CORRESPONDENCE

'PLATFORM'—A MISLEADING TERM

SIR,

I keep hearing and seeing the word Platform used to describe those parts of a warship which are not the Combat System. I submit that no such animal either can or does exist.

A warship is a combination of many systems and sub-systems and some equipments in a hull. That is uncontroversial. A Combat System has been defined loosely as those parts of the warship which contribute to its fighting task; e.g. the CMS, the communication systems, the navigation systems, the sensors and the weapons systems and the appropriate personnel. But hold on! Don't the main engines, the steering and stabilizer systems contribute to the fighting task of the ship? What about the cooling system for the special service air compressor? It contributes to the warfighting capability of the ship surely.

So where can we stop? I believe we cannot. The SHIP = PLATFORM AND COMBAT SYSTEM (see JNE vol. 32 No. 3 p. 458) but no one can define the RHS of the above equation clearly and unequivocally. Perhaps a bright young engineer will prove me wrong.

Let us therefore be more precise and call a warship exactly that, not a platform!

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Director Surface Ships/C

SOVIET SUBMARINE 'KOMSOMOLETS'

SIR,

I am very grateful for the interesting article on the disaster to the MIKE Class boat on 7 April 1989. I had heard something of the *Komsomolets* story but I had not appreciated that there had been quite so many fires in recent years—in US boats as well. It is hard to credit that anyone could think of using freon as a fire extinguisher material, when it breaks down into hydrochloric and hydrofluoric acid gases at about 400°C and burns at 580°C.

Reading between the lines, one cannot escape the feeling that the main culprit in the story is the person who agreed to having compartments 5 and 6 probably completely unmanned (because they *both* had a good deal of radio-acitivity in them, not just 5), which would be the case if she had a lead/bismuth cooled/moderated reactor; and had only one man on watch in compartment 7, (killed in the accident); yet at the same time did not install proper T/V monitoring of the compartments—or, it would seem, any substitute instrumentation.

I also liked the dig at Captain Selivanov, whose boat caught fire because he had condoned chaps making rabbits with an electric grinder secured to the side of the electrolyser!

(*Sgd.*) John B. Hervey
Rear-Admiral
Naval Consultant

THERMAL POWER SOURCES FOR AUVs

SIR,

The recent article on this subject[1] concludes that it will be some time before advanced electro-chemical systems for AUVs are available. It goes on to say that in the near term the use of thermal power systems appears attractive especially if metal combustion heat sources are used. For the latter concept a lithium/sulphur hexafluoride (SF_6) reactor was chosen.

One important aspect which has been overlooked in the article is the running cost associated with the various reactants. Compared with the reactants for electro-chemical systems such as fuel cells (diesel or methanol/LOX or high test peroxide(HTP)), the cost of those for thermal power systems is prohibitive. The following tables compare the approximate costs of various reactants.

Thus, the running costs of the chosen thermal system, per kg of reactants, could be between 500 and 2000 times those for a fuel cell system.

TABLE I—*Approximate costs of electro-chemcial system reactants (in £/kg)*

Diesel	*Methanol*	*LOX*	*HTP*
0.2	0.2	0.08	0.8

TABLE II—*Approximate costs of thermal power system reactants (in £/kg)*

Lithium	*SF_6*
200	300

TABLE III—*Approximate costs of some other metallic reactants in the article (in £/kg)*

Aluminium	*Beryllium*	*Magnesium*	*Sodium*
17 upwards depending on form	*3000*	*2 to 50 depending on form*	*40 to 70 depending on form*

(*Sgd.*) V. W. Adams
Sea Systems Controllerate, Bath

Reference

1. Hawley, J. G., Potter, L. J., and Reader, G. T.: Thermal power sources for extended AUV mission requirements: *Journal of Naval Engineering*, Vol. 33, no. 1, June 1991, pp. 115–126.

SIR,

We would like to thank the Editor for the opportunity to reply to the comments made by Mr Adams of the Sea Systems Controllerate about our recent paper. We would also like to thank Mr Adams, a well-known fuel cell expert, for the comments.

Mr Adams suggests that in the paper we overlooked the issue of cost. This is not the case. We did not address the issue since the theme of the paper was to discuss the technical feasibility of using thermal systems in AUVs. This approach is not uncommon in the technical literature for it is usually better to establish the viability of a system before investigating cost matters. If a system is not viable then there is little point in trying to estimate how much it will cost. Nevertheless, at some point in a project, even a conceptual study, costings will have to be made especially when there are competing systems.

The estimation of costs is a complex problem[1,2,3] and there are many factors involved in the pricing of a power system, of which reactant cost is but one. Thus we are a little surprised that Mr Adams has chosen a single factor on which to make a cost comparison. (We also note that his data are not in total harmony with other published information). Most certainly reactant price is a factor which has to be taken into account when determining running costs but even then it is not usually the gravimetric (per unit mass) cost that is important. The cost per unit energy (per kWh) or per unit power (per kW) are more commonly used bases on which to estimate fuel or reactant costs.

