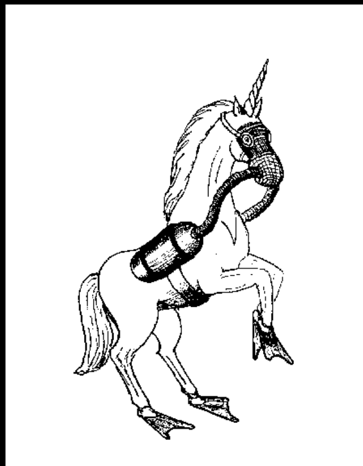
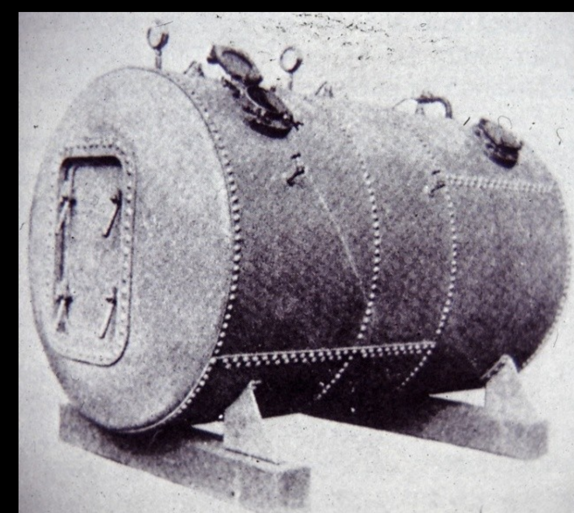
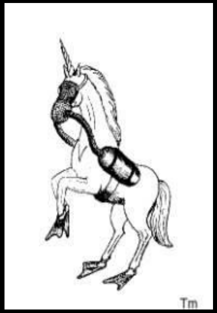


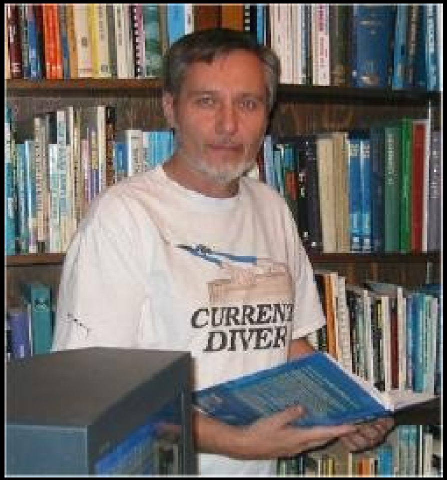
Hyperbaric Chambers
Larry “Harris” Taylor, Ph.D.
Diving Safety Coordinator, U of Michigan



Your Instructor

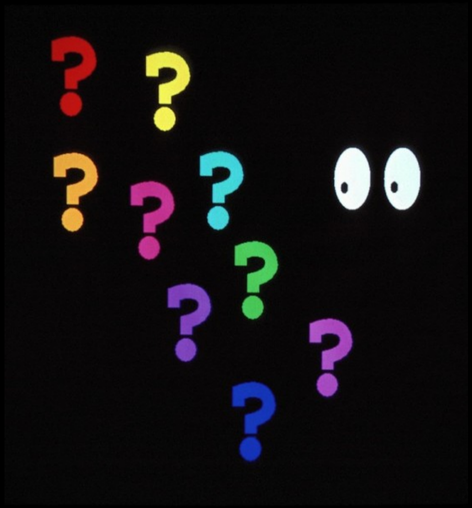
U of MI Diving Safety Coordinator
AAUS sanctioned Diving Safety Officer
Internationally rated 3 - star instructor (CMAS)
National Master Scuba Instructor (President's Council)
> 100 Diving Certifications
> 200 Diving Publications
> 1,200,000 visitors to "Diving Myths & Realities" web site
Library: one of the best resources in North America
Scuba Diver since 1977
Scuba Instructor since 1980
DAN Instructor since 1991
EAN_x Instructor since 1992
Ph.D. Biochemistry



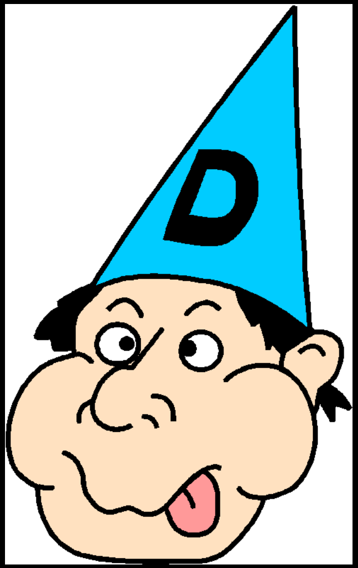


Lecture is a Democracy!

You control speed with your questions



There are no "stupid questions" !



The only "Dumb Question"
is the one that is unanswered 'cause it was not asked

The "Dumbest Question"
is the unasked question that could've solved a problem

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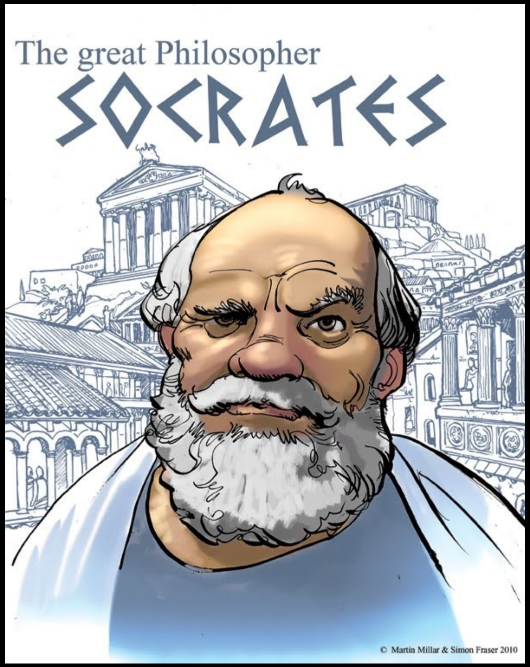
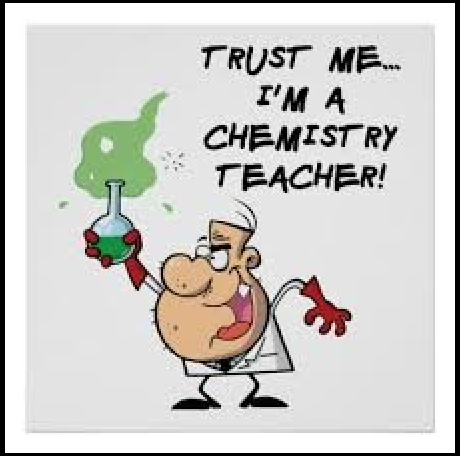


Socratic Method:

Asking & Answering Questions

Still one of the best learning tools



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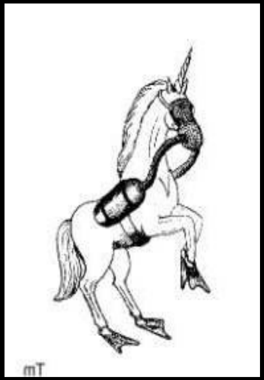
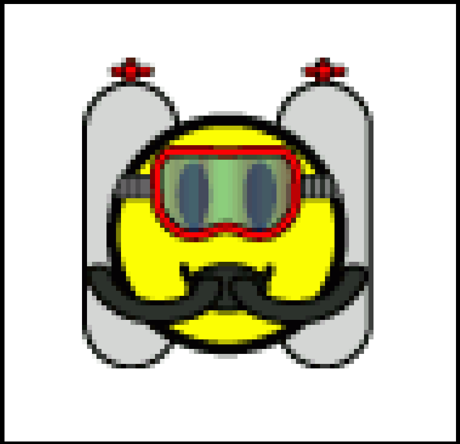
Knowledgeable, Physically Fit Divers

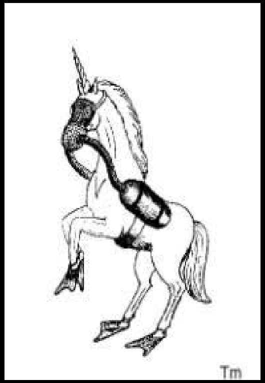
Gospel

According to “Harris”

Have More Fun!







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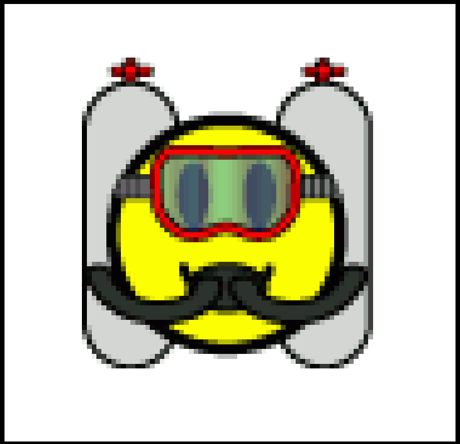
HBO
Hyperbaric Oxygen Therapy

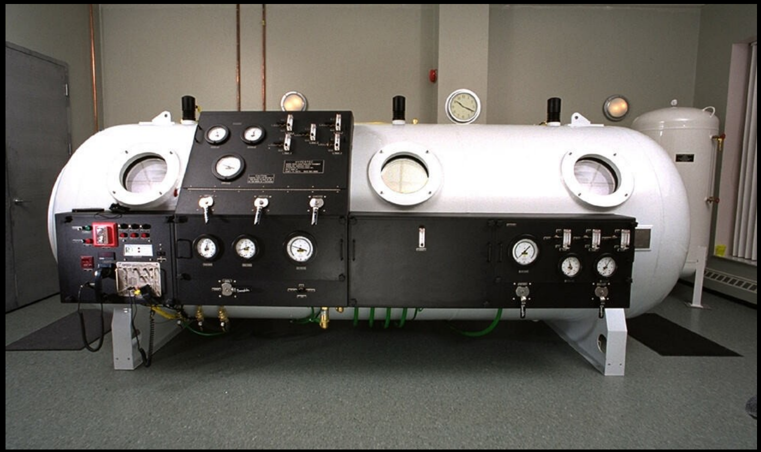


Purpose of a Hyperbaric Chamber

Provides Physical Containment For Elevated Pressures

Allows use of breathing gases other than air

- Treatment for barotrauma emergencies
- Treatment of a variety of non-diving related maladies
- Treatment of wounds
- Research in diving physiology
- Testing equipment used in diving



Hyper = higher

Baric = pressure

Hyperbaric Oxygen Therapy

Mechanical Effects of Pressure:

- Pressure reduces bubble size
  - May remove bubbles blocking circulation
- May reduce nerve conduction blocks
- Promotes re-absorption of bubbles
- Reduces further bubble growth
- Some oxygenation of hypoxic tissues
- May promote immune system response

Hyperbaric Oxygen Therapy

Dive malady treatment can be expensive:

Can be tens of thousands of dollars or more

- **Cost of transport to chamber**
  - **Ambulance (land, sea, or air)**
- **Hospital costs**
  - **ER admission, diagnosis, tests**
  - **Gases**
  - **Medications**
  - **Medical staff**
- **Chamber treatment(s)**
- **Possible hospital stay**

DAN diver's insurance is wise

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Hyperbaric Oxygen Therapy

Diver injury treatment cannot sustain cost of chamber facility

FDA HBOT approved treatments for chamber facilities:

- Radiation tissue damage
- Diabetic lower extremity wounds (diabetic foot ulcers)
- Failed skin grafts and flaps
- Crush injury & other acute traumatic ischemias
- Necrotizing soft tissue infection
- Carbon monoxide poisoning and smoke inhalation
- Cyanide poisoning
- Central retinal artery occlusion
- Non-healing wounds
- Gas gangrene
- Brain injuries / dysfunction
- Refractory bone infections
- Diving Injuries

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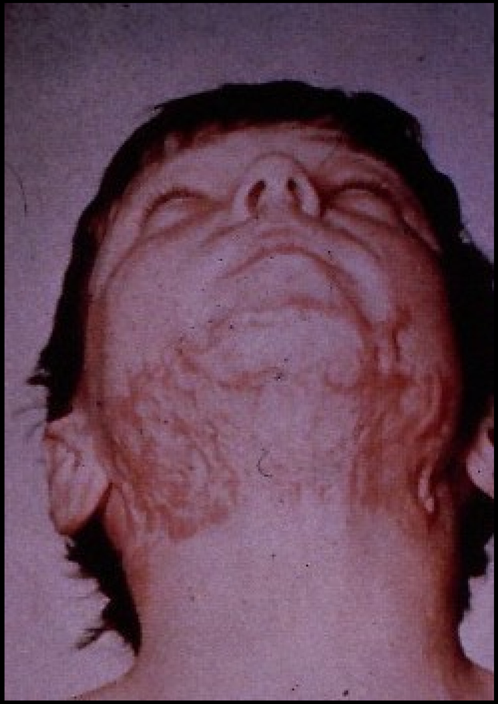
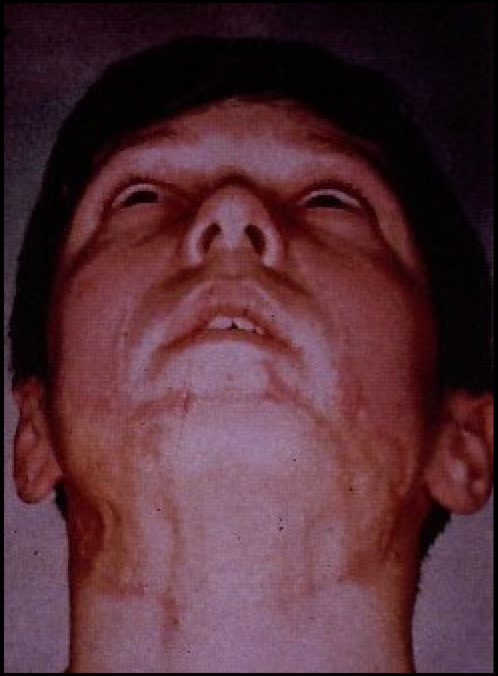
Hyperbaric Oxygen Therapy

Wound Healing is considered "Miraculous" For Skin grafts and thermal burns



Burn Scarring



1 Year After HBOT

Davis & Host, Hyperbaric Oxygen Therapy, p.238

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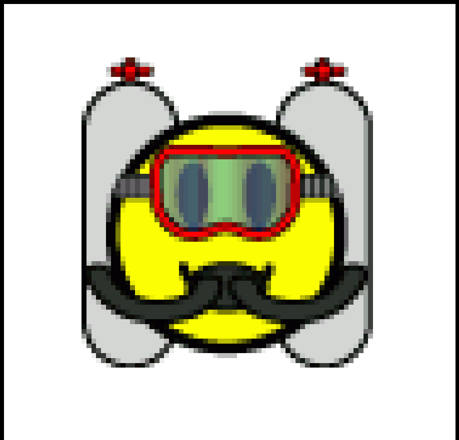
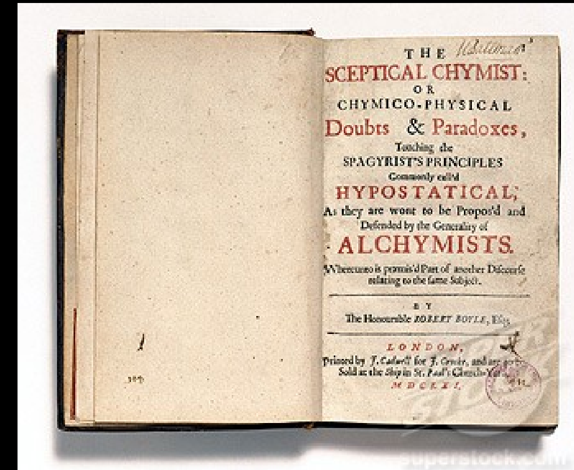
Some History



Robert Boyle

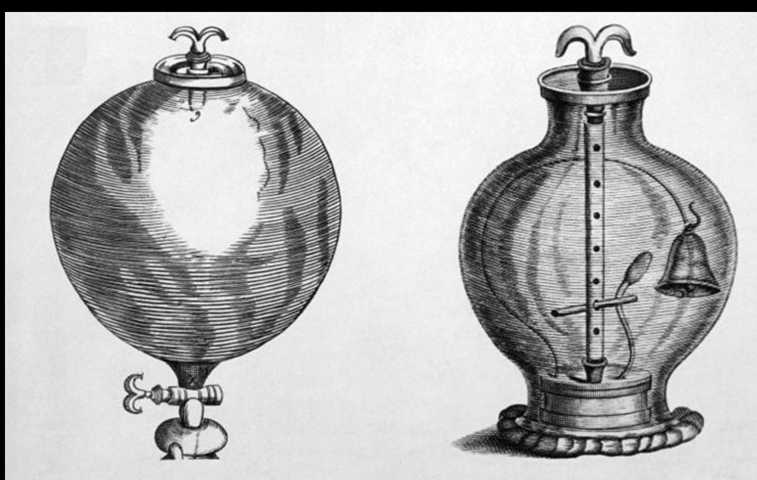
Irish Alchemist
Father of modern chemistry
Founder of Royal Society



Pressure - Volume relationship (1660)

New Experiments: Phsico-Mechanical Touching the spring of air and their effects (1660)

The Sceptical Chymst (Air, Earth, Fire, & Water not elements) (1661)



In an evacuated chamber
Observed bubble in snake's eye
- **Reduced Pressure Changes Physiology**
- **First documentation of "bubble trouble"**

Bell produced no sound
- **Air needed to carry sound**

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1662: Nathaniel Henshaw

English physician and theologian

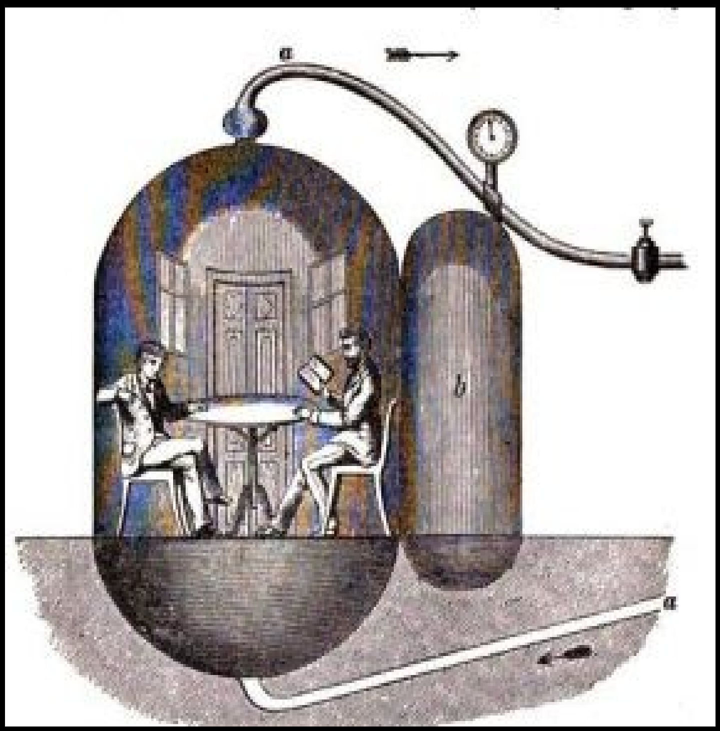
Built Chambers (Henshaw's Domicilium)
Used organ bellows to alter internal pressure
both hyper- and hypo- baric
(most likely little change from atmospheric pressure)

Published "Aero-Chalinos" (1664)

"In times of good health this domicilium is proposed as a good expedient to help digestion, to promote insensible respiration, to facilitate breathing and expectoration and consequently, of excellent use for prevention of most affections of the lungs."

