from the waste gases will run from 10 to 20 percent of the cost of the utility plant. Additionally, many existing plants do not have sufficient space in which to place this added equipment. Also, the capital cost is so high that it is questionable whether these methods can be used by smaller space heating installations.

In addition to the waste gas absorption processes now under most active development, there are many less sophisticated methods or systems that have been proposed which may prove to be more successful than those now under development. In any case, a partial solution to the problem will probably be found within the next few years and research now underway may provide more feasible methods for an overall solution to the sulfur oxides problems. An additional factor which the Bureau of Mines research has taken into account is that sulfur or sulfuric acid, which could be recovered, is presently in world short supply.

A third approach for the removal of sulfur oxides bears promise of providing a solution applicable to certain combustion processes. In this process, the oxides of sulfur are fixed during combustion by the use of an additive material such as powdered dolomite or limestone which are low in cost, and the resulting calcium or magnesium sulfate can later be removed as a solid by methods similar to those used for removing particulate matter from gases. The information presently available is insufficient to assess the true potential of the process.

However, it may prove of appreciable importance both for small installations which cannot afford the high capital expenditures for removing the sulfur oxides from the stack gases, and for existing large plants where there is insufficient space to install the large amounts of additional equipment.

It has been shown that no single approach will solve the sulfur oxides pollution problem. For this reason, we believe a systems approach will prove most fruitful. A program is under study in the Bureau which will consider technologic development needs in terms of recognized air quality requirements. This systems approach will include: studies to delineate our coal and oil resources in terms of their sulfur content; selective mining operations; desulfurization of the fuel before combustion; fixation of sulfur during the combustion process; and desulfurization of the waste gases before release to the atmosphere. Interrelationships between process factors will be studied to assure the development of a method or combination of methods which will give the desired air quality at the lowest economic burden.

AUTO EXHAUST

The second major air pollution abatement problem concerns the reduction of pollutants produced by automobiles, trucks, and buses. These vehicular exhausts contain very large quantities of smog-producing constituents which are the major source of air pollution in certain areas. With the increasing population growth and the anticipated 3 to 4 percent a year increase in the number of automobiles on the highways, the Federal standards for auto exhausts, which will become effective with the 1968 model automobiles, will prove to be inadequate long before the end of this century.

Much progress has been made in our understanding of the types of pollutants that are emitted from automobile engines, but additional major engineering developments will be required before our technology is adequate. Although the requirements for all 1968 model cars will reduce the average level of emissions per vehicle by approximately two-thirds, we still do not really know whether the constituents from the exhaust which are largely responsible for smog production will be eliminated. It is believed that only a few of the constituents of the exhaust are the primary cause of the difficulty, while many of the other compounds present are relatively inactive. If abatement of automotive exhaust pollution is to be fully achieved, an overall systems approach should be employed which would include not only study of the fuel, but also of the engine and the exhaust system. The development of an optimum design for the automotive system involves many new techniques that have not as yet been developed. Many new engineering developments will doubtless be required before a better economic solution to the problem becomes available.

A number of different approaches to the automotive exhaust problem have been proposed and should be investigated. These include variations in fuel composition, radical changes in engine design, use of catalytic and noncatalytic afterburners, and many similar avenues.