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IMPLEMENTING TRADABLE PERMITS FOR SULFUR OXIDES EMISSIONS

A Case Study in the South Coast Air Basin

MAIN TEXT

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ABSTRACT

Tradable emissions permits have important theoretical advantages over source-specific technical standards as a means for controlling pollution. Nonetheless, difficulties can arise in trying to implement an efficient, competitive market in emissions permits. Simple workable versions of the market concept may fail to achieve the competitive equilibrium, or to take account of important complexities in the relationship between the pattern of emissions and the geographical distribution of pollution. Existing regulatory law may severely limit the range of market opportunities that states can adopt.

This report examines the feasibility of tradable permits for controlling particulate sulfates in the Los Angeles airshed. Although the empirical part of the paper deals with a specific case, the methods developed have general applicability. Moreover, the particular market design that is proposed -- an auction process that involves no net revenue collection by the state -- has attractive features as a general model.

ACKNOWLEDGEMENTS

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SUMMARY AND RECOMMENDATIONS

As the controlled trading options of the Environmental Protection Agency become more widely adopted, the concept of a market for emissions permits becomes closer to reality -- and less an academic exercise. This project has examined the issue of the feasibility of tradable emissions permits (TEP) as a means for controlling particulate sulfates in the South Coast Air Basin. It is intended to be a test case of the general approach of a relatively unfettered market in emissions permits. The methods of analysis employed are intended to provide a guide for attacking similar feasibility problems in other regions and/or for other pollutants.

The controlled trading options of EPA can be regarded as allowing some transactions within the framework of traditional command-and-control regulation. The focus of our work has been a system in which primary reliance in deciding the pattern of abatement among sources is placed upon the market, with regulators using the standards approach to set an overall emissions ceiling in a region and, on occasion, to deal with specific sources that require some constraints on their acquisition of permits (and hence emissions) through the market.

The desirability of the market approach depends on its performance according to several different criteria. First, TEP must realize their principal design advantages: reduce the costs of compliance with environmental standards and increase the flexibility with which firms in the region can enter or expand. Second, this must be accomplished within the constraint that overall environmental objectives are not sacrificed -- that is, that the implementation of TEP does not degrade air quality. Third, the effects on the distribution of wealth and the industrial structure of the region must be politically acceptable. While we offer no index of political acceptability, an analysis of any major regulatory reform must provide decisionmakers with useful information about these impacts which they can use to assess this element of feasibility. Fourth, the reform must be made to fit into the body of law regarding regulation and administrative processes. Reforms must either be legal under current law, or must be accommodated by changes in law that are regarded as reasonable in the sense that they do not violate the spirit of public policies towards environmental protection, due process, etc.

To attack these issues, we have assembled the following information: abatement cost data for major source categories of sulfur oxides emissions in the air basin, an emissions inventory under current standards, a working model of the relationship between emissions and air quality, and the relevant statutory and case law in both environmental and public utility regulation. We have used the data on costs, emissions and air quality to simulate the results of different market designs to determine the properties in terms of costs and air quality of several different approaches to a TEP system. We have used work in economic theory and small group experiments to check whether the hypothetical market institutions that we have considered can be expected to work in practice. And, we have assessed the important legal barriers to implementing a relatively full-blown tradable emissions permit system.

A number of technical and economic questions need to be addressed explicitly to demonstrate the feasibility of the TEP concept. Can a competitive market in TEP be established -- one that has the desirable features of flexibility and cost-minimization of competitive equilibrium in economic theory? Or will the market be monopolized, or have so few traders, that it does not produce an efficient result? And, if competitive allocations of permits are attained, what effect will this have on air quality? Assuming that the result is acceptable from both an efficiency and an environmental point of view, what will be the effect on abatement costs, the profitability of local industry, and the structure of the regional economy? Finally, assuming that these other questions can be answered in an acceptable fashion, what exactly has to be done -- in law and in working out the details of the market -- in order actually to implement the plan?

The results of the work on this project indicate that, indeed, a system of tradable emissions permits is feasible -- but that it must be carefully designed to avoid some pitfalls. Moreover, there are some legal and regulatory policy issues that need to be worked out to adopt the form of a permits market that is likely to work the best. Selecting a design for TEP in Los Angeles is in part a matter of technical and economic analysis, but it is also partly a matter of judgment. It requires an assessment of the political realities constraining reform, and of the types of risks that a regulatory agency is more and less willing to run.

In Los Angeles, the possibility of monopolistic practices and thin markets apparently are a far more important design issue than is the possibility of undermining environmental objectives. Theoretically, any environmental objective can be obtained by creating a large enough number of different kinds of permits, each of which relates to pollution at a specific geographical location. Practically, fine-tuning the system in terms of multiple markets for sulfur oxides emissions promises gains, yet presents formidable problems of transactions costs and market structure. Consequently, a system in which permits are simply stated in terms of allowable quantities of SO_2-equivalent emissions anywhere in the region appears to be the most desirable.

The Los Angeles airshed has a relatively large number of sources producing a small quantity of emissions, but only ten firms account for about 85 percent of the total. Consequently, imperfectly competitive and thin markets are a potential problem for large transactions. The implication is that the method selected for initializing and maintaining the system should encourage an active, competitive market.

The most attractive method for the initial allocation is an auction. This provides a thick market (all permits are transacted in the initial distribution) and, because all polluters are placed on the same side of the market, it minimizes the likelihood of monopolistic imperfections. The mechanics of the proposed mechanism are as follows. Each source would be asked to write down the number of permits it would seek to purchase at each of several prices. The firm would be free to choose as many price gradations as it wanted. It could write down one price-quantity pair (e.g., X tons per day at any price up to $Y per ton). It could provide a step function of several jumps, such as X tons per day for prices between $Y and $Z ($Y being larger), and X+W tons for prices below $Z. Permits would then be allocated to the highest bidders at the quantities requested, descending down the price bids until the permits were completely allocated. The final price could be determined by either of two methods. The simplest to understand is a "first-price auction," in which the price is the lowest successful bid. The alternative is a "second-price auction," in which the price is the highest unsuccessful bid. The second-price auction is slightly superior theoretically because it is more likely to produce a competitive allocation and be free of strategic manipulation by a participant with a large share of the market.

A separable equity issue accompanying the auction is the allocation of the net costs of the permits. Whereas the permit price determined above could actually be paid to the state, an alternative is to pay the revenues according to a previously arranged provisional permit allocation. As a political matter, the chances of implementing a tradable permits system may be greater if the revenues do not accrue to the governmental treasury, and if the provisional allocation of the rights to receive the revenues from the permit auction does not reward firms who have been most resistant to current environmental regulations. For example, one possible alternative is to base allocations on an amended list of existing emissions, with the few remaining uncontrolled sources being put through an emissions standard process before the initial allocation of tradable permits is made.

In any case, the provisonal allocation would be used solely for allocating auction revenues. Each polluting firm would make bids on permits, and thereby receive a final allocation of emission permits according to its bids at the price of the highest excluded bid. The firm would pay for these permits at the established price, and receive revenues at the same price for the permits which it held provisionally. The net payment for a particular source would be the product of the auction price and the difference between its final allocation based upon the bidding procedure and its provisional allocation based upon its emissions baseline. For all firms taken together, the net payment would be zero.

It is worth noting that in this type of auction, if a firm reports its true cost-minimizing demand for permits, any difference between the final and provisional allocations is a net financial gain. A firm will end up buying permits only if these permits allow an even greater savings in abatement costs, and will sell permits only if the revenues from the sale exceed the costs of the additional abatement that the sale will require. Hence, participation in an auction that reallocates all auction revenues in this way can harm a firm only if it is not truthful in stating its demand for permits. This is true even if the market is not competitive.

To provide a continuing opportunity for entry and expansion, the initial permits could be separated into vintages according to useful life and periodically reissued by the same process. A predesignated portion of the permits would expire every few years -- for example, permits could be valid for nine years, with one-third expiring every three years. Prior to the expiration date, the regulators would determine how many permits would be issued to replace the expired ones, based upon considerations of cost and air quality. The new permits could be allocated by the same auction procedure as was used for the initial allocation. Provisional allocations for purposes of distributing auction revenues would be based upon holdings of the expiring permits, but the final allocation would be based upon an auction. Meanwhile, between auctions businesses could negotiate trades if they so chose.

The system of permits with sequenced expiration introduces flexibility into the regulatory process while still retaining a substantial amount of stability. More risk-averse firms, or firms seeking to pursue abatement strategies involving long-term capital investments, could adjust their portfolio to hold permits with late expiration dates. Each three-year regulatory review would introduce the opportunity for altering total emissions in response to new information or political changes.

The system described above addresses the major questions about a tradable permits approach.

1. An auction process for sequentially expiring permits guarantees regularized transactions that involve all sources in the airshed and, in addition, appears capable of producing a stable, competitive price for permits.

2. There is no significant loss in efficiency or air quality if the entire region is treated as a single, homogeneous market.

3. The Cass model of the relationship between emissions and air quality provides a good basis for establishing the air quality impact of an initial quantity of total emissions, and the sequential expiration of permits easily accommodates further adjustments to account for whatever errors might be present in the model's predictions.

4. Sequenced expiration of permits can also provide the possibility for long-term stability for firms that desire it, facilitating capital investments in abatement methods for firms that want to use them, while still letting the regulatory system adjust to changes in information or political values.

5. The sequenced expiration dates for permits plus the auction method for allocating them facilitate easy entry and expansion of emissions sources without altering environmental quality.

6. Even using the abatement cost information available to us, which is likely to overstate abatement costs, implementation of tradable permits will cause no dislocations in the local economy, in part because the cost-minimizing abatement strategy does not impose costs on any industry that would cause a significant reduction in output, and in part because the auction mechanism avoids the problems of temporary, distorted prices that create false incentives to industry.

Thus, tradable emissions permits are an attractive alternative to command and control regulation for the specific case of particulate sulfates in the Los Angeles area. We also believe that the analysis contained in this report has wider applicability. First, the most important questions about the feasibility of tradable permits are likely to be pretty much the same for all pollutants in all regions. Second, the design concepts that have been developed for this particular problem do not appear to us to be idiosyncratic. This project, then, provides a methodological guide for examining the prospects for this approach in other areas for other pollution problems.

A comprehensive TEP program faces two important legal barriers before it could be implemented. Although the Clean Air Act apparently does allow markets for emissions among old sources, it is quite specific in requiring that major new sources use up-to-date control technology, even if to do so causes significant differences to emerge in compliance costs between old and new sources. Thus, a limited TEP system -- confined to old sources -- could be implemented with minor changes in state and local laws and practices, but a TEP system that included new sources would violate Section 111 and Section 116 of the Clean Air Act. This is unfortunate, for one of the major advantages of TEP is the ease with which entry and expansion of new sources can occur without undermining air quality goals. Thus, a most effective system requires amendment of the Clean Air Act. Most promising would be to authorize a special experiment in innovative regulatory methods, limited to this one case, with provision for later evaluation. But even if such an amendment is not feasible, a TEP system that is constrained by new source performance standards is both useful and feasible.

A second legal issue has to do with the methods and practices of public utility regulation. Electric utilities are a major source of emissions in Los Angeles, and therefore can be expected to be a major force in a permits market -- assuming that they can and will participate. Unfortunately, their participation is not a foregone conclusion. Methods for regulating prices and profits of utilities in California are not particularly harmonious with the idea of an intangible asset in pollution permits that can enter the calculations of allowable costs for a utility. To cause the incentive effects of a permits market to be appropriately imposed on a utility requires that permits enter the allowed cost calculations of the firm, and that revenues from the sale of permits be available for abatement expenditures or other uses, rather than returned to ratepayers in lower prices. Current regulatory practice in California would not lead to this result for some of the alternatives to structuring a permits market that we have examined -- including the EPA's controlled trading options.

There are ready solutions to the utility rate-making problem, the details of which are described in Chapter 5. The general recommendation we have is that the Public Utilities Commission should use the authorization for experiments in rate regulation in the Public Utilities Regulatory Policies Act to treat tradable emissions permits in a somewhat novel fashion that will apply "replacement cost" valuation methods (even though California is an "original cost" state) and that will use the legal analogy of long-term leases to determine whether permits expenditures will be regarded as capital or operating expenses.

CHAPTER 1

INTRODUCTION

Roger G. Noll

One of the reforms of environmental regulation that has received considerable attention in the past few years is to replace source-specific standards with a system of tradable emissions permits (TEP). The theoretical case for the proposal is strong; however only recently have analysts devoted much attention to developing a strategy for implementing such a system. A synopsis of the research on TEP is contained in Appendix A.

This report addresses the problems of setting up an efficient market in emissions permits. We first develop the case for using tradable permits to solve environmental problems. Then we raise and attempt to answer some of the implementation questions that decisionmakers raise about the proposal. Because this is essentially a feasibility study, our answers to these implementation problems are presented in the context of a particular problem: the case of particulate sulfates in the Los Angeles airshed. The results of the empirical work for this case study are also included.

THEORETICAL ADVANTAGES OF MARKETABLE PERMITS

Decentralized, market-oriented methods for abating pollution have several theoretical advantages. Before discussing these advantages, it is useful to separate the methods available to regulate air pollution into four general categories. One is <u>input standards</u>: regulators tell polluters what kind of equipment or abatement strategies to adopt, such as requiring a utility to install stack gas scrubbers and/or burn low-sulfur fuel at a generation facility. A second is <u>output standards</u>, in which each polluter is told the quantity of emissions allowed at each source. Here the polluting firm is allowed to select the method for achieving the emissions target as long as the result is in compliance with the standard. A third method is <u>tradable permits</u>, whereby a target rate of emissions is set for a region and a market mechanism is relied upon to determine how these permits are allocated among emissions sources. A fourth approach is <u>monetary incentives</u>, which includes abatement subsidies and emissions taxes. Under such schemes a polluter is charged some amount for each unit of emissions and/or subsidized for each unit of emissions reductions beyond a specified baseline.[1] Subsequent discussion focuses on taxes. Emissions taxes seem more likely to be implemented than subsidies because the former do not have to confront the problems of seeming to reward pollution, encouraging entry of polluting industries, and raising revenues for subsidizing industrial abatement efforts. Nevertheless, subsidies are now used in one case -- grants for sewage treatment facilities -- and might prove politically more attractive if coupled with an emissions tax as the source of revenues for the subsidies.

In all cases, the purpose of environmental regulation is to achieve some overall reduction in pollution; for the case of air pollution, the target is an ambient air quality standard. In each case, an emissions target is selected that is thought to be consistent with the overall objective in terms of pollution reduction, although the link between environmental quality and emissions is often subject to considerable uncertainty. But in principle, input standards, output standards, emissions taxes and the number of tradable permits all can be chosen to achieve some target level of environmental quality.

In practice, environmental regulation has become a hybrid of all four approaches. In the Los Angeles airshed, for example, both input standards and emissions limits are used, a relatively low emissions fee is charged, and emissions permits can be traded according to the "controlled trading methods" that have been developed through the Environmental Protection Agency (EPA) in the late 1970s. Moreover, nationally there is relatively little difference in the way that input standards and output standards are adopted. An input standard is imposed upon a firm because regulators anticipate that it is the best feasible strategy for reducing emissions; an output standard is imposed on the basis of analysis of the technical abatement alternatives, and is normally set after a demonstration that a particular technical alternative can achieve the standard. In fact, standards are often really a combination of the two: an output target is set, and an acceptable technical approach is identified.

All standards must be adopted in a quasi-judicial process that is subject to judicial review on the basis of the procedures that were followed and the adequacy of the evidentiary basis for the decision. In the process of setting the standard, the regulatory authority bears the burden of proving that the regulations are reasonable with respect to cost and effectiveness; hence the tendency to deal with both inputs and outputs in setting standards for a particular source. Once a standard is adopted, if a polluting firm wishes to adopt another method of abating the emissions, it then bears the burden of proving that the other technical option will work at least as well. In both cases, the process of adopting a standard requires considerable time and expense, especially if regulated firms or environmentalists elect to challenge the standards in the courts. Thus, a key feature of the system of source-specific standards is that they are costly -- in dollars and time -- to establish and to change.

One factor influencing the choice of a standard is ease of enforcement. When the technology of choice is a specific piece of capital equipment, enforcement is the simple task of inspection to see if the equipment is present and working. Emissions taxes, tradable emissions permits and output standards require monitoring to determine compliance. Monitoring performance is usually more costly and technically more difficult than inspecting inputs. In the long run all regulatory approaches will be evaluated in terms of their performance with respect to pollution, and experience to date suggests that input regulation is too crude a control on performance to make worthwhile its lower enforcement costs. In Los Angeles, performance monitoring is relatively sophisticated already, so that no special problems are associated with a possible switch to tradable permits. Some questions about the design of fines in enforcement are considered in Appendix B.

The standard-setting approach to environmental regulation has several important shortcomings.[2] A regulatory system that deals with each specific source of emissions -- sometimes several at a particular plant -- requires that regulators must learn enough about the production process that they are regulating and the abatement opportunities available to it that they can determine the optimal emissions reduction for it. Because of the adversarial nature of the process, firms are likely to be reluctant to go to great lengths to provide accurate information to regulators. Moreover, some abatement strategies may involve changes in the production process that, if revealed in a public regulatory process, would give away economically significant trade secrets. Consequently, the standards that are adopted are not likely to be the set of cost-minimizing steps to achieve the overall air quality objective. Significant differences among firms in the costs of complying with regulation not only are inefficient, but also can upset competition among firms in the same industry.

Standards also provide blunted incentives for technological innovation in abatement. In the current regulatory system, industries that produce abatement equipment have a strong incentive to invent new equipment that reduces emissions; however, the firms that are the objects of regulation lack that incentive, and indeed can be expected to fight the adoption of better performing but more expensive abatement technologies. In addition, the case-by-case regulatory approach raises the cost of any technical change by requiring preimplementation approval by the regulators.

Finally, standards inhibit the entry of new firms into an area. Before a firm may enter any area, it must obtain approval of its emissions from the regulatory authority. And, if the area is not in compliance with ambient air quality standards, entry can be foreclosed if the new or expanded facility generates <u>any</u> emissions at all. In general, emissions standards for new plants tend to be substantially more rigorous -- and expensive -- than are standards for established plants in the same industry using the same production technology.[3]

In sum, standards do not lead to the most cost-effective abatement strategies, are promulgated in a costly, time-consuming process, and impede technological change and new business investments. Given these problems, the question naturally arises as to whether taxes and tradable permits are better ways of meeting a prescribed set of environmental policy objectives.

The purpose of a marketable permits system is to achieve the ambient air quality standard for a particular pollutant at minimum total cost, including both the direct abatement cost and the cost associated with the regulatory process. This is achieved by relying on decentralized decisions to rationalize abatement strategies at all sources. Each firm faces an abatement cost function -- that is, a relationship between the amount of emissions that it will produce and the costs it will face. If the tradable permits market works efficiently (an issue that is examined in the next section), the best strategy for each firm is to abate emissions to the point at which the price for additional emissions (either the actual price of buying more permits or the opportunity cost of keeping, rather than selling, the permits it already has) equals its marginal abatement cost. If this solution holds for all firms, then all firms will pay the same amount for the last unit of pollution that they abate, and all firms together will achieve at minimal total cost the air quality standard that is implicit in the number of permits that are issued.[4] Moreover, this cost-minimizing abatement strategy will emerge without the necessity of a regulatory review of the costs and performance of the abatement strategies available to the sources and a formal approval of the technical approaches that are selected.

Emissions taxes have many of the same theoretical virtues as tradable permits. If firms are cost minimizers, effluent taxes also can lead to the cost-minimizing solution.[5] Like tradable permits, they provide a continuing incentive for cost reductions. Moreover, because taxes do not entail the introduction of a market, they avoid the implementation problems of permits, assuming that an efficient, competitive market will emerge.

While the theoretical case for taxes is strong, they have seldom been implemented. One reason is political -- they confer benefits on the general public, but they force firms to pay both abatement costs and emissions taxes. The extent to which firms pay taxes out of profits depends on whether the increase in taxes can be passed along to consumers. Nevertheless, it is usually in industry's interest to oppose taxes in comparison with standards because the latter avoid the tax. Tradable permits also can avoid net payments to the government if licenses are initially given away rather than auctioned.

Emissions taxes also present some difficulties in dealing with the entry of new sources of pollution. Unless taxes adjust upward, they will lead to ever-worsening environmental quality; however, if taxes are to be adjusted when entry occurs, something like a regulatory process must be used to examine the implications of each new entry and set an appropriate new tax. By contrast, entry under a permits regime requires only the acquisition of the necessary permits from other sources, neither posing a threat to environmental standards nor requiring a formal review of the entrant's likely emissions and abatement opportunities.

As mentioned above, all performance-related regulatory approaches raise questions of enforcement costs because of the difficulty of monitoring pollution. Emissions fees, however, are somewhat more difficult to enforce because they require continuous monitoring to estimate total emissions for the purpose of determining tax liabilities. An emissions fee is normally some price per unit of emissions; hence total emissions during a tax period need to be estimated. Moreover, for the tax to be collectable, the monitoring process must be accurate enough to withstand legal challenges.

Performance standards and emissions permits can be enforced by intermittent monitoring. The key issue in either case is if a firm is in compliance with its emissions ceiling, whether the ceiling is established by a regulatory process or by acquisition of permits through a market. Noncompliance fines need not be based upon the extent to which the firm is out of compliance (e.g. on total measured emissions), although the fines must be high enough and the probability of detection great enough so that a firm prefers to emit within its ceiling rather than to run the risk of being caught with excess emissions.

Another characteristic of taxes that has caused opposition to them is that the consequence of uncertainties over the cost-effectiveness of abatement techniques emerges in an emissions tax system as unpredictability in the quantity of emissions. By contrast, both output standards and a permits scheme would specify the overall quantity of emissions in advance, and the uncertainties in the system are with respect to cost. Input standards suffer from both uncertainties, because the use of a technology, not its effectiveness in reducing emissions, is the measure of compliance.

The reforms of environmental regulation pursued by EPA since the enactment of the Clean Air Act amendments of 1977 foresee a limited role for emissions fees in the context of traditional standard-setting methods. This role entails the use of "noncompliance fines" for firms that fail to meet the standards, with the fees designed to be high enough to provide incentives to comply before all legal avenues for fighting compliance are exhausted. This, of course, avoids some of the political and technical problems of emissions taxes, but it also sacrifices their principal advantages in terms of minimizing abatement costs and providing an incentive to beat the standards.

The theoretical advantages of a tradable permits system make them worthy of further serious investigations. Indeed, both federal and state regulators have expressed considerable interest in this method. As mentioned above, EPA has developed several limited variants of a tradable permit system that are being applied experimentally around the nation. These so-called "controlled trading methods" are:

1. Bubbles. A single plant that has several emissions sources may be permitted to increase emissions beyond the current standard at one location if it makes a greater reduction in emissions somewhere else at the same facility;[6]

2. Offsets. A firm may add new emissions in a geographic area if it pays for a greater reduction in emissions somewhere else in the same area; and

3. Banks. A firm that reduces its emissions below the applicable standard may deposit as a credit some fraction of its excess emissions reductions in an emissions bank. These banked emissions credits can then be sold to some other firm that seeks emissions permits.

All of these policies are designed to introduce some flexibility into the means by which firms comply with environmental regulations by introducing the possibility of trading emissions at one place for emissions somewhere else. In this sense they are conceptually similar to tradable permits. But all retain important elements of the standard-setting approach as well. Each trade requires regulatory approval, and the source using the traded permit assumes a burden of proof that the trade is consistent with overall environmental policy.

Current distinctions in the stringency of regulations between new and old sources are retained in all of these policies. Thus, firms seeking to locate an environmentally significant new source of emissions by acquiring tradable permits must still operate at lowest attainable emissions rates. For new sources, the trading policies are regarded as a means for providing the possibility for entry when compliance with new source standards would still not be sufficient to comply with ambient air quality standards.

As of early 1982, the new policies did not yet have completely defined rules and procedures governing transactions, nor in most cases a convenient institutional arrangement for facilitating them. The offset policy has no formal process for informing prospective participants in an offset about the identity of potential partners, the likely cost of reducing their emissions, or the expected price of their emissions permits. Each offset transaction is the result of bilateral negotiations outside of any formal institutional structure established by the government. Emissions banks do have a formal record-keeping method for tracking the amount and source of marketable emissions credits, but at present the formal rules and procedures regarding trades are still being worked out. For both offsets and banks, trades must be approved by local regulatory authorities, although formal approval from the EPA can now be avoided if the trading system is established according to EPA guidelines.

A final problem with all three methods is that the long-term status of traded permits is not clear in any program. If environmental quality in any area falls short of the policy target, all permits -- traded or not -- are subject to revision; however, traded permits and banked credits from sources that reduced emissions below standards appear more likely to be confiscated or severely reduced in value than other permits do. For example, in listing the options available to a local air pollution control authority should a revision be necessary in the amount of emissions that is allowed, the EPA manual for setting up an emissions bank cites four alternatives:

1. A moratorium on the use of permits obtained from the emissions reduction credit bank;

2. On a source by source basis, a revision in the number of permits from the bank that are necessary to produce a unit of emissions at that source;

3. An across the board reduction in the amount of emissions permitted for a permit acquired through the bank; or

4. A forfeiture of all traded permits.[7]

Thus, a traded emissions permit may have secondary regulatory status in comparison with an untraded permit, making the former less valuable. The possibility that traded permits will be treated this way will make firms reluctant to reduce emissions beyond current requirements in order to create marketable permits out of concern that their additional emissions reductions will be confiscated rather than made available to others. Potential trading partners will be equally reluctant to make long-term capital investments on the basis of emissions permits that have such an uncertain status.

The tradable permits system examined here is a more radical institutional change than has thus far been contemplated by regulatory authorities. It would eliminate distinctions among sources because of age, ownership, industry or method of acquiring permits. It would simply establish a ceiling on total emissions within a geographic area, and it would allow the allocation of emissions among sources in the area to be determined solely by the market. No regulatory review of the methods used by any source nor of the distribution of emissions permits among the sources would be undertaken. Policy issues relating to the differential air quality effects of different geographical distributions of emissions permits would be dealt with by the way in which trading regions were defined, and by the rules for trading across regional boundaries, as will be discussed below. The role of the government would be reduced to the following activities: (1) establish ambient air quality standards; (2) determine the total amount of emissions that is consistent with the air quality standard; (3) issue permits and maintain a record of their ownership and a market for them; and (4) enforce the emissions limits by ascertaining whether each source is producing no more emissions than the quantity of permits it holds and by imposing noncompliance penalties.

DESIGN PROBLEMS FOR TRADABLE PERMITS

The main purpose of a tradable permits system is to convey to polluters -- new and old -- appropriate price signals about the social cost of emissions so that each can select a combination of capital investments, operating practices and emissions releases that minimize the sum of abatement costs and permits costs. The economic efficiency of the system depends on firms being able to buy and sell permits relatively easily, with incidental transactions costs, at competitive prices. The principal implementation problems associated with a tradable permits system are related to the question of whether these conditions for an efficient market can be satisfied in a manner that is equitable, legal and politically feasible.

One problem is the possibility of "thin" markets -- that is, markets in which transactions are rare, and in which few firms are willing to buy or sell. In such a situation, the transactions costs of trading permits can prevent the market from being much of an improvement over source-specific standards. If a firm that seeks to buy permits must invest substantial time and resources in finding a potential trading partner, and then engage in bilateral negotiations to determine a price, the ability of the permits market to find a cost-minimizing total cost of achieving ambient air quality standards is undermined. Moreover, infrequent trades arranged through negotiations are less likely to convey clear price signals to potential entrants, firms contemplating expansion, or sources considering further abatement and the sale of some emissions permits.

A second problem is related to the structure of the permits market. In some airsheds, one or two firms can account for a very large share of emissions. Moreover, there is some tendency for regulators to require somewhat greater abatement efforts from the largest firms. In this situation, if a tradable permits system is initiated by making tradable the emissions permits that are implicit in current standards, it is conceivable that only one or two firms will be seeking to buy permits, with all other firms seeking to be sellers. If so, the market may not settle on the competitive equilibrium price, but a monopsonistic price instead. More generally, the degree to which a market diverges from the competitive ideal depends on the initial allocation of permits, and in any situation it is technically possible to pick an initial allocation that produces a monopoly or a monopsony. Thus, a design problem for a tradable permits market is to avoid an initial allocation that has this property.

A third problem has to do with the definition of markets and permits. As discussed briefly above, the relationship between emissions and pollution is often very complex. Pollution at any given receptor point is the consequence of emissions from several locations, and often depends on their interactions as well. Similarly, every source of pollution has a unique pattern of polluting effects, which, because of interactions, may also depend on emissions from other sources. In general, to achieve theoretical efficiency (ignoring transactions costs and possible market imperfections) requires a separate transformation function for each source of pollution that maps its holdings in pollution permits at any source to its emissions allowances. Of course, this degree of complexity is impractical to implement. Hence, an important design problem is to make simplifications in the definition of permits and regions in which permits are valid that do not sacrifice too much in the way of the potential efficiencies of a market mechanism. At one extreme, a large geographic region can be treated as one market, with the implication that the region will be treated as one large mixing bowl in which emissions from all sources are uniformly spread across the region. As a description of reality, no pollution problem -- not even emissions into standing bodies of water -- has this fully mixed property; however, as a practical matter it may be a workable assumption. A somewhat more complicated strategy is to define a few receptor points at which pollution is measured and require firms to purchase emissions permits for pollution at each receptor point where their emissions cause pollution.

The best way to organize the market -- the definition of a permit and the sources that must hold it -- depends only in part on the physical aspects of the pollution problem. It also depends on the economic incentives operating upon sources. If abatement cost functions for all sources lead to more or less the same degree of abatement (e.g., they are all reducing emissions by roughly the same proportion), a permits market that is defined crudely, even wildly incorrectly, as a mixing bowl may still be workable. In the worst case -- in which each receptor point is polluted by only one source -- the cost-minimizing distribution of emissions may still produce approximately the same amount of abatement at all sources.

In most regions, pollution problems exhibit both kinds of characteristics: localized, single-source pollution, and effects from the combined emissions of many sources. A plume from a smokestack may be the primary cause of pollution on receptors a few miles downwind, but as distance from the stack increases its emissions will mingle with the releases from other facilities. To take an extreme example, the problem of acid rain in Canada, New York and New England is probably the cumulative effect of emissions from literally thousands of sources, some more than a thousand miles away. Whether a tradable permits market is workable, then, depends on the relative importance of the local versus long-distance effects, and on the likely pattern of abatement that will emerge from the market.

A fourth issue in the design of a tradable permits system is its flexibility with respect to changes in ambient air quality or total emissions targets. Because the relationship between emissions and air quality and the effect of air quality on health are not well understood, there is a good chance that new knowledge will cause regulators to want to change emissions levels. A decision to create more permits is relatively straightforward to deal with; regulators can give away or sell some net increment to the total emissions rights in an area. But a decision to reduce the number of permits raises potential difficulties. The heart of the issue is still another dimension of the definition of an emissions permit. Is its lifetime perpetual, or of fixed duration? Can it be redefined by fiat, or as an outcome of a regulatory process, or must changes in the number of permits be accomplished by purchase of the state? Obviously, the ease with which the number of permits can be changed depends on the answers to these questions. Moreover, a constraining factor on building into the permits system a mechanism for changing the number of permits is the effect of the mechanism on the willingness of firms to hold permits. If polluting entities are made to believe that the value of an emissions permit is subject to significant change at the whim of the state, abatement strategies -- in terms of both the amount of abatement and its distribution between long-term capital investments and changes in operating methods -- are likely to be affected.

Fifth, the implementation of a tradable emissions permits system can have an important effect on the distribution of income in a region. The permits themselves have economic value, so that the choice of methods for distributing them initially will make the recipients of the permits wealthier. Moreover, the costs of the system of air pollution regulation to polluting industry will also be affected. On the one hand, industry in general will face lower total abatement cost and lower costs of participating in the regulatory process. But firms that are required to purchase permits may face more than offsetting expenses on permits -- depending on how the permits are distributed initially. Regulators can affect these distributional consequences, for the method of implementing TEP will be an important factor in determining how and by how much the TEP system will immediately alter the industrial structure of the region and the distribution of wealth. This issue is not only a matter of equity, but affects the political feasibility of the system as well, since these economic impacts will play an important role in the decisions of key groups to support or to oppose the reform. A more complete discussion of the source of political resistance to the TEP approach is contained in Appendix B.

Sixth, an element of system design is the state of the law that surrounds regulatory policy. Three important areas of regulatory law are important: environmental law, as represented by the Clean Air Act; administrative law, which establishes the bounds on the procedures and methods that a regulatory agency can adopt; and public utility law, by which the prices and profits of electric utilities are regulated, including the accounting practices for passing through to ratepayers the costs of environmental regulation. None of these areas of law has developed with the idea of dealing with the use by regulators of decentralized market forces to achieve social objectives. Consequently, the concept of tradable emissions permits does not fit comfortably into the body of established law. An important question for regulators is how existing law constrains the design of a tradable emissions permits system, and how law needs to be changed to accommodate the most attractive system.