His work was basically ignored by the medical community

1832: French Pneumatic Chamber



Physicians:
Tabarie (1832)
Junod (1834)
Pravez (1837)

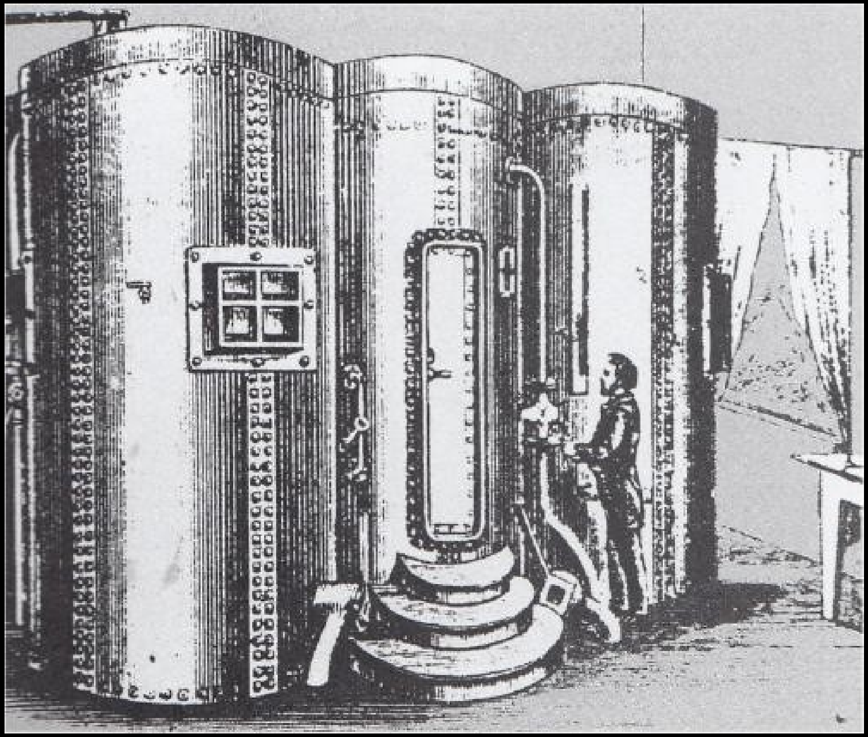
"Compressed Air Baths"
2 – 4 ata

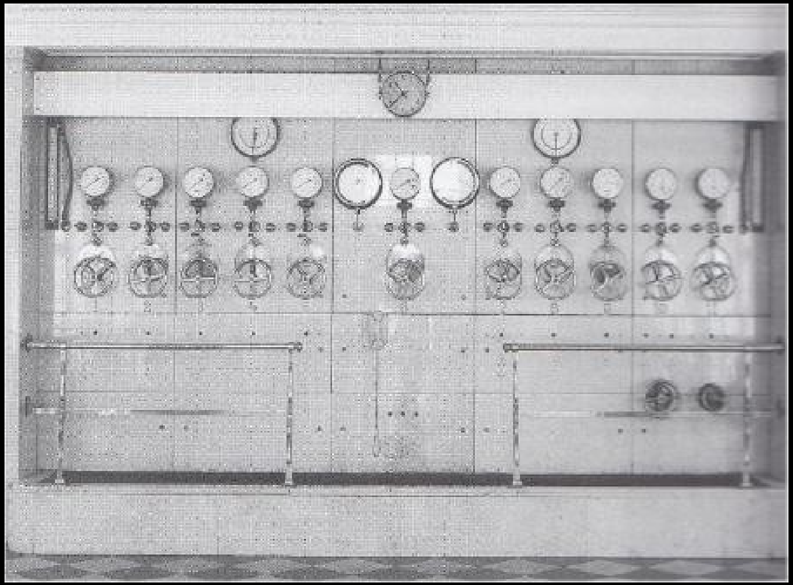
Claimed "baths" were panacea for:
lung diseases such as tuberculosis, laryngitis, tracheitis, and pertussis and
Other maladies:
deafness, cholera, rickets , menorrhagia and conjunctivitis

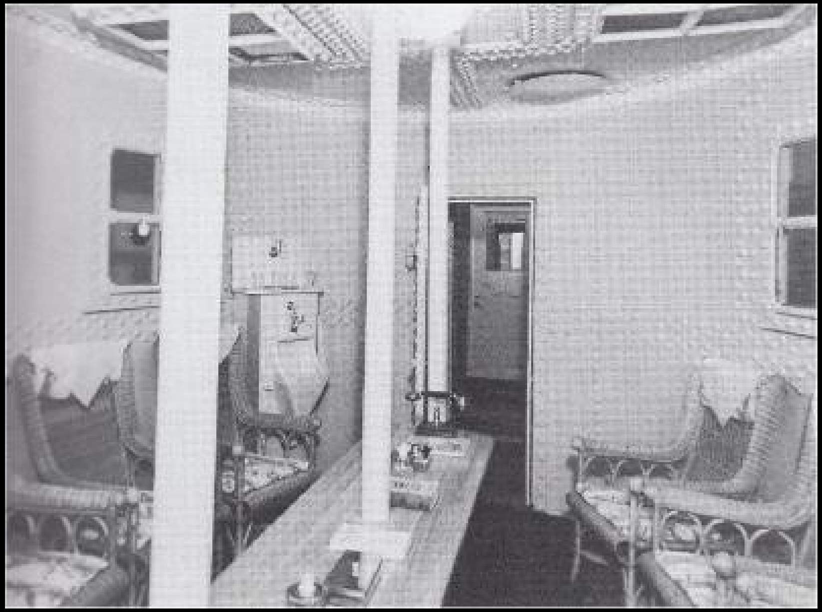
1856: Georg von Liebig

“Pneumatic Chambers”
5-11 chambers
Max capacity 64 patients

At Bad Reicherthall Spa







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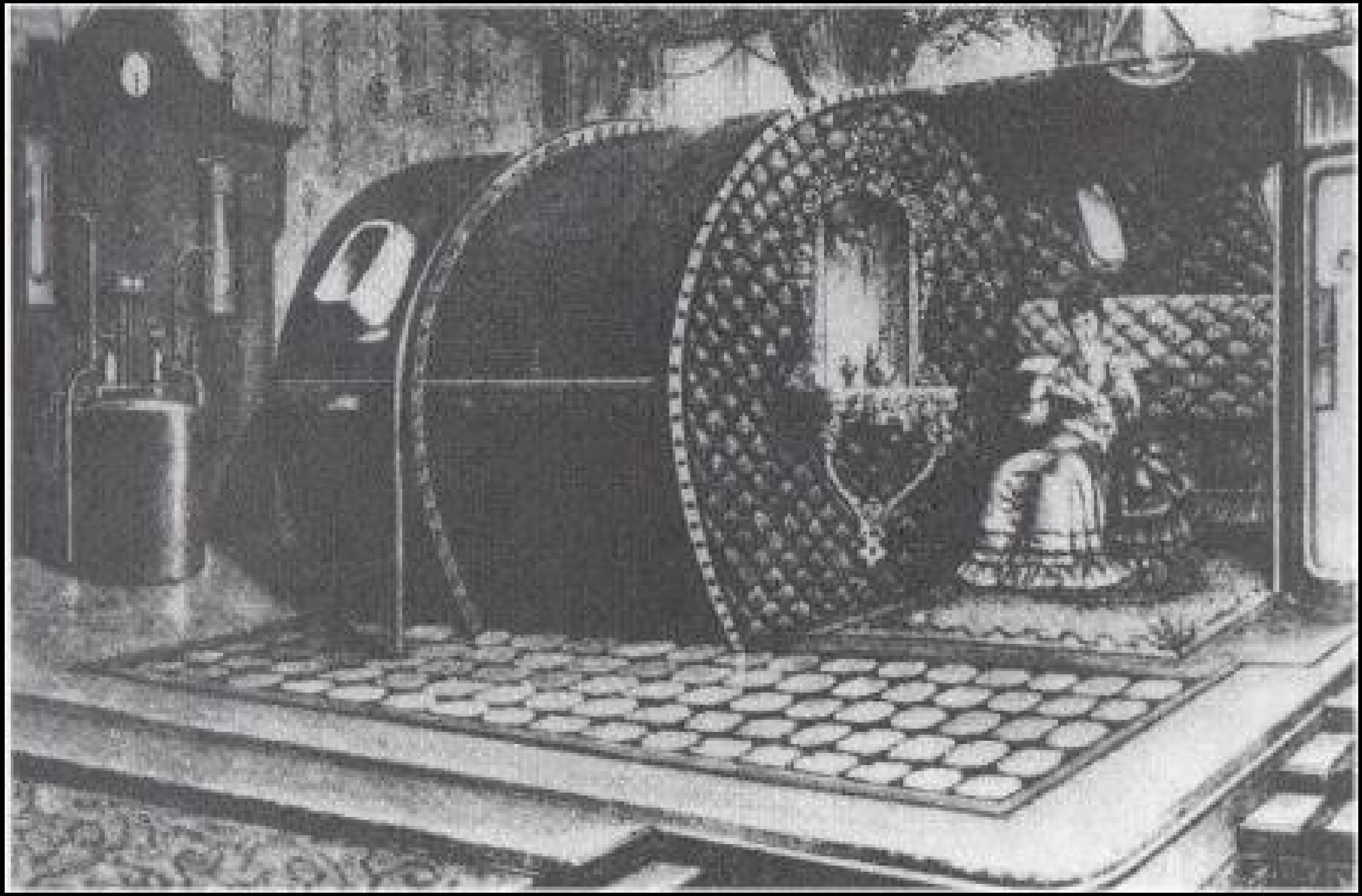
1875: Carlo Forlanini

Lavish Italian "Pneumatic Institutes"



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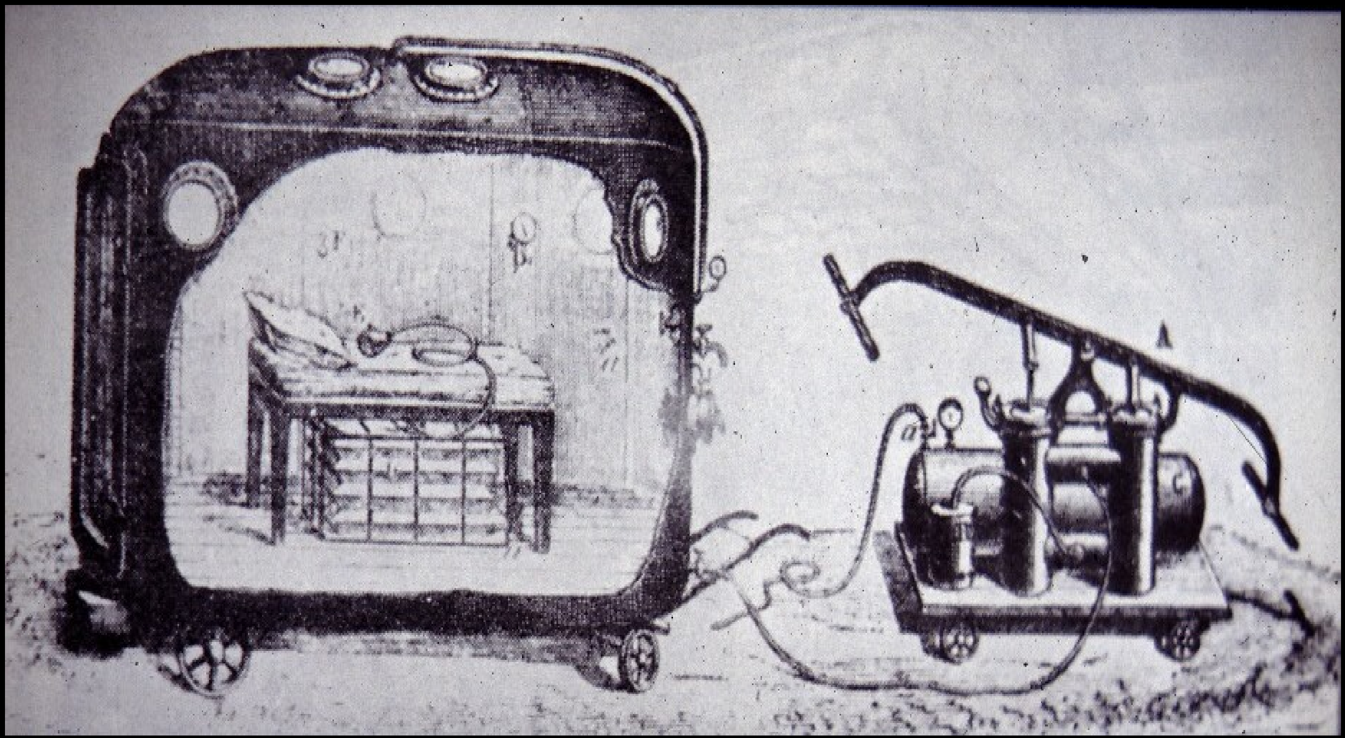
1879: J.A. Fontaine



French Surgeon
Mobile Operating Room
2-4 ata
~20 surgeries: faster healing and no infections

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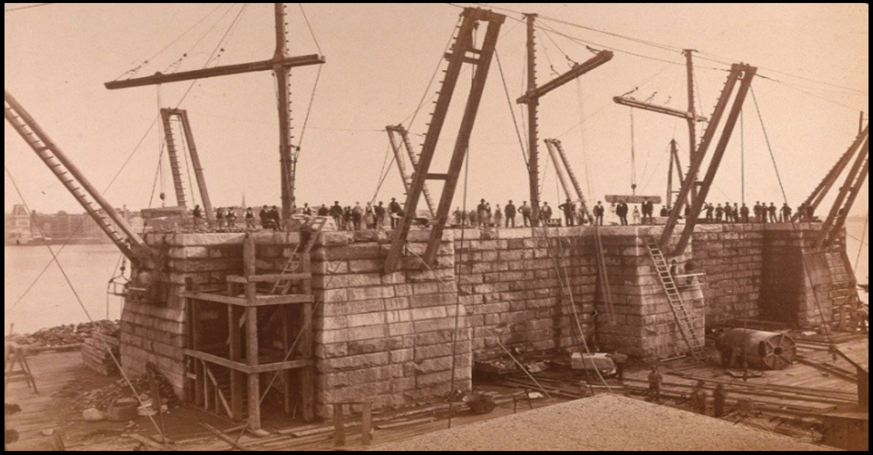
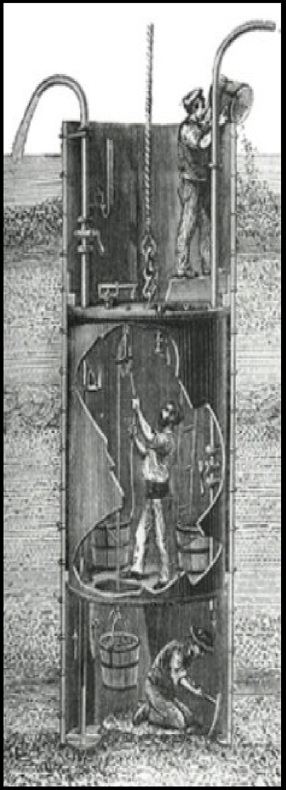
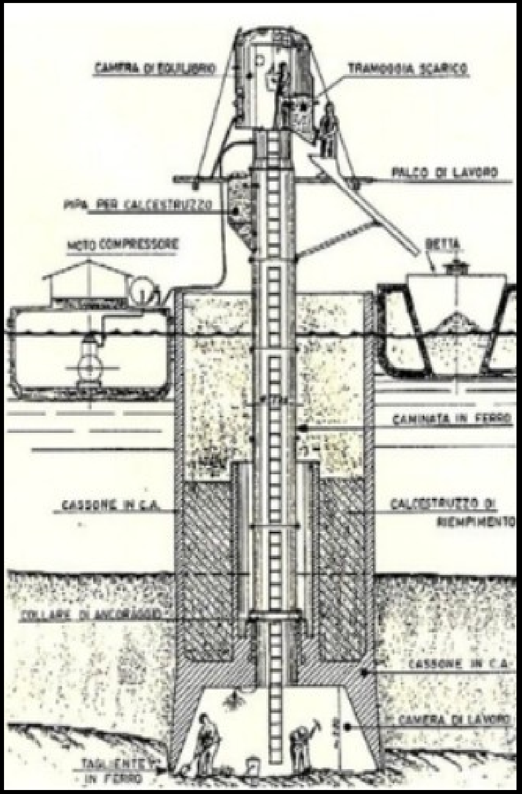
Origin of term "The Bends"

