BY JOHN C. RATLIFF

HISTORY OF BUOYANCY CONTROL FOR SCUBA DIVERS

NAVY UNDERWATER SWIMMERS SCHOOL, KEY WEST, FL 1967

WE ORIGINALLY DOVE WITH MINIMUM GEAR

US NAVY SCHOOL FOR UNDERWATER SWIMMERS, 1967

MINIMUM GEAR & BUOYANCY

PJ WITH SCUBA, JUMP TANKS, AND NO WEIGHTS

WARM WATER GEAR

INFLATION VERSES WEIGHTING STRATEGIES

- No wet suit, no need for buoyancy compensation, as there is no loss in buoyancy.
- With a wet suit, the neoprene compresses, changing buoyancy with depth.
- Dry suits provide their own buoyancy compensation by adding air as the diver descends.

HOW TO MAKE A WET SUIT

- DIVERS ACTUALLY GLUED TOGETHER THEIR OWN WET SUITS FROM SHEET NEOPRENE
- THIS LED DIRECTLY TO CUSTOM WET SUITS
- I USED TO MAKE MY OWN THREE-FINGER MITTS IN THIS MANNER
- WET SUITS LED TO THE NEED FOR BUOYANCY COMPENSATION

UNDERWATER DRESS

Those divers who don't have the good fortune to be near bodies of water where temperatures range from 80 to 90 degrees will have to think about wearing some sort of underwater dress to be comfortable in the water. Bathing trunks and thick skins are enough for short swims in waters that range as low as 60 degrees, but loss of body heat in waters of 60 degrees and less is noticeable to a marked extent and can be very dangerous to the swimmer if he remains too long in the water.

With adequate protective dress the diver can remain in the water for a much longer time with no loss of endurance or strength from the cold. Cold-water suits are divided into two general categories: wet and dry. The dry suit covers the diver from head to toe. The only part of the body not covered is the mouth and chin portion of the face just below the mask. Heavy underwear and socks are worn beneath the rubber suit to provide an insulating layer of air which keeps the diver warm. This trapped air increases the diver's buoyancy so that six to eight pounds of additional weights are required for diving.

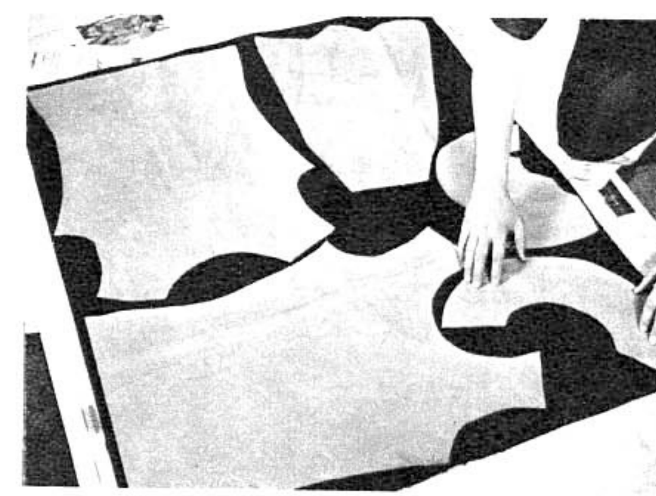
Wet suits are made of smooth or foam rubber. Underwear can be worn with the smooth-rubber model. These suits do not prevent water from entering and getting next to the wearer's skin, but the water does not circulate freely enough to cool the body. It is trapped by the cloth or the foam rubber and is warmed by body heat.

Various sleeve and leg lengths give the diver coverage and insulation to suit his individual needs. Suits range from $30 to $90 in price and must be treated with care.

Suits are recommended for diving and spearfishing in the Great Lakes and other cold inland waters, the New England area, the Atlantic seaboard north of Florida, and the Pacific Coast from Santa Barbara north. But use your own judgment. Some of us are less sensitive to cold than others. •

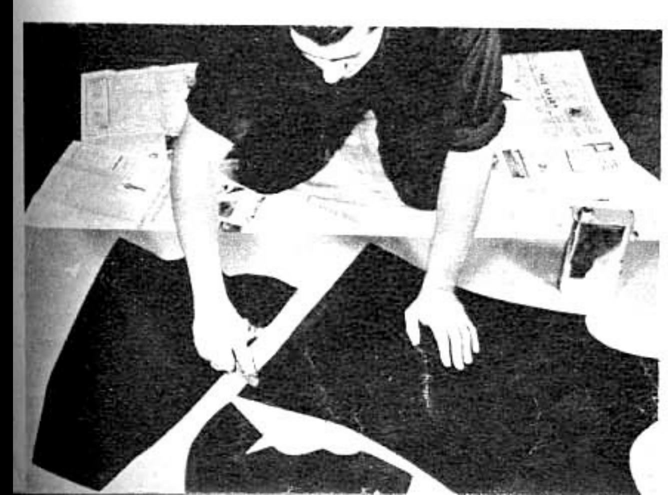
MAKE YOUR OWN COLD-WATER SUIT

For skin divers who would like to extend their diving season and swim in comfort, but who can't afford the price of a good, ready-made rubber suit, there are kits available now with materials for making your own suit. Fenjohn puts out an inexpensive kit that includes three large sheets of sponge neoprene, cement and a full set of paper patterns (small, medium or large) from which you can make a full-length suit and helmet. You'll even have enough sponge neoprene left over for mittens and socks, and for patches should you someday get snagged on a piece of coral or other hazard. Complete assembly, using a Fenjohn kit, as pictured here and on the following pages, took two men less than six hours of actual working time—and it was their first try! If you don't have the time or talent for this sort of work, call in the womenfolk.



Arrange paper patterns on sheets of sponge neoprene; trace outlines, cut out parts carefully.

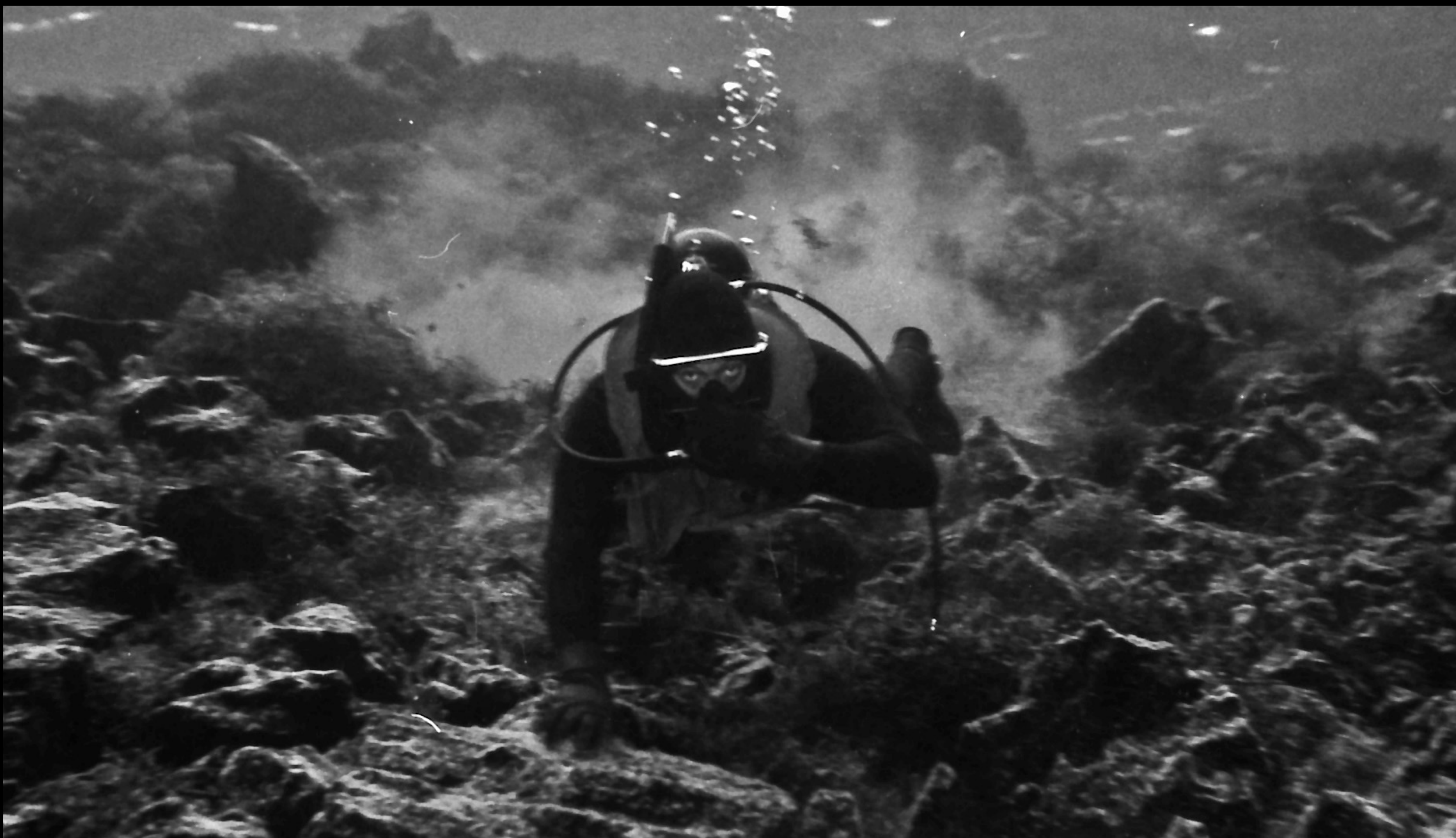
Before starting assembly, wipe all edges to be glued with Toluol, Xylene, or a similar solvent.



Cement side seam of jacket, matching corners at armpit and working toward waist; set in sleeve.

IN THE BEGINNING, COLD WATER GEAR

A WET SUIT, WEIGHT BELT AND A VEST.



WEIGHT DETERMINED BY DEPTH

WE USED A SINGLE HOSE REGULATOR AND WEIGHTED OURSELVES ACCORDING TO THE DIVE.

