Technical Comments

Comment on "Thermodynamic Performance Evaluation of a Hydroduct Using a Thermite Fuel"

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IN a recent paper, Hacker and Lieberman[1] discuss the feasibility of using a hydroduct as a power source for an underwater vehicle. They conclude, among other things that 1) the hydroduct does not develop sufficient thrust to overcome drag effects and 2) the cruising velocity of the hydroduct is determined by the launch velocity....

Basing the opinion on the graphs and calculations presented by the authors, it is believed that neither of these conclusions is valid. Considering the first conclusion, a cigarette grain with a burning area of 10 in.[2] is given with the reasoning that this was the best design possible for the available space. It is not stated what duration was expected but a cigarette burning grain is not the best solution in cases of marginal thrust and it could be easily modified to supply more thrust (heat) for shorter periods, even while retaining its basic end-burning character.

An estimate was made (based on the burning area and on various sources in Ref. 2) of the size of the present vehicle and using the value of 450-lb drag at a velocity of 200 fps an approximate diameter of 0.45-ft and about 4-ft length was obtained for the vehicle in question. Now this is fairly small for a vehicle carrying a payload but the important point is that by increasing the dimensions of the vehicle the drag increases approximately by the second power of the dimensional increase but the volume, and consequently the energy storage capacity, increases by the third power. The authors' conclusion neglects these scale effects. A similar calculation performed for a standard torpedo (21-in. diam) will show that even with its greater drag at this velocity (about 12,000 lb) there is enough volume to give it a meaningful range.

Considering the second conclusion, the sample design calculation does not show in any way that the thrust is a function of the launch velocity (as stated at the end of Sec. II of the paper) except possibly the initial thrust of an accelerating or decelerating vehicle; neither does cruise velocity depend on the launch velocity but on drag and thrust and their dependence on the velocity, assuming of course that the vehicle does attain terminal velocity and that it is launched at some velocity which is higher than the minimum at which the hydroduct will operate at all.

Let us consider Fig. 2; barring severe transients in operation any vehicle will accelerate as long as there is a net thrust, namely, thrust minus drag has a positive value. Terminal velocity is achieved when thrust equals drag.

There is no technical justification for fixing the launch velocity at 250 fps particularly that the calculations are performed at 200 fps; furthermore, based on the calculations presented in the paper there is no reason for the drop in thrust around 250 fps but on the other hand, at $V = 0$, the thrust should be nearly zero: see Eq. 3 and the strong dependence of the burning rate and consequently the thrust on the pressure. Finally, considering the dependence of the drag on V^2 and cavitation the drag curve is all wrong. (Since no other definition is given it is assumed that drag is defined by the classical equation $\frac{1}{2}\rho V^2 C_D S$ or $\frac{1}{2}\rho V^2 C_F S$.) It appears that Fig. 2 in the paper should look as shown in Fig. 1 here.

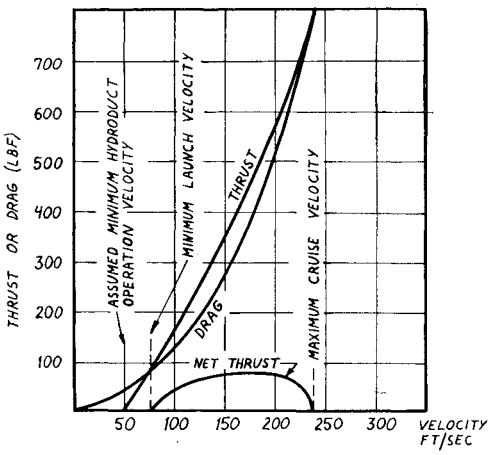

Fig. 1 Thrust and drag vs velocity.

References

[1] Hacker, D. S. and Lieberman, P., "Thermodynamic Performance Evaluation of a Hydroduct Using a Thermite Fuel," *Journal of Hydronautics*, Vol. 3, No. 3, July 1969, pp. 139–144.

[2] Greiner, L., ed., *Underwater Missile Propulsion*, 1st ed., Compass Publications, Arlington, Va., 1967.

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Reply by Author to A. K. G. Lorber

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IN response to Lorber's[1] comments on our recent paper, let us say that while it is quite true that other burning configurations are possible, the selection of the end burning cigarette grain is only typical of a heat source in which one could study this modified ramjet propulsion system. The combustion process is nonspecific with respect to the thermodynamic performance of the device. This fact may have been obscured by the sample calculation. Therefore, we concur with the respondee's first conclusion that effects of scaling have not been considered in this study.

With respect to the second comment, there is some question whether the thrust calculation obtained in Fig. 2 is correct. Lorber believes that the results should be a monatonic function of velocity. The criticism of this approach is that it assumes that operation is independent of the process that

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