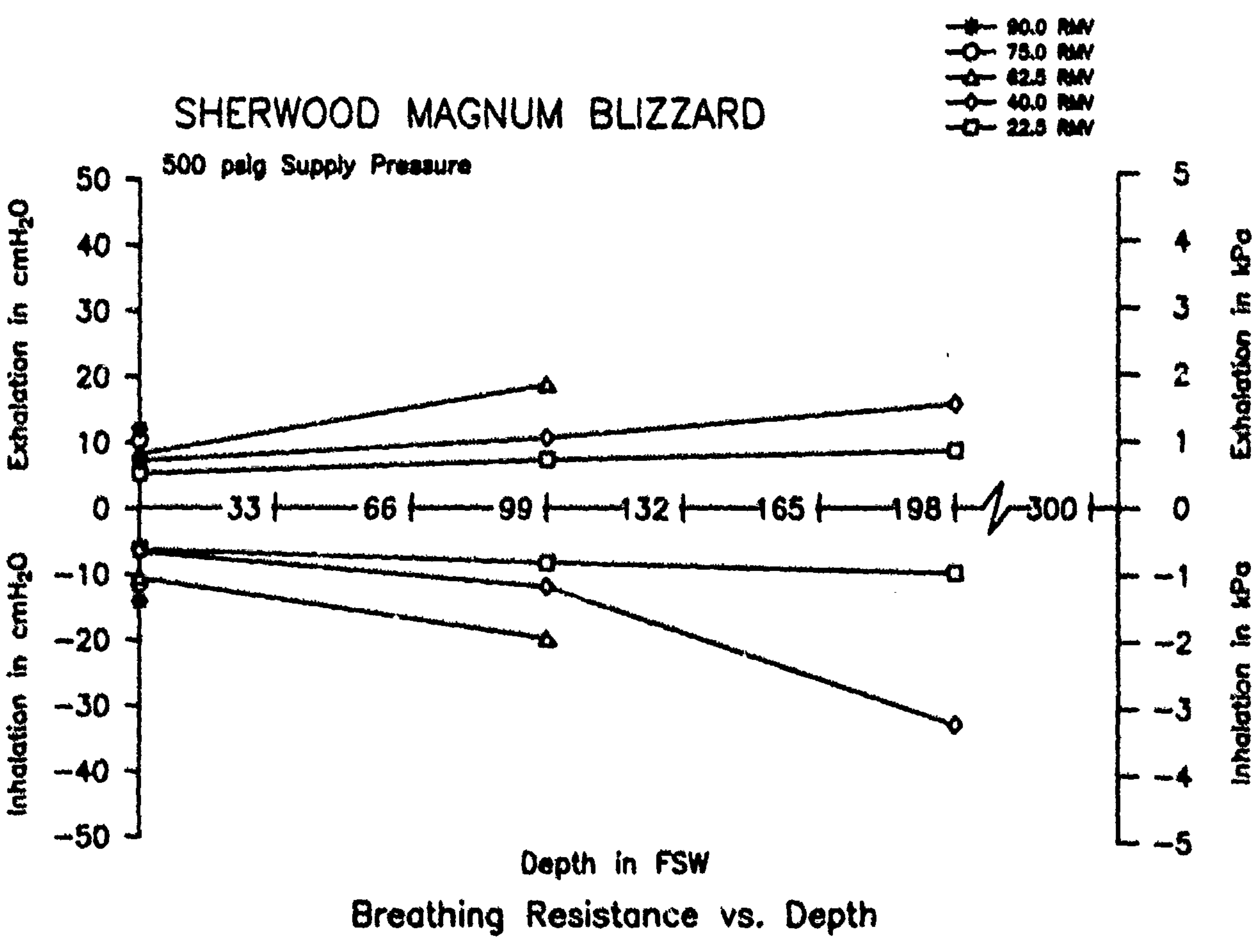

SHERWOOD BRUT SRB 2100
1000 psig Supply Pressure
NEDU Limit at 0.14 kg·m/l
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Work in kg·m/l
Breathing Work vs. Depth



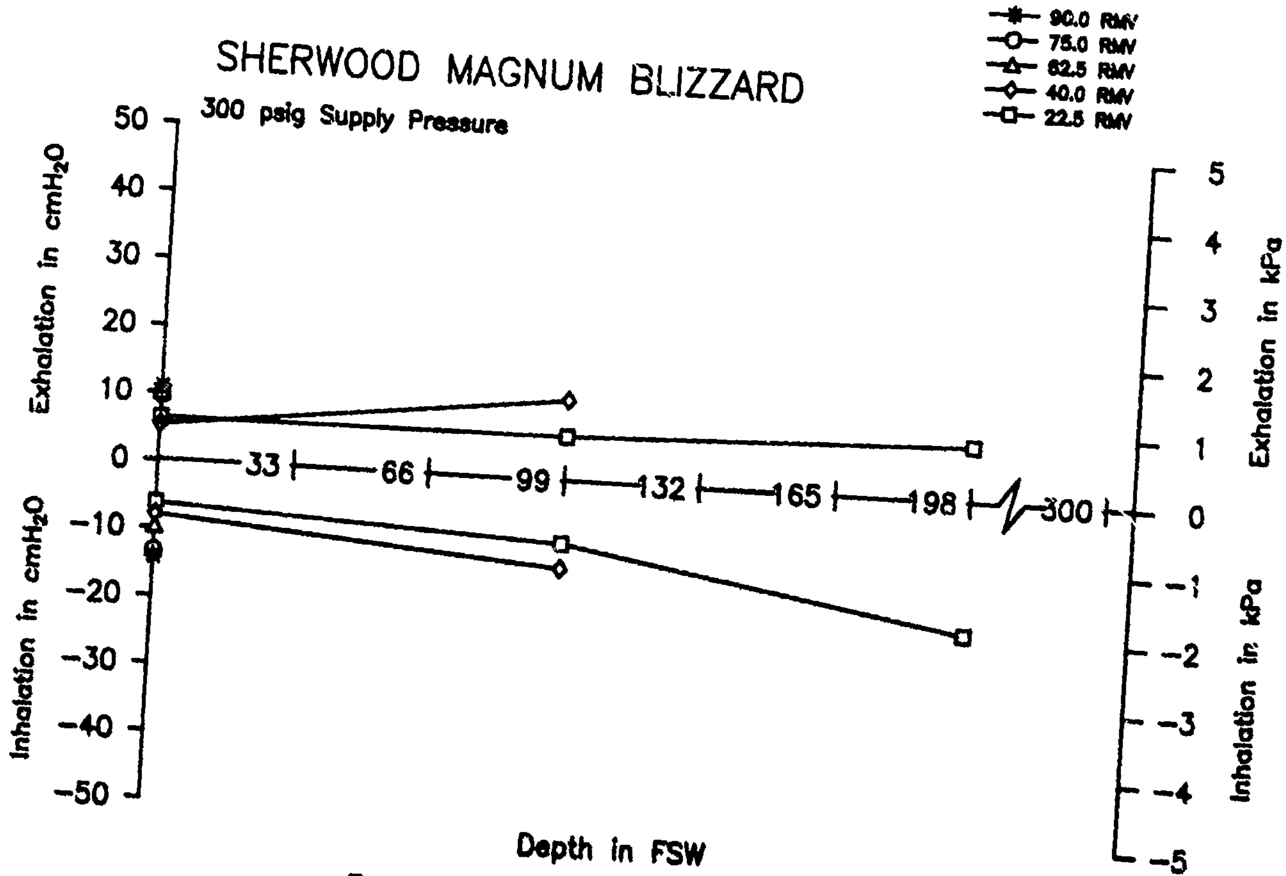
SHERWOOD BRUT SRB 2100
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
Pressure Drop in kPaG
0
10
20
30
40
50
60
70
80
0
100
200
300
400
500
600
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth



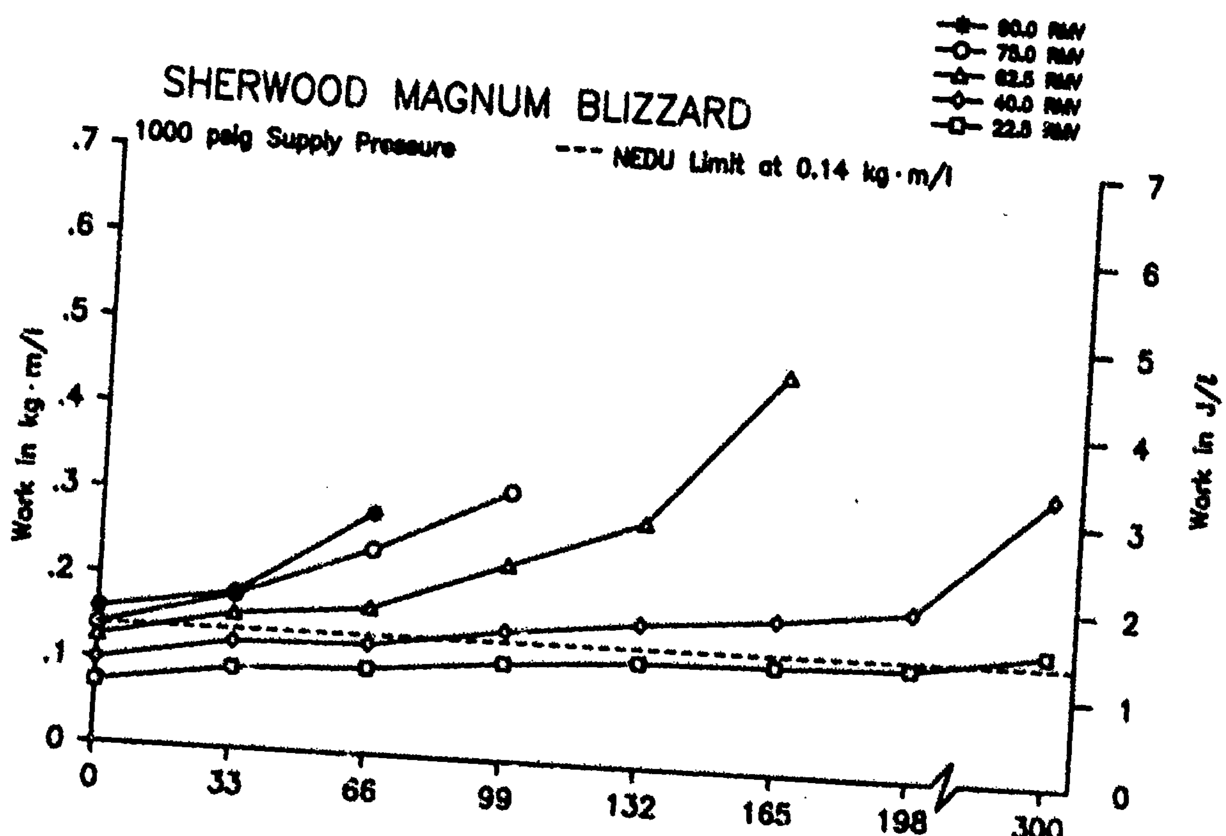
SHERWOOD MAGNUM BLIZZARD
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
−10
−20
−30
−40
−50
5
4
3
2
1
0
−1
−2
−3
−4
−5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



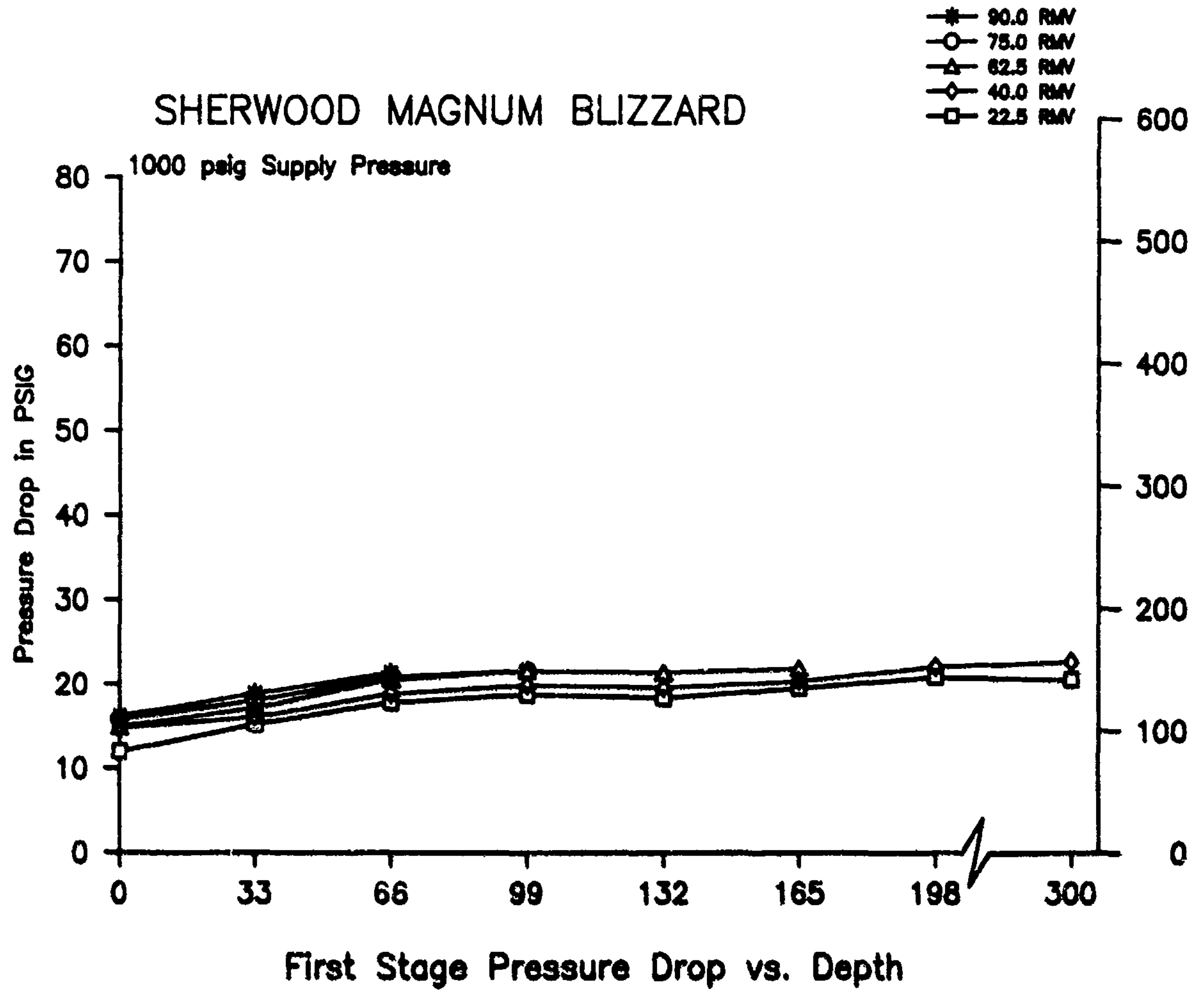
SHERWOOD MAGNUM BLIZZARD
500 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
−10
−20
−30
−40
−50
5
4
3
2
1
0
−1
−2
−3
−4
−5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



