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SUMMARY OF SYMPOSIUM ON USE OF SELF-CONTAINED UNDERWATER BREATHING APPARATUS ("SCUBA"), AT MEETINGS OF PACIFIC DIVISION OF AMERICAN SOCIETY OF LIMNOLOGY AND OCEANOGRAPHY, LOS ANGELES, CALIFORNIA, JUNE 22, 1955.

Notes taken by G. P. Cooper

The Pacific Division of the American Society of Limnology and Oceanography met with the Pacific Division of the AAAS at Los Angeles on June 22 and 23, 1955. They devoted a full day of their program to a symposium on the use of self-contained underwater breathing equipment as it is being used in connection with fisheries research work, especially in marine habitats on both the Atlantic and Pacific coasts and also to some extent in fresh water. The several speakers on the symposium were mostly from fisheries research stations on the Pacific coast, especially the Scripps Institution of Oceanography. A list of the speakers and their subjects is as follows:

(1) Ramsey Parks, of Scripps Institution. Subject: Underwater Diving Equipment.

(2) Robert Huffer, of Scripps Institution. Subject: The Scripps Training and Safety Program.

(3) John H. Steelquist, 2120-4th Street, San Diego. Subject: Physiology on Diving.

(4) Conrad Limbaugh, of Scripps Institution. Subject: Natural-Light Underwater Photography.

(5) Conrad Limbaugh. Subject: Motion Pictures of Marine Life.

(6) Frank Hetzel, Key Laboratories, San Diego. Subject: Underwater Television Developments.

(7) Hugh Bradner, U. of California, Berkley. Subject: European "SCUBA" Equipment and Diving Techniques.

(8) David G. Moore, Geological Diving Consultants, San Diego, California. Subject: Underwater Geological Observations.

(9) David G. Moore. Subject: Motion Pictures of Geological Explorations.

(10) Andreas B. Rechnitzer, of Scripps Institution. Subject: Recent Scientific Applications of "SCUBA".

(11) Comdr. Payne, U. S. Navy. Subject: Use of Underwater Diving Equipment in Demolition and Salvage.

(12) David M. Owen, Woods Hole Oceanographic Institution, Woods Hole, Mass. Subject: The Status of Free Diving at Woods Hole Oceanographic Institution.

(13) David M. Owen, Subject: Motion Pictures of Fish Trawl in Operation.

The balance of the present report is a summary of notes based on each speaker's comments. These notes were taken down in considerable detail, but there was no opportunity to recheck the notes with each speaker, and therefore there is some chance for an occasional misinterpretation of what a particular speaker actually said, or intended to say; but these instances would be at a minimum.

REMARKS BY MR. PARKS, ON EQUIPMENT

Face masks should be glass; plastic is not satisfactory. Swim fins should fit tightly. The weight belt should always have a safety release, which can

be released readily and easily by one hand. Weight belts are generally weighted with lead.

Diving suits may be of the "wet type" or "dry type". Neoprene or foam rubber suits are somewhat compressible in deep water, and therefore lose some of their buoyancy in depths of 50 feet or more. This would not be an important factor in shallow-water diving (under 30 feet) in Michigan lakes. A disadvantage of the "dry suit" is that a snagged suit will fill with water and the diver loses some of his buoyancy. Also, using the "dry suit" in deep water, air trapped within the suit compresses with descent, causing a loss of buoyancy, and often causing wrinkles in the suit which may result in skin blisters. A type of constant-volume "dry suit" can be obtained with which the amount of air inside the suit can be adjusted upon descent, thus overcoming some of the disadvantages of the "dry suit".

For the Aqua-lung, several types of air regulators are available, but the speaker recommended that the beginning diver start out with the simplest type of air regulator; after becoming an expert with diving equipment and in the use of the air regulator, more specialized types of regulators can then be used to some advantage.

The speaker rated the Scott Hydro-pack diving equipment as "good" so far as efficiency is concerned, but later remarks by this and subsequent speakers indicated that practically all divers on the Pacific Coast are using the Aqua-lung rather than the Hydro-pack.

A type of breathing apparatus is available which consists of a rubber bag, and the diver re-breathes the same air out of, and back into this rubber bag. Air is reoxygenated chemically in the bag. This equipment is much more dangerous to use than equipment involving breathing of compressed air, the re-breathing equipment requiring more maintenance; and it should not be used below a depth of 30 feet. It should be used only by highly trained personnel.