MY 1975 EQUIPMENT

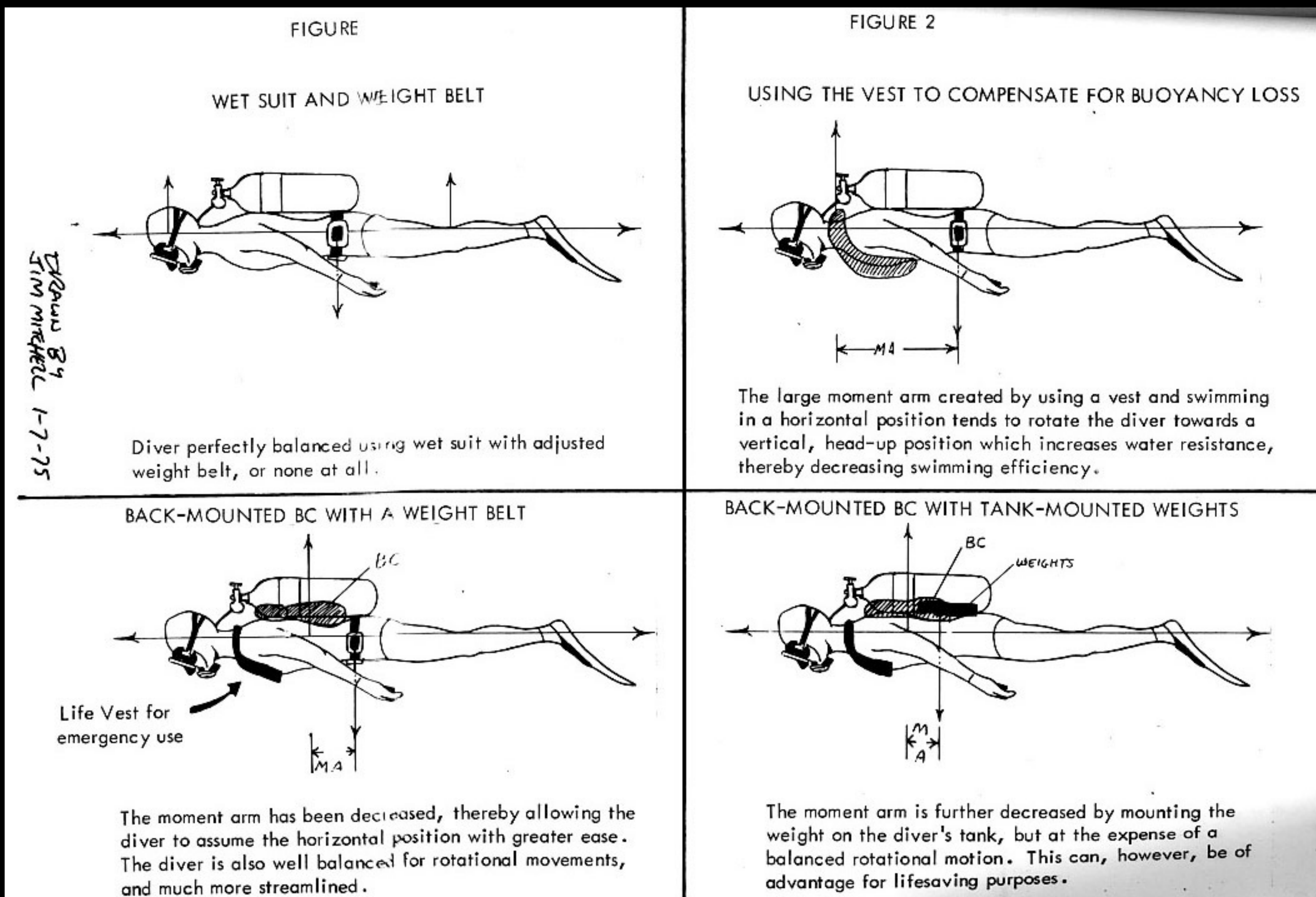
- Dacor inflatable vest (expandable)
- wet suit
- weight belt (not the means of securing the weights)

1973

NAUI ITC CLASS PHOTO

IQ6 DIAGRAM

MOMENT ARMS OF BUOYANCY



LAKE CHALAN DIVE, 1972

AQUEON BUOYANCY

VINTAGE DIVING

- SCUBA
- Weight Belt
- Wet Suit
- Mask, fins & snorkel

ONE OF MY EARLY DRAWINGS

EARLY CONCEPTS IN BUOYANCY CONTROL—BACK OF WETSUIT BC

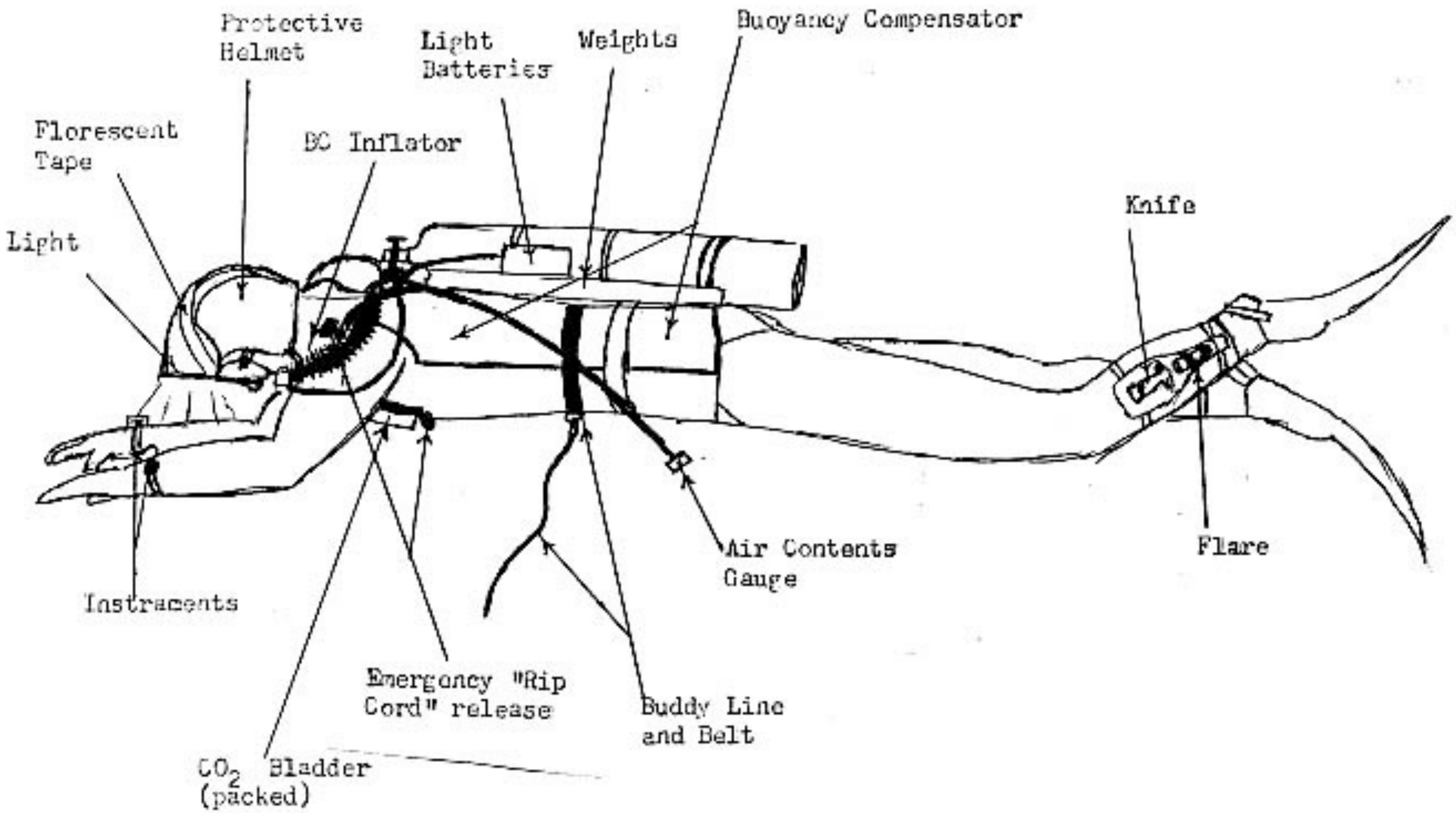


Figure I

POSSIBLE NEW CONFIGURATIONS

- Tank-mounted weights
- BC integrated into the back of the wet suit—Bill Herter, Deep Sea Bill's contribution.
- Use of a bladder on the SCUBA shoulder hooks.

