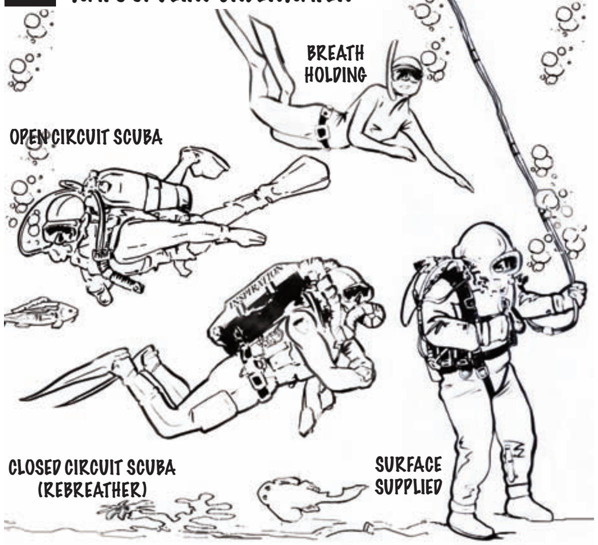
16.3 UNDERWATER CINEMATOGRAPHY

Underwater means anything that relates to beneath the surface of water, either fresh or seawater. Compared to filming on dry land working under water presents several major differences that make even the simplest task more difficult. A good rule of thumb when it comes to working underwater is to multiply time, people and money by three: a task that normally takes one person 1 minute and costs £ 100 will take three people 3 minutes and cost £ 300.

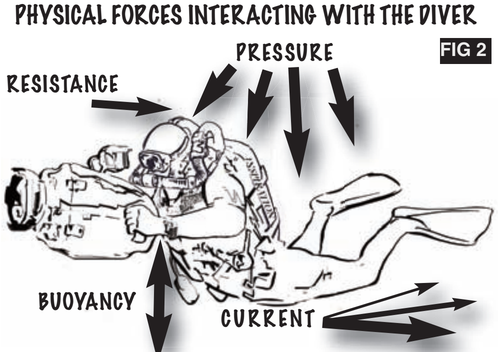
FIG 1 WAYS OF BEING UNDERWATER



There are many potential hazards when working in or around water. The equipment is normally heavier because it's built to withstand pressure and corrosion, surfaces are slippery, and everything needs to be made safe to prevent the risk of electric shock, especially when lights are involved.

There are basically four ways of being underwater: breath holding, open circuit scuba (Self Contained Breathing Apparatus), rebreather and surface supplied; all four require great care, attention and serious consideration because humans are not designed to be underwater, let alone work there.

PHYSICAL FORCES INTERACTING WITH THE DIVER FIG 2



The majority of underwater filming is achieved on scuba using cylinders containing compressed air. Scuba diving is considered a multitask activity and since operating a camera is also a multitask activity one can well imagine that combining the two is not everyone's natural activity. A certain predisposition is often desirable, not to mention a good fitness level and appropriate training and technical diving qualifications.

There are several physical forces affecting a diver underwater and this increases his workload (fig 2). This is the reason why in several countries worldwide working underwater is considered a hazardous activity and a commercial diving qualification is required. Specific safety measures are put in place, such as safety divers and a finite and carefully monitored time in the water, in order to protect everyone involved, in front of as well as behind the camera.

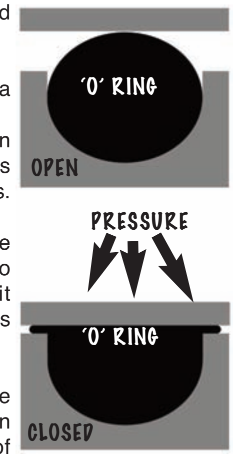
16.3.1 Housings

Water has a density of 998.2 Kg/m3, while air, at the same temperature of 20ºC, has a density of 1.2 Kg/m3. This factor makes water 829 times denser than air.

Pressure equals force applied to a unit area of surface, which in diving is one metre. One bar approximates to one atmosphere, 14.5lb per square inch, one kilogram centimetre squared, or the pressure exherted at the depth of 10 metres.

This means that in addition to the normal atmospheric pressure, water exerts increasing pressure on a submerged body, approximately 1 bar or 14.7 psi for every 33 feet or 10 meters of depth.