Building of Brooklyn Bridge (1870's)
~ 100 Caisson workers experienced pain on surfacing
Assumed postures similar to women dancing "Grecian Bend"
Wanted to return to work to lessen the pain
Being "Bent" was an insult

Suggested:
Caisson's disease and
Sponge Diver's disease
Same malady







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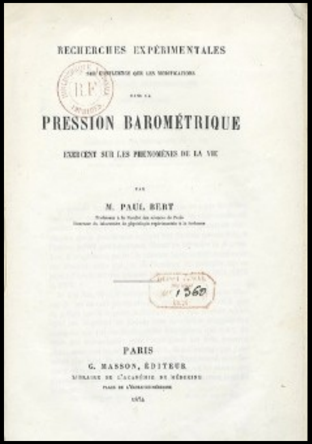
1877: Paul Bert


RECHERCHES EXPÉRIMENTALES

PRESSION BAROMÉTRIQUE

EXERCENT SUR LES PHÉNOMÈNES DE LA VIE

M. PAUL BERT

PARIS

G. MASSON, ÉDITEUR

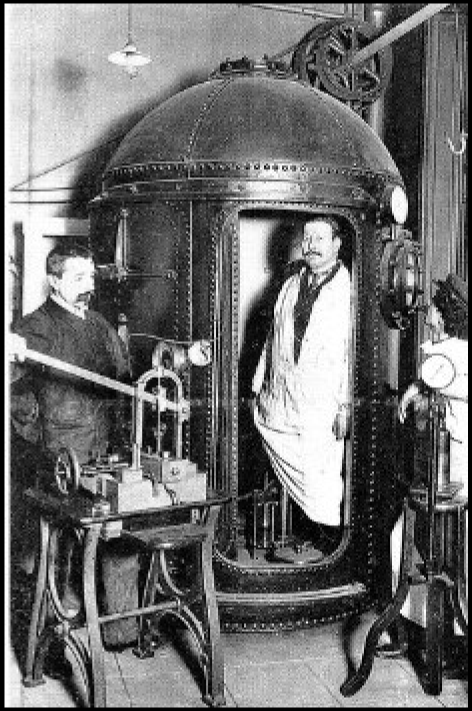
LIBRAIRE DE L'ACADÉMIE DE MÉDECINE

Studied Caisson's Disease and Sponge Diver's Disease

Concluded they had the same mechanism

Nitrogen from air at higher pressures dissolved in body tissues

Suggested slow ascent from bottom to surface prevented symptoms



Demonstrated:

Hyperbaric treatment relieved pain

Oxygen facilitated pain recovery

But

Oxygen at higher pressures was "toxic"

CNS Oxygen Toxicity:

Termed "Paul Bert Effect"

1878: Published "La Pression Barométrique"

"The gases that make up the air interact chemically with the body and in proportion to the pressure"

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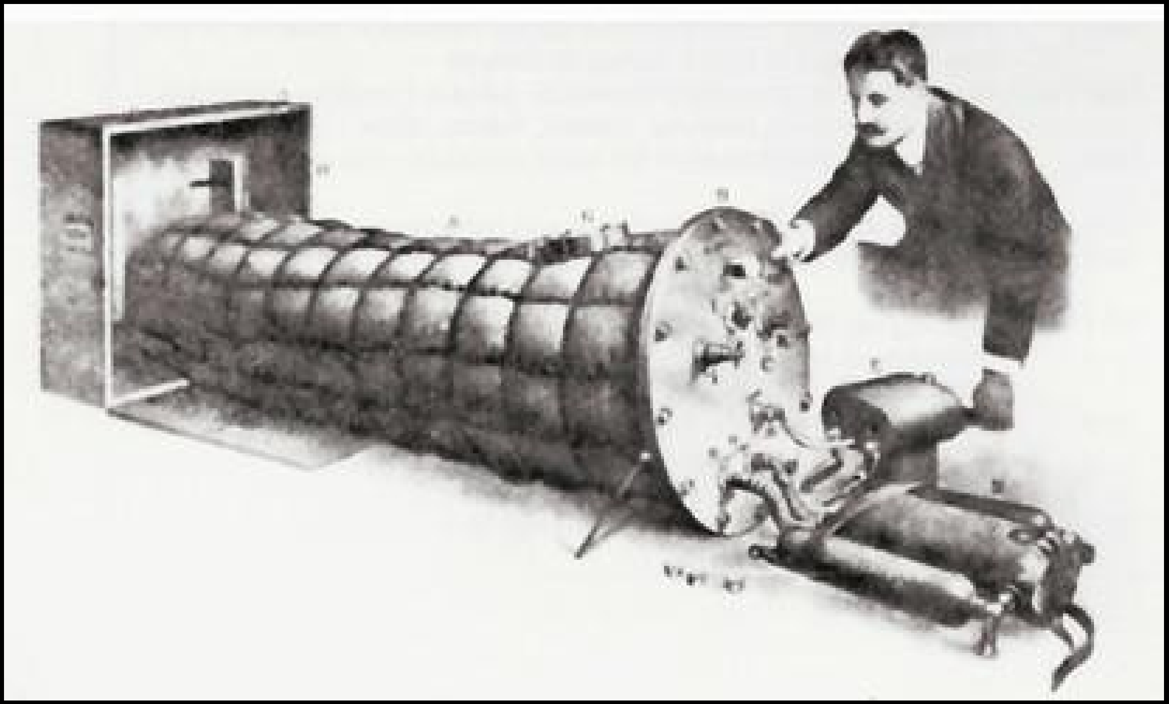
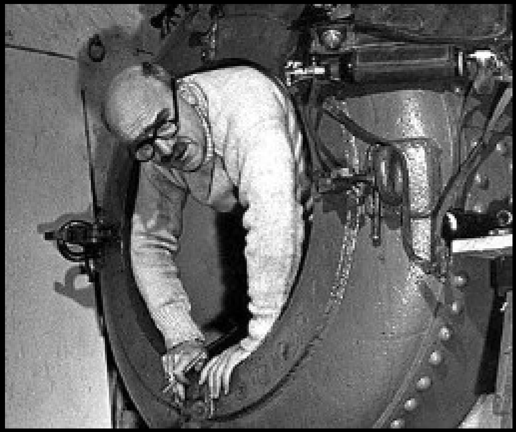
1917: Drager's First Portable Chamber

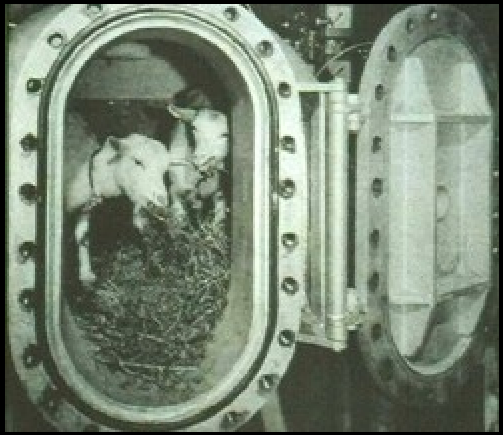


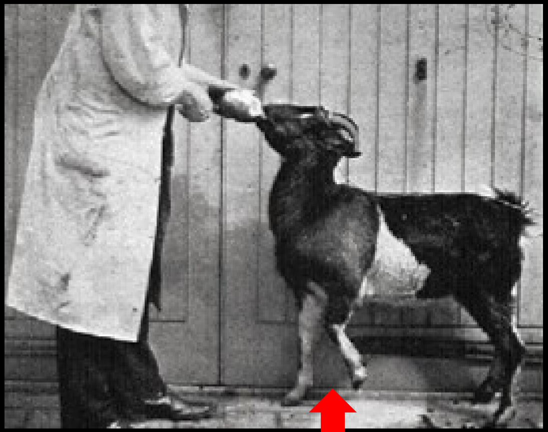
Allowed home treatments
Hand-powered compressor
For those who could not access "air baths"

Early 1900's: John Scott Haldane

Scottish physiologist
Used goats as a model for decompression sickness
Developed first successful set of decompression tables
Deduced that nitrogen gas followed Henry's Law in dissolving in tissues





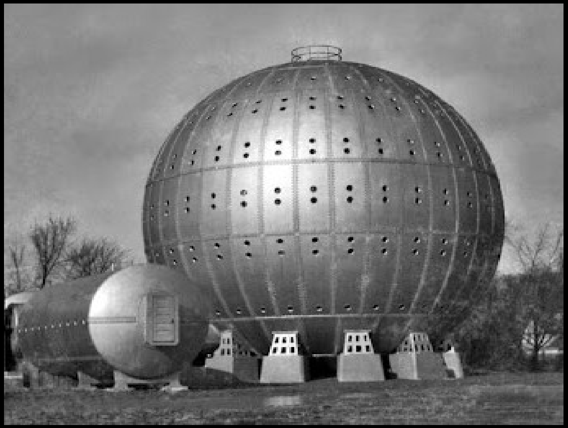


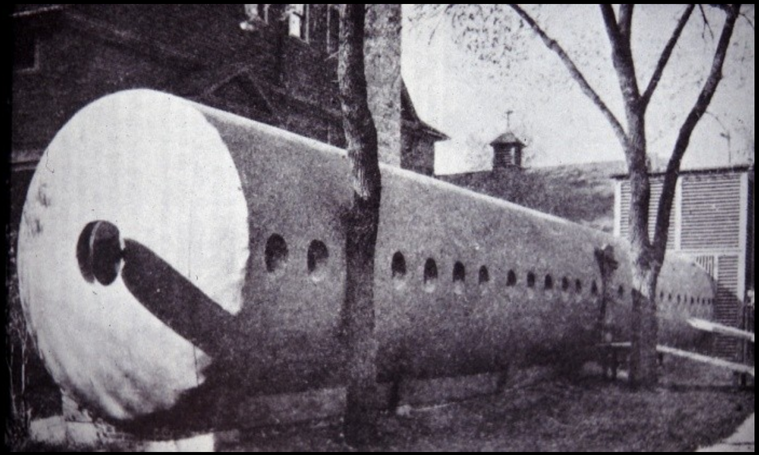
Tables compiled that did not bend goat forelegs
Goats bent foreleg was used as indication of being "bent"

Late 1920's: Cleveland Hyperbaric Hotel

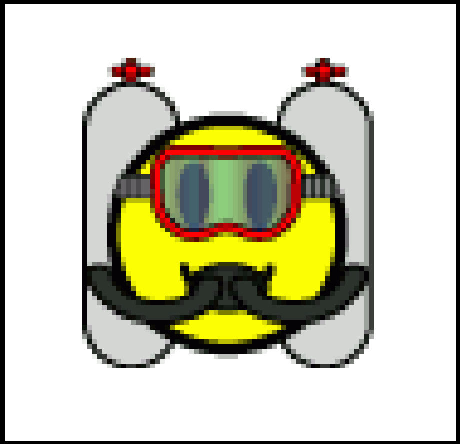
Opened in 1928
Designed by Orval Cunningham
Operated at 2 ata
Assumed hyperbaric environment
  would cure bacterial infections

Banned by US Medical Community
1934 – closed
1942 – demolished for metal content





Oxygen Toxicity



Oxygen Necessary For Life

Metabolism: narrow oxygen partial pressure window

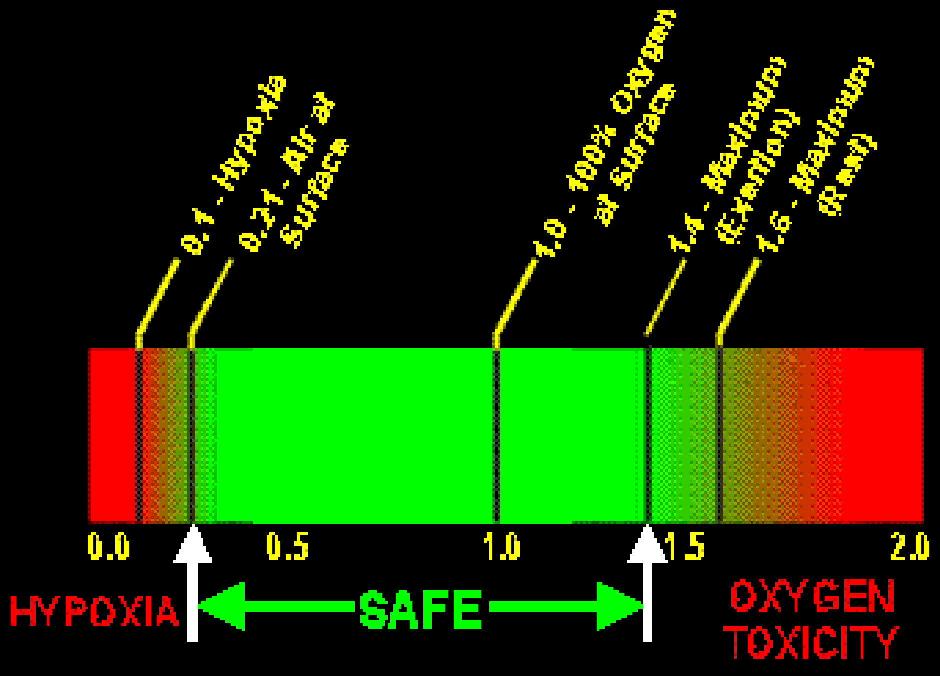
Too little oxygen (hypoxic) ➔ no life

$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$

Too much oxygen (hyperoxic) ➔ toxic reaction

Cellular components + O_2 ➔ "Bad stuff" (ROS)

Hypoxia
$pO_2 < 0.16$ ata

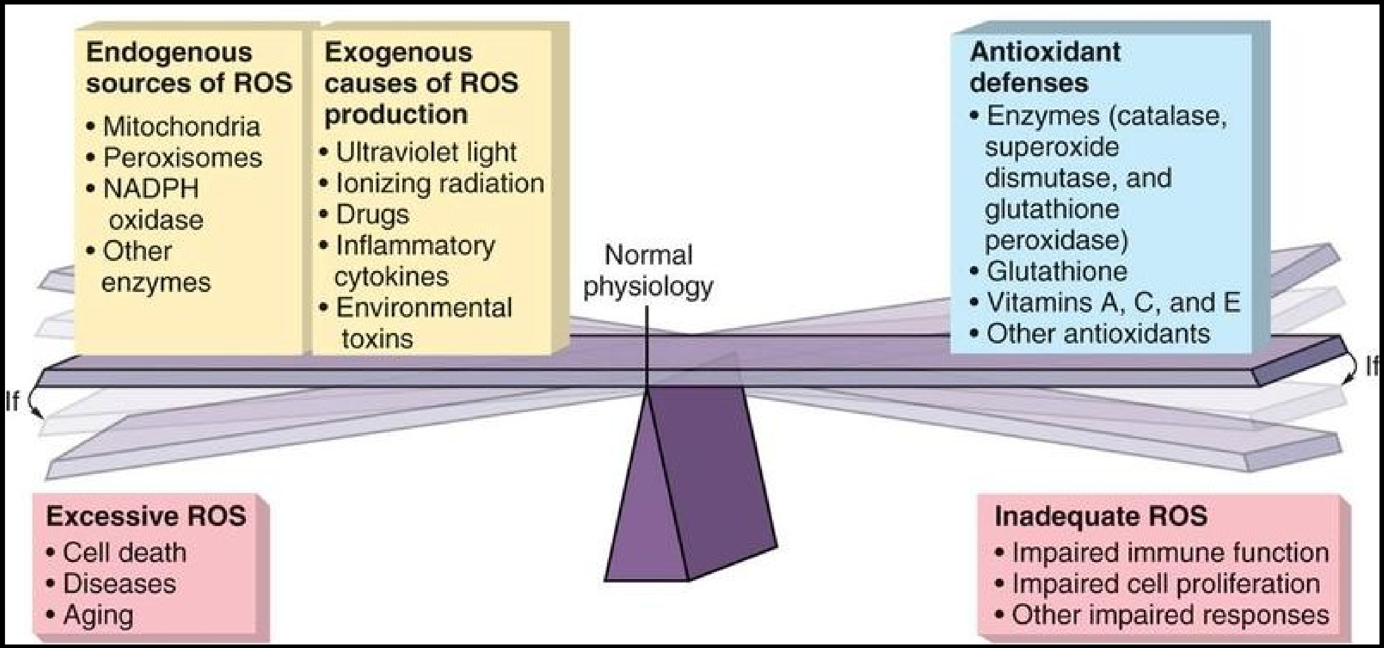


Hyperoxia
$pO_2 > 1.6$ ata

Hyperoxia

Reactive Oxygen Species (ROS) Constantly Produced

Direct result of oxygen molecule's chemical reactivity



ROS are biologically very destructive

Numerous biological defenses against ROS

- **SOD Superoxide Dismutase**
- **GTP Glutathione Peroxidase**
- **Lots of anti-oxidant molecules**

