

are usually in rural areas—remote from the more densely populated areas of volume-power utilization. The difficulty with this type of scheme is that the SO_2 atmospheric concentrations over large geographical areas eventually may be at levels high enough to endanger human life, vegetation, and materials. Tall smoke stacks—even those 800 feet high—are not a permanent solution to the problem because rural communities might be contaminated at distances as far as 25 miles from a given power plant.

Most U.S. crude petroleum is relatively low in sulfur, and residual fuel oil produced from it usually contains approximately 1.5% sulfur. However, less and less residual oil is being produced by U.S. refineries each year; at present it amounts to only about 8% of the domestic crude oil output. Many foreign crudes are much higher in sulfur content, and the usual residual fuel oils produced from them and imported into this country contain as much as 3% sulfur. During refinery operations, the sulfur tends to concentrate in the high boiling fractions—the ones with the lowest value per gallon. Since residual fuel oil sells for less than the crude from which it is produced, there is no economic incentive to process it further to remove the sulfur.

Technological aspects of sulfur control

(a) Precombustion removal of sulfur

The problem in removing sulfur from coal is compounded by the fact that not only do some coals contain as much as 6% sulfur, but the sulfur in all coals occurs in two major forms—organic and pyritic. Organic sulfur, which may be as much as 20 to 60% of the total, is actually part of the coal structure, and there is no known practical way by which this sulfur can be removed. Pyritic sulfur is at least theoretically removable; combined in mineral form as pyrites, it is physically imbedded in coal—not chemically bound to it.

Depending on their size, pyrite particles can be removed from coal with varying efficiency by such conventional coal cleaning processes as jigging, dense media, and concentrating tables. But, these processes are designed primarily to reduce ash content. If the coal is crushed sufficiently, the finer pyrite particles can be released. Information is available for only a few coal seams, but indications are that coal must be crushed to less than 100-mesh size to release most of the pyrites. Since material this fine cannot be transported except at greatly increased freight rates, release of the pyrites by crushing would have to be done at the point of use.

Success with these physical methods would have a very beneficial effect on the sulfur content of coals now being mined. If only an additional 0.5% of sulfur could be removed, more than 67 million tons of our present production would become "low-sulfur coal" containing less than 1% sulfur.

A variety of chemical methods—acid treatment, air and biological oxidation, gasification, carbonization, hydrogenation, and solvent extraction—through which coal is converted to other products have been suggested as means for removing sulfur. Right now, none of the methods except gasification appears to be economical, nor do they show prospects of becoming so in the near future. Gasification is the exception because it offers potential additional advantages for combining steam and gas turbine cycles to increase overall central station efficiency.

The sulfur compounds occurring in *residual fuel* oil are chemically bound to the oil molecules and their removal could require drastic treatment. Three major types of chemical processes have been suggested for reducing the sulfur content, and from a technological standpoint there should be no major obstacles for application to residual oils. The processes are (1) treating and extraction processes, (2) thermal and contact-catalyst processes, and (3) hydrosulfurization. Unfortunately, the processes are not simple, and there are serious economic obstacles to their use. Of the three methods, hydrosulfurization appears to hold the most promise.

Estimates for different-size plants and for differing processes and final-product specifications show costs ranging from 37 to 77 cents per barrel for any reasonable reduction in sulfur. Assuming an optimistic 50 cents per barrel as the cost of reducing sulfur, this would represent a price increase of about 25%—or about 7 cents per million Btu—over present posted prices for residual oil.

Another method for reducing the sulfur content of residual fuel involves blending the high-sulfur residuals with low-sulfur distillate to achieve low average levels. Estimates show that the cost of such blending would be extremely high. For example, reduction in sulfur from 3% to 2%, could increase the cost per mil-