Underwater accessories which are regularly used by divers in fisheries research include compass, watch, writing pad and grease pencil, depth gauge, and underwater cameras, all of which are especially constructed for underwater use.

REMARKS BY ROBERT HUFFER ON TRAINING AND SAFETY AT SCRIPPS INSTITUTION

Scripps Institution has a regular training program for biologists and geologists in the use of underwater equipment for diving. The diver must pass a physical examination (by an M. D.). He should be a good swimmer, able to swim at least 1000 feet without accessories. He must be able to swim at least 75 feet under water.

The special training and indoctrination on equipment and safety involves about 20 hours. Very extensive training on the use of equipment is first carried on in an indoor swimming pool. The diver becomes completely at home with the gear to the point where he can take the gear off and put it on again under water. He practices this by swimming to the bottom of the pool (depth about 12 feet), shedding the equipment on the bottom of the pool and coming to the surface; he then dives back down again, puts the equipment on, clears the breathing tubes of water, opens the valves and breathes again through the equipment. It is an important part of this training for two divers to go to the bottom of the pool, and remain there for some time, the two divers breathing from one mouthpiece and one set of diving equipment.

The diver also practices in the use of emergency floatation gear ("May Wests.")

REMARKS BY DR. STEELQUIST ON PHYSIOLOGY OF DIVING

Dr. Steelquist, an M. D., Specializes in lung surgery.

When a diver breathes from a compressed air tank, while at a considerable

distance underwater, he is taking air into his lungs at a pressure considerably greater than normal atmospheric pressure. This pressure doubles at 33 feet, trebles at 66 ft., and so forth. Doubling the pressure at 33 feet also doubles the solubility of inhaled gasses in the blood stream. The increased pressure of gas in the lungs, and increase in solubility of gas in the blood stream, are among the chief reasons for accidents which occur to divers. Dr. Steelquist discussed six types of accidents, of a physiological nature, which can occur to divers, as follows:

(1) Squeeze. A compression of air in the inner ear and sinuses, as the diver descends, accompanied by pain. Colds, sinus infection, and so forth aggrevate the situation. Rupture of the ear drum and bleeding of nasal sinuses sometimes result. No diving if a person has a severe cold. Normally there is a slow passage of air to the inner ear and to the sinuses as an adjustment to this pressure, but this is impossible with a bad cold. A "dry hood" (tight head gear) makes adjustment of inner ear more difficult.

(2) Air embolism. Potentially this is one of the more serious physiological hazards to the diver. A deep diver when breathing from a compressed air unit, say at a depth of 33 feet, is inhaling air with twice the normal (surface) pressure. If at a depth of 33 feet the diver filled his lungs from the breathing apparatus, and then swam to the surface while keeping all of this air inside his lungs, the air in his lungs would tend to expand to twice its volume. The result is that this expansion of air within the lungs will tear lung tissue, and allow air bubbles to get into the blood stream by entering blood vessels in the lung area. These air bubbles may then be carried in the blood stream to various parts of the body causing serious damage. The diver may bleed at the mouth and nose, due to hemorrhaging in the lungs, and

the air bubbles carried within the circulatory system (embolism) may block tiny capillaries and cause serious damage to the brain and other vital organs.

The precaution against air embolism is that a diver who has been breathing from a compressed air unit should not hold his breath while coming to the surface. Rather he should constantly exhale air during this ascent. The rule which divers recommend is that the ascending swimmer should constantly exhale a small stream of air, and that he should swim to the surface no more rapidly than the rate of ascent of the exhaled air bubbles (no faster than about 25 feet per minute). Air embolism can happen upon ascent from depths of as little as 15 feet. If the diver has had some trouble with his breathing equipment, the worst thing he can do is to get panicky, hold his breath, and swim rapidly to the surface; all three actions are wrong. Don't come up any faster than the rate of rise of the smallest air bubbles.

(3) Oxygen poisoning. Occurs when a diver is using breathing equipment involving pure oxygen. Oxygen poisoning can occur only when diving in depths of about 35 feet or more, and when the diver stays down for about 30 minutes or more. Breathing pure oxygen at considerable depths for an extended period, resulting in too great a concentration of oxygen in the blood stream, may result in convulsions.

(4) Carbon dioxide poisoning. May result from long dives and a partial failure of the air supply, during which the diver is getting too little oxygen and is being slowly poisoned by his own carbon dioxide. This would be most apt to happen after the diver had become lethargic, and had been breathing only small gulps of air, with considerable

rebreathing of carbon dioxide from his own face mask and breathing tubes. The symptoms are dizziness and nausea. The diver should use regular and deep breathing.

(5) Nitrogen narcosis. A function of pressure. After long exposure to deep pressures, the blood stream has accumulated an unusually large quantity of nitrogen in solution. The physiological effect is that the diver partly loses his senses and becomes carefree ("slap happy"). Divers refer to the sensation as "wanting to take off the face mask and make friends with the fish." The condition is also referred to as "raptures of the depths." The condition is not apt to occur among divers working for no longer than a half hour or so in water less than 35 to 50 feet deep.

(6) Bends. At the increased pressure to which divers are subjected, the blood stream absorbs a higher-than-normal concentration of nitrogen in solution. If a diver rises too rapidly to the surface, nitrogen bubbles appear in the blood stream. These bubbles may then block the circulation of blood through tiny capillaries. The effect is dizziness, pain in muscles, joints and tendons, and damage to the nervous system. Bends is a potential danger when diving in depths of over 65 feet, but not at lesser depths. Presumably divers in Michigan lakes will not work at depths exceeding 65 feet. The U. S. Navy has a standard table of decompression rates, for prevention of bends, giving the maximum rate at which divers should ascend from various depths, and giving the rate at which divers with the bends should be treated in a decompression chamber.

REMARKS BY MR. LIMBAUGH ON UNDERWATER PHOTOGRAPHY

Mr. Limbaugh discussed mostly the problem of light penetration into water,

and the matter of exposure times for underwater photography at various depths.

If a light meter shows that the correct f stop for a photograph immediately above the surface of the water is a certain value (for example f8), the correct f stop for a photograph immediately below the surface of the water would be f4 (1/2 the above-surface value). Exposure times and f stops are adjusted accordingly for increase in depth. With very clear and transparent water the correct f stop for a depth of 10 meters would be f 2.8 (if the correct f stop just above the surface was f8). Exposures and f stops must also be adjusted for differences in transparency of the water.

The speaker gave a general rule for the distance between camera and photographic subject under water, this distance being about 1/2 the distance of a Secchi Disc reading.

REMARKS BY MR. HETZEL ON UNDERWATER T. V.

The speaker pointed out that underwater T. V. is a relatively new tool, not yet fully exploited. Apparently one of the first uses of underwater T. V. was at Bikini in 1947. In 1951, the British Navy used underwater T. V., at depths of 200 to 300 feet, for salvage of wrecked ships. It has also been used for locating underwater wreckage of air craft. At present, underwater T. V. equipment has been designed for work at depths of up to 2000 feet, with surface controls for adjusting the intensity of artificial light.

DISCUSSION

At this point in the symposium there was discussion from the floor which brought out the following:

Along the West Coast of the U. S., at least two persons have been drowned

while using underwater diving equipment. Thus most of the colleges along the West Coast have banned the use of underwater diving equipment by members of their staff, on university property, or on university research projects. Scripps Institution at La Jolla is about the only institution on the West Coast where underwater diving is officially sanctioned, and there it is approved only after the intensive training program described above. The accidents which have occured have been the result of ignoring standard safety rules and because the divers were not expert in the use of their diving equipment. All speakers emphasized the fact that divers always work in pairs, using the "buddy system." No diver ever goes into the water alone.

All speakers emphasized the fact that divers, if they have been underwater a while, do not think so clearly as when above water. This lethargy is due to becoming chilled in cold water and due to various other physiological disturbances (nitrogen accumulation, restricted breathing, and so forth, as discussed by Dr. Steelquist).

REMARKS BY MR. BRADNER ON EUROPEAN "SCUBA"

Considerable diving has been done in France and Italy since about 1948, in the Mediterranean, mostly with pure-oxygen equipment. In Germany and England, divers have been active only during the past two years or so. In Europe, much of the diving is by private individuals for recreation, and very few scientists employ diving as a means of research. However, Europe has made good progress in the use of underwater T. V. and photography. They use artificial light for both still pictures and movies underwater, using lighting up to 10,000 watts. For underwater still pictures they are using both photoflash and stroblight.

Some of the amateur European divers are very careless on safety precautions.

REMARKS BY MR. MOORE ON "SCUBA" FOR GEOLOGICAL OBSERVATIONS

Geological observations of underwater rock formations along the Pacific Coast and around Pacific islands are being carried on intensively. These underwater geological surveys include mapping of compass directions and "strike" of rock layers, mapping of underwater canyons, studying the ripple structure of sediments, and so forth. Geologists have made about 2500 dives off the California coast, in depths up to 100 feet, without accident. Their men take "SCUBA" training at Scripps, follow safety rules closely, and always follow the "buddy system." They work as a three-man team, always with one of the three men in the boat, and the extra man in the boat is an alternate diver (taking turns). The two divers swim traverses, both make observations, recording observations underwater on a writing slate with a grease pencil, and recheck their notes underwater.

While working in shallow water of 10 to 25 feet, they can stay down for as much as an hour, but they believe it best to limit their dives to 15 to 20 minutes duration, after which they come to the surface for an extensive recording of notes.

MR. RECHNITZER ON RECENT SCIENTIFIC APPLICATION OF "SCUBA"

In addition to the routine collection of fish and making direct observations of fish life histories, divers have found it possible to make direct observations on water layers of differential densities, on plankton concentrations, on interphases between well-defined water layers as in thermocline, and on the occurrence and movement of distinct "pools" or "tongues" of water of different temperatures, densities or salinities. Along the Pacific Coast divers have also made archeological explorations on Indian relics (up to 10,000 years of age), down to a depth of 100 feet. There is an extensive archeological exploration going on at the present time off the California Coast near La Jolla.

Another use of "SCUBA" along the California Coast is the inventory of kelp beds which are harvested commercially.

COMMENTS BY COMMANDER PAYNE, U. S. NAVY

Comdr. Payne introduced his subject by stating that, "man for man, the underwater diver is the most important man in the armed forces." In the Navy the diver is used for underwater demolition activities, for the removal of wrecks in bays and harbors, charting bottoms for beach landings, and so forth. Navy divers frequently use pure-oxygen equipment, so that tell-tale bubbles do not appear at the surface. Navy divers adhere closely to safety rules.

REMARKS BY MR. OWEN ON "SCUBA" AT WOODS HOLE

Underwater diving has been going on at Woods Hole, Massachusetts, for the past three years. Eighteen full-time employees have used "SCUBA" to some extent, and 7 to 8 use it regularly. They have had one minor casualty, developing hemorrhage of the inner ear in one diver, with only temporary effect.

In the marine water of Woods Hole, underwater visibility is generally about 6 feet, the waters are cold, and diving is difficult.

Diving is used for direct observations on interphase layers in the thermocline, scattering layers, observations of fishing banks, bottom topography, and for photography of fishing nets in action.

All divers are subject to a formal training program involving a detailed physical examination and comprehensive tests in an indoor swimming pool. Divers have a physical examination annually.

Woods Hole has 6 Aqua-lungs and 2 Hydro-packs. They have not used their Hydro-packs so far, except in swimming pools.

One of the tests which their divers must pass in training is as follows: The diver, with swim fins, and on one breath of air, swims underwater the length of a 25-yard pool and gets into his Aqua-lung outfit underwater.

Woods Hole has a film describing "SCUBA" training.

FURTHER COMMENTS BY MR. PARKS ON THE AQUA-LUNG VS. THE HYDRO-PACK

Following the symposium, Mr. Parks was "cornered" for a further discussion of the merits of the Hydro-pack. He stated that Scripps Institution and others on the West Coast are using the Aqua-lung. None are using the Hydro-pack at the present time, although Scripps has one of these outfits. Reasons: Aqua-lungs are cheaper, more flexible in use, involve less maintenance, and are possibly basically safer. Mr. Parks' opinion was that the Hydro-pack gives a false sense of security because of the complete face mask, but that it is basically less safe in case of an emergency such as if a face mask should be broken. With the Aqua-lung, two people can breathe from one outfit (after considerable experience), but this is not so with a Hydro-pack. Mr. Parks also suggested that with the Hydro-pack, the diver should not stay in over 35 feet of water for more than 15 or 20 minutes time, because of the danger of carbon dioxide poisoning.

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