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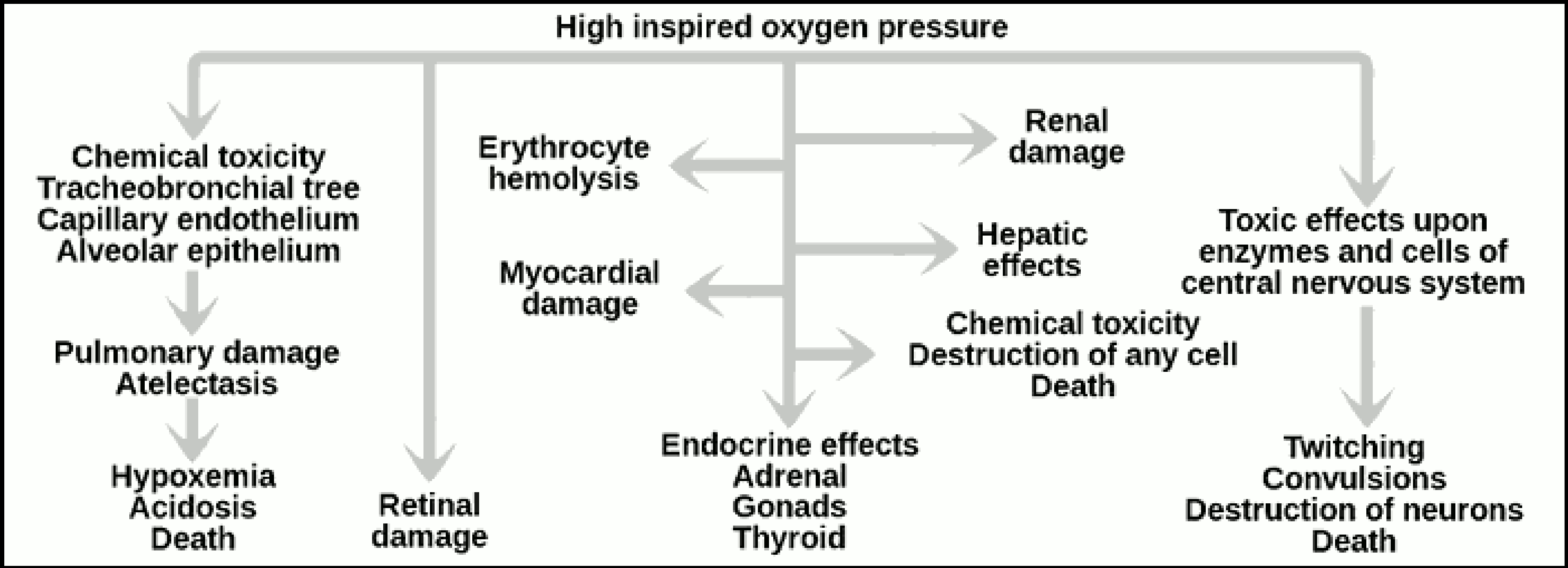
Hyperoxia Effects

Higher pO_2 increases ROS concentrations

Le Châtelier's Principle

Increase partial pressure: drive reaction to the right

Cellular components + O_2 ➔ "Bad stuff" (ROS)



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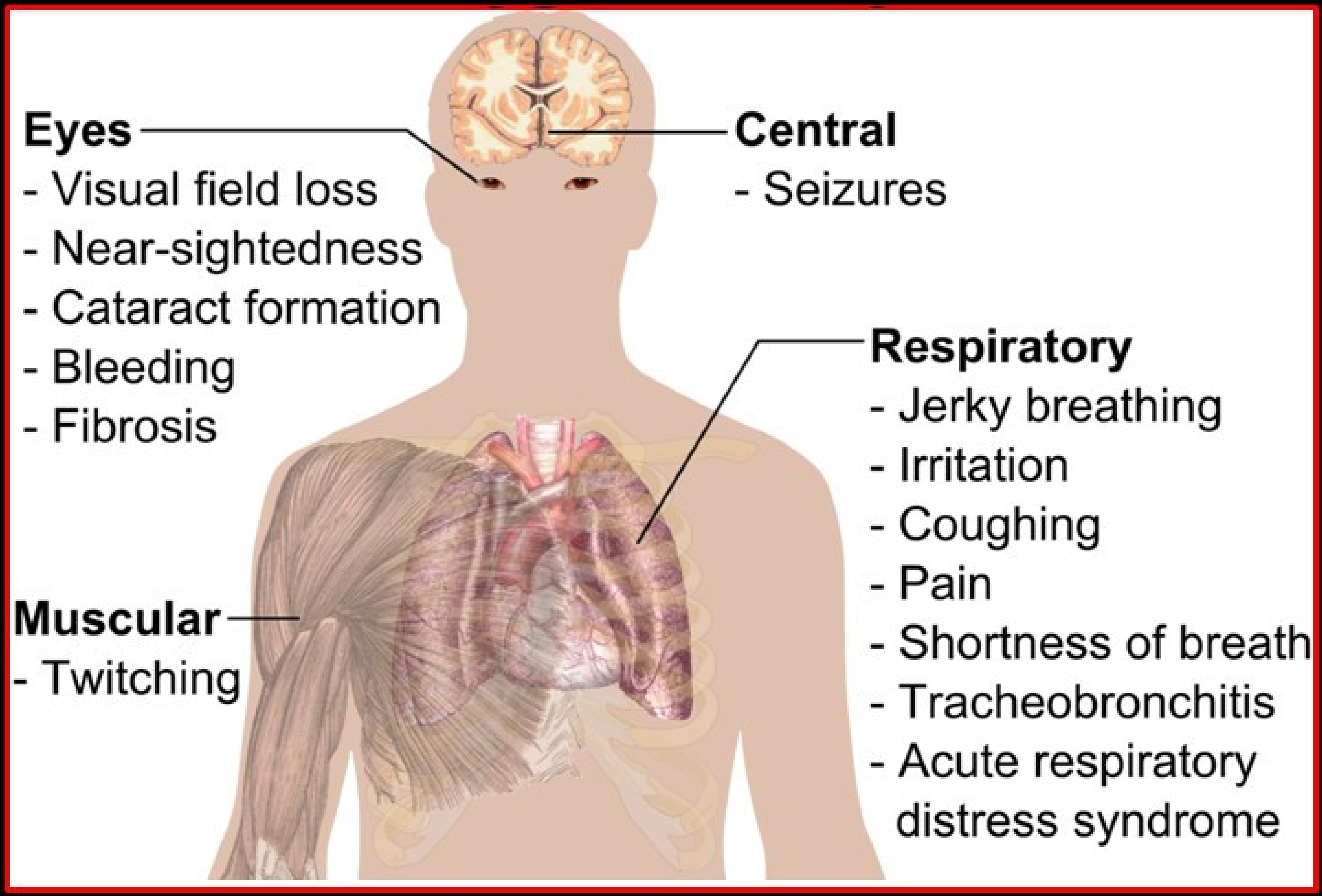
Hyperoxia Effects



Symptoms depend on pO_2 and exposure time

Hyperoxia Effects on CNS

VENTID – C

V	Vision
E	Ears
N	Nausea
T	Twitching
I	Irritability
D	Dizziness
C	Convulsions

ConVENTID

Not a progression … maybe no warning
May start with convulsions

Twitching usually starts at lower lip

Historically, CNS Effects termed "Paul Bert Effect"

Hyperoxia Effects on CNS

Oxygen toxicity effects may be enhanced by:

- Heavy exercise
- Breathing dense gas
- Breathing against resistance
- Increased CO_2 buildup
- Chilling or hypothermia
- Water immersion (as opposed to "chamber diving")

Individual tolerance to oxygen toxicity varies over time
Tolerance varies from individual to individual

Oxygen tolerance tests no longer considered valid

Hyperoxia Effects on CNS

Anecdotal suggestion that Sudafed increases seizure risk (seizures are a side effect in children)

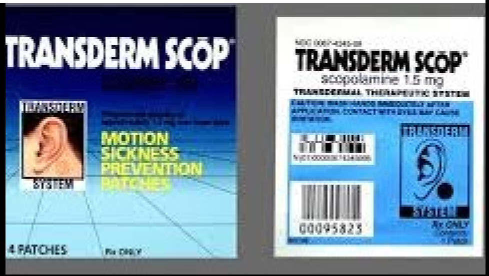
Other concerns:

anti-motion drugs (especially transderm (scopolamine))

aspirin, caffeine, viagra, nitro heart medication

Never rigorously studied

Best to avoid diving with any drugs



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Biological Defenses Occasionally Sold to Divers

No evidence that ingestion of unprotected SOD has any physiological effects

Ingested SOD is broken down into amino acids before being absorbed

SOD bound to wheat proteins MIGHT improve its ROS protection

Nitrox Therapy is a power workout Nitric Oxide promoter

An absolute contraindication for diving

(Nitric oxide implicated in oxygen toxicity convulsions)

Recent Findings suggest eating dark chocolate bar
~ 30 minutes pre-dive offers some protection from oxidative cell damage

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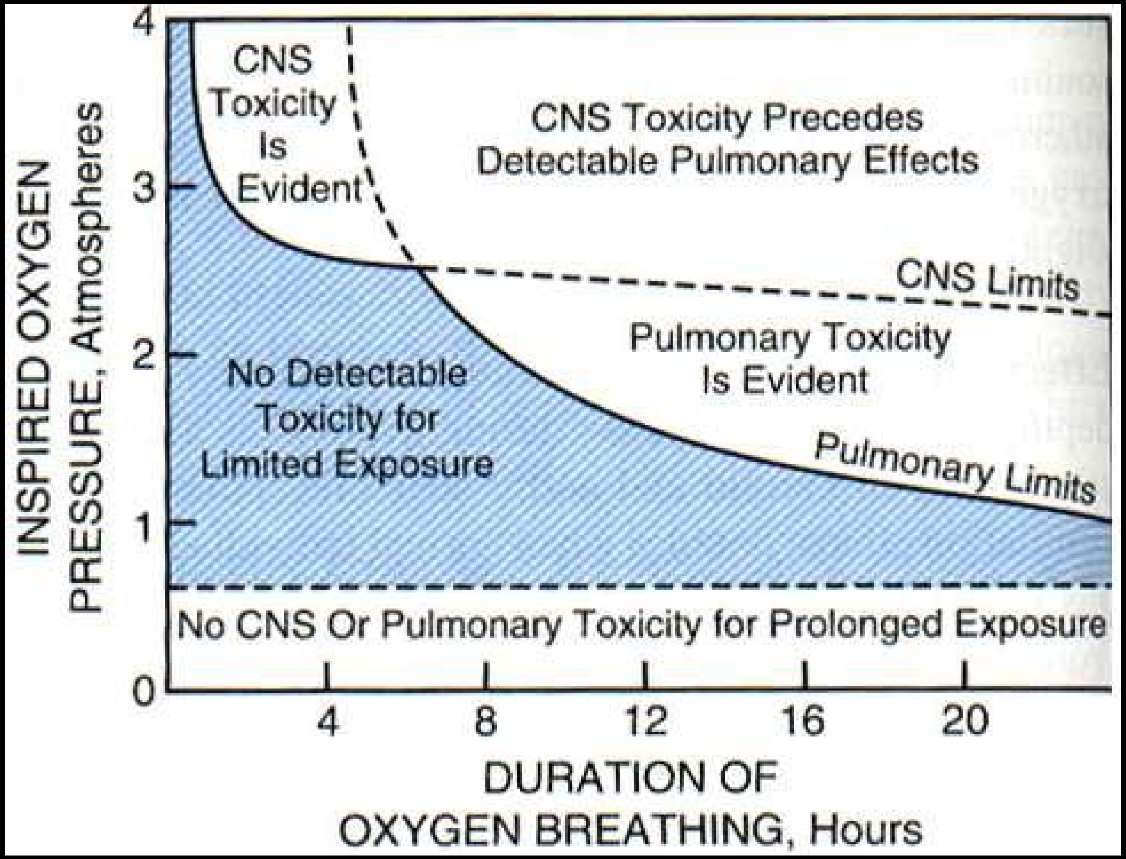
Whole Body Oxygen Toxicity

Formerly Pulmonary Toxicity (Lorrain Smith Effect)

Contrasted to CNS Toxicity (Paul Bert Effect)



CNS:
Rapid Onset

Whole Body
Slow Onset

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Whole Body Oxygen Toxicity

No-deco stop diving concerned primarily with CNS toxicity

Whole Body a concern for:

- Extended range
- Deco diving
- Intensive, multiple dive operations
- Mixes with high O_2 concentration

Onset: breathing high pO_2 (> 0.5 ata) for hours

Relief: breathing pO_2 < 0.5 ata

Primarily effects the lungs

Typically, not a concern in standard range diving

Whole Body Oxygen Toxicity

Symptoms

Pulmonary

- Chest pain or discomfort
- Coughing
- Chest tightness
- Fluid in the lungs
- Reduction in vital capacity

Non-pulmonary

- Skin numbness and itching
- Headache
- Dizziness
- Nausea
- Visual disturbances
- Diminished aerobic capacity

Body optimized for 21% O_2

High pO_2 alters tissue structure

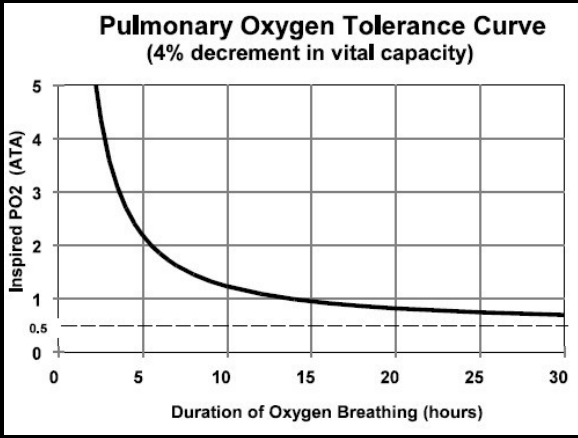
Lung tissue

- Thickens
- Becomes less pliable
- Reduces vital capacity

Oxygen Toxicity Units (OTU)

Based on decreased lung vital capacity while breathing 100 % O_2

1 OTU = Breathing 100% O_2 for 1 minute



At constant depth:

$$OTU = t\,[\,(pO_2 - 0.5) / 0.5\,]^{-0.83}$$

Ascending and descending:

$$OTU = \frac{0.27\, t}{pO_{2\,f} - pO_{2\,i}}\,[\,\{(pO_{2\,f} - 0.5) / 0.5\,)\}^{1.83} - \{(pO_{2\,i} - 0.5) / 0.5\,\}^{1.83}]$$

time (t) in minutes

pO_2 at constant depth in absolute atmospheres

$pO_{2\,f}$ at final condition in absolute atmospheres

$pO_{2\,I}$ at initial condition in absolute atmospheres

Solving involves integration of pressure over time ➔ best done by computer

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Oxygen Toxicity Units (OTU)

EAN$_x$ diving below OTU threshold, so typically not tracked

OTU Daily (24 hours) Limits

Allowed Daily Exposure: 1440

Typical DCS Treatments:

- Table 5: 297
- Table 6: 607
- Table 6A: 820

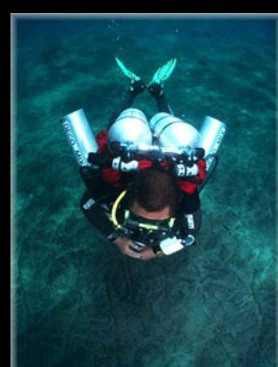
EAN$_X$ Diving: ~ 40 - 300

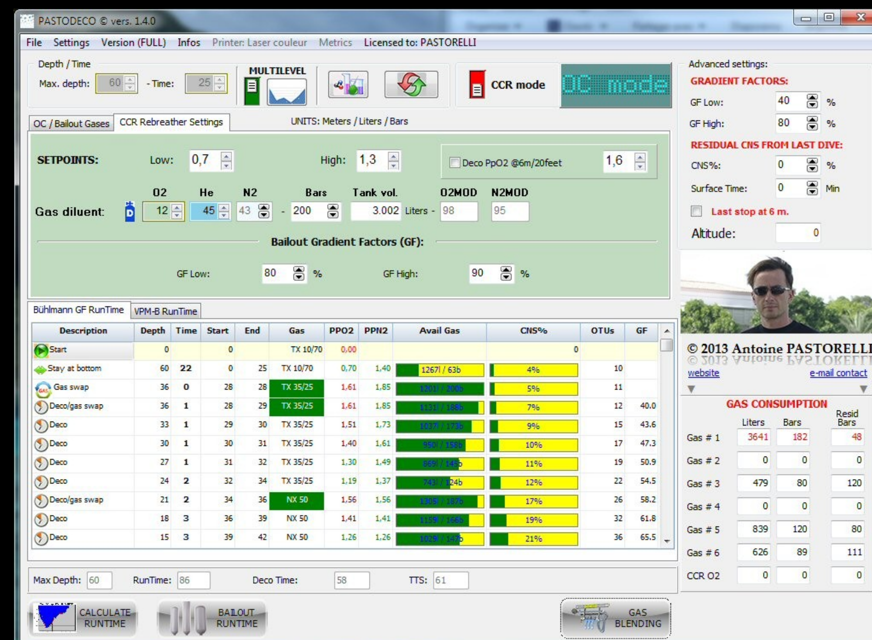
Extended Range Diving: ~850

Typical Technical: ~300 - 400

Divers Track OTU's By

- Computer Planning Software
- In-water Dive Computers
- OTU Tables
- OTU Spreadsheets





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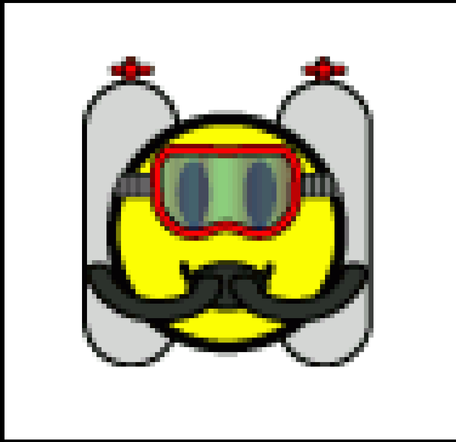
Treatment Tables



