TESTED
Dive Lab®
Panama City Beach
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Surface Supply Breathing Requirements & Recommendations

For Kirby Morgan® Helmets and Masks

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INTRODUCTION

Dive Lab prepared this document to help users of Kirby Morgan® KMDSI helmets and full-face masks to get the maximum performance from their equipment. Supply pressure and volume requirements are often misunderstood; it is our goal with this document to explain the requirements for KMDSI diving helmets and full-face masks, including the basic concepts behind how and why they apply.

To understand surface supply breathing requirements, you must first have a good understanding of the elements that make-up breathing rates, and how breathing is measured. Regardless of what type of helmet or full-face mask is in use, you must have a basic understanding of how components individually, and as a complete system can affect breathing performance. It is also important that professional divers and support personnel have a good understanding of the regulations and requirements that govern commercial diving operations.

Although this document focuses on the breathing performance requirements of KMDSI demand-mode equipment, the basic concepts also apply to other demand-mode helmets and full-face masks. This article includes background information on free flow and demand-mode surface supplied diving, as well as guidance for conducting flow testing of umbilicals, low-pressure compressors, and high-pressure regulated supply systems. Questions may be directed to Dive Lab, Inc. at divelab@divelab.com.

TERMS/DEFINITIONS

ACFM	Actual Cubic Feet per Minute
ALPM	Actual Liters per Minute
Ambient Pressure	Surrounding Pressure
ATM	Atmospheres. The weight of the atmosphere at sea level, equal to 14.7 psig or 33 FSW
ATA	Atmospheres Absolute. Depth in atmospheres + 1 ATM
Bar	Metric pressure measurement = 14.5 psig
BPM	Breaths per Minute
CFM	Cubic feet per minute
EGS	Emergency Gas System
EXH MBR	Exhalation Pressure in Millibars (MBR)
EXH WOB	Exhalation Work of Breathing in Joules Liter
FSW	Feet Sea Water
FFW	Feet Fresh Water
I.D.	Inside Diameter
HP	High Pressure
LP	Low Pressure
INH MBR	Inhalation Pressure in Millibars (MBR)
INH WOB	Inhalation Work of Breathing in Joules Liter
Jouls/Liter (J/L)	The measurement of work effort
Millibar (MBR)	Metric pressure measurement 68.947 MBR = 1 PSI
PSIG	Pounds per Square Inch Gauge
RMV	Respiratory Minute Volume, also known as work rate. Is the tidal volume times the number of breaths per minute

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SCFM	Standard Cubic Feet per Minute, measured at surface also known as surface cubic feet per minute
SEV	Surface Equivalent Value, normally used when computing the partial pressure of oxygen at depth
SLPM	Standard Liters per Minute, volume measure at surface, also known as Surface Liters per Minute
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 & CONVERSIONS

One Atmosphere in PSI	14.7 PSI = 1.014 BAR
ATM	Depth in atmospheres, FSW ÷ 33
ATA	(FSW + 33) ÷ 33 = ATA
PSI for Depth Salt Water	Depth in Feet x .445 psi
Minimum Supply Pressure for Depth	= (Depth x .445) + 135 psi - PSI Over Bottom Pressure (Old Formula) For KMDSI Demand Mode Helmets/Full-Face Masks
Liters To Cubic Feet	Liters ÷ 28.317 = CF
Cubic Feet to Liters	Cubic Feet x 28.317 = 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	((FSW x .445) + 14.7) ÷ 14.7 = ATA
FSW to PSI	1 FSW = .445 psi
FFW	1 FFW = .432 psi

COMMERCIAL DIVING EQUIPMENT REGULATIONS/HISTORY/BACKGROUND

In the U.S.A., commercial diving regulations are primarily governed by OSHA (29CFR Part 1910 Subpart-T) for general industry and the U.S. Coast Guard (46 CFR part 197) for vessel-related operations. The CFR regulations were introduced in the 1970s-1980s. The non-government, commercial diving consensus standard was produced by the Association of Diving Contractors ADC. These standards were promulgated in a joint effort between the (ADC) Board of Directors Medical and Safety Committee, along with representatives from both the USCG and OSHA. The goal was to gain a National Consensus standard between the U.S. inland and offshore diving industries. These ADC Consensus Standards were quickly endorsed and recognized by OSHA and the USCG as ***Industry Best Practice.*** By the late 1990s the (ADC) became the Association of Diving Contractors International (ADCI) and continually revises and upgrades their commercial diving safety standards to meet the worldwide industry practices and safety requirements. However, even considering the combination of these Regulations and Standards, they still fall short in some areas, such as describing breathing performance

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requirements. As previously mentioned, the CFR regulations were originally written back in the 1970s and used breathing volume and performance requirements from the U.S. Navy. At that time, the US Navy breathing requirements for diving helmets were primarily based on free flow diving and not demand mode diving. It was not until 1981, that the U.S. Navy, as well as NATO Navies adopted the basic breathing testing as Respiratory Minute Volumes (RMV). In addition, they standardized breathing simulator testing practices as it pertains to diving.

In the mid to late 1970s the use of demand mode diving “exploded” due to the boom in deep offshore oil field diving in the U.S. Offshore diving companies started switching from free flow systems in the late 1960s to the Kirby Morgan® Band Masks. With the BandMask®, the diver could get dressed easier and quicker, had greater overall mobility, better communications, and could operate using less air. The KMDSI demand mode BandMask® quickly became the norm for most surface supplied diving operations. In the mid-1970s the SuperLite® 17 helmet was introduced, and the U.S. Army was one of the first costumers. The Army saw the advantages of the SuperLite® 17 over the old heavy gear free flow systems and was the first US Military group to adopt it. The US Navy (USN) did not make the switch to KMDSI helmets until 1989 to the early 1990s. In today’s commercial / military diving world, the majority of the surface supply diving is done with demand mode helmets and full-face masks. All U.S. Military and Government umbilical diving is done with demand-mode helmets and full-face masks.

In the early 1980s, the USN and NATO militaries established standardized breathing performance test rates as *respiratory minute volume* (RMV). RMV is the amount of air in liters breathed in one minute (LPM) and is defined by the size of the breath in liters multiplied by the number of breaths per minute. Diving breathing rates can vary from as little as 7 RMV to over 75 RMV. To accurately measure breathing performance, diving equipment is tested using breathing simulator systems and universally accepted test procedures and data acquisition techniques. Dive Lab tests KMDSI equipment to EU and other internationally recognized performance requirements and standards as well as Dive Lab’s own *Commercially Rated* (CR) test criteria.