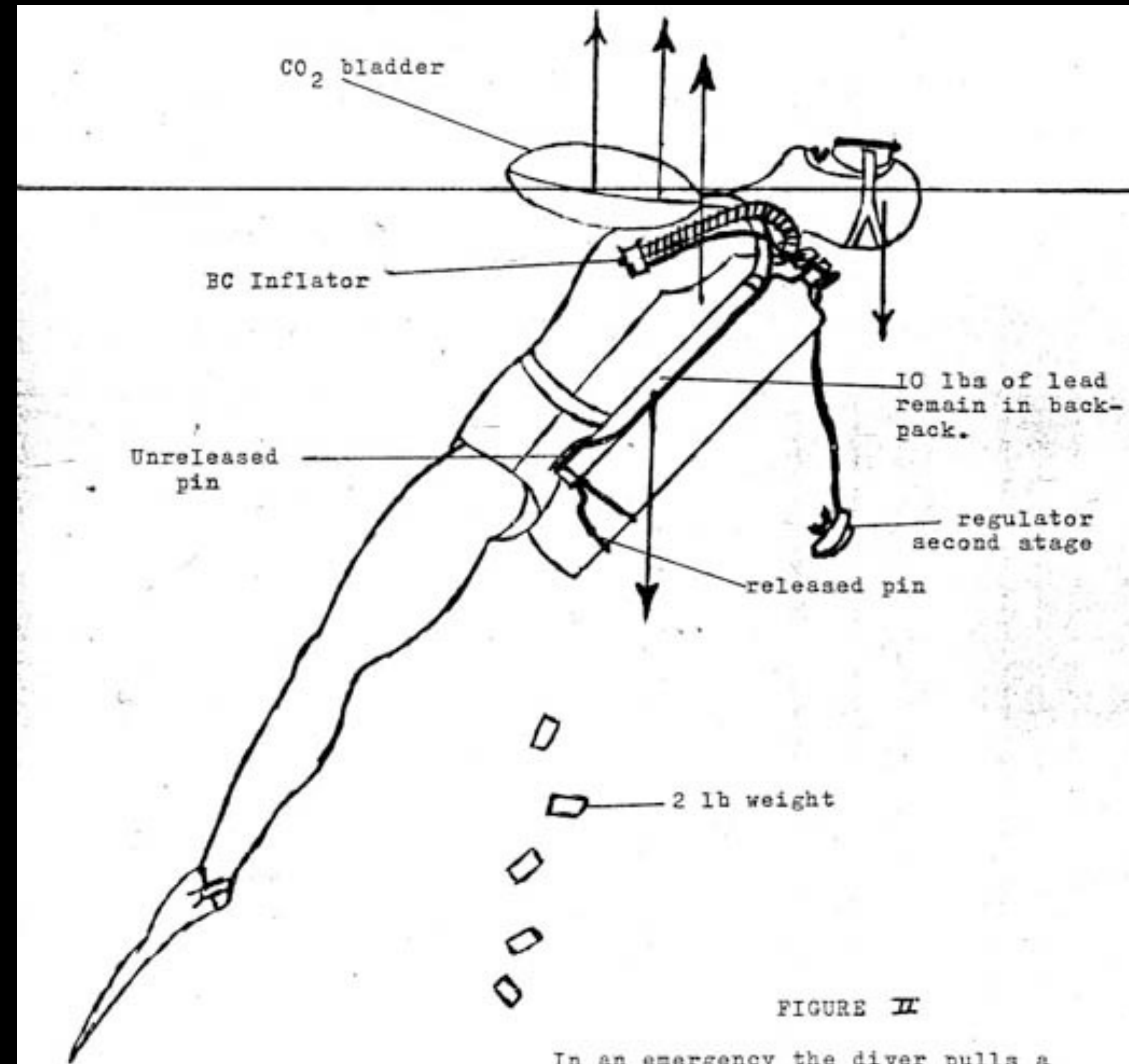


FIGURE II

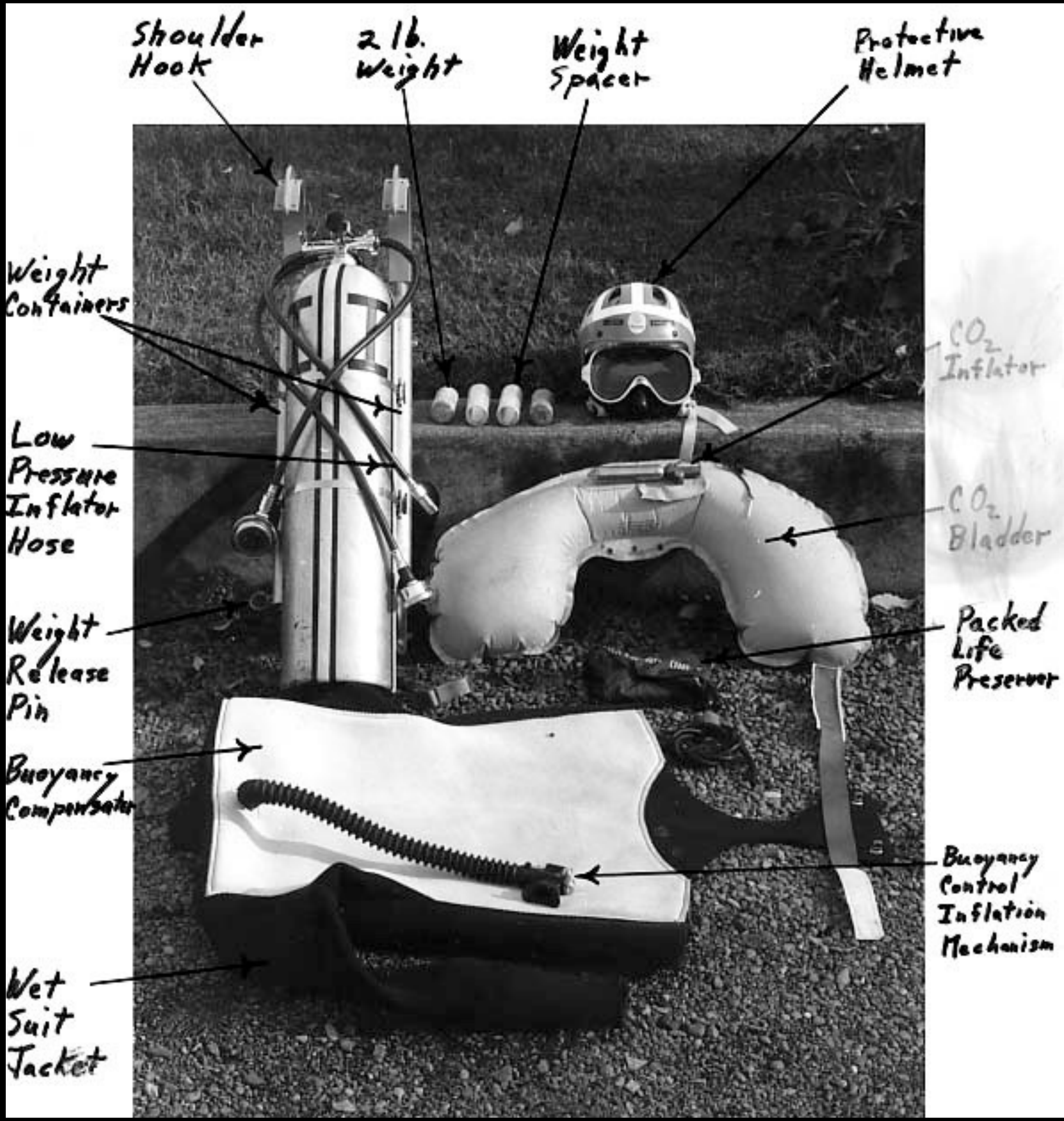
In an emergency the diver pulls a ball on his shoulder harness which drops 10 lbs of lead (here shown in 2 lb cylinders) and inflates a CO_2 activated bladder. Ten lbs of lead stay in the backpack to anchor the diver in a stable face-up position. Arrows indicate force vectors.

1Q6

DEMONSTRATING BC CONCEPTS

INTEGRATION OF SCUBA EQUIPMENT

- scuba with harness
- weights integrated into harness
- low pressure inflator
- buoyancy compensator in back of wetsuit
- packed life preserver (based upon USAF ULP



TESTING INTEGRATED SCUBA

- river test
- using double hose regulator with inflator (Trieste II)
- Mar-Vel backpack with weights
- Bill Herter's BC design (see white area on back of wet suit)

1975

CLEAR LAKE DIVE USING BILL HERTER'S BACK BC INTEGRATED INTO THE WET SUIT.

Dry suits provide warmth, but also different buoyancy characteristics

EARLY AQUALA DRY SUIT, WITH POWER INFLATOR

Photo by Bruce Higgins, Clear Lake, Oregon

DACOR NAUTILUS CONSTANT VOLUME SYSTEM (CVS)

AN INTEGRATED, HARD-SHELL SYSTEM BASED UPON CONCEPTS OF A SUBMARINE

DACOR CORPORATION

NAUTILUS CONSTANT VOLUME SYSTEM (CVS)

NAUTILUS CVS FLOATING

DACOR NAUTILUS CVS

- Constant volume, like a submarine
- Upper right shows overpressure relief valve
- Below is water intake valve
- Has a regulator on the inflation hose that automatically adds air as the unit goes deeper
- Required a certification course by Dacor authorized dive shop.

DACOR NAUTILUS

USED WITH DECOR PACER REGULATOR

DACOR NAUTILUS CVS

PROFILE IN THE CURRENT

THE NAUTILUS CVS ON LAND CAN BE A PROBLEM DUE TO CG ASPECTS OF THE SYSTEM

WHITE STAG HARD-SHELL BC

SMALLER AND SIMPLER THAN THE DACOR NAUTILUS CVS

WHITE STAG HARD SHELL

PROFILE IN THE WATER
NOT A CONSTANT VOLUME SYSTEM!

WHITE STAG HARD SHELL

APPROXIMATE LIFT—15 POUNDS; BUT LOOK AT THE DIFFERENCE IN SIZE!