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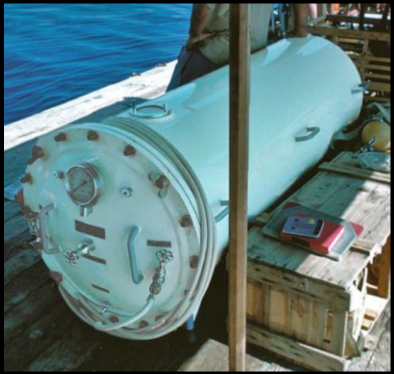
Treatment Tables:

Time / depth profiles defining treatment protocols
Standard protocols for hyperbaric medicine

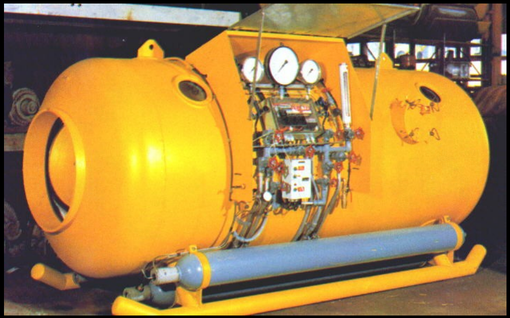
Table Selection:

- Chamber capabilities
- Hospital / medical support
- Gases available
- Nature of injury
- Patient response
- Physician Evaluation





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Non-Diving Uses of Hyperbaric Chambers

Indication	Treatment Table	Minimum # Treatments	Maximum # Treatments
Carbon Monoxide Poisoning and Smoke Inhalation	Treatment Table 5 or Table 6 as recommended by the DMO	1	5
Gas Gangrene (Clostridial Myonecrosis)	Treatment Table 5 TID × 1 day then BID × 4-5 days	5	10
Crush Injury, Compartment Syndrome, and other Acute Traumatic Ischemia	Treatment Table 9 TID × 2 days BID × 2 days QD × 2 days	3	12
Enhancements of Healing in Selected Wounds	Treatment Table 9 QD or BID	10	60
Necrotizing Soft-Tissue Infections (subcutaneous tissue, muscle, fascia)	Treatment Table 9 BID initially, then QD	5	30
Osteomyelitis (refractory)	Treatment Table 9 QD	20	60
Radiation Tissue Damage (osteoradinecrosis)	Treatment Table 9 QD	20	60
Skin Grafts and Flaps (compromised)	Treatment Table 9 BID initially, then QD	6	40
Thermal Burns	Treatment Table 9 TID × 1 day, then BID	5	45

QD = 1 time in 24 hours BID = 2 times in 24 hours TID = 3 times in 24 hours

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USN Treatment Table 1A

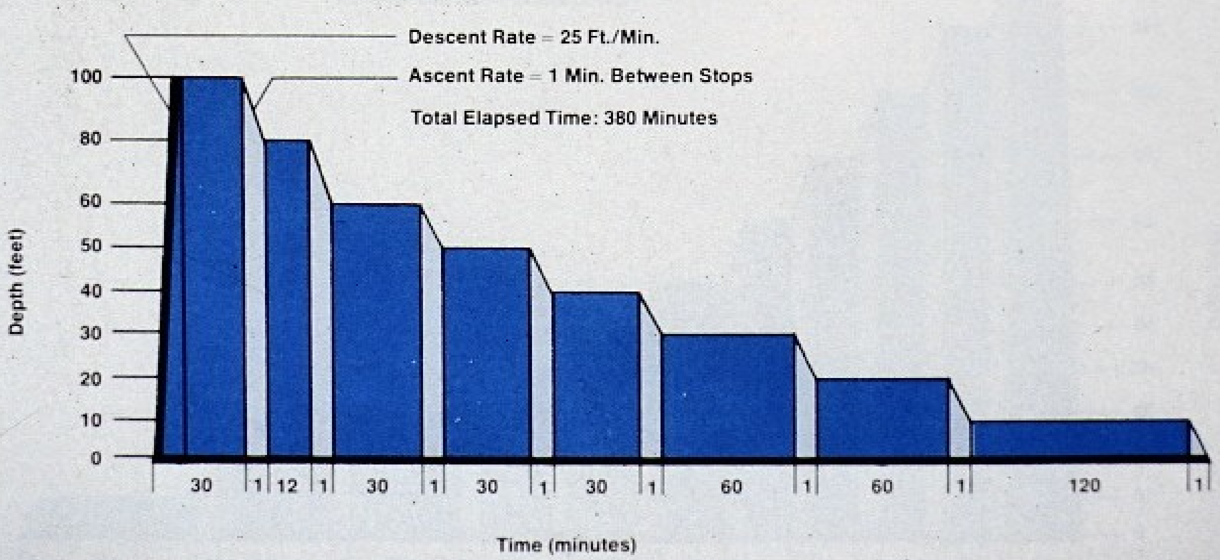
TABLE 1A NOTES—

1. Use—treatment of pain-only decompression sickness when oxygen cannot be used and pain is relieved at a depth less than 66 feet.
2. Descent rate—25 ft/min.
3. Ascent rate—1 minute between stops.
4. Time at 100 feet—includes time from the surface.
5. If the piping configuration of the chamber does not allow it to return to atmospheric pressure from the 10 foot stop in the one minute specified, disregard the additional time required.

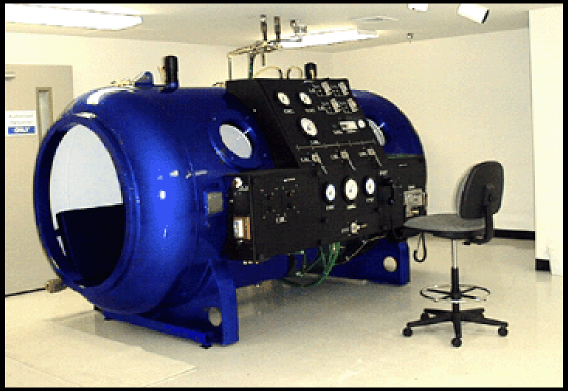
TABLE 1A

Depth (feet)	Time (minutes)	Breathing Media	Total Elapsed Time (minutes)
100	30	Air	30
80	12	Air	43
60	30	Air	74
50	30	Air	105
40	30	Air	136
30	60	Air	197
20	60	Air	258
10	120	Air	379
0	1	Air	380

TABLE 1A DEPTH/TIME PROFILE



Air Table
For DCS or Air Embolism



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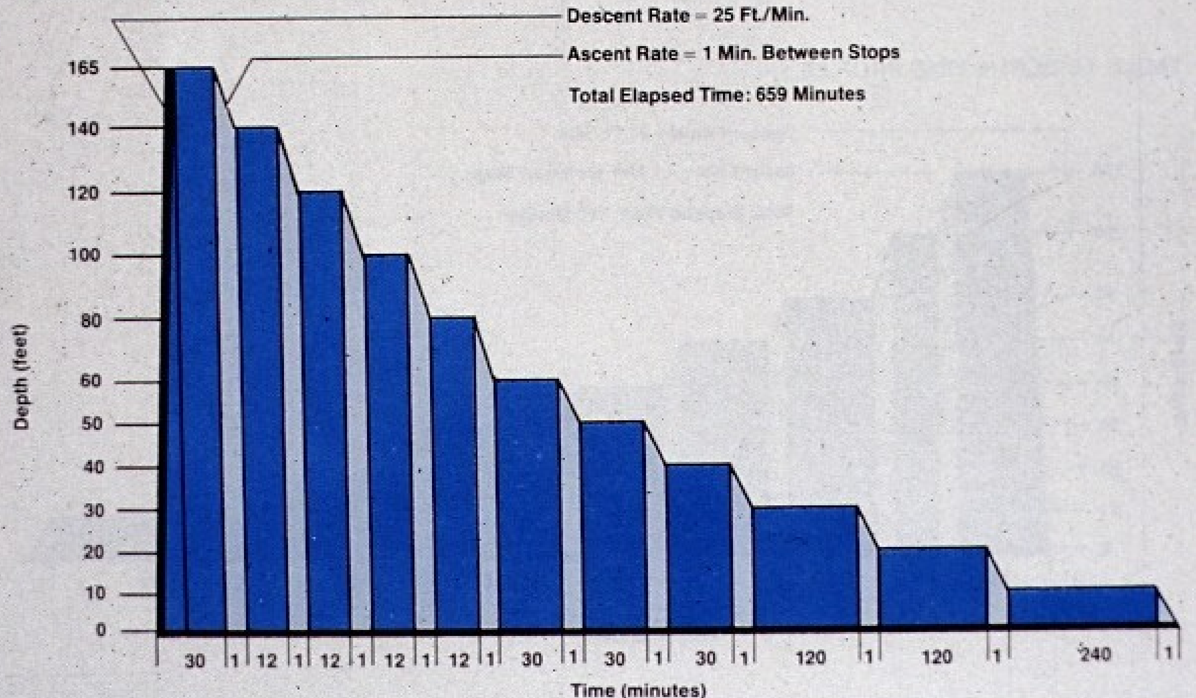
USN Treatment Table 2A

1. Use—treatment of pain-only decompression sickness when oxygen cannot be used and pain is relieved at a depth greater than 66 feet.
2. Descent rate—25 ft/min.
3. Ascent rate—1 minute between stops.
4. Time at 165 feet—includes time from the surface.
5. If the piping configuration of the chamber does not allow it to return to atmospheric pressure from the 10 foot stop in the one minute specified, disregard the additional time required.

Depth (feet)	Time (minutes)	Breathing Media	Total Elapsed Time (minutes)
165	30	Air	30
140	12	Air	43
120	12	Air	56
100	12	Air	69
80	12	Air	82
60	30	Air	113
50	30	Air	144
40	30	Air	175
30	120	Air	296
20	120	Air	417
10	240	Air	658
0	1	Air	659

TABLE 2A DEPTH/TIME PROFILE



Air Table
For DCS or Air Embolism

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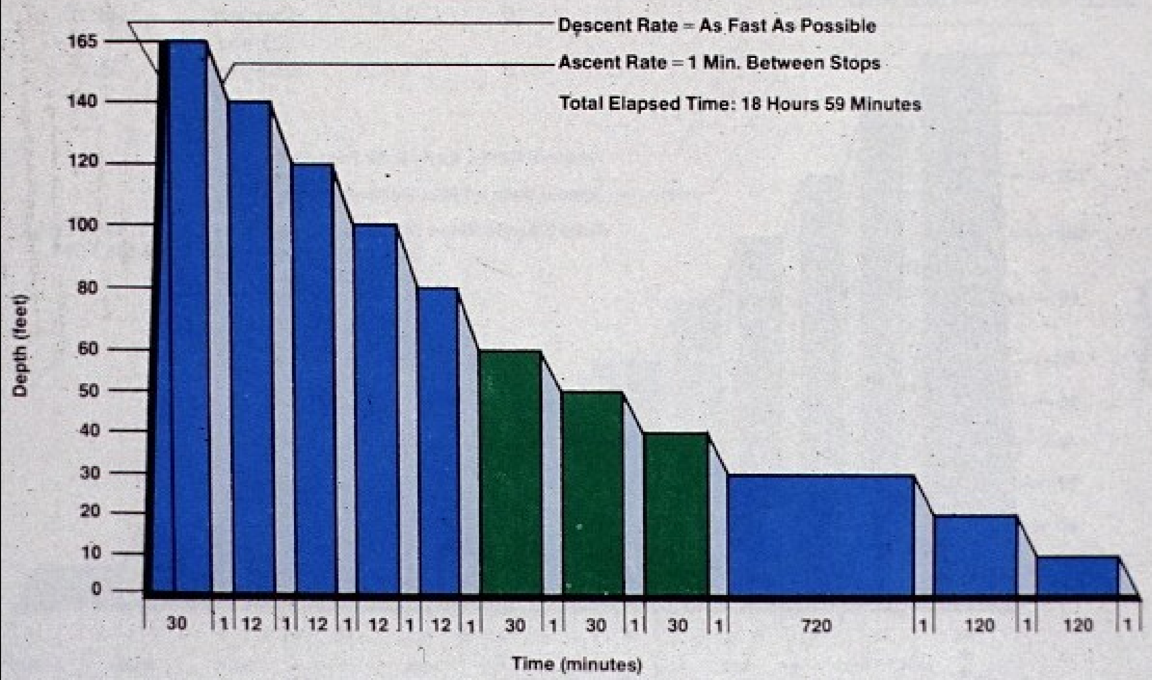
USN Treatment Table 3

1. Use—treatment of serious symptoms when oxygen cannot be used and symptoms are relieved within 30 minutes at 165 feet.
2. Descent rate—as fast as possible.
3. Ascent rate—1 minute between stops.
4. Time at 165 feet—includes time from the surface.
5. If the piping configuration of the chamber does not allow it to return to atmospheric pressure from the 10 foot stop in the one minute specified, disregard the additional time required.

Depth (feet)	Time	Breathing Media	Total Elapsed Time (hrs:min)
165	30 min.	Air	0:30
140	12 min.	Air	0:43
120	12 min.	Air	0:56
100	12 min.	Air	1:09
80	12 min.	Air	1:22
60	30 min.	Oxygen (or air)	1:53
50	30 min.	Oxygen (or air)	2:24
40	30 min.	Oxygen (or air)	2:55
30	12 hr.	Air	14:56
20	2 hr.	Air	16:57
10	2 hr.	Air	18:58
0	1 min.	Air	18:59

TABLE 3 DEPTH/TIME PROFILE



Air Table
For DCS or Air Embolism

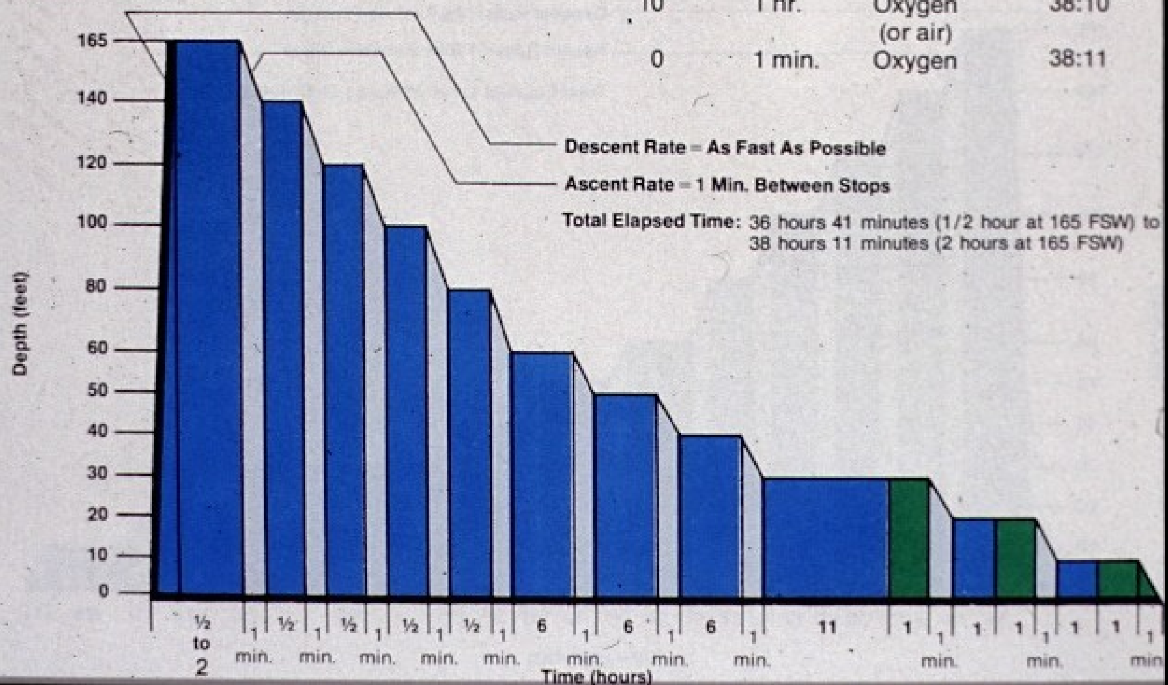
LPT

USN Treatment Table 4

1. Use—treatment of serious symptoms or gas embolism when oxygen cannot be used or when symptoms are not relieved within 30 minutes at 165 feet.
2. Descent rate—as fast as possible.
3. Ascent rate—1 minute between stops.
4. Time at 165 feet—includes time from the surface.
5. No modification or extension of this table is permitted except by a Diving Medical Officer.
6. If the piping configuration of the chamber does not allow it to return to atmospheric pressure from the 10 foot stop in the one minute specified, disregard the additional time required.