COMMERCIAL DIVING EQUIPMENT REQUIREMENTS

In the United States, except for the military, there are very few breathing performance requirements for diver worn demand mode breathing equipment. In Europe, all diving equipment is required to undergo “CE type testing” to harmonized European Union (EU) Standards and Directives. The CE directives mandate breathing performance requirements and various testing such as hot and cold storage, seawater exposure, proof pressure, reinspired CO_2, field of vision, hydrostatic imbalance to name a few. Additionally, they require manufacturing quality assurance documentation, including component drawings, manufacturing procedures, assembly, inspection, and test documentation. Products must have operating procedures, maintenance procedures, failure modes and effects analysis as well as other documentation.

Each EU member country may have their own commercial diving regulations, but all are required to use the CE harmonized standards for testing, certification, and procurement of diving equipment. The Surface Supply CE Standard EN:15333 2008 requires helmets, and full-face masks meet breathing performance requirements at the surface, as well as at the European air depth limit of 50 meters (164 FSW) on air.
The intent of CE certification had noble intensions; however, it lacks detail in many areas especially on specific tests and guidance for the sequence of tests and explaining test rational. In addition, standards are not free. To

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purchase standards cost money. The money for purchasing standards pays salaries. Same with ISO, ASME, NIST and the list goes on and on. Unfortunately, standards often go many years before any changes are made let alone reviewed.
In the case of EN:15333 it is obvious that the standards committee had little input and guidance from actual professional divers, supervisors, and equipment manufactures. In many cases; portions of the standard were simply adopted /cloned requirements from other standards. Examples, such as field of vison requirements from firefighting masks, harness requirements from high rise widow washing standards, even noise requirements in which there are no standards for measuring sound at elevated ambient pressures. Much of the basic requirements for the surface supply standards came from the very first EN 250 diving standard for SCUBA diving. The notified body, (professional certification witness) in many cases have limited diving and diving equipment knowledge and go by the wording of the standard and their own interpretation of the standard.

The EU Standards are supposed to be reviewed for possible revision every five years, however at the time of this writing (2026), the surface supply standard EN:15333 2008, and the open circuit SCUBA EN:250 2014 has not been revised or updated within that time frame. Once standards are adopted it is often difficult to make changes. Manufacturers are required to completely retest and re-certify each product every 5 years. Many manufactures struggle to find test facilities that can perform the required testing**.** The EU does not solicit or seek input from experts of non-CE countries or participation by the equipment manufactures unless they are from an EU country. Lastly, a CE mark does not guarantee the equipment is safe, it only means it has been tested to a particular standard.

FREE FLOW SURFACE SUPPLIED BREATHING SYSTEMS

Free flow helmets and masks are the most basic form of surface supplied diving and have been around longer than any other type of umbilical supplied equipment. Typically, most free flow helmets have a large internal volume allowing for free head movement. These helmets use a simple multiturn supply valve to manually regulate a steady flow of air into the helmet, much like a valve on garden hose, and a simple multiturn spring-loaded exhaust valve assembly to control exhaust pressure. Free flow helmet diving concepts and principals have changed very little over the past 150 years. With free flow helmets, the diver inhales from the helmet interior and then exhales back into the same space. Exhaling back into the helmet results in elevated carbon dioxide (CO_2) rich exhalation air mixing with the incoming air. To keep re-inhaled CO_2 levels low, it requires high air flow to ventilate the system, especially if the helmet is attached and open to a variable volume dry suit.

A good example of a free flow helmet is the old standard U.S. Navy MK-V copper deep sea helmet system with attached suit. This type of system has been in use for over 150 years, was used by the U.S. Navy until 1981. With the MK-V helmet weighing 54 lbs., shoes 17 lbs. each, weight belt 83 lbs., and canvas suit 18 lbs., the diver's total worn weight is 189 lbs. In some parts of the world these systems and variations are still in use today. At light to moderate breathing rates on the surface, it required a minimum of 4 ACFM (113 SLPM). At 66 FSW (20 MSW) that works out to 12 ACFM (339 LPM). Heavy work, of 6 ACFM at 66 FSW (20 MSW) 18 ACFM is (510 LPM).
Compare the MK-V to a demand mode helmet or full-face mask breathing at 40 RMV, at a depth of 66 FSW which only requires 120 LPM at the same depth. The free flow helmet requires almost three times what a demand system uses at 40 RMV (heavy work). At the extreme work rate of 62.5 RMV, the free flow helmet

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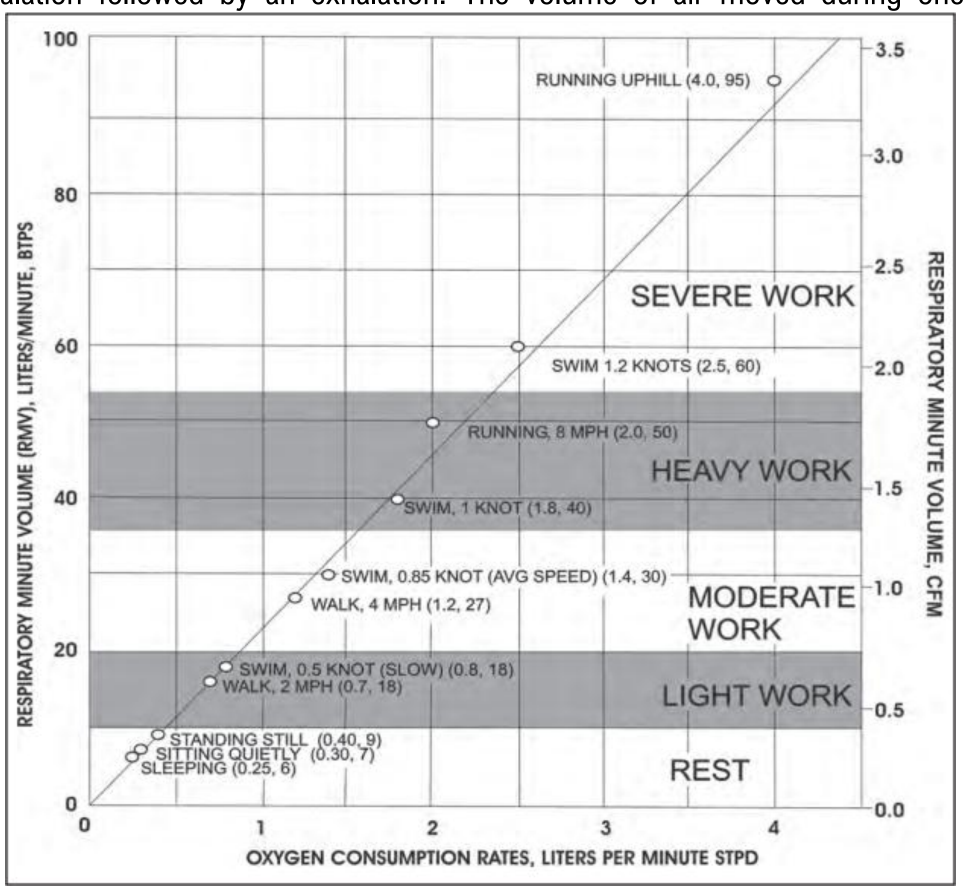
requires 6.0 ACFM, which at 66 FSW is 18 CFM (510 SLPM), as compared to the demand helmet at 66 FSW of 6.6 CFM (188 LPM).

