letters

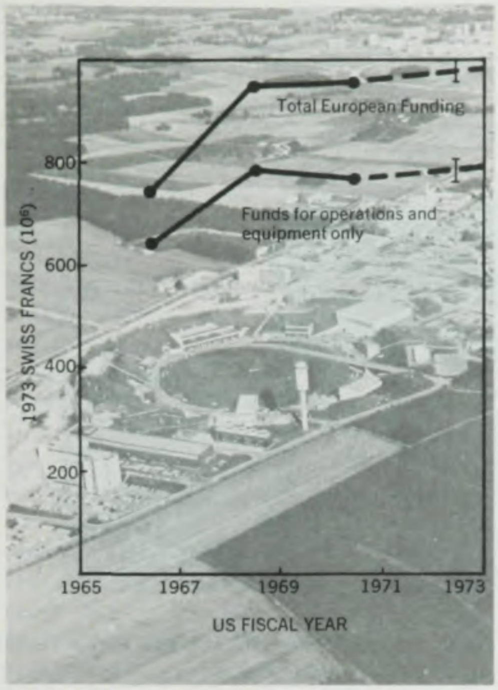
No increase in funds for European high-energy physics

The comparison between American and European funding of high-energy physics in the article by Wolfgang Panofsky in your June issue (page 23) and your editorial comment in the same issue (page 88) are very misleading in respect to the recent trend in European funding levels.

Panofsky, in commenting on figure 3 in his article, says "support of high-energy physics in Western Europe is still increasing at a substantial rate," and you add "Two years ago the European level of funding first exceeded the US level in real dollars and has since climbed to the point where it now exceeds US funding by over $100 million."

This apparent rise since 1970 does *not* correspond to an increase in resources in Europe, but simply reflects the recent devaluations of the dollar with respect to Western European currencies—now by 30% compared with the 1970 parity. The effect of this devaluation appears in Panofsky's graph as a rise in 1972 by nearly $100 million, simply as a result of converting the European data in Swiss francs into a dollar expenditure at the new rate of exchange.

To clarify this point I show in the attached figure the total European annual expenditures in 1966, 1968, 1970, and a provisional estimate for 1972, in 1973 Swiss francs, corrected for inflation as are the figures in Panofsky's curves. This graph shows clearly that there has been essentially no increase in the real financial resources for high-energy physics in Western Europe since 1968. The recent dollar devaluations have had hardly any effect, since only a small fraction of the total costs corresponds to dollar purchases of equipment directly from the US.



Annual costs of European high-energy physics. Difference between two curves is annual cost of construction of large projects, such as ISR, large bubble chambers, and in 1972, start of 300-GeV accelerator.

Within this constant funding, which is not likely to increase in future, will have to be found the major capital expenditures on the 300-GeV accelerator project, which only begin to show up in 1972 and which will increase considerably in the coming years at the expense of operations and equipment funds for the rest of the European high-energy physics program.

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More on solar-sea power

I want to add a few more comments about the article "Solar Sea Power" by Clarence Zener (January, page 48).

Zener is suggesting that a "heat engine operating in tropical oceans on the temperature differential between upper and lower levels could provide a source of economical, pollution-free electricity." The proposed heat engine will operate on a Rankine cycle using fluids such as ammonia as a working fluid. The working fluid will have a maximum temperature of 20°C and be condensed at 10°C.

Zener states that the sea-water volumetric flow rate through the solar sea power plant boiler is comparable to the water flow through a hydroelectric plant operating with a head of 93 feet. He makes the assumption that the solar sea power plant cycle efficiency is 0.033, which is close to Carnot-cycle efficiency of 0.034. High-performance steam power plants using superheat, reheat, and many stages of feedwater heating have efficiencies that are approximately two-thirds of their corresponding Carnot-cycle efficiency. The solar sea power plant will not be able to employ feedwater heating because the temperature differences involved are too small. Consequently, this type of power plant would have an efficiency at best equal to one-half its Carnot-cycle efficiency or 0.017. We can now examine water-flow rates that would be required for this plant from a more realistic point of view. Any plant that would make a significant impact on our electrical power generation must be 1000 MWe or more. A boiler obtaining heat from sea water entering at 25°C and leaving at 23°C would require a mass flow rate of 5.6×10^{10} pounds per hour to produce 1000 MWe in a power plant with a 0.017 efficiency. Hydroelectric plants operate with efficiencies of the order of 85%. For a 1000-MWe hydroelectric plant, the water-flow rate with a head of 93 feet would be 3.3×10^{10} pounds per hour. This flow rate is about 60% of that through the solar sea power plant, however, this comparison is still not valid because the condenser of the solar sea power plant must also have a sea-water flow rate of 5.6×10^{10} pounds per hour. Therefore, water-flows through the solar sea power plant are triple those through hydroelectric plants operating with a 93 foot head.

If one refers to figure 2 of Zener's article, it appears that an approximate 1000-meter separation would be necessary between the inlet ducts for the boiler and condenser. Consequently, for a 1000-MWe power plant a sea-water flow rate of 5.6×10^{10} pounds per hour would have to travel a distance of the order of 1000 meters, no matter what type of configuration was envisioned for the power plant. A considerable amount of power would be required to force sea water circulation, which has not been accounted for in estimating the efficiency of the solar sea power plant. These power requirements could be kept small if duct cross-sectional areas are of the order 10^5 square feet.

One may wish to compare relative costs of solar sea power plants with those of eixsting power plants. Because of the enormous size of the boiler and condenser one can reasonably assume that the cost of solar sea power plants consists mainly of the cost of the boiler and condenser. For a 1000-MWe solar sea power plant with an efficiency of 0.017 the heat load on the boiler would be 2×10^{11} Btu per hour. The same heat load would apply to the condenser because so little heat energy is converted into mechanical work. We can compare this with a 1000-MWe pressurized water reactor operating with an efficiency of 0.33. The heat load on the steam generator is 1.03×10^{10} Btu per hour and the heat load on the condenser of 0.69×10^{10} Btu per hour. By assuming that heat exchanger areas can be obtained from the expression $Q = UA\Delta T$ where U is the *overall* heat-transfer coefficient (Btu/hr ft^2 °F), we can write for the ratio of boiler and condenser areas for solar sea and nuclear power plants as

$$\frac{A_{ss}}{A_{nuc}} = \frac{Q_{ss}}{Q_{nuc}} \frac{U_{nuc}}{U_{ss}} \frac{\Delta T_{nuc}}{\Delta T_{ss}}$$

The overall heat-transfer coefficients for the boiler and condenser of nuclear power plants will exceed that of solar sea power plants because they can tolerate much higher fluid velocities with their greater pressure losses. However, in order to be conservative, it is assumed this ratio is unity. For pressurized water reactors ΔT in the steam generator is in excess of 100°F and is of the order of 20°F in the condenser. For the solar sea power plant ΔT in the boiler is of the order of 10°F and 7.2°F in the condenser. Therefore, the area ratios are estimated to be

$$\frac{A_{ss}}{A_{nuc}} \text{ boiler} \approx 200$$

$$\frac{A_{ss}}{A_{nuc}} \text{ condenser} \approx 80$$

Capital costs of nuclear power plants are now of the order of \$350 per kWe. I would estimate that the cost of steam generators and condensers is of the order of 10% of the plant cost with possibly 8% attributed to the steam generator and 2% to the condenser. With these estimates, nuclear steam generators would cost of the order of \$28/kWe and the condenser of the order of \$7/kWe. We will assume that on a unit area basis nuclear boilers cost 20 times that of solar power plants and condensers on nuclear power plants cost twice as much as those on solar sea power plants. On this basis the cost of the boiler and condenser for the solar sea power plant would approximate \$560 per kWe. All assumptions are conservatively in favor of solar sea power that still resulted in costs considerably higher than expected for nuclear power plants. No allowance has been made for the greatly increased cost of transmitting energy from equatorial regions whether it be in the form of hydrogen or electrical energy.

It is reasonable to assume that the economics of solar sea power is unfavorable compared to nuclear power and there is probably doubt from a technical point of view whether such a power plant would even work.

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The author comments: An analysis of James Rust's letter reveals some intrinsic advantages of solar sea power plants over conventional power plants not mentioned in my paper.

As Rust points out, high-performance fossil-fuel plants employ superheating, reheating, and many stages of feedwater heating, and still obtain a cycle efficiency of only two-thirds of the Carnot efficiency. In contrast, in a solar sea power plant, almost all the heat input to the working medium is at the boiling temperature. Only 2% of the total heat input is required to heat the working medium temperature. Whereas the Carnot efficiency of the solar sea power plant is admittedly low, the actual cycle efficiency closely approaches this Carnot efficiency.