Depth (feet)	Time	Breathing Media	Total Elapsed Time (hrs:min)
165	½ to 2 hr.	Air	2:00
140	½ hr.	Air	2:31
120	½ hr.	Air	3:02
100	½ hr.	Air	3:33
80	½ hr.	Air	4:04
60	6 hr.	Air	10:05
50	6 hr.	Air	16:06
40	6 hr.	Air	22:07
30	11 hr.	Air	33:08
30	1 hr.	Oxygen (or air)	34:08
20	1 hr.	Air	35:09
20	1 hr.	Oxygen (or air)	36:09
10	1 hr.	Air	37:10
10	1 hr.	Oxygen (or air)	38:10
0	1 min.	Oxygen	38:11

TABLE 4 DEPTH/TIME PROFILE



Air Table
For DCS or Air Embolism

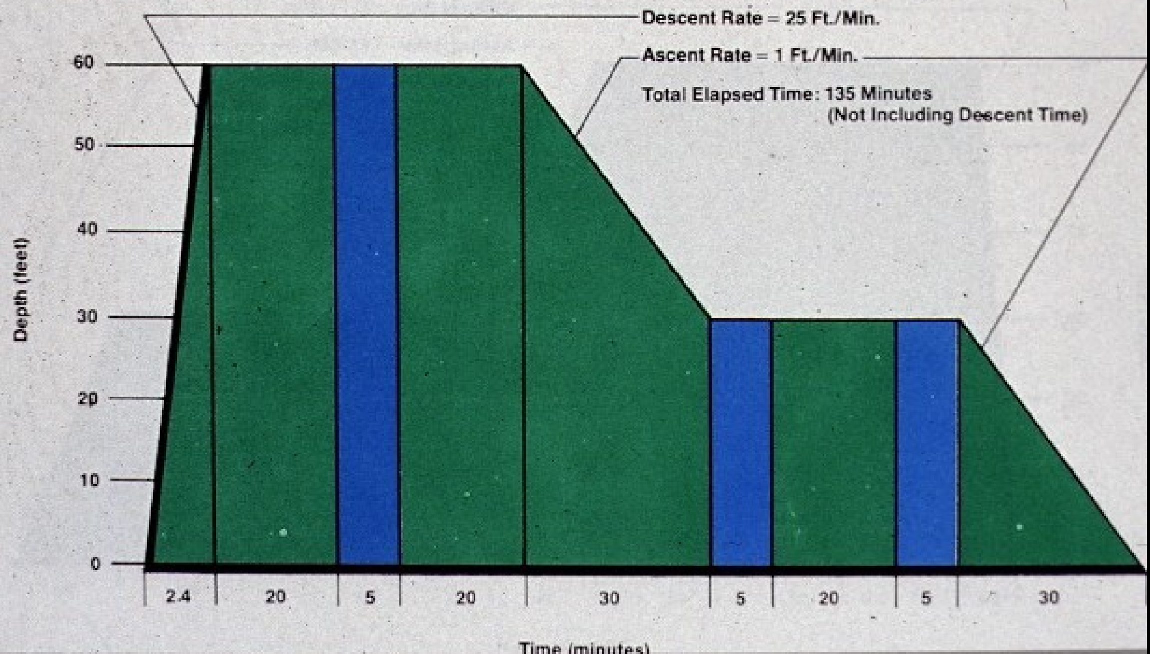
LPT

USN Treatment Table 5

1. Use—treatment of pain-only decompression sickness when oxygen can be used and symptoms are relieved within 10 minutes at 60 feet. Patient breathes oxygen from the surface.
2. Descent rate—25 ft/min.
3. Ascent rate—1 ft/min. Do not compensate for slower ascent rates. Compensate for faster rates by halting the ascent.
4. Time at 60 feet begins on arrival at 60 feet.
5. If oxygen breathing must be interrupted, allow 15 minutes after the reaction has entirely subsided and resume schedule at point of interruption.
6. If oxygen breathing must be interrupted at 60 feet, switch to TABLE 6 upon arrival at the 30 foot stop.
7. Tender breathes air throughout. If treatment is a repetitive dive for the tender or tables are lengthened, tender should breathe oxygen during the last 30 minutes of ascent to the surface.

Depth (feet)	Time (minutes)	Breathing Media	Total Elapsed Time (minutes)
60	20	Oxygen	20
60	5	Air	25
60	20	Oxygen	45
60 to 30	30	Oxygen	75
30	5	Air	80
30	20	Oxygen	100
30	5	Air	105
30 to 0	30	Oxygen	135

TABLE 5 DEPTH/TIME PROFILE



Air Table
For DCS or Air Embolism
Minimal Oxygen Table

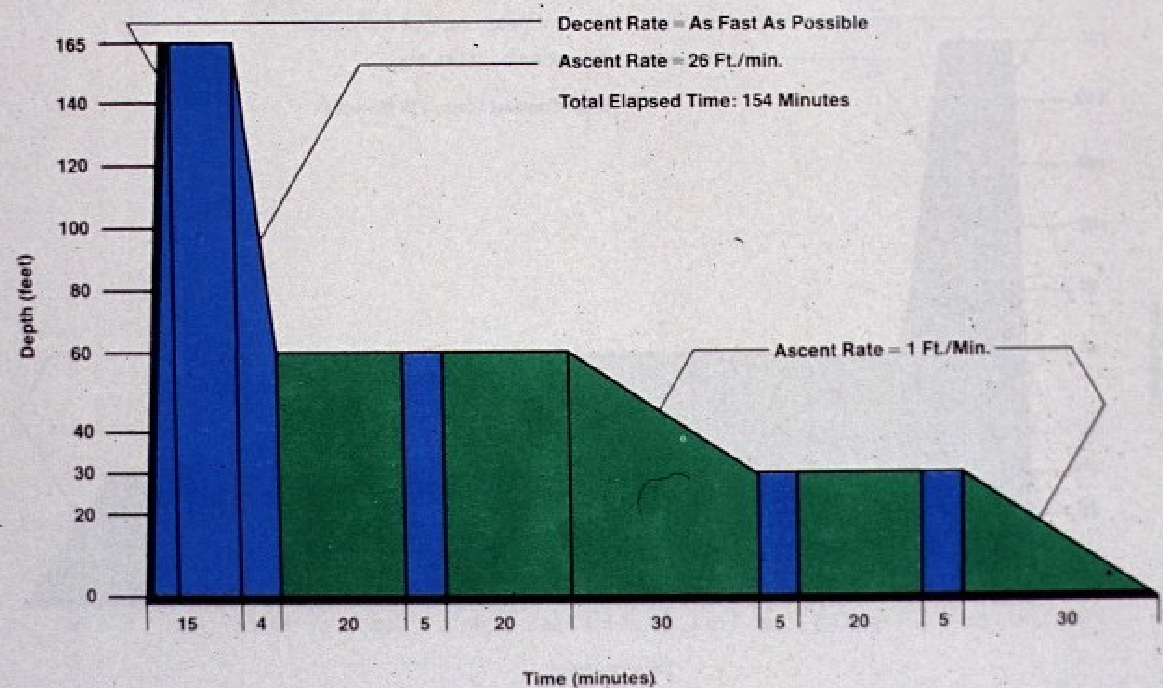
LPT

USN Treatment Table 6

1. Use—treatment of gas embolism when oxygen can be used and symptoms are relieved within 15 minutes at 165 feet.
2. Descent rate—as fast as possible.
3. Ascent rate—1 ft/min. Do not compensate for slower ascent rates. Compensate for faster ascent rates by halting the ascent.
4. Time at 165 feet—includes time from the surface.
5. If oxygen breathing must be interrupted, allow 15 minutes after the reaction has entirely subsided and resume schedule at point of interruption.
6. Tender breathes air throughout. If treatment is a repetitive dive for the tender or tables are lengthened, tender should breathe oxygen during the last 30 minutes of ascent to the surface.

Depth (feet)	Time (minutes)	Breathing Media	Total Elapsed Time (minutes)
165	15	Air	15
165 to 60	4	Air	19
60	20	Oxygen	39
60	5	Air	44
60	20	Oxygen	64
60 to 30	30	Oxygen	94
30	5	Air	99
30	20	Oxygen	119
30	5	Air	124
30 to 0	30	Oxygen	154

TABLE 5A DEPTH/TIME PROFILE



Air Table
For DCS or Air Embolism
Deep Extension

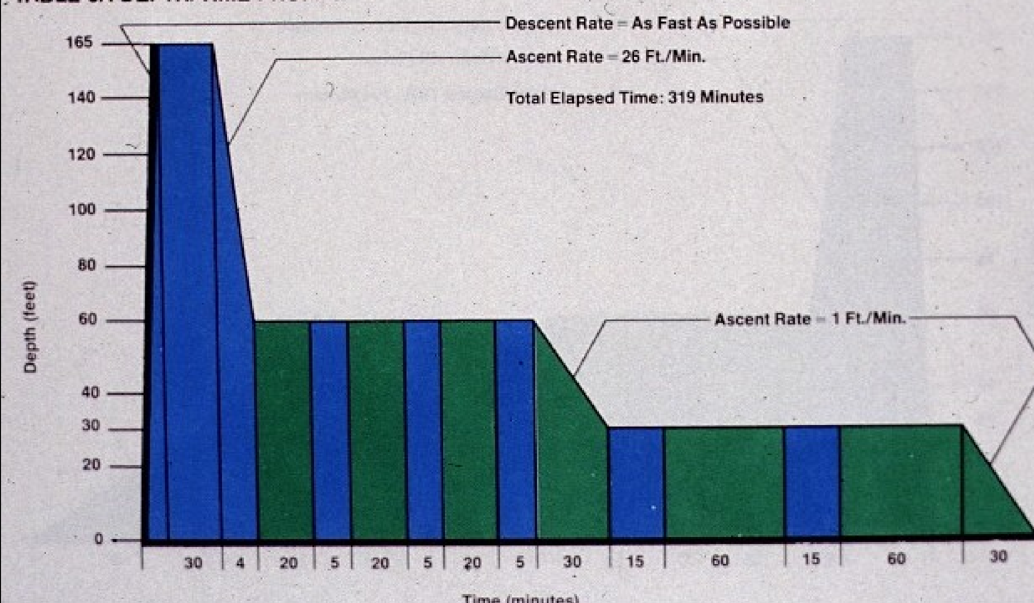
LPT

USN Treatment Table 6A

1. Use—treatment of gas embolism when oxygen can be used and symptoms moderate to a major extent within 30 minutes at 165 feet.
2. Descent rate—as fast as possible.
3. Ascent rate—1 ft/min. Do not compensate for slower ascent rates. Compensate for faster ascent rates by halting the ascent.
4. Time at 165 feet—includes time from the surface.
5. If oxygen breathing must be interrupted, allow 15 minutes after the reaction has entirely subsided and resume schedule at point of interruption.
6. Tender breathes air throughout. If treatment is a repetitive dive for the tender or tables are lengthened, tender should breathe oxygen during the last 30 minutes of ascent to the surface.
7. Table 6A can be lengthened by an additional 25 minutes at 60 feet (20 minutes on oxygen and 5 minutes on air) or an additional 75 minutes at 30 feet (15 minutes on air and 60 minutes on oxygen), or both.

Depth (feet)	Time (minutes)	Breathing Media	Total Elapsed Time (minutes)
165	30	Air	30
165 to 60	4	Air	34
60	20	Oxygen	54
60	5	Air	50
60	20	Oxygen	79
60	5	Air	84
60	20	Oxygen	104
60	5	Air	109
60 to 30	30	Oxygen	139
30	15	Air	154
30	60	Oxygen	214
30	15	Air	229
30	60	Oxygen	289
30 to 0	30	Oxygen	319

TABLE 6A DEPTH/TIME PROFILE



Air Table
For DCS or Air Embolism
Extended Deep Extension

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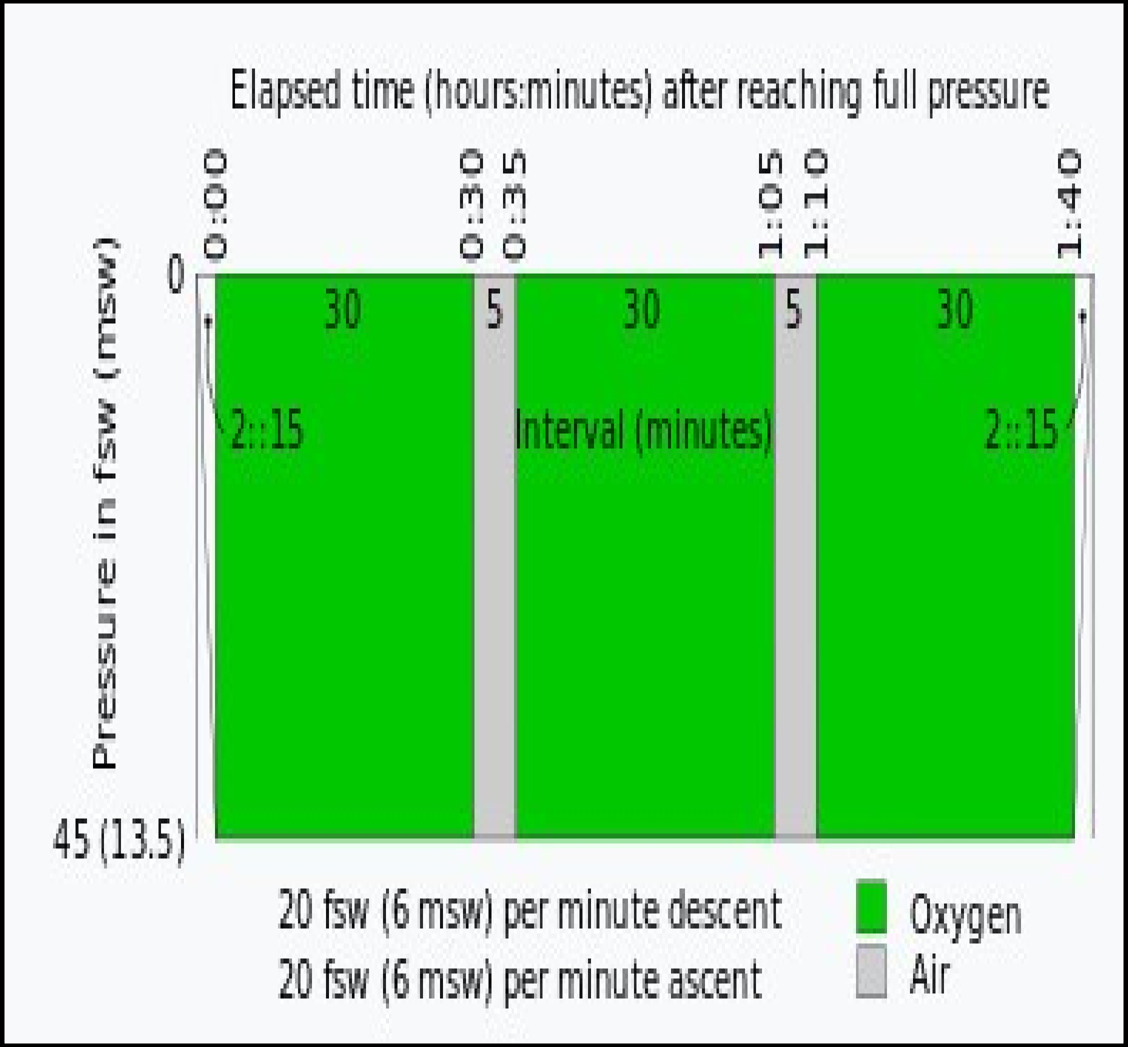
USN Treatment Table 9

Used only on Diving Medical Officer recommendation

Oxygen Treatment
For Residual Symptoms
CO or CN Poisoning
Smoke Inhalation



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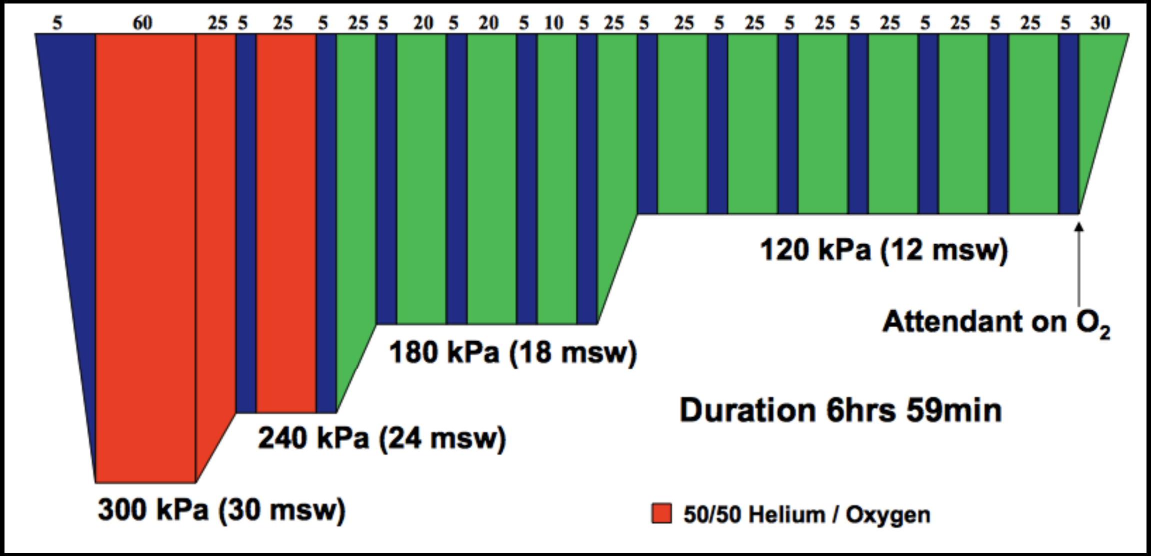
COMEX Table