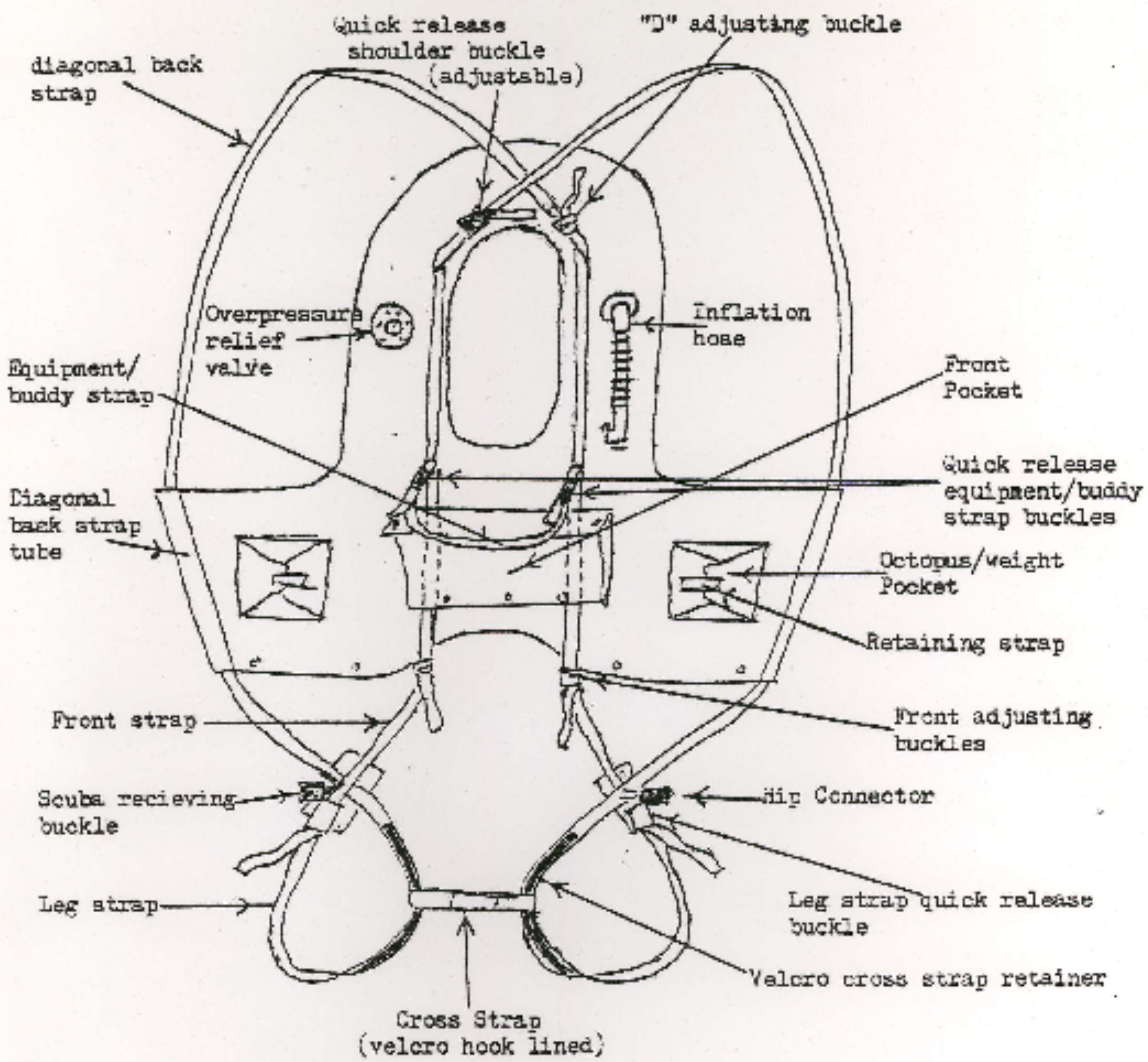
PARACHUTE HARNESS DESIGN

SMOKEJUMPER AT NCSB

PARASCUBA WITH THE USAF—RICK HARDER, "THE BAGGER"

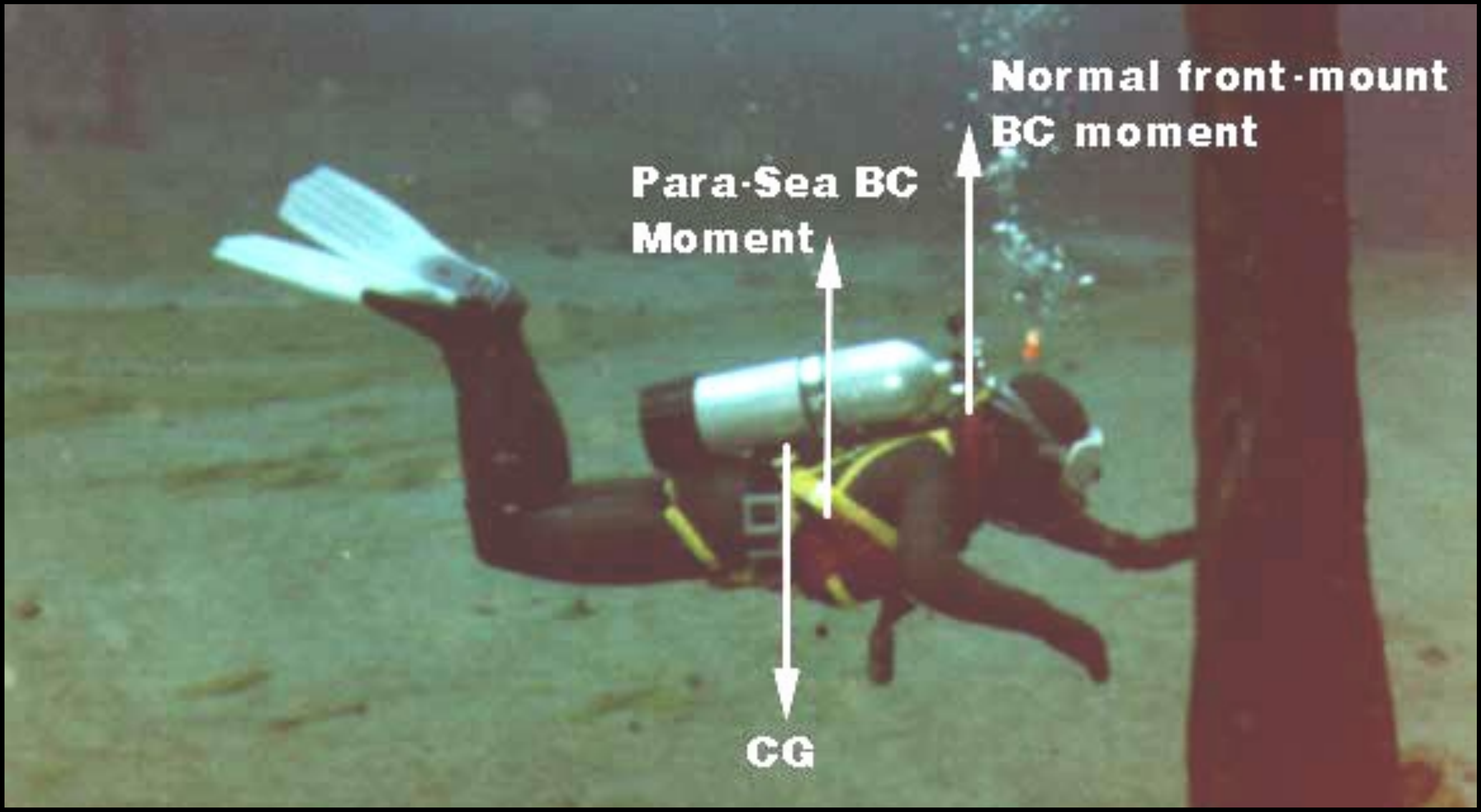
- 304TH AEROSPACE RESCUE AND RECOVERY SQUADRON
- PARACHUTE OVER SCUBA
- THE HARNESS WORKS WHEN JUMPER IS SUSPENDED
- DETAILS IMPORTANT—NOTE MASKING TAPE ON THE MASK STRAP!
- SINGLE HOSE USD CALYPSO REGULATOR, WITH A SINGLE HOSE
- DUCK FEET FINS

