U.S. NAVY GENERAL SPECIFICATION FOR THE DESIGN, CONSTRUCTION, AND REPAIR OF DIVING AND HYPERBARIC EQUIPMENT

Revision 1

August 23, 2006

DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
SUPERVISOR OF DIVING
AND SALVAGE
WASHINGTON, DC 20376

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FOREWORD

"Why can't somebody clearly establish the requirements to design, build and repair U. S. Navy diving systems so that when it comes time to certify them we don't have to fight over differing interpretations of requirements?"

For longer than we'd like to think about, that's a question that has been asked throughout the diving Navy. We've all asked it. So we decided to answer it. The express purpose of this technical publication – U.S. Navy General Specification for the Design, Construction, and Repair of Diving And Hyperbaric Equipment (aka "GENSPEC for DLSS") – is to authoritatively establish technical requirements for design, construction and repair for afloat diving and hyperbaric systems for use in the U.S. Navy.

The first publication of this document approximately one year ago provided the early results of a complex job of defining DLSS and hyperbaric technical requirements. This most recent edition (Revision 1) continues the effort by rewriting the section on testing requirements, adding diver handling system testing requirements, adding a section for design requirements for specific systems (surface supplied diving systems, recompression chambers and saturation systems) and by including addition of joint identification (JID) examples in Appendix D.

Some of you may immediately recognize that the most recent edition of the U.S. Navy Diving and Hyperbarics Systems Safety Certification Manual (SS521-AA-MAN-010) also contains some technical requirements for design, construction and repair of these same systems. That is soon to change. We have stripped technical requirements out of the next revision to "MAN-10" so that GENSPEC for DLSS is now the principal technical authority document for afloat diving and hyperbaric systems. A revised MAN-10 will soon be issued; it will remain the principal document that defines the process (not the requirements) for safety certification – a process that includes validating that requirements established by GENSPEC for DLSS are met. In all cases, the GENSPEC for DLSS takes precedence over MAN-10 for issues of technical requirements; MAN-10 takes precedence for the DLSS Safety Certification process.

Disclaimer: A careful review of this new revision to this technical publication will reveal it is not yet fully comprehensive. Several sections and appendices are yet to be completed. And we're sure there are some great ideas from the Fleet that we've not thought of that need to get incorporated. Send them in (james.r.wilkins@navy.mil or robert.c.whaley@navy.mil) so we can better support you. We'll continue to update and release revised GENSPEC for DLSS in the near future to make sure we stay current.

So here it is – the authoritative (though not yet comprehensive) U.S. Navy technical requirements document for design, construction, and repair of afloat diving and hyperbaric systems. Looking forward to your feedback to make this even better!

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U.S. Navy General Specification for the Design, Construction, and Repair of Diving and Hyperbaric Equipment

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1-1. INTRODUCTION

1-1.1. PURPOSE.

Part 1 provides guidance, rules, requirements and preferred disciplines and approaches for use by an experienced engineer for designing a diving system for U.S Navy use. The mission of a diving system is to safely take personnel to a specified depth, maintain life and perform some task at that depth, then safely return the personnel to the surface. Such a mission may take hours or, if saturation diving is involved, days or even weeks. The diving system Designer must understand the special hazards to human beings that exist while diving. Application of the these guidelines will not always assure a safe manned diving system nor will it always assure acceptance of the design. The final responsibility for all aspects of a safe design ultimately lies with the Designer and cannot be delegated to any manual or textbook.

1-1.2. SCOPE.

This design specification applies to all U.S. Navy diving and manned hyperbaric systems under the Technical Authority of the Supervisor of Salvage and Diving (SUPSALV), Naval Sea Systems Command (NAVSEA) 00C. U.S. Navy diving and manned hyperbaric systems include all surface-supplied diving systems, saturation diving systems, manned recompression chamber systems, diving bells, and handling systems used for maneuvering diving systems or personnel during manned operations. Throughout this part, where the term "diving systems" is used, it is meant to include manned hyperbaric systems. This part is not intended to impose rigid procedures for design, nor discourage initiative and innovation in the use of new methods, components or materials.

1-1.3. REFERENCES

The publications listed below are representative of those that may be useful in diving system design. Unless otherwise indicated, the most recent issue or revision of each shall be used. Information for locating Department of Defense Single Stock Point (DODSSP) for Military Specifications, Standards and Related Publications is available at the Defense Supply Center website http://www.dscc.dla.mil/Programs/MilSpec/ and most can be downloaded at the Documentation Automation and Production Service website http://assist1.daps.dla.mil/quicksearch/.

STANDARDS

DEPARTMENT OF DEFENCE

DOD-STD-1399-301A	Interface Standard for Shipboard Systems, Section 301A Ship Motion and Attitude (Metric)
MIL-DTL-1222J	General Specification for Studs, Bolts, Screws and Nuts for Applications Where a High Degree of Reliability is Required
MIL-E-917	Electric Power Equipment, Basic Requirements
MIL-F-22606	Flask, Compressed Gas, and End Plugs for Air, Oxygen, and Nitrogen
MIL-G-27617	Grease, Aircraft and Instrument, Fuel and Oxidizer Resistant
MIL-HDBK-61A	Configuration Management Guidance
MIL-HDBK-470	Designing and Developing Maintainable Products and Systems
MIL-HDBK-1791	Design for Internal Aerial Delivery in Fixed Wing Aircraft
MIL-L-20213	Lithium Hydroxide (LiOH), Technical
MIL-O-27210	Oxygen, Aviators Breathing, Liquid, Gas
MIL-P-24534	Planned Maintenance System: Development of Maintenance Requirement Cards, Maintenance Index Pages, and Associated Documentation

MIL-PRF-27210	Oxygen, Aviator's Breathing, Liquid and Gas
MIL-PRF-27407	Helium
MIL-S-1222	Studs, Bolts, Hex Cap Screws, Socket Head Cap Screws and Nuts
MIL-STD-22D	Welded Joint Design
MIL-STD-438	Schedule of Piping, Valves, Fittings and Associated Piping Components for Submarine Service
MIL-STD-499A	Engineering Management (*Cancelled*)
MIL-STD-777	Schedule of Piping, Valves, Fittings, and Associated Piping Components for Naval Surface Ships
MIL-STD-810	Test Method Standard For Environmental Engineering Considerations And Laboratory Tests
MIL-STD-882	System Safety Program Requirements
MIL-STD-889	Dissimilar Metals
MIL-STD-973	Configuration Management
MIL-STD-1246	Product Cleanliness Levels and Contamination Control Program
MIL-STD-1310	Shipboard Bonding, Grounding, and other Techniques for Electromagnetic Compatibility and Safety, Standard Practice for,
MIL-STD-1330	Standard Practice for
MIL-STD-1472	Human Engineering
MIL-STD-1474	Noise Limits
MIL-STD-1622	Cleaning of
MIL-STD-1627	Bending of Pipe or Tube for Ship Piping Systems
MIL-STD-2036	Electronic Equipment Specifications, General Requirements for,
MIL-STD-2193	Hydraulic System Components, Ship
MIL-V-24439	Valves, Oxygen, Helium and Helium Oxygen Mixture, High Pressure for Gas Services
NASA JSC 20584	Spacecraft Maximum Allowable Concentration for Airborne Limits
NAVFAC DM-39	Design Manual Hyperbaric Facilities
NAVFAC MO-406	Hyperbaric Facilities Maintenance Manual
NAVSEA 0900-LP-001-7000	Fabrication and Inspection of Brazed Piping Systems
NAVSEA S9AA0-AA-SPN-010	General Specifications for Ships of the United States Navy (GENSPEC)
NAVSEA S9AA0-AB-GSO-010	General Specifications for Overhaul of Surface Ships (GSO)
NAVSEA S6430-AE-TED-010	Piping Devices, Flexible Hose Assemblies, Technical Directive for; Volume 1
NAVSEA S9074-AR-GIB-010/278	Fabrication Welding and Inspection, and Casting Inspection and Repair for Machinery, Piping, and Pressure Vessels, Requirements for
NAVSEA S9086-H7-STM-010/262	Naval Ships' Technical Manual Chapter 262 Lubricating Oils, Greases, Specialty Lubricants, and Lubrication Systems.

NAVSEA S9086-RK-STM-010/505	Naval Ships' Technical Manual Chapter 505, Piping Systems
NAVSEA S9086-S4-STM-010/556	Naval Ships' Technical Manual Chapter 556, Hydraulic Equipment (Power Transmission and Control)
NAVSEA S9086-SY-STM-010/551	Naval Ships' Technical Manual Chapter 551, Compressed Air Plants and Systems
NAVSEA S9086-T4-STM-010/589	Cranes
NAVSEA S9086-UU-STM-010/613	Wire and Fiber Rope and Rigging
NAVSEA S9510-AB-ATM-010	Nuclear Powered Submarine Atmosphere Control Manual
NAVSEA S9505-AM-GYD-010	Submarine Fastening Criteria (Non-Nuclear)
NAVSEA SS521-AA-MAN-010	U.S. Navy Diving and Manned Hyperbaric Systems Safety Certification Manual
NAVSEA SS521-AG-PRO-010	U.S. Navy Diving Manual
NAVSEA SS521-AH-PRO-010	Diving Umbilical Description, Material and Assembly

NAVSEA Letter 10560 Ser 00C/3112 of 15 May, Diving Equipment Authorized for Navy Use (ANU)

NAVSEAINST 4130.12B	Configuration Management Policy and Guidance
NAVSHIPS 0994-LP-003-7010	U.S. Navy Diving-Gas Manual
NMRL RPT 83-3	Naval Submarine Medical Research Laboratory Report 83-3, Anthropometric Indices of U.S. Navy Divers

AMERICAN BUREAU OF SHIPPING

ABS Rules for Building and Classing Steel Vessels

ABS Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities

DET NORSKE VERITAS

DNV-OS-E402	Offshore Standard for Diving Systems
DNV Certification Notes No. 2.7-2	Offshore Service Containers

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

ASME B31.1	Power Piping
ASME/ANSI PVHO-1	Safety Standard for Pressure Vessels for Human Occupancy
ASME Y14.100	Engineering Drawing Practices
ASME Y14.24	Types and Applications of Engineering Drawings
ASME Y14.34	Associated Lists
ASME Y14.35	Revisions of Engineering Drawings and Associated Documents
Boiler and Pressure Vessel Code	Section VIII, Division 1, Unfired Pressure Vessels, and Division 2, Alternative Rules for Pressure Vessels

ASTM

ASTM A182269	Standard Specification for Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service, Forged or Rolled Alloy-Steel Seamless and Welded Austenitic Stainless Steel Tubing for General Service

ASTM F1166	Marine Systems, Equipment and Facilities, Human Engineering Design for
ASTM G63	Evaluating Non-metallic Materials for Oxygen Service, Standard Guide for,
ASTM G88	Designing Systems for Oxygen Service, Standard Guide for
ASTM G93	Cleaning Methods for Material and Equipment Used in Oxygen-Enriched Environments, Standard Practice for,
ASTM G94	Evaluating Metals for Oxygen Service, Standard Guide for,
U.S. GOVERNMENT	
A-A-59503	Commercial Item Description; Nitrogen, Technical
BB-A-1034	Air, Compressed for Breathing Purposes
DDS-100-4	Strength of Structural Members
FED-SPEC-RR-W-410D	Wire Rope and Strand
23 CFR 658	Truck Size and Weight Regulation
29 CFR 1910	Occupational Safety and Health Standards
46 CFR, Subchapter F	Marine Engineering
46 CFR, Subchapter J	Electrical Engineering
INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS	
IEEE-45	Recommended Practice for Electrical Installations on Shipboard
IEEE-1580	Recommended Practice for Marine Cable for Use on Shipboard and Fixed or Floating Platforms
INTERNATIONAL STANDARDS ORGANIZATION	
ISO 2041	Vibration and Shock
ISO 5805	Mechanical vibration and shock - Human exposure - Vocabulary
ISO 2631-1	Mechanical Vibration and Shock - Evaluation of Human Exposure to Whole-body Vibration - Part l: General Requirements
ISO 9000	International Standards for Quality Management
ISO 10007:2003	Quality Management Systems – Guidelines for Configuration Management
NATIONAL FIRE PROTECTION ASSOCIATION	
NFPA 13	Standard for the Installation of Sprinkler Systems.
NFPA 53	Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres
NFPA 70	National Electrical Code
NFPA 99	Healthcare Facilities, Chapter 19
MISCELLANEOUS	
ANSI/EIA-632	Process for Engineering a System
EIA-649	Electronics Industry Association National Consensus Standard for Configuration Management

EN-13445	European Standard for Unfired Pressure Vessels
IMCA/AODC-035	Code of Practice for the Safe Use of Electricity Underwater
IMCA D 002	Guidance Note for Battery Packs in Pressure Housings
IMO Resolution A.536(13)	Code of Safety for Diving Systems (as Amended by Res. A.831 (19))
SOLAS	International Convention for the Safety of Life at Sea, 1974, as amended
PD5500	British Standard for Unfired Fusion Welded Pressure Vessels and Inspection Procedures/Testing Criteria
SAE J429	(Society of Automotive Engineers)Mechanical and Material Requirements for Externally Threaded Fasteners
SAE J995	(Society of Automotive Engineers) Mechanical and Material Requirements for Steel Nuts

INSTRUCTIONS

DEPARTMENT OF DEFENSE

DOD Directive 5000.1	Defense Acquisition
DODINST 5000.2	Defense Acquisition Management Policies and Procedures
OPNAVINST 3150.27	US Navy Diving Program
OPNAVINST 4790.4	Ship's Maintenance and Material Management (3-M) Manual
OPNAVINST 5100.23	Hearing Conservation and Noise Abatement
PNSY INST 0558-839	Puget Sound Naval Shipyard Industrial Process Instruction, Life Support Gas Systems; Cleaning

1-1.4. DEFINITIONS

1-1.4.1. Added Mass Effect.

The mass of water particles surrounding an object immersed in water that is accelerated with the object as the object is accelerated through the water. When a body is accelerated in a fluid, it behaves as though its mass is greater than it actually is due to the effect of the surrounding fluid. This additional mass must be added to the actual body mass to account for the change in inertia.

1-1.4.2. Allocated Baseline.

The currently approved documentation describing a configuration item's functional, interoperability, and interface requirements and the verification required to demonstrate the achievement of those specified characteristics. The allocated baseline is controlled by the Designer and is established after the preliminary design review.

1-1.4.3. Ancillary Equipment.

Any equipment providing services to a hyperbaric chamber or diving system e.g., compressors, booster/transfer pumps, hot water heater, water conditioning, atmosphere heating and cooling, electrical power supply, hydraulic power supply, breathing and atmosphere gas supplies.

1-1.4.4. Appurtenance.

An accessory structure directly affecting the integrity of the pressure vessel. Major categories of appurtenances include viewports, doors, hatches, closures, penetrations, and piping.

1-1.4.5. Collapse Pressure.

The lowest pressure at which any one of a series of nominally identical hull structures would collapse.

1-1.4.6. Configuration Item (CI).

A configuration item is an aggregation of hardware and/or software that satisfies an end use function and is designated by the Government for separate configuration management

1-1.4.7. Critical Design Review (CDR).

This review determines if the system design documentation (product baseline including detail, material, and process specifications) is satisfactory to start initial manufacturing (i.e., the design meets all technical and safety requirements). The review will examine how well the detail design satisfies cost, schedule, and performance requirements, the producibility of the production design, the control over the projected production processes, and assess configuration item(s) risk areas (on a technical, cost, and schedule basis).

1-1.4.8. Designer.

An individual, partnership, company, corporation, association, or other service having a contract with the government for the design of the diving system. The Designer is responsible and liable for the safe design of the Diving System that, meets or exceeds contract specifications, can be produced by a competent manufacturer, and is certifiable by the SCA. The Designer shall use acceptable engineering principles and prove adequacy of the design through analyses and calculations.

1-1.4.9. Design Load.

The maximum force due to the rated load plus some or all of the following: (1) added mass effects, (2) entrained water, (3) any external payloads, (4) drag or wind loads, and (5) dynamic loads which are derived with the aid of the dynamic load factor.

1-1.4.10. Dynamic Load.

The load imposed on a system due to accelerations of gravity and ship (or other transportation) motion. It is dependent upon the magnitude and frequency of ship motions, ship attitude, and the location of the handling system on the ship.

1-1.4.11. Dynamic Load Factor.

A calculated number given in acceleration units, g; where 1g is the acceleration of gravity. The force exerted by the system on its supports is determined by multiplying the dynamic load factor by the weight of the system.

1-1.4.12. Fail-safe.

Components within the handling system that are designed to prevent uncontrolled dropping, shifting, or sudden movement of the diving system during a hydraulic or electrical system failure or component/equipment malfunction.

1-1.4.13. Functional Baseline (FBL).

The initially approved documentation describing a system's functional, interoperability, and interface requirements and the verification required to demonstrate the achievement of those specified characteristics. The functional baseline is controlled by the Government Procurement Representative and is established after the system requirements review.

1-1.4.14. Functional Configuration Audit (FCA).

The formal examination of functional characteristics of a diving system, prior to acceptance, to verify that the item has achieved the requirements specified in its User Design Specifications.

1-1.4.15. Government Procurement Representative.

The government individual responsible for the procurement and certification of a new construction diving system to meet the user’s operational needs. The Government Procurement Representative shall be accountable for cost, schedule, and performance.

1-1.4.16. Handling System.

The mechanical, electrical, structural equipment and rigging used on board a support platform to launch and recover divers or a manned diving system.

1-1.4.17. Human Systems Integration (HSI).

A process to ensure that the system is built to accommodate the characteristics of the user population that will operate, maintain, and support the system. HSI includes design and assessment of requirements; concepts and resources for system manpower, personnel, training, safety and occupational health, habitability, personnel survivability; and human factors engineering.

1-1.4.18. Load Bearing.

Those components of the handling system that support the loads resulting from launching and recovering of a manned diving system.

1-1.4.19. Load Controlling.

Those components of the handling system that position, restrain, or control the movement of a manned diving system. Towing is excluded from the SOC.

1-1.4.20. Maintainability.

The relative ease and economy of time and resources with which an item can be kept in, or restored to, a fully operational and safe condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair. In this context, it is a function of design.

1-1.4.21. Maximum Operating Pressure

The highest pressure that can exist in a system or subsystem under normal operating conditions. This pressure is determined by such influences as pump or compressor shutoff pressures, pressure regulating valve lockup (no-flow) pressure, and maximum chosen pressure at the system source.

1-1.4.22. Maximum System Pressure

The highest pressure that can exist in a system or subsystem during any condition exclusive of water or steam hammer. The nominal setting of the relief valve (see 1-3.7.10.3, which covers relief valve setting and installation) is the maximum system pressure in any system or subsystem with relief valve protection. Relief valve accumulation may be ignored.

1-1.4.23. Minimum Operating Pressure

The lowest pressure that can exist in a system or subsystem under normal operating conditions. This pressure is usually determined by such influences as the minimum allowable oil supply pressure to a bearing or situations where corrective action shall be taken when pressure drops below a safe minimum pressure rather than exceeding a maximum pressure.

1-1.4.24. Nominal Operating Pressure

The approximate pressure at which an essentially constant pressure system operates when performing its normal function. This pressure is used for the system basic pressure identification.

1-1.4.25. Nonmetallic.

Any material, other than a metal, or any composite in which the metal is not the most easily ignited component and for which the individual constituents cannot be evaluated independently.

1-1.4.26. Open System Approach.

A systems engineering process, described in DOD Instruction 5000.1, The Defense Acquisition System, that includes the use of well-defined, widely-used, non-proprietary processes and DOD adopted standards set by recognized standards organizations, such as International Standards Organization (ISO), American Society of Mechanical Engineers (ASME), Society of Automotive Engineers (SAE) and National Fire Protection Association (NFPA).

1-1.4.27. Operational Suitability.

The degree to which a system can be placed and sustained satisfactorily in field use with consideration given to availability, compatibility, transportability, interoperability, reliability, wartime usage rates, maintainability, safety, human factors, habitability, manpower, logistics, supportability, logistics supportability, natural environment effects and impacts, documentation and training requirements.

1-1.4.28. Performance Specification.

A statement of requirement in terms of required results with criteria for verifying compliance, without stating methods for achieving the required results. It defines the functional requirements for the item, the environment in which it must operate, and the interface and interoperability requirements.

1-1.4.29. Preliminary Design Review (PDR).

This review evaluates the progress, technical adequacy, and risk resolution (on a technical, cost, and schedule basis) of the selected design approach; the functions, performance, and interface requirements that will govern design of the items below system level and assures the design will meet overall system performance requirements; and the degree of definition and assess the technical risk associated with the selected manufacturing methods/processes of each configuration item (CI) or aggregate of CIs.

1-1.4.30. Product Baseline (PBL).

The initially approved documentation describing all of the necessary functional and physical characteristics of the configuration item and the selected functional and physical characteristics designated for production acceptance testing and tests necessary for support of the configuration item. The product baseline is controlled by the Government Procurement Representative and is established after the critical design review.

1-1.4.31. Rated Load.

The maximum weight that shall be lifted by the assembled handling system at its rated speed and under parameters specified in the equipment specifications (e.g., hydraulic pressures, electrical current, electrical voltages).

1-1.4.32. Rigging.

Running rigging consists of the rope (wire rope or synthetic line) and end fittings intended to handle the diving system that passes over sheaves or through rollers. Standing rigging is rope that is stationary and provides mechanical support to the handling system.

1-1.4.33. Scope of Certification (SOC).

The SOC of a diving system encompasses life-critical elements of all systems, subsystems, components and the associated maintenance and operational procedures required to ensure the continuous physical well being of the diving system operators, divers, and other occupants during system operations. It also includes emergency systems and procedures required to return them safely from the maximum operating depth to the surface following a non-catastrophic accident or casualty that prevents continued normal operation of the system.

1-1.4.34. Static Test Load.

A weight equal to 200 percent of the rated load of the handling system. It is used to physically verify the structural integrity of the handling system, and the adequacy of its brakes and fail-safe components.

1-1.4.35. Support Platform.

Any platform used to transport, launch, and retrieve a diving system. Ships, boats, vessels, barges, and submarines are included in this definition. An example of a submarine support platform is one modified to carry a Dry Deck Shelter for operations with SEAL Delivery Vehicles.

1-1.4.36. Survivability.

Ability of a system, sub-system, component, or equipment to withstand the effects of adverse environmental conditions that could otherwise render the system unusable or unable to carry-out its designed function. Survivability also enables a rapid restoration of the system, sub-system, component, or equipment and to increase the sustainability of the war-fighting or peacetime operations.

1-1.4.37. System Certification Authority (SCA).

The organization within the NAVSEA that is delegated, through the Navy chain of command – specifically OPNAVINST 3150.27, Navy Diving Program, the responsibility to conduct certification of diving systems under its cognizance.

1-1.4.38. System Design Pressure

The pressure used in calculating minimum wall thickness of pressure vessels, piping and piping components. The system design pressure shall not be less than the maximum system pressure.

1-1.4.39. System Design Review (SDR)

This review evaluates the contractor's optimization, traceability, correlation, completeness, and the risk of the allocated requirements including the corresponding test requirements in fulfilling the system/subsystem requirements (the functional baseline).

1-1.4.40. System Requirements Review (SRR).

This review evaluates the contractor's understanding of the contract requirements documents (specification, SOW, contract schedule, etc.) and the adequacy of the contractor's efforts in defining system technical requirements. To determine initial direction and progress of the contractor's system engineering management effort.

1-1.4.41. Total Ownership Cost (TOC).

Also referred as Life Cycle Cost. The total cost to the government of acquisition and ownership of that system over its useful life. It includes the cost of research, development, acquisition, operations, and support (to include manpower and training), and where applicable, disposal.

1-1.5. ABBREVIATIONS AND SYMBOLS

ABS	American Bureau of Shipping
ACGIH	American Conference of Governmental Industrial Hygienists
ADS	Atmosphere Dive System
ANU	Authorized for Navy Use
ASME	American Society of Mechanical Engineers
ATA	Atmospheres, Absolute
atm	Atmospheres
BIBS	Built In Breathing System
BTPS	Body Temperature; Ambient Barometric Pressure; Saturated with Water Vapor
CDRL	Contract Data Requirements List
CFR	Code of Federal Regulations
CITIS	Contractor Integrated Technical Information Services
CGA	Compressed Gas Association
CO_2	Carbon Dioxide
COC	Certificate of Compliance
COTS	Commercial-Off-The-Shelf
DC	Direct Current
DDS1	Deep Diving System
DDS2	Dry Deck Shelter
DFARS	DOD Federal Acquisition Regulations Supplement
DFS	Departure From Specification
DLSS	Divers' Life Support System

DOD	Department of Defense
DOT	Department of Transportation
DP	Design Pressure
DSRV	Deep Submergence Rescue Vehicle
EHP	Electrical Hull Penetrator
FADS	Fly Away Dive System
FMECA	Failure Mode, Effects and Criticality Analysis
FID	Flame Ionization Detector
FMGS	Flyaway Mixed Gas System
F_{O2}	Percent by Volume of Oxygen
GSO	General Specifications for Overhaul of Surface Ships
HAZCAT	Hazard Category Level
HAZID	Hazard Identification
HP	High Pressure
HPU	Hydraulic Power Unit
IR	Insulation Resistance
L	Liter
LP	Low Pressure
LSS	Life Support System
LWDS	Light Weight Dive System
MCM	Mission Configuration Matrix
MES	Milestone Event Schedule
MP	Medium Pressure
MT	Magnetic Particle Inspection
NASA	National Aeronautics and Space Administration
NAVFAC	Naval Facilities Engineering Command
NAVSEA	Naval Sea Systems Command
NDE	Nondestructive Examination
NFESC	Naval Facilities Engineering Center, East Coast Detachment
Ni-Al-Brz	Nickel-Aluminum-Bronze
Ni-Cu	Nickel-Copper
Ni-Cu-Al	Nickel-Copper-Aluminum
NIOSH	National Institute for Occupational Safety and Health
NITROX	Nitrogen-Oxygen
NOx	Nitrogen Oxides
NSMRL	Naval Submarine Medical Research Laboratory
O_2	Oxygen
O&M	Operating and Maintenance
OAS	Obstacle Avoidance System
OPNAV	Office of the Chief of Naval Operations
OP/EP	Operating and Emergency Procedures
OQE	Objective Quality Evidence
OSHA	Occupational Safety and Health Administration
PID	Photoionization Detector
PM	Program Manager
PMS	Preventive Maintenance System
PP_{CO}	Partial Pressure of Carbon Monoxide
PP_{CO2}	Partial Pressure of Carbon Dioxide
PP_{O2}	Partial Pressure of Oxygen
PTIMP	Maximum Allowable Internal Working Pressure
PTexp	Maximum Allowable External Working Pressure
ppb	Parts per Billion
PPE	Personal Protective Equipment
ppm	Parts per Million
psia	Pounds per Square Inch, Absolute
psig	Pounds per Square Inch, Gauge

PSOB	Pre-Survey Outline Booklet
PT	Dye Penetrant Inspection
PTC	Personnel Transfer Capsule
PVHO	Pressure Vessels for Human Occupancy
QA	Quality Assurance
REC	Re-entry Control
RM&A	Reliability, Maintainability and Availability
RMS	Root Mean Square
RQ	Respiratory Quotient
SCA	System Certification Authority
scfh	Standard Cubic Feet per Hour
SCUBA	Self-contained Underwater Breathing Apparatus
SDI	Ship's Drawing Index
SECNAV	Secretary of the Navy
SEV	Surface Equivalent Value
SHIPALT	Ship Alteration
slpm	Standard Liters per Minute
S_m	Allowable Operating Stress
SNDLRCS	Standard Navy Double Lock Recompression Chamber System
SOC	Scope of Certification
SOLAS	Safety of Life at Sea
SSDS	Surface Supplied Diving System
STPD	Standard Temperature and Pressure, Dry
TA	Technical Authority
TLV	Threshold Limit Value
TR	Time Required
TRCS	Transportable Recompression Chamber Systems
UBA	Underwater Breathing Apparatus
UIPI	Uniform Industrial Process Instruction
UL	Underwriters Laboratories
UQC	Underwater Telephone
USN	United States Navy

1-2. DESIGN PROCESS

This section discusses the design aspects of the overall Systems Engineering Process for a Diving System. Throughout this section, MIL-STD-499A, Engineering Management, (now cancelled.), and American National Standards Institute (ANSI)/Electronics Industries Alliance (EIA) Standard 632, Processes for Engineering a System have been tailored to provide the designer specific guidance for designing a diving system for the U.S Navy (see Figure 1). Throughout the design process, the designer shall use effective commercial and military practices and processes in the design of the diving system. In addition to the guidance given in this section, the Designer is encouraged to use an open system approach and to provide options for expansion or upgrading with minimal impact on the system schedule and budget. The Designer must also identify the best practices and innovative engineering approaches, such as employment of Concurrent Engineering and Integrated Product Development principles, to meet the Navy's performance requirements. Integral to the design process is configuration management, risk management, and system safety program.

1-2.1. DESIGN PROCESSES

1-2.1.1. Requirements Analysis.

Requirements analysis or Requirements Definition Process (as referred in ANSI/EIA 632) is used to develop functional and performance requirements; that is, government (customer) objectives and requirements are translated into a set of system technical requirements that define what the system must do (functional) and how well it must perform (performance). The designer must ensure that the technical requirements are understandable, unambiguous, comprehensive, complete, and concise so that lower level item performance specifications and technical requirements can be developed.

Requirements analysis must clarify and define functional and performance requirements and design constraints. Functional requirements define quantity (how many), quality (how good), coverage (how far), time lines (when and how long), and availability (how often). Design constraints define those factors that limit design flexibility, such as: environmental conditions or limits; and contract, customer or regulatory standards. For a simple diving system, the system requirements in the statement of work, delivery order or contract may be adequate to develop lower level item specifications and technical requirements.

The requirements analysis identifies the following system functional and performance requirements and characteristics:

a. Operational requirements:

    (1) Operational environments and constraints on system
    - Mission performance requirements including maximum mission duration, currents and sea states

    (2) Operational interfaces with other systems

    (3) Identification of anticipated hazards

b. System functions

    (1) Measures of effectiveness

c. System performance

    (1) Anticipated design life and service period (useful life, number of cycles, etc.)

    (2) Survivability requirements (see 1.3)

    (3) Requirements for reliability, maintainability, and availability

d. System design verification requirements

    (1) Measures of performance

e. System configuration:

(1) Interface descriptions

(2) Characteristics of information displays and operator controls

(3) Relationships of operators to system/physical equipment

(4) Operator skills and levels required to operate, support and maintain the system (Manning requirements)

(5) Communications requirements

(6) Emergency equipment requirements and capabilities

f. Physiological considerations of occupants/divers/operators:

(1) Thermal protection requirements

(2) Limits for breathing gas composition, pressure, flow, temperature, and humidity

(3) Specification of breathing gas contamination limits

(4) Constraints (movement or visual limitations)

g. System Physical Limitations:

(1) Physical limitations (capacity, power, size, weight)

- Depth/pressure limitations
- System volumes/capacities
- Temperature limits for both normal and emergency operating conditions
- Permissible sound, mechanical shock and vibrations parameters

(2) Technology limitations (range, precision, data rates, frequency, language)

(3) Government Furnished Equipment (GFE), Commercial-Off-the-Shelf (COTS), Non-developmental Item (NDI), and reusability requirements

(4) Corrosion allowance/resistance requirements

h. Mandatory military standards and applicable industry design codes and standards

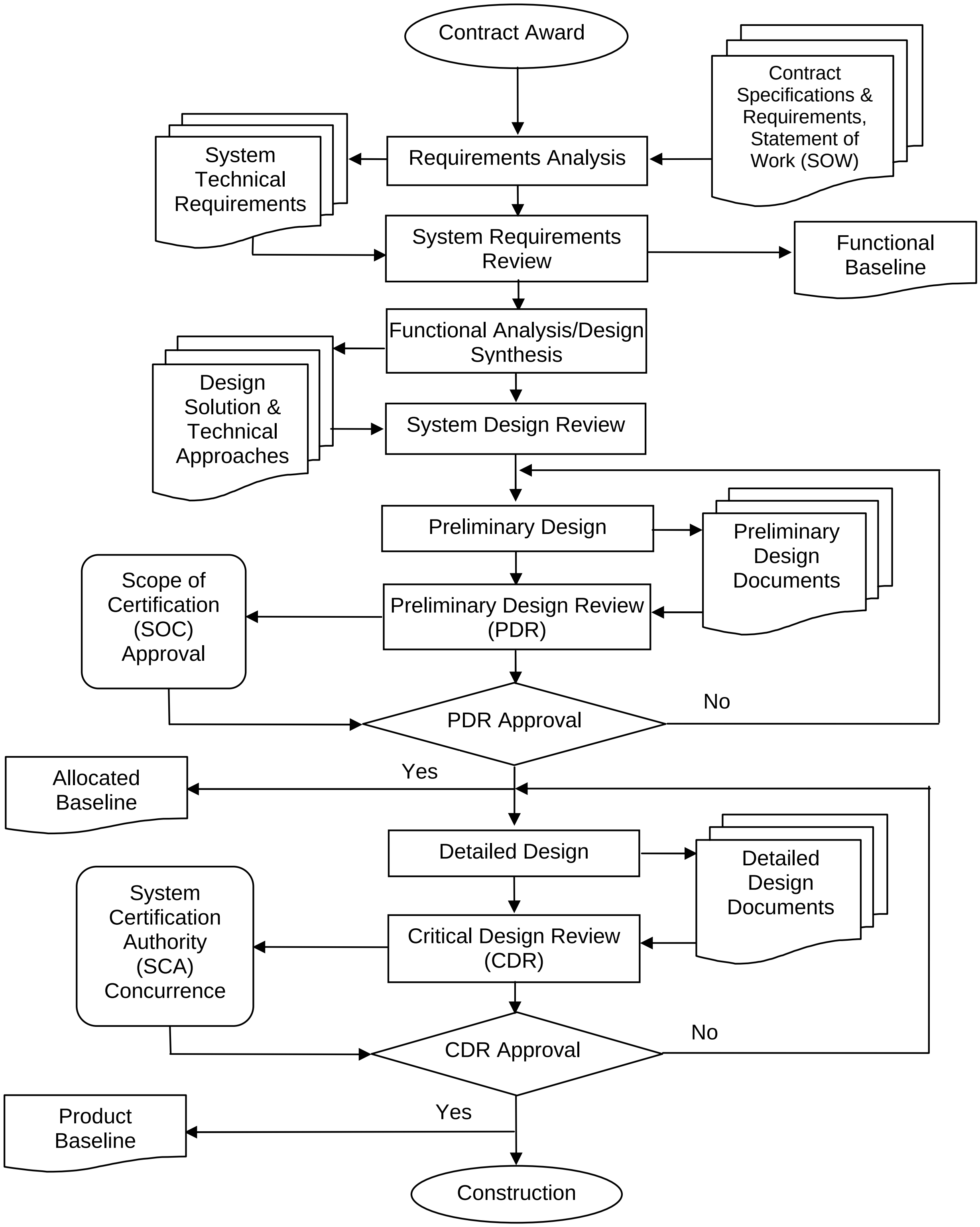


Figure 1: Engineering Design Process

1-2.1.2. Functional Analysis/Design Synthesis.

The functional analysis/design synthesis process or Solution Definition Process (as referred in EIA 632) transforms the system-level functional, performance, interface and other requirements that were identified through requirements analysis into design concepts and technical approaches to achieve a design solution capable of satisfying the stated requirements. System requirements are allocated and defined repeatedly to define successively lower level functional and performance requirements, thus defining architectures at ever-increasing levels of detail to provide design and verification criteria to support the integrated system design.

From these architectures, system and lower-level requirements are translated into design concepts and technical approaches. The Designer then synthesizes the best design solution that is capable of performing the require system function and performance. In selecting the optimal design, the Designer shall use a trade-off analysis (trade study) to evaluate alternative solutions to optimize cost, schedule, performance, and risk.

During this process, configuration items (CI) of the diving system will be determined. For a simple system, the system itself shall be considered a CI; more complex systems like the saturation diving system will have numerous CI, all of which will have their own control and tracking.

Outputs from this process include a systematic block diagram (Building Block Development referred to in EIA 632), a work breakdown structure (WBS) (see MIL-HDBK-881, Work Breakdown Structures), and documentation providing traceability of performance requirements to components. This documentation is presented at the system design review (SDR).

1-2.1.3. Preliminary Design

During the preliminary design phase, subsystem and component descriptions are developed, and detailed interfaces between all system components are defined. Design calculations and analyses are produced. Technical management processes are formalized, (e.g., configuration management plan, system safety plan, quality control plan, certification plan, test and evaluation master plan). Assessments are continuously performed and updated (e.g., risk assessment, hazard analysis). Component material selection and item design requirements are identified. Availability of critical components and technologies are assessed. Major components and subassemblies and their interdependencies are identified and flow diagrams, electrical schematics, system arrangement drawings are completed. Detailed drawings are being produced. As the hazard analysis is conducted and SOC boundaries are defined, single point failures are identified. These are mitigated by design changes or by requiring specific attributes for the components.

1-2.1.4. Detailed Design.

During the detailed design phase, further lower level item physical descriptions and performance requirements are defined and detailed drawings are developed. All design calculations and analyses are completed. The objective of this phase is to have sufficient specifications and drawings to start ordering materials and begin construction of the diving system. The hazard analysis is refined and the design of hazard related components is modified, or specific attributes are required, to mitigate the hazard.

1-2.2. DESIGN REVIEWS.

The Navy requires formal technical reviews and audits in addition to or in conjunction with recognized Code (ASME, ASME PVHO) or classification society (ABS) technical reviews and audits (if these rules and organizations are contractually invoked). These technical reviews and audits are typically found in the system procurement specifications specified in the Statement of Work (SOW). These reviews include:

a. System Requirements Review (SRR). This review is to determine the adequacy of the Designer's efforts in defining system requirements to meet performance requirements and standards of the diving system SOW.

b. System Design Review (SDR). This review evaluates the optimization, correlation, completeness, and risks associated with the allocated technical requirements as well as the Designer's system engineering processes that produced the allocated technical requirements. The Designer shall have completed a conceptual design for presentation at this review.

c. Preliminary Design Review (PDR). This is a formal technical review of the basic design approach. The review is usually held when about 15 percent of the drawings are complete. This review evaluates the progress, technical adequacy, and risk resolution based on technical, cost and schedule basis of the selected design approach.

d. Critical Design Review (CDR). This review is conducted prior to fabrication/production of the diving system to ensure that the detailed design calculations and analyses and engineering drawings satisfy the performance requirements and standards of the diving system. Generally, 85 percent of all drawings are complete prior to this review.

Certification design reviews using NAVSEA SS521-AA-MAN-010 will normally be conducted concurrent with PDR and CDR.

1-2.3. CONFIGURATION MANAGEMENT.

When establishing a configuration management program, the Designer shall follow the guidance in NAVSEAINST 4130.12B, Configuration Management Policy and Guidance, EIA-649, National Consensus Standard for Configuration Management or current version and/or MIL-HDBK-61A, Configuration Management Guidance. ISO 10007:2003, Quality Management Systems – Guidelines for Configuration Management; and SECNAVINST 4130.2, Department of the Navy Configuration Management Policy may also be consulted.

The Designer is responsible for establishing configuration control of the diving system design documentation. A configuration management program ensures that designs are traceable to requirements, that change is controlled and documented, that interfaces are defined and understood, and that there is consistency between the product and its supporting documentation. Configuration management provides documentation that describes what is supposed to be designed, what is being designed, what has been designed, and what modifications have been made to what was designed. The configuration management system shall require the removal of obsolete drawings and specifications from all points of issue and use.

Configuration management comprises five interrelated efforts: Identification, Control, Status Accounting, and Audits (see EIA-649 and/or MIL-HDBK-61A). Configuration management is performed on baselines, and the approval level for configuration modification can change with each baseline. The Government Procurement Representative shall maintain configuration control of the functional and performance requirements only and give the designer responsibility for the detailed design.

1-2.3.1. Functional baseline

This is referred to as the Requirements Baseline in EIA-649. The functional baseline is the approved configuration documentation describing a system's or top level configuration item's (CI) performance (functional, inter-operability, and interface characteristics) and the verification required to demonstrate the achievement of those specified characteristics. The Government Procurement Representative will maintain control of the functional baseline. This baseline is established after the system requirements review.

1-2.3.2. Allocated baseline

The allocated baseline is the current approved performance oriented documentation, for a CI to be developed, which describes the functional and interface characteristics that are allocated from those of the higher level CI and the verification required to demonstrate achievement of those specified characteristics. The Designer shall have control over his design and associated technical documentation that defines the evolving design solution during development of a CI. Any changes or modification of system functional or performance requirements will require the Government

Procurement Representative approval. This baseline is established after the preliminary design review.

1-2.3.3. Product baseline

The product baseline, referred to as the Design Release Baseline in EIA-649, is the approved technical documentation including product level drawings that describes the configuration of a CI during the production, fielding/deployment and operational support phases of its lifecycle. The product baseline prescribes:

- All necessary physical or form, fit, and function characteristics of a CI
- The selected functional characteristics designated for production acceptance testing
- The production acceptance test requirements

The Government Procurement Representative will maintain control of the product baseline, including digital format. This baseline is established after the critical design review.

1-2.3.4. Configuration Changes.

There are two types of change documents used to control baselines associated with government configuration management: Engineering Change Proposal, Request for Deviation or Waiver.

a. Engineering Change Proposals (ECP), referred to as Change Proposals in EIA-649, identify need for a permanent configuration change. Upon approval of an ECP a new configuration is established.

b. Requests for Deviation or Waiver propose a temporary departure (specific number of units or specific time period) from the baseline. They allow for acceptance of non-conforming material. After acceptance of a deviation or waiver the documented configuration remains unchanged.

Classification, submittal, approval and management of configuration shall be in accordance with EIA-649 and/or MIL-HDBK-61A.

1-2.3.5. Electronic Document Management.

The Designer is encouraged to use commercial electronic engineering document management software that allows transfer and access to configuration documentation. The use of MIL-STD-974, Contractor Integrated Technical Information Services (CITIS); Defense Acquisition Deskbook, Section 3.7, Continuous Acquisition and Life-cycle Support (CALS); and appropriate Integrated Digital Environment to provide the Navy on-line access to, or delivery of, programmatic and technical data in digital form is required unless waived by the Government Procurement Representative. The Government Procurement Representative shall maintain configuration control of the configuration documentation and its defining integrated digital data.

1-2.4. SYSTEM SAFETY PROGRAM.

System safety applies engineering and management principles, criteria, and techniques to achieve acceptable mishap risk, within the constraints of operational effectiveness, time, and cost, throughout the system design. It draws upon professional knowledge and specialized skills in the mathematical, physical, and scientific disciplines, together with the principles and methods of engineering design and analysis, to specify and evaluate the environmental, safety, and health mishap risk associated with a system. Experience indicates that the degree of safety achieved in a system is directly dependent upon the emphasis given. A safe design is a prerequisite for safe operations, with the goal being to produce an inherently safe product that will have the minimum safety-imposed operational restrictions.

System Safety interfaces with other aspects in the overall engineering design process including human engineering; reliability, maintainability, and availability; operability, survivability, and environmental, safety, and occupational health.

1-2.4.1. System Safety Plan.

The Designer shall document system safety engineering approach. This documentation shall:

a. Describe the program's overall system safety plan and implementation including milestones, definitions of hazard severity and probability of hazards, and a detailed risk level matrix (severity and probability). Include identification of each hazard analysis and mishap risk assessment process used.

b. Include information on system safety integration into the overall system engineering process.

c. Include the following safety analyses: Health Hazard Assessment, System Hazard Analysis (see 1-2.4.2), Component Level Hazard Analysis, System Level Hazard Analysis (see 1-2.4.2) and Failure Modes and Effects Analysis (FMEA)(see 1-2.7.1.1).

d. Define how hazards and residual mishap risk are communicated to and accepted by the appropriate risk acceptance authority and how hazards and residual mishap risk will be tracked.

e. Include a Hazard Tracking and Closeout Plan. This plan shall maintain a tracking system that includes hazards, their closure actions, and residual mishap risk throughout the design. The Designer shall keep the Government Procurement Representative advised of the hazards and residual mishap risk.

1-2.4.2. Hazard Analysis.

As part of the design process for a diving system or equipment, a hazard analysis must be developed to evaluate the effects of all possible failures. Both a component type hazard analysis and an system level hazard analysis shall be performed. The component level hazard analysis is typically performed assuming that only one failure occurs in any one subsystem at a time, not multiple failures occurring at the same time. The operational level hazard analysis shall account for the multiple effects to a system due to any single failures. The hazard analysis shall describe the possible effects of a hardware failure (mechanical, electrical), software failure or operator error for each component or subsystem. Those failures that could affect the safety or recoverability of personnel shall clearly show what features, warnings or procedures have been incorporated into the design, operation and maintenance of the system to preclude or minimize the probability of failure. It is the responsibility of the Designer to ensure that conditions identified as significant safety hazards are eliminated or reduced to the lowest practical level.

Mishaps are not always the result of equipment failure. Human error when responding to a routine command or a minor problem, or operation of a control function at the wrong time can result in catastrophe. Operating and emergency procedures must be specific, clear and concise in order to avoid confusion. The hazard analysis shall show that this type of failure has been considered in the design of the system and that safeguards have been taken to reduce the likelihood of such an occurrence. MIL-STD-882 provides an acceptable set of guidelines for the conduct of a hazard analysis. The application and tailoring guidelines given in MIL-STD-882 should be carefully followed in order to make the hazard analysis no more complex than is necessary to prove the safety of the design. The System Safety Society's System Safety Analysis Handbook provides expanded guidance on implementation of a system safety program described in MIL-STD-882 including step-by-step instruction for completing required analyses.

Components of a hazard analysis include hazard identification, hazard assessment, and hazard mitigation as discussed below.

1-2.4.2.1. Hazard Identification.

Identify hazards through a systematic hazard analysis process encompassing detailed analysis of system hardware and software, the environment (in which the system will exist), and the intended use or application. Consider and use historical hazard and mishap data, including lessons learned from other systems. Identification of hazards is a responsibility of all program members. During hazard identification, consider hazards that could occur over the system life cycle.

1-2.4.2.2. Hazard Assessment.

Assess the severity and probability of the mishap risk associated with each identified hazard, i.e., determine the potential negative impact of the hazard on personnel, facilities, equipment, operations, the public, and the environment, as well as on the system itself.

1-2.4.2.3. Hazard Mitigation.

Identify potential mishap risk mitigation alternatives and the expected effectiveness of each alternative or method. Mishap risk mitigation is an iterative process that culminates when the residual mishap risk has been reduced to a level acceptable to the Government Procurement Representative. The system safety design order of precedence for mitigating identified hazards is:

a. Eliminate hazards through design selection. If unable to eliminate an identified hazard, reduce the associated mishap risk to an acceptable level through design selection.

b. Incorporate safety devices. If unable to eliminate the hazard through design selection, reduce the mishap risk to an acceptable level using protective safety features or devices.

c. Provide warning devices. If safety devices do not adequately lower the mishap risk of the hazard, include a detection and warning system to alert personnel to the particular hazard.

d. Develop procedures and training. Where it is impractical to eliminate hazards through design selection or to reduce the associated risk to an acceptable level with safety and warning devices, special procedures and training shall be developed. Procedures shall include the use of personal protective equipment. For hazards assigned Catastrophic or Critical mishap severity categories, avoid using warning, caution, or other written advisory as the only risk reduction method.

1-2.5. SCOPE OF CERTIFICATION (SOC).

The SOC is part of the certification process defined in NAVSEA SS521-AA-MAN-010, U.S. Navy Diving and Manned Hyperbaric Systems Safety Certification Manual. SOC consists of all portions of the diving system and its ancillary equipment required to ensure personnel safety. The scope of certification boundaries shall be submitted by Designer and approved by the Government Procurement Representative at PDR. The Designer must justify limiting the SOC using engineering criteria and supporting documentation. Systems and components, not initially shown to be within the SOC by the Designer, shall be reviewed by the Government Procurement Representative for their contributions to the overall safety of design. Negotiation between the Designer and the Government Procurement Representative may be required to define the SOC boundaries.

1-2.5.1. SOC Definition.

As an aid in defining the SOC, especially for complex systems, the Designer should refer to the Hazard Analyses (see 1-2.4.2). Systems, components, procedures and documentation that must be included in the SOC are those:

a. where failure creates an immediate hazard that may result in severe injury or death.

b. where malfunction or failure could prevent the safe return of the operators, divers, or occupants to the surface.

c. that keep operators, divers, or occupants safely on the surface following an ascent.

d. used to rescue personnel from the diving system and return them to the surface, support platform, or, in the case of hyperbaric chambers, to ambient conditions outside the chamber.

e. associated with temporary test equipment affecting trim and stability conditions, both surfaced and submerged, that could threaten safe recovery of personnel.

f. written operating procedures (OP) including predive and post-dive procedures, emergency procedures (EP), and maintenance procedures for systems, subsystems, and components within the SOC including the operation and maintenance (O&M) manual and preventative maintenance system (PMS).

g. drawings required in the construction, operation, and maintenance of the system.

> **NOTE**
>
> The SOC boundaries shall be shown in one or more drawings of the diver's life support system.

1-2.5.2. SOC Included Systems and Equipment.

Since individual diving system designs may vary extensively, no single list can encompass the entire spectrum of SOC. The Designer must evaluate each item and system within a diving system to determine SOC applicability. The listing of items shown below generally requires inclusion in the SOC. This list is provided for purposes of illustration and should not be considered all-inclusive or universally applicable:

a. The pressure hull, pressure vessels, hard structure, and appurtenances.

b. The ballast/buoyancy systems used to maintain adequate freeboard when operating a submersible capsule or habitat on the surface.

c. Jettisoning and emergency ballast blow systems used to return the diving system to the surface in event of emergency.

d. Normal and emergency life-support systems that provide an acceptable atmosphere to the diving system personnel (may include metabolic oxygen admission, carbon dioxide removal, odor removal, humidity and temperature control equipment, Built-in-Breathing System (BIBS)).

e. Non-compensated equipment, subject to pressure, which may implode or explode. (See NAVSEA SS521-AA-MAN-010, U.S. Navy Diving and Manned Hyperbaric Systems Safety Certification Manual, Appendices C and D)

f. Release devices for external appendages.

g. Firefighting devices or systems.

h. Communication systems allowing personnel using the diving system to communicate with support personnel i.e. diver to topside, submersible or habitat to surface support platform.

i. Monitoring/detecting devices, such as atmosphere/breathing gas analysis or depth indication, necessary to ensure the safety of diving system personnel and to prevent exceeding system operating limits.

j. Emergency recovery equipment that includes systems required for recovery of personnel from the system following a casualty.

k. Flotation or buoyancy systems whose failure or inadequacy could prevent the safe return of personnel to the surface or, once on the surface, to remain there.

l. Electrical power subsystems and components, including external and internal electrical protective devices, where failure could result in malfunctions of a critical component or subsystem or become a shock hazard to diving system personnel.

m. Electrical equipment and accessories that have sufficient electrical potential to cause a shock hazard to diving system personnel and are not equipped with an electrical protective device.

n. External obstacle avoidance systems, such as active sonar, fathometers, passive sonar, TV viewing systems, optical viewing devices, and periscopes.

o. Propulsion system for submersibles operating under or near overhangs, cliffs, in canyons, in wreckage, or when the operating scenarios require propulsion to ensure operator safety.

p. Any potential toxic or flammable material within manned spaces of the diving system.

q. Support platform handling systems and components such as cranes, A-frames, trolleys, winches, brakes, cables, and their ancillary equipment used when the diving system is handled, through the air/sea interface or onboard the support platform, with personnel aboard (man-rated).

r. Systems and components that protect personnel directly or indirectly against accidents and hazards.

s. Systems and components providing control of the diver's body temperature and protecting the diver against accidents and hazards in the underwater environment.

t. Subsystems located on the gas supply side of the diver's umbilical or supply hose. For surface supplied diving systems and recompression chamber systems, the scope normally encompasses the entire diver's gas mechanical system. This is usually composed of, but not limited to, compressors, flasks, filtration and purification, carbon dioxide scrubbers, separators, reducing stations, receivers, valving and piping up to and including the diver's manifold(s) and recompression chamber and its appurtenances.

u. Diver-worn equipment, which includes the subsystems and components located on the diver side of the umbilical or supply hose connection required to ensure and preserve the safety and well-being of the diver, such as:

   (1) Breathing gas subsystems and components including tubing, valves and regulators, breathing gas containers, and carbon dioxide absorbers.

   (2) Headgear, face masks, mouthpieces, breathing bags and helmets.

   (3) Breathing gas hose, umbilicals, gas fittings, connectors, fasteners, and clothing.

   (4) Instrumentation, sensors, alarms, computers and (predive) set up equipment.

   (5) Electrical and communication subsystems.

When considering components for inclusion in the SOC, it should be realized that most accidents result from a series of events beginning with a single failure, often relatively minor, which places diving system personnel or equipment under additional stress. The avoidance or prevention of such initial failures in the normal operation of equipment enhances the overall safety of the system.

1-2.6. HUMAN SYSTEMS INTEGRATION (HSI).

The Designer shall consider personnel, training, environment, safety and occupational health; habitability, human factors, and personnel survivability into the design process to optimize total system performance and minimize Total Ownership Costs (TOC).

1-2.6.1. Personnel and Training.

The Government Procurement Representative shall determine the knowledge, skills, and abilities (KSA) of system operators, maintainers, and support personnel and provide that information to the Designer. The goal is to design a system for use by the Navy diving population without having to modify or create new Navy Enlisted Classifications (NEC) or provide additional training requirements. The Designer shall identify, process improvements, design options, or other initiatives to reduce manpower and improve the efficiency or effectiveness of support services. The Government Procurement Representative shall be informed as soon as possible if additional KSAs or NECs will be required.

1-2.6.2. Personnel Survivability and Habitability.

The Designer shall address special equipment, gear or services needed to sustain maximum personnel effectiveness in the operational environment and anticipated working conditions.

1-2.6.3. Human Factors Engineering (HFE).

HSI encompasses the Human Engineering and manning determinations, and is part of the diving system’s design and development. HSI data influences system, component, or equipment design to achieve effective user-system interaction. Examples of Human Factors Engineering include:

a. Physical Human Factors, which addresses physical attributes of the human body such as height, weight, arm reach, center of gravity, etc. The Designer shall consider physical human factors based on the 5th and 95th percentile male unless otherwise specified.

b. Physiological Human Factors, which address visual acuity, tolerance to extreme temperatures, and frequency range of human hearing, etc.

c. Psychological or Behavioral Human Factors, which address mental reaction time to various stimuli, capabilities and limitations of short term memory, and "expectancy" as an element of perception.

Design shall ensure accommodation, compatibility, operability, and maintainability by the user population. Physical accommodation is defined as having adequate reach, strength, and endurance necessary to perform all physical tasks; adequate clearance for movement, to ingress/egress work area, and perform all required tasks; adequate internal and external visibility to perform all required operations; and adequate fit of personal protective equipment to successfully perform all mission duties while receiving optimal protection from adverse environmental threats and conditions. The Designer should refer to MIL-STD-1472, Human Engineering, and other non-government standards for human engineering guiding criteria in the design of the diving system.

Design shall reflect applicable system and personnel safety factors, including minimizing potential human error in the operation and maintenance of the system, particularly under emergency or non-routine conditions. Design of non-military-unique workplaces and equipment shall conform to Title 29, Code of Federal Regulations Part 1910 (29 CFR 1910) unless military applications require more stringent limits.

1-2.6.3.1. Sound.

The Designer shall consider the effect of sound levels on the system occupants in accordance with the guidelines and calculations provided in OPNAVINST 5100.23, Chapter 18, Hearing Conservation and Noise Abatement and MIL-STD 1474, Noise Limits. When considering time-weighted averages of sound levels in decimals on a A-weighted scale (dB(A)) for frequencies of 20 to 16,000 Hertz (Hz), the systems covered in this manual can be divided into two categories: manned hyperbaric facilities/underwater habitats and diving helmets.

a. For manned hyperbaric facilities and underwater habitats, the following permissible exposure limits (PEL) are applicable (see OPNAVINST 5100.23, Chapter 18):

(1) During work periods (not to exceed 16 hours in any 24-hour period), the noise level shall not exceed 80 dB(A). During sleep/rest periods (a minimum of 8 hours in any 24-hour period), the noise level shall not exceed 70 dB(A).

(2) When an intermittent noise greater than 70 dB(A) exists, the PELs must be recalculated using the following formula.

$$T = \frac{16}{2^{\left[\frac{L-80}{4}\right]}}$$

Where:
T = time in hours (decimal)
L = effective sound level in dB(A)

(3) For impact/impulse noises the maximum sound pressure level is 140 dB.

(4) When two or more periods of noise exposure of different levels comprise the daily noise exposure, their combined effect must be considered. If the sum of the following expression exceeds unity (i.e., >1), then the mixed exposure exceeds the PEL.

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots. \frac{C_n}{T_n}$$

Where C indicates the total time of exposure at a specified noise level and T represents the time of exposure permitted at that level.

b. For diving helmets also follow the guidance in 1-2.6.3.1.a above.

The Designer shall minimize the ambient noise level to the extent feasible through effective sound reduction or attenuation to meet the ambient sound levels above. See MIL-STD-1474, Noise Levels, Requirement 5 for further guidance on equipment noise acceptance criteria in meeting sound level thresholds.

1-2.6.3.2. Vibration.

The following provisions apply to whole body vibration, as defined by ISO 2041, Vibration and Shock, and ISO 5805, Mechanical vibration and shock - Human exposure - Vocabulary, where the vibratory motions are limited to those transmitted to the human body as a whole through supporting surfaces. This includes the feet for the standing occupant, the buttocks, back, and feet for the seated occupant, and the supporting surface of the occupant lying on his or her back. The applicable frequency range is defined as:

0.1 to 0.5 Hz for motion sickness
0.5 to 80 Hz for health, comfort, and perception

Evaluation of vibration and its possible effects on health, comfort, and perception, and motion sickness should conform to ISO 2631-1, Mechanical Vibration and Shock - Evaluation of Human Exposure to Whole-body Vibration - Part l: General Requirements, as described below:

a. Health. To minimize the effects of whole-body vibration on health, the root-mean square (RMS) value of the frequency-weighted translation accelerations should not exceed the health guidance caution zones for the expected daily exposures defined by ISO 2631-1, Annex B. If possible, exposure within the health guidance caution zone should be avoided. Frequencies below 20 Hz should be avoided. Evaluation of environments where the vibration crest factor is above 9, or for environments containing occasional shocks of transient vibration, should conform to paragraph 6.3 of ISO 2631-1.

b. Performance. The RMS value of the frequency-weighted translation acceleration should fall below the health guidance caution zone for the expected daily exposures defined in ISO 2631-1, Annex B. Whole body vibration should also be minimized in the frequency range below 20 Hz where major body resonance occurs. To preclude impairment of visual tasks, vibration between 20 and 70 Hz should be minimized. The transmission of higher frequency vibration through the seating system should also be minimized, especially where transmission of vehicle vibration to the head at such higher frequencies that can occur for seating conditions in which the body or head come in contact with the seatback or a headrest.

c. Comfort. Where specific levels of comfort are listed in ISO 2631-1, Annex C must be maintained; the applicable overall vibration RMS values indicated therein should not be exceeded.

d. Motion sickness. The weighted RMS acceleration in the z-axis (between 0.1 and 0.5 Hz) should be sufficiently low to preclude or minimize motion sickness as assessed by the methods and assessment guidance specified by ISO 2631-1, Annex D.

e. Equipment vibration only. Where whole-body vibration of the human operator or parts of the body is not a factor, equipment oscillations should not impair required manual control or visual performance.

1-2.6.3.3. Operability and Maintainability.

The ease and economy with which operations and maintenance can be performed is partly a function of how well the Designer has considered human limitations and abilities in regard to strength, perception, reach, dexterity, and biology. The Designer must consider human engineering factors during design efforts to ensure the required range of expected human maintainers can indeed accomplish the tasks.

The Designer shall submit an Operating and Support Hazard Analysis in accordance with the System Safety Program used to evaluate the operability of the system. The Operating and Support Hazard Analysis (O&SHA) evaluates the potential for hazards and the degree of risk resulting from the implementation of operational and support procedures (e.g., maintenance, transport, disposal, etc.) performed by personnel supporting the system. The O&SHA considers the relation of the system to each phase of activity; facility interfaces; planned operating environments; support equipment; safety and occupational health regulatory requirements; and the potential for unplanned events, including hazards introduced by human errors.

As determined by system complexity, such analyses should include an information flow diagram, an operational sequence diagram, a human engineering analysis of the instrumentation and control layouts, and an analysis of the life -support control and monitoring systems. Design of the man-machine and operator-system interfaces should be based on the 5th and 95th percentile physical attributes identified in NSMRL Report 83-03, Anthropometric Indices Among U.S. Navy Divers. Human engineering design shall be integral to the design process using guidance provided in MIL-STD-1472, Human Engineering.

Maintainability is directly related to the anthropometrical and psychological characteristics of the human beings who will operate and maintain the diving system. Anthropometrical characteristics determine how large access openings must be, the need for stands, how far replaceable units shall be placed inside a compartment and still be reachable, and so forth. Psychological factors determine what types of warnings are most effective, which way a calibration knob should turn, whether a continuously variable or detented knob should be used, and so forth.

1-2.7. RELIABILITY, MAINTAINABILITY AND AVAILABILITY (RM&A).

1-2.7.1. Maintainability.

The Designer shall follow the guidance of MIL-HDBK-470, Designing and Developing Maintainable Products and Systems, for determining the maintainability and reliability of the diving system. Maintainability analyses include:

- Maintainability Design Evaluation
- Failure Modes and Effects Analysis (FMEA)
- Testability Analysis
- Human Factors Analysis

1-2.7.1.1. Failure Modes and Effects Analysis (FMEA).

The Designer shall perform a Failure Modes and Effects Analysis (FMEA) to identify mission or safety critical single point failures and steps mitigating them, i.e., elimination through design or making the design robust through redundancy, graceful degradation, or insensitivity to the cause of the failure. See MIL-HDBK-470, Designing and Developing Maintainable Products and Systems, Volume I, paragraph 4.4.1.3.3; Society of Automotive Engineers (SAE) J-1739, Potential Failure Mode And Effects Analysis in Design (Design FMEA) and Failure Mode And Effects Analysis in Manufacturing and Assembly Processes (Process FMEA) Reference Manual, Recommended Practice; and Automotive Industries Action Group (AIAG), Potential Failure Modes and Effects Analysis (FMEA) for guidance.

1-2.7.1.2. Reliability-Centered Maintenance.

The Designer shall use the reliability-centered maintenance (RCM) process of MIL-P-24534, Planned Maintenance System: Development of Maintenance Requirement Cards, Maintenance Index Pages, and Associated Documentation, in the development of preventative and corrective maintenance procedures if contractually invoked. Other programs such as NAVAIR 00-25-403 or non-government RCM processes may be considered and will require Government Procurement Representative approval. The RCM analysis shall show that the design permits rapid positive identification of malfunctions, and rapid isolation and repair of these items by system personnel.

1-2.7.2. Reliability.

The diving system must perform reliably under worst-case conditions. The reliability performance objective shall be in terms of mean time between failures (MTBF). MTBF must be longer than the longest operational mission profile. All failures should be given design consideration since a large number of non-critical failures will become a burden and drive up total ownership cost (TOC). See MIL-HDBK-470, Designing and Developing Maintainable Products and Systems, Volume I and Volume II; MIL-STD-189, Reliability Growth Management; SAE M-102, Reliability, Maintainability, and Supportability Guidebook, and the Reliability Analysis Center, http://rac.alionscience.com for guidance.

1-3. GENERAL DESIGN REQUIREMENTS

The requirements of this section are applicable to ALL systems and components fabricated in accordance with this specification. Requirements peculiar or supplemental to a specific type of system are covered by the section governing that system (see section 1-4). Where supplemental or differing requirements are specified in the section governing the system, the system section requirements take precedence.

1-3.1. DESIGN CALCULATIONS.

Design calculations as well as acceptance criteria are mandated by recognized industry codes and standards. The Designer shall request written approval from the Government Procurement Representative on the proposed codes and standards to be used in the design of the system prior to conducting calculations.

Design calculations shall be provided showing minimum material dimensions, and clearly stating all design assumptions and load conditions. The calculations shall be in standard engineering data sheet format that clearly indicate that the design as depicted in the drawings is fully satisfactory and meets all design requirements of the applicable code or standard, and be signed by the design engineer.

For calculations completed before drawings are placed under configuration management, calculations must later be validated as applicable to the configuration baseline drawing. All calculations affecting SOC parts must be traceable to respective production drawings.

1-3.1.1. Minimum Calculation Requirements

Calculations by the Designer must demonstrate the adequacy of design in terms of the design parameters of the diving system and clearly state all design assumptions and load conditions. Components, equipment and systems shall be designed to properly operate at the most limiting design conditions. Design calculations shall use worst case material dimensions. The designer shall produce documentation in sufficient detail to permit an independent analysis of the design. Calculations should provide, at a minimum, the following information:

a. Pressure vessels designed for human occupancy design calculations shall clearly show the design meets all requirements of ASME PVHO-1 Safety Standard for Pressure Vessels for Human Occupancy or alternative pressure vessel design codes may be proposed by the Designer but must be approved by the Government Procurement Representative prior to use..

b. Structural design calculations shall show the effect of fabricating to worst case material dimensions. Potential effects of corrosion caused by oxidation, pitting, galvanic interaction of dissimilar metals, stress corrosion cracking and embrittlement must be considered. Appropriate reference shall be made to applicable test data, codes and standards, safety standards and operating experience when used to support a calculation technique.

c. Piping and mechanical systems, loads, power supplies, etc. shall have calculations to show the capability of the system to perform its intended function. This includes system flow characteristics, e.g., velocity, flow rates, pressure, and storage and/or air bank capacity, where applicable. Flow rates and storage capacities shall be based on the most demanding cases, including emergency situations where the system may see service.

d. Design calculations for electrical equipment and systems will contain as a minimum:

  (1) Electrical load and power analysis.

  (2) Maximum heat generated by the equipment, and the maximum anticipated temperature.

  (3) Voltage-drop calculations including fault current analysis and coordination of protective devices analysis.

  (4) Where available, information obtained from the manufacturers of the electrical/electronic equipment may be used in lieu of actual calculations provided that technical justification to support the manufacturer's information is provided.

1-3.1.2. Stress Analysis.

The Designer shall verify the adequacy of the design by performing detailed stress analyses and conducting the tests described herein, when appropriate. Applicable sections and provisions of pressure vessel and piping design codes shall be applied. The test program shall consider all ramifications of the stress analyses. Stress analyses and test reports shall also consider the most critical loading case that includes the cumulative detrimental effects of design allowances, dimensional variations, and tolerances. The Designer may request that specific designs utilizing standard materials or components be exempted from stress analysis, based on technical justification. In cases where the pressure boundary is a unique and complex shape, destructive testing can be accomplished if the validity of a stress analysis is in question. The Government Procurement Representative and applicable Code Inspector or classification society Surveyor will make a determination of those materials and systems that do not require stress analyses. Examples of loads to be considered are:

a. Weight of water used for hydrostatic testing

b. Forces encountered while transporting, securing, removing, or handling the system or its components

c. Static loads imposed by the clamping or securing devices used to secure the system

d. Maximum operating pressure of gas within the system

e. Thermal stresses due to the maximum operating temperature range of the system

f. Reactions due to differential thermal expansion between the system and the structure to which it shall be fixed or due to elastic expansion of the system caused by internal pressure

g. Vibration transmitted from the shipping platform transporting the components of the system

h. Shock, including accidental blows

i. Vertical and horizontal loads on foundations

j. Forces developed by shipboard accelerations, ship vibrations or imposed by ship motions

k. Dynamic loads, such as those encountered:

  (1) When launching, retrieving, or handling the diving system

  (2) In normal or casualty operations such as explosively jettisoning external equipment

  (3) From collapse of any non-pressure compensated elements

l. Fatigue load life of the pressure resisting components and piping for a specified number of cycles in a cold water environment.

m. Effects of Corrosion

1-3.1.3. Fatigue.

A fatigue analysis shall be submitted for all piping systems, pressure vessels and hard structures in accordance with requirements of the specific design code that was use for the design. This fatigue analysis may be based on specimen and/or model tests. Prior to conducting the analysis, technical justification for the basis of the fatigue analysis shall be provided to and approved by the Government Procurement Representative. Suitable fatigue strength reduction factors shall be applied to the specimen or model test results to account for variations in properties, scatter in the test results and the uncertainties involved in applying specimen and model fatigue data to fabricated full-scale structures. The fatigue analysis must consider at least the following design parameters:

a. Magnitude and nature of peak stresses - stress concentration factors used in the calculation of peak stresses shall be based on experimental data on similar structures.

b. Material properties and method of fabrication.

c. Maximum deviation in material thickness, assembly techniques and allowable flaws.

d. Geometry of the structure and details of penetrations and attachments.

e. Previous fabrication, stress-loading, and operating history of the material.

f. Effects of residual stresses, thermal stresses and strain rate.

g. Type and method of loading and environmental effects such as corrosion/erosion.

h. Maximum anticipated number of load cycles.

1-3.2. DRAWINGS

1-3.2.1. Drawing Requirements and Standards.

All diving systems drawings shall meet the requirements of ASME Y14.100, Engineering Drawing Practices. A tailoring guide, Appendix A, is included in ASME Y14.100 to facilitate the tailoring process. Since ASME Y14.100 is general in nature, ASME Y14.100, ASME Y14.24, Types and Application of Engineering Drawings; ASME Y14.34M, Associated Lists; and ASME Y14.35M Revisions of Engineering Drawings and Associated Documents should be regarded as a closely interdependent set of ASME standards. The required drawing fidelity (i.e., Developmental Design Drawings, Product Level Drawings, etc.) must be defined during the Requirements Analysis of the design process, and adhered to throughout design.