Mr Adams estimates the cost of the lithium and sulphur hexafluoride to be 200 and 300 per kg respectively. Even if these data are correct it would have been more meaningful to quote the cost of the $Li + SF_6$ 'fuel' per kWh and compare that on a similar basis to hydrogen + oxygen reaction of the fuel cell. The results of this type of comparison are usually more useful. For example, depending upon which data are used, the cost of the lithium reaction is approximately £2 to 3 per kWh whereas the cost of the hydrogen + oxygen is between £0.9 and 2.4 per kWh, hardly the order of magnitude difference implied by the quoted gravimetric data.

Perhaps, Mr Adams was trying to make the case for the fuel cell. If that is so then we would support the thrust of his comments for it is apparent that in the future such systems will become increasingly attractive. Indeed it has been forecast in several extensive US Government studies that in the period 2005–2008 fuel cells will begin to make a significant impact in the power generation market, the main problem holding them back at the moment being cost[4]. Of course in the naval environment where mission-effectiveness is as important as cost-effectiveness the fuel cell could be in service by the end of the century. The West German submarine fuel cell programme appears to be gaining pace and other nations, such as Canada, are becoming more involved in fuel cell development. However, one of the largest potential users, the USA, decided in the mid 1980s that the development of the fuel cell for marine purposes, in isolation, would be too expensive and that it would be better to wait until it had been fully developed for the utilities industry.

There are also exciting technical developments in the area of advanced primary and secondary batteries. For example, initial results suggest that the Anglo-American aluminium-HTP battery will be cheaper and a better performer than the fuel cell. Similar claims are being made for certain types of lithium battery. It is clear that present developments involving advanced electro-chemical power systems will become technically mature by the next century and will provide the bases for high performance underwater power systems. In the meantime, existing thermal systems offer the possibility of an interim solution for extended AUV missions. The metal combustion systems and metallic thermal storage devices developed by Philips and General Motors in the 1960s and 1970s for naval applications and since further developed by Dowty in the UK and Garrett in the USA could have a role to play—hence the reason for our paper.

We regret that we did not succeed in our paper in making it clear that thermal systems could provide a technically feasible interim solution to the AUV power system problem and would like, once agan, to thank Mr Adams for raising an issue which has allowed us to address this deficiency.

(*Sgd.*) J. G. Hawley
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1. Gutherie, J. A. S. *et al.*: 'A survey of dynamic power sources for underwater applications': UEG Group Report UR4, 1973.
2. Allmendinger, E. E.: *Submersible vehicle systems design*; Society of Naval and Marine Engineers, 1990, ISBN 0 939773 06 6.
3. Lee, A. *et al.*: Power sources for unmanned underwater vehicles; *Sea Technology*, Oct. 1989, pp. 25–32.
4. Appleby, A. J. and Foulkes, F. R.: *Fuel cell handbook*; Van Nostrand Reinhold, 1989, ISBN 00 442 31926 6.

SIR,

The above reply by Hawley *et al.*[1] to my letter[2] on thermal power sources for extended AUV mission requirements prompted discussion between Lieutenant-Commander Hawley and myself on the difficulties in obtaining bulk prices for the chemicals proposed for the metal combustion heat sources. The prices for these quoted in my letter[2] were based on the current catalogue from the Aldrich Chemical Co Ltd UK. I have since obtained the following budgetary prices in £/kg for the bulk supply (units of 1 tonne and excluding containers) of lithium and sulphur hexafluoride (SF_6) from the Aldrich Chemical Co Ltd UK:

Lithium	SF_6
130	12

Based on the reaction,

$$8Li + SF_6 \rightarrow 6LiF + Li_2S + 14kWh/kg \text{ of } Li,$$

the theoretical energy density is 3.9 kWh/kg of the total reactants (Li and SF_6). Thus, for the above reaction the cost of the total reactants is about £44/kg or £11/kWh compared with £2/kWh to £3/kWh quoted by Hawley *et al.*[1]

For the hydrogen/oxygen fuel cell case, Hawley *et al.*[1] quote £0.9 to £2.4/kWh. The approximate prices for the fuel cell reactants (diesel fuel or methanol/LOX or HTP) quoted in my letter[2] are for bulk supplies (Durham Chemicals for methanol, British Oxygen for LOX and Interox for 85% HTP). Using these prices and depending upon the type of fuel cell the cost of reactants are:

(*a*) £0.2/kWHh to £0.22/kWh for diesel or methanol (assuming 90% reforming efficiency) and LOX.

(*b*) £1.3/kWh to £1.6/kWh for diesel or methanol (assuming 90% reforming efficiency) and 85% HTP (assuming 90% decomposition efficiency).

Thus, the cost in terms of £/kWh (which, as Harley *et al.*[1] correctly point out, is a more useful comparison than £/kg) the running costs of the chosen thermal system[1] could be between about 7 and 55 times those for a fuel cell system using HTP and LOX, respectively. The selection of a system would depend on a comparison of life cycle costs, including the unit production costs, and considerations such as reliability, safety, overall system weights/volumes and mission requirements.

(*Sgd.*) V. W. Adams
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References

1. Hawley, J. G. *et al.: Journal of Naval Engineering*, this issue, pp. 516-517.
2. Adams, V. W.: *Journal of Naval Engineering*, this issue, p. 516.