Deep Diving (Saturation) Contractor



Proprietary Tables: Competitive Advantage

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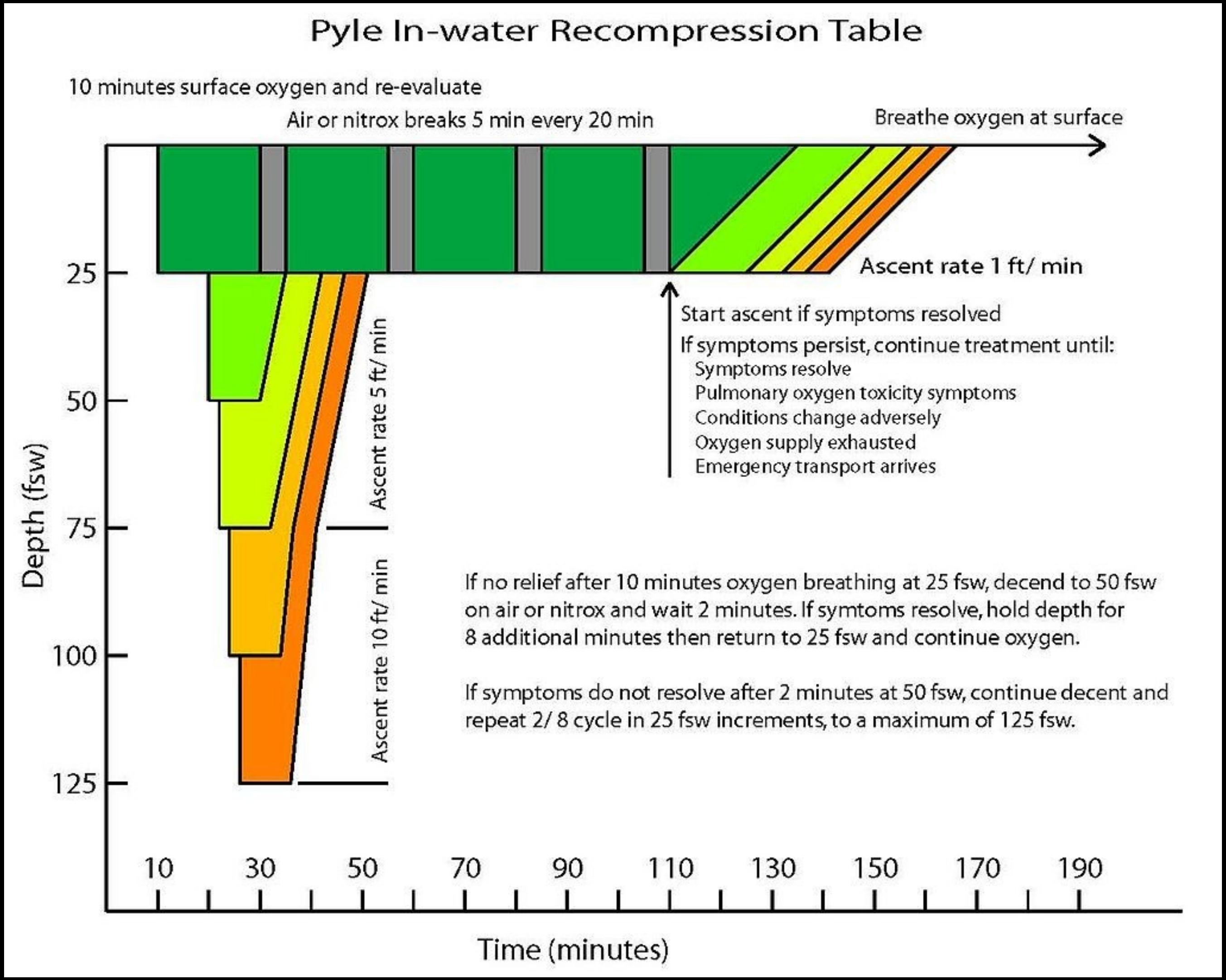
In-Water Recompression

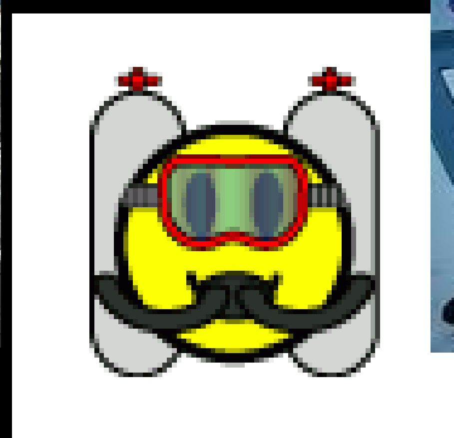
Considered non-viable in North America



Need:

- Large Gas Supply
- Full Face Mask
- Communication
- Cold Protection

Recompression Chambers



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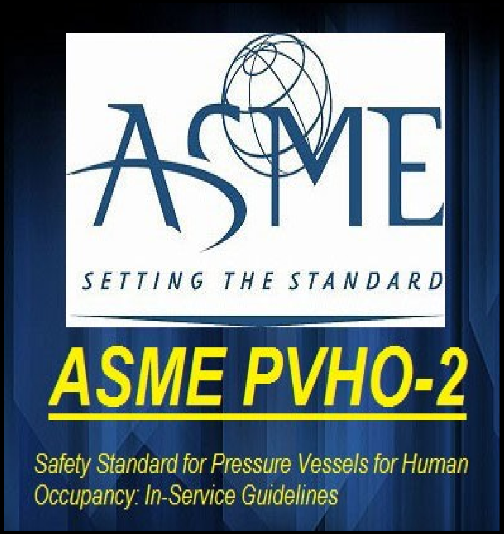
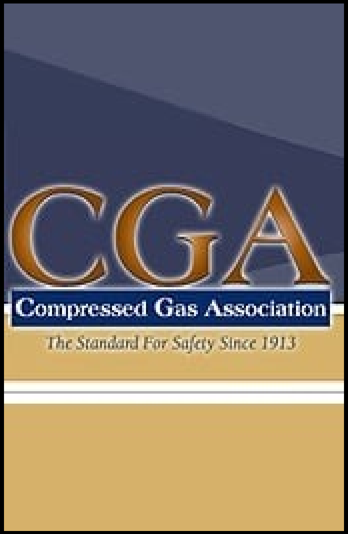
Chambers Are Pressurized Containers

Made of Steel, Aluminum or Lucite

Must meet standards / codes of:

- **ASME (American Society Mechanical Engineers)**
- **PVHO (Pressure Vessels For Human Occupancy)**
- **NFPA (National Fire Protection Association)**
- **CGA (Compressed Gas Association)**





Chamber Specifications

Diving Community: Diameter of the Chamber
Medical Community: Patient Capacity

1 Bunk = 3 people

Personal Chambers

Small
Can be air-lifted
Often inflatable
Home use for non-diving maladies

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Monoplace Chambers

Typically pressurize to 60 fsw or less (often with O_2)
Used primarily for non-diving injury treatments
Lucite pressure-containment vessel

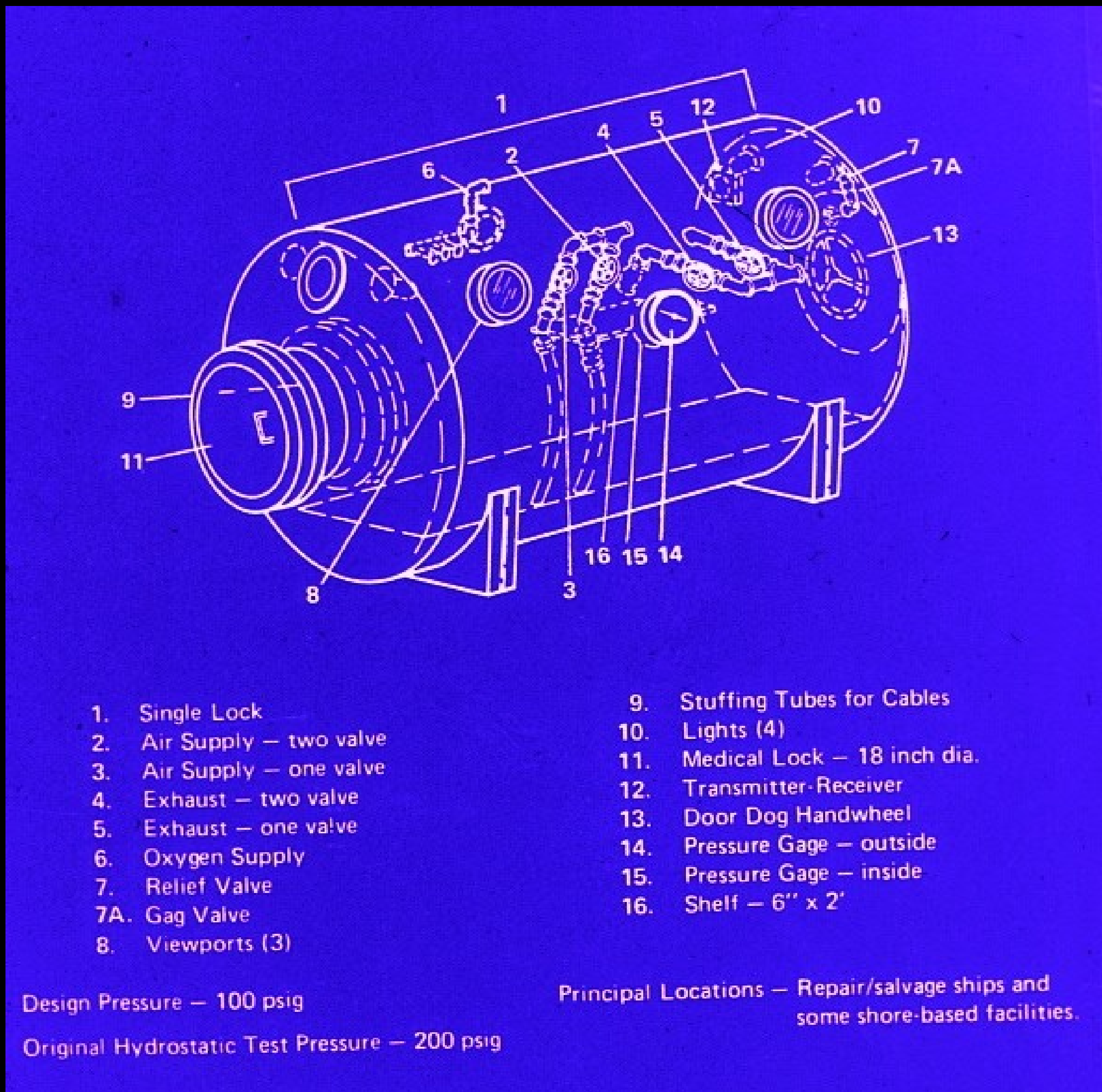


Single Lock Chamber

Typically only room for one person
No ability for medical staff to enter / exit chamber

Single Lock Chamber

Schematic from USN Dive Manual



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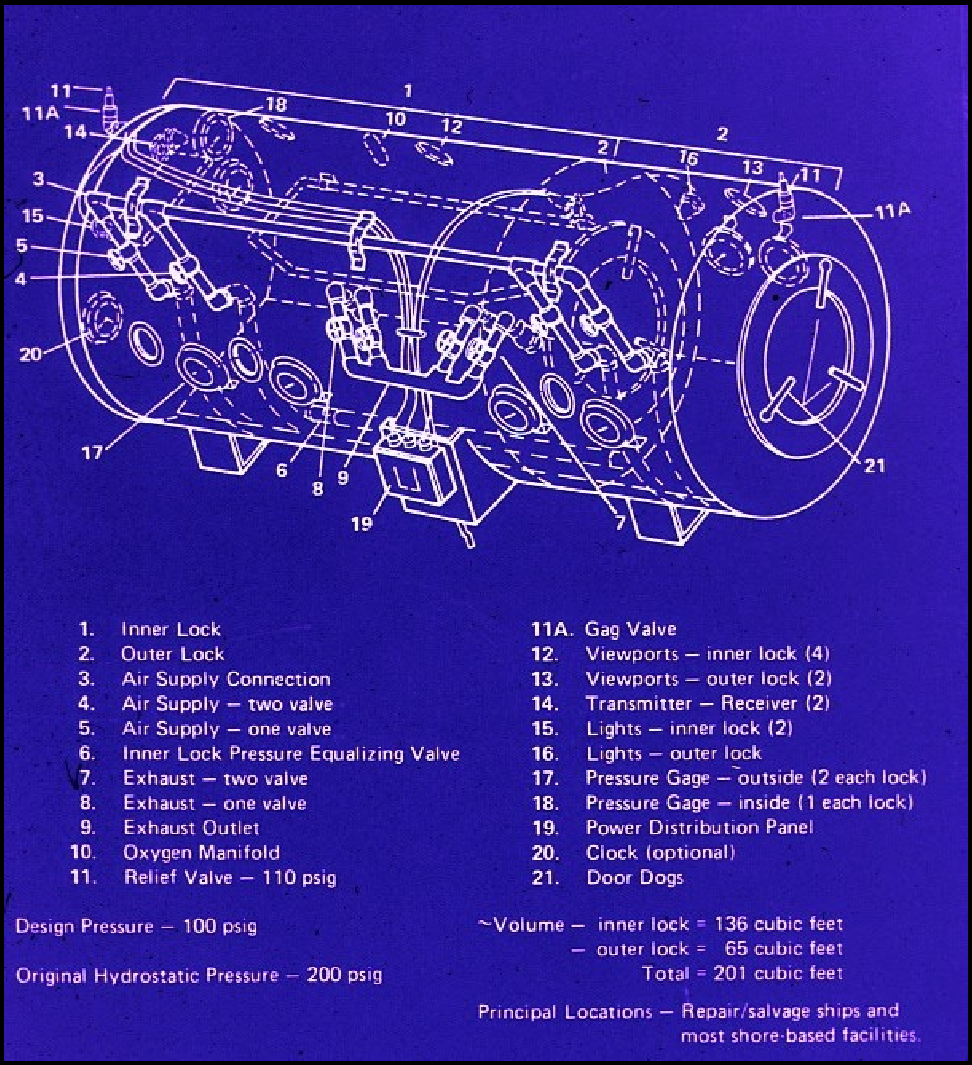
Dual-Lock Chamber

Two separate, but connected pressurized containers
Allows movement of personnel / equipment between chambers

Dual-Lock Chamber

Schematic from USN Dive Manual



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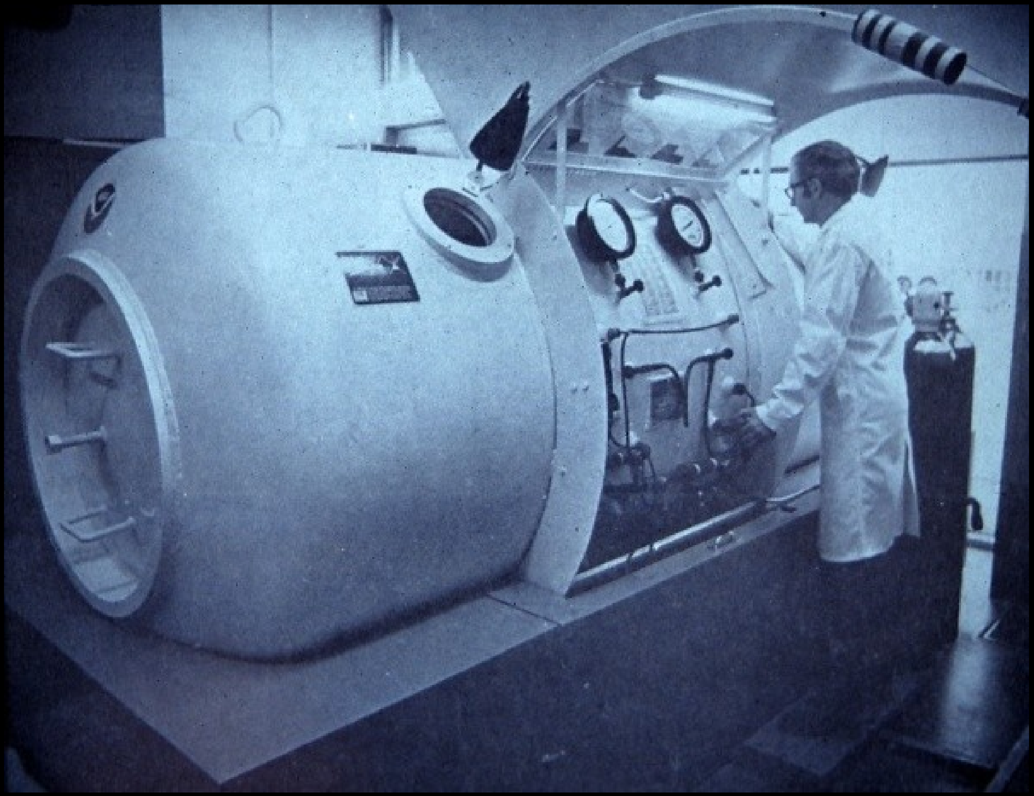
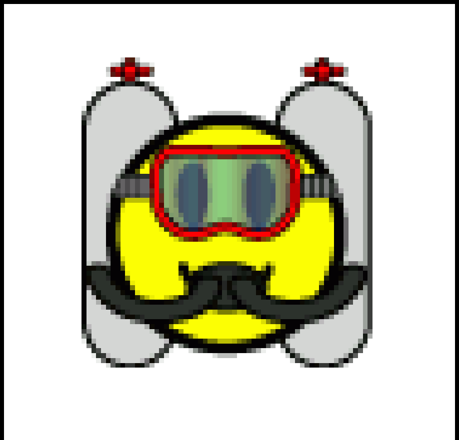
Former U of Michigan Chamber



Used to train chamber attendants and instructors
Used for treating diving injuries
Donated to Guam when Lee Somers Retired

Dual-Lock Deck Chamber

Chamber Facility Physical Plant



Physical Plant Components

- One or More Pressure Vessels (Chambers)
- Pressurization (Compressors) System
- Gas Supply / Analysis
- Plumbing
- Electrical System
- Communication System
- Environmental Control
- Fire Suppression System
- Patient Care

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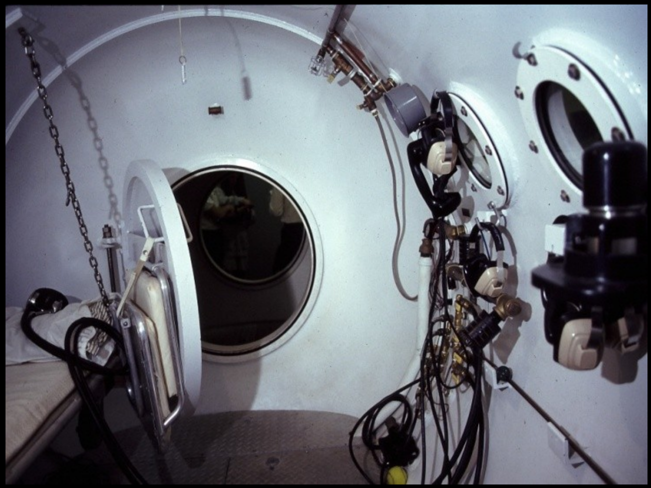
Chamber Doors

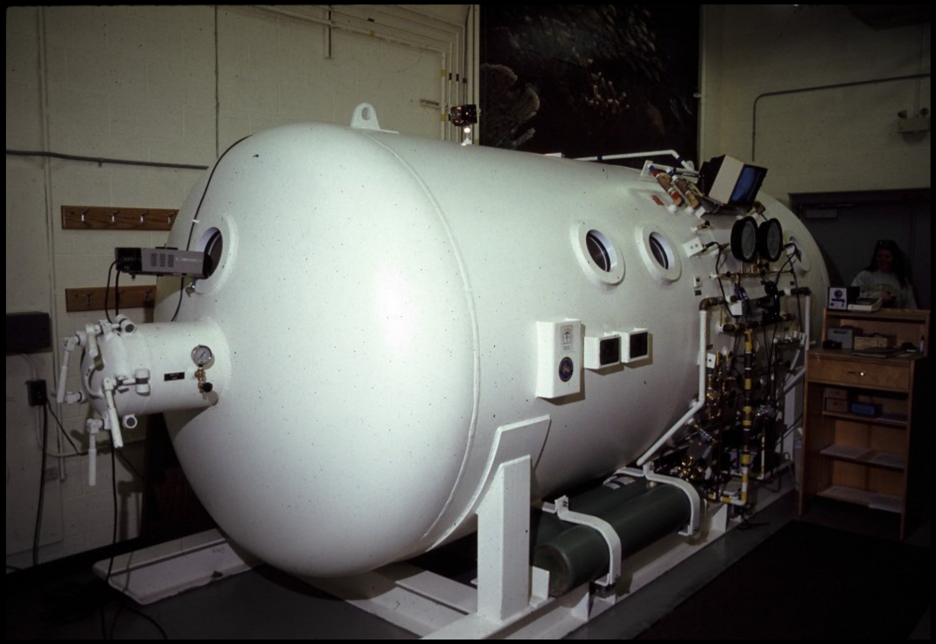
O-Ringed Seal
Designed to "seal" with pressure
(Prevents accidental opening)

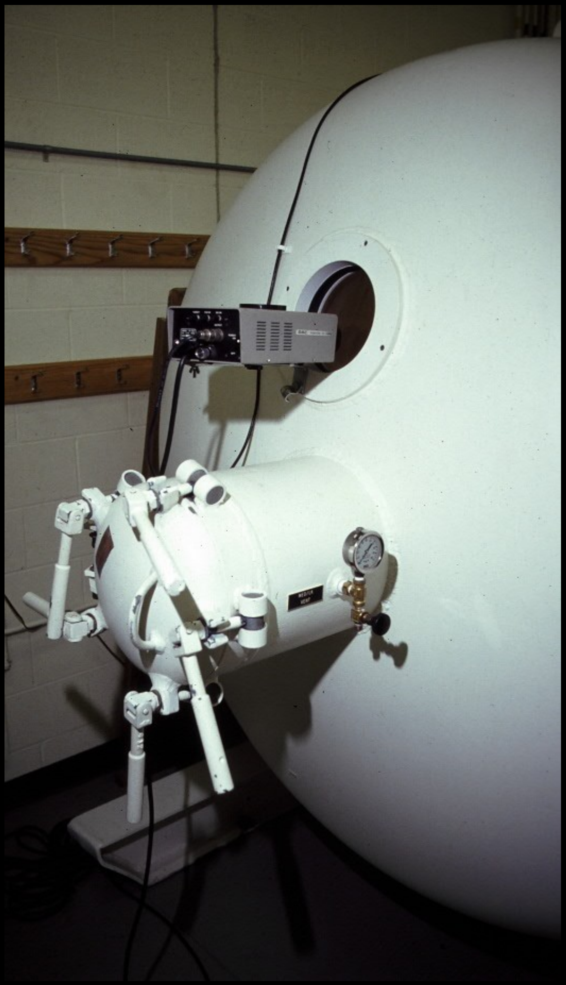


Medical Lock

Small appendage to chamber
Allows convenient passage of:

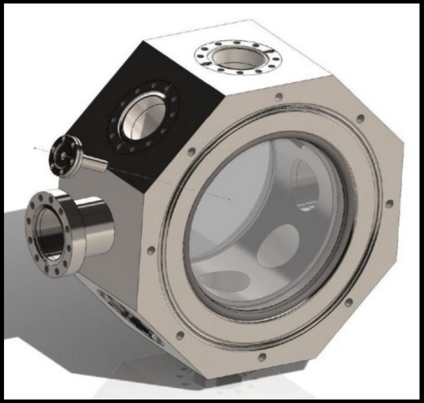
- Food
- Body waste
- Medical supplies
- Equipment
- Instruments

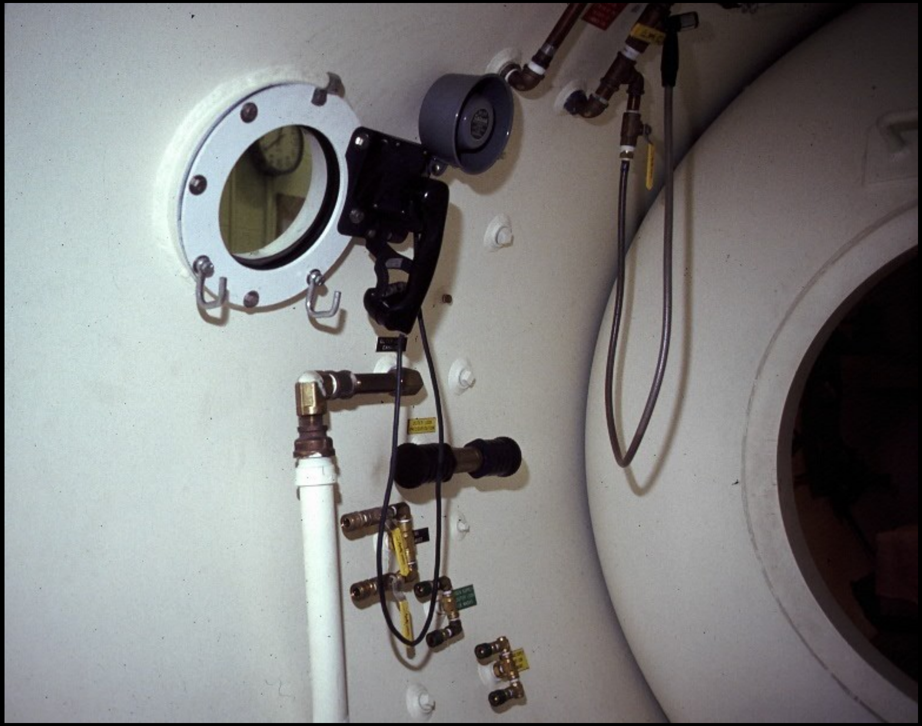




Acrylic Viewports

Allows viewing interior of chamber





Temperature

Entering gas:

Cooled with chilled water

Heated with hot water / steam

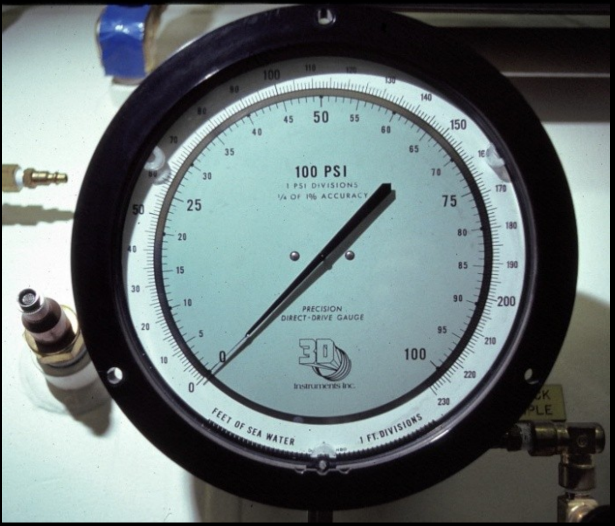
Descending: Adiabatic compression increases temperature

Ascending: Adiabatic expansion decreases temperature

Environmental Controls / Instrumentation

Accurate pressure / depth
Temperature
Humidity
Time
Gas analysis
- Total hydrocarbons
- % O_2 in exhaust
- % O_2 in chamber
- % Other gases

TV monitor



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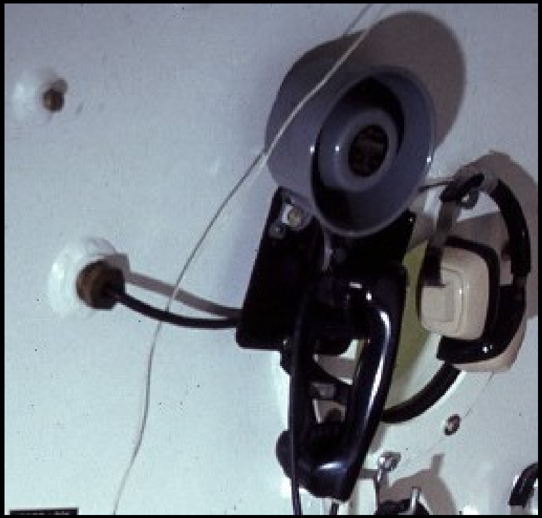
Communication

Lock-to-Lock
Lock to Outside
Voice Powered



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Gas Supply: Compressors

Main and backup medical grade air compressors
Compressed gas cylinders for each gas used in treatment

Gas Supply: Gas Cylinders

Compressed gas cylinders for each gas used in treatment
Enough for two complete chamber fills at maximum pressure

GAS	USA	INTERNATIONAL
oxygen	Green	White
Carbon dioxide	Gray	Gray
Nitrous oxide	Blue	Blue
helium	Brown	Brown
Nitrogen	Black	Black
air	Yellow	White & black

Gas Supply: Storage

Compressors feed storage cylinder bank
Gas to chamber from storage cylinders

USCG Specs
Bring to operating pressure:
- 2 ata / min to 60 fsw
- 1ata / min thereafter

Air Standards:
- O_2: 20-22 % by volume
- CO_2: < 1000 ppm
- CO: < 20 ppm
- Solids: < 5 mg / m^3
- Hydrocarbons: < 25 ppm

Piping

Must:

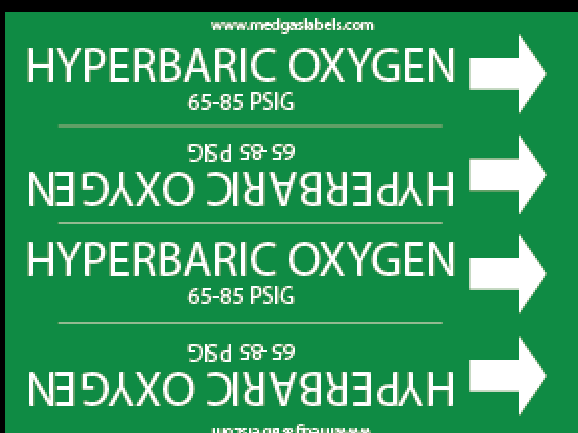
- **Meet supply demands**

Identify:

- **Function**
- **Contents**
- **Maximum pressure**
- **Direction of flow**

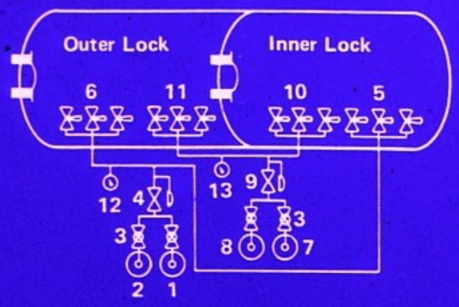
Gas Flow:

- **Enter at Top**
- **Exit at Bottom**
- **Assists particle removal**
- **Toxic gasses heavier than air**



Piping

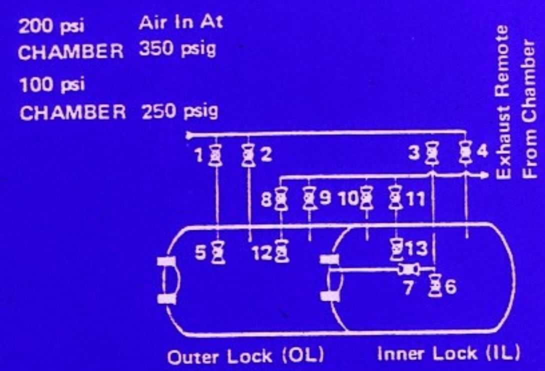
Schematics from USN Manual



OX 1. "Breathing Oxygen" High Pressure Cylinders.
OX 2. Oxygen Cylinder Valve
OX 3. Cylinder Isolation Valve
OX 4. Oxygen Regulator—75 psig
OX 5. Oxygen Manifold Valves—inner lock
OX 6. Oxygen Manifold Valves—outer lock
HE OX 7. 80% Helium—20% Oxygen High Pressure Cylinders
HE OX 8. He-O_2 Cylinder Valve
HE OX 9. He-O_2 Regulator 75 psig
HE OX 10. He-O_2 Manifold Valves—inner lock
HE OX 11. He-O_2 Manifold Valves—outer lock
HE OX 12. Oxygen Supply Pressure Gage
HE OX 13. He-O_2 Supply Pressure Gage

OX = Oxygen
HE OX = Helium Oxygen

Piping Schematic—Oxygen and Helium—Oxygen Supplies



ALP = Air Low Pressure
EXH = Exhaust

ALP 1. Two-Valve Air Supply—outside valve—OL
ALP 2. One-Valve Air Supply—OL
ALP 3. Two-Valve Air Supply—outside valve—IL
ALP 4. One-Valve Air Supply—IL
ALP 5. Two-Valve Air Supply—inside valve—OL
ALP 6. Two-Valve Air Supply—inside valve—IL
ALP 7. Inner/Outer Lock Equalization Valve
EXH-1 8. Two-Valve Exhaust—outside valve—OL
EXH-2 9. One-Valve Exhaust—OL
EXH-3 10. One-Valve Exhaust—IL
EXH-4 11. Two-Valve Exhaust—outside valve—IL
EXH-5 12. Two-Valve Exhaust—inner valve—OL
EXH-6 13. Two-Valve Exhaust—inner valve—IL

Piping Schematic—Chamber Air Supply and Exhaust

Fire Suppression

Everything inside must be non-flammable (Rigid NFPA Codes)
Water sprinkler system
  Can deliver to pressurized chamber
Non-flammable gases
Spark free clothing of occupants

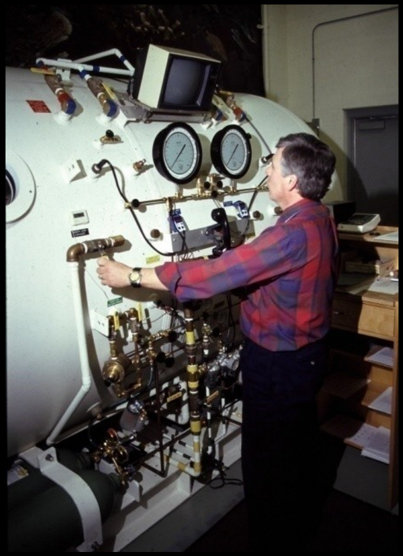
Extinguishers:
  Foam
  Water

Records Maintained

Time Vs:
- Chamber Pressure
- Temperature
- Humidity
- pO_2 in exhaust
- pCO_2 in chamber
- Gas concentrations
- Changes to chamber

Medical Treatments

Staff



Chamber Supervisor

- Overseas all chamber functions
- Communications with rescue responders
- Interacts with medical team

Responsible for all aspects of chamber operations

Tender

- Inside: Manages patient
- Outside: Assists in chamber operation

Staff

Physician
- Evaluates patient
- Assigns treatment protocol
- Oversees all medical aspects

Recorder
- Maintains all records
- Monitors time
- Informs staff of needed chamber changes

EMT's / First Responders
- Stabilize patient for transport
- Transport to chamber
- Operate under medical supervision

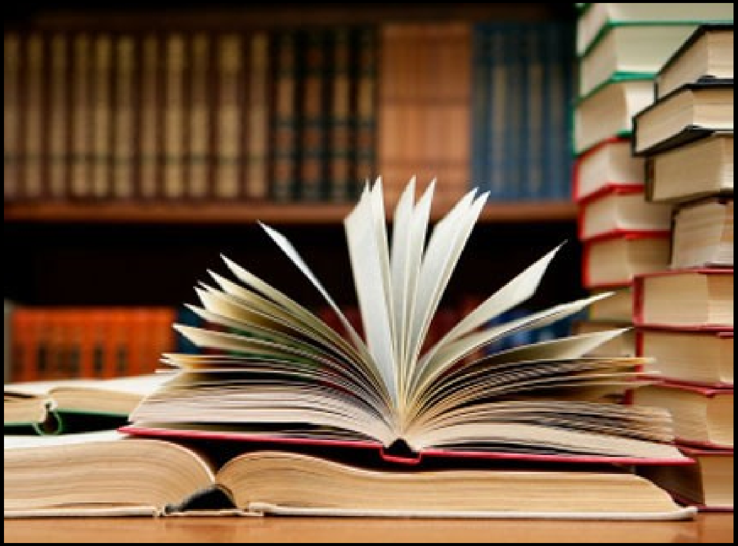
References:

Gerhard Haux: History of Hyperbaric Chambers
Lee Somers: Hyperbaric Chamber Attendant's Handbook
Dick Rutowski: Recompression Chamber Life Support Manual

Images:

Those taken by author:
- Bronson Hospital Chamber Facility
- Catalina Island Chamber Facility

Google Images




"That's all Folks!"


Woo Hoo!
All done!


End of Class This Is


Dive long and prosper

LPT