

Pratt and Whitney—batteries based on the distinguished work begun over thirty years ago by Mr. F. T. Bacon.

Portable (carriable by one or two men).—Successful application within three years seems certain with power sources for military communication equipment in a preferred position.

Transportable (carriable by vehicle with batteries for propulsion excluded).—Already installed by Brown Boveri (Figure 4). Successful military applications of other types at higher ratings seem likely.

Propulsion.—Successful applications will come first on military vehicles. Golf carts with *hydrazine* batteries have been demonstrated by Allis-Chalmers. Military fork-lift trucks should operate on fuel batteries within 10 years. The Swedish submarine effort was mentioned above.

The passenger automobile seemingly affords the fuel battery a great opportunity, but unit capital cost is such a formidable hurdle now that other problems are scarcely worth discussing. For the present, effort should be concentrated on automobiles that use storage batteries (8) perhaps new types not yet in use, which might be replaced or augmented by satisfactory fuel batteries. English opinion holds that the locomotive or the fuel-battery-powered railroad car is a more promising application than the passenger automobile. Hydrogen/oxygen batteries to operate all three could be built at a high price today; it will be remembered that Allis-Chalmers used such a battery to power a tractor in 1959.

The Home.—Steady progress (Broers, TNO, Holland; Institute for Gas Technology, Chicago) being made on methane/air batteries with molten-carbonate electrolytes leads one to expect experimental home installations exceeding 20% in comparative thermal efficiency within 5 years; such fuel batteries would be connected to banks of storage batteries as energy reserve for peak loads.

Central Stations.—The earlier prediction (6) stands with a few added remarks. The central station ranks with the passenger automobile in difficulty as an application for the fuel battery. It differs from the automobile in that unit capital cost is a less serious hurdle here than overall energy cost. The future of the fuel battery in the large-scale generation of electricity seems linked to the future of natural gas. The growth of atomic energy installations, and the effect this will have on the coal industry, both enter the picture because one must look perhaps a decade ahead for the earliest time that a central-station fuel-battery might begin to be used. But there is hope for the fuel battery in smaller central stations that serve a single community—stations in which the use of heat and of electrical energy will be efficiently combined, and distribution costs will be reduced.

The reader wishing to reconcile our prediction with that of Reference 7 will note that we have stressed fuel batteries of low ratings, and included space and military applications.

A logical position at present seems to be that fuel-cell research should continue so long as significant progress is made, and that the engineering development of H_2/O_2 and of H_2 /air batteries for favorable applications should be emphasized. Fuel batteries will prove themselves indispensable in some applications and useful in many others.

I gladly thank Dr. E. J. Cairns for his help on this paper.

REFERENCES

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2. Private communication, H. G. Plust, Brown, Boveri and Company, March 22, 1966.
3. H. A. Liebhafsky and E. J. Cairns, General Electric Report No. 60-RL-2382C, "The Fuel Cell and The Power Industry", March 1960.
4. G. D. Friedlander, IEF Spectrum, 1, No. 10, 58, October 1964.
5. *Abrams v. U.S.*, 250 U.S. 616, 624 (1919), Holmes, J., dissenting.
6. H. A. Liebhafsky and D. L. Douglas, Ind. Eng. Chem., 52, 293 (1960).
7. Lord Rothschild, Science Journal, 1, 82 (1965).
8. See for example Maxwell Boyd, "Electric 60 mph 'mini' out soon", London Sunday Times, Feb. 27, 1966.