DEMAND MODE BREATHING SYSTEMS

Unlike free flow helmets and masks, demand mode helmets and masks primarily flow air on demand when the diver inhales. Demand mode helmets use a combination of a snug fitting oral nasal mask to minimize dead space, as well as a head cushion/liner to keep the head and face planted into the oral nasal. When a demand helmet is properly fitted and adjusted, the reinspired CO_2 can stay much lower than a free flow helmet. With demand mode the breathing gas enters and exits the oral nasal mask resulting in far less re-inspired CO_2, due to the low volume. Both free flow and demand systems require a certain minimum supply pressure to deliver the required volume at depth. Free flow helmets generally require far less peak umbilical supply pressure than demand helmets but require a much greater overall air flow to keep CO_2 levels within an acceptable range.
Demand mode helmets and most commercial full-face masks also have a free flow mode intended for face plate demisting, ventilation, and dewatering and can also be used for breathing in an emergency.

BREATHING DEFINED (RESPIRATORY MINUTE VOLUME)

A single breathing cycle is one inhalation followed by an exhalation. The volume of air moved during one inhalation or exhalation cycle is called the “Tidal Volume”. The actual lung volume of humans varies by body’s physical size. Typically, the average male will have a total lung volume of 6 liters, while the average female will have around 4.5 liters. During extreme heavy breathing, less than half the total volume is moved. The volume left in the lungs that is not moved is known as residual volume.
To determine the tidal volume, physiologists measure the volume of air moved in liters during various levels of exercise. The tidal volume and number of breaths per minute make up what is known as “Respiratory Minute Volume” (RMV). To convert liters to cubic feet you simply divide the liters by 28.32
As a diver’s physical work increases, so does the ventilation rate, which can be from very small breaths as low as 0.50 liters at complete rest, to as much as 3.0 liters or more during extreme heavy work.



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Proper training teaches the diver to never push the breathing work rate beyond normal labored breathing, where the diver has trouble carrying on a slightly winded conversation with topside. For the average fit professional diver heavy work falls into the 38-54 RMV range as shown in the **U.S. Navy respiration chart above**. These are averages only, the actual RMV varies with the diver's physical size and fitness level. The chart below shows universally accepted breathing simulator test rates. Dive Lab uses these rates as well as others when performing breathing performance tests on helmets and breathing equipment.

Work Rate	*RMV LPM*	*Test Rates RMV*	*NOTE*
Rest	7 - 10	10 RMV = 1.0 LPM x 10 BPM	The test rates shown are universally accepted diving test rates that Dive Lab uses. However, other test rates may apply in certain circumstances, especially when testing other types of breathing equipment.
Light Work	11 - 20	22.5 RMV = 1.5 LPM x 15 BPM	
Moderate Work	21 - 37	40 RMV = 2.0 LPM x 20	
Heavy Work	38 - 54	50 RMV = 2.5 LPM x 20	
Severe Work	55 - 100	62.5 RMV = 2.5 LPM x 25 75 RMV = 3.0 LPM x 25 90 RMV = 3.0 LPM x 30	

IMPORTANT BREATHING CONSIDERATIONS

Most commercial divers average work rate is usually less than 40 RMV but at times could exceed 75 RMV or more for very short periods. When the divers breathing rate reaches the 38-54 RMV range, the diver is in the heavy breathing range. How long a diver can breathe in this range is primarily based on the diver's fitness level, as well as the equipment and system's performance capabilities. *Fifty (50) RMV is equivalent to a person running at 8 MPH (12.8 KPH).*

When inhalation oral pressures (mouth pressure) reach around negative -15 to -18 millibars (-6" to -7" H2O) the diver's ability to breathe in a comfortable and productive manner is significantly affected. The only way a professional working diver can measure the work rate is to rely on experience, training, and a simple rule of thumb that states, *If the diver's work rate is so great that the diver cannot carry on a slightly winded coherent conversation with topside, then the diver is working too hard and needs to slow down.* The "*Winded Conversation Rule"* applies to all divers regardless of their fitness level. Working to the point of being excessively winded can pose significant breathing challenges that are not present when doing the same level physical exertion on the surface.

Unlike breathing on the surface dry, breathing effort underwater increases due to gas density, resistive effort of the breathing apparatus, hydrostatic imbalance, (diver's position) and lastly, movement restrictions caused by the diver's dress, harness, and weighting. As work effort increases, so does CO_2 output, and at air depths of 100 FSW (30 MSW (4 ATA) or deeper, the combination nitrogen narcosis and CO_2 intoxication can complicate things by adding confusion, anxiety, and in rare cases panic, muscle spasms and unconsciousness.