For each component or item on a drawing, the manufacturer's model or type number, part number, material, vendor identification, applicable military specification, federal specification or standard as appropriate shall be identified. The drawings shall specify any special material control requirements. Each component that provides a control, sensing or similar essential function that impacts on the operation of the system (valves, gauges, pressure regulators, etc.) shall have a unique identifier made up of a system designation and a number. These unique identifiers shall be shown on the drawings and shall be used in the operating and emergency procedures, and the system hazard analysis. Dimensional inspection points required as SOC attributes shall be identified on drawings for each dimension that is an SOC attribute.

Drawings must completely identify the pressure vessel(s) and all the appurtenances (foundations, penetrations, attachments, etc). All welds shall be detailed and fully located. All components shall be fully specified on the Bill of Material/Material List and notes shall fully explain or define processes, specifications, procedures and/or special instructions. Pressure vessel(s) weight, internal (floodable) volume and cycle life (when required) shall be stated on the Top Assembly Drawing for each vessel. When cycle life is defined, cyclic requirements (inspections, tests) shall also be stated.

All fabrication drawings shall contain all manufacturing, assembly, cleaning and testing information necessary to permit operators to maintain the diving system after its fabrication. Each component and welded or mechanical joint within the SOC shall have a unique identification number on the Joint Identification Drawing which will be used for documentation and traceability throughout construction. (see Part 2, 1.6.3)

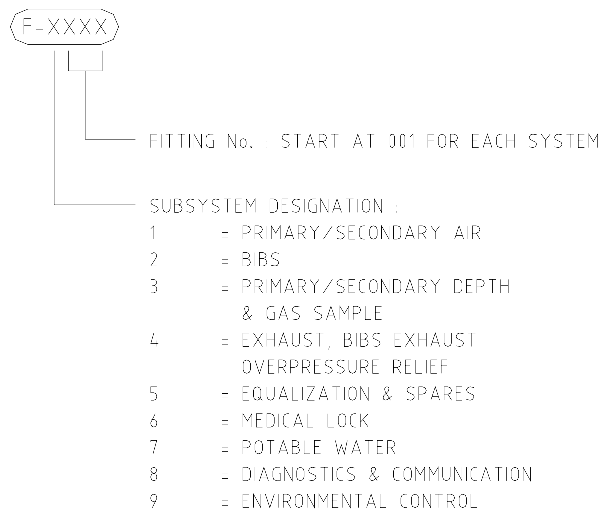
1-3.2.2. Joint Identification Drawings

The Designer shall develop Joint Identification Drawings (JID) for the divers life support system (DLSS) and welded pressure vessels of any diving or hyperbaric system designed according to this specification. JIDs are used not only during the fabrication of the system but also throughout the life of the equipment for maintenance and record keeping. It is imperative that these drawings are complete and accurate.

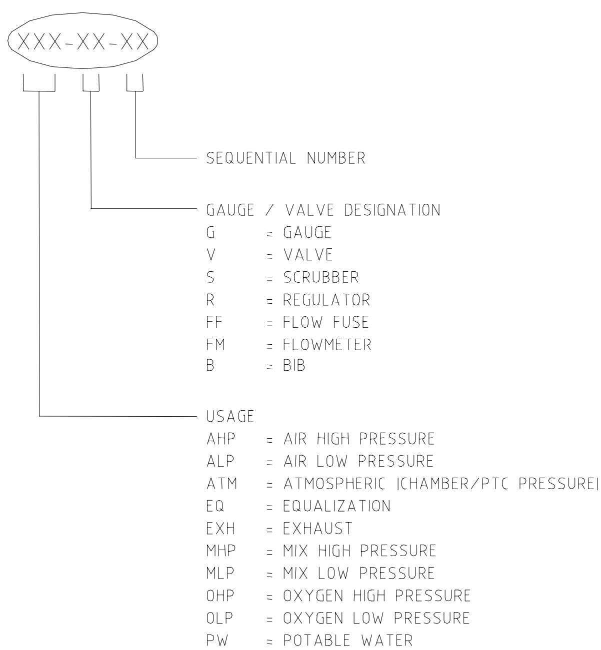
JIDs are a schematic and parts list of the piping systems, pressure vessels, and components that are within the SOC. The schematics shall show all piping/tubing, fittings, valves, gauges, and joints. The piping, components, and joints shall be identified as described in 1-3.2.2.1 through 1-3.2.2.4. The JID shall also list the minimum wall thickness required (after bending) for piping and tubing. This is required for the proper fabrication of pipe/tubing bends. An example of a JID is shown in Appendix D.

For some diving systems it may be advantageous to use different subsystem designations than those shown in 1-3.2.2.1 through 1-3.2.2.4. For example, a surface supplied diving system may use volume tank, control console, and flask rack assemblies as subsystems rather than primary/secondary air, BIBS and exhaust. If different designations are determined to be more efficient, the Designer shall submit the requested change in writing to the Government Procurement Representative for approval.

1-3.2.2.1. JID Fitting Designations

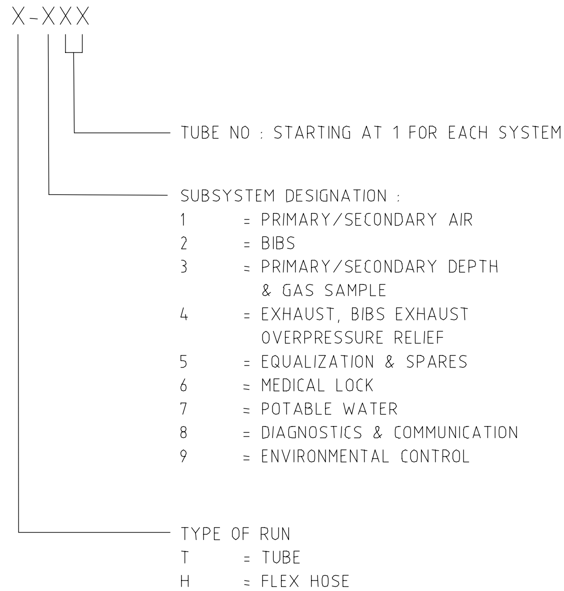


1-3.2.2.2. JID Valve, Gauge, Miscellaneous Component Designations

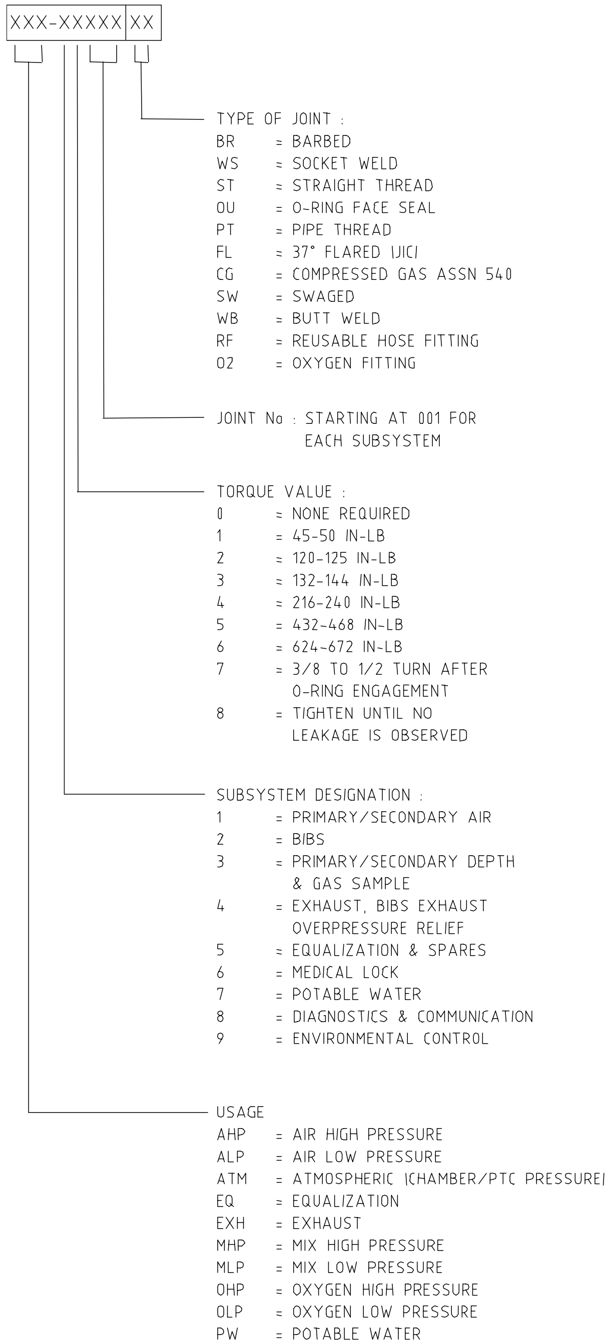


For some diving systems it may be advantageous to use different or additional usage types. If different designations are determined to be more efficient, the Designer shall submit the requested change in writing to the Government Procurement Representative for approval.

1-3.2.2.3. JID Piping, Tubing, and Hose Designations



1-3.2.2.4. JID Joint Designations



1-3.2.3. Revisions

Once the Government Procurement Representative approves the design after CDR and the product baseline is established, all drawing revisions shall be formally documented and the reason and approval for each revision shall be explicitly stated on the drawing. The Government Procurement Representative must approve all revisions. ASME Y14.35M "Revisions of Engineering Drawings and Associated Documents" shall be used.

1-3.3. ACCESS TO VITAL CONTROLS/EQUIPMENT.

Access to vital components and equipment is defined as the ability to reach, read and/or operate components and equipment identified as vital to the recovery and emergency operation of the diving system. The Designer shall ensure unrestricted accessibility to vital components and equipment using the following guidelines:

a. Access to and operation of the component or equipment must not be obstructed or restricted by structure, piping, machinery, or other equipment.

b. If a component or piece of vital equipment is located behind a locker front, false panel, or other covering, ensure that there is adequate access to the component and that the panel is clearly marked with the component location on the outside. Ensure access covers, if any, are readily removable and cannot be locked into place.

c. The component or equipment should be within arm's reach of the operator without having to assume an unusual position or stretch excessively to operate the component or equipment after reaching around, through or over structure, piping, or habitability coverings.

1-3.4. WELD DESIGN.

Weld design shall be in accordance with MIL-STD-22, Welded Joint Design, unless other wise directed in section 1-4.

1-3.5. THREADED FASTENERS.

The design of all threaded fasteners within the SOC, including bolts, studs and nuts shall meet the requirements of MIL-DTL-1222 or SAE J429 (Mechanical and Material Requirements for Externally Threaded Fasteners) or SAE J995 (Mechanical and Material Requirements for Steel Nuts). MIL-DTL-1222 is continually being revised to reflect adopted non-government standards for use in military systems and applications. Material, number, type, size, and method of tightening should be in accordance with recognized design code. Studs and bolts should be of sufficient length so that, when nuts are tightened to their appropriate torque values, at least 1 thread is exposed. Where practicable, the number of threads exposed shall not exceed 5; however, in no case shall the thread exposure exceed 10 threads.

1-3.5.1. Locking Devices for Critical Fasteners.

The need for locking devices on mechanical fasteners shall be evaluated by the Designer where the loss of the fastener would cause a critical failure. Generally, a locking device should provide a positive locking action, be simple to install, and should lend itself to easy inspection without disturbing the locking feature.

If the locking device does not meet the above guidance, or is unique in design, the Designer shall furnish sufficient information to justify the safety and integrity of the device. The justification shall include recommended inspection procedures and acceptance standards. If locking devices are not practical, critical fasteners shall be marked with a "torque stripe" identifying the relative locations of parts under proper torque. For further design guidance on fastening devices, refer to NAVSEA S9505-AM-GYD-010 Submarine Fastening Criteria (Non-Nuclear).

1-3.6. DIVER LIFE SUPPORT SYSTEMS (DLSS)

1-3.6.1. Background and General Requirements

Diver life support systems (DLSS) shall be designed to provide a safe, controlled environment for diving system personnel. Environmental control systems for diving shall provide adequate oxygen for the occupants while removing the carbon dioxide produced by metabolic processes. They must remove gas contaminants and maintain temperature and humidity at comfortable levels. The Designer shall show that DLSS capabilities satisfy the life support requirements of the most demanding mission, such as the duration of diving system operation (length of mission), operational scenario, number of personnel embarked in the diving system, physical activity of personnel, volume of the enclosure used by personnel and ambient environment. The DLSS shall provide a secondary and emergency (where required) life support systems to return the personnel to a safe haven in the event of a failure of the primary life support system. The hazard analysis (see 1-2.4.2) shall verify that the DLSS can recover from a single point failure during operations. Analysis may be based on previous history of use or on test results.

The Designer shall provide detailed calculations to show that the breathing gas supply will provide gas at the required flow rate and pressure to meet the conditions of the most imposing diving mission, including emergencies. For surface supplied diving systems and recompression chambers, the gas requirements specified in NAVSEA SS521-AG-PRO-010, U.S Navy Diving Manual must be met for each type of equipment used. Enough gas must be available to compress to the maximum depth, maintain depth for as long as required and return the divers to the surface, including decompression. The Designer must also determine whether additional gas is needed for upward excursions and/or for lock runs based on the operational requirements of the system.

The design of DLSS shall address the following items necessary for atmosphere control and monitoring, based on the mission and complexity of the dive system:

a. Breathing gas supply.
   - (1) Stored breathing gas.
   - (2) Primary breathing gas supply.
   - (3) Secondary breathing gas supply.
   - (4) Emergency breathing gas supply (when required by the U.S. Navy Diving Manual).

b. Environmental control and monitoring.
   - (1) Carbon dioxide control and monitoring.
   - (2) Oxygen control and monitoring.
   - (3) Gas purification and filtering.
   - (4) Humidity control and monitoring.
   - (5) Temperature control and monitoring.
   - (6) Environmental monitoring instrumentation.

1-3.6.1.1. Oxygen.

In the closed environment of a diving system, the occupants will consume oxygen as part of their normal metabolic process. Figure 2 shows the range of oxygen consumption rates for various activities. From a practical standpoint the minimum oxygen consumption rate for an individual is 0.33 Liters/minute (STPD), and the maximum is 4.0 Liters/minute (STPD).

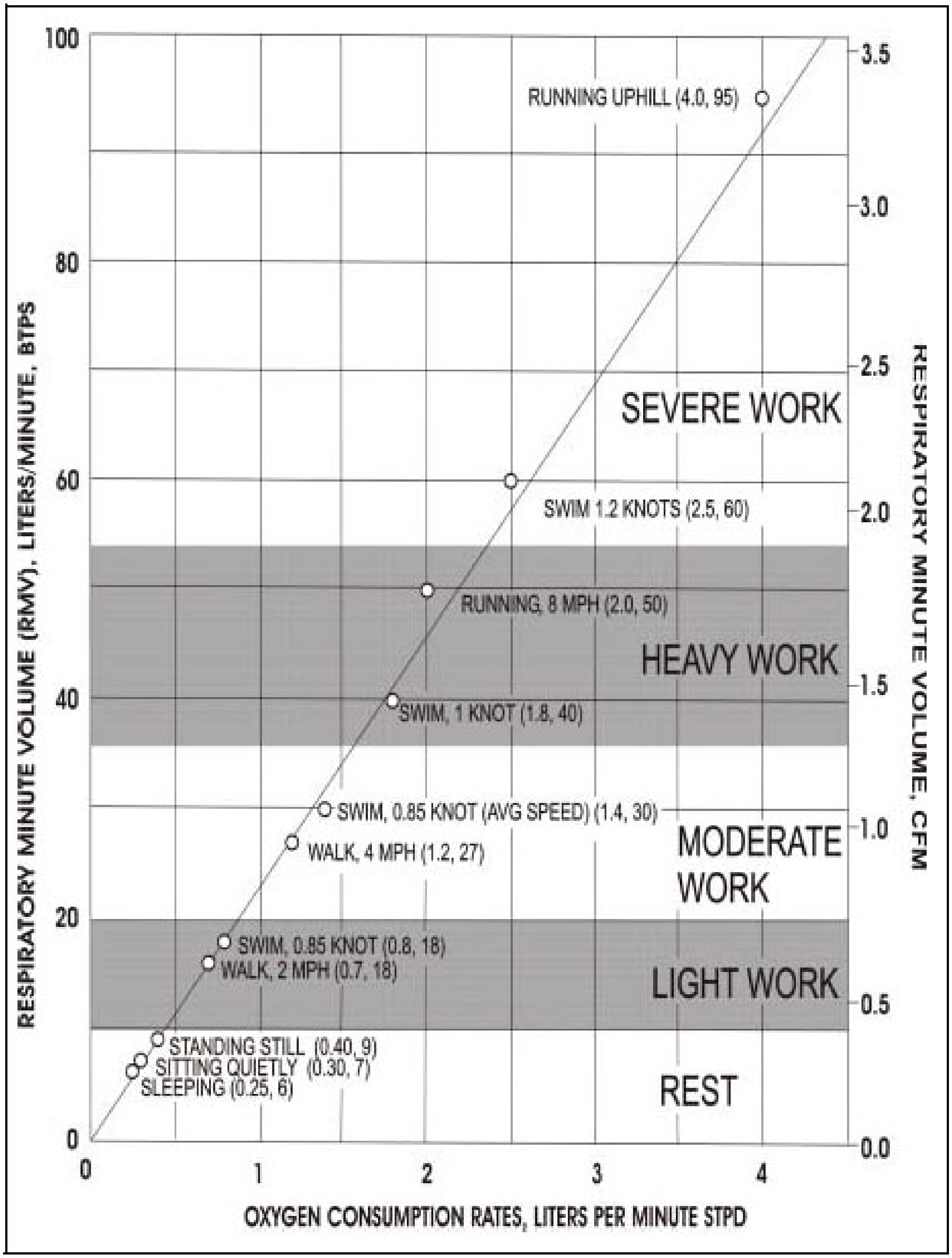


Figure 2: Relation of Respiratory Minute Volume and Oxygen Consumption Rate to Type and Level of Exertion

1. Ref: NAVSEA SS521-AG-PRO-010, U.S. Navy Diving Manual; Volume 1, Diving Principles and Policy, Figure 3-6.

Oxygen deficiency, or hypoxia, is an abnormal deficiency of oxygen in the arterial blood that causes the tissue cells to be unable to receive sufficient oxygen to maintain normal function. Severe hypoxia will stop the normal function of any tissue cell in the body and will eventually kill it, but the cells of the brain tissue are by far the most susceptible to its effects. Air contains a PP_{O2} of 0.21 ata at the surface and this is ample, but a drop to 0.14 ata will cause the onset of hypoxic symptoms. If the PP_{O2} goes as low as 0.11 ata most individuals become hypoxic to the point of helplessness. Consciousness is usually lost at about 0.10 ata and at much below this level, permanent brain damage and death will most likely occur.

Most diving operations should use a PP_{O2} of 0.30 ATA as the lower limit at the working depth. The U.S. Navy Diving Manual (NAVSEA SS521-AG-PRO-010) spells out the PP_{O2} permissible exposure times for closed and semi-closed SCUBA; surface supplied UBAs, saturation diving, and recompression therapy and also describes the signs and symptoms of both pulmonary and central nervous system oxygen toxicity. For very long exposures measured in hours to days, pulmonary symptoms may appear if the PP_{O2} is allowed to exceed 0.5 ATA. The U.S. Navy normally maintains PP_{O2} between 0.44 to 0.48 ATA during saturation dives. The exact upper and lower PP_{O2} limit requires knowledge of the diving system mission as well as the expected dive duration.

High pressure oxygen poisoning, or central nervous system (CNS) oxygen toxicity, is most likely to occur when divers are exposed to more than 1.6 atmospheres of oxygen. CNS O_2 Toxicity's most serious direct consequence is convulsions. Sometimes, recognition of early symptoms may provide sufficient warning to permit reduction in oxygen partial pressure and prevent the onset of more serious symptoms. Some of the warning symptoms are: tunnel vision, nausea, twitching, and irritability. To prevent the onset of CNS O_2 Toxicity in most divers, the design of the diving system or recompression chamber shall be such that partial pressure of oxygen delivered to the user shall typically be at 1.4 ata or below. Closed-system oxygen rebreathing systems may require lower partial pressures while surface supplied helium-oxygen systems usually permit higher PP_{O2}.

Table 1: Allowable Oxygen Partial Pressures by System Type

OPEN CIRCUIT AIR AND NITROX DIVING	1.4 ATA (MAX)[1]
OPEN CIRCUIT HELIOX DIVING (SURFACE SUPPLIED)	1.3 ATA (MAX, ON-BOTTOM)[2]
OPEN CIRCUIT HELIOX DIVING (SATURATION)	1.25 ATA (MAX, FOR EXCURSION DIVES)[3]
CLOSED CIRCUIT OXYGEN DIVING	Limits shall be provided by the Government Procurement Representative in terms of depth and allowable exposure time rather than PP_{O2}. The diver will have no knowledge of the PP_{O2} in the breathing mix and can only operate on the basis of depth and time.
CLOSED CIRCUIT CONSTANT PP_{O2} DIVING	1.3 ATA (TIME WEIGHTED AVERAGE)[4]
SEMI-CLOSED CIRCUIT NITROX DIVING	Variable depending on flow rate, oxygen percentage, workload, rig kinetics, and work rest timing cycles

1. Dives with higher PP_{O2} are allowed but with restricted exposure times.
2. Brief exposures to PP_{O2} as high as 1.9 ATA are allowed during decompression.
3. See 1-4.3 for requirements on PP_{O2} in Deck Decompression Chamber.
4. 1.9 ATA max during compression and 1.3 ATA minimum during decompression. The PP_{O2} limits are the same for NITROX and HELIOX diving as the same UBA is currently used in both cases.

If the Designer has a question on what the limits for oxygen partial pressures should be, they are responsible for requesting the information from the Government Procurement Representative.

1-3.6.1.2. Carbon Dioxide.

Respiration accounts for most of the carbon dioxide generated in a diving system. During the breathing cycle, oxygen is removed from the breathing gas and replaced in a certain proportion by CO_2. The ratio of volume of CO_2 produced to the volume of O_2 consumed is termed respiratory quotient (RQ) and varies from 0.7 to 1.1, depending upon the chemical composition of the energy source, level of exertion, and other factors. At rest, the RQ is normally around 0.85. During moderate to hard work, the RQ approaches 1.

The average resting oxygen consumption is approximately 0.44 L/min (STPD) or 1.0 ft3/hr (STPD) per man, and the corresponding average CO_2 generation rate has been observed to lie between 0.352 and 0.374 L/min (STPD) or 0.80 and 0.85 ft3/hr (STPD). This amounts to about 46 gm or 0.1 lb per man-hour. Therefore the average resting RQ should be about:

$$RQ = \frac{V_{CO_2}}{V_{O_2}} = \frac{0.374L(STPD)/\min.}{0.44L(STPD)/\min.} = 0.85$$

Excessive amounts of carbon dioxide in the breathing gas results in toxic effects, the severity of which depends upon exposure time and the partial pressure of carbon dioxide.

Figure 3 shows the relation of physiological effects of carbon dioxide for different concentrations and exposure periods. In Zone I, no perceptible physiological effects have been observed. In Zone II, small threshold hearing losses have been found and there is a perceptible increase in depth of respiration. In Zone III, the zone of distracting discomfort, the symptoms are mental depression, headache, dizziness, nausea, air hunger, and decrease in visual discrimination. Zone IV represents marked physical distress leading to dizziness and stupor, with the inability to take steps for self-preservation. The final state is unconsciousness.

The bar graph at the right of Figure 3, for exposure of 40 days, shows that partial pressure of carbon dioxide in air of less than 0.005 atm partial pressure (Zone A) causes no biochemical or other effects. CO_2 partial pressures between 0.005 and 0.03 atm partial pressure (Zone B) cause adaptive biochemical changes, which may be considered a mild physiological strain, and partial pressures above 0.03 atm partial pressure (Zone C) cause pathological changes in basic physiological functions.

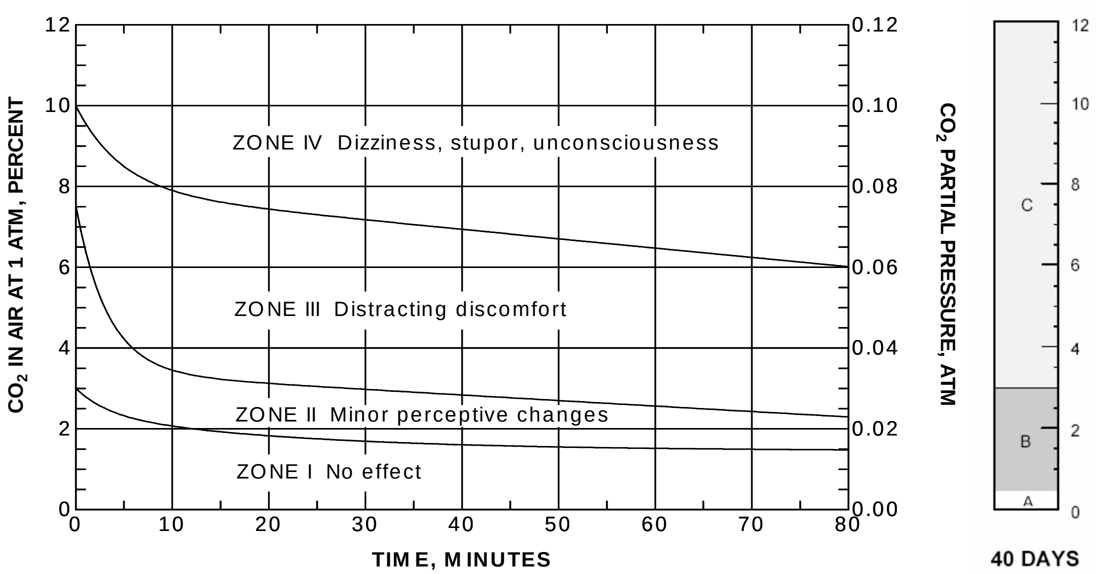


Figure 3: Relation of Physiological Effects of CO_2 Concentration and Exposure Period[1]

1. The partial pressures of CO_2 shown in the right hand bar graph should be multiplied by 0.01.

Figure 4 shows CO_2 tolerance zones as a function of CO_2 percentage and depth for a 1-hour exposure period. The percentage of CO_2 that can be tolerated in the breathing gas decreases with increasing depth, because of the partial pressure governs the biological effects.

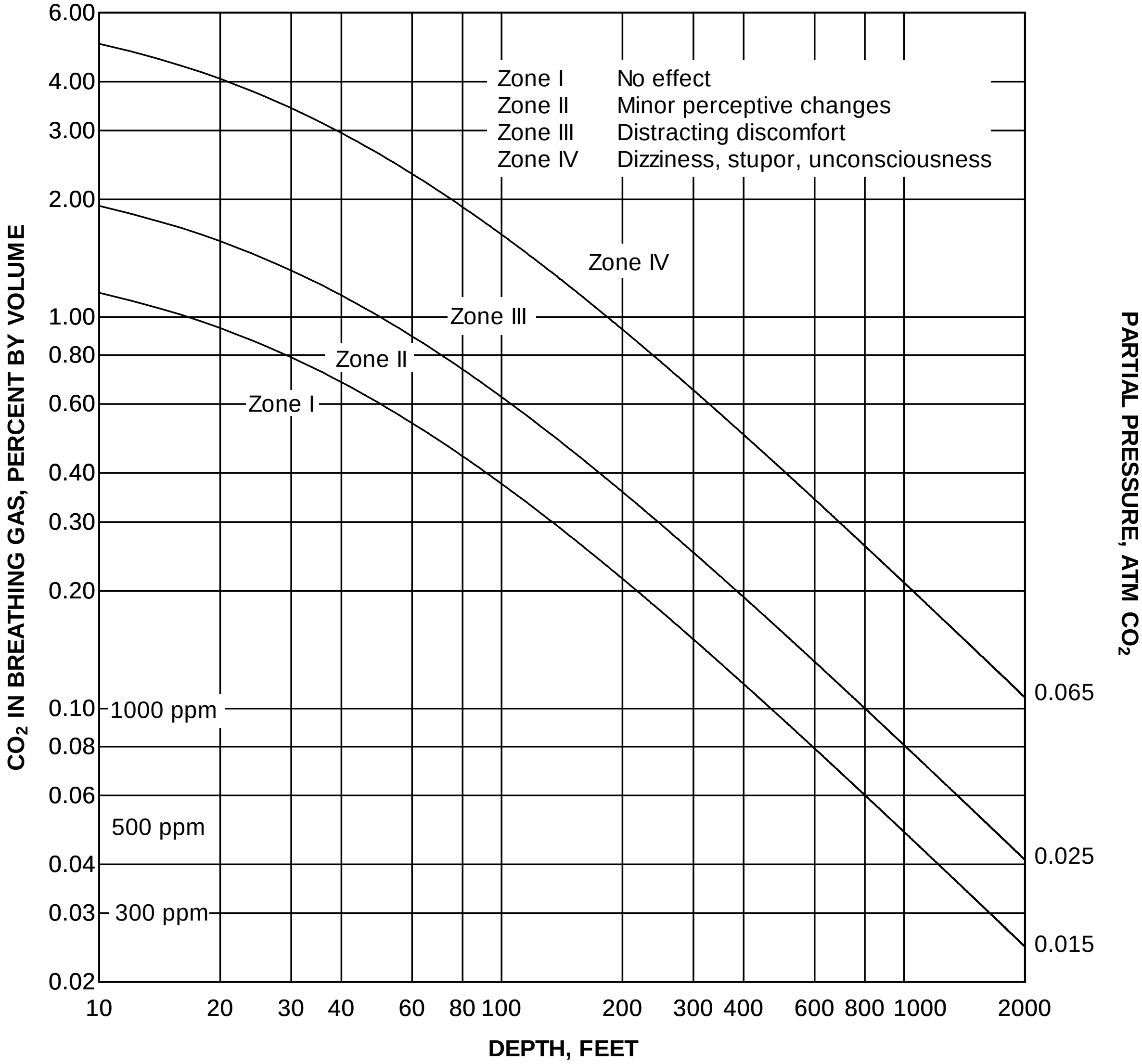


Figure 4: Relation CO2 Tolerance Zones to Depth and Percentage CO2 in Breathing Gas

1-3.6.1.3. Carbon Dioxide Removal.

In the closed environment of a diving system, CO_2 is usually removed by a material that absorbs it chemically, for example, calcium hydroxide or sodalime. In ventilated systems, fresh gas is used to dilute carbon dioxide. A CO_2 removal system shall remove a sufficient amount of CO_2 to keep the PP_{CO2} level below 0.02 ATA for ventilated chambers or open circuit diving apparatus. For saturation diving systems PP_{CO2} shall be kept below 0.005 ATA with allowable short peaks to 0.008 ATA. See 1-4.3.5.2.4.1 and 1-4.3.5.2.4.2 for additional requirements for saturation diving systems CO_2 scrubbers.

Calculations and/or test data shall be provided to document the adequacy of the CO_2 removal system. If ventilation is the method of removal, the Designer shall determine the amount of gas required to ventilate the diving system throughout the most rigorous operational requirement (most personnel, longest time, deepest depth).

1-3.6.2. Types of Gas Supply Systems

1-3.6.2.1. Closed and Semi-Closed Circuit Systems.

Closed and semi-closed circuit systems use CO_2 scrubbers that remove CO_2 from expired gas. In closed systems, all gas is scrubbed. In semi-closed systems, some gas is vented.

1-3.6.2.1.1. CO_2 Scrubber Capacity.

One may estimate the CO_2 load by multiplying the total estimated oxygen consumption by an estimate of the respiratory exchange ratio (R). For missions longer than 12 hours, a mean oxygen consumption rate of 1.0 L/min (STPD) per diver is probably reasonable. With an assumed R of 0.9, CO_2 production would be 0.9 L/min. For shorter missions, an oxygen consumption of 2.0 L/min (STPD) per diver should be assumed (divers can work harder on shorter missions). CO_2 production would thus be about 1.8 L/min. CO_2 production rates of up to 2.5 L/min (STPD) for up to 10 minutes must be accommodated.

1-3.6.2.1.2. Closed Circuit Systems Oxygen Requirements.

Since closed circuit diving systems need add only enough oxygen to make up for metabolic losses, the amount of oxygen required is equal to the anticipated metabolic demand. As with CO_2 production, oxygen consumption can be estimated by adding the volume consumed for each anticipated level of exertion or can be estimated by assuming a mean value of 2.0 L/min (STPD) per diver for missions of less than 12 hours and 1.0 L/min (STPD) per diver for longer missions.

1-3.6.2.1.3. Semi-Closed Circuit Systems Oxygen Requirements.

Systems such as the SIVA VSW semi-closed circuit UBA adds oxygen continuously to the UBA as a component of the fresh gas being injected through a constant mass flow orifice. The fresh gas is usually a mixture of O_2 and a suitable inert (dilutent) gas. In practice, the oxygen content of gas breathed by the diver varies as a function of diver work rate (metabolic oxygen consumption), the fresh gas injection rate, and the percentage of oxygen in the fresh gas supply. Typically, inspired oxygen fraction within the UBA varies considerably across a working dive, as does the PP_{O2}.

1-3.6.2.1.4. Dilutent Gas Requirements.

Dilutent gas (nitrogen or helium) with some O_2 is used to make up volume during descent. Because gas is vented and lost during ascent, the dilutent gas storage capacity must be adequate for the anticipated numbers of downward excursions.

1-3.6.2.2. Demand Systems.

On inspiration, demand systems supply fresh gas to the diver from a high-pressure reservoir through a regulator. Common examples are SCUBA regulators and recompression chamber built-in breathing system (BIBS) masks. In these cases, the controlling factor for gas consumption is the volume required to ventilate the lungs. Thus, once the mean oxygen consumption rate for the mission is known, the actual volume of gas required can be estimated. The depth must be considered when estimating gas consumption because the standard volume increases proportionally with depth,.

1-3.6.2.3. Ventilated Systems (Open Circuit).

In diving systems such as recompression chambers without scrubbers and free flow open circuit diving apparatus, CO2 is eliminated by ventilating the atmosphere with CO2-free gas. In estimating the total gas requirement, assume a CO2 production rate of 1.8 L/min (STPD) per diver for short missions, and 0.9 L/min (STPD) per diver for missions longer than 12 hours. For diving systems with large volumes, such as recompression chambers, short bursts of activity will not significantly raise chamber CO2. However, underwater breathing apparatuses generally have small volumes (and consequently small halftimes), and the inspired CO2 levels can rise rapidly with exertion. Therefore, adequate flow should be available at all times to keep the PP_{CO2} below 15.2 Torr (15.2 mmHg, 2.0 kPa) with a CO2 production rate of up to 2.5 L (STPD)/min for each diver. A continuous flow of 170 actual liters/min, STPD (6 ACFM) per diver will accomplish this, while more flow will be needed if intermittent ventilation is to be used.

See paragraph 1-4.2.2.2 for recompression chamber ventilation requirements.

1-3.6.3. Breathing Gas Supply

The breathing gas supply lines in the diving system shall be constructed of corrosion resistant, seamless wall, rigid piping. Flexible hose may be used to connect the rigid piping to components that move (in relation to one another) or vibrate during operation or transportation of the system. Adequate strength and size (to permit required flow rates and pressure), and compatibility with breathing gas mixtures are primary design requirements. The Designer shall demonstrate by calculation and/or test that the strength, size, and material compatibility of piping components are adequate. For the design of piping and components see 1-3.7.

The following are general requirements for breathing gas supplies of diver life support systems (except UBAs):

a. Open circuit breathing gas systems that do not incorporate separate emergency breathing systems shall have not less that two independent sources of breathing gas; one of which must be from a stored supply. For these designs, acceptable configurations are either two stored breathing gas sources or one breathing gas compressor(s) and one stored gas supply. If a system would be improved using compressors to provide both primary and secondary gas, the Designer shall request written approval from the Government Procurement Representative to develop the system in this way. If approval is granted, the compressors shall be independently powered.

b. Life support systems with closed circuit normal breathing designs shall include an emergency breathing system (see 1-3.6.3.4).

c. Breathing gas systems shall be designed to permit cleaning in accordance with MIL-STD-1330.

d. Any breathing gas pressure control subassembly provided in the form of a variable volume gas reservoir (e.g., a breathable bag) shall be:

(1) Puncture and tear resistant.

(2) Mold and fungus resistant.

(3) Configured to permit accessibility to other components.

(4) Easily removable for cleaning and drying.

(5) Resistant to collapse during normal use.

(6) Resistant to mold and mildew.

e. System design shall permit sampling of gas supplies.

f. Oxygen and carbon dioxide levels shall be controlled and monitored in closed loop and closed environment systems.

g. All breathing gas supplies shall be filtered both at the compressor inlet and discharge, and at the inlet to all gas supply regulators. See 1-3.7.12 for additional requirements for filters.

h. Automatic transfer to reserve breathing gas supply, if provided, shall actuate a warning signal, both audible and visual. Provision may be made for turning off the warning device once it has been activated. Consideration should be given to providing automatic reactivation of the warning after a specified time.

1-3.6.3.1. Stored Breathing Gas.

Breathing gas storage systems may be used to provide air, helium, nitrogen, mixed gas or oxygen to the diving system. When stored breathing gas is used, the minimum storage pressure must be stated in system drawings. The minimum storage pressure is that necessary to provide adequate pressure for satisfactory system operation throughout the longest planned mission. This pressure will be used in the system calculations for determining maximum mission length. The Designer shall establish independent breathing gas storage capacities based on varying compositions or pressure ranges of respective systems. Particular attention should be paid to those systems that may be used in more than one mission scenario.

When breathing gas containers are installed in a diving system, the following items shall be considered:

a. The capacity of the primary supply must meet or exceed the consumption rate of the designated number of divers for the full duration of the dive (bottom time plus decompression time). The maximum depth of the dive, the number of divers, and the equipment to be used must be taken into account when sizing the supply.

b. All DLSS shall be equipped with separate primary and secondary breathing gas supplies.

NOTE

The primary and secondary gas supplies shall be separated such that they include separate gas banks, piping and pressure regulators. The separation shall be maintained from the storage flasks, all the way to the diver's manifold (surface supplied or saturation diving system) or pressurization manifold (recompression chamber). If approved by the Government Procurement Representative, the secondary breathing gas supply can cross-connect with the primary breathing gas supply, provided there are suitable isolation valves or other devices installed to prevent inadvertent operation.

c. Suitable valve protection shall be provided to prevent inadvertent depressurization of the containers. For flasks that are permanently installed and recharged in place, double valve protection shall be provided on fill lines.

d. All air flasks shall be equipped with a means to drain accumulated moisture. Flask drain valves must be accessible for operation. Flask drain tubing must be directed so that the operator can see whether there is moisture coming from the outlet without risk of injury while observing the draining process.

e. Containers shall be secured to prevent their accidental detachment. They shall also be supported or restrained to prevent the imposition of a load on other components that are not designed as supports.

f. Primary and secondary breathing stored gas supplies shall have provisions to monitor pressure with self-powered instrumentation such as mechanical gauges.

1-3.6.3.2. Primary Breathing Gas Supply.

The primary system shall be capable of sustaining all diving system personnel for the length of the longest planned mission. If stored gas is to be used as the supply, the gas storage flasks shall provide sufficient gas for the longest, most demanding mission for which the diving system is designed. The Designer shall justify the gas storage system capacity by calculations. For long duration missions, the calculations shall account for probable leakage rates and environmental temperature fluctuations.

When the system breathing gas is air, either an air compressor or stored compressed air may be used as the primary supply.

When an air compressor is to be used to support diving operations, verification of adequate flow rate shall be required. Flow rate testing is required for all newly installed and overhauled air compressors.

Prior to connecting an air compressor into a diver's air system, the compressor outlet must be sampled for gaseous and particulate contaminants.

1-3.6.3.3. Secondary Breathing Gas Supply.

A secondary breathing supply system shall be provided for use in case of a failure of the primary gas supply. Secondary gas supply shall not be used during normal system operations. The secondary supply must be separate, distinct and totally independent from the primary breathing supply. In some cases it may be desirable to have the secondary system cross-connect with the primary gas supply system. In this case, the Designer shall request approval from the Government Procurement Representative. If approval is given, the cross connect system must provide suitable isolation valves or other devices to prevent inadvertent operation.

The secondary supply must be capable of immediately providing proper breathing mixtures at the correct pressure and flow rate in the event of failure of the primary system. The secondary supply must be sized to be able to support recovery of all divers to the surface (or a safe haven) if the primary supply sustains a casualty at the worst-case time (for example, immediately prior to completion of planned bottom time of maximum dive depth, when decompression obligation is greatest). The basis for the capacity of the secondary supply shall be reviewed and approved by the Government Procurement Representative during formal system design reviews. The adequacy of the secondary supply capacity shall be justified by calculations.

1-3.6.3.4. Emergency Gas Supply

An emergency gas supply (EGS) system shall be provided in accordance with NAVSEA SS521-AG-PRO-010, U.S. Navy Diving Manual. Not all systems require an emergency gas supply.

1-3.6.3.5. Emergency Breathing Supply

An emergency breathing supply (EBS) shall be provided in accordance with NAVSEA SS521-AG-PRO-010, U.S. Navy Diving Manual. Not all systems require and emergency breathing supply.

1-3.6.4. Diving Gases – Purity Standards

The following are the purity requirements for gases used in diving systems and recompression chambers:

a. Diver's air compressed from ANU or U.S. Navy certified diving system sources shall meet the standards contained in Table 2. Diver's breathing air from other sources must meet the requirements of FED SPEC BB-A-1034 Grade A Source I (pressurized container) or Source II (compressor).

Table 2: U.S. Military Diver's Compressed Air Breathing Purity Requirements for ANU Approved or Certified Sources

Constituent	Specification
Oxygen (percent by volume)	20-22%
Carbon dioxide (by volume)	1,000 ppm (max)
Carbon monoxide (by volume)	20 ppm (max)
Total hydrocarbons (as CH_4 by volume)	25 ppm (max)
Odor and taste	Not objectionable
Oil, mist, particulates	5 mg/m^3 (max)

b. Oxygen quality shall meet MIL-PRF-27210 (series) Type I and must be verified as to purity by the supplier.

c. Helium quality shall meet MIL-PRF-27407 Type I, Grade B and must be verified as to purity by the supplier.

d. Nitrogen quality shall meet FED SPEC A-A-59155 (Nitrogen, High Purity, Special Purpose) Type I Grade and must be verified as to purity by the supplier.

The purity standards shown above are not applicable to air compressed from atmospheres having other contaminants (e.g., submarine atmospheres). In the case of use of submarine atmosphere air for diving, specific procedures have been adopted for several types of operations (Dry Deck Shelter and Advanced Seal Delivery System) that are described in NAVSEA S9592-AP-MMM-A30, Dry Deck Shelter System, SSN688 Class Host Ship, Operating and Emergency Procedures and NAVSEA S9ASD-AA-MAN-010, ASDS Operating Procedures and Instructions.

The air provided by ships' low pressure air compressors for general shipboard use is not suitable for use as breathing air unless specifically tested and certified according to OPNAVINST 5100.19B CH-1 of 23 Oct 1990. Additionally, air taken from machinery spaces or from downwind of the exhaust of an engine or boiler may contain excessive concentrations of carbon dioxide, carbon monoxide, and other toxic contaminants and therefore is unacceptable for divers breathing air. Normal atmospheric air may contain small concentrations of toxic gases, including sulfur dioxide, oxides of nitrogen and gaseous hydrocarbons, and particulates. The source of these is usually from the exhaust of internal-combustion engines or other high-pressure, high-temperature combustion. Care should be taken in selecting a suitable location for air compressor inlets to ensure that they are upwind of exhaust stacks and similar areas where noxious or toxic gases may accumulate.

1-3.6.5. Environmental Control and Monitoring.

The life support system shall incorporate control and monitoring sub-systems to provide adjustment of environmental conditions during a dive. Environmental limits are further discussed in NAVSEA SS521-AG-PRO-010, U.S. Navy Diving Manual.

Circulation of gases within larger hyperbaric chambers and complexes is necessary to prevent pocketing or layering of gases such as oxygen, carbon dioxide and helium. Placement of the gas inlets and outlets should be chosen to ensure maximum atmosphere circulation. Inadequate atmosphere circulation can also affect the efficiency of carbon dioxide scrubbers.

Gauges and thermometers shall be installed to indicate pressures, temperatures, liquid levels, and flow rates, as necessary for the safe operation, control, and trouble shooting of systems, machinery, tanks, and equipment.

1-3.6.5.1. Atmospheric Contaminants.

Saturation diving systems, and other diving systems where the diver might be expected to stay for some time shall employ some sort of chemical absorbent to remove volatile contaminants. Most volatile contaminants are introduced into the closed chamber environment through normal bodily functions and items that may be brought into the chamber from outside. Typically, chemical absorbents are used to remove these contaminants. Activated charcoal or activated alumina (Purafil) is commonly used for this purpose. In these cases, the absorbent can remove some of the contaminants originating from the supply gas or the diving system itself. However, these absorbents should not be expected to remove all volatile contaminants from the diving atmosphere.

The level of atmospheric contaminants in a diving system can affect the maximum depth at which a diving complex can be safely used. In the case of volatile contaminants in the supply gas, the partial pressure exposure by divers to these contaminants will be directly dependent on depth. For atmosphere contamination arising from the chamber complex itself, the off gassing rate may be independent of depth, and, thus, there may be no influence of depth on the level of diver exposure to these contaminants.

1-3.6.5.1.1. Controlling Personnel Generated Contaminates.

The build-up and control of other personnel generated contaminants such as carbon monoxide, methane, ethanol, hydrogen, ammonia, hydrogen sulfide and amino-based hydrocarbon compounds needs to be addressed during the design of the diving system Environmental Control System. Factors such as number of personnel, mission duration, occupied space volume, human waste stowage, and breathing gas exchange are used to determine if control of these contaminants is necessary. The simplest form of control includes passive methods such as the following:

a. Activated Carbon can absorb high molecular weight hydrocarbons, alcohols, ketones, aldehydes, and organic acids. When impregnated with phosphoric acid, it can also remove ammonia and other organic bases.

b. Purafil (activated alumina impregnated with potassium permanganate) adsorbs a number of acid and alkaline gases, and will also oxidize many unsaturated hydrocarbon compounds.

c. Unheated Hopcalite (a mixture of oxides of manganese, copper, cobalt and silver) will remove carbon monoxide via catalytic oxidation, and to a lesser extent, hydrogen. Unheated Hopcalite is often used on diesel driven and/or oil lubricated compressors providing breathing air.

With the exception of saturation diving systems, control of gaseous contaminants, other than carbon dioxide, is not typically required due to the short mission durations.

1-3.6.5.2. Carbon Dioxide Control and Monitoring.

The carbon dioxide (CO_2) removal subsystem shall be sized in accordance with the calculated maximum CO_2 production rate. Formulas for calculating CO_2 production rates are provided in 1-3.6.1.2. The CO_2 level must be controlled and monitored when the primary and secondary breathing gas supplies are recirculated to the diving system or to the diver in semi-closed and closed circuit breathing equipment. CO_2 monitors shall provide high-level alarms that should be visual as well as audible.

Most CO_2 control systems operate by passing expired gas through a canister containing CO_2 absorbent material. Only NAVSEA-approved CO_2 absorbent material shall be used in diving systems. CO_2 control systems must maintain the partial pressure of CO_2 in the breathing gas below the specified allowable level for the duration of the longest mission for which the system is designed. In the event of a failure of the primary CO_2 absorbers, there shall be a back-up CO_2 control method capable of maintaining acceptable CO_2 levels. The back-up method may include absorbers, a way to ventilate the system, a way to operate the system in an open circuit mode, or a combination of these.

The Designer shall provide data showing the expected length of time the CO_2 absorbent will maintain CO_2 below the specified limits. This shall be done at the maximum and minimum operating depths and temperatures, and at the maximum calculated CO_2 production rate.

All hydroxide-type absorbents are caustic, and contact may be harmful to personnel as well as damaging to equipment. Therefore, canister designs must incorporate filter elements or other appropriate means to ensure that particles of the absorbent do not escape the canister. The use of lithium-hydroxide absorbents is prohibited due to its extremely caustic nature.

CO_2 absorber canister materials must also be highly resistant to caustic attack and seawater corrosion. CO_2 absorber canisters must be capable of being easily refilled and replaced during system operation. Sufficient absorbent must be available to permit completion of the longest anticipated mission plus 50%. The time required to isolate, replace, and restore the absorber to operation shall not result in an unsafe level of CO_2 build-up in the diving system.

The absorber design must provide a means to remove moisture produced from the CO_2 absorbent reactions. This moisture may fog the diving system viewports or the diver's faceplate, accumulate in breathing gas passages, increase resistance to gas flow through the absorbent, and decrease the effectiveness of the absorbent.

CO_2 Scrubber designs should include the following features:

a. Minimum flow resistance.

b. Maximum utilization of absorbent.

c. Neutral buoyancy in closed or semi-closed circuit underwater breathing apparatuses.

d. Minimum gas-flow channeling that severely restricts mission duration by reducing absorbent utilization.

e. Minimum heat transfer in cold water for closed or semi-closed circuit underwater breathing apparatuses.

f. Filtration to prevent CO_2 absorbent from entering the gas stream beyond the absorber canister.

Additional information regarding CO_2 scrubber design may be found in Naval Coastal Systems Center Technical Manual 4110-1-83, "Design Guidelines for Carbon Dioxide Scrubbers", May 1983.

1-3.6.5.3. Oxygen Supply, Control, and Monitoring

The primary oxygen supply system capacity shall be based on providing, as a minimum, sufficient oxygen to meet the human oxygen consumption rates given in 1-3.6.1.1. A secondary oxygen supply system is required in case of failure of the primary oxygen supply system, unless exempted by the Government Procurement Representative.

Oxygen monitoring equipment shall be provided, shall be capable of easy calibration before each use, and shall incorporate high and low partial pressure or percent level alarms. For air systems, the alarms should be both visual and audible. For a standard recompression chamber, alarm set points should be 18 and 23 percent. This is equal to 0.33 ATA and 0.42 ATA at 60 FSW. Under no circumstances should the oxygen concentration fall below 0.16 ata partial pressure. If the alarm limits are exceeded, immediate corrective action should be taken. In some cases, the system must be ventilated if the oxygen control or monitoring system fails. When the breathing gas is closed loop or semi-closed loop in design, the Designer shall incorporate a method of maintaining the proper partial pressure of oxygen.

Surface supplied diving systems are exempt from oxygen monitoring.

1-3.6.5.4. Carbon Monoxide.

A common example of an atmospheric contaminant is CO, which is produced at very low rates by normal metabolism. If no other source of CO is present, CO will normally not rise to levels of concern. The maximum allowable amount CO in diver’s breathing gas is 20 ppm for depths to 800 FSW. At depths greater then 800 FSW CO shall be limited to 10.5 ppm in the diver’s breathing gas.

Concentrations of CO higher than those noted above can be tolerated with levels of discomfort in emergencies. For example, breathing air containing 150 to 250 ppm of CO at one atmosphere for many hours will result in a severe headache. On the other hand, breathing air containing 1600 ppm of CO at one atmosphere for one hour will cause confusion and ultimate collapse. In current diving system design, the only way to remove CO is by ventilation, although some compressor purification systems are capable of converting CO to CO_2.

1-3.6.5.5. Gas Purification and Filtering Systems.

The Designer shall provide adequate purification and filtration to protect diving system personnel and equipment from harmful contaminants (both gaseous and particulate) in the breathing gas. The Designer shall justify the extent to which diving system provides personnel protection from hydrogen, carbon monoxide, toxins and noxious odors.

During system design, the Designer shall identify all likely gaseous and particulate contaminants that might enter the diving system. Purification and filtration components shall be capable of limiting the harmful gaseous and particulate contaminants to the levels given in 1-3.6.5.1. Actual sampling and analysis shall be verified during the diving system prototype/first article tests (see 2-9.9).

1-3.6.5.6. Humidity Control and Monitoring.

Humidity control is required for hyperbaric chambers used for saturation diving. The relative humidity shall be maintained between 30 and 80 percent. Maintaining relative humidity levels of 50 to 80 percent is desirable for divers' comfort.

1-3.6.5.7. Temperature Control and Monitoring.

Heating and cooling systems may be required to maintain diver comfort, performance and safety. The heating requirements in a hyperbaric chamber will vary, depending on the type of gas being used and the dive depth. Helium-oxygen requires higher temperatures than air to keep the divers comfortable and to prevent hypothermia. Water temperature, depth, current, diver rate of work, breathing gas and the insulating properties of the diving suit affect the heating requirements for a diver heating system. See NAVSEA SS521-AG-PRO-010, U.S. Navy Diving Manual for temperature requirements for specific diving systems.

The Designer shall justify, by calculation and performance testing, the adequacy of the following characteristics of the temperature control system:

a. Size, weight and flexibility (diver thermal unit only).

b. Personnel protection from any additional hazards presented by the heating equipment.

c. Temperature distribution.

d. Heat capacity as related to mission requirements.

e. Temperature regulation.

f. Buoyancy characteristics (diver thermal unit only).

g. Effect of depth on system operation (i.e., insulating characteristics, heat and pressure loss in water-supply hose, and voltage loss in electrical supply line).

h. Heat transfer characteristics of the breathing gas.

i. Failure modes and emergency procedures.

j. Ease of maintenance and repair.

Hyperthermia is a potential risk any time air temperature exceeds 90°F or water temperature is above 82°F. The internal temperature of chambers exposed to direct sunlight may rise to dangerous levels. A means for cooling diving personnel should be provided in such situations.

Heating and/or insulating the CO_2 absorbers in semi-closed and closed circuit breathing apparatuses may be necessary to ensure an adequate operating life for the CO_2 absorbent material.

Heating the diver's inspired gas is necessary for deep diving in cold water. The rate of respiratory heat loss increases as the temperature of the inspired gas is lowered, as the gas density increases with depth, and as the volume of gas breathed increases with increased physical exertion.

The minimum inspired gas temperature is a function of the operating depth and is given in Table 3 for a 4-hour mission. These limits are the minimum allowable temperatures from a safety standpoint and assume that all other measures are being taken to keep the diver warm.

Depth (FSW)	Minimum Inspired Gas Temperature	
	°C	°F
350	-3.1	26.4
400	1.2	34.2
500	7.5	45.5
600	11.7	53.1
700	14.9	58.8
800	17.3	63.1
900	19.2	66.6
1000	20.7	69.3
1100	22.0	71.6
1200	23.0	73.4
1300	23.9	75.0
1400	24.7	76.5
1500	25.4	77.72

Table 3: Guidelines for Minimum Inspired Helium Oxygen Temperatures for Saturation Depths Between 350 and 1500 FSW. [1.]

1. Ref: NAVSEA SS521-AG-PRO-010, U.S. Navy Diving Manual; Volume 3, Mixed-Gas Surface-Supplied Diving Operations, Table 15-1

1-3.6.6. DLSS Instrumentation

Instrumentation for diving systems shall be provided to warn personnel of unsafe conditions. It shall be sufficiently accurate and will operate satisfactorily within the range of the diving system environmental and design parameters. Suitable redundant instrumentation shall be provided and designed to operate in the event of normal power failure.

Instrumentation shall be reliable and easy to calibrate. Calibration should be able to be accomplished while the instrument is in-place.

Instrumentation requirements in a system will vary widely depending upon depth and exposure times. For complex systems, especially saturation diving systems, substantial instrumentation may be necessary. Instrumentation may include, but not be limited to, the following:

a. Carbon dioxide sensors.

b. Oxygen sensors.

c. Gas flow sensors.

d. Gas source pressure indicators/sensors

e. Physiological sensors.

f. Heated suit sensors.

g. Respiratory gas temperature sensors.

h. Low and high level/pressure warning devices.

i. Pressure/depth indicators.

j. Fire detection devices.

k. Temperature sensors of diving systems interior.

l. Humidity sensors.

m. Electrical defect sensors (ground detectors)

n. Ammeter(s) and voltmeter(s)

Any automatic transfer to secondary or emergency breathing gas supply, if provided, shall actuate a warning signal, both audible and visual. Provisions shall be made for turning off the audible warning device after it has been activated. The visual warning device shall remain activated until system parameters are again within acceptable limits. Consideration shall be given to providing automatic reactivation of the audible warning after a specified time.

Test data must be furnished which establishes the ability of the measuring devices to meet the accuracy requirements in the intended environment. The design shall utilize a backup means for providing measurements of critical functions (i.e., O_2 and CO_2 monitors). Failure of one measuring device must not impair the function of the other.

Electronic sensors shall meet the requirements of 1-3.10.

1-3.7. PIPING SYSTEM AND COMPONENTS

Piping, piping system components and the piping system itself shall be designed in accordance with ASME B31.1, Power Piping (Chapter 2: DESIGN) and MIL-STD-777, Schedule of Piping, Valves, Fittings, and Associated Piping Components for Naval Surface Ships except where otherwise stated in this specification. Component types and materials shall be chosen IAW MIL-STD-777, ASME B31.1, Power Piping (Chapter 3: Materials), 1-3.8.5, and 1-3.8.6 of this document. If a conflict occurs between any of these documents, the Government Procurement Representative shall be notified in writing and shall take the necessary corrective action.

The Designer shall consider structural adequacy and fatigue life of the piping system for all anticipated in-service conditions such as:

a. Weight of pipe fittings, valves and other components including cleaning or testing fluids.

b. Internal or external pressure, both static and cyclic.

c. Dynamic effects of shipboard motion, deflections and rotations of structure and equipment at points of pipe attachment

d. Handling loads, especially in transportable systems

e. Restraint of hangers and supports.

f. Thermal expansion and contraction.

g. Shock, impact, vibration and water hammer.

h. Mechanical loads caused by operation of the system.

i. Effects of the corrosive seawater and salt air environment.

Piping which, if ruptured, would depressurize the diving system shall be protected against damage. This may be accomplished by suitable routing, shielding, etc.

The breathing gas supply lines in the diving system shall be constructed of corrosion resistant, seamless wall, rigid piping where possible. Flexible hose may be used to connect the rigid piping to components that move or vibrate during operation or transportation of the system. Adequate strength and size (to permit required flow rates and pressure), and compatibility with breathing gas mixtures are primary design requirements.

Only seamless piping or tubing is authorized in Navy diving systems. Consideration shall be given to material type, wall thickness, minimum bend radius, back-wall thinning allowance and inner radius wrinkling when specifying the method of piping system fabrication.

Piping connections shall be designed and arranged so that it is physically impossible to inadvertently connect a system of one pressure or service to a system of a different pressure or service. In cases where different gases may share a common line (e.g., oxygen and NITROX in a Built In Breathing System (BIBS)), those gases shall be kept separate through use of block and bleed valves or similar methods to ensure that both gases are never connected to the common header at the same time.

Where possible, normal and emergency breathing gas supply lines should be arranged separate from each other, and away from possible ignition or contamination sources.

Piping and tubing shall not be used as support for heavy components such as regular line valves, relief valves, check valves, strainers, or filters. One pipe line shall not be used to support another. Block type hangers may be used to supports two or more pipe lines with the assembly-type hangers attached to suitable structural members.

All piping and components including fittings shall be identified in sufficient detail on the system drawings (e.g., description, material, part number, pressure rating) to permit replacement with the same part. All piping, hoses, valves, pressure vessels, gauges, filters, etc. must be marked or labeled to indicate function, content and direction of flow on the drawings.

All piping and piping system components used for the transmission or monitoring of liquid or breathing gas within a system shall be marked and color-coded to identify the specific gas or liquid contained and the direction of flow. Where piping is located behind a panel, an accurate color-coded schematic shall be permanently attached to the panel face. A labeling system shall be used to identify each component by type of gas or liquid, by color and by word or letter symbol. The hand wheel or operating lever of all system valves shall be color coded also. All material used for color-coding components (e.g., paint or plastisol) located inside a closed breathing environment must meet toxicity and flammability requirements. Color codes shall be in accordance with Table 4.

System	Designation	Color Code
Helium	HE	Buff
Oxygen	OX	Green
Helium-Oxygen	HEOX	Buff & Green
Nitrogen	NIT	Light Gray
Nitrogen-Oxygen	NITROX	Light Gray & Green
Air (low pressure)	ALP	Black
Air (high pressure)	AHP	Black
Exhaust	EXH	Silver
Potable Water	PW	Blue
Chilled Water	CW	Blue & White
Hot Water	HW	Red & White
Fire Fighting	FP	Red

Table 4: Color Code and Component Designation for Diving Systems

Piping system components must have a standardized labeling scheme throughout, with unique component identifiers that match the system drawings and system operating and emergency procedures. Such standardization is important for approval of operating and emergency procedures, continuity of system manuals and personnel training.

1-3.7.1. Piping Systems Component Structural Design Consideration

The Designer shall perform a stress analysis of each piping system component in accordance with ASME B31.1 (Chapter 2: DESIGN) or shall provide manufacturers documentation that prove the adequacy of the component. This analysis shall consider all anticipated loading conditions including the loads calculated in the piping flexibility analysis discussed in 1-3.7.3. These calculations shall be provided to the Government Procurement Representative for review and acceptance at the Preliminary Design Review, the Critical Design Review, and at final delivery.

Pressure ratings for all piping and components shall be equal to or greater than the maximum system pressure of the system or line of which they are a part.

The structural design requirements used for externally pressurized components shall not be less than the requirements for the pressure hull and hard structure. Piping subject to external pressure shall be designed for the maximum differential pressure that can exist in either direction during operating, shutdown or test conditions; otherwise suitable overpressure protection shall be provided.

Peak stresses, including effects of local stress concentrations, must be limited by fatigue considerations, as discussed in 1-3.1.3.

Consideration of the following should be included in the analysis:

a. Erosion/corrosion allowances

b. Mechanical strength to accommodate fabrication processes

c. Item identification marking (vibro-etch, etc.)

d. Redundancy, safety features, remote and emergency operation.

For components whose geometry is not amenable to analytical evaluation, and when considered appropriate by the Designer, the structural adequacy of piping system components may be verified experimentally. In this case, an experimental stress analysis and burst test such as specified in the ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, Appendix 6, may be performed in lieu of an analytical stress analysis. This approach should be detailed and approved by the Government Procurement Representative prior to use as an acceptance method.

For components constructed of Category 3 material, the Designer is not required to use the structural design basis outlined above. However, as in the case of pressure hulls constructed of Category 3 material, the Designer must show that the design basis used is at least as inclusive and conservative as the basis discussed above. Further, the structural adequacy of components constructed of Category 3 material must be verified by tests of full-scale prototype components.

1-3.7.2. Design of Piping Systems and Components

All piping components shall be designed or selected to meet the maximum flow that is required for the mission conditions expected for the Diving System. These conditions shall be specified when justifying the design or selection.

a. All manually operated piping components shall be readily accessible and easily operated under normal and emergency conditions.

b. Unless directed otherwise, pressure-reducing valves shall be provided with inlet and outlet isolation valves, and a valve with associated piping which allows bypassing flow when the pressure-reducing valve inlet and outlet isolation valves are shut. The flow capacity of the pressure-reducing valve bypass shall be no greater than the flow capacity of the downstream relief valve. The piping from the outlet of the pressure-reducing valve downstream to and including the outlet isolation valve shall be designed and tested to the pressure at the inlet of the pressure-reducing valve.

A bypass shall be provided in any system where the ability to maintain uninterrupted service is required. All particulate filters shall be installed so that a clogged filter can be bypassed without disrupting the fluid or air flow to the end –use point. The bypass can be either internal or external to the filter.

A check valve or "non-return" valve is required in any system where two-way flow is possible but one-way flow is required for the safety of the Diving System personnel or for normal operation of the equipment.

Flareless, mechanical friction, compression or bite-type connections will not be used on piping components whose failure could cause uncontrolled depressurization or flooding of pressure vessels, life support systems, ballast tanks, electrical assemblies, or other life-critical components. The use of such connections in control and monitoring systems must be approved by the Government Procurement Representative.

Lines which are routinely disconnected must be provided with suitable closure devices for each exposed connection to prevent entrance of foreign materials and debris when the system pressure boundary is broken. Routine disconnections are those associated with inspections, overhauls, and the normal Diving System setup, operation, and takedown. Both male and female connections shall be so protected. Caps that introduce moisture and tapes that leave adhesive deposits shall not be used for this purpose. When not in use, closure devices should be stored in a way that prevents contamination.

1-3.7.3. Piping Flexibility.

Piping shall be designed to have sufficient flexibility to prevent failures resulting from the conditions listed in paragraph 1-3.7a through i. Piping shall be designed to have sufficient system flexibility to prevent premature failures and/or prevent:

a. Overstressing of the piping

b. Leakage of mechanical joints

c. Excessive force and moments translated to connected equipment and structures which exceed the limits specified or allowed for them or renders the inoperable.

The structural adequacy of the piping system shall be demonstrated by the Designer for all anticipated service loadings. In addition, the Designer shall show that fatigue life of the piping system is adequate by performing a fatigue analysis.

In certain cases (i.e., saturation diving systems), piping flexibility calculations are required as a further measure of assurance prior to system fabrication. Where required, calculations shall show maximum stresses and their location in each section of piping under examination. Detailed sketches of piping under examination shall be required with the calculation report. Calculations shall be submitted in sufficient detail to allow easy review and shall include statements delineating the following:

a. Theoretical basis of the calculations.

b. Method of performing the calculations.

c. Simplifying assumptions.

d. Sign and symbol conventions.

e. Assumed material and dimensional data.

f. Other pertinent information such as hull deflections.

g. Fatigue reduction factors.

h. Stress intensification factors.

i. Allowable stress range.

j. Miscellaneous pertinent information (e.g., support/hanger deflections).

The piping flexibility analysis shall also address the flexibility of piping components. Flexibility factors shall be in accordance with ASME B31.1 (Power Piping) code for pressure piping. Piping components for which there are no flexibility factors listed in ASME B31.1 shall be considered rigid unless the Designer can justify the use of added flexibility. The piping flexibility analysis shall include calculations of the bending moments, twisting moments, and reaction forces imposed on each critical component in the piping system. Flexibility analysis is not required for pipe up to and including 3/8 inch NPS or for tubing up to and including 1/2 inch OD. Additional information on the flexibility analysis can be found in ASME B-31.1 Power Piping.

1-3.7.4. Special Considerations for Oxygen Systems.

A diving life support oxygen system is one that contains a gas mixture where the fraction of oxygen (F_{O2}) is 0.25 or 25 percent by volume or greater. The Designer shall give special consideration and analysis to the use of oxygen in the specific diving system design. An oxygen leak may be a contributor to a fire hazard and may also be toxic to diving system personnel under pressure. Every attempt shall be made to design oxygen piping systems to eliminate the possibility of leaks. Use of seamless copper or nickel alloy (Monel®) piping/tubing is preferred in high-pressure oxygen systems although austenitic seamless 300 series (304L, 316L) stainless steel with a minimum of 1/8-inch wall thickness may be used provided the Designer has taken all precautions to limit the flow velocity in the pipe and has incorporated sufficient filtration to eliminate particulate which may cause spark ignition. It should be remembered that 300 series stainless steel has lower ignition temperature-pressure and will have increased burn propagation once ignition has occurred.

High-pressure portions of the oxygen system piping shall be welded, vice using mechanical fittings, wherever possible. When used, oxygen system mechanical joints shall not be located where leakage or failure could ignite surrounding material. Examples include locating oxygen mechanical joints next to a hydraulic system or next to electrical components with heated surfaces. Where arrangement cannot eliminate all reasonable hazards, and the joints cannot be moved, flame shields or other appropriate method should be used.

NOTE:

Pipe threads shall not be used in stainless steel piping systems because of the possibility of particulates being shed in the joining process.

Quick-opening valves shall not be used in high-pressure oxygen systems and should not be used in low pressure oxygen systems except in cases where the valve is used for emergency shutoff (e.g. chamber hull stops).

Metallic materials wetted by oxygen shall not propagate a flame, shall not burn, and shall be impact resistant with oxygen at the maximum operating pressure of the system in accordance with ASTM G94, Standard Guide for Evaluating Metals for Oxygen Service. Non-metallic material wetted by oxygen shall be resistant to auto-ignition, shall be resistant to impact ignition, and shall have the lowest possible heat of combustion in accordance with ASTM G63, Standard Guide for Evaluating Non-Metallic Materials for Oxygen Service. Additionally, where non-metallic material is installed, the design shall minimize the surface area and volume exposed to oxygen. See 1-3.8.5 for additional requirements for material to be used in oxygen systems.

Where oxygen flasks are to be stored and operated in an enclosed space, electrical equipment which may spark while in used, shall not be installed in the vicinity of the flasks or interconnecting hoses. Signs shall be posted in the space to state that no smoking or open flames shall be permitted due to oxygen being in use. In addition, an oxygen monitor, with visual and audible alarm shall be installed in the immediate vicinity of the oxygen flasks. Oxygen flasks shall not be located inside the diving system (e.g. recompression chamber or diving bell) without technical justification from the Designer and approval from the Government Procurement Representative.

The Designer shall follow the guidance found in ASTM G88, Standard Guide for Designing Systems for Oxygen Service and NFPA 53, Recommended Practice on Materials, Equipment, and Systems Used in Oxygen-Enriched Atmospheres and CGA Pamphlet G-4.4, Industrial Practices for Gaseous Oxygen Transmission and Distribution Systems. The Designer shall be familiar with ASTM Manual 36, Safe Use of Oxygen and Oxygen Systems: Guidelines for Oxygen System Design, Materials Selection, Operations, Storage, and Transportation, ASTM G63, Standard Guide for Evaluating Non-metallic Materials for Oxygen Service, and ASTM G94, Standard Guide for Evaluating Metals for Oxygen Service, when selecting materials to be used in elevated oxygen environments and piping systems.

Deviation from any of the above criteria requires technical justification and approval from the Government Procurement Representative.

1-3.7.5. Pipe Joints.

Only pipe joint designs that are fabricated, assembled and tested in accordance with this specification shall be used (e.g., butt welds, socket welds, mechanically formed and bolted flange connections and O-ring faced fittings) in diving systems. Other joint designs (e.g., bite type, flared, compression fittings and NPT threaded joints) must be approved by the Government Procurement Representative.

The number of mechanical pipe joints shall be kept to a minimum and be accessible for inspection. Wherever possible, bending of the pipe shall be used. See 1-3.7.6 for pipe/tube bending requirements.. For portable and shipboard systems, the bend radius of piping shall be limited to 5 nominal diameters, unless the contractor can demonstrate, through normal procedures, tighter bends without distortion. All pipe and tube fittings shall be used only at temperatures and pressures not exceeding the manufacturer's rating recommendations.