THE PARA-SEA BUOYANCY COMPENSATOR



MY CONTRIBUTION TO BC'S

PARA-SEA BC CONCEPT



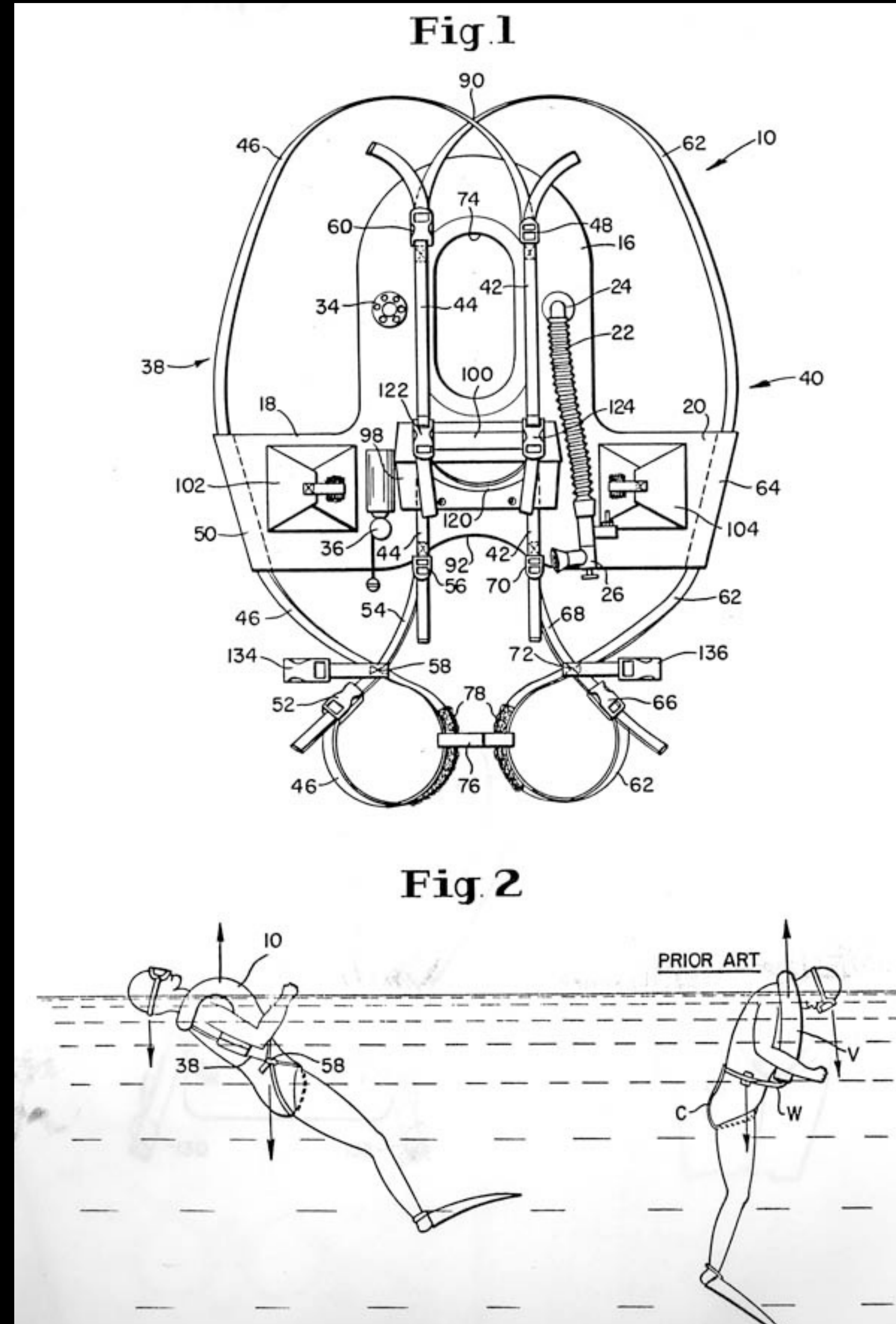
NASA—APOLLO 11 RECOVERY, NOTE INFLATION BALLOONS

APOLLO 11, STABLE 2

APOLLO RECOVERY OPS

APOLLO 11 IN THE WATER

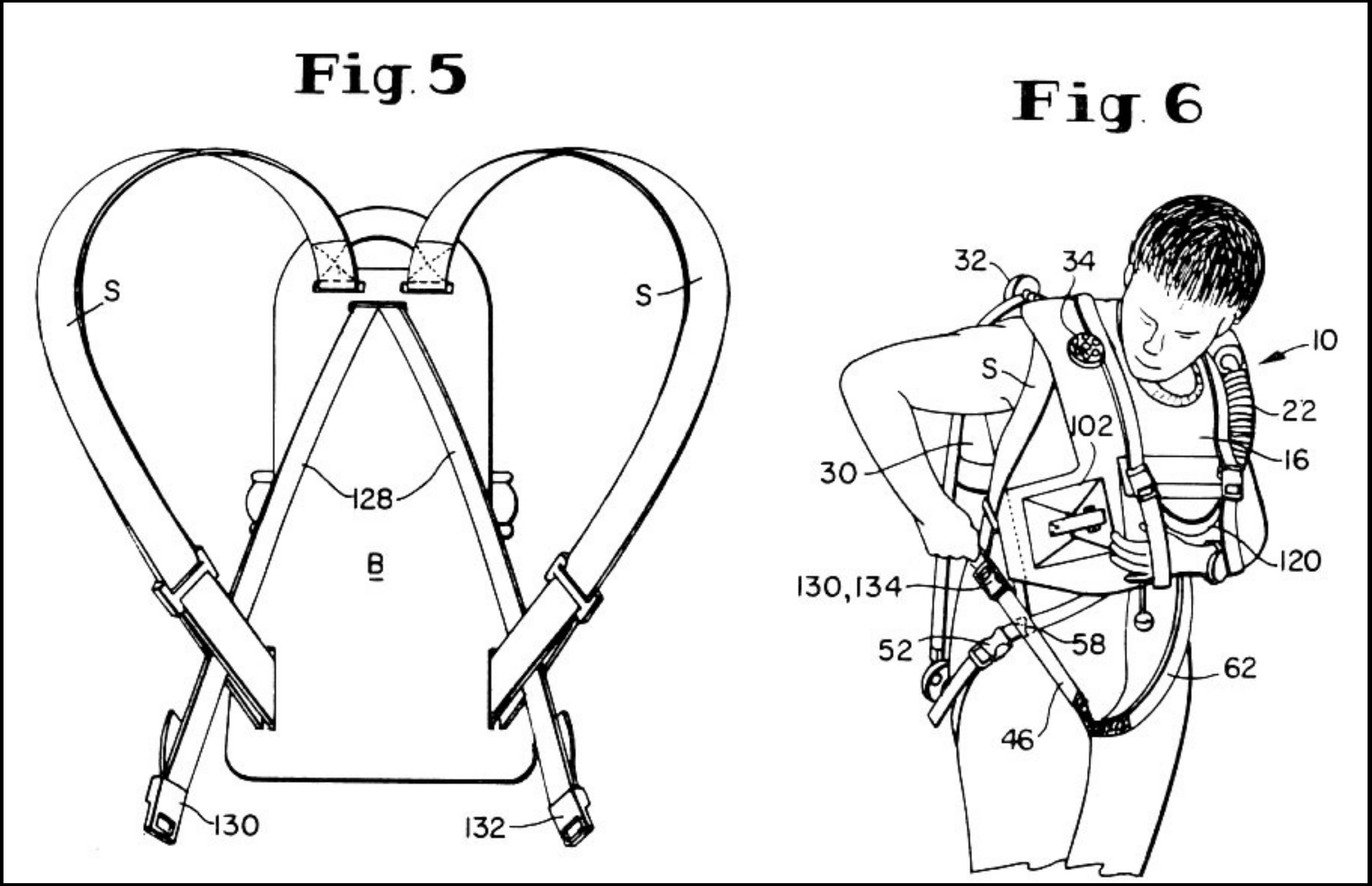
PARA-SEA BC
PATENT DRAWING



- Stable 1—face up.
- Stable 2—face down.

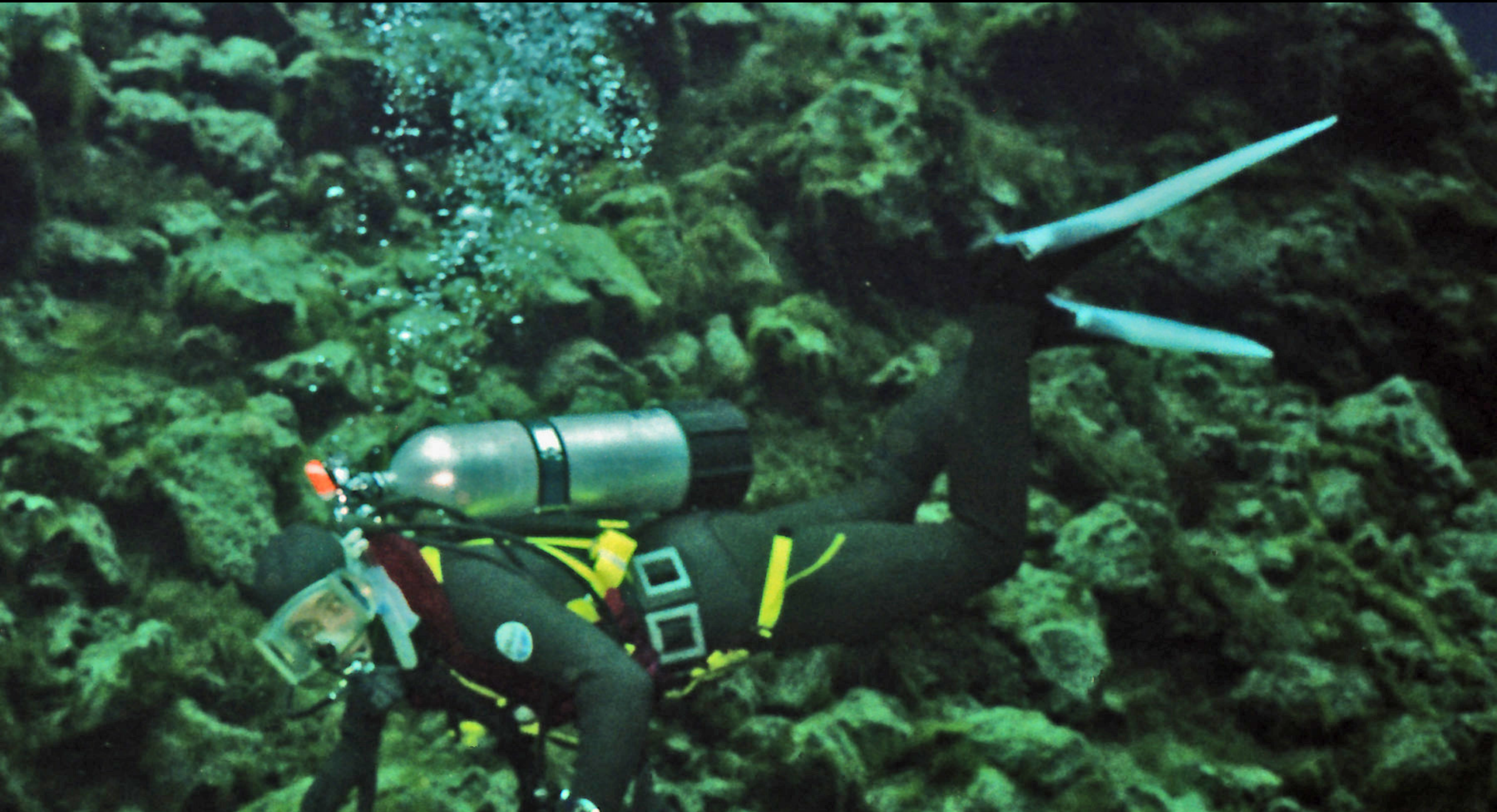
PARA-SEA BC CONCEPT

INTEGRATION OF THE BACKPACK



CLEAR LAKE

TESTING PARA-SEA BC



PARA-SEA PERSONAL FLOATATION DEVICE (PFD)

- great for canoeing or water sports
- easy to get on
- can be donned in a seated position
- can be used by handicapped individuals

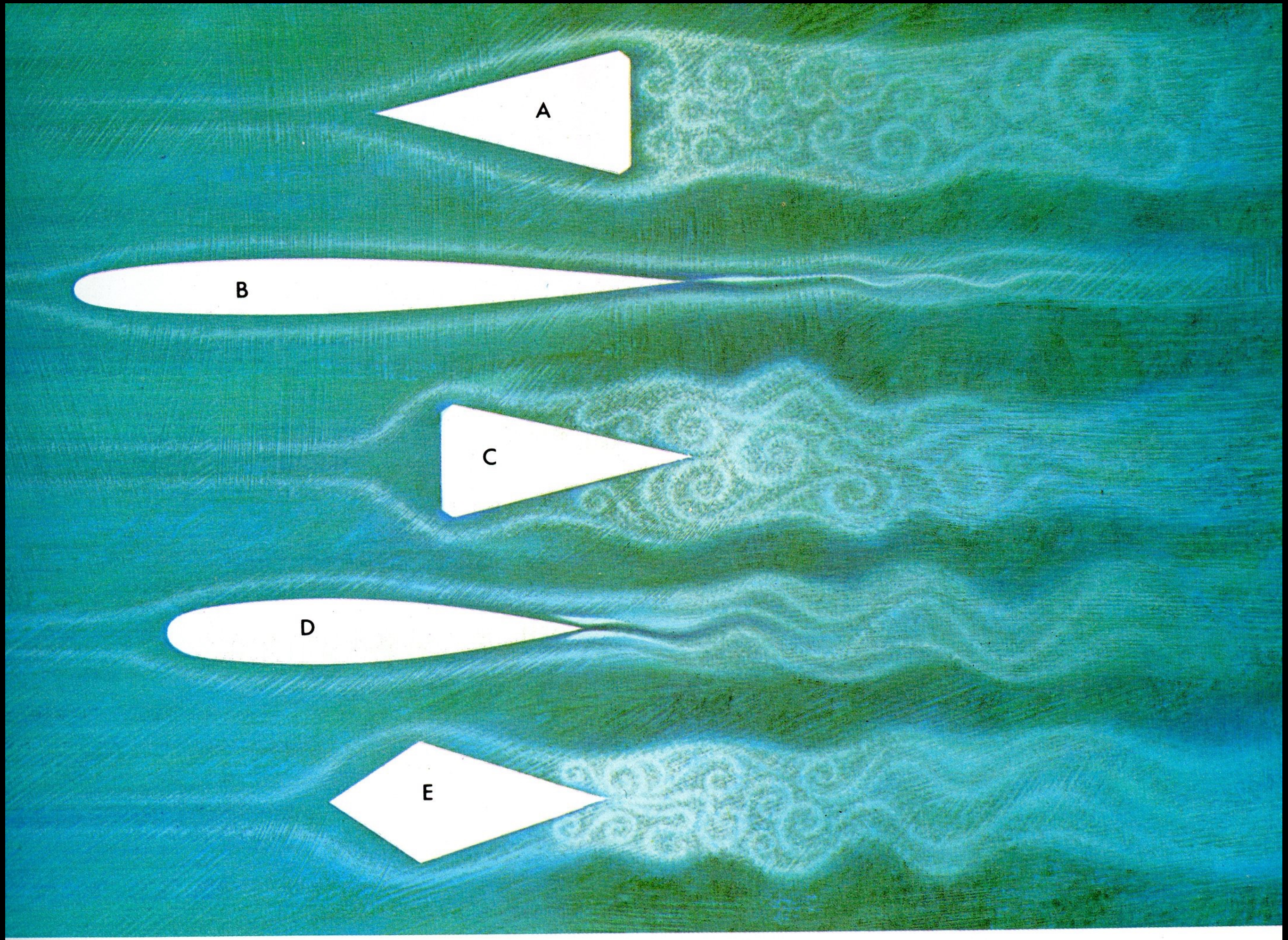
The Para-Sea PFD prototype.

PARASEA PFD

CANOEING, NORTH UMPQUA RIVER

THE ART OF MOTION— THE OCEAN WORLD OF JACQUES COUSTEAU

- Early divers looked like example "D" or "E."
- Finswimmers look like "B."
- Today's Technical divers look like example "C."
- We have lost our ability to move freely in the water if we dive as "Technical Divers."



Streamlining

Water flow can be *laminar* (smooth), *turbulent* (irregular), or *transitional.* Laminar flow creates the least drag, and turbulent flow the most. In practice, any fish or mammal or man-made hull produces transitional flow, as perfect laminar or totally turbulent flows are never encountered.

Streamlined bodies promote laminar flow and the faster an object travels through water, the more streamlined it must be.

Turbulence begins to set in when the thin layer of water immediately next to the moving body (the "boundary layer") becomes unstable. Such instability is, at least partially, inevitable in man-made rigid hulls. If the turbulence in the boundary layer can be stabilized, then laminar flow can be maintained over the entire organism. It seems that fish and marine mammals have such a stabilization mechanism: by constantly changing their shape to conform their body surfaces to the lines of flow they are able to move at speeds that could not be matched by exact, but rigid, replicas of their forms.

A / Pointed nose. *This shape eases cutting through the water, but the broadness of the after portion causes heavy drag and boiling up of water just behind the body.*

B / Long and slim. *This characteristic bullet shape of the fusiform body like that of a barracuda or a shark. It creates less turbulence as this drawing based on a photographic study indicates.*

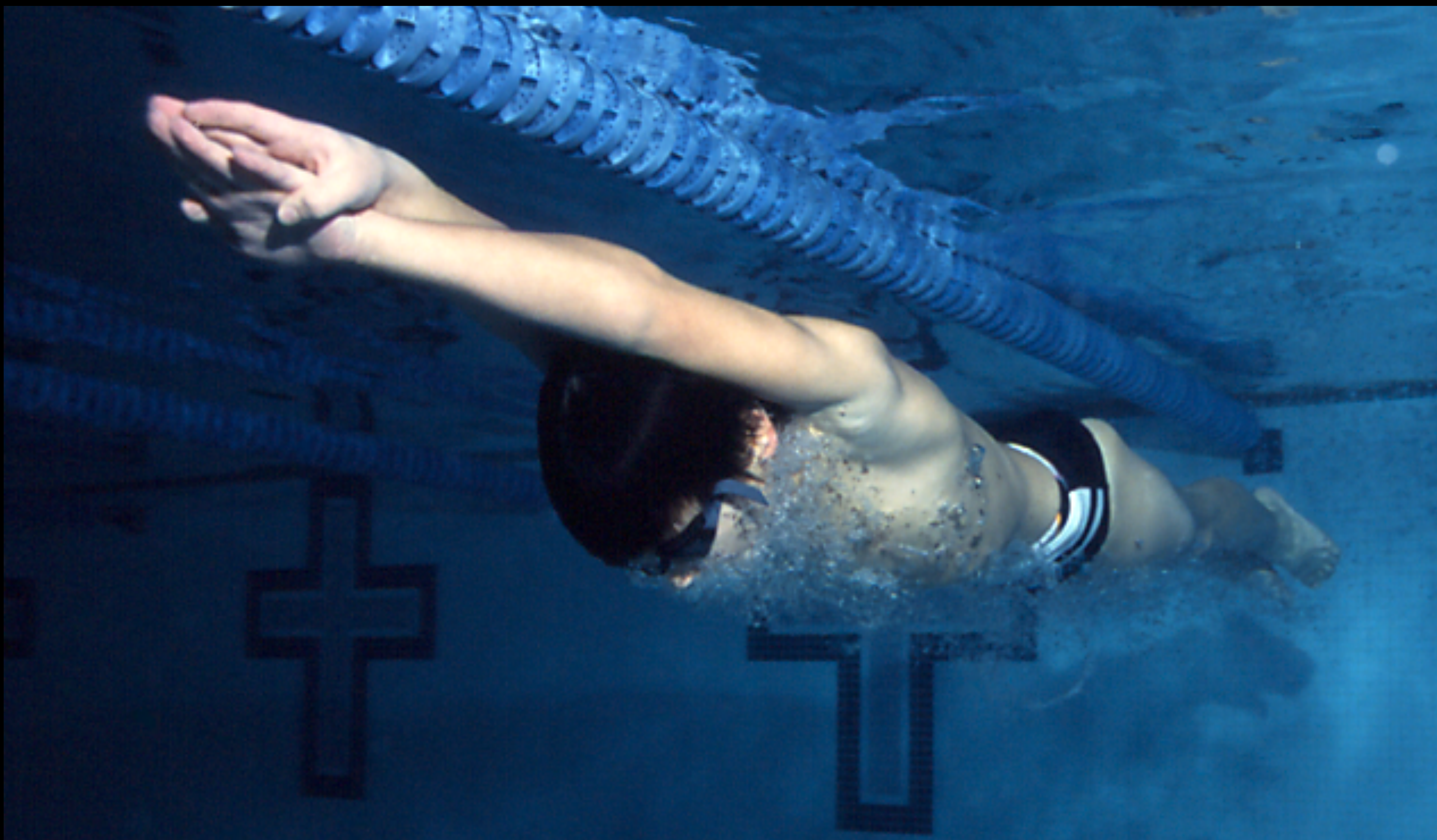
C / Blunt front. *This is the least efficient shape shown; it stirs water and creates the most turbulence.*

D / Shortened and broadened. *This shape creates greater turbulence than does the fusiform body.*

E / Angular on the sides. *This shape creates still greater turbulence.*

SON NATHAN RATLIFF DEMONSTRATES COMPETITIVE SWIMMER'S STREAMLINING

STREAMLINING



BUOYANCY CONTROL TODAY—TECHNICAL DIVING

POTENTIAL ERGONOMIC PROBLEMS WITH DUEL INFLATION SYSTEMS

https://en.wikipedia.org/wiki/Technical_diving

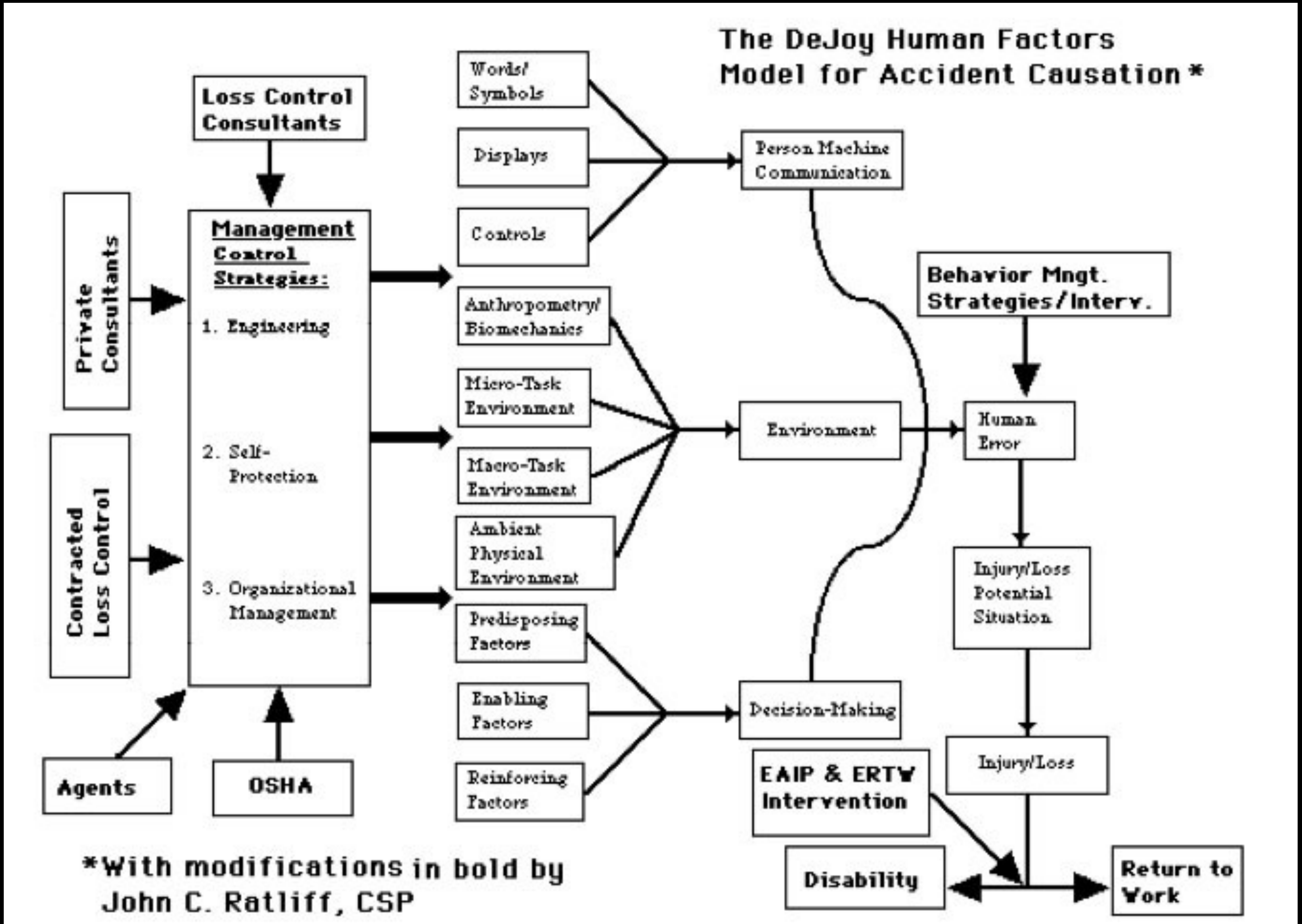
TECHNICAL DIVING—ADD A DRY SUIT; HTTP://OCEANEXPLORER.NOAA.GOV/TECHNOLOGY/DIVING/TECHNICAL/TECHNICAL.HTML

TWO BCD'S, 4 REGULATORS, TWO DIFFERENT METER SYSTEMS, HEAD'S UP DISPLAY IN MASK. MOVEMENT VERTICALLY FAIRLY EASY, BUT DEPENDENT UPON THE BC.

Tom and Brett on the deco bar at 20 feet.
Brett watches over Tom and Jill as they perform
their decompression obligation prior to surfacing.

DIVING ACCIDENTS INVOLVING BUOYANCY PROBLEMS

PAY PARTICULAR ATTENTION TO THE TOP LINE—PERSON-MACHINE COMMUNICATIONS



BRITISH SUB AQUA CLUB 2007 ANNUAL REPORT

September 2007 07/334

Equipment

Two divers entered the water to conduct a shore dive. After 60 min one of the divers discovered that her BCD was dumping air and she could not maintain her buoyancy. She tried to remove her weight belt but it became entangled around her wrist. The divers were at the surface in 6m of water. The divers called for assistance, the Coastguard was alerted and a helicopter and a lifeboat were tasked to assist. The divers managed to move to shallower water and release their weights. A local fishing boat helped them to the shore. Neither diver suffered subsequent ill effects. It is thought that the BCD valve was faulty or jammed open. (Coastguard report).

April 2007 07/063

Two divers dived to a maximum depth of 27m. At 20m one of the pair lost control of his buoyancy and made a fast ascent to the surface. His buddy tried to slow him but lost him at 8m. The diver then re-descended to 20m followed by his buddy. They moved to the edge of a reef at 15m where they checked air. The diver who had made the buoyant ascent was found to be out of air. They surfaced using the buddy's octopus regulator and completed a 3 min stop at 6m. The divers were recovered from the water and the diver who had been out of air was placed on oxygen. No subsequent ill effects were experienced.

CPSC RECALLS [HTTP://WWW.CPSC.GOV/EN/RECALLS/](http://www.cpsc.gov/en/recalls/)

- Aqua Lung buoyancy compensators with SureLock II weight pocket handles; the rubber handles can detach as divers are trying to remove the weight pockets to rise to the surface in an emergency. This poses a drowning hazard. 2014
- Sea Elite BCD—The spring in the overpressure valve can corrode and break preventing the buoyancy control device from retaining air, posing a drowning hazard…2011
- Edge and HOG (Highly Optimized Gear) BCD, the spring in the overpressure valve can corrode and break preventing the buoyancy control device from retaining air, posing a drowning hazard…2011
- Cressi-sub S.p.A.; a slow leak from the shoulder exhaust caused by expansion of an internal cable housing could result in slow deflation. This could impact the diver's ability to control buoyancy. 2005

RECALLED AQUA LUNG BCD

- November 12, 2014 recall date
- CPSC Recall number 15-022
- Weight handles can dislodge.
- http://www.cpsc.gov/en/Recalls/2015/Aqua-Lung-Expands-Recall-of-Buoyancy-Compensators/

“Vintage diving can lead divers into the 21st Century”

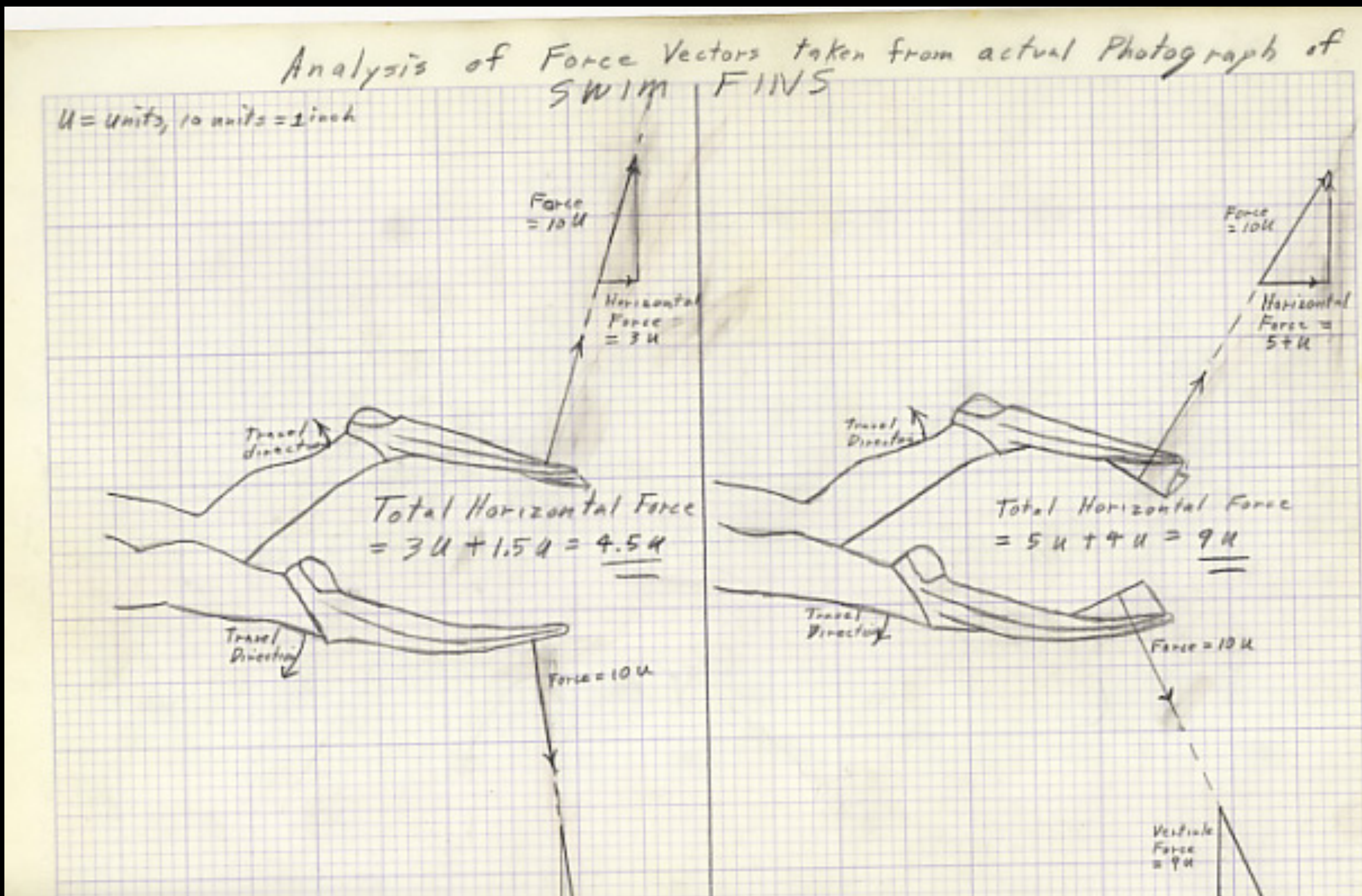
JOHN C. RATLIFF

EXTRA SLIDES

- Integrating equipment designs with underwater swimming techniques
- Adding new designs for better, more streamlined and powerful horizontal swimming
- Adapting the Para-Sea BC to use by double amputees

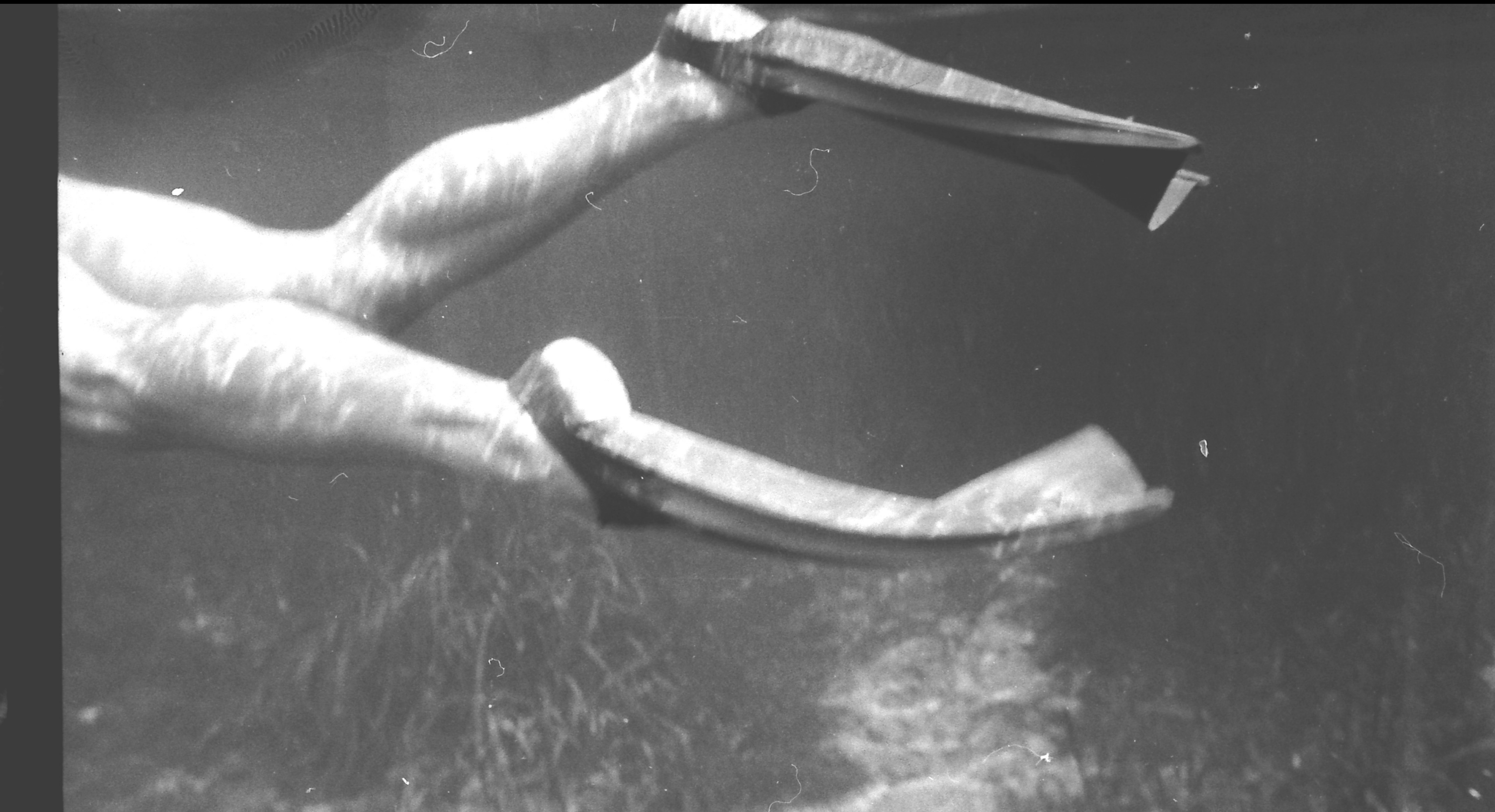
SEARAT'S SCUBA INTEGRATED UNITS

SCOOP FIN VECTOR ANALYSIS



SEARAT'S SCUBA INTEGRATED UNITS

AMF VOIT V66 MODIFIED SCOOP FINS



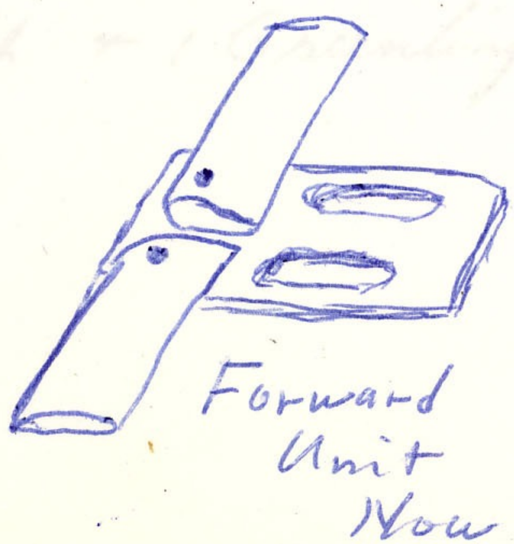
SEARAT'S SCUBA INTEGRATED UNITS

PLANA AVANTI MODIFIED SCOOP FIN

SEARAT'S SCUBA

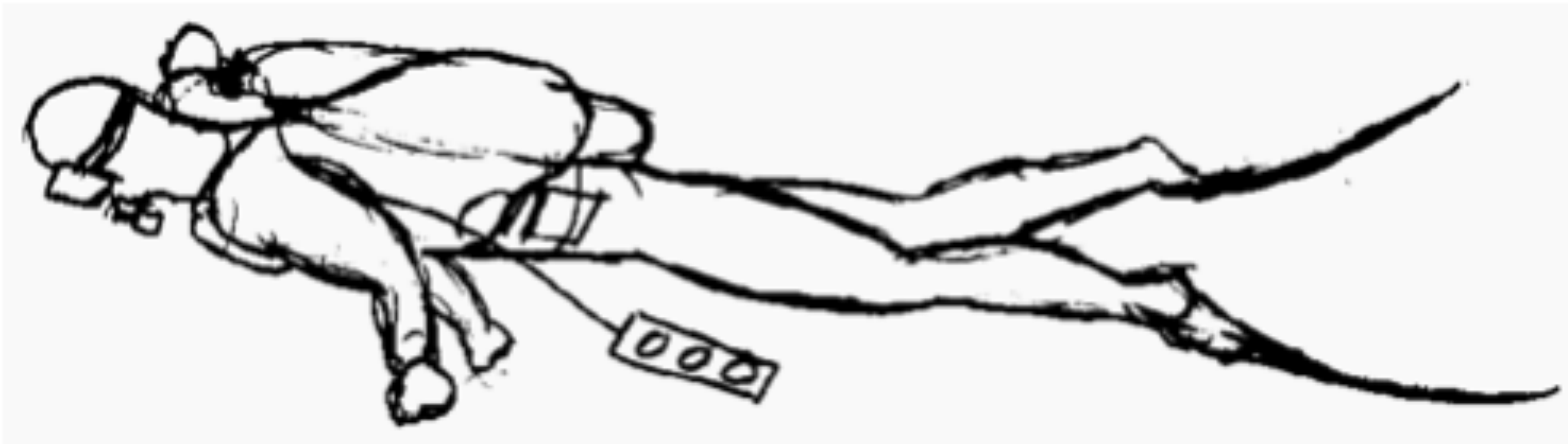
HAMMERHEAD UNIT
FORWARD UNIT EVALUATION 1976

Special Problems and Ideas: ① Should conduct experiments in a large pool. ② Must build a forward unit ③ Had to abort dive due to leaks in my mits (Left thumb froze) ④ Hand grips on forward unit cramped fingers (no wet suit gloves) badly - need handgrips



SEARAT’S SCUBA

SEA-TURTLE:DOLPHIN SWIMMING

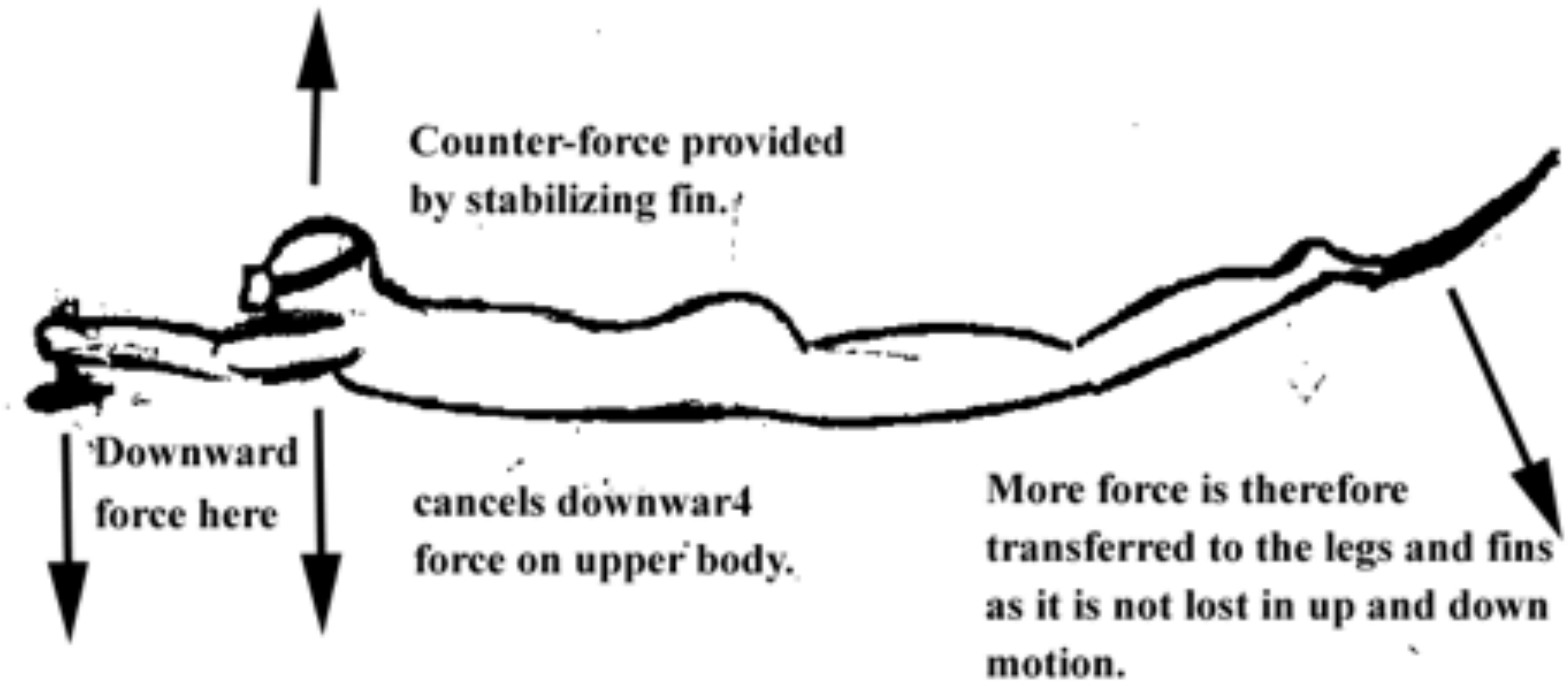


Today’s diver

Diver with the Hammerhead Unit

SEARAT'S SCUBA

SEA-TURTLE:DOLPHIN SWIMMING



Swimming with the Hammerhead Unit is easy, and allows the unit to cancel out the forces created by the dolphin kick.

SEARAT'S SCUBA INTEGRATED UNIT

PARA-SEA BC HARNESS INTEGRATED WITH HOLDER FOR DIVERS WITH DOUBLE AMPUTATIONS, USING THE HAMMERHEAD FORWARD UNIT AND MODIFIED SCOOP FINS