Rust is quite correct in emphasizing the importance of the boiler and condenser cost. I therefore believe a detailed reply to his analysis of these costs is in order. Rust writes

$$\frac{A_{ss}}{A_{nuc}} = \frac{Q_{ss}}{Q_{nuc}} \cdot \frac{U_{nuc}}{U_{ss}} \cdot \frac{\Delta T_{nuc}}{\Delta T_{ss}}$$

Because the cycle efficiency of a solar sea power plant is essentially the Carnot efficiency, the first factor is only half of that given by Rust, namely 10. From a manufacturer's catalogue, we find that a steam generator passing 2100×10^6 Btu/hr has 45 miles of $^7/_8$-inch outside-diameter Inconel tubing. These data lead to a heat flux rate of

$$U_{nuc} \Delta T_{nuc} = 32\,000 \text{ Btu/hr ft}^2$$

In contrast, in a solar sea power plant's boilers and condensers, we estimate that the sophisticated surfaces mentioned in my paper will give a heat flux of 20 000 Btu/hr ft^2. We thereby obtain the ratio

$$A_{ss}/A_{nuc} = 16$$

for the boiler, in contrast to the estimate

made by Rust of 200.

One place where Rust has erred is in the ΔT of the pressurized water reactor's steam generator. In a typical steam generator, the reactor coolant flow enters at 618.5°F, and leaves at 557.2°F, whereas the boiling temperature on the steam side is 544.6°F, corresponding to a pressure of 1000 psi. We deduce a mean driving ΔT of not more than 44°F, while Rust assumes a ΔT_{nuc} of at least 100°F. Further, it appears that the heat-transfer coefficient U_{nuc} is less than U_{ss}, presumably because of thermal impedance on the boiling side.

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Light sources for holography

I would like to elaborate on a point concerning holography made by Toraldo di Francia in his February article, which discussed the importance of the laser to holography (page 32). This light source is valuable not only for the off-axis method, but indeed for nearly all of holography. Our own experience indicates in fact that the laser source offers no particular bias in favor of the off-axis configuration. This new source offered reduced exposure time, ease of setting up interferometer configurations, and the possibility of holographing arbitrary, three-dimensional objects in reflected light. It did not, however, affect our development of off-axis holography. Our first published off-axis hologram (1962), a rather simple one, was made with the conventional mercury-arc source. In the ensuing year, we labored to perfect the process, and thereby produced the vastly improved and more complex results of our 1963 paper. The improvements came about by the use of better quality optical components and by improvement of techniques for avoiding the artifacts (dust, dirt, scratches, striations, and so on) on or within the various optical elements. At about the middle of this effort the laser became available, and we tried it. It offered no decisive advantages, and we shifted between the laser and the mercury source, uncertain as to which would best help us attain our goal. In the end we chose the laser, primarily because this permitted exposure time of seconds instead of minutes, and saved the bother of equalizing the reference beam and object beam optical paths. So far as image quality was concerned, there was little difference, except that the mercury source gave slightly higher quality.

The lack of any overwhelming advantage for the laser was of course a consequence of using transparencies for objects; the several-centimeter coherence length of the helium-neon gas laser was quite unnecessary for this type of object, and indeed made the artifact noise worse. We noted in our 1963 publication that the laser, though helpful, was not required, and that we had achieved comparable results with mercury sources. We always had adequate coherence with the mercury source.

Later research demonstrated that, with proper interferometer arrangements, the coherence requirements of off-axis holography reduce exactly to those of in-line holography.

The great advantages of the laser became manifest when we advanced from transparencies to arbitrary, reflecting objects, and when B. J. Thompson and G. B. Parrent used the pulsed laser to holograph moving objects. These were accomplishments that, so far as I know, cannot be carried out with the classical coherent sources.

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PhD production

We find it regretable that such a fine article as that entitled "Physics in Perspective" (July 1972, page 23) by D. Allan Bromley should give such a distorted view concerning the changing patterns in PhD production. Not only is the semi-logarithmic plot given in figure 3 misleading, but more important, the caption is in our opinion incorrect. Most of the "leading" institutions did not realize until 1969 or 1970 the seriousness of the employment situation, and it was at this time that