The safest course for the diver is to keep all equipment properly maintained and adjusted for minimal breathing resistance and know the capabilities and limitations of the supply system and helmets or masks in use, and always use the ***Winded Conversation Rule****.*

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REQUIRED VOLUME AT DEPTH

As the diver's depth increases, so must the supply pressure to maintain breathing performance. The supply volume available is directly related to the supply pressure and depth. Air usage on the surface (1 ATA) is measured in Standard Liters Per Minute (SLPM) or another way to think of it is, Surface Liters Per Minute (SLPM). The actual liters per minute (ALPM) of air required to fill the lungs at depth is the same as it is at the at the surface, however, because of gas density at depth, the SLPM of air delivered from the surface needs to be much greater based on the ambient pressure. For example, if a diver takes a two-liter breath on the surface, that same breath if taken at a depth 33 FSW (10 MSW), (2 ATA) requires 4 liters. Every 33 FSW (10 MSW) = 1 ATA. To find the pressure in ATA's, you simply take the depth in FSW, add 33 FSW to it, then divide the result by 33, and you have ATA's. Multiplying the ATA's by the RMV gives you the volume required per minute in liters. If you want to convert to SCFM simple divide the liters by 28.32 to get SCFM.

Knowing both the required volume and pressure for depth is essential to ensure the topside supply system can deliver the necessary breathing gas. In general, most experienced professional divers sustain work rates below 40 RMV, although rates may briefly exceed 62.5 RMV or even 75 RMV. For air/gas consumption planning, Dive Lab recommends using an average work rate of 40 RMV. For maximum breathing performance, Dive Lab recommends basing minimum system capability on 62.5 RMV at all depths.

Example: To compute the required air volume at depth based on a breathing rate of 62.5 RMV on the surface you simply multiply 62.5 RMV by 1 ATA which equals 62.5 liters per minute at the surface (1 ATA). Breathing the same 62.5 RMV at a depth of 164 FSW (6 ATA's) the formula looks like this

[(164 FSW +33 FSW) ÷33] X 62.5 RMV

(197 ÷ 33) X 62.5 RMV

(6.0 ATA) x 62.5 RMV = 373 SLPM

The example above shows, it requires a minimum of 373 liters per minute from the surface while maintaining the required topside supply pressure called out for depth. To convert 373 liters to SCFM, you simply divide the 373 by 28.32 liters, which results in 13.2 SCFM. That means it requires 373 SLPM (13.2 SCFM) from topside, at the supply pressure in use for the depth and type of KMDSI demand regulator in use.

SYMPTOMS OF INADEQUATE SUPPLY

Most seasoned surface supplied divers have experienced symptoms of inadequate supply. When the topside minimum manifold pressure (MMP) falls below the minimum pressure required for the work rate (RMV), inhalation effort will increase and the diver may not be able to breathe at heavy work rates.

The symptoms of inadequate supply can be very subtle, often starting with slightly hard breathing toward the middle or end of inhalation, to almost no flow when a big suck is taken. After each inhalation, it requires a certain amount of time for the umbilical pressure to recover for the next inhalation.

The recovery time is based on supply pressure, therefore it's important that the side block pressure returns to the minimum required pressure quickly so the demand regulator can work properly. Experienced divers know this and usually know the limitation of their supply system. In many cases it may be known that the system cannot support heavy work beyond a certain depth for two divers, so often the practice is to pace their work so as not to over-breathe the system. While this may be smart in one respect it can be dangerous, especially if suddenly the standby diver must be deployed on the same system. By following the surface supply guidelines and the information in this document, inadequate supply can be avoided. Performing simple flow tests as shown

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further on in this document will identify supply capability and limitations. The supply system in use must be capable of supporting all the divers that are being supplied by it, including a standby diver that is well briefed on the hazards of the dive and capable of responding quickly and effectively.

BREATHING PERFORMANCE REQUIREMENTS

The KMDSI performance requirements are based "in part" on the resistive effort formula from the EN 15333-1 Surface Supply Standard and USN requirements. The formula used is 0.5 + (.03 x RMV) for all breathing rates from 10 RMV to 62.5 RMV, and for 75 RMV uses 0.5 + (.04 x RMV). However instead of using a maximum limit of -25 MBR as with the CE requirements, KMDSI uses a maximum inhalation limit of -15 MBR.
At the time of the development of the CE standard for surface supply diving, (2008) the standard committee did not take into consideration that most of the commercial surface supply air diving is done using LP compressors, especially air diving to depths less than 100 FSW (30 MSW). The EU standard requires surface supply air testing at only two depths, the surface, 1 ATA wet, and 6 ATA's 50 MSW (164 FSW). The KMDSI equipment supply tables cover pressures for all depths from the surface to 200 FSW (60 MSW).

DETERMINING THE REQUIRED SUPPLY PRESSURE

The required supply pressure for all KMDSI helmets and masks comes from the surface supply tables on the KMDSI web site found in the Surface Supply module under the support in Manuals and Blowaparts. There are *Low Pressure (LP) Compressor Tables and High Pressure (HP) Regulated Tables* for each model demand regulator.

LP COMPRESSOR TABLES - CLICK TO VIEW

The low-pressure compressor tables start at 90 PSI (6 Bar) and increase in 10 PSIG increments to a maximum output pressure of 220 PSIG. The supply pressure for each table is the required topside supply pressure when using a 3/8" I.D. umbilical of 600 feet or less in length. At each of the supply pressures it shows the maximum depth capability based on three breathing rates, 50, 62.5 and 75 RMV. This was done to accommodate the large variety of LP compressors in use.

HP REGULATED TABLES - CLICK TO VIEW

The HP Regulated Tables provide the recommended supply pressure for each KMDSI model demand regulator, based on 50, 62.5 and 75 RMV. Dive Lab recommends using the pressure required to perform at a minimum work rate of 62.5 RMV.

ORIGINAL UMBILCAL SUPPLY PRESSURE FORMULA FOR THE SUPERFLOW® 350

The SuperFlow® and SuperFlow® 350 demand regulators are of a non-pneumatically assisted design. These demand regulators were designed and developed over 60 years ago and require greater supply pressure than that of the balance/pneumatically assisted design like the other KMDSI regulators such as the 455 Balanced, Rex® and 450 Balanced Regulator.