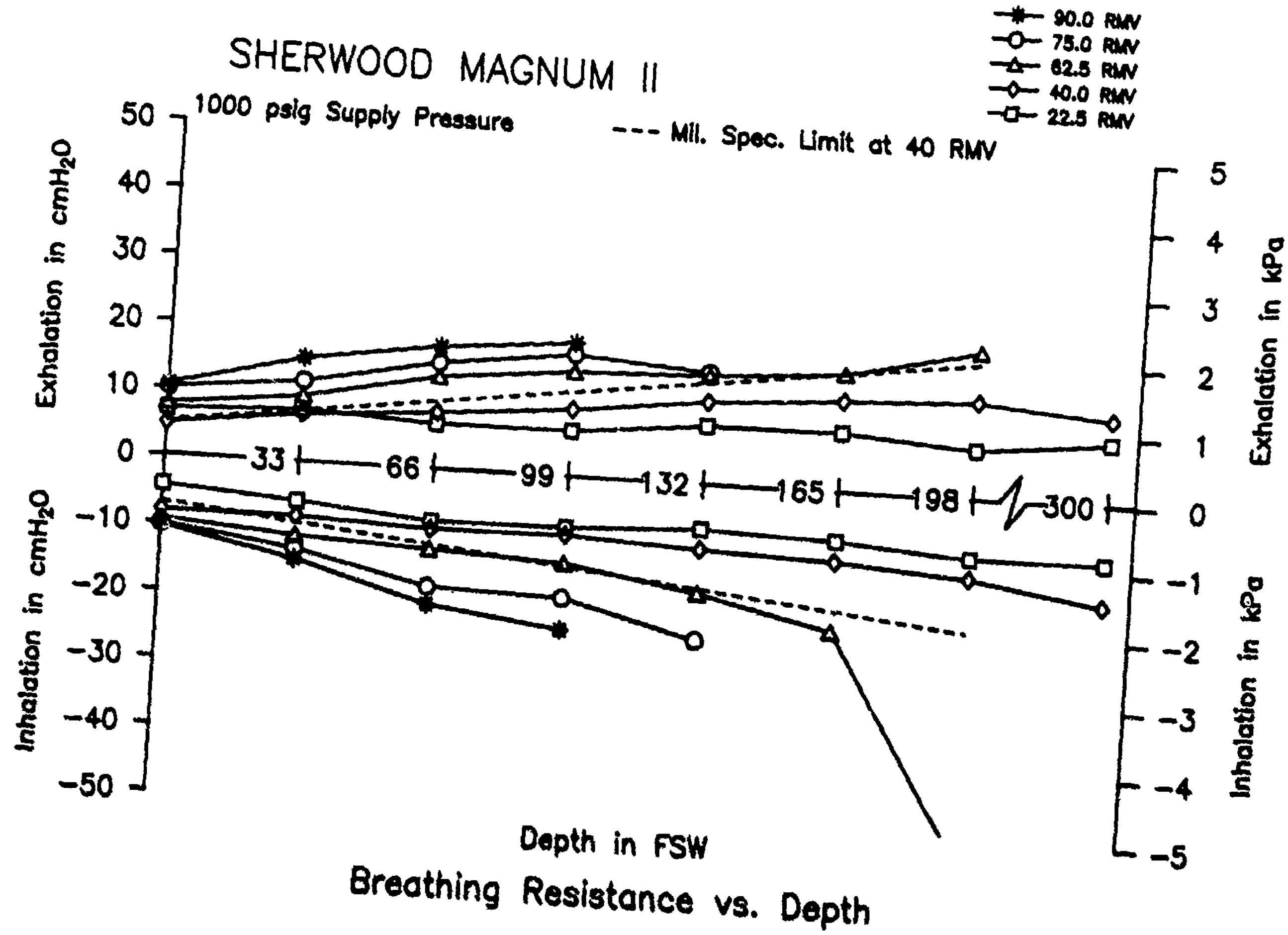
Breathing Resistance vs. Depth

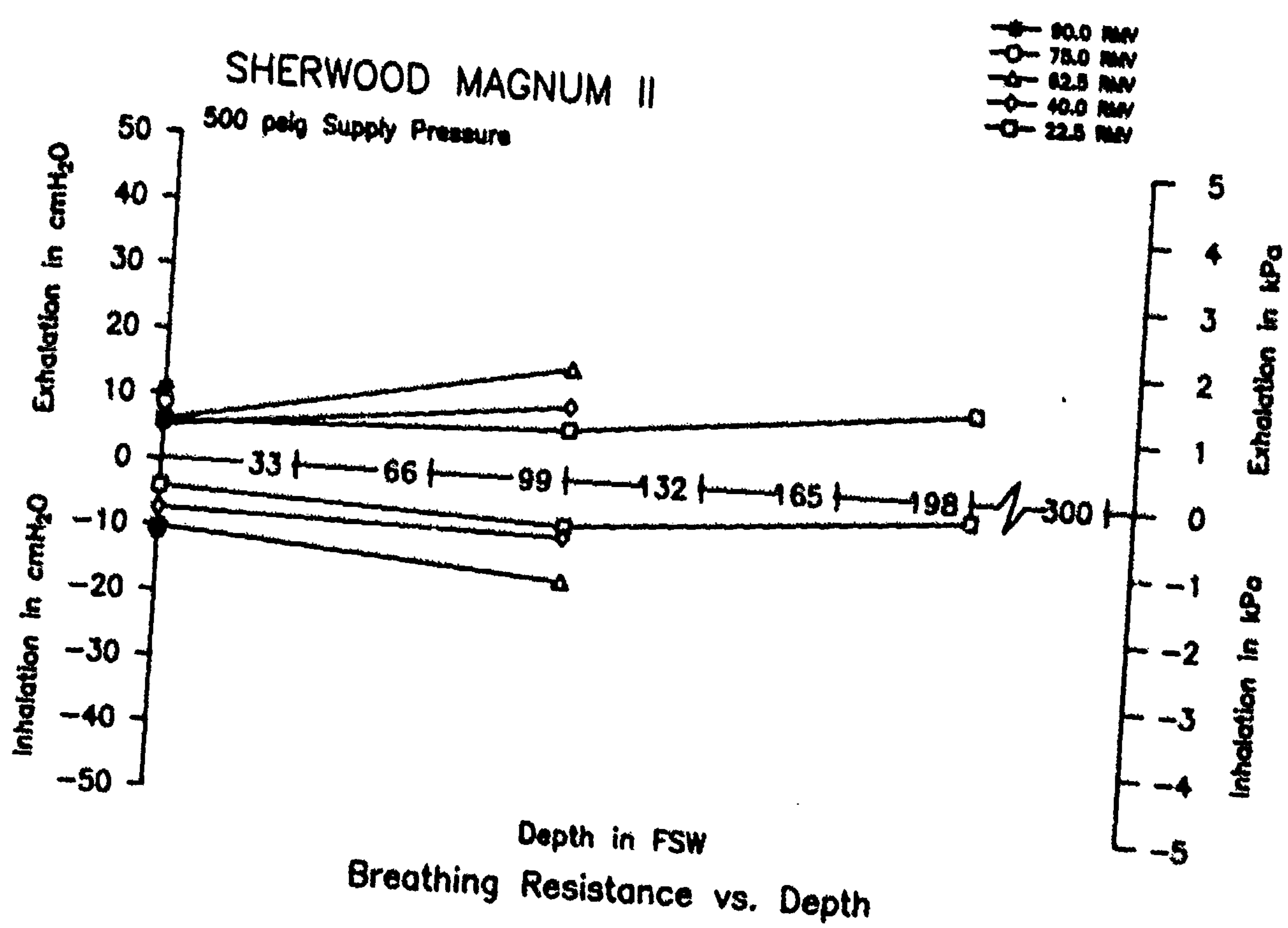


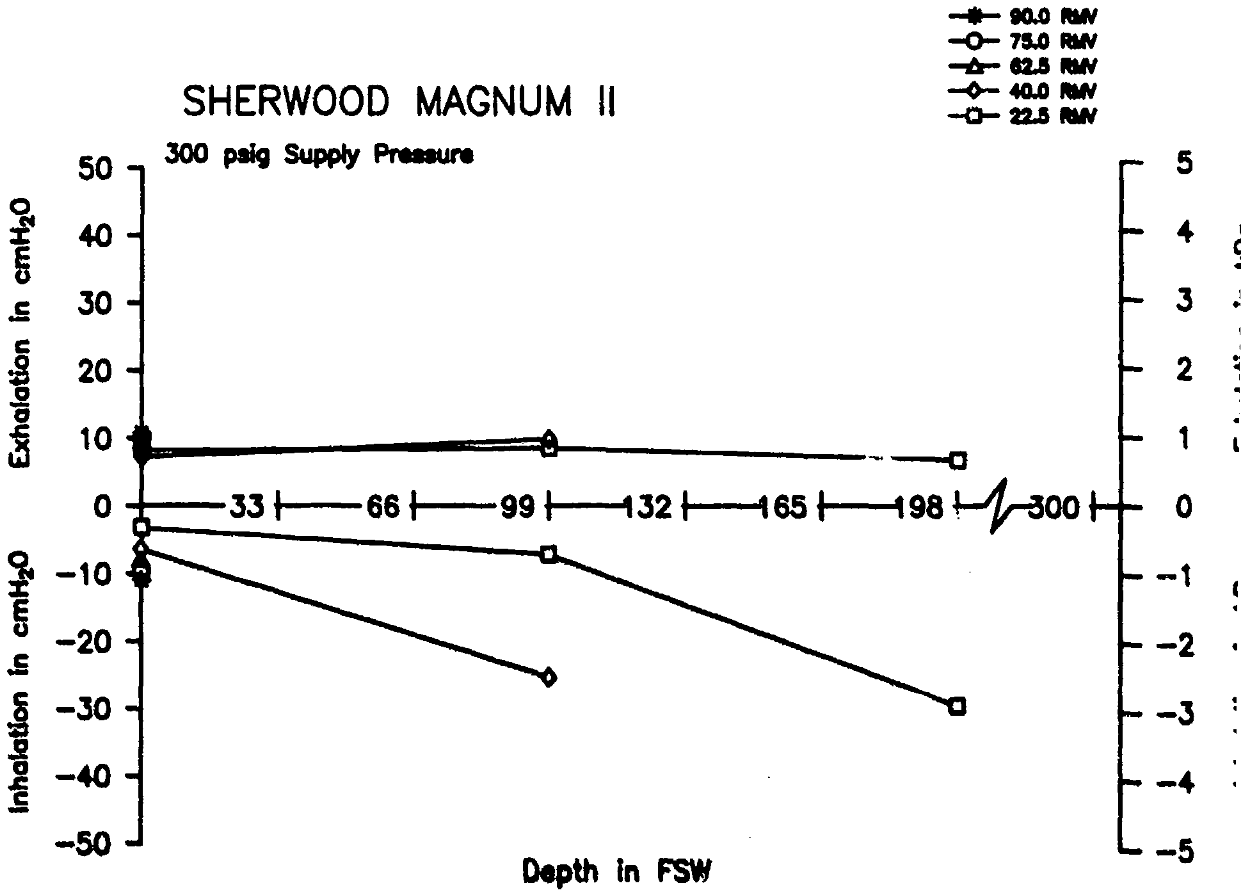
Breathing Work vs. Depth



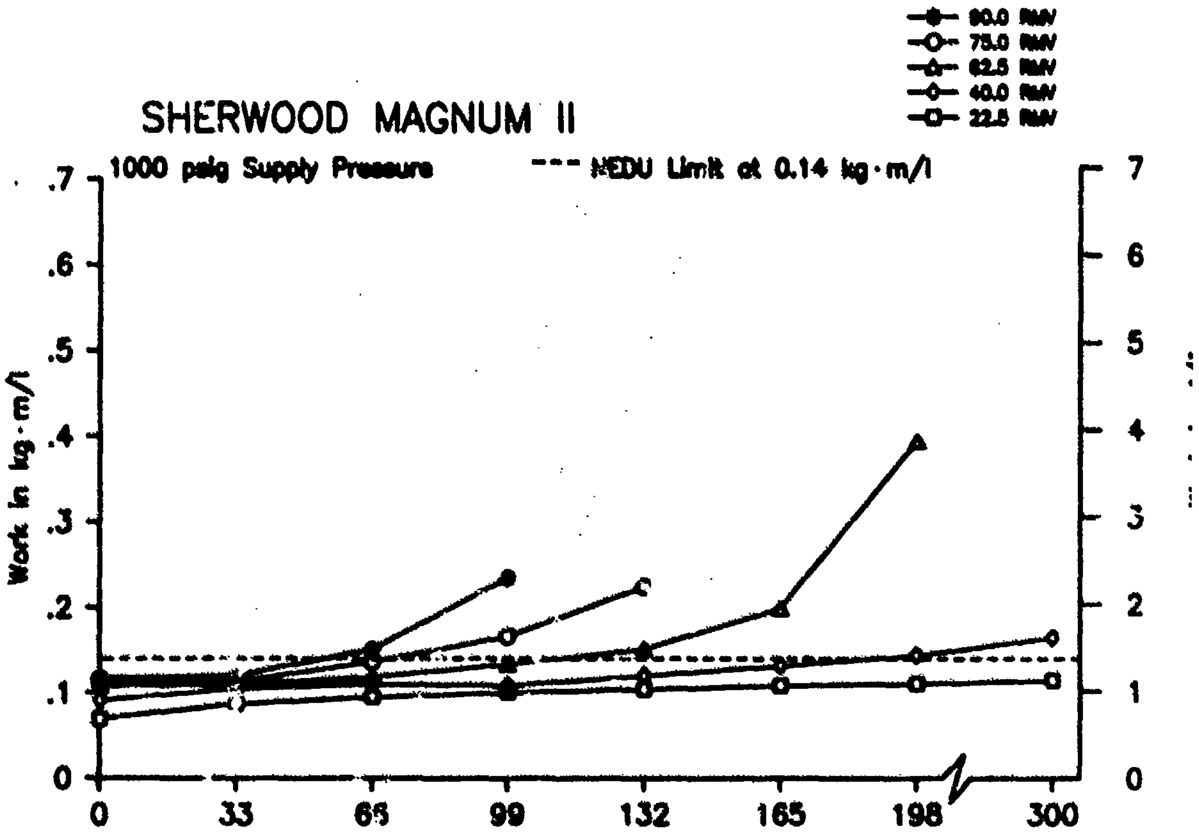
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
SHERWOOD MAGNUM BLIZZARD
1000 psig Supply Pressure
Pressure Drop in PSIG
0
10
20
30
40
50
60
70
80
0
100
200
300
400
500
600
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth


SHERWOOD MAGNUM II
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
-10
-20
-30
-40
-50
5
4
3
2
1
0
-1
-2
-3
-4
-5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth

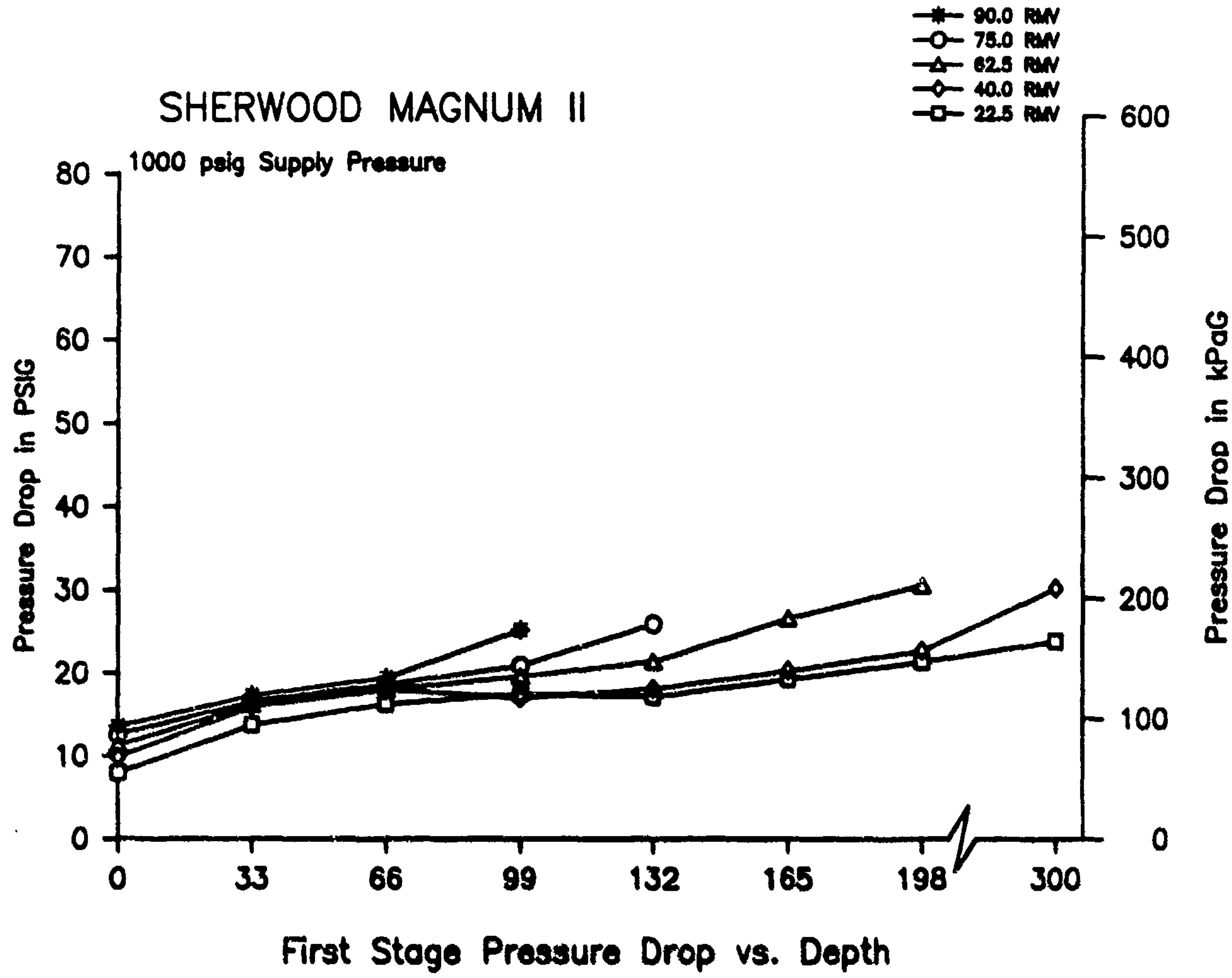

SHERWOOD MAGNUM II
500 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
50
40
30
20
10
0
-10
-20
-30
-40
-50
5
4
3
2
1
0
-1
-2
-3
-4
-5
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



