The Cost of Power Underwater

Richard Tuson

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There at least two principal reasons why people go underwater, they are: to work and to enjoy not working. In most cases where diving is undertaken in conjunction with other interests, as in marine biology or archaeology, the amateur diver probably works as hard as the professional, so it is hoped that some quite general observations on the cost of power underwater will be of value to those main diving interests.

Power is important because any activity, even if it is only moving from place to place, consumes it. One can look further and try to compare various systems from the point of view of cost effectiveness of available power, but any attempt to compare all feasible variations of the available systems would obviously be impossible in a brief paper. Therefore, in order to show the wide range of costs of useable power, I have chosen nine highly stylised and representative operational diving systems for us to consider. In these examples, except where it is shown that the power source is actually a part of the whole system, I have assumed in the first case that only the power output of the diver himself is available.

Of course, there are pneumatic, hydraulic and electrically powered tools available for use by divers and, to power such tools, equally autonomous power packs for deployment on the sea bed, but if the source of power is at the surface, power losses increase with depth of operation, and handling long hose assemblies becomes extremely difficult. Power packs solve this problem but impose other restrictions on the diving system. Generally, the diver uses hand tools of the types developed for surface use but modified to these special conditions, and he is capable of a sustained power output of about a quarter of a horse-power (probably even only a half of that, but in order to be generous and to cater for the vast differences in conditions to be met, I have in fact chosen a quarter of a horsepower.)

The simplest way to dive is always available and requires no equipment. One only has to swim to the desired place, take a breath and swim down. Simple refinements such as a mask and fins can be added, and a small boat adds to ones comfort and efficiency. This method has been exploited to about the human physiological limits by pearl divers who are reputed to work down to about 45 metres, and by Japanese Amas who, working in shallower waters, achieve 60 to 90 dives per day. They are paid very little, and if one takes these women divers as an example in their diving system, the cost per horsepower hour of their time on the bottom works out at about five pounds Sterling.

The next simplest form of diving is that of wearing an aqualung and minor accessories. The range of equipment that could be included with aqualung diving, and the resulting variation in cost, is so great that only the basic case is considered here. Except in the previous example of pearl divers in which the cost of a boat was included, the calculations for this and subsequent examples of diving systems do not include a boat or ship, but support ships are included in submersible operations later. In this case I have assumed a minimal semi-professional team, working a six to eight hour day at a depth of about 10 metres. With a somewhat doubtful continuous power output of about a quarter of a horsepower, the cost per horsepower hour is about ten pounds Sterling.

Standard diving needs little introduction and little qualification except to remark that its main use today is in cold or polluted waters where long hours of heavy work are required. A minimal team is once more considered and with it a long working day in water no deeper than about 10 metres. In this case the cost is about twenty pounds Sterling per horsepower hour.

The technique of supplying the diver with mixed gases - either oxy/nitrogen or oxy/helium - from surface demand diving equipment is well-known, and the advantages are, in general terms, increased time on the bottom or shorter decompression schedules compared with when compressed air is used.

At greater depths - say, down to 80 metres - a much larger surface support team than in the earlier examples will be required. The system demands a high standard of operational procedure: reliability of equipment, advanced diver training and something more than the minimal team. Therefore as depth is increased, conveniently short decompression schedules necessitate a reduction in bottom time: repetitive dives and more divers are required for reasonable work outputs to be sustained. I am assuming the team and equipment necessary to achieve one hour's bottom time per day for a number of bounce dives to about 80 metres. The cost per horsepower hour will be about 1,200 pounds Sterling, but this is obviously greatly influenced by the exact system used. This is extremely expensive in terms of horsepower hour, and no doubt a more economical system could be devised, but I have chosen to exaggerate yet remain within the bounds of possibility in order to accentuate the point of this example.

Again considering bounce diving to 80 metres with a total bottom time of one hour per day, if one dispenses with the SDDE system and instead supplies the diver with a fully mobile power source for his hand tools via a diver transport vehicle with autonomous breathing equipment, a dramatic change in the calculations is possible. If one assumes exactly the same basic costs per day per diving team and equipment and an added cost of 47 pounds Sterling per day for a diver transport vehicle which, by the way, allows for a capital cost of 10,000 pounds Sterling amortised over about eight years, and 2,000 pounds Sterling per battery pack - with 50 cycles life in a battery pack of solar zinc cells - then the cost per horsepower hour can be reduced by a factor of eight on the previous one, which produces a final figure of 150 pounds Sterling per horsepower hour.

The armoured diving suit provides a special and interesting case: the diver remains at atmospheric pressure within the suit, with the result that the equipment and team can be deployed, and if necessary returned from the diving site, very quickly. Little support equipment is required other than a means of raising and lowering the suit, although operations in water approaching its maximum rated depth may well necessitate guidance systems to the work site. The most interesting aspect of this system is the speed of deployment and possible rates of descent and ascent with no decompression times, with the result that a small team can achieve a six-hour working day on the bottom and if one assumes that only diver power is available, the cost would be about 300 pounds Sterling per horsepower hour.

Saturation diving is the most advanced, complex and expensive diving system in these examples. The great range of costs for such systems is dependent on the depth of operation, the amount of underwater work required per day and hence the size of the team. For this example I have assumed that the requirement is for a sustained presence at the diving site - which could well be a production platform in an offshore oil field - and something approaching a round-the-clock diving schedule in depths of about 260 metres. I accept “round-the-clock” as meaning about two two-hour sorties from the chamber complex each day. I have also assumed that no powered tools are being used and so we only have the power output of the divers themselves to consider. In this case, a cost of about 2,000 pounds Sterling per horsepower hour would be the average. It could obviously be considerably more; it could also be considerably less.

A diver lock-out submersible provides a unique feature to diving operations: only in this case can the diving supervisor, stand-by diver and working diver be within a few feet of each other during a deep dive. The diving control centre is on the bottom in a submersible and, with a good diver to supervise communications, work plans can be modified during the dive and the system becomes very flexible. The diver can be moved from site to site quickly and easily, but the greatest advantage is that power is available where it is required. One can assume that at least half the energy in the submersible’s batteries is available for useful work, certainly in depths equivalent to those in the previous example - about 280 metres - and, theoretically, to the maximum operating depth of the submersible which is about 366 metres. The submersible can therefore perform work at a much higher rate than even the divers supplied with power tools. Ideally, if two divers work together from a Perry Pc15 diver combination making one sortie per day, there would be a total of about 36 horsepower hours on demand. At current quoted charter rates this produces a figure of about 128 pounds Sterling per horsepower hour.

With the submersible alone divers are not involved and, although this makes an exception to the general theme of this paper, it is justified because, without divers - as with the armoured diving suits - the physiological problems are removed, and even greater flexibility of operation is achieved. If we consider the Pisces I, II and III family of submersibles, with depth ranges down to 1097 metres and 28 horsepower hours of stored energy available for work and an equal quantity for propulsion, manoeuvring and hotel load, a 122 pounds Sterling per horsepower hour, the cost is less than for a diver lockout submersible system.

In conclusion, one must remember that the purpose of this necessarily brief review of diving and submersible cost effectiveness is only to consider the price paid for horsepower hours of work at the site on the seabed. It can be seen that with the more sophisticated or heavy systems the area over which the diver can work is usually quite limited, either by considerations of safety or tolerable umbilical length, whereas, due to the simplicity of the system, the free aqualung diver can move about at will and in safety, as long as he remains in shallow water.

Using a diver transport vehicle increases the bottom area over which a diver can move; the armoured diving suit can be walked around a work site, but if even relatively short distances need to be covered it is probably more economical to move the parent craft and to re-deploy the suit. The submersibles have far greater range, but it is assumed that they would move no further from the parent craft than the limit of their underwater communications system, which is up to 2,000 metres.

Lately, although it has been shown that submersible systems are very cost effective in terms of power output, there are other equally important factors to consider if an appropriate system is to be chosen for a particular task. The dexterity of the diver is of greater value, as was shown in the film that Henri Delauze showed you yesterday; obviously the diver was moving around in a very restricted area, climbing around on a BOP stack, inserting himself in confined spaces and using his hands; examining closely a relatively inaccessible task. Thus, it is evident from the great variety of types of work and the differences in conditions surrounding these tasks, that every system so far successfully developed will continue to be needed.

THE COST OF POWER UNDERWATER

	Cost /HP/HR	**Depth metres**	**Radius metres** *
Breathhold diving	5	10	3
SCUBA	10	10	50
Standard Diving Rig	20	10	10
Surface Demand (mixed gases)	1200	80	10
Diver transport vehicles (autonomous)	150	80	100
Armoured Diving Suit	300	300	10
Saturation Diving	2000	280	10
Diver Lockout Submersible	128	280	2000
Submersible	122	1097	2000

* Radius of operation is limited by endurance or tethers, or for boats, by normal range of ship communications.

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Brief Profile

Kenneth Richard Tuson joined the RN Scientific Service as Scientific Assistant at the Admiralty Materials Laboratory, Poole, in 1947, and by 1950 was working on instrumentation, high speed photography, the physics of bubble production, and problems associated with diving research.

his work then developed into diving navigational systems studies in streamlining, the development of breathing apparatus, and trials thereof.

He obtained special leave to work as Project Manager for DHB Construction Ltd on the production, testing and trials of JIM, the armoured diving suit.

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