"O"-RING SEAL FIG 3



To film underwater either digitally or on film, a camera has to be enclosed in a housing, which is usually a sealed container with ports, controls to access the functions of the camera and monitors to check framing and functions.

All housings should be tested in the water WITHOUT the camera first, especially if the equipment has travelled by air.
The change of pressure within the cargo hold during flight can damage delicate parts of the housing and that is why housings should always be left slightly OPEN when stored in their cases.

Without the weight of the camera inside it's likely that the housing will be positively buoyant and it will be necessary to add weight to the outside of the housing to balance it (putting them inside would risk damage to the controls and is therefore unadvisable).

A small but sudden change of pressure can damage the housing, especially the port. The housing can be checked in just a few meters of water, since the most critical change of pressure happens within the first 15' (5 meters). Once deeper the increased pressure helps to maintain a good seal, especially on metal housings with an "o"-ring seal system (fig 3), if properly maintained and seated

A constant stream of bubbles going towards the surface indicates a leak: it is good practice to rotate the housing on different axis underwater to make sure all parts maintain the seal under pressure. All external controls should be operated to make sure they will not leak when used. Often rental companies add to the kit an instruction sheet on basic checks and procedures.
We can distinguish two types of housings: shallow water and deep water.
Shallow water housings are sometimes a "soft" sealed container, made mostly of neoprene and rubber, sealed by a zip like the one found on drysuits, with a purge valve to exhale trapped air and submerge the housing. A low-pressure inflator is sometimes present to add air and equalize pressure inside the housing.

This type of housing should not be used outside the recommended rated working depth, in fact one should use them in a conservative manner (if rated at 6 metres it would be better to stay within the 4 metres range). Wear and tear is possible because of the material used to build these housings and all seams and moving parts are prone to leaks. The sharp edges of some accessories attached to the camera, such as bars or plates, as well as some parts of the camera, can tear the shell and cause water ingress.
Sharp edges in contact with the shell should be padded.

The housing should be carefully inspected and tested before being used with a camera inside. Splash housings should not be submerged at all, since they are not designed to withstand pressure but only to protect the camera from water sprays. Deep-water housings are normally made of marine grade aluminium or clear polycarbonate. These housings have a seal made by an o-ring and the housing opens in two sections, to allow easy access to the camera in order to change the set up and to replace batteries, storage systems or to reload film.

All deep water housings should be treated as fragile objects and no one should be fooled by the bulk and weight: they are in fact quite delicate; a hard knock can compromise the seal leading to water flooding the inside.
All housings should be fitted with a water alarm sensor, to alert the operator while underwater as soon as water enters the housing. Sometimes these alarms can be triggered by condensation inside the housing, but in any case it is better to ascend safely and check inside. Before opening the housing after taking it out of the water it is good practice to dry the exterior well and so avoid water dripping on to the camera when releasing the latches.

16.3.2 Flat and dome ports

DOME PORT FIG 4

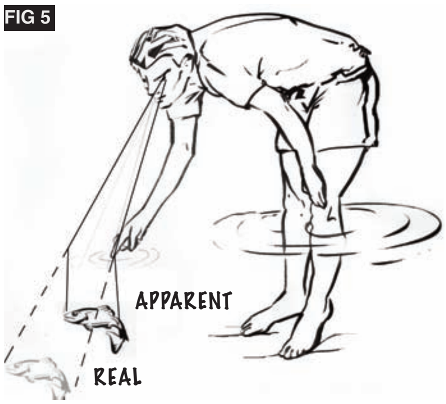
Housings are fitted with either a flat port or a dome port, often having both included in the kit. They can be made of glass or acrylic, and even though the acrylic can be quite good, glass is optically better, and less prone to scratch.

A dome port is preferable when using wide-angle lenses as it corrects the distortion that water causes because of the difference in density compared to air.

Water has a higher refractive index than air, 1.3 to be precise, because light travels through air at approximately 300,000 km/s and through water at 225,000 Km/s.

This causes a phenomenon called Apparent Distance, where objects appear to the eye (looking through glass, either mask or port) enlarged and in a different position. (Fig5)

FIG 5



This is summed up by the Fermat principle, which states that the Real Distance multiplied by the Air Index equals the Apparent Distance multiplied by the Water Index (RDxAI=ADxWI). In other words, distance appears to be shortened by 25%.

Therefore focus underwater can only by judged by eye through a viewfinder or, if using a tape measure, by compensating for the 25% magnification (1 metre on the tape should be marked 133 centimetres (1ft marked as 16 inches) as an object placed at 1metre underwater will appear as if 75cm away from camera, and also displaced (not on the same axis).
A dome port, thanks to the curvature of the glass, can correct the refraction caused by the water and bring the focal length of a lens to its equivalent on air (fig 6.)

TABLE A
LENS EQUIVALENTS COMPARISON CHART USING A FLAT PORT (SEAWATER)

	ABOVE WATER FOCAL LENGTH	ABOVE WATER ANGLE OF VIEW	UNDER WATER FOCAL LENGTH	UNDER WATER ANGLE OF VIEW
35mm	12	(80°)	16	(60°)
	16	(65°)	21	(49°)
	24	(45°)	32	(34°)
	35	(32°)	47	(24°)
	50	(25°)	67	(19°)
16mm	12	(45°)	16	(34°)
	16	(20°)	21	(15°)
	24	(12°)	32	(9°)
	35	(17°)	47	(13°)
	55	(10°)	73	(8°)
2/3" VIDEO	12	(40°)	16	(30°)
	16	(30°)	21	(23°)
	24	(20°)	32	(15°)
	35	(115°)	47	(86°)
	55	(9°)	73	(7°)

If a flat port makes a 35mm lens closer to a 50mm (considering 35mm film plane) the dome port will adjust the refraction and keep the field of view almost intact.

The concentric dome port creates a virtual image of a subject at infinity positioned at the entrance node at 4x the radius of the dome.

The entrance node of the camera lens must be aligned inside the dome matching the entrance node of the dome, positioned at the middle of the virtual sphere that the dome would create with its curvature. If the subject is closer to the dome, not at infinity, the virtual image will be created closer to the dome than the lens. In fact a dome port acts as a strong demagnifying lens.

Dome ports are marked with a measure in inches that indicates the inside diameter of the sphere created by the dome. Therefore, a 6 inch dome has a curvature radius of 3 inches. For this reason a dome with a large radius is preferable, as the virtual image is positioned further away from the camera plane allowing a wider choice of lenses, not just the ones

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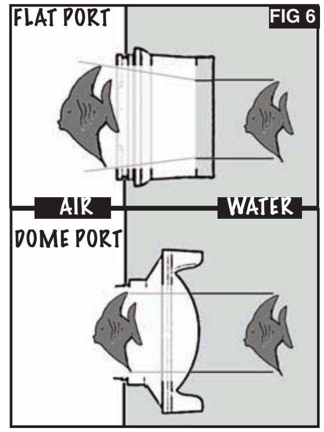


with very close focus capabilities.
Smaller radius domes also introduce chromatic aberrations such as colour fringing.

Most zoom lenses are not a good choice when it comes to underwater because the minimum focus is not short enough to focus on the dome, as well as the fact that the majority of zoom lenses are not as sharp as primes and not as fast in terms of aperture, and quite often zoom lenses, because of their bulk, do not fit inside most housings.

If the lens cannot focus close enough, a diopter can be used to focus the lens to the dome's virtual image. Often a +2 diopter is enough to adjust focus.
As a rule of thumb it is better to use a flat port for long lenses or macro photography and use a dome (hemispheric) port for any wide-angle lenses.

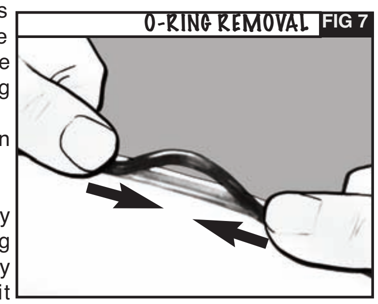
Remember that a flat port will produce colour fringing and aberrations if used with wide-angle lenses. When the shot starts or ends outside the water it is advisable to use a flat port. If the shot is half in half out of the water it is better to use a dome with a wide angle to avoid the huge difference in size of the part of subject that is underwater compared to the part above water, given by the flat port.
For anamorphic lenses a flat port is preferable.

Dome ports should be treated with care, as if handling a lens, and cleaned as if cleaning the front element of a lens. A minor scratch on the outside surface of the port will be filled by the water and it won't affect the quality of the image while a scratch on the inside of the port will be visible.

The diagonal coverage of a lens is affected by the refraction caused by water using a flat port. In table "A" we show lens comparison values for various formats.
Dome ports maintain the lens focal length at almost the same value, a 20mm lens still performs as a 20mm lens if a dome port is used.

16.3.3 Care and maintenance

All underwater equipment should be thoroughly inspected and tested before use, "O"-rings must be clean of dirt and LIGHTLY greased with silicone grease to keep the "o"-ring supple in its groove. Excessive greasing must be avoided because it increases the chance of sand and other debris getting trapped and damaging the seal.
Even a tiny grain of sand can compromise a good seal.

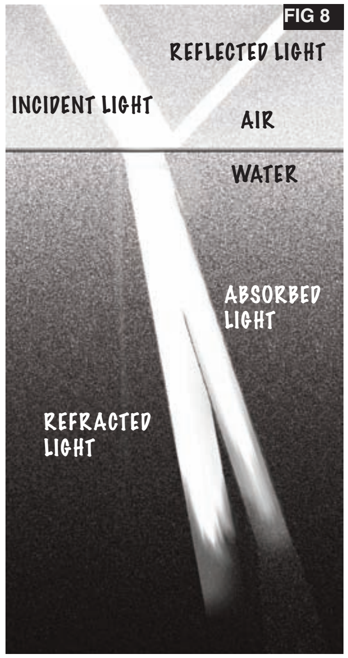


"O"-rings can be removed by gently pressing with your thumbs and easing the o-ring out of its groove (fig 8) and by using a piece of hard plastic (ie a credit card) with round edges or an orange stick but never anything metallic or sharp (finger nails included) because the "O"-ring can be easily damaged; even slightly damaged "O"-rings must be discarded and replaced.

All equipment that has been used in seawater should be washed in fresh water at the end of the day or as soon as possible to prevent corrosion.
Housings are bulky and can be very heavy, the average housing for a digital or film camera weighs (all in) 65 lbs (30 kgs) and some are over 100 lbs (45 kgs).
It is important to remember that a complete underwater kit will be of considerable weight and that should be accounted for when organising shipping or when moving and lifting cases.

When working with underwater equipment every assistant should have: a low pressure hose connected to a first stage and air gun (this can be attached to a diving cylinder)

to clean and dry equipment, towels, WD-40, cotton buds (to clean the "O"-ring grooves), silicon grease, allen key sets (imperial and metric), adjustable wrench, cling film, silica gel, alcohol and sanitary towels for reasons given further on.
Obviously it's important to wear appropriate clothing, since the chances of getting wet are very high.
In case the housing gets flooded it is important to remove all batteries immediately, handling them carefully since the acid in contact with water can produce caustic material and even catch fire.



If it happened in salt water then rinse with fresh water and after drying the camera with a towel, pour alcohol over the camera to dry the water inside, even though in the majority of cases all equipment with electronics will be irreversibly compromised, as salt quickly corrodes most electrical components.

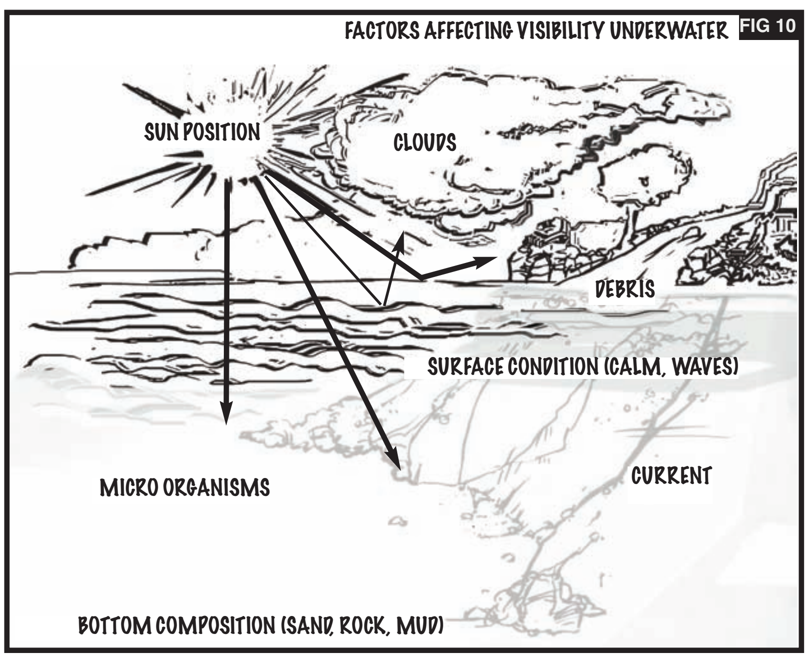
Lenses should also be treated in the same way, or mould will form damaging them beyond repair. A little tip is to secure a tampon or sanitary towel within the housing to absorb water in case of small leak or heavy condensation. A pack of silica gel can also be secured inside or on the camera to help prevent condensation.

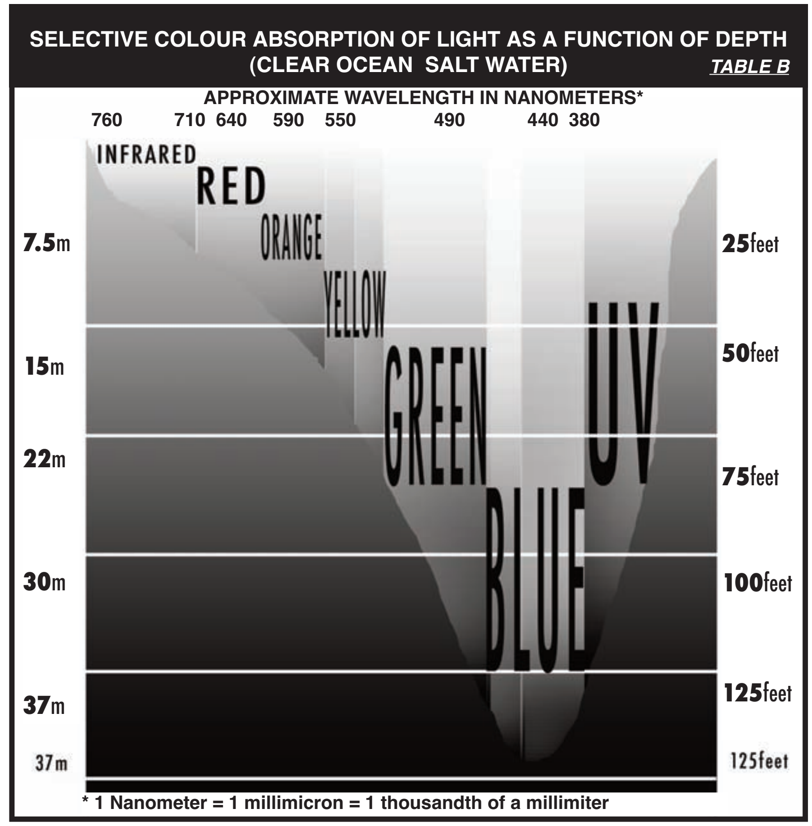
16.3.4 LIghting underwater

Irrespectively of shooting in open water (ocean, sea or lake) or in a tank, shooting underwater can be best represented as if filming in an environment filled with smoke, since turbidity is almost a constant in various degrees.

Several factors affect water clarity such as suspended particles (silt, sand), micro-organisms (such as plankton or algae) and even water temperature. (fig 10)

The factors affecting how light interacts underwater with the subject are reflection, refraction, (fig 8) absorption and back-scatter.





For these reasons, cross-lighting is preferable to front-lighting because back-scatter will show up, and if filming on location it is best to have the sun at an ideal angle, in most cases between 10am and 2pm in a windless calm sea to make the most of sunlight coming through. (fig 10)

Available light is affected by sea conditions, since waves will reflect back some of the sunrays and the clouds can reflect some of the light bouncing off the water surface back on to the sea.

TABLE C

RED FILTER FACTOR TABLE (ABSORBS BLUE+GREEN)	
CC0.25	-
CC0.5R	1/3
CC10R	1/3
CC20R	1/3
CC30R	2/3
CC40R	2/3
CC50R	1

If using artificial lighting from top-side, the best angle for the lamp is as perpendicular to the water surface as possible, always secured and operated well within the most stringent safety parameters.

Water, even freshwater, acts as a filter, diffusing and absorbing, and the column of water (the amount of water between the subject and the camera) absorbs light. The longer wave lengths, such as red and yellow, are absorbed first, normally in the first 6 to 10 feet.
To compensate, colour-correction (CC) filters can be used (see table "C").

Given the choice it is better to film as shallow as possible, ideally within 30 feet.

To help with colour rendition, it is advisable that the choice of colours for costumes, props or within the set bear this in mind, remembering that anything white will tend to have a halo-effect as water tends to diffuse.

At sea a white sandy bottom will help reflect the light coming from above back on to the subject and the same can be achieved in a tank by laying reflective material on the floor.

Once past a certain depth, no filtration on the lens can restore the colour-

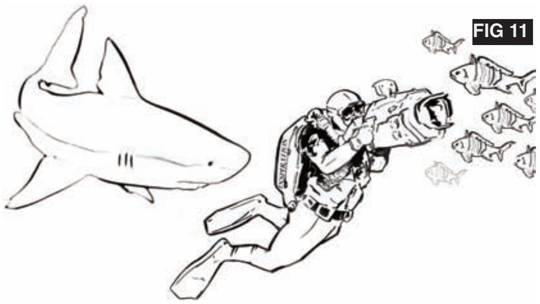


FIG 11

loss, and artificial lighting is essential.

There are many available sealed lighting units available, HMI, incandescent and fluorescent, in various sizes and wattages.

It is fundamental that the manufacturer's maximum depth-rating is respected. An implosion or malfunction of equipment at depth can bear tragic consequences for all people nearby.

16.3.5 Safety

Due to the nature of the underwater environment and the fact that humans are not designed to operate underwater, several factors can be dangerous: pressure, temperature, water resistance, assisted breathing, entanglement, marine life and weight of the equipment.

A very simple baro-trauma (pressure-related injury) can cause serious injury or death even at the shallow depth of a couple of metres. Running out of air can happen when working hard and overexertion underwater is very dangerous.
Getting snagged either on to wrecks, in nets or trapped in a set are all serious considerations to be taken into account before engaging in underwater work.

Safety should be the primary concern of everyone involved, either behind or in front of the camera and proper briefing before any operation should always be taken, putting in place a proper communication system between topside and divers.

Communication can be via mechanical means (rope), radio transmission (underwater comms, hydrophone), visual (strobe or torches) or sound (metal banged against metal underwater). Everything should be rehearsed on land and properly planned, then executed as planned with no variations. A detailed risk assessment should be made well ahead of any underwater activity.

Water is a very powerful coolant and hypothermia is a serious, debilitating condition. In open water there are plenty of animals large and small that can kill or maim a diver. In any case safety divers should always be present, co-ordinated by a diving supervisor, together with medically trained personnel. Proper evacuation procedures should be put in place as well as hyperbaric facilities within useful reach in case emergency decompression is necessary.

16.3.4 Diving and the Law

In the United Kingdom, on the 1st April 1998, the Diving at Work Regulation 1997 SI2776 came into force, regulating all work, even if unpaid, performed in UK waters. Copies of these regulations can be obtained from the Health and Safety Executive (www.hse.gov.uk).

A breach of these regulations, especially if resulting in an accident, will be prosecuted as a criminal offence. Many countries have implemented similar regulations (Canada with the Regulations for Diving Operations Reg. 629/94, Australia and some parts of the US for instance) and many more are following suit.

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In many countries worldwide diving for work, even when not retributed, is allowed only to people having a commercial diver certificate, and a breach of these regulations can carry severe penalties or worse.

Furthermore it is useful to remember that most insurance companies do not cover diving activities, including underwater filming, and the ones that do have many limitations in place and require a proven accident free track record as well as proper relevant up-to-date diving and medical certificates.