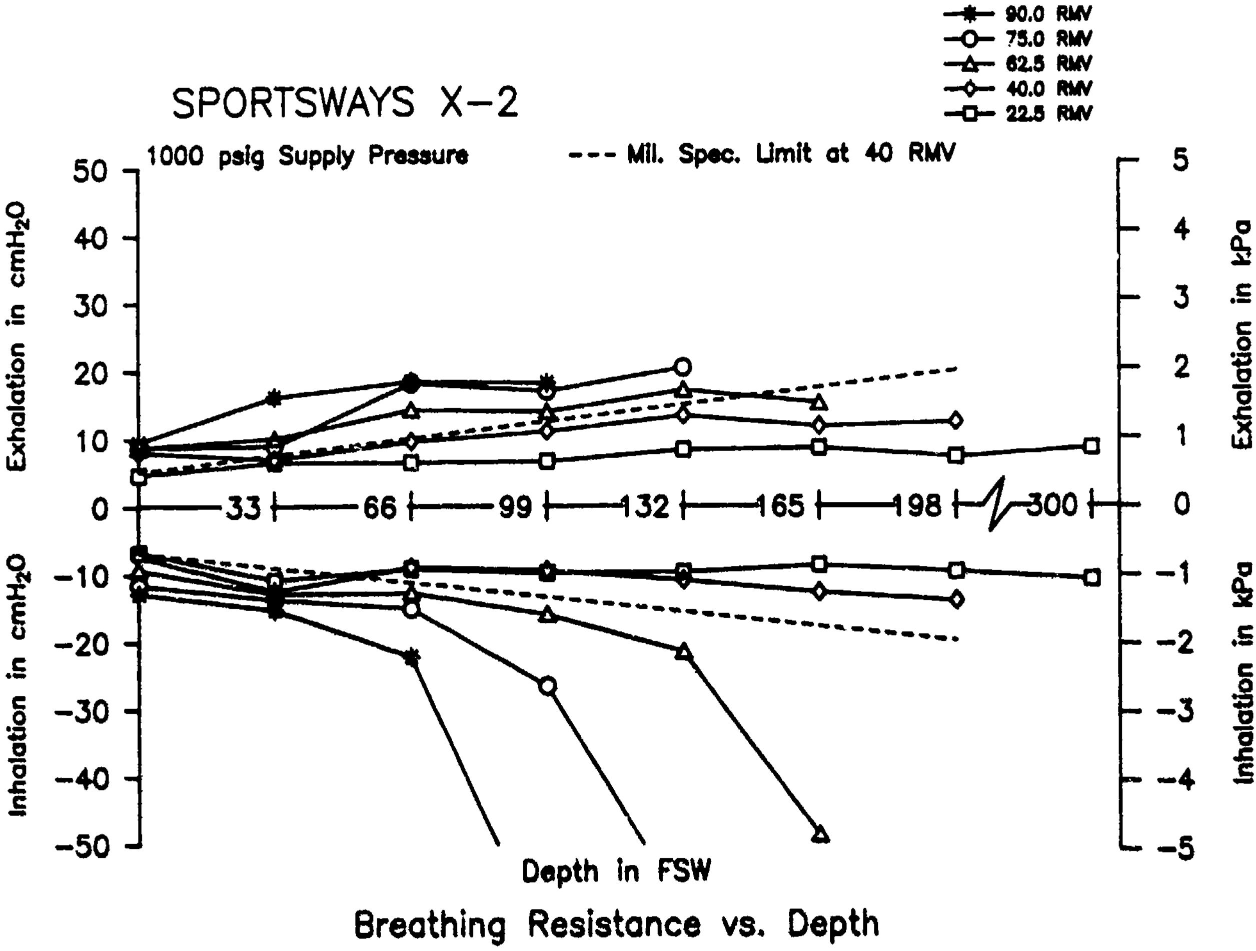
Breathing Resistance vs. Depth



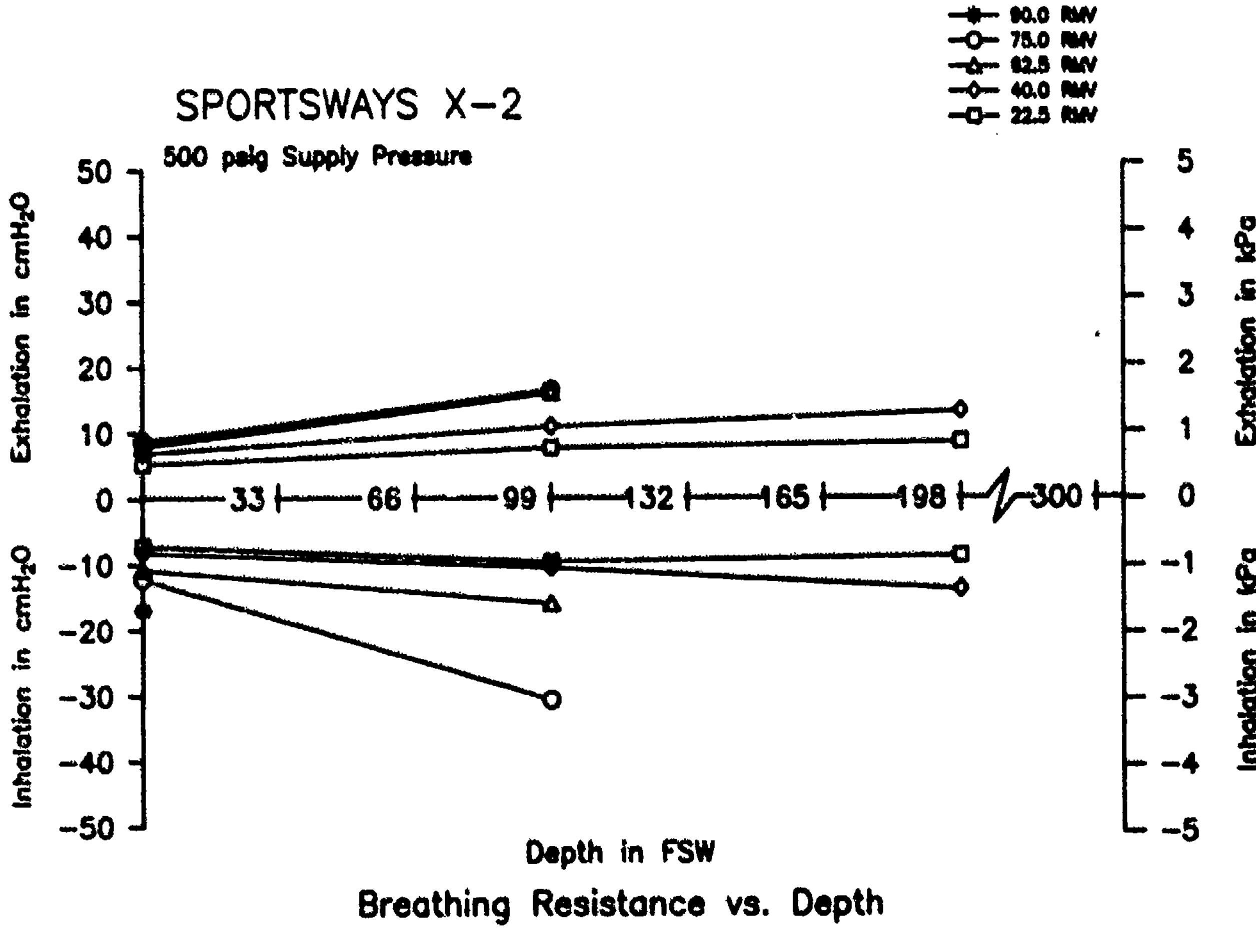
Breathing Work vs. Depth



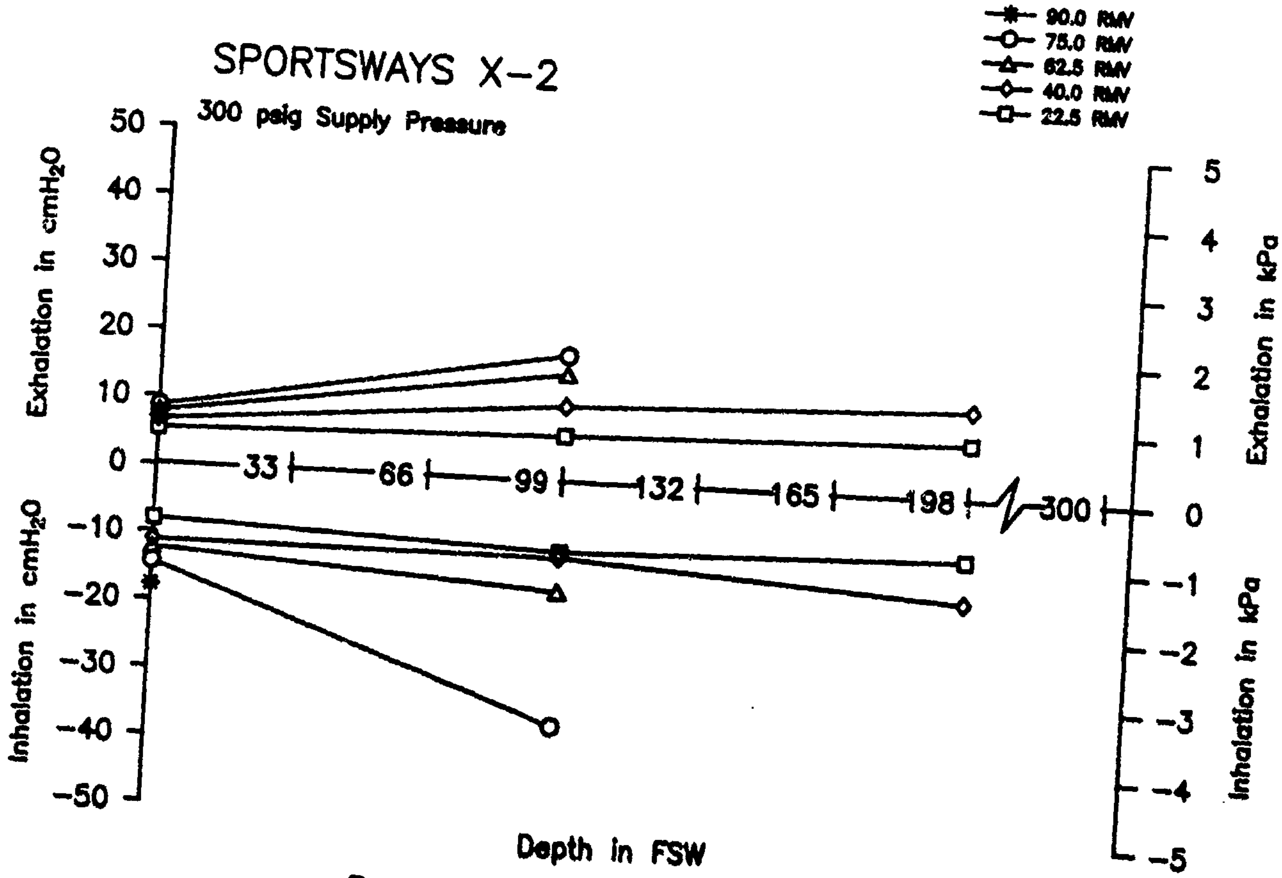
SHERWOOD MAGNUM II
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
Pressure Drop in kPaG
0
10
20
30
40
50
60
70
80
100
200
300
400
500
600
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth



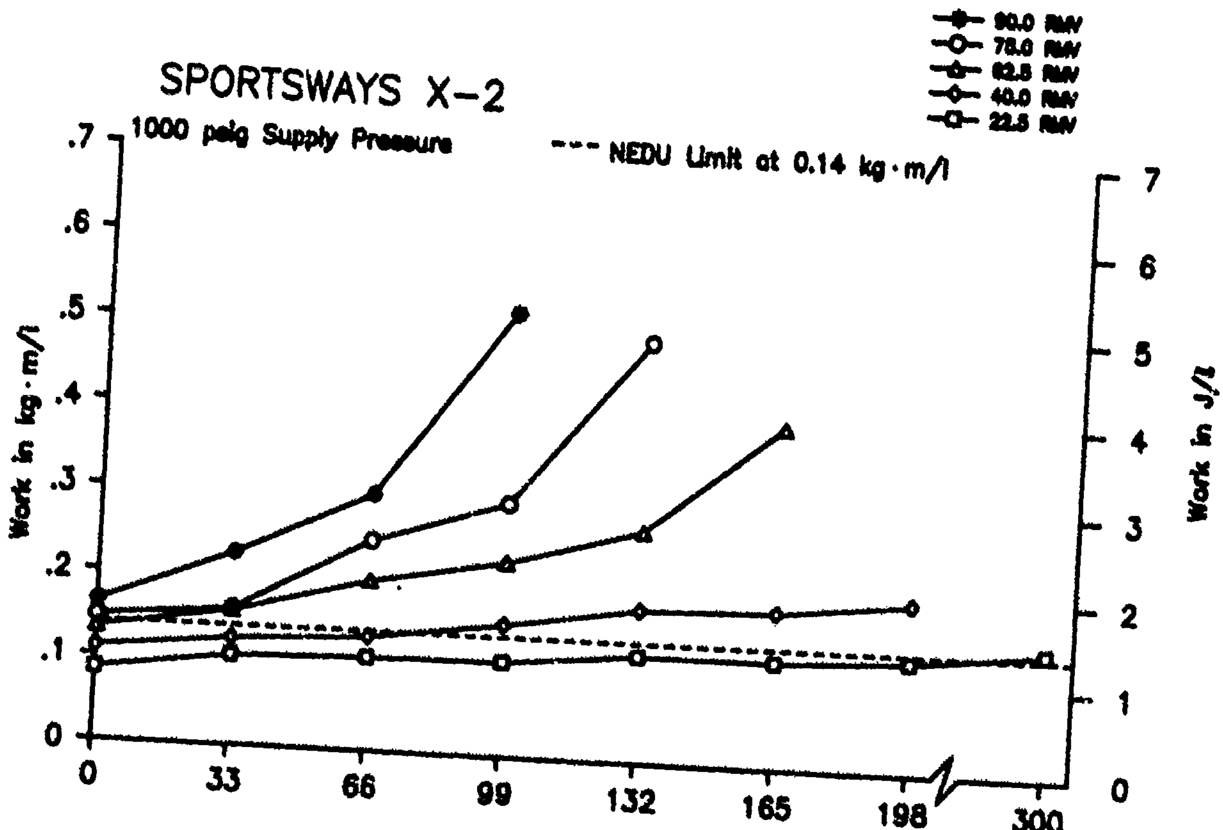
SPORTSWAYS X-2
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



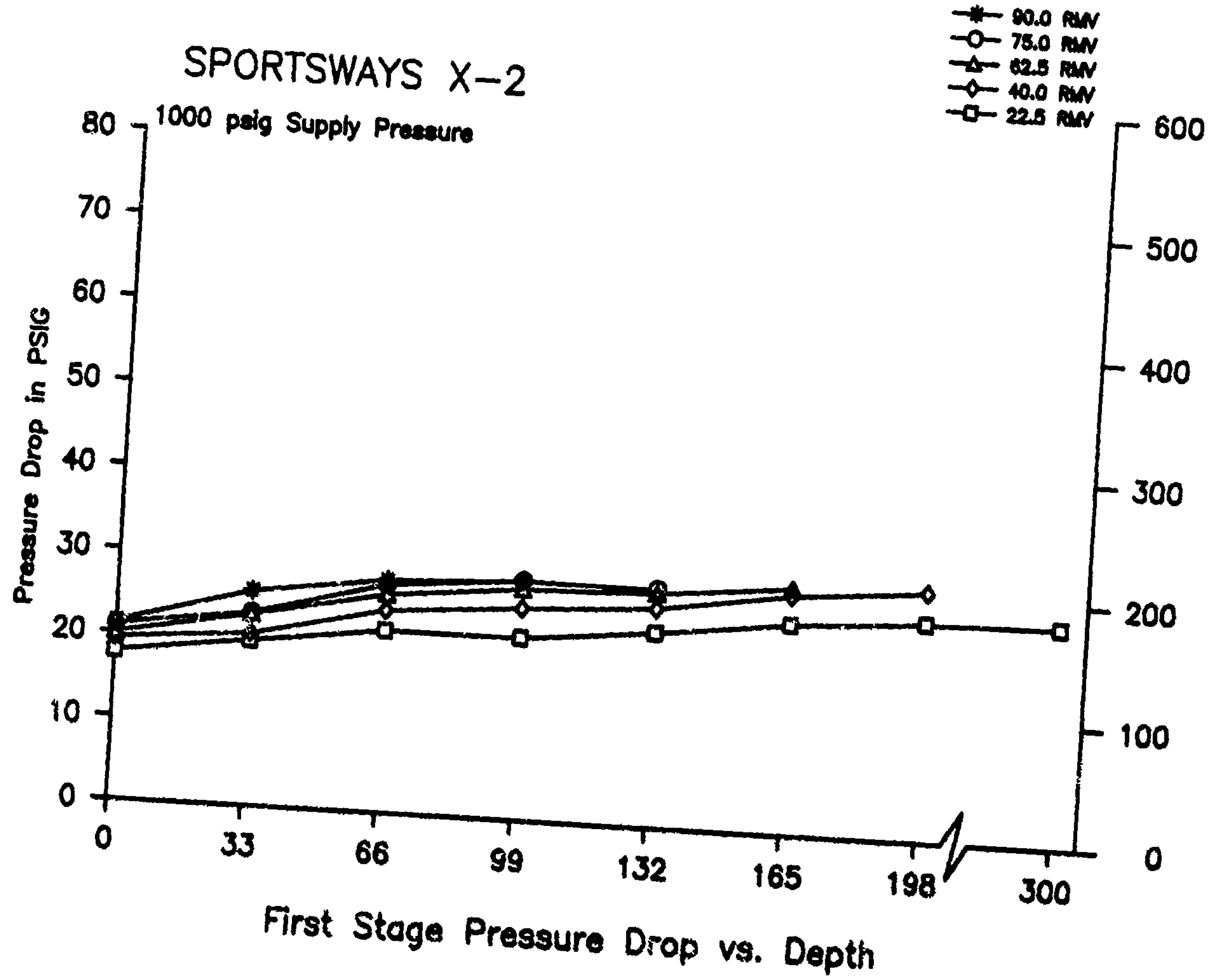
SPORTSWAYS X-2
500 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth

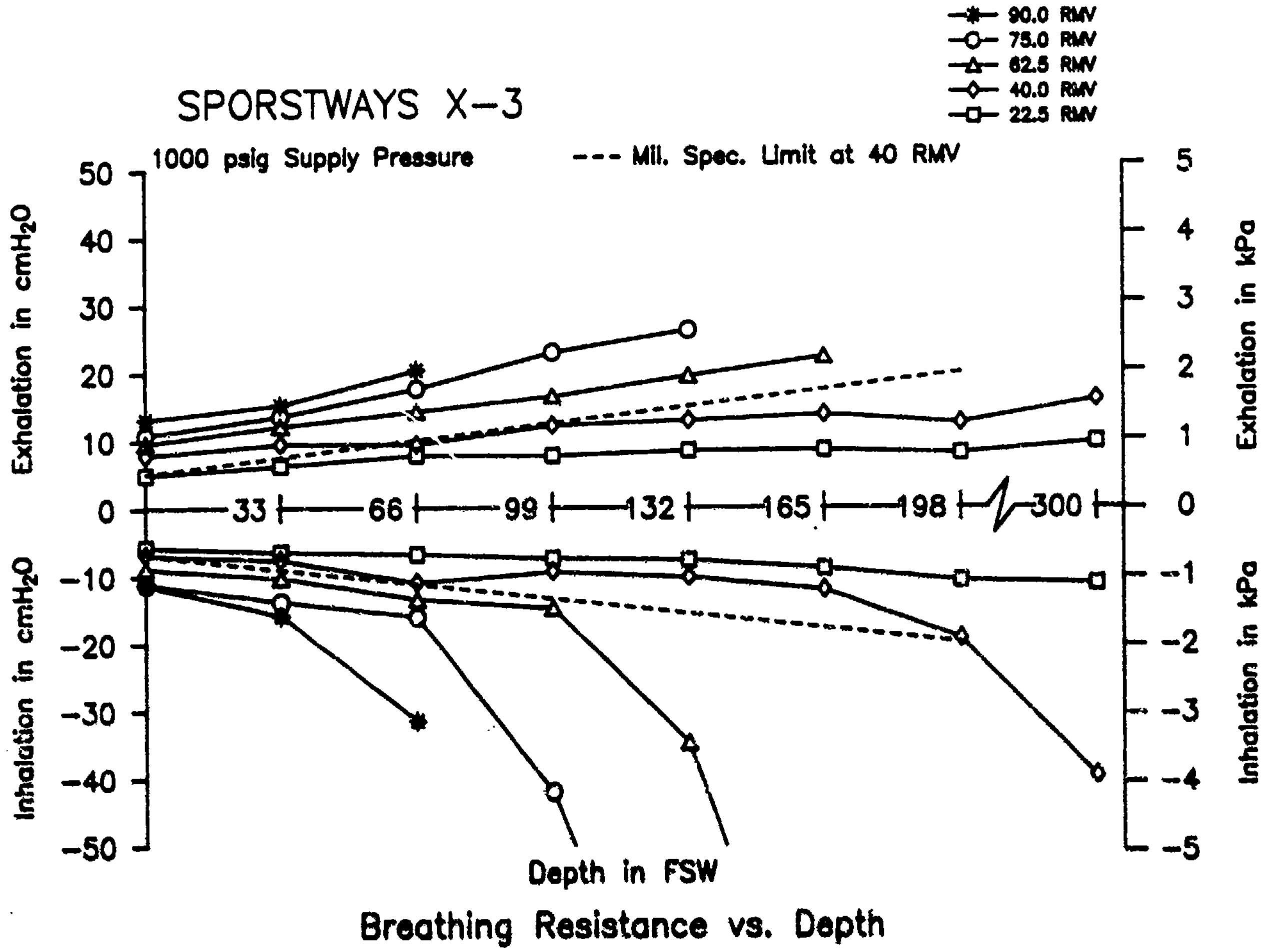


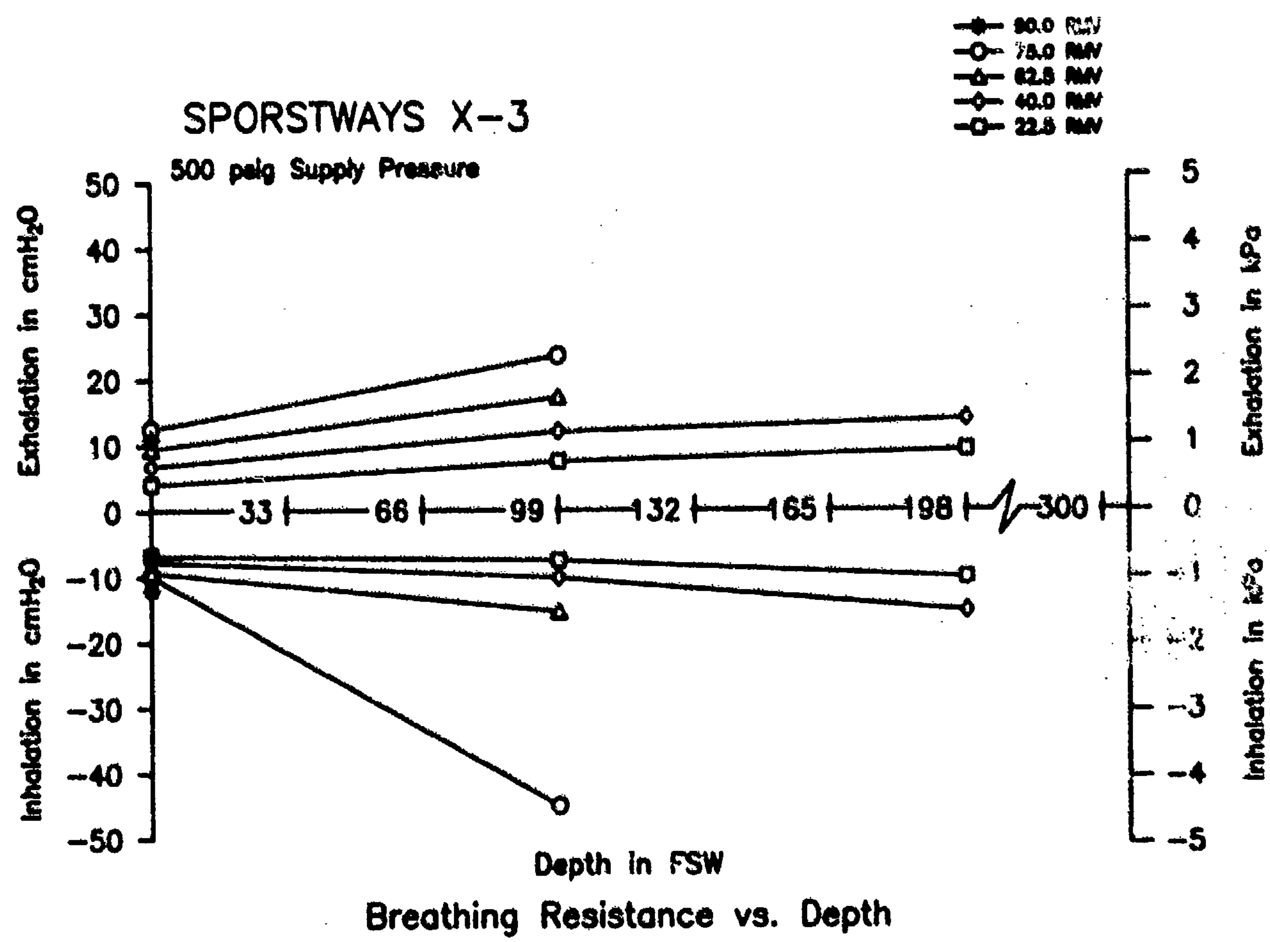
Breathing Resistance vs. Depth

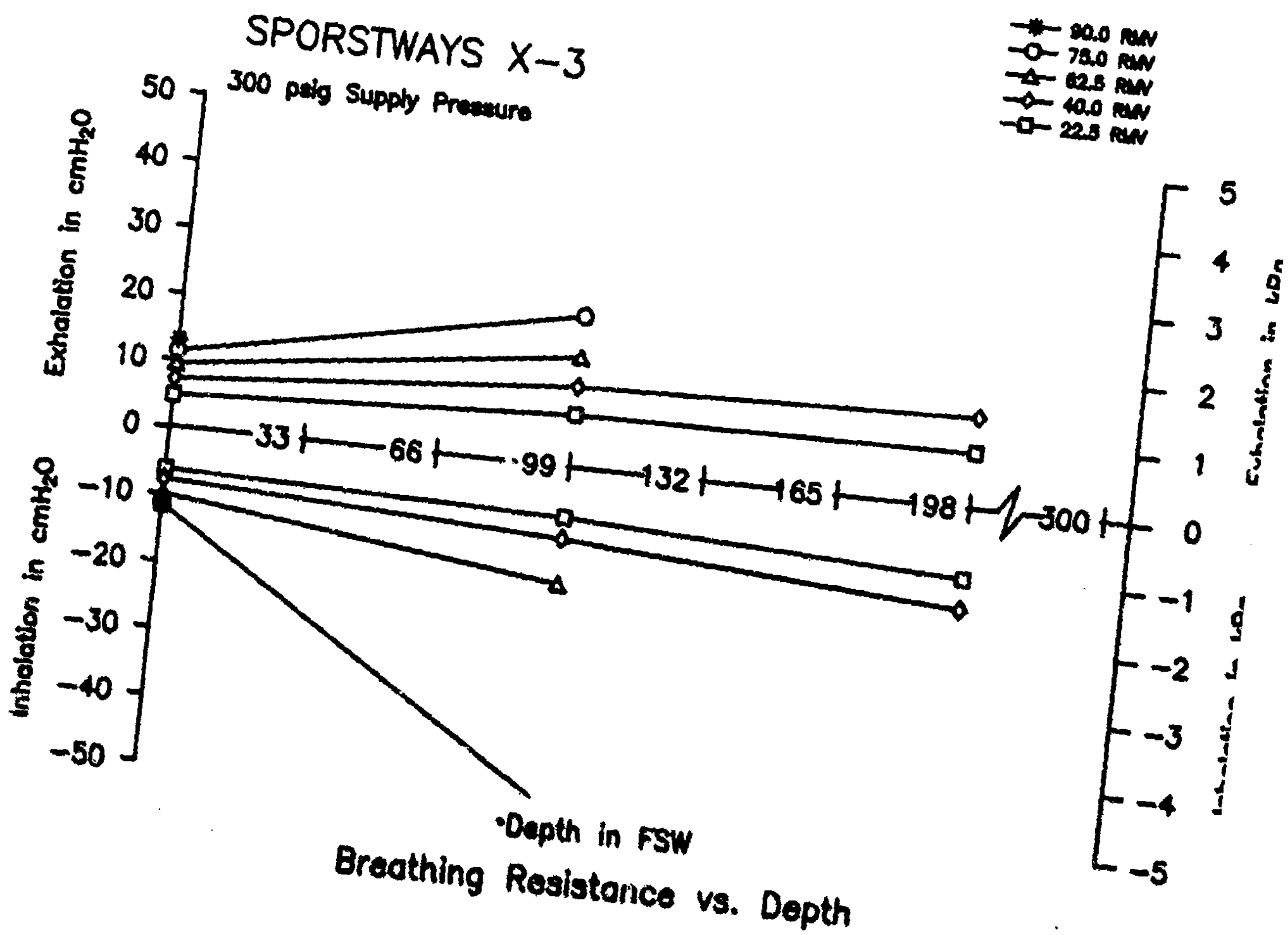


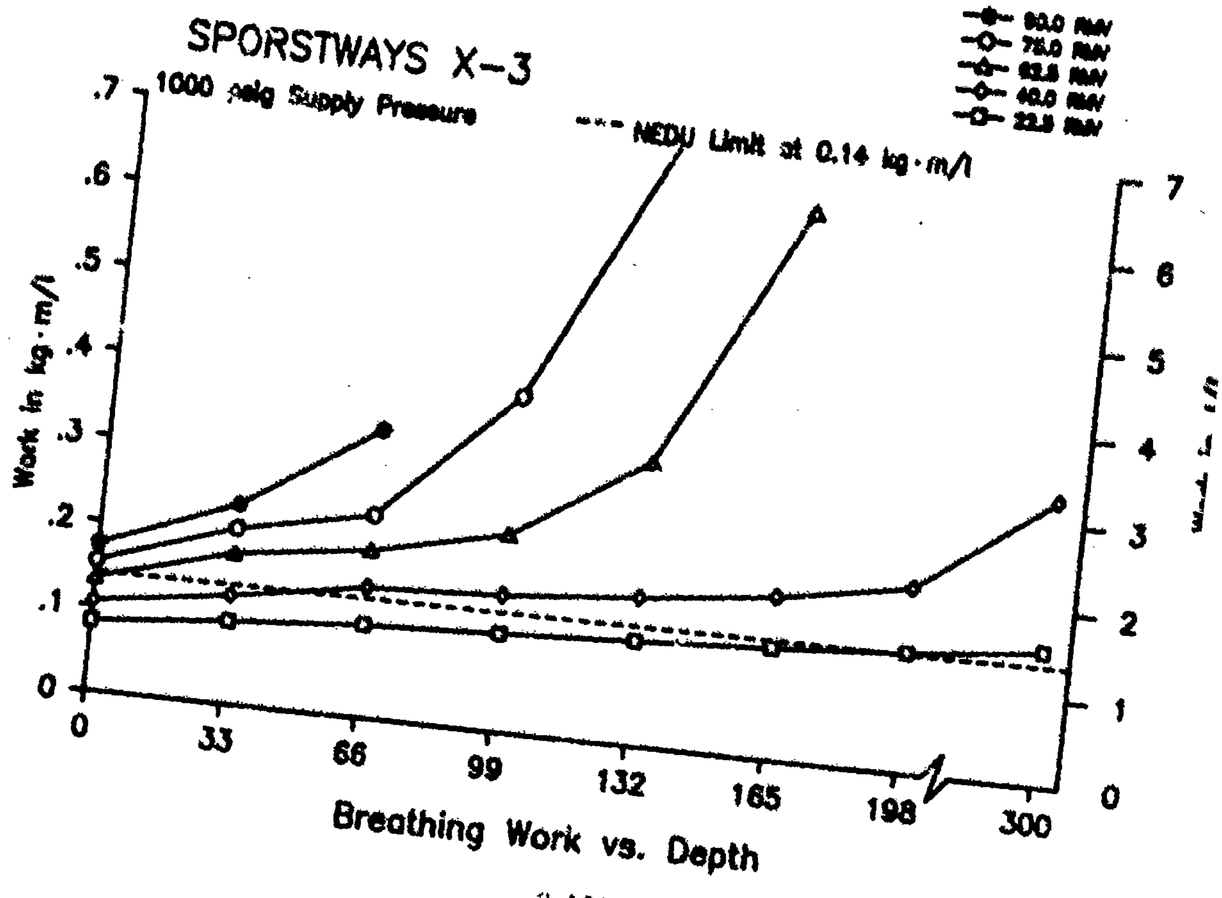
Breathing Work vs. Depth

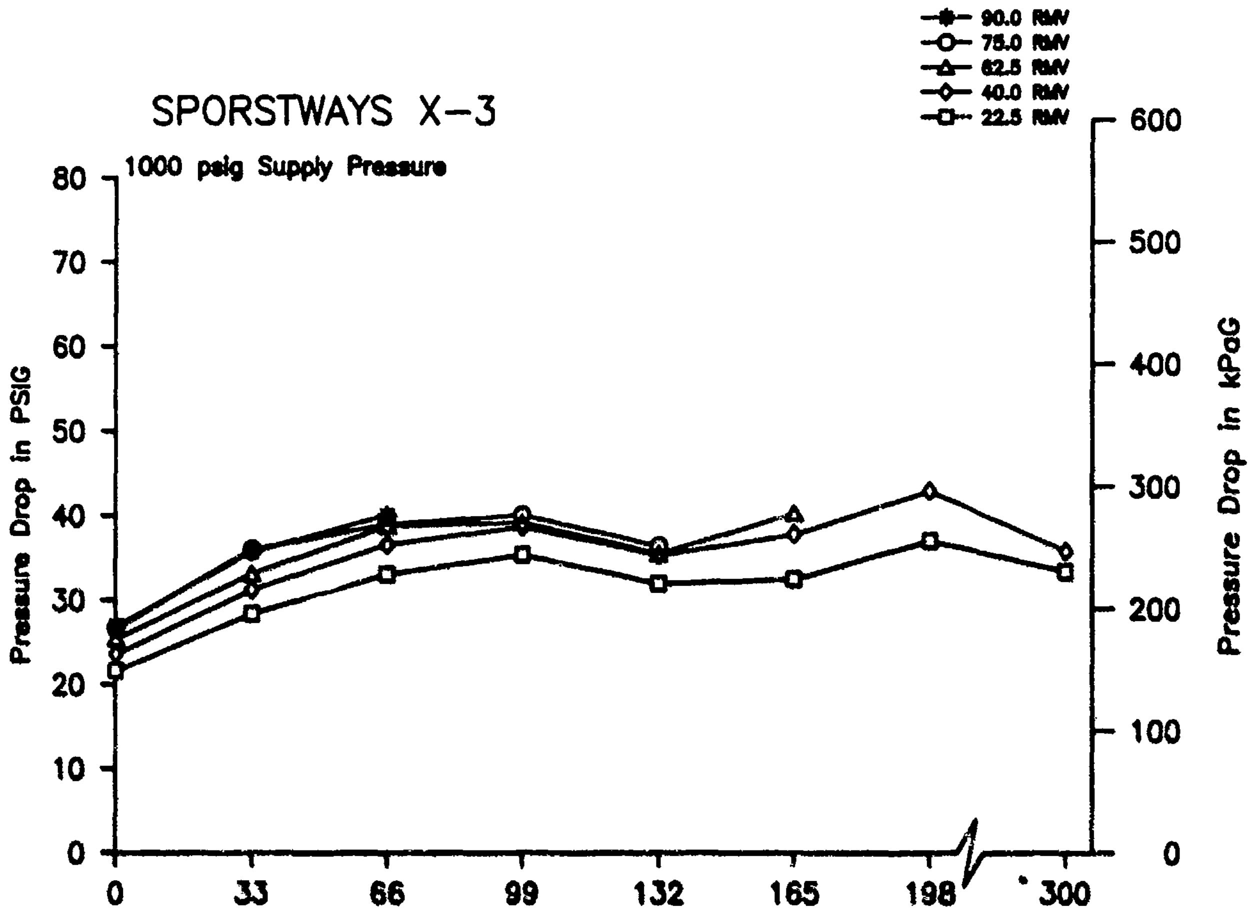

SPORTSWAYS X-2
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
80
70
60
50
40
30
20
10
0
600
500
400
300
200
100
0
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth


90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
SPORSTWAYS X-3
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth

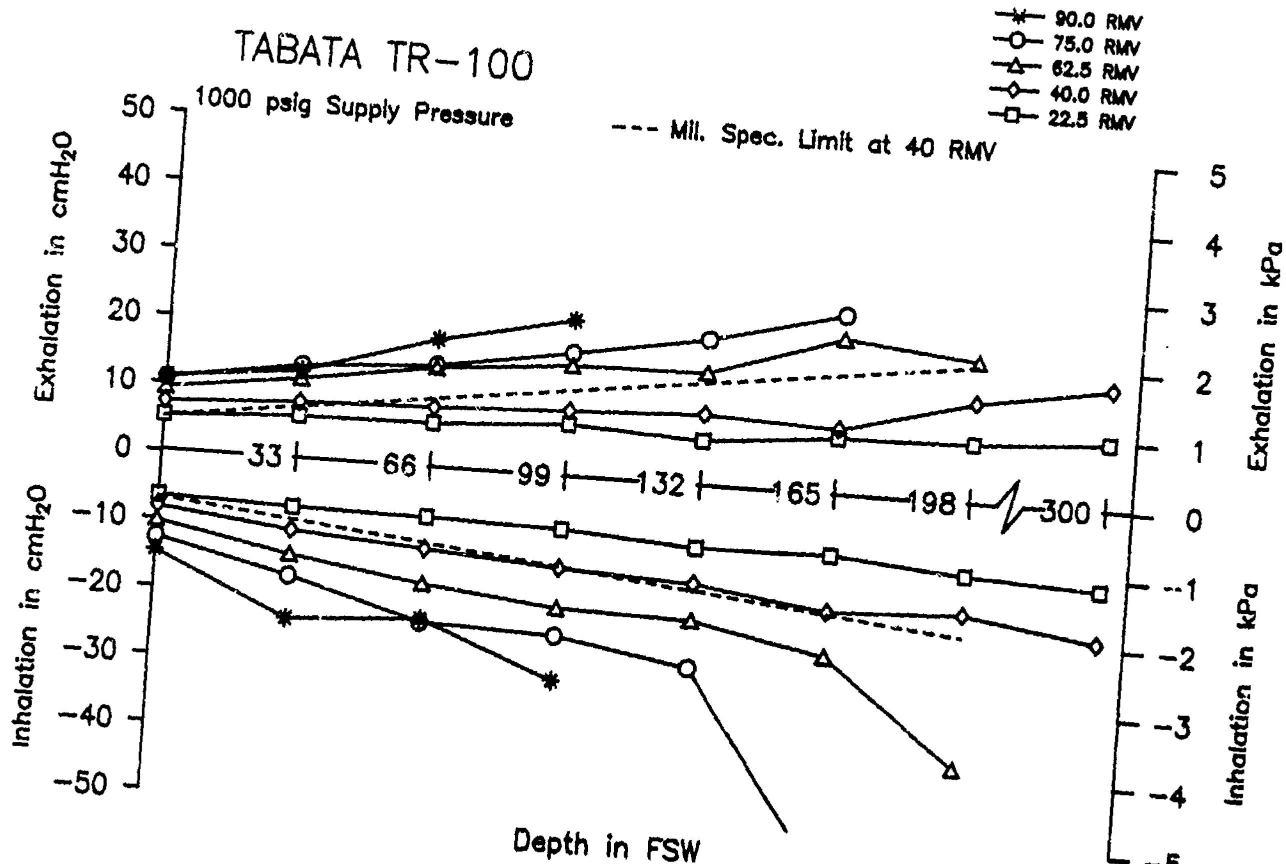

90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
SPORSTWAYS X-3
500 psig Supply Pressure
Exhalation in cmH_2O
Inhalation in cmH_2O
Exhalation in kPa
Inhalation in kPa
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth


SPORSTWAYS X-3
300 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth

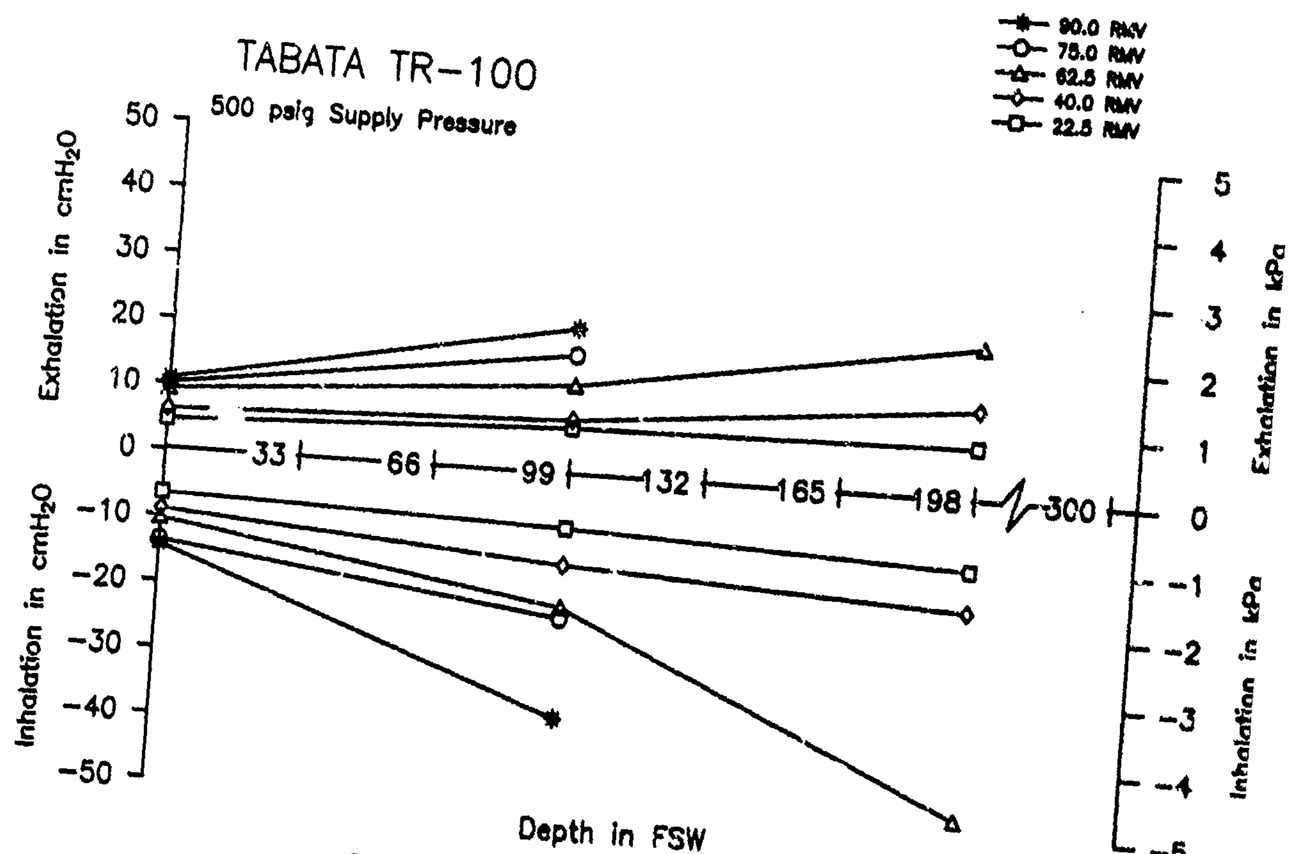

SPORSTWAYS X-3
1000 psig Supply Pressure
NEDU Limit at 0.14 kg·m/l
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Work in kg·m/l
0
33
66
99
132
165
198
300
Breathing Work vs. Depth



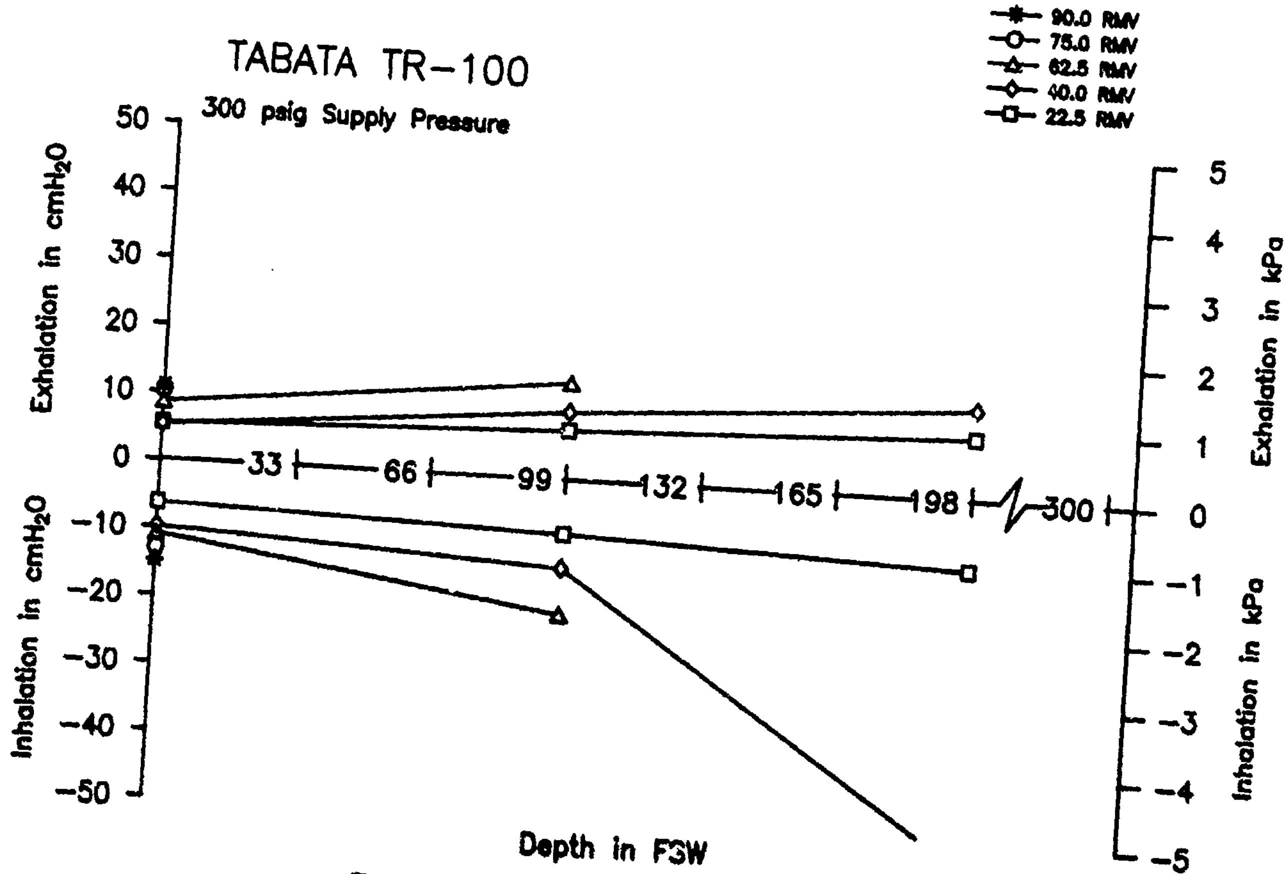
First Stage Pressure Drop vs. Depth



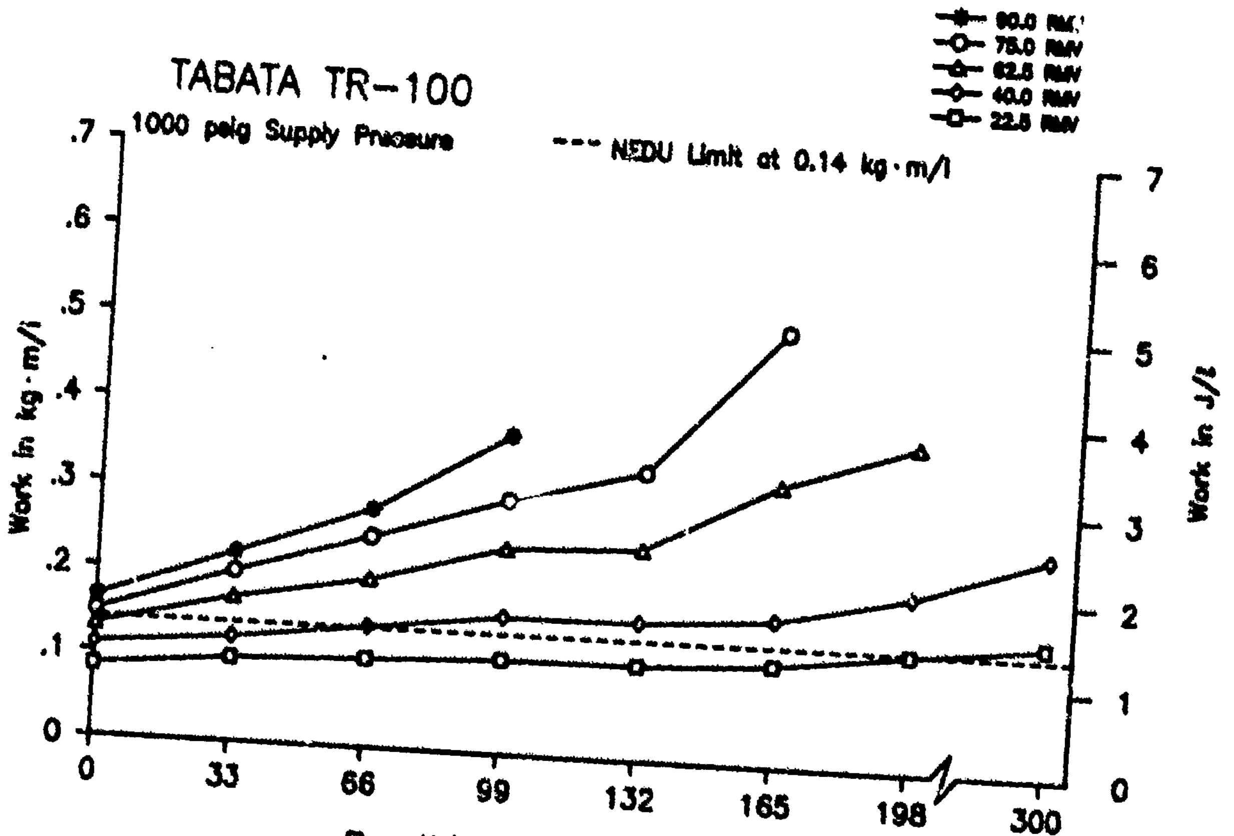
Breathing Resistance vs. Depth



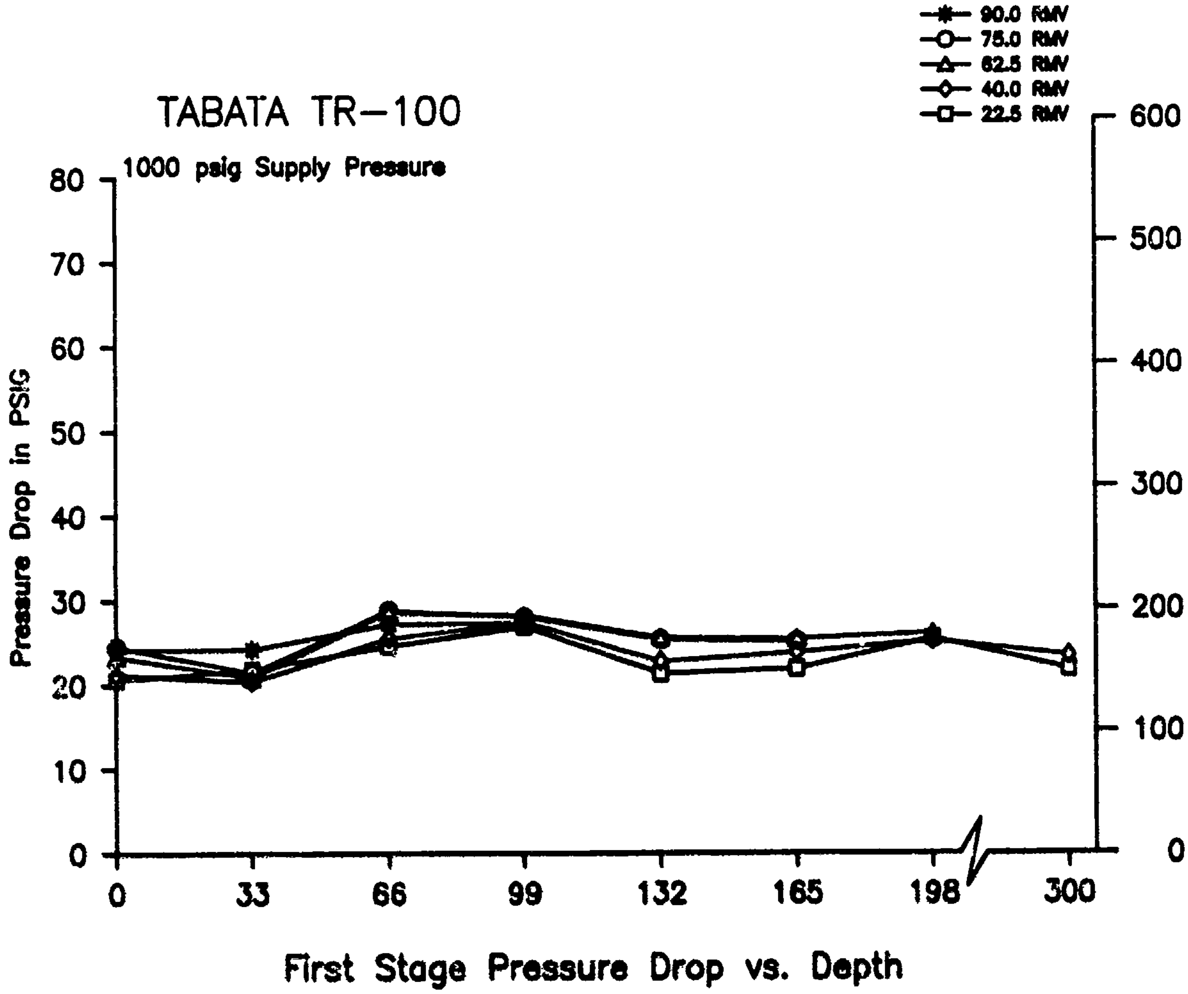
Breathing Resistance vs. Depth



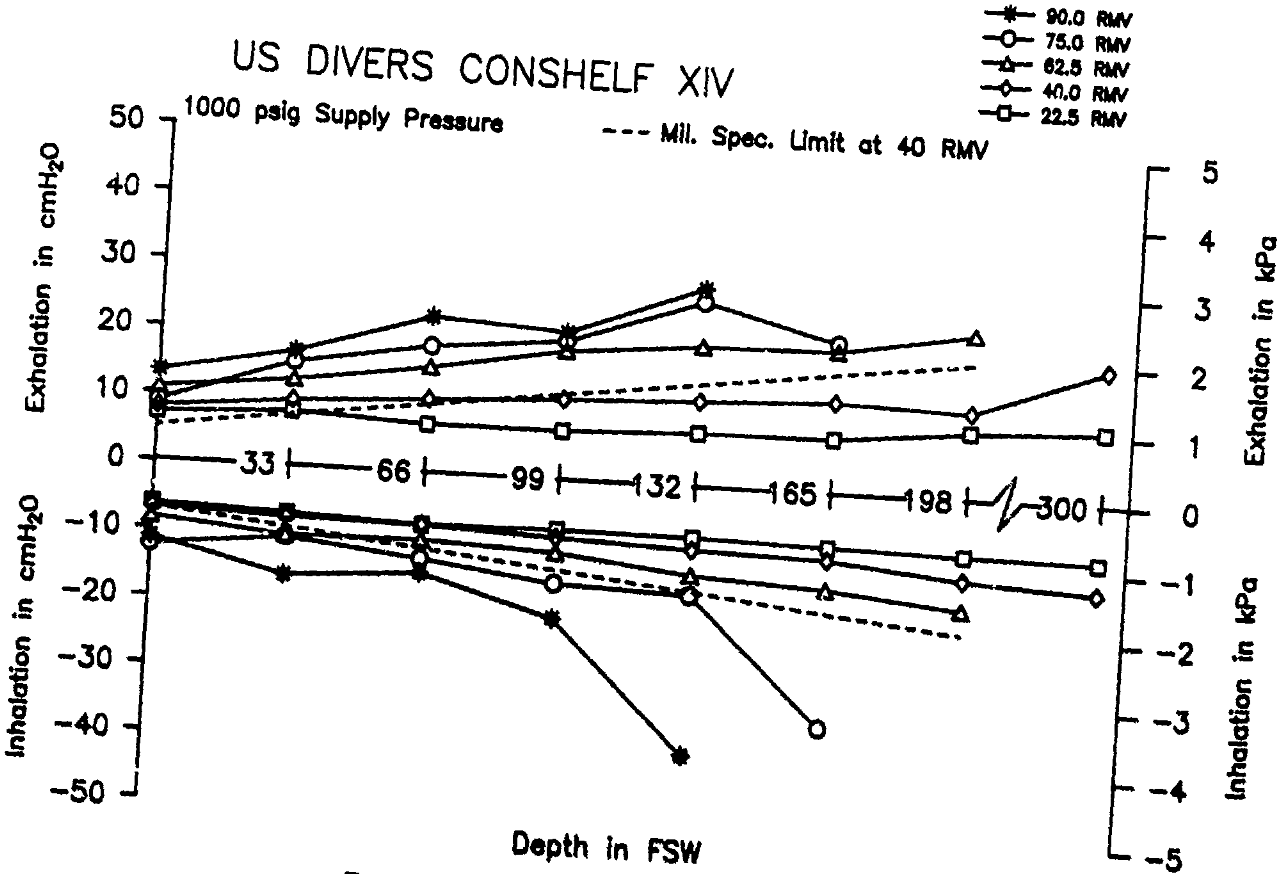
Breathing Resistance vs. Depth



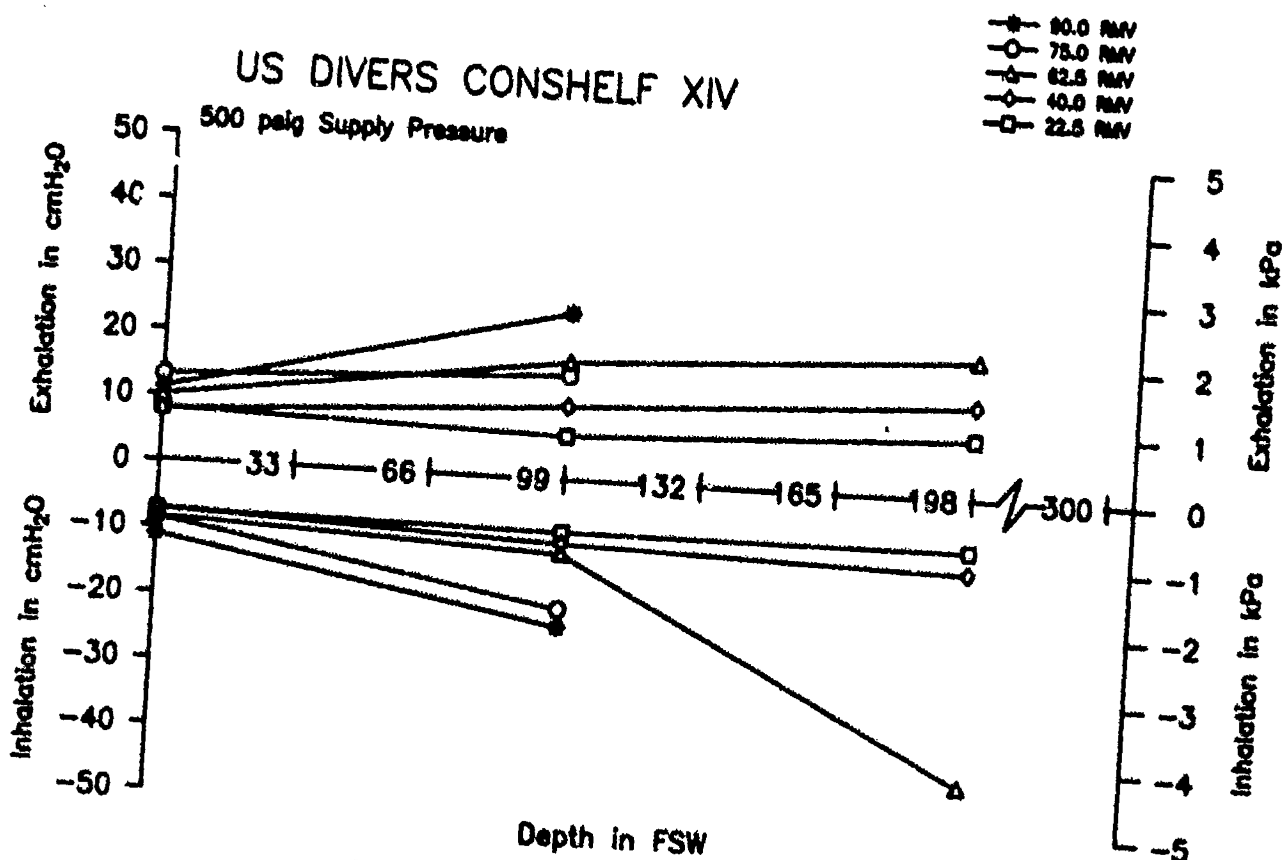
Breathing Work vs. Depth



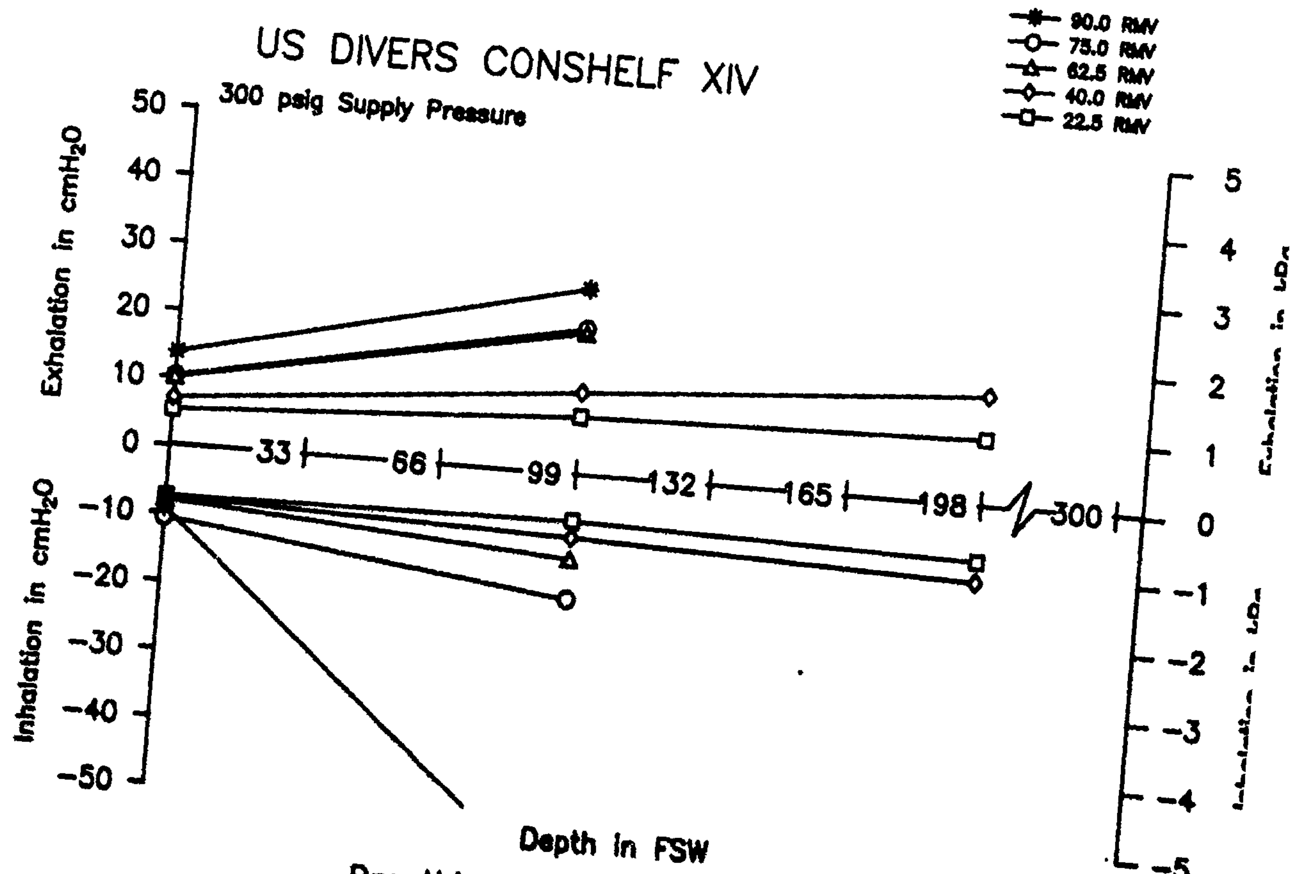
TABATA TR-100
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
80
70
60
50
40
30
20
10
0
600
500
400
300
200
100
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth



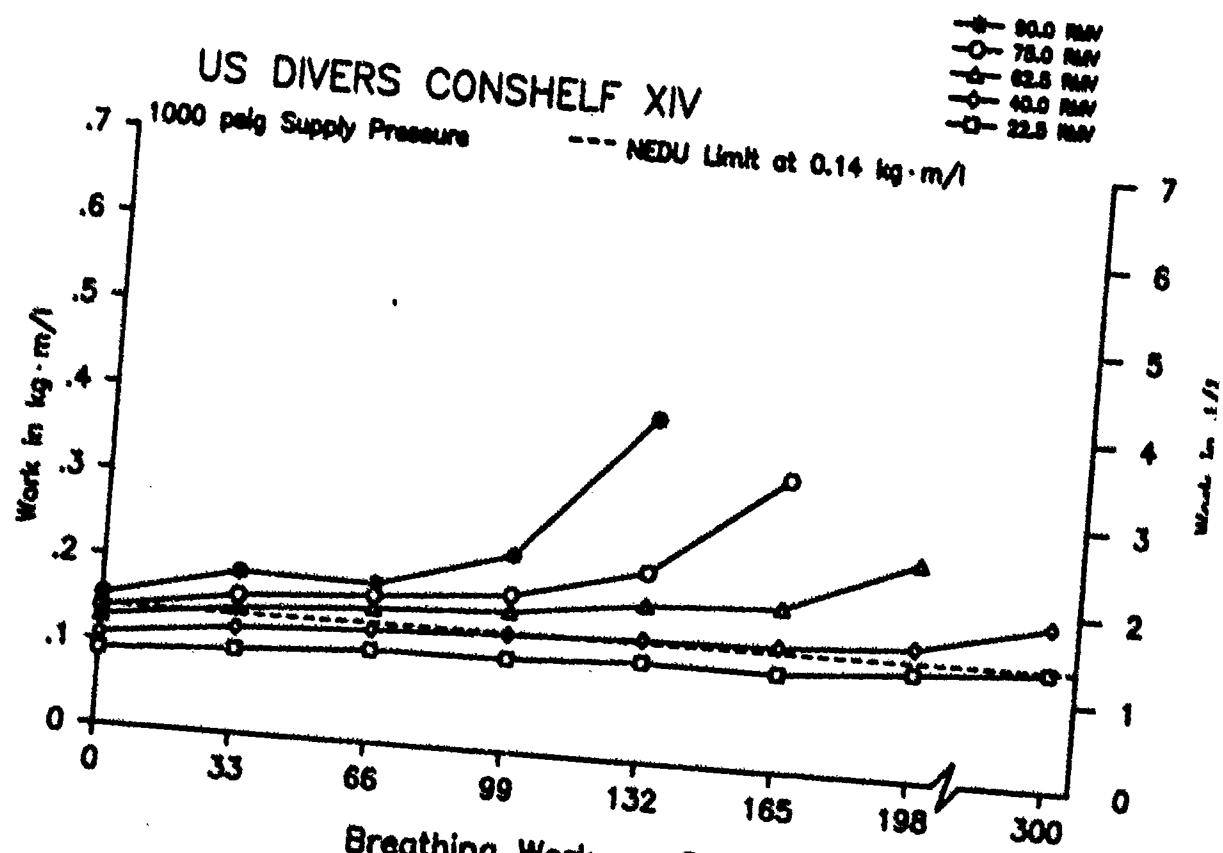
Breathing Resistance vs. Depth



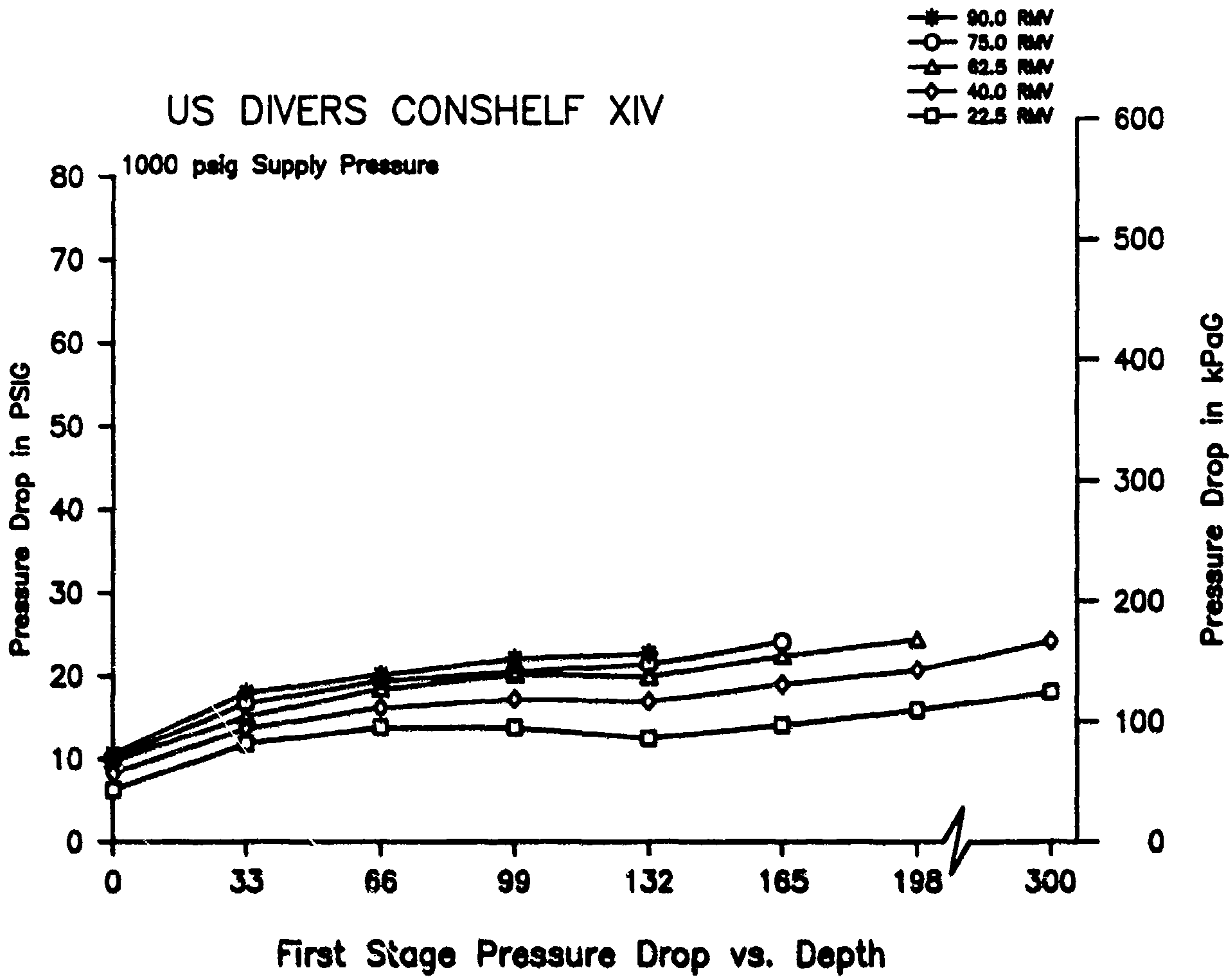
Breathing Resistance vs. Depth



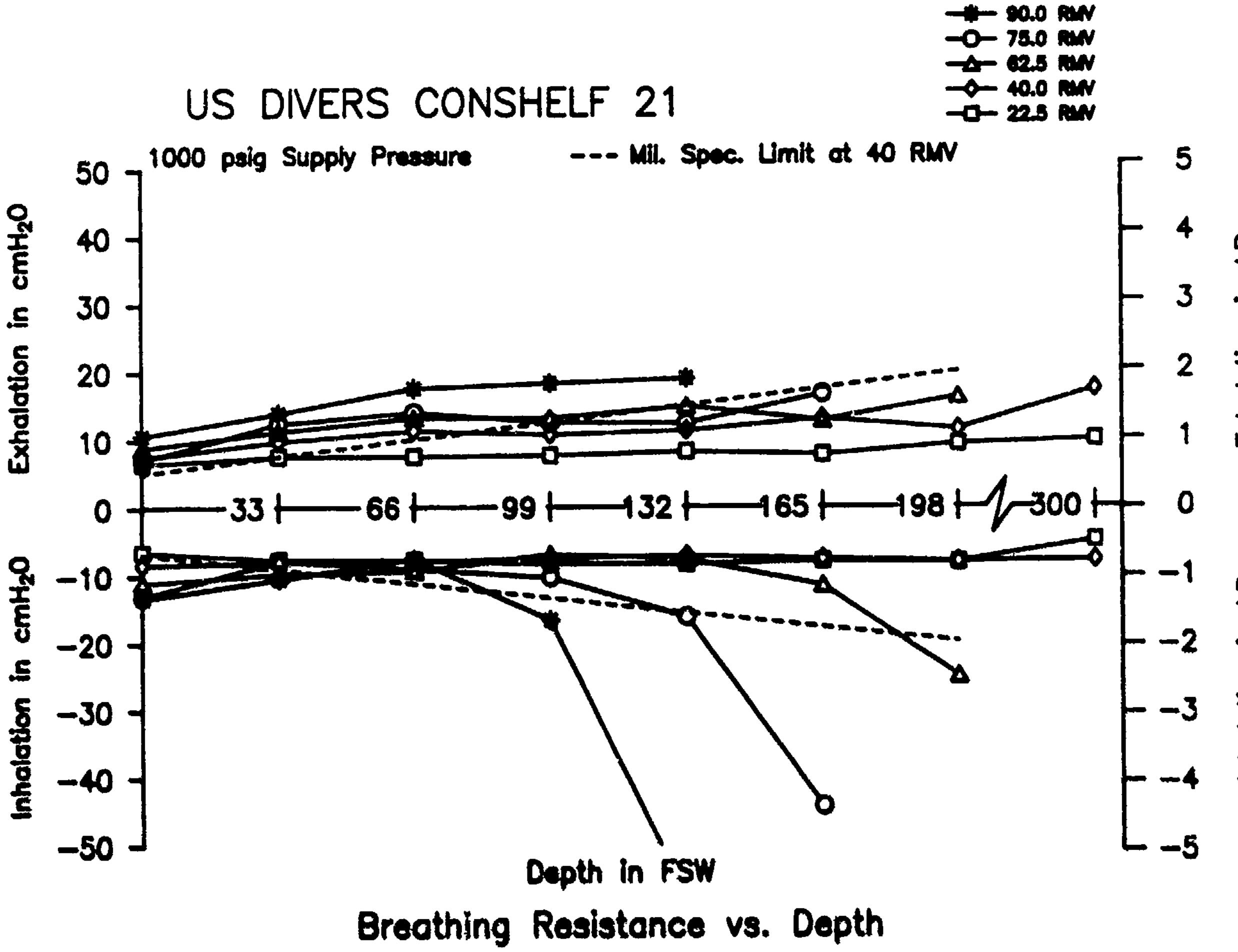
Breathing Resistance vs. Depth

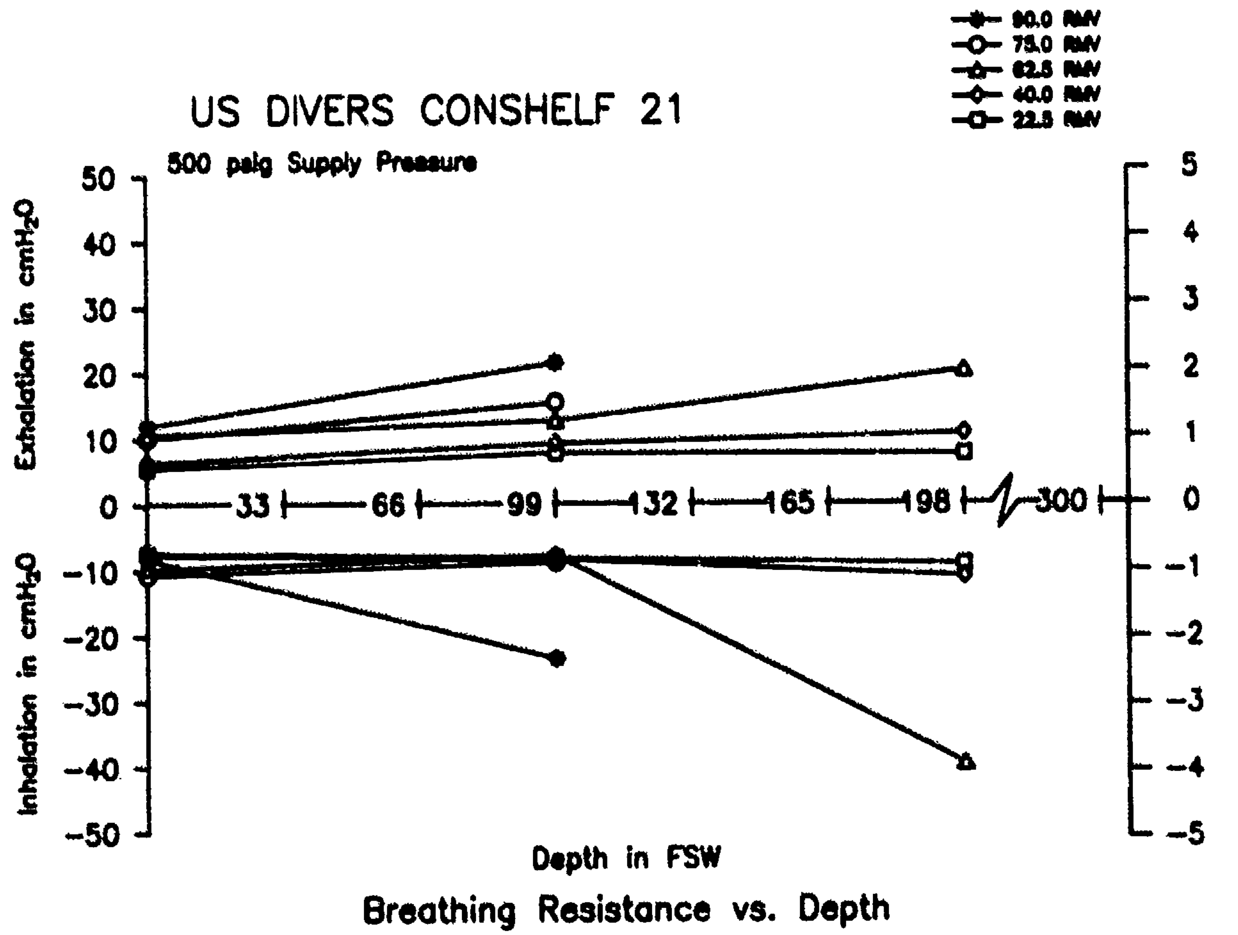


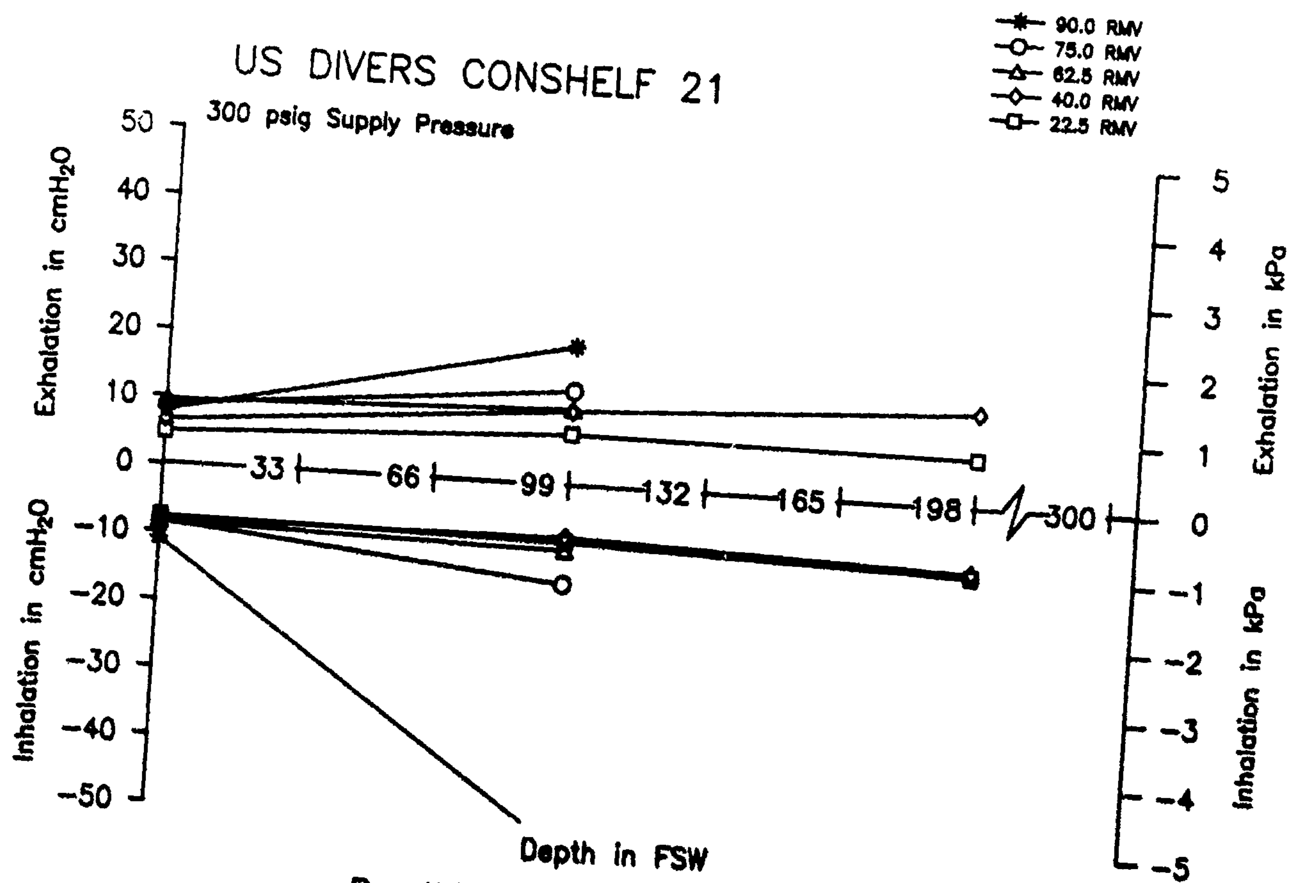
Breathing Work vs. Depth



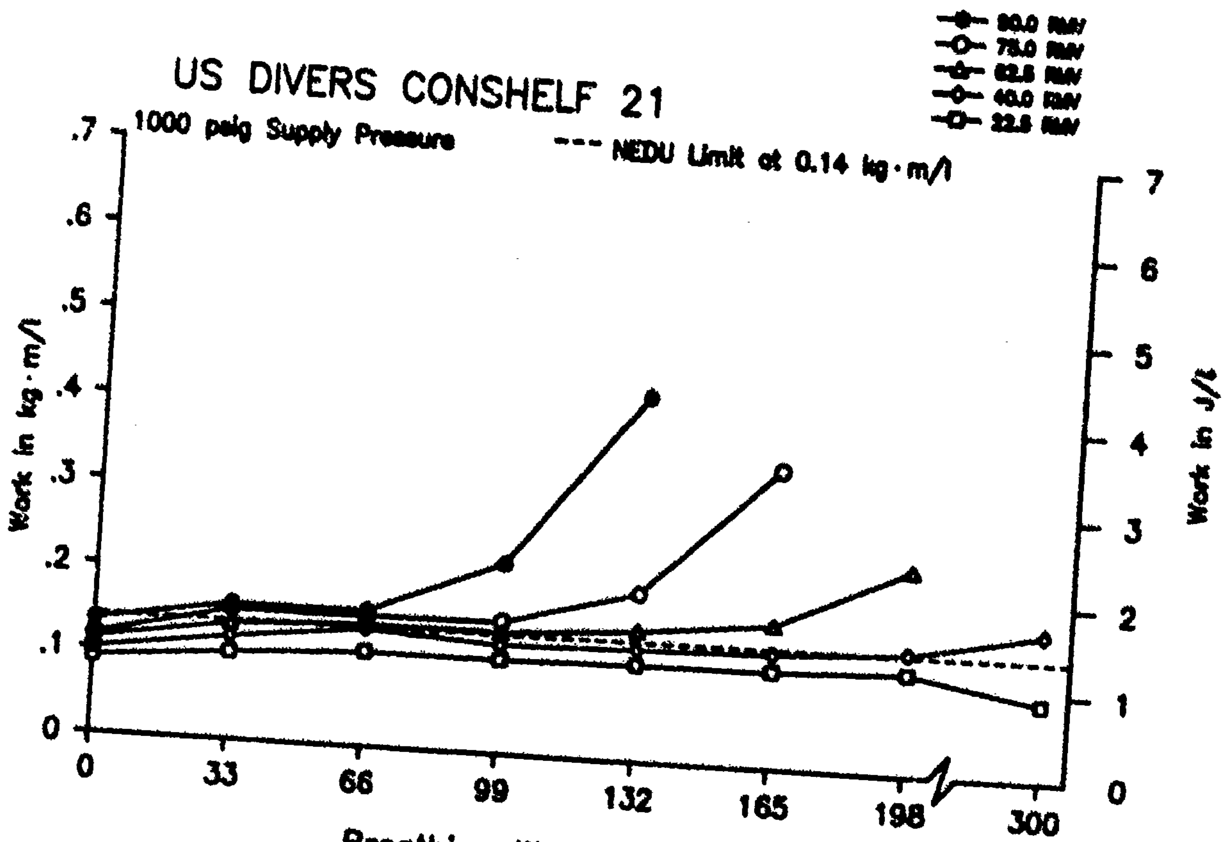
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
US DIVERS CONSHELF XIV
1000 psig Supply Pressure
Pressure Drop in PSIG
Pressure Drop in kPaG
80
70
60
50
40
30
20
10
0
600
500
400
300
200
100
0
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth


US DIVERS CONSHELF 21
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH2O
Inhalation in cmH2O
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth

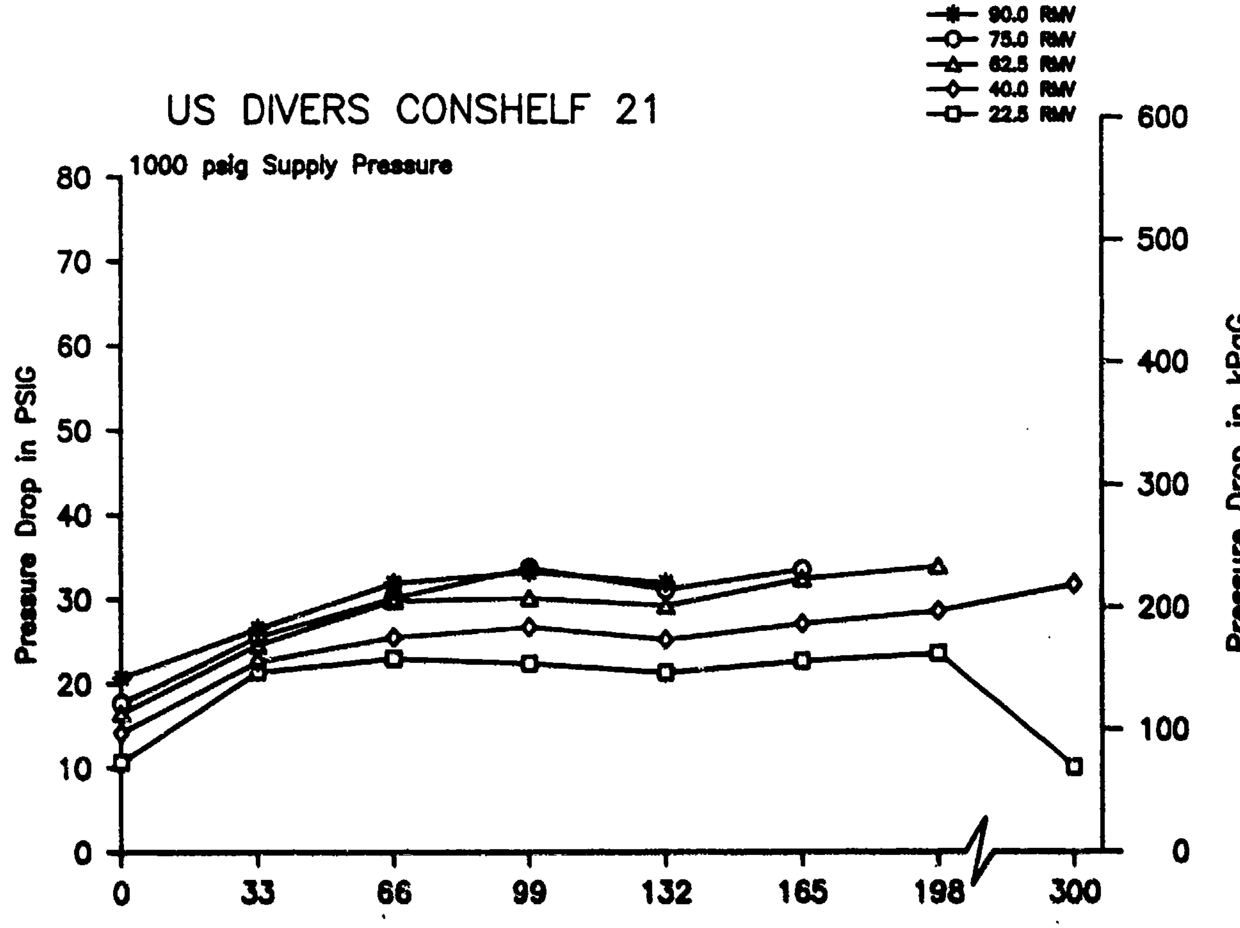

US DIVERS CONSHELF 21
500 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Exhalation in cmH2O
Inhalation in cmH2O
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



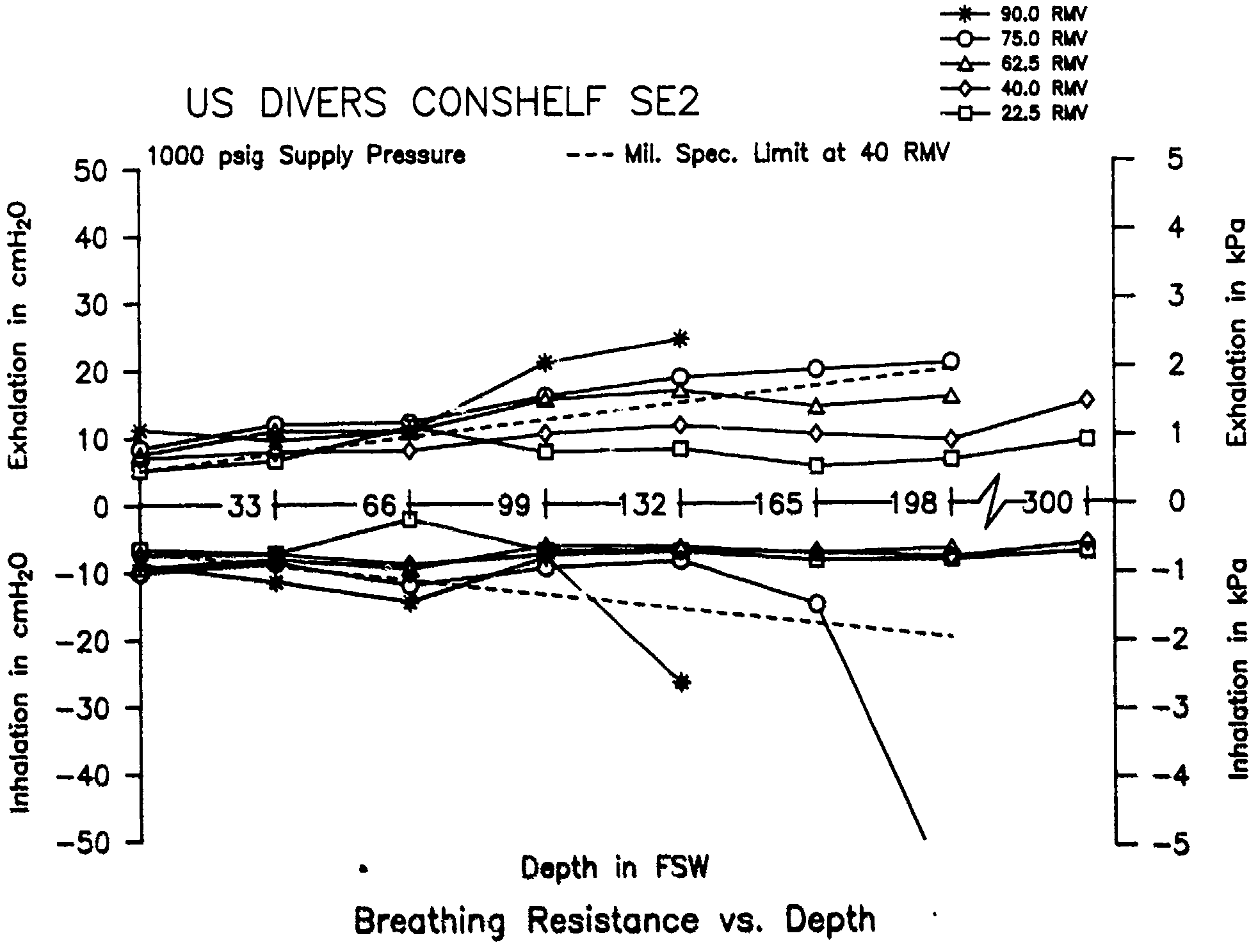
Breathing Resistance vs. Depth

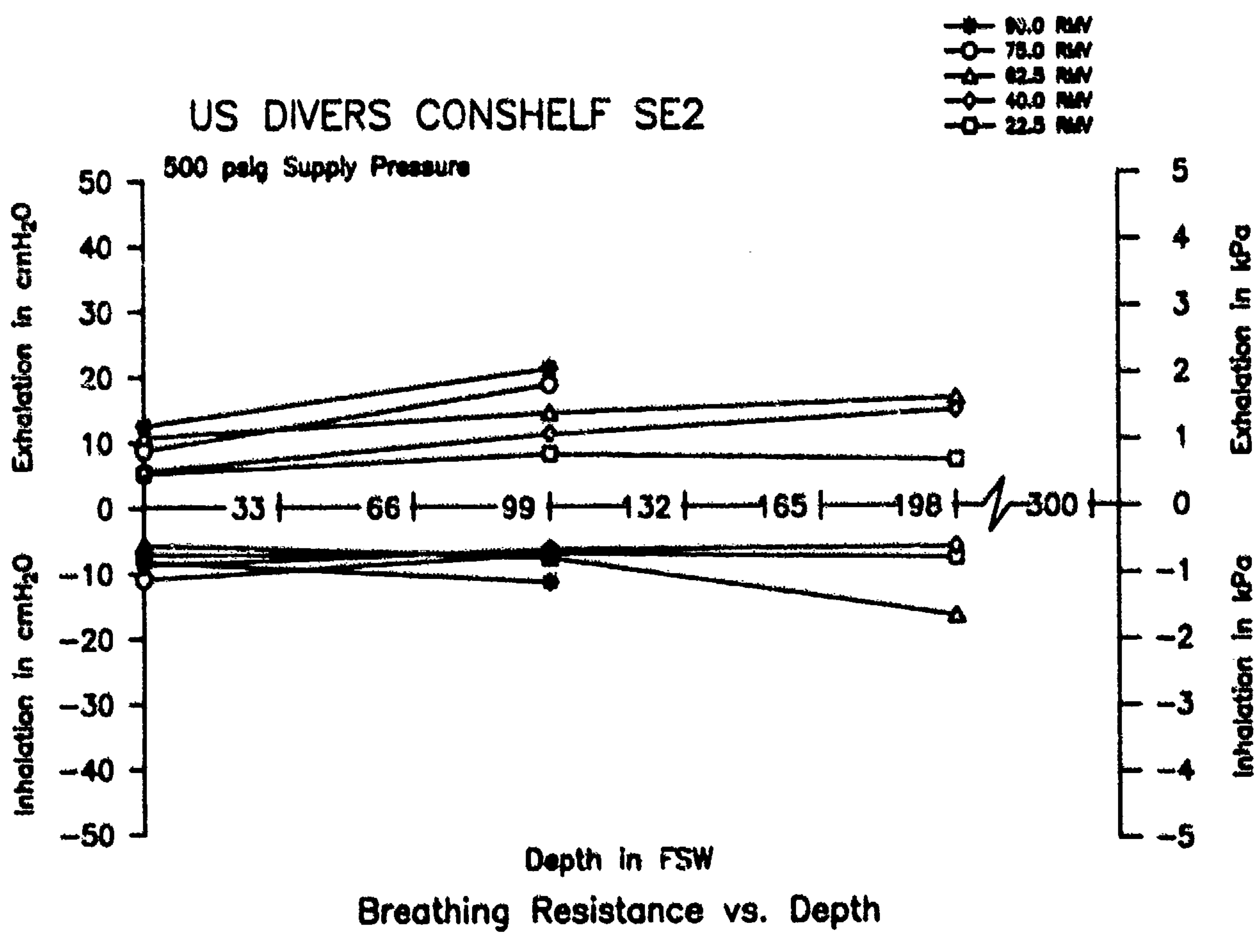


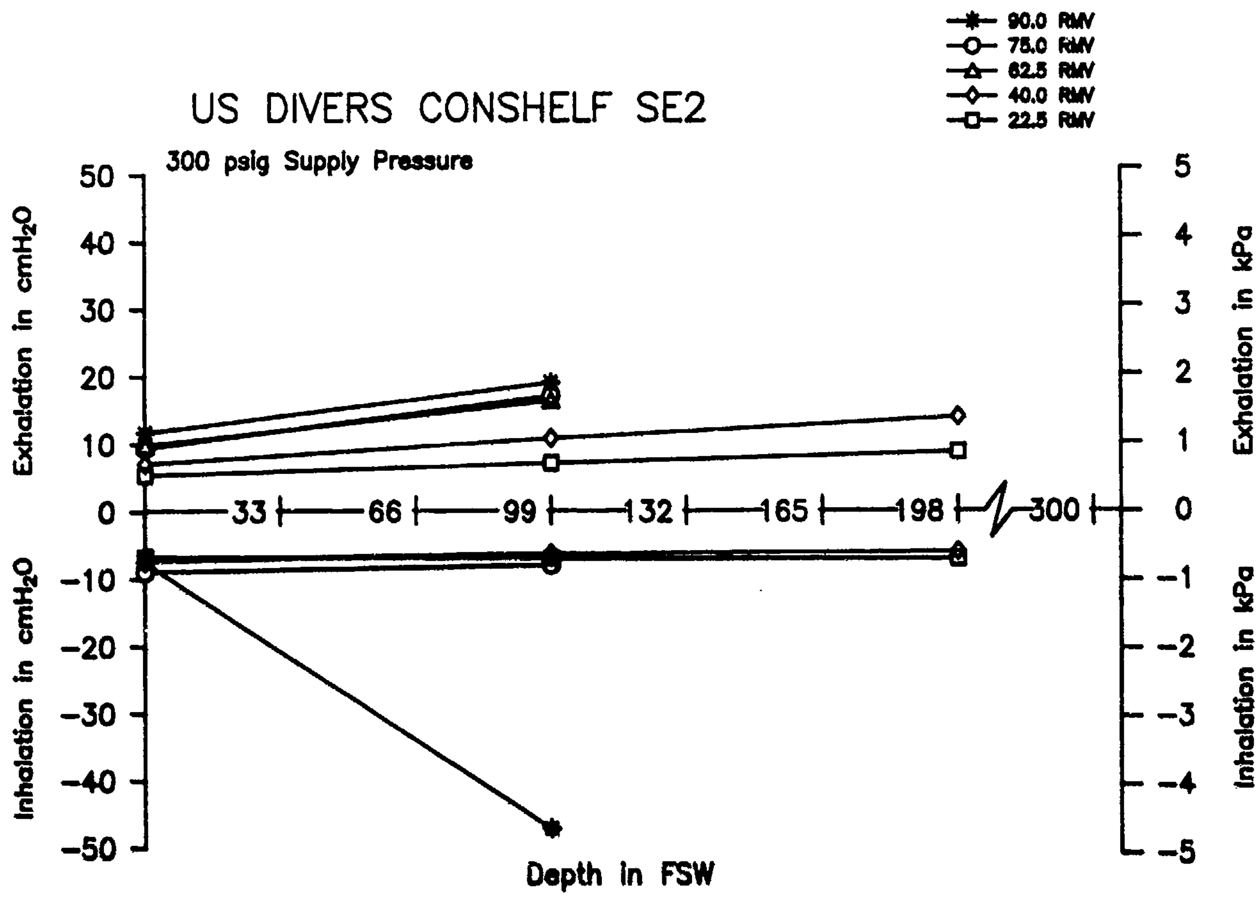
Breathing Work vs. Depth



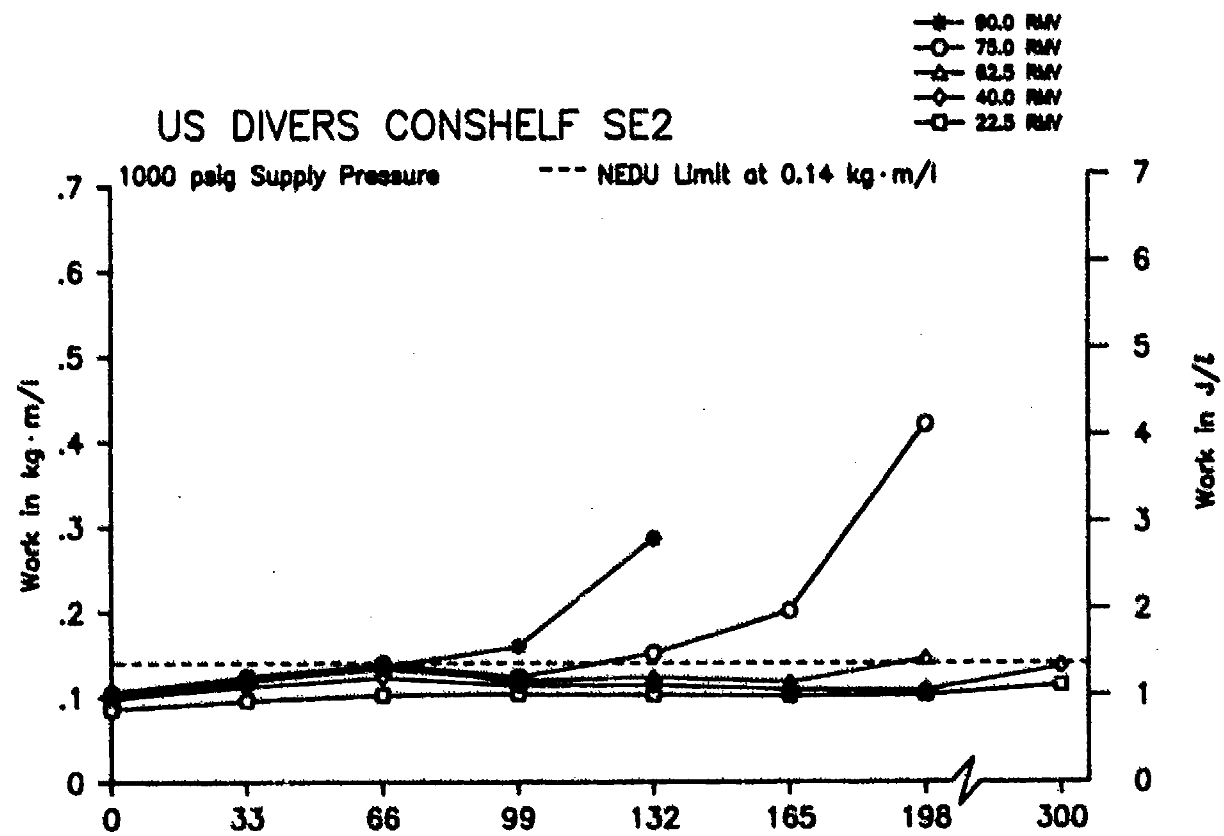
First Stage Pressure Drop vs. Depth


90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
US DIVERS CONSHELF SE2
1000 psig Supply Pressure
--- Mil. Spec. Limit at 40 RMV
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth

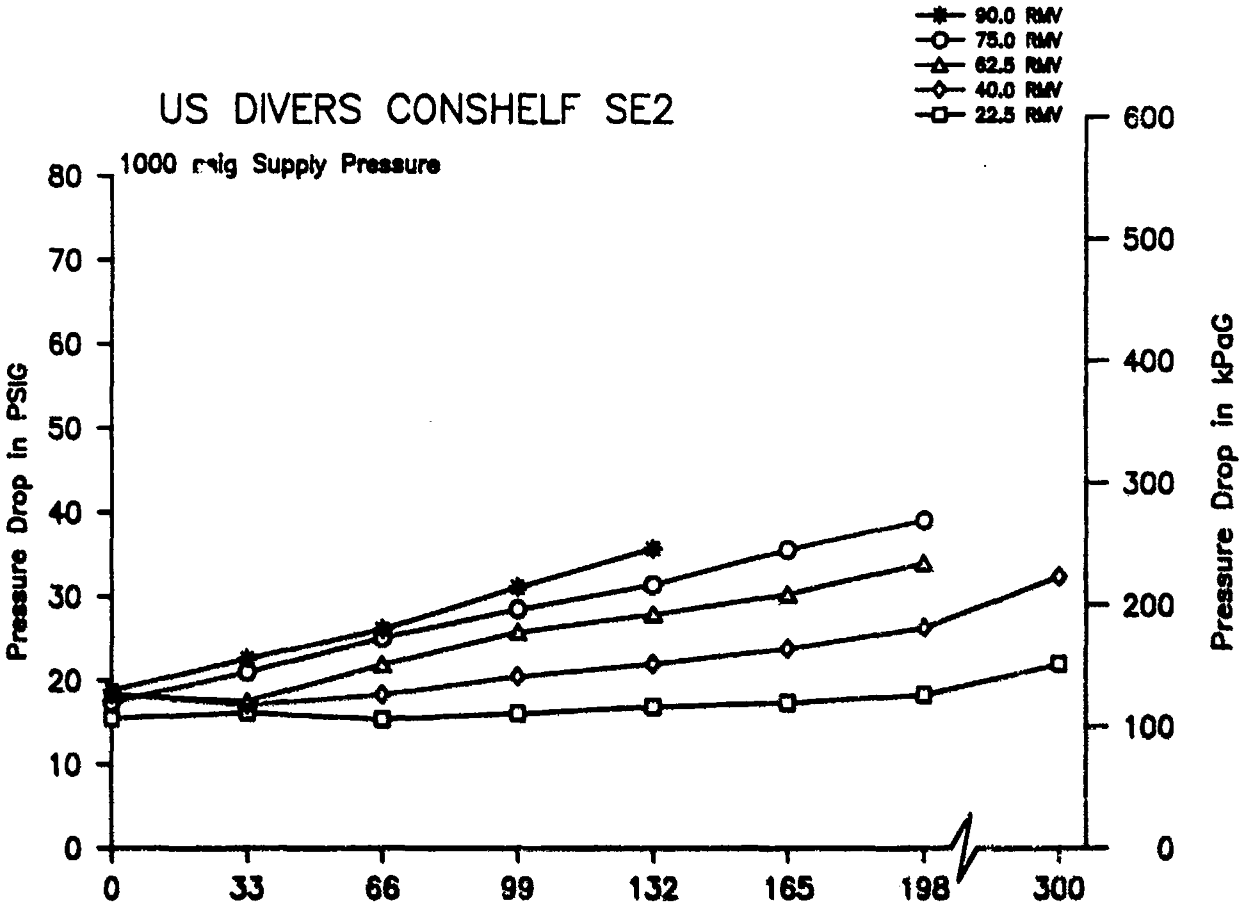

90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
US DIVERS CONSHELF SE2
500 psig Supply Pressure
Exhalation in cmH2O
Inhalation in cmH2O
Exhalation in kPa
Inhalation in kPa
33
66
99
132
165
198
300
Depth in FSW
Breathing Resistance vs. Depth



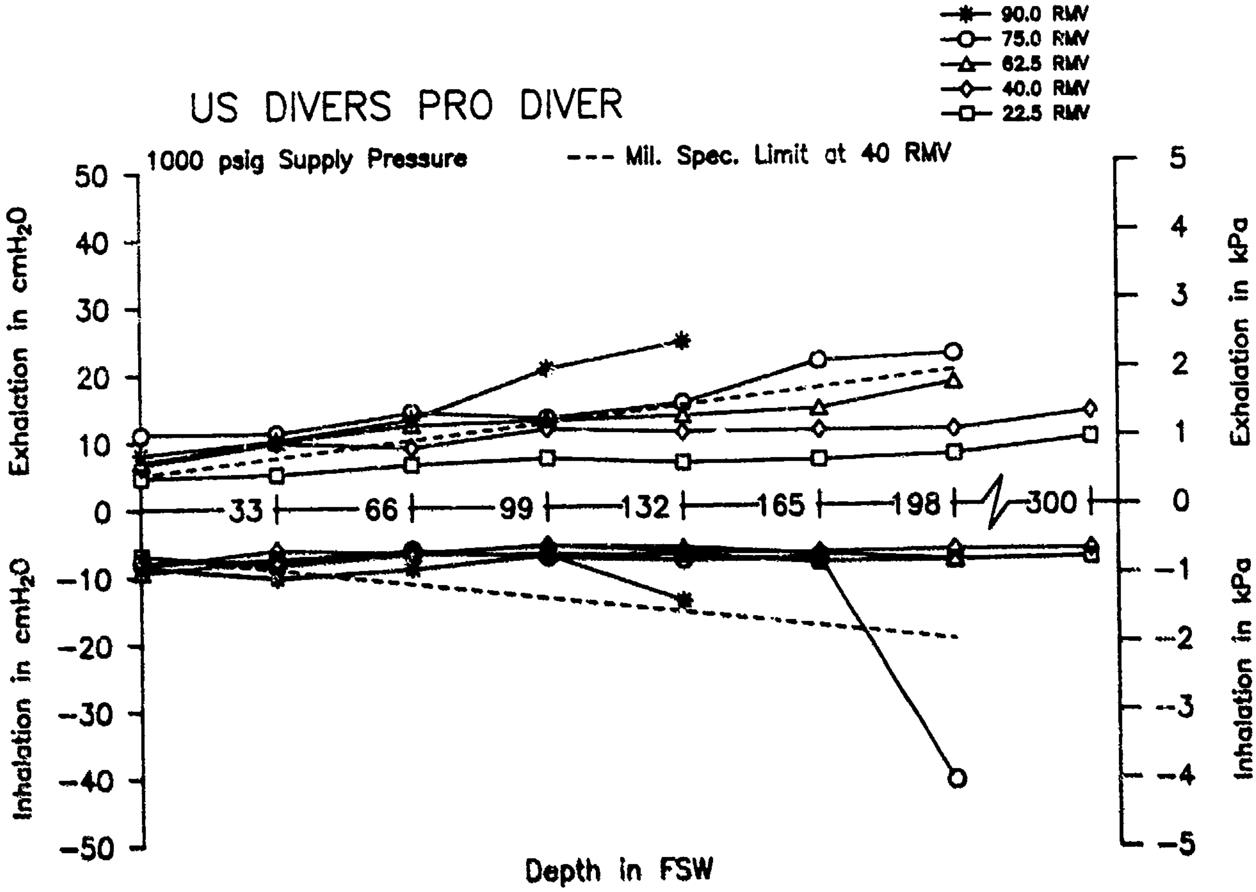
Breathing Resistance vs. Depth



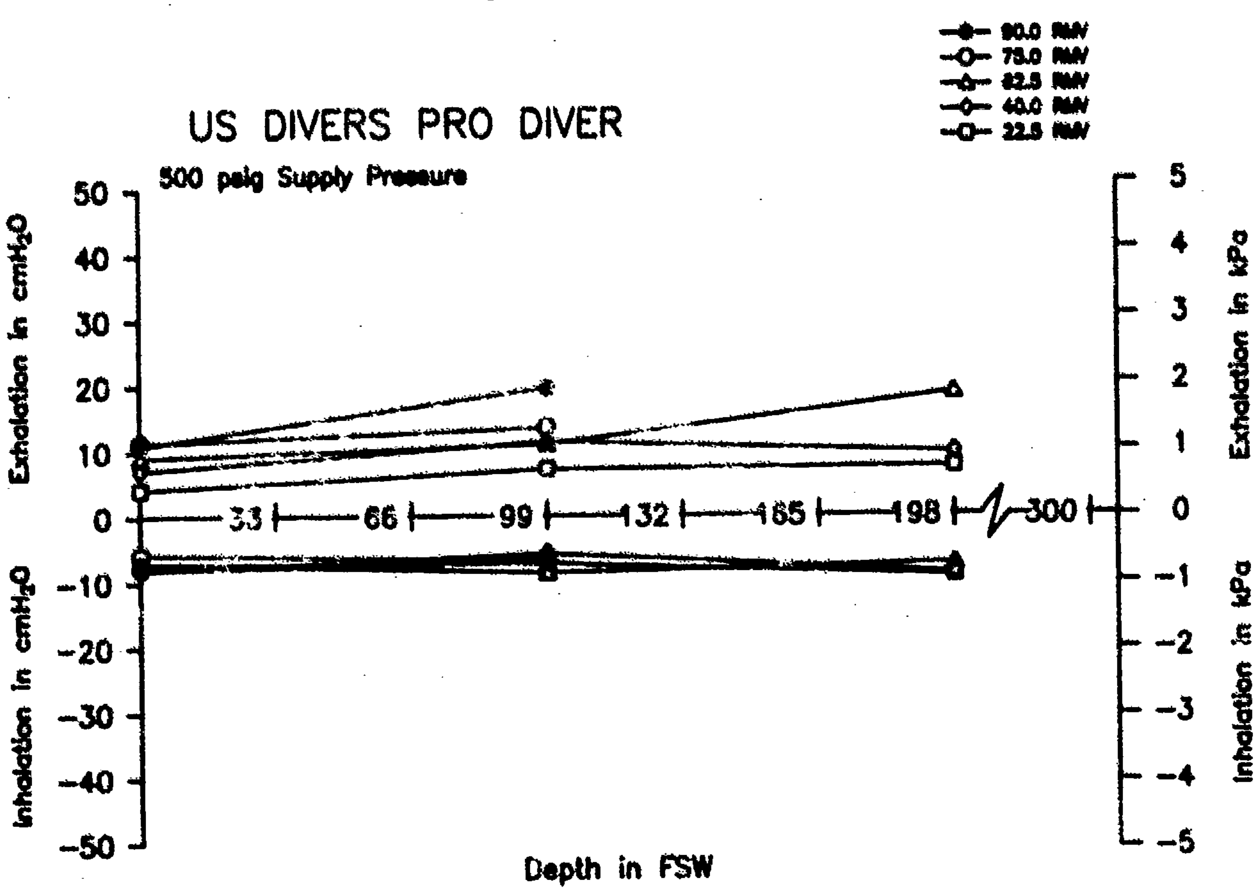
Breathing Work vs. Depth



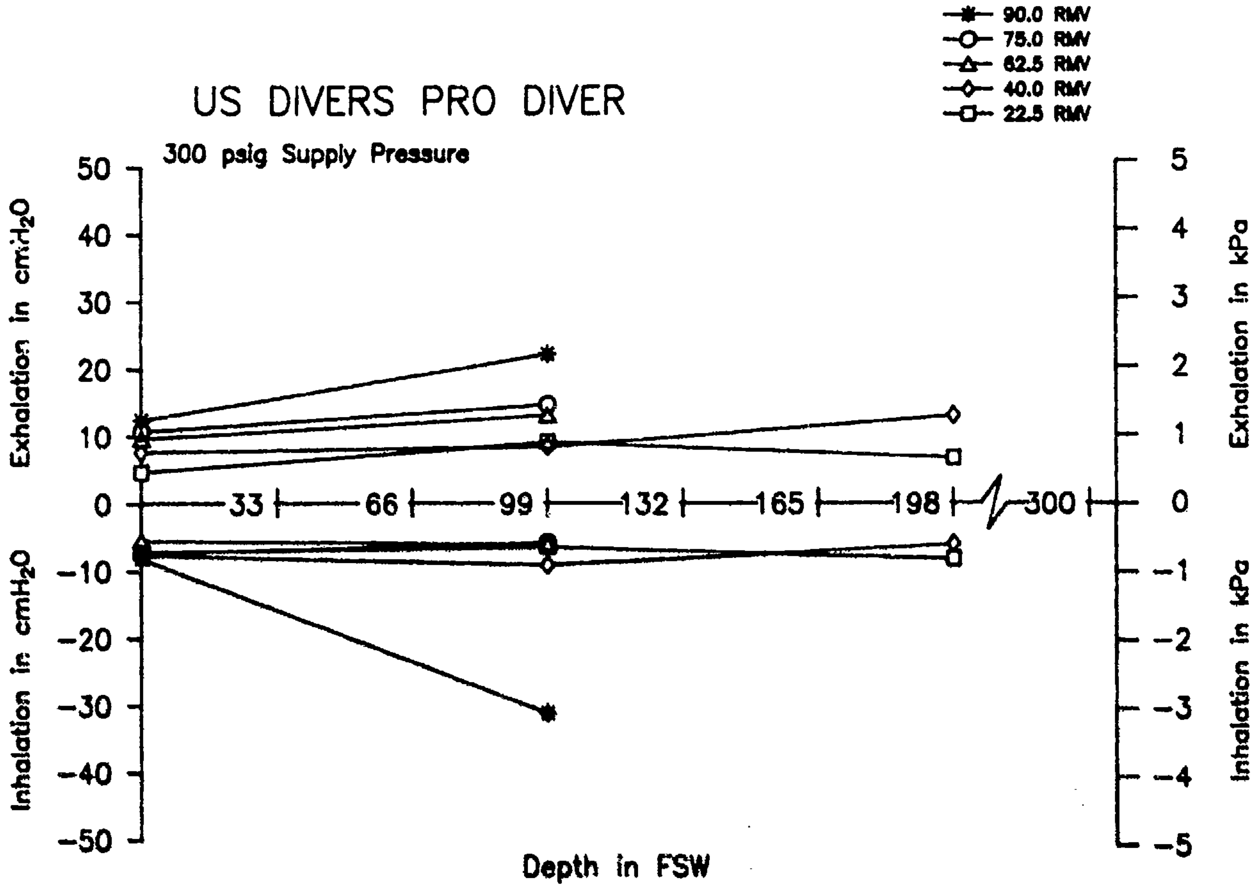
First Stage Pressure Drop vs. Depth



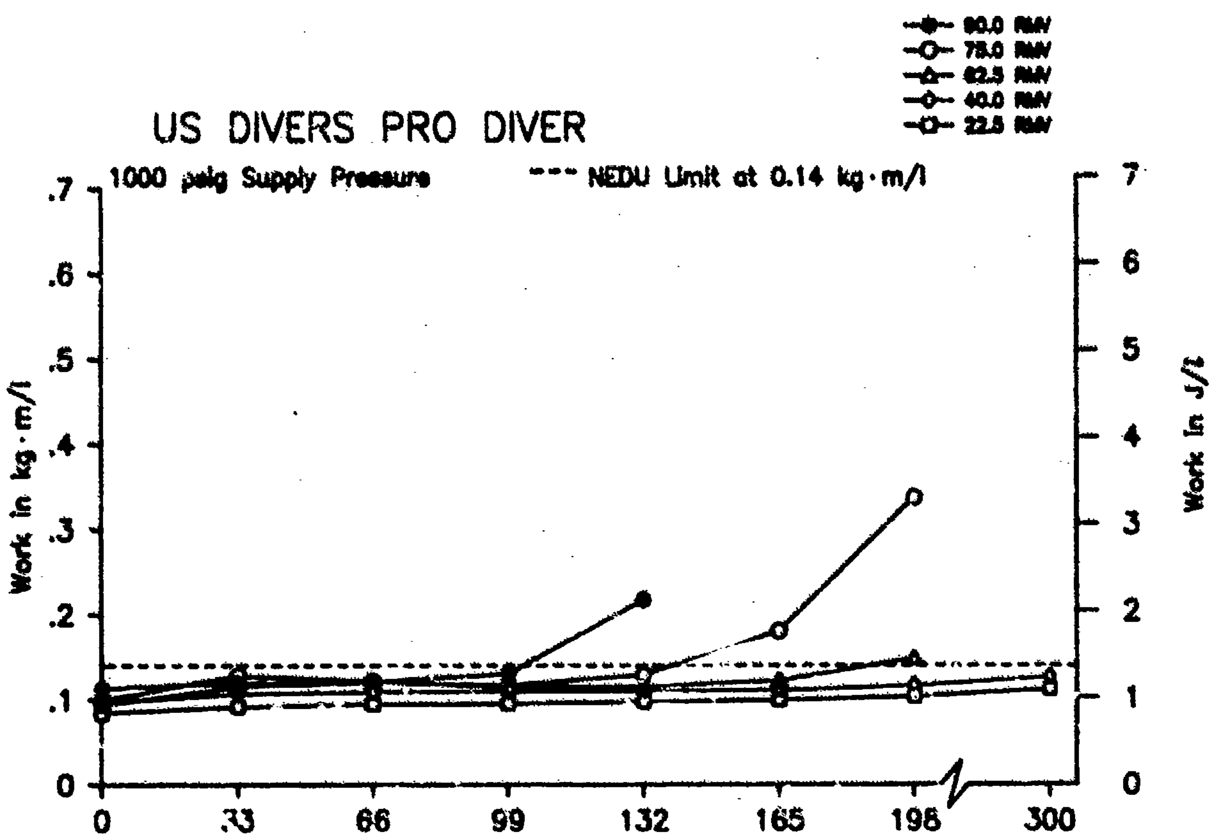
Breathing Resistance vs. Depth



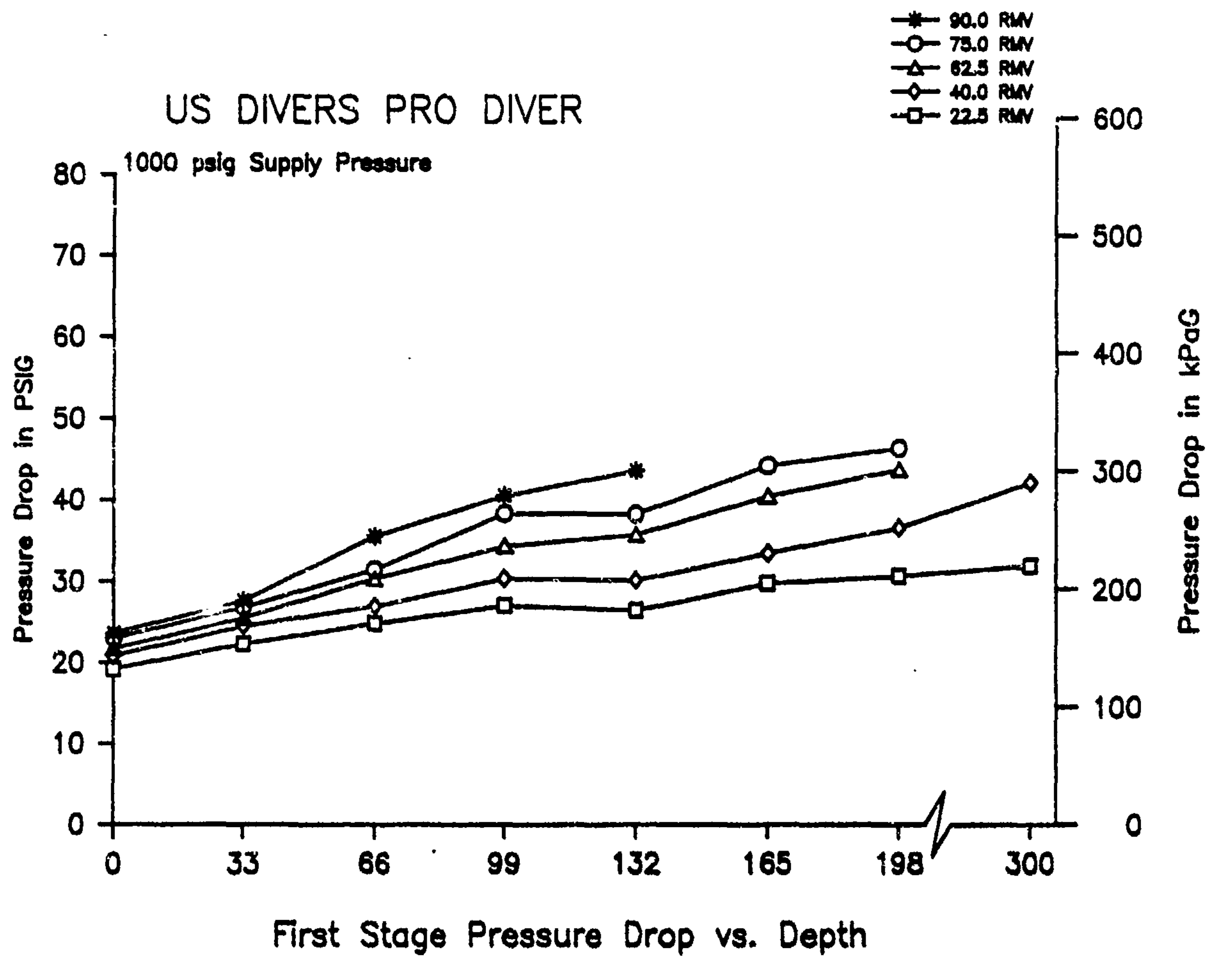
Breathing Resistance vs. Depth



Breathing Resistance vs. Depth



Breathing Work vs. Depth



US DIVERS PRO DIVER
1000 psig Supply Pressure
90.0 RMV
75.0 RMV
62.5 RMV
40.0 RMV
22.5 RMV
Pressure Drop in PSIG
Pressure Drop in kPaG
80
70
60
50
40
30
20
10
0
600
500
400
300
200
100
0
0
33
66
99
132
165
198
300
First Stage Pressure Drop vs. Depth