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The original method of determining supply pressure for KMDSI Helmets and BandMasks® equipped with SuperFlow® and SuperFlow® 350 demand regulators was to take the diving depth, add 33 feet to get the total depth, then multiply this by .445 this gives the PSIG at depth. Next, you take the pressure at depth and add the over-bottom pressure called out in the table for the diving depth range. The over-bottom pressure formula for depth as follows, **(Depth in FSW + 33 x .445) + PSIG over bottom pressure for depth)** from the table below.

FORMULA	DEPTH		OVER BOTTOM PRESSURE	
(FSW +33) x 0.445) + Recommended Over Bottom Pressure = PSIG	FSW	MSW	PSIG	BAR
	0 - 60	0 - 18	90	6.2
	61 - 100	18 - 30	115	7.9
	101 - 132	30 - 40	135	9.3
	133 - 200	40 - 61	165	11.4

LP COMPRESSOR IMPORTANT FACTS

All low-pressure compressor systems used for surface supply umbilical diving require a volume tank for proper operation and efficiency. The main purpose of the volume tank is to remove moisture from the air as it expands when flowing into the volume tank. The water then collects at the bottom of the volume tank, where it can be periodically drained off. To further reduce moisture, LP compressor systems should have a proper moisture separator and filter. Without the volume tank as well as a moisture separator and filter the moisture will condense in the umbilical causing very wet air, and if diving in a cold environment where temperatures are below freezing, ice can form in the umbilical that is on deck. Ice in the umbilical can reduce or even stop air flow altogether to the diver. In addition, without the volume tank, the compressor would have to run non-stop, working at a constant set discharge pressure significantly reducing the compressor's life span. For this reason, most compressors use an adjustable pressure cycling valve. The cycling valve trips when the maximum set pressure is reached allowing the compressor to run under no load (free wheel) until the volume tank pressure reaches the low-end set pressure at which point the cycling valve kicks in and allows the compressor to pump back up to the high-end pressure. Lastly the volume tank also provides smoother air delivery.

LP COMPRESSOR SUPPLY TABLES EXPLAINED

The KMDSI low-pressure compressor tables are intended to show the wide range of diving depths possible based on LP compressors output pressure. These LP tables show the recommended supply pressure using the minimum required pressure to be maintained at depth based on 50, 62.5 and 75 RMV breathing rates.

NOTE: Dive Lab recommends users always have the pressure and volume to allow for a minimum work rate of 62.5 RMV. To put things into perspective, 50 RMV requires approximately the same physical effort as running at 8 MPH (12.8 KPH). A supply pressure that allows for 62.5 RMV will ensure the divers supply requirements for severe RMV are met.

Besides the KMDSI LP compressor and HP Regulated tables for the SuperFlow® and SuperFlow® 350 regulators, the original over bottom formula for the SuperFlow® 350 can still be used. However, for simplicity we recommend using the HP Regulated Tables for each model of KMDSI type of regulator. The LP compressor tables are based on the low cycling pressure and show what RMV's can be done based on the depth, and supply pressure. Users can determine the maximum depth and work rate capability allowing for maximizing the equipment performance based on the low-end cycling pressure and depth. Unlike LP compressor tables the HP Regulated tables show recommended pressure range for depth.

LP COMPRESSOR VERSUS HP REGULATED SOURCE

Worldwide, there are far more LP compressor supply systems used for surface supplied air diving than HP regulated / reduced systems. Low pressure compressors systems offer great flexibility for day in day out daily diving operations. In addition, if a recompression chamber is required - large LP compressors can provide instant high volumes of air for recompression chamber operations. LP compressors come in many output sizes in both pressure and volume and are probably the best all-around choice for long term continuous diving operations, especially when diving at depths less than100 FSW (30 MSW).

For those that routinely dive deeper than 100 FSW (30 MSW), a properly designed HP reducing system, with HP storage banks, can provide the required supply pressure and volume for air dives of 165 FSW or deeper. The HP system can also be used in conjunction with the LP compressor system.

HP control systems with proper sized regulators do not require a volume tank, because the high-pressure air is dried by the compressors moisture separator, molecular sieve and filtration systems before storage. HP systems are preferred by the militaries due to portability. The choice of which type of system should be based on the needs of the user.

LP COMPRESSOR FLOW TESTING

If testing a low-pressure compressor for output, we recommend using a flow meter that can flow more than the compressor can discharge, based on the minimum and maximum compressor cycling pressures. You need to do the testing at the minimum cycling pressure. For medium large compressors like 50 SCFM (1400 LPM), we recommend using a 1400 LPM flow meter. For large compressors like a 5120, that can put out up to100 CFM (2832 LPM), we recommend using a 2800 LPM flow meter.

Compressors less than 50 SCFM (1419) can use a 1400 LPM flow meter. We recommend flowing the compressor and umbilicals as a complete system with the longest umbilical's normally used with the system. One flow meter attached to each umbilical outlet in the same manner as the reduced supply system testing.

The manufacturer of the compressor normally lists the maximum discharge volume based on a certain pressure. If the discharge pressure is set higher the flow will be less. If the set pressure is set lower than what the manufacturer calls out the output will be greater. See LP Compressor Tables for pressure required for depth.

FLOW TESTING UMBILICALS EXPLAINED

When flow testing umbilicals as a routine check, the supply pressure used is not as important as using the same pressure each time you do the test. Ideally, you should use test pressure that puts the flow on the flowmeter in the mid to upper range. For this reason, using a 100-700 or 200-1400 LPM flow meter works best. The umbilical flow table makes pressure selection easy based on the flow meter being used. Once you have tested each umbilical the first time, you can then use that supply pressure for future tests of the same or other umbilical's of the same length. We recommend testing of umbilical's annually, whenever fittings have been changed, and / or whenever flow is in question. In addition to the basic umbilical flow test, a flow test of the entire topside supply system can be conducted to document the system's supply capability.

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Components which are normally flow tested include the LP compressors, interface whips and diver umbilical's. The procedure described herein will explain flow testing using high-quality simple gravity flowmeters (often known as Rotameters). Using these flow meters is simple, accurate, and takes very little time to conduct. Dive Lab has much experience and history with the Dwyer® brand shown below. These flowmeters are very robust and if kept visually clean, should not require re-calibration.

The most important thing that the umbilical flow test will show - is that the umbilical being tested can flow the same as it did when first put into service and the same as previous tests. To do this you need to test using the same range flow meter and a low-pressure gauge of known accuracy at a temperature within 10°F degrees of the last time you tested. Flowmeters like pressure gauges, are normally factory calibrated at sea level at 70°F.