Finally, some account needs to be taken of so-called air pollution episodes: periods when meteorological conditions are exceptionally unfavorable, and so air pollution builds up over a number of days. To limit emissions to a level consistent with good air quality on these worst days is irrational; it is far less costly to curtail economic activity for a few days a year than to build in abatement capacity that would keep air quality high regardless of the weather. The current practice is to announce the degree of unfavorability of conditions a day in advance, and to invoke special regulations when conditions look especially bad. To do something much more complicated than this is of dubious value, because the frequency and magnitude of air pollution episodes is not very high, and will be lower still as limits on emissions are lowered.

The tradable permits systems could easily adopt the present approach to episodes, with the emissions permits applying only in the vast majority of days when there is no special condition. Alternatively, separate emissions permits markets could be implemented, one for normal conditions, and one or more for episodes, with regulators announcing each day which permits apply tomorrow. Because this problem is relatively easy compared to the others it will not be addressed in the remainder of this report.

VARIANTS IN SYSTEM DESIGN

The design features available to construct a workable permits market are as follows.

1. Permit Life. Regulators could elect to make the durability of emissions permits uncertain by stating that they were valid until a formal regulatory procedure declared them to be invalid or changed the amount of emissions allowed by a single permit. Such a system would create incentives among firms to adopt production methods with some flexibility in emissions, and to hold more permits than were actually used. Alternatively, regulators could define the time period in which a permit is valid. At one extreme, permits could be perpetual, requiring regulators to buy them back to reduce total emissions. Or, regulators could assign a fixed life. If regulators decided to alter the number of permits, they could do so by allowing firms to trade in old permits for new at a specified exchange rate. Finally, regulators could have several different kinds of permits: some perpetual, some of a fixed, long-term duration, and some with a short life (e.g., one year). Some periodic variability in the number

of permits could be accomplished through the process of reissuing the permits with the short life; somewhat greater variability could be introduced as the intermediate-duration permits expired.

2. Market Definition. An emissions permit pertains to a particular geographic area. The size of the region and the variety of permits a source must hold for a given emissions allowance is a design feature of the system. Regulators could define emissions permits as freely tradable among all sources in a wide geographic area. Alternatively, a region could be subdivided into smaller areas, with trades between areas either barred or permitted according to some transformation of the value of a permit across area boundaries. Or, markets could be defined according to the location of receptors. In each area of the region, a coefficient would be estimated that related the effect of a unit of emissions on ambient air quality at a receptor point. Sources could then be required to hold permits to pollute at a receptor point equal to their quantity of emissions multiplied by the corresponding coefficient.

3. Market Initialization. Regulators must select a method for initially distributing the permits. One possibility is to give them away according to some rule. Examples of allocation rules are: in proportion to precontrol emissions, in proportion to emissions allowed under existing standards, or equal to the expected equilibrium distribution of emissions if abatement costs were minimized. Alternatively, permits could be given to entities other than sources of pollution: the poor, schools, etc., presumably any of which would then elect to sell them. Or the government could allocate the permits by auctioning them. The latter two options suggest that sources of pollution would have to pay for permits; however, this is not necessarily the case for a state auction. Ownership of permits could be conferred on sources according to one of the rules for giving permits aways, but sources could then be required to use an auction process to allocate the permits among themselves, with the revenues from the auction divided among the sources in proportion to their ownership shares.

4. Market Operations. Once an initial allocation has been made, provisions must also be adopted for later transactions. Government could leave the problem of organizing a continuing market to the private sector. Alternatively, given the recordkeeping requirements of the government for purposes of enforcement, the government could act as a marketplace by providing information about potential buyers and sellers to anyone requesting it. Or the government could be more than a passive marketing agent by actually requiring regular opportunities for reallocation of permits. This could be accomplished by forcing periodic reauctioning (with proceeds redistributed among the sources) of some fraction of the permits. A reauctioning process fits naturally with a system in which permits have fixed durations, for then the replacement of old permits by new ones can be accomplished through an auction of the same sort as used to accomplish the initial allocation.

SOLVING THE DESIGN PROBLEM: A CASE STUDY

The following report uses a particular example -- the control of sulfate particulates in Los Angeles -- to illustrate how the implementation problems can be addressed. This analysis is based upon relatively complete information about abatement costs, legal constraints, emissions inventories, and the relationship between emissions and air quality throughout the region. Los Angeles probably has the most sophisticated regulatory system for air pollution in the world, in part because local agencies have been collecting emissions and air quality information for three decades and in part because these data have been extensively used by research scholars to study the Los Angeles air pollution problem. This information, of course, is especially helpful for illustrating the way that issues of designing a permits market might be resolved and for designing a particular set of market institutions for this pollutant in this region. It is not necessary, however, to have all of this information in order to move towards a tradable permits system. In addition to the discussion of the Los Angeles sulfate problem we will also discuss methods of approaching the same design problems when the available information is less reliable.

The problem of sulfate particulates in Los Angeles is somewhat unusual in that the state, not the federal government, is primarily responsible for its regulation. Sulfate particulates are suspected of being a health hazard and having other damaging effects, but the principal justification for controlling them in Los Angeles is that they account for a very large part -- between one-third and one-half -- of the reduced visibility due to air pollution in Los Angeles. There is no federal ambient air quality standards for sulfate particulates; however, the state has adopted a standard of 25 micrograms per cubic meter, averaged over a 24-hour period.

Although sulfates are released directly into the atmosphere by some sources, by far the most important cause of sulfates is the release and subsequent atmospheric oxidation of SO_2, nearly all of which is associated with petroleum products that contain sulfur as an impurity. There is a federal ambient air quality standard for SO_2; however, Los Angeles is not in violation of it. Hence, the state standard for sulfates is the binding constraint on SO_2 releases.

To control sulfate particulates in Los Angeles requires controlling emissions from over thirty different categories of sources. The most important sources are electric utilities that burn oil to generate electricity, petroleum refiners, coke calciners, glass manufacturers, a steel mill, industries that are heavy fuel burners, and mobil sources burning gasoline or diesel fuel. A tradable emissions permit system must be designed to account for emissions from these major sources.

The tools with which to undertake an analysis of the design of a permits market in Los Angeles are a detailed model of the relationship between emissions and air quality, and estimates of the abatement cost functions for all major sources in the region. The abatement cost functions provide estimates of the costs to each source of various degrees of abatement of its sulfur oxides emissions. A firm seeking to minimize the sum of its expenditures on permits and its abatement costs would elect to abate up to the point at which the marginal cost of abatement equaled the market price of a permit; therefore, the abatement cost functions provide a means for predicting the quantity of permits that each source would seek to hold at any given permit price. When all of the abatement cost functions are combined, the relationship between abatement and permit prices for the entire region can be estimated. Thus, given a limit on total emissions for the entire region -- e.g., the number of permits to be issued -- the abatement cost data yield a prediction about the price of a permit, the distribution of remaining emissions in the airshed, and the expenditures on abatement (in total and by source). When combined with information about how permits were initially distributed, these data can be used to estimate the effects on the costs of each industry of implementing any given design of a permits system and the extent to which market failure problems threaten the efficient operation of a TEP market.

The remainder of this report deals with each of the major areas of implementation analysis. The approach to air quality modelling that we have used is described in Chapter 2. Chapter 3 deals with the problem of simulating the performance of the permits market, using information on abatement costs and the emissions/air quality relationship to investigate the potential problems discussed above. Chapter 4 examines the environmental and administrative law that is pertinent to the issue of the legality of tradable emissions permits. Chapter 5 deals with the problems associated with public utility regulation: how economic regulation of electric utilities might affect the participation of utilities in a permits market.

FOOTNOTES

1. For an analysis of how taxes and subsidies affect entry, see Page (1976).

2. For a more detailed discussion, see Noll (1981).

3. See, for example, Ackerman and Hassler (1981).

4. A formal proof of this result is contained in Montgomery (1972) for the case where licenses are defined in terms of the ultimate pollutant to be regulated. If licenses are defined in terms of emissions, then the solution may not be the cost-minimizing strategy for achieving a given air quality target. The reason is that the same amount of emissions may have a different effect on ambient air quality if emitted at different locations. If so, charging firms the same price for a "unit" of emissions will typically imply that the marginal cost of improving the level of air quality will differ across firms. This result holds because firms are being charged a uniform price for emissions and not for pollution. An estimate of the difference in costs between the two pricing approaches has been developed by Atkinson and Lewis (1974) for the case of particulates in the St. Louis Air Quality Control Region.

5. See Baumol and Oates (1975), pp. 140-144, for a rigorous proof of this assertion.

6. Recently, the U.S. Environmental Protection Agency has extended this concept to include "multi-plant" bubbles, which is conceptually similar to the offset method.

7. ICF (1980), p. 26.

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CHAPTER 2

TECHNICAL ASPECTS OF THE LOS ANGELES SULFUR OXIDES AIR QUALITY PROBLEM

Glen R. Cass

When the smog problem in the Los Angeles Basin was first investigated, attention was focused on sulfur oxides emissions from industrial sources. Most of these emissions to the atmosphere were in the form of sulfur dioxide gas. Additional atmospheric measurements also identified particulate sulfur compounds, often referred to in the early literature as sulfuric acid mist or its gaseous precursor, sulfur trioxide. These particulate sulfur compounds were initially believed to be responsible for "thirty to sixty percent of the total reduction in visibility" at Los Angeles (Los Angeles Air Pollution Control District, 1950). It was also soon recognized that there was something unusual about Los Angeles sulfate air quality. The Los Angeles atmosphere exhibited sulfate concentrations comparable to those of cities in the industrial northeastern United States despite the fact that both sulfur dioxide emissions and ambient SO_2 concentrations in Southern California were modest by comparison. At the conclusion of an extensive aerometric survey of the Los Angeles area (Renzetti, et al., 1955), the question was posed, "Why are the sulfate and nitrate concentrations in the particulate loading in smog higher in Los Angeles than in other cities?" Twenty years later that question is beginning to be answered.

As local sulfur dioxide emission control programs succeeded in reducing ambient SO_2 concentrations, and as the extremely complex chemical nature of photochemical smog became better understood, public attention was directed at the control of emissions from the automobile which dominated other aspects of local air quality. Recently, two things have happened which have caused control strategies for sulfur oxides in Los Angeles to be reviewed.

The first of these is a rekindling of scientific interest in the role of particulate sulfates in the Los Angeles atmosphere. Particulate sulfates accounting for a few percent of the sulfur content of fuel are emitted directly from most combustion processes. Additional sulfates form from atmospheric oxidation of SO_2 downwind from a sulfur oxides source. These water-soluble sulfur oxides particles accumulate in a size range around 0.5 microns in diameter in the Los Angeles atmosphere (Hidy et al., 1975). Particles of this size are extremely effective scatterers of light (Middleton, 1952), and also are capable of deep penetration into the lung (Task Group, 1966). Recent studies indicate that sulfates contribute to visibility deterioration (Eggleton, 1969; Charlson et al., 1974; Waggoner et al., 1976; Weiss et al., 1977; White and Roberts, 1977; Cass, 1979) and to the acidification of rain water (Cogbill and Likens, 1974; Likens, 1976) throughout the United States and Europe.

A second compelling reason for focusing on Los Angeles is the potential for increase in basin-wide combustion of fuel oils containing sulfur if curtailment of natural gas deliveries to Southern California should occur. Figure 1 shows the Pacific Lighting Corporation's (1974) estimated gas supplies from existing sources in contrast to projected requests for service as seen in 1974. It had been estimated by the Los Angeles Air Pollution Control District (1975a) that substitution of sulfur-bearing fuel oil for natural gas combustion over the following few years could have increased SO_2 emissions in Los Angeles County from a low of 257 tons per day in 1970 to a level of about 470 tons per day by 1979 in the absence of any further emission controls beyond those existing in 1974. On the same basis, the California Air Resources Board estimated that SO_2 emissions in the entire South Coast Air Basin (which contains Los Angeles County) could have increased from a 1973 level of 515 tons per day to a level of between 720 and 920 tons per day by 1983 (California Air Resources Board, 1975). Control of the impact of this potential increase in sulfur oxides emissions brought forth a heated public debate.

Prompted by the increase in fuel oil combustion, the local findings concerning visibility, and a concurrent national debate over the health consequences of sulfate air quality, the California Air Resources Board adopted an air quality goal for total suspended particulate sulfates. A 24-hour average sulfate concentration of 25 micrograms per cubic meter is not to be exceeded. Air pollution control strategy studies aimed at evaluating the least costly means for sulfate air quality improvement have recently been completed by Cass (1978) and by the South Coast Air Quality Management District (1978). To date, initial steps have been taken to blunt any expected SO_x emissions increase by decreasing the sulfur content of fuel burned in the Los Angeles Basin. Other industrial processes will be modified in the future. While studies indicate that further emission control is feasible, as yet no comprehensive emission control strategy has been adopted which would meet the state sulfate air quality goal in Los Angeles over the long term. If such actions are taken, they undoubtedly will be quite expensive. Substantial savings might be achieved by better understanding the options available for managing sulfate air quality in this particular air basin in an economically efficient manner.

CASE STUDY OF THE EMISSIONS AND AIR QUALITY PROBLEM

The technical description upon which our test markets will be built is based on the sulfate air quality control strategy study

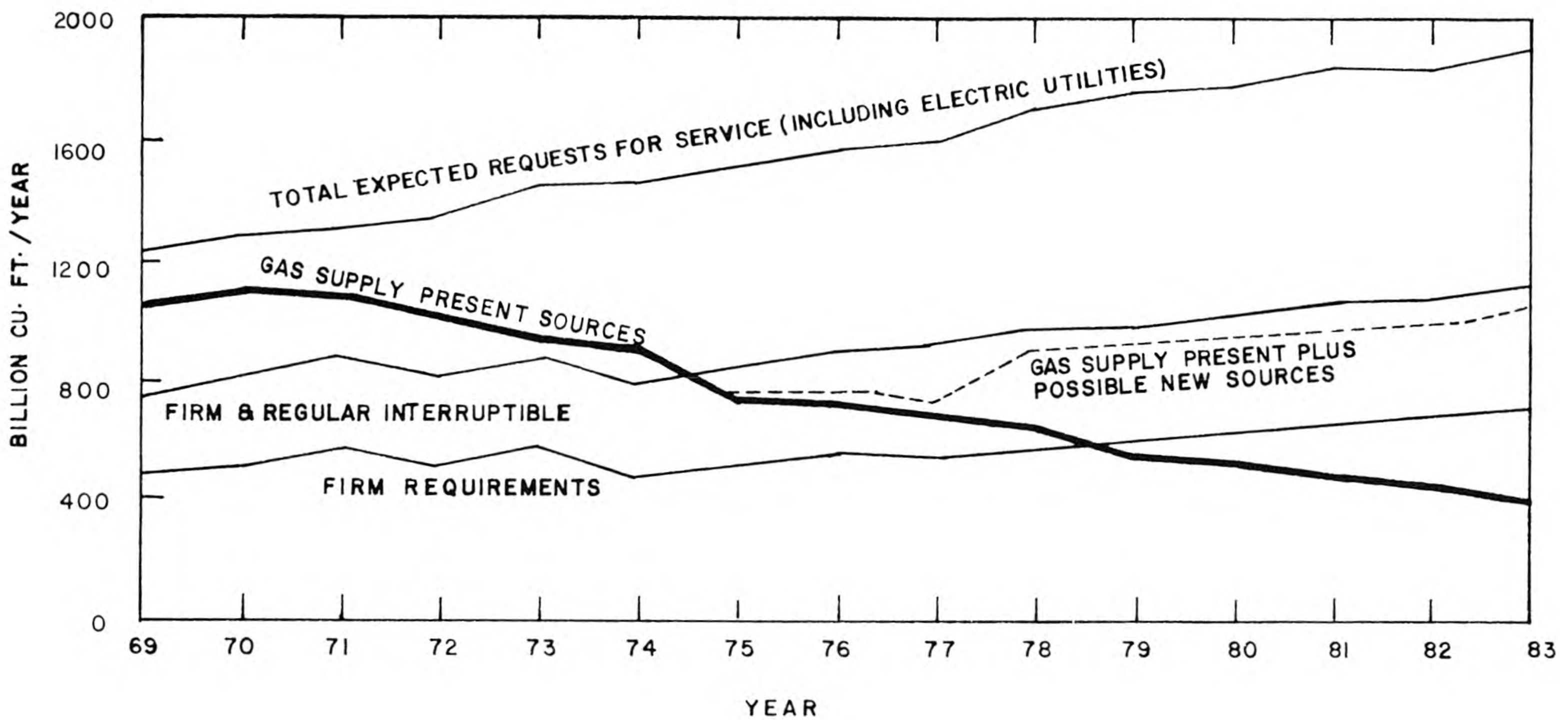


Fig. 1 Pacific Lighting Corporation

Natural Gas Supply vs. Requests for Service as Expected in 1974 completed for Los Angeles by Cass (1978). The research plan for that study is shown in Figure 2. Mathematical models were formulated and tested which relate sulfur oxides emissions to observed sulfate air quality and to air quality effects on visibility. That study was conducted in a way that emission control opportunities and costs can be compared in a rational manner to assess the least costly means of meeting an air quality objective. As a result of that work, a great deal is known about how this particular air pollution problem operates.

The geographic region of interest is the South Coast Air Basin which surrounds Los Angeles, as shown in Figure 3. Spatial gradients in sulfate air quality indicate that the atmosphere over metropolitan Los Angeles is enriched in sulfates due to local emissions sources. Annual mean sulfate concentrations above 14 $\mu g/m^3$ were measured over central Los Angeles at a time when background concentrations in incoming marine or desert air averaged 3 to 5 $\mu g/m^3$. This localized sulfate enrichment is illustrated in Figure 4. In contrast to the problems arising from long distance transport of sulfates in the Eastern United States, a sulfate air quality model can be validated in the South Coast Air Basin while employing only local emissions data plus a small increment from background sulfates.

Sulfate concentrations observed at the downtown Los Angeles station of the Los Angeles Air Pollution Control District during the decade 1965 through 1974 are shown in time series in Figure 5a. Concentration fluctuations from day to day are quite large, with high values occurring at least occasionally in all seasons of the year. However, the data can be filtered statistically to reveal seasonal trends, as shown in Figure 5b. It is seen that a broad summer seasonal peak in sulfate concentrations occurs in all years of record, with clusters of very high sulfate concentrations also observed in two of nine winters examined (winter 1970-71 and winter 1971-72). A successful air quality control strategy study must consider both high summer and high winter sulfate conditions in the Los Angeles area.

In order to assess the sources contributing to such an air quality problem, a source emissions inventory must be constructed. A 50 by 50 mile square grid was laid down over the metropolitan Los Angeles area as shown in Figure 6.

Emissions estimates for both sulfur dioxide and primary sulfates resolved over that grid system were obtained for the twenty-six classes of mobile and stationary sources listed in Table 1 for each month of the years 1972 through 1974. Major off-grid sources at locations shown in Figure 6 also were surveyed for inclusion in air quality model calculations. The spatial distribution of average daily total sulfur oxides emissions during 1973 illustrated in Figure 7 was obtained by overlaying similar maps developed for each source class of interest.

Research Plan

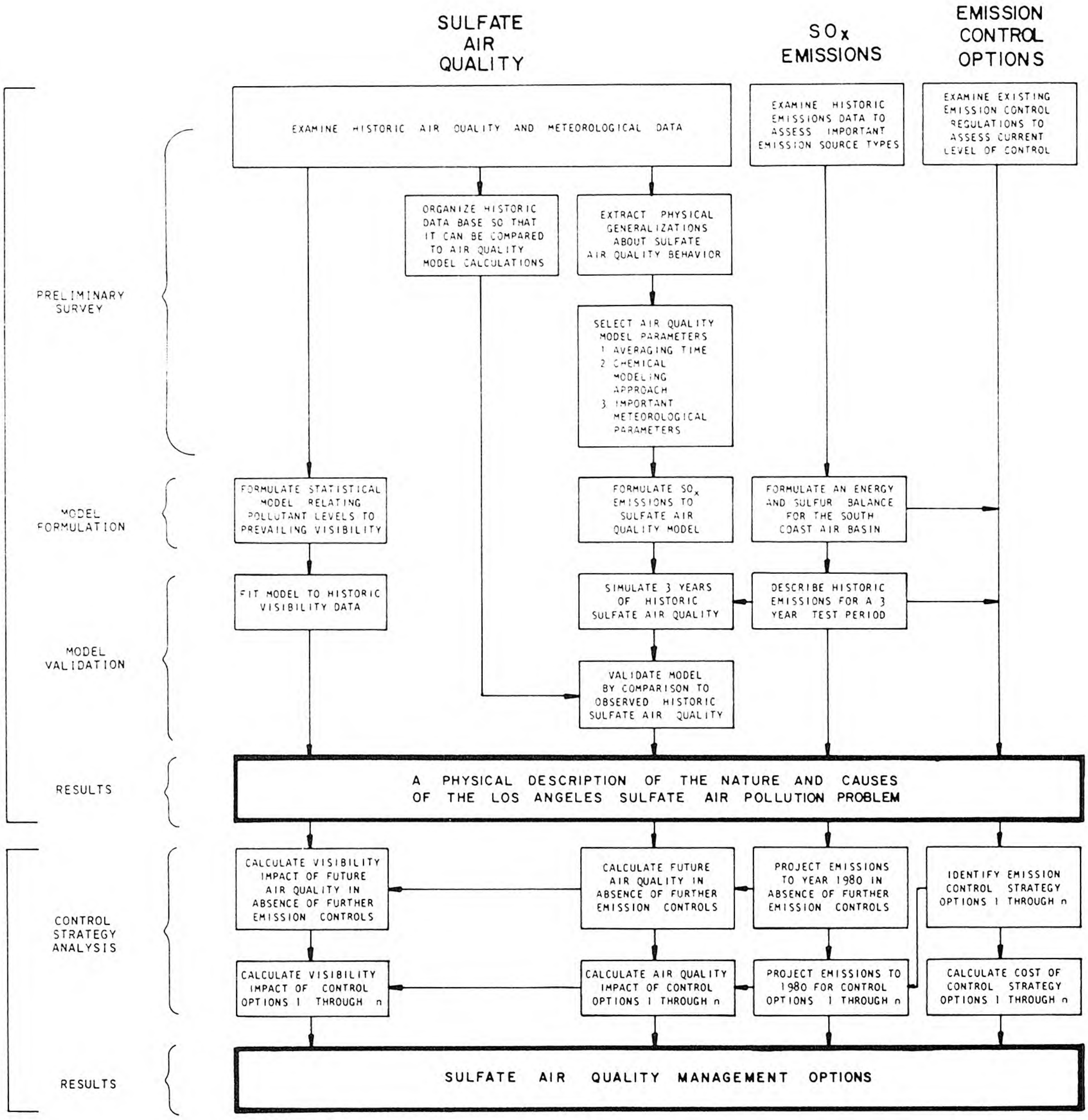


Fig. 2

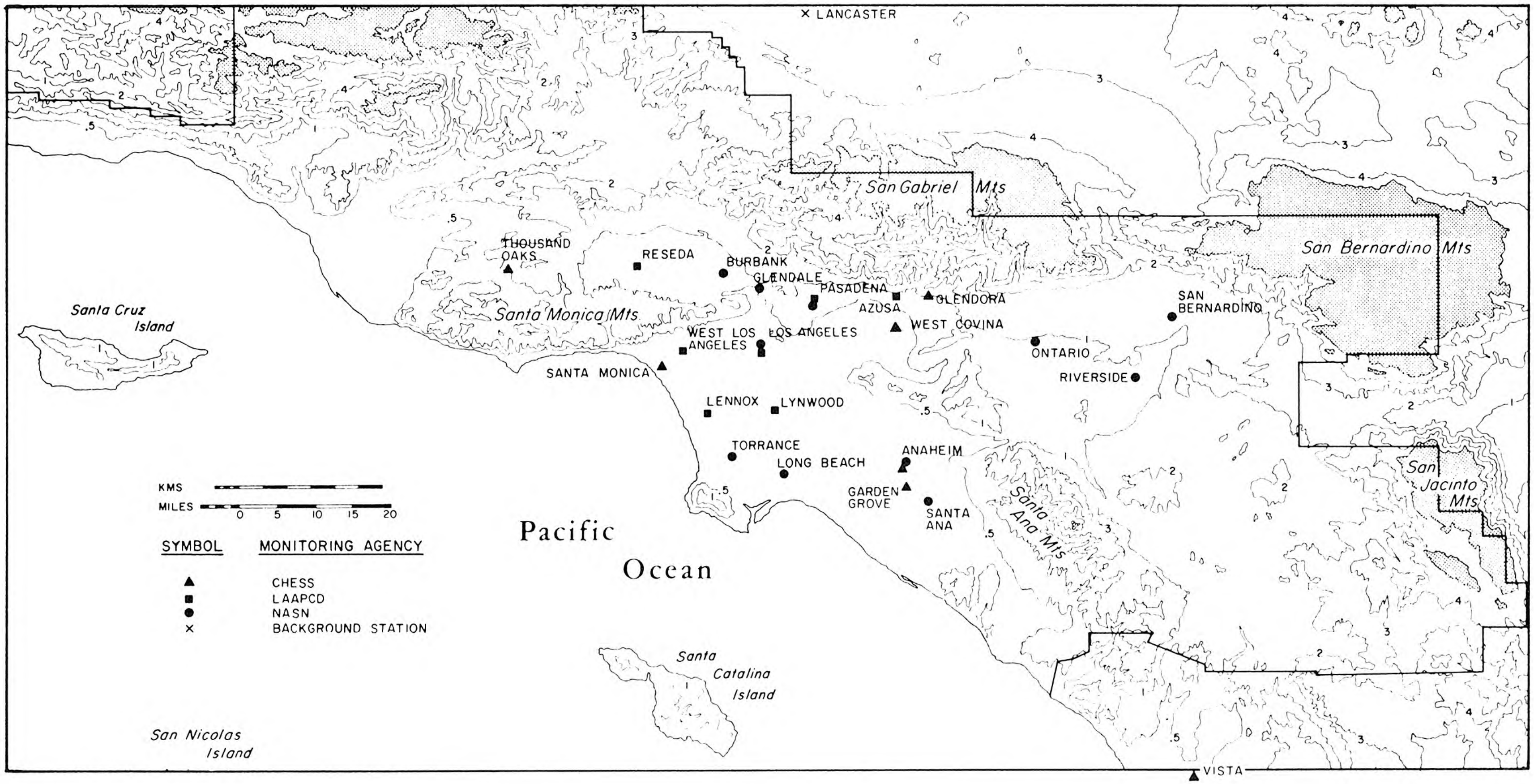


Fig. 3 Sulfate Air Quality Monitoring Sites in or near the South Coast Air Basin

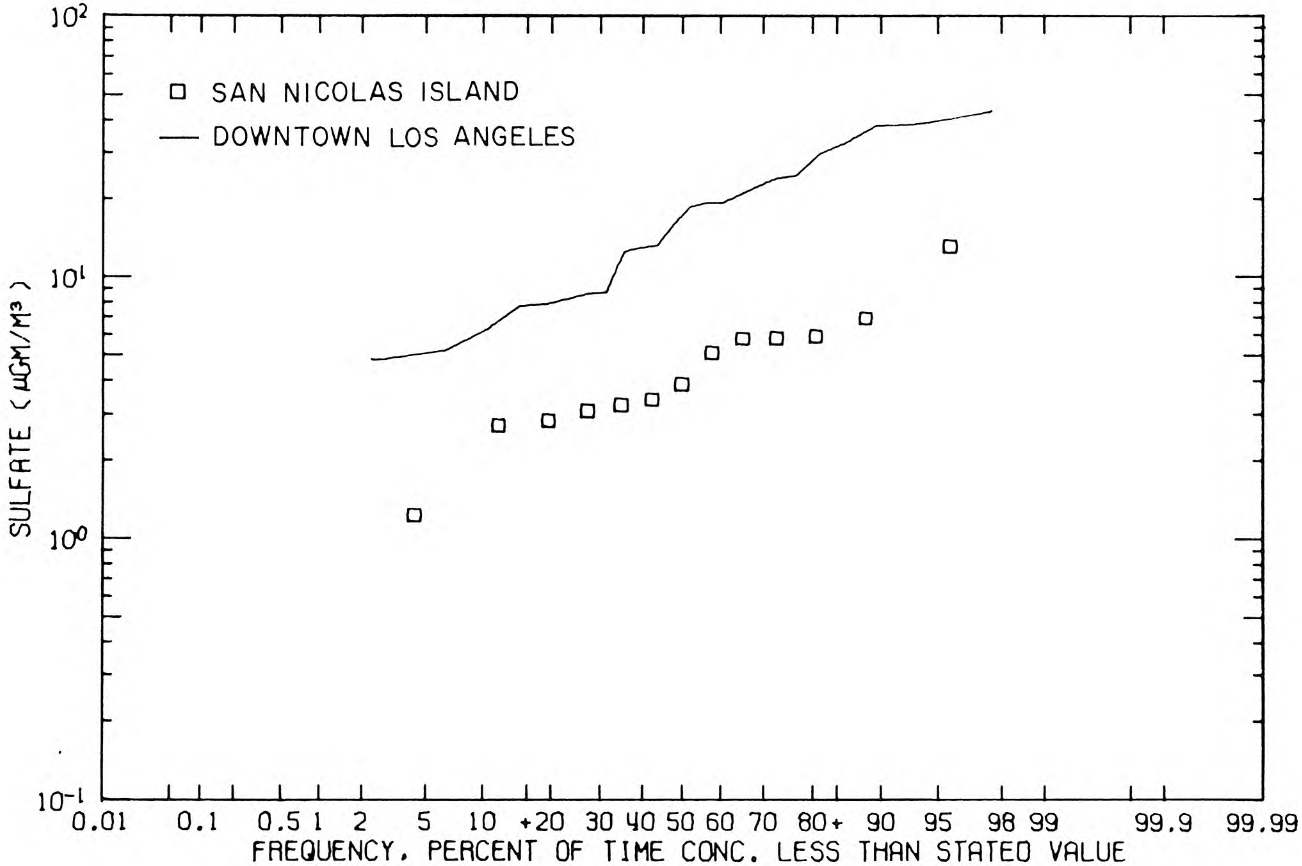


Fig. 4 Sulfate at San Nicolas Island vs. Downtown Los Angeles
July through October 1970