Lines, which must be connected and disconnected during system operation, shall be equipped with appropriate pressure venting capabilities. Lines, which are required to be disconnected during set-up and takedown of the diving system, must be provided with suitable caps or plugs to maintain cleanliness and prevent damage to threads. Both male and female connections shall be so protected. Caps that allow introduction of moisture and tapes that leave adhesive deposits shall not be used for this purpose. Closure devices, when not in use, shall be stored in a way that prevents contamination.

1-3.7.5.1. Welded Pipe Joints.

Welding is the preferred method of joining pipe that will not require disassembly for system repair or maintenance. The welding process melts the base metal to form a joint that is often as strong as the surrounding piping and resists cracking due to piping flexure. Shipboard and portable diving system welded pipe joints shall meet the requirements of NAVSEA S9074-AR-GIB-010/278, Category P-1, and shall be performed in accordance with NAVSEA-approved procedures.

1-3.7.5.2. Brazed Pipe Joints.

Brazed joints are not permitted in new dive systems. Brazed pipe joints are used to permanently join piping material that is not weldable (i.e., copper and copper-nickel). Brazed joints are not as strong as welded joints because the process only melts the soft filler metal, not the base metal. All repairs to existing diving system brazed pipe joints shall meet the requirements of NAVSEA 0900-LP-001-7000, Category P-3a, Special Category (I) and shall be performed in accordance with NAVSEA-approved procedures.

1-3.7.5.3. Mechanically Attached Fittings.

Mechanically attached fittings (MAF) are permanent pipe fittings that cannot be removed after installation without deforming the pipe or fitting. These fittings are not reusable and considered permanent. Mechanically attached fittings include elastic strain preload (ESP), swaged (Category I UIPI) and shape memory alloy (SMA) types. These fittings are not authorized for use in diving systems without Government Procurement Representative approval.

1-3.7.5.4. O-ring and Flanged Pipe Joints.

Mechanical piping unions and flanges include a wide variety of designs that rely on a mechanical action (i.e. torque of bolts or nuts) to compress a soft seal. Flange fittings are most often used in designs for large diameter shore-based liquid or steam system piping. The use of face seal o-ring unions is recommended over bolted flanges. Flange fittings are far more prone to leakage du to pipe flexure in shipboard and portable systems than are face seal o-ring fittings. Removal of the o-ring/gasket material and seal welding of the union nut is required for some shipboard oxygen systems located below the main deck. MS boss fittings, with o-ring seals, are preferred over threaded pipe joints because galling of the threads is less likely and the threads are not relied upon to form the seal. Additional design requirements for bolted flanges and blanks and all alignment and assembly requirements for mechanical joints shall be in accordance with NSTM, Chapter 505 and ASME B-31.1. Bolted flanged joints shall not be used in piping subjected to submerged environments or high stresses without Government Procurement Representative approval.

Mechanically formed face seal flanges have been approved for use in portable systems (e.g., flange seal fittings - Parker Parflange). The procedures and equipment for manufacturing these joints must be approved by NAVSEA prior to fabrication.

1-3.7.5.5. Threaded Pipe Joints.

Pipe threads are typically not allowed in life support systems or systems subjected to external pressure without specific NAVSEA approval. Experience has shown that pipe thread connections are susceptible to corrosion, shock and vibration damage, and leakage. Consideration must be given to pressure limitations due to a reduction in wall thickness of the pipe at the tapered threads. Should a component only be procurable with pipe threaded end fittings, a means must be provided upstream and downstream of the component to permit its removal without disturbing the threaded joints. Any compound (e.g., anti-seize thread tape) or lubricant used in threaded joints shall be suitable for the service conditions and shall not react unfavorably with the service fluid or piping materials. Chlorotrifluoroethylene (CTFE) greases such as Halocarbon Products Halocarbon 25-5S® and Hooker Chemical Fluorolube® GR362 are not compatible with aluminum alloys. For further information on lubricants, see NAVSEA S9086-H7-STM-010/CH-262, Naval Ships' Technical Manual, Chapter 262, Lubricating Oils, Greases, Specialty Lubricants, and Lubrication Systems.

NOTE

Halocarbon oils and greases shall not be mixed

1-3.7.5.6. Flared Pipe Fittings.

Flared pipe fittings and their joints shall conform to the range of wall thickness and method of assembly recommended by the manufacturer. Care should be taken with cutting and flaring tools so as to not induce work hardening of the tube end, which can make the material more susceptible to brittle fracture. Flared fittings shall not be used without technical justification from the Designer and approval from the Government Procurement Representative.

1-3.7.5.7. Flareless Pipe Fittings.

Flareless, mechanical friction or bite-type connections shall not be used on piping components where failure could cause uncontrolled depressurization or flooding of pressure vessels, life support systems, electrical assemblies or other life-critical components. The use of such fittings in control and monitoring systems may be permitted only if the component can be quickly isolated from the rest of the system in case of failure and redundant means of providing the control and monitoring functions is available; or the fittings are on ANU equipment.

Flareless and non-standard fittings, including proprietary fittings, shall not be used without specific Government Procurement Representative approval. Approval for joint design shall be based on past experience and/or tests that demonstrate that the joint is safe for the operating conditions.

1-3.7.6. Pipe/Tubing Bends

All piping shall be bent in accordance with MIL-STD-1627 (see also 2-7.4 of this document). The drawings shall list the minimum bend radius and the minimum wall thickness (after bending) for all piping and tubing. When specifying piping products, the Designer shall consider what the minimum bend radius of each section of pipe will be. Table 5 provides a recommended minimum thickness prior to bending for different bend radii.

1-3.7.6.1. Minimum Wall Thickness

The minimum wall thickness for piping or tubing extrados (back wall) after bending shall not be less than the minimum wall thickness required for straight piping or tubing. In addition to specifying the specific piping/tubing products to use in the drawings, the Designer shall also list the minimum wall thickness.

Table 5: Recommended Thickness of Piping Prior to Bending

Radius of Bends	Min. Thickness Recommended Prior to Bending[1]
6 pipe diameters[3] or greater	$1.06t_m$[2]
5 pipe diameters	$1.08t_m$
4 pipe diameters	$1.14t_m$
3 pipe diameters	$1.25t_m$

1. Interpolation is permissible for bending to intermediate radii.
2. t_m is the minimum wall thickness required for straight pipe/tube.
3. Pipe diameter is the outside diameter of the pipe/tube.

1-3.7.6.2. Minimum Bend Radius

Piping shall not be bent to a radius less than 2D. If the design dictates that a larger bend radius is required, this radius shall be listed in the drawings.

1-3.7.7. Pipe Hanger Requirements

Arrangement and design of pipe hangers shall be carefully considered as a basic element of the piping design. Pipe hanger spacing requirements for various pipe and tube sizes are provided in Table 6 for afloat and portable systems. For additional guidance on hanger design, refer to NAVSEA drawing 804-1385781 for surface ships, NAVSEA 5000-S4823-1385782 for submarines, and NSTM, Chapter 505. Piping support spacing for shore-based systems shall be based on Table 7.

Piping and tubing should be supported as close to bends as possible. Piping shall not be used as the sole support for relatively heavy components (e.g., large valves, moisture separators or filter housings). Components shall be supported so that the force required to operate them (or other normal operational loads) does not cause visible deflection, rotation or vibration. One line shall not be used to support another, although clamp blocks may be used to support two or more adjacent lines as long as the blocks are attached to non-piping structural members.

Pipe Support Spacing		
Nominal Pipe Size (Inches)	Span in Inches	
	Gas Service	Liquid Service
1/8	24-28	18-24
1/4	38-44	30-36
3/8	50-60	40-46
1/2	60-70	50-56
3/4	85-95	65-75
1	95-110	85-100
1-1/4	120-140	110-120
1-1/2	120-140	110-120
2	120-140	110-120
2-1/2	120-140	110-120
3	120-140	110-120
Tubing Support Spacing		
Normal Tubing Size	Span in Inches	
	Gas and Liquid Service	
1/8	18-24	
1/4	24-30	
5/16	30-40	
3/8	40-50	
1/2	50-60	
3/4	60-70	
1	70-80	

Table 6: Afloat and Portable Pipe Support Spacing

Nominal Pipe Size (Inches)	Suggested Maximum Span in Feet	
	Water Service	Steam, Gas, or Air Service
1	7	9
2	10	13
3	12	15
4	14	17
6	17	21
8	19	24
12	23	30

Table 7: Shore-Based Pipe Support Spacing

1-3.7.8. Flexible Hoses

The use of flexible hose shall be limited to applications where excessive flexing or vibration of rigid piping dictates its use. Additionally, flexible hose shall be used in portable systems where elements must be assembled/disassembled on a regular basis for operation or maintenance. When a flexible hose assembly is to be subjected to considerable vibration or flexing, sufficient slack shall be provided to avoid mechanical loading. Sharp bends or twisting shall be avoided. Bend radii shall not be less than the manufacturer's recommended minimum bend radius. Kinked hoses shall be immediately discarded because there is no way to determine the extent of damage done to the thin hose liner.. All hoses shall have a rated working pressure equal to or greater than the system design pressure for the system in which they are used. A pressure safety factor of four times the hose rated working pressure to burst pressure shall be the minimum used for flexible hose. Flexible hose material shall be compatible with the intended service, and shall not give off noxious or toxic gasses or vapors. Cleaning solutions must be compatible with the hose materials and must be able to clean the hose to the same level as the system in which it is used.

When hoses and connectors are used in applications where they may be subjected to mechanical loading they shall be provided with strain relief devices. These devices shall be designed to prevent damage to the hoses and connectors as well as to prevent accidental disconnection of the hoses if they are pulled. Provisions shall be made to connect the strain relief device to a nearby structural member. The most common form of strain relief is a small diameter wire cable (1/8”-3/8” stainless steel) with eyes at each end to which shackles are attached. The strain relief shall be attached to the hose by marlin at regular intervals (no greater than 36 inches). All high-pressure hoses are required to have this strain relief device except those that are permanently installed in an area where personnel will no be injured should a failure occur.

Where hand-held fire hoses are provided inside a diving system, they shall be electrically conductive and grounded to reduce the risk of electrical shock to the user in case they should be inadvertently used on live electrical equipment.

The safe working life for each flexible hose used in the diving system shall be specified. The use of rubber hoses in diving systems is discouraged due to the life span limitations of the material.

The information needed to identify hoses is the manufacturer's part number and the size or dash number (dash number is the nominal inside diameter in sixteenths of an inch). Hoses built to military specification requirements will contain the specification number and, where applicable, the class of hose, the quarter and year of manufacture and the manufacturer's trademark. This information is molded or otherwise permanently repeated at regular intervals on the hose cover (sometimes referred to as the "lay line marking") or provided on a hose tag. For interpretations of commercial lay line markings, refer to the appropriate manufacturer's catalog.

All flexible hoses, which are not permanently installed, shall be provided with suitable end caps that protect the hose end fittings from mechanical damage and prevent contamination when not connected for use.

In general, flexible hose fittings shall meet the same design requirements as those for pipe fittings. Additionally, all flexible hose end fittings shall be designed so they cannot be connected into the wrong system. This can be done by size selection, key fitting, or end fitting type. Color coding or identification alone is not generally considered sufficient to ensure that hoses are not connected to the wrong system. Devices used for alignment or prevention of incorrect connection shall be sturdy enough to resist normal handling damage and manual override of any keying devices. Other fitting considerations are material compatibility, corrosion resistance, flammability, ease of operation/connection and tight sealing. Fittings must be identified by the manufacturer's part number, the size of the end connection which joins to the piping system, and the dash number to show the size hose to which it mates. For interpretation of manufacturers' markings, consult the appropriate manufacturer's catalog. Fittings meeting military specification requirements will have the specification number, class of fitting (where applicable), type, size and manufacturer's trademark clearly indicated.

Quick disconnect fittings used on flexible hoses shall be readily accessible and capable of being disconnected under pressure in an emergency. Provision shall be made to prevent accidental disconnection, i.e., a positive locking mechanism requiring more than one mechanical action to disconnect. Quick disconnect fittings shall not be used on diver's umbilical breathing gas hoses unless specifically approved by NAVSEA.

Hoses used in oxygen systems shall have a liner made of PTFE.

All hoses must meet the requirements of this specification and those in NAVSEA S6430-AE-TED-010/ Volume 1, Technical Directive, Piping Devices, and Flexible Hose Assemblies. NAVSEA S6430-AE-TED-010/ Volume 1 also includes information on determining the criticality of application for hoses.

1-3.7.8.1. Umbilicals.

Umbilical hoses must meet all the requirements for flexible hoses (see 1-3.7.8). Umbilicals are made up of hoses and cables that tether a diving system or a diver to a supply source for breathing gas, fluids, electrical power, communications and mechanical strength. They shall be resistant to abrasion; impact damage, cracking and deterioration under the conditions of the mission profile and retain sufficient flexibility for free movement. Umbilicals must possess adequate tensile strength for their design use, adequate flexibility to withstand coiling for storage and reeving over sheaves, and adequate burst strength (four times rated working pressure). Occasionally, hoses are subjected to external seawater pressure that is greater than internal pressure. In these applications, it must be demonstrated that the hose has sufficient reserve crush resistance for the intended service.

Umbilical assemblies shall be fabricated in accordance with U.S. Navy Diving Umbilical Description, Materials and Assembly Manual, SS521-AH-PRO-010. Umbilicals shall be designed to include complete identification of the hoses by a metal tag on each.

All umbilical connections shall be provided with suitable end caps/plugs that protect the hose end fitting from mechanical damage and that prevent entrance of contamination when not connected for use. Fittings on the dive system connections shall be similarly protected.

1-3.7.8.2. Hose Tags

A tag containing the information listed below shall be attached to all hose assemblies:

a. Hose Number

b. Proof Test Activity

c. Date Installed

d. Maximum Operating Pressure

e. Proof Pressure

f. Date Tested

The tags shall be made of a material that does not tarnish or rust and should be readable from a distance of 2 to 3 feet. Tags may be attached to the hose assembly using plastic tie wraps or corrosion resistant wire and should be in a place where they are easy to read. For umbilicals and pneumofathometer hoses, tags should be attached away from the diver, where the hose meets a bulkhead or console.

1-3.7.9. General Requirements for Piping System Components

Care must be exercised when designing piping components for the diving system to ensure that gas or liquid flow is in the proper direction through the component. Most components have a designed direction for flow and this should be observed. Where components permit bi-directional flow, they shall be installed to take best advantage of the design. For example, valves serving as both inlet and outlet on high-pressure flasks shall be installed so that when they are closed the flask pressure acts from below the seat and not on the valve stem packing. Piping components shall always be installed in accordance with the manufacturers' recommendations, unless a deviation is approved by NAVSEA.

All manually operated piping system components shall be readily accessible and easily operable under normal and emergency conditions.

All piping system components shall be selected to permit adequate flow for the most demanding mission conditions expected for the diving system. These conditions shall be specified when justifying the selection of a component.

Adequate stop valve and/or check valve protection shall be provided to prevent loss of control of the system. For example, isolation valves shall be provided for all gauges and regulating valves and double valve protection shall be provided on fill and drain lines for all gas flasks. Double valve protection shall consist of one isolation valve for each flask bank and isolation valves for each flask in the bank. Flask drain lines shall be separate for each individual flask. Flask drain lines shall not be manifolded. Hull and back-up valves are required on PVHOs to prevent uncontrolled depressurization or flooding.

1-3.7.10. Valves

For guidance on the selection of valves for a particular application refer to MIL-STD-777, NSTM Chapter 505, ASME B31.1 or NAVFAC DM-39. Valves utilizing a soft seat design are preferable to those employing a metal-to-metal seat design. Pressure boundary hydrostatic and seat tightness testing of valves shall be in accordance with 2-9.5 and 2-9.6.

1-3.7.10.1. Stop Valves.

Stop valves are the most common component in a piping system. These valves provide positive control of system fluid flow. Stop valves are generally hand operated, although they may be fitted with remote operators in special instances.

The term "stop valve" applies to globe, needle, ball and plug valves that are able to completely stop the flow through a piping system. In addition, globe and needle valves are designed to permit throttling of system flow (e.g., a pressure regulator bypass valve). Ball and plug valves, on the other hand, are not designed for precise throttling flow control, but rather as quick-opening/quick-closing valves. Because of the inherent dangers of oxygen, quick-opening valves (e.g., plug or ball valves) shall not be used in high-pressure oxygen systems without prior NAVSEA approval.

Stop valves are required on all high-pressure gas flasks, on all piping penetrations to a pressure vessel and at the boundary between primary and secondary systems. The above are only examples and are not meant to encompass all areas where stop valves may be required based on a specific system design. For instance, a hazard analysis performed on a specific system may generate a requirement for additional stop valves to isolate specific components from systems in case of failure.

1-3.7.10.2. Check Valves.

Check valves are used in piping systems when one-way flow is required for the safety of the diving system personnel or for normal operation of the equipment. While check valves offer additional system safety to prevent reverse flow, they shall not be used to replace positive acting stop valves in life support systems without the written approval of the Government Procurement Representative. Check valves should be used downstream of the charging connection at charging stations to prevent backflow through the connection. Check valves should also be installed in the discharge piping of air compressors to prevent backflow through the compressor after it shuts down.

1-3.7.10.3. Pressure Relief Valves/Devices.

Piping systems shall be provided with overpressure relief devices capable of relieving system pressure at not more than 110 percent of the maximum operating pressure. In unusual applications, where 110 percent relief pressure is not appropriate, this fact shall be specifically addressed, justified and approved by the Government Procurement Representative. When a single pressure relief device is used for a pressure vessel, the relief pressure setting shall not exceed the system design pressure. When fully open, relief valves shall be capable of relieving maximum system flow without pressure build up. Relief valves must reseat above the maximum operating pressure of the system.

Relief valves shall be installed at the discharge of all air compressors (both high pressure and medium pressure), gas transfer pumps, receivers/volume tanks, the low-pressure side of pressure-reducing valves, and at external charging stations. Relief valves shall be located so that they cannot be isolated from the system or component they protect from over-pressurization. Hyperbaric chamber relief valves are the exception to this requirement. Relief valves on hyperbaric chambers shall be equipped with a quick acting, ball-type gag valve located between the chamber pressure hull and each relief valve. This gag valve shall be safety wired in the open position with frangible wire. Relief valves shall not exhaust inside of a PVHO. If a relief valve is installed inside a manned pressure vessel, the exhaust shall be piped to the outside. Relief valves shall not be used to protect the pressure hull of diving bells.

Fusible/frangible burst discs are often used to protect DOT and ASME gas flasks. Fusible discs protect against expansion due to rising temperatures. Frangible discs protect against excessive pressure. Unlike pressure relief valves, burst discs cannot reseat and, therefore, only operate once before requiring replacement. Frangible discs shall be carefully selected including effects of disc corrosion.

Pressure relief valves or burst discs shall not present a hazard to operators, divers, or occupants by causing rapid decompression should they be actuated by a malfunction or pressure spike. Relief valve discharge shall be directed away from personnel to reduce possible injury. Relief valves used in oxygen systems, located in enclosed spaces, must have outlets piped to the weather.

Inlet piping connecting the pressure vessel, main, or other component being protected, to the relief valve shall be as short and direct as possible.

Where relief valve discharge piping is to be provided, it shall be arranged and sized so that back pressure does not cause unsatisfactory relief valve operation, either from a stability or capacity standpoint. Back pressure build-up shall be based on the maximum capacity of the installed relief valve rather than the minimum required relief valve flow rate based on source flow. The two types of backpressure mentioned herein are superimposed backpressure and total backpressure. Superimposed backpressure is defined as pressure at the discharge of a relief valve prior to the opening of that relief valve. Superimposed backpressure can exist where a relief valve discharges into a common line shared with other relief valves, or discharges into a pressurized or closed system. Total backpressure is defined as the total pressure that can exist at the discharge of a relief valve, and can comprise the combination of any superimposed backpressure plus the built-up backpressure created by the discharge flow of the relief valve. Where a total backpressure in excess of 10 percent of the set pressure of the relief valve can exist, a relief valve of balanced design shall be used. Where total backpressure is less than 10 percent of the set pressure and no superimposed backpressure exists, a relief valve of unbalanced design may be used. Where a superimposed backpressure can exist, a relief valve of balanced design shall be used, except that in cases where it is shown that the magnitude of the superimposed backpressure is never high enough to adversely affect the protection provided to the system or pressure vessel by the relief valve, an unbalanced relief valve may be used. In no case shall the total back pressure be in excess of 25 percent of the set pressure.

1-3.7.10.4. Pressure Reducing/Regulating Valves.

Pressure reducers (regulators) shall be designed to maintain outlet pressure within required limits despite varying inlet pressures. When set to the required outlet pressure, pressure regulation shall not be affected by position, motion, activity, or ambient temperature. Pressure must be maintained satisfactorily within the system design operating range. Gauges indicating upstream and downstream pressures shall be located adjacent to the regulating valve or in the vicinity of the system control console. The preferred method of ensuring redundancy is to provide a secondary pressure regulator in case the primary regulator fails. If a secondary regulator is not feasible, a by pass around the regulator is required. In this case, the Designer must prove, by testing, that the regulator bypass valve can adequately control the system pressure and flow rates during operations.

If a bypass is installed around the reducer, the downstream (LP) side of the bypass valve shall be protected by a relief valve to prevent damaging the system in the event of inadvertent over pressurization of the piping. Unless non-isolatable over pressure protection is provided, all piping on the downstream (LP) side of a pressure reducing valve must be designed to withstand the upstream maximum system pressure. The bypass shall be capable of manually regulating pressure and passing the required design flow rate. Appropriate isolation valves and relief valves shall be installed, as necessary, to support maintenance and protect downstream components.

Suitable filtration shall be installed upstream of the pressure regulator to remove particulate, moisture, and gaseous contamination.

1-3.7.10.5. Flow Control Valves

Flow control valves are used in systems when a constant flow must be maintained or as a method of providing protection from too high a flow rate. If a flow-control component is adjustable, it shall provide smooth, even flow changes as it is operated. If orifices are used to control flow, the orifice size shall be easily identifiable (on the component and on drawings). Filtration should be provided upstream of orifices. Provisions shall be made for clearing or bypassing clogged orifices during use.

1-3.7.11. Remote Control Systems.

The Designer shall furnish detailed design information for all remote control systems and components. These systems provide remote operation capabilities for the diver life support system, e.g., the actuation of hull stops. Information provided to the Navy must clearly discuss the capability of the system to function in the intended environment (i.e., temperature, pressure, humidity). Descriptions must be furnished for all remote control systems. The descriptions shall include an analysis of the consequences of a failure or loss of normal mode, and describe automatic and manual backup control features available for emergency recovery or surfacing procedures. Test data in support of system and component reliability for the intended service must also be provided. Design information and test data must be in sufficient detail to permit an independent evaluation of the adequacy of the controls in their environment, under all normal and emergency operating conditions.

1-3.7.11.1. Remote Control Power Systems.

Remote control power supplies shall be manual, mechanical, pneumatic, hydraulic, or electrical. The choice shall be based on reliability in the environment in which the power supply must function. The Designer shall furnish information that substantiates the reliability of the power supply in the intended environment. This information may be based either on previous use of the power supply or on tests.

All remote controls must have two independent sources of power. Failure of one of the power sources shall not hinder the use of the other power source.

1-3.7.11.2. Remote Control Monitoring Systems.

Remote control systems shall contain devices that monitor system status and responses. Indication of malfunction or failure in a control actuator must be provided to the operator or diver. The Designer shall define the level of monitoring required based on the criticality of the system. The monitoring system design shall be submitted to the Navy for concurrence.

1-3.7.11.3. Remote Control Actuators.

A remote control actuator is any device or group of devices used to accomplish a desired control function. The design shall ensure the control actuator will be resistant to false alarms or extraneous signals that produce undesired responses. Switches and controls that are used to manually energize a control actuator must be located so that they are not inadvertently energized.

Remote control actuators shall be designed to be failsafe. Failure of any portion of a control actuator shall not in any way prevent the ability of the diving system to return to the surface.

Individual remote control actuators shall be capable of being isolated from other remote control actuators that share a common power supply. For electrical remote control actuators, this requires either fuses or circuit breakers on all lines connecting each remote control actuator to the power supply. For hydraulic or pneumatic remote control actuators, this requires appropriate check valves or isolation valves on all lines connecting the power supply to the remote control actuator.

Remote-operating control actuators, used to operate system valves from control stations, may be mechanical, hydraulic, pneumatic, or electric. Local overrides shall be required for all remotely operated valves. Failure modes for remotely operated valves shall be evaluated during the system hazard analysis. For additional information, see paragraph 1-2.4.2.

Where a remote control actuator normally operates automatically, provision shall be made to allow the operator or diver to manually override the automatic control. The manual control shall bypass as much of the automatic control system as is practical.

1-3.7.12. Filters

All breathing gas supplies shall be filtered both at the compressor intake, discharge, and at the inlet to all gas supply regulators (in-line filter). Additional in-line filtration shall be installed to remove particulate, moisture, oil mist, and gaseous contamination if warranted. Filtration in air systems shall be 50 microns nominal, and 10 microns nominal in oxygen, helium, and mixed gas systems. Filters in breathing gas systems must be sized so that gas flow is not restricted. In-line filter elements shall be made of a material that is compatible with the breathing gas. While stainless steel filter elements are satisfactory for air systems, monel or bronze elements are required for use in any gas system where the oxygen concentration could exceed 40% by volume.

See 1-3.15 for the requirements pertaining to compressor inlet and outlet filters.

1-3.8. MATERIALS

Selection of the proper material to be used in the design and manufacture of diving systems is a critical factor affecting system safety. The specific end use of each component must be evaluated on the basis of its operating environment (particularly when used in combination with other materials), loading conditions, and life expectancy. The use of an inappropriate material in a diving system may result in a catastrophic failure and cause fatal or critical injury to personnel. Requirements which provide assurance of adequate material performance are contained primarily in this section but other (more specific) material requirements are found throughout this document.

Only Category 1 materials in accordance with 1-3.8.15 shall be selected by the Designer and/or Builder. The use of Category 2 or 3 materials must be approved by the Government Procurement Representative. All materials that fall within the Scope of Certification must be identified.

1-3.8.1. Toxicity.

Non-metallic materials, such as paints, insulations, sealants, adhesives, plastics, fabrics, fittings, and other items and equipment containing material or components which may give off noxious or toxic fumes at any temperature below 200 degrees Fahrenheit or which could cause occupational illness, shall not be installed or applied within the diving system's pressure vessels and on other surfaces in contact with breathing gases. For paints, sealants or adhesives, this requirement applies after drying or curing.

Mercury, asbestos, cadmium, magnesium and beryllium are examples of materials that shall not be used in a diving system without adequate protection and justification. NAVSEA S9510-AB-ATM-010, Nuclear Powered Submarine Atmosphere Control Manual, provides a comprehensive list of materials that are prohibited in closed atmospheric environments.

The Designer shall compile a list of all potentially toxic materials used inside closed environments, such as recompression chambers, and submit this to the Government Procurement Representative for review.

1-3.8.2. Flammable/Combustible Materials.

Every effort shall be made to eliminate, or at least minimize, flammable material in the diving system. Flammable materials are those that will ignite or explode from an electric spark or when heated and will continue burning in the presence of air or in any oxygen enriched atmosphere. Materials that are nonflammable at atmospheric pressures may be highly flammable when subjected to increased oxygen concentrations and/or elevated pressure.

Diving system stationary furniture, such as bunks and chairs, shall be made of a conducting material to minimize the possibility of accumulation of a static electric charge. Bare aluminum is conductive; however, most aluminum used for furniture is anodized. This anodized finish is highly insulating and blocks the desired electrical discharge path. In this case, provisions shall be made to ground the furniture and have electrical resistance of less than 1 megohm (MΩ). If aluminum paint is used inside a diving system, precautions shall be taken to ensure that it is not applied over rusted steel. A primer, not containing red lead or iron oxide, shall be used under the aluminum paint.

Magnesium and alloys containing significant amounts of magnesium shall not be used in the diving system because of their high combustibility.

Due to the potential for oxygen concentration to exceed 25 percent in oxygen and mixed-gas diving systems, and inside hyperbaric chambers, the Designer is strongly urged to follow the guidance found in ASTM G88, Standard Guide for Designing Systems for Oxygen Service. The Designer should also be familiar with ASTM G63, Standard Guide for Evaluating Non-metallic Materials for Oxygen Service, and ASTM G94, Standard Guide for Evaluating Metals for Oxygen Service, when selecting materials to be used in elevated oxygen environments and piping systems.

The Designer shall compile a list of all potentially flammable materials used inside PVHO's and provide sufficient information to permit an independent evaluation of the suitability and adequacy of the materials to be used.

1-3.8.3. Corrosion

Corrosion effects must be considered during the initial selection of the material and throughout the design process. Pressure vessels, subject to thinning by corrosion, erosion, or mechanical abrasion, shall have provision made for the desired life of the vessel by increasing the thickness of the material over that determined by design calculations or by using some other suitable means of protection. The following list represents typical types of corrosion that must be considered:

a. Electrolytic corrosion. The most common form of corrosion in the marine environment occurs through oxidation and reduction. Electrons pass from the site of oxidation (corrosion) to the site of reduction. The site of oxidation (corrosion) is the anode. The site of reduction is the cathode. The electrolytic path for the electron flow can be supplied or supplemented by a seawater environment. The following are various types of electrolytic corrosion:

(1) General/Pitting Corrosion. Large surface areas will corrode due to adjacent points within the area switching from cathode to anode and back again. On the other hand, small areas that start functioning as anodes will continue to do so, causing a pitted surface. Pitting can be a serious problem in pressure vessels and components. Pitting is normally limited to alloy steels and aluminums. Hatch and viewport seating surfaces have been known to leak due to pitting.

(2) Crevice corrosion. Crevices in or between materials retard the formation of oxide film within these crevices. The oxide film that forms on the surrounding surface will act as a cathode and the crevice will act as an anode that accelerates the corrosion within the crevice.

(3) Plate corrosion. Certain types of metal alloys in sheet or plate form will tend to corrode in planes parallel to the rolling plane of the material.

(4) De-alloying corrosion. In some alloy compositions, corrosion will attack one or more of the components of the alloy that will result in weakening of the material.

(5) Galvanic corrosion. When two different metals are coupled in the marine environment, one will act as an anode and the other will act as a cathode depending on the relative positions of the metals within the galvanic series and the relative size of the exposed metal surfaces of each. Galvanic corrosion can be very dramatic and result in catastrophic failure in a relatively short time.

b. Stress corrosion. Certain alloys (e.g., silicon aluminum bronze) are susceptible to stress corrosion cracking, which can only occur when the material is exposed to a corrosive environment while under tensile stress. In the case of some high strength steels and titanium alloys, this form of corrosion can be propagated at highly accelerated rates, depending on environmental conditions.

Some of the traditional methods of protection against corrosion, such as waterproof grease, are unacceptable in diving systems. Painting, anodizing and plating are all common and cost-effective methods of corrosion protection. However, these processes provide only a thin layer protection. When this surface protection is scratched, the exposed bare metal is subject to accelerated local corrosion.

1-3.8.4. Pressure Vessels

Materials selection shall be in accordance with the design code/standard used in the design of the pressure vessel and this specification. The selection of proper materials to be used in the design of pressure vessels and hard structures is critical in ensuring system safety. The use of inappropriate materials in a pressure vessel may result in a catastrophic failure and cause fatal or critical injury to personnel.

1-3.8.5. Acceptable Material for Oxygen Atmospheres.

The Government Procurement Representative must approve all non-metal items used in oxygen systems and environments. Fluorocarbon plastics, elastomers, greases and high viscosity oils are typically used in U.S. Navy systems. Examples of approved fluorocarbon materials are: polytetrafluoroethylene (PTFE), polychlorotrifluoroethylene (PCTFE), vinylidenefluoride hexafluoropropylene (FKM) are DuPont Teflon®, Vespel® SP21, Viton®, 3M Kel-F® (no longer manufactured), Diakin Neoflon M400H, lubricating greases per MIL-G-27617 or DOD-L-24574 including PTFE greases such as DuPont Krytox 240AC®, and chlorotrifluoroethylene (CTFE) greases such as Halocarbon Products Halocarbon 25-5S® and Hooker Chemical Fluorolube® GR362 (CTFE is not compatible with aluminum alloys). Mechanical components in recompression chambers may be lubricated with MIL-S-8660. For further information on lubricants, see NAVSEA S9086-H7-STM-010/CH-262, Naval Ships' Technical Manual Chapter 262 Lubricating Oils, Greases, Specialty Lubricants, and Lubrication Systems.

O-rings made in accordance with the cancelled standard MIL-STD-83248 will, in most cases, be approved.

See 1-3.14.11 and 1-3.8.6 for materials acceptable for piping.

See NAVSEA SS521-AG-PRO-010, Chapter 22 for approved items allowed in hyperbaric chambers.

1-3.8.6. Piping Systems/DLSS Materials

In general, piping system materials shall be selected in accordance with MIL-STD-777. Consideration should be given to eliminate contact between dissimilar metals where galvanic effects of corrosion may occur. The Government Procurement Representative must approve the use of nonmetallic piping and piping components. See 1-3.8.15 for additional requirements.

As a minimum, the Designer shall submit the following:

a. The applicable military, federal, or commercial specifications, including a detailed list of exceptions or deletions.

b. Data covering extended time periods justifying the expectancy of the material or component to perform in its expected temperature, pressure, humidity, and atmospheric conditions to which it will be subjected.

c. Data demonstrating that the material or component presents no toxic hazards to diving system personnel due to its application and location (see 1-3.8.1).

d. Data establishing that the material or component is nonflammable under the conditions of anticipated use or, if flammable, that suitable precautions will be taken based on its application and location (see 1-3.8.2).

1-3.8.7. Coatings

Finishes applied to pressure-containing and critical load bearing elements shall not be of a type likely to permit the development of hidden pitting. High pressure air flasks may be internally coated with powdered fluorpolymer coating (MIL-C-24782) in accordance with NAVSEA S6560-AH-INS-010. Flasks containing nitrogen, oxygen or helium are to be left as bare metal.

1-3.8.7.1. Paint on PVHOs

The Navy has approved a few paint systems for use on steel or stainless steel PVHO vessels. The Government Procurement Representative can provide additional information to the Designer and/or Builder on the pre-approved paints.

Steel chambers shall be painted utilizing the following paint system:

a. INSIDE: Prime coat with NSN 8010-01-302-3608 and finish coat with white NSN 8010-01-302-3606.

b. OUTSIDE: Prime coat with NSN 8010-01-302-3608 and finish coat with grey NSN 8010-01-302-6838 or white NSN 8010-01-302-3606.

In the chamber is constructed of material other than steel or if another paint is determined to be more appropriate for the interior of a PVHO, it shall be tested to meet the off-gas requirements of 2-9.10. The Designer/Builder shall prepare a test procedure and it shall be submitted to the Government Procurement Representative for approval. Once written approval on the testing procedure has been given, the testing may be performed. The results of this testing shall be provided to the Government Procurement Representative for review. The Government Procurement Representative may disapprove the paint system, require additional testing or approve the paint system as they deem appropriate. Whenever the interior of a pressure vessel, containing breathing gas (chamber, bell, volume tank, etc.) is painted, atmospheric sampling is required. Specific contaminates are dependant on the paint system being employed. In cases when the Navy has specified the paint system to be used, the Navy will also provide the list of contaminates to be included in testing and the allowable limits. When the Designer chooses an alternate paint system, a list of possible contaminates and allowable limits shall be provided to the Government Procurement Representative for review and approval.

Aluminum recompression chambers shall not be painted.

1-3.8.7.2. Metal Coatings

The Designer must justify the use of metal applied as a surface finish, coating or cladding as not presenting an unacceptable corrosion potential, or toxic or flammability hazard. Metal applied as a surface finish, coating, or cladding shall be lower on the electrochemical scale than the metal to which it is applied.

For more guidance on galvanic corrosion protection see MIL-STD-889.

1-3.8.8. Viewport Materials

Windows and viewports that are part of a pressure vessel shall be acrylic and meet the material requirements of ASME PVHO-1. Window materials that are designed and installed IAW ASME PVHO-1 shall be considered Category I.

1-3.8.9. O-rings

Fluorocarbon rubber O-rings are recommended for DLSS piping systems. See NSTM Chapter 078, Volume 1, Seals, for acceptable O-ring materials for specific piping systems. That chapter also identifies O-ring standards, dimensions and National Stock Numbers. Information is also provided on back-up rings which are typically used to prevent O-ring extrusion at pressures over 1500 psi.

1-3.8.10. Lubricants/Sealants

Only lubricants meeting the requirements of MIL-PRF-27617, Type III Grease may be used on any component in contact with the diver's breathing gas. Do not mix lubricants on a component.

NOTE

Never mix halocarbon and fluorocarbon lubricants.

1-3.8.11. Floatation/Ballast Materials.

As a minimum, information covering the following points shall be submitted:

a. The applicable military, federal, or commercial specification with a detailed list of exceptions or deletions.

b. Data demonstrating that the material presents no hazards to diving system personnel involving toxicity due to its application and location.

c. Specific gravity as a function of pressure and temperature.

d. Sustained hydrostatic collapse load, creep behavior, moisture absorption, and cyclic fatigue life of solid buoyant materials in a seawater environment.

e. Information establishing that material is nonflammable under the conditions of use or, if flammable, that suitable precautions have been taken in its application and location.

f. Information to establish that the material can perform satisfactorily as a buoyancy or ballast material in the proposed applications. Items considered should include at least the long -term storage of the material including cyclic temperature effects in an air environment, exposure to the environmental factors of pressure, temperature, humidity, and so forth, and compatibility with both seawater and any containment or protective materials.

1-3.8.12. Fairing and Miscellaneous Nonstructural Materials.

As a minimum, the Designer will provide the following information:

a. The applicable military, federal, or commercial specifications, including a detailed list of exceptions or deletions.

b. Information covering resistance to deterioration in seawater, compatibility with mating structural materials, and resistance to dynamic loads such as wave slap and loads encountered in operating, handling, or docking the diving system.

1-3.8.13. Hydraulic System Fluids

As a minimum, the Designer shall submit the following:

a. The applicable military, federal, or commercial specifications, including a detailed list of exceptions or deletions

b. Information covering resistance to deterioration, flammability, and compatibility with selected hydraulic system components

c. Information relating to possible toxicological hazards from the fluid, based on its application and location

1-3.8.14. Electrical/Electronic System Materials

The manufacturer will submit the following information as justification for the material use:

a. Materials used in electrical equipment must be shown, by test or experience, to be resistant to deterioration caused by the environmental extremes of heat, cold and pressure, or by the saltwater environment.

b. If a material is not purchased to a MIL-SPEC, a specification sheet shall be made available for review and approval by the Government Procurement Representative along with production type test data and any additional required test data to demonstrate the equipment/component adequacy.

c. If the material is purchased to a MIL-SPEC, all test data required by the MIL-SPEC shall be made available for review and approval.

d. See 1-3.8.1 for toxicity and 1-3.13.1.1.3 for flammability guidance.

e. Guidance for electrical/electronics systems is contained in MIL-E-917/MIL-DTL-2036, respectively as well as NFPA 70, National Electrical Code.

1-3.8.15. Categorization of SOC Materials and Components

1-3.8.15.1. Introduction

The Designer must justify the use of materials and intended applications as proposed in the design of the diving system within the expected service environments. All of the materials considered to be within the SOC shall be identified. Their environmental exposure and location shall be addressed. Also, verification of the compatibility of one material with other adjacent materials must be evaluated or demonstrated, and documented for given environmental extremes.

This section contains guidelines for evaluating and assigning categories to SOC materials and/or components based on their history and service experience in the anticipated operational environment. The proposed application, configuration, design concept, joining technique, etc., is compared to a similar usage from previous naval applications for determination of the proper categorization. If the proposed application cannot be correlated with historical naval experience, additional proof or validation testing to justify the intended use must be negotiated with the Government Procurement Representative.

It is emphasized that the material and component categories detailed in this manual should not be confused with the hazard level categories of MIL-STD-882. The material and component categories of this specification were conceived to aid in assessing the probable reliability of materials and components used in specific diving system applications. They do not correspond to the MIL-STD-882 hazard level categories, which are based on the significance and possible failure of such materials or components.

It is anticipated that new materials, materials made to foreign standards and new applications for proven materials may be employed. It is not the intent of this section to limit materials and their applications. The intent is to permit the use of new material or materials in new applications whenever sufficient data or reasonable rationale exists to show that the material adequacy of the diving system will be assured. Materials having a minimal amount of available information and experience in a particular application, place a greater burden upon the Designer to justify their adequacy. All materials and/or components are grouped into the following three categories.

1-3.8.15.2. Category 1 Materials

Category 1 materials and components are those for which considerable operating experience is available. For hull/pressure vessel materials and external piping, this would include experience in fabrication, testing and operation in a sea water and/or salt air environment. For piping systems, compatibility with both the internal and external medium must be known.

Table 8 through Table 10 list typical materials and/or components with their application and category. The specifications listed are representative of specific requirements for the material identified and are provided for guidance. Untested or unusual configurations or applications of these materials and/or components might place them in a different category. Also, exposure to unusual environmental conditions such as unusually high or low operating temperatures has to be considered to determine if these materials should be evaluated in a different category.

Table 8: Category 1 Pressure Hull/Vessel materials

Material	Stock	Specification	Remarks
HY-80/100	Plate Forging Bars Castings Heads	MIL-S-16216* MIL-S-23009* MIL-S-21952* MIL-S-23008* MIL-S-24451*	Category 1 when fabricated and welded to requirements of NAVSEA T9074-AD-GIB-010/1688, or ASME PVHO-1
Carbon steel for pressure vessels for moderate and lower temperature service.	Plate Plate Forging	ASTM A537** ASTM A516, Grade 70** ASTM A350**	ABS Rules for Building and Classing Steel Vessels or ASME PVHO-1
Stainless Steel (Grade 316L or 304L)	Plate Forgings/Flanges/Fittings Castings	ASTM A240 QQ-S-763 ASTM A336 ASTM A182 ASTM A350 ASTM A351	
Stainless Steel (Grade 318)	Plate	ASTM A240	
Cast Polymethyl methacrylate plastic	Viewports	ASME PVHO-1	

*These military specifications include impact property requirements for HY-80/100 material in military applications. Consideration will be given to lower impact values for HY-80/100 where the material meets the toughness requirements of ASME PVHO-1, Safety Standard for Pressure Vessels for Human Occupancy.

**When specified to a maximum Nil Ductility Temperature of 60°F below the minimum design temperature, or a dynamic tear value of at least 200 ft/lbs from a 5/8 -inch specimen tested at the minimum design temperature. These materials would be Category 2 when subjected to a seawater environment.

Table 9: Category 1 Piping, Electrical, and Life Support Systems Materials and Components

Material	Stock	Specification
Stainless Steel	Pipe and Tubing Forgings, Flanges, and Fittings Castings	MIL-P 24691 ASTM A312 ASTM A213 QQ-S-763, ASTM A336, ASTM A182, ASTM A350 ASTM A351
Ni-Cu (Monel)	Cast Wrought Tubing	ASTM A494 MIL-C-15726 ASTM B171 Alloy 715 MIL-T-16420 ASTM B466 Alloy 715
70/30 Cu-Ni	Cast Wrought Tubing	ASTM B369 MIL-C-15726 ASTM B171 Alloy 715 MIL-T-16420 ASTM B466 Alloy 715
Valve Bronze		ASTM B61
Oxygen Valves		MIL-V-24439
Aluminum Bronze***	 Wrought	MIL-B-24480 ASTM B271 Alloy 958 ASTM B150 Alloy E 63200 ASTM B148 (temper annealed per MIL-B-24480)
Compressed Gas Flasks	 Composite*	MIL-F-22606 ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 DOT-3AA DOT-E-10945
CO_2 Absorbent	Calcium Hydroxide w/NaOH w/BaOH Lithium Hydroxide**	 Dive SorbPro: Draeger Soda-Sorb: WR Grace Sofnolime-Grade 408L with no indicator: Molecular Products Baralyme: Commercial MIL-L-20213
Electrical Equipment		MIL-E-917
Electronic Equipment		MIL-STD-2036

*Composite flasks are considered Category 2 when subjected to a seawater environment.

**Because of the possibility of severe caustic burns, lithium hydroxide shall not be used in UBAs, or any environment where the operator may come in contact with it.

***Silicon-Aluminium Bronze alloys (e.g. C64200) are not allowed. The specifications listed are for families of alloys. Other alloys included in these specifications (e.g. C63200 Nickle-Aluminium Bronze) are acceptable.

Table 10: Category 1 Mechanical Bolting Material

Material	Stock	Specification
Ni-Cu-Al Alloy (K-Monel)	Round Stock	MIL-S-1222
Ni-Cu	Round Stock	MIL-S-1222
CRES	Round Stock	ASTM A193

1-3.8.15.3. Category 2 Materials

This category includes materials and components that have not been extensively used in DLSS applications, but are classified as conventional due to their extensive use in other applications and identification by military or federal specifications, or recognized American commercial standards. Materials or components available as standard stock items and built to a recognized commercial or federal standard will be considered in this category. Components that are presently considered to be in Category 2 are certain types of aluminum, titanium, and some steels that are fabricated, welded and heat treated for use as pressure hull/vessel and exostructure. The determination of acceptable properties and allowable operating stress values will be based on the technical evaluations and supporting information provided by the Designer and approved by the Government Procurement Representative.

1-3.8.15.3.1. Category 2 Structural Materials

For pressure hull/vessel and other structural materials, the Designer should submit the following information as justification for the use of a Category 2 material:

a. The applicable military, federal, or commercial specification with a detailed list of exceptions or additions.

b. Material properties of the base metal in the condition it will be used and, if the material is to be welded, of the weld metal and the material in the heat affected zone.

c. Tensile properties, including, but not limited to; tensile strength, creep behavior, yield point, percent elongation, reduction of area, elastic modulus, and stress-strain curves (tension and compression), for the material at its service environment temperature. The material specimens tested should represent any defects and variations in material properties introduced by manufacturing and fabrication processes. Should the preparation of specimens with intentional defects or property variations prove unfeasible, the Designer may fabricate a first article and conduct inspections and destructive testing. If the first article is satisfactory, all follow-on production articles that meet or exceed the quality of the first article will satisfy this part of the requirement.

d. Impact and fracture toughness properties over the material temperature range for the intended service environment (e.g., transition temperature and shelf energy values). Desirable tests include Charpy V-notch transition curves and dynamic tear as well as drop-weight tests per ASTM procedures, and/or explosive bulge tests. Where appropriate, the Designer should show that the material’s fracture toughness properties in the applicable environment are adequate for its intended use. In this regard, a fracture mechanics type of test is useful to study the effect of seawater on fracture resistance.

e. Proof of weldability and machinability in accordance with the testing requirements of NAVSEA T9074-AD-GIB-010/1688 or approved industrial standard. These test results shall include tensile and impact properties of both weld metal and heat affected base metal. A list of specific applications should also be provided. Specific considerations include quantities and thickness of material, welding processes used, inspection standards used, manufacturer's name and fabrication experience, history of component service environment and length of service, pre-weld and post-weld heat treatments, if any, and the type of requirements and inspections required of the material supplier in the material purchase specifications.

f. Fatigue data, preferably data in the low-cycle range (below 10,000 cycles), which considers the effect of the environment. Testing conducted to generate the required data must include loads equivalent to the peak stress encountered during operation at maximum design depth.

g. Basic process to be used in producing the material. This includes electrodes if the fabrication process involves welding.

h. Data over a sufficient time period to justify the adequacy of the materials with respect to general corrosion and to stress corrosion cracking in its intended environment.

i. NDE requirements to be applied to base material and weld joints, as appropriate.

1-3.8.15.4. Category 3 Materials

Category 3 materials and components include items for which definitive information and experience are not available. Proof and validation of acceptability for these materials or components justifying proposed acceptance criteria must be provided by the Designer. The design, fabrication, testing, and maintenance requirements for Category 3 materials will be submitted for Government Procurement Representative concurrence. This manual neither specifies acceptance tests for new components or materials nor arbitrarily defines allowable operating parameters. For example, the Designer must demonstrate the effect of defects, manufacturing tolerances, and production variations upon the reliability of the material or component by appropriate model and/or prototype testing in a simulated service environment.

Examples of Category 3 pressure hull/vessel and other structural materials are those that are generally characterized by low ductility such as ultrahigh strength metals, solid glass or carbon fiber reinforced plastic and ceramic material, excluding gas flasks fabricated to DOT exceptions.

1-3.8.15.4.1. Category 3 Pressure Hull/Vessel and Other Structural Materials

The Designer must demonstrate that components fabricated using the new material possess a factor of safety that can be compared to the proven materials used in a similar application. As a minimum, the Designer will submit to the Government Procurement Representative for technical review and approval the following information as justification for the use of a Category 3 material.

a. Material chemical properties

b. Material mechanical properties including changes to properties such as proportional limit stress as a result of material forming

c. Basic process to be used in producing the material. Sufficient information is required to demonstrate that the procedures ensure that repeatable material properties are obtainable by the process used.

d. Data demonstrating material and structural performance when subjected to dynamic shock resulting from explosively jettisoning external equipment, and implosion of a flotation sphere or any other air-backed component or equipment mounted on or transported by the diving system.

> **NOTE**
>
> While the above paragraph establishes performance criteria (must survive) for the candidate material under the conditions of explosively jettisoning external equipment, it does not impose pass/fail criteria for material performance during implosion shock loading. That is, it is not required to demonstrate that the material would survive the shock; rather, the requirement is to demonstrate how the material actually performs. The resulting data will be used to conduct the evaluation of implodable and explodable volumes specified in Appendix B.

e. Effects of flaws such as cracks or defects on material performance

f. Effects of temperature on material performance and resistance to crack propagation

g. Results of tests to destruction of samples fabricated from the materials and comparison of these results with the design basis predictions of the failure point. These include implosion and/or rupture test of scale models of the proposed structure as applicable.

h. Failure modes and effect analysis (FMEA)

i. Service environment fatigue data in the high-strain, low-cycle range (less than 10,000 cycles). Testing conducted to generate the required data must include loads equivalent to the peak stress encountered during operation.

j. Data covering an extended time period establishing the adequacy of the material with respect to general corrosion and to stress corrosion cracking in the applicable service environment.

k. Fabrication characteristics, including data verifying the repeatability of results

l. NDE requirements to be applied to the base material and joints as appropriate

m. Hazards involved in fabrication or use of material with respect to toxicity or flammability

1-3.9. PRESSURE GAUGES

Pressure gauges shall meet the requirements of MIL-STD-777 and this specification. The need for accurate, reliable, readable pressure gauges in diving systems cannot be overstated. Sufficient gauges shall be located throughout the system so that operators are able to monitor gas pressures at all times. Location of gauges at the following points in a system is mandatory:

a. Pneumofathometers.

b. Diver's manifold.

c. Volume tanks.

d. H.P. bank manifold.

e. Upstream and downstream of reducing valves and regulators.

f. On each compressor stage and at outlet.

g. Two totally independent on each occupied lock, and one on the medical lock, of recompression chambers.

h. Recompression chamber pressurization supply manifold.

i. Recompression chamber oxygen BIBS manifold.

Select a gauge whose full-scale reading approximates 130% to 160% of the maximum operating pressure of the system. For example, if the maximum operating pressure for a system were 3000 psi, a gauge with a full-scale reading of 4000 psi or 5000 psi would be satisfactory for installation.

Selecting gauge accuracy and precision should be based on the type of system and how the gauge will be used. For example, a high level of precision is not required on air bank pressure gauges where only relative values are necessary to determine how much air is left in the bank or when to shut down the charging compressor. However, considerable accuracy (0.25% of full scale for saturation diving operations and 1% of full scale for surface supplied operations) is required for gauges that read diver depth (pneumofathometers and chamber depth gauges). Depth gauge accuracy is critical to selecting the proper decompression or treatment table. Table 11 lists types of gauges and their required accuracy.

Table 11: DLSS Gauge Accuracy Requirements

Gauge Type	Accuracy Grade [1]
Recompression Chamber Depth (Primary and Secondary)	1A
Surface Supplied Diving System Pneumofathometer	1A
Saturation Diving System Pneumofathometer	3A
Saturation Diving System Deck Decompression Chamber Depth (Primary and Secondary)	3A
Saturation Diving System PTC Depth (Internal)	3A
Saturation Diving System PTC Depth (External)	1A
HP Gas Manifold	A
Diver's Manifold	A
Upstream/Downstream of Regulators	1A
Volume Tank Pressure	A
Recompression Chamber Medical Lock Depth	D
Compressor Stage Pressure	D
Compressor Outlet Pressure	A
Air/Oxygen/NITROX/HELIOX BIBS Manifold	A

1. See Table 12 for additional information on Accuracy Grades.

Table 12: Gauge Accuracy Grades

	Permissible Error (+/- Percent of Span)(Excluding Friction)			
Accuracy Grade	Lower 1/4 of Scale	Middle 1/2 of Scale	Upper 1/4 of Scale	Maximum Friction (% of Span)[2]
4A	0.10	0.10	0.10	See Note 1
3A	0.25	0.25	0.25	0.25
2A	0.50	0.50	0.50	0.50
1A	1.0	1.0	1.0	1.0
A	2.0	1.0	2.0	1.0
B	3.0	2.0	3.0	2.0
C	4.0	3.0	4.0	3.0
D	5.0	5.0	5.0	3.0

1. Grade 4A gauges must remain within specified tolerance before and after being lightly tapped.
2. During gauge testing/calibration, at each test point, the gauge shall be read, lightly tapped, and then read again. The difference of the readings is the Friction Error.

Unless specifically exempted by the Government Procurement Representative, each gauge shall be provided with a gauge isolation valve that is readily accessible and shall be closed to isolate a defective gauge from the system. Valves that act as both isolation valve and calibration connection port are recommended.

All pressure gauges must be securely mounted in a location that permits easy reading of the dial and access for removal. Gauges must be protected from mechanical vibration, shock and inadvertent mechanical damage. All pressure gauges shall be equipped with a pressure blow-out plug (usually located on the back of the case) to prevent the gauge face from blowing out in case of a tubing rupture inside the gauge. Care must be taken when mounting gauges not to obstruct or block the operation of the "blow-out" plug. Fluid-filled gauges are not permitted in breathing gas systems unless specifically authorized by the Government Procurement Representative. If authorized, only halocarbon oil may be used in a fluid filled gauge.

1-3.10. ELECTRICAL SYSTEMS

Consideration must be given to the electrical requirements for all diving systems and supporting equipment. These systems and equipment cover a wide range of equipment from heavy machinery such as pumps, compressors and handling equipment to precise instrumentation for monitoring, control, communications and data acquisition. Although they cannot always be eliminated, electrical components exposed to high oxygen concentrations inside a diving system pressure hull are potentially hazardous to personnel. The Designer shall justify their use and show their potential for creating a fire/personnel hazard in a hazard analysis. Electrical systems for shore-based facilities must be designed to the requirements of NFPA-99.

1-3.10.1. Power Requirements.

Unless provided by the Government Procurement Representative, the Designer shall determine the power requirements, both normal and emergency, to support the diving system. The Designer shall show how much power is required from the support platform/facility and how much of the diving system is self-supporting.

Where the electrical system is required for the operation of equipment within the certification scope boundaries, separate primary and emergency power is required. The exception to this requirement is when the back-up for a primary system is not electrically powered. It is strongly recommended that an automatic bus transfer system be used to prevent power interruption in case there is a failure of the primary power supply. The emergency power supply must be capable of returning the divers from the maximum system operating depth to the surface.

1-3.10.2. Material Selection.

See 1-3.8.14.

1-3.10.3. Wiring Methods.

Cables subjected to deep submergence pressure shall be either pressure compensated, of a solid core construction, or the method of construction must be technically justified for the intended applications.

Pressure-compensated cable shall not be used in the interior of the diving system due to the possibility of contamination by the compensating fluid.

Cable shall be selected so that the effect of any fire damage due to a fault will be minimized with respect to damaging other cabling in the distribution system.

Cables shall be protected against damage from accidental contact, crushing, shearing or use as a handhold. Cable and wire housed inside a pressure vessel shall be arranged so as to avoid interference with personnel movement. Protect portable electrical equipment conductors from excessive flexure, kinking, tension, being caught between movable objects or being stepped on. Regardless of protection, conductors shall be resistant to such abuse.

A means of support shall be provided at the cable/plug interface to minimize bending during diving system operation. Sufficient slack must be left in the cable at penetrators to permit connection and disconnection without stressing the cable excessively.

Underwater cables shall be capable of withstanding sea pressure without damage or changing the insulation and conductivity characteristics, or be oil compensated. Underwater cables shall be nonwicking and shall be pressure rated to a depth of 1.25 times the maximum system depth, and capable of withstanding an external hydrostatic test of 1.5 times the maximum system depth.

Cables and connectors subjected to pressure (either wet or dry) shall be free of voids and air pockets. Voids have been known to burst during rapid depressurization (especially in a helium environment), causing a safety hazard.

For some diving systems, especially hyperbaric chambers, the wiring should be enclosed in rigid or flexible metal conduit using materials safe for use in hyperbaric environments with threaded fittings in accordance with NFPA 70 Article 351.

Conductors within cables shall be electrically insulated from each other, from the diving system, and from operators and occupants. All wiring used in a diving system shall have only low smoke insulation and meet the requirements of MIL-L-917 or NFPA 70 Article 504 and 1-3.10.5.2.

Conventional switches, outlets and other wiring devices that may cause a spark must not be installed inside the diving system. Electrical devices that are used inside the diving system shall be intrinsically safe and non-sparking, qualified by underwriters or other technical agencies, and technically justified for their intended application.

1-3.10.4. Ungrounded System.

All afloat electrical distribution circuits must be fed from isolation transformers to isolate the diving system from the effects of grounds on the support platform, and vice versa. All equipment designed to employ chassis grounds must be isolated from the electric power system by a transformer to a suitable isolation device. To minimize corrosion due to electrolysis, the use of the hull/support platform as an electrical conductor or as a common reference is prohibited.

1-3.10.5. Electrical Shock Prevention Requirements

All electrical powered equipment or enclosures shall be adequately grounded to prevent shock hazards to personnel (see MIL-STD-1310 for guidance).

Ground fault detectors (GFD) and/or ground fault circuit interrupters (GFCI) shall be provided for all diving system circuits unless the Designer can justify not using them. GFCIs shall be used in those areas where a shock hazard to divers or occupants may exist. Protection shall meet the requirements for safe body currents as given in the "Code of Practice for the Safe Use of Electricity Under Water", by the Association of Offshore Diving Contractors, Sep. 85 (NAVSEA letter Serial 00C3/1266 of 17 Aug 1987). The following is some general information concerning GFCIs:

a. GFCIs are required when line voltage is above 7.5 VAC or 30 VDC.

b. GFCIs shall be capable of tripping within 20 milliseconds (ms) after detecting a maximum leakage current of 30 milliamps (ma).

c. GFCIs require an established reference ground in order to function properly. Cascading GFCIs could result in loss of reference ground; therefore, GFCIs or equipment containing built-in GFCIs should not be plugged into an existing GFCI circuit.

All shore-based hyperbaric chambers shall be provided with an independent ground strap connected to the building ground or a ground rod. All shipboard recompression chambers shall be grounded to the support platform hull. All portable hyperbaric systems shall be connected to a suitable earth or shipboard ground.

The environment for electrical components used in diving systems (e.g., cabling, connectors, protective devices, motors, power supplies) may differ markedly from normal shipboard conditions. The components may be oil or saltwater immersed, subject to full sea pressure, operate at low temperatures, or be subject to high vibration and high humidity. The Designer shall furnish specific test information that verifies the ability of the electrical component to function in the intended environment for its design life and over the design range of pressures, temperatures, humidity, voltages, etc.

1-3.10.5.1. Fault Current Protection.

Fault current protection devices shall be provided for each unit of electric generating equipment or power supply and for each unit of power consuming equipment connected to the distribution system. When mounted internal to the diving system, these devices shall be installed in purged (with inert gas) explosion-proof enclosures, proof-tested and technically justified for their intended application. The design of the fault current protective devices shall meet the basic requirements of Section 21.57 of IEEE Standard No. 45 "Recommended Practice for Electric Installation on Shipboard" for afloat facilities or the National Electrical Code for shore-based facilities. Fuses and thermal devices are prohibited in helium-oxygen environments; fault current protective devices of magnetic design shall be utilized. Fuses and other thermal devices to be used in oil-filled, compensated enclosures should be specifically designed for that environment.

1-3.10.5.2. Electrical Insulation/Isolation.

Electrical insulating materials shall be selected on the basis of their ability to insulate the diving system equipment and to provide the proper functional and mechanical characteristics. Electrical insulating materials shall be nonflammable and nontoxic (see MIL-E-917 for guidance). Examples of electrical functional characteristics are dielectric strength, insulation resistance, and arc resistance. Mechanical properties include impact strength, tensile strength, elongation, flexibility, and adhesion and abrasion resistance. Teflon-coated wire or kapton polyamide film over FEP-type insulation is generally preferred for diving system applications. Because Teflon can cold flow, wires insulated with Teflon should not make sharp bends over metals edges. The minimum allowable insulation resistance of wire used in a diving system is 1 megohm (MΩ) if not subject to sea pressure and 5 megohm (MΩ) if the wire is subject to sea pressure when corrected to 25°C. Older systems having difficulty meeting these minimum resistance levels may be granted a waiver by the Government Procurement Representative on a case-by-case basis.

1-3.10.6. Electrical Connectors and Penetrators.

The bodies of pressure vessel electrical connectors and penetrators exposed to salt spray or seawater shall be made of corrosion resistant material. Connector pins and sockets shall be corrosion resistant or plated to prevent corrosion and electrical discontinuities. Provisions shall be made to protect the pressure vessel from corrosion in the gasket areas of the penetrators. Electrical penetrations to the pressure envelope shall be gas/water-tight, even when the connecting cables have been damaged.

Electrical connectors and individual hull penetrator designs shall be technically justified for their intended applications.

1-3.10.6.1. Electrical Connectors.

Connector design shall permit the diving system operator or diver to readily disconnect the umbilical and any other electrical conductor without receiving an electrical shock. Both system design and operating procedures shall not allow disconnecting connectors when the circuit is energized. Electrical connectors shall be sealed against water intrusion at operating pressure.

All cables terminating in pressure-type connectors must have connectors attached in such a manner as to exclude all voids from the cable connector assemblies and to impose no undue mechanical stresses on conductors or connectors.

System designs shall provide electrical penetrators subject to sea pressure, with adequate protection against the hazards associated with a short circuit at the connector.

The materials and methods used to join connectors and fittings to umbilical cables and hoses shall provide a strong bond capable of withstanding severe handling and operating conditions.

Electrical connectors must be designed to prevent incorrect connection and accidental disconnection. Size selection, key fitting, or other means shall accomplish this. Color-coding or other visual identification alone is usually insufficient.

1-3.10.6.2. Electrical Penetrators.

Pressure vessel electrical cable penetrators must provide a high pressure, gas tight, water barrier at the hull to prevent flooding of the diving system in the event of failure of the external cable. Stuffing tube-type penetrators into pressure vessels and noncompensated hard structures are not acceptable and will not be permitted in new construction. Pin-type connections for cable entrances into compensated enclosures are preferred; however, terminal tube entrances are acceptable provided evidence of compatibility of the cable jacket and insulation with the compensating medium is provided.

The electrical hull penetrator is part of the primary pressure boundary. Therefore, pressure test data shall be provided to assure that its hydraulic life is defined in relation to the design life of the hull and thermal shock to the connector. The electrical penetrators must be rated for the maximum system pressure of the vessel and pressure tested to 1.5 times the maximum system pressure in the medium to which is subject (e.g. electrical penetrators for a recompression chamber shall be pneumatically tested).

Where an electrical penetrator forms a pressure boundary for a human-occupied structure, each current-carrying pin with voltage limits in excess of 30 volts dc or 7.5 volts ac must have overcurrent protection. If an electrical penetrator which is submerged in the water column contains both positive and negative leads (Government Procurement Representative approval required, see 1-3.10.6.1), the system design shall provide adequate protection against the hazards associated with a short circuit at the connector.

1-3.10.7. Lighting Systems.

Diving system chambers and capsules shall be equipped with both normal and emergency lighting systems for occupants operated from separate power supplies. Where applicable, emergency lighting shall be provided for operators in the immediate vicinity of critical controls.

In hyperbaric applications, it is preferred that light sources be located external to the diving system and provided internally through ports, light pipes, or other suitable means. In this case, infrared filters or other means may be required to dissipate heat from the acrylic viewport.

When lights are installed inside a diving system chamber or capsule, the housings must be adequately designed so as not to explode or implode, and the wiring to the fixture must be sufficiently rugged to withstand inadvertent impact and mechanical loads without causing a fire or shock hazard.

Adequate lighting shall be provided on surface supplied diving systems to permit the system operator to see critical components and controls and to launch and recover divers during night diving operations. Emergency lighting shall also be provided for use in the event of lighting system failure.

1-3.10.8. Instrumentation/Data Acquisition.

Instrumentation/data acquisition devices must be electrically isolated from the diving system personnel, but not located in a manner that might subject it to erroneous readout. Electrical failure of one instrument/device must not impair the use of another. All instrumentation/data acquisition must be compatible with its intended environment and must not create a fire, electrical or toxic hazard.

1-3.10.9. Batteries

The ABS Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities, Section 11 provides the guidelines and requirements that must be considered and taken under advisement during design and specification development for Diving System batteries.

1-3.11. COMMUNICATION SYSTEMS.

In all operating conditions of a diving system, there shall be a primary and a backup communication system (except when using SCUBA). The backup communication systems between operator stations will provide redundancy in all modes of operation. The systems shall be designed such that they operate independent of each other and the failure of one system shall not impair the use, or result in the loss of the other.

A primary voice communication system such as intercom, telephone or radio equipment shall be provided to permit diving system occupants and divers to communicate with support personnel and/or with other divers. An underwater telephone and radiotelephone should be provided for deep diving systems for both submerged and surfaced communications. Hyperbaric chambers and diving bells shall have a separately powered backup to the primary system.

The Government Procurement Representative shall specify the range and water conditions for which these systems are required to be effective.

Other communication systems, which may be required in a diving system, include helium speech unscramblers, through-water communicators and closed circuit TV monitoring systems. All equipment must be compatible with the environment and must not create a fire, electrical or toxic hazard.

1-3.12. ENVIRONMENTAL CONDITIONING

Diver heating/cooling and hyperbaric chamber heating/cooling systems are required where environmental conditions dictate. The electrical components of heating/cooling systems shall be located outside the diving system pressure hull whenever possible. Heated/cooled gas or water may flow through the pressure hull, or the hull itself may be heated/cooled. If the hull is to be heated or cooled by an electrical device, the Designer shall provide verification that no electrical current will pass through the hull. All electrical heating equipment must be compatible with the environment and must not create a fire, electrical or toxic hazard.

Heating/cooling components internal to the diving system, or those that are exposed to the breathing atmosphere of the diving system personnel must not produce toxic or noxious fumes.

The Designer shall pay particular attention to the arrangement of equipment in close proximity to the heater. This is necessary in order to preclude possible off gassing due to local elevated temperatures. All equipment must be installed in accordance with manufacturer's instructions.

The Designer shall consider whether electrical heating/cooling systems should be provided with emergency power for use in the event of main power failure. All diver heating systems shall incorporate a high temperature shutdown that will activate when the hot water to the diver exceeds acceptable temperature limits.

1-3.13. FIRE SAFETY/SUPPRESION REQUIREMENTS

The Designer shall address provisions for effectively fighting fires that may occur in the interior of a diving chamber or manned pressurized submersible as well as protecting the exterior of the diving system and its ancillary equipment and protection of the operators and support personnel.

Materials that are noncombustible or nonflammable under normal atmospheric conditions may become combustible in a hyperbaric environment. When a chamber is pressurized with air or oxygen/inert gas mixture the partial pressure of oxygen is directly proportional to the increase in absolute pressure and in-turn increases the fire hazard even though the percent of oxygen remains the same. When a chamber is at surface pressure, the absolute pressure (ata) is 14.7 psia or 101.3 kPa, and correlates to 0 psig or 1 ata. At 1 ata, the partial pressure of oxygen (PPO_2) is 3.09 psia or 0.21 ata and the fraction or percent by volume of oxygen (F_{O2}) is 0.21 or 21 percent.

When the chamber is pressurized with air to 33 feet of seawater (fsw), the pressure in the chamber will be 29.4 psia or 202.6 kPa correlating to 14.7 psig or 2 ata. At this pressure, PPO_2 will increase to 6.18 psia or 0.42 ata. Although the F_{O2} is still .21, the increased PPO_2 that now has a surface equivalent value (SEV) of 42 percent has increased the fire hazard. This increased fire hazard due to the increase in atmosphere pressure is usually referred to as the “Fire Zone”. As a chamber is pressurized on air or oxygen/inert gas mixture, the fire hazard increases as pressure increases and the fire zone becomes indefinite in terms of depth. However, if at some point further compression of the chamber is continued using 100% helium, the ability of the chamber atmosphere to support combustion will decrease. Although the PPO_2 will remain constant, the F_{O2} will eventually fall below 0.06 or 6 percent, which is generally accepted as the value where combustion cannot take place.

For example, saturation diving requires PPO_2 to be maintained between 0.44 – 0.48 ata. To establish this PPO_2, the chamber is compressed using air or 79/21 HeO_2 to 40 fsw to establish PPO_2 of 0.46 ata followed by further compression using 100% helium. Using F_{O2} of 0.06 and PPO_2 of 0.48 ata, the fire zone will be limited to depths less than 231 fsw.

$$P = \frac{PPO_2}{F_{O_2}} = \frac{0.48ata}{0.06} = 8ata - 1ata \times 33\,fsw = 231\,fsw$$

See NAVSEA SS521-AG-PRO-010, Chapter 15 for further discussion on the fire zone and Chapter 22 for precautions to be taken to minimize fire hazard. See NFPA 53 for further information on fire hazards in oxygen-enriched atmospheres.

Fire and explosive hazard warning signs shall be provided inside and outside the diving chamber. The following is an example:

WARNING
Fire/Explosion Hazard. No matches, lighters, electrical appliances, or flammable materials permitted in chamber.

1-3.13.1.1. Fire Protection Considerations.

1-3.13.1.1.1. System Arrangement and Structural Considerations.