Accuracy of the flow meter is primarily affected by ambient pressure (altitude), temperature and pressure gauge accuracy. The actual flow pressure used should be high enough to put the flow in mid to upper 80% range of the flowmeter being used. With this test you're making sure the umbilical flow is the same under the same conditions as when you last tested. If suddenly you notice a 10-20% decrease in flow from when you did the last test, you may have a dirty umbilical, hose damage, or simply a pressure gauge that is inaccurate.


FLOW METERS


INTERFACE FITTINGS

Below is a surface flow table that Dive Lab produced. The table shows the flow of three separate 3/8" umbilical's: one at 600' (183 M) long, one at 300' (91 M) and one at 200' (61 M). Flow testing with each length of umbilical was done with two different size flowmeters, a Dwyer® 100-700 LPM, model # VFC-131 and a 200-1400 LPM flowmeter model #VFC-132. For the most accurate results, select a supply pressure from the table below as identified in the yellow highlighted area. The flow meters provide the greatest accuracy when used with a flow between 50-80% of the flow meters range.

NOTE: *The actual flow you get with various HP reducing regulators can vary based on the HP supply as well as the piping and fittings. Some reducers will flow more with a HP supply of 500 psig supply than a 1000 psig supply.*
Example: IF flow testing a 600' umbilical using the 100 - 700 LPM (marked in green color) flowmeter, for best accuracy use pressures in the range of 90-130 PSIG as shown the highlighted yellow flow on the flow table.

UMBILICAL LENGTH/ 3/8" I.D.	FLOW METER RANGE LPM	90 PSIG	100 PSIG	110 PSIG	120 PSIG	130 PSIG
600 feet	100 - 700	420	460	520	560	600

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What this means is, if using 100-700 LPM the flow test supply pressure, the flow should be close to the number shaded in yellow, directly below the pressure you used. In this case, if using 130 PSIG (9 Bar), you should see a flow of 600 LPM +/- 20 LPM.

Another example: Same 600' umbilical, but this time using the 200 - 1400 LPM (Marked in red color) flowmeter and using 200 PSIG as the flow pressure, the flow you get should be 950 LPM or very close within +/-20 LPM.

IMPERIAL UMBILICAL FLOW TABLE

UMBILICAL LENGTH/ 3/8" I.D.	FLOW METER RANGE LPM	90 PSIG	100 PSIG	110 PSIG	120 PSIG	130 PSIG	140 PSIG	150 PSIG	160 PSIG	170 PSIG	180 PSIG	190 PSIG	200 PSIG	210 PSIG	220 PSIG
600 feet	100 - 700	420	460	520	560	600	650	700	BEYOND RANGE						
	200 - 1400	410	450	510	550	600	650	700	750	800	850	900	950	1010	1080
300 feet	100 - 700	580	640	700	BEYOND RANGE										
	200 - 1400	560	640	690	760	840	900	990	1050	1140	1200	1300	1390	BEYOND RANGE	
200 feet	100 - 700	620	680	BEYOND RANGE											
	200 - 1400	610	690	750	840	900	990	1050	1140	1200	1300	1390	BEYOND RANGE		

METRIC UMBILICAL FLOW TABLE

UMBILICAL LENGTH/ 9.5 mm I.D.	FLOW METER RANGE LPM	6.2 BAR	6.9 BAR	7.6 BAR	8.3 BAR	9 BAR	9.7 BAR	10.3 BAR	11 BAR	11.7 BAR	12.4 BAR	13 BAR	13.8 BAR	14.5 BAR	15.2 BAR
183 meters	100 - 700	420	460	520	560	600	650	700	BEYOND RANGE						
	200 - 1400	410	450	510	550	600	650	700	750	800	850	900	950	1010	1080
92 meters	100 - 700	580	640	700	BEYOND RANGE										
	200 - 1400	560	640	690	760	840	900	990	1050	1140	1200	1300	1390	BEYOND RANGE	
61 meters	100 - 700	620	680	BEYOND RANGE											
	200 - 1400	610	690	750	840	900	990	1050	1140	1200	1300	1390	BEYOND RANGE		

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HP REGULATED SUPPLY SYSTEM FLOW TESTING

Properly designed high pressure reducing systems with high flow regulators can generally offer greater flow capability than LP compressor systems. This is especially true when diving to depths of 165 FSW (50 MSW) or deeper because they can maintain higher LP pressures. Most high-pressure reducing systems usually have at least two individual bank systems and a regulator for each diver. The most accurate flow of the entire system test is to flow each diver circuit of the system with the longest umbilical normally used. If the HP regulators are intended to supply more than one diver or as a backup through a cross connect, this too can be checked by flowing two umbilicals with one regulator. We recommend flow tests using an HP supply of 1000 PSIG first then at 500 PSIG (69–34 bar) or even lower.

Portable HP supply systems that use physically small regulators with a HP regulator outlet of less than 3/8" I.D (9.5MM) will generally be limited in flow which can limit dive depth. Most good quality high flow regulators with ½" (12.7MM) outlets can allow moderate to high flow until the bank pressure drops down to 500 (34 bar) or less.

NOTE
The actual flow you get with various HP reducing regulators can vary based on the HP supply as well as the piping and fittings configuration. Some reducers will flow slightly more with an HP supply of 500 PSIG (34 bar) supply than a 1000 PSIG (69 bar) supply. Such is the case with Aqua Environments model 873-400. To do an accurate system flow test, the HP and LP pressures must be monitored so that the minimum required HP supply pressure can be determined, while maintaining the required LP discharge pressure.

The two examples below show Dive Lab flow testing. The first shows flow testing two 600' (183 M) 3/8" I.D. umbilicals at the same time using a single Aqua Environments® model 873-400 high-pressure reducing regulator being supplied with an HP supply pressure of 500 PSIG (34 bar). The second example shows a test of a single (600' 183 M) umbilical being supplied with both a 500 PSIG (34 bar) HP supply, and then at 1000 PSIG (69 bar) supply pressure.

It is important to have a simple umbilical and system maintenance and test record log. Record the umbilical serial number, length, type of fittings, flow test date, temperature, flow meter used, and procedure used. Pictures are helpful. Write up your basic test procedures for each type of test and give them a procedure number. You can then simply fill in the test log with the date, test and inspection procedure, serial number/ component identification, pressure and flow, as well as any other type of information.

Example of flow testing two 600’ 3/8” I.D. umbilicals at the same time, using a 200-1400 LPM Dwyer® flow meter

	TOPSIDE SET	***FLOW SLPM***	
	LP UMBILICAL SUPPLY	**UMBILICAL GREEN**	**UMBILICAL RED**
HP BANK SUPPLY 500 PSIG	100	460	450
	125	580	650
	150	700	650
	175	840	800
	200	940	1000
	225	1020	1100
	250	1240	1150

Example of flow testing a single 600’ 3/8” I.D. umbilical, using a 200-1400 LPM Dwyer® flow meter

TOPSIDE SET PRESSURE PSIG	***FLOW SLPM***	
LP UMBILICAL SUPPLY	**500 PSIG HP SUPPLY**	**1000 PSIG HP SUPPLY**
100	450	450
150	700	720
200	950	1000
220	1220	1250

HP REGULATED FLOW TEST PROCEDURE

The HP regulated flow procedure is intended to show the flow capability of each diver circuit with umbilical as well as the flow with two umbilicals being fed from one regulator through the cross connect. The best way is to choose the deepest diving depth that might be encountered for the model KMDSI regulator in use. Next, attach two umbilicals to outlet supply manifold. For this test with high-performance regulators like the Aqua Environments 873-400, using the Dwyer® 200-1400 LPM flow meters will work best.

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Start with the two umbilical supply valves shut, then you load the panel regulator to the desired pressure and open both umbilical supply valves. You may need to fine tune the regulator slightly to achieve and maintain the required supply pressure stated on the supply table for depth and RMV. You can do this test using the umbilical supply pressures for both the deepest possible dive depth as well as shallower, you can also do this test varying the HP supply to the panel to identify at what HP pressure you would have to do a bank shift.

Example: If diving a SuperLite17B® or any KMDSI helmet or mask using a SuperFlow® or SuperFlow® 350 demand regulator, and you want to verify system flow for a depth of 165 FSW (50 MSW), the SuperFlow® 350 HP Regulated table shows a recommended supply pressure of 220 PSIG to support an extreme breathing rate of 62.5 RMV. At that depth, each diver breathing at 62.5 RMV would use 375 LPM. Therefore, two divers at 62.5 RMV, would require a total topside flow of (375 X 2) = 750 lpm. If both divers were to be supplied by one reducer it would need to be capable of flowing at least 750 LPM while being able to maintain a 220 PSIG (15 bar) topside reading.

If using 600" (183M) umbilicals and each had a 1400 LPM flow meter attached, you should see an overall combined flow of around 2100-2150 SLPM with a steady topside pressure of 220 PSIG (15 bar). This is more than twice the required flow for each diver at 165 FSW (50 MSW). If you were using 300' (91 M) umbilicals the flow would be even greater. Keep in mind flow can be significantly affected by the I.D. of piping and valves.

BASIC UMBILICAL FLOW TEST LP COMPRESSOR

Simple flow testing of umbilical's only using an LP compressor is done in the same manner as with a HP reducing supply system however instead, you can throttle one of the other discharge valves venting the system to maintain the steady test pressure used in previous tests. With this test it is best to use a 100-700 LPM flow meter. Manufactures of LP compressors normally state the maximum SCFM (SLPM) flow based on a certain pressure. If a higher pressure is used, the discharge volume will be reduced. For this reason, LP compressors can be limited in some respects.

It must be understood that many systems components may affect the flow. Tubing is normally measured by outside diameter, while pipe is measured by inside diameter. For this reason, two exact model regulators or valves may not show the same flow if the tubing is used instead of piping. For maximum flow, the internal bore of fittings and valves should be sized close to the internal diameter of the piping or tubing used.

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DIAGRAM 1 - LOW PRESSURE COMPRESSOR

Configuration 1 - shows flowing an umbilical from the discharge manifold. Note: it may be necessary to use flow from one of the other discharge valves to maintain the compressor discharge pressure.

Configuration 2 - compressor flow normally done using one or more flowmeters, at the discharge manifold to maintain the required discharge pressure.

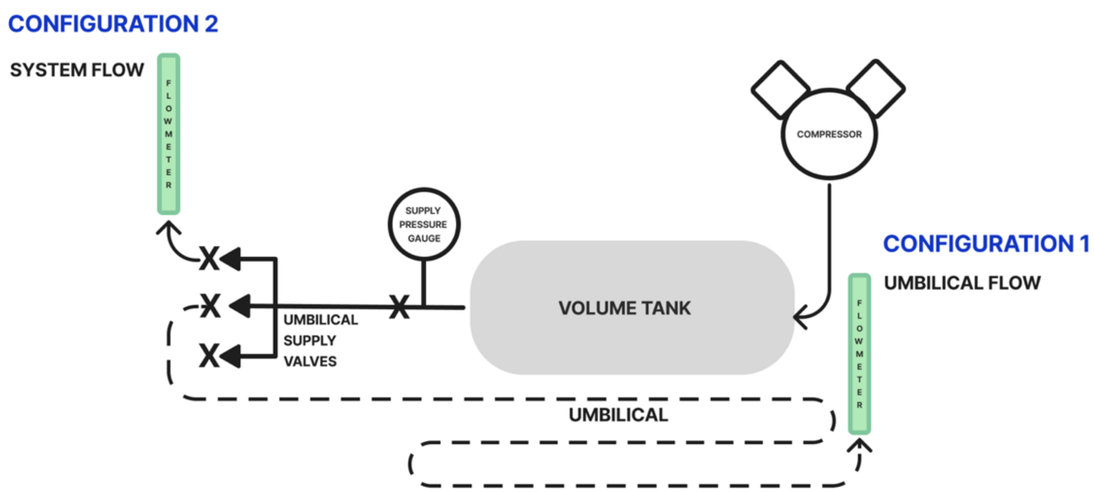

DIAGRAM 2 - HP REDUCING SYSTEM FLOW

Shows the basic configuration for flow testing the system. **Note:** This ***<u>may require</u>*** using more than one flow meter attached to the discharge manifold.

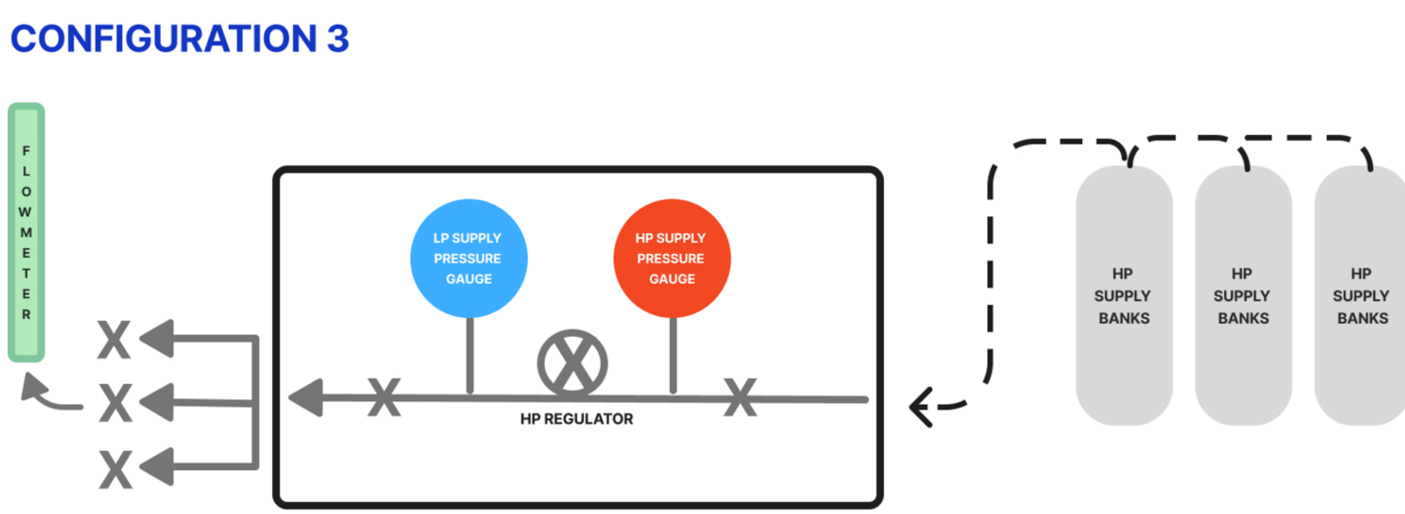

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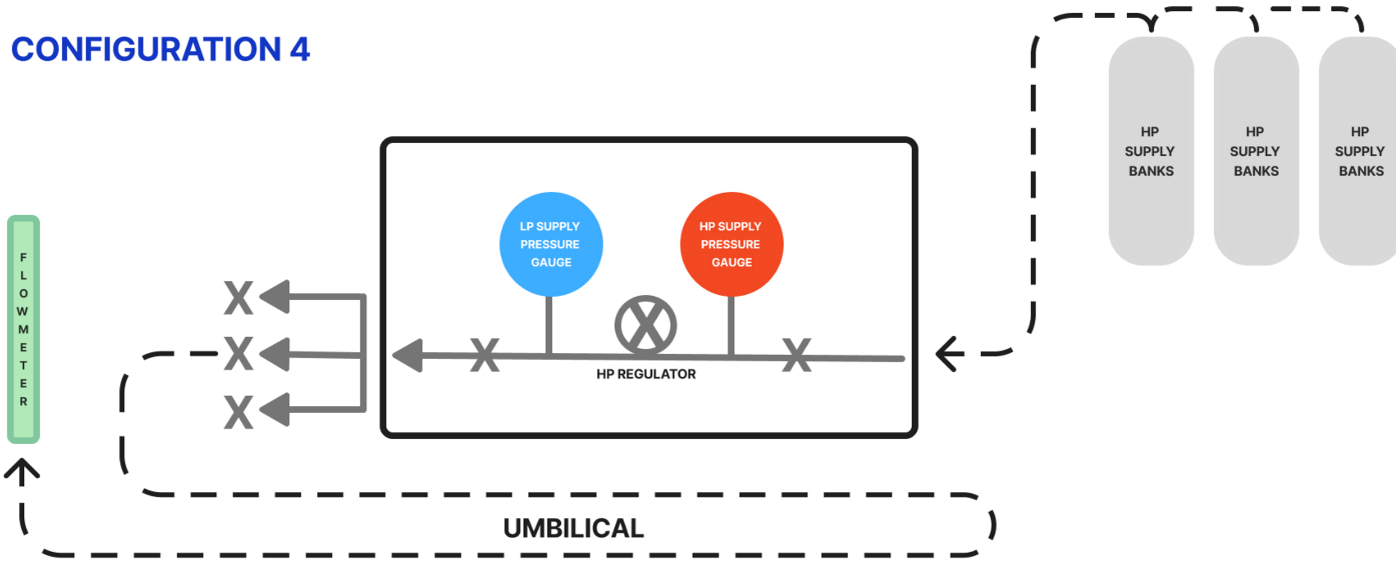
DIAGRAM 3 - HP REDUCING SYSTEM SIMPLE UMBILICAL FLOW TEST

CONFIGURATION 4



BEST PRACTICE

- When using an LP compressor always base the output pressure on the lowest pressure during compressor cycling.
- Recommend completing a flow test of the compressor and or HP supply systems to validate the system supply capability. Repeat this test anytime system repairs and / or modifications are done.
- Pressure test, and flow test all umbilical’s once a year and anytime fittings are replaced. Umbilicals used with LP compressor’s supply should be cleaned at least once a year and/or whenever cleanliness is in question.
- Recommend using 40 RMV for breathing gas duration planning purposes.
- For breathing performance planning, 62.5 RMV is strongly recommended.
- For optimal demand regulator performance, the diver should always keep the regulator bias adjustment knob set for the least inhalation resistance.
- Always dive with a fully functional emergency gas supply system (EGS) of sufficient capacity based on depth and the hazards of the dive. Always have the cylinder valve open and the emergency valve on the side block shut. All EGS assemblies should be equipped with an over pressure relief valve on the LP circuit and a submersible pressure gauge that the diver can monitor.

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- 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 umbilical's 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.

- Always take the standby diver into consideration when planning air usage and supply requirements.