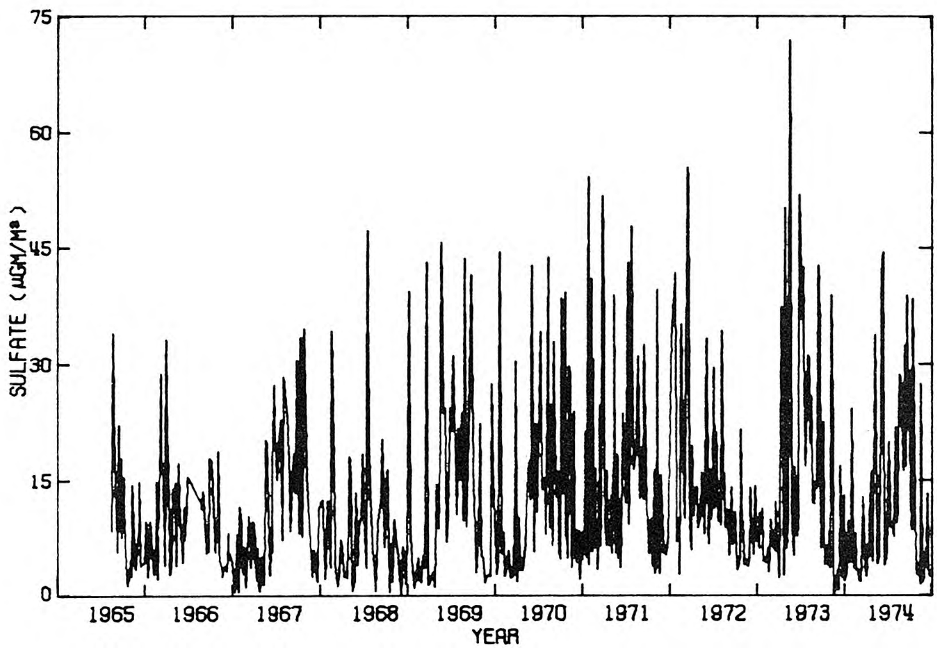


Fig. 5a LAAPCD Sulfate Data at Downtown Los Angeles

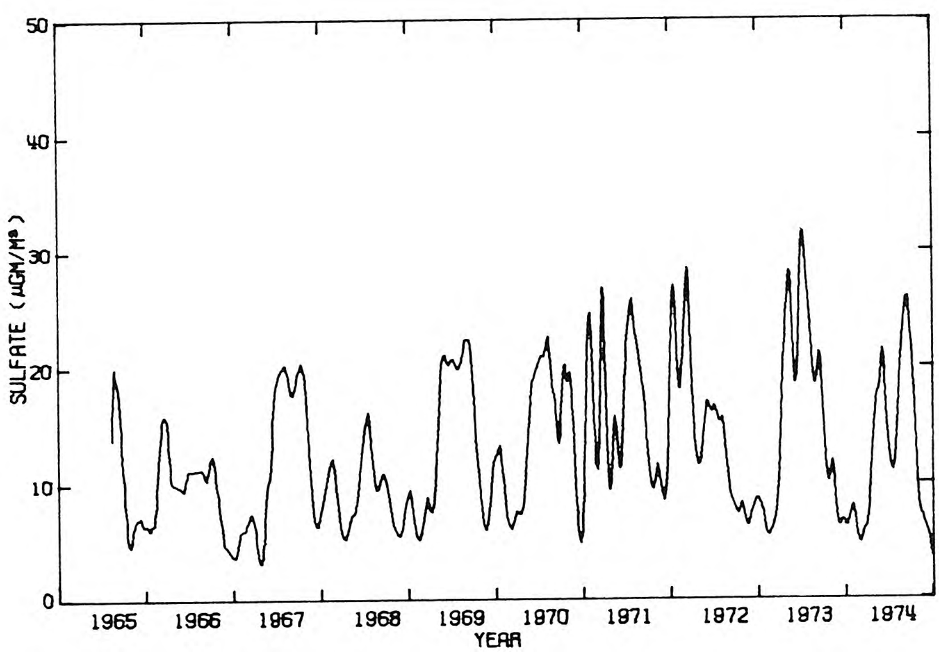


Fig. 5b Sulfate Seasonal Trend at Downtown Los Angeles

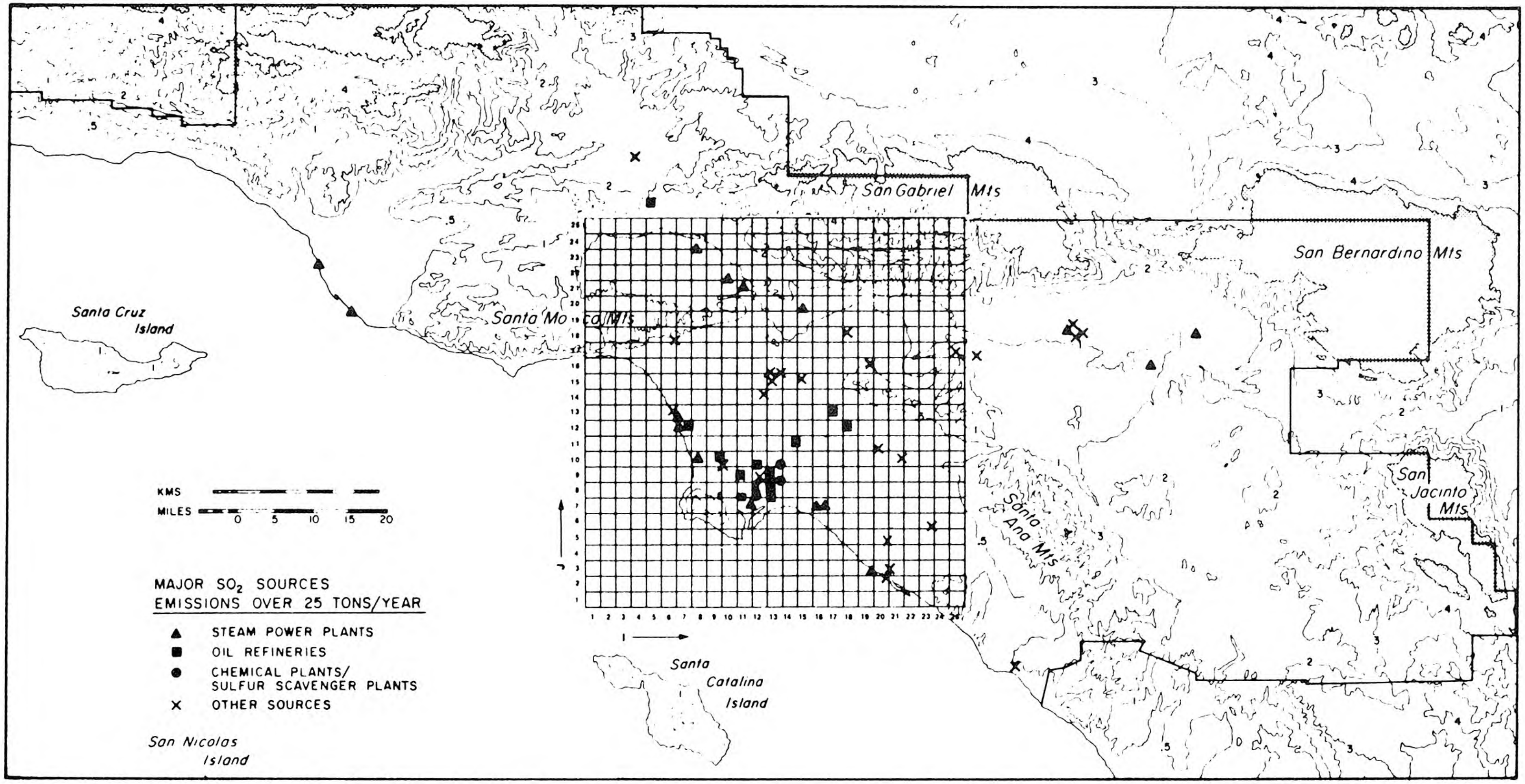


Fig. 6 The Central Portion of the South Coast Air Basin
Showing the Grid System Used

TABLE 1a

1973 SULFUR OXIDES EMISSIONS WITHIN THE 50 by 50 MILE SQUARE GRID

(IN SHORT TONS PER DAY AS SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Fuel Combustion													
Electric Utilities	232.77	212.31	212.13	123.36	139.48	163.87	157.77	189.23	174.16	192.05	229.72	155.48	181.71
Refinery Fuel	25.07	13.50	10.61	4.26	3.99	3.73	2.91	2.14	2.37	4.01	21.69	18.96	9.42
Other Interruptible Gas Customers	12.78	2.24	2.07	0.98	0.81	0.39	0.39	0.40	0.43	0.76	3.58	2.57	2.29
Firm Gas Customers	0.46	0.46	0.37	0.33	0.26	0.21	0.17	0.16	0.19	0.20	0.26	0.36	0.29
Chemical Plants													
Sulfur Recovery	57.18	57.18	57.18	57.18	57.08	57.08	50.70	66.20	66.20	66.20	66.20	66.20	60.40
Sulfuric Acid	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Other Chemicals	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Petroleum Refining and Production													
Fluid Catalytic Crackers	52.07	52.07	52.07	52.07	52.07	52.07	52.07	52.07	52.07	52.07	52.07	52.07	52.07
Sour Water Strippers	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Delayed Cokers	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28
Misc. Refinery Process	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Oil Field Production	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
Misc. Stationary Sources													
Petroleum Coke Kilns	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52	25.52
Glass Furnaces	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Metals Industries	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78	8.78
Mineral Products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sewage Treatment Digesters	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
Other Industrial Processes	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Permitted Incinerators	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
MOBILE SOURCES													
Autos and Lt. Trucks-Surface	17.17	17.75	18.56	18.76	14.27	14.15	14.05	14.36	13.51	13.51	16.95	15.70	15.71
Autos and Lt. Trucks-Freeway	10.98	11.35	11.87	12.01	9.13	9.05	8.99	9.19	8.64	8.64	10.85	10.05	10.05
Heavy Duty Vehicles-Surface	10.18	10.50	10.94	11.05	10.99	10.88	10.80	10.99	10.35	10.34	10.71	9.90	10.64
Heavy Duty Vehicles-Freeway	6.51	6.72	7.00	7.07	7.03	6.96	6.91	7.03	6.62	6.61	6.85	6.33	6.80
Airport Operations	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
Shipping Operations	10.13	10.13	10.13	10.13	10.13	10.13	10.13	10.13	10.13	10.13	10.13	10.13	10.13
Railroad Operations	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32
TOTAL	504.73	463.64	462.36	366.63	374.67	397.95	384.27	431.33	414.10	433.95	498.44	417.18	428.94

TABLE 1b

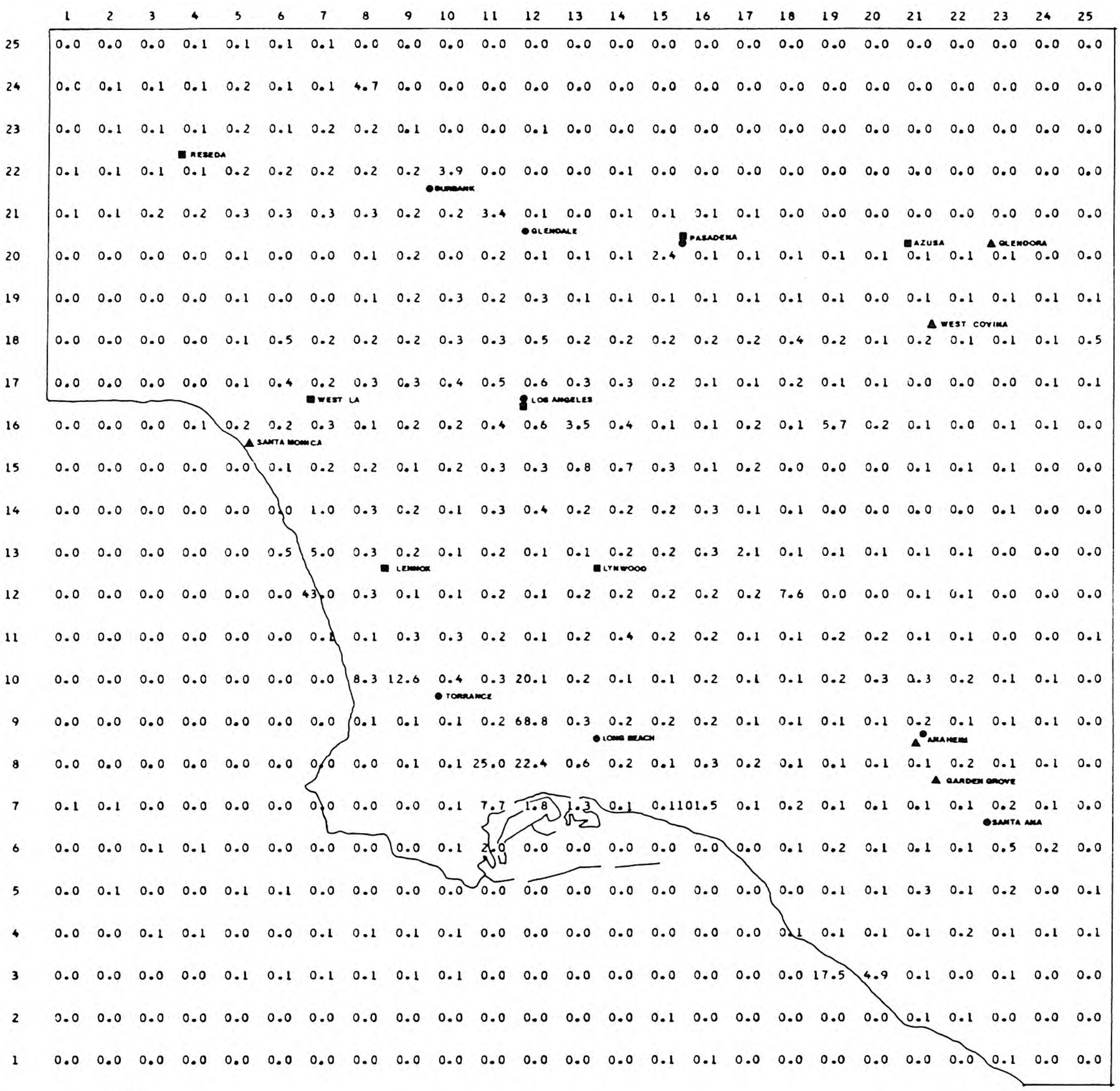
MAJOR OFF-GRID EMISSION SOURCES INCLUDED WITHIN THE 1973 SOUTH COAST AIR BASIN

SULFUR OXIDES MODELING INVENTORY

(IN SHORT TONS PER DAY AS SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Fuel Combustion													
Electric Utilities	60.19	45.46	57.94	39.18	53.62	64.68	54.07	58.97	45.38	59.69	91.75	66.46	58.20
Refinery Fuel	---	---	---	---	---	---	---	---	---	---	---	---	---
Other Interruptible Gas Customers	---	---	---	---	---	---	---	---	---	---	---	---	---
Firm Gas Customers	---	---	---	---	---	---	---	---	---	---	---	---	---
Chemical Plants													
Sulfur Recovery	---	---	---	---	---	---	---	---	---	---	---	---	---
Sulfuric Acid	---	---	---	---	---	---	---	---	---	---	---	---	---
Other Chemicals	---	---	---	---	---	---	---	---	---	---	---	---	---
Petroleum Refining and Production													
Fluid Catalytic Crackers	---	---	---	---	---	---	---	---	---	---	---	---	---
Sour Water Strippers	---	---	---	---	---	---	---	---	---	---	---	---	---
Delayed Cokers	---	---	---	---	---	---	---	---	---	---	---	---	---
Misc. Refinery Processes	---	---	---	---	---	---	---	---	---	---	---	---	---
Oil Field Production	---	---	---	---	---	---	---	---	---	---	---	---	---
Misc. Stationary Sources													
Petroleum Coke Kilns	---	---	---	---	---	---	---	---	---	---	---	---	---
Glass Furnaces	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Metals Industries	41.46	41.46	41.46	41.46	41.46	41.46	41.46	41.46	41.46	41.46	41.46	41.46	41.46
Mineral Products	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
Sewage Treatment Digesters	---	---	---	---	---	---	---	---	---	---	---	---	---
Other Industrial Processes	---	---	---	---	---	---	---	---	---	---	---	---	---
Permitted Incinerators	---	---	---	---	---	---	---	---	---	---	---	---	---
TOTAL	103.78	89.05	101.53	82.77	97.21	108.27	97.66	102.56	88.97	103.28	135.34	110.05	101.79

TOTAL SOX EMISSIONS FOR 1973 IN TONS/DAY AS SO2



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.C	0.1	0.1	0.1	0.2	0.1	0.1	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.1	0.1	0.1	0.2	0.1	0.2	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	3.9	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2	3.4	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.2	0.0	0.2	0.1	0.1	0.1	2.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
19	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.2	0.3	0.2	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1
18	0.0	0.0	0.0	0.0	0.1	0.5	0.2	0.2	0.2	0.3	0.3	0.5	0.2	0.2	0.2	0.2	0.2	0.4	0.2	0.1	0.2	0.1	0.1	0.1	0.5
17	0.0	0.0	0.0	0.0	0.1	0.4	0.2	0.3	0.3	0.4	0.5	0.6	0.3	0.3	0.2	0.1	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.1	0.1
16	0.0	0.0	0.0	0.1	0.2	0.2	0.3	0.1	0.2	0.2	0.4	0.6	3.5	0.4	0.1	0.1	0.2	0.1	5.7	0.2	0.1	0.0	0.1	0.1	0.0
15	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.1	0.2	0.3	0.3	0.8	0.7	0.3	0.1	0.2	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.3	0.2	0.1	0.3	0.4	0.2	0.2	0.2	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.5	5.0	0.3	0.2	0.1	0.2	0.1	0.1	0.2	0.2	0.3	2.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	43.0	0.3	0.1	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.2	7.6	0.0	0.0	0.1	0.1	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.3	0.2	0.1	0.2	0.4	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.0	0.0	0.1
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	12.6	0.4	0.3	20.1	0.2	0.1	0.1	0.2	0.1	0.1	0.2	0.3	0.3	0.2	0.1	0.1	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	68.8	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	25.0	22.4	0.6	0.2	0.1	0.3	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.0
7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	7.7	1.8	1.3	0.1	0.1	101.5	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.0
6	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.1	0.5	0.2	0.0
5	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.1	0.2	0.0	0.1
4	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
3	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.5	4.9	0.1	0.0	0.1	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0

SOX
TONS/DAY
428.945

Fig. 7

Figure 8 shows the time history of sulfur oxides emissions from sources located within the 50 by 50 mile square grid over three past years. An underlying increment to sulfur oxides emissions from mobile sources is observed which shows little seasonal variation. Added to that is a nearly constant contribution from miscellaneous stationary sources (principally from petroleum coke calcining kilns). Petroleum refinery process emissions are shown, mostly from refinery fluid catalytic cracking units. Emissions from chemical plants (which constituted the largest single emissions source class during 1972) decline sharply during our three year period of interest as local sulfur recovery and sulfuric acid plants added new emissions control equipment.

A strong seasonal variation in emissions from fuel burning sources is observed. Peak sulfur oxides emissions from electric utilities occur in the winter months as high priority home heating customers increase their consumption of natural gas forcing low priority gas customers, including electric utilities and some industries, to shift to combustion of sulfur-bearing fuel oil. A successful air quality model applied in Los Angeles will have to be able to track strong seasonal changes in emissions source strength which are usually six months out of phase with the summer peak sulfate concentrations observed.

The origin of Los Angeles sulfur oxide air pollutant emissions also can be examined on the basis of energy and sulfur balance calculations. Flows of energy resources which contain sulfur as they pass from crude oil suppliers to refiners to electric utilities, and to end users such as light industry or motorists can be reconciled. Table 2 shows the results of such an energy balance. Over 3.7 quadrillion BTU´s per year of energy resources were tracked throughout the Los Angeles area, with less than a 1 percent net difference between documented resources and sinks. The key feature of such a survey is that a material balance on sulfur supplied within those fuels also can be performed, as shown in Table 3. That analysis identifies several very important features:

1. Virtually all of the sulfur entering the air basin in that year arrived in a barrel of crude oil. Refiners thus exercise choice over the potential sulfur oxides emissions in the basin at the time that they make an initial selection of crude oil quality.

2. Nearly 50 percent of the sulfur arriving was recovered at the refinery level as elemental sulfur or sulfuric acid. Refiners can and do recover enormous amounts of sulfur as a consequence of cracking and hydrotreating activities at their plants. The extent of this desulfurization operation could be increased (at some cost).

3. Approximately 25 percent of the sulfur was segregated into products like petroleum coke, asphalt and exported high sulfur fuel oil which would not be burned locally. Refiners can respond to concerns over product quality by shunting high sulfur refined products

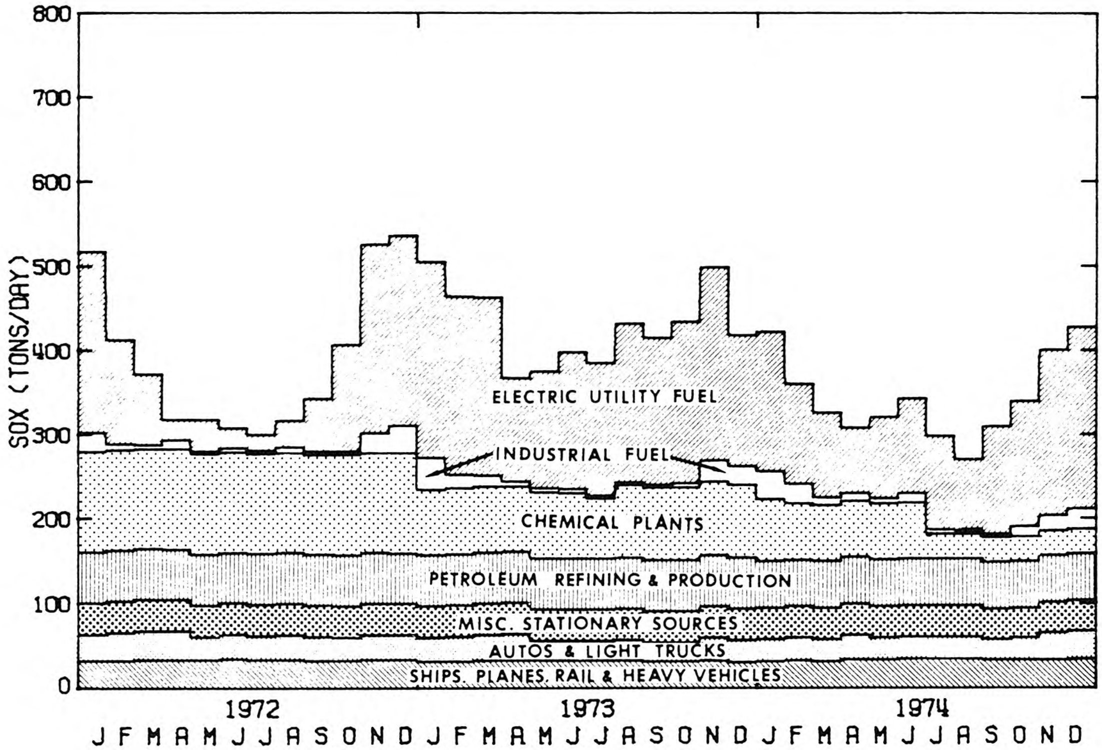


Fig. 8 Sulfur Oxides Emissions Within
the 50 by 50 Mile Square

TABLE 2

South Coast Air Basin Energy Balance--1973
(10^{12} BTUs per year)

	Electricity	Natural Gas	Crude and Unfinished Oils	NGL	LPG	Still Gas for Fuel	Gasoline	Jet Fuel	Light and Middle Distillate Fuel Oil	Residual and Heavy Distillate Fuel Oil	Petroleum Coke	Lubri-cants	Asphalt and Road Oil	Other Hydro-carbons	Coal	Digester Gas	TOTAL
SOURCES																	
Resource base: imports plus local crude oil and natural gas production	97.3	1050.3	2182.3	20.9	14.4		69.6	4.4	83.6	127.6	5.5	12.3	0.1	4.6	57.4	2.6	3732.9
Adjustments: change in gas storage; out-of-basin electric use	-13.1	-25.2	—	—	—		—	—	—	—	—	—	—	—	—	—	-38.3
Subtotal	84.2	1025.1	2182.3	20.9	14.4		69.6	4.4	83.6	127.6	5.5	12.3	0.1	4.6	57.4	2.6	3694.6
TRANSFORMATION SECTOR																	
Refinery feedstock (-)			-2124.8[a]	-23.9	-8.7									-16.9[b]			-2174.3
Refinery fuels (-)	-9.8	-48.5				-149.8				-11.8							-219.9
Refinery production(+)					36.1	108.4	863.0	224.3	126.9	581.2	112.0	18.5	88.0	60.3			2218.7
Utility fuels (-)		-160.9							-2.7	-386.3						-0.3	-550.2
Utility production (+)	179.9	—	—	—	—		—	—	—	—	—	—	—	—		—	179.9
Subtotal	170.1	-209.4	-2124.8	-23.9	-14.0		863.0	224.3	124.2	183.1	112.0	18.5	88.0	43.4		-0.3	-545.8
CONSUMED IN BASIN AS ENERGY RESOURCE																	
System uses; losses	-28.8	-20.5															-49.3
Residential/commercial	-133.8	-431.4			-6.6				-8.1	-8.1					-0.2		-588.2
Industrial (other than refinery)	-71.2	-153.9			-1.0				-15.6	-19.5					-57.2	-2.3[a]	-320.7
Transportation (civilian)					-1.9		-650.3	-17.3	-59.9	-9.1							-738.5
Military							-2.2	-6.1	-6.5	-0.1							-14.9
Miscellaneous	-21.9	-8.7			-3.0		—	—	-14.5	-0.6					—	—	-48.7
Subtotal	-255.7	-614.5			-12.5		-652.5	-23.4	-104.6	-37.4					-57.4	-2.3	-1760.3
CONSUMED AS A RAW MATERIAL[c]		-18.6			-8.4						pass through	-10.8[a]	-71.6[a]	-42.9[a]			-152.3
EXPORTS																	
As a commodity (by ship)			-57.5		-0.2		-47.9	-17.4	-89.7	-155.1	-109.4	-20.0	-16.5	-5.1			-518.8
As a commodity (overland)		-186.8[d]					-194.7	-21.8	-52.9	-27.9							-484.1
In transport mode fuel tanks		—	—		—		-3.8	-111.5	-2.7	-86.0	—	—	—	—			-204.0
Subtotal		-186.8	-57.5		-0.2		-246.4	-150.7	-145.3	-269.0	-109.4	-20.0	-16.5	-5.1			-1206.9
SUMMARY																	
Total sources (+ flows)	277.2	1050.3	2182.3	20.9	158.9		932.6	228.7	210.5	708.8	117.5	30.8	88.1	64.9	57.4	2.6	
Total sinks (- flows)	-278.6	-1054.5	-2182.3	-23.9	-179.6		-898.9	-174.1	-252.6	-704.5	-109.4	-30.8	-88.1	-64.9	-57.4	-2.6	
Absolute difference	-1.4	-4.2	(a)	-3.0	-20.7		33.7	54.6	-42.1	4.3	8.1	(a)	(a)	(a)		(a)	29.3
Difference as % of sources	-0.51%	-0.40%	(a)	-14.35%	-13.03%		3.61%	23.87%	20.0%	0.61%	6.89%	(a)	(a)	(a)		(a)	
Difference as % of total energy resources	-0.04%	-0.11%		-0.08%	-0.56%		0.91%	1.48%	-1.14%	0.12%	0.22%						0.79%

Notes: (a) Obtained by difference
(b) May include some natural gas
(c) Or put to other non-energy resource use
(d) Includes exchange with out-of-basin utility

TABLE 3

SOUTH COAST AIR BASIN SULFUR BALANCE -- 1973
(1000s LBS. SULFUR PER DAY)

	Natural Gas	Crude Oil; Unfinished Oils & Other Refinery Feedstocks	LPG and Still Gas for Fuel	Gasoline	Light and Middle Distillates & Jet Fuel	Residual and Heavy Distillate Fuel Oil	Petroleum Coke	Misc. Petroleum Products	Coal	Digester Gas	Hydrogen Sulfide	Sulfur	Acid Sludge	Sulfuric Acid	Misc. Indus. Raw Materials Sufficient to Balance Process Losses	Solid or Liquid Waste	Atmospheric Emissions: Industrial Process	Atmospheric Emissions: Fuel Burning	TOTAL
SOURCES																			
Resource base: imports plus local crude oil and natural gas production	0.81	3942.5	0.01	4.40	29.76	77.70	16.11	small	91.73	0.63		0.06			17.69				
Adjustments: change in gas storage	-0.02																		
Subtotal	0.79	3942.5	0.01	4.40	29.76	77.70	16.11		91.73	0.63		0.06			17.69				4181.38
TRANSFORMATION SECTOR																			
Refinery																			
Feedstock sulfur		-3551.5																	
Fuel sulfur	-0.04		-2.45			-9.19													
Products and wastes			2.65	81.88	135.65	761.31	332.11	67.49			1980.4		363.4	-363.4		134.95	53.77	11.68	
Sulfur Recovery and Sulfuric Acid																			
Feedstock sulfur											-1980.4	-420.8	-363.4						
Products and wastes								5.80				1720.7		959.4			81.46		
Electric Utilities																			
Fuel sulfur	-0.12				-0.18	-235.22				-0.07								235.59	
Subtotal	-0.16	-3551.5	0.20	81.88	135.47	516.90	332.11	73.29		-0.07	0	1299.90	0	596.0		134.95	135.23	247.27	1.47
END USE CONSUMPTION SECTOR																			
(Fuel Combustion in Basin)																			
System uses; losses	-0.02																	0.02	
Residential/commercial	-0.33		-0.005		-2.80	-4.64			-0.32									8.10	
Industrial (other than refinery)	-0.12		-0.001		-5.40	-11.18			-91.41	-0.56						50.05		58.62[a]	
Transportation (civilian)			-0.001	-41.15	-23.03	-21.64												85.82	
Military				-0.14	-2.88	-0.24												3.26	
Miscellaneous	-0.01		-0.002		-4.63	-0.34												4.98	
Subtotal	-0.48		-0.01	-41.29	-38.74	-38.04			-91.73	-0.56						50.05		160.80	0.00
ADJUSTMENT FOR EFFECT OF RAW MATERIALS PROCESSING INDUSTRIES	-0.01		-0.01				-25.52								-17.69		43.21[b]		-0.02
EXPORTS																			
As a commodity (by ship)	-0.07	-121.8	~0	-3.03	-32.83	-302.57	-320.44					-1.67							
As a commodity (overland)	-0.07			-12.32	-20.18	-16.99						unknown							
In transport mode fuel tanks				-0.24	-8.88	-206.24													
Subtotal	-0.14	-121.8	~0	-15.59	-61.89	-525.80	-320.44					-1.67							-1047.33
SINK FOR MISC. NON-FUEL RESOURCES WHOSE ULTIMATE CUSTOMER WILL NOT BE SOUGHT								-73.29				-1298.29		-596.0					-1967.58
SUMMARY																			
Total sources (+ flows)	0.81	3942.5	2.66	86.28	165.41	839.01	348.22	73.29	91.73	0.63	1980.4	1720.76	363.4	959.4	17.69	185.00	586.51		
Total sinks (- flows)	-0.81	-3673.3	-2.47	-56.88	-100.81	-808.25	-345.96	-73.29	-91.73	-0.63	-1980.4	-1720.76	-363.4	-959.4	-17.69				
Absolute difference	0	269.2	0.19	29.40	64.60	30.76	2.26						0						393.41
Difference as % of sources	0	+6.8%	+7.1%	34.1%	39.1%	3.7%	0.65%												
Difference as % of total sulfur input of 4181.38 thousand lbs/day	0	6.4%	~0%	0.70%	1.54%	0.74%	0.05%										14.0%		

Notes: (a) This fuel burning total includes 41.36 thousand pounds of sulfur per day from combined fuel burning and industrial processes activities at Kaiser Steel.

(b) These industrial process emissions include

misc. chemical industries	0.09
oil field production	4.50
petroleum coke kilns	25.52
glass furnaces	2.23
metals industries	8.88
minerals industries	1.90
other industrial processes	0.02
incinerators	0.07

away from an air basin which presents serious emissions control problems.

4. Only about 14 percent of the sulfur which could have been emitted to the atmosphere from combustion and processing of fuels actually did escape from the system into the Los Angeles atmosphere.

The energy and sulfur balance results show that the Los Angeles sulfur oxides control problem possesses great inherent flexibility as well as an advanced stage of technical maturity. Emissions control is possible (and indeed is occurring) by means in addition to direct application of control technology to emissions points. Perhaps the most important choices affecting sulfur oxides emissions involve industrial process selection in the first place, and substitutions between alternate energy resources. These factors affecting emissions might respond to a continuously variable system of economic incentives like transferable emissions rights in a way that is not captured by a hardware-oriented emissions source performance standard or single go/no-go limits on the maximum sulfur content of a certain type of fuel.

EMISSIONS/AIR QUALITY RELATIONSHIPS

Assessment of the particular emissions sources contributing to sulfate air quality at a specific location is a difficult task. In Los Angeles, sulfur oxides emissions from over one hundred large sources and several thousand minor ones are co-mingled by the wind and transported wherever the wind blows. Within this dynamic system, chemical reactions act to oxidize SO_2 to form additional sulfates over time, and to remove pollutants by deposition at the ground.

The problem of tracking individual source contributions to observed air quality in such a situation is too complex to be handled by pencil and paper. Instead, a large computer simulation model can be built which will track individual air parcels and perform the necessary accounting.

The air quality model used in this study was formulated by Cass (1978) and has been described briefly as follows. Single mass points marked with the magnitude and initial chemical composition of sulfur oxides emissions from each source are inserted at measured time intervals into a mathematical representation of the atmospheric fluid flow above the location of their points of origin. Depending on the plume rise characteristics of each source and meteorological conditions at the time of release, a pollutant parcel may be inserted either above or below the base of the temperature inversion which separates a well mixed layer next to the ground from a stable air mass aloft. As these sulfur oxides laden air parcels are transported downwind, chemical reactions and surface removal processes act to alter the mass of SO_2 and sulfates represented by each particle. Sulfur oxides residing within the mixed layer next to the ground are affected both by ground level dry deposition and by atmospheric oxidation of SO_2 to form additional sulfates. Pollutant parcels stored within the stable layer aloft are isolated from surface removal processes but still are available for chemical reaction. Exchange of air parcels between the mixed layer next to the ground and the stable layer aloft occurs as inversion base height changes over time.

The trajectories of successive particles released from a source form streaklines downwind from that source. Streaklines present at each hour of the month are computed and superimposed. The horizontal displacement of each particle located below the inversion base is paired with the particle's probable chemical status and divided by the depth of the mixed layer at the time that the streakline of interest was computed. The resulting magnitudes are assigned to a matrix of receptor cells by summing the contribution for all particles falling within the same receptor cell. Totals are accumulated separately for SO_2 and for sulfates. The accumulated totals are divided by the dimensions of a receptor cell and the number of time steps being superimposed in order to directly obtain the spatial distribution of long-term average SO_2 and sulfate concentrations appearing throughout the airshed.

By repeating that process for each source in the airshed and superimposing the results onto an estimate of sulfate background air quality, a multiple source urban air quality model for sulfates is obtained. Superposition is permitted because all chemical processes are modeled in a form that is linear in emissions.

The gridded emissions inventory previously described was matched to the air quality model. The model's ability to track sulfate concentrations was tested over each month of the years 1972 through 1974. Source class contributions to observed air quality were computed and compared in time series to observations at monitoring sites such as those shown in Figures 9 and 10. The spatial distribution of sulfate concentrations was computed both for the air basin as a whole and for the partial contribution of each major source type, as shown in Figures 11, 12 and 13. Comparison between observations and predictions at all monitoring sites shown in Figure 11 for which monthly average data could be computed typically appear as shown in Figure 14.

ECONOMICALLY EFFICIENT STRATEGIES FOR SULFATE AIR QUALITY IMPROVEMENT

Analysis of the source class contributions to observed sulfate air quality shown in Figures 9 and 10 yields an important conclusion. No single source type contributes more than a relatively small fraction to the total sulfate pollutant burden in the air basin. An emissions control strategy which requires significant air quality changes must be diversified over a large number of dissimilar types of sources. Even relatively small source classes, like heavy duty diesel vehicles, should not be overlooked.

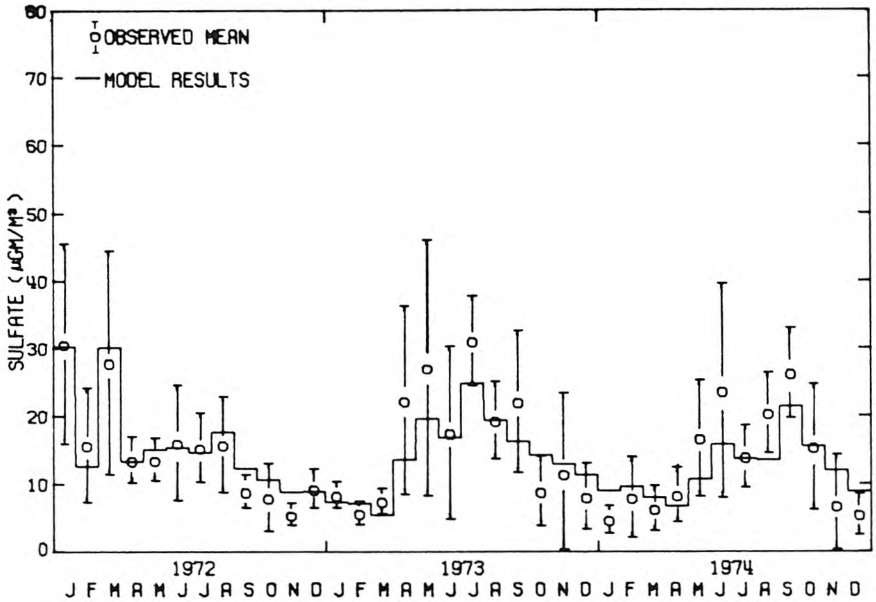


Fig. 9a Monthly Arithmetic Mean Sulfate Concentrations at Downtown Los Angeles (APCD)
Air Quality Model Results vs. Observed Rules

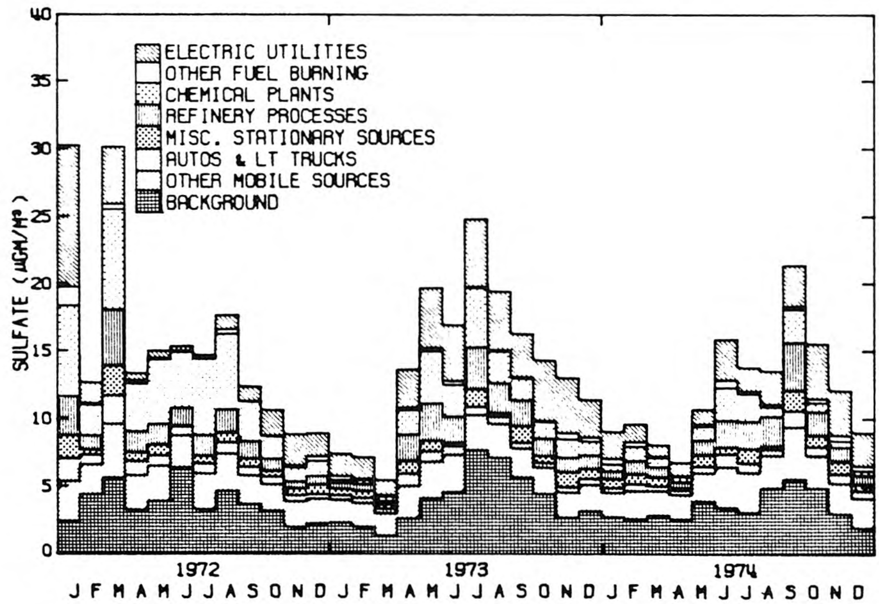


Fig. 9b Source Class Contribution to Sulfate Concentrations Observed at Downtown Los Angeles (APCD)

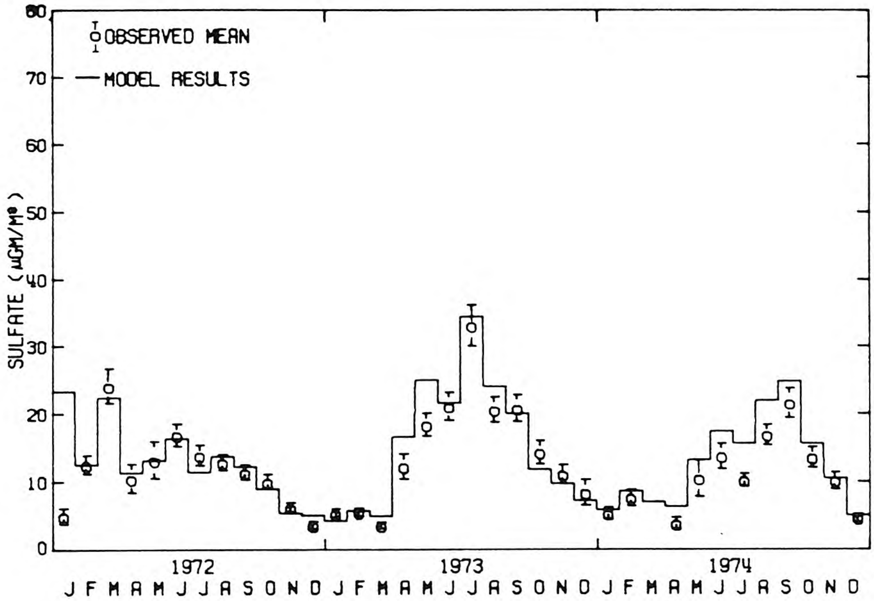


Fig. 10a Monthly Arithmetic Mean Sulfate Concentrations at Glendora (Chess)
Air Quality Model Results vs. Observed Values

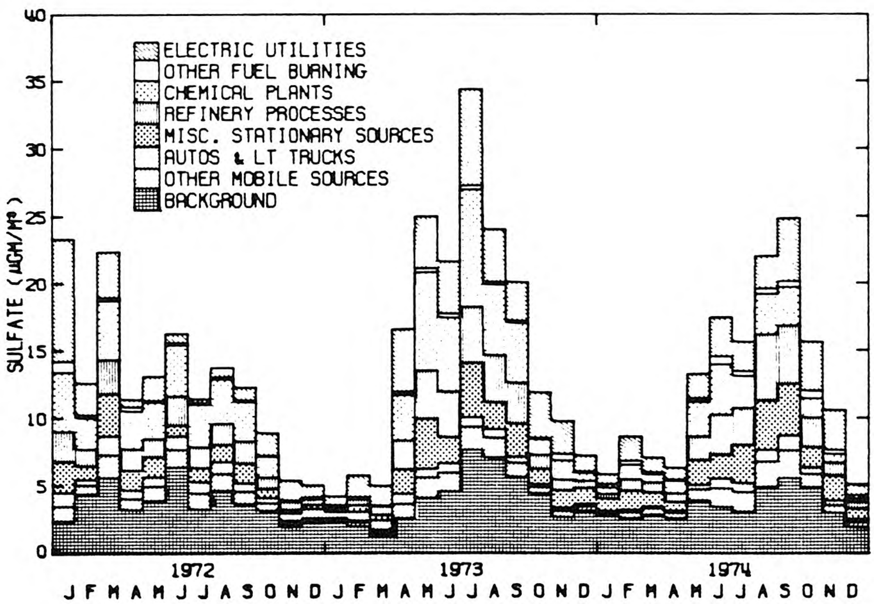


Fig. 10b Source Class Contribution to Sulfate Concentrations Observed at Glendora (Chess)

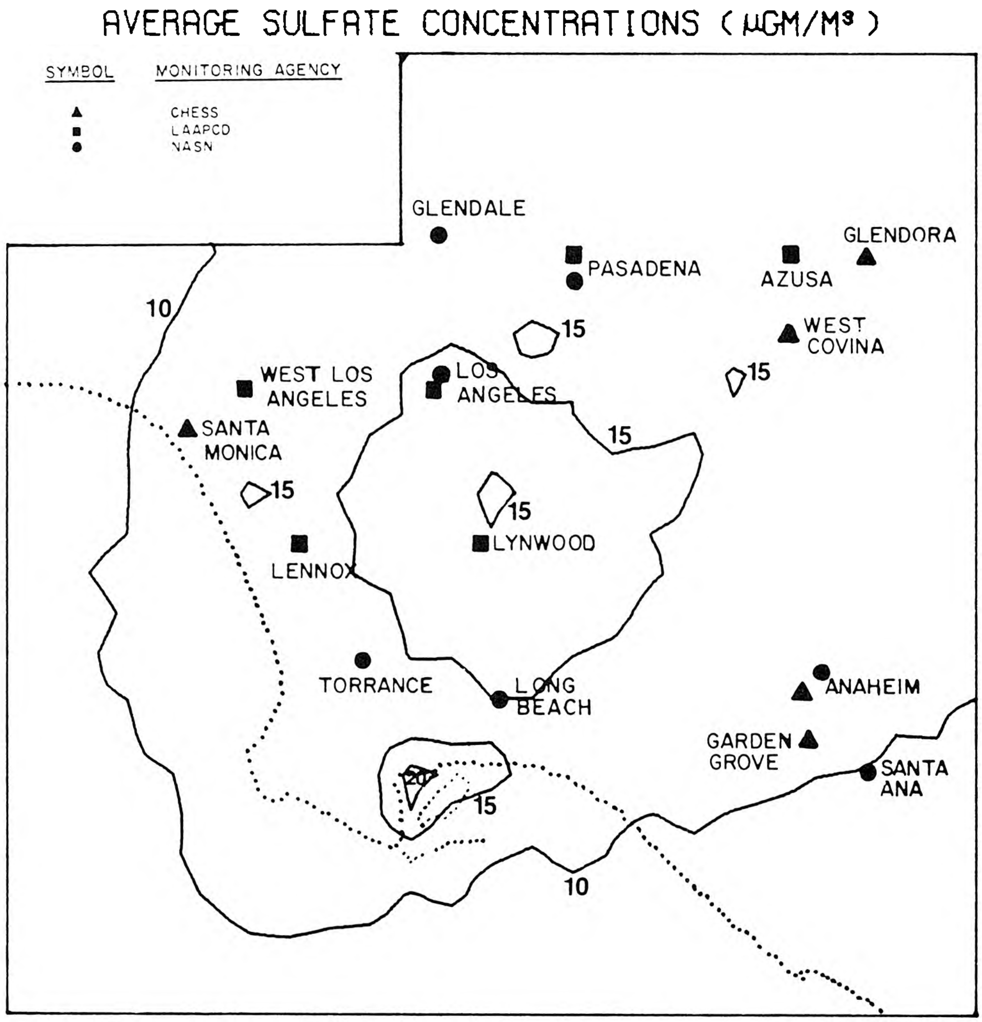


Fig. 11 Calendar Year 1972

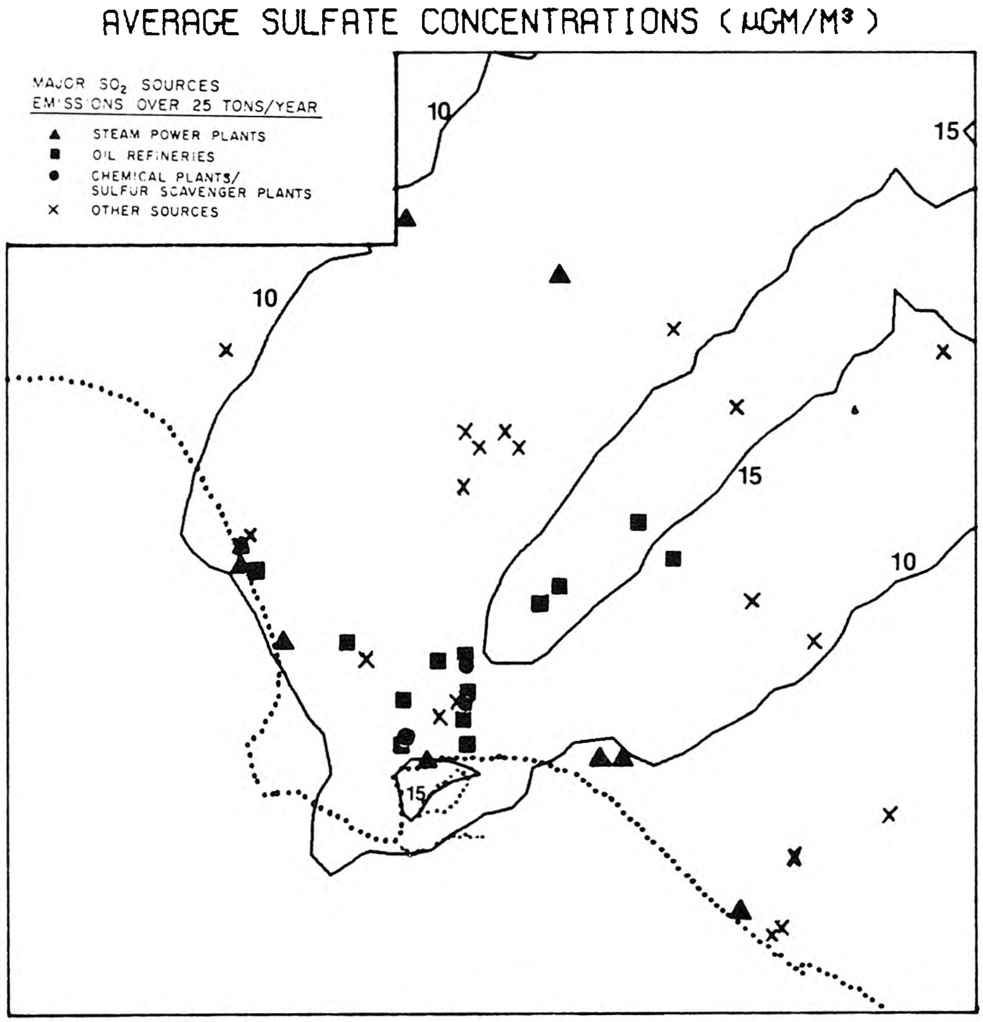


Fig. 12 Calendar Year 1973

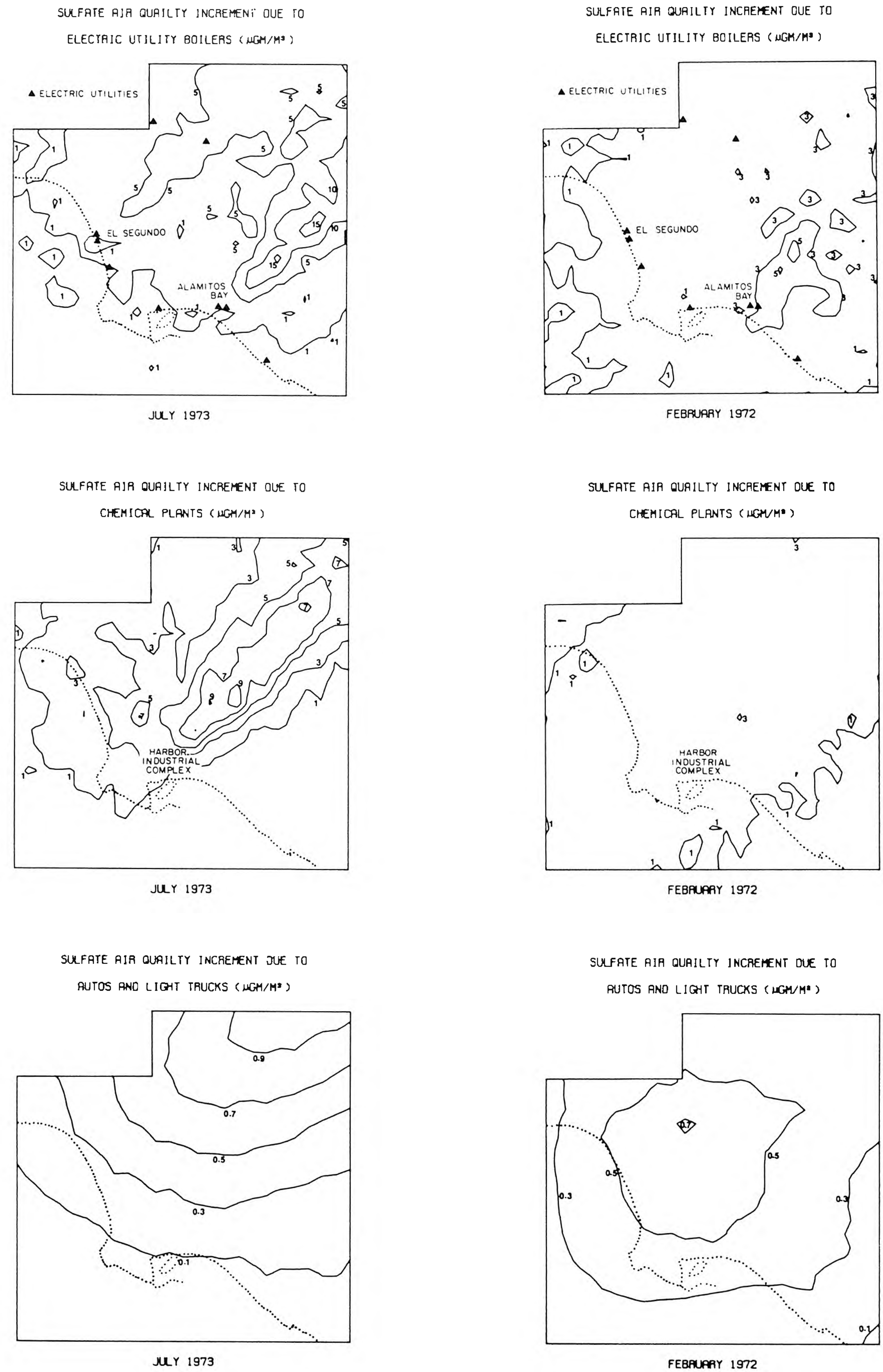

SULFATE AIR QUAILTY INCREMENT DUE TO
ELECTRIC UTILITY BOILERS (µGM/M³)
▲ ELECTRIC UTILITIES
EL SEGUNDO
ALAMITOS BAY
JULY 1973
SULFATE AIR QUAILTY INCREMENT DUE TO
ELECTRIC UTILITY BOILERS (µGM/M³)
▲ ELECTRIC UTILITIES
EL SEGUNDO
ALAMITOS BAY
FEBRUARY 1972
SULFATE AIR QUAILTY INCREMENT DUE TO
CHEMICAL PLANTS (µGM/M³)
HARBOR INDUSTRIAL COMPLEX
JULY 1973
SULFATE AIR QUAILTY INCREMENT DUE TO
CHEMICAL PLANTS (µGM/M³)
HARBOR INDUSTRIAL COMPLEX
FEBRUARY 1972
SULFATE AIR QUAILTY INCREMENT DUE TO
AUTOS AND LIGHT TRUCKS (µGM/M³)
JULY 1973
SULFATE AIR QUAILTY INCREMENT DUE TO
AUTOS AND LIGHT TRUCKS (µGM/M³)
FEBRUARY 1972

Fig. 13

SULFATE AIR QUALITY MODEL RESULTS - 1973

MONTHLY MEANS AT TEN AIR MONITORING STATIONS

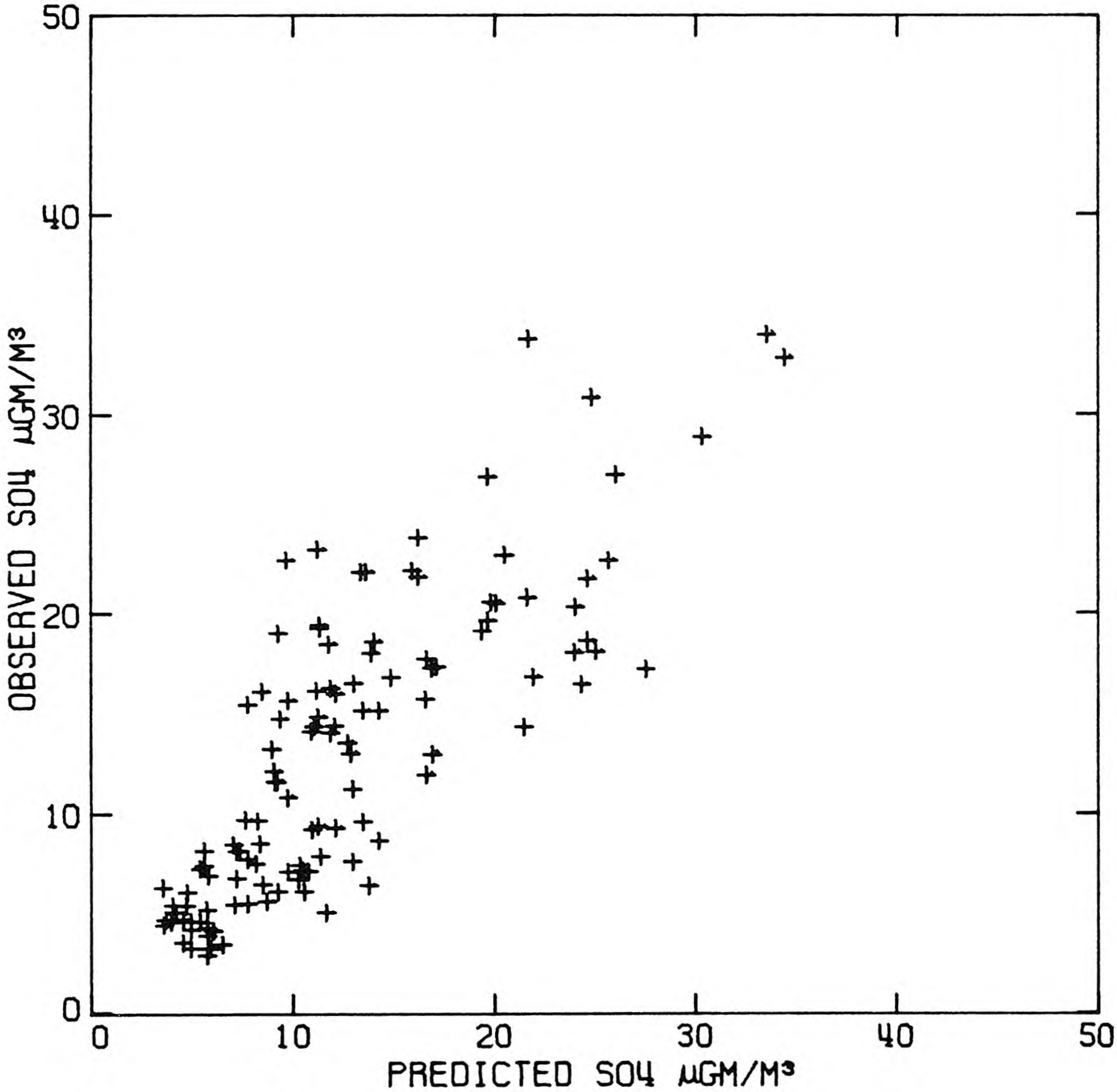


Fig. 14

Because the emissions to air quality model is linear in most types of SO_x emissions changes, the results of the air quality modeling studies can be used to evaluate sulfate air quality control strategy options. The first step in a procedure for design of emission control strategies by engineering methods is indicated in Table 4. Technological control measures identified by Hunter and Helgeson (1976) are listed in that table along with the annual average SO_x emissions for the year 1973 to which each control measure would apply. The incremental sulfate air quality improvement at downtown Los Angeles shown in Table 4 is that which would have been realized in 1973 if each candidate control strategy option had been installed and in operation in that year. That air quality impact estimate for each source class was obtained from the 1973 air quality model validation effort. The air quality model generates a set of <u>transfer coefficients</u> that give the effect on sulfate air quality at each monitoring site of a spatially homogeneous unit increase or decrease in SO_x emissions across <u>all</u> members of a <u>single</u> source class. These transfer coefficients, in $\mu g\ m^{-3}$ per ton SO_x emitted per day, when multiplied by the number of tons per day of emission control contemplated for a source class yield an estimate of the resulting improvement in sulfate air quality. In general, the magnitudes of these transfer coefficients differ between monitoring sites and source types due to the geographical distribution of the sources, and due to differences in source stack height and fraction sulfates initially present in each source's exhaust.

The last column of Table 4 shows that a measure of source emission control option effectiveness can be computed from the above data, in terms of sulfate concentration reduction at Los Angeles per dollar spent on SO_x control. If the limited set of control measures defined by Hunter and Helgeson (1976) were used to control 1973 sulfate concentrations, the least costly progression of air quality improvement versus cumulative control cost would have been as shown in the upper curve of Figure 15.

The South Coast Air Quality Management District (1978) also has used these air quality modeling results combined with a forecast emissions inventory to evaluate another set of available control technologies under conditions expected to prevail in the mid-1980s as shown in Figure 16. On the basis of rollback calculations, they determined the basinwide emission levels likely to be associated with attainment of various state and federal standards for SO_2 and for particulate sulfates, as shown in Table 5. Annual mean sulfate concentrations predicted by rollback for each of their candidate control strategies were tested against the predictions of the full scale sulfate simulation model of Cass (1978). It was found that the rollback model results did not differ greatly from the simulation model outcome for the cases tested.

TABLE 4

ANNUAL COST AND SULFATE AIR QUALITY IMPACT OF STATIONARY SOURCE SO_x EMISSIONS CONTROL TECHNOLOGIES IF APPLIED TO SO_x EMISSIONS IN THE SOUTH COAST AIR BASIN AS THEY EXISTED IN 1973

Emission Control Strategy Option	SO_x Emissions Control Effectiveness When Applied to 1973 Emissions Inventory				Incremental Cost of Emission Control Option (1975-76 Cost Basis)		Annual Mean Sulfate Air Quality Improvement at Downtown Los Angeles		Cost Effective-ness Index
	Degree of Control	Emissions from Source Class to Which Control Measure Would Apply (tons/day)	Emissions from Source Class After Application of that Control Measure (tons/day)	Total Reduction in Annual Average Emissions (tons/day)	Dollars Per Ton SO_x Removed	Total Annual Cost (10^6 Dollars)	$\mu gm/m^3$ $SO_4^=$ Reduced per ton/day Emission Reduction	Total Incremental Sulfate Reduction ($\mu gm/m^3$)	$\mu gm/m^3$ $SO_4^=$ Reduced per 10^9 Dollars Annual Cost
Electric Utility Residual Fuel Oil Desulfurization (a)									
(a) Reduction in fuel sulfur limit from 0.5% to 0.4%	-20%	239.9	191.9	48.0	377 (b)	6.60	0.0138 (e)	0.662	100.3
(b) Further reduction from 0.4% S to 0.3% S	-25%	191.9	143.9	48.0	471 (b)	8.25	0.0138 (e)	0.662	80.2
(c) Further reduction from 0.3% S to 0.2% S	-33%	143.9	95.9	48.0	942 (b)	16.50	0.0138 (e)	0.662	40.1
(d) Further Reduction from 0.2% S to 0.1% S	-50%	95.9	47.9	48.0	1695 (b)	29.70	0.0138 (e)	0.662	22.3
Industrial Residual Fuel Oil Desulfurization (a)									
(a) Reduction in fuel sulfur limit from 0.5% S to 0.4% S	-20%	8.3	6.6	1.7	377 (b)	0.23	0.0158	0.027	117.4
(b) Further reduction from 0.4% S to 0.3% S	-25%	6.6	5.0	1.6	471 (b)	0.28	0.0158	0.025	89.3
(c) Further reduction from 0.3% S to 0.2% S	-33%	5.0	3.3	1.7	942 (b)	0.58	0.0158	0.027	46.6
(d) Further reduction from 0.2% S to 0.1% S	-50%	3.3	1.7	1.6	1695 (b)	0.99	0.0158	0.025	25.2
Chemical Plant Emission Limit Met at 500 ppm SO_x (or less) in exhaust (Rule 53.3)	-93%	80.0	5.5	74.5	235 (c)	6.39	0.0217	1.617	253.0
(a) Claus tail gas clean-up units applied to sulfur plants									
(b) Additional absorption units, de-misters, or plant derating applied to H_2SO_4 plants									
Petroleum Refining and Production									
(a) Caustic scrubber applied to refinery fluid catalytic crackers (FCC)	-95%	52.1	2.6	49.5	1144	20.67	0.0257	1.272	61.5
(b) Claus plant applied to oil field fire flooding operation exhaust	-90%	4.5	0.5	4.0	312	0.46	0.0257 (d)	0.103	223.9
Petroleum Coke Calcining Kiln Emissions Reduction Obtained From Scrubbing Coke Dust Prior to Combustion	-80%	25.5	5.1	20.4	600	4.47	0.0165	0.337	75.4
Steel Mill									
(a) Desulfurization of coke oven gas	-90%	21.2	2.1	19.1	122	0.85	0.0024	0.046	54.1
(b) Scrubber applied to mill sinter plants	-80%	4.8	1.0	3.8	470	0.65	0.0024	0.009	13.8

Notes

(a) Middle distillate fuel oil desulfurization was not addressed by Hunter and Helgeson (1976) and thus will be excluded from this example.

(b) The additional cost *beyond 0.5% sulfur fuel* was estimated by Hunter and Helgeson (1976) as \$0.12, \$0.27, \$0.57, and \$1.11 per barrel for fuel meeting 0.4% sulfur, 0.3% sulfur, 0.2% sulfur, and 0.1% sulfur rules respectively. Thus 0.3% sulfur fuel would cost (\$0.27 - \$0.12) = \$0.15 more per barrel than 0.4% sulfur fuel. See Chapter 7 footnotes 2 and 3 for additional information and assumptions.

(c) No specific cost data for sulfuric acid plant control were given, but rules affecting both sulfur recovery and acid plants were adopted simultaneously and are assumed to be equally cost-effective.

(d) The air quality impact shown is proportional to the petroleum processing source class as a whole. This source is physically distant from downtown Los Angeles and this may not have an impact at downtown Los Angeles which is proportionately as large as from the FCC units which dominate that source class. However, the cost effectiveness of controlling that source is so high that control strategy conclusions would be distorted little even if the air quality impact estimate were reduced several fold.

(e) Based on emissions from both on-grid plus off-grid power plants located within the 1973 boundaries of the South Coast Air Basin. If only a subset of those power plants were to be considered for control, the impact per ton of SO_x emissions reduced would be expected to vary depending on the group of generating stations chosen.

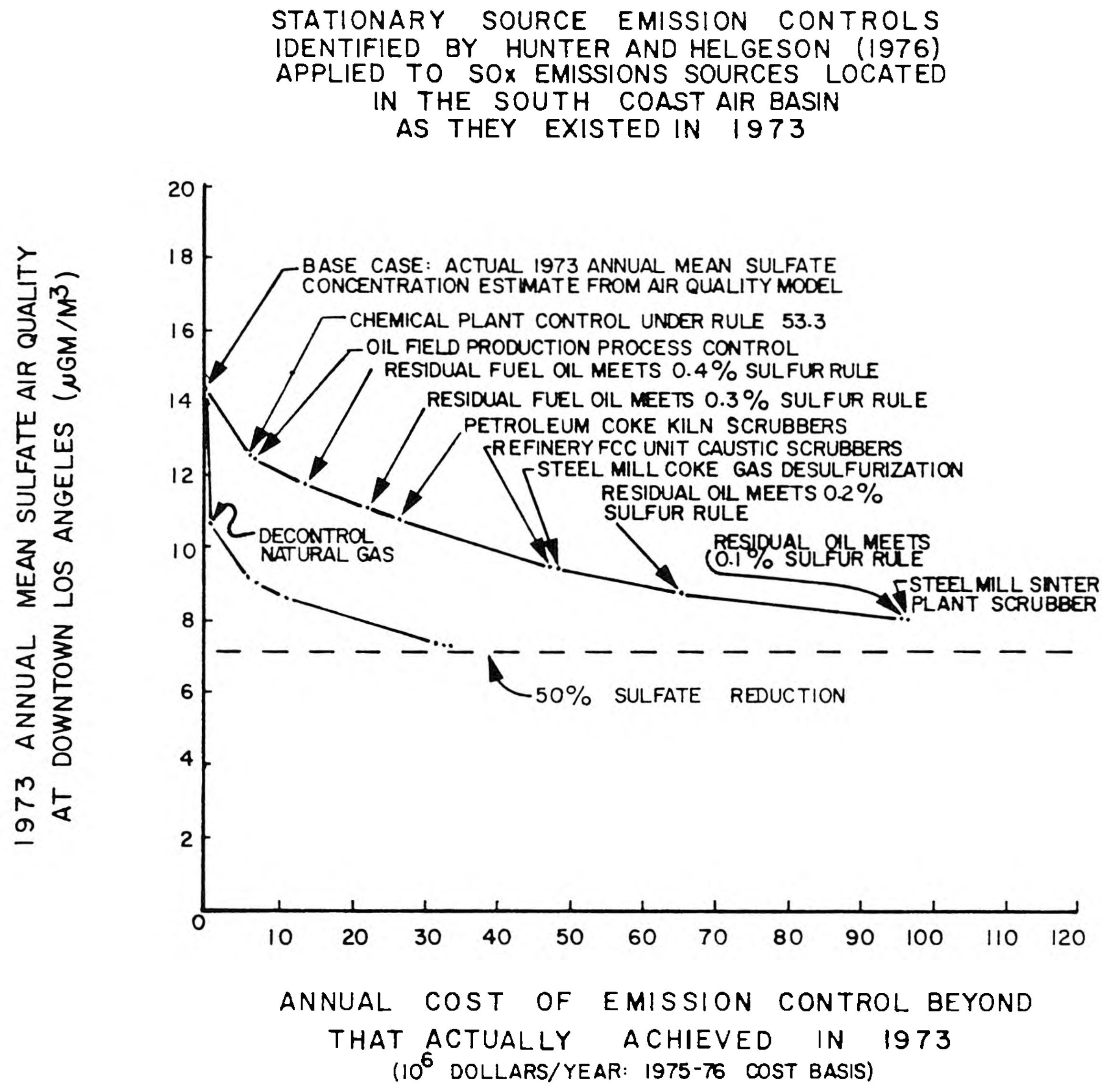

STATIONARY SOURCE EMISSION CONTROLS
IDENTIFIED BY HUNTER AND HELGESON (1976)
APPLIED TO SOx EMISSIONS SOURCES LOCATED
IN THE SOUTH COAST AIR BASIN
AS THEY EXISTED IN 1973
1973 ANNUAL MEAN SULFATE AIR QUALITY
AT DOWNTOWN LOS ANGELES (μGM/M3)
BASE CASE: ACTUAL 1973 ANNUAL MEAN SULFATE
CONCENTRATION ESTIMATE FROM AIR QUALITY MODEL
CHEMICAL PLANT CONTROL UNDER RULE 53.3
OIL FIELD PRODUCTION PROCESS CONTROL
RESIDUAL FUEL OIL MEETS 0.4% SULFUR RULE
RESIDUAL FUEL OIL MEETS 0.3% SULFUR RULE
PETROLEUM COKE KILN SCRUBBERS
REFINERY FCC UNIT CAUSTIC SCRUBBERS
STEEL MILL COKE GAS DESULFURIZATION
RESIDUAL OIL MEETS 0.2%
SULFUR RULE
RESIDUAL OIL MEETS
(0.1% SULFUR RULE
STEEL MILL SINTER
PLANT SCRUBBER
DECONTROL
NATURAL GAS
50% SULFATE REDUCTION
20
18
16
14
12
10
8
6
4
2
0
10
20
30
40
50
60
70
80
90
100
110
120
ANNUAL COST OF EMISSION CONTROL BEYOND
THAT ACTUALLY ACHIEVED IN 1973
(10^6 DOLLARS/YEAR: 1975-76 COST BASIS)

Fig. 15

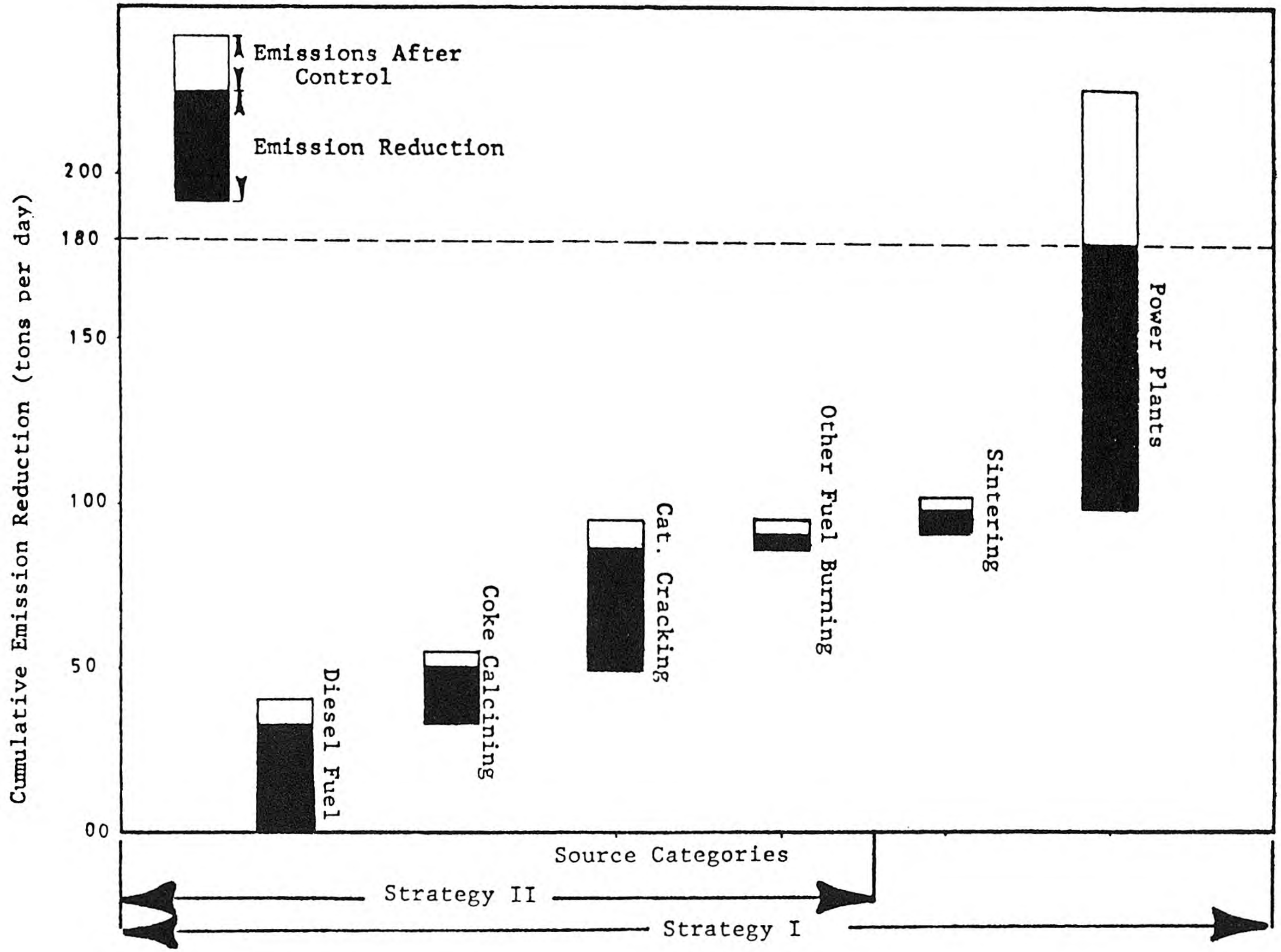


Fig. 16 Control Strategy I Cumulative SO_2 Reductions from Affected Source Categories

TABLE 5

ALLOWABLE SO_x EMISSIONS IN THE SOUTH COAST AIR BASIN
(based on the 1978 South Coast
Air Quality Management District Study)

Air Quality Objective	Allowable SO_x Emissions in the South Coast Air Basin (a) (tons/day)	Equivalent allowable SO_x Emissions within the On-Grid Plus Off-Grid Inventory Region used in this Study (b) (tons/day)
1. Attain all state and Federal SO_2 standards plus the California Sulfate Air Quality Standard.	142	149
2. Attain all state and Federal SO_2 standards but violate California Sulfate Standard 3 percent to 5 percent of the time.	227	238
3. Attain all state and Federal SO_2 standards but violate California Sulfate Standard regularly.	297	312

(a) South Coast Air Quality Management District (1978); based on a four county emission inventory region.

(b) Increased by a factor of 1.05 above SCAQMD values in order to account for Ventura County power plants that are included in the present survey.

TECHNICAL PROBLEMS POSED BY A SYSTEM OF TRANSFERABLE LICENSES TO EMIT AIR POLLUTANTS

The air quality model and control strategy optimization procedure just described raises several serious questions about the technical advisability of a market for transferable licenses to emit air pollutants. First, if the least costly combination of control equipment needed to reach an air quality target can be computed from engineering calculations, what do we gain from a market system? Secondly, Table 4 shows that different sources have different effects on air quality per ton of SO_x emitted. The minimum cost solution to this air quality problem in principle involves capitalizing on these air quality differences so as to control the high impact sources to a greater degree than low impact sources. If source owners are allowed to trade emissions on the basis of permits denominated in tons per day, we loose the ability to systematically handicap the high leverage sources. Does this matter? Finally, is it not possible that a market system would redistribute permitted emissions spatially in a way that would create local "hot spots," or neighborhoods with extremely bad air quality?

The first of these questions is readily answered using results from the 1973 sulfate control strategy study (Cass, 1978). Engineering optimization of a solution to the Los Angeles sulfate problem is extremely sensitive to assumptions about the level of natural gas availability. If fuel oil burning sources could be switched to natural gas, better air quality could be achieved at a much lower cost, as shown in Figure 15. However, the level of natural gas supply is not under state or local control, and is not readily forecast. Thus fixed emission control regulations designed by engineering means to minimize control cost at one level of gas supply would quickly become obsolete when the natural gas supply changes. Regulatory lags are inevitable, thus one would likely be operating with a sub-optimal set of control regulations in place at all times. A transferable license system, by specifying a total level of SO_x emissions but not a specific set of control hardware or fuel sulfur content, preserves the flexibility of source owners to respond quickly to a rising or falling level of natural gas supply.

The remaining questions about the degree of inefficiency implied when one ignores the spatial distribution of emission sources and allows all source owners in Los Angeles to freely trade SO_x emissions licenses can only be answered empirically. In this particular air basin, would an open market in licenses result in redistribution of emissions so that high impact sources were left uncontrolled or so that new air quality hot spots were created where none existed previously?

The air quality model developed by Cass (1978) can be used to answer those questions. The procedure is as follows. The SO_x emissions potential of the South Coast Air Basin during the early 1980s first will be assessed. This emissions projection must be made in a manner that is very flexible with respect to altered natural gas supply. That is because these emission data must be used later to test the emission license market's ability to respond to large changes in gas supply. Next the air quality model will be combined with the new emissions data and used to determine the transfer coefficients that relate emissions strength to air quality given the spatial distribution of sources that could prevail in the early 1980s. These transfer coefficients giving the air quality impact of each source type on each monitoring site can then be combined with new data on emission control costs. The least costly way to attain any level of air quality can be computed in an engineering sense and compared to the distribution of emissions and air quality that would result from a simulation of the effect of a transferable license market. In this way one can see whether great cost savings might result from imposition of the engineering optimization scheme. If not, the flexibility of the transferable license approach is well worth a small loss in static cost minimization.

Finally, the spatial distribution of air quality under projected 1980s emission patterns will be examined. It will be determined whether future "hot spots" (neighborhoods with much poorer than average air quality) will result, or whether sulfate air quality in the Los Angeles area will remain fairly uniformly distributed geographically in the future as it has been in the past.

THE SULFUR OXIDES EMISSION POTENTIAL OF THE SOUTH COAST AIR BASIN

A projection of the potential for sulfur oxides emissions from sources located in the central portion of the South Coast Air Basin was assembled. Emission data were sought that would be appropriate to evaluation of pollution control problems during the early part of the 1980s. That inventory will serve as the base case against which emission control strategies for improving sulfate air quality will be tested.

A complete description of all assumptions built into the emission inventory is presented in Appendix E to this report. The approach taken was not to try to predict the actual SO_x emission rate for a particular future year. The actual level of sulfur oxides emissions in the Los Angeles area in any given year is a strong function of the level of natural gas supply. When natural gas is plentiful, most stationary combustion sources burn gas rather than sulfur-bearing fuel oil, and SO_x emissions are relatively low. Conversely, in years with a poor natural gas supply, several hundred additional tons per day of SO_2 are emitted from residual and distillate oil combustion. Natural gas supplies have been observed to fluctuate widely in response to Federal regulations that are beyond the control of state and local pollution abatement authorities. Hence the actual level of SO_x emissions in any particular year is not readily forecast, and any abatement plan that is inflexible to the point of requiring a firm emissions forecast is liable to fail dramatically.

Instead, the approach taken here was to develop a spatially and temporally resolved inventory of the <u>potential</u> for sulfur oxides emissions as they would occur under conditions of low natural gas supply. This inventory forms a realistic estimate of the <u>upper limit</u> on SO_x emissions in Los Angeles in the early 1980s. From this base case, emissions rates that would prevail in the presence of any arbitrary level of natural gas supply can be quickly constructed by attenuating the SO_x emissions from fuel burning sources in proportion to the additional gas supply contemplated.

A basic starting point will be taken that is similar to that assumed by the South Coast Air Quality Management District (1978) emissions forecast. New emission control measures agreed upon or adopted prior to January 1978 will be assumed to be implemented in future years. Emissions from all other sources not affected by recent changes in regulations will be projected into the early 1980s assuming that trends apparent in 1977 remain unchanged into the near future. As a practical matter, this means that base case emissions from electric utilities were computed in the presence of a 0.25 percent limit on the sulfur content of fuel oil, while other fuel burning sources were allowed to burn up to 0.50 percent sulfur fuel oil. Rules adopted prior to January 1978 governing emission reductions at chemical plants, steel mills, and secondary lead smelters were assumed to be implemented during the early 1980s. The effect of reductions in emissions from nonutility fuel burning sources, refinery fluid catalytic crackers, petroleum coke calcining kilns proposed prior to January 1978 but not adopted by that time were excluded from the base case emission inventory. The decision to include or exclude any particular emission control proposal when making these emission projections will not bias the outcome of this study. That is because removal or addition of all candidate emission control systems will be considered as a possible perturbation from the base case when evaluating likely actions by source owners under a transferable license system. It is merely necessary at this point that the base case be precisely defined.

Appendix A2 of the study by Cass (1978) presented a spatially and temporally resolved SO_x emissions inventory for the central portion of the South Coast Air Basin during each month of the years 1972, 1973, and 1974. That emissions inventory was projected into early 1980s while maintaining nearly the same organization of sources into groups of like equipment. Major point sources and dispersed area-wide sources of sulfur oxides were assigned to appropriate locations within the 50-by-50 mile square grid shown in Figure 6. Major equipment items located beyond that grid system were itemized separately, while small off-grid area sources were neglected as before. The most important parameter of that emission projection is the chosen level of natural gas supply. The approach taken to setting a base case level of natural gas supply thus bears detailed attention.

THE LEVEL OF NATURAL GAS SUPPLY

The principal source of sulfur oxides emissions in the United States is from the combustion of sulfur bearing fossil fuels (U.S. Environmental Protection Agency, 1974). Historically, the cornerstone of the South Coast Air Basin sulfur oxides emission control strategy has rested on desulfurization of refinery gas, plus provision of a high level of natural gas supply to industry and electric utilities. Low sulfur oil was to be used only in the event that cleaner burning gaseous fuels became unavailable. This policy of promoting gaseous fuel use was so successful that in 1970, only about 21 percent of Los Angeles County SO_x emissions were derived from stationary source fuel combustion (Southern California Air Pollution Control District, 1976).

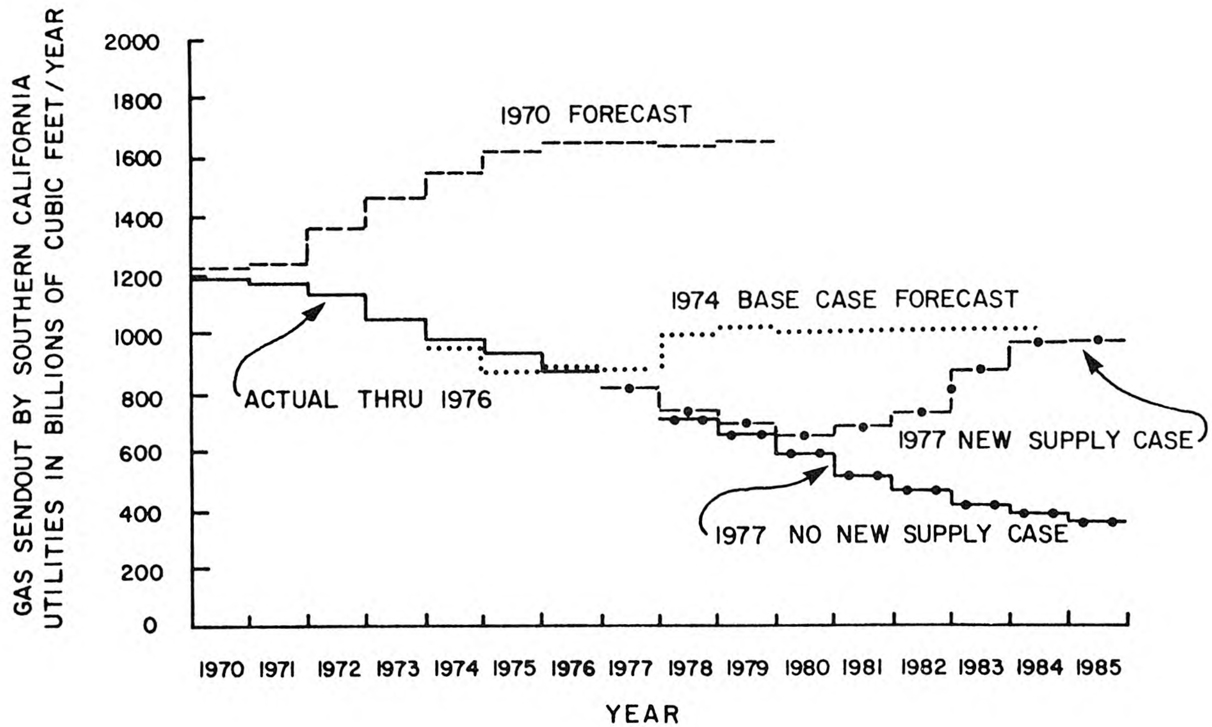
Since about the year 1970, natural gas deliveries to Southern California have steadily declined under the combined effects of interstate natural gas price regulations imposed by the Federal government, plus regulation-aggravated declines in both gas exploration and new gas reserve accumulation. While the amount of energy needed to run the economy of the South Coast Air Basin might be projected from historical data given in the energy and sulfur balance portion of the study by Cass (1978; Appendix A3), emissions of sulfur oxides cannot be forecast without knowing the combination of gas and oil that will be available to meet that energy requirement. In order to address that issue with reasonable accuracy, reliable information must exist on whether the natural gas supply will continue to deteriorate or will improve.

Forecasts of future natural gas deliveries to southern California customers are prepared annually by the utility systems serving California (for example, see the 1977 California Gas Report). The Pacific Lighting Companies act as the largest purchasing agent for natural gas sold in southern California, and as such should be in the best position to know their distribution capabilities, customers' requests for service, and the supply of gas available to them from producer's around the world (including LNG). If they cannot forecast their own level of natural gas purchase more than a year or so in advance, then it would be unwise for us to place much faith in our ability to second guess their behavior more than a few years hence under the assumption that trends apparent in 1977 continued into the future.[1]

Figure 17 provides a comparison of forecast natural gas deliveries to southern California[2] prepared by California utilities at three different times during the 1970s (California Gas Report, 1970, 1974, and 1977 editions). The 1970 forecast contained a prediction for steady growth in natural gas deliveries, reaching a level of greater than 1.6 trillion cubic feet per year in 1979. Instead, actual gas deliveries began an almost immediate decline. The 1974 forecast tended to show a short-term decline followed by a subsequent recovery of gas supply to 1974 levels. By 1977, however, the forecast

SOUTHERN CALIFORNIA NATURAL GAS SUPPLY FORECASTS

COMPARISON OF UTILITY INDUSTRY NATURAL GAS DELIVERY FORECASTS MADE DURING THE 1970's



SOURCE: CALIFORNIA GAS REPORT 1970, 1974, and 1977 Editions

Fig. 17

for a quick recovery was abandoned in favor of continued decline in gas deliveries until at least 1980. From 1980 forward, two forecasts diverge. The "new supply" case which anticipates completion of several international supply projects shows recovery to 1974 levels by 1985, while the "no new supply" case projects a continued decline into the future. About the only trend common to more than one of these forecasts is that a lower bound to gas supply is provided by the extension of the 1970 through 1976 actual delivery line through to the 1977 "no new supply" case. A crosssection taken through all forecasts at the year 1979 indicates a divergence between forecasts made at seven-year intervals which is larger than the amount of gas then expected actually to be delivered in 1979.[3] The inference must be that any seven-year forecast prepared in this manner should be treated as a possibility to be encouraged or discouraged as one sees fit, but should not be relied upon as a given. On the other hand, the utility forecaster's track record over a two-to-three year time period following the date of a particular forecast is not too bad.

With the above discussion in mind, natural gas supply conditions in Southern California during the early 1980s will be represented not by a forecast that one expects will actually happen but rather by a case which falls within the range of the forecasts shown in Figure 17 and which has public policy implications so important that that case should be examined closely. The level of gas service chosen for study corresponds to a gas delivery rate of 0.655 Tcf per year to Southern California. At that level of service in the early 1980s, all high priority gas customers with no capability to use alternate fuels (California Public Utilities Commission priority groups 1 and 2A, plus underground injection) would receive service equal to 100 percent of their natural gas requirements. All other industries and electric utilities with alternate fuel capability would have their service almost completely curtailed (<u>1977 California Gas Report</u>, Table 1b-sc).

That level of natural gas service is chosen as the base case for our study for several important reasons. First, it corresponds to utility estimates for natural gas supply in the early 1980s at a time when the "new supply" and "no new supply" cases are nearly identical. Secondly, it represents an approximate average between the "new supply" and "no new supply" forecasts during the remainder of the first half of the 1980s. Most importantly, it represents the maximum amount of natural gas curtailment possible before small customers and thus the local economy would become seriously damaged financially. As such, it represents the point at which the California Public Utilities Commission would probably intervene to protect small customers by transferring gas from Northern to Southern California. In that case, the supply forecast is reinforced on its lower bound.

After the base case level of natural gas supply to Southern California was selected, then electricity generation plans were obtained on a unit-by-unit basis from major electric utilities in the air basin. Fuel use needed to generate those quantities of electricity were computed. From that fuel use estimate, electric utility SO_x emissions estimates were derived. A forecast of total thermal energy consumption by refinery and industrial fuel burners next was made on a spatially resolved basis for the early 1980s. Then the natural gas supply forecast was used to estimate the level of fuel oil and refinery gas consumption required to meet that industrial energy demand under conditions of low natural gas supply. SO_x emissions were then computed from fuel use as before.

Industrial process SO_x emissions estimates for the early 1980s were obtained by personal interview with South Coast Air Quality Management District engineers. An equipment list compiled from the historical emissions inventory of Appendix A2 of the study by Cass (1978) was used as a check list for this interview procedure. Each item of equipment emitting over 25 tons of SO_x annually was reviewed to determine if it was still in operation, if its emissions were expected to be impacted by regulations or consent agreements adopted prior to January 1978, or if an improved estimate of future emissions could be made.

Finally, mobile source emissions data were updated. A freeway and surface street traffic growth survey was used to forecast 1980 traffic volumes on a spatially resolved basis. Then highway traffic was subdivided into catalyst-equipped and non catalyst-equipped gasoline-fueled vehicles, plus diesel trucks and buses. Fuel combustion estimates for railroads, ships, and aircraft were projected to the early 1980s based upon conversations with transportation industry personnel.

EMISSIONS PROJECTION SUMMARY AND DISCUSSION

Figure 18 summarizes the sulfur oxides emissions projection for the central portion of the South Coast Air Basin under conditions of low natural gas supply. In the event of the loss of the industrial natural gas supply, emissions within the 50-by-50 mile grid would total about 355 tons per average day. Major off-grid sources would amount to another 64.3 tons per day of SO_x emissions. Those figures correspond quite closely to the 343 tons per day on-grid, plus 91 tons per day off-grid during the year 1974. In spite of the introduction of several new emissions control regulations during the late 1970s future air quality might look much like past air quality if large amounts of fuel oil were burned by local industries.

Comparison of Figure 18 to Figure 8 shows that annual average data hide some remarkable changes which would have occurred between 1974 and any future year in which natural gas supplies run low. The strong seasonal variation in electric utility fuel SO_x emissions present in the early 1970s would be absent under conditions of low natural gas supply. The annual average value of those utility fuel SO_x emissions would remain about the same in spite of a great increase in oil combustion because the sulfur content of fuel was cut from a

SULFUR OXIDES EMISSIONS WITHIN THE 50 BY 50 MILE SQUARE

UNDER CONDITIONS OF LOW NATURAL GAS SUPPLY

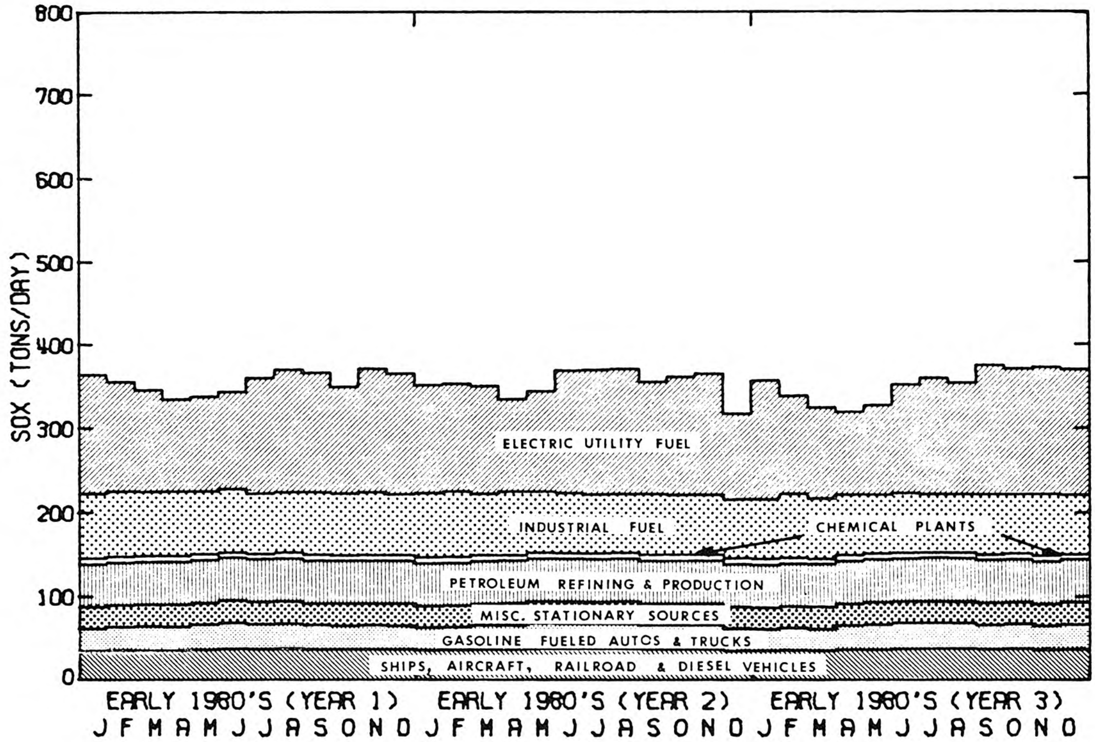


Fig. 18

maximum of 0.50 percent by weight in 1974 down to a maximum of 0.25 percent sulfur by weight at present.

A second major change in emissions between the early 1970s and the early 1980s involves the nearly complete elimination of SO_x emissions from chemical plants. However, in place of the chemical plant emissions, more than 70 tons per day of SO_x emissions could occur from nonutility industrial fuel burning under conditions of low natural gas supply. Bringing fuel burning emissions under control through maintenance of the natural gas supply or installation of desulfurization or emissions control equipment thus is seen to be critical during the decade of the 1980s if sulfate air quality is to be improved beyond 1974 levels.

Tables 6 through 8 show the monthly emissions history for individual source and equipment types within the general source categories of Figure 18. The emissions inventory created for air quality model use contains spatially resolved source strength data defined on the 50-by-50 mile grid for each of the 28 source types shown in Tables 6 through 8 for each month of three test years. An itemization of large off-grid sources also is included.

One principal reason for compiling emissions on a source-by-source basis is to be able to display the spatial distribution of SO_x emission strength. Figures 19 through 21 summarize annual average SO_x emissions density for those test years. It is seen that the largest SO_x emission source densities are still located in a narrow strip along the coastline stretching from Los Angeles International Airport (near Lennox) on the north to Huntington Beach (opposite Santa Ana) on the south. However, sulfur oxides emissions in the downtown Los Angeles area would grow beyond levels observed in the early 1970s if increased industrial fuel oil use were to occur in the presence of a low natural gas supply.

THE RELATIONSHIP BETWEEN EMISSIONS AND AIR QUALITY UNDER BASE CASE CONDITIONS

The emissions to air quality model described by Cass (1978) was employed to explore the air quality consequences of the emissions projection just described. The objective of this exercise was two-fold. First, a reestimation of the transfer coefficients that map emissions strength from each source class into observed air quality at each monitoring site was desired given a geographic distribution of emissions characteristic of the 1980s. Secondly, we wish to examine the spatial distribution of air quality that would result from a major change in emissions (in this case a change to all-oil combustion by industry) in order to see if any major "hot spot" neighborhoods are generated that would experience very poor air quality.

Tables 6 through 8 provide 36 consecutive monthly emissions estimates for each source type of interest. These three years of

TABLE 6a

Sulfur Oxides Emissions Within the 50 by 50 Mile Square Grid
Early 1980's Test Year 1
(in short tons per day as SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
FUEL COMBUSTION													
ELECTRIC UTILITIES													
RESIDUAL OIL	139.80	127.93	119.15	107.61	110.18	113.12	136.13	143.48	139.07	124.44	144.54	141.57	128.95
DISTILLATE OIL	2.28	2.09	1.94	1.76	1.80	1.85	2.22	2.34	2.27	2.03	2.36	2.31	2.10
REFINERY FUEL	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
LOW PRIORITY NATURAL GAS CUSTOMERS	49.41	50.28	48.75	49.98	47.89	48.44	44.64	45.67	47.99	46.76	48.29	45.39	47.77
HIGH PRIORITY NATURAL GAS CUSTOMERS	0.46	0.43	0.29	0.27	0.24	0.20	0.17	0.15	0.16	0.18	0.30	0.40	0.27
CHEMICAL PLANTS													
SULFUR RECOVERY	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
SULFURIC ACID	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08
OTHER CHEMICALS	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
PETROLEUM REFINING AND PRODUCTION													
FLUID CATALYTIC CRACKERS	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95
SOUR WATER STRIPPERS	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
DELAYED COKERS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MISC. REFINERY PROCESS	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
OIL FIELD PRODUCTION	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30
MISC. STATIONARY SOURCES													
PETROLEUM COKE KILNS	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82
GLASS FURNACES	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
NON-FERROUS METALS	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
FERROUS METALS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MINERAL PRODUCTS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEWAGE TREATMENT DIGESTERS	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
OTHER INDUSTRIAL PROCESSES	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
PERMITTED INCINERATORS	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
MOBILE SOURCES													
CATALYST-EQUIPPED LT. DUTY VEHICLES - SURFACE	7.06	7.38	7.57	7.50	7.84	8.26	7.92	8.13	7.74	7.61	7.71	7.67	7.70
CATALYST-EQUIPPED LT. DUTY VEHICLES - FREEWAY	4.92	5.14	5.27	5.23	5.46	5.76	5.52	5.66	5.39	5.30	5.37	5.34	5.36
NON-CATALYST LT. DUTY VEHICLES	14.55	15.20	15.59	15.45	16.16	17.02	16.32	16.75	15.95	15.67	15.88	15.80	15.86
HEAVY HIGHWAY DIESEL VEHICLES	17.15	17.91	18.38	18.21	19.04	20.06	19.23	19.74	18.80	18.47	18.71	18.62	18.69
AIRPORT OPERATIONS	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
SHIPPING OPERATIONS	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21
RAILROAD OPERATIONS	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33
TOTAL	365.35	356.08	346.66	335.73	338.33	344.43	361.87	371.64	367.09	350.18	372.88	366.82	356.4

TABLE 6b

Major Off-Grid Emission Sources Included within the South Coast Air Basin Sulfur Oxides Modeling Inventory Early 1980's Test Year 1 (in short tons per day as SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
FUEL COMBUSTION													
ELECTRIC UTILITIES													
RESIDUAL OIL	51.38	47.02	43.79	39.55	40.50	41.58	50.03	52.74	51.11	45.74	53.13	52.03	47.40
DISTILLATE OIL	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03	0.03	0.02
REFINERY FUEL	---	---	---	---	---	---	---	---	---	---	---	---	---
LOW PRIORITY NATURAL GAS CUSTOMERS	---	---	---	---	---	---	---	---	---	---	---	---	---
HIGH PRIORITY NATURAL GAS CUSTOMERS	---	---	---	---	---	---	---	---	---	---	---	---	---
CHEMICAL PLANTS													
SULFUR RECOVERY	---	---	---	---	---	---	---	---	---	---	---	---	---
SULFURIC ACID	---	---	---	---	---	---	---	---	---	---	---	---	---
OTHER CHEMICALS	---	---	---	---	---	---	---	---	---	---	---	---	---
PETROLEUM REFINING AND PRODUCTION													
FLUID CATALYTIC CRACKERS	---	---	---	---	---	---	---	---	---	---	---	---	---
SOUR WATER STRIPPERS	---	---	---	---	---	---	---	---	---	---	---	---	---
DELAYED COKERS	---	---	---	---	---	---	---	---	---	---	---	---	---
MISC. REFINERY UNITS	---	---	---	---	---	---	---	---	---	---	---	---	---
OIL FIELD PRODUCTION	---	---	---	---	---	---	---	---	---	---	---	---	---
MISC. STATIONARY SOURCES													
PETROLEUM COKE KILNS	---	---	---	---	---	---	---	---	---	---	---	---	---
GLASS FURNACES	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
NON-FERROUS METALS	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
FERROUS METALS	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55
MINERAL PRODUCTS	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
SEWAGE TREATMENT DIGESTERS	---	---	---	---	---	---	---	---	---	---	---	---	---
OTHER INDUSTRIAL PROCESSES	---	---	---	---	---	---	---	---	---	---	---	---	---
PERMITTED INCINERATORS	---	---	---	---	---	---	---	---	---	---	---	---	---
TOTAL OFF-GRID STATIONARY SOURCES	68.12	63.74	60.53	56.29	57.24	58.32	66.77	69.49	67.85	62.48	69.88	68.78	64.14

TABLE 7a

Sulfur Oxides Emissions Within the 50 by 50 Mile Square Grid
Early 1980's Test Year 2
(in short tons per day as SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
FUEL COMBUSTION													
ELECTRIC UTILITIES													
RESIDUAL OIL	126.10	126.41	126.70	107.76	117.74	143.06	145.77	146.63	131.75	138.79	141.45	99.46	129.31
DISTIALLATE OIL	2.06	2.06	2.07	1.76	1.92	2.33	2.38	2.39	2.15	2.26	2.31	1.62	2.11
REFINERY FUEL	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
LOW PRIORITY NATURAL GAS CUSTOMERS	49.69	50.23	45.16	48.16	45.85	44.77	43.41	42.88	45.17	44.38	45.19	42.73	45.60
HIGH PRIORITY NATURAL GAS CUSTOMERS	0.46	0.46	0.37	0.33	0.26	0.21	0.17	0.16	0.19	0.20	0.26	0.36	0.28
CHEMICAL PLANTS													
SULFUR RECOVERY	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
SULFURIC ACID	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08
OTHER CHEMICALS	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
PETROLEUM REFINING AND PRODUCTION													
FLUID CATALYTIC CRACKERS	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95
SOUR WATER STRIPPERS	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
DELAYED COKERS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MISC. REFINERY PROCESS	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
OIL FIELD PRODUCTION	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30
MISC. STATIONARY SOURCES													
PETROLEUM COKE KILNS	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82
GLASS FURNACES	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
NON-FERROUS METALS	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
FERROUS METALS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MINERAL PRODUCTS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEWAGE TREATMENT DIGESTERS	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
OTHER INDUSTRIAL PROCESSES	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
PERMITTED INCINERATORS	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
MOBILE SOURCES													
CATALYST-EQUIPPED LT. DUTY VEHICLES - SURFACE	7.19	7.41	7.72	7.79	8.16	8.08	8.02	8.15	7.68	7.67	7.67	7.09	7.72
CATALYST-EQUIPPED LT. DUTY VEHICLES - FREEWAY	5.01	5.16	5.38	5.43	5.68	5.63	5.58	5.68	5.35	5.34	5.34	4.94	5.38
NON-CATALYST LT. DUTY VEHICLES	14.82	15.27	15.90	16.06	16.81	16.65	16.52	16.80	15.82	15.80	15.80	14.60	15.91
HEAVY HIGHWAY DIESEL VEHICLES	17.46	17.99	18.74	18.92	19.81	19.62	19.46	19.80	18.65	18.62	18.62	17.20	18.75
AIRPORT OPERATIONS	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
SHIPPING OPERATIONS	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21
RAILROAD OPERATIONS	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33
TOTAL	352.51	354.71	351.76	335.93	345.95	370.07	371.03	372.21	356.48	362.78	366.36	317.72	354.79

TABLE 7b

Major Off-Grid Emission Sources Included within the
South Coast Air Basin Sulfur Oxides Modeling Inventory
Early 1980's Test Year 2
(in short tons per day as SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
FUEL COMBUSTION													
ELECTRIC UTILITIES													
RESIDUAL OIL	46.35	46.46	46.57	39.61	43.28	52.58	53.58	53.90	48.42	51.01	51.99	36.56	47.53
DISTILLATE OIL	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.03	0.02	0.02
REFINERY FUEL	---	---	---	---	---	---	---	---	---	---	---	---	---
LOW PRIORITY NATURAL GAS CUSTOMERS	---	---	---	---	---	---	---	---	---	---	---	---	---
HIGH PRIORITY NATURAL GAS CUSTOMERS	---	---	---	---	---	---	---	---	---	---	---	---	---
CHEMICAL PLANTS													
SULFUR RECOVERY	---	---	---	---	---	---	---	---	---	---	---	---	---
SULFURIC ACID	---	---	---	---	---	---	---	---	---	---	---	---	---
OTHER CHEMICALS	---	---	---	---	---	---	---	---	---	---	---	---	---
PETROLEUM REFINING AND PRODUCTION													
FLUID CATALYTIC CRACKERS	---	---	---	---	---	---	---	---	---	---	---	---	---
SOUR WATER STRIPPERS	---	---	---	---	---	---	---	---	---	---	---	---	---
DELAYED COKERS	---	---	---	---	---	---	---	---	---	---	---	---	---
MISC. REFINERY UTNIS	---	---	---	---	---	---	---	---	---	---	---	---	---
OIL FIELD PRODUCTION	---	---	---	---	---	---	---	---	---	---	---	---	---
MISC. STATIONARY SOURCES													
PETROLEUM COKE KILNS	---	---	---	---	---	---	---	---	---	---	---	---	---
GLASS FURNACES	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
NON-FERROUS METALS	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
FERROUS METALS	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55
MINERAL PRODUCTS	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
SEWAGE TREATMENT DIGESTERS	---	---	---	---	---	---	---	---	---	---	---	---	---
OTHER INDUSTRIAL PROCESSES	---	---	---	---	---	---	---	---	---	---	---	---	---
PERMITTED INCINERATORS	---	---	---	---	---	---	---	---	---	---	---	---	---
TOTAL OFF-GRID STATIONARY SOURCES	63.09	63.20	63.31	56.35	60.02	69.33	70.33	70.65	65.16	67.75	68.74	53.30	64.27

TABLE 8a

Sulfur Oxides Emissions Within the 50 by 50 Mile Square Grid
Early 1980's Test Year 3
(in short tons per day as SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
FUEL COMBUSTION													
ELECTRIC UTILITIES													
RESIDUAL OIL	139.95	114.63	106.43	95.91	104.17	126.70	137.08	130.43	151.04	147.32	149.40	147.41	129.31
DISTILLATE OIL	2.28	1.87	1.74	1.57	1.70	2.07	2.24	2.13	2.46	2.40	2.44	2.41	2.11
REFINERY FUEL	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
LOW PRIORITY NATURAL GAS CUSTOMERS	43.34	48.64	44.06	44.94	43.13	44.22	41.44	41.98	44.85	43.53	46.16	42.39	44.01
HIGH PRIORITY NATURAL GAS CUSTOMERS	0.41	0.41	0.35	0.27	0.23	0.21	0.17	0.15	0.16	0.17	0.25	0.35	0.26
CHEMICAL PLANTS													
SULFUR RECOVERY	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
SULFURIC ACID	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08
OTHER CHEMICALS	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
PETROLEUM REFINING AND PRODUCTION													
FLUID CATALYTIC CRACKERS	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95	44.95
SOUR WATER STRIPPERS	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
DELAYED COKERS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MISC. REFINERY PROCESSES	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
OIL FIELD PROCESSES	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30
MISC. STATIONARY SOURCES													
PETROLEUM COKE KILNS	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82	22.82
GLASS FURNACES	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
NON-FERROUS METALS	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
FERROUS METALS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MINERAL PRODUCTS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SEWAGE TREATMENT DIGESTERS	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
OTHER INDUSTRIAL PROCESSES	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
PERMITTED INCINERATORS	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
MOBILE SOURCES													
CATALYST-EQUIPPED LT. DUTY VEHICLES - SURFACE	6.91	7.19	6.95	7.70	7.98	8.18	8.23	8.19	7.76	8.01	7.58	7.94	7.72
CATALYST-EQUIPPED LT. DUTY VEHICLES - FREEWAY	4.82	5.01	4.84	5.37	5.56	5.70	5.73	5.70	5.40	5.58	5.28	5.53	5.38
NON-CATALYST LT. DUTY VEHICLES	14.24	14.81	14.31	15.87	16.45	16.85	16.96	16.86	15.98	16.50	15.61	16.35	15.91
HEAVY HIGHWAY DIESEL VEHICLES	16.78	17.46	16.87	18.70	19.38	19.85	19.99	19.88	18.83	19.44	18.40	19.27	18.75
AIRPORT OPERATIONS	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
SHIPPING OPERATIONS	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21	13.21
RAILROAD OPERATIONS	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33	4.33
TOTAL	358.45	339.74	325.27	320.05	328.32	353.50	361.56	355.04	376.25	372.67	374.84	371.37	353.18

TABLE 8b

Major Off-Grid Emission Sources Included within the
South Coast Air Basin Sulfur Oxides Modeling Inventory
Early 1980's Test Year 3
(in short tons per day as SO_2)

STATIONARY SOURCES	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
FUEL COMBUSTION													
ELECTRIC UTILITIES													
RESIDUAL OIL	51.44	42.13	39.12	35.25	38.29	46.57	50.38	47.94	55.51	54.15	54.19	54.18	47.53
DISTILLATE OIL	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.02
REFINERY FUEL	---	---	---	---	---	---	---	---	---	---	---	---	---
LOW PRIORITY NATURAL GAS CUSTOMERS	---	---	---	---	---	---	---	---	---	---	---	---	---
HIGH PRIORITY NATURAL GAS CUSTOMERS	---	---	---	---	---	---	---	---	---	---	---	---	---
CHEMICAL PLANTS													
SULFUR RECOVERY	---	---	---	---	---	---	---	---	---	---	---	---	---
SULFURIC ACID	---	---	---	---	---	---	---	---	---	---	---	---	---
OTHER CHEMICALS	---	---	---	---	---	---	---	---	---	---	---	---	---
PETROLEUM REFINING AND PRODUCTION													
FLUID CATALYTIC CRACKERS	---	---	---	---	---	---	---	---	---	---	---	---	---
SOUR WATER STRIPPERS	---	---	---	---	---	---	---	---	---	---	---	---	---
DELAYED COKERS	---	---	---	---	---	---	---	---	---	---	---	---	---
MISC. REFINERY UNITS	---	---	---	---	---	---	---	---	---	---	---	---	---
OIL FIELD PRODUCTION	---	---	---	---	---	---	---	---	---	---	---	---	---
MISC. STATIONARY SOURCES													
PETROLEUM COKE KILNS	---	---	---	---	---	---	---	---	---	---	---	---	---
GLASS FURNACES	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
NON-FERROUS METALS	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
FERROUS METALS	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55	14.55
MINERAL PRODUCTS	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
SEWAGE TREATMENT DIGESTERS	---	---	---	---	---	---	---	---	---	---	---	---	---
OTHER INDUSTRIAL PROCESSES	---	---	---	---	---	---	---	---	---	---	---	---	---
PERMITTED INCINERATORS	---	---	---	---	---	---	---	---	---	---	---	---	---
TOTAL OFF-GRID STATIONARY SOURCES	68.16	58.87	55.86	51.99	55.03	63.31	67.12	64.68	72.26	70.90	71.66	70.93	64.27

TOTAL SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR I UNDER CONDITIONS OF LOW NATURAL GAS SUPPLY, IN TONS/DAY AS SO2

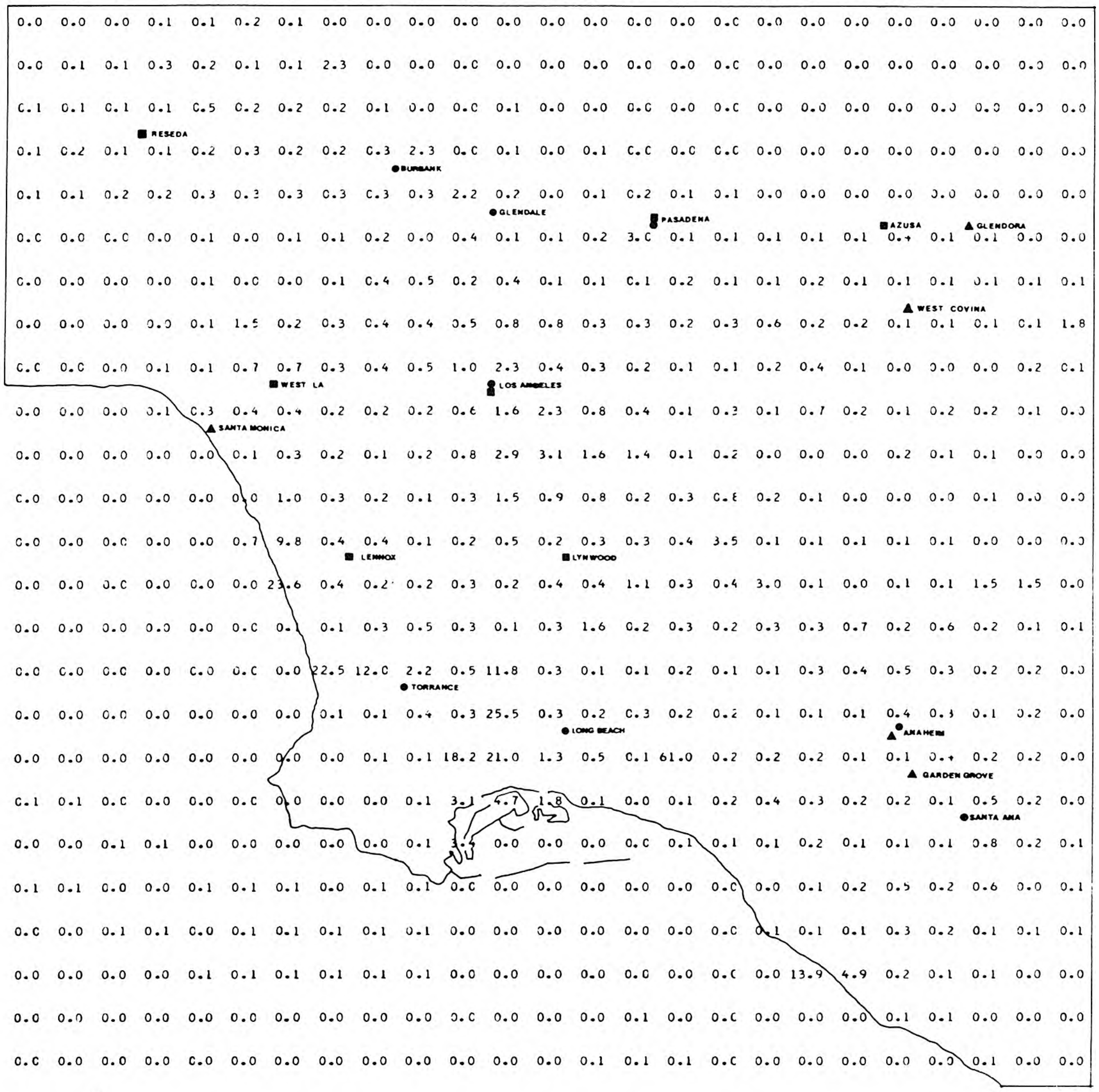
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.1	0.1	0.3	0.2	0.1	0.1	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.1	0.1	0.1	0.1	0.5	0.2	0.4	0.3	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.1	0.2	0.1	0.1	0.2	0.3	0.2	0.2	0.4	2.4	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	2.2	0.2	0.0	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.2	0.0	0.4	0.1	0.1	0.2	3.0	0.1	0.1	0.1	0.1	0.1	0.4	0.1	0.1	0.0	0.0
19	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.5	0.5	0.2	0.5	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
18	0.0	0.0	0.0	0.0	0.1	1.6	0.2	0.4	0.4	0.4	0.5	0.8	0.8	0.3	0.3	0.2	0.3	0.6	0.2	0.2	0.1	0.1	0.1	0.1	1.9
17	0.0	0.0	0.0	0.1	0.1	0.7	0.6	0.3	0.4	0.5	1.0	2.4	0.4	0.3	0.2	0.1	0.1	0.2	0.4	0.1	0.0	0.0	0.0	0.2	0.1
16	0.0	0.0	0.0	0.1	0.3	0.4	0.4	0.2	0.2	0.2	0.7	1.9	2.5	1.0	0.4	0.1	0.3	0.1	0.7	0.2	0.1	0.2	0.2	0.1	0.0
15	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.2	0.1	0.3	0.7	2.8	2.8	1.5	1.4	0.1	0.2	0.0	0.0	0.0	0.2	0.1	0.1	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.3	0.2	0.1	0.3	1.4	1.4	0.8	0.2	0.3	0.7	0.2	0.1	0.0	0.0	0.0	0.1	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.7	9.8	0.4	0.4	0.1	0.2	0.5	0.3	0.4	0.3	0.4	3.6	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	23.6	0.5	0.2	0.2	0.3	0.2	0.4	0.4	1.1	0.3	0.4	3.0	0.1	0.0	0.1	0.1	1.5	1.5	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.3	0.1	0.3	1.5	0.2	0.3	0.2	0.3	0.3	0.7	0.2	0.6	0.2	0.1	0.1
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.5	12.0	2.2	0.5	11.7	0.3	0.1	0.1	0.2	0.1	0.1	0.3	0.4	0.5	0.3	0.2	0.2	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.4	0.3	25.5	0.3	0.2	0.3	0.2	0.2	0.1	0.1	0.1	0.4	0.3	0.2	0.1	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	18.2	21.0	1.2	0.5	0.1	60.8	0.2	0.2	0.2	0.1	0.1	0.4	0.2	0.2	0.0
7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	3.1	4.8	1.8	0.1	0.0	0.1	0.2	0.4	0.3	0.2	0.2	0.1	0.5	0.2	0.0
6	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	3.2	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.8	0.2	0.1
5	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	0.2	0.6	0.0	0.1
4	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.3	0.2	0.1	0.1	0.1
3	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.9	4.9	0.2	0.1	0.1	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0

RESEDA
BURBANK
GLENDALE
PASADENA
AZUSA
GLENDORA
WEST COVINA
WEST LA
LOS ANGELES
SANTA MONICA
LENNOX
LYNWOOD
TORRANCE
LONG BEACH
ANAHEIM
GARDEN GROVE
SANTA ANA

SOX
TONS/DAY
356.460

Fig. 19

TOTAL SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 2 UNDER CONDITIONS OF LOW NATURAL GAS SUPPLY, IN TONS/DAY AS SO2



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.1	0.1	0.3	0.2	0.1	0.1	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.1	0.1	0.1	0.1	0.5	0.2	0.2	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.1	0.2	0.1	0.1	0.2	0.3	0.2	0.2	0.3	2.3	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	2.2	0.2	0.0	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.2	0.0	0.4	0.1	0.1	0.2	3.0	0.1	0.1	0.1	0.1	0.1	0.4	0.1	0.1	0.0	0.0
19	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.4	0.5	0.2	0.4	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
18	0.0	0.0	0.0	0.0	0.1	1.5	0.2	0.3	0.4	0.4	0.5	0.8	0.8	0.3	0.3	0.2	0.3	0.6	0.2	0.2	0.1	0.1	0.1	0.1	1.8
17	0.0	0.0	0.0	0.1	0.1	0.7	0.7	0.3	0.4	0.5	1.0	2.3	0.4	0.3	0.2	0.1	0.1	0.2	0.4	0.1	0.0	0.0	0.0	0.2	0.1
16	0.0	0.0	0.0	0.1	0.3	0.4	0.4	0.2	0.2	0.2	0.6	1.6	2.3	0.8	0.4	0.1	0.3	0.1	0.7	0.2	0.1	0.2	0.2	0.1	0.0
15	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.2	0.1	0.2	0.8	2.9	3.1	1.6	1.4	0.1	0.2	0.0	0.0	0.0	0.2	0.1	0.1	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.3	0.2	0.1	0.3	1.5	0.9	0.8	0.2	0.3	0.8	0.2	0.1	0.0	0.0	0.0	0.1	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.7	9.8	0.4	0.4	0.1	0.2	0.5	0.2	0.3	0.3	0.4	3.5	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	23.6	0.4	0.2	0.2	0.3	0.2	0.4	0.4	1.1	0.3	0.4	3.0	0.1	0.0	0.1	0.1	1.5	1.5	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.3	0.1	0.3	1.6	0.2	0.3	0.2	0.3	0.3	0.7	0.2	0.6	0.2	0.1	0.1
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.5	12.0	2.2	0.5	11.8	0.3	0.1	0.1	0.2	0.1	0.1	0.3	0.4	0.5	0.3	0.2	0.2	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.4	0.3	25.5	0.3	0.2	0.3	0.2	0.2	0.1	0.1	0.1	0.4	0.3	0.1	0.2	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	18.2	21.0	1.3	0.5	0.1	61.0	0.2	0.2	0.2	0.1	0.1	0.4	0.2	0.2	0.0
7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	3.1	4.7	1.8	0.1	0.0	0.1	0.2	0.4	0.3	0.2	0.2	0.1	0.5	0.2	0.0
6	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	[illegible]	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.8	0.2	0.1
5	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	0.2	0.6	0.0	0.1
4	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.3	0.2	0.1	0.1	0.1
3	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.9	4.9	0.2	0.1	0.1	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0

SOX
TONS/DAY
354.791

Fig. 20

TOTAL SOX EMISSIONS IN THE EARLY 1980'S: TEST YEAR 3 UNDER CONDITIONS OF LOW NATURAL GAS SUPPLY, IN TONS/DAY AS SO2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
25	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.1	0.1	0.3	0.2	0.1	0.1	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.1	0.1	0.1	0.1	0.5	0.2	0.3	0.2	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.1	0.1	0.1	0.1	0.2	0.3	0.2	0.2	0.3	2.3	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.3	2.2	0.2	0.0	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.2	0.0	0.4	0.1	0.1	0.2	3.0	0.1	0.1	0.1	0.1	0.1	0.4	0.1	0.1	0.0	0.0
19	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.4	0.5	0.2	0.4	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
18	0.0	0.0	0.0	0.0	0.1	1.3	0.2	0.3	0.3	0.4	0.4	0.8	0.7	0.3	0.3	0.2	0.3	0.6	0.2	0.2	0.1	0.1	0.1	0.1	1.6
17	0.0	0.0	0.0	0.2	0.1	0.5	0.6	0.3	0.4	0.5	0.9	1.6	0.4	0.3	0.2	0.1	0.1	0.2	0.3	0.1	0.0	0.0	0.0	0.2	0.1
16	0.0	0.0	0.0	0.1	0.3	0.3	0.4	0.2	0.2	0.2	0.6	1.6	2.2	0.8	0.3	0.1	0.3	0.1	0.7	0.2	0.1	0.2	0.2	0.1	0.0
15	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.2	0.1	0.2	0.7	3.0	3.5	1.5	1.5	0.1	0.2	0.0	0.0	0.0	0.2	0.1	0.1	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.3	0.2	0.1	0.3	1.5	1.3	0.7	0.2	0.3	0.7	0.2	0.1	0.0	0.0	0.0	0.1	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.7	9.8	0.4	0.4	0.1	0.2	0.5	0.2	0.3	0.3	0.4	3.5	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	23.6	0.4	0.2	0.2	0.3	0.2	0.3	0.4	1.1	0.3	0.4	3.0	0.1	0.0	0.1	0.1	1.5	1.5	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.3	0.1	0.3	1.5	0.2	0.3	0.2	0.2	0.3	0.7	0.2	0.6	0.2	0.0	0.1
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.5	12.0	2.4	0.5	11.8	0.3	0.1	0.1	0.2	0.1	0.1	0.3	0.4	0.4	0.3	0.2	0.2	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.3	25.7	0.3	0.2	0.3	0.2	0.2	0.1	0.1	0.1	0.4	0.3	0.1	0.2	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	18.2	21.1	1.2	0.5	0.1	61.0	0.2	0.2	0.2	0.1	0.1	0.4	0.2	0.2	0.0
7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	3.0	4.7	1.8	0.1	0.0	0.1	0.2	0.4	0.3	0.2	0.2	0.1	0.5	0.2	0.0
6	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	3.3	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.8	0.2	0.1
5	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	0.2	0.6	0.0	0.1
4	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.3	0.2	0.1	0.1	0.1
3	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.9	4.9	0.2	0.1	0.1	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0

RESEDA
BURBANK
GLENDALE
PASADENA
AZUSA
GLENDORA
WEST COVINA
WEST LA
LOS ANGELES
SANTA MONICA
LENNOX
LYNWOOD
TORRANCE
LONG BEACH
ANAHEIM
GARDEN GROVE
SANTA ANA

SOX
TONS/DAY
353.179

Fig. 21

example emissions data were matched with three different years of historically observed meteorological data so that a range of air quality possibilities could be examined using the air quality simulation model. Meteorological data taken from years 1972 through 1974 form an attractive set of test conditions. Those years contain two instances of typical weather conditions leading to high summer sulfates and low winter sulfates (as in 1973 and 1974), plus one counter example yielding high winter sulfates with low summer sulfates (as in 1972). In order to capture the interplay between weather conditions and fuel use, the seasonal variation in energy consumption observed in those years was factored into the emissions projections at the time that those projections were made.

Remaining data needed to complete the air quality simulation are as described in Chapter 5 of Cass (1978). Estimates of the seasonal variation in sulfate background air quality and in SO_2 oxidation rate can be matched to appropriate meteorological conditions by basing those values within this simulation on historical observations during the years 1972-1974.

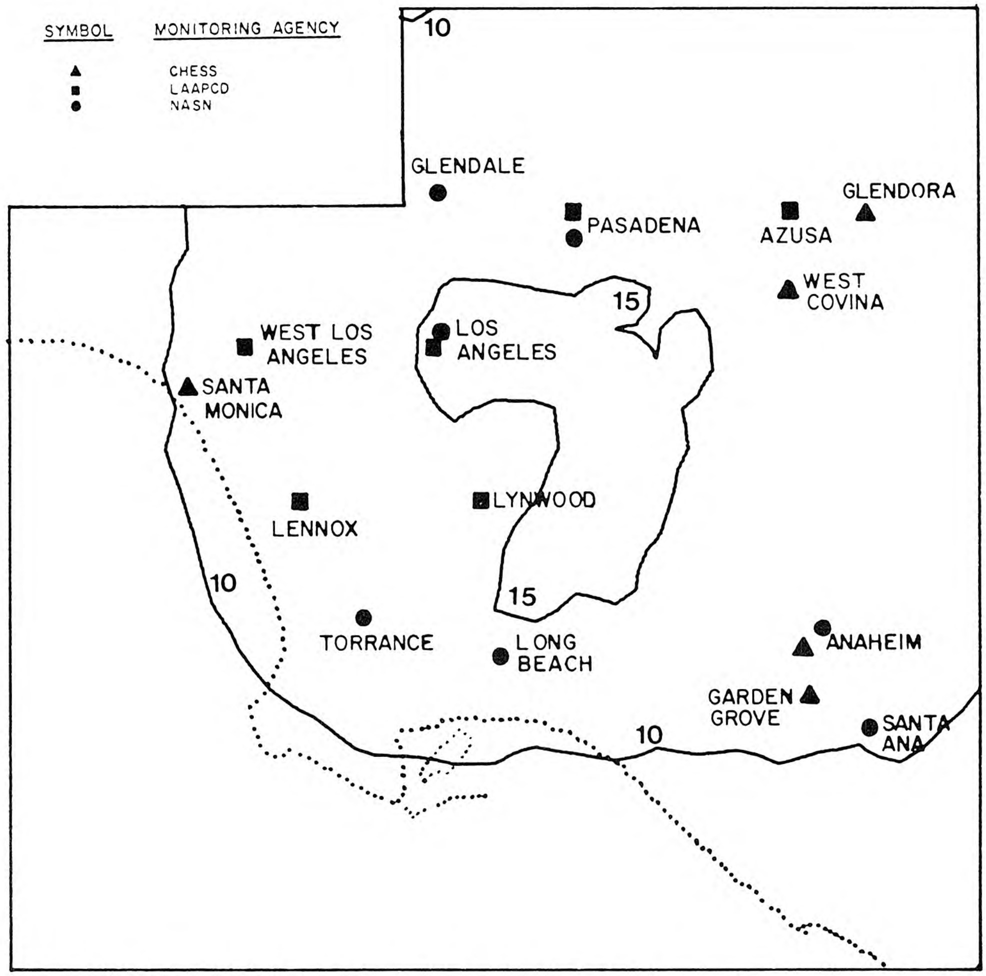
Annual mean sulfate concentrations that would result from the base case emissions pattern under three alternative years of meteorological events are shown in Figures 22 through 24. A composite average of these three test cases is given in Figure 25. By comparison with Figure 11, it is seen that sulfate concentration patterns in the 1980s under low natural gas supply conditions would not differ greatly from air quality observations in the early 1970s. The spatial distribution of sulfate air quality on the average in Figure 25 is fairly uniform over the most populous areas of the air basin, with most neighborhoods having sulfate concentrations averaging from 10 to 15 $\mu g\ m^{-3}$ over the long run.

The sources contributing to sulfate concentrations at a number of monitoring sites are presented in Figures 26-45. As was the case in the early 1970s, air quality at each monitoring site is due to the combined effects of small contributions from a large number of diverse source types. Sulfate concentrations attributed to automobiles have increased due to small additions of primary sulfates from catalyst equipped cars introduced to the vehicle fleet since 1975. Chemical plant emissions and air quality impacts have been nearly eliminated when compared with the early 1970s (see Figures 8,9,10). A substantial air quality increment due to stationary fuel burning sources would occur at each monitoring site if the low natural gas supply case were actually to occur in the 1980s. One can quickly visualize air quality in the presence of a <u>high</u> natural gas supply by eliminating the top two subdivisions on the bar graphs of Figures 26-45.

When each source class' contribution to air quality at a monitoring site is divided by basin-wide emissions from that source type, transfer coefficients are generated that show the effect on resulting air quality of a unit change in emissions from the source.

ANNUAL AVERAGE SULFATE CONCENTRATIONS ($\mu GM/M^3$)

UNDER LOW NATURAL GAS SUPPLY CONDITIONS

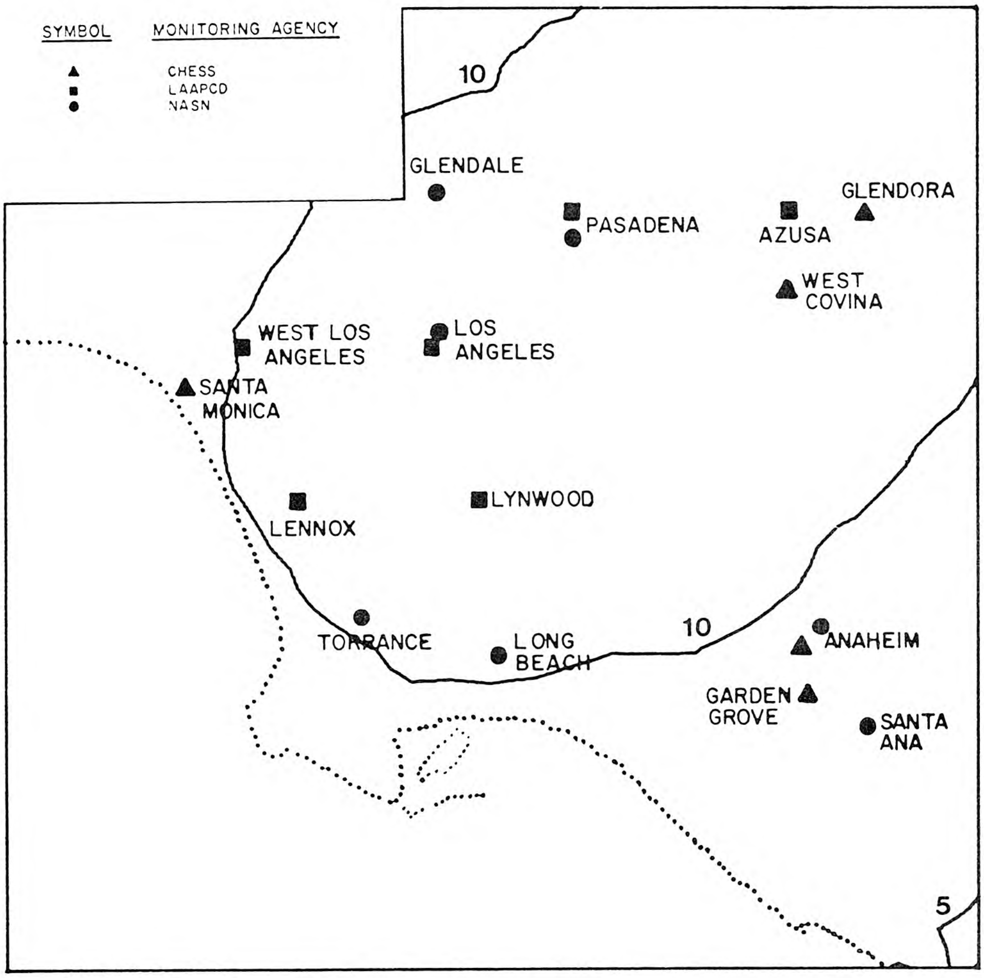


EARLY 1980'S - TEST YEAR 1

Fig. 22

ANNUAL AVERAGE SULFATE CONCENTRATIONS (μGM/M^3)

UNDER LOW NATURAL GAS SUPPLY CONDITIONS

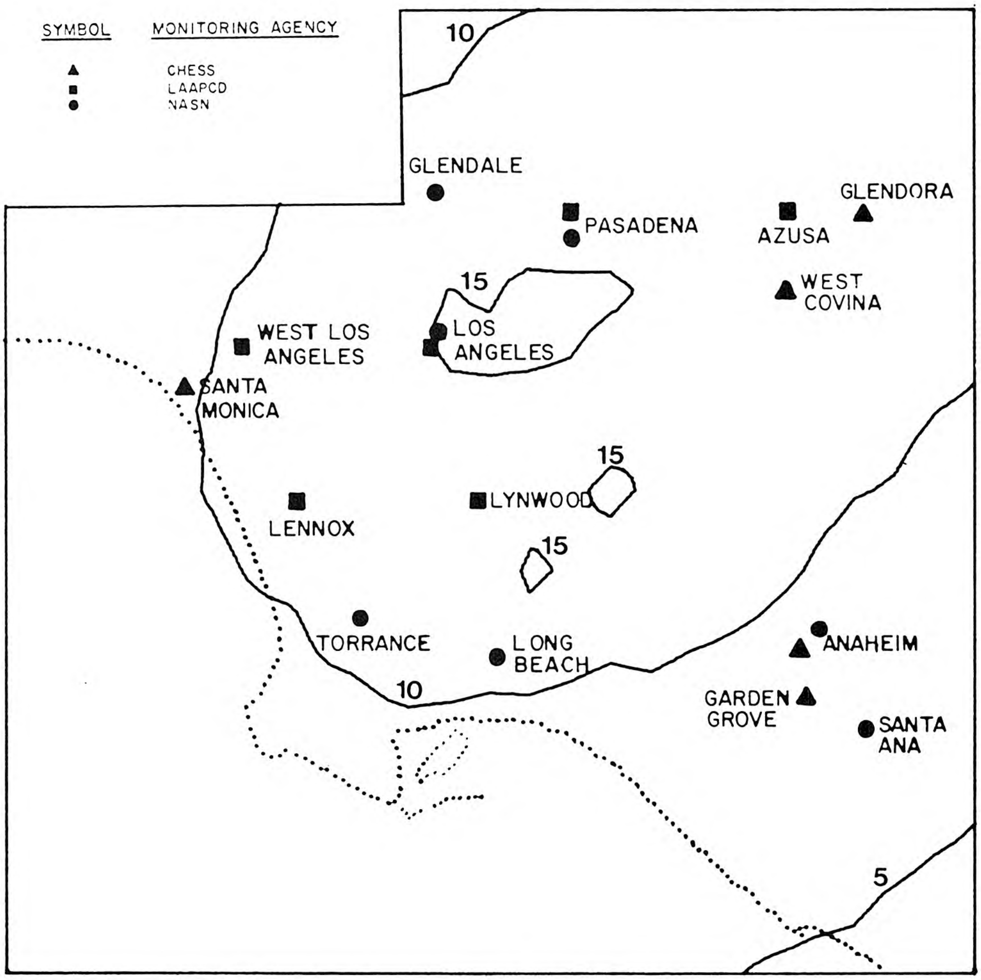


EARLY 1980'S - TEST YEAR 2

Fig. 23

ANNUAL AVERAGE SULFATE CONCENTRATIONS ($\mu GM/M^3$)

UNDER LOW NATURAL GAS SUPPLY CONDITIONS

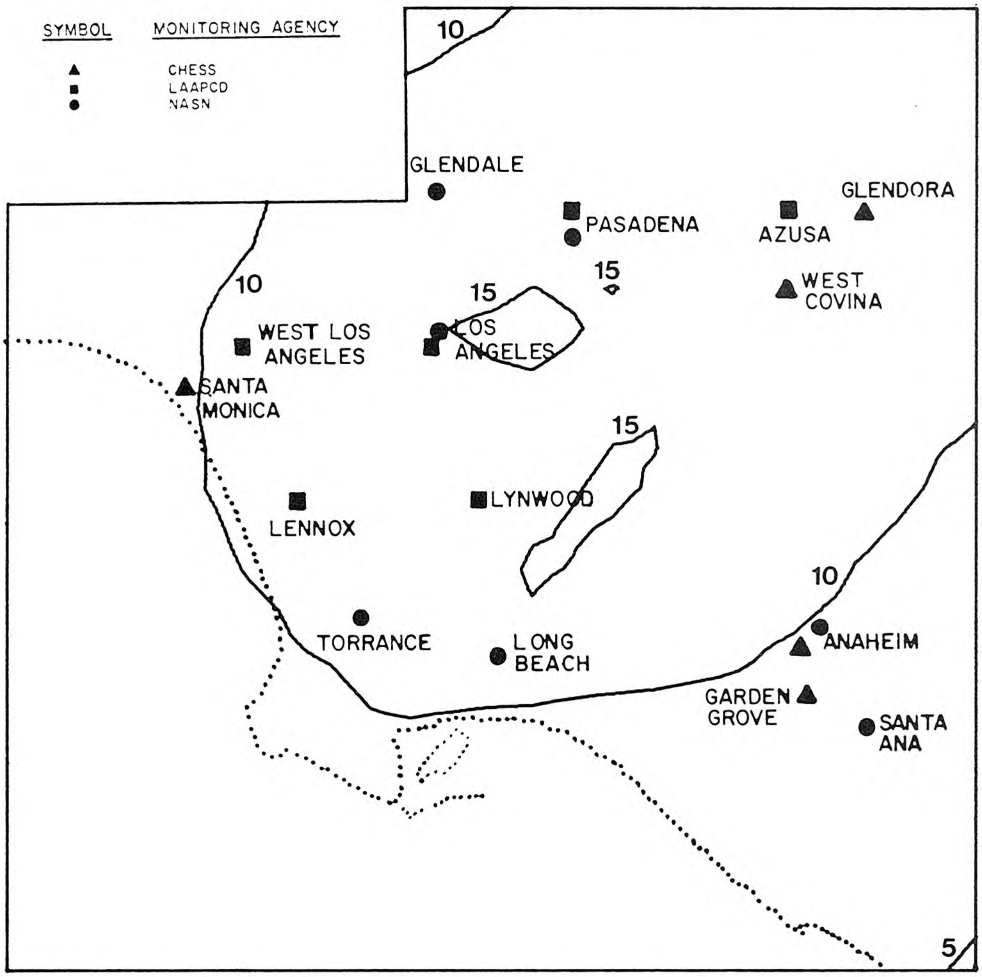


EARLY 1980'S - TEST YEAR 3

Fig. 24

LONG TERM AVERAGE SULFATE CONCENTRATIONS (μGM/M^3)

UNDER LOW NATURAL GAS SUPPLY CONDITIONS



EARLY 1980'S - COMPOSITE OF THREE TEST YEARS

Fig. 25

SOURCE CLASS CONTRIBUTION TO SULFATE CONCENTRATIONS
EXPECTED AT DOWNTOWN LOS ANGELES (APCD) MONITORING STATION
UNDER LOW NATURAL GAS SUPPLY CONDITIONS

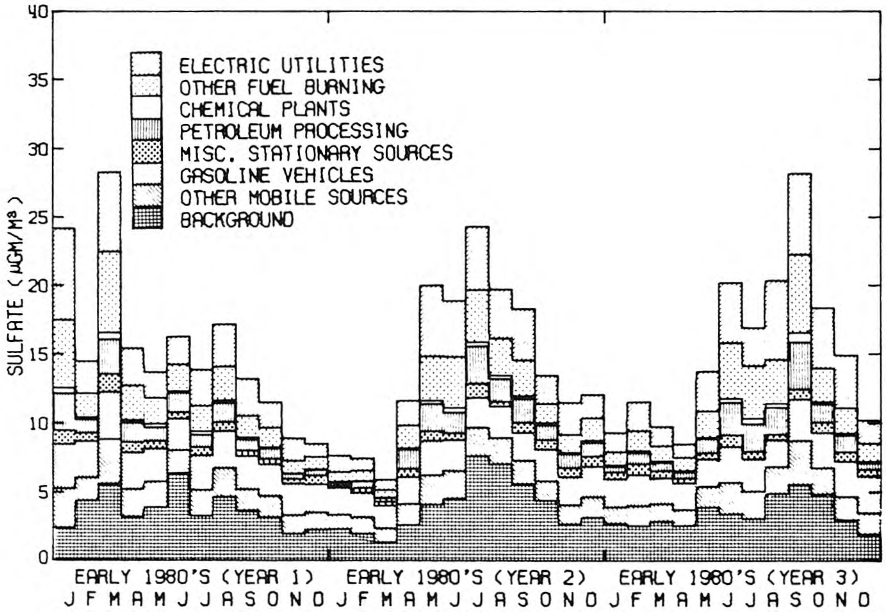


Fig. 26

SOURCE CLASS CONTRIBUTION TO SULFATE CONCENTRATIONS
EXPECTED AT LENNOX (APCD) MONITORING STATION
UNDER LOW NATURAL GAS SUPPLY CONDITIONS

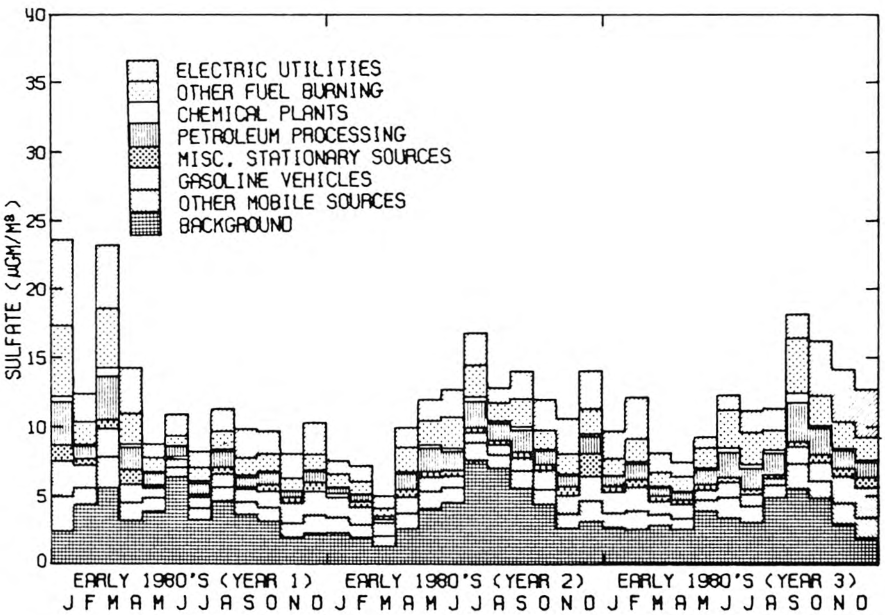


Fig. 27

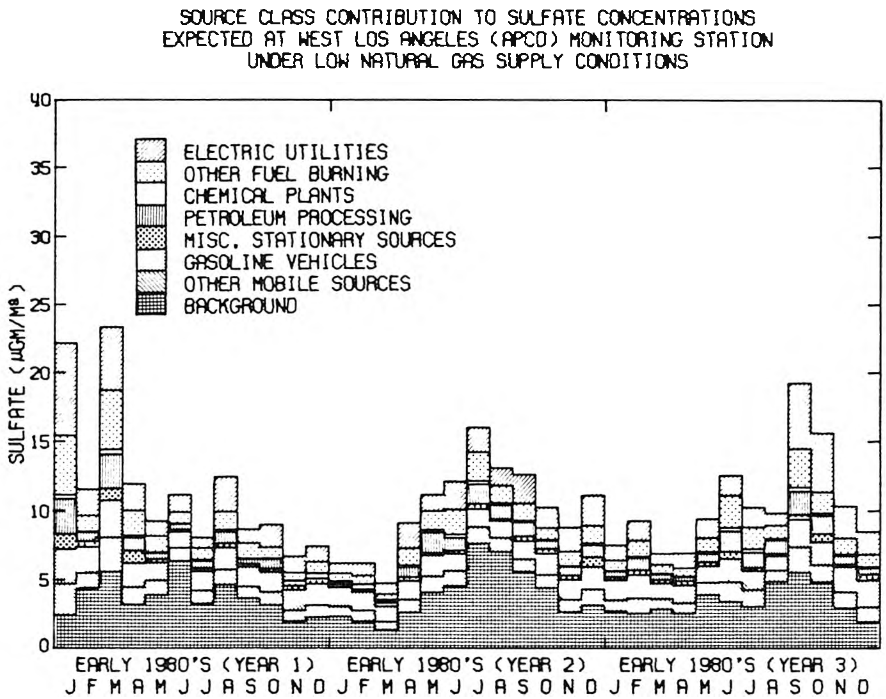

SOURCE CLASS CONTRIBUTION TO SULFATE CONCENTRATIONS
EXPECTED AT WEST LOS ANGELES (APCD) MONITORING STATION
UNDER LOW NATURAL GAS SUPPLY CONDITIONS
ELECTRIC UTILITIES
OTHER FUEL BURNING
CHEMICAL PLANTS
PETROLEUM PROCESSING
MISC. STATIONARY SOURCES
GASOLINE VEHICLES
OTHER MOBILE SOURCES
BACKGROUND
SULFATE (µGM/M³)
0
5
10
15
20
25
30
35
40
EARLY 1980'S (YEAR 1) EARLY 1980'S (YEAR 2) EARLY 1980'S (YEAR 3)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D

Fig. 28

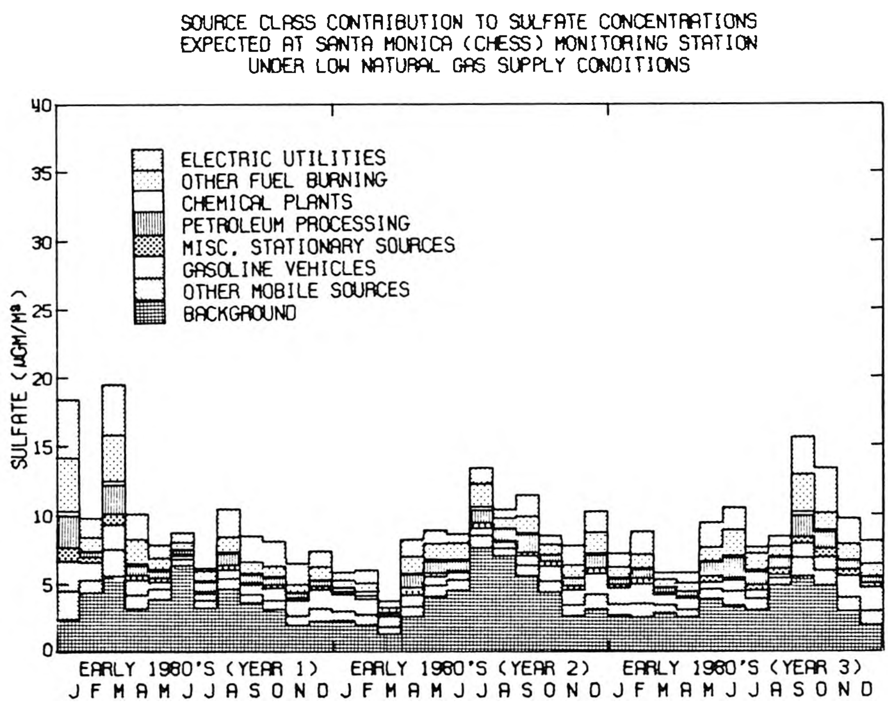

SOURCE CLASS CONTRIBUTION TO SULFATE CONCENTRATIONS
EXPECTED AT SANTA MONICA (CHESS) MONITORING STATION
UNDER LOW NATURAL GAS SUPPLY CONDITIONS
ELECTRIC UTILITIES
OTHER FUEL BURNING
CHEMICAL PLANTS
PETROLEUM PROCESSING
MISC. STATIONARY SOURCES
GASOLINE VEHICLES
OTHER MOBILE SOURCES
BACKGROUND
SULFATE (µGM/M³)
0
5
10
15
20
25
30
35
40
EARLY 1980'S (YEAR 1) EARLY 1980'S (YEAR 2) EARLY 1980'S (YEAR 3)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D

Fig. 29

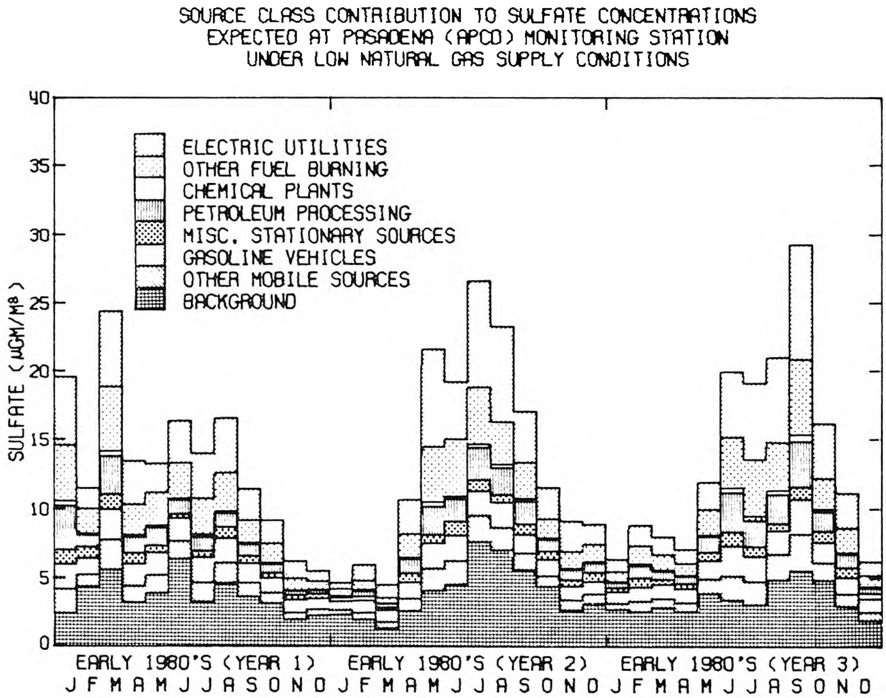

SOURCE CLASS CONTRIBUTION TO SULFATE CONCENTRATIONS
EXPECTED AT PASADENA (APCD) MONITORING STATION
UNDER LOW NATURAL GAS SUPPLY CONDITIONS
ELECTRIC UTILITIES
OTHER FUEL BURNING
CHEMICAL PLANTS
PETROLEUM PROCESSING
MISC. STATIONARY SOURCES
GASOLINE VEHICLES
OTHER MOBILE SOURCES
BACKGROUND
SULFATE (μGM/M³)
0
5
10
15
20
25
30
35
40
EARLY 1980'S (YEAR 1)
EARLY 1980'S (YEAR 2)
EARLY 1980'S (YEAR 3)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D

Fig. 30

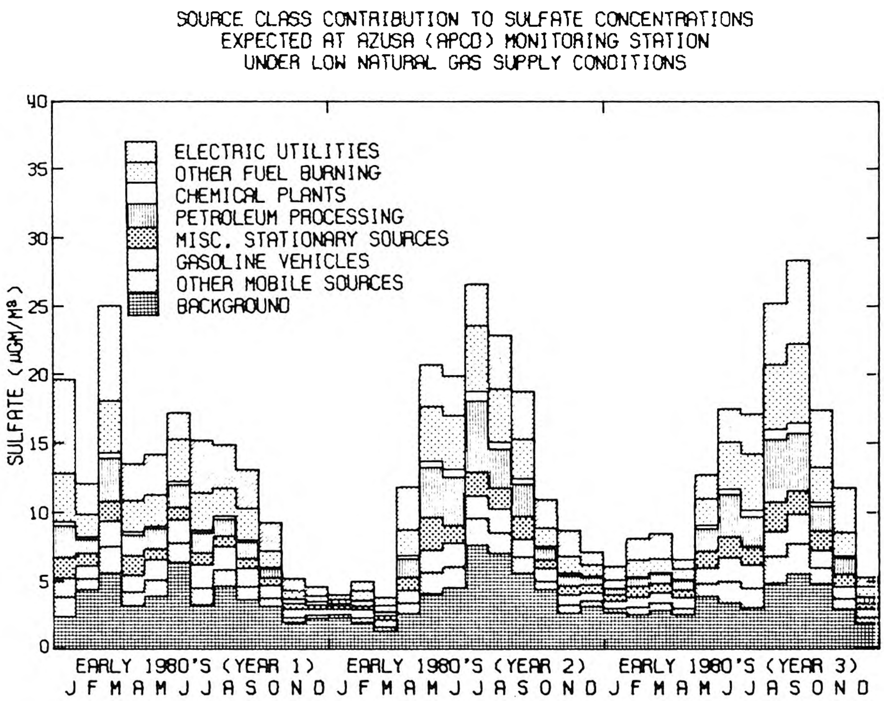

SOURCE CLASS CONTRIBUTION TO SULFATE CONCENTRATIONS
EXPECTED AT AZUSA (APCD) MONITORING STATION
UNDER LOW NATURAL GAS SUPPLY CONDITIONS
ELECTRIC UTILITIES
OTHER FUEL BURNING
CHEMICAL PLANTS
PETROLEUM PROCESSING
MISC. STATIONARY SOURCES
GASOLINE VEHICLES
OTHER MOBILE SOURCES
BACKGROUND
SULFATE (μGM/M³)
0
5
10
15
20
25
30
35
40
EARLY 1980'S (YEAR 1)
EARLY 1980'S (YEAR 2)
EARLY 1980'S (YEAR 3)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D

Fig. 31

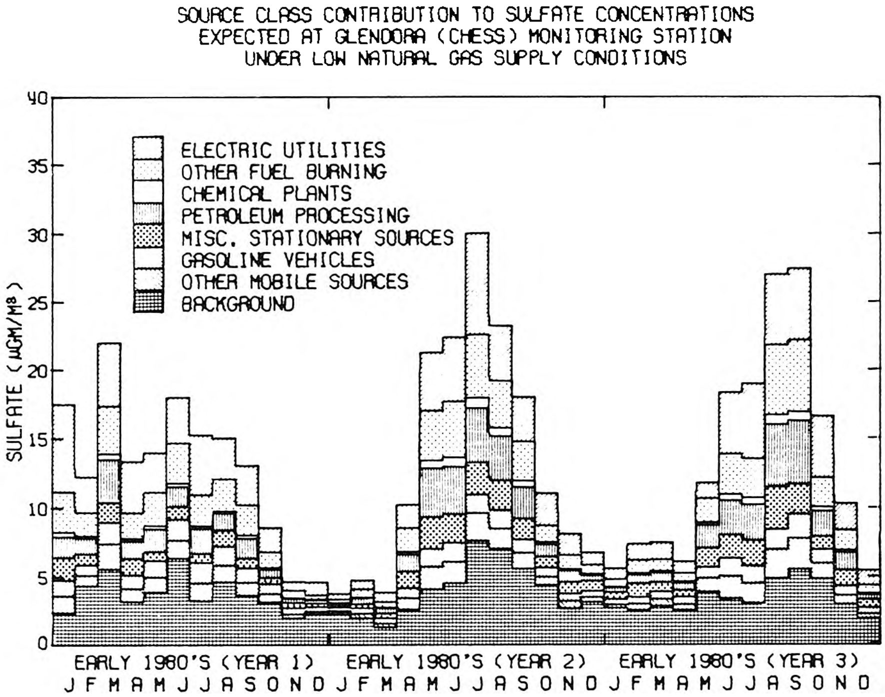

SOURCE CLASS CONTRIBUTION TO SULFATE CONCENTRATIONS
EXPECTED AT GLENDORA (CHESS) MONITORING STATION
UNDER LOW NATURAL GAS SUPPLY CONDITIONS
ELECTRIC UTILITIES
OTHER FUEL BURNING
CHEMICAL PLANTS
PETROLEUM PROCESSING
MISC. STATIONARY SOURCES
GASOLINE VEHICLES
OTHER MOBILE SOURCES
BACKGROUND
SULFATE (µGM/M³)
0
5
10
15
20
25
30
35
40
EARLY 1980'S (YEAR 1)
EARLY 1980'S (YEAR 2)
EARLY 1980'S (YEAR 3)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D

Fig. 32

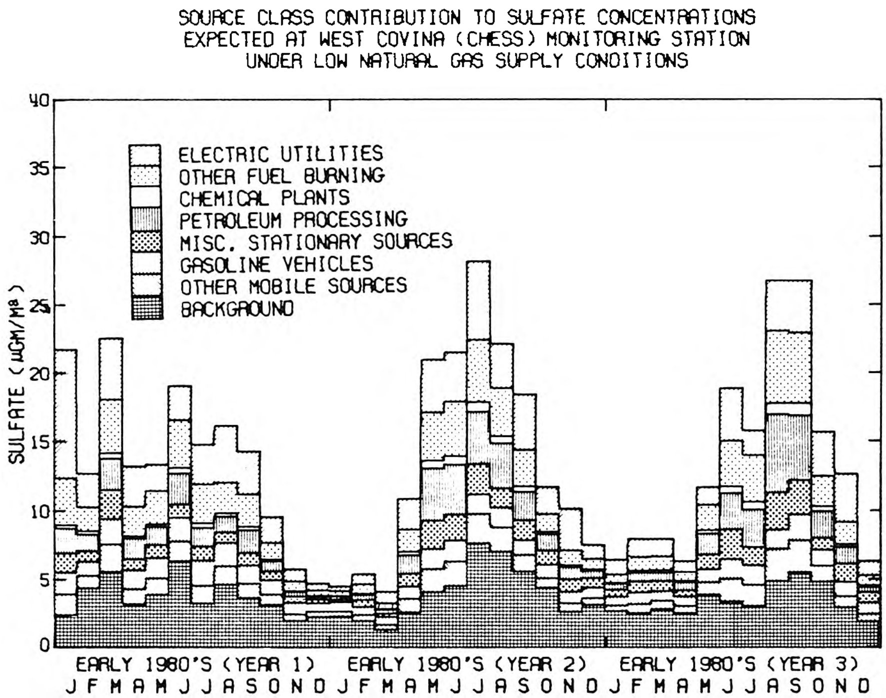

SOURCE CLASS CONTRIBUTION TO SULFATE CONCENTRATIONS
EXPECTED AT WEST COVINA (CHESS) MONITORING STATION
UNDER LOW NATURAL GAS SUPPLY CONDITIONS
ELECTRIC UTILITIES
OTHER FUEL BURNING
CHEMICAL PLANTS
PETROLEUM PROCESSING
MISC. STATIONARY SOURCES
GASOLINE VEHICLES
OTHER MOBILE SOURCES
BACKGROUND
SULFATE (µGM/M³)
0
5
10
15
20
25
30
35
40
EARLY 1980'S (YEAR 1)
EARLY 1980'S (YEAR 2)
EARLY 1980'S (YEAR 3)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D

Fig. 33

SOURCE CLASS CONTRIBUTION TO SULFATE CONCENTRATIONS
EXPECTED AT ANAHEIM (CHESS) MONITORING STATION
UNDER LOW NATURAL GAS SUPPLY CONDITIONS

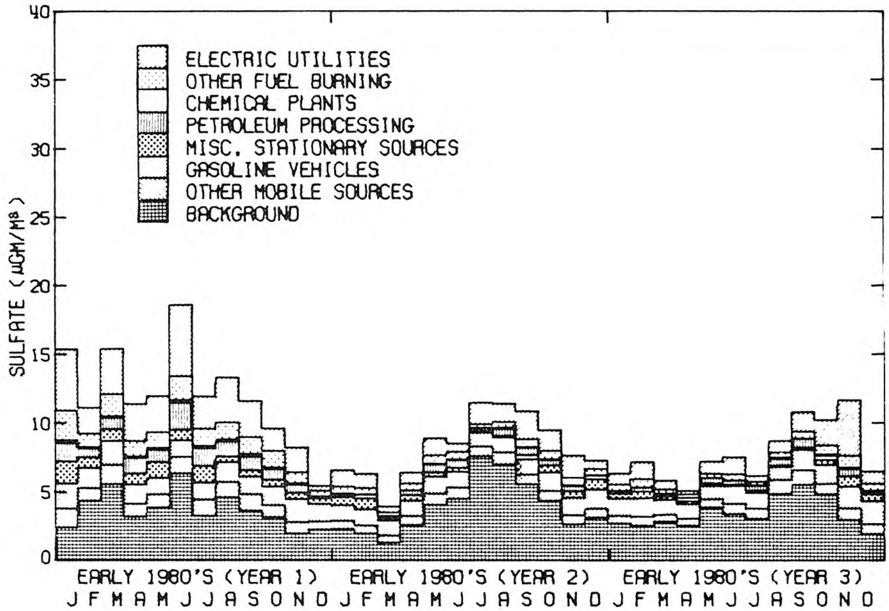


Fig. 34

SOURCE CLASS CONTRIBUTION TO SULFATE CONCENTRATIONS
EXPECTED AT GARDEN GROVE (CHESS) MONITORING STATION
UNDER LOW NATURAL GAS SUPPLY CONDITIONS

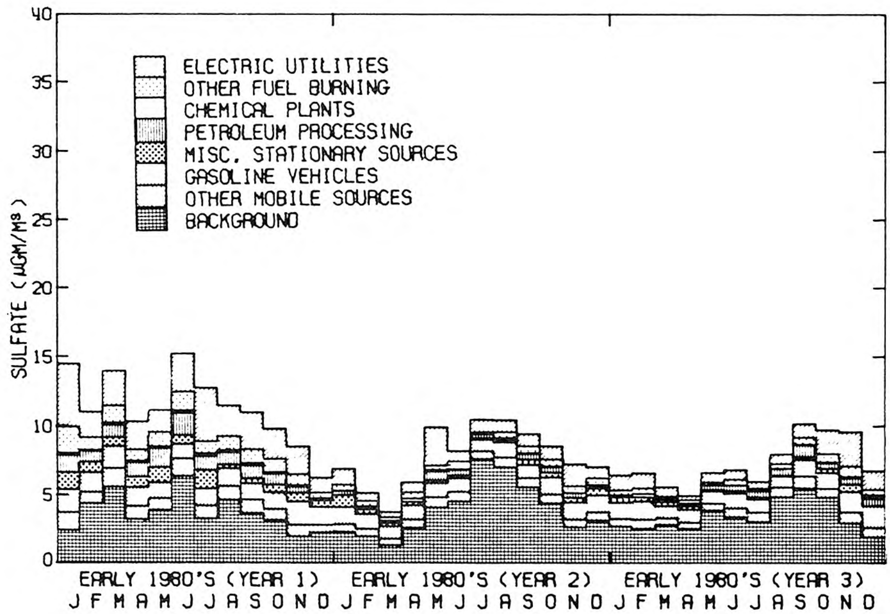


Fig. 35

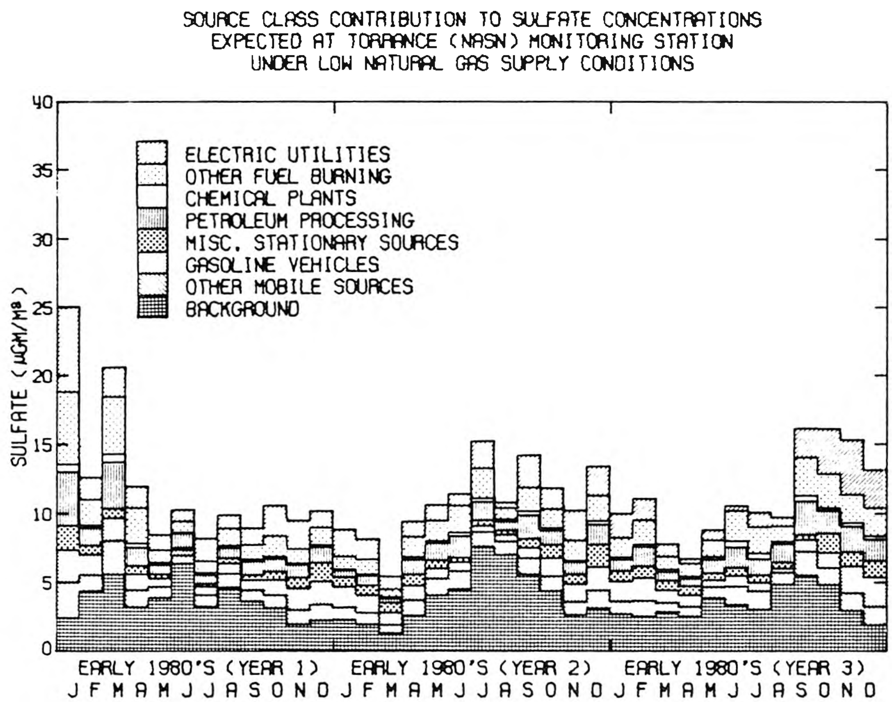

SOURCE CLASS CONTRIBUTION TO SULFATE CONCENTRATIONS
EXPECTED AT TORRANCE (NASN) MONITORING STATION
UNDER LOW NATURAL GAS SUPPLY CONDITIONS
ELECTRIC UTILITIES
OTHER FUEL BURNING
CHEMICAL PLANTS
PETROLEUM PROCESSING
MISC. STATIONARY SOURCES
GASOLINE VEHICLES
OTHER MOBILE SOURCES
BACKGROUND
SULFATE (µGM/M³)
0
5
10
15
20
25
30
35
40
EARLY 1980'S (YEAR 1)
EARLY 1980'S (YEAR 2)
EARLY 1980'S (YEAR 3)
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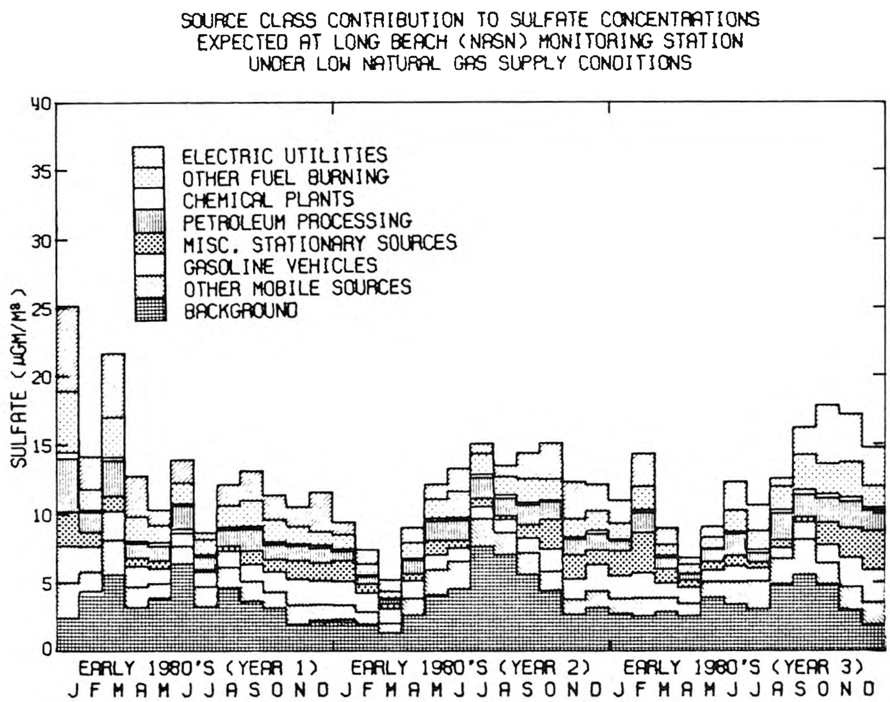
Fig. 36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UNDER LOW NATURAL GAS SUPPLY CONDITIONS
ELECTRIC UTILITIES
OTHER FUEL BURNING
CHEMICAL PLANTS
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MISC. STATIONARY SOURCES
GASOLINE VEHICLES
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Fig. 37

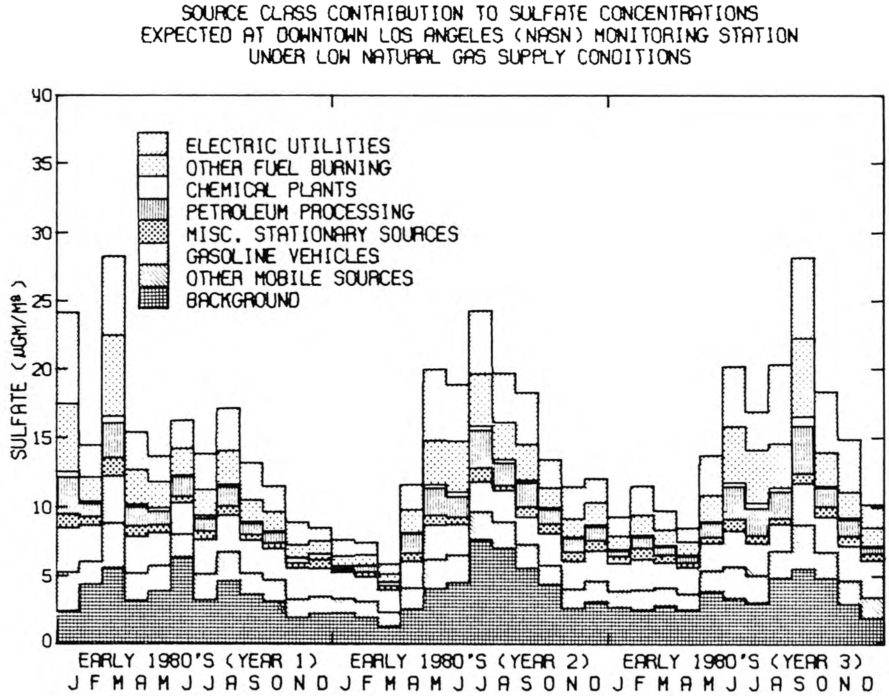
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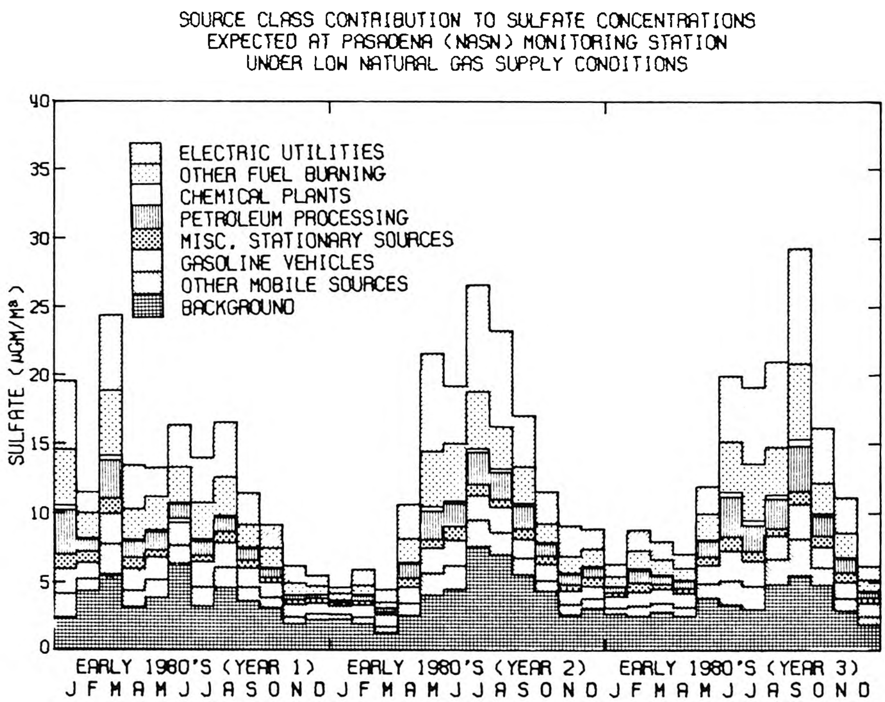
Fig. 38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GASOLINE VEHICLES
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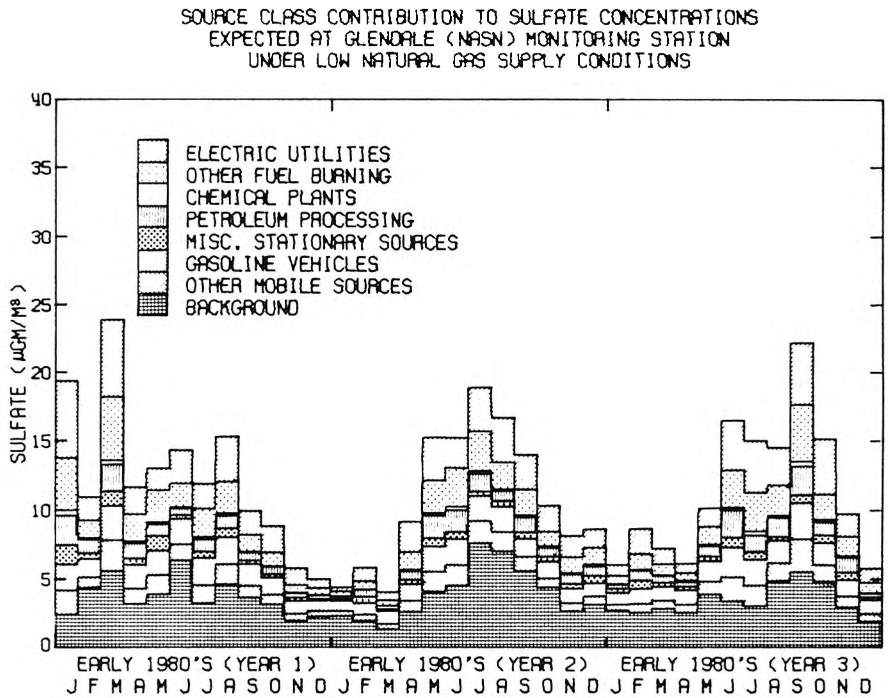
Fig. 39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CHEMICAL PLANTS
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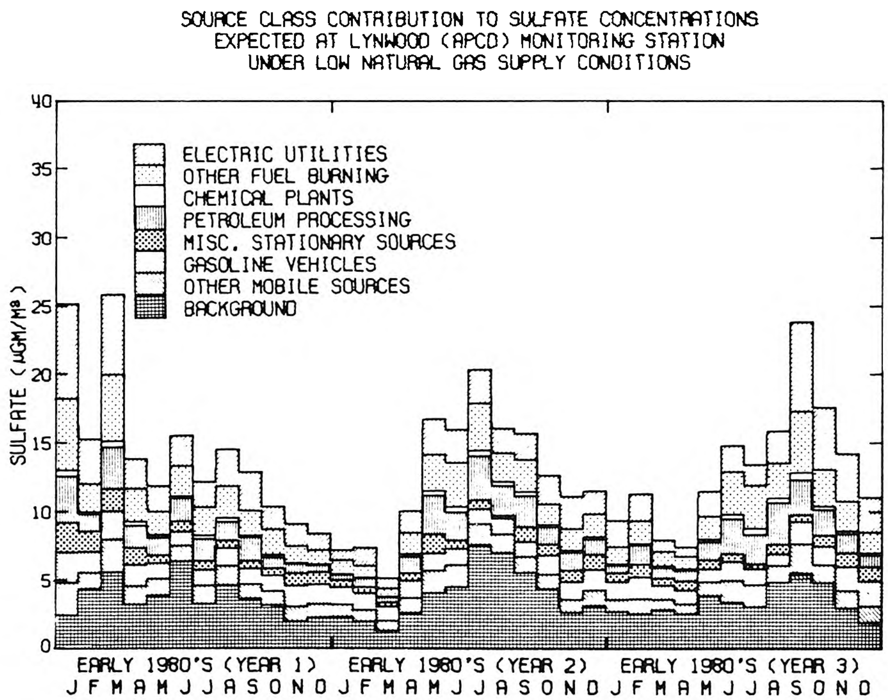
Fig. 40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OTHER FUEL BURNING
CHEMICAL PLANTS
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MISC. STATIONARY SOURCES
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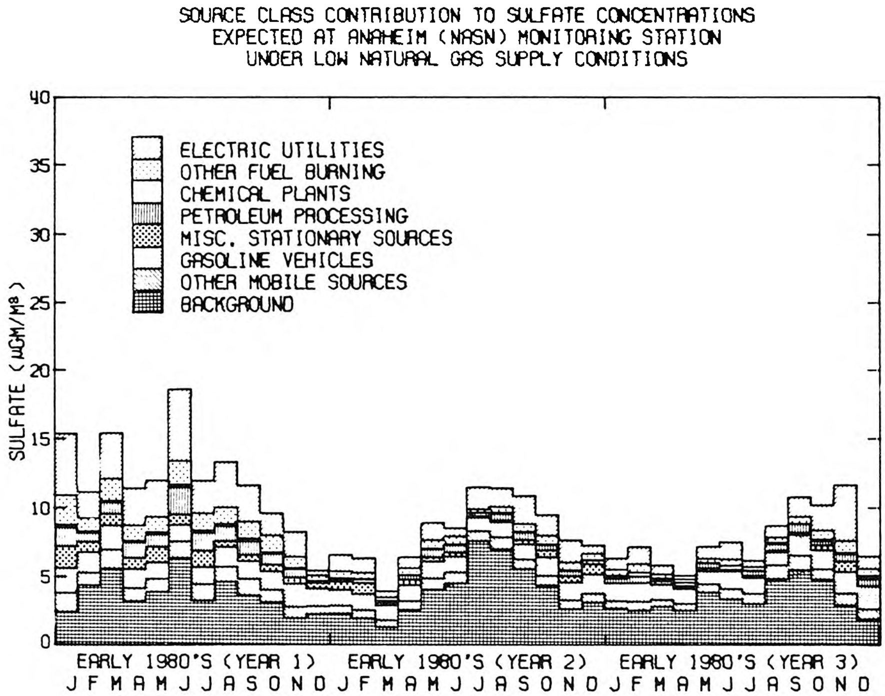
Fig. 41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OTHER FUEL BURNING
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GASOLINE VEHICLES
OTHER MOBILE SOURCES
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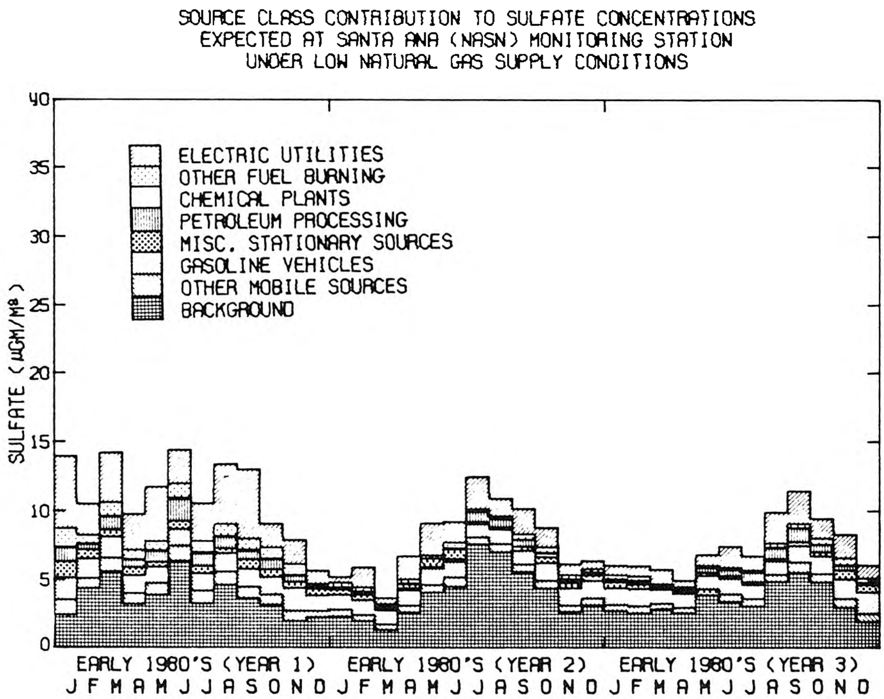
Fig. 42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UNDER LOW NATURAL GAS SUPPLY CONDITIONS
ELECTRIC UTILITIES
OTHER FUEL BURNING
CHEMICAL PLANTS
PETROLEUM PROCESSING
MISC. STATIONARY SOURCES
GASOLINE VEHICLES
OTHER MOBILE SOURCES
BACKGROUND
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EARLY 1980'S (YEAR 1)
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EARLY 1980'S (YEAR 3)
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D

Fig. 43

SOURCE CLASS CONTRIBUTION TO SULFATE CONCENTRATIONS
EXPECTED AT PEAK LOCATED IN EAST LOS ANGELES
UNDER LOW NATURAL GAS SUPPLY CONDITIONS

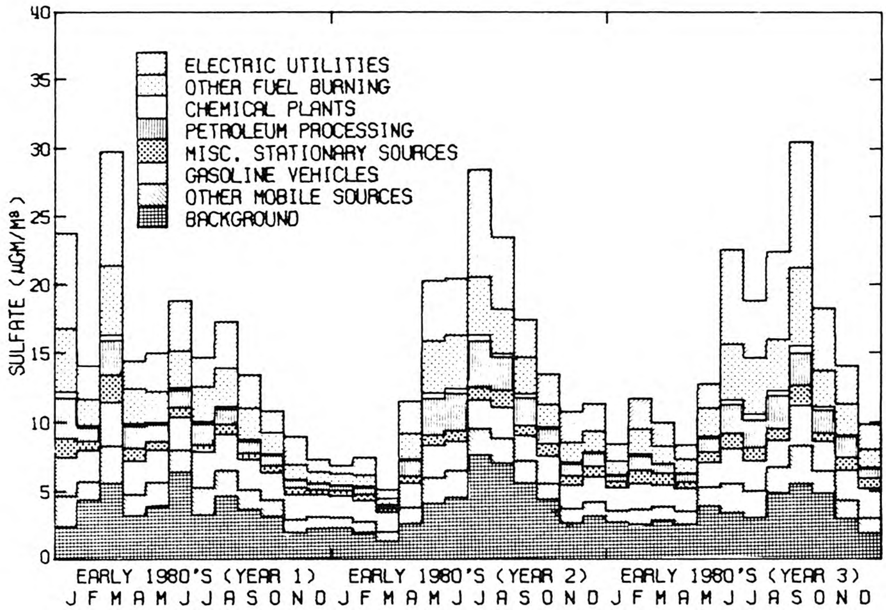

Fig. 44

SOURCE CLASS CONTRIBUTION TO SULFATE CONCENTRATIONS
EXPECTED AT PEAK LOCATED IN SANTA FE SPRINGS
UNDER LOW NATURAL GAS SUPPLY CONDITIONS

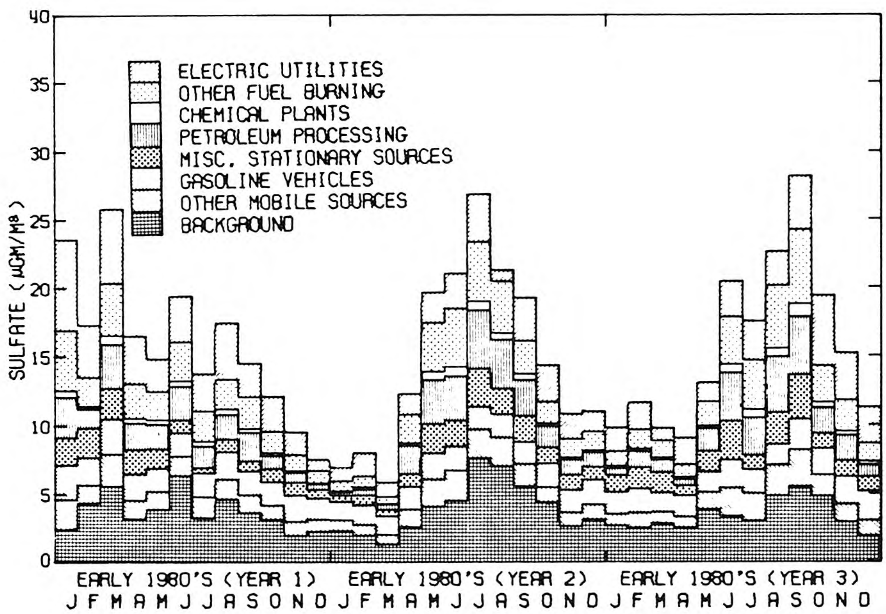

Fig. 45

An example set of these transfer coefficients, computed from the base case air quality projection, is shown in Table 9. A complete set of these normalized air quality impact values is given in Appendix H for 15 air monitoring sites and for the two peak concentration neighborhoods appearing in Figure 25.

A procedure for testing the air quality impact of any particular redistribution of emissions that would occur under a transferable license system is now available. A basin wide limit an emissions can be set at any desired level, in tons of SO_x per day. From the economic analysis of emission control alternatives to be described in subsequent chapters of this report, an estimate of the equilibrium combination of emissions control hardware and licenses to emit pollutants that would be purchased under a marketable permits system can be obtained for each source type. The magnitude of the remaining emissions from each source class when multiplied by the influence coefficients for that source class given in Table 9 and Appendix H yields an estimate of the air quality impact of each source type. Adding all incremental sulfate contributions from all sources to our prior estimate of sulfate background concentrations permits reconstruction of total sulfate concentrations at all monitoring sites for the license distribution under study.

CONCLUSION

The Los Angeles sulfur oxides air pollution problem is interesting for a host of scientific and public policy reasons. The traditional measure of pollution by sulfur oxides is in terms of SO_2 concentrations, which do not exceed Federal standards in this air basin. Meanwhile, the well known Los Angeles visibility problem is being aggravated through light scattering by the decay products of SO_2: sulfate aerosols. These sulfate air pollutant concentrations are unregulated at the Federal level but exceed a state-imposed standard that requires a major reduction in sulfur oxides emissions from existing sources. Attainment of good air quality and a strong economy over time will require that problems which surround the siting of new sources, like the abandoned SOHIO pipeline project, be resolved. Federal energy policies will also affect the attainment of air quality goals, because natural gas curtailments could cause increases in fuel oil combustion that would work against the intended improvements from existing and proposed emission controls.

In addition to the public policy importance of the Los Angeles sulfate problem, there are purely technical considerations which make it an ideal choice for a case study of transferable licenses to emit air pollutants. The emissions potential for sulfur oxides in the South Coast Air Basin has been documented in a way that permits examination of emission control problems under widely varying degrees of natural gas supply. Emissions to air quality relationships for sulfur oxides pollutants have been defined through an air quality simulation model and are relatively easy to manipulate. The major SO_x

TABLE 9

TRANSFER COEFFICIENTS RELATING SO_x EMISSIONS TO ANNUAL MEAN SULFATE AIR QUALITY AT PASADENA ($\mu g\ m^{-3}$ sulfate/ton per day SO_x emitted)

TEST YEAR	UTILITY RESID.	UTILITY DIST OIL	REFINERY FUEL	OTHER FUEL	SULFUR PLANTS
1	0.01564	0.02345	0.02751	0.03244	0.02633
2	0.01915	0.01648	0.02733	0.02927	0.02458
3	0.01833	0.01597	0.02958	0.03306	0.03249
	SULFURIC ACID	**REFINERY FCC UNIT**	**OTHER REFINERY**	**OIL FIELDS**	**COKE KILNS**
1	0.02090	0.02501	0.02274	0.01028	0.01725
2	0.02296	0.02417	0.02093	0.00655	0.01544
3	0.02658	0.02932	0.02216	0.00688	0.01588
	GLASS FURNACES	**FERROUS METALS**	**MISC. UNITS**	**CAT AUTO STREET**	**CAT AUTO FREEWAY**
1	0.05357	0.00314	0.01514	0.04803	0.13577
2	0.04964	0.00288	0.01493	0.03906	0.12949
3	0.06041	0.00247	0.01630	0.04410	0.13992
	NON-CAT VEHICLES	**DIESEL VEHICLES**	**AIRPORT**	**SHIPPING**	**RAILROAD**
1	0.02576	0.03625	0.02926	0.02054	0.04686
2	0.01860	0.02926	0.02977	0.01999	0.04445
3	0.02212	0.03312	0.03742	0.02292	0.05061

sources in the air basin are few enough to make the problem tractible, but numerous enough to perhaps support a competitive market in emissions licenses. As will be seen in the next chapter, control measures necessary to limit SO_x emissions are available. Thus the remaining question is to choose between control alternatives -- which is exactly the problem that a market in licenses to emit air pollutants will be designed to solve.

FOOTNOTES

1. This problem is distinct from our ability to assess the opportunities for natural gas supply. While we might be able to make rather strong statements about what gas supplies could be made available in future years, we might not be able to forecast what will happen if events are left to unfold along their present course.

2. Not the South Coast Air Basin, but rather all of California south of the Pacific Gas and Electric service area.

3. That is, a 1970 forecast of greater than 1.6 trillion cubic feet delivered in 1979, a 1974 forecast for about 1.0 trillion cubic feet in 1979, and a 1977 forecast for less than 0.7 trillion cubic feet in 1979.

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CHAPTER 3

DESIGNING AN EFFICIENT PERMITS MARKET

Robert W. Hahn and Roger G. Noll

The purpose of this chapter is to investigate the economic characteristics of different ways to set up a market for permits to emit sulfur oxides in Los Angeles. The general strategy is to calculate an estimate of the competitive equilibrium distribution of permits, examine the air pollution consequences of this equilibrium, and investigate the likelihood that the various problems discussed in the first chapter will emerge. For problems that may emerge, we then proceed to assess their importance and the extent to which they can be avoided or ameliorated by particular decisions about the design of the market.

A competitive equilibrium in the permits market is of interest because if it is attained the total abatement costs of all sources of pollution in the airshed are minimized. A comprehensive theoretical analysis of the linkage between abatement costs and a permits market is contained in Appendix G. Attainment of competitive equilibrium depends on all participants in the market having a small enough share of sales so that they cannot alter the price of permits by strategic manipulation of purchases or buys. It also depends on buyers and sellers having easy access to information about the price at which permits can be purchased, and facing no protracted negotiations or other sources of substantial costs in arranging transactions. One important criterion by which alternative ways to implement a market ought to be judged is whether they will lead to a competitive equilibrium in the permits market, and if not, how serious a loss of efficiency will result.

A key element in determining the behavior of businesses in a permits market is the abatement cost function that the business faces. An abatement cost function is constructed by examining the full range of abatement possibilities available to a firm and estimating the minimum cost method of achieving each level of abatement. In some cases, a firm faces a choice among a small number of abatement technologies, each of which produces a greater amount of abatement at ever increasing costs. In other cases, the firm can pick almost any degree of abatement it wants. An example of the latter is the almost continuous range of choices with respect to the sulfur content of fuels, with lower sulfur fuel having a higher price.

A major task of the project was to estimate abatement cost functions for the primary sources of sulfur oxides emissions in Los Angeles. Over twenty-five source categories were identified, and abatement costs estimated for each. The published literature, regulatory proceedings, and interviews with representatives of local industry and state and local regulatory personnel were relied upon to generate preliminary cost estimates. The information typically obtained from a particular source was a point estimate: the cost at some historical date of using a particular method to obtain a specific rate of emissions from a particular kind of facility. These were combined to produce a step function for abatement costs for representative facilities in each source category based on 1977 regulatory conditions, with corrections made to put the costs in 1977 dollars. The results of these analyses were submitted as industry studies to the relevant firms operating in Los Angeles, with requests for comments. The additional data received in this manner were used to produce a final cost study, including indications of the amount of disagreement about costs among the sources of information. These cost studies constitute Appendix F of this report.

A number of factors make these cost estimates upwardly biased as estimators of the costs that would be experienced if a system of tradable permits were instituted. First, for source categories for which no control cost estimates could be found, emissions were assumed to be uncontrollable. In fact, these sources, if facing a permits market, would undoubtedly find ways to abate in order to save permit costs. Second, production and energy use at emitting facilities was assumed to be independent of the amount of control. In reality, firms with especially high emissions and stiff abatement costs are likely to reduce output or to make more efficient use of energy. Third, although in many cases emissions can be reduced by process changes, firms are reluctant to reveal these possibilities because they are trade secrets that may confer significant competitive advantages in a more stringent regulatory environment. No allowance for these process changes is made in the study. Fourth, Kaiser Steel was included as a source in all of our simulations, and it has recently announced plans to cease its operations. Removal of this source will reduce abatement costs for the region. Fifth, the use of step functions surely overstates abatement costs at levels of abatement between the known data points.

Because SO_x emissions in Los Angeles result largely from the combustion of petroleum products, the availability of natural gas, which has negligible amounts of sulfur, can significantly affect SO_x emissions. This, in turn, will affect the demand for permits and, hence, their price. Price regulation has led to excess demand for natural gas since the mid-1960s, and to uncertainties about the availability of gas in the future, even though gas is now scheduled to be deregulated. For this reason, three separate cases were analyzed: one which assumes low availability of natural gas; a second which corresponds to a historical supply year (1973) in which an intermediate supply of gas was available; and a third which assumes a high supply of natural gas. All three cases are based on emissions projections for the early 1980s with 1977 regulations assumed to be in place. In all cases, access to natural gas is assumed to be determined by regulatory allocation priorities, rather than the market. This has an important effect on the results because regulatory allocation priorities are not related to the value of natural gas in terms of either its direct use or the effects of its use on air quality.

With these caveats in mind, the cost data were used to estimate the demand for emissions permits and the distribution of permits that an efficient market would produce.

THE COMPETITIVE MODEL

In all of the models discussed, it is assumed that firms attempt to minimize the sum of abatements costs plus permit costs. In this section, a baseline competitive equilibrium distribution of emissions permits is simulated. Firms are assumed to be price-takers, which is to say they assume that the equilibrium price of a permit is unaffected by their actions. A permit is defined as the right to emit one ton SO_2 equivalent of sulfur oxides per day anywhere in the airshed. After examining this baseline case, it will be compared to a fine-tuned definition of permits that takes account of the geographical locations of sources and receptors, and to a simulated distribution of emissions when the permits are monopsonized.

To simulate the market, it is necessary to specify an air quality target. For the purposes of analysis, four targets are examined, ranging from no further net emission control down to about a 60 percent reduction in emissions. The latter is needed to meet the California sulfate standard. The four cases are summarized in Table 1.

The calculations in the table are based on a linear rollback model of the relationship between emissions and sulfate pollution. The estimates of the emissions/air quality relationship would probably change if a more sophisticated air pollution model were employed, but the rollback model suffices for the purpose of showing how the permit price and abatement costs vary with the choice of an air quality target. Figure 1 illustrates the equilibrium price of a permit to emit one ton/day of SO_x in Los Angeles for the case in which there is a low natural gas supply. All price and cost estimates are given in 1977 dollars.

The decreasing step function in Figure 1 represents the derived demand curve for permits over the range of interest. Points on this curve show the estimated price of permits for each possible choice of a ceiling on total emissions, or, alternatively, the number of permits sources would want to purchase at each possible price. The curve was drawn as a step function because most of the engineering cost estimates which were used to generate the demand curves were given in this form.

TABLE 1

SELECTED AIR QUALITY TARGETS FOR THE SOