CHAPTER 5 - MESMA

"Module d'energie sous marine"

MESMA is a French system made by Bertin et Cie and collaborating companies under the auspices of the Navy. MEMSA is a closed loop steam turbine, a Rankine Cycle. The French engineers have essentially made a smaller and slightly adapted version of the steam cycle that they use in a nuclear submarine.

The present embodiment of the MESMA system is represented in figure MESMA

It seems however that this represents a considerable evolution from the original idea. In earlier papers it is clear that the idea was to have a LOX tank holding liquid at about 60 Bara and that it was intended to liquefy the carbon dioxide that results from combustion of the fuel and to hold this in the boat. This would have two beneficial effects as far as a naval architect designing submarines was concerned : the weight of the boat would stay constant and there would be no problem with the emission of carbon dioxide into the sea.

These matters seem to be particularly important in the French thinking because it seems clear that they are trying to unify their thought on a light nuclear submarine/heavy AIP submarine. A hull will be offered into which either a nuclear reactor or a MESMA module could be fitted. The matter becomes less simple if the nuclear boat is a constant weight device and the AIP version is not.

The designers seem to have abandoned the original concept for two reasons. Firstly the increased weight needed of the 60 Bara tank meant that they could carry only about 80% of the LOX that they could manage with a 10-20 Bara tank. This alone would have been a powerful reason. However, and again the literature does not state it explicitly, but I very much doubt that the carbon dioxide can be liquefied in the manner in which they hoped. This is a matter of a some little complexity and I have examined it further in a later chapter.

The literature states that the system can work either on diesel fuel or on ethanol, but the consensus of thought is that the ethanol option is preferred because it creates less soot in the gas cycle pipes. Originally it appears that methanol was the preferred fuel, but that the toxic nature of the material caused the designers to change to ethanol. Although I cannot find mention of it in the literature, I think that the calorific value of the fuel must also have been a factor in the minds of the engineers. The heat of combustion of ethanol is 29.7 kJ/gram as opposed to 22.2 kJ/gram for methanol; both are still a long way short of diesel fuel which comes in at about 43 kJ/gram.

Although ethanol is not a very conventional fuel, I can't really see that there would be a difficulty in supplying it. Certainly ethanol rich fuels are used in some countries for use in road vehicles. It would seem to me to be preferable to bring a tanker of ethanol to the dockside rather than a tanker of hydrogen. Furthermore I think that you would be more likely to be able to obtain alcohol than hydrogen in a still developing country.

One is bound to ask whether there is a lesson here for the fuel cell designers, who are keen on the idea of a chemical reforming process based on methanol for the provision of the hydrogen. If methanol would cause a problem in the one case would it not in another ?

The MESMA system has a high pressure burner running on pure oxygen, and so must use re-circulated carbon dioxide to keep the actual burner heads cool enough that they do not melt. The essential matter is that you have to have some fairly inert buffer gas present to "soak up" the heat of combustion. This buffer gas is normally nitrogen when you are talking about everyday flames. In the case of burners where nitrogen is not available it is natural to make a recirculation loop in which some of the CO_2 is cooled and fed back to the combustion chamber.

The object of the exercise is to keep the walls of the combustion chamber under the working temperature of the materials and so steps are taken to lead the cooled gas onto the inside walls of the chamber. This is not the end of the technical considerations. Carbon dioxide, especially hot carbon dioxide, is not so inert as nitrogen and flames taking place in a carbon dioxide ballast rather than in nitrogen seem to produce more smoke. I'm not entirely sure why this is.

The MESMA burner runs at 60 Bara and this pressure is not dependent on the depth of the submarine. Incidentally, I am not quite sure how the oxygen from the tank at say 20 Bara is raised to the 60 Bara working pressure. This high pressure requires some fairly sophisticated design work to be carried out on the burner. You certainly cannot take an atmospheric burner and raise the pressure to even 5 Bara and expect it to work unchanged. The fuel is being fed in pretty well as a liquid so its volume does not change much with pressure, whereas the gas and particularly the oxygen is much more concentrated, so at the very least and without doing any calculations, you can be sure that the shape and extent of the flame will change.

There is surprisingly little experience of designing high pressure burners, especially not at 60 Bara and most certainly not with a carbon dioxide diluent. On the other hand there has been, and is still presently, much rapid development taking place on computerised gas flow simulation packages. FLUENT and PHOENIX are two design tools that are much in evidence at the moment. Of course, you are straight into acronym land with anything to do with computers and the buzz word is now CFD which stands for Computerised Fluid Dynamics. At any rate I think we can take it that the French have a very interesting little burner which will consume ethanol and oxygen up to 60 Bara and is cooled with carbon dioxide. It will be interesting to see in due course how they manage to light it when starting from cold. You can't just stick a match in at 60 Bara !

However adroit the designers have been in designing their submarine burner, there is still a problem and this is to do with the *up-down capability* which I mentioned in connection with Stirling engines. A burner that will work at 60 Bara using a carbon dioxide diluent will hardly work at one bar when fed with air. So unless something is done, the undersea plant cannot be used for propulsion on the surface. You have to remember that a submarine is not a peace time machine which is only expected to work on fine days. People get angry with submarines and drop things on them. A submarine therefore needs to be able to work all its systems under various disadvantageous circumstances. If it surfaces after an attack and its snort diesel is not working, it would be very nice to still be able to get a knot or two from the AIP plant.

The way MESMA is presented gives no clue that it could work on the surface and perhaps it can't. But perhaps the French do not tell us everything. Perhaps there is a second atmospheric burner that can be valved in to get some bit of power out of the system ? It will be interesting to find out later.

The MESMA system would appear to have a lower efficiency than some other systems. You would expect this from a steam system. Primary data published by the French manufacturers are given in the table.

Combustion chamber pressure	60 Bara
Ethanol flow rate	110 kg/hr
Oxygen flow rate	228 kg/hr
Combustion thermal power *	800 kWth
Combustion gases temp	700 degC

Rankine Cycle design

Turbine mechanical power	245 kW
Alternator electrical power	225 kW
Parasitic power	25 kW
Net electrical power	200 kW

** The combustion thermal power appears to be in error in the table above. The molecular weight of ethanol is 46 grams and so an ethanol flow rate of 110 kg/hr is about 0.66 moles/sec. The Lower Calorific Value of ethanol is 1327 kJ/mole so that the fuel will burn to produce heat at a rate of 881 kW. Therefore the overall efficiency is 200/881=0.227*

Efficiency calculated in this way can be difficult to interpret in terms of performance. For someone designing a submarine, it seems natural to ask how long the submarine can be driven submerged at some power on a certain quantity of LOX. Suppose we have 40 tes of LOX in the boat (a fairly typical figure) then at 200 kW the boat will be able to travel for (40,000 kg)/(228 kg/hr) =175 hours or 7.3 days. The LOX flow in a Closed Cycle diesel producing the same net power is 196 kg/hr and the endurance is 204 hrs or 8.5 days.

Although the MESMA system has less endurance in the example shown, this should not be taken to mean the system is worse. The factors that go into the selection of a submarine and its power source are many and varied (and sometimes have little to do with engineering at all) and one slightly worse factor may be set off against other factors deemed to be important to the customer.

I believe at the moment that a MESMA submarine will leave a stream of bubbles in its wake. It is always rather easy to make this sort of criticism when you have not seen the system, and I may be doing Bertin et Cie a gross injustice. However, it has to be said that the matter of the bubbles has been raised on several occasions and no explanation as to how the bubbles are dealt with has been forthcoming. I have considered this matter of bubbles in more detail in both the chapter on carbon dioxide and in the chapter on Russian experiments. The stark fact is that some types of AIP, which I believe includes MESMA, pump carbon dioxide overboard as a stream of bubbles and that these bubbles are more visible to an active sonar than the submarine itself.

I believe also that the MESMA system must throw unburned oxygen overboard. As I explained in the chapter on Stirling engines, it seems to me to be difficult to run a flame in which all the oxygen is burned. You have to have excess oxygen. So far as we know MESMA has no system for separating oxygen from exhaust gases and so part of your valuable resources in the LOX tank is simply thrown away.

The MESMA system has an advantage over some other systems in that it apparently uses very well characterised machinery, the burner aside. Bertin et Cie are obviously very familiar with the steam machinery in their nuclear boats and have made adaptations for use with MESMA. One would expect the system to be very reliable and well characterised in terms of mean time between failures. *All* the competing AIP systems have some aspect of engineering novelty : The closed cycle has a custom built water management system (which ensures that oxygen is not thrown into the sea !), the Swedes use the otherwise disregarded Stirling engine as their prime mover, and fuel cell systems are about as robust as a Swiss watch.

MESMA shares with the Closed Cycle Diesel the ability to produce large amounts of power. It seems clear that the Bertin engineers could make a unit of pretty well any size they wanted. Similarly in the case of the CCD, diesels can be bought “off the shelf” up to a few tens of MW. This ability contrasts sharply with Stirling Engines which come in one size of 60 kW, and the fuel cell which (in a form suitable for submarine use) comes in blocks of no more than 200 kW.

REFERENCES

Ref (1) There are a number of papers embodying the idea of Figure 1. See for example P. Kerros, P. Leroy and D. Grouset "MESMA : AIP system for submarines" RINA Warship 93 Heathrow Penta 11-13 May 1993.

Readily accessible web articles which seem to be regularly updated can be found at :

http://www.naval-technology.com/contractors/propulsion/dcn/dcn.html and http://dcintl.com/htdocs/fich16.htm

Ref (2) J. L. Boy-Marcotte, M Dancette, C. Loenard and A. Verneau RINA Warship 99