Manned, multiple occupancy hyperbaric chambers and all ancillary equipment located inside a building shall be protected by 2-hour fire resistant construction, except when the chamber and ancillary equipment is housed in its own free-standing dedicated building (See NFPA 99, Chapter 20 for detailed guidance). A hydraulically calculated automatic wet pipe sprinkler system meeting the requirements of NFPA 13 shall be installed in the room housing the chamber and in any ancillary equipment rooms.

Portable and support-platform-installed diving systems including hyperbaric chamber(s) and ancillary equipment shall be located in compartments or on deck where explosive gas-air mixtures will not occur (e.g., not located over or adjacent to fuel tanks or fuel feed machinery spaces, in the vicinity of ventilation openings from machinery spaces, engine/gas turbine or boiler exhausts, or ventilation outlets from galleys).

Diving systems within enclosed shipboard compartments shall be separated from adjacent spaces by means of A-60 class bulkheads and decks in accordance with SOLAS, Chapter II-2. Piping and cables essential for operation of the diving system should be laid in separate structural ducts insulated to the A-60 class standard.

Enclosed control and support stations (e.g., SNDLRCS, containerized diving systems, saturation control van, auxiliary equipment van, shipboard control, chamber and equipment compartments) shall have two means of access located as remote from each other as practicable. Any glass windows shall be shatter-resistant. Controls for firefighting system shall be located in or as close as possible to the diving system control station.

Efforts should be made to keep oxygen flasks and interconnecting hoses away from heat and sources of potential arcing (e.g. electrical outlets, light switches, and electric motors). Where high pressure flasks and hoses are installed in an enclosed environment, an oxygen monitor with visual and audible alarms shall be placed in the vicinity of the flasks.

1-3.13.1.1.2. Personnel Protection.

All watchstanders critical to keeping occupants within the diving system safe while aborting diving operations and/or evacuating the divers (diving supervisor, console/rack operator, handling system operator, life support operator, tenders) shall have a portable self-contained breathing apparatus (SCBA) available in case of fire. Each chamber occupant shall have a built-in breathing system (BIBS) mask supplied by a suitable breathing mixture independent of the chamber.

1-3.13.1.1.3. Flammability Analysis.

Materials to be used in a diving system shall be evaluated based on their ability to resist burning. The Designer is strongly urged to follow the guidance in ASTM G63, Standard Guide for Evaluating Non-metallic Materials for Oxygen Service, and ASTM G94, Standard Guide for Evaluating Metals for Oxygen Service. Manufacturer's flammability data shall be reviewed to determine material acceptability. If data is not conclusive for the environment in which the material will be used, the material shall be tested and evaluated. For material to be used in environments normally maintained at one atmosphere, no elevated oxygen environments are required to be used. For material to be used in other than one-atmosphere environments, the maximum oxygen concentration permitted in the diving system shall be used. For saturation diving systems, an evaluation at the anticipated worst case fire zone pressure and oxygen concentration shall be performed. The testing shall be conducted at both one atmosphere and at the maximum operating pressure of the system. Flammable materials shall be evaluated under both normal and emergency atmospheric conditions.

Material evaluation using the data sheets and appropriate testing as required in ASTM 63 and ASTM 94 is an acceptable format for justification of selected materials. To justify the acceptance of the material by the Navy, the Designer must compare the demands of its intended use with the material’s probability to avoid ignition. The Designer must address the material’s probability of igniting, ease of ignition, potential to involve other materials, hazardous effect to the system, function and performance, and ability to satisfy its intended function.

If flammability testing of a complete equipment assembly will lead to its destruction, the following alternative analysis is recommended:

a. If possible, identify types and amounts of all materials used in the assembly. Evaluate commercial flammability data for these materials, if available.

b. If the equipment is energized when operating, it must be built in accordance with a recognized government or commercial specification (i.e., MIL-SPEC, UL, etc.).

c. If the equipment is energized when operating, perform a 24 hour "burn in bench test" to determine the maximum temperature the energized unit reaches. Identify any local hot spots.

d. Determine if assembly is mounted next to any other installed heat sources. This should be avoided if possible, but if not, address how the assembly will be protected from these heat sources (e.g., insulated with a nonflammable material such as NOMEX®) and assess the impact of co-location.

e. Determine if the assembly is a heat source itself. If so address how surrounding areas will be protected.

f. If the assembly is energized, operators must be able to de-energize the hardware quickly to secure power to the ignition source.

1-3.13.1.2. Detection.

The diving system operators, divers, occupants and support personnel can detect a fire quickly. If an automatic fire detection system is desired, it shall respond within one second after flame origination. Total response time of an automatic system from detection to activation shall not exceed 1 second. Automatic detectors must have proven reliability to activate the system when an actual flame is detected and not respond to false alarms drenching occupants and equipment needlessly. A fire suppression system must provide a visual and audible indication of system activation at the operator's station, disconnect all ungrounded electrical circuits, and activate emergency lighting and communications.

1-3.13.1.3. Extinguishing.

For shore-based systems, the requirements of NFPA 99, Chapter 20 for "Class A Chambers" shall be met. The fire suppression system shall consist of independently supplied and operated handline and deluge type water spray systems. A deluge system is required in each chamber compartment designed for manned operation. A handline system will be installed in all chamber compartments. Manual activation and deactivation shall be at the operator's station and each compartment containing a deluge system. The room housing the chamber and its ancillary equipment shall meet the requirements in 1-3.13.1.1.1.

Portable and afloat hyperbaric chambers and diving systems are not required to meet the fire suppression requirements of shore-based systems. A means of extinguishing a fire inside the diving system shall be provided. This means of fighting an interior fire could range from providing wet towels for the MK 6 Transportable Recompression Chamber System (TRCS) to fire extinguishers and deluge system for a saturation diving system. Specific guidance on fire extinguishers and fire suppression systems can be found in SS521-AG-PRO-010, Chapter 22. Diving systems located on the deck or enclosed space of a platform shall have means of protecting the system from a fire, until the divers and occupants have been evacuated, using the support platform's fire main and accessibility to at least two fire hoses. Portable fire extinguishers shall be stationed at possible sources of fire such as diesel fired hot water heaters, diesel generators, diesel driven compressors, hydraulic power units. Gas storage vessels located in an unmanned enclosed spaces of a support platform shall have a sprinkler system of sufficient flow to keep gas storage flasks cool.

1-3.14. PRESSURE VESSELS

1-3.14.1. Gas Storage Cylinders

Gas storage cylinders shall meet the requirements of MIL-F-22606, ASME BPV Code, Section VIII Division 1, or U.S. Department of Transportation regulations governing cylinders contained in Title 49 of the Code of Federal Regulations. If another code is deemed advantageous by the Designer, they may submit a written request to the Government Procurement Representative who will approve or disapprove the request.

Each gas flask shall have a readily accessible isolation valve to stop gas flow to the system. The flask isolation valve must be able to withstand full flask pressure. The flask valve shall be installed so that the pressure in the flask is under the seat (i.e. so that the valve stem seal will not be exposed to pressure when the valve is closed). This eliminates the possibility of the contents of the flask leaking through the stem seal when the flask is not in use..

Each gas flask containing divers air shall be equipped with a drain line and a drain valve. The drain line outlet shall be visible during draining operations so the operator can see when the moisture is drained. Drains are no required on oxygen, helium, nitrogen, or mixed gas flasks where the gas in the cylinder has a required dew point of -14°F or less. Lightweight portable flasks, such as SCUBA bottles or LWDS flasks, do not require drains as long as provisions are made to permit the flasks to be inverted to be periodically drained.

Gas storage cylinders used in transportable systems shall meet the requirements and be stamped or marked in accordance with the U.S. Department of Transportation or MIL-F-22606..

Gas flasks or cylinders should normally be located outside of a manned pressurized space. The Designer must justify locating compressed gas flasks in a manned pressurized space and approval must be received from the Government Procurement Representative. If gas flask or cylinders, are located inside a manned pressure vessel, the designer shall provide a readily-accessible valve to stop the flow of gas from the flask and perform calculations showing that inadvertent release of stored contents of these flask will not increase the pressure inside the chamber by more than 1 atm over ambient or exceed the limits of a safe breathing atmosphere.

1-3.14.2. Receivers and Volume Tanks.

All divers' air systems that are supplied air directly from a compressor shall incorporate medium or low-pressure receivers or volume tanks. These components help to eliminate pulsations in the compressor discharge, and act as storage tanks, allowing the compressor to shut down during periods of light load. Receivers and volume tanks shall be fabricated using approved specifications for pressure vessels described in 1-3.14.1. In general, receivers and volume tanks are fabricated in accordance with Section VIII of the ASME Boiler and Pressure Vessel Code. All receivers and volume tanks shall be equipped with pressure gauges, drain valves and relief valves. More information on receivers and volume tanks can be found in NSTM Chapter 551.

1-3.14.3. Pressure Vessels for Human Occupancy (PVHO)

Pressure vessels for human occupancy (PVHOs) shall be designed in accordance with the most current version of ASME PVHO-1. This includes the design of viewports and penetrations but not piping. Piping systems shall be designed in accordance with 1-3.7.

1-3.14.4. Design of Internally Loaded Pressure Vessels/Hard Structures

NOTE

Pressure hulls/vessels, hard structures, and components which are subjected to both external and internal pressure shall be designed to withstand the highest loadings both internally and externally.

Internally loaded pressure vessels include hyperbaric/recompression chambers, diving bells, air receivers, and gas storage flasks. The Designer shall demonstrate the structural integrity of the pressure vessel under loading conditions representative of those expected in service. As such, the design must take into consideration the effects of temperature, cyclic loading, creep, ductility, and anisotropy. Examples of pertinent variables include pressure, temperature, number of load cycles, material reproducibility, fabrication flaws and defects, design tolerances, local stress concentrations, fatigue, vessel openings, intersection of different shells of revolution, reinforcements, residual fabrication stresses, corrosion rates, and deviations from nominal geometry.

1-3.14.4.1. Stress Analysis

The Designer shall perform a complete stress analysis of the vessel or hard structure and demonstrate that all stresses are within the design criteria for the Diving System, and that its fatigue life is adequate for the intended service life. For Category 1 and 2 materials (see 1-3.8.15), the allowable stresses under internal pressure shall be in accordance with ASME PVHO-1. For Category 3 materials, the foregoing design requirements and guidelines may not be appropriate or adequate. The design requirements used must be comprehensive and provide at least the same degree of conservatism as the design requirements for Category 1 and 2 materials.

1-3.14.4.2. Verification of Calculated Design Operating Pressure

For designs made of Category 1 and Category 2 (see 1-3.8.15) materials, the calculated design operating pressure must be verified by model testing or use of existing model test data. There are three alternative methods of verification.

a. Where comparable vessel geometries and identical materials have been successfully tested to a pressure greater than the design failure pressure of the vessel to be certified, use of the existing test data can be substituted for destructive model testing of the structure under review. When this method is used, and even minor differences exist between the hull structure tested and that requiring verification, the differences must be analyzed and submitted to the Government Procurement Representative for approval.

b. For new designs that do not fall within the parameters described in paragraph 1-3.14.4.2.a above, the calculated failure pressure may be verified by performing destructive model tests, either full or reduced scale. When such testing is performed, the structural model shall be sufficiently large to contain representative prototype geometries, material properties and fabrication process restraints, tolerances, and residual stresses.

c. For new or existing vessels, the structural integrity of the vessel to be put into service may be verified by performing a pressure test of the actual vessel to 1.5 times the maximum operating pressure. When this method is used, the calculated failure pressure of the vessel must be greater than 1.5 times the maximum operating pressure by a margin sufficient to preclude damaging the vessel during the test. Government Procurement Representative approval of the margin of safety shall be obtained prior to testing.

For Category 3 materials, the foregoing testing requirements may not be appropriate or adequate. Therefore, the testing used must demonstrate at least the same degree of conservatism as the testing requirements for Category 1 and 2 materials.

1-3.14.4.3. Testing Procedures/Test Instrumentation

For all structures, a detailed test procedure shall be developed by the Designer and submitted to the Government Procurement Representative for review and approval prior to testing. The test shall be of sufficient duration to demonstrate that sustained loading does not produce permanent deformation or damage in the structure at maximum operating pressure and temperature. The test procedure shall include a detailed strain gage plan which specifies the number, type and location of all gages. The test procedure shall duplicate the loading conditions expected in service and, where applicable, shall be such that the mode of failure is identifiable. Upon completion of testing, the recorded strain gage data shall be used to verify the calculated performance of the structure. The complete test report shall be provided to the Government Procurement Representative for approval.

1-3.14.5. Design of Externally Loaded Pressure Vessels/Hard Structures

> **NOTE**
>
> Pressure hulls/vessels, hard structures, and components which are subjected to both external and internal pressure shall be designed to withstand the highest loadings both internally and externally.

For pressure vessels and hard structure of Diving Systems subjected to greater external pressure than internal pressure, the Designer shall provide evidence that the structure has sufficient collapse strength to withstand maximum operating pressure (including a factor of safety).

In general, the modes of failure in a pressure vessel subjected to external pressure are caused by either elastic or inelastic instability. The Designer shall demonstrate that the collapse pressure of the hull and hard structure is at least 1.5 times the maximum operating pressure under loading conditions (environment, loading rate, and duration) representative of those expected in service. Exceptions to this criteria require Government Procurement Representative approval. The collapse pressure is defined as the lowest pressure at which any one of a series of nominally identical hull structures would collapse. As such, the design collapse pressure (analytical or experimental) must take into consideration the effect of basic material characteristics, including creep, ductility, and anisotropy, and must account for statistical fabrication and geometrical variations to assure adequate reproducibility. Examples of pertinent variables include in-service material reproducibility, fabrication flaws and defects, hull openings and intersections of different shells of revolution and attendant reinforcement(s), residual fabrication stresses, and deviations from the nominal geometry (i.e., flat spots, mismatch, frame tilt, out-of-roundness, out-of-fairness, and out-of-sphericity). Out-of-roundness, out-of sphericity deviations, and material discontinuities are of major concern in the design and fabrication of externally loaded pressure vessels. Even small deviations in a sphere or cylinder's geometry will significantly weaken a pressure vessel. Additionally, the Designer must bear in mind that seawater corrosion must be taken into account when the pressure vessel is to be submerged. The sections that follow give the requirements that shall be met in order to accomplish this objective.

1-3.14.5.1. Inelastic Stability

For Category 1 and 2 materials (see 1-3.8.15) used in stable pressure vessels and hard structures (i.e., stiffened or unstiffened shells which permit the level of load-induced membrane stresses to approach the material yield point at collapse pressure), the collapse pressure must be no less than 1.5 times the maximum operating pressure. In determining the pressure at which collapse occurs, all fabrication and design-induced restraint and geometrical variables must be considered since the strength of moderately stable structures can be detrimentally affected by such variables.

For Category 3 materials, an appropriate ratio of collapse to operating pressure shall be justified by the Designer and submitted to the Government Procurement Representative for approval.

1-3.14.5.2. Elastic Stability

For stiffened or unstiffened hull structures fabricated from either Category 1 or Category 2 material and having a propensity for failure in an elastic instability mode (i.e., collapse occurring at actual stress levels appreciably below the material yield point), the collapse pressure at which failure due to instability occurs must be no less than 1.5 times the maximum operating pressure.

For Category 3 materials, an appropriate ratio of collapse to operating pressure shall be justified by the Designer and submitted to the Government Procurement Representative for approval.

1-3.14.5.3. Stress Analysis

The Designer shall perform a complete stress analysis of the pressure vessel and hard structure and submit it to the Government Procurement Representative for approval. The analysis shall demonstrate that all stresses are within the design criteria and that its fatigue life is adequate for the intended life of the Diving System. For Category 1 and 2 materials (see 1-3.8.15), the static stress levels shall be limited to the values below.

a. The average shell membrane stress at maximum operating pressure shall be limited to two-thirds of the minimum specified yield strength of the material.

b. The highest combined value of average shell membrane stress and bending stress (excluding effects of local stress concentrations) at maximum operating pressure shall be limited to three-fourths of the minimum specified yield strength of the material. The effect of all loading conditions, transitions, and stiffener-to-shell connections must be considered.

c. The maximum peak stress at any point in the hull, including effects of local stress concentrations, shall be limited to the minimum specified yield strength of the material and shall take into account all fatigue considerations as discussed in section 1-3.14.6.

To ensure an adequate fatigue resistance for some designs using Category 1 and 2 materials, it may be necessary to reduce the level of allowable stress below that given in paragraphs1-3.14.5.3.a, b, and c above.

The Designer shall calculate stresses in the pressure vessel and hard structure by means of recognized stress formulas or proven computer programs. The validity of the stress analysis methods used shall be demonstrated by experimental results, manually obtained predictions, and prior experience with similar structures.

For hulls and hard structures constructed of Category 3 material, the foregoing design requirements and guidelines may not be appropriate or adequate. Therefore, the design basis used must be comprehensive and at least as conservative as the design basis for Category 1 and Category 2 materials.

1-3.14.5.4. Verification of Calculated Collapse Pressure

NOTE

The requirements of this section only apply to the prototype of each design. All IDENTICAL reproductions of a prototype shall be tested to the requirements of section 2-9.11, unless otherwise required by the Government Procurement Representative.

For pressure vessels, hard structures, and penetration fittings made of Category 1 and 2 materials (see 1-3.8.15), the calculated collapse pressure must be verified by model testing or use of existing destructive and/or nondestructive tests. There are three alternative methods which can be used. The method chosen shall have Government Procurement Representative concurrence.

a. When comparable hull geometries and identical materials have been successfully tested to a pressure at least 1.5 times the maximum operating pressure of the structure, use of this test data can be substituted for destructive testing of the structure under review. In instances when this method is applicable, and when even minor differences exist between the hull structure tested and that requiring verification, the differences must be analyzed and submitted to the Government Procurement Representative for approval.

b. For new designs that do not fall within the parameters described in paragraph 1-3.14.5.4a, the calculated collapse pressure may be verified by performing representative destructive model tests, either full or reduced scale. When such testing is performed, the structural model shall be sufficiently large to contain representative prototype geometries, material properties and fabrication process restraints, tolerances, and residual stresses.

c. Testing of the actual hull structure to 1.5 times the maximum operating pressure will be accepted as verification of the calculations. When this option is chosen, the calculated collapse pressure must be greater than 1.5 times maximum operating pressure by a margin sufficient to preclude damaging the structure during the test. Government Procurement Representative approval of the safety margin shall be obtained prior to the test.

For Category 3 materials, the ratio of collapse pressure to maximum operating pressure may need to be greater than 1.5, depending on the material characteristics. Additionally, the calculated collapse pressure and the reproducibility of this collapse pressure shall be verified by destructive model tests and/or appropriate destructive tests of a duplicate prototype hull. An acceptable destructive model test is one performed on a model which incorporates all structural details of the full-scale structure and whose scale is such that the mechanical properties of the material are either identical to or differ by a known factor or magnitude from those in the full-scale structure built from the same material. The Designer shall submit the factor of safety and all test parameters to the Government Procurement Representative for approval.

1-3.14.5.4.1. Testing Procedures/Test Instrumentation

For all structures, a detailed test procedure shall be developed and provided to the Government Procurement Representative for review and approval prior to testing. The test shall be conducted at a pressure which is at least 1.5 times maximum operating pressure (or by the approved factor of safety in the case of a Category 3 material) and shall be of sufficient duration to demonstrate that sustained loading does not produce permanent deformation or damage in the structure at maximum operating pressure. The test procedure shall include a detailed strain gage plan which specifies the number, type and location of all gages. The test procedure shall duplicate the loading conditions expected in service and, where applicable, shall be such that the mode of failure is identifiable. For instance, the tested structure should be filled with liquid and vented to prevent total disintegration of the structure during collapse. Upon completion of testing, the recorded strain gage data shall be used to verify the calculated performance of the structure. Subsequent to testing, pressure boundary weld NDE may be specified or required by the Government Procurement Representative. The complete test report (including post test NDE) shall be provided to the Government Procurement Representative for approval.

1-3.14.6. Fatigue.

A fatigue analysis shall be conducted in accordance with 1-3.1.3.

When designing a pressure vessel to comply with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, a fatigue analysis may not be necessary since the code requires the use of specific geometries and imposes a high factor of safety upon the nominal stresses that are calculated. When designing a pressure vessel to comply with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, a fatigue analysis is not necessary if all of condition A or all of condition B of Article AD- 160.2 are met. The Designer shall obtain concurrence from the Government Procurement Representative and Code Inspector or classification society Surveyor on the decision not to conduct a fatigue analysis.

When a pressure vessel or hard structure are constructed of Category 3 material (see 1-3.8.15), sufficient destructive fatigue tests of full scale prototypes or models must be performed to experimentally determine the fatigue life of the design. A fatigue test plan shall be submitted by the Designer to the Government Procurement Representative for their approval prior to the start of any testing.

1-3.14.7. Fracture Toughness

The Designer shall ensure that the materials used to fabricate the pressure vessel, hard structure, or any pressure boundary component exhibit adequate resistance to fracture. Specifically, the design analysis submitted to the Government Procurement Representative and Code Inspector or classification society Surveyor shall demonstrate that brittle fracture is not a possible mode of failure by considering at least the following:

a. Magnitude, nature and rate of stresses (both applied and residual).

b. Maximum temperature range to which the structure shall be subjected in service.

c. Size, location and density of flaws initially present in the material and those that occur as a result of cyclic operations.

d. Environmental effects such as corrosion and/or erosion. Specifically, the environmental effects on crack initiation and propagation (e.g., stress-corrosion cracking), especially when the structure will be immersed in an electrolyte such as saltwater, must be evaluated.

e. Effects of creep and strain rate on fracture toughness.

f. Localized effects due to penetrations, attachments and other vessel or component restraints (i.e., stress risers).

g. Effects of fabrication processes and heat treatments on the fracture characteristics of the material. In particular for welded construction, properties of the weld rod and base metal within the heat-affected zone and resultant induced internal stresses shall be considered.

h. Material thickness.

The material properties used in the fracture analysis should be based on appropriate tests such as tensile and compressive strength tests, K_{Ic} (fracture toughness) tests, K_{Iscc} (stress corrosion cracking) tests, Charpy V-notch impact tests, dynamic tear tests, drop-weight tests and explosion bulge tests. Where appropriate test data is not available, fracture mechanics-type tests shall be conducted. Further, the design analysis must consider possible variations in material properties and, in particular, the effect of material thickness on fracture characteristics. The structural design basis used by the Designer for the analysis of brittle fracture shall be verified by destructive testing of pressure hull and component models and structures, or, where possible, by reference to existing information and service experience.

All plates, parts and components must demonstrate adequate strength and toughness over the range of design operating temperature. Toughness characteristics of ferrous materials shall be referenced to the Nil Ductility Transition Temperature (NDTT).

1-3.14.8. Penetrations

Design of openings in the pressure vessel shall be in accordance with the specified design code/standard to which the vessel is designed. Article D-5, Section VIII, Division 2 of the ASME Pressure Vessel Code provides design criteria for opening shape as well as area replacement and its distribution. Article D-5 does not satisfy the requirements of a fatigue analysis, nor does it include piping loads that may be imposed on the nozzle and/or shell portion and that may be added to the pressure loading. The Designer must carefully consider such additional loadings and make provision for them. ASME PVHO-1 Nonmandatory Appendix C also includes recommendations for the design of through pressure-boundary penetrations. These should be utilized when possible.

1-3.14.8.1. Piping Penetrations.

Piping penetrations in the pressure vessel shall be located and arranged so that, in the event of flooding, loss of atmosphere or similar emergency, a maximum amount of atmosphere will become entrapped in the diving system. Emergency shutoff capability shall be provided to protect the internal breathing atmosphere from exhaust, full flooding, or contamination. Hull stop and/or check valves should be located as close as possible to the penetrator.

1-3.14.8.2. Electrical Penetrations.

The bodies of electrical penetrators and connectors that may be exposed to seawater or spray shall be made of corrosion-resistant material. Electrical penetrations in the pressure vessel shall be gas/watertight, even when the connecting cables have been damaged. Pin-type connections or cable entrances into compensated enclosures are the preferred methods and should be used on all new design pressure vessels. Terminal tube entrances are acceptable on existing pressure vessels when evidence of compatibility of the cable jacket and insulation with the compensating medium is provided.

Electrical penetrators that are submerged in water shall not contain both positive and negative leads in a single connector. Previous experience has shown that a single flooded connector can result in a short circuit with catastrophic results. (See 1-3.10.6 for additional requirements).

1-3.14.9. Viewports.

Viewport designs and viewport penetrators shall conform to ASME PVHO-1 unless prior written authorization from the Government Procurement Representative has been obtained.

The Designer shall show that the viewport design is adequate for the system pressure and temperature range, environmental conditions, and expected number of pressure cycles. Each port's field of view within the Diving System shall be shown on the system drawings. Only acrylic materials in accordance with ASME PVHO-1 and having adequate fatigue strength for the stress levels incurred over the expected service life of the viewport shall be used in U.S. Navy chambers. Resistance to stresses applied continuously over a long period, as well as cyclic stresses, must be properly considered. Full specification must be made of the materials used; their composition; thermal, chemical, or physical treatment required; dimensions and tolerances; and renewal or replacement criteria. Where necessary, viewports shall be protected from accidental impact or other mechanical abuse.

The service life of chamber viewports depends upon design and the environment that the viewport is subjected to, both during chamber operation and while transporting or storing the chamber and is subject to Government Procurement Representative approval. For example, the service life of viewports designed in accordance with ASME PVHO-1 and inspected in accordance with ASME PVHO-2 is 10 or 20 years, depending upon the viewport design and the operating, transportation and maintenance environment of the chamber.

1-3.14.10. Hatches/Closures.

The design of all hatches must permit safe operation under all specified ship motions and operating conditions. The ease and speed with which a closure can be opened or closed, and whether tools are required to do so, are design considerations. The reasoning behind the design of a hatch/closure shall be documented in the design calculations for the diving system.

For Category 1 and 2 materials, all closures, including hatches for personnel or materials, port covers (deadlights), and caps or plugs for openings shall have a demonstrated factor of safety at least as stringent as that used for the design of the pressure hull. Hydrostatic testing of all hatches, covers, caps, and plugs shall be to 1.5 times the maximum operating pressure of the pressure vessel or as required by the design code. For Category 3 materials, the criteria stated for Category 1 and 2 materials may not be appropriate or adequate. Therefore, the Program Manager may apply an alternative criteria which demonstrates at least the same degree of conservatism as the criteria for Category 1 and 2 materials. Corrosion protection must be provided.

Hatches and doors should be designed such that they seat in the same direction as the system differential pressure. Where hatches or doors are required to seal against differential pressure, an interlock is required to ensure that the hatch or door cannot be opened until pressure on both sides are equal. The mating flanges of all hatches and doors shall be integral to the pressure vessel shell.

The ease and speed with which a closure can be opened or closed, and whether tools are required to do so, should be a design consideration.

Hatch/door hinging, closing, locking, and sealing elements must be made resistant to or be protected from abuse due either to rough handling or to possible accidents such as impact from a personnel transfer capsule which is being attached to the diving system in rough weather.

Hatch assembly seating surfaces shall be resistant to corrosion. While the preferred method is to manufacture the entire forging and door/hatch from corrosion resistant material, clad welding of these surfaces generally provides acceptable corrosion protection.

1-3.14.11. Seals.

Sealing materials and techniques must be shown to be adequate for the range of pressures, temperatures, gas mixtures, vibrations, lubricants, and atmospheric environments specified for the system. Captive O-ring designs (e.g., dovetail) where the capture is in the direction of differential pressure are preferred. Seals shall not be subject to failure due to the effects of a non-lethal extinguishable fire inside or outside the system, attack by the fire extinguishing agent(s) used by the system, or by thermal shock caused by the application of the extinguishing agent(s). The effects of ultraviolet light, pressure cycling, stress concentrations, differential thermal expansion, differences in moduli of elasticity, tolerances and aging shall be considered when designing seals.

It is essential that all seals, gaskets and o-rings in diving systems be fabricated from the proper material. In systems capable of containing elevated oxygen concentrations, only oxygen compatible materials shall be used. Because of their superior compatibility, fluorocarbon seals are preferred for diving systems. Asbestos-containing gasket material shall not be used. Additional guidance concerning seal, gasket and o-ring material is provided in NSTM Chapter 078, NSTM Chapter 505, MIL-STD-777, and ASME PVHO-1.

1-3.14.12. Vacuum in Manned Pressure Vessels.

All hyperbaric pressure vessels designed for human occupancy, especially ones that can be flooded and gravity drained or if the pressurized atmosphere of the occupied spaces is evacuated by mechanical means, shall be designed to prevent the possibility of unintentionally causing a pressure of less than one atmosphere (i.e. drawing a vacuum) while the chamber is occupied. Design features such as vacuum breakers shall be sized for the highest flow rate possible.

All suction, drain, and exhaust lines in hyperbaric manned compartments must be equipped with an anti-suction device to prevent injury from personnel being sucked up to the inlet.

1-3.14.13. Miscellaneous Pressure Vessels and Hard Structures

It is recognized that many existing pressure vessels were designed, built, and tested to criteria less stringent than current pressure vessel codes and this specification, and/or may lack OQE which assures that the pressure vessel is in conformance with design parameters. Acceptance of such a vessel, manufactured from Category 1 or 2 material, shall include pressure testing in accordance with paragraph 1-3.14.5.4.c and/or 1-3.14.4.2.c in addition to any other certification attributes or testing deemed necessary by the Government Procurement Representative in order to prove the adequacy of the structure for its intended use.

1-3.15. COMPRESSORS

NOTE

All divers' air systems that are supplied air directly from a compressor shall incorporate medium or low-pressure receivers or volume tanks.

1-3.15.1. General Considerations

When selecting a compressor to supply breathing air, the output flow rate, pressure, and air purity are the primary considerations. For afloat and portable diving systems, compressors shall be selected from the ANU list. Other compressors may be used with prior approval from the Government Procurement Representative.

The following general requirements shall be met for all compressors:

a. The compressor inlet system shall not restrict the flow of air to the compressor and shall be constructed of non-off-gassing and breathing-compatible materials.

b. Consideration must be given to the location of the compressor inlet in regards to possible contamination from machinery exhaust fumes or other airborne contaminants. Proper inlet filtration shall be provided. A dry type, non-shedding inlet filter is required. Oil bath filters are not authorized in breathing gas systems.

c. Pressure gauges for each stage of compression, running hour meter, high-pressure shutdown, high temperature shutdown/alarm and low oil pressure shutdown/alarm shall be provided.

d. Both low pressure cut-in and high-pressure cutout switches are to be installed where medium or high-pressure compressors are used to directly provide diver's breathing air during operations.

e. It is recommended that a CO detector/alarm/shutdown device and automatic condensate drains be installed on compressors used to provide breathing air.

f. The compressor shall provide sufficient breathing gas to support 150 percent of the greatest breathing demand.

g. Breathing gas compressors shall incorporate cooling to reduce output gas to a breathable temperature.

h. Suitable outlet filtration shall be installed to remove particulate, moisture, oil mist, and gaseous contamination. Acceptable diving compressor particulate, oil mist and odor filters and moisture separators can be found in NAVSEA INST 10560.2 (ANU List). See also 1-3.15.4.

i. High pressure air compressors shall be equipped with a back-pressure regulator located downstream of the oil/water separator (see 1-3.15.3).

1-3.15.2. Coolers.

Compressors generally supply output air at temperatures too high for breathing purposes. Additionally, high temperatures associated with high-pressure air compressors may cause compressor lubricants to break down. Therefore, interstage coolers and after coolers may be required to bring the compressor discharge temperatures down to an acceptable level.

1-3.15.3. Back Pressure Regulators.

High-pressure air compressors shall be equipped with a backpressure regulator located downstream of the moisture separator. Backpressure regulators shall be designed to maintain a specified minimum operating pressure (normally 1000 psig or greater in accordance with the compressor manufacturer's requirements) at the compressor outlet. The backpressure regulator is used to seat the compressor piston rings and prevent excessive compressor lubricating oil from entering the system piping. Backpressure regulators should be located downstream of the moisture separator and upstream of the outlet filter. For compressors equipped with filtration tower packages, the backpressure regulator shall be installed downstream of the filtration package.

1-3.15.4. Purification System.

1-3.15.4.1. Moisture Separators.

All high-pressure air compressors require moisture separators to remove liquid contaminants from the compressed air. The moisture separator capacity is selected according to compressor output flow rate and temperature and the anticipated environment that the compressor will be used in. Separators shall be located downstream of any after coolers to trap the condensation resulting from the air cooling process and compressor oil that may enter the outlet gas stream. All separators must be provided with drain valves to remove collected liquid. For maximum efficiency, moisture separators should be installed in a straight length of pipe at least 10 pipe diameters downstream of the nearest valve or fitting and should be drained regularly during operation. All moisture separators shall be visually and hydrostatically tested every three years or in accordance with PMS requirements.

1-3.15.4.2. Dehumidifiers.

The air purification system should provide a means of removing water vapor from the breathing air. Dehumidification is accomplished through the use of a desiccant or refrigeration. If installed in a high pressure air charging system, the dehumidifier should bring the dew point down to –40°F and provide a visual indication that the dehumidifier is working properly.

1-3.15.4.3. Filters/Cartridges.

Compressor outlet filters are to be located downstream of the moisture separator and backpressure regulator and upstream of the rest of the system. For compressors equipped with filtration tower (air purification) packages, the filtration tower shall be installed upstream of the backpressure regulator and the rest of the system. Only filters listed on the ANU list shall be used unless specifically authorized by NAVSEA. All air or gas shall be filtered before reaching the diver or occupants. Bypass piping around filters is not permitted. Depending on system design, additional particulate filters may be required to protect sensitive system components.

Although not a NAVSEA requirement, air purification systems on compressors for portable and afloat systems are strongly recommended. Only purification systems listed in NAVSEA Letter 10560 Ser 00C/3112 of 15 May 1997 shall be used unless specifically exempted by NAVSEA. The design of the purification system shall prevent the possibility of operating the system without properly installed purification cartridges. An electronic purification monitor with warning light indicator, which activates prior to cartridge exhaustion and automatically shuts down the compressor when the cartridge is exhausted, shall be provided.

1-3.15.4.4. Particulate/Oil Mist.

No more than 0.005 mg/l of oil, mist, and particulates are permitted to be delivered by the compressor.

1-3.15.4.5. Carbon Monoxide (CO) and Hydrocarbon Removal.

See 1-3.6.5.1. For CO and hydrocarbon limit in breathing air, see Table 2.

1-3.16. NAVAL ARCHITECTURE DESIGN

The naval architectural requirements that the Program Manager shall consider as a minimum are: static and dynamic stability, both transverse and longitudinal; the conditions of list and trim; the strength of the Diving System; and the dynamic consideration of stability and motion of the Diving System in a seaway.

1-3.16.1. Stability and Equilibrium

The Designer shall demonstrate, where applicable, both by calculation and by tests, that a Diving System has adequate static and dynamic stability under the various loadings and conditions encompassed by the design (e.g., surfaced, submerged, and all possible emergency surfacing conditions). Any limiting conditions for sea state, winds, temperatures, water density variations, and so forth, must be identified. Extreme loading conditions and the resulting stability shall also be analyzed. For example, some Diving Systems jettison relatively large weights to achieve buoyancy in an emergency. There is an attendant risk that significant weights might be jettisoned inadvertently while performing normal operations. The Designer must show that the safety of Diving System personnel would not be jeopardized under these conditions. Detailed information on the criteria for stability and reserve buoyancy must be furnished to operating personnel to permit proper control of loading and to avoid danger of capsizing or foundering in heavy seas or swells. The Designer shall also demonstrate that the Diving System is adequate to withstand such factors as wave slap and that the strength of the structure of the Diving System is adequate in the surfaced condition. Protection shall be provided against foundering.

a. If the Diving System is manned while being handled it must remain stable while being removed from the sea to its cradled position aboard ship or on another platform. The Designer must demonstrate that the Diving System and its handling system are capable of passing through the sea/air interface without damage to the Diving System or its occupants.

b. The Designer shall identify the systems and components that provide any necessary stability and buoyancy for the Diving System under operating conditions. A failure analysis will be provided by the Designer to address the consequences of a failure or loss of displacement by any of the systems and buoyancy components. The adequacy of specific materials must be justified as discussed in section 1-3.8.

c. Some Diving Systems (e.g., tethered submersibles, saturation diving systems) are operated while either permanently or temporarily mounted on a surface platform. In these cases, the surface platform shall provide sufficient stability so that the divers or occupants, while in the water, shall not be endangered because support personnel on the surface are unable to provide vital functions in a seaway.

d. The Designer must show that the structural strength of the Diving System in a seaway does not endanger the safety of personnel. A Diving System may also operate in close proximity to the ocean bottom. This means that there will be a hazard of striking objects, grounding, or even deliberate bottoming. There is also the hazard of bumping against or colliding with the surface support ship. The Designer must show that a Diving System can withstand such incidents or demonstrate that sufficient precautions can be taken to avoid such situations.

1-3.16.1.1. Inclining Experiments and Trim Dives for Submersibles and Submerged Habitats

See 2-9.18 for requirements.

1-3.16.2. Additional Conditions

The Designer must demonstrate the adequacy of all unique conditions of the candidate Diving System. Any unique condition, such as mating a Diving System to a deck decompression chamber, must be capable of being performed under all sea state conditions specified by the Government Procurement Representative without endangering the embarked personnel. If the Diving System is to be secured to a host ship or other platform it must be designed to have adequate attachment capability to withstand the sea state conditions specified by the Government Procurement Representative.

1-3.17. ENVIRONMENTAL CONSIDERATIONS

1-3.17.1. Exposure to Marine Conditions

1-3.17.2. System Arrangement and Layout.

The layout of the diving system shall ensure protection from incidental damage and personnel hazards and allow accessibility for safe operation, maintenance, and inspection. The diving system should be located in a safe area with respect to fire, explosion, weather and sea state. The diving system shall be located so that diving operations will not be affected by support platform propulsion or mooring.

1-3.17.3. Stability and Buoyancy.

The Designer shall demonstrate, where applicable, both by calculation and by tests, that a diving system has adequate static and dynamic stability under the various loadings and conditions encompassed by the design (e.g., surfaced, submerged, and all possible emergency surfacing conditions). The Designer shall also identify any limiting conditions of sea state, current, winds, temperatures, water density variations, and so forth. Extreme loading conditions and the resulting stability shall also be analyzed. For example, some diving systems jettison relatively large weights to achieve buoyancy in an emergency. There is an attendant risk that significant weights might be jettisoned inadvertently while performing normal operations. The Designer shall show that the diving system has adequate stability under these conditions also.

The criteria of adequate stability and reserve buoyancy must be furnished to operating personnel to permit proper control of loading and to avoid capsizing or foundering in heavy seas or swells. Where applicable, the diving system must remain stable while being removed from the sea to its moored condition onboard support platform. The Designer shall demonstrate that the diving system and its handling system are capable of passing through the sea/air interface without damage to the diving system or its occupants (see 1-4.4.1).

The Designer shall identify the systems and components providing any necessary stability and buoyancy for the diving system under operating conditions. An analysis of the consequences of a failure or loss of displacement by any of the buoyancy components shall be included (see 1-2.4.2).

Some diving systems are operated while either permanently or temporarily mounted on a surface support platform (e.g., Surface Supported Diving Systems). In such cases, the surface platform shall provide sufficient stability so that the divers or occupants, while in the water, shall not be endangered because support personnel on the surface are unable to provide vital functions. The Designer shall show that the structural strength of certain diving systems in a seaway does not endanger the safety of personnel.

A diving system may operate in close proximity to the ocean bottom. This means there is the possibility of striking objects, grounding, or even deliberate bottoming. There is also the possibility of bumping against or colliding with the surface support platform during launch and recovery. The Designer shall either show that the diving system can withstand such incidents or demonstrate that sufficient precautions can be taken to avoid such situations.

Any unique conditions, such as mating a personnel transfer capsule to a deck decompression chamber, must be capable of being performed under all sea state conditions specified by the Navy without endangering the divers/operating personnel. If the diving system is to be secured to a support platform it must be designed to have adequate attachment capability to withstand the sea state condition specified.

1-3.17.4. Loading on At-Sea Systems

Diving support platform or submersible motion in a seaway includes roll, pitch, yaw, surge, sway and heave. Diving support platform or submersible attitude caused by loading, wind, or control surface forces includes list, trim, and heel. Diving support platform or submersible motion and ship attitude generate forces which are both static and dynamic in nature and exert a cumulative effect in terms of gravitational and dynamic acceleration. Dynamic effects vary depending upon the location in the diving support platform or submersible and increase with distance from the diving support platform or submersible motion axes. Static effects such as permanent list are uniform throughout the diving support platform or submersible.

These forces must be considered in their combined “worst-case”’ value and applied to the design of the diving systems so that diving system structure, appurtenances, systems or equipment will perform in accordance with design requirements when exposed to such conditions. The Designer should refer to DOD-STD-1399 (Section 301A) for guidance in determining loading factors and overall design limits.

1-3.17.4.1. Sea State.

Sea State is a measurement of severity of sea conditions which include wave height, period, and energy distribution with wave frequency and direction. Sea conditions generate ship motions producing dynamic forces. These dynamic forces depend on ship motion amplitudes and periods that depend upon the support platform’s responsiveness to the characteristics of the seaway.

The Designer must show that the diving system is safe for operation and emergency egress under the specified operating and survivability sea states. The Designer shall also demonstrate that the diving system is adequate to withstand such forces as wave slap and that the strength of the structure of the diving system is adequate in the surfaced condition. The system shall be designed to operate in specified sea state. The Designer shall show that the diving system is safe for emergency egress under these conditions. The Sea State definitions found in DOD-STD-1399 (Section 301A) are shown below in Table 13 and shall be used:

Table 13: Sea State Definitions

Sea State	Significant Wave Height
3	0.1 – 0.5 m (0.3 – 1.6 ft)
4	1.25 – 2.5 m (4.1 – 8.2 ft)
5	2.5 – 4.0 m (8.2 – 13.1 ft)
6	4.0 – 6.0 m (13.1 – 19.7 ft)
7	6.0 – 9.0 m (19.7 – 29.5 ft)

1-3.17.4.2. Survivability.

Survivability refers to a system in a sea state that is more severe than the sea states in which the system is intended to operate. After sea conditions subside, mission essential systems should be serviceable and the diving system is capable of continuing operations without returning to port for repairs.

1-3.17.4.3. Wave Slap.

All supporting structures and foundations, directly mounted to a ship's deck and exposed directly to the waves, shall be designed to withstand a wave slap loading of 500 pounds per square foot. Structures not directly deck mounted or not directly exposed to the waves, including control and auxiliary equipment vans, external doors, panels, and appurtenances, shall be designed to withstand wave slap loads of 200 pounds per square foot. All equipment exposed to the air/water interface shall be designed to withstand a wave slap loading of 1000 pounds per square foot.

1-3.17.4.4. Ships Motion.

Unless otherwise specified, the diving system shall be capable of operating under the following conditions:

a. When the support platform is permanently trimmed down by the bow or stern as much as 5 degrees from the normal horizontal plane.

b. When the support platform is permanently listed up to 15 degrees from normal vertical plane.

c. When the support platform is pitching 10 degrees up or down from its normal horizontal plane.

d. When the support platform is rolling up to 45 degrees to either side of the vertical plane.

1-3.17.4.5. Inclining Experiments and Trim Dives for Submersible Components.

If the diving system is of such complex geometry that reliable curves of form cannot be readily calculated, air, surface, and submerged inclining experiments must be performed. Where the curves of form, or the pre-calculated form characteristics are available, only the surface and submerged inclining experiments are required. In addition, a trim dive is necessary to determine the proper weight and location of ballast, both permanent and variable, that will permit the system to operate under the design conditions of loading.

1-3.18. TRANSPORTABILITY.

The Designer shall demonstrate, through the use of appropriate design calculations, that the diving system meets transportability requirements, including the types of trucks, cargo aircraft and vessels of opportunity to be used as specified in the system performance specification. At a minimum, portable diving systems should meet the following specification for the desired modes of transportability:

a. The diving system shall be designed and equipped to provide all necessary handling and shipping equipment, rigging, and mechanisms necessary to interface with air and ground transports and associated ground handling equipment.

b. Sea Transportation. The diving system must be configured for shipping by either containerizing or by direct attachment or tie down to the deck. The system in the transport mode should meet the requirements of 1-3.17.4, 1-3.17.4.1, 1-3.17.4.3, and 1-3.17.4.4 when exposed to the environmental conditions.

c. Ground transportation. The diving system must be capable of being re-configured, into modules sized for shipping by U.S. over-the-road truck transport without the need for special permits or routes on public roads rated for truck transport in accordance with Title 23, Code of Federal Regulations, Part 658, Truck Size and Weight Regulation.

d. Air Transportation. The diving system must be capable of being re-configured to air transport pallets or other suitable means compatible with the U.S. Air Force 463L Air Cargo System using MIL-HDBK-1791 for guidance. All gas storage flasks (storage vessels) requiring pressurization during transport shall be designed and fabricated to permit gas cylinders to be flown while charged in accordance with the Department of Transportation under Title 49, Code of Federal Regulations, Part 171-180 and using MIL-HDBK-1791 for guidance. The diving system and its components as well as the aircraft itself shall not be damaged, nor shall subsequent operational performance be degraded as a result of being subjected to the following loads applied independently when in the Transport Mode:

(1) Forward 3.0 g

(2) Aft 1.5 g

(3) Lateral 1.5 g

(4) Up 2.0 g

(5) Down 4.5 g

e. Transport Vibration. The diving system shall be designed to withstand vibration loading as shown in Figures 514.5C-1, US Highway Truck; 514.5C-6, Jet Aircraft Cargo; and 514.5C-15, Shipboard Random, of MIL-STD-810F.

1-4. DESIGN REQUIREMENTS FOR SPECIFIC SYSTEM TYPES

1-4.1. SURFACE SUPPLIED DIVING SYSTEMS (SSDS)

Surface supplied diving systems are designed to provide air and/or mixed gas from a gas source above the water surface via an umbilical to a diver in the water column. The Government Procurement Representative should provide the designer with the depth/time profile for the worst-case dive that the system will be used to support, the number of divers, and the UBA to be utilized. If this information is not provided or if additional information is required, the Designer shall request the information, in writing, from the Government Procurement Representative.

1-4.1.1. Gas Supply Requirements (Air System)

The diver's air supply may originate from an air compressor, a bank of high-pressure air flasks, or a combination of both.

1-4.1.1.1. Requirements for Air Supply

Regardless of the source, the air must meet certain established standards of purity, must be supplied in an adequate volume for breathing, and must have a rate of flow that properly ventilates the helmet or mask. The air must also be provided at sufficient pressure to overcome the bottom water pressure at the maximum depth of the system (over bottom pressure) and the pressure losses due to flow through the diving hose and system piping. The air supply requirements depend upon specific factors of each dive such as depth, duration, level of work, number of divers being supported, and type of diving system being used.

1-4.1.1.1.1. Air Purity Standards

See 1-3.6.4

1-4.1.1.1.2. Air Supply Pressure and Flow Requirements

Different Underwater Breathing Apparatus (UBAs) require different flow rates and overbottom pressures. The open-circuit air supply system must have a flow capacity (in ACFM) that provides sufficient ventilation at depth to maintain acceptable carbon dioxide levels in the mask or helmet. Carbon dioxide levels must be kept within safe limits during normal work, heavy work, and emergencies. In order to supply the diver with an adequate flow of air, the air source must deliver air at sufficient pressure to overcome the bottom seawater pressure and the pressure drop that is introduced as the air flows through the hoses and valves of the system.

It is imperative that the Designer know what UBA(s) the SSDS is to be designed to operate with. The current USN UBAs, their flow, and overbottom pressure requirements are shown in Table 14. If another UBA is to be used with the SSDS, it is the responsibility of the Designer to ensure that the flow rate and pressure requirements are met.

Table 14: UBA Flow and Overbottom Pressure Requirements

UBA	Flow Requirement	Overbottom Pressure
MK 21 MOD 0	1.4 ACFM average sustained flow	0-130 FSW - 135-165 psig 131-190 FSW - 165 psig
MK 20 MOD 0	1.4 ACFM	90 psig (all depths)
EXO BR MS	1.4 ACFM	0-130 FSW - 135-165 psig 131-190 FSW - 165-225 psig

1-4.1.1.1.3. Water Vapor Control

The air supplied to the diver shall not reach it's dewpoint. Controlling the amount of water vapor (humidity) in the supplied air is normally accomplished by: moisture separators, dehydrators, and drying towers in a filtration package.

1-4.1.1.1.4. Standby Diver Air Requirements

Air supply requirements cannot be based solely on the calculated continuing needs of the divers who are initially engaged in the operation. There must be an adequate reserve to support a standby diver should one be needed. The primary and secondary air requirements (pressure, flow, and volume) for the standby diver are the same as those for the other divers.

1-4.1.1.1.5. Primary and Secondary Air Supply

All surface-supplied diving systems must include independent primary and secondary air supplies. The primary supply must be able to support the air flow and pressure requirements for the diving equipment to be used during the most demanding scenario. The capacity of the primary supply must meet the consumption rate of the designated number of divers for the full duration of the dive (bottom time plus decompression time). The maximum depth of the dive, the number of divers, and the equipment to be used must be taken into account when sizing the supply.

The secondary supply must be sized to be able to support recovery of all divers (including the standby) using the equipment and dive profile of the primary supply if the primary supply sustains a casualty at the worst-case time (for example, immediately prior to completion of planned bottom time of maximum dive depth, when decompression obligation is greatest). Primary and secondary supplies may be either high-pressure (HP) bank-supplied or compressor-supplied.

1-4.1.2. Mixed Gas Surface Supplied Diving System Requirements

For surface-supplied mixed gas diving, the diver gas supply system shall be designed so that helium-oxygen, nitrogen-oxygen, oxygen, or air can be supplied to the divers as required. All surface-supplied mixed-gas diving systems require a primary and secondary source of breathing medium consisting of helium-oxygen and oxygen in cylinder banks and an emergency supply of air from compressors or high-pressure flasks. Each system must be able to support the gas flow and pressure requirements of the specified equipment. The gas capacity of the primary system must meet the consumption rate of the designated number of divers for the duration of the dive. The secondary system must be able to support recovery operations of all divers and equipment if the primary system fails. This may occur immediately prior to completing the planned bottom time at maximum depth when decompression obligations are the greatest. An emergency air supply shall be provided in the event that all mixed-gas supplies are lost.

1-4.2. RECOMPRESSION CHAMBER

1-4.2.1. General

All recompression chambers shall be designed and built in accordance with ASME PVHO-1 and this specification.

1-4.2.2. Gas Supply

1-4.2.2.1. Pressurization and Ventilation Rate Requirements

Recompression chambers designed for use in non-saturation diving shall be capable of delivering enough gas to pressurize the main lock to 50 FSW in 30 seconds or less, 100 FSW in 1 minute or less, and 165 FSW in 8 minutes or less.

Pressurization and ventilation rates for chambers used in saturation diving are specified in 1-4.3.7.

1-4.2.2.2. Air Storage

A recompression chamber system must have separate primary and secondary air supply systems that satisfy Table 15. The purpose of this requirement is to ensure that the recompression chamber system at a minimum, is capable of conducting a USN Treatment Table 6A (TT6A) with all authorized extensions (see NASEA SS521-AG-PRO-010, U.S. Navy Dive Manual for information on treatment tables). If the system is to be used for a more extensive or rigorous treatment protocol, the Designer shall request that the Government Procurement Representative provide the most demanding treatment protocol that the system is to be designed for. Calculations shall be provided to the Government

Procurement Representative that clearly explain the rationale used in determining the required air volumes.

The basic rules for ventilation are presented below. These rules permit rapid computation of the cubic feet of air per minute (ACFM) required under different conditions as measured at chamber pressure (the rules are designed to ensure that the effective concentration of carbon dioxide will not exceed 1.5 percent (11.4 mmHg) and that when oxygen is being used, the percentage of oxygen in the chamber will not exceed 25 percent).

a. When air is breathed, provide 2 ACFM for each diver at rest and 4 ACFM for each diver who is not at rest (i.e., a tender actively taking care of a patient).

b. When oxygen is breathed from the built-in-breathing-system (BIBS), provide 12.5 ACFM for a diver at rest and 25 ACFM for a diver who is not at rest. When these ventilation rates are used, no additional ventilation is required for personnel breathing air. These ventilation rates only apply to the number of people breathing oxygen and are used only when no BIBS dump system is installed.

c. If a BIBS dump system is used for oxygen breathing, the ventilation rate for air breathing may be used.

d. If portable or installed oxygen and carbon dioxide monitoring systems are available, ventilation may be adjusted to maintain the oxygen level below 25 percent by volume and the carbon dioxide level below 1.5 percent surface equivalent (SEV).

e. These rules assume that there is good circulation of air in the chamber during ventilation. If circulation is poor, the rules may be inadequate. It is the responsibility of the Designer to ensure that ventilation of the chamber is adequate. Locating the inlet near one end of the chamber and the outlet near the other end improves ventilation.

Table 15: Recompression Chamber Air Supply Requirements

Recompression Chamber Configuration	Primary Air Requirement	Secondary Air Requirement
CATEGORY A: No BIBS overboard dump No CO_2 Scrubber No Air BIBS No O_2 and CO_2 monitor	Sufficient air to press the IL once and the OL twice to 165 FSW and vent during one TT6A for one tender and two patients with maximum extensions.	Sufficient air to press the IL and OL once to 165 FSW and vent for one hour at 70.4 SCFM.
CATEGORY B: BIBS overboard dump No CO_2 Scrubber No Air BIBS O_2 and CO_2 monitors	Sufficient air to press the IL once and the OL twice to 165 FSW and vent for CO_2 during one TT6A for one tender and two patients with maximum extensions.	Sufficient air to pressurize the IL and OL once to 165 FSW and vent for one hour at 70.4 SCFM.
CATEGORY C: BIBS overboard dump CO_2 Scrubber No Air BIBS O_2 and CO_2 monitors	Sufficient air to press the IL once and the OL twice to 165 FSW.	Sufficient air to press the IL and OL once to 165 FSW and vent for one hour at 70.4 SCFM.
CATEGORY D: BIBS overboard dump CO_2 Scrubber Air BIBS O_2 and CO_2 monitors	Sufficient air to press the IL once and the OL twice to 165 FSW.	Sufficient air to press the IL and OL once to 165 FSW and enough air for one tender and two patients (when not on O_2) to breathe air BIBS during one TT6A with maximum extensions.
CATEGORY E: BIBS overboard dump CO_2 Scrubber No Air BIBS O_2 and CO_2 monitors Spare CO_2 scrubber Secondary power supply NITROX BIBS	Sufficient air to press the IL once and the OL twice to 165 FSW.	Sufficient air to press the IL and OL once to 165 FSW and enough air/NITROX for one tender and two patients (when not on O_2) to breathe air/NITROX BIBS during one TT6A with maximum extensions.

Notes:
1) For chambers used to conduct surface decompression, sufficient air is required to conduct a TT6A in addition to any planned surface decompression.
2) For systems that employ air driven CO_2 scrubbers, enough additional air must be included to power the scrubber.

1-4.2.2.3. Oxygen Storage

See paragraph 1-3.6.5.3.

1-4.3. SATURATION DIVING SYSTEM

The configuration and the specific equipment composing a deep diving system vary greatly based primarily on the type of mission for which it is designed. Modern systems, however, have similar major components that perform the same functions despite their actual complexity. Major components are listed below:

a. Personnel Transfer Capsule (PTC)/Diving Bell. The PTC is a tethered spherical, submersible pressure vessel that can transfer divers in full diving dress, along with work tools and associated operating equipment, from the deck of the surface platform to their designated working depth.

b. Deck Decompression Chamber (DDC). The DDC furnishes a dry environment for accomplishing decompression and, if necessary, recompression therapy. The DDC is a multi-compartment, horizontal pressure vessel that is mounted on the surface-support platform. Each DDC is equipped with living, sanitary, and resting facilities for the dive team. A service lock provides for the passage of food, medical supplies, and other articles between the diving crew inside the chamber and topside support personnel.

c. PTC Handling System. The handling system is used to launch and recover the PTC during operations.

1-4.3.1. Systems Engineering

1-4.3.1.1. Reliability, Maintainability, and Availability (RM&A)

Performance requirements for RM&A are outlined in Table 16:

Table 16: RM&A Performance Requirements

Parameter	Objective/Desirable	Threshold/Minimum	Requirement
Reliability ($MTBMOF_{SYS}$)[1]	720 Hours	720 Hours	MIL-HDBK-470A
Maintainability MTTR[2] MTBM[3]	 4 Hours 24 Hours	 6 Hours 12 Hours	MIL-HDBK-470A
Availability (A_o)[4]	85%	75%	MIL-HDBK-470A

[1] $MTBMOF_{SYS}$ (Mean Time Between Mission Operational Failure - System)
[2] MTTR (Mean Time To Repair) Corrective time to restore function.
[3] MTBM (Mean Time Between Maintenance) Addresses all corrective and preventative maintenance
[4] A_o (Operational Availability) = MTBM/(MTBM + MDT) and represents the probability of the system being available for an operational mission upon official tasking. MDT (Mean Downtime) MDT includes MTTR and all other time involved with downtime, such as delays. A_o takes into account the inherent design of the system, the availability of maintenance personnel and spares, maintenance policy and concepts, and other non-design factors.

1-4.3.1.2. Interoperability

Provide capability to supply high-pressure oxygen and bottom mix to the FMGS control console and/or charging of the Oxygen Supply Rack Assembly (OSRA) or Helium Oxygen Supply Rack Assembly (HOSRA). The FMGS must be diving to the same depth as the saturation diving system (i.e., no deeper than 300 fsw).

1-4.3.1.3. Human Factors Engineering

a. Human engineering design will be integral to the design process using guidance provided in MIL-STD-1472.

b. Design of the man-machine and operator-system interfaces should be based on the 5th and 95th percentile physical attributes identified in NSMRL Report 83-03, Anthropometric Indices Among U.S. Navy Divers.

c. Particular attention shall be given to accessibility of equipment, controls and monitors by the diving system operator. Personnel positioning shall be considered to minimize discomfort and permit adequate visual and physical identification of controls and equipment under emergency conditions.

1-4.3.1.4. System Safety

The deck decompression chamber will comply with all applicable safety requirements of:

(1) ASME PVHO-1-2002 Safety Standard for Pressure Vessels for Human Occupancy

(2) DNV-OS-E402 Offshore Standard for Diving Systems

(3) DNV Certification Notes No.2.7-2 Offshore Service Containers

(4) International Marine Contractors Association/Association of Offshore Diving Contractors IMCA/AODC-035 Code of Practice for the Safe Use of Electricity Under Water

(5) MIL-STD-1472, Human Engineering, paragraph 5.13

(6) National Fire Protection Association NFPA 99-2002 Health Care Facilities Handbook

(7) NAVSEA SS521-AA-MAN-010 U.S. Navy Diving and Manned Hyperbaric Systems Safety Certification Manual, Revision 1

(8) NAVSEA SS521-AG-PRO-010 U.S. Navy Diving Manual, Revision 4, Change A

(9) This document

At a minimum, all applicable safety requirements of NAVSEA SS521-AA-MAN-010 U.S. Navy Diving and Manned Hyperbaric Systems Safety Certification Manual, Revision 1 shall be met or exceeded.

1-4.3.2. Design Parameters

a. Performance requirements for design parameters are outlined in Table 17:

Table 17: Environmental (External) Design Parameters

Parameter	Objective/Desirable	Threshold/Minimum	Requirement
Sea State[(1)]:			
Operational	6	5	
Launch	4	4	
Recovery	5	4	
Survivability[(2)]	7	6	
Air Temperature[(3)]			
Operating			
Max.	120°F (48.9°C)	100°F (37.8°C)	
Min.	0°F (-17.8°C)	0°F (-17.8°C)	
Non-operating			
Max.	150°F (65.6°C)	130°F (54.4°C)	
Min.	0°F (-17.8°C)	0°F (-17.8°C)	
Water Temperature[(3)]			
Max.	88°F (31.1°C)	82°F (27.8°C)	
Min.	28°F (-2.2°C)	29°F (-1.6°C)	
Maximum U/W Current:	2.5 knots (1.29 m/sec)	2.0 knots (1.03 m/sec)	

[(1)] Sea States based on DOD STD 1399, Interface Standard For Shipboard Systems, Section 301A, Ship Motion And Attitude for a VOO defined as: Length Between Perpendiculars (LBP) = 64.4m (211.3 ft), Beam (B) = 18m (59 ft), Draft (D) = 6m (19.7ft), Displacement = 5390 metric tonnes (t) (5305 long tons), Metacentric Height (GM) = 1.63 m (5.34 ft), Roll Period (T_{roll}) = 10.8 seconds.
[(2)] Survivability refers to a system in sea conditions that are more severe than those in which various subsystems are operational. After sea conditions subside, personnel are not seriously injured and mission essential subsystems are without serious damage and are capable of continuing operations without returning to port for repairs.
[(3)] Based on operations between latitudes 60°N and 60°S. Source from US Navy Marine Climate Atlas of the World Version 1.1 August 1995.

b. Lockout diver excursion limits within NAVSEA SS521-AG-PRO-010 Table 15-7 and Table 15-8 or diver reclaim system limitations, which ever is less.

c. Lockout diver depth limits within diver reclaim system limitations.

d. Physiological factors used in design calculation shall be based on the assumptions in Table 18.

Table 18: Physiological Factors

Physiological Factor	Design Assumption	Source
Oxygen Consumption and CO_2 Production	In DDC RMV: 12.0 lpm (average rest) O_2 consumption: 0.48 slpm CO_2 production: 0.44 slpm In Bell# RMV: 22.5 lpm (light work) O_2 consumption: 0.90 slpm CO_2 production: 0.81 slpm Primary Diver# RMV: 45.0 lpm (heavy work) O_2 consumption: 1.80 slpm CO_2 production: 1.62 slpm Standby Diver# RMV: 62.5 lpm (severe work) O_2 consumption: 2.50 slpm CO_2 production: 2.25 slpm	USN Diving Manual Figure 3-6 and paragraph 3-4.8/USN Diving Gas Manual/Draft General Spec for Design, Construction & Repair of Diving and Hyperbaric Equipment
Water Vapor Produced	4 lb per day	ABS Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities, Section 8, 5.3
Heat Output	Latent - 220 BTU per hour Sensible - 250 BTU per hour	ABS Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities, Section 8, 5.3

e. Design calculations are based on the following definitions:

- Respiratory quotation for CO_2 to O_2 = 0.9.
- Slpm = liters per minute at standard temperature (0°C), standard pressure (760 mm Hg absolute).
- Average rest = sleeping, sitting, standing, normal housekeeping activities.
- Light work = bell load-out, bell checks, diver deployment and recovery.
- Heavy work = normal underwater work activities
- Severe = assistance and recovery of a fouled, injured, or unconscious diver
- Pressure equivalent to depth of seawater at 32°F (0°C) with 3.5% salinity may be taken as 1.006 bar or 1 atm (14.7 psi) per 33 fsw (10 msw) as a mean value between 0-1000 fsw (304 msw).

1-4.3.3. Command & Control

1-4.3.3.1. Control & Monitoring

a. The system shall provide safe and efficient management of all critical system parameters including depth control, DDC and diving bell LSS, gas handling systems, handling system, power systems, and auxiliary systems. Instrumentation used for measuring pressure shall have an accuracy of 1 percent (1%) of full-scale value.

b. Monitor and control depth of DDC LC and OL, diving bell interior and exterior, and lock-out divers and standby diver. Depth indication accuracy shall be ¼ of a percent (0.25%) of full scale value.

c. The system shall provide operators/supervisors with the ability to manage all critical functions from a centralized station protected from the external environment.

d. Primary remote control station shall be provided with a local secondary control for critical systems.

e. The system shall provide operators/supervisors with warning/alarms of out-of-parameter indications/readings/conditions.

f. The system must provide interface between control van and the VOO Bridge to coordinate and monitor critical system and VOO functions specifically emergency conditions such as loss of electrical power, fire, collision, flooding, or loss of mooring/DP.

1-4.3.3.2. Communications

1-4.3.3.2.1. Audio

a. The communication systems shall provide intelligible communication between all critical control locations including the VOO Bridge and Nav and/or DP stations and within the DDC compartments and diving bell.

b. The communication systems shall provide intelligible two-way communications between bell/diver control station in control van and the lockout/standby divers as well as diver-to-diver.

c. Primary and secondary means of communication shall be provided for all critical communication functions. If hardwired, the primary and secondary systems shall be in separate deck cables.

d. The system shall facilitate audio recording of critical operations such as bell handling operations, bell and lock-out/standby divers deployment, and DDC operations.

e. A stand-alone system shall facilitate emergency through-water communication to the bell. (DNV-OS-E402, Section 5, D304)

1-4.3.3.2.2. Video

a. The control van operators/supervisors shall be able to monitor all critical areas of the system from their control stations. (DNV-OS-E402, Section 5, D201 & D202)

b. Areas to be covered shall include as a minimum:
    - DDC interior compartment
    - Diving bell interior
    - Mating trunk
    - Handling operations
    - Diver operations

c. The system shall provide capability to send video to VOO control stations.

d. Video recording capability shall be provided for mission documentation and accident investigation

1-4.3.4. Power Systems

a. Design of electrical power system shall be in accordance with applicable sections of the following recognized codes and standards:
    - IEEE-45 Recommended Practice for Electrical Installations on Shipboard, dated September 2002.

- IEEE- 1580 Recommended Practice for Marine Cable for Use on Shipboard and Fixed or Floating Platforms dated June 2001.
- Det Norske Veritas DNV OS E402, Offshore Standard for Diving Systems, dated January 2001.
- IMCA/AODC-035 Code of Practice for the Safe Use of Electricity Under Water
- IMCA D 002, Guidance Note for Battery Packs in Pressure Housings
- ABS Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities, Section 11 Electrical Installations
- National Fire Protection Association, Health Care Facilities Handbook -NFPA 99-2002
- NAVSEA SS521-AA-MAN-10, U.S. Navy Diving and Manned Hyperbaric Systems Safety Certification Manual

b. Power system supplying essential services related to divers and/or the diving system shall be supplied from a normal and an emergency source of power, via an isolated power distribution system. (DNV-OS-E402, Sec 5, B201)

c. The independent AC and DC emergency power sources (uninterruptible power source) shall be capable of feeding the following critical services (DNV-OS-E402, Sec 5, B202):
   - Emergency lighting
   - Emergency communications
   - Emergency life support systems
   - Emergency heating system
   - Environmental monitoring system
   - Controls/Alarms for emergency systems
   - Emergency handling of the bell/divers

1-4.3.5. Life Support

1-4.3.5.1. PVHO

a. All pressure vessels for human occupancy (PVHO) will be designed, fabricated and tested in accordance with requirements meeting one of the following:
   - ASME PVHO-1 using ASME VIII Boiler and Pressure Vessel Code Division 1 and ASME Pressure Piping Code B31.1
   - ABS Rules for Building and Classing Steel Vessels Part 4, Chapter 4 and Underwater Vehicles, Systems, and Hyperbaric Facilities Section 6.
   - DNV Offshore Standard for Diving Systems DNV-OS-E402 Section 3 using ASME VIII Boiler and Pressure Vessel Code Division 1 or EN-13445 European Standard for Unfired Pressure Vessels applying Pressure Equipment Directive (PED) 97/23/EC using category 4 or PD5500 British Standard for Unfired Fusion Welded Pressure Vessels.

b. DDC must be capable of reaching the divers' maximum excursion depth in case of decompression sickness during upward excursion to start decompression (SS521-AG-PRO-010 paragraph 15-23.8.2) or other emergency.

1-4.3.5.2. Environmental Control

System must be capable of maintaining DDC within limits of SS521-AG-PRO-010, Chapters 15 & 21. DDC environmental control system shall have sufficient circulation to ensure a homogenous gas content (DNV-OS-E402, Section 4, F501).

1-4.3.5.2.1. Temperature Control

Temperature must be maintained below 85°F for an air atmosphere (SS521-AG-PRO-010, 21-5.6.5) and 85°F to 93°F in a helium-oxygen (HeO_2) atmosphere at depth (SS521-AG-PRO-010, 15-16)

1-4.3.5.2.1.1. DDC Living Compartment (LC) and Outer Lock (OL) Temperature Control

a. Cooling capacity must meet the following criteria for full occupancy (six divers) at light work:
- Human, internal equipment, radiant, convective, and conductive loads must be accounted for.
- Maintain 75°F (23.8°C) internal atmosphere (air) temperature at 70% relative humidity (RH) with ambient temperature of 110°F (43.3°C) with compartment at the surface.
- Maintain 75°F (23.8°C) internal atmosphere (79% He/21% O_2) temperature at 70% relative humidity (RH) with ambient temperature of 110°F (43.3°C) with compartment at the surface.
- Maintain 85°F (29.4°C) internal atmosphere (98% He/2% O_2) temperature at 70% relative humidity (RH) with ambient temperature of 110°F (43.3°C) with compartment at 1,000 fsw.

b. Heating must meet the following criteria:
- Radiant, convective, and conductive loads must be accounted for.
- Loads associated with reheating gas subsequent to passing over condensing coils (for moisture removal) must be accounted for.
- Human and internal equipment heat sources should not be considered to offset required heating.
- Maintain 75°F (23.8°C) internal atmosphere (air) temperature at 70% relative humidity (RH) with ambient temperature of 0°F (-17.8°C) with compartment at the surface.
- Maintain 75°F (23.8°C) internal atmosphere (79% He/21% O_2) temperature at 70% relative humidity (RH) with ambient temperature of 0°F (-17.8°C) with compartment at the surface.
- Maintain 93°F (33.9°C) internal atmosphere (98% He/2% O_2) temperature at 70% relative humidity (RH) with ambient temperature of 0°F (-17.8°C) with compartment at 1,000 fsw.
- Equipment redundancy shall provide adequate thermal protection in event of primary system failure.

1-4.3.5.2.1.2. Diving Bell Temperature Control

Heating must meet the following criteria:

- Radiant and conductive loads must be accounted for.
- Human and internal equipment heat sources should not be considered to offset required heating.
- Maintain 90°F (32.2°C) internal atmosphere (98% He/2% O_2) temperature at 70% relative humidity (RH) with ambient air temperature of 0°F (-17.8°C) with compartment at 1,000 fsw.
- Maintain 90°F (32.2°C) internal atmosphere (98% He/2% O_2) temperature at 70% relative humidity (RH) with ambient water temperature of 29°F (-1.7°C) with compartment at 1,000 fsw.
- Provide a secondary means of thermal protection (active or passive) for 24 hours in the event of primary system failure. (DNV-OS-E402, Section 4, F104)

1-4.3.5.2.2. Humidity Control

System must maintain relative humidity (RH) between 30 – 80% with 50 – 70% being desirable range (SS521-AG-PRO-010 paragraph 15-16).

1-4.3.5.2.2.1. DDC LC Humidity Control

Must be capable of removing physiologically generated moisture load for six divers at light work plus 25%, for providing "pull down" capacity to handle moisture from shower, meals, and wet gear, as well as moisture generated by CO_2 scrubber reaction with the atmosphere at 70% RH.

1-4.3.5.2.2.2. DDC OL Humidity Control

Must be capable of removing physiologically generated moisture load for three divers at light work plus 25%, for providing "pull down" capacity to handle moisture from shower and wet gear, as well as moisture generated by CO_2 scrubber reaction with the atmosphere at 70% RH.

1-4.3.5.2.3. Oxygen Addition

The oxygen addition system must maintain the DDC and diving bell atmosphere PPO_2 between 0.44 – 0.48 ata (SS521-AG-PRO-010 paragraph 15-14).

1-4.3.5.2.3.1. DDC LC and OL Oxygen Addition

- Must be capable of replacing metabolic oxygen consumption for six divers at light work plus losses due to system leakage, losses from supply lock and mating trunk runs, sanitary tank operations, and losses to compartment depressurization while maintaining an atmosphere PPO_2 between 0.44 – 0.48 ata.
- Must provide a primary and secondary means of oxygen addition.

1-4.3.5.2.3.2. Diving Bell Oxygen Addition

- Must be capable of replacing metabolic oxygen consumption for three divers at light work plus losses due to system leakage while maintaining an atmosphere PPO_2 between 0.44 – 0.48 ata.
- Must provide a primary and secondary means of oxygen addition.
- Must be capable of replacing metabolic oxygen consumption for six divers at average rest plus losses due to system leakage during hyperbaric evacuation or loss bell scenario for 24 hours.

1-4.3.5.2.4. Carbon Dioxide CO_2 Removal

1-4.3.5.2.4.1. DDC LC and OL Carbon Dioxide CO_2 Removal

- Must be capable of removing physiological CO_2 production for six divers at light work maintaining $PPCO_2$ below 0.005 ata with time between CO_2 absorbent change-out of at least system MTTR.
- If internal conditioning units are used, CO_2 absorbent canisters must be capable of lock-in/lock-out through the supply lock.
- Must provide primary and secondary CO_2 removal capability.

1-4.3.5.2.4.2. Diving Bell Carbon Dioxide CO_2 Removal

- Must be capable of removing physiological CO_2 production for three divers at light work for 18 man-hours maintaining $PPCO_2$ below 0.005 ata (bell operator/standby diver and two lockout divers 1 hour transfer-descent-deploying lock-out divers and recovery of lock-out divers-ascent-transfer, plus 8 hours for bell operator/standby diver plus 4 hours having a second diver not diving).
- CO_2 absorbent canisters must be capable of lock-in/lock-out through the supply lock.
- Must provide primary and secondary (active or passive) CO_2 removal capability.
- Must be capable of removing physiological CO_2 production for six divers at average rest maintaining $PPCO_2$ below 0.02 ata for 24 hours during a hyperbaric evacuation or loss bell scenario (DNV-OS-E402, Section 4, F603).

1-4.3.5.3. Breathing Gas & Atmosphere Analysis

1-4.3.5.3.1. DDC LC and OL Atmosphere Analysis

- Provide means of analyzing and monitoring atmosphere for temperature, humidity, oxygen (O_2), and carbon dioxide (CO_2).

- An alternate means of analyzing and monitoring atmosphere must be provided, either electronic or mechanical.
- Monitor minimum operating range for O_2 shall be 0 - 2 atm pp O_2 or 0 - 100%; CO_2 shall be 0 – 2% SEV, and humidity shall be 0 – 100%RH.

1-4.3.5.3.2. Diving Bell Atmosphere Analysis

- Provide means of analyzing and monitoring atmosphere for temperature, oxygen (O_2), and carbon dioxide (CO_2).
- Analyzer readouts must display in the bell and in the control van.
- Monitor minimum operating range for O_2 shall be 0 - 2 atm pp O_2 or 0 - 100%, and CO_2 shall be 0 – 2% SEV.
- An alternate means of analyzing and monitoring atmosphere must be provided, either electronic or mechanical in case of hyperbaric evacuation or lost bell scenario.

1-4.3.5.3.3. DDC, Diving Bell, and Lock-out/Standby Diver Breathing Gas Analysis

Provide means of analyzing the following gas sources for oxygen (O_2) and carbon dioxide (CO_2):

- Primary and secondary DDC LC and OL pressurization headers
- Diving bell pressurization header (onboard emergency gas will be checked during pre-dive checks)
- Bell mixed gas header
- Primary and secondary DDC LC and OL emergency gas headers
- Diver breathing gas supply sampled continuously (e.g., from Gasmizer™ processing unit)

1-4.3.5.4. Emergency Breathing System

A Built-In Breathing System (BIBS) will be provided in the DDC LC and OL and in the diving bell to supply primary and secondary emergency breathing gas with a PPO_2 between 0.16 – 1.25 ata to each occupant/diver. (SS521-AG-PRO-010 paragraph 15-14).

1-4.3.5.4.1. DDC LC and OL Built-In Breathing System (BIBS)

- Provide supply of emergency gas and overboard dump of exhalation gas for six occupants plus an additional spare seventh station.
- Provide supply of treatment gas with a PPO_2 between 1.5 – 2.8 ata and overboard dump of exhalation gas for six occupants plus an additional spare seventh station.
- Provide personal BIBS mask assembly for six occupants plus an additional spare mask in the chamber.
- Provide interface for use of U.S. Navy MK-18 Emergency Breathing Apparatus (GFE) for diver in the event of long-term emergency gas breathing such as a contaminated atmosphere.

1-4.3.5.4.2. Diving Bell Built-In Breathing System (BIBS)

Provide personal BIBS mask assembly for three occupants plus an additional spare mask in the bell.

1-4.3.5.5. Diver Thermal Protection

- Provide primary and secondary hot water supply, control and monitoring to interface with thermal protection equipment (hot water suits, SLS backpack and helmet side block and regulator hot water shroud) for all three divers.
- Hot water supply must provide 4 gpm per diver at a maximum of 110°F (43°C). Provide ability to reduce individual hot water supply temperature to each diver by 10°F (5.6°C) to allow for diver comfort.

- Minimum inspired breathing gas temperature shall meet requirements of SS521-AG-PRO-010 Table 15-1 (Minimum inspired breathing gas temperature ranges between 26.4°F (-3.1°C) at 350 fsw to 69.3°F (20.7°C) at 1,000 fsw).

1-4.3.5.6. Diver Breathing Gas Supply & Reclaim

- Provide breathing gas of adequate quantity with PPO_2 between 0.44 – 1.25 ata to two lockout divers at heavy work and a standby diver at severe work.
- Provide interface for two lockout divers to be served by surface supported diver gas recovery system (e.g., Divex Electric Gasmizer™ Diver Gas Recovery System using DSI Superlite 17C helmet outfitted with an Ultraflow 601 Demand Regulator and Jewel 601 Exhaust Valve).
- Provide means of processing, monitoring, and pumping controlled mixture of gas to the divers at depths to 1,000 fsw and reclaiming the exhalation gas with efficiency better than 90%.
- Provide interfaces for standby diver using MK-22 Bandmask.
- Provide means to automatically provide onboard emergency gas source to all divers.

1-4.3.5.7. Survival

- Provide protection for three divers for 24 hours in event of a loss bell scenario or for six divers in event of a hyperbaric evacuation (DNV-OS-E402, Section 4, F202, F601):
- Provide a passive thermal heating system for divers.
- Provide emergency carbon dioxide (CO_2) removal (passive or active).
- Provide drinking water
- Provide an onboard emergency oxygen (O_2) storage and addition system. (DNV-OS-E402, Section 4, B105)

1-4.3.6. Auxiliary Systems

1-4.3.6.1. Fire Safety

1-4.3.6.1.1. Prevention

At a minimum, the following fire prevention measures shall be taken (SS521-AA-MAN-010, 3-2.11 and DNV-OS-E402, Section 6, A300 & B100):

- Container vans shall provide a minimum rating of A-60 protection for personnel and critical LSS equipment from flames and heat radiation.
- Combustible/flammable and toxic material shall be avoided in the construction of container vans and PVHOs as practicable.
- Furnish data establishing the materials and components are nonflammable under the conditions of anticipated use.
- Diving System stationary furniture, such as bunks and chairs, shall be conductive to minimize the possibility of accumulation of a static electrical charge.
- Identification of all potentially toxic and/or flammable materials to be used during construction, or to be installed or used in operating and maintaining the diving system. (Toxic materials may be paints, insulation, adhesives, sealants, gaskets, bedding, clothing, lubricants, equipment, instruments, fittings or other items that could give off noxious fumes at operating pressures and temperatures or at any temperature below 200°F. Flammable materials are those which will ignite or explode from an electric spark or when heated and will continue burning in the presence of air or in any oxygen-enriched atmosphere.)
- Flammable materials shall be evaluated under both normal and emergency atmospheric conditions.

1-4.3.6.1.2. Fire Detection and Alarm System

Provide a fire detection and alarm system meeting the following requirements (DNV-OS-E402, Section 6, C and DNV Certification Note No. 2.7-2):

- An automatic fire detection and alarm system shall be provided for all compartments of container vans and DDC.
- Provisions shall be made for detection of faults in the fire detection and alarm system.
- At a minimum, at least one fire detector is to be located in each compartment of container vans and DDC. A smoke detector is suitable for the control van.
- A manual fire alarm button shall be provided within the container vans and DDC.
- Provisions shall be provided to notify diving system personnel and VOO Bridge of fire alarm system activation as a result of either a fire within the diving system or on the VOO.
- Fire detection and alarm system activation shall automatically shutdown container van mechanical ventilation.

1-4.3.6.1.3. Extinction

- Provide a means of fighting a fire inside the DDC and diving bell while in the fire zone and protect critical equipment and personnel essential for the hyperbaric evacuation of divers in the event of a fire onboard the VOO. (SS521-AG-PRO-010, 22-6.2.6.1 and DNV-OS-E402, Section 6, A400 & D105)
- At a minimum, a portable fire extinguisher meeting requirements of DNV-OS-E402, Section 6, E200, shall be located in each compartment of container vans and DDC. DDC fire extinguishers shall be water type extinguishers.
- Provide fire fighting breathing apparatus for control stations manned during recovery of the diving bell or launching the diving bell during a hyperbaric evacuation. (DNV-OS-E402, Section 6, E100)

1-4.3.6.1.4. Escape Routes

Provide two separate means of escape from each container van compartment where personnel are stationed or in machinery spaces. At a minimum, requirements of DNV Certification Note 2.7-2 must be satisfied.

1-4.3.6.2. Lighting

- Provide DDC LC and OL and diving bell with normal and emergency lighting.
- Provide normal lighting of manned stations and operating areas including machinery spaces with minimum illumination of 325 lux (30 foot-candles).
- Provide emergency lighting of critical/essential control stations and operating areas with a minimum illumination of 30 lux (3 foot-candles).
- PVHO lighting shall be limited to 24 VDC and designed to withstand maximum operating depth.
- Provide diving bell with 360° of exterior lighting below the lower bumper ring.

1-4.3.6.3. Potable Water/Sanitary System

The system must provide facilities for maintaining personal hygiene including showering and removal of metabolic waste, food and wash water waste. Shower and toilet facilities should be located in a compartment separated from the living compartment. As a minimum, the DDC OL will provide the following (DNV-OS-E402, Section 4, I104 and I302):

- Provide hand-washing basin and hand-held showerhead supplied with hot and cold potable water.

- Provide a flush type toilet routed to an external sanitary waste tank with safety interlocks to preclude flushing when in-use or the sanitary waste tank being drained.
- Provisions for a scavenging or cleaning facility to get rid of shower water, bacteria, and odors.
- Provisions for transferring waste from external sanitary waste tank to the VOO waste collection, holding, and transfer (CHT) system.
- Water and sanitary plumbing lines to be used in diving systems shall be designed to function at the maximum operating pressure of the diving system. Flushing systems on toilets shall have appropriate interlocks for safe function while operated under pressure. It is recommended that flushing systems be designed to operate when the diving system is at the surface as well as at depth.
- Information on the deactivation chemicals used, a description of the system and a list of the design parameters used to size the storage facilities shall be provided to the Navy for review.

1-4.3.6.4. Food Supply.

Provisions for the storage and preparation of food and for the purification and storage of drinking water shall be given consideration by the Designer. Information to allow evaluation of the suitability of food storage and preparation facilities, a description of the water supply system including the cleanliness standards, purification chemicals used and tests made to determine the solid, salt and bacterial content of the drinking water shall be provided to the Government Procurement Representative for review.

If the diving system does not have adequate storage facilities for food and water, the Designer shall provide a means of introducing the supplies needed to sustain the diving system personnel for the maximum mission duration.

If food, water and medical supplies are to be introduced into the diving system through specially designed locks, the Designer shall use the design criteria previously presented for pressure vessels and piping.

1-4.3.6.5. Bell Emergency Locating

- Bell shall have an emergency-locating device in accordance with IMO Code of Safety for Diving Systems, Para. 2.12.5 of Resolution A.536(13) as amended by Res. A.831(19).
- A surface locating device such as a strobe light or VHF radio and a subsurface locating device such as an acoustic pinger, sonar reflector or buoy are to be provided. (ABS Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities Section 3, paragraph 7)

1-4.3.6.6. Control Van HVAC

a. Cooling capacity must meet the following criteria for control van occupancy (three personnel) at light work:
    - Human, internal equipment, radiant, convective, and conductive loads must be accounted for.
    - Maintain 75°F (23.8°C) internal atmosphere (air) temperature at 50-70% relative humidity (RH) with ambient temperature of 110°F (43.3°C).

b. Heating must meet the following criteria for control van occupancy (three personnel) at light work:
    - Radiant, convective, and conductive loads must be accounted for.
    - Loads associated with reheating gas subsequent to passing over condensing coils (for moisture removal) must be accounted for.
    - Human and internal equipment heat sources should not be considered to offset required heating.

- Maintain 75°F (23.8°C) internal atmosphere (air) temperature at 50-70% relative humidity (RH) with ambient temperature of 0°F (-17.8°C).

1-4.3.6.7. Entertainment

This subsystem shall provide the means to deliver audio-visual entertainment media to the DDC occupants. The subsystem will also have the capability to display digital data such as photos and schematics/drawings for briefing divers. The entertainment subsystem shall be a stand alone, non-critical system that can be incorporated to enhance the Voice communication system and video system.

1-4.3.7. Gas Handling

1-4.3.7.1. Gas Distribution

- Provide primary and secondary sources of required gases for pressurization, oxygen addition, decompression, emergency breathing and treatment. Required gases are helium (He), oxygen O_2, air, treatment gas helium-oxygen (HeO_2), emergency gas HeO_2, and divers breathing gas HeO_2. (DNV-OS-E402, Section 4, C101)
- All gas distribution piping shall be designed, fabricated and tested in accordance with requirements meeting ASME PVHO-1 and ASME Pressure Piping Code B31.1
- Emergency breathing gas supply shall be separate for each compartment of the DDC. (DNV-OS-E402, Section 4, C102)
- Oxygen addition supply for each compartment of the DDC shall be separate. (DNV-OS-E402, Section 4, C102)
- Provide two sources of gas to the diving bell umbilical. (DNV-OS-E402, Section 4, C103)
- Provide all piping systems with a means of manually relieving pressure. Reduced pressure systems shall be provided with a pressure relief valve with sufficient capacity to maintain system pressure at no more than 110% of MAWP. The discharge from an overpressure device shall not lead to a location where a hazard is created. (DNV-OS-E402, Section 4, E100)
- Provisions shall be made to prevent unintentional gas mixtures to be delivered (e.g., air into the pressurization header once initial atmosphere is establish for a SAT dive, pure O_2 into emergency gas header that is supplying HeO_2 mixture). (DNV-OS-E402, Section 4, C105). The potential for cross-contamination of gas sources shall be minimized.

1-4.3.7.2. Bell Gas Storage and Distribution

a. The bell and lockout divers shall be provided with a normal supply from surface and an independent self-contained emergency supply from the bell. (DNV-OS-E402, Section 4, C201).

b. On board HeO_2 emergency gas must provide suitable gas volume at maximum operating depth to meet the most demanding of the following requirements (DNV-OS-E402, Section 4, B105):
   - Dewatering the bell flooded to 40%
   - Supply standby diver at severe work and lockout divers at hard work for 15 minutes
   - Supply all divers on BIBS during contaminated atmosphere for 45 minutes (15 minute at light work preparing to leave work site, 15 minutes at average rest while traveling to the surface, and 15 minutes at light work to mate diving bell to OL and transfer divers).

c. Provide an onboard emergency oxygen (O_2) storage and addition system with a minimum capacity of 210 ft^3 (6 m^3) of O_2 (35 ft^3 or 1 m^3 per diver in case of hyperbaric evacuation). (DNV-OS-E402, Section 4, B105)

d. The bell shall be provided with two independent means for exhaust. One shall allow the diver to partially flood the bell to aid his entering and can be operated from the lower part of the bell. The exhaust systems shall not permit flooding above electrical equipment when the bell is in an upright position. (DNV-OS-E402, Section 4, C203)

e. The exhaust system shall allow the removal of water in case of a tilted bell with a closed hatch and trapped water inside. (DNV-OS-E402, Section 4, C204)

f. The exhaust system not intended for partial flooding shall be equipped with a spring-loaded valve that closes when the valve handle is released. (DNV-OS-E402, Section 4, C205)

1-4.3.7.3. PVHO Pressurization and Depressurization

Provide the means necessary to pressurize (compression), depressurize (decompression), and maintain stable depth within the DDC LC and OL, mating trunk, supply lock, and diving bell in accordance with established standards listed below:

a. Compression rates:

- Compression to storage depth (SS521-AG-PRO-010, Table 15-6):
  - 0-60 fsw 0.5-30 fsw/min
  - 60-250 fsw 0.5-10 fsw/min
  - 250-750 fsw 0.5-3 fsw/min
  - 750-1000 fsw 0.5-2 fsw/min
- Compression rate for air treatment (SS521-AG-PRO-010, 21-5.2.1)
  0-165 fsw 20 fsw/min
- Compression rate for saturation treatment (SS521-AG-PRO-010, 15-23.8.1)
  5 fsw/min
- Service Locks / Transfer Trunk
  100 fsw/min
- Bell Excursion (DNV-OS-E402, Sec 4, C100)
  30 fsw/min

b. Decompression rates:

- Saturation decompression (SS521-AG-PRO-010 Table 15-9)
  - 1000-200 fsw 6 fsw/hr
  - 200-100 fsw 5 fsw/hr
  - 100-50 fsw 4 fsw/hr
  - 50-0 fsw 3 fsw/hr
- Air Treatment (SS521-AG-PRO-010, 21-5.2.1)
  1 fsw/min
- Service Locks / Transfer Trunk
  100 fsw/min
- Bell Excursion (DNV-OS-E402, Sec 4, C100)
  30 fsw/min

c. Provide a positive means of selecting and securing pressurization gases (air and helium). Minimize the potential for cross-contamination of gas sources.

d. PVHO pressurization and exhaust systems shall be arranged to ensure an even mixing of gas. (DNV-OS-E402, Sec 4, F502)

e. Provisions to ensure independent pressurization and decompression of each PVHO compartment. (DNV-OS-E402, Sec 4, G102)

f. Provide detection and warning for over-pressurization of the diving bell. (DNV-OS-E402, Sec 4, E201)

1-4.3.8. Bell Handling

a. The diving bell handling system shall be designed, fabricated, and tested in accordance with DNV-OS-E402 Offshore Standard for Diving Systems Section 7 or ABS Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities, Appendix 4. In addition, it shall meet the requirements contained in this specification (see 1-4.4).

b. Loads shall be based on DOD STD 1399, Interface Standard For Shipboard Systems, Section 301A, for launch and recovery in sea state 4, desire to recover in sea state 5, and ship motion and attitude for a commercial VOO defined as: Length Between Perpendiculars (LBP) = 64.4m (211.3 ft), Beam (B) = 18m (59 ft), Draft (D) = 6m (19.7ft), Displacement = 5390 metric tonnes (t) (5305 long tons), Metacentric Height (GM) = 1.63 m (5.34 ft), Roll Period (T_{roll}) = 10.8 seconds. Baseline VOO described above is a Rolls-Royce UT-722 Anchor Handling and Supply Vessel.

c. Motion compensation shall be provided to mitigate vertical motion of the diving bell during operations and to mitigate impulse loads imparted in the handling equipment.

d. The handling system shall facilitate repeatability of positioning the diving bell for mate-up with the DDC.

e. Provisions shall be provided for a guide-wire system to prevent twisting of the diving bell in current, limit the amount of drift at the work site, and limit motion of diving bell during recovery at the surface.

f. Provisions shall be provided for two emergency systems to recover the diving bell in addition to the normal system. One emergency system is the use of normal hoisting, guide-wire system of umbilical and shall be independently powered from the normal system and shall incorporate all transportation required to mate the diving bell to the DDC. Another emergency system could consist of an arrangement on the diving bell that permits the divers inside to activate a buoyant ascent of the diving bell.

g. Bell shall be equipped with emergency release of hoisting wire, guide-wires, and umbilical that is activated from inside the bell in case of an emergency buoyant ascent.

h. Provisions shall be made for handling the diving bell umbilical.

i. The diving bell shall provide adequate buoyancy and stability to keep it in an upright position after release of the drop weight during an emergency buoyant ascent and remain on the surface in an upright position after an emergency buoyant ascent or during a hyperbaric evacuation.

1-4.3.8.1. Transportability

a. Performance parameters for transportability are outlined in Table 19.

Table 19: Transportability Performance Parameters

Parameter	Objective/Desirable	Threshold/Minimum	Requirement
Transportability:[1]			
Sea	ARS 50 Class	VOO	
Air	USAF C-130H	USAF C-17	
Land (Truck)	US and International	US and International	
[1] VOO to accommodate personnel, diving system, IMO Class II dynamic positioning (DP) preferred, 4-point mooring acceptable.			

b. The system must be able to withstand loading produced by motion and vibration in accordance with MIL-STD-810F (vibration), MIL-HDBK-1791 (air transport), and DOD-STD-1399 (NAVY), Section 301A (ships motion).

1-4.4. HANDLING SYSTEMS

Handling systems include any weight handling systems that are used to launch and recover divers through the air/sea interface from a support platform. These systems may consist of a simple block and tackle arrangement, using a davit and capstan to raise and lower a diver stage, or may consist of a complex A-frame system that is used to launch and recover manned tethered underwater vehicles, such as a saturation diving bell.

Diving system handling equipment includes, but is not limited to, cranes, booms, davits, and A-frames as well as their associated winching and rigging components. Hydraulic, electrical, and pneumatic subsystems are also considered part of the handling system.

Weight handling components are typically included within the SOC of the diving system or a separate SOC is developed to cover only the weight handling components. This latter case is applicable when a single weight handling system is used to support the operations of more than one diving system. When the weight handling system is portable, it must be included within the SOC for each diving system it will be used to support.

1-4.4.1. Design Criteria and Guidelines.

This section provides guidelines and criteria for the design and analysis of handling system components and associated structures. Alternatively, the Navy may elect to impose commercial design criteria administered by the American Bureau of Shipping (ABS). If the ABS is used, the ABS Rules for Building and Classing Underwater Vehicles, Systems, and Hyperbaric Facilities Appendix 4 shall be followed.

1-4.4.1.1. Types of Loads.

The initial step in designing any handling system is to determine the design load that the system will encounter. The design load is derived from a combination of forces under worst-case operating conditions. Components should be sized according to the greatest design load, or combination of loadings that will be encountered. The following loads and forces should be considered when designing handling systems:

a. Asymmetric loads. When sizing structural members for handling systems that employ more than one load-carrying member to support their payload, consideration should be given to factors that might cause asymmetric loading. Such factors affecting the diving system that would result in asymmetric loading include, but are not limited to, the following: external water, free surface effects in the internal tanks, a shift in ballast, and external payloads.

b. Dynamic loads. In addition to the load generated by lifting the normal rated capacity of the handling system, dynamic forces due to wave-induced motions on the support platform must also be considered. Analysis should be conducted in accordance with DOD-STD-1399, Section 301A or equivalent, unless support platform motions are known. If support platform motions have been measured at sea, or have been determined through the application of proven computer programs, the results can be used in lieu of DOD-STD-1399, Section 301A.

c. Dead loads. The minimum dead load consists of the weight of the structural parts of the handling system and materials permanently attached to the structure.

d. Wind Forces. The wind loads on the projected area of the handling system structure and on the diving system, appropriate to the design conditions, are to be considered.

e. Maximum Forces. Structural members are to be sized using the appropriate loads and factors of safety. The general requirements in applying factors of safety to all U.S. Navy weight handling systems that perform manned lifts are presented in 1-4.4.2.1.1.1

1-4.4.1.2. Environmental Considerations.

Handling systems are subjected to extremely harsh and powerful environmental factors that significantly impact the operational and maintenance characteristics of the system. Environmental factors which should be considered in the system design parameters are: sea state, air temperature, water temperature, precipitation (rain and snow), ice, wind velocity, currents, and the corrosive affects of the salt water environment.

1-4.4.1.2.1. Sea State.

For the sea state specified in Table 20, the uppermost value for the wave heights of the significant wave or the 1/10th highest wave should be taken as the design wave. The period of maximum energy of the sea spectrum should be chosen as the design period (see 1-3.17.4.1). The effect of wave slap to components exposed to the sea must be considered (see 1-3.17.4.3).

1-4.4.1.2.2. Air and Water Temperature.

The maximum and minimum design operating temperatures of both the air and water must be taken into account during handling system design. This is particularly important for hydraulic systems where hydraulic fluid may become too viscous in extreme cold or lose its lubricating properties in extreme heat. Additionally, extremely cold air temperatures may affect the ductility of some metals and render structural members unsafe if not adequately designed. Unless otherwise specified by the Navy, the handling system shall meet the temperature requirements of Table 20.

Requirement	Objective/Desirable	Threshold/Minimum
Sea State: Operational	6	5
Launch	4	4
Recovery	5	4
Survivability	7	6
Air Temperature:		
Operating Max.	120^{0}F (48.9^{0}C)	100^{0}F (37.8^{0}C)
Min.	0^{0}F (-17.8^{0}C)	0^{0}F (-17.8^{0}C)
Non-operating Max.	150^{0}F (65.6^{0}C)	130^{0}F (54.4^{0}C)
Min.	0^{0}F (-17.8^{0}C)	10^{0}F (-12.2^{0}C)
Water Temperature: Max.	95^{0}F (35.0^{0}C)	88^{0}F (31.1^{0}C)
0-1000 fsw (0-366 msw) Min.	28^{0}F (-2.2^{0}C)	28^{0}F (-2.2^{0}C)
Maximum U/W Current: 0-1000 fsw (0-366 msw)	2.5 knots (1.29 m/sec)	2.0 knots (1.03 m/sec)

Table 20: Objective and Threshold Limits

1-4.4.1.2.3. Precipitation.

The effect of rain and snow can be dramatic on topside equipment not designed for it. Electrical connectors, junction boxes and motors not rated for harsh outside environments often fail in shipboard service. All pivoting or sliding load bearing surfaces should either be sealed from the weather or be designed to permit thorough inspections and be provided with an adequate number of lubrication fittings. Waterproof grease is required for these applications. Also, steels must have a protective coating of paint designed for a salt spray environment.

1-4.4.1.2.4. Wind Velocity.

Side loads may be induced in the handling system by high winds. This loading may be significant if either the Diving System or the handling system itself has a large surface area. The Designer will account for possible wind related effects in the system design.

1-4.4.1.2.5. Ocean Currents.

In the same manner that wind affects the handling system topside, ocean currents affect any submerged components of the Diving System. Drag effects caused by ocean currents may be significant depending on the geometry of the Diving System and/or any submerged portions of the handling system. Drag effects must be taken into account in the design of the handling system.

1-4.4.1.3. System Considerations.

The operation of the handling system is an integral part of the total Diving System, and as such, is limited by the coordination of personnel on deck and interface of the Diving System, handling system, and support vessel. For safe and efficient launch and recovery evolutions, the following items must be addressed when developing a handling system:

a. Positive Control. The motion of the Diving System during launch and recovery operations must be under positive control at all times.

b. Fail-Safe. A provision designed to automatically stop or safely control any motion when a hydraulic or electrical failure occurs. The handling system shall be provided with interlocks, safety devices, and protective devices so that it will be fail-safe.

c. Motion effects. The physical location of the handling system on board the support ship should be such that the effects of the ship's motions on the Diving System during handling evolutions are minimized.

d. Weight. The weight of the handling system should be minimized to limit the weight added to the support vessel and the adverse effects on its sea keeping ability.

e. Shock mitigation. Dynamic motions of the support ship at-sea can cause shock loads to the Diving System and its personnel through the handling system. Motion compensating devices shall be considered to minimize these shock loads.

f. Environmental effects. The handling system shall be adequately designed and maintained to withstand the elements and dynamic loads imposed by heavy weather.

g. Recovery speed. The ability of the handling system to control the equipment through the air-sea interface at sufficient speed to avoid excessive wave action.

h. Mating. For PTCs (Diving Bells) there shall be a method of restraining the movement of the PTC during mating to the Deck Decompression Chamber (DDC).

1-4.4.1.4. Human Engineering and Operational Design Considerations.

Handling systems are designed to transport personnel in a restricted and hazardous environment under the direct supervision and control of support personnel. A human engineering evaluation should be conducted to ensure the ability of support personnel to control and supervise the safe and coordinated movement of the Diving System. The following are some critical areas that should be addressed in the evaluation (see 1-2.6):

a. Hazardous exposure. Due to the nature of handling system operations, some evolutions will be inherently hazardous. However, hazards should be eliminated whenever possible. There should be a minimum of support personnel exposed to hazardous operations during handling evolutions.

There should be minimal diver/swimmer involvement during launch and recovery of the Diving System.

b. Coordination and control. Safe and timely operation of handling systems requires precise control and coordination of all personnel involved. The system arrangement should be simple and require minimal supervision. In addition, there must be clear communications between the handling support personnel, the support ship personnel responsible for maneuvering the ship, and the Diving Supervisor.

c. Monitoring equipment status. Control and support personnel responsible for the operation of the handling system should have access to monitoring devices to enable them to evaluate the status of the equipment. This is to ensure the system is operating within its capability limits (e.g., speed, load, pressure, temperature). These factors, along with the observed sea state, can then be evaluated to determine their effect on the operating parameters of the Diving System.

d. Manning. Minimizing the number of personnel required to operate and maintain the system should be considered.

1-4.4.1.5. Emergency Conditions and Reduced Operating Capability.

The handling system shall be designed to minimize the effects of component failures. To identify and define the failures, and to determine how to resolve them, a hazard analysis shall be performed (see 1-2.4.2). The hazard analysis can also be used to evaluate the system's capability to continue to operate and safely recover Diving System personnel. All handling system components shall be operable in sea states specified by the mission profile. In the event of a control console failure, an alternate or backup means of system operation is required.

1-4.4.2. Design Requirements.

The following covers the design of handling systems. NAVSEA review requirements are also presented. Alternatively, the Navy may elect to impose commercial design and criteria administered by ABS. If the ABS is used, the ABS Rules for Building and Classing Underwater Vehicles, Systems, and Hyperbaric Facilities Appendix 4 shall be followed.

Load bearing component requirements are discussed in 1-4.4.2.1 and cover structural, rigging, and machinery component criteria; hydraulic and pneumatic system requirements are discussed in 1-4.4.2.2; and power requirements and controls are discussed in 1-4.4.2.3.

Design analyses for handling systems must be based on recognized engineering analytical methods and standards. Loads imposed by the environmental conditions specified in the requirements documentation must be included in the analyses. The design of all load bearing and load controlling elements must be submitted to the Government Procurement Representative for review and approval.

1-4.4.2.1. Load Bearing Component Requirements.

All elements of the handling system that support the weight of the Diving System when occupied by personnel shall be designed, fabricated, and maintained in accordance with the following requirements:

1-4.4.2.1.1. Load Bearing Component Design.

Design analyses must indicate forces, loads, shears, and moments for all structural members, welds, and connections including interaction forces with the supporting deck and ropes. Components shall be analyzed considering tensile, compressive, bending, shear, and torsional loadings. Structural members subject to pure compression shall be evaluated in accordance with DDS-100-4 or AISC Manual of Steel Construction, Specifications and Codes. The allowable stresses and safety factors used shall be revised as required to meet the safety factors specified in 1-4.4.2.1.1.1. Analyses for rigging gear must also be included in the design documentation.

Calculations shall take into account the wet and dry weight of the Diving System, entrained water weight, added mass effects (if applicable), crew and payload weights, the dynamic affects due to the motion of the support ship and Diving System at sea, and the effects of the wind forces. The support platform's motions shall be analyzed for the maximum operating sea conditions, sea state or swells specified in the requirements documentation.

The worst-case loading due to heave, roll, pitch, or any combination thereof, shall be used in the calculations.

1-4.4.2.1.1.1. Design Factors of Safety.

Factors of safety for handling systems are based on Navy engineering practices, and are related to the material used and the conditions of the operating environment conditions. Relatively high safety factors are necessary, even though the materials and their properties are well known, because they are used in uncertain environments and are subjected to uncertain stresses. Material justification will be required in accordance with 1-3.8 to certify handling system components within the SOC, even when the design meets the requirements of this section. Items requiring material justification will be identified by the Government Procurement Representative during the conceptual design phase and during design reviews.

a. Structural and machinery components.

(1) For surface support platforms, the factor of safety for all structural and machinery components shall be 2.5 on material yield strength, or 4 on material ultimate tensile strength; whichever is greater.

(2) For submarine support platforms applications, the factor of safety shall be 3 on material yield, or 5 on material ultimate tensile strength; whichever is greater.

The above factors of safety shall be based on the design load.

b. Rigging and Fittings.

(1) Factors of safety for wire and synthetic rope are given in Table 21. These factors shall be based on the design load of the handling system and the specified nominal breaking strength for wire rope or average breaking strength for synthetic rope.

When used with wire or synthetic rope, the factor of safety for fittings shall be equal to or greater than the commercial rating for the Diving System design load.

Material Application	Critical Component	Non-critical Component	D/d Ratio[1]
Wire rope standing rigging	5	5	-
Wire rope running rigging	6	5	18:1
Rotation resistant wire rope			
- standard construction	7[2]	6	34:1
- formed through a die	6	5	18:1
Synthetic rope[3]			
- Braided	7	5	8:1
- Twisted/Plaited	7	5	10:1
- Aramid (Kevlar®)	6	5	20:1

Table 21: Factors of Safety for Rigging

1. Ratio of sheave or drum diameter (D) to wire rope or synthetic line diameter (d).
2. This factor of safety is for rotation resistant wire rope supporting a free hanging load. If a guideline system is used that does not allow the load to rotate, this factor of safety can be reduced to 6. Under no circumstances shall the factor of safety for wire ropes be less than 6 for manned lift systems.
3. When wet, the safety factor for nylon rope shall be applied to the breaking strength minus 15 percent unless a suitable marine overlay finish is used.

1-4.4.2.1.2. Submission of Drawings and Calculations for Load Bearing Components.

The Designer shall submit the design of the handling system to the Government Procurement Representative for review and approval. If the handling system is certified to ABS requirements, submission of documentation required by ABS Rules for Underwater Vehicles, Systems and Hyperbaric Facilities, Appendix 4, will satisfy the requirements sited below. As a minimum, the following documentation shall be submitted:

a. Design analyses and calculations that provide the basis for the system design, including all assumptions governing the design. The analyses must include the following when results of computer calculations are submitted: input data, summaries of input and program assumptions, output data, and summaries of conclusions drawn from the output data.
b. General arrangements showing equipment locations and the rated capacity of the system.
c. Details showing sizes, sections, and locations of all structural members.
d. Details of all reeving components showing sizes, safe working loads, materials, manufacturer, and part number.
e. For synthetic rope: length, size, material, construction, average breaking strength, manufacturer, and specification (if applicable).
f. For wire rope: length, size, construction, preformed or non-preformed, lay, finish, grade (IPS, EIPS, or traction steel), core type, lubrication, and manufacturer.
g. Foundation and support arrangements.
h. Structural material specifications.
i. Drawings must show all welding proposed for the principal parts of the structure. The welding process, filler metal, and joint designs are to be shown on detail drawings or in separate specifications.
j. The areas to be nondestructively inspected and methods of inspection are to be shown on the drawings, or in separate specifications.
k. Winch drum details.
l. Type and size of bolts.
m. Reeving diagram.
n. Testing requirements and procedures.
o. List of all materials and fittings, for all components.
p. The components within the SOC must be identified.

1-4.4.2.2. Hydraulic and Pneumatic System Requirements.

Hydraulic systems shall be designed and tested in accordance with the requirements of this subsection. These requirements can also pertain to pneumatic systems; however, it is recommended the Designer discuss any unique requirements with the Government Procurement Representative prior to initial design efforts.

1-4.4.2.2.1. System Design.

Hydraulic and pneumatic systems and components shall be designed to operate the rated load at the rated speed when the differential pressure across the actuator is not more than two-thirds of the maximum operating pressure. This will ensure the handling system will operate efficiently under dynamic conditions at sea as well as when undergoing load testing.

Hydraulic and pneumatic systems and components shall be designed in accordance with MIL-STD-2193, Hydraulic System Components, Ship; with piping, valves, fittings and gasket material selected from MIL-STD-777, Schedule of Piping, Valves, Fittings, and Associated Piping Components for Naval Surface Ships (or MIL-STD-438 for submarine applications), ASME B31-1, Power Piping or an approved industrial standard. Naval Ship's Technical Manual Chapter 556, Hydraulic Equipment (Power Transmission and Control); Naval Ship's Technical Manual Chapter 505, Piping Systems; or Naval Ship's Technical Manual Chapter 551, Compressed Air Plants and Systems, can be used as guidance.

Hydraulic and pneumatic systems and components shall be designed such that they are fail-safe and the brake on any winches, traction machines, cranes, or elevators shall set and stop motion if there is a loss of power.

The Navy may also elect to design the handling system in accordance with the requirements of Title 46, Code of Federal Regulations (CFR), Subchapter F, Marine Engineering, or an approved industrial standard. However, applicable parts and subparts of the commercial specification must be defined by the Designer and Government Procurement Representative prior to initiating the design.

The following requirements shall also be met:

a. The maximum operating pressure shall not exceed pump or compressor and motor manufacturer's continuous ratings.

b. Pump or compressor drive electric motor current shall not exceed nameplate rating at the design load.

The Designer shall submit the design of the handling system hydraulic and pneumatic systems to the Government Procurement Representative for review and approval. If the handling system is certified to ABS requirements, submission of documentation required by ABS Rules for Underwater Vehicles, Systems and Hyperbaric Facilities, Appendix 4, will satisfy the requirements sited below. As a minimum, the following documentation shall be submitted:

a. Design analyses and calculations that provide the basis for the system design, including all assumptions governing the design. The analyses must include the following when results of computer calculations are submitted: input data, summaries of input and program assumptions, output data, and summaries of conclusions drawn from the output data.

b. Plan showing manufacturer’s ratings, braking capabilities and power drive requirements for hydraulic equipment.

c. Plan showing details on emergency source of power.

d. Hydraulic schematic that shows:

    (1) Relief valve settings

    (2) Material specifications, size, and pressure ratings of all pipe fittings, valves, flexible hoses, pumps, filters, and accumulators.

    (3) Testing and cleaning requirements.

e. Drawings and design calculations, or a Certificate of Compliance (COC) from the manufacturer is required for each hydraulic or pneumatic cylinder to identify its burst pressure.

f. Testing procedures.

g. The components within the SOC must be identified.

1-4.4.2.3. Electrical Power Requirements and Controls.

Attention should be given to each component's electrical power requirements in view of the total system power drain on the support vessel or independent power source. When the design/configuration requires the Diving System to be lifted from the water in order for the Diving System operator(s) to disembark, two separate and independent power sources shall be provided to support operation of the handling system.

1-4.4.2.3.1. System Design

Design and installation of the handling system electrical power distribution system shall be in accordance with the requirements of Title 46, Code of Federal Regulation (CFR), Subchapter J, Electrical Engineering, or an approved industrial standard.

Electrical systems and components shall be designed such that they are fail-safe and the brake on any winches, traction machines, cranes, or elevators shall set and stop motion if there is a loss of power.

The controls shall be service-proven, and meet U.S. Coast Guard regulations or other authoritative specification.

(1) All controls used during the normal handling system operating cycle shall be located within easy reach of the operator while at the operator's station.

(2) Control levers shall return automatically to their center (neutral) position when released.

(3) Control operations and functions shall be clearly marked and easily visible from the operator station.

Control system plans and information submitted to the Acquisition Manager, for review and approval, shall be in accordance with Title 46, CFR, Subpart 110.25-1 of Subchapter J, as determined to be applicable by the Design Agent. The components within the SOC must be identified.

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U.S. Navy General Specification for the Design, Construction, and Repair of Diving and Hyperbaric Equipment

PART 2: CONSTRUCTION

2-1. INTRODUCTION

2-1.1. PURPOSE

This part provides the construction specifications necessary to comply with NAVSEA standards for fabrication of U.S. Navy diving and manned hyperbaric systems. Changes/revisions will be made to the document to include advances in technology of life support systems and development of new testing methods

2-1.2. SCOPE

This fabrication specification applies to all U.S. Navy diving and manned hyperbaric systems under the Technical Authority of the Supervisor of Salvage and Diving (SUPSALV), Naval Sea Systems Command (NAVSEA) 00C. U.S. Navy diving and manned hyperbaric systems include all surface-supplied diving systems, saturation diving systems, manned recompression chamber systems, diving bells, and handling systems used for maneuvering diving systems or personnel during manned operations

2-1.3. APPLICABILITY

This section of the specification is applicable to the fabrication of diving and hyperbaric systems for the U.S. Naval Sea Systems Command.

2-1.4. DEFINITIONS

The following definitions are applicable to this document.

2-1.4.1. Certification

(1) The process of certification application, review, survey, and approval of all items and procedures within a diving or hyperbaric system scope of certification (SOC) that affect the safety of diving personnel. (2) Written statement attesting that an item, procedure or system meets specified requirements.

2-1.4.2. Design Test Depth Pressure

The pressure equivalent to the maximum depth to which the diving system was designed to operate.

2-1.4.3. Explodable Volume

Any noncompensated pressure housing containing a compressible fluid at a pressure above the external ambient sea pressure (at any depth) which has the potential to burst (typically due to on gassing under pressure in an helium atmosphere). Note that some volumes may be explodable at shallow depths and implodable at deeper depths.

2-1.4.4. Government Procurement Representative

The individual issuing the purchase order/contract to the Builder for the construction of the diving or hyperbaric system.

2-1.4.5. Hydrostatic (Strength and Porosity) Test

A test which subjects pressure containing structural boundaries of pressure vessels, pipe, and piping components to a specified test pressure above the maximum system pressure and inspects for leaks and deformation.

2-1.4.6. Implodable Volume

Any noncompensated pressure housing containing a compressible fluid at a pressure below the external ambient sea pressure (at any depth down to maximum operating depth) which has the potential to collapse. The outer shell volume is used when calculating the volume of an implodable. Subtracting the volume of items internal to the implodable is not allowed.

2-1.4.7. Isolation Valve

Any valve used as a distinct pressure boundary which in the no-flow position (closed) does not incorporate a self-operating feature (e.g., check valves and regulating valves).

2-1.4.8. Joint Tightness Test

A test which subjects mechanically joined pressure containing boundaries of pipe, and piping components to an internal pressure equal to 100 percent of maximum system pressure and, if applicable, to an external pressure equal to 100 percent of diving system design test depth pressure.

2-1.4.9. Life Support System

A structure (sphere, chamber, or habitat at one atmosphere or greater internal pressure) which provides a livable environment for personnel or a piping system which provides and/or monitors a metabolic breathing mixture suitable and safe for use by divers and/or operators of Deep Submergence Vehicles, DSRV, DDS, Submarine Rescue Chambers, or Recompression Chambers.

2-1.4.10. Maximum Operating Pressure

The highest pressure that can exist in a system or subsystem under normal operating conditions. This pressure is determined by such influences as pump or compressor shutoff pressures, pressure regulating valve lockup (no-flow) pressure, and maximum chosen pressure at the system source.

2-1.4.11. Maximum System Pressure

The highest pressure that can exist in a system or subsystem during any condition exclusive of water or steam hammer. The nominal setting of the relief valve (see 1-3.7.10.3, which covers relief valve setting and installation) is the maximum system pressure in any system or subsystem with relief valve protection. Relief valve accumulation may be ignored.

NOTE

For systems with pressure-regulating valves where the downstream piping does not incorporate a relief valve, the maximum system pressure of the upstream side of the pressure-regulating valve shall be the maximum system pressure of the downstream side of the pressure-regulating valve for test purposes.

2-1.4.12. Minimum Operating Pressure

The lowest pressure that can exist in a system or subsystem under normal operating conditions. This pressure is usually determined by such influences as the minimum allowable oil supply pressure to a bearing or situations where corrective action shall be taken when pressure drops below a safe minimum pressure rather than exceeding a maximum pressure.

2-1.4.13. Nominal Operating Pressure

The approximate pressure at which an essentially constant pressure system operates when performing its normal function. This pressure is used for the system basic pressure identification.

2-1.4.14. Objective Quality Evidence (OQE)

OQE is any statement of fact, either quantitative or qualitative, pertaining to the quality of a product or service based on observations, measurements, or tests which can be verified. Evidence shall be expressed in terms of specific quality requirements or characteristics. These characteristics are identified in drawings, specifications, and other documents which describe the item, process, or procedure. One of the main objectives of the certification survey is to review the OQE to ensure that the system is actually built as designed, and that it will perform safely to the limits for which certification is requested. Accordingly, the survey team shall review OQE in sufficient detail and depth to support a conclusion as to the acceptability of the system. The applicant shall ensure, prior to survey, that necessary OQE not previously submitted to the SCA is readily available for the survey team. Appendix K of SS521-AA-MAN-010, U.S. Navy Diving and Manned Hyperbaric Systems Safety Certification Manual provides additional guidance on OQE.

2-1.4.15. Pressure Drop Test

A test which identifies long term leakage of a system. Compressed gas flasks, pipe, and piping components are initially pressurized to 100 percent of maximum operating pressure. Data is then taken to measure the change in pressure and corrected for temperature over an extended period of time.

2-1.4.16. Scope of Certification (SOC)

The Scope of Certification (SOC) of a diving system is a list of those systems and components required to ensure and preserve the safety and well-being of its operators and divers. It encompasses life-critical elements of all systems, subsystems, components, and portions of the system, including normal operating and maintenance procedures which are required to ensure the continuous physical well-being of the operators and divers. Detailed requirements are specified in paragraph 2-2.2.

2-1.4.17. Seat Tightness Test

An internal pressure test that checks a valve's shut-off/isolation capabilities.

2-1.4.18. System Certification Authority (SCA)

The office (code) within Naval Sea Systems Command (NAVSEA) assigned the final responsibility and authority for granting certification for the Life Support System being designed and/or built. The working responsibility for certification is vested in NAVSEA 00C4.

2-1.4.19. System Design Pressure

The pressure used in calculating minimum wall thickness of pressure vessels, piping and piping components. The system design pressure shall not be less than the maximum system pressure.

2-1.5. REFERENCED DOCUMENTS

The following specifications, standards and other documents form a part of this document to the extent specified herein.

STANDARDS

DEPARTMENT OF DEFENSE

MIL-STD-22	Welded Joint Design
MIL-STD-1330	Standard Practice for Precision Cleaning and Testing of Shipboard Oxygen, Helium, Helium-Oxygen, Nitrogen, and Hydrogen Systems.
MIL-STD-1622	Cleaning of Shipboard Compressed Air Systems
MIL-STD-1627	Bending of Pipe or Tube for Ship Piping Systems
MIL-STD-2035	Nondestructive Testing Acceptance Criteria,
MIL-STD-882	Standard Practice for System Safety
MIL-A-18455	Argon, Technical

AMERICAN WELDING SOCIETY

AWS A5.12	Specification for Tungsten and Tungsten Alloy Electrodes for Arc Welding and Cutting

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

ASME PVHO-1-2002	Safety Standard for Pressure Vessels for Human Occupancy
ASME VIII	Boiler and Pressure Vessel Code; Rules for Construction of Pressure Vessels

ASME IX	Boiler and Pressure Vessel Code; Welding and Brazing Qualifications

AMERICAN NATIONAL STANDARDS INSTITUTE

ANSI (NCSL) Z540-1	General Requirements for Calibration Laboratories and Measuring and Test Equipment

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

ISO 9000:2000	Quality Management Systems – Fundamentals and Vocabulary

SPECIFICATIONS

DEPARTMNENT OF DEFENSE

S9074-AQ-GIB-010/248	Requirements for Welding and Brazing Procedure and Performance Qualification.
T9074-AS-GIB-010/271	Requirements for Nondestructive Testing Methods
S9074-AR-GIB-010/278	Requirements for Fabrication Welding and Inspection, and Casting Inspection and Repair for Machinery, Piping, and Pressure Vessels
0900-LP-001-7000	Fabrication and Inspection of Brazed Piping Systems
MIL-PRF-27617F	Grease, Aircraft and Instrument, Fuel and Oxidizer Resistant

AMERICAN SOCIETY FOR TESTING AND MATERIALS

ASTM A967	Standard Specification for Chemical Passivation Treatments for Stainless Steel Parts

PUBLICATIONS

DEPARTMENT OF DEFENSE

NAVFAC P-307	Management of Weight Handling Equipment
NSTM Chapter 262	Lubricating Oils, Greases, Specialty Lubricants, and Lubrication Systems.
SS521-AG-PRO-010	U.S. Navy Diving Manual, Revision 4
ST700-F1-PRO-010	Instrument and Gauge Cleaning for MIL-STD-1330 Applications; Procedures Manual
SS521-AA-MAN-010	U.S. Navy Diving and Manned Hyperbaric Systems Safety Certification Manual
S9086-RK-STM-010/CH-505	Piping Systems

2-1.6. BASIC REQUIREMENTS

The basic requirements to construct diving or hyperbaric equipment is described in the following paragraphs.

2-1.6.1. Material/Equipment/Traceability

All material, such as valves, piping and pipe fittings, used in the life support portions of the system must be procured with sufficient objective quality evidence to assure it complies with system material specifications. All required evidence throughout the entire process of purchase, assembly, and installation in the system must be documented and retained. Equipment which is approved by the Navy for use in diving systems is to be the specific model, type, and vendor approved by NAVSEA. The purpose of the certification process is to document and prove that the equipment, components, and material installed are in accordance with the system drawings. Any equipment, component, or material installed that is not in accordance with the system drawings must have an approved waiver or deviation.

2-1.6.2. Quality Control System

A quality control system shall be established by the builder to assure that the completed diver life support system has been fabricated in accordance with all required specifications, that traceability for all materials requiring system certification can be accomplished, and that standards of workmanship comply with requirements. The quality control system will also include inspection, non-destructive testing, and adequate records. Detailed requirements are discussed in section 2-2.

2-1.6.3. Joint Identification Drawing (JID)

Each component and welded or mechanical joint within the scope of certification (SOC) shall have a unique identification number on the JID which will be used for documentation and traceability throughout construction. The JID shall be used throughout the procurement, fabrication, and assembly of the dive system. The purpose of the JID is to provide documentation to verify actual installation, identity, and specific location of each element within the SOC, and therefore provide accountability. If a JID is not supplied with the drawing package, it is the Builders responsibility to create this drawing. Prior to beginning construction, the JID shall be submitted to the Government Procurement Representative for approval.

See 1-3.2.2 for additional requirements on JIDs.

2-1.6.4. Fabrication and Assembly Procedures

The fabrication and assembly of the diver life support system within the scope of the certification boundaries shall be accomplished in accordance with the highest standards of workmanship and fabrication processes. This will entail the use of qualified mechanics, written work procedures for such processes as welding, cleaning and prefabrication of subassemblies, and assembly sequence planning.

2-1.6.5. Dimensions

The dimensions on structural monodetail parts are supplied for ease of manufacture. Meeting monodetail dimensions and tolerances will not guarantee the final weldment tolerances are met. The Builder is responsible for ensuring all structural weldments are in accordance with the applicable fabrication documents.

2-1.6.6. Cleanliness

2-1.6.6.1. Divers Life Support System Cleanliness Requirements

The completed divers life support system must be free of all contaminates, such as hydrocarbons and particulate matter, to ensure clean life support gas. Any piping, valve, o-ring, or other component that will be wetted with greater than 25% oxygen by volume during normal operation shall be cleaned and documented in accordance with MIL-STD-1330 Standard Practice for Precision Cleaning and Testing of Shipboard Oxygen, Helium, Helium-Oxygen, Nitrogen, and Hydrogen Systems. All other piping and components that form part of the gas supply system shall be cleaned and documented in accordance with MIL-STD-1330 or MIL-STD-1622 Cleaning of Shipboard Compressed Air Systems. Any component cleaned in accordance with MIL-STD-1622 shall be considered a “critical application” as defined in MIL-STD-1622. Additional cleaning requirements are provided in section 2-8.

2-1.6.6.2. Hydraulic/Pneumatic Systems Cleanliness Requirements

Cleaning, flushing and preservation of hydraulic system piping and components shall be in accordance with ASTM D4171, Standard Practice for Cleaning, Flushing, and Purification of Petroleum Fluid Hydraulic Systems, or an applicable commercial specification, subject to approval by the Government Procurement Representative.

Cleaning and flushing of pneumatic systems shall be accomplished using best commercial practice and using compatible cleaning agents to remove all loose scale, rust, grit, filings, oil, and grease.

If a hydraulic/pneumatic line is flushed with water, prior to installation, they must be blown dry with dry air. Filtered system fluid should normally be used for flushing.

2-1.6.7. Testing

Component and system tests are required to provide assurance that the system has been fabricated and assembled in accordance with the applicable specifications and that it will safely function to provide the diver with the required quantity of clean gas. Some of the tests include strength, tightness, cleanliness and operational testing. Detailed requirements are discussed in section 2-9.

2-1.6.8. Installation Checks

2-1.6.8.1. Fluid Mechanical System

The builder shall verify the system has been built IAW the JID. Verification shall be on the Fluid Mechanical System Installation Record form, paragraph 2-14.3.As a minimum, the following information should be recorded:

a. Verify that the system has been installed in accordance with the JID (see paragraph 2-1.6.3).
b. Inspect all mechanical joints for completeness.
c. Inspect all welded joints for completeness.
d. Inspect the surfaces of piping and components for possible damage during fabrication, such as gouges, dents, arc strikes, weld spatter, etc.
e. Inspect each component for completeness (e.g., valves for presence of handwheels).
f. Inspect the system for presence of required label plates, tags, etc.

If the system is determined to be incomplete or damaged, it is the Builder's responsibility to repair or complete the construction prior to the Material Certification Review and delivery.

2-1.6.9. Records

In order to provide traceability of material, assure compliance with approved work procedures, and preserve non-destructive testing and system test results, a complete set of auditable records must be retained by the builder during the entire procurements, fabrication, installation, inspection, and testing process. Upon delivery of the equipment, two (2) copies of those records will be provided to the Government Procurement Representative. The exact content of the records will be as required throughout this specification. Paragraph 2-14 of this specification provides extensive direction on the format and content of most of the required data forms.

2-1.6.10. Shipping and Handling

The builder shall develop and monitor procedures for transporting and handling life support system components to prevent damage, contamination, or material substitution. Among the precautions to be taken are the following:

a. Personnel involved in handling material shall be trained and indoctrinated in the necessity for care in handling dive system material and components. This includes fork-lift operators, riggers, storekeepers, etc.
b. Special wrapping or lined containers to prevent chafing shall be provided for components such as pressure gauges, filters, temperature instruments, etc.
c. Special precautions shall be taken to prevent contamination when transporting material between shops and work areas by using clean, covered containers.
d. All pre-cleaned parts shall be double-bagged in heat-sealed bags. Tags shall list cleaning procedures used, clean facility, and date of cleaning.

2-1.6.11. Construction Reviews

The Builder shall prepare for and host Construction Review Meetings with the Government Procurement Representative and other U.S. Navy Personnel. The first Construction Review shall be held within 30 days after contract award. The date of subsequent Construction Reviews shall be approved by the Government Procurement Representative. The Builder shall have available all necessary data and personnel so that the reviews may be conducted in a timely and efficient manner. The primary emphasis of the Construction Reviews will be on cost, schedule, technical issues, and any problem areas. At a minimum, each Construction Review will cover the following issues:

a. Cost

b. Program Schedule

c. Status of Action Items

d. Quality Assurance

e. Status of Deliverables

f. Subcontractor Management

g. Test Results

2-1.6.11.1. Material Certification Review

The final Construction Review will be conducted by the U.S. Navy System Certification Authority (SCA) (NAVSEA 00C4). Prior to acceptance of the diving or hyperbaric system by the Government Procurement Representative, it must be certified by the SCA. When the Builder is ready for final delivery (i.e., the system is completely built and all of the paperwork is complete) he will schedule with the Government Procurement Representative for the SCA to visit the facility and conduct the review. The SCA will conduct an in-depth inspection of the equipment and paperwork to ensure that they are in compliance with this specification, the system drawings, and any other applicable contract documents. Any discrepancies from this specification, the drawings, or other applicable contract documents noted by the SCA, are the sole responsibility of the Builder to correct prior to final delivery of the system to the Government.

2-1.6.12. Electrical System Installation

During diving system construction, installed cables shall be protected against mechanical damage, burning by welders' torches and contact with oils and solvents.

2-1.6.13. Deviations/Changes

Any deviations from this specification, the system drawings, or any other contract document relating to the fabrication of the hyperbaric or diving system shall be approved in writing by the Government Procurement Representative. Any changes must be requested by the Builder in writing to the Government Procurement Representative and written approval must be given to the Builder prior to making the change. The deviation request must include all technical and cost implications due to the change.

2-1.6.14. Conflicts

Any conflicts between this document, the system drawings, and any other contract documents shall be brought to the attention of the Government Procurement Representative. The Government Procurement Representative shall resolve all conflicts and shall provide the resolution in writing to the Builder.

2-2. QUALITY ASSURANCE

2-2.1. GENERAL

The Builder shall submit, for approval, a Quality Assurance Plan. This plan shall be approved by the Government Procurement Representative prior to the start of procurement or fabrication by the Builder. The contractor's Quality Assurance Plan shall be in accordance with ANSI/ASQC Q9000 or ISO-9000, as an equivalent. As a minimum content, the program plan shall disclose the contractors planned approach for fulfilling the requirements of the chosen quality standard. A description of the organization that will fulfill the quality program requirements for this project, with a definition of the responsibility and authority of each functional element, shall be included. All of the contractor's documented policies and procedures, which implement the quality program, shall be identified in appropriate places within the plan. A summary of the objective or purpose of each policy and procedure shall be given. The plan must delineate, by flowchart or similar technique, where inspection, audit, and other controls are applied to assure compliance with the contract quality requirements and must identify each controlled work procedure, and inspection instruction applicable to the contract hardware and show where it is applied. The plan shall describe the method by which the plan will be applied to subcontractors.

Records are the major forms of Objective Quality Evidence (OQE) to verify compliance with contract requirements. Records shall be complete, signed, dated, and made available to Government Procurement Representative for review. The Builder is responsible to make arrangements for the retention, storage and retrieval of all QA documents until they are delivered to the Government Procurement Representative. The Quality Assurance Program shall result in recorded data that includes but is not limited to:

a. Configuration management and drawing control. The contractor shall implement an internal configuration management system for the control of design drawings, design documentation, and production specifications related to manufacturing of the system. Production specifications include process control procedures and work instructions. The configuration management procedures shall include a clearly defined and documented system of change and revision.

b. Material control. The material control program shall show that materials and components installed in the system are the same as received, inspected and as specified in the system drawings.

c. Fabrication and manufacturing control. The contractor’s quality program shall result in production records as required by system drawings and invoked manufacturing specifications and this specification.

d. Cleanliness control.

e. Testing and inspection control.

f. Re-entry control (IAW section 10)

2-2.2. SCOPE OF CERTIFICATION (SOC)

If not provided during the design process, the Builder shall submit to the Government Procurement Representative an initial list of all portions of the system and its ancillary equipment that are expected to fall within the Scope of Certification (SOC) as defined herein. This submittal shall be made no more then two (2) weeks following the award of the contract. In addition, the Builder shall include the criteria and supporting justification for limiting the scope of certification. Subsystems and components not initially shown by the Builder to be within the SOC shall be reviewed by the Government Procurement Representative for their contributions to the overall safety of design. Negotiations between the Builder and Government Procurement Representative may be required to define the SOC boundaries. The scope of certification boundaries shall be finalized by the Builder and approved or modified by the Government Procurement Representative prior to the start of fabrication.

As an aid in defining the SOC, especially for complex systems, the Builder should refer to the Hazard Analysis created for the system during the design process (refer to Part 1 of this specification and

MIL-STD-882 *System Safety Program Requirements*, for additional information on Hazard Analysis). Subsystems, components and procedures that must be included in the SOC are:

a. Those which, through malfunction or failure, could prevent the safe return of the operators, divers, or occupants to the surface

b. Those required to keep operators, divers, or occupants safely on the surface following an ascent

c. Those provided to rescue personnel from the diving system and return them to the surface, support ship, or, in the case of hyperbaric chambers, to ambient conditions outside the chamber

d. Those associated with temporary test equipment affecting trim and stability conditions, both surfaced and submerged, which could affect the safe recovery of personnel

e. Written and approved operating and emergency procedures (OPs/EPs) including predive and postdive procedures for subsystems within the SOC

f. Written maintenance and test procedures for systems within the SOC

g. Operating and maintenance (O&M) manuals and/or procedures

h. Drawings outlining the certified baseline configuration

It is recognized that individual diving system designs may vary to such an extent that no single list can encompass the entire spectrum of SOCs. The following is a list of areas that generally require inclusion in the SOC. This list is provided for purposes of illustration and should not be considered all-inclusive or universally applicable:

a. The pressure hull, pressure vessels, hard structure, and appurtenances (penetrations, seals, etc.)

b. The ballast/buoyancy subsystems used to maintain adequate freeboard when operating a submersible capsule or habitat on the surface

c. Jettisoning and emergency ballast blow systems used for emergency ascent

d. Normal and emergency life -support subsystems which provide an acceptable atmosphere to the diving system personnel (may include oxygen admission, carbon dioxide removal, odor removal, humidity and temperature control equipment)

e. Built-in-Breathing System (BIBS) for the treatment of diving related illness or for use in contaminated closed environments.

f. Noncompensated equipment, subject to pressure, which may implode or explode (see Appendices B and C)

g. Release devices for external appendages

h. Firefighting devices or subsystems

i. Communication subsystems for two-way communications between the system operators and support personnel

j. Monitoring/detecting devices

k. Equipment which actuates recovery subsystems (includes subsystems which may be required for recovery of personnel from the system following a casualty)

l. Flotation or buoyancy subsystems where failure or inadequacy could prevent the safe return of personnel to the surface or, once on the surface, to remain there

m. Electrical power subsystems which include internal and external electrical protective devices where failure could result in malfunction of a critical component or subsystem or create a shock hazard

n. Support vessel handling subsystems and components such as cranes, winches, brakes, cables, and their ancillary equipment used when the system is handled, through the air/sea interface or onboard the support vessel, with personnel aboard.

o. Subsystems and components that protect personnel directly or indirectly against the effects of accidents and hazards

p. Diver-worn equipment, which includes the subsystems and components located on the diver side of the umbilical or supply hose connection required to ensure and preserve the safety and well-being of the diver, such as:

    (1) Breathing gas subsystems and components including tubing, valves and regulators, breathing gas containers, and carbon dioxide absorbers

    (2) Headgear, face masks, mouthpieces, breathing bags and helmets

    (3) Breathing gas hose, umbilicals, gas fittings, connectors, fasteners, and clothing

    (4) Instrumentation, sensors, alarms, computers, and set up (predive) equipment

    (5) Electrical and communication subsystems

q. Subsystems that provide control of the diver's body temperature and subsystems and components that protect the diver against accidents and hazards in the underwater environment

r. Subsystems located on the gas supply side of the diver's umbilical or supply hose. For surface-supplied diving systems and recompression chamber systems, the scope normally encompasses the entire diver's gas mechanical system. This is usually composed of, but not limited to, compressors, flasks, carbon dioxide scrubbers, filters, separators, reducing stations, receivers, valving and piping up to and including the diver's manifold(s) and recompression chamber and its appendages.

s. Gas analysis subsystems and components

When considering components for inclusion in the SOC, it should be realized that most accidents result from a series of events beginning with a single failure, often relatively minor, which places the diving system personnel or equipment under additional stress. The avoidance or prevention of such initial failures in the normal operation of equipment enhances the overall safety of the system.

2-2.3. CONTROLLED WORK PROCEDURES

Controlled work procedures must define the scope of work and provide production personnel with step-by-step instructions on how the work is to be accomplished. When controlled work procedures are written to accomplish repairs, maintenance or modifications, they shall state the specific reason for performing the work. These instructions are required wherever fabrication, assembly, cleaning and/or testing of components or systems, within the SOC boundaries, are to be performed. Controlled work procedures shall also provide all inspection, test, and retest requirements and any warnings or cautions which must be observed while performing the work. Controlled work procedures shall be generated prior to commencing work. Where work procedures already exist (e.g., technical manuals, standard process instructions, approved drawings, PMS), the specific paragraphs from those documents shall be called out in the controlled work procedures. Procedures shall be signed with printed name and signature by the person responsible for completing the work, inspections and retest of the system or component. Any change to the scope of work being performed shall cause a revision to the controlled work procedure to be issued. All controlled work procedures shall be made available to the Government Procurement Representative for review during on-site surveys.

2-2.3.1. Process Instructions

Process instructions are those standardized procedures which have been developed by a production activity for work which they commonly perform. In order to be used in a controlled work procedure, the process instruction must provide step-by-step instructions for accomplishing the work. All process instructions which the production activity intends to use during fabrication or repair of a diving system shall be provided to the Government Procurement Representative for review. In cases where critical training and skills are involved (e.g., welding, NDE, and cleaning), process instructions must be approved by the Government Procurement Representative prior to use.

2-2.3.2. Assembly Procedures

Special procedures for assembly of components and systems (e.g., torque specifications, lubrication requirements) should normally be called out in technical manuals and approved drawings. Where used, assembly procedures shall be issued prior to the start of production and shall be followed by personnel performing the work. All assembly procedures to be used shall be called out in the controlled work procedure. Where assembly procedures are provided by drawing notes or technical manuals, the controlled work procedure shall call out the specific paragraphs which apply. Assembly procedures shall be verified as completed by the person responsible for the work and these records shall be available to the SCA during the Material Certification Review.

2-2.4. RECORDS

The builder shall keep complete and auditable records of purchases, inspections, fabrication, and testing of the system. The records must meet the intent of data sheet examples in Section 14. The records shall be filed in suitable containers and protected from damage or destruction by water, fire, or other causes and shall be traceable to each individual component. An access system shall be developed by which the records can be quickly obtained for inspection by the Government Procurement Representative. The records described in the following paragraphs shall be originated and retained as documentation to support Material Certification of the diving system. Two (2) copies of all records, pertaining to items contained within the SOC, are required to be submitted to the Government Procurement Representative at the time of the Material Certification Review (paragraph 2-1.6.11.1).

2-2.4.1. Material Traceability Records

a. Copies of purchase documents

b. Vendor's certificates of material and equipment, certifying compliance with applicable specifications and containing detailed chemical, physical, and test data as required by this specification, the system drawings, and other contract documents.

NOTE

Documentation (purchase documents, vendor certificates, etc.) for consumable items used in the construction of the diving system (such as filler metals for welding) must be provided with the Material Certification paperwork.

c. Receipt inspection records

d. Builder-conducted chemical or physical tests on material or equipment

e. Gauge and relief valve calibration sheets

f. Approved waivers or deviations

2-2.4.2. Construction Records

a. Copies of all controlled work procedures and process instructions.

b. Welding procedure qualification records and approval documents

c. Welder or welder operator qualification records , including, current eye exam near field acuity record and quarterly process use record, if applicable.

d. Installation, storage, and handling procedures

e. In-process surveillance procedures and records

f. Welding joint history records

g. NDE reports

h. NDE inspector certification documents ,including, method, level, date of certification, and annual eye exam record

i. Mechanical joint fabrication records

j. Hose logs

k. Fluid mechanical system installation record

2-2.4.3. Assurance Records

a. Builder's quality assurance plan

b. Qualification records of non-destructive test personnel (including data and results of visual acuity test)

c. Records of all installation checks

2-2.4.4. Cleanliness

a. Cleaning procedure(s)

b. Builder's cleaning data sheets (required for both MIL-STD-1330 and MIL-STD-1622 cleaning)

c. Vendor's certification of cleanliness of items supplied in a clean condition

d. Vendor's cleaning data sheets, tags, or stickers for items supplied in a clean condition (required for both MIL-STD-1330 and MIL-STD-1622 cleaning)

e. Hose and other non-metallic off-gassing test records or documented prior history of use in a similar application.

f. Air purity testing documentation

2-2.4.5. Component Testing

a. Copies of all approved component test procedures

b. Signed test data sheets

2-2.4.6. System Testing

a. Copies of all approved system test procedures

b. Signed test data sheets

2-2.4.7. Operational Testing

a. Copies of approved operational test procedures

b. Signed copies of data sheets

2-2.4.8. System Integration Testing

a. Copies of approved system integration test procedures

b. Signed copies of data sheets

2-3. PROCUREMENT

2-3.1. GENERAL

It is critical that the procurement of materials for diving and hyperbaric systems is done correctly. If the documentation of the equipment and materials is incomplete, the system will not be accepted by the Government Procurement Representative. Builders should pay special attention when issuing purchase orders to vendors and ensure that all the documentation that is required for the specific components being ordered are explicitly requested.

2-3.2. PURCHASE DOCUMENTS

The requisition or purchase order shall specify the Military/Federal/Commercial material/equipment specification to which the item is being procured, and shall identify each item which requires marking and traceability. The specific documentation, which must accompany the shipment, shall be described in the purchase document as follows:

a. Material must be traceable by a unique number (heat number, lot/batch number, etc.) to documentation which accompanies the shipment.

b. Chemical Test: Where chemical analysis is required, the purchase document shall request a certified quantitative chemical analysis which includes the actual numerical values of every chemical element contained in the tested material.

c. Physical Tests: Where physical test documentation is required, the purchase document shall request that the physical property test document include the actual numerical value for each mechanical property specified (e.g., yield, elongation).

NOTE

The chemical and physical tests are normally required together. The following materials require chem./phys tests: gas cylinder materials, PVHO shell materials, pressure retaining plates or penetrators used on PVHO shells, PVHO viewports and any materials that are required by the drawings or other contract documents to have chem./phys test results.

d. Heat Treatment: Where heat treatment is specified, the purchase document shall request a furnace chart and certified statement that the required heat treatment has been accomplished and shall include actual numerical value for temperature and time.

e. Cure Dates: O-rings (with the exception of Viton) require the submittal of cure dates for the material, as well as composition of material.

f. Lot Numbers: The paperwork shall clearly indicate which items are part of which lot number and the results of any testing done on the lot shall be traceable to the lot number.

g. Tests: Where tests such as valve seat leak tests, hydrostatic tests, operational tests, off-gassing test, etc. are required, the purchase order shall request that the certification accompanying the shipment list actual parameters such as pressure, temperature, duration, etc. of the test, the results of those tests, test instrument calibration data, and the dated signature of the person performing the work.

h. Cleanliness: Where manufactured parts are supplied pre-cleaned, the purchase document shall request the appropriate cleaning procedure used and individual cleaning certification documentation for each item.

Descriptive language on all purchase documents shall be clear and detailed so no doubt is left regarding exactly what material is being furnished or will be used. All procurement documents shall be serialized (i.e., assigned a unique number). A recommended purchase order form that may be used for all purchases is given in paragraph 2-14.3.

2-3.2.1. Traceability Exclusions

The following items are specifically excluded from traceability between the documentation and material. Any testing, cleaning, or other information that is required for the material or item is still required to be provided, but the item does not need to include any markings that specifically identify it and link it to the purchase order:

a. Packing glands (follower and retainers, integral, flanged, or separated)

b. Gaskets and similar sealing members used in conjunction with joining two pressure boundary parts

c. Valve soft goods (see paragraph 2-3.2.1.1)

2-3.2.1.1. Valve Seal Exclusions

O-rings, seals, gaskets and other soft goods that are part of a standard (non-custom) valve from a reputable vendor do not require individual testing, cleanliness, or cure date documentation. Where valves are supplied for use in oxygen, NITROX, or HEOX systems, verification of seal/soft good compatibility is required on the purchase order. The valve assembly as a whole is to be provided with testing and cleaning documentation that shall suffice for the parts of the valve. The valve as a whole is required to be traceable to all documentation that accompanies the shipment.

2-3.3. RECEIPT INSPECTION

This paragraph establishes the minimum requirements for inspection of material/equipment which is delivered by a Vendor to the Builder and requires traceability. The recommended form to use when conducting the receipt inspection is shown in paragraph 2-14.3.

a. All material shall be inspected upon receipt for shipping damage, completeness, proper type, and for presence of all documentation (certification, etc.) required by the purchase document and that it meets the requirements set forth in the system drawing.

b. Each package in each shipment shall be inspected for proper identity, including the vendor's name or trademark, material type, material grade, nominal size, and vendor lot or traceability number.

c. Each document required by the purchase document shall be inspected to assure it is properly completed, it contains the proper information (i.e., the material specification and each chemical element and mechanical test required are reported), and that it is traceable to the material received.

d. Material/equipment received in a clean condition shall be examined upon receipt for proper packaging and seals which will prevent contamination. Where partial disassembly is required to verify that parts have been properly identified, they shall be examined under clean conditions and resealed or immediately installed. In addition, cleaning documents shall be inspected to ensure that they are correct, complete, signed and traceable to the individual component.

e. Material which has been found acceptable shall have identification affixed containing the identification number on pipe, fitting, component, etc., together with a short description (e.g., 1-inch diameter CRES pipe, 1-inch globe valve), the date of inspection, and the inspector's identifying number and name. The tag shall remain with the item until final installation in the system.

f. Dimensional inspection of critical areas shall be accomplished to ensure fit-up tolerances will meet specifications.

g. Some items may require a sample liquid penetrant inspection, of pipe and fitting, to detect possible porosity and/or cracks.

2-4. MATERIAL

2-4.1. GENERAL

All material used in the construction or repair of diving and hyperbaric systems shall be in accordance with the system drawings, specification and other contract documents. Any deviation shall be requested by the Builder, in writing, and submitted to the Government Procurement Representative. All deviations must be approved by the Government Procurement Representative in writing prior to implementation by the Builder.

2-4.2. CORROSION CONTROL

The diving system must be adequately protected to resist corrosion in a marine environment. Only materials specified in the drawings may be used in the system.

2-4.2.1. Lubricants

Only lubricants meeting the requirements of MIL-PRF-27617, Type 3 Grease may be used on any component in contact with the diver's breathing gas. Do not mix lubricants on a component.

NOTE

Never mix halocarbon oils and greases.

2-4.2.2. Coatings

Coatings such as, anodizing, powder-coating and painting shall conform to the appropriate fabrication drawing or contract document.

2-4.2.3. Passivation

Stainless steel pipe, tube and fittings shall be passivated in accordance with ASTM-A967 when required on the fabrication drawing.

2-4.3. PIPING

Pipe/tubing shall be bent in accordance with MIL-STD-1627 *Bending of Pipe or Tube for Ship Piping Systems*.

2-4.4. TRACEABILITY

All items or materials within the SOC shall be marked to provide traceability from the items to the associated documentation and vice versa.

2-4.4.1. Marking of Material

2-4.4.1.1. General

This section provides the general requirements for marking components, component parts, and piping material for the purpose of material control and traceability to meet certification requirements.

2-4.4.1.2. SOC Piping Systems

The Joint Identification Numbers (JIN) from the JID's shall be permanently marked on the components located within the SOC. Items, such as piping, that shall not be marked directly or small fittings that are not large enough to be marked, shall have tags affixed that provide the JIN. If tags are used, they shall be affixed in such a way that it is clear which joint the JIN is applicable to.

2-4.4.1.3. Types of Permanent Markings

The acceptable types of permanent markings are:

a. Electrochemical etching: The electrolyte used shall be compatible with the material to be marked. Total halide, sulfur, and lead content of the electrolyte shall not exceed 250 ppm.

b. Raised markings: Raised identification markings that are cast or forged integrally with the part are acceptable.

c. Nameplates: The method of attaching nameplates to parts shall be indicated in applicable drawings and shall minimize stress concentrations. Nameplates, where welded, shall be welded in accordance with the applicable equipment specifications. Welds on or to pressure boundaries of P-1 piping systems are considered P-1 welds under *Requirements for Fabrication Welding and Inspection, and Casting Inspection and Repair for Machinery, Piping and Pressure Vessels* (NAVSEA-278) and are required to meet all quality requirements including inspections and pressure tests after welding label plates.

d. Die stamping: Permanent identification marking by this method shall be limited only to carbon and nonferrous materials other than NiCu alloys, NiCrFe alloys, CuNi alloys, and cobalt base alloys. Only round bottom, low stress die stamps may be used and impression depths shall be limited to 0.010 inch. The wall thickness shall not be reduced below the minimum wall thickness required by the applicable drawing or specification. The marking shall be applied to a low stress area, a flange rim, or an integral pad or boss. Tube and pipe shall not be marked by this method.

e. Vibrating marking tools: The tools shall be fitted with a carbide marking point, or equivalent, and shall be adjusted to provide a legible shallow rounded impression not to exceed 0.010 inch in depth. The marking tool tip radius shall not be less than 0.005 inch.

f. Rotary grinders shall not be used for any marking application.

g. Electric arc marking pencils are acceptable for marking applications.

2-4.4.1.4. Limitations of Permanent Markings

The following limitations apply to all permanent marking:

a. All permanent identification markings and their locations shall be indicated on the applicable drawings or in a specification or procedure.

b. Hardened materials shall be marked only by electrochemical etching.

c. Temporary marking on the surface of hard, brittle materials, such as 17-4PH stainless steels or Haynes 25 alloy, shall be applied by ink using rubber stamps or fabric marking pens. Metallic tags used for temporary marking and the materials used to attach the tag shall be of the same material which affords cathodic protection to the material being marked.

d. Tubing or pipe is not to be permanently marked.

2-4.4.2. Handling and Storage After Receipt Inspection

a. Material/equipment within the scope of certification shall be segregated and controlled at the builder's site so that identification of such material/equipment can be maintained throughout the storage, fabrication, and assembly process and no inadvertent substitution of material can take place.

b. The builder shall require and monitor the use of procedures to prevent handling damage. Handling procedures of this type include the use of special crates, boxes, containers, and transportation vehicles.

c. Protection shall also be provided for the prevention of deterioration, contamination, and damage in storage.

2-4.4.3. In-Process Control of Material

The builder shall establish controls which will preclude substitution of material or improper material identification, and which will assure that traceability of material from initial receipt to final installation will not be lost. As a minimum, the following requirements shall be met:

a. Whenever pipe, tubing, or fittings are cut, machined, or worked in any manner which could remove process control identification, the identification shall be similarly indicated on the cut piece in accordance with paragraph 2-4.4.1.

b. The builder shall prepare written procedures for items in storage, issue, transportation, and assembly for controls to ensure preservation of marking and/or tagging of containers and individual components.

2-4.4.4. In-Process Inspection

Surveillance shall be maintained during each phase of the fabrication process to include verification of cleanliness controls and non-destructive testing for material (pipe, fittings, filler metal, fasteners, etc.), components, and equipment. Prior to installation, all components used in an oxygen system shall have documentation verifying acceptable cleaning in accordance with MIL-STD-1330. Any component not passing inspection shall be documented and re-cleaned until a successful examination is performed.

2-4.4.5. Installation Checks

Inspections shall be conducted to verify that all material used in the system are those specified, all markings are visible and legible and provide the required traceability, the equipment is installed as specified on the drawings, and the system is ready for any required cleaning and testing.

2-4.4.6. Records

Records must be maintained to satisfy system certification requirements for traceability. See paragraphs 2-1.6.9 and 2-2.4 for detailed record requirements.

2-5. WELDING

2-5.1. GENERAL

Welding of Hyperbaric and Diving Systems shall be accomplished in accordance with the provisions of NAVSEA Tech Pub S9074-AR-GIB-010/278 and NAVSEA Tech Pub S9074-AQ-GIB-010/248 (NAVSEA–248) with the exception of Pressure Vessels for Human Occupancy (for the welding requirements of PVHOs see section 2-13). In Appendix A of this specification is an approved procedure for welding common joints of a life support system. This procedure contains all of the essential requirements of NAVSEA Tech Pub S9074-AR-GIB-010/278, 1 Aug '95 (NAVSEA-278). The builder shall qualify to this procedure or other procedures suitable for the material and type of welds required with welders and equipment in accordance with NAVSEA-248 and submit the required data to the Government Procurement Representative for approval.

Other welding specifications and/or procedures may be utilized if prior written authorization is given by the Government Procurement Representative.

2-5.2. WELD HISTORY RECORD

The Builder must provide traceability between the joint record and the actual welded joint for each welded pipe joint or structural weld joint. The Builder shall record the following information as a minimum for all welds in diving and hyperbaric systems with the exception of class M-2 welds (see S9074-AR-GIB-010/278 for a description of class M-2 welds).

a. Joint Identification Number (from Joint Identification Drawing)

b. Joint Design

c. Base Material Type (including heat or lot identification)

d. Filler Material Type (including heat or lot identification)

e. Fit-up

f. Welding Procedure Used

g. Heat Treatments (including any preheat, interpass, and post-weld heat treatment temperatures or controls used)

h. Welder's Identification

i. Inspection Methods and Results

j. Deposition of Weld

k. Repairs to Weld

l. Inspection Procedure

m. Inspector's Identification

n. System/Subsystem

o. Serial Number

Paragraph 2-14.3 contains the weld history record form.

2-5.3. WELDING PROCEDURE QUALIFICATION

Each weld procedure used in welding joints in the diving or hyperbaric system shall be qualified in accordance with NAVSEA-248 if welding is to be completed IAW NAVSEA-278.

2-5.3.1. Welder Qualification

Each welder employed for welding joints in the diving or hyperbaric system shall be qualified by demonstrating the ability to produce sound and satisfactory joints and certifying the same in accordance with NAVSEA 248. Welders, performing structural welds on items that are outside of the

SOC, do not require formal performance qualification, but shall be experienced in all material types, joints, and processes used.

2-5.3.2. ASME IX

Each welding procedure and welder employed for welding joints on PVHOs shall be qualified by demonstrating the ability to produce sound and satisfactory joints and certifying the same in accordance with ASME IX. See paragraphs 2-13.3.1 through 2-13.3.2.8 for additional requirements on welding PVHOs.

2-5.4. WELDING FABRICATION

The fabrication welding for a diving or hyperbaric system shall meet requirements of S9074-AR-GIB-010/278.

2-5.4.1. Piping

All welds to piping contained within the SOC shall be Class P-1 welds as described in NAVSEA-278.

2-5.4.2. Filler Material

The Builder shall establish a control program which will ensure that that proper filler material is issued in the welding process. The program shall include a written procedure for the selection, identification marking, special handling, traceability, and inspection of filler material throughout the procurement, fabrication, and installation phase of the life support system. Filler materials shall comply with S9074-AR-GIB-010/278. Paragraph 2-5.6 includes the requirements for conditioning and maintenance of welding filler metals.

2-5.4.3. Defect Rework

Areas ground to remove rejectable discontinuities shall be dimensionally examined. Minimum wall thickness or weld size as specified in the applicable pipe or fitting specification must not be less than acceptable levels. Where wall thickness or weld size has been ground below minimum levels, the area shall be reworked in accordance with initial weld procedure and examined to the same standards as the original weld. No cracks other than crater cracks may be reworked and only one cycle of rework is allowed. Rework shall be documented on the weld history record. Document excavation location and dimensions, including remaining wall thickness, prior to any weld repair.

2-5.5. INSPECTION

This section contains the minimum requirements for inspection of welded joints for use in the fabrication of diving and hyperbaric systems. Additional welding requirements may be found in paragraph 2-13.3.1

2-5.5.1. Fabrication Welds

Nondestructive testing of welds shall be in accordance with the requirements of S9074-AR-GIB-010/278. Hydrostatic testing of welds shall be in accordance with the requirements of this specification, the applicable drawing, or test document.

2-5.5.2. Rework Welds to Fabrication Welds

Prior to rework welding, mechanical removal of the defect shall be verified by repeating the inspection which originally disclosed the defect. Except for defects originally disclosed by leak tests, reinspection may be delayed until after repair welding. Excavations requiring rewelding shall be inspected at 5x magnification or by liquid dye penetrant. Remove minimum amount of metal to remove defect and present a suitable contour for welding. Document final excavation size (length, width, depth) and location. The repaired weld shall be inspected to the same degree as required for the original weld.

2-5.5.3. Repair Welds to Wrought Base Materials

Prior to repair welding, removal of the defect shall be verified by repeating the inspection which originally found the defect. Leak tests may be delayed until after repair welding.

On completion of repair welding, satisfactory repair shall be verified by repeating the inspection that disclosed the defect. Liquid dye penetrant (PT) inspection of the final surface of all weld repairs to piping and components is required in accordance with the applicable Specification (this includes ½ inch of base metal beyond the toe of the repair weld). Acceptance criteria shall be based on weld or base metal requirements in accordance with the applicable Specification.

Radiographic inspection of wrought base metal repair may be required on a case basis.

Hydrostatic testing of rework or repair welds shall be in accordance with the requirements of applicable drawings or test documents.

2-5.5.4. Inspection Standards

NDE inspections shall be performed IAW T9074-AS-GIB-010/271 and evaluated in accordance with MIL-STD-2035 and this specification utilizing the appropriate class (1, 2 or 3) as directed by S9074-AR-GIB-010/278.

2-5.6. REQUIREMENTS FOR CONDITIONING AND MAINTENANCE OF WELDING FILLER METALS

Welding electrodes, including rods, covered types and bare spooled electrode (wire form) shall be handled and stored in accordance with S9074-AR-GIB-010/278.

2-6. BRAZING

2-6.1. GENERAL

Brazed joints are typically not permitted. If a written exemption has been issued by the Government Procurement Representative it may be allowed. In piping systems fabricated with brazed joints, all brazing shall be performed in accordance with written and approved brazing procedures which meet or exceed the requirements described in NAVSEA 0900-LP-001-7000, *Fabrication and Inspection of Brazed Piping Systems*. The Builder shall submit the written brazing procedures and the brazer/brazing operator qualification, for Government Procurement Representative review and approval. Any repairs to joints involving heat or brazing shall be accomplished in accordance with approved written requirements and subjected to the tests and inspections specified for the joint repaired.

2-7. PIPING SYSTEM FABRICATION

2-7.1. WELDED PIPE/TUBE

See 2-5 for welding requirements.

2-7.2. MECHANICAL JOINT FABRICATION

Assembly of each mechanical joint within the SOC boundaries shall be witnessed by a qualified inspector. Prior to joint make-up, the joint shall be inspected for fit and alignment. Joint parallelism and concentricity shall be maintained so that torque in excess of fitting manufacturer recommendations is not required for seal. At the time of the joint make-up, the witnessing inspector shall enter the following information on the Mechanical Joint Assembly Record form (see paragraph 2-14.3)

a. Joint Identification Number (from Joint Identification Drawing)

b. Joint Type (flanged, threaded, union, etc.)

c. Base Material Type (316L CRES for pipe, etc.)

d. Type of Seal Used (gasket, O-ring, etc.)

e. Joint Alignment Inspection Results

f. Joint Make-up Torque (torque values listed on JID)

NOTE

Pipe threads shall not be used in stainless steel piping systems because of the possibility of particulates being shed in the joining process.

2-7.3. TUBE FLARING AND FLANGING PROCEDURES

All tube flaring/flanging shall be performed in accordance with qualified written procedures that include joint fabrication and torque requirements. Tube flaring/flanging procedures shall specify requirements and acceptance criteria for each applicable category of tube flaring/flanging material. Tube flaring/flanging procedures shall be qualified for each type of flaring/flanging equipment. Both the written procedures and qualification results shall be delivered to Government Procurement Representative for approval prior to fabrication.

2-7.4. PIPE/TUBE BENDING

Piping and tubing shall be bent in accordance with MIL-STD 1627, “Bending of Pipe or Tube for Ship Piping Systems”. The minimum wall thickness for piping or tubing extrados (back wall) after bending shall not be less than the minimum wall thickness required for straight piping or tubing which shall be listed in the system drawings. Piping or tubing shall not be bent to a radius less than 2 times the pipe diameter. See 1-3.7.6 for additional information on pipe bending.

2-7.5. FLEXIBLE HOSES

Flexible hoses shall be fabricated as shown in the system drawings. After cleaning and testing, a hose tag shall be affixed to the hose assembly in accordance with 1-3.7.8.2.

2-8. CLEANING

2-8.1. GENERAL

All parts of life support system through which gas flows for delivery to the divers shall meet the cleanliness criteria stated in paragraph 2-1.6.6. This includes hoses, pipe, fittings, valves, gauges, filters, air flasks, volume tank, reducers, etc.

All material/components shall be cleaned by the builder before assembly into the life support system to the cleanliness standards in the approved specification. However, material/components received from a supplier in a clean condition in accordance with the requirements of paragraph 2-1.6.6 need not be recleaned unless they have been contaminated in storage, welding, or handling. Any items that are supplied in a clean condition must have all of the appropriate documentation and that documentation must be provided to the government upon system delivery.

2-8.2. CLEANING PROCEDURES

Cleaning of breathing gas systems shall be performed in accordance with written cleaning procedures that are developed by the Builder and are in accordance with MIL-STD-1330 and possibly MIL-STD-1622. Cleaning procedures shall include methods for sampling and criteria for acceptance. Quantitative analysis to verify system cleanliness must be performed prior to manned testing of the system. Hydrocarbon contamination is of particular concern because hydrocarbons may be both toxic and flammable. The cleaning procedure shall be submitted to the Government Procurement Representative for approval. No cleaning shall take place until written approval of the cleaning procedure has been granted by the Government Procurement Representative.

2-8.3. CLEANING CONTROLS

2-8.3.1. Storage

Temporary storage of cleaned equipment, piping, or components must be in an environment that will prevent contamination. The storage area shall meet the following requirements:

a. Material shall be stored in enclosed structures, free of debris and contaminants such as oil and grease.

b. Shelves shall be free of dust and other contaminants.

c. Storage building shall be locked with entry limited to authorized personnel.

d. Temperature shall be kept between 40ºF and 100ºF.

2-8.3.2. Fabrication Controls

Materials/components must remain in a clean condition when removed from storage for fabrication. The following procedures will ensure that cleanliness is maintained:

a. Prior to leaving the storage area, the packaging of all cleaned materials shall be inspected. If the outer package is torn or damaged, but the inside package is intact, replace the outer package. If the inside package is damaged and exposing the cleaned item to the ambient atmosphere, the item shall be recleaned and recertified to the applicable cleaning specification.

b. All visual inspections which require that a cap or seal be removed from a clean item shall be conducted in a clean area.

c. Fit-up of clean pipe and components shall be accomplished in a clean enclosure.

d. Items transported from storage to fabricating area shall be protected from damage to caps and seals and from internal contamination.

2-8.4. SUBASSEMBLY CLEANING

At the option of the Builder, material/components fabricated into subassemblies may be flushed of any contaminants which may have entered the subassembly prior to installation in the entire system.

The flushing procedure shall be in accordance with MIL-STD-1330 or MIL-STD-1622 as appropriate and it shall be previously approved by the Government Procurement Representative.

2-8.5. HOSE CLEANING

All rubber hoses shall be cleaned in accordance with MIL-STD-1330 or MIL-STD-1622 as appropriate and pass an off-gassing test prior to acceptance. A sample off-gassing procedure is included in paragraph 2-9.10. A hose log shall be maintained which identifies the hose, date cleaned, and cleaning process used. The same log shall be used during testing of the hose and the log shall be provided to the Government Procurement Representative during the Material Certification Review.

2-8.6. GAUGE CLEANING

Gauges used in systems wetted with greater than 25% by volume of Oxygen shall be cleaned in accordance with Naval Ship's Technical Manual (NSTM) ST700-F1-PRO-010. Other gauges shall be cleaned in accordance with NSTM ST700-F1-PRO-010 or MIL-STD-1622.

2-8.7. DOCUMENTATION

Documentation of cleaning shall be in accordance with MIL-STD-1330 or MIL-STD-1622 as applicable. An example data sheet that may be used by the Builder, is presented in paragraph 2-14.3. All data required for MIL-STD-1622 cleaning of "critical components" must be completed for each component cleaned by the Builder in accordance with MIL-STD-1622. This documentation shall be provided as part of the data package delivered to the Government Procurement Representative during the Material Certification Review.

NOTE

MIL-STD-1622 does not require the use of data sheets but does require a vendor to provide a sticker or tag in the packaging with specific information. These stickers or tags from Vendors must be retained by the Builder and delivered as part of the documentation package with the system.

2-9. TESTING

2-9.1. GENERAL

The Builder shall be responsible for developing and implementing a System Testing Program for the diving equipment being fabricated. All tests shall be conducted in the presence of the Government Procurement Representative, except where such representative may authorize the Builder to conduct, report, and certify the tests. A schedule and location for the testing shall be supplied by the Builder to the Government Procurement Representative no later than 4 weeks prior to the commencement of testing.

All material, labor, equipment, and instrumentation necessary to perform the tests shall be provided by the builder, unless otherwise specified. All instruments used in the conduct of the test shall be calibrated in accordance with ANSI Z540-1.

2-9.2. SYSTEM TESTING PROGRAM

The Builder shall develop and submit a written test program, to the Government Procurement Representative, for approval. It shall outline a comprehensive and integrated series of tests which fully demonstrates the adequacy of all systems and equipment within the SOC. The testing shall not be implemented until a written approval of the testing program has been received from the Government Procurement Representative. The test program shall consist of the following elements:

a. A test procedure index which is a listing of all individual test procedures (test memos) with an identification number, title, latest revision number, and date of issue.

b. A test plan which indicates the sequence in which the individual test procedures are to be accomplished, thereby establishing the prerequisite(s) for each succeeding test procedure. A PERT chart or bubble chart which clearly shows all parallel and convergent paths is a useful method of presenting this information

c. The individual test procedures which clearly show the type of testing to be performed, step by step procedures for conducting the test, required test instrumentation and acceptance criteria. The procedure must also include examples of all data sheets required to record the test results. Such procedures shall contain, as a minimum, the following information:

   (1) Step by step procedures for conducting the test.

   (2) Prerequisites or required preparations for the test.

   (3) Equipment required for test including calibration data for calibrated equipment.

   (4) Components which must be removed from the system before testing.

   (5) Location of all spools, jumpers, or blanks to be installed.

   (6) Inlet and outlet points for water, nitrogen, air, etc.

   (7) Data forms for recording test results and verification signatures.

   (8) Valve line-up sheets showing valve line-up for test.

   (9) Pressure, temperature, flow rates, etc.

   (10) Acceptance criteria for each test.

   (11) Precautions to be followed, such as proper isolation of portions of system to prevent contamination of cleaned and tested system parts.

2-9.2.1. System Testing Program Submittal

The Builder shall submit the System Testing Program to the Government Procurement Representative prior to conducting the actual tests. The test program shall have written Government Procurement Representative approval prior to execution and shall be kept current by the Builder. Any changes to the test program must be submitted in writing to the Government Procurement Representative for approval prior to implementation. It may become necessary for support facilities and/or subcontractors to assign new identification numbers, compatible with local procedures, to individual tests being performed. If so, a cross reference of test procedure index numbers shall be provided to facilitate test record verification.

2-9.2.2. Items that Require Testing

Items that require testing include:

a. Pressure vessel systems

b. Flotation and buoyancy systems

c. Mechanical systems

d. Structural systems within the SOC

e. Emergency deballasting and jettisoning systems operation

f. Life-support systems including breathing gas purity control

g. Handling equipment systems

h. Electrical power, control and communications systems

i. Instrumentation and monitoring systems

j. Safety feature operation.

2-9.2.3. Test Documentation

The Builder must provide written test results (data) to the Government Procurement Representative during the Material Certification Review.

2-9.3. TEST CATEGORIES

The test categories, listed in paragraphs 2-9.3.1 through 2-9.3.4. below, are all unmanned tests which must verify that the candidate system operates safely as designed. Manned testing is not covered by this specification. All manned testing, unless otherwise stated in the contract documents, shall be the responsibility of NAVSEA 00C3.

2-9.3.1. Factory Acceptance Tests (FAT)

This category covers testing which is performed by an equipment or component manufacturer to ensure that the material functions within specified limits. FATs should be required on all material where operation is of such a critical nature that failure to perform within the specified limits would jeopardize the safety of the Divers or Operators. The reason for testing of this material at the factory is, usually, that the diving system fabricator may not have the necessary test apparatus. Syntactic foam and acrylic for viewports are examples of material which require FATs. If a FAT is required it shall be noted on the Purchase Documents (see paragraph 2-3.2).

2-9.3.2. Prototype First Article Testing (PFT)

This category of test may be required to prove the design of critical components or entire systems which are developmental in nature. Performance of materials, components and systems which are unique or untried in a similar environment and are within the Scope of Certification (SOC) must be demonstrated by such tests prior to manned use. PFTs will often incorporate life cycle testing to verify that a component or system will operate within design limits and will not fail prematurely.

2-9.3.3. Pre-Installation (PIT) and Pre Operational (POT) Tests

Those tests which are performed on components prior to installation in a system (often referred to as bench tests). Hydrostatic and seat tightness testing of valves are examples of PIT level testing. Pre-operational tests (POT) are those tests performed at the system level, but prior to operating the system. Insulation resistance and continuity tests and mechanical system tightness tests are examples of POT level testing. These tests shall normally be conducted on each system produced.

2-9.3.4. System Operational (SOT) and System Integration (SIT) Tests

System operational tests (SOT) are required to verify that separately each subsystem operates satisfactorily within its design parameters. System integration tests (SIT) are performed to verify that all subsystems can be operated concurrently, as designed. SITs are also used to verify that the system operating procedures can be used to operate the system safely prior to conducting manned operational testing.

2-9.4. ELECTRICAL TESTING

The Builder shall submit test procedure(s) designed to demonstrate the adequacy of electrical continuity and Insulation Resistance (IR) of all electrical circuits that are in the SOC.

2-9.4.1. Dielectric Strength Test

A dielectric strength test at 60 Hertz for one minute shall be performed on all electrical cable assemblies, equipment, and devices within the SOC. The dielectric test voltage shall be the test voltage of twice-rated plus 1000 volts. Where standards for electrical devices, other than switching or interrupting devices, call for lower test voltages, such devices may be disconnected during the dielectric test. Such devices should be individually tested in accordance with their applicable standard. The cable dielectric tests shall be performed between all conductors and the sheath and also between individual conductors. This is a go/no go criteria test. For previously tested electrical cable assemblies, equipment and devices where a dielectric strength has been performed, re-testing is not required unless damage is suspected. Subsequent dielectric strength testing shall be conducted at 75% of the voltage applied the first time. Dielectric strength tests shall always be followed by an IR test.

2-9.4.2. IR Testing

All IR testing shall be with DC voltage. The DC voltage shall not be less than 500 volts held for one minute for electrical cables, equipment, or devices unless it can be shown that such a test would be detrimental to the equipment (e.g., pyrotechnic jettisoning devices). However, if the instrument reading indicates that an insulation resistance meets the specified limit, and is steady or increasing, the test may be terminated before the end of the specified period. Ten megohms is acceptable for each circuit when newly installed. One megohm is acceptable system IR. If the measured IR does not meet requirements, IR values shall be corrected to 25°C. If the corrected value meets requirements, then the test is acceptable. Both the measured and corrected values shall be recorded. If the system IR drops an order of magnitude and the fault cannot be removed, an operational abort should be considered.

2-9.4.3. Testing Requirements for Electrical Component Exposed to Ambient Pressures Greater than One Atmosphere or Sea Water

2-9.4.3.1. Introduction

Electrical components with differential pressure boundaries exposed to ambient pressures greater than one atmosphere or those components exposed to sea water require special testing to ensure the design of the electrical component is adequate for its intended use and the watertight integrity maintained. This section provides the minimum mandatory testing requirements for new and maintained electrical components with differential pressure boundaries exposed to ambient pressures greater than one atmosphere or those components exposed to seawater. It provides requirements for hydrostatic testing, joint tightness testing, insulation resistance, continuity, and the OQE necessary to document accomplishment of the testing. Where the requirements of this section conflict with existing directives, specifications, or requirements, document the conflict and address it to the Government Procurement Representative for resolution.

2-9.4.3.2. Test Pressure Tolerance

The tolerance for the hydrostatic pressure test and the joint tightness test is - 0,+ 5%. The tolerance for a vacuum test is ± 2 inches of mercury.

2-9.4.3.3. Testing Requirements

All components that are newly installed (or have undergone repair) require strength testing in accordance with 2-9.4.3.4. Permanently or temporarily mounted external implodable and explodable items shall also meet the requirements of Appendix B. Explodable items due to decompression shall also meet the requirements of Appendix C.

For each component, electrical testing shall be conducted in accordance with 2-9.4.3.5.

2-9.4.3.4. Pressure Testing

Pressure testing may be accomplished by satisfactorily conducting a hydrostatic strength test as defined below or by conducting either critical implodable or explodable volume testing which meets the requirements stated below.

2-9.4.3.4.1. Hydrostatic strength testing

Perform the test in a pressure tank filled with fresh water. Prior to the first cycle and after the last cycle, measure the IR of the component being tested in accordance with 2-9.4.3.5 and record all test data. Visually inspect for damage or deformation prior to and after completion of testing. As a minimum, conduct hydrostatic strength tests as follows:

(1) 0 to maximum system operating pressure – hold for five minutes, cycle three times.

(2) 0 to 1.5 times maximum system operating pressure – hold for a minimum of one hour, cycle one time.

NOTE

In some cases it is impracticable to hydrostatically strength test a component by applying pressure from the outside. In these cases, the Government Procurement Representative shall approve a suitable substitute method to test the strength of the component.

2-9.4.3.4.2. Testing of Critical Implodable and Explodable Components

Conduct implodable or explodable testing in accordance with the requirements of Appendix B or Appendix C. Prior to the first cycle and after the last cycle, measure the IR of the component being tested in accordance with 2-9.4.3.5 and record all test data.

2-9.4.3.5. Electrical Testing

The IR of current carrying conductors shall not be less than ten megohms for each circuit when newly installed, and one megohm for in-service circuits. One megohm is acceptable system IR. If the measured IR does not meet requirements, IR values shall be corrected to 25°C. If the corrected value meets requirements, then the test is acceptable. Both the measured and calculated values shall be recorded. The DC voltage for IR testing shall not be less than 500 volts, unless it can be shown that such a test would be detrimental to the equipment (e.g., pyrotechnic jettisoning devices, cameras, etc). If the instrument reading indicates that an insulation resistance meets the specified limit, and is steady or increasing, the test may be terminated before the end of the specified period. Lower voltage may be used when specified and approved by Government Procurement Representative.

> **NOTE**
>
> The length of the cable may be sufficiently long to preclude these readings. In that case, an acceptable IR can be derived, using manufacturer's data, and submitted to Program Manager for approval.

Perform all electrical testing using calibrated test equipment.

2-9.4.3.6. Test Documentation

For electrical systems that include differential pressure boundary components, the Builder shall submit OQE documenting the satisfactory accomplishment of all required testing in a format suitable for review and audit. As a minimum, for components subjected to testing in accordance with 2-9.4.3.4 and 2-9.4.3.5, record the information specified in 2-9.4.4.

2-9.4.4. Electrical Test Documentation

Document the following information for electrical tests:

a. Platform and system tested

b. Component or circuit tested

c. Serial number of components with differential pressure boundaries exposed to ambient pressures greater than one atmosphere or those components exposed to seawater

d. Pass/fail criteria

e. Type of test

f. Actual test data, including but not limited to continuity before/after the hydrostatic test (if applicable) and insulation resistance before/after hydrostatic test

g. Date test conducted

h. Calibration due dates & serial number of test equipment

i. Required test pressure or vacuum

j. Actual test pressure or vacuum

k. Required test fluid

l. Required duration (pressure or vacuum test)

m. Actual duration

n. Test acceptance signature. The test acceptance signature shall be annotated as attesting that the person who actually performed or witnessed the test is verifying that all associated test parameters were met.

> **NOTE**
>
> The Test Acceptance Signature shall be annotated as attesting that the person who actually performed or witnessed the test is verifying that all associated test parameters were met

2-9.5. HYDROSTATIC TESTING

All pressure retaining components (e.g. piping, pressure vessels and valves) that are within the SOC shall be hydrostatically tested. Hydrostatic testing shall take place prior to joint tightness testing, pressure drop testing, valve seat tightness testing, and operational testing.

2-9.5.1. Test Instrumentation

2-9.5.1.1. Pressure Gauge

a. A calibrated test pressure gauge shall be used that has the test pressure within the calibrated range of the gauge, with accuracy less than or equal to the required test tolerance.

b. The test pressure gauge shall have been calibrated in accordance with ANSI Z540-1.

2-9.5.2. Overpressure Protection

a. To prevent damage to the system due to possible overpressure during testing, either the installed relief valve or a temporary self-actuating relief valve must be used.

b. The rated relieving capacity of the relief valve at test pressure shall be greater than the source being used to pressurize the system.

c. The test relief valve setting shall be 10% or 50 psig above test pressure, whichever is less.

2-9.5.3. Component Removal

Pressure regulators, air filters, system relief valves, pressure gauges and other components may be removed and replaced with spools, jumpers, plugs, or caps during hydrostatic testing of a system where the test is required to be conducted at a pressure higher then the rated pressure of the components or if they are incompatible with the test fluid. The removed components shall be tested separately to their required test pressure.

2-9.5.4. Test Procedure

a. Use only Grade B water filtered through a 10 µm (maximum) filter for hydrostatic testing of the system.

b. A hydrostatic test pressure pump capable of generating pressures sufficient to meet requirements specified in the approved test procedure shall be used. Pump surfaces which contact the test fluid shall be cleaned in accordance with the requirements of paragraph 2-1.6.6. Lubricants, if used, shall be in accordance with Naval Ship's Technical Manual Chapter 262, *Lubricating Oils, Greases, Specialty Lubricants, and Lubrication Systems*. No seals or packing may be used which could possibly fragment or disintegrate into the test fluid.

c. Piping and fittings in the high pressure portion of the system shall be hydrostatically tested to 150% maximum system pressure (+10%, −0) psi. The piping and fittings, including the volume tank and filter housings in the low pressure system, shall be hydrostatically tested to 150% maximum system pressure (+10%, −0) psi. The flex hoses in the system shall be tested to two times (2X) the maximum system pressure (+10%, -0%).

d. Pressure vessels (recompression chambers, gas cylinders, diving bells) shall be hydrostatically tested in accordance with the commercial or government specification that was used in their design and fabrication.

e. Hold pressure for 15 minutes while visually inspecting the system for deformation, distortion, or leakage. There shall be no leakage across a valve seat or through a valve packing.

f. Dry the system piping and components by purging with dry nitrogen. A humidity of 20°F dew point shall be reached.

2-9.5.4.1. Hydrostatic Test of Piping and Piping Components

The following test requirements are applicable to piping, valves, gauges and other similar components.

a. Hydrostatic testing, including acceptance criteria, of diving and hyperbaric system piping and piping components shall be as specified in Naval Ship's Technical Manual S9086-RK-STM-010/CH-505, Piping Systems, MIL-STD-1330 and as specified herein when applicable. If there is a conflict between the testing specified in the NSTM or MIL-STD and this manual, then the requirements of this manual take precedence.

b. Pipe and piping components whose pressure boundary is internally loaded when the system is on the surface, but is externally loaded to a pressure greater then internal pressure at depth, shall be hydrostatically tested in both the internal and external directions.

c. Pipe and piping components whose pressure boundary is externally loaded by sea pressure, but whose internal minimum operating pressure is equal to or greater than diving system design test depth pressure, shall only require an internal hydrostatic test.

d. Pipe and piping components whose pressure boundary is externally loaded by sea pressure, but whose internal maximum operating pressure is one atmosphere shall only require an external hydrostatic test.

NOTE

In the event that a required external hydrostatic test is unable to be conducted due to equipment availability, test component configuration, etc., an internal hydrostatic test at a pressure equal to 150 percent of the diving system design test depth may be substituted. NAVSEA approval shall be obtained prior to substituting an internal hydrostatic test for any required external hydrostatic test. Approval will be dependant on documentation that demonstrates the ability of the pipe and/or piping component(s) to withstand the required external pressure and that sea and joint design will perform equally well when subjected to either internal or external pressure.

e. Pipe and piping components that penetrate any hull integrity boundary (tanks, spheres, skirts, etc.) where a single failure could result in internal flooding or depressurization of the diving/hyperbaric system shall be hydrostatically tested from the hull integrity boundary penetration inboard to the first isolation valve at a pressure equal to 150 percent of the maximum operating pressure.

f. Pipe and piping components open to internally pressurized tanks and/or enclosures (including hyperbaric chambers) shall be hydrostatically tested internally from the tank and/or enclosure penetration outboard to the first isolation valve at a pressure equal to the pressure used to hydrostatically test the tank and/or enclosure.

g. Leakage past mechanical joints or valve seats during hydrostatic testing shall not be cause for rejection.

> **NOTE**
>
> Incompressible fluid system mechanical joints which experience zero leakage during a hydrostatic test do not require joint tightness testing in the direction applied by the hydrostatic test. Compressed gas system mechanical joints which experience zero leakage during hydrostatic test still require joint tightness testing because the physical difference in test fluids (liquid versus gas).

h. External hydrostatic test acceptance criteria of "no permanent deformation" for pipe shall, in addition to a complete visual inspection, be verified by out-of-roundness measurements (defined as the difference between the major and minor outside dimensions at any one cross-section). Out-of-roundness measurements not within the pipe specification, approved drawing, or MIL-STD-1627 (for pipe bends) shall be cause for rejection of the item

> **NOTE**
>
> Measurements for out-of-roundness shall be taken as close as possible to the center of the unsupported axial length. As an example, given a pipe assembly with 6 feet of pipe between two flange unions, the point of measurement would be at the midpoint of the 6 foot pipe length. Out-of-roundness measurements shall not be taken for pipe fittings.

2-9.5.5. Acceptance Criteria

There shall be no leakage or permanent distortion in any pressure-containing part of the system.

2-9.5.6. Component Replacement

All spools, jumpers, plugs, or caps shall be removed and replaced with the components which were removed IAW paragraph 2-9.5.3.

2-9.5.7. Hydrostatic Retest

A hydrostatic retest is not required after replacing valve packing, bonnet gaskets, discs, or other valve software, provided no structural modifications are made, no strength member has been deformed or otherwise modified, and a seat leakage test has been performed. Following replacement of parts, as previously noted, the unit shall be checked for leakage at normal operating pressure. A hydrostatic retest is required if repairs involve welding or structural modification in any part of the pressure-containing system.

2-9.5.8. Hydrostatic Test Documentation

The following information, as a minimum, shall be recorded as documentation of the hydrostatic testing:

a. Platform and system tested

b. Date test conducted

c. Test boundary

d. Calibration dates and serial numbers of test equipment

e. Test fittings, blanks and jumpers (if applicable)

f. Required test pressure

g. Actual test pressure

h. Test fluid used

i. Required duration

j. Actual duration

k. Allowable leakage

l. Measured leakage

m. Results of inspections/out of roundness measurements

n. Valve line up for test (typically shown as a schematic)

> **NOTE**
>
> Valve line-ups for pressure testing shall provide the following information: Valve designator and/or valve nomenclature, required valve positions, initials and date of the Valve Positioner verifying by observation the actual valve positions, and test entry point when an external pressure source is used for an internal pressure test.

o. Test acceptance signature

> **NOTE**
>
> The test acceptance signature shall be annotated as attesting that the person who actually performed or witnessed the test is verifying that all associated test parameters were met.

2-9.6. VALVE SEAT TIGHTNESS TEST

New, refurbished, or repaired valves and regulators shall be seat tightness tested. This testing shall be performed after component cleaning and prior to operational testing.

2-9.6.1. General

The valve seat tightness test shall be performed in accordance with paragraph 2-9.6.4 or 2-9.6.5 below and recorded on a Test Data Sheet. Helium may be used for O_2 systems if nitrogen at the required pressure is not available. However, compliance with leakage requirements may prove more difficult because of the lighter (less dense) gas. The tolerance on all test pressures shall be $\pm$ 2% of the test pressure for test pressures below 1000 psig, and the tolerance shall be $\pm$ 20 psig for test pressures above 1000 psig.

Globe type valve designs and poppet valves shall be tested in the direction that tends to unseat the valve. Globe-type designs and poppet valves shall also be tested in the direction that tends to seat the valve when the valve acts as a boundary closure between two distinct operating pressure systems/subsystems.

NOTE

Valves which act as a boundary closure between two distinct pressure systems or subsystems shall have the test pressure of each port identified by a temporary tag when testing is performed in a shop or on a test bench and the ports are not to be otherwise marked or identified. The temporary tags can be removed after the valve has been installed. The purpose of the tagging is to alert personnel to the correct orientation of the valve in the system.

Ball valves shall be tested in the direction of flow as determined by the orientation of the valve in the diving system. Ball valves that act as a pressure boundary closure between two distinct operating pressure systems or subsystems shall be tested from both directions. Ball valves that are designated flood control closures shall, in addition to being tested at the maximum operating pressure, be tested from the direction of the flooding source at a pressure of 100 psig.

NOTE

The test pressure applied to each port shall be identified by temporary tags when testing is performed in a shop or on a test bench and the ports shall not be otherwise marked or identified. The temporary tags can be removed after a valve has been installed. The purpose of the tagging is to alert personnel to the correct orientation of the valve in the system.

2-9.6.2. He, HeO_2, O_2, Life Support and Exhaust Systems Only

Pressurize each valve under the seat with helium (O_2 systems with nitrogen) to the maximum operating pressure of the system. Use the recommended procedure given in paragraph 2-9.6.4 for verifying that the seat leakage is less than 0.6 cc/minute (zero with nitrogen).

2-9.6.3. Air Systems

Pressurize each valve under the seat with nitrogen to the maximum operating pressure of the system. Use the recommended procedure given in Paragraphs 2-9.6.4 and/or 2-9.6.5 for verifying that the seat leakage is zero.

2-9.6.4. Leak Capturing Method

Pressurize each valve, from anywhere upstream of the “under-the-seat” side of the valve, with helium (nitrogen) to the operating pressure of the system. Attach a ¼ –inch I.D. clear Tygon tube to the first available point any distance downstream of the valve under test. Shut the next valve downstream of this test point to isolate this section of pipe so that all leakage must flow through the Tygon tubing. Mark 2 inches of the end of the Tygon tubing in ¼ –inch increments. Roll up some of the length of tubing in order to squeeze air out, then immerse the free end in a beaker of water. Unroll tubing and return it to its original shape. This action will draw some water up into the tubing. Hold the tubing vertical in the beaker and move up or down until the water level inside the tubing is lined up with the level in the beaker. Note where this level falls on the ¼-inch markings on the tubing. This will ensure that there is only one atmosphere pressure on the isolated section of piping. Wait for one minute then realign the water levels inside and outside the tubing. This will ensure that there is again only one atmosphere pressure on the isolated portion of the piping and any leak rate read in atm. Cc/min. regardless of the volume of the isolated portion. A ¾-inch change in level in one minute equals 0.6 cc/min. (For air systems, the level should not change in one minute).

2-9.6.5. Pressure Drop Method

If it is not possible to capture the leakage and only as a last resort, an installed gauge upstream of the valve under test may be used for the seat tightness test. Isolate the gauge and the test valve by closing the first valve upstream of the gauge. The downstream side of the test valve shall be open to atmospheric pressure. Observe the gauge for 30 minutes minimum. The pressure should not drop.

NOTE

The acceptance leak rate of 0.6 cc/minute would drop a 3000 psi test pressure 1 psi in one hour if the volume of the isolated section was 500 cc. It is therefore apparent that this is not a satisfactory method for discerning small leak rates and therefore should only be used when absolutely necessary.

2-9.6.6. Valve Seat Tightness Test Documentation

The following information, as a minimum, shall be recorded as documentation of the valve seat tightness testing:

a. Platform, system, and valve tested

b. Date test conducted

c. Test boundary

d. Calibration dates and serial numbers of test equipment

e. Test fittings, blanks and jumpers (if applicable)

f. Required test pressure

g. Actual test pressure

h. Test fluid used

i. Required duration

j. Actual duration

k. Allowable leakage

l. Measured leakage (Leak Capture Method)
Initial and final gauge pressure (Pressure Drop Method)

m. Valve line up for test (typically shown as a schematic)

NOTE

Valve line-ups for pressure testing shall provide the following information: Valve designator and/or valve nomenclature, required valve positions, initials and date of the Valve Positioner verifying by observation the actual valve positions, and test entry point when an external pressure source is used for an internal pressure test.

n. Test acceptance signature

> **NOTE**
>
> The test acceptance signature shall be annotated as attesting that the person who actually performed or witnessed the test is verifying that all associated test parameters were met.

2-9.7. JOINT TIGHTNESS TEST

This test subjects mechanically joined pressure containing boundaries of pipe and piping components to an internal pressure equal to 100 percent of maximum operating pressure, and if applicable, an external pressure equal to 100 percent of Diving System design test depth pressure.

New, major or minor repaired pipe and piping components shall be subjected to an internal joint tightness test prior to system operational testing or use. Oxygen systems shall be pressurized using clean, dry nitrogen. Air systems may be pressurized using air or nitrogen. HeO_2 systems shall be pressurized using a gas mixture containing at least 15% helium.

Joint tightness tests conducted on components prior to installation in the system shall have a duration of at least 5 minutes. Joint tightness tests of components after installation in the system shall have a duration of at least 15 minutes followed by time to inspect each mechanical joint.

Pipe and piping components whose pressure boundary is externally loaded by sea pressure, but whose internal maximum operating pressure is always equal to or greater than Diving System design test depth pressure, shall only require an internal joint tightness test.

Pipe and piping components whose pressure boundary is externally loaded by sea pressure, but whose internal minimum operating pressure is less than Diving System design test depth pressure shall require both external joint tightness testing and internal joint tightness testing.

> **NOTE**
>
> The ability to conduct external joint tightness testing is extremely limited. Recognizing the limitations, accomplishment of this testing may be deferred by assembling the affected joints using "controlled assembly" procedures, similar to those specified by Forces Afloat Quality Assurance Manuals, and completing a controlled dive to design test depth which results in no leakage.

Pipe and piping components open to internally pressurized tanks and/or structural enclosures (including hyperbaric chambers) shall be joint tightness tested internally from the tank and/or enclosure penetration outboard to the first isolation valve at a pressure equal to 100 percent of the maximum internal operating pressure of the tank and/or enclosure.

Pipe and piping components that penetrate any hull integrity boundary (tanks, spheres, skirts, etc.) where a single failure could result in internal flooding of the Diving System shall be joint tightness tested from the hull integrity boundary penetration inboard to the first isolation valve at a pressure equal to 100 percent of Diving System design test depth pressure or 100 percent of system maximum operating pressure, whichever is greater.

Acceptance criteria for joint tightness testing shall be zero leakage, unless helium is used as a test medium. When helium is used as a test medium the allowable leakage shall be 0.6 cc/minute. If leakage rates are specified in the system drawings, those rates take precedence over those listed herein.

2-9.8. PRESSURE DROP TESTS

Recompression chambers, saturation diving systems, and gas supply and storage systems shall all be pressure drop tested. The pressure drop test(s) shall be performed following the completion of the hydrostatic, joint, and seat tightness testing and prior to operational testing. The duration of this test shall be equal to the longest duration that the system is anticipated to be pressurized during operation or 24 hours, whichever is less.

2-9.8.1. He and HeO_2 Systems

Test the system using a mixture of gasses that includes at least 15% helium and following the procedures of 2-9.8.4 or 2-9.8.5 as appropriate. If leakage rates are specified in the drawings for systems being tested with helium, those rates take precedence over those given in 2-9.8.4 and 2-9.8.5.

2-9.8.2. Oxygen Systems

Test the system using nitrogen and following the procedures of 2-9.8.4 or 2-9.8.5 as appropriate.

2-9.8.3. Air Systems

Test the system using air and following the procedures of 2-9.8.4 or 2-9.8.5 as appropriate.

2-9.8.4. High Pressure System

> **NOTE**
>
> All measurements shall be documented on system serialized test record.

a. Ensure isolation from low pressure side of system by appropriate blanks.

b. Charge the system with dry oil-free nitrogen to maximum operating pressure ± 100 psig. High pressure clean air may be used on air systems.

c. Record the atmospheric temperature and test pressure at the start of the test and again at the conclusion.

d. Correct the final pressure as described in paragraph 2-9.8.6.

e. Acceptance Criteria: Allowable pressure drop is 1% of the initial test pressure (corrected to atmospheric conditions at the start of the test) for air systems. No leakage is allowed on oxygen systems. If the pressure drop is greater than allowed, all connections and joints shall be soap tested to determine the point of leakage. The leak shall be repaired and documented, and the system shall be retested.

2-9.8.5. Low Pressure System

a. Charge the low pressure system with dry, oil-free nitrogen to operating pressure ± 5 psig. Clean pressurized air may be used on air systems.

b. Record the atmospheric temperature and test pressure at the start of the test and at the conclusion.

c. Correct the final pressure as described in paragraph 2-9.8.6.

d. Acceptance Criteria: Allowable pressure drop for air systems is 1% of the initial corrected test pressure. No leakage is allowed in oxygen systems. If the pressure drop is greater than allowed, all connections and joints shall be soap tested to locate the leak. The leak shall be repaired and documented, and the system shall be retested.

2-9.8.6. Temperature Correction

The test pressure at the conclusion of the test must be corrected to the atmospheric conditions existing at the start of the test. The correct pressure is obtained as follows:

(1) Add 14.7 psi to the initial test pressure recorded to obtain absolute pressure.

(2) Add 460 degrees to the initial temperature (ºF) recorded to obtain absolute temperature.

(3) Add 460 degrees to the final temperature (ºF) recorded after 24 hours to obtain absolute temperature.

(4) Multiply the initial absolute pressure calculated in step 1 by the final absolute temperature calculated in step 3.

(5) Divide the result obtained in step 4 by the initial absolute temperature calculated in step 2.

(6) Subtract 14.7 psi from the result obtained in step 5. This result will be the corrected final pressure in psig.

Gay-Lussac's Law:

$$(P/T)_1 = (P/T)_2$$

2-9.8.7. Pressure Drop Test Documentation

The following information, as a minimum, shall be recorded as documentation of the pressure drop testing:

a. Platform and System Tested

b. Date Test Conducted

c. Test Boundary

d. Calibration Dates and Serial Numbers of Test Equipment

e. Test Fittings, Blanks and Jumpers (if applicable)

f. Required Test Pressure

g. Actual Test Pressure

h. Test Fluid Used

i. Required Duration

j. Actual Duration

k. Allowable Leakage

l. Measured Leakage

m. Temperature and Pressure Data Supporting Drop Test

n. Valve Line Up for Test (typically shown as a schematic)

> **NOTE**
>
> Valve line-ups for pressure testing shall provide the following information: Valve designator and/or valve nomenclature, required valve positions, initials and date of the Valve Positioner verifying by observation the actual valve positions, and test entry point when an external pressure source is used for an internal pressure test.

o. Test Acceptance Signature

> **NOTE**
>
> The test acceptance signature shall be annotated as attesting that the person who actually performed or witnessed the test is verifying that all associated test parameters were met.

2-9.9. AIR PURITY TEST

A gas sample from the diving system shall be taken after fabrication has been completed to ensure that gaseous contaminants are not present.an acceptable atmosphere for its occupants. Both the atmosphere within the system and its compressed gas supply must be checked and evaluated for contaminants under normal operating conditions. Evaluations of closed-atmosphere systems entail three basic requirements: a valid sampling program, effective analysis techniques, and meaningful interpretation of the data obtained. Any contaminants found must be evaluated in terms of personnel safety, taking into account their toxic and corrosive hazard potentials, the durations of exposures to them, their sources, and potential methods of their removal. Contaminants may be introduced into the diving system from a number of sources including materials of construction, as contaminants from compressed gases, and from other sources such as solvents used to clean the system. Contaminants may also be introduced into the diving system by divers or maintenance personnel.

Regardless of how thorough it may be, no analysis of gas from diving systems can rule out all potential hazards. Nevertheless, these guidelines are based on expectations of potential contaminants in both the atmosphere of the diving system and the supply gases. These procedures are designed to screen for a wide range of volatile organic compounds (VOCs), including hydrocarbons, and to ensure that supply gases are of high purity, (i.e., that they do not contain significant amounts of other fixed gases such as oxygen, nitrogen, helium, carbon dioxide, or carbon monoxide). The presence of VOCs, which are routinely seen in diving systems and supply gases, should be expected in any samples taken.

The need for testing for additional volatile contaminants beyond what is described here will depend on 1) experience with each diving system and 2) contaminants expected from specific materials and gear used in the complex. Since no testing can ensure complete safety, as a general rule any unknown odor or the observation of any aerosol (i.e., mist or smoke) associated with the diving system should be treated as potentially hazardous until that odor or aerosol is shown otherwise.

Some potential contaminants (e.g., chlorine, hydrochloric acid, ozone, nitrogen dioxide) are very reactive and toxic. However, these chemicals readily react with metal surfaces and probably do not persist very long. Consequently, such species probably are not present in a diving system except after an engineering casualty. Furthermore, no easy and reliable testing methods useful for diving systems are available for these types of volatile contaminants.

2-9.9.1. Setup

Using standard procedures, set up the diving system for operation. Systems shall not contain carbon dioxide or contaminant absorbants (e.g. Sodasorb or Purafil); any contents of charcoal filters should be removed. The system shall contain all gear and equipment (i.e. hoses, masks, bunks) that are normally inside the system during operations, so that a total systems check can be made. If the diving system consists of two or more connected chambers, leave all interchamber hatches open so that the entire complex is tested.

2-9.9.2. Hyperbaric Systems

Air tightness test and valve seat tightness test of the system shall have been satisfactorily completed and the entire system assembled. Cyclically pressurize the hyperbaric system at least 3 times between atmospheric pressure and approximately 8 ATA, or its maximum operating pressure, whatever is less, using hydrocarbon—free air or helium. This will reduce the level of any contaminants initially inside the diving system. Then, compress the system to approximately 4 ATA or to its maximum operating pressure, whichever is less. Let the system sit at depth, preferably for 72 hours but for at least 24 hours, to allow any offgassing chemicals to build up. Once the test has begun, do not add any gas to maintain depth because of leakage. However, if the depth at the end of the test period is less than 90 percent of the starting depth, the test must be repeated after leaks have been repaired. When practical, operate the life support system (i.e. scrubber fan),without carbon dioxide or contaminant adsorbent, for at least 2 hours before sampling the gas to ensure that the atmosphere has been well mixed within the system.

At the end of the 24 hours (minimum), attach a stainless steel whip to the system plumbing via a high pressure valve and purge all hardware in the sampling line with gas at an audible flow rate for at least 5 min. To ensure reliable sampling, the whip's point of attachment will be as close to the actual system atmosphere as possible. Gas should contact only metal tubing and high-pressure valves that have been previously cleaned to oxygen—safe specifications (MIL-STD-1330). Depending on the volume of dead space estimated between the whip attachment site and the system atmosphere, a purge time longer than 5 min may be required to flush the sampling line with a minimum volume of 3 times the dead space.

Following purging, draw duplicate gas samples into high pressure stainless steel gas collection cylinders that have been previously heated and evacuated to at least 50 millitorr. To ensure an adequate volume of gas for analysis, these cylinders should have an internal volume of at least 500 ml and should be suitable for storing ppm levels of volatile organic compounds (VOCs) for up to one month. The cylinder shall be connected to the whip while gas is flowing from it to purge any dead space in the connection. The cylinder valve adjacent to the whip is then opened slowly and 1 minute allowed for the cylinder to equalize with system pressure before the valve is closed. Leave gas flow on as the first cylinder is disconnected from the sample line and as the second cylinder is attached.

After the second cylinder is filled, the gas flow is stopped. Record all sampling procedures and conditions, including:

a. Date, time, and system pressure at beginning of pressure test;

b. Date, time, and system pressure at time of gas sampling;

c. Contents of system;

d. Sample location, including location of whip attachment;

e. Atmospheric Internal temperature within of the tested system at several times during the test;; and

f. Summary of test procedures.

2-9.9.3. One-ATA Systems

Purge the closed diving system atmosphere with hydrocarbon-free air or helium sufficiently to remove all initial gas. Let the system sit closed preferably for 72 hours, but for at least 24 hours, to allow any off gassing chemicals to build up. When practical, operate the life-support system without carbon dioxide or contaminant adsorbent for at least 2 hours before sampling the gas, to ensure that the atmosphere has been well mixed within the system.

At the end of the 24 hours (minimum), take gas samples using a stainless steel bellows gas pump or other type of vacuum/pressure pump capable of pressurization to at least 40 psig and suitable for pumping gas with ppm levels of VOCs without significantly changing the composition. To accomplish this task, first attach a stainless steel whip to the system plumbing via a system valve. To ensure reliable sampling, the whip's point of attachment should be as close to the actual system atmosphere as possible. The pump is then attached to the other end of the whip, the system valve opened, and the pump turned on for at least 5 min to equilibrate all sampling hardware with the system gas. Gas should contact only metal tubing and valves that have been previously cleaned to oxygen-safe specifications MIL-STD-1330. Depending on the flow characteristics of the pump and the volume of dead space estimated between the pump and the system atmosphere, a longer time than 5 min between when the pump is turned on and actual sampling may be required to flush the sampling line with a minimum volume of 3 times the dead space.

Following purging, draw duplicate gas samples into high-pressure stainless steel gas collection cylinders that have been previously heated and evacuated to at least 50 millitorr. To ensure an adequate volume of gas for analysis, these cylinders should have an internal volume of at least 500 ml and should be suitable for storing ppm levels of VOCs for up to one month. The cylinder shall be connected to the pump as pumping continues to purge any dead space in the connection. The cylinder valve adjacent to the pump is then be opened slowly while the pump is operating and left opened for at least 2 minutes but long enough to achieve full pressure (i.e., 40 psig). Leave the pump on as the first cylinder is disconnected from the pump and as the second cylinder is attached. After the second cylinder is filled, the pump can be stopped. Record all sampling procedures and conditions including:

a. Date and time at beginning of test;

b. Date and time of sampling;

c. Contents of system;

d. Sample location, including location of whip attachment;

e. Atmospheric Internal temperature of within the tested system at several times during the test

f. Cylinder filling pressure in PSIG.

g. Summary of test procedures.

2-9.9.4. All Systems – Supply Gas

Draw duplicate gas samples from each supply gas bank header in a fashion similar to that described for hyperbaric systems. The header shall be pressurized for at least 24 hours before sampling. A high-purity regulator (e.g., with a stainless steel diaphragm) may be needed upstream of the sample whip to allow samples to be collected at 4 ATA. Again, record sampling procedures and conditions.

2-9.9.5. Analytical Procedures

The laboratory performing the chemical analysis must demonstrate quality assurance practices consistent with provisions of ANSI/ASQC Q2, Quality Management and Quality System Elements for laboratories-Guidelines; or ASTM E548 General Criteria Used for Evaluating Laboratory Competence; or equivalent.

Gas samples will be analyzed as described below. These procedures, or alternate ones that meet or exceed the specifications listed below, must be followed. Both duplicate cylinders from each sampling exercise will be analyzed for all constituents defined below when sufficient sample gas is available.

Gas samples will be screened initially using Gas Chromatography (GC) with flame ionization detection (FID) or with a methodology of equivalent sensitivity and precision. Gas chromatographs should be configured to allow detection of a wide range of VOCs. To ensure detection of the most likely contaminants, GC's should be configured for detection of:

a. Highly volatile light compounds such as:

 (1) Ethane

 (2) Propane

b. Less volatile heavier compounds such as:

 (1) Benzene

 (2) Toluene

 (3) Xylenes

 (4) Trimethyl benzenes

c. Highly polar compounds such as:

 (1) Isopropyl alcohol

More than one GC configuration combined with different detectors (e.g., column type, temperature profile, carrier gas flow) may be necessary to analyze for this range of compounds. The specific chemicals listed above are representative of the three classes of VOCs that may be present in diving systems; they do NOT comprise a list of all the individual compounds that may be expected. GC, with a variety of detectors, should be used to detect the range of VOCs defined by the above chemicals to effectively screen the gas in diving systems. Gas standards, certified by the vendor to +/-5% or better, of representative VOCs including those listed above should be used for the analysis.

Gas chromatographs with FID flame ionization detectors must be capable of detecting the VOCs down to a level of 0.5 PPM or lower (depending on the specific compound being analyzed). The precision of a GC for repeat injections depends on the type of compound being analyzed, how good the chromatographic separation or resolution is for each compound, and what concentration level is being tested. In general, precision of VOCs analyzed at a level of 5-10 PPM should be +/-5% or better. Gas standards should be certified to +/-5% or better depending on the accuracy required. Gas standards should be certified and traceable to National Standards. Preconcentration (e.g., on solid sorbent packing or by cryogenic trapping) may be necessary prior to GC-FID or GC/MS analysis when levels of contamination are low (<= 0.1 PPM). Quantitation will be done based upon data obtained from calibration using on the GC peak areas from the certified gas standards. Individual contaminants other than the actual chemicals in the calibration standards will be quantified relative to the species in the standard closest to their GC retention times. Identification of direct injection of chemical species into the GC and/or GC/Mass Spectrometry will be used to identify any unknown GC gas chromatograph peaks from the GC-FID analysis estimated greater than 1 ppm. Preconcentration (e.g., on solid sorbent packing or by cryogenic trapping) may be necessary prior to identification when levels of contamination are low (<= 1 PPM). will require additional analysis using a Gas chromatograph equipped with a Mass Selective detector. (GC-MSD). The GC-MSD data analysis software will give names to the unknown GC-FID chromatographic peaks. Quantitation of the GC-MSD chromatographic peaks is normally done by comparing the MSD instrument response to the unknown to that of a certified Benzene standard .

Gas supply samples will be analyzed for VOCs as well as for the fixed gases, oxygen, nitrogen, helium, carbon dioxide, and carbon monoxide. An analytical methodology such as GC equipped with methanization/FID or infrared spectroscopy should be used to measure carbon dioxide and carbon monoxide. Such a method must be able to detect 5 ppm carbon monoxide. GC with thermal conductivity detection should be used to analyze the other fixed gases. Precision should be at least 1 percent for both a 20 to 22% 02 gas standard and a . Precision for CO and 2500 to 5000 ppm CO2 standard. should be at least +/-5%. Fixed gas quantitation will based on gas standards certified by the vendor to +/-1%.be done by using certified standards traceable to national Standards, and certified to +/-2% or better.

Results will be reported as follows for each sample:

a. For VOCs (>1 ppm): identification and quantitation to the nearest 0.1 ppm.

b. For fixed gases (only gas supply samples):

   (1) Oxygen, nitrogen, and helium to the nearest 0.1 percent;

   (2) Carbon dioxide to the nearest 5 ppm; and

   (3) Carbon monoxide (>5 ppm) to the nearest 1 ppm.

2-9.9.6. Interpretation of Results

Results from analysis of both the atmosphere samples and the supply gases shall first be examined in terms of differences between duplicate samples. Any major differences such as presence of a contaminant in one of the gas samples and its absence in the duplicate sample will necessitate that the diving system be retested or the gas supply header be re-sampled.

Results from analysis of atmosphere samples shall then be compared to those from the VOC analysis of the actual supply gas used during the system test. Any VOCs found in the supply gas should be subtracted from the results from the system atmosphere to correct for the supply gas contribution. These modified atmosphere sample results shall then be corrected for depth by converting to surface equivalent values (SEV). This conversion is accomplished by multiplying the reported values of any contaminant by the test depth at the time of sampling. Example: 2 ppm toluene measured using GC in gas after being collected from a chamber tested at 4 ATA would have an SEV equal to 8 ppm (2 ppm x 4 ATA) toluene.

A few selected contaminants that may be present in hyperbaric complexes are given in Table 15-5 in NAVSEA SS521-AG-PRO-010, U.S. Navy Diving Manual, revision 4, with their 90-day continuous exposure limits (or 7 -day limits, where a 90-day limit is unavailable). In the absence of specific guidelines for hyperbaric exposures, these limits will be used as safe limits for manned hyperbaric systems.

Where any of these chemicals are found in atmosphere samples, the calculated SEV shall be compared to the limit in Table 15-5 of the Diving Manual. If the SEV exceeds this limit shown in Table 15-5, the chamber is unsafe for use. If two or more contaminants are reported or if a limit for the reported contaminant is not listed in Table 15-5, contact one of the agencies listed in the next paragraph. the Government Procurement Representative for guidance.

Results from samples taken from the supply gas shall also be compared to the limits listed. When only one contaminant is reported and its limit is listed, that limit shall be divided by the reported concentration to produce the maximum safe depth in atmospheres to which the gas can be used in operating the chamber. When the supply gases contain undesired levels of other fixed gases (e.g., oxygen, nitrogen, helium, carbon dioxide, carbon monoxide), retesting should be performed to confirm findings. Corrective action may then be required to ensure the desired level of gas purity; such action may include recharging of the gas banks and/or reevaluating current gas handling procedures and hardware.

Additional advice on toxicity considerations not covered in available publications may be obtained from the Toxicology Detachment, Naval Health Research Center, Wright-Patterson Air Force Base, Ohio or the Naval Experimental Diving Unit, Panama City, Florida..

2-9.10. OFF-GASSING TEST PROCEDURE

2-9.10.1. General

Non-Metallic material shall be off-gas tested prior to installation unless there is documented historical evidence that the material is safe for use in U.S. Navy diving systems. If testing is not conducted on non-metallic components, it is the Builders responsibility to provide documentation to the Government Procurement Representative proving that the material is safe for use in the intended application. The Builder should contact NAVSEA 00C3 to provide guidance on the off-gassing tests required.

The laboratory performing the chemical analysis must demonstrate quality assurance practices consistent with provisions of ANSI/ASQC Q2, Quality Management and Quality System Elements for laboratories-Guidelines; or ASTM E548 General Criteria Used for Evaluating Laboratory Competence; or equivalent.

2-9.11. VERIFICATION OF AS -BUILT STRENGTH (PROOF TEST) FOR EXTERNALLY LOADED PRESSURE HULLS/VESSELS AND HARD STRUCTURES

> **NOTE**
>
> The requirements of this section apply only to identical reproduction of a prototype which has successfully met the requirement of section 1-3.14.5.4.

A proof test to at least 1.5 times the maximum operating pressure shall be conducted on all pressure vessels, hard structures, and penetration fittings that are subject to external pressure.

> **NOTE**
>
> "Hard structure" typically refers to Diving System components whose function is to enable the storage, transfer, or controlled movement of a working fluid at relatively low system pressure, while resisting the external force due to ambient sea pressure. For example, variable ballast tanks might be classified as hard structure. Volumes external to the pressure hull, designed to maintain a static, dry, nominally one atmosphere environment within the volume for the purpose of protecting pressure -sensitive components, are usually classified as implodables and are treated in Appendix B. Camera housings and lights are examples of implodable volumes. It is important to note also that components/volumes inside the pressure hull, which themselves may be internally exposed to ambient sea pressure, may be classified as hard structure. This explanation is provided as general guidance and does not preclude the Government Procurement Representative from providing justification for classifying a particular component as either hard structure or implodable.

For hull structures which have had full-scale model tests, described in paragraphs 1-3.14.5.4 b or c, in accordance with section 1-3.14.5.4.1, the proof test required by this section does not have to be instrumented.

For hull structures which have not had full-scale model tests described in paragraphs 1-3.14.5.4 b or c,, the proof test required by this section shall be an instrumented (strain gage) pressure test in accordance with section 1-3.14.5.4.1, except that the test pressure shall be at least 1.0 times the maximum operating pressure. Subsequent to testing, pressure boundary weld NDE may be specified or required by the Government Procurement Representative. The results of this test shall be compared to strain gage data obtained during reduced scale model testing, similar item model testing, and/or calculations . Where multiple pressure vessels or hard structures are fabricated to identical designs, only the first item (i.e., prototype) will require instrumentation during the proof test. All items subsequent to the prototype require proof tests to at least 1.0 times the maximum operating pressure, but need not be instrumented.

2-9.11.1.1. Proof Testing Procedures/Instrumentation

For all pressure vessels, Government Procurement Representative approval of the proof test procedure shall be obtained prior to commencing the proof test. The proof test procedural requirements shall be similar to the model test procedural requirements of section 1-3.14.5.4.1.

2-9.12. TESTING PARAMETERS FOR PERMANENTLY OR TEMPORARILY MOUNTED EXTERNAL IMPLODABLE AND EXPLODABLE ITEMS

This section provides guidelines for ensuring that Diving Systems or Diving System personnel are not subjected to underwater explosion or implosion loading, resulting from the failure of an uncompensated Diving System component. The requirements for testing and components to be tested can be found in Appendix B.

2-9.13. TESTING PARAMETERS FOR EXPLODABLE ITEMS DUE TO DECOMPRESSION

During the design process, particular attention will be given to the shrapnel effects produced by the explosion of items such as interior lights and instrument bulbs inside the Diving System and to the prevention of these occurrences. Many devices are subject to inadvertent explosion during decompression because they have been infiltrated by helium or other gases during a compression cycle. These devices, in themselves, may become hazards within the Diving System and such this phenomena should have been considered during the design process. There is no known analytical method for determining the material adequacy of items within a Diving System which may explode and cause a casualty. All items that may explode due to decompression shall be evaluated in accordance with Appendix C.

2-9.14. GAUGE CALIBRATION/VERIFICATION

All gauges installed on a new system shall have their calibration and accuracy verified by testing in accordance with this section. The gauges shall be verified to be within the accuracy tolerances shown on the drawings or meet the requirements of the gauge accuracy grade required by paragraph 2-12.1.1. Vendors or activities providing gauge calibration or verification services must be approved in writing by the U.S. Navy METCAL program.

2-9.14.1. Master Test Gauge Requirements

The master test gauge shall have nominal errors no greater that ¼ of those permitted for the gauge being tested. For example, when testing a 200 psi Grade 1A (1%) gauge, the master test gauge must have errors no more then ¼ of 1%, or 0.5 psi. The range of the standard must be no less than that of the gauge under test but may be higher, as long as the errors do not exceed 0.5 psi. A 200 psi Grade 3A gauge, with errors of 0.25% of 200 (0.5 psi), or a 500 psi Grade 4A gauge, with errors of 0.1% of 500 (0.5 psi) or a 1000 psi digital gauge with errors of 0.05% of 1000 (0.5 psi) may be used. In addition to the requirements of this paragraph, the master test gauge must also meet the requirements of ANSI Z540-1.

2-9.14.2. Testing Medium

Testing for air gauges shall be conducted using clean dry air suitable for divers. Gauges in systems other then air system (i.e. O_2, HeO_2, NITROX) shall be tested using clean, dry nitrogen.

2-9.14.3. Testing Alignment

Mounting a pressure gauge in a position other than that at which it was calibrated can affect it's accuracy. Verification of the calibration shall take place in such a manner that the gauge is oriented as it would be during system operation.

2-9.14.4. Verification Test Procedures

The following procedures shall be used to determine it's compliance with the drawings and/or the accuracy grades defined in Table 12 of this document.

2-9.14.4.1. Reference Temperature

A temperature of 73ºF ±2ºF (23ºC ±1ºC) shall be the reference standard.

2-9.14.4.2. Reference Barometric Pressure

A barometric pressure 29.92 in. Hg. (1.0132 E+05 Pa) shall be the reference standard. Only absolute pressure gauges with the pointer set to indicate 14.7 psia will be affected by changes in barometric pressure.

2-9.14.4.3. Procedures.

2-9.14.4.3.1. Accuracy Test

a. Grades 3A and 4A. Before conducting the accuracy test, subject the gauge to a pressure equal to the maximum indicated pressure (or vacuum). Conduct the accuracy test within 10 minutes.

b. All Grades. Known pressure shall be applied at each test point on increasing pressure (or vacuum). At each test point the gauge shall be read, lightly tapped, and then read again. The difference in the readings is friction error. Both readings shall be recorded on the test data sheet. The same sequence shall be repeated on decreasing pressure (or vacuum). The entire set of upscale and downscale readings shall then be repeated and recorded.

Accuracy Grade	Minimum Number of Test Points[1]
4A	10
3A, 2A, 1A, A	5
B, C, D	3

1. The test points shall be distributed over the dial range and shall include points within 10% of the ends of the dial range.

c. The error can be determined from the data obtained in the two pressure cycles and is equal to the maximum error at each test point, in either direction, after tapping. When expressed as a percentage of the span, the error shall not exceed the limits in Table 12 of section 1-3.9 for the applicable grade of accuracy.

2-9.15. INSTRUMENTATION CALIBRATION/VERIFICATION

All instrumentation installed in the system such as gas monitors, temperature indicators, or flow meters shall be tested to ensure they meet the requirements set forth in the system drawings. The vendor or activity that performs the testing must be approved in writing by the U.S. Navy METCAL program

2-9.16. TESTING OF LIFTING POINTS AND RIGGING

2-9.16.1. Padeyes, Lifting Lugs, and Hard Points

All arrangements for handling and supporting weights (including weights of any personnel), all arrangements for taking heavy strains, and all parts where the safety of the system or life depend, shall be given a static load test equal to twice the specified working load unless otherwise specified in the drawings. In cases where the working load is not specified the test load shall be based on the expected duty of the arrangement. For hoisting arrangements, the static loads test shall be suspended clear of all supports and held suspended for a sufficient period to permit inspection of welds and other fastenings. After relieving the static test load, there shall be no evidence of permanent deformation of structure. Documentation of this test shall be delivered along with the equipment.

2-9.16.2. Rigging

Rigging shall be tested, marked and certified in accordance with NAVFAC P-307 Management of Weight Handling Equipment, section 14. All records required by P-307 shall be delivered along with the equipment.

2-9.17. DIVER HANDLING SYSTEM TESTING REQUIREMENTS

All new Diver Handling Systems must be tested prior to initial certification and operational use. In addition, all modified or extensively repaired handling systems shall be inspected and tested as required in this section. These tests are intended to confirm the adequacy of the design, the operational characteristics, and the validity of the operating procedures. For modified or repaired systems, the purpose of these tests is to verify the adequacy of the work performed, and to ensure the handling system continues to meet its design and certification criteria.

Test procedures for all load tests and System Operational Tests (SOTs) shall be submitted to the Government Procurement Representative for review and approval.

The following paragraphs identify the requirements for conducting static, dynamic, and rated load tests. In addition, maintenance testing requirements after completing maintenance tasks are also addressed.

2-9.17.1. No Load Test

No load tests are conducted to evaluate the functioning of the Diver Handling System. The Diver Handling System shall be operated through its full range of motions and directions. Check for unusual noise, vibration, or overheating in machinery and control components. Also check for proper operation of all indicator lights and gages.

2-9.17.2. Static Load Test

A static load test physically verifies the structural integrity of the fully assembled Diver Handling System. Test loads may be applied with certified test weights or by mechanical devices with calibrated load measuring gages.

a. The static test load shall be equal to 200 percent of the operational load of the handling system, and shall be held for a minimum of ten minutes by the brake without power to the system. No evidence of structural or rigging component deformation, or brake slippage is allowed.

b. Upon completion of the static load test, the critical load bearing components and strength welds of the handling system shall be inspected to verify there is no permanent set, deformation, cracking, or other damage to any part of the structure, foundations, machinery, and reeving components. For initial certification, or if load bearing component repair or modification work was accomplished, the level of inspection shall be as specified on the drawings or in separate specifications to include MT or PT as applicable.

c. End fittings on ropes included in the test shall be inspected for slippage and damage.

d. Verify the system will hold the static load for one minute without power to the system.

e. The static load test shall be conducted when the support ship is pier-side and experiencing no significant motion. The handling system shall be tested in the position of maximum loading.

2-9.17.3. Dynamic Load Test

A dynamic load test demonstrates the capability of the Diver Handling System to operate with the rated load under the dynamic conditions of the support ship's motions at sea. The test shall demonstrate the handling system's overload capabilities throughout its complete operating range. Care must be taken to ensure specific operating limits of the components being tested are not exceeded.

a. The dynamic load test shall be equal to 150 percent of the rated load of the handling system. Test loads shall be moved through one complete cycle of the handling system, with all limits of its operating modes (raising, lowering, traversing, traveling, rotating, etc.) included in the test. The handling system, with the test load, shall be stopped at least three times in each direction to ensure proper brake operation. No speed is specified; however, the maximum speed attainable with the test load shall be used.

b. During the dynamic load test, the handling system shall be checked for any signs of binding, abnormal noise or vibration, and overheating. As a minimum, the following equipment parameters shall be recorded during the test: motor amperage, hydraulic fluid temperatures and pressures (including main loop, servo, and replenishing pressures), operating speeds for all modes of operations (i.e., booming out, booming in, and/or raising and lowering, etc.). In general, the following shall be verified and noted: smooth operation, and proper stopping and holding of the test weight.

c. Upon completion of the dynamic load test, the handling system shall be inspected for any indications of the following: warping or permanent deformation; leaking hydraulic fluid from any component or connections; wear patterns on sheaves, ropes, and gear trains; and proper drum spooling.

d. The dynamic load test shall be conducted when the support ship is pier-side and experiencing no significant motion.

2-9.17.4. Rated Load Test

A rated load test demonstrates the capability of the Diver Handling System to operate with its intended load at its rated speed. It also verifies that all hydraulic and electrical components operate within their specified operating limits.

The rated load test shall be equal to 100 percent of the rated load of the Diver Handling System. Test loads shall be moved completely through the handling system's full operating range, and within limits of all operating modes (raising, lowering, traversing, traveling, rotating, etc.). The system shall be capable of hoisting the Diving System at the system's rated speed when the hoist wire rope or synthetic line is on the outermost layer of the drum. The test load shall be run through at least three cycles to demonstrate proper operation. Each cycle is to be run at the specified normal operational speed of the handling system.

2-9.17.5. Maintenance Testing Requirements

Conducting the full range of load tests (i.e., static, dynamic, and rated load tests) is not always necessary after completing corrective maintenance actions or some repair tasks. Table 22 identifies the tests required after performing various tasks on structural, rigging, or machinery components. Some handling systems have unique components and may require additional or modified testing. The test documents for those tests shall be submitted to the Government Procurement Representative for review and approval on a case basis. The system drawings/specifications should be consulted for further testing requirements. The tests specified in Table 22, and the applicable tests specified by a drawing or specification shall be conducted for each maintenance task identified. If there is a conflict between the tests specified in Table 22 and the test specified by the applicable drawing or specification, then the requirements of this document take precedence, unless specifically authorized by the Government Procurement Representative.

NOTE

If the system is certified to ABS requirements fully documented maintenance actions and testing is still required to be submitted to the Government Procurement Representative and retained for review by the SCA.

Table 22: Maintenance Testing Requirements – Load Bearing Components

Maintenance Task	Test Requirements
Drum or sheave repair, replacement, or modification	Static load test[1], dynamic load test, rated load test.
Hook[1] repair, replacement, or modification	Static load test[1].
Main lift rope(s) replacement (wire rope and synthetic line)	Pull test[3], no-load test.
Coupling, shaft, or bearing repair or replacement	Dynamic load test, rated load test.
Non-load bearing shafts or bearing repair or replacement	No-load test.
Gear repair and replacement (load bearing or load controlling only)	Static load test[1], dynamic load test, rated load test.
Gear bearing oil-seal replacement	No-load test.
Hydraulic cylinder repair or replacement (when the cylinder is used to support the weight of a vehicle, PTC, or divers stage)	Static load test[1], dynamic load test, rated load test.

1. Only the repaired, replaced, or modified component needs to be statically load tested. If the affected component can be rigged such that the 200 percent test load can be applied to it only, then the test would suffice for the static load test.
2. "Hook" in this section is a generic term for the interface device between the diving system and the handling system.
3. All wire rope end fitting installations must be pull-tested to either 200 percent of the design load of the handling system, or to 40 percent of the nominal breaking strength of the wire rope. All synthetic line eye splices shall be proof tested to 200 percent of the design load of the handling system.

2-9.17.6. Handling System Hydraulic and Pneumatic System Test Requirements

Hydraulic and pneumatic systems and components shall be tested in accordance with the requirements of this subsection. However, systems designed to the requirements of Title 46, CFR Subchapter F, Marine Engineering or an approved industrial standard may be tested to the requirements of those standards, providing the Fabricator can show there will be no detrimental effect on system safety.

All test procedures for items within the SOC, including Factory Acceptance Test (FAT) procedures, shall be submitted to the Government Procurement Representative for review and approval.

2-9.17.6.1. Hydrostatic Testing Requirements

a. All new piping and pressure-containing components shall be hydrostatically tested. In addition, any piping, pressure-containing components, or tanks (accumulators, cylinders, etc.) that have been subject to repairs or modifications affecting its structural integrity (such as welding, brazing, or reboring) must be retested to verify the work has had no detrimental effect.

b. Hydrostatic test pressure for piping and piping components shall be 150 percent of maximum operating pressure. The pressure used to perform the test shall be within ± 3 percent (but no greater than ± 100 psig) of the designated test pressure, unless otherwise specified.

c. The duration of hydrostatic tests for pipe and piping components, including piece parts, conducted in a shop or on a test bench shall be not less than 1 minute, plus the time required for inspection.

d. The duration of hydrostatic tests for pipe and piping components, including piece parts, conducted in the as-installed configuration shall be not less than 15 minutes, plus sufficient time for inspection of mechanical joints and components within the test boundaries.

e. Hydrostatic testing of hydraulic system piping should be performed with system fluid. However, water or other flushing fluids are permissible when accomplished in accordance with MIL -STD - 419, Cleaning, Protecting, and Testing Piping, Tubing, and Fittings for Hydraulic Power Transmission Equipment or an approved industrial standard. Hydrostatic tests of installed systems shall be conducted with system fluid only. However, hydrostatic testing of pneumatic systems should be conducted with demineralized water.

f. For flexible hoses the hydrostatic test procedure and pressure shall be in accordance with paragraph 8.2 of NAVSEA S6430-AE-TED-010, Piping Devices, Flexible Hose Assemblies or an approved industrial standard.

g. Acceptance criteria for hydrostatic tests shall be no permanent deformation as determined by visual inspection. Leakage past mechanical joints or valve seats during the test shall not be cause for rejection as long as the test pressure can be maintained. However, any leakage shall be noted in the test results section of the test procedures.

2-9.17.6.2. System Tightness Testing Requirements

a. All new and repaired pipe and piping components shall be subjected to a tightness test prior to operating the system.

b. The tightness test pressure shall be 100 percent of the maximum allowable working pressure. The pressure used to perform the test shall be within ± 3 percent (but no greater than ± 100 psig) of the designated test pressure, unless otherwise specified.

c. The duration of tightness tests for pipe and piping components conducted in the as-installed configuration shall be not less than 15 minutes soak time at system operating pressures and temperatures, plus sufficient time for inspection of mechanical joints and components within the test boundaries.

d. Tightness testing should be conducted using system fluid.

e. Acceptance criteria for tightness testing of joints being accepted by the test shall be zero external leakage.

2-9.17.6.3. Maintenance Testing Requirements

Table 23 identifies system level tests required after performing various hydraulic system maintenance tasks. Some handling systems have unique components and may require additional or modified testing. The test procedures for those tests shall be submitted to the SCA for review and concurrence. The tests specified below and tests specified by drawing or specification shall be conducted for each maintenance task identified. If there is a conflict between the tests specified below and the test specified by the applicable drawing or specification, then the requirements of this manual take precedence.

Table 23: Maintenance Testing Requirements – Hydraulic Systems

Maintenance Task	Test Requirements
Hydraulic Pump or hydraulic motor repair or replacement	Dynamic load test, rated load test.
Servo valve, high pressure piping and components repair or replacement	No-load test.
Hydraulic cylinder repair or replacement (when cylinder is used to support the weight of the diving system)	Static load test, Dynamic load test, rated load test.
All other hydraulic system components and piping repair or replacement	No-load test.
Major brake repair or replacement	Static load test, dynamic load test, rated load test.
Routine adjustment or alignment of brake	Rated load test.

2-9.17.7. Handling System Relief and Counter-Balance Valve Test Requirements

The safety of divers and diving system operators depend on the proper operation of these valves. Relief valves are used in motion compensated circuits as well as for protecting the hydraulic system from overpressurization. Counter-balance valves are used to stop the diving system from moving uncontrollably in the event of a sudden loss of system pressure.

All new or repaired relief or counter balance valves installed in a diver handling system shall have seat tightness testing and have their cracking pressure verified.

NOTE

Seat tightness testing and cracking pressure verification may be accomplished after installation while the system is being adjusted.

2-9.17.7.1. Seat Tightness Testing

a. The duration of seat tightness tests conducted in a shop or on a test bench shall be not less than 5 minutes.

b. The duration of seat tightness tests conducted in the as-installed configuration shall be based on the time necessary for the minimum leakage to be detected at the point of observation or monitoring.

c. Acceptance criteria for seat tightness testing shall be zero leakage or that allowed in the manufacturer's specifications or approved test documents.

d. The seat tightness test shall be conducted at a pressure equal to the maximum allowable working pressure.

e. System fluid is the preferred test medium for seat tightness testing.

2-9.17.7.2. Verification of Cracking Pressure

a. Cracking pressures shall be verified in accordance with system drawings or manufacturer's specifications. The actual cracking pressure and date verified shall be etched or stamped on a metal or plastic tag and affixed to the component.

b. Operating characteristics of relief valves and counter-balance valves shall be verified by either test bench methods or when adjusting the system during installation or maintenance.

2-9.17.8. Electrical System Testing for Divers Handling Systems

Electrical system and component testing and inspection shall be in accordance with Title 46, CFR, Subpart 110.30 of Subchapter J. Additionally, each major component shall have a COC that shows the component meets specific requirements acceptable to the Navy.

All test procedures for items within the SOC, including FAT procedures, shall be submitted to the Acquisition Manager for review and approval. The SCA shall review test procedures for all components within the SOC.

As a minimum, the following tests shall be conducted after the Diver Handling System is installed on board a support ship:

a. Continuity and insulation resistance (IR) checks.

b. System Operational Test (SOT) and/or System Integration Test (SIT) as applicable.

2-9.17.8.1. Maintenance Testing Requirements

The following table identifies the functional tests required after performing various electrical system maintenance tasks. Some handling systems have unique components and may require additional or modified testing. The test procedures for these tests shall be submitted to the Acquisition Manager for review and approval on a case basis. The tests specified below, and the applicable tests specified by a drawing, specification or technical manual shall be conducted for each maintenance task identified in Table 24. If there is a conflict between the tests specified in Table 24 and the tests specified by the applicable drawing, specification or technical manual, then the requirements of this document take precedence.

Table 24: Maintenance Testing Requirements – Electrical Systems

Maintenance Task	Test Requirements
Power distribution system repair	Continuity checks, insulation resistance checks, voltage readings, no-load test.
Electrical control circuitry adjustment, alignments, or repairs	No-load test.
Electrical motors for HPUs	No-load test, rated load test.
Limit switch repair or replacement	No-load test.

2-9.18. INCLINING EXPERIMENTS AND TRIM DIVES FOR SUBMERSIBLES AND SUBMERGED HABITATS

If the Diving System is of such complex geometry that reliable curves of form cannot be readily calculated, then air, surface, and submerged inclining experiments must be performed. When the curves of form, or the precalculated form characteristics are available, only the surface and submerged inclining experiments are required. If the Diving System vessel is not too large, the longitudinal trimming moment can be determined by direct measurement or by a longitudinal inclining experiment. In addition, a trim dive is necessary to determine the proper weight and location of ballast, both permanent and variable, that will permit the vessel to operate under the design conditions of loading and in water of any density. The Fabricator shall submit the inclining experiment and the trim dive results with the evaluation of the stability of the vessel.

2-9.19. OPERATIONAL TESTS

After all life support system strength, tightness, and purity tests have been satisfactorily completed, the system must demonstrate that it will operate properly and will deliver specified purity gas at the designated volume, pressure, and temperature to the divers in the various modes of operation. The tests shall simulate the intended use of the system under worst case conditions. If the specific acceptance criteria for these tests are not provided in the contract documents, the Builder shall request this information from the Government Procurement Representative prior to developing his Test Plan.

2-10. REENTRY CONTROL

2-10.1. PURPOSE

Reentry control procedures only apply after certification by NAVSEA and are established to document and maintain the integrity, cleanliness, and safety of a life support system. Reentry control data must be recorded wherever maintenance is performed which requires entry into the Reentry Control boundaries after material certifications have been accomplished. These procedures will be used by a Builder only if repairs or modifications are required on a system after NAVSEA 00C4 has completed material certification for the system. If reentry control is required the Builder shall follow the procedures in the U.S. Navy Standardized Diver Re-Entry Control Procedures which can be found at www.supsalv.org.

2-11. SHIPPING

2-11.1. GENERAL

Delivery of the system shall be as specified in the contract documents. When the Builder is directed by the contract documents to deliver the system to a location other than the place of construction, it will be the Builder's responsibility to ensure that the equipment arrives undamaged and whole. Any damage to the system, missing components, or missing documentation are the responsibility of the Builder to correct.

2-12. GAUGES AND MONITORS

2-12.1. GAUGES

2-12.1.1. Gauge Accuracy

Gauges used in diving or hyperbaric systems shall meet the accuracy requirements specified in the drawings or contract documents. If it is not so specified, they shall be chosen so that they meet the requirements of Table 11 and section 1-3.9.

2-12.1.2. Gauge Testing Requirements.

See 2-9.14.

2-12.2. MONITORS

Monitors used in diving or hyperbaric systems shall be as specified in the drawings and specifications.

2-12.2.1. Monitor Testing Requirements

Monitors shall be tested to ensure they meet the accuracy requirements specified in the drawings or those stated by the manufacturer of the monitor where no requirements are given in the system drawings.

2-13. PRESSURE VESSELS

2-13.1. GENERAL

This section details the requirements for both gas supply and human occupancy pressure vessels.

2-13.2. FABRICATION OF PRESSURE VESSELS TO COMMERCIAL CODES

Pressure vessels within the scope of certification shall be fabricated in accordance with the ASME Boiler and Pressure Vessel (BPV) Code, Section VIII, or the applicable DOT regulation or specification.. Pressure vessels designed for human occupancy shall also comply with the additional requirements of ASME PVHO-1 and this specification (see paragraph 2-13.3).

2-13.2.1. Documentation Requirements for Pressure Vessels Built to Commercial Codes

When using commercial codes in fabricating a pressure vessel, the delivery of documentation, as outlined in the following subsections, in addition to that which is specified in the commercial code is required to be delivered to the Government Procurement Representative.

2-13.2.1.1. Manufacturer's Documentation

The Manufacturer's Data Report shall be submitted for each vessel fabricated in accordance with ASME VIII. Copies of the completed and signed ASME Manufacturer's Data Reports for Pressure Vessels (Form U-1/U-1A) shall be submitted with applicable ASME Manufacturer's Partial Data Reports (Form U-2).

For pressure vessels designed for human occupancy, Manufacturer's Data Reports, Form PVHO-1, shall be submitted with all applicable Forms U-1 and Forms U-2 attached.

For vessels fabricated to standards other than ASME VIII, all documentation required by the standard shall be delivered to the Government Procurement Representative. This shall include records of all testing performed and the results of the tests.

A copy of the Certification of Authorization from the ASME boiler and pressure vessel committee, or the equivalent from other approved commercial code committees, authorizing the manufacturer to fabricate vessels of the designed class shall be attached to the Manufacturer's Data Report.

2-13.2.1.2. Paint Preparation and Application Procedures and Data

Procedures used for the surface preparation and painting of the vessel interior and/or internal components shall be provided to the Government Procurement Representative for approval prior to the commencement of painting. Documentation shall be provided to verify that the coating system used on the interior of the vessel is properly applied and does not off-gas toxins. The off gassing test procedure (see paragraph 2-9.10) shall be conducted on a sample of painted shell material prior to actual painting of the PVHO. This sample shall meet the acceptance criteria of the test prior to the Government Procurement Representative giving approval for the painting procedure. After painting of the PVHO an air purity test shall be conducted in accordance with paragraph 2-9.9. The air sample must meet the acceptance criteria for the test in order for the system to be accepted by the Government Procurement Representative. Material Safety Data Sheets (MSDSs) shall be submitted to the SCA for all paints used on vessel interiors.

2-13.3. PRESSURE VESSELS FOR HUMAN OCCUPANCY

Pressure Vessels for Human Occupancy shall be constructed in accordance with ASME PVHO-1 and this specification.

2-13.3.1. Welding of PVHO

Welding of PVHOs shall be in accordance with the system drawings, ASME PVHO-1, ASME VIII, and ASME IX. All weld procedures, procedure qualification records, and welder qualifications shall be submitted to the Government Procurement Representative for approval prior to welding on the PVHO. The Builder will not commence welding until written approval from the Government Procurement Representative has been granted.

2-13.3.2. Additional Documentation Required

The following paragraphs (2-13.3.2.1 through 2-13.3.2.8) describe additional documentation that is required to be provided to the Government Procurement Representative in excess of what is already required by ASME PVHO-1, ASME VIII and ASME IX.

NOTE

All documentation that is required by ASME PVHO-1, ASME VIII, and ASME IX for the welding of PVHOs shall be provided to the Government Procurement Representative as part of the material certification package.

2-13.3.2.1. Material Verification

All materials comprising the pressure vessel (pressure containing material) and all materials welded to the pressure vessel shall be documented to verify compliance with the system drawings and applicable specifications. This PVHO material shall be provided with mill heat and lot numbers. In addition chemical and physical data for the material shall be provided to the Government Procurement Representative at the Material Certification Review. These documents shall be traceable to the materials used in the system. This shall also include welding rods used on the pressure boundary.

2-13.3.2.2. Welding Procedures

Copies of all welding procedures required for the fabrication of the pressure vessel and attachments shall be provided to the Government Procurement Representative prior to starting actual welding operations. Documentation verifying approval of these procedures shall also be provided.

2-13.3.2.3. Welder Qualifications

Documentation shall be provided to the Government Procurement Representative verifying that all welders that produce welds on the pressure vessel are qualified to the approved welding procedure for the type and position of each weld made. The document shall clearly state that the welder is qualified to perform the procedures and his qualifications are current under applicable code requirements.

2-13.3.2.4. Weld Records and Maps

The weld records shall consist of a chamber weldment joint identification drawing, or map, for each chamber pressure shell and piping system. All chamber joint weld locations shall be shown and a joint identification number assigned to each weld. A chamber weldment record form for each welded joint, including nonpressure retaining joints and brackets, shall be prepared and delivered to the Government Procurement Representative as part of the material certification package. The weldment record form shall contain the following information:

a. Joint Identification Number (JID) number

b. Joint design type

c. Base metal type with heat and lot number

d. Filler metal type with heat and lot number

e. Fit up and inspection results

f. Welding procedure number

g. Heat treatment if required

h. Welder/brazer number

i. Type of inspection and results

j. Disposition of joint (pass/fail)

k. Any repairs of joint conducted

l. Inspection procedure number

m. NDE inspection number

n. Signature and date

2-13.3.2.5. NDE Records

Copies of all nondestructive testing (NDE) records shall be provided to the Government Procurement Representative as part of the material certification package. Nondestructive test personnel qualification records shall be maintained and provided to the Government Procurement Representative prior to testing.

2-13.3.2.5.1. Dye Penetrant (PT) Inspection

Records of dye penetrant inspections, as specified in ASME VIII, shall be delivered and shall consist of:

a. Type(s) of dye penetrant tests

b. Identification of assembly, part, etc.

c. Number of discontinuities

d. Type(s) of discontinuities

e. Signature and date by the assigned responsible individual verifying all specified PT inspection including PT of any required repairs has been accomplished and is satisfactory.

2-13.3.2.5.2. Magnetic Particle (MT) Inspection

Records of magnetic particle inspections as specified in PVHO-1 and ASME VIII shall be delivered along with the PVHO.

2-13.3.2.5.3. Radiographic (RT) Inspection

RT inspection data sheets as well as the radiographs themselves will be submitted to the Government Procurement Representative. Chambers are required to have full radiographic testing (RT) of all pressure retaining butt welds (joint efficiency of 1). Records of radiographic weld inspection shall contain, as a minimum, the following:

a. Date of exposure of the radiograph

b. Positively identified location of weld radiographed

c. Type of material and material thickness

d. Type of weld joint

e. Approved procedure identification

f. Energy source (isotopes type, intensity, kilovoltage and focal spot size of x-ray machine)

g. Type of film, screens, source-to-film distance, and exposure time

h. Penetrameter designation

i. Image Quality Indicator (IQI) sensitivity reading

j. Applicable acceptance standards

k. Flaws (unacceptable slag, porosity, or other indications)

l. Acceptance or rejection

m. Date of interpretation and signature of film interpreter(s)

n. Interpreter's documented qualification level shall be noted

o. Diagram (radiograph) indicating the specific location of each radiograph coded to its unique number. Where required by contract, a copy of the actual radiographs shall be provided to the government.

2-13.3.2.5.4. Ultrasonic (UT) Inspection

Records of ultrasonic inspection, when required by PVHO-1 and/or ASME VIII, shall contain, as a minimum, the following:

a. Date of ultrasonic inspection
b. Description and unique item identification, weld location and joint identification
c. Type of material and material thickness
d. Type of weld joint and length of weld inspected
e. Approved procedure identification
f. Equipment used for inspection (instrument and search unit): manufacturer and model number, transducer size and type, search beam angle, test frequency, couplant
g. Calibration standard number
h. Applicable acceptance standard
i. Reference block identification
j. Discontinuities that exceed DRL (Disregard Level)
k. Acceptance or rejection
l. Signature of inspection personnel and date
m. If supplemental ultrasonic inspection techniques are used that contribute to the final inspection results, they shall be recorded

These records shall be delivered along with the PVHO.

2-13.3.2.6. Heat Treatment Procedures and Records

Copies of the procedures and records of all heat treatments performed on the chamber shall be attached to the Manufacturer's Data Report

2-13.3.2.7. Charpy Impact Test Data

When Charpy Impact testing of materials is required by PVHO-1 or ASME VIII, a copy of the Charpy Impact Test data shall be attached to the Manufacturer's Date Report

2-13.3.2.8. Material Repair Report

A report on repairs of any defects in the materials used for the fabrication of chambers shall be attached to the Manufacturer's Data Report.

2-13.3.3. PVHO Test Requirements

2-13.3.3.1. ASME Certification Tests

The Chamber(s) shall be tested in accordance with this specification, the ASME Boiler and Pressure Vessel Code, Section VIII and ASME PVHO-l. Failure of any ASME test shall constitute non-conformance with the requirements of this contract.

2-13.3.3.2. Hydrostatic Test

The Builder shall perform a hydrostatic strength test of the chamber(s) in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1. The hydrostatic test pressure shall be 1.5X the maximum system pressure of the PVHO. The Builder shall be responsible for bracing the chamber to support the full weight of the flooded chamber without damage to any part of the system.

The penetrators and viewports shall be installed and tested during this test. The contractor shall first perform the test on the inner lock, followed by a test of the inner and outer lock together (if applicable). In addition, the Builder shall perform the test in a manner that the pressure integrity of the Medlock can be determined. The Builder shall inspect all welds, joints, penetrations and pressure-retaining assemblies for evidence of distortion or leaks, and record any such distortion or leakage observed. Any distortions indicating structural failure shall be immediately reported to the Government Procurement Representative. Included in this report shall be the contractors plan to remedy the failure and meet contract requirements. Upon notifying the Government Procurement Representative of the failure and the plan for remediation, the contractor shall repair all defects and repeat the hydrostatic test.

2-13.3.3.3. Pressure Drop Test

A pressure drop test shall be conducted after the chamber(s') hydrostatic strength test in accordance with paragraph 2-9.8. The chamber, including all viewports and penetrators, shall be finally assembled for this test; any later disassembly shall mandate a new pressure drop test. The chamber(shall be pressurized with air, oxygen, dry nitrogen, or HEOX as applicable to 1.0X the maximum operating pressure and permitted to stabilize, and then isolated from the pressurization source. The chamber pressure, corrected for changes in temperature, shall not drop more than 1 percent over the duration of the test. The contractor shall first perform the test on the inner lock, followed by a test of the inner and outer locks together. In addition, the contractor shall perform the test in a manner that the pressure integrity of the Medlock can be determined. Any leaks found shall be eliminated and the entire chamber shall be retested.

2-13.3.3.4. Pressure Vessel Weld Testing

All pressure vessel welds shall be tested and inspected in accordance with ASME PVHO-1. Written records shall be prepared and maintained for each welded joint in accordance with NAVSEA-278, paragraph 4.1.3. These records shall be submitted to the Government Procurement Representative at final delivery. The records shall included a weld joint identification (JID) drawing (or “weld map”) for each chamber, with all chamber joints shown, with each JID assigned. A weld record shall be prepared for each joint, including non-pressure retaining joints. The weld record shall contain the information required in paragraph 2-13.3.2.4.

2-13.3.3.5. Heat Treatment Records

Two copies of records of all heat treatments on the chamber shall be provided. In addition to impact testing of base material, production impact testing shall be conducted on samples of all welds and heat affected zones in accordance with paragraph AT-203 of ASME Boiler and Pressure Vessel Code, Section VIII, Division 2.

2-13.3.3.6. Penetrators

Prior to final installation, hollow bolt penetrators shall be hydrostatically tested (internally) at 1.5X the maximum system pressure separately from the chamber.

2-13.3.3.7. Strain Gauge Testing

For PVHOs of new design, the Builder shall conduct strain-gauge testing on the prototype vessel. The Builder shall submit for approval, a strain-gauge test plan including as a minimum, the location and type of strain gauges. The final test report must include a comparison between calculated stress values and those obtained by strain gauges.

2-13.4. GAS CYLINDERS

2-13.4.1. General

Non-PVHO gas storage cylinder and volume tanks shall be manufactured and stamped in accordance with all applicable DOT regulations and specifications or ASME VIII. If the vessel was designed in accordance with ASME VIII it shall also be fabricated in accordance with ASME VIII. If the vessel was designed to DOT specifications it shall also be fabricated in accordance with DOT specifications.

2-13.4.2. Testing Requirements

Testing of gas cylinders shall be as specified in paragraph 2-9 of this document.

2-13.4.3. Documentation Requirements

For commercial-off-the-shelf (COTS) gas cylinders the documentation shall include records of pressure testing. For custom built cylinders (i.e., those with fabrication drawings as part of the system drawing package or those designed by a fabricator to a performance specification) the following additional documentation shall be delivered:

a. Weld Map. The fabricator shall develop a map of all welds in the pressure vessel. Each weld shall have a unique Joint Identification Number.

b. Weld History Record (see paragraph 2-5.2).

c. Pressure Testing Documentation (see paragraph 2-9).

d. Records of all NDE performed

2-14. FORMAT OF REQUIRED DATA SHEETS

2-14.1. INTRODUCTION

The data sheets provided in this section are recommended for use by the Builder in compiling the Material Certification Data Book. These sheets include the information that would be required by the Government Procurement Representative on each form. The Builder may modify these forms or use their own forms as they see fit but the same information shall be required as specified throughout this document.

2-14.2. MATERIAL CERTIFICATION DATA BOOK

2-14.2.1. Material Certification Review (MCR)

Prior to acceptance of each new system, it will undergo a Material Certification Review (MCR). This review shall be conducted at the Builder's site and must be satisfactorily completed prior to acceptance by the Government Procurement Representative. Additional requirements and explanation of the MCR can be found in paragraph 2-1.6.11.1. The Government Procurement Representative or their representative will thoroughly review the Material Certification Data Book and inspect the equipment during this process in order to ensure that it meets the requirement of this specification, the drawings and any other applicable contract documents.

2-14.2.2. Material Certification Data Requirements

This section prescribes the recommended format for the presentation of documents and record keeping of the tests and procedures required by this specification. These records/documents will be made available to the government during progress meetings and other times as agreed to in the contract. They will also be completed and provided to the appropriate government representatives for the MCR and delivered with the product.

The JID serves as the MCR road map. Identification of individual components and their respective material documentation shall flow from and to the JID. Each system JID will be supported by a completed material certification package. Table 25 is a sample Table of Contents required to support each JID.

NOTE

When a purchase order covers multiple components that are used in systems covered by more then one JID, copies of the purchase orders and documentation received with the goods shall be included in each JID section (i.e., Air Supply, BIBS Supply, Exhaust, etc.)

The forms provided are pro forma and are not meant to be exclusive of other data. What is important is that the data be organized and provided in the manner set forth to demonstrate compliance with the record keeping requirements of this specification, the system drawings, and all other applicable contract documents.

Table 25: Sample TOC for Material Certification Data Book (non-PVHO system)

Section	Information	Supporting Documentation
1.0	System (JID #)	Approved JID
1.1	**Welded Joints**	Weld Joint History Record NDE Inspection Reports as required provided by Inspector Welding Procedure Welder's PQR Inspectors Qualification and Vision Test

		Record
1.2	Mechanical Joints	Mechanical Joint Assembly Record
1.3	Hydrostatic Test and Cleaning Data	
1.3.1	Fittings	Component Cleaning and Testing Record
1.3.2	Tubing	Component Cleaning and Testing Record
1.3.3	Gauges	Component Cleaning and Testing Record Gauge Calibration Form
1.3.4	Valves	Component Cleaning and Testing Record Relief Valve Test Data
1.3.5	O-Rings	Component Cleaning and Testing Record
1.4	System Testing	System Test Plan
1.4.1	Hydrostatic Test	Hydrostatic Test Record as appropriate
1.4.2	Pressure Drop Test	Drop Test Record as appropriate
1.4.3	Gas Analysis	Gas Analyses Certificate as appropriate
1.4.4	Electrical Component Test Data	Electrical Component Test Record as appropriate
1.5	Material Certifications	
1.5.1	Fittings	Purchase Order Receipt Inspection as appropriate A C of C can be provided for multiple issues but must reference all items it covers
1.5.2	Tubing	Same as above
1.5.3	Gauges	Same as above
1.5.4	Valves	Same as above
1.5.5	Miscellaneous	

NOTE:

A purchase order and a receipt inspection shall be provided in the data book(s) for all components, materials and equipment within the SOC used in constructing a diving or hyperbaric system.

2-14.2.2.1. Pressure Vessels for Human Occupancy

Material Certification Data for pressure vessels for human occupancy (PVHO) built in accordance with ASME Section VIII Div 1 and PVHO-1 shall be segregated from other data and submitted in accordance with the requirements of this section.

Table 26: Sample TOC for Material Certification Data Book (PVHO only)

Section	Information	Supporting Documentation
2.1	**Manufacture Data Reports**	ASME Section VIII Div I Form U-1 ASME Section VIII Div I Supplementary Form U-4 ASME PVHO-1 ASME PVHO-2
2.2	QA/QC Documentation	Inspection and Test Plan (ITP) In Process (Assembly/Visual Dimension) Inspection Record Non Conformance (Head Thickness checks)

		Plate Edge Thickness Report
2.3	Material Certification	Purchase Orders Receipt Inspections Material Certificates Chemicals and Physicals Charpy Impact Test Records
2.4	Welding Information	Weld Map Weld Joint History Record Weld Procedures Welder Qualifications Welding Consumable Batch Certs Heat Treatment Records
2.5	Non Destructive Testing	Non Destructive Examination (NDE) Reports (as referenced in Weld Register) Radiographs from RT In House Dye Penetrant Inspection of Root Runs In House Dye Penetrant Inspection of Skid
2.6	Pressure Testing	Hydrostatic Test Certificates Dimensional Inspection Record Load Test Record Life Test Deflection Check Stamping Work Instruction & Carbon Rubbing
2.7	Design Records	Design Report Design Calculations
2.8	Drawings	

NOTE:

A purchase order and a receipt inspection shall be provided in the data book(s) for all components, materials and equipment used in constructing a diving or hyperbaric system.

2-14.3. DATA SHEETS

The following pages include examples of some of the required data forms.

Data Form I: Purchase Order

COMPANY NAME

PURCHASE ORDER

P.O. Number
Date Required

Order Date	Ordered By	Terms	F.O.B.	Ship Via

VENDOR	**SHIP TO**
Address	Address
POC Telephone Fax	POC Telephone Fax

Line Number	**Item**	**Description**	**Price Per Unit**	**Units**	**Quantity Ordered**	**Total Cost**
					TOTAL	

IMPORTANT - SPECIAL INSTRUCTIONS INDICATED

- ☐ *Certificates of conformance to drawings and/or specifications signed by an authorzed representative of your company must accompany each shipment.*
- ☐ Test reports covering detail examination and testing shall be furnished by supplier with certification of compliance to applicable drawings and specifications.
- ☐ Physical and chemical test reports are required on this order.
- ☐ *Drawings and/or specifications attached.*

____

Authorized Signature

This order subject to all conditions on the face and attachments if any.

Data Form II: Receipt Inspection

COMPANY NAME

RECIEPT INSPECTION

Customer:	**Activity:**
Contract Number:	**Item Number:**
Job Number:	**Date:**

Purchase Order Number:
Part Number:
Material Description:

QTY Ordered:	**QTY Received:**	
Is there damage to packaging or materials ordered?	Yes	No
Is all documentation required by purchase order included?	Yes	No

Comments:

I certify that the above information is true and correct to the best of my knowledge and have attached any and all supporting data that may be required.

Signature & Title

Date

Data Form III: Component Cleaning and Testing Record

COMPANY NAME

Component Cleaning and Testing Record

Date	Referenced Specification	Job Number	Contract Number	Lab Number

Project:	Hull Number:	System:
Description:	Part Number:	Serial Number:

SOLVENT HYDROCARBON ANALYSIS

			Technician Initials
Accept/Reject Criteria:		**Date:**	
Solvent	**Method Used**	**Total Hydrocarbons**	

PARTICULATE AND FIBER ANALYSIS

Accept/Reject Criteria:		**Date:**	
SAT:	**UNSAT:**		

COMPONENT HYDROCARBON PRESENCE

Accept/Reject Criteria:		**Date:**	
Ultraviolet Inspection Results:	**SAT:**	**UNSAT:**	

RESIDUAL SOLVENT ANALYSIS

Accept/Reject Criteria:	**Date:**	
Rinse Water ph Level:		

PURGE GAS ANALYSIS

Accept/Reject Criteria:		**Date:**	
Dew Point Reading:	**Oven Dried:**		
Residual Solvent Content:			

VALVE SEAT TIGHTNESS TEST

Accept/Reject Criteria:		**Date:**	
Test Pressure:	**SAT:**	**UNSAT:**	

HYDROSTATIC TEST DATA

Accept/Reject Criteria:		**Date:**	
Medium Used:	**Working Pressure**	**SAT:**	
Test Gauge Number:	**Test Pressure**	**UNSAT:**	
Date Calibrated:	**Length of Test**		

Technician: ______________ **Signature:** ______________________________

Data Form IV: Weld Joint History Record

COMPANY NAME

WELD JOINT HISTORY RECORD

Date	Project	Job Number	Contract Number	Customer

Hull Number	Item Number	System	Location

Joint Identification Number:

Weld Procedure:

Welders Identification Number:

Welders Name:

Fitting Material:	**Filler Material:**
Fitting Material Specification:	**Filler Specification:**
Pipe Material:	**Filler Size:**
Pipe Material Specification:	**Shielding Gas:**
Fitting Size:	**Pipe Size:**
Fitting Wall Thickness:	**Pipe Wall Thickness:**
Fitting Socket Identification:	**Pipe Outside Diameter:**
Fitting Socket Depth:	**Maximum Pre-Heat:**
Joint Type:	**Maximum Interpass:**
	Post Heat:
Fit-Up Inspection: SAT: UNSAT:	**Drawing Number:**
Fit-Up Inspector:	**Identification Number:**
Original Joint:	**Repair Joint:**

NDT REQUIREMENTS

VT Root:	**SAT:**	**UNSAT:**	**Inspector**	**I.D. #:**
PT:	**SAT:**	**UNSAT:**	**Inspector**	**I.D. #:**
MT:	**SAT:**	**UNSAT:**	**Inspector**	**I.D. #:**
RT:	**SAT:**	**UNSAT:**	**Inspector**	**I.D. #:**

ACCEPTED: **REJECTED:**

Q.A. ACCEPTANCE SIGNATURE

Data Form V: Mechanical Joint Assembly Record

COMPANY NAME

MECHANICAL JOINT ASSEMBLY RECORD

Date	Project	Job Number	Contract Number	Customer

Hull Number	Item Number	System	Location

Joint Identification Number:

Technician's Name:

Joint Type: **Type of Seal:**

Joint Size: **Joint Make Up Torque from JID:**

Pipe/Fitting Material:

Pipe/Fitting Material Specification:

Fit-Up Inspection: **SAT:** **UNSAT:** **Drawing Number:**

Fit-Up Inspector:

Original Joint: **Repair Joint:**

TORQUE REQUIREMENTS

Joint Make Up Torque from JID:

Torque Applied to Joint: **Technician's Initials:** ____________________

ACCEPTED: **REJECTED:** ________________________________

Q.A. ACCEPTANCE SIGNATURE

Data Form VI: Gauge Calibration Form

COMPANY NAME

GAUGE CALIBRATION FORM

Date	Project	Job Number	Contract Number	Customer

Hull Number	Item Number	System	Location

Gauge Mfg. Model No.	Dial Size	Range	Increments

Gauge Serial No.:

Gauge Accuracy: **Allowable Error:** **Test Medium:**

CERTIFICATION OF TEST INSTRUMENTS

Deadweight Tester SN: **Master Gauge:**

Accuracy: **Allowable Error:** **Relative Humidity:**

Temperature: **Position Calibrated In:**

NIST #:

All STANDARDS ARE TRACEABLE TO THE NATIONAL STANDARDS INSTITUE OF TECHNOLOGY.

GAUGE READINGS

Actual Pressure	RUN 1				RUN 2			
	FSW Up	Error	FSW Down	Error	FSW Up	Error	FSW Down	Error

NOTE: *FSW stands for feet of seawater. 1 psi = 2.2448 FSW*

Special Conditions/Notes: **Lab #:**

Date: Technician's Signature: ______________________

Date: QA Signature: ______________________

Data Form VII: Fluid Mechanical System Installation Record Form

COMPANY NAME

FLUID MECHANICAL SYSTEM INSTALLATION RECORD FORM

Date	Project	Job Number	Contract Number	Customer

Hull Number	System

Has the system been installed in accordance with the joint identification drawing?	YES	NO
Are all mechanical joints complete and is all associated paperwork complete?	YES	NO
Are all welded joints complete and is all associated paperwork complete?	YES	NO
Inspect the surfaces of piping and components for damage, such as, gouges, dents, arc strikes, weld splatter, etc.	SAT	UNSAT
Inspect each component for completeness (I.e., valves for presence of handwheels).	SAT	UNSAT
Ensure that piping runs to not touch other installed components or piping in the system.	SAT	UNSAT
Are all required label plates, tags, etc. installed?	YES	NO

ACCEPTED: **REJECTED:**

____

Q.A. ACCEPTANCE SIGNATURE

2-14.3.1. PVHO Records

Records for PVHOs shall be in accordance with this specification, ASMEVIII, and PVHO-1.

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U.S. Navy General Specification for the Design, Construction, and Repair of Diving and Hyperbaric Equipment

PART 3: REPAIR

3-1. INTRODUCTION

3-1.1. PURPOSE

This chapter of the document provides the specifications necessary to comply with the U.S. Navy's requirements for the repair of hyperbaric and diving systems and their components.

3-1.2. SCOPE

This chapter applies to all U.S. Navy diving and hyperbaric systems.

3-1.3. DEFINITIONS.

3-1.4. REFERENCED DOCUMENTS.

PUBLICATIONS

DEPARTMENT OF DEFENSE

	Standardized Diver Re-Entry Control Procedures

SPECIFICATIONS

DEPARTMENT OF DEFENSE

NAVSEA S9AA0-AB-GSO-010	The General Specifications for Overhaul of Surface Ships

3-1.5. GENERAL REQUIREMENTS

All work and testing accomplished during repair and maintenance shall be in accordance with the requirements of Part 2 (Construction) of this specification and the U.S Navy's Standardized Diver Re-Entry Control (REC) Procedures. Repairs and modification to existing installations or new installations shall in no manner degrade the capability of the overall system to meet its performance requirements.

3-1.5.1. Major Overhauls

If the diving or hyperbaric system is undergoing a major overhaul or reconfiguration the system certification may be terminated by the System Certification Authority (SCA). If the certification is terminated then the personnel or contractor performing the work shall do so in accordance with Part 2 (Construction) of this specification and this part of the specification only. There is no need to meet the requirements of the REC Procedures. In addition to the documentation required in Part 2, the following shall be delivered to the Government Procurement Representative prior to commencing any work on a major overhaul:

(1) Results of Pre-Overhaul Test and Inspection

(2) A detailed definition of the scope of the overhaul, including a list of repairs, SHIPALTS to be accomplished, components to be replaced, modifications, etc.

(3) The overhaul or repair work package including appropriate drawings, description of work, tests and inspection to be accomplished and procedures to be followed.

(4) Quality assurance provisions of the overhaul work package.

(5) A schedule showing major overhaul milestones.

After the submittal of the required pre-work documentation package the Repair Facility shall not begin the overhaul on the system without written approval of the package from the Government Procurement Representative.

3-1.6. RETEST REQUIREMENTS

Any systems disturbed during a repair, overhaul, or modification shall be tested in accordance with the requirements of Part 2 of this specification. All test plans and documentation of the testing shall be submitted as required by the applicable paragraph.

3-1.7. SHIPALT'S.

In cases where repair or overhaul of a diving or hyperbaric system require a SHIPALT, the additional requirements of *The General Specification for Overhaul of Surface Ships* (GSO) shall be met.

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APPENDIX A : NAVSEA APPROVED WELDING PROCEDURES

A-1. PROCEDURE FOR WELDING HIGH ALLOY STEEL (S-8) PIPING AND COMPONENTS

The following paragraphs A.1.1 through A.1.16XXX are included as an example of an approved welding procedure. All welds must have a procedure, approved by NAVSEA 00C3, IAW NAVSEA-278 and 271 prior to being fabricated. All procedure qualification data and welder certification data shall be submitted to NAVSEA 00C3 for approval.

This procedure is applicable to socket welding high alloy stainless steels (S-8) for piping and component applications and meets the requirements of MIL-STD-278F. This procedure has been approved for use by qualified personnel of the Naval Surface Weapons Center, Panama City, Florida.

This procedure contains both mandatory requirements (indicated by the words “shall” or “will”) and guidance information considered important for quality workmanship (indicated by the words “should” or “may”).

Appropriate sections of this procedure shall be used in conjunction with the technique or data listed in Table 28.

A-1.1. BASE MATERIAL

Base material shall conform to the material specifications and/or equivalent listed in Table 27 and to the System Specification contained in the appropriate appendix.

Base material condition shall be in accordance with applicable plan or specification requirements.

Base material preparation (bevels, counterbores, excavations, etc.) should be accomplished by suitable mechanical means.

Weld preparation and adjacent base material surfaces for a minimum of one inch on each side of the weld preparation shall be free of grease, oil, rust, corrosion, slag, water, paint, temperature crayon, and any other harmful matter.

Weld preparation and adjacent areas shall be thoroughly dry and maintained dry during welding.

Table 27: Base Material Identification

Material Specification	Type or Classification	Description
QQ-S-763	Class 304, 304L, 309, 310, 316, 316L, 321, 347	Bars, wire, shapes, and forgings
MIL-S-23196	Class 304, 304L, 347, 348	Plate, sheet, and strip
MIL-P-1144	Class 304, 304L, 316, 316L, 321, 347	Pipe, seamed and seamless
MIL-T-23226	Class 304, 304L, 347, 348	Tube and pipe, seamless

Table 28: Welding Data Sheet

Title: Manual GTAW Pipe Welding of Stainless Steel (300 Series CRES) Thin Wall Socket Joints

Data Sheet No: 001
Class: P-1

Pipe Size Range: All Thin Wall Pipe and Tube
Wall Thickness Qualified: .035" - .058"

Base Materials:	Stainless Steel (300 Series CRES) (E-8)
Filler Materials:	MIL-E-19933 *(See Note 2 for type)*
Welder Qualifications:	.035" thru .058", GTAW
Positions:	All
Joint Design (MIL-STD-22):	P-14
Process:	GTAW
Polarity:	DCSP
Torch Type:	Linde HW-9, HW-20 or equivalent
Tungsten Electrode Type:	2% Thoriated
Size:	1/16:Dia.
Cup Size:	¼" (#4)

WELDING PARAMETERS/ELECTRICAL CHARICTARISTICS

Pipe Size:	.049" thru .096"	**Weld Passes:**	All (2 min)
Filler Material:	TYPE: *Note 2*	**Size:**	.035" or .045"
Amperage:	20-30	**Voltage:**	10 – 12
Shielding Gas:	TYPE: Argon	**Flow:**	14 – 16 CFH
Purge Gas:	TYPE: Argon	**Flow:**	10 – 12 CFH
Preheat Temp:	60°F Min	**Interpass Temp:**	150°F max
Post-Heat Treatment:	None Required		
NDE Inspections:	In accordance with MIL-STD-276, Table IX		

NOTES:

1. OCV shall be 70 volts minimum.
2. Select filler material for base material combination as follows:

Base Material	Filler Material
304 to 304	308 or 308L
304L to 304L or 304	308L
316 to 316, 304, or 304L	316 or 316L
316L to 316L, 316, 304L, or 304	316L
347 to 347, 316L, 316, 304L, or 304	347

Approval Authority: ______________________

Test Report No. ____________ Prepared By ______________________

Date: ______________________

Cancels ______________________

Approved By ______________________ Date ________

A-1.2. FILLER METAL

Filler material shall conform to the specifications listed in Table 29.

Receipt inspection requirements for filler metals shall be in accordance with a written procedure and the Quality Program. Welding material will be checked for markings, certification, and correctness of materials.

Bare rod filler metals should be cleaned using silicon carbide or aluminum oxide abrasive cloth to remove surface oxides prior to welding, and wiped with an acetone dampened lint-free cloth to remove harmful residue.

Welding filler metals shall comply with the conditioning and maintenance requirements listed in paragraph 2-5.6.

Table 29: Filler Metal Selection GTAW Process

Base Material Combination	Filler Metal Specification
308, 308L, 308HC, 309, 310, 312, 316, 316L, 317, 318, 321, 347	MIL-E-19933
308, 308L, 310, 312, 316, 316L, 348	MIL-I-23413 (inserts)

A-1.3. JOINT DESIGN

Joint designs and fit-up dimensions shall conform to MIL-STD-22D or the fabrication drawings. Sockets will have proper withdrawal.

A-1.4. TORCH SHIELDING GAS

Torch shielding gas and flow rate shall be as specified on the data sheet (Table 28). Argon gas shall conform to specification MIL-A-18455 and the flow rate measured using an argon flowmeter.

A-1.5. WELDING EQUIPMENT

Welding equipment for Gas TIG Arc Welding (GTAW) and automatic GTAW processes shall be as follows:

a. The power supply unit may be a variable voltage rectifier or generator and should be equipped with high frequency current for arc starting and current decay controls for weld termination.

b. The torch, unless otherwise specified on the data sheet (Table 28), shall be a water or air cooled type capable of efficient operation within the current range used, and shall be equipped with a ceramic or Pyrex gas shielding cup and gas lens.

c. The electrode should be 2-percent thoriated tungsten conforming to Federal Specification QQ-E-445, Type III, Class 1, or ASTM-B297. Typical maximum currents are as follow:

Electrode Diameter (inch)	Typical Maximum Current (amps)
1/16	120
3/32	200

The electrode shall be taper ground on the arc end for arc stability and heat concentration. Taper grinding should be done in a ¼-inch length and should reduce the end diameter to one-third the original diameter (about a four-to-one taper). The tip should be slightly blunted or rounded to avoid tungsten spitting into the weld puddle.

d. Pulse units may be used for GTAW welding. The pulse unit shall be an Airco Model PTC or Linde Model 120M, or equivalent. Pulse units shall be used in conjunction with 200 ampere Airco or Miller power sources only.

A-1.6. PREHEAT AND INTERPASS TEMPERATURES

Preheating is not required (ambient room temperature of 60°F or higher, to assume no moisture on the filler metal, is sufficient). The maximum interpass temperature is 150°F for thin wall tubing.

Temperature measurements may be accomplished using a surface contact pyrometer approximately ½-inch from the starting point of the next weld bead. Temperature crayons shall not be used on the weld preparation area, on weld metal, nor within 1 inch of the expected edge of the weld. Temperature crayons shall not contain sulfur, lead, or other low melting point metals nor deleterious material. "Comfortable to touch" may be used in lieu of indicating device or crayon for satisfactory interpass temperature control.

Forced cooling shall not be used to reduce temperature.

A-1.7. PURGING REQUIREMENTS

Purging requirements are as follows:

a. The inner pipe surface of all socket type welds when the pipe wall thickness is less than 0.095-inch shall be purged to completion.

b. Purge gas shall be argon conforming to MIL-A-18455.

c. The purge gas flow rate shall be 15 cfh minimum as measured using an argon flowmeter. During welding, argon inlet pressure should be maintained at about ½-inch of water as measured on a magnehelic gauge or equivalent.

d. Prior to welding, the purge gas should be allowed to flow sufficiently to provide at least six volume changes within the area purged. Branch lines or dead legs should be vented and dry; after pre-purging and prior to welding, they should be sealed if possible. Clean, heated nitrogen may be used to dry excessively moist piping prior to argon purging. If possible, purge should be confirmed by an oxygen analyzer showing vented purge gas downstream of the joint to contain less than 1 percent oxygen.

A-1.8. FABRICATION REQUIREMENTS

A minimum of two complete layers shall be used for all welded joints.

All welding should be accomplished in an area free from drafts that could disrupt the shielding of the arc. When ventilation piping is used, the suction orifice should be at least ten inches away from the welding arc.

All welding, including tack welds, shall progress symmetrically so that shrinkage stresses on opposite sides of the pipe will be equalized and misalignment minimized.

A-1.9. WELDING TECHNIQUE

All welding shall be accomplished by a qualified welder using the operational data specified on the data sheet. Good workmanship will be practiced.

Down-hill welding shall not be used.

Arc strikes outside the weld preparation area shall be avoided. Arc strikes remaining on base metal after the weld joint is completed will be examined at 10x magnification for cracks and the arc strike removed. Remove the minimal amount of metal necessary to preserve minimum wall thickness of the base metal.

Tack welds shall be made with the same filler metal and procedure as the final weld and made in such a way as to facilitate incorporation into the field weld. Tack welds will be visually examined and poor quality, cracked, or broken tack welds corrected or removed. If they can be completely remelted in the first layer without loss of joint fit-up or quality, they need not be removed.

Welding parameters shall be a specified on the data sheet. Weld starts and stops should be removed by burning or grinding. When possible, weld starts and stops should be made on previously deposited weld metal or in the weld prep area to facilitate their removal.

Each weld bead shall be cleaned prior to the deposition of subsequent weld defects removed by suitable mechanical means.

When welding with the GTAW or automatic GTAW process, a minimum of ¼ inch of the fused end of the used filler metal wire should be removed prior to initiating the arc for the next bead, to assure that no oxides or contaminants are incorporated into the weld.

When welding with the GTAW or automatic GTAW process, care should be taken to assure that the tungsten electrode does not contact the filler metal or the molten puddle. If the tungsten electrode does contact the molten weld puddle or filler metal, all welding should cease and the contaminated weld metal should be removed by butting or grinding.

The contaminated tungsten electrode should not be used until it has been reground to the original configuration.

A-1.10. INTERPASS CLEANING

Prior to depositing subsequent weld beads, the previous bead shall be cleaned of all slag and/or surface oxide.

Cleaning should be accomplished by using Scotch Brite or abrasive paper, slag or dental picks, jeweler's needle files, small stainless steel hand wire brushes, or carbide-tipped burning tools.

Cleaning tools and media shall be clean and not previously used on other metals such as aluminum, iron or mild/alloy steel, lead, copper, etc.

Only aluminum-oxide or silicon-carbide grinding wheels and carbide-tipped rotary burrs shall be used for grinding and burring.

Care should be taken not to overheat the base or weld metal during burring or grinding.

When pneumatic tools are used, the air supply should be dry and free of oil or other contaminants.

Excavations resulting from removing metal need not be weld repaired if:

(1) the contour blends smoothly and does not interfere with inspection

(2) sufficient metal remains to meet dimensional and minimum wall requirements, and

(3) rejectable defects are removed or rendered acceptable.

A-1.11. POST-WELD SURFACE PREPARATION

All welded surfaces, following the removal of slag and surface oxide, may be considered suitable for inspection without contouring if the final contour does not interfere with the interpretation of test results.

A-1.12. POST-WELD HEAT TREATMENT

Stainless steel (S-8) weldments shall not be post-weld heat treated without prior approval.

A-1.13. REWORK AND REPAIR

Rework to welded joints shall be accomplished using the operational data specified for welding the original joint and documented on or with the original Weld Joint History Record or Card.

Weld repair to base material shall not be accomplished on piping components (pipe, valves, fittings, etc.) without a specific written weld procedure.

Approved thickness range of a procedure applies to the measured depth of the repair excavation or weld buildup.

A-1.14. INSPECTION

A-1.14.1. FABRICATION WELDS

Nondestructive testing of welds in piping shall be in accordance with the requirements of Section 2. Hydrostatic testing of welds shall be in accordance with the requirements of the applicable drawing or test document.

A-1.14.2. REWORK WELDS TO FABRICATION WELDS

Prior to rework welding, mechanical removal of the defect shall be verified by repeating the inspection which originally disclosed the defect. Except for defects originally disclosed by leak tests, reinspection may be delayed until after repair welding. Excavations requiring rewelding shall be inspected at 5x magnification or by liquid dye penetrant. Remove minimum amount of metal to remove defect and present a suitable contour for welding. Document final excavation size (length, width, depth) and location. The network weld shall be inspected to the same degree as required for the original weld.

A-1.14.3. REPAIR WELDS TO WROUGHT BASE MATERIALS

Prior to repair welding, removal of the defect shall be verified by repeating the inspection which originally found the defect. Leak tests may be delayed until after repair welding.

On completion of repair welding, satisfactory repair shall be verified by repeating the inspection that disclosed the defect. Liquid dye penetrant (LDP) inspection of the final surface of all weld repairs to piping and components is required in accordance with the applicable Specification (this includes ½ inch of base metal beyond the toe of the repair weld). Acceptance criteria shall be based on weld or base metal requirements in accordance with the applicable Specification.

Radiographic inspection of wrought base metal repair may be required on a case basis.

Hydrostatic testing of rework or repair welds shall be in accordance with the requirements of applicable drawings or test documents.

A-1.14.4. INSPECTION STANDARDS

Visual and LDP inspections shall be performed and evaluated in accordance with paragraph 2-5. Visual inspection sequence is contained in A-1.14.4.1and LPT inspection sequence is listed in A-1.14.4.2.

A-1.14.4.1. VISUAL INSPECTION

Qualified inspection personnel shall visually inspect each weld for the total weld circumference at the designated intervals of welding per Table IX of MIL-STC-278F. Additional in-process inspection by the welder will be done to maintain and correct for weld quality as required. Inspectors or welders will visually inspect, verify, and document the following requirements as satisfactory.

a. Prior to Welding. Prior to welding, perform the following functions:

   (1) Perform weld preparation, dimensions, and finish of base materials,

   (2) Identify base materials as correct, as specified on control documents,

   (3) Ensure cleanliness of joint and base material,

   (4) Identify filler materials; ensure cleanliness and compliance with the Data Sheet and MIL-STD-278F,

   (5) Perform joint alignment and fit-up dimensions, including clearances and tolerances,

   (6) Inspect mark or target dimensions to measure from in order to determine final fillet size, and document,

(7) Ensure preheat temperature is satisfactory, and

(8) Ensure argon purge is accomplished and maintained.

b. After Tack Welding and Prior to First Layer. After tack welding and prior to first layer, perform the flowing functions:

(1) Examine tack welds by 5x magnification for quality, and remove or repair as necessary, and

(2) Ensure joint fit-up alignment is maintained satisfactory.

c. During Welding. During welding, perform the following functions:

(1) Ensure preheat and interpass temperature requirements are maintained,

(2) Ensure weld amperage and voltage is satisfactory,

(3) Ensure bead sequence and joint alignments are maintained or corrected.

(4) Check and remove arc strikes, tungsten inclusions, oxide, scale, slag, silicon balls, porosity, start and stop craters, crater cracks, ect.,

(5) Determine purging requirements, and check torch gas, flow rate, and reserve supply,

(6) Verify correct filler metal for compliance with procedure, and

(7) Conduct 5x visual or liquid dye penetrant inspection after completing root layer.

d. Post-Weld Acceptance Inspection. After welding, perform the following inspections:

(1) Contour and final surface finish

(2) Weld and grinding undercut

(3) Mishandling or excessive grinding

(4) Dimensions of final weld, including sufficient fillet leg length using marks or targeting taken during fill-up

(5) Joint alignment (5 degrees maximum misalignment allowed)

(6) Internal surface finish and proper withdrawal when internal surface accessible.

A-1.14.4.2. LIQUID DYE PENETRATION INSPECTION

Each weld shall be LDP inspected by qualified inspection personnel. The LPT inspection sequence on the surface to be tested is as follows:

(1) Verify that the surface is free of slag or scale,

(2) Verify surface is free of grease, dirt, or other matter which could interfere with the test,

(3) Wipe surface with acetone, or denatured ethanol,

(4) Coat the surface with penetrant,

(5) Uniformly apply the developer in a thin coat on the surface.

(6) The surface is LPT inspected by a qualified inspector.

(7) After testing, clean and remove penetrant and developer from the test surface, and

(8) Document test results.

A-1.15. WELDER QUALIFICATION

Prior to performing any production work, each welder or welding machine operator shall be qualified in accordance with NAVSEA-248. Special qualification is required for material with thickness less than 0.058-inch per Note 1 on Table XI of NAVSEA-248. Socket welders may qualify for the thinner wall by welding a satisfactory 0.035-inch wall thickness pipe socket joint tested in accordance with Note 3 of Table VII of NAVSEA-248. All welders or welding machine operators must pass a Jaeger vision test.

A-1.16. SAFETY

Good safety practices will be maintained around electrical equipment and hot metal. Eye protection will be worn when cutting, welding, grinding, or burring. Equipment will be maintained in good mechanical condition.

APPENDIX B : TESTING PARAMETERS FOR PERMANENTLY OR TEMPORARILY MOUNTED IMPLODABLE AND EXPLODABLE ITEMS

B-1. INTRODUCTION

This appendix provides guidelines for ensuring that Diving Systems or Diving System personnel are not subjected to underwater explosion or implosion loading, resulting from the failure of an uncompensated Diving System component. This appendix is applicable to equipment permanently or temporarily mounted on the Diving System, and exposed to ambient submergence pressure during operations. This includes:

a. Equipment mounted anywhere on a Diving System designed to maintain the Diving System personnel in a submerged ambient environment

b. Equipment mounted external to a hyperbaric diving chamber (e.g., PTC) or carried by divers but not previously qualified and listed as ANU by divers

c. Equipment located in the water column, which may not be part of a diving system but may come in close proximity to divers

NOTE: Lockout submersibles represent a hybrid case in which the Diving System personnel are maintained in a dry environment for part of the mission, and are exposed to wet ambient conditions for part of the mission. In this case, all explodable or implodable volumes will be evaluated for their effect on the Diving System at the maximum design depth. All such volumes classified as critical will be tested in accordance with Sections B-4 and/or B-5 using the maximum design depth of the Diving System as the basis for determining the test pressure. Without exception, all other explodable or implodable volumes will be tested in accordance with Sections B-4 and/or B-5 using the maximum depth at which Diving System personnel (divers) are expected to enter or exit the Diving System as the basis for determining the test pressure.

B-1.1. IMPLODABLE ITEMS

All volumes that contain gas at a pressure less than the ambient external sea pressure have the potential to implode. When such a volume does implode it releases a pressure pulse similar to that which is produced when the expanded gas bubble from an underwater explosion collapses. In the event of an implosion it is the initial pressure pulse that is of concern.

B-1.2. EXPLODABLE ITEMS

All volumes that contain gas at pressures greater than the ambient external sea pressure have the potential to explode. When such a volume does explode it releases an explosive shock wave. During an explosion a gas bubble expands beyond the point of equilibrium with the surrounding hydrostatic sea pressure. This expanded volume of gas then collapses, causing a pressure pulse. The gas bubble continues to expand and collapse, releasing pressure pulses of decreasing magnitude, until equilibrium with the surrounding hydrostatic pressure is reached. It is the initial explosive shock wave and subsequent pressure pulse that are of concern in the event of an explosion.

B-1.3. EXPLODABLE ITEMS DUE TO DECOMPRESSION

This appendix does not cover the requirements for explosive decompression testing of volumes used in pressurized gaseous environments (e.g., recompression chambers or saturation diving chambers). Volumes used in such environments are subject to helium intrusion (or intrusion of some other gas) while at elevated pressures and thus have the potential to explode during the decompression cycle, as well as implode during the compression cycle. For all such volumes subject to explosive decompression, the requirements of Appendix C, in addition to the requirements of this section, apply.

B-1.4. PRESSURE VESSELS

Pressure hulls/vessels, personnel spheres, buoyancy tanks, air flasks, syntactic foam, and like items are implodable or explodable volumes by definition but are exempt from the requirements of this appendix. These items shall be designed and tested in accordance with Part 1 and 2 of this specification.

B-2. DETERMINATION OF WHETHER OR NOT AN EXPLODABLE OR IMPLODABLE IS CRITICAL OR NONCRITICAL

In order to determine whether or not an implodable or explodable volume is critical (requires testing) or noncritical (does not require testing), the effects of the initial explosive shock wave and/or the initial implosion pulse on all critical systems or components must be analyzed to ascertain whether or not the explosion or implosion would jeopardize the safety of the Diving System personnel. If the effects jeopardize the safety of the Diving System personnel, then the explodable or implodable is to be classified as critical. Otherwise, the explodable or implodable is classified as noncritical. All explodable or implodable volumes on a Diving System designed to maintain the operators in an ambient sea pressure environment, and which were not tested to a more severe requirement, will be classified as critical and tested in accordance with Sections B-4 and/or B-5 using the maximum depth at which Diving System personnel are expected to operate the Diving System as the basis for determining the test pressure.

B-3. TESTING REQUIRED FOR NONCRITICAL IMPLODABLE/EXPLODABLE VOLUMES

There are no testing requirements for implodable or explodable volumes which have been classified as noncritical volumes. It is therefore imperative to determine the minimum required standoff for all noncritical implodable or explodable volumes and to retain this information in such a manner that ensures that all noncritical volumes are located no closer than the minimum required standoff to the system/component of interest.

B-4. TESTING NECESSARY FOR CRITICAL IMPLODABLE VOLUMES

All volumes designated as critical implodable volumes, at any depth, shall be tested to 1.5 times the maximum allowable operating pressure (PTimp) for 10 cycles: cycles 1 through 9 shall each be held at (PTimp) for 10 minutes and cycle 10 shall be held at (PTimp) for 1 hour. The test shall be conducted in 35°F seawater, if practical. Leakage or visible signs of damage shall be cause for test failure.

NOTE: All volumes that are certified in this manner will require recertification by implosion testing if repairs or modifications are made which alter the "as-tested" configuration of the volume. The following are examples (not a complete list) of work or conditions that if performed or noticed on a certified (successfully tested) implodable volume will require a retest: welding, grinding, machining, any work that removes material, excessive corrosion, or replacement of a pressure boundary part (except O-rings, gaskets, etc.)

B-5. TESTING NECESSARY FOR CRITICAL EXPLODABLE VOLUMES

All volumes designated as critical explodable volumes, at any depth, shall be tested by pressurizing the volume internally to 1.5 times the maximum allowable internal operating pressure (PTexp) for 10 cycles: cycles 1 through 9 shall each be held at (PTexp) for 10 minutes and cycle 10 shall be held at (PTexp) for 1 hour. Leakage or visible signs of damage shall be cause for test failure.

NOTE: All volumes which are certified in this manner will require recertification by explosion testing if repairs or modifications are made which alter the "as tested" configuration of the volume. The following are examples (not a complete list) of work or conditions that if performed or noticed on a certified (successfully tested) explodable volume will require a retest: welding, grinding, machining, any work that removes material, and excessive corrosion.

B-6. TEST RECORD OQE REQUIRED FOR CRITICAL IMPLODABLE AND EXPLODABLE VOLUMES

A submergence Pressure Test Record shall be kept for all components tested in accordance with Sections B-4 and B-5. Records, as a minimum, shall include the following information:

a. Name(s) and serial number(s) of component(s) tested

b. Date of test

c. Serial number(s) of gauge(s) used for the test

d. Last calibration date of the pressure gauge(s) used in the test

    (1) Next calibration due date of the pressure gauge(s) used in the test

e. Test medium temperature required and actual test medium temperature used

f. Pressure range and accuracy of gauge(s) used

g. Test pressure for each pressure cycle

h. Required and actual duration of each pressure cycle

i. Results of inspection for leakage or visible signs of damage

j. Printed name(s) and signature(s), or Identification Number(s) and signature(s) of test conductor(s) and/or inspector(s) and the date of each signature.

B-7. EXEMPTIONS TO REQUIRING CRITICAL IMPLODABLE/EXPLODABLE VOLUMES

The Design Agent may request an exemption from testing those implodable/explodable volume components that have a maximum design depth rating of four or more times the maximum operating depth of the diving system and have a first article test of the item performed, as required above, to the item's maximum operating depth.

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APPENDIX C : TESTING PARAMETERS FOR EXPLODABLE ITEMS DUE TO DECOMPRESSION

C-1. INTRODUCTION

Many devices, such as interior lights and instrument bulbs inside the Diving System, are subject to inadvertent explosion during decompression because they have been infiltrated by helium or other gases during a compression cycle. These devices may become hazards within the Diving System. At the present time, there is no known analytical method for determining the material adequacy of items within a Diving System that may explode and cause a casualty. To achieve a maximum reasonable level of assurance for these items, the following paragraphs contain the requirements for determining the material adequacy of all such items.

C-2. DESCRIPTION AND ORIENTATION

A list shall be generated which describes the size, quantity, and locations of all potentially explodable items. All such items shall be explosively tested as described below. If 100 percent batch testing is impractical or otherwise considered unnecessary, the Builder may request a waiver of the 100 percent testing requirement and shall provide detailed justification for the waiver and shall provide a procedure for selecting the batch sample size. The approved sample will be tested in accordance with the requirements of this appendix.

C-3. TEST PROCEDURE

Each item selected should be tested as follows:

a. Subject the item to a pressurized soak test, using a test medium (e.g., air, helium) representative of the actual environment in which the explodable item will operate. For convenience, it may be permissible to substitute a test medium (e.g., air for water or helium for air) that is more likely to infiltrate the test article. The time of the soak shall be 2 times the maximum expected exposure period or 24 hours, whichever is least. The pressure shall be the maximum operating pressure of the Diving System.

b. Following the soak test, depressurize the test chamber at a rate not less than 1.5 times the maximum depressurization rate of the manned space. For items that may be locked in or out of manned spaces, the maximum travel rate of the service lock must be considered.

c. Items that do not show evidence of physical deterioration or damage shall be acceptable for service.

d. Items that do show evidence of physical deterioration or damage shall be rejected.

e. Depending on the type of failure, rejected items may be allowed to be repaired and then undergo a retest. If these items successfully pass the retest they will be acceptable for service.

C-4. POROUS OR VENTED COMPONENTS

Porous or vented components of an explodable item, which by their construction or design are known or intended to continuously equalize their internal pressure with ambient external pressure, shall be shown to have the ability to intake and exhaust a test medium, representative of the actual operating environment, within the maximum pressurization/depressurization rates of the system in order to provide assurance that the porous or vented components will not explode during pressurization or depressurization. Testing done in accordance with Section C-3 above, including authorized substitutions of test medium, will provide this assurance.

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APPENDIX D : JOINT IDENTIFICATION DRAWING EXAMPLE

D-1. GENERAL

This appendix includes some of the JIDs from the Standard Navy Double Lock Recompression Chamber System (SNDLRCS)). These are to be used as an example only. The actual requirements for a JID are found in 1-3.2.2 and 2-1.6.3. It should be noted that the method for designating certain components in these drawings is different then what is shown in 1-3.2.2. This would be acceptable if written authorization was granted by the Government Procurement Representative. In most cases, authorization to deviate from the exact documentation method will be granted to a Designer or Builder as long as the information required in the JID will still be present.

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THIRD ANGLE PROJECTION

REVISION	REV STATUS OF SHEETS
SHEET	

REVISIONS

ZONE	REV	DESCRIPTION	DATE	APPROVED
-	1	REVISED TO AS BUILT.		
-	2	NOTES 30 - 37 ADDED.		
-	3	ADDED NOTE 38	2/26/02	RMW
-	4	ADDED NOTE 39.	24JUL02	
-	5	ADDED NOTE 40.	04SEP02	
-	6	ADDED NOTE 41.	06SEP02	RMW
-	7	ADDED NOTE 42.	10SEP02	RMW
-	8	NOTE 11 WAS 60 MICRON FILTER. NOTE 43 ADDED.	18SEP02	
F6,D9	9	ECS ADDED TO USAGE SECTION OF JID & VALVE/GAUGE I/D CODING.	10DEC02	
-	10	-	-	

NOTES: UNLESS OTHERWISE SPECIFIED

1. THIS JOINT IDENTIFICATION DRAWING (JID) PROVIDES INFORMATION FOR THE INSTALLATION/ASSEMBLY OF THE STANDARD NAVY DOUBLE LOCK (SNDL) LIFE SUPPORT SYSTEMS.
2. ITEM TO BE CLEANED TO AIR CLEANING STANDARD, MIL-STD-1622.
3. APPLY CHRISTOLUBE TO ALL O-RING FACE SEALS PRIOR TO INSTALLATION.
4. APPLY TEFLON TAPE (OXYGEN SERVICE APPROVED) TO MALE THREAD PRIOR TO INSTALLATION. APPLY TEFLON TAPE TO WITHIN ONE THREAD IN FROM END BY WRAPPING IN OPPOSITE DIRECTION TO THREAD DIRECTION.
5. F.F.W.R DENOTES FLATS FROM WRENCH RESISTANCE.
6. ITEM TO BE CLEANED TO OXYGEN SERVICE STANDARD, MIL-STD-1330.
7. ALL TUBE, CONNECTIONS AND GAUGE SIZES ARE IN INCHES.
8. COLOUR CODING OF TUBES, QUICK DISCONNECTS, GAUGES SHALL BE IN ACCORDANCE WITH SS521-AG-PRO-010 "U.S NAVY DIVING MANUAL".
9. ALL ITEMS REQUIRE CERTIFICATE OF CONFORMANCE.
10. ALL COMPONENTS TO BE PNEUMO/HYDROSTATICALLY TESTED AND DOCUMENTED WITH IAW COWAN MANUFACTURING PTYL LTD, FACTORY ACCEPTANCE PROCEDURE.
11. ITEM TO BE PURCHASED WITH A 15 MICRON MONEL FILTER.
12. VALVE TO BE WIRED OPEN WITH FRANGIBLE WIRE.
13. ITEM TO BE PURCHASED WITH A CALIBRATION CERTIFICATE VALID FOR 12 MONTHS.
14. ITEM TO BE PURCHASED WITH HYDROSTATIC TEST RESULTS.
15. ALL BRASS COMPONENTS TO BE MANUFACTURED FROM ASTM B16 GRADE OR EQUIVALENT
16. THE TORQUE METHOD OF ASSEMBLY IS THE PREFERRED METHOD OF ASSEMBLY. IT REDUCES THE RISK OF HUMAN ERROR DURING ASSEMBLY THAT IS MORE PREVALENT IN THE FLATS FROM WRENCH RESISTANCE (F.F.W.R) METHOD. TO ENSURE THE MOST ACCURATE ASSEMBLY OF THE SEAL-LOK FITTING IT IS STRONGLY RECOMMENDED THAT THE TORQUE METHOD BE UTILIZED.
17. RELIEF VALVE TO BE SUITABLE FOR BREATHING AIR SERVICE (NO OIL) AND SUPPLIED WITH ASME CERTIFICATE.
18. SUPPLIED OIL FREE FOR BREATHING AIR SERVICE, HAVE FILTER DAMPENING, WITH WITH CALIBRATION CERTIFICATE.
19. SUPPLIED OIL FREE FOR BREATHING AIR SERVICE, HAVE FILTER DAMPENING, WITH CERTIFICATE OF CONFORMANCE.
20. SUPPLIED FOR OXYGEN SERVICE, HAVE FILTER DAMPENING, WITH CERTIFICATE OF CONFORMANCE & CLEANING.
21. ORDER WITH SENSOR SAMPLE CAP C/W 1/4" HOSE BARB.
22. REQUIRES VITON O RING 2-011 V90 (MIL-R-83248 TYPE 1 CLASS 2) 1/4" TUBE.
23. REQUIRES VITON O RING 2-012 V90 (MIL-R-83248 TYPE 1 CLASS 2) 3/8" TUBE.
24. REQUIRES VITON O RING 2-014 V90 (MIL-R-83248 TYPE 1 CLASS 2) 1/2" TUBE.
25. REQUIRES VITON O RING 2-021 V90 (MIL-R-83248 TYPE 1 CLASS 2) 1" TUBE.
26. REQUIRES VITON O RING 2-029 V90 (MIL-R-83248 TYPE 1 CLASS 2) 1 1/2" TUBE.
27. REQUIRES VITON O RING 3-904 V90 (MIL-R-83248 TYPE 1 CLASS 2) SAE 1/4"
28. REQUIRES VITON O RING 3-906 V90 (MIL-R-83248 TYPE 1 CLASS 2) SAE 9/16"
29. REQUIRES VITON O RING 2-215 V75 (MIL-R-83248 TYPE 1 CLASS 1) VCO 1" TUBE.
30. ASTM A269 ANNEALED 316 SST SEAMLESS HYDRAULIC TUBE, SCRATCH FREE AND SUITABLE FOR BENDING, MILL CERTIFICATION AND PROPERTIES REQUIRED. OD AND WALL THICKNESS TO BE MEASURED ON RECEIPT.
31. TUBE SIZE 6.35 OD x 0.89 WALL.

JOINT IDENTIFICATION CODING.

XXX-XXXXXXXX

TYPE OF JOINT :
BR = BARBED.
WJ = WELDED JOINT.
ST = STRAIGHT THREAD.
OU = O-RING FACE SEAL.
PT = PIPE THREAD.
FL = 37° FLARED (JIC).
CG = COMPRESSED GAS ASSN 540.

JOINT No: STARTING AT 001 FOR EACH SUBSYSTEM

TORQUE VALUE :
00 = NONE REQUIRED.
01 = .250 - .500 F.F.W.R - (220 - 242 IN-LB)
02 = .250 - .500 F.F.W.R - (360 - 396 IN-LB)
03 = .250 - .500 F.F.W.R - (480 - 528 IN-LB)
04 = .250 - .500 F.F.W.R - (720 - 792 IN-LB)
05 = .250 - .500 F.F.W.R - (1020 - 1122 IN-LB)
06 = .250 - .500 F.F.W.R - (1140 - 1254 IN-LB)
07 = .250 - .500 F.F.W.R - (1320 - 1452 IN-LB)
08 = .250 - .500 F.F.W.R - (1680 - 1848 IN-LB)
09 = .250 - .500 F.F.W.R - (2160 - 2376 IN-LB)
10 = 4320 - 4752 IN-LB
11 = 2-3 TURNS PASS FINGER TIGHT
12 = 2-3 TURNS PASS FINGER TIGHT
13 = 2-3 TURNS PASS FINGER TIGHT
14 = 2-3 TURNS PASS FINGER TIGHT
15 = 2-3 TURNS PASS FINGER TIGHT
16 = 1.5 - 2.5 TURNS PASS FINGER TIGHT
17 = 1.5 - 2.5 TURNS PASS FINGER TIGHT
18 = 1.5 - 2.5 TURNS PASS FINGER TIGHT
19 = 1.5 - 2.5 TURNS PASS FINGER TIGHT
20 = 156 - 172 IN-LB
21 = TIGHT TILL NO LEAKS

SUBSYSTEM DESIGNATION :
1 = AIR GAS SYSTEM.
2 = OXYGEN GAS SYSTEM.
3 = MIXED GAS SYSTEM.
4 = EXHAUST, BIBS EXHUST, CHAMBER RELIEF VALVE SYSTEMS.
5 = DEPTH PRESSURE GAUGE & GAS SAMPLE SYSTEMS.
6 = EQUALISATION & SPARES.
7 = MEDICAL LOCK.
8 = DIANOGSTICS AND COMMUNICATION.
9 = ENVIRONMENTAL CONTROL.

USAGE :
ALP = AIR LOW PRESSURE.
ATM = ATMOSPHERE (CHAMBER PRESSURE).
EQ = EQUALISATION.
EXH = EXHAUST.
OLP = OXYGEN LOW PRESSURE.
MLP = MIXED LOW PRESSURE.
ECS = ENVIRONMENTAL CONTROL SYSTEM

FITTING IDENTIFICATION CODING.

F-XXXX

FITTING No. : START AT 001 FOR EACH SYSTEM.

SUBSYSTEM DESIGNATION :
1 = AIR GAS SYSTEM.
2 = OXYGEN GAS SYSTEM.
3 = MIXED GAS SYSTEM.
4 = EXHAUST, BIBS EXHUST, CHAMBER RELIEF VALVE SYSTEMS.
5 = DEPTH PRESSURE GAUGE & GAS SAMPLE SYSTEMS.
6 = EQUALISATION & SPARES.
7 = MEDICAL LOCK.
8 = DIANOGSTICS AND COMMUNICATION.
9 = ENVIRONMENTAL CONTROL.

VALVE & GAUGE IDENTIFICATION CODING.

XXX-X-XX

SEQUENTIAL NUMBER

GAUGE / VAVLE DESCRIPTION :
G = GAUGE.
V = VALVE.
S = CO2 SCRUBBER.
R = REGULATOR

USAGE :
ALP = AIR LOW PRESSURE.
ATM = ATMOSPHERE (CHAMBER PRESSURE).
EQ = EQUALISATION.
EXH = EXHAUST.
OLP = OXYGEN LOW PRESSURE.
MLP = MIXED LOW PRESSURE.
ECS = ENVIRONMENTAL CONTROL SYSTEM

TUBE IDENTIFICATION CODING.

XX-X-XXX

SEQUENTIAL NUMBER

TYPE :
T = TUBE.
F = FLEXIBLE HOSE.

SUBSYSTEM DESIGNATION :
M = MIXED GAS SYSTEM.
O2 = OXYGEN GAS SYSTEM.
AS = AIR GAS SYSTEM.
ML = MEDICAL LOCK.
EXH = EXHAUST SYSTEM.
ATM = DEPTH PRESSURE, GAS SAMPLE.
ECS = ENVIRONMENTAL CONTROL UNIT.

NOTES CONTINUED: UNLESS OTHERWISE SPECIFIED

32. TUBE SIZE 9.525 OD x 0.89 WALL.
33. TUBE SIZE 12.7 OD x 1.2 WALL.
34. TUBE SIZE 25.4 OD x 1.6 WALL.
35. TUBE SIZE 38.1 OD x 1.6 WALL.
36. WELD IAW GPC APPROVED PROCEDURE.
37. COMPONENT IDENTIFICATION NUMBERS TO BE ENGRAVED ON EACH ITEM.
38. ITEM NOT AS SHOWN FOR VCM 197. SEE 7317813
39. VALVE TAG MUST BE ATTACHED. REF ITEM 592-7317789-97 FOR DETAILS.
40. NOTCH OUT COMMS BOX SHELL TO ALLOW ELECTRICAL CONNECTION TO ENTER THROUGH BASE.
41. EXH-T-006, 007, 011 & 012 MOUNTED TO CABLE TRAY USING 1/4" P-CLIP (SWAGELOCK PART NUMBER SS-TBP-4). P-CLIPS ATTACHED TO CABLE TRAY WITH 3/16 UNC X 1/2 LONG PAN PHILLIPS MOUNTS, NYLOCK NUT AND FLAT WASHER. THERE ARE 25 PER SYSTEM.
42. NUMBERS ENGRAVED ON PIPING COMPONENTS ARE FITTING NUMBERS AND NOT JID NUMBERS. USE THIS DRAWING (592-7317812) TO CROSS REFERENCE FITTING NUMBERS WITH JID NUMBERS FOR USE IN REENTRY CONTROL PROCEDURES.
43. VALVE MUST BE SET TO 200PSI BEFORE SERVICE.
44. REPLACEMENT FILTER ELEMENT IS NORMAN PART NUMBER 416G-20VN.

DWG NO 592-7317812 SH 1 REV 10

QTY REQD		CAGE CODE	PART OR IDENTIFYING NO.	DESCRIPTION	SPECIFICATION	ZONE	ITEM NO.

PARTS LIST

PART DASH NO.	QTY REQD PER ASSY NEXT	FINAL	NEXT ASSY	USED ON
			APPLICATION	

INCHES
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
TOLERANCES ARE: .X ± 0.3 .XX ± 0.13 ANGLES: ± 1°
CAD FILE No. 7812-s01.dwg
DESIGN BY FINK ENGINEERING PTY LTD MELBOURNE, AUSTRALIA

CONTRACT NO. -
CONTRACTOR: GPC - A JOINT VENTURE P.O. BOX JK WILLIAMSBURG, VIRGINIA 23187

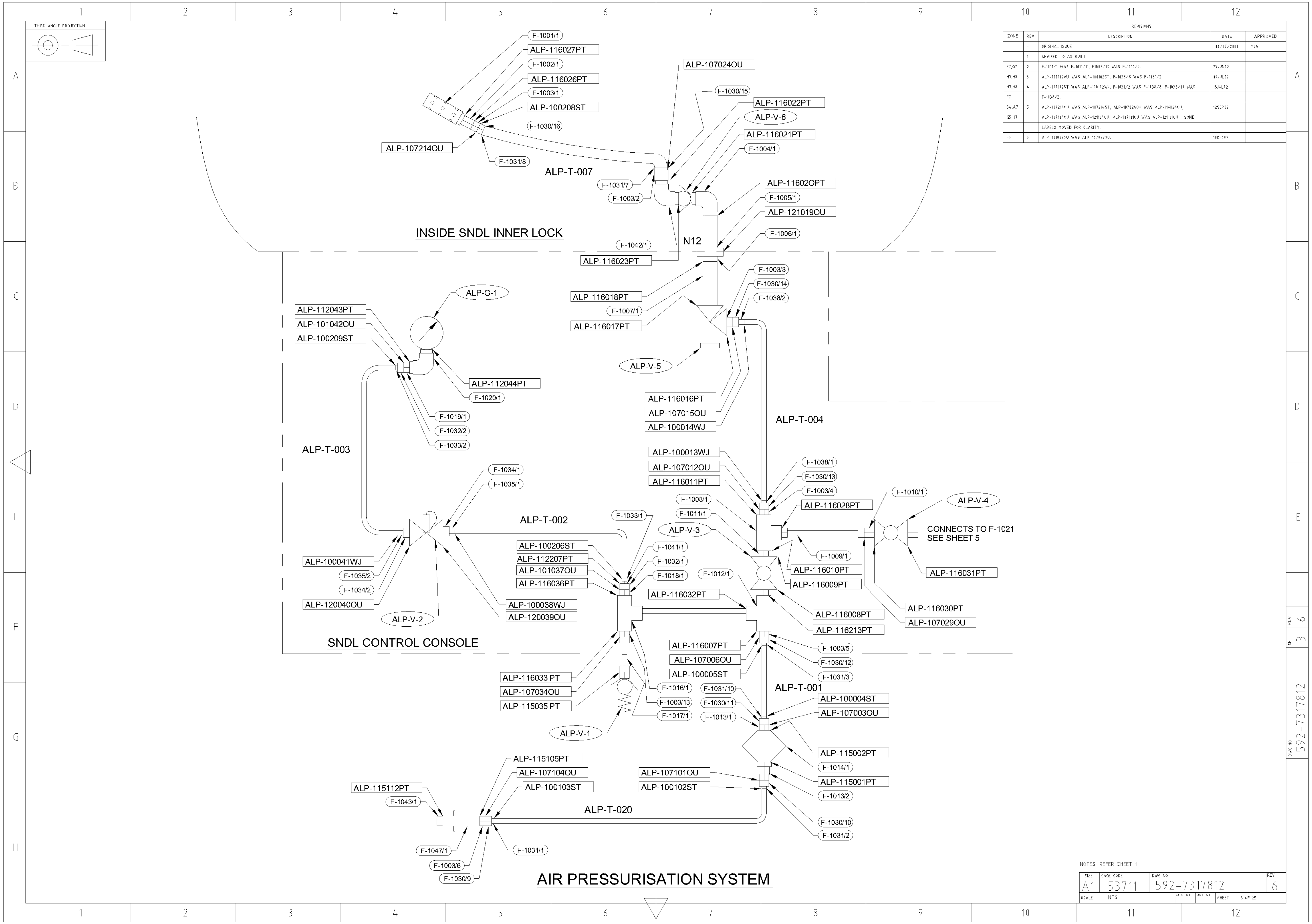
PREPARED	MARK ANDERSON	05.07.2001
CHECKED	HOWARD ROME	06.07.2001
ENGINEER	RYAN WEBB	10/15/2001
ACCEPTED BY NAVSEA	MICHAEL P. LEESE (SIGNATURE DOES NOT DENOTE APPROVAL)	12/9/03
APPROVED FOR NAVSEA	MICHAEL P. LEESE (SIGN ONLY IF ENGINEERING HAS BEEN 'PROVED' BY MANUFACTURE AND TEST)	12/9/03

DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
ARLINGTON VIRGINIA 22242

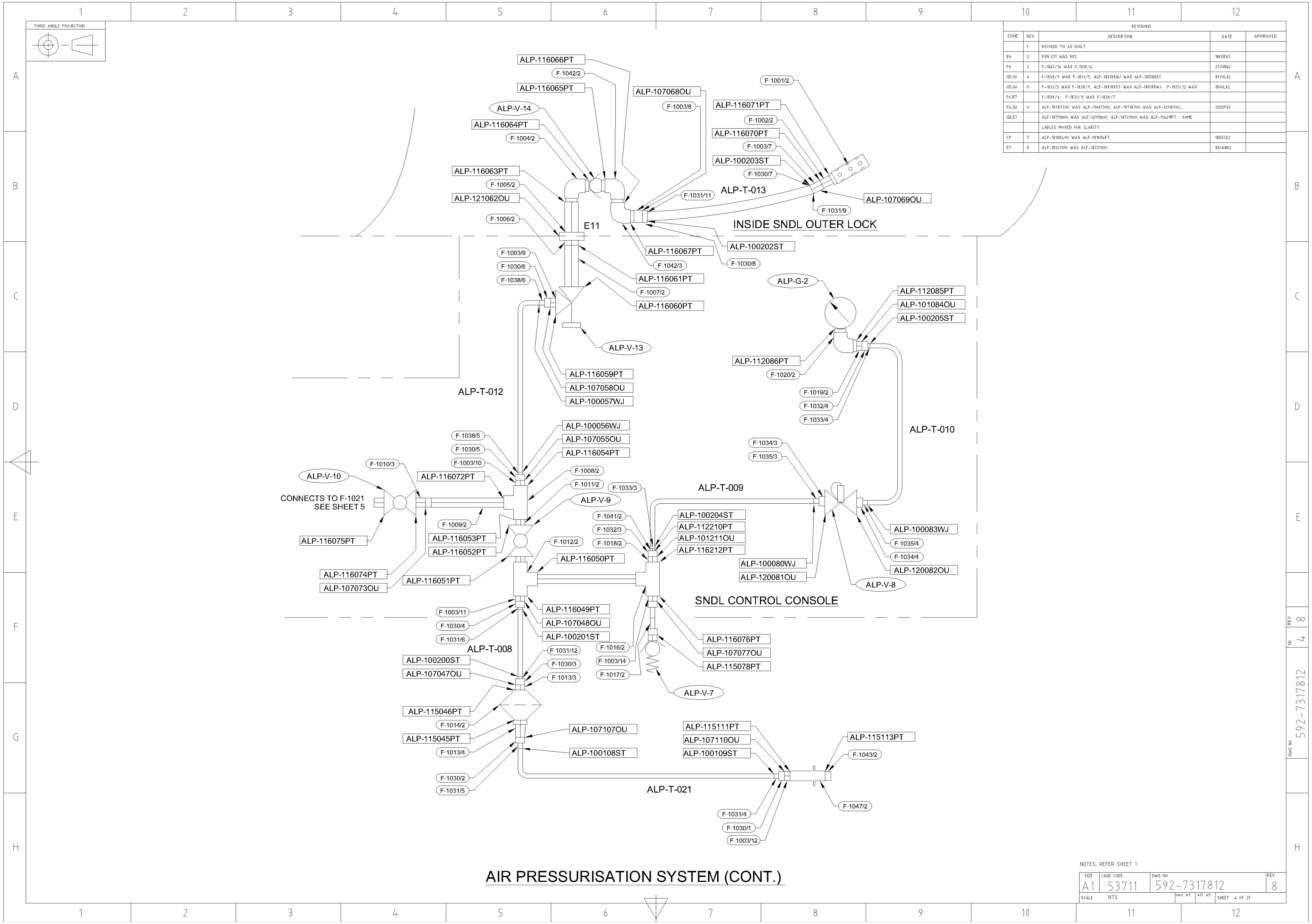
TITLE
JOINT IDENTIFICATION DRAWING

SIZE	CAGE CODE	DWG NO	REV
A1	53711	592-7317812	10

SCALE N.T.S CALC.WT. ACT.WT. SHEET 1 OF 25

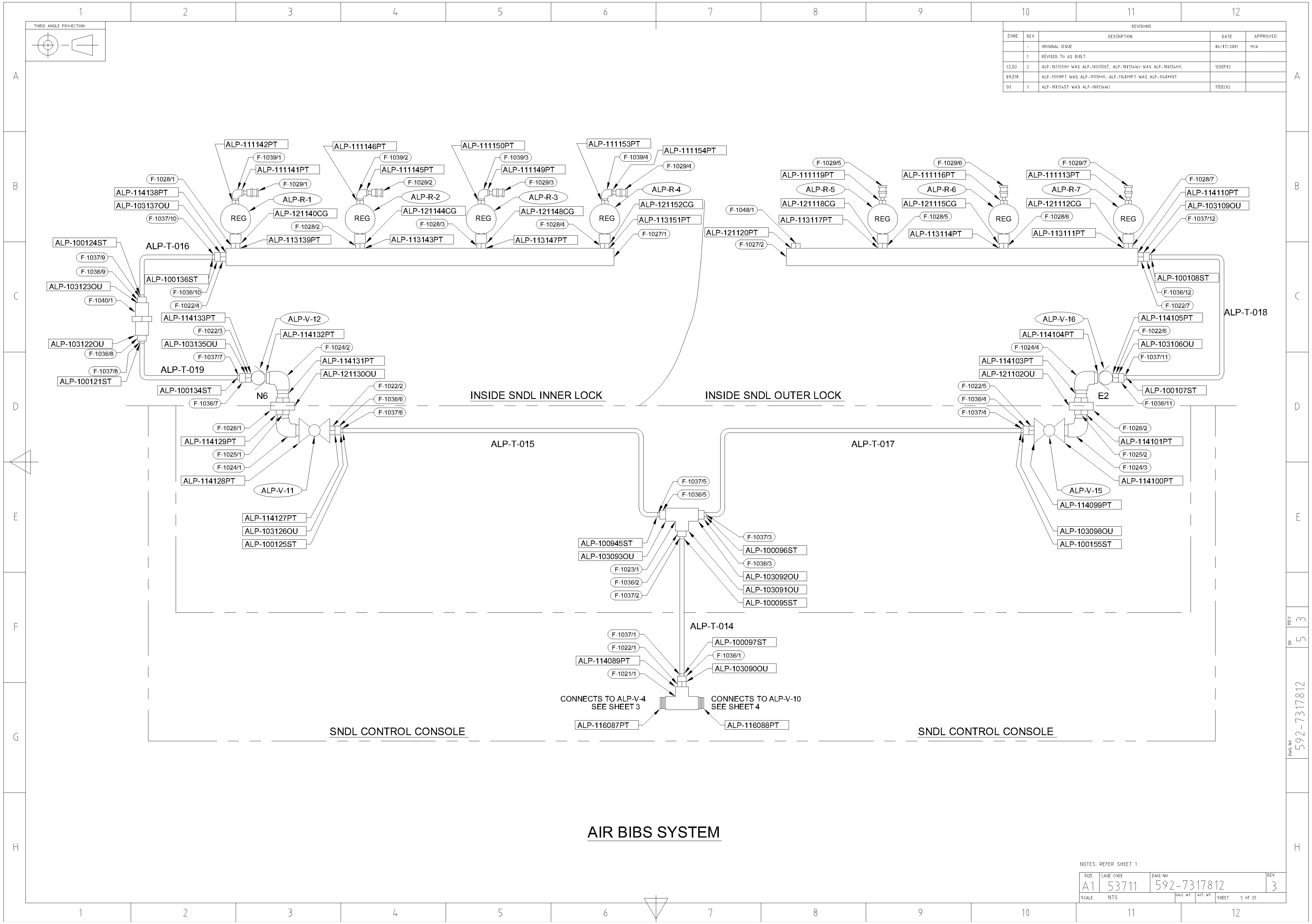


REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	-	ORIGINAL ISSUE	06/07/2001	MJA
	1	REVISED TO AS BUILT.		
E7,G7	2	F-1011/1 WAS F-1011/11, F1003/13 WAS F-1010/2.	27JUN02	
H7,H8	3	ALP-100102WJ WAS ALP-100102ST, F-1038/8 WAS F-1031/2.	09JUL02	
H7,H8	4	ALP-100102ST WAS ALP-100102WJ, F-1031/2 WAS F-1038/8, F-1038/10 WAS	18JUL02	
F7		F-1038/3.		
B4,A7	5	ALP-107214OU WAS ALP-107214ST, ALP-107024OU WAS ALP-116024OU,	12SEP02	
G5,H7		ALP-107104OU WAS ALP-121104OU, ALP-107101OU WAS ALP-121101OU. SOME		
		LABELS MOVED FOR CLARITY.		
F5	6	ALP-101037OU WAS ALP-107037OU.	10DEC02	



REVISIONS

ZONE	REV	DESCRIPTION	DATE	APPROVED
	1	REVISED TO AS BUILT.		
B6	2	PEN E11 WAS N12.	18FEB02	
F6	3	F-1003/14 WAS F-1010/4.	27JUN02	
G5,G6	4	F-1038/9 WAS F-1031/5, ALP-100108WJ WAS ALP-100108ST.	09JUL02	
G5,G6	5	F-1031/5 WAS F-1038/9, ALP-100108ST WAS ALP-100108WJ. F-1031/12 WAS	18JUL02	
F6,B7		F-1038/4. F-1031/11 WAS F-1038/7.		
F4,G6	6	ALP-107073OU WAS ALP-116073OU, ALP-107107OU WAS ALP-121107OU,	12SEP02	
G8,E7		ALP-107110OU WAS ALP-121110OU, ALP-107211OU WAS ALP-116211PT. SOME		
		LABLES MOVED FOR CLARITY.		
C9	7	ALP-101084OU WAS ALP-101084PT.	10DEC02	
E7	8	ALP-101211OU WAS ALP-107211OU.	08JAN02	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ALP-R-2
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ALP-R-4
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ALP-100134ST
F-1036/7
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F-1036/6
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INSIDE SNDL OUTER LOCK
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ALP-T-017
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SEE SHEET 3
CONNECTS TO ALP-V-10
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SNDL CONTROL CONSOLE
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53711
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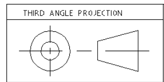
SHEET 5 OF 25

THIRD ANGLE PROJECTION



REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	-	ORIGINAL ISSUE	06/07/2001	MJA
	1	REVISED TO AS BUILT.		
	2	NOTES ADDED TO TUBE LISTING.	11FEB02	
	3	CORRECTED PART NUMBER FOR ALP-V-7.	4/2/02	RMW
	4	CHANGED F-1043 FROM 1" MNPT TO 1" CPV.	4/3/02	RMW
	5	NOTE 39 ADDED TO ALP-V-1 & ALP-V-7.	24JUL02	
	6	PART NO & DESCRIPTION CHANGED ON ALP-V-3, -4, -9 & -10.	02AUG02	
	7	F-1039 WAS DESIGNATED AS .125MNPT - .125MNPT. MIL SPEC ADDED TO	16SEP02	
		ALP-V-002 AND ALP-V-008 PART NUMBER.		
	8	ALP-V-005 AND ALP-V-013 DID NOT HAVE 'A-' PREFIX. PART NUMBER DELETED FROM TUBE LISTING.	19SEP02	
	9	ADDED FITTING QUANTITIES.	25SEP02	RMW
	10	MODIFIED QUANITITIES FOR F-1003 & F-1031	20MAY2003	RMW
C6	11	ADDED NOTE 44 TO F-1014	2JUNE2003	RMW

FITTING LISTING

ITEM NO.	QTY	NOMINAL SIZE	DESCRIPTION	PART NUMBER	MATERIAL SPEC.	O-RING ITEM No.	NOTES	MANUFACTURER
F-1001	2	1.00 MNPT	SILENCER	ANA1-N-10	PLASTIC	-	2	SMC
F-1002	2	1.00 MNPT- 1"FNPT	FEMALE HEX COUPLING	16-16 FHC-B	BRASS	-	2,15	PARKER HANNIFIN
F-1003	14	1.00 MNPT - 1.00 TUBE	MALE PIPE CONNECTOR	16 FLO-SS	316 SST	-	2,10,25	PARKER HANNIFIN
F-1004	2	1.00 MNPT - 1.00 MNPT	MALE ELBOW	16-16 ME-B	BRASS	-	2	PARKER HANNIFIN
F-1005	2	1.00 FNPT - 1.00 FNPT	PENETRATOR, 42	592-7317811-1	316 SST	2-032-V75 MIL R-83248	2,10	COWAN MANUFACTURING
F-1006	2	1.625-18 UNEF-2B	PENETRATOR NUT, 42	592-7317811-2	BRASS	-	2,15	COWAN MANUFACTURING
F-1007	2	1.00 MNPT - 1.00 MNPT	MALE CLOSED COUPLING	16-16 MCN-B	BRASS	-	2,15	PARKER HANNIFIN
F-1008	2	3 x 1.00 FNPT	FEMALE TEE	16-16-16 FT-B	BRASS	-	2,15	PARKER HANNIFIN
F-1009	2	1.00 MNPT - 1.00 FVCO	CONNECTOR	SS-16-WVCO-1-16	316 SST	-	2	CAJON
F-1010	2	1.00 MNPT - 1.00 MVCO	MALE CONNECTOR	SS-16-VCO-1-16	316 SST	V70	2	CAJON
F-1011	2	1.00 MNPT - 1.00 MNPT	MALE HEX. NIPPLE	16-16 MHN-B	BRASS	-	2,15	PARKER HANNIFIN
F-1012	2	1.00 FNPT - 2x1.00 MNPT	STREET TEE	16-16-16 ST-B	BRASS	-	2,15	PARKER HANNIFIN
F-1013	4	.750 MNPT - 1.00 TUBE	MALE CONNECTOR	16-12 FLO-SS	316 SST	-	2,25	PARKER HANNIFIN
F-1014	2	.750 FNPT - .750 FNPT	FILTER	43 26 G G 20 V N	316 SST	-	2,44	NORMAN
-	-	-	-	-	-	-	-	-
F-1016	2	2x1.00 FNPT - 1.00 MNPT	MALE BRANCH TEE	16-16-16 MBT-B	BRASS	-	2,15	PARKER HANNIFIN
F-1017	2	.750 FNPT - 1.00 FVCO	RELIEF VALVE ADAPTOR	592-7317811-24	BRASS	-	2,15	COWAN MANUFACTURING
F-1018	2	1.00 MNPT - .250 FNPT	REDUCING ADAPTOR	16-4 RB-B	BRASS	-	2,15	PARKER HANNIFIN
F-1019	2	.250 MNPT - .250 TUBE	MALE PIPE CONNECTOR	4-4 FLO-SS	316 SST	-	2,22	PARKER HANNIFIN
F-1020	2	.250 FNPT - .250 FNPT	FEMALE ELBOW	4-4 FE-B	BRASS	-	2,15	PARKER HANNIFIN
F-1021	1	2x1.00 MNPT - .500 FNPT	BRANCH TEE	592-7317811-7	316 SST	-	2	COWAN MANUFACTURING
F-1022	7	.500 MNPT - .500 TUBE	MALE PIPE CONNECTOR	8-8 FLO-SS	316 SST	-	2,24	PARKER HANNIFIN
F-1023	1	3x.500 TUBE	UNION TEE	8 JLO-SS	316 SST	-	2,24	PARKER HANNIFIN
F-1024	4	.500 MNPT - .500 MNPT	MALE ELBOW	8-8 ME-B	BRASS	-	2,15	PARKER HANNIFIN
F-1025	2	1.125-12 UNF-2A	NUT, 29	592-7317811-4	BRASS	-	2,15	COWAN MANUFACTURING
F-1026	2	.500 FNPT - .500 FNPT	PENETRATOR, 29	592-7317811-3	316 SST	2-027-V75 MIL R-83248	2,10	COWAN MANUFACTURING
F-1027	2	.500 FNPT - 4x.375 FNPT	BIBS BLOCK AIR	592-7317811-11	BRASS	-	2,15	COWAN MANUFACTURING
F-1028	7	.375 MNPT - CGA 540	ADAPTOR, .903-14 (CGA-540)	592-7317811-8	BRASS	-	2,15	COWAN MANUFACTURING
F-1029	7	.125 MNPT	QUICK DISCONNECT	18969-00	BRASS	-	2,15	SCOTT AVIATION
F-1030	16	1.4375-12 UNF-2A	O-RING FACE SEAL TUBE NUT	16 BL-SS	316 SST	-	2	PARKER HANNIFIN
F-1031	12	1.00	ORING FACE SEAL MECH. ATTACHABLE SLEEVE	16 TPL-SS	316 SST	-	2,10	PARKER HANNIFIN
F-1032	4	.5625-18 UNF-2A	O-RING FACE SEAL TUBE NUT	4 BL-SS	316 SST	-	2	PARKER HANNIFIN
F-1033	4	.250	ORING FACE SEAL MECH. ATTACHABLE SLEEVE	4 TPL-SS	316 SST	-	2,10	PARKER HANNIFIN
F-1034	4	.250	CPV SKT TUBE NUT	950-4SS	316 SST	-	2	CPV
F-1035	4	.250	CPV WELED GLAND	949R-4SS	316 SST	-	2,10	CPV
F-1036	12	.8125-18 UNF-2A	O-RING FACE SEAL TUBE NUT	8 BL-SS	316 SST	-	2	PARKER HANNIFIN
F-1037	12	.500	ORING FACE SEAL MECH. ATTACHABLE SLEEVE	8 TPL-SS	316 SST		2,10	PARKER HANNIFIN
F-1038	4	1"	O-RING FACE SEAL SOCKET WELD GLAND	592-7317811-20	316 SST	-	2,10	COWAN MANUFACTURING
F-1039	4	.125FNPT - .125MNPT	STREET ELBOW	2-2-SE-SS	316 ST	-	2	SWAGELOK
F-1040	1	.500 TUBE/.500 TUBE	UNION	8 HLOSS	316 SST	-	2,24	PARKER HANNIFIN
F-1041	2	.250 MNPT/.250 TUBE	MALE PIPE CONNECTOR	4-4 FLO SS	316 SST		2.22	PARKER HANNIFIN
F-1042	3	1.00 MNPT/1.00 FNPT	STREET ELBOW	SS-2-SE	BRASS	-	2,15	PARKER HANNIFIN
F-1043	2	1.00 CPV - 1.0 TUBE	MALE CONNECTOR	H854-16-16	616 SST	-	2,10	CPV
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
F-1047	2	1.00 FNPT	3000# FULL COUPLING	1" FNPT 3000#	316 SST	-	2,10	PROCHEM
F-1048	1	.375 MNPT	HEX. HEAD PLUG	6-PH-B	BRASS	-	2,15	PARKER HANNIFIN

TUBE LISTING

TUBE No.	PART NUMBER	TYPE	SIZE	MATERIAL GRADE	NOTES
ALP-T-001	-	1"TUBE ASS'Y	1"TPL-1"TPL	316L SST	2,14,30,34,37
ALP-T-002	-	1/4" TUBE ASS'Y	1/4"TPL-1/4"TPL	316L SST	2,14,30,31,36,37
ALP-T-003	-	1/4" TUBE ASS'Y	1/4"TPL-1/4"TPL	316L SST	2,14,30,31,36,37
ALP-T-004	-	1"TUBE ASS'Y	1"TPL-1"TPL	316L SST	2,14,30,34,36,37
ALP-T-007	-	1"TUBE ASS'Y	1"TPL-1"TPL	316L SST	2,14,30,34,37
ALP-T-008	-	1"TUBE ASS'Y	1"TPL-1"TPL	316L SST	2,14,30,34,37
ALP-T-009	-	1/4" TUBE ASS'Y	1/4"TPL-1/4"TPL	316L SST	2,14,30,31,36,37
ALP-T-010	-	1/4" TUBE ASS'Y	1/4"TPL-1/4"TPL	316L SST	2,14,30,31,36,37
ALP-T-012	-	1"TUBE ASS'Y	1"TPL-1"TPL	316L SST	2,14,30,34,36,37
ALP-T-013	-	1"TUBE ASS'Y	1"TPL-1"TPL	316L SST	2,14,30,34,37
ALP-T-014	-	1/2" TUBE ASS'Y	1/2"TPL-1/2"TPL	316L SST	2,14,30,33,37
ALP-T-015	-	1/2" TUBE ASS'Y	1/2"TPL-1/2"TPL	316L SST	2,14,30,33,37
ALP-T-016	-	1/2" TUBE ASS'Y	1/2"TPL-1/2"TPL	316L SST	2,14,30,33,37
ALP-T-017	-	1/2" TUBE ASS'Y	1/2"TPL-1/2"TPL	316L SST	2,14,30,33,37
ALP-T-018	-	1/2" TUBE ASS'Y	1/2"TPL-1/2"TPL	316L SST	2,14,30,33,37
ALP-T-019	-	1/2" TUBE ASS'Y	1/2"TPL-1/2"TPL	316L SST	2,14,30,33,37
ALP-T-020	-	1"TUBE ASS'Y	1"TPL-1"TPL	316L SST	2,14,30,33,37
ALP-T-021	-	1"TUBE ASS'Y	1"TPL-1"TPL	316L SST	2,14,30,33,37

VALVE LISTING

VALVE No.	NOMINAL SIZE	DESCRIPTION	PART NUMBER	MATERIAL SPEC.	TYPE	NOTES	MANUFACTURER
ALP-V-1	.750 MNPT	RELIEF VALVE	19-301-300	BRASS	RELIEF	2,15,17,39	CONBRACO
ALP-V-2	.250 TUBE	INSTRUMENT VALVE	PLC10669 / MIL-V-24578B	316 SST	NEEDLE	2	CPV
ALP-V-3	1.00 FNPT	2 WAY VALVE, BLK OVAL HANDLE	B-65TF16/SS-51K-65K-BK	BRASS	BALL	2,15	WHITEY
ALP-V-4	1.00 FNPT	2 WAY VALVE, BLK OVAL HANDLE	B-65TF16/SS-51K-65K-BK	BRASS	BALL	2,15	WHITEY
ALP-V-5	1.00 FNPT	SOFT SEAT 2 WAY VALVE	A-818-75-15-K-R	316 SST	NEEDLE	2	DRAGON
ALP-V-6	1.00 FNPT	CHECK VALVE	B-16C4-1/3	BRASS	CHECK	2,15	NUPRO
ALP-V-7	.750 MNPT	RELIEF VALVE	19-301-300	BRASS	RELIEF	2,17,39	CONBRACO
ALP-V-8	.250 TUBE	INSTRUMENT VALVE	PLC10669 / MIL-V-24578B	316 SST	NEEDLE	2	CPV
ALP-V-9	1.00 FNPT	2 WAY VALVE, BLK OVAL HANDLE	B-65TF16/SS-51K-65K-BK	BRASS	BALL	2,15	WHITEY
ALP-V-10	1.00 FNPT	2 WAY VALVE, BLK OVAL HANDLE	B-65TF16/SS-51K-65K-BK	BRASS	BALL	2,15	WHITEY
ALP-V-11	.500 FNPT	2 WAY VALVE	B-63TF8-QT-B	BRASS	BALL	2,15	WHITEY
ALP-V-12	.500 FNPT	CHECK VALVE	B-8C4-1/3	BRASS	CHECK	2,15	NUPRO
ALP-V-13	1.00 FNPT	SOFT SEAT 2 WAY VALVE	A-818-75-15-K-R	316 SST	NEEDLE	2	DRAGON
ALP-V-14	1.00 FNPT	CHECK VALVE	B-16C4-1/3	BRASS	CHECK	2,15	NUPRO
ALP-V-15	.500 FNPT	2 WAY VALVE	B-63TF8-QT-B	BRASS	BALL	2,15	WHITEY
ALP-V-16	.500 FNPT	CHECK VALVE	B-8C4-1/3	BRASS	CHECK	2,15	NUPRO
ALP-R-1	-	REDUCING REGULATOR	801804-00	BRASS	REGULATOR	2,15	SCOTT AVIATION
ALP-R-2	-	REDUCING REGULATOR	801804-00	BRASS	REGULATOR	2,15	SCOTT AVIATION
ALP-R-3	-	REDUCING REGULATOR	801804-00	BRASS	REGULATOR	2,15	SCOTT AVIATION
ALP-R-4	-	REDUCING REGULATOR	801804-00	BRASS	REGULATOR	2,15	SCOTT AVIATION
ALP-R-5	-	REDUCING REGULATOR	801804-00	BRASS	REGULATOR	2,15	SCOTT AVIATION
ALP-R-6	-	REDUCING REGULATOR	801804-00	BRASS	REGULATOR	2,15	SCOTT AVIATION
ALP-R-7	-	REDUCING REGULATOR	801804-00	BRASS	REGULATOR	2,15	SCOTT AVIATION
-	-	-	-	-	-	-	-

PRESSURE GAUGE LISTING

GAUGE No.	PORT SIZE	DESCRIPTION	PART NUMBER	PRESSURE RANGE	O-RING ITEM No.	NOTES	MANUFACTURER
ALP-G-1	.250 MNPT	2.5", BACK CONNECTION, ACCURACY 2%	25502-27B21 GDA LHFI	0-500 PSIG	-	2,13	3D INSTRUMENTS
ALP-G-2	.250 MNPT	2.5", BACK CONNECTION, ACCURACY 2%	25502-27B21 GDA LFHI	0-500 PSIG	-	2,13	3D INSTRUMENTS
-	-	-	-	-	-	-	-

NOTES: REFER SHEET 1

SIZE	CAGE CODE	DWG No	REV
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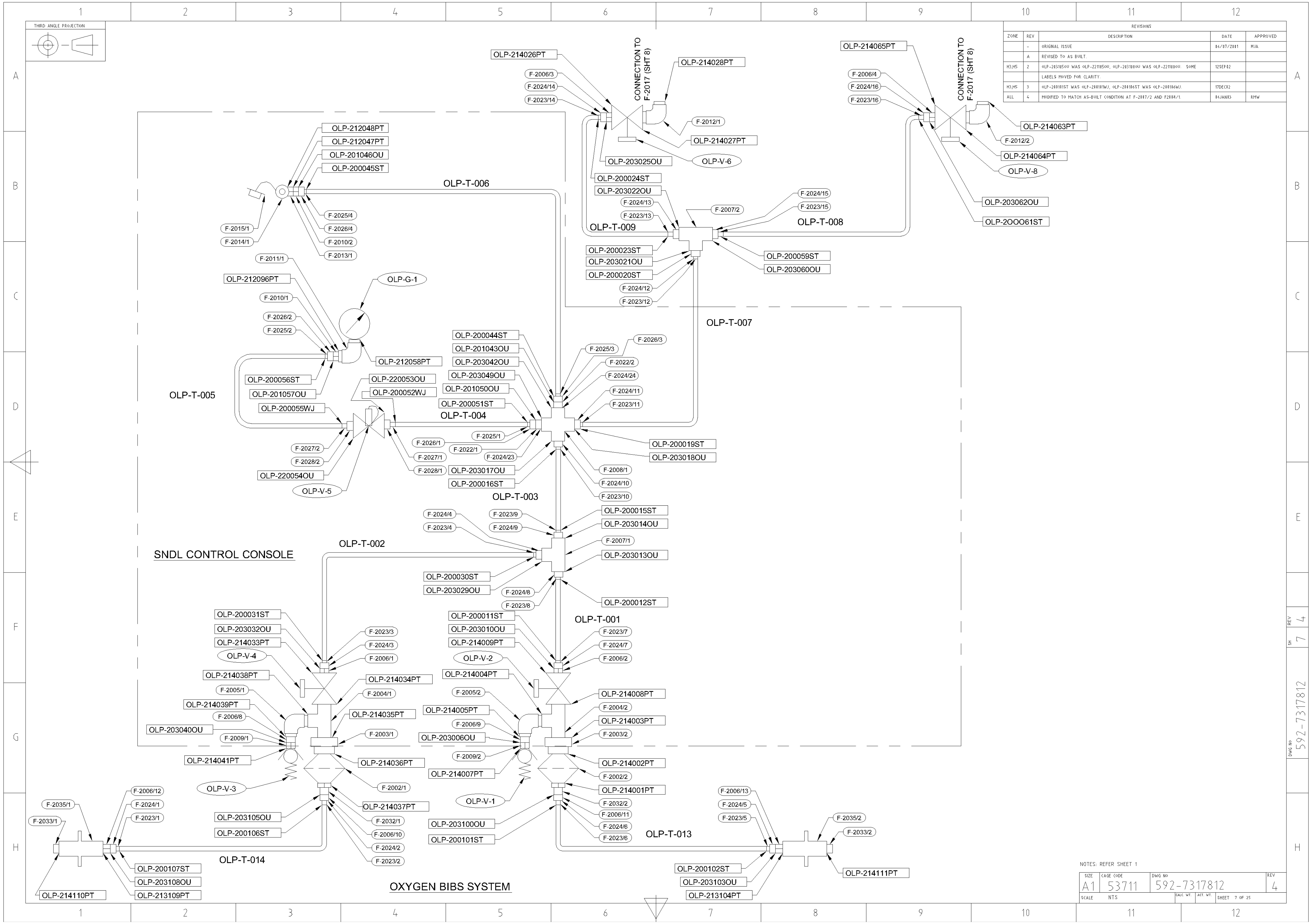
SCALE		SHEET 6 of 25	

DWG No 592-7317812 SH 6 REV 11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OLP-V-6
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F-2006/4
F-2024/16
F-2023/16
CONNECTION TO F-2017 (SHT 8)
OLP-214063PT
F-2012/2
OLP-214064PT
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F-2007/2
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F-2023/13
OLP-T-009
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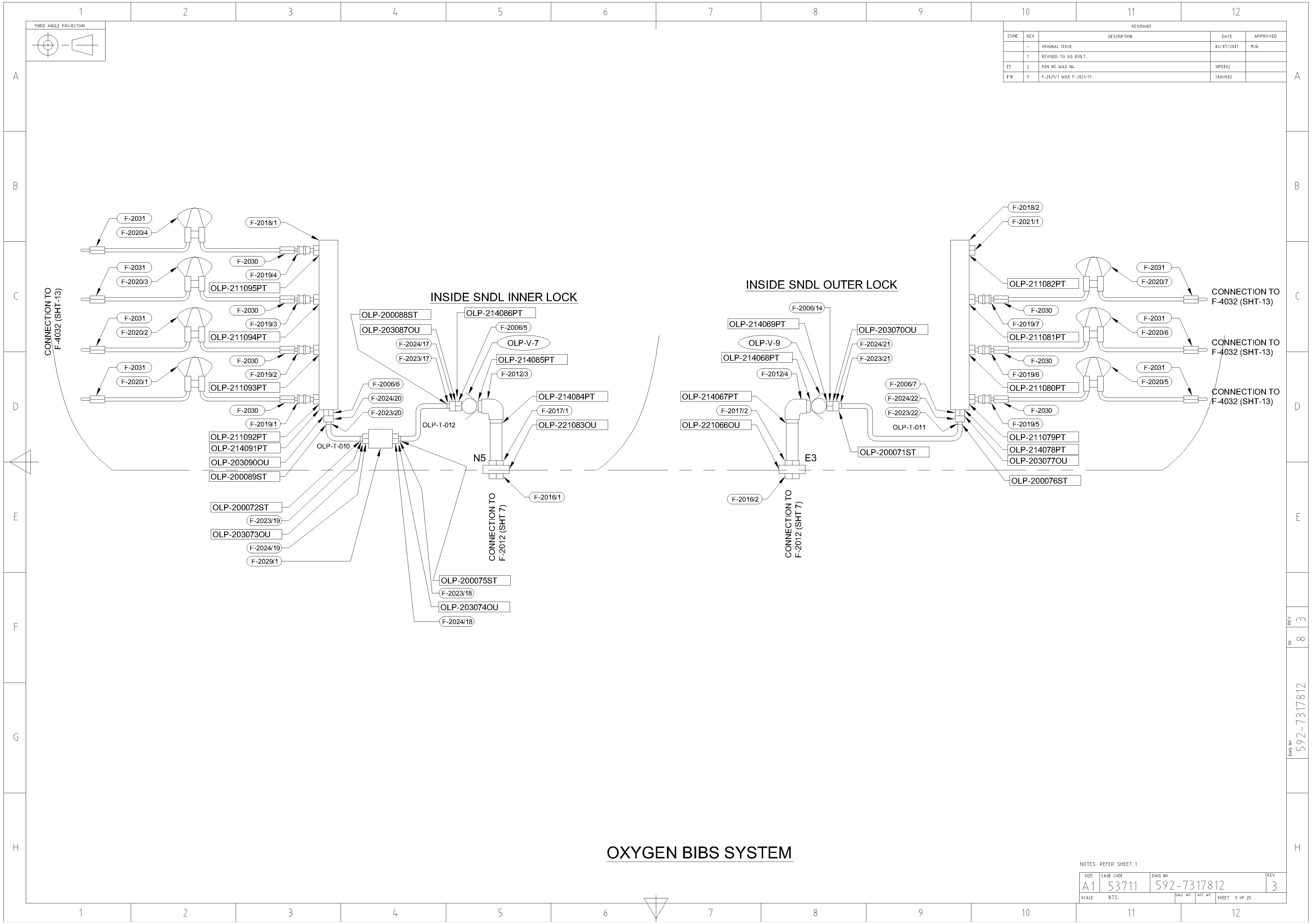
4
NTS
SHEET 7 OF 25


THIRD ANGLE PROJECTION
REVISIONS
ZONE | REV | DESCRIPTION | DATE | APPROVED
- | ORIGINAL ISSUE | 06/07/2001 | MJA
1 | REVISED TO AS BUILT.
E5 | 2 | PEN N5 WAS N4. | 18FEB02
B10 | 3 | F-2021/1 WAS F-2021/11. | 30AUG02
INSIDE SNDL INNER LOCK
INSIDE SNDL OUTER LOCK
CONNECTION TO F-4032 (SHT-13)
CONNECTION TO F-2012 (SHT 7)
OLP-V-7
OLP-V-9
OLP-T-010
OLP-T-011
OLP-T-012
N5
E3
OLP-211095PT
OLP-211094PT
OLP-211093PT
OLP-211092PT
OLP-214091PT
OLP-203090OU
OLP-200089ST
OLP-200088ST
OLP-203087OU
OLP-214086PT
OLP-214085PT
OLP-214084PT
OLP-221083OU
OLP-200072ST
OLP-203073OU
OLP-200075ST
OLP-203074OU
OLP-214069PT
OLP-214068PT
OLP-214067PT
OLP-221066OU
OLP-203070OU
OLP-200071ST
OLP-211082PT
OLP-211081PT
OLP-211080PT
OLP-211079PT
OLP-214078PT
OLP-203077OU
OLP-200076ST
F-2031
F-2030
F-2018/1
F-2018/2
F-2021/1
F-2016/1
F-2016/2
F-2029/1
F-2017/1
F-2017/2
F-2012/3
F-2012/4
OXYGEN BIBS SYSTEM
NOTES: REFER SHEET 1
SIZE A1
CAGE CODE 53711
DWG NO 592-7317812
REV 3
SCALE NTS
CALC. WT.
ACT. WT.
SHEET 8 OF 25

THIRD ANGLE PROJECTION

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	-	ORIGINAL ISSUE	06/07/2001	MJA
	1	REVISED TO AS BUILT.		
	2	ITEM F-2013 WAS 1/4"MNPT-1/8"FNPT. NOTES ADDED TO TUBE LISTING.	11FEB02	
	3	ITEM F-2002 DESCRIPTION, PART No., AND MANUFACTURER CHANGED.	26FEB02	
D11	4	ADDED NOTE 38 TO OLP-T-13 & 14.	7 JUN 02	
	5	ADDED NOTE 39 TO OLP-V-1 & OLP-V-3.	24JUL02	
	6	MIL SPEC ADDED TO OLP-V-5.	16SEP02	
	7	OLP-V-1 AND OLP-V-3 WERE B-8CPA2-200, AND HAVE NOTE 43 ADDED. PART NUMBER DELETED FROM TUBE LISTING.	18SEP02	
	8	ADDED FITTING QUANTITY.	25SEP02	RMW

FITTING LISTING

ITEM NO.	QTY	NOMINAL SIZE	DESCRIPTION	PART NUMBER	MATERIAL SPEC.	O-RING ITEM No.	NOTES	MANUFACTURER
-		-	-	-	-	-	-	-
F-2002	2	.500 MNPT - .500 MNPT	TF FILTER HOUSING, MONEL 15 MICRON ELEMENT M-8F-K4-15	B-8TF2-15	BRASS	-	6,11,15	NUPRO
F-2003	2	.500 FNPT - .500 FNPT	CONSOLE COUPLING	592-7317811-9	BRASS	-	6,10,15	COWAN MANUFACTURING
F-2004	2	3x.500 MNPT	MALE TEE	8-8-8 MT-B	BRASS	-	6,15	PARKER HANNIFIN
F-2005	2	.500 FNPT - .500 FNPT	FEMALE ELBOW	8-8 FE-B	BRASS	-	6,15	PARKER HANNIFIN
F-2006	14	.500 MNPT - .500 TUBE	MALE PIPE CONNECTOR	8-8 FLO-SS	316 SST	-	6,24	PARKER HANNIFIN
F-2007	2	3x.500 TUBE	UNION TEE	8 JLO-SS	316 SST	-	6,24	PARKER HANNIFIN
F-2008	1	4x.500 TUBE	UNION CROSS	8-KLO-SS	316 SST	-	6,24	PARKER HANNIFIN
F-2009	2	.500 FNPT - .500 FLO	RELIEF VALVE ADAPTOR	592-7317811-25	BRASS	-	6,15	PARKER HANNIFIN
F-2010	2	.250 MNPT - .250 TUBE	MALE PIPE CONNECTOR	4-4 FLO-SS	316 SST	-	6,22	PARKER HANNIFIN
F-2011	1	.250 FNPT - .250 FNPT	FEMALE ELBOW	4-4 FE-B	BRASS	-	6,15	PARKER HANNIFIN
F-2012	4	.500 MNPT - .500 MNPT	MALE ELBOW	8-8 ME-B	BRASS	-	6,15	PARKER HANNIFIN
F-2013	1	.250 FNPT - .125 FNPT	FEMALE HEX COUPLING	4-2 FHC-B	BRASS	-	6,15	PARKER HANNIFIN
F-2014	1	.125 MNPT	MALE PIPE BULKHEAD COUPLING	2MH-Q4CN-BBPC	BRASS	-	6,15	PARKER HANNIFIN
F-2015	1	.125 QD	DUST PLUG	4006 4003-06	RUBBER	-	6,15	PIRTEK
F-2016	2	1.125-12 UNF-2A	NUT, 29	5927317811-4	BRASS	-	6,10	COWAN MANUFACTURING
F-2017	2	.500 FNPT - .500 FNPT	PENETRATOR, 29	592-7317811-3	316 SST	2-027-V75 MIL R-83248	6,10	COWAN MANUFACTURING
F-2018	2	.500 FNPT - 4x.125 FNPT	OXYGEN BIBS BLOCK	592-7317811-10	BRASS	-	6,10,15	COWAN MANUFACTURING
F-2019	7	.125 MNPT	QUICK DISCONNECT	18969-00	BRASS	-	6,15	SCOTT AVIATION
F-2020	7	-	SCOTT PRESSURE VAK 2, c/w REGULATOR	803139-01-02	-	-	6	SCOTT AVIATION
F-2021	1	.125 MNPT	HEX HEAD PLUG	2 PH-B	BRASS	-	6,15	PARKER HANNIFIN
F-2022	2	.500 TUBE - .250 TUBE	TUBE END REDUCER	8-4 TRLO-SS	316 SST	-	6,22	PARKER HANNIFIN
F-2023	22	.500 TUBE	O-RING FACE SEAL, MECH. ATTACHABLE SLEEVE	8 TPL-SS	316 SST	-	6,10	PARKER HANNIFIN
F-2024	24	.8125-16 UNF-2A	O-RING FACE SEAL, NUT	8 BL-SS	316 SST	-	6	PARKER HANNIFIN
F-2025	4	.250 TUBE	O-RING FACE SEAL, MECH. ATTACHABLE SLEEVE	4 TPL-SS	316 SST	-	6,10	PARKER HANNIFIN
F-2026	4	.5625-18 UNF-2A	O-RING FACE SEAL, NUT	4 BL-SS	316 SST	-	6	PARKER HANNIFIN
F-2027	2	.250 TUBE	CPV, WELD GLAND	949R-4SS	316 SST	-	6,10	CPV
F-2028	2	.250	CPV, NUT	950-4SS	316 SST	-	6	CPV
F-2029	1	.500 TUBE	UNION	8-HLO-SS	316 SST	-	6,24	PARKER HANNIFIN
F-2030	7	.125 FNPT	HOSE PLUG	18970-00	BRASS	-	6,15	SCOTT AVIATION
F-2031	7	.375 BARB	HOSE PLUG	59852-00	BRASS	-	6,15	SCOTT AVIATION
F-2032	2	.500 FNPT - .500 FNPT	FEMALE HEX. COUPLING	8-8 FHC-B	-	-	6,15	PARKER
F-2033	2	9/16-18 RH-1/2" MNPT 600 PSI	CGA/NPT ADAPTER	AF1062	BRASS	-	6,10	AMRON
-	-	-	-	-	-	-	-	-
F-2035	2	.500 FNPT	3000# FULL COUPLING	.5" FNPT-3000#-SS	316 SST	-	6,10	PROCHEM
-	-	-	-	-	-	-	-	-

TUBE LISTING

TUBE No.	PART NUMBER	TYPE	SIZE	MATERIAL GRADE	NOTES
OLP-T-001	-	1/2" TUBE ASS'Y	1/2"TPL-1/2"TPL	316L SST	6,8,10,30,33,37
OLP-T-002	-	1/2" TUBE ASS'Y	1/2"TPL-1/2"TPL	316L SST	6,8,10,30,33,37
OLP-T-003	-	1/2" TUBE ASS'Y	1/2"TPL-1/2"TPL	316L SST	6,8,10,30,33,37
OLP-T-004	-	1/4" TUBE ASS'Y	1/4"TPL-1/4"TPL	316L SST	6,8,10,30,31,36,37
OLP-T-005	-	1/4" TUBE ASS'Y	1/4"TPL-1/4"TPL	316L SST	6,8,10,30,31,36,37
OLP-T-006	-	1/4" TUBE ASS'Y	1/4"TPL-1/4"TPL	316L SST	6,8,10,30,31,37
OLP-T-007	-	1/2" TUBE ASS'Y	1/2"TPL-1/2"TPL	316L SST	6,8,10,30,33,37
OLP-T-008	-	1/2" TUBE ASS'Y	1/2"TPL-1/2"TPL	316L SST	6,8,10,30,33,37
OLP-T-009	-	1/2" TUBE ASS'Y	1/2"TPL-1/2"TPL	316L SST	6,8,10,30,33,37
OLP-T-010	-	1/2" TUBE ASS'Y	1/2"TPL-1/2"TPL	316L SST	6,8,10,30,33,37
OLP-T-011	-	1/2" TUBE ASS'Y	1/2"TPL-1/2"TPL	316L SST	6,8,10,30,33,37
OLP-T-012	-	1/2" TUBE ASS'Y	1/2"TPL-1/2"TPL	316L SST	6,8,10,30,33,37
OLP-T-013	-	1/2" TUBE ASS'Y	1/2"TPL-1/2"TPL	316L SST	6,8,10,30,33,36,37,38
OLP-T-014	-	1/2" TUBE ASS'Y	1/2"TPL-1/2"TPL	316L SST	6,8,10,30,33,36,37,38

VALVE LISTING

VALVE NO.	NOMINAL SIZE	DESCRIPTION	PART NUMBER	MATERIAL SPEC.	TYPE	NOTES	MANUFACTURER
OLP-V-1	.500 MNPT	RELIEF VALVE	B-8CPA2-150	BRASS	RELIEF	6,15,39,43	SWAGLOCK
OLP-V-2	.500 FNPT	2 WAY VALVE	B-18VF8-G	BRASS	NEEDLE	6,15	WHITEY/ SWAGLOCK
OLP-V-3	.500 MNPT	RELIEF VALVE	B-8CPA2-150	BRASS	RELIEF	6,15,39,43	SWAGLOCK
OLP-V-4	.500 FNPT	2 WAY VALVE	B-18VF8-G	BRASS	NEEDLE	6,15	WHITEY/ SWAGLOCK
OLP-V-5	.250 CPV	INSTRUMENT VALVE	PLC10669 / MIL-V-24578B	316 SST	NEEDLE	6	CPV
OLP-V-6	.500 FNPT	2 WAY VALVE	B-18VF8-G	BRASS	NEEDLE	6,15	WHITEY/ SWAGLOCK
OLP-V-7	.500 FNPT	CHECK VALVE	B-8C4-1/3	BRASS	CHECK	6,15	NUPRO
OLP-V-8	.500 FNPT	2 WAY VALVE	B-18VF8-G	BRASS	NEEDLE	6,15	WHITEY/ SWAGLOCK
OLP-V-9	.500 FNPT	CHECK VALVE	8-8C4-1/3	BRASS	CHECK	6,15	NUPRO
-	-	-	-	-	-		-

PRESSURE GAUGE LISTING

GAUGE No.	PORT SIZE	DESCRIPTION	PART NUMBER	PRESSURE RANGE	O-RING ITEM No.	NOTES	MANUFACTURER
OLP-G-1	.250 MNPT	2.5", BACK CONNECTION, ACCURACY 2%	25502-27B21	0-500 PSIG	-	6,20	3D INSTRUMENT
-	-	-	-	-	-	-	-

NOTES: REFER SHEET 1

SIZE	CAGE CODE	DWG No	REV
A1	53711	592-7317812	8
SCALE	CALC. WT.	ACT. WT.	SHEET 9 OF 25

REV 8 SH 9 DWG No 592-7317812

APPENDIX E : INDEX