DIVE LAB, INC.

SURFACE SUPPLY BREATHING REQUIREMENTS AND RECOMMENDATIONS FOR KIRBY MORGAN HELMETS AND BAND MASKS

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This document was written by Dive Lab, Inc., for Kirby Morgan Diving Systems Inc., to assist users of KMDSI products in obtaining the maximum performance from their equipment. The rationale behind air supply requirements for diving helmets and masks can be confusing and is often misunderstood. It is our goal to explain the pressure and volume requirements for Kirby Morgan diving helmets and full face masks, and the basic requirements and concepts of how and why breathing performance tests on all equipment is done. The tables and pressures listed herein should only be used with KMDSI helmets and masks and have not been tested or approved for other manufacturers equipment. This document also includes information and guidance for flow testing surface supplied systems and umbilicals. The information contained herein is accurate to the best of our knowledge. As technology changes, so too will the equipment, procedures, and the contents of this document, as well as the procedures used by Dive Lab.

Dive Lab works closely with the Military, Commercial, and Scientific diving communities worldwide. As we learn, we will continue to add and revise this document as well as the Dive Lab CR standards and KMDSI equipment / training guides.

To have an understanding of surface supply pressure and volume requirements, you must first have a good understanding of the elements that make-up how and why breathing is measured, and how each component individually and as a system can effect breathing performance. Questions regarding this document can be directed to Dive Lab, Inc., at divelab@aol.com. Tel. 850-235-2715

Terms / Definitions:

ACFM: Actual Cubic Feet per Minute, measured at depth

ALPM: Actual Liters per Minute, measured at depth

Ambient Pressure: Surrounding pressure

Atmospheres Absolute: Depth in atmospheres + 1 (counts surface pressure as 1 Atm., which is added to total.)

Bar: Metric pressure measurement, one BAR = 14.5 PSIG

BPM: Breaths per Minute

CFM: Cubic feet per minute

EGS: Emergency Gas System

EXH MBR: Exhalation Pressure in Millibars

EXH WOB: Exhalation Work of Breathing

I.D.   Inside Diameter

INH MBR: Inhalation Pressure in Millibars

INH WOB: Inhalation Work of Breathing

Jouls/Liter (J/L): The measurement of work effort

Millibar (MBR): Metric pressure measurement 68.947 MBR = 1 PSI

One Atmosphere: = 14.696 PSIG,   .9869 BAR

PSIG: Pounds per Square Inch Gauge

RMV: Respiratory Minute Volume, also known as work rate, and is the tidal volume times the number of breaths per minute.

SCFM: Standard Cubic Feet per Minute, measured at surface

SEV: Surface Equivalent Value

SLPM: Standard Liters per Minute, volume measure at surface

Tidal Volume: The amount of gas moved in one inhalation, measured in liters

WOB: (Work of Breathing) the resistive effort produced by the breathing apparatus only

Helpful Formulas and Conversions

Determining ATA's for Depth Salt Water
(Depth + 33) ÷ 33 = ATA'S

PSI for Depth Salt Water
Depth in Feet x .445 psig

Computing PSIG Over Bottom Pressure (Old Formula)
Minimum Supply Pressure for Depth = (Depth x .445) + Manufacturer's Recommended O.B. Pressure = PSIG OB

Converting Liters to Cubic Feet
Liters ÷ 28.31= CF

Converting Cubic Feet to Liters
Cubic Feet x 28.31 = Liters

PSI to Bar
PSI ÷14.5 = Bar

Bar to PSI
14.5 x Bar = PSI

Feet to Meters
Feet ÷ 3.28 = Meters

Meters to Feet
Meters x 3.28 = Feet

Atmospheres Absolute
D+33÷33=ATA

PSI TO ATA'S
{(Depth x .445) + 14.7 }÷14.7=ATA's

Atmospheres Absolute to PSIG

D+33x.445=PSIG

1 FSW = .445 PSIG

1 FFW = .432 PSIG

Measuring Breathing Performance:

To accurately measure the breathing performance of diving equipment, test laboratories use specially designed breathing simulator systems along with universally accepted test equipment, methods, and procedures. A breath is made up of one inhalation cycle and one exhalation cycle. The volume of air moved during one inhalation or exhalation cycle is called the tidal volume. The physical lung volume of humans varies because of lung size, however, for measurement purposes, physiologists use established averages. To determine the tidal volume (how deep we breathe) physiologists measure the volume of air in liters moved during various levels of exercise and the number of breaths per minute. The tidal volume of the breath, and the number of breaths per minute, make up what is known as the Respiratory Minute Volume (RMV). RMV is the basis by which all breathing performance is measured. As the work rate increases, the body will increase the size of the tidal volume and the number of breaths per minute. As the diving depth increases, so does the ambient pressure, requiring more air for a given ventilation rate.

Breathing gas usage on the surface is measured in standard liters per minute (SLPM). When measuring air usage or requirements at depth, usage is measured in actual liters per minute (ALPM) then multiplied by the depth in atmospheres absolute (ATA'S) and expressed as standard liters per min (SLPM). To convert LPM to cubic feet (CF), you divide by 28.31. The work rates as RMV are shown below. These work rates are regarded as universal and can be used to determine gas usage rates by simply multiplying the RMV by the depth in atmospheres absolute (ATA) and then dividing by 28.31 to convert to standard cubic feet per minute.

Work Rates as RMV

Work Rate	RMV	SCFM
Rest	7 -10 RMV	0.24 - 0.35 SCFM
Light Work	11-20 RMV	0.35 - 0.70 SCFM
Moderate Work	21-37 RMV	0.70 - 1.30 SCFM
Heavy Work	38–54 RMV	1.30 - 1.90 SCFM
Severe Work	55–100 RMV	1.94 - 3.5 SCFM

Breathing Resistive Effort:

As we breathe in and out, there is a certain amount of resistance to the flow of the air from the natural configuration of the human breathing system. When a diver breathes using a helmet, mask, or any mechanical device, inhalation and exhalation resistance increases. This additional increase is known as resistive effort of the mechanical breathing apparatus. Resistive effort is also commonly referred to as work of breathing (WOB) and is actually the amount of physical effort required to breathe the diving apparatus only. Work of breathing can only be accurately measured using a breathing simulator system. The simulator actually breathes the equipment underwater at the required RMV, depth, supply pressures, and temperatures. The breathing simulators computer, monitors and records the inhalation and exhalation pressures, as well as other information over the entire breathing cycle taking hundreds of pressure samples per second. The computer then converts the pressure volume data from volume averaged pressure readings to work effort and presents it as in a work measurement known as Jouls/Liter (J/L). The repeatability and reliability of properly designed and maintained breathing systems is excellent, and there is no better way to measure and evaluate breathing equipment because the breathing simulators can work the equipment harder than any human and can be called on later to duplicate the same exact test.

Breathing Performance Requirements:

Currently, in the United States there is are no government/industry mandated breathing performance standards for commercial diving equipment. In Europe, diving helmets, full-face masks, and associated support equipment undergo CE type testing to European

Union, (EU) standards and directives. The test standards for air diving require helmets and masks meet minimum set performance requirements to a maximum depth of 50 meters (165 feet seawater (FSW). Other tests such as CO_2 washout, field of vision, and durability tests are also required. The standard also mandates a full technical package including assembly and component drawings, manufacturing procedures, quality assurance inspection, and assembly procedures, as well as failure modes and effects analysis and other documentation. The intent of CE certification is good, however, the actual testing and certification is not closely policed or regulated between the EU countries in the same manner. Consistency between notified bodies is greatly lacking. CE tests directives for diving equipment mandate what types of tests are to be done but does not always give clear guidance or direction as to how or why. Unfortunately, those that wrote the standard did not seek advice or assistance from those that design, manufacture, test and use the equipment. It is appears that many involved in writing the standards need additional assistance from the actual designers and users to achieve a useful, and harmonious test criteria, that will truly improve diver safety. Also, it appears that through a lack of understanding or outright manipulation of the test data, certain test houses and manufacturers look for loop holes and /or ways to interpret the standards to their favor using the vague nature of the standards itself. Because of this, test data is not only inaccurate in certain cases, but out right wrong and the presence of a "CE" mark on some of this equipment proves the point. The presence of the CE mark does not necessarily mean the equipment is safe or that it has even been tested properly. Further, adding to this problem, actual performance and use of the equipment in the workplace is not inspected, checked, or accurately gauged, even in the event of a mishap. In many cases, when a diving accident occurs resulting in injury or death things get hushed up, and often get settled out of court with the agreement of non disclosure, therefore, there are no lessons learned and others are free to make the same mistakes. Simple laws of physics and mathematics can be applied to expose those who make false claims.

Dive Lab develops all performance standards and requirements for all Kirby Morgan Helmets, Full Face Masks and associated equipments.

The inhalation / exhalation limits below were developed from breathing simulator testing and human trials. The limits below are set by Dive Lab for KMDSI equipment and represent a slightly more conservative approach than the current European limits and the U.S. Navy performance goals.

Table 1
Dive Lab (CR) Performance Limits for KMDSI Helmets and Full Face Masks

RMV	Inh MBR	Exh MBR	Inh WOB	Exh WOB	Max Overall WOB
10	10	10	0.4	0.4	0.8
22.5	10	10	0.7	0.5	1.2
40	15	15	1.2	1.2	1.7
50	15	15	1.3	1.3	1.9
62.5	15	17	1.3	1.3	2.3
75	15	18	1.7	1.5	2.7

Diver Work Rates:

The divers work rate, also known as respiratory minute volume (RMV), is basically how hard the diver breathes. As the diver's physical exercise increases, so does the ventilation rate. Proper training teaches the diver to never push the work rate beyond normal labored breathing. (This is in the 30-50 RMV range). To put things in perspective, heavy work for a physically fit person:

Swimming at one knot is about	38 RMV.
Running at 8 miles per hour is about	50 RMV.

Once the diver hits 55 RMV, he is entering the extreme range. Many fit divers can do 75 RMV for one to two minutes providing the inhalation resistive effort of the breathing system is not much above 1-1.3 J/L. Once the resistive effort gets into the moderate or heavy range or when the divers work effort exceeds 1.5 J/L the diver will not be able to sustain the level for long periods. The divers work rate should never be so heavy that the diver cannot carry on a simple conversation with topside.

When the work rate gets into the moderately heavy to heavy range 40-50 RMV the diver needs to slow down!!

Working to the point of being excessively winded should be avoided at all costs!!!

REMEMBER ; A diver must be able to slow himself down before reaching the danger of overexertion. Even without increased breathing resistance from the increased air density at depth and increased mechanical resistance from any breathing apparatus a competition runner can collapse from overexertion.

Working at work rates greater than 58 RMV underwater is "extreme", and can pose hazards that are not present when doing extreme rates on the surface. When underwater, inhalation and exhalation resistive effort increases due to the density of the breathing gas and resistive effort of the equipment. The increase in resistive effort can cause an increase in blood level Co2 because the diver cannot ventilate as freely as when breathing at the surface. At deeper depths on air, nitrogen narcosis can mask CO_2 symptoms which can then allow the situation snowball into even heavier breathing, often resulting in confusion, panic, and in rare cases muscle spasm, unconsciousness, sometimes resulting in death. In some rare cases high ventilation rates has been suspected as the cause of respiratory barotraumas, including arterial gas embolism. The possibility of suffering a respiratory over inflation event during high work rates while underwater could be even greater for divers that smoke, or have previous known or unknown lung disease or respiratory damage. The safest course for the diver is to keep his equipment properly maintained for peak performance and to know and understand the capabilities and limitations of the equipment including all breathing supply systems. Users of KMDSI equipment should have a good understanding of the information in this article and the KMDSI manuals for the equipment they use.

So, why is it many divers get away with using compressors that put out far less than is required? The reason is simple!! Most professional working divers do not do sustained work much greater than "40 RMV". Most experienced divers pace their work. Professional divers are trained to breathe slow and deep and not to over exert. As breathing becomes harder they slow down. In order to be safe, all divers should know the capability of the system they are using.

Symptoms of Inadequate Supply:

Most experienced surface supplied divers have probably experienced symptoms of inadequate supply volume caused from not having enough supply pressure or having a restriction in the system. When diving from a compressor or fixed pressure source that does not deliver enough air for the work rate at depth, the diver may experience large pressure drops at the side block. The side block is the best place on the diver's helmet to measure the supply pressure that is actually reaching the demand regulator after passing through the rest of the supply system from the surface. When the side-block pressure drops too low the demand valve velocity drops and the demand regulator can no longer flow enough air to supply the needs of the diver at heavy to extreme work rates. The symptoms can be very subtle or very abrupt from slightly hard breathing toward the middle or end of inhalation to almost no flow when a big suck is made. The main cause is "FAILURE OF THE UMBILICAL PRESSURE TO RECOVER". The pressure cannot build fast enough during the exhalation cycle following the last inhalation, opening the steady flow will give air but will also drop the umbilical and side block pressure even lower because air is flowing during the exhalation cycle as well, preventing the umbilical pressure from increasing to a level where the the demand regulator can work properly. Some divers know this, and they know their system cannot support heavy or extreme works so they pace their work so as not to over-breath the system. By following the guidelines for supply pressures and the information within this document and the KMDSI manuals, this can be avoided. Also by performing flow tests on the supply system, deficiencies or limitations can be identified.

As mentioned before, WOB is the work required to breathe the "helmet or mask only" and does not take into account resistance added by a tight fitting suit, harness or neck dam/hood.

The performance table (page 8) gives the respiratory limits used to formulate the WOB limits for all KMDSI Helmets and Band Masks. This table was produced by Dive Lab for KMDSI and is a slightly more conservative adaptation of what is found in the new European CE surface supplied diving standard. KMDSI sets the maximum inhalation limit at -15 MBR and maximum exhalation at 18 MBR. The European Standard allows -25 MBR for inhalation and +25 for exhalation. All properly configured, maintained, KMDSI helmets and band masks have the capability and should perform at an overall WOB of less than 1.85 J/L at heavy to extreme work rates and normally less than 1 J/L at moderate to heavy work rates when used in accordance within the KMDSI guidelines and the supply tables for depth and RMV.

Heavy work starts at around 38 RMV. KMDSI and Dive Lab recommend using no less than 40 RMV for average air consumption planning and recommends using supply pressures that will allow the diver to work at a minimum of 50-62.5 RMV.

Free Flow and Demand Mode Systems:

There are two basic types of helmets and masks used for surface supplied diving, free flow systems and demand systems. This article mainly focuses on Kirby Morgan Helmets and Full Face Masks which are demand mode systems, however, to be able to put things in perspective, its important to have a good understanding of free flow systems.

Free flow systems are the most basic form of surface supplied diving, and have been around longer than any other type of surface supplied equipment. The typical free flow helmet has a rather large internal volume where the head is free to move. Free flow helmets use a simple multi turn throttling valve to supply a steady flow of air into the helmet flushing the helmet interior and then dumping out into the water through a spring loaded exhaust valve. As this steady flow of air is passing through the helmet the diver inhales from the flow then exhales back into the helmet. Since the exhalation goes into the helmet and not directly out, free flow helmets require great quantities of air to dilute and flush CO_2.

Unlike free flow helmets, demand helmets have a snug fitting oral nasal mask that fits over the nose and mouth to minimize dead space. As long as the mask fits properly, and the regulator is adjusted properly, CO_2 will stay much lower than a free flow helmet because the air delivered from the demand valve flows directly to the oral nasal mask during the inhalation cycle only. During exhalation, the air is exhaled back into the oral nasal mask and out through the exhaust valves. Both free flow and demand systems require a certain minimum supply pressure to deliver the required volume at depth to allow good breathing performance and to keep CO_2 levels low.

All Kirby Morgan oral nasal masks have a rubber mushroom one-way valve that allows the diver to inhale gas from the steady flow (de-fogger flow) that is provided by activating the side block free flow valve. The mushroom valve in the oral nasal should always be positioned to allow air in the helmet/mask to be drawn into the oral nasal by the diver's breathing. The one-way valve should never be positioned to allow the diver's exhaled air to vent out into the helmet. The valve must only allow gas to enter the oral nasal this way the exhalation will be contained in the oral nasal and forced out into an isolated chamber (water trap / exhaust train) and then directly into the water.

If the diver's exhalation air is allowed to enter the helmet/mask dead space, the build up of Co2 can become extremely dangerous to the diver. In effect, the breathing cycle becomes a "rebreather". This is because when the diver inhales he will inhale any free gas from the helmet until the demand regulator activates and supplies fresh gas. the maximum amount of re-inhaled CO2 must never exceed 1% SEV at resting work rates or 2% SEV at heavy work rates.

Umbilicals:

Umbilicals used with demand mode helmets and masks for air diving have an inside diameter (I.D.) ranging from as small as a ¼", to as large as ½" I.D. The ¼" lightweight umbilicals up to 300 feet in length can normally only be used with high performance demand mode helmets and full-face masks to a maximum depth of approximately 75 FSW (23 MSW) and are mostly used with lightweight surface supplied systems and rarely used for commercial diving. Some special medium pressure ¼" umbilicals with special systems allow diving to 165 FSW (50 MSW). The 3/8" (9.5 MM) I.D. umbilicals are probably the most common umbilicals used for commercial diving and are normally used in lengths from 200' to 600' (61-182 meter) long. 3/8" umbilicals are often used to depths of 220' FSW (60 MSW) on air.

Use of 3/8" umbilicals longer than 300 feet with free flow helmets to depths deeper than 50 meters (165 FSW) may require higher supply pressures, and/or the use of ½" I.D. hose in order to deliver the required volume at depth to keep CO_2 levels low at heavy work rates. Regardless of I.D., as the umbilical length and number of interface fittings increase, so too does flow resistance caused by the friction developed as the air molecules pass along the hose walls. As depth increases, air density increases, and flow decreases. For the least amount of flow resistance the length and number of fittings should be kept to a minimum. The manufacturer of the helmet or mask should provide guidance for the minimum I.D., maximum length, and number of unions that can be used while maintaining performance within acceptable limits. Flow testing of the umbilicals and supply systems should be done by the user to ensure the system flow capability meets the minimum requirements for the type of diving to be done.

Using non standard umbilical configurations and / or home made supply systems without performing complete system flow tests could present a serious hazard for divers using the system. The design of the complete supply system should take into account the flow and pressure requirements of all circuits.

Umbilicals should be carefully maintained and inspected. Pressure testing and internal cleaning should be accomplished once a year or any time serviceability is in question. For cleaning, a 20-30 minute detergent and water flush followed by a 10-minute rinse, then drying using diver's air or nitrogen. Flow meter surface flow tests or timed flow of known volume should be performed to ensure flow capability. All Umbilical maintenance and testing should be logged and documented. See Umbilical flow testing (page 18).
(See Fig. 1 and Fig. 2 – on page 34)

<u>Volume Tanks:</u>

LP compressor supplied systems used for umbilical diving require a volume tank for proper operation and efficiency. The main purpose of the volume tank is to remove moisture, and to allow the compressor to rest via the cycling valve. Without a volume tank the compressor would have to run non-stop working at the maximum discharge pressure. The compressor life would be greatly reduced. By having a volume tank, the compressor can use a cycling valve that allows the compressor to pump up to a pre determined, pre set pressure, then the cycling valve trips and allows the compressor to free cycle at no load until the pressure in the volume tank drops to the low set pressure then the cycling valve resets and the compressor pumps back up until the volume tank is at the high end set pressure. The volume tank also serves as an expansion tank to help dry the air. Drying is accomplished when the air expands in the volume tank allowing the moisture to condense and drop to the bottom of the volume tank where it is periodically drained off. Volume tanks are a must for LP compressors but not necessary for properly designed HP supplied systems. Unlike LP systems, HP systems have the volume stored in the high-pressure banks and simply use pressure regulators to deliver the stored gas. Properly designed High Pressure (HP) control systems do not require volume tanks, however, it is often a common practice to interface HP systems with the LP compressor system with a one way valve to act as a back-up system or to augment the LP system. Interfacing a HP supply system with a volume tank can be done if desired.

Free Flow Helmet Air Pressure / Volume Requirements:
Unlike demand mode helmets, free flow helmets flow air during both inhalation and exhalation. The required volume of air for proper ventilation is dependent on the respiratory work rate and depth. Free flow helmets have much greater dead space volume than demand systems, and often rely on the compliant volume of the flexible neck dam and/or dry suit to reduce inhalation effort by acting as a breathing bag. Because of the large dead space, more air is needed for flushing in order to keep the accumulating of CO_2 within limits. On average, free flow helmets require at least 3 times as much air as demand mode helmets. The minimum required gas flow for free flow systems while doing light work is 4.5 actual cubic feet per minute (ACFM) (127 ALPM) and a minimum of 6.0 ACFM (170 ALPM) when performing heavy work rates. The supply pressure required for flow at depth is primarily dependent on the depth, length, and internal diameter of the umbilical, as well as any flow restrictions within the system. The actual pressure needed for half inch diameter umbilical up to 600' long is determined by the following formula, (Depth x 0.62) + 42 PSIG.

Required Pressure:

Example: Determine the minimum supply pressure for a dive to 150 FSW using a ½" I.D. umbilical 500' long.

Minimum supply pressure = (150 FSW x 0.62) + 42 PSIG
93 + 42 = 135 PSIG

Required Volume Free Flow Helmets:
For free flow helmets the volume required in SCFM when doing light work is a minimum of 4.5 ACFM at depth. The minimum required volume for heavy work is 6.0 ACFM. ACFM is the actual cubic feet per minute that is being used at depth. The ACFM is multiplied by the depth in atmospheres absolute to arrive at the standard cubic feet per minute of air needed from topside. Note: Compressors are normally rated in Standard Cubic Feet per Minute (SCFM) in the U.S. In Europe volume is measure in Liters and pressure in bars. When determining the volume required at depth the following formula is used:

[(Depth +33) ÷33] x 6.0 ACFM for moderate to heavy work, and 4.5 ACFM for light work

Example:

Compute the required volume needed by a diver working at a heavy work rate at a depth of 175 FSW.

(175+33)÷33] x 6.0 ACFM
6.03 x 6.0
36.18 SCFM

To determine the minimum volume required based light work you would use 4.5 ACFM in place of the 6.0 ACFM. To convert CFM to Liters Per Minute (lpm) you multiply CFM by 28.31. To convert liters to CFM you divide the liters by 28.31.

Demand Mode Air Requirements:

As mentioned before, demand helmets and masks provide the diver breathing gas during inhalation only, thereby reducing noise and overall resistive effort. Properly designed demand mode helmets and masks have very little dead space volume because the helmet uses a oral nasal mask attached directly to the inhalation and exhalation valves.

When properly designed and used, demand systems will keep re-inspired CO_2 levels well below the 2% surface equivalent (SEV) limit, requiring less than half the volume of air for a given RMV than that which is needed for a free flow system because the only gas used is that which is needed to inhale. In order to provide low inhalation performance at depth, the supply pressure to the helmet or mask must be high enough to allow optimal demand regulator operation and performance.

To determine the required supply pressure needed for a demand helmet or mask, the manufacturer performs tests using specific size umbilicals with various supply pressures. The breathing simulator is the most accurate way to document and record the resistive effort performance of the helmet or mask and to get an idea of overall performance.

New KMDSI Supply Pressure Tables:

KMDSI has recently developed "New" (November 2007 or more recent) surface supply pressure tables for all KMDSI helmets and masks. There are four (4) tables total, that cover the three basic KMDSI regulators found on all KMDSI helmets and band masks, three LP compressor tables, and two tables for HP regulated sources such as panels and consoles. The Low Pressure (LP) compressor tables are designed for compressors that put out pressures from 90 PSIG (6 bar) to 220 PSIG (15 bar). The HP supply tables run higher pressures and are intended to maximize inhalation performance at all depths and RMV'S because the high-pressure reducers can be adjusted to meet the supply pressure requirements of the table. The tables are easy to use and do not require using over-bottom calculations. There is a set of LP and HP tables for the SuperFlow / SuperFlow 350 Regulators and separate tables for the SF-450SS and Rex Regulator. The pressure needed can be read from the table as long as the depth and target or maximum anticipated RMV is known. The "old" (any supply pressure tables earlier than November, 2007) KMDSI tables were based on a minimum work rate of 62.5 RMV. The old table and formula may still be used if desired, however, performance in some cases may be limited to a maximum of 62.5 RMV. See new tables - Appendix A.

Standard KMDSI Surface Supply Pressure Formula - Old Method:

The old method of determining supply pressure was to multiply the dive depth by .445 PSI and then add the over-bottom pressure called out in the depth ranges for the depth from the KMDSI operations manual. The old method was based on a minimum RMV of 62.5. to depths of 165 FSW . This method can still be used. The old method used the formula called out over bottom pressures for depth as follows [(FSW x .445) + PSIG for depth] from the table below.

Depth in Feet and Meters		Over Bottom Pressure	
0-60 FSW (0-18 MSW)		90 PSIG (6.2 Bar)	
61-100	(18-30)	115	(7.9)
101-132	(30-40)	135	(9.3)
133-165	(40-50)	165	(11.4)
166-220	(50-67)	225	(15.5)

Example:

Using the old supply pressure formula, determine the over bottom pressure required for a dive to 100 FSW using a SuperLite® 17. From the manual, the minimum pressure required for 100 FSW is 115 PSIG over the bottom pressure. You determine the bottom pressure by multiplying the depth in feet by .445, then adding the required over bottom pressure for 100 FSW from table above.

(100 FSW x.445) + 115 PSIG
44.5 + 115 = 159 PSIG.

This means the gauge reading topside should be maintained at 159 PSIG in order to ensure the diver will have adequate flow at depth to allow the diver to breathe at a minimum of 62.5 RMV. Besides the pressure requirements, the supply system must be capable of providing sufficient volume.

Demand Mode Diving Using Low Pressure Compressors:

When using a low-pressure compressor for demand mode diving, the primary factors that determine breathing performance are umbilical pressure, RMV, and depth. Volume and pressure are very closely related and other factors such as umbilical length, diameter, and number of fittings also play an important role in allowing flow. LP compressors used for surface supplied diving have output pressures ranging from 90 to 200 (6.2-14 bar) and even up to 225 (15.5 bar) PSIG. Generally 140-190 PSIG (9.6-13 Bar) is probably the most common discharge range. The volume output of the compressor is based on the bore size, stroke, and RPM. Some compressors are as small as 5-20 SCFM (141-566 LPM) for small, movable by hand portable units, to large 50-90 SCFM (1415-2550 LPM) or larger that weigh in at 1000-4000 lbs. The first factor, “pressure”, could be a limiting factor because the pressure needed at depth may not be available due to the increased water pressure. Additionally, if the breathing rate (RMV) gets too great, the umbilical may not be capable of flowing sufficient air to the demand valve to keep up with demand. Using a compressor that makes large volume but cannot reach the required over-bottom pressure, will not deliver the needed volume at depth. Inversely, using a compressor that can deliver adequate pressure must be able to do so at enough volume to support the needs at depth or the air will be used faster than the pressure can build and be maintained. The easy way to remember this is, “volume is what is needed”, but it’s the pressure that pushes the volume down the hose to depth, and the pressure needs to be high enough for the helmet or masks demand valve to work properly. To determine compressor output for depth, first you need to know the depth and the highest anticipated work rate and/or usage and simple math will let you know what the capability should be and assuming the compressor and system has been properly maintained and configured. First you should know what the manufacturer says the compressor will put out in both pressure and flow. The manufacturer always gives a flow along with a discharge pressure. For example a Quincy® 5120 running at 1000 RPM will put out about 85 SCFM (2406 LPM) at 200 psig (13.8 bar). To check this you can attach a flow meter at the discharge end of a manifold valve then simply get the flow by throttling the outlet valve until you are maintaining a constant discharge pressure at low cycling setting, then read the flow. (See LP compressor flow testing page 18).

Before demand systems came along, free flow systems were the only systems in use and although they required a much greater volume for ventilation of the helmet, they required a much lower pressure than demand systems. Most of the world’s commercial and military diving communities made the switch from free flow to demand mode diving many years ago because demand systems offered better breathing performance, were much quieter, used far less air/gas, were faster and easier to deploy, allowing greater mobility and better access to small spaces.

Volume and Pressure Requirements:

Volume:
To determine the required volume needed in standard cubic feet a minute (SCFM) or standard liters per minute (SLPM) for demand diving, establish the depth and maximum high end work rate (anticipated) in LPM, then multiply the depth in "atmospheres absolute" by the respiratory work rate (RMV) in liters per minute; this gives you the amount of air needed at depth for maximum ventilation (heavy work). For normal air consumption planning 30-40 RMV should be adequate. Keep in mind the diver fills his lungs at depth with the same physical volume of gas as he does on the surface. Since the inhaled air is at the same pressure as the surrounding water, the actual volume breathed at depth if measured at the surface would be much greater, depending on the diver depth. The average tidal volume for diver at rest moves about .75-1 liter per breath at around 10 -12 breaths per minute. Moderate work is between 1.5-2.0 liters and about 15-20 breaths per minute. Heavy work 2.5-3 liter, 20-25 breaths per min. These are averages. As an example, if the diver is taking 2 liter breaths and is breathing 20 times in a minute the diver is doing 40 RMV, (2.0 liters x 20 breaths = 40 RMV). When you multiply the depth in atmospheres absolute by the actual breathing volume as RMV, you end up with standard liters also known as surface liters. You can convert standard liters to cubic feet by dividing the liters by 28.31. The answer is in standard cubic feet SCF.

Here is an example. The SL-27 diver is intending on working at 100 FSW (30.5 MSW) at a heavy work rate of 50 RMV. You want to know how much air he will be using and what he needs for a minimum volume and supply pressure. To find out you simply multiply 50 RMV by the depths in atmospheres absolute and you will know how much air he will be using. The formula would look like this [(100 FSW+33)÷33] x 50 RMV

(133÷33) x 50 RMV

(4 x 50RMV)

200 LPM

This means the diver would be using 200 SLPM. The compressor or supply system must be capable of producing at least 200 LPM just to stay even, but it is always a good idea to plan for 20% more. 200 x .20 = 40. 200 + 40 = 240 LPM. To change this to cubic feet divide the 240 liters by 28.31. = 8.47 CFM. The bottom line is you need a compressor that can put out a minimum of 8.47 CFM.

Pressure:
In order to get the required volume to the diver, you need to have the proper supply pressure. KMDSI has new supply pressure tables for use with LP compressors and also tables for use when using regulated high-pressure sources. For the above dive, if using a LP compressor you would use the low cycling pressure setting that your compressor is set for. In this case, the compressor in use cycles between a low end cycling pressure of 160

PSIG and a high end of 180 PSIG. The table for the SuperFlow® regulator shows that at 160 PSIG we could do 50 RMV to a maximum depth of 124 FSW. So 160 PSIG will be plenty of pressure to allow proper operation of the demand regulator providing the diver does not do sustained work above 50 RMV. There are LP tables for each of the three types of KMDSI demand regulators.

If you used the older supply pressure table it would have do the over bottom formula like this….. D = [(100x.445)x .445]+115

(100 x .445)+115

(44.5+115)

159.5 PSIG

Before you can determine if the compressor or supply system is adequate to supply the diver at a given depth, you need to know what the output capability of the system is. For LP compressor systems the manufacturers information tag may provide this data but it is always best to verify the flow by performing a flow test.

Low Pressure Compressor Flow Testing

Background:

Simple flow tests of surface supply system with and without umbilicals can be done to ensure equipment can adequately supply to the diver. The components used for testing are relatively inexpensive and easy to use and readily available. Conducting flow tests at regular intervals will establish a flow history of the system and components, and will help identify restrictions or flow deficiencies. Simple surface flow tests can be conducted which can be used to calculate what can be delivered at depth. (See Fig 1 and Fig 2 – page 34)

The components normally flow tested include the HP and / or LP compressors, interface whips, and diver umbilicals. Flow tests can be done using various methods, which include timed charging using a known volume, laminar flow elements, and simple gravity flow meters. The procedure described herein will only discuss the use of a simple gravity flow meter.

Temperature, altitude, barometric pressure, all have an effect on flow tests, however, unless the altitude is much greater than 1000 feet, altitude will not be a big factor. Temperature will probably have the greatest effect so it is best to try to test as close to the same temperature each time. Flow meters are calibrated at sea level at 70°F, and as long as the temperature does not change more than 10 degrees the flow will not be significantly affected. The warmer the discharge air is above 70°F the lower the flow, the colder the air the greater the flow. For correction formulas, refer to the manufacturers information sheet provided with the flow meter. For the greatest accuracy, the temperature and pressure corrections provided by the manufacturer can be applied. keep in mind these tests are primarily intended to identify flow problems, and / or compare to previous tests.

Flow Testing:

When testing LP compressors, you will need a flow meter in the range for the compressor flow capability, but not too large. Try to use a flow meter that looks at the flow in the mid to upper range of the meter. Standard flow ranges are available in 750 LPM (25 SCFM), 1400 LPM (50 SCFM); the 1400 LPM meter will usually cover all umbilical flow testing. For doing large LP compressors like the 5120 the 2800 LPM (99 SCFM) should do the job. Other ranges are also available. The flow meters normally have a 1" female pipe thread inlet and outlet connections. When testing LP compressors attach the flow meter to a large bore valve on the discharge manifold that normally feeds the umbilical. It is important that the valve flow be capable of more air flow than the compressor can pump. If necessary, use a separate valve and fitting so the flow is greater than the compressor can maintain.

For testing a compressor, the flow meter will have to be attached to the outlet valve coming off the volume tank or tank manifold. LP compressors used for diving are equipped with an adjustable cycling valve. During compressor operation, the compressor pressure rises until the maximum high end set pressure is reached activating the cycling valve and the compressor free wheels until the volume tank pressure drops to the low set point pressure where the loader kicks in and the compressor pumps the volume tank back up until the high end set pressure is reached.

Basic Test Steps:

Note: All flow tests explained in this paper are open flow tests. This means the outlet to the flow meter is open and is not attached to anything.

1. With the compressor not running, shut all discharge valves.
2. Attach the flow meter to a manifold outlet valve and then check to ensure the outlet of the flow meter is not plugged off with a protective cap.
3. Start the compressor and allow the compressor to pump up to the maximum high pressure until the compressor unloads, then start venting the manifold through the flow meter until the minimum set pressure is reached and the compressor starts pumping, note the pressure.
4. Throttle the valve by opening and closing as necessary and once the discharge pressure is holding steady at the minimum cycling pressure, record the pressure and the flow. As long as the pressure is not increasing or decreasing, you will be at the maximum discharge volume.
5. Log the LP discharge pressure, as well as the first stage pressure, and the flow. You will now know the free flow capacity at the surface.

HP Control Panel/Console
Properly designed high pressure supplied control panels can offer greater flow capability for surface supplied air diving than compressors because they can reach higher pressures due to the regulator being supplied by higher pressure banks. Properly designed panels / consoles with good quality high performance pressure reducers do not need a LP volume tank as long as the HP regulators can maintain a steady manifold pressure and the components are matched for good flow. One important feature in selecting a system is the regulators capacity for high flow when the HP banks get low. Ensuring the regulators are capable of flowing high volumes even when the bank pressures get as low as 400-300 PSIG will enable you to get the most from the HP banks, maximizing supply capabilities. Control consoles will start to lose flow once the supply pressure feeding the regulator drops to a point where the reduced pressure cannot be maintained. Properly designed systems will allow the banks to be used to a very low pressure before a switch to a higher bank is needed. To do a proper flow test, the HP supply pressure must be monitored so that so that the minimum HP supply pressure can be determined while flow testing the rest of the system. This information is useful so you will know at what pressure a bank switch must be done at during the dive. For a simple flow test use the systems normal HP supply banks, you will only want to use one cylinder so you can get a faster pressure drop. For small portable panels where SCUBA cylinders are used, one SCUBA cylinder will work for flow testing. Most high flow, high-pressure reducers will usually start showing a loss of flow when the HP supply drops to between 800- 500 psig.

HP Control Panel / Console Flow Testing:
Caution: when conducting a flow test, the regulator will get very cold due to the adiabatic cooling of the gas going from high pressure to low pressure. This cooling can also affect flow. For this reason it is always best to do the testing at approximately the same temperature and the same starting HP pressure for each test. Using 800-1000 PSIG as the flow starting point is reasonable because most regulators will not show a significant reduction in flow until the supply pressure drops below 500 PSIG.
Ensure the high and low pressure gauges are accurate and have been compared to gauges of known accuracy. Additional gauges can be tapped into the system for comparison if required. The control panel can be flowed with and without umbilicals attached. Regardless of the method, ensure the procedure is written up in detail including pictures so the test can be accurately duplicated later. Properly engineered panel/console systems have separate circuits including separate regulators for each diver, therefore, require flow testing of each circuit.
Note: The maximum flow capability of the console circuit itself may not be realized if the discharge valve and fitting at the outlet of the console is not large enough; usually a 3/8" or larger outlet valve or larger will be required to allow maximum flow. Have an HP supply with at least 1000 psig so that as the HP pressure drops you can check and log the

LP pressure and flow. This test is a little more involved than other flow tests because you want to find out how low you can take the bank pressure before outlet flow to the diver is affected and you start getting a significant reduction in flow.

1. Attach the flow meter directly to the outlet valve using the appropriate adapters. Ensure the flow meter has the flow capacity and range for the anticipated flow, and insure the outlet port of the flow meter is open.

2. Ensure the outlet valves are shut and the regulators are backed off, then slowly load the regulator to the normal maximum discharge pressure.

3. Slowly open the valve and start the flow. Readjust the regulator to get the desired discharge pressure on the LP gauge, as the HP pressure drops, record the LP pressure and flow every 100 psig starting at 1000-800 PSIG, until you reach about 200 psig. It is easier to have one person call out the HP pressure each 100 PSIG while another person adjusts the regulator dynamically and records the LP pressure and flow. By doing the test this way you will learn where HP supply starts to have a large effect and you can determine how low you can go with the HP supply before having to shift banks.

4. The main concern with HP regulators is "DROOP". You want to make sure the regulator can return to the set pressure. Seeing pressure pulsing on the surface LP gage of more than 15-20 PSIG when the diver is breathing, could indicate a significant droop in the regulator indicating the regulator may be having trouble keeping up with the demand. Testing of all circuits should be done to ensure each diver's circuit flow's properly.

5. After you have tested the panel/console, flow test each umbilical to ensure they flow properly.

6. To do this, attach the topside end of the umbilical to the discharge valve on the panel or console. Attach the flow meter to the divers end of the umbilical using adapter fitting. A 1" NPT – 3/8"(9.4 mm) oxygen or - 4 AN.

Note: The longer the umbilical the less flow you will have at a given discharge pressure due to the resistance to flow.

It is important to record the fittings and procedure used so the same system can be used for future tests. Taking pictures and documenting the procedure will help for future tests. What pressure to use with the umbilical is not as important as using the same pressure each time you do the test. Probably the easiest way for surface flow testing is to test somewhere around 180 PSIG (12.5), then always use those pressures when verifying system flow and umbilical flow. If you are using a LP compressor, you should use the low setting of the cycling valve. Flow testing of the umbilicals and deck whips should be accomplished at least annually, and/or whenever flow is in question. Flow testing the umbilical using a low pressure compressor or HP control system will identify the surface flow capability of the umbilical and supply system and can also be used to identify possible flow deficiencies or system restrictions.

Umbilical Flow Testing:

After flow testing the compressor or HP supplied panel, the umbilical can be flow tested one at a time. The most important thing that the umbilical flow test will show is that the umbilical being tested can flow the same as it did during the last test, and / or approximately the same as other umbilicals of the same make, length and configuration. If suddenly you notice a 20% decrease in flow from when you do the flow test you will know you may have a dirty or obstructed umbilical. Its is best to flow at the normal discharge pressure of your system, up to about 200 psig for 300’ umbilicals, so you can stay within the flow meters range when using the 1400 LPM flow meter. Longer umbilicals can be flowed at higher pressures without exceeding the 1400 LPM flow meter. Umbilicals of the same length using the same fittings should be within about 5% of each other when flow tested. Ensure the umbilical is coiled with no sharp bends or tight radius.

For 3/8” hoses 300 feet long or less, the 1400 lpm flow meter will be the best choice when using pressures of 200 PSIG (14 bar) or below. The adapters needed to attach the umbilical to the flow meter can be simple hardware store PVC adapters sealed with Teflon® tape and hand tightened. Dirty umbilicals may flow considerably less air. This is especially true for umbilicals that have oil residue. Below are some approximate average flow figures.

Typical Surface Flows using Gates® 33 HB hose (At sea level, 72°F)

PSIG	300’ Long	600’ Long (Two 300’ Coupled)
100	640 LPM	420 LPM
120	740 LPM	510 LPM
140	840 LPM	550 LPM
160	950 LPM	620 LPM
180	1080 LPM	740 LPM
200	1180 LPM	790 LPM

1. Attach the umbilical to the air supply control valve on the manifold as it is normally made up and keep the flow meter upright and level. If temperature corrections are to be used, set a temperature probe at the discharge end of the flow meter will need to be monitored.

2 Slowly open the supply valve to the umbilical and allow air to flow for at least 15-30 seconds.

3. Adjust the regulator dynamically to maintain the desired outlet pressures. Record and log the pressure and flow data for comparison to past and future comparison.

Determining Volume / Depth

Once you know what the system can flow at a given pressure, you can then compute what the system would flow at a given depth by multiplying the depth in ATA's by the RMV. for planning heavy work a minimum of 50-60 RMV should be used. As an example, a diver working at 130 FSW (39 MSW) doing 60 RMV, (132+33) ÷ 33) x 60 LPM

(165 ÷ 33) x 60 LPM

5 ATA's x 60 LPM

300 SLPM

The above example shows that you will need to supply a minimum of 300LPM. Add a 20% safety factor and your up to 360 SLPM (12.7 SCFM). This would insure an adequate peak supply for 60 RMV providing the pressure requirements can be met. The topside delivery pressure for this dive according to the SuperFlow 350 tables would be 200 PSIG (13.8 bar). In comparison the KM-47 and 77 could be dived to 174 FSW (53 MSW) using the same 200 psig pressure.

In the above example the average fit working diver could probably not sustain this work rate for more than a minute or two without becoming exhausted.

APPENDIX A – TABLES

TABLE FOR MANUAL
Supply Pressure Requirements for Helmets & Masks equipped with SUPERFLOW® and SUPERFLOW® 350 Regulators

SUPPLY PRESSURE	RMV	DEPTH FSW	DEPTH MSW	ATA	Required SLPM	w/20% safety margin	Required SCFM
90 PSIG / 6.21 BAR	40	76	23	3.30	132.12	158.55	5.60
	50	63	19	2.91	145.45	174.55	6.17
	62.5	44	13	2.33	145.83	175.00	6.18
	75	33	10	2.00	150.00	180.00	6.36
100 PSIG / 6.9 BAR	40	86	26	3.61	144.24	173.09	6.11
	50	72	22	3.18	159.09	190.91	6.74
	62.5	55	17	2.67	166.67	200.00	7.06
	75	42	13	2.27	170.45	204.55	7.23
110 PSIG / 7.59 BAR	40	100	31	4.03	161.21	193.45	6.83
	50	83	25	3.52	175.76	210.91	7.45
	62.5	67	20	3.03	189.39	227.27	8.03
	75	50	15	2.52	188.64	226.36	8.00
120 PSIG / 8.28 BAR	40	112	34	4.39	175.76	210.91	7.45
	50	91	28	3.76	187.88	225.45	7.96
	62.5	71	22	3.15	196.97	236.36	8.35
	75	57	17	2.73	204.55	245.45	8.67
130 PSIG / 8.97 BAR	40	122	37	4.70	187.88	225.45	7.96
	50	100	31	4.03	201.52	241.82	8.54
	62.5	82	25	3.48	217.80	261.36	9.23
	75	60	19	2.82	211.36	253.64	8.96
140 PSIG / 9.66 BAR	40	137	42	5.15	206.06	247.27	8.73
	50	108	33	4.27	213.64	256.36	9.06
	62.5	84	26	3.55	221.59	265.91	9.39
	75	65	20	2.97	222.73	267.27	9.44

SUPPLY PRESSURE SURFACE GAUGE	RMV	DEPTH		ATA	Required SLPM	w/20% safety margin	Required SCFM
		FSW	MSW				
150 PSIG / 10.35 BAR	**40**	145	44	5.39	215.76	258.91	9.15
	50	120	37	4.64	231.82	278.18	9.83
	62.5	95	29	3.88	242.42	290.91	10.28
	75	69	21	3.09	231.82	278.18	9.83
160 PSIG / 11.04 BAR	**40**	157	48	5.76	230.30	276.36	9.76
	50	124	38	4.76	237.88	285.45	10.08
	62.5	100	31	4.03	251.89	302.27	10.68
	75	76	23	3.30	247.73	297.27	10.50
170 PSIG / 11.73 BAR	**40**	167	51	6.06	242.42	290.91	10.28
	50	135	41	5.09	254.55	305.45	10.79
	62.5	107	33	4.24	265.15	318.18	11.24
	75	86	26	3.61	270.45	324.55	11.46
180 PSIG / 12.42 BAR	**40**	181	55	6.48	259.39	311.27	11.00
	50	148	45	5.48	274.24	329.09	11.62
	62.5	115	35	4.48	280.30	336.36	11.88
	75	93	28	3.82	286.36	343.64	12.14
190 PSIG / 13.11 BAR	**40**	190	58	6.76	270.30	324.36	11.46
	50	154	47	5.67	283.33	340.00	12.01
	62.5	122	37	4.70	293.56	352.27	12.44
	75	100	31	4.03	302.27	362.73	12.81
200 PSIG / 13.8 BAR	**40**	192	59	6.82	272.73	327.27	11.56
	50	166	51	6.03	301.52	361.82	12.78
	62.5	132	40	5.00	312.50	375.00	13.25
	75	102	31	4.09	306.82	368.18	13.01
210 PSIG / 14.49 BAR	**40**	212	65	7.42	296.97	356.36	12.59
	50	175	53	6.30	315.15	378.18	13.36
	62.5	137	42	5.15	321.97	386.36	13.65
	75	108	33	4.27	320.45	384.55	13.58
220 PSIG / 15.18 BAR	**40**	220	67	7.67	306.67	368.00	13.00
	50	182	56	6.52	325.76	390.91	13.81
	62.5	147	45	5.45	340.91	409.09	14.45
	75	111	34	4.36	327.27	392.73	13.87

End SuperFlow and SuperFlow 350 Table

Rex® Regulator / KM-47 / KM-77

Low Pressure Compressor Table
Supply Pressure Requirements
For New Operations Manual

SUPPLY PRESSURE SURFACE GAUGE READING	RMV	DEPTH FSW	MSW	ATA	Required SLPM	w/20% safety margin	Required SCFM
90 PSIG / 6.21 BAR	**40**	104	32	4.15	166.06	199.27	7.04
	50	76	23	3.30	165.15	198.18	7.00
	62.5	61	18.8	2.85	178.03	213.64	7.55
	75	50	15.4	2.52	188.64	226.36	8.00
100 PSIG / 6.9 BAR	**40**	108	33	4.27	170.91	205.09	7.24
	50	90	27	3.73	186.36	223.64	7.90
	62.5	75	22.9	3.27	204.55	245.45	8.67
	75	59	18	2.79	209.09	250.91	8.86
110 PSIG / 7.59 BAR	**40**	117	35	4.55	181.82	218.18	7.71
	50	100	30	4.03	201.52	241.82	8.54
	62.5	83	25	3.52	219.70	263.64	9.31
	75	68	21	3.06	229.55	275.45	9.73
120 PSIG / 8.28 BAR	**40**	117	35	4.55	181.82	218.18	7.71
	50	112	34	4.39	219.70	263.64	9.31
	62.5	93	28	3.82	238.64	286.36	10.12
	75	75	23	3.27	245.45	294.55	10.40
130 PSIG / 8.97 BAR	**40**	145	44	5.39	215.76	258.91	9.15
	50	125	38	4.79	239.39	287.27	10.15
	62.5	106	32	4.21	263.26	315.91	11.16
	75	85	26	3.58	268.18	321.82	11.37

REX® REGULATOR / KM-47 / KM-77 (Continued)							
SUPPLY PRESSURE SURFACE GAUGE	RMV	DEPTH FSW	MSW	ATA	Required SLPM	w/20% safety margin	Required SCFM
140 PSIG / 9.66 BAR	40	160	48	5.85	233.94	280.73	9.92
	50	135	41	5.09	254.55	305.45	10.79
	62.5	114	35	4.45	278.41	334.09	11.80
	75	95.5	29	3.89	292.05	350.45	12.38
150 PSIG / 10.35 BAR	40	170	52	6.15	246.06	295.27	10.43
	50	149	45	5.52	275.76	330.91	11.69
	62.5	126	38	4.82	301.14	361.36	12.76
	75	105	32	4.18	313.64	376.36	13.29
160 PSIG / 11.04 BAR	40	186	57	6.64	265.45	318.55	11.25
	50	157	48	5.76	287.88	345.45	12.20
	62.5	134	41	5.06	316.29	379.55	13.41
	75	112	34	4.39	329.55	395.45	13.97
170 PSIG / 11.73 BAR	40	203	62	7.15	286.06	343.27	12.13
	50	170	52	6.15	307.58	369.09	13.04
	62.5	143	43	5.33	333.33	400.00	14.13
	75	121	37	4.67	350.00	420.00	14.84
180 PSIG / 12.42 BAR	40	219	67	7.64	305.45	366.55	12.95
	50	180	55	6.45	322.73	387.27	13.68
	62.5	158	48	5.79	361.74	434.09	15.33
	75	130	39	4.94	370.45	444.55	15.70
190 PSIG / 13.11 BAR	40	220	67	7.67	306.67	368.00	13.00
	50	192	58	6.82	340.91	409.09	14.45
	62.5	165	50	6.00	375.00	450.00	15.90
	75	141	43	5.27	395.45	474.55	16.76

REX® REGULATOR / KM-47 / KM-77 (Continued)							
SUPPLY PRESSURE SURFACE GAUGE	RMV	DEPTH FSW	MSW	ATA	Required SLPM	w/ 20% safety margin	Required SCFM
200 PSIG / 13.80 BAR	**40**	220	67	7.67	306.67	368.00	13.00
	50	205	62	7.21	360.61	432.73	15.29
	62.5	174	53	6.27	392.05	470.45	16.62
	75	147	45	5.45	409.09	490.91	17.34
210 PSIG / 14.49 BAR	**40**	220	67	7.67	306.67	368.00	13.00
	50	215	65.8	7.52	375.76	450.91	15.93
	62.5	186	56	6.64	414.77	497.73	17.58
	75	159	48	5.82	436.36	523.64	18.50
220 PSIG / 15.18 BAR	**40**	220	67	7.67	306.67	368.00	13.00
	50	220	67	7.67	383.33	460.00	16.25
	62.5	194	59	6.88	429.92	515.91	18.22
	75	165	50	6.00	450.00	540.00	19.07

End Rex Regulator KM-47 / KM-77 Table

KM-57 Low Pressure Compressor Table
Supply Pressure Requirements
For New Operations Manual

SUPPLY PRESSURE SURFACE GAUGE READING	RMV	DEPTH FSW	MSW	ATA	Required SLPM	w/20% safety margin	Required SCFM
90 PSIG / 6.21 BAR	**40**	90	27	3.73	149.09	178.91	6.32
	50	76	23	3.30	165.15	198.18	7.00
	62.5	62	19	2.88	179.92	215.91	7.63
	75	44	13	2.33	175.00	210.00	7.42
100 PSIG / 6.9 BAR	**40**	101	31	4.06	162.42	194.91	6.88
	50	86	26	3.61	180.30	216.36	7.64
	62.5	67	20	3.03	189.39	227.27	8.03
	75	55	17	2.67	200.00	240.00	8.48
110 PSIG / 7.59 BAR	**40**	111	34	4.36	174.55	209.45	7.40
	50	99	30	4.00	200.00	240.00	8.48
	62.5	74	22	3.24	202.65	243.18	8.59
	75	65	20	2.97	222.73	267.27	9.44
120 PSIG / 8.28 BAR	**40**	125	38	4.79	191.52	229.82	8.12
	50	111	34	4.36	218.18	261.82	9.25
	62.5	90	27	3.73	232.95	279.55	9.87
	75	72.5	22	3.20	239.77	287.73	10.16
130 PSIG / 8.97 BAR	**40**	141	43	5.27	210.91	253.09	8.94
	50	115	35	4.48	224.24	269.09	9.51
	62.5	100	30	4.03	251.89	302.27	10.68
	75	76	23	3.30	247.73	297.27	10.50
140 PSIG / 9.66 BAR	**40**	160	49	5.85	233.94	280.73	9.92
	50	123	37	4.73	236.36	283.64	10.02
	62.5	110	33	4.33	270.83	325.00	11.48
	75	83	25	3.52	263.64	316.36	11.17

KM-57 LP Table (Continued)

SUPPLY PRESSURE SURFACE GAUGE	RMV	DEPTH FSW	MSW	ATA	Required SLPM	w/20% safety margin	Required SCFM
150 PSIG / 10.35 BAR	**40**	172	52	6.21	248.48	298.18	10.53
	50	137	41	5.15	257.58	309.09	10.92
	62.5	115	35	4.48	280.30	336.36	11.88
	75	93	28	3.82	286.36	343.64	12.14
160 PSIG / 11.04 BAR	**40**	185	56	6.61	264.24	317.09	11.20
	50	147	45	5.45	272.73	327.27	11.56
	62.5	130	40	4.94	308.71	370.45	13.09
	75	102	31	4.09	306.82	368.18	13.01
170 PSIG / 11.73 BAR	**40**	200	61	7.06	282.42	338.91	11.97
	50	161	49	5.88	293.94	352.73	12.46
	62.5	136	41	5.12	320.08	384.09	13.57
	75	110	33	4.33	325.00	390.00	13.78
180 PSIG / 12.42 BAR	**40**	211	64	7.39	295.76	354.91	12.54
	50	169	51	6.12	306.06	367.27	12.97
	62.5	145	44	5.39	337.12	404.55	14.29
	75	116	35	4.52	338.64	406.36	14.35
190 PSIG / 13.11 BAR	**40**	221	67	7.70	307.88	369.45	13.05
	50	173	53	6.24	312.12	374.55	13.23
	62.5	153	46	5.64	352.27	422.73	14.93
	75	126	38	4.82	361.36	433.64	15.32
200 PSIG / 13.80 BAR	**40**	222	67	7.73	309.09	370.91	13.10
	50	191	58	6.79	339.39	407.27	14.39
	62.5	165	50	6.00	375.00	450.00	15.90
	75	133	40	5.03	377.27	452.73	15.99

SuperFlow 450 LP Table (Continued)							
SUPPLY PRESSURE SURFACE GAUGE	**RMV**	**DEPTH FSW**	**MSW**	**ATA**	**Required SLPM**	**W/20% safety margin**	**Required SCFM**
210 PSIG / 14.49 BAR	**40**			1.00	40.00	48.00	1.70
	50	191	58	6.79	339.39	407.27	14.39
	62.5	166	50	6.03	376.89	452.27	15.98
	75	140	42	5.24	393.18	471.82	16.67
220 PSIG / 15.18 BAR	**40**			1.00	40.00	48.00	1.70
	50	202	61	7.12	356.06	427.27	15.09
	62.5	170	51	6.15	384.47	461.36	16.30
	75	148	45	5.48	411.36	493.64	17.44

End KM-57 Table

HP Tables:

SuperFlow® / SuperFlow® 350 Regulator High Pressure Regulated Source Supply Pressure Requirements					
Depth		Regulator Setting Surface Gauge in P.S.I.G.		Regulator Setting Surface Gauge in BAR	
FSW	MSW	Minimum P.S.I.G.	Maximum P.S.I.G.	Minimum Bar	Maximum Bar
0-60	0-18	150	225	10.3	15.5
61-100	19-30	200	250	13.8	17.2
101-132	31-40	250	275	17.2	18.9
133-165	41-50	250	300	17.2	19.6
*166-220	51-61	300	325	20.6	22.4

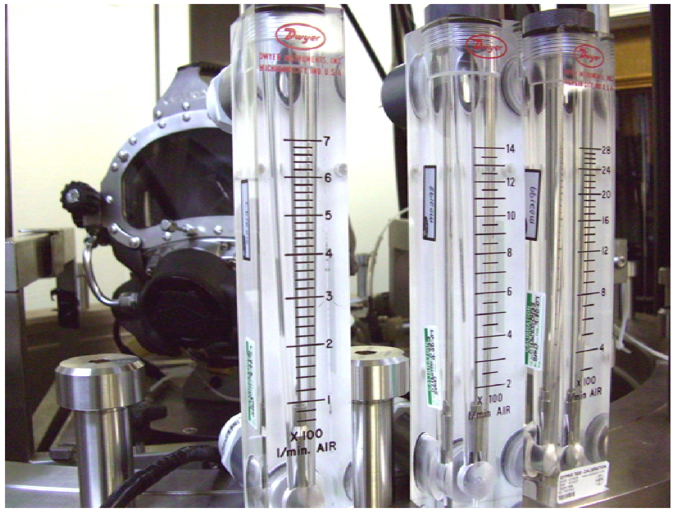
*May not be capable of performing at 75 RMV deeper than 165 FSW.

Performance is based on a minimum of 75 RMV to 165 FSW (50 MSW) and 62.5 RMV to 220 FSW (67 MSW) using a 3/8" (9.5 mm) umbilical 600 foot (183 meters) long, made up of two 300 foot (91 meter) sections.

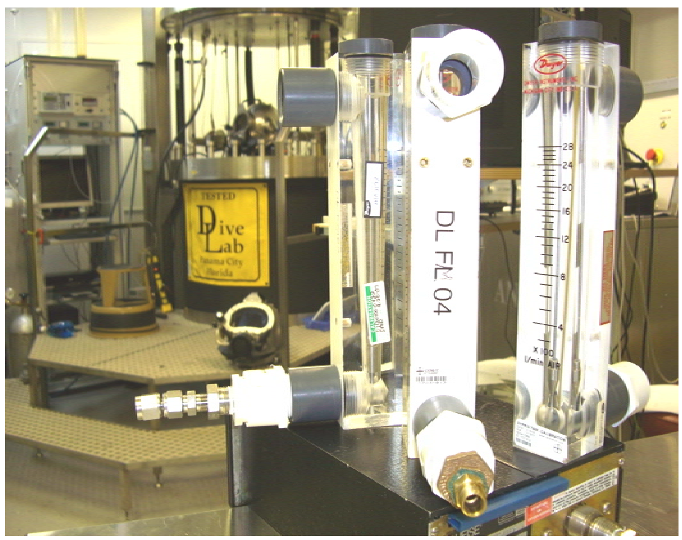
Rex® Regulator / KM-47 / KM-77 / SF450SS High Pressure Regulated Source Supply Pressure Requirements					
Depth		Regulator Setting Surface Gauge in P.S.I.G.		Regulator Setting Surface Gauge in BAR	
FSW	MSW	Minimum P.S.I.G.	Maximum P.S.I.G.	Minimum Bar	Maximum Bar
0-60	0-18	140	200	9.7	13.8
61-100	19-30	165	220	11.4	15
101-132	31-40	180	250	12.4	17
133-165	41-50	220	300	15	20.7
166-220	51-61	270	300	18.6	20.7

Performance is based on a minimum of 75 RMV to depths of 220 FSW (67 MSW) using a 3/8" (9.5 mm) umbilical 600 foot (183 meters) long, made up of two 300 foot (91 meter) sections.

End HP Tables



Typical Flow Meters - Fig. 1



Umbilical and Interface Fittings - Fig. 2

Summary

The diving operations authority, be it military, commercial, scientific, government agency, commercial diving contractor or other, should select the ideal boundaries for their operation from the tables and information. Remember, that a diver (similar to most humans) cannot sustain a WOB much above 50 or so RMV. Test requirements of 62.5, 75, and especially 90 RMV may show that the equipment can perform at those RMV's, but divers cannot, and trained divers are trained not to over exert. This means not trying to work at severe work rates. Planning for a sustained 40 RMV work rate is sufficient for planning air usage for moderate to moderately heavy work. Planning for 50-60 RMV is reasonable for planning minimum heavy WOB performance requirements. It must be remembered that in an emergency, the EGS can be used to immediately supply the diver with a higher-pressure for the higher RMV, however, it is strongly recommended that anytime the diver goes on EGS, the dive should be aborted. During ascent, the surface supplied pressure will increase over the water pressure allowing increased RMV.

Users should ensure that the compressor or supply system meets both the supply pressure and output volume required for the deepest anticipated depth and ventilation rate. Below is the formula used for computing the Minimum Volume of air required for ventilation at depth.

Note: This is the bare minimum. As a safety margin, it is safer to plan on an additional 10%-20% to ensure the supply system can keep up. Using the new supply tables will allow the greatest flexibility. When in doubt, the old pressure for depth formula tables can be used.

$$\{(\text{Depth} + 33) \div 33\} \times \text{RMV}\} \times .10 \text{ or } .20 \text{ \% safety margin.}$$

Best Practice:

- When using a LP compressor always base the output pressure on the lowest pressure during compressor cycling.
- Complete a flow test of the compressor / air system at least once a year.
- Clean, pressure test, and flow test all umbilicals at least once a year.
- Always take the standby diver into consideration when planning air usage and supply requirements.
- Always allow for at least 10-20% greater volume than what is needed for the maximum ventilation anticipated.

- Never use less than 40 RMV for planning purposes.

- Refrain from high flow use of the helmet steady flow valve.

- “Always dive with a fully functional man worn emergency gas supply system (EGS) of sufficient capacity based on the hazards of the task. Always have the cylinder valve open and the emergency valve on the side block shut.

- When using HP supply systems (Control Consoles) use the recommended pressures for depth as listed in the chart for High Pressure Supply Systems. For best overall performance, avoid using pressures excessively higher than what is required for depth especially if diving shallow.

If using umbilicals longer than 600 feet or umbilicals with an internal diameter less than 3/8” (9.5mm), or other configurations not mentioned, E-mail or call KMDSI or Dive Lab, Inc., for further guidance and information.

Questions on this article, as well as any volume and supply issues, can be addressed to Mike Ward at Dive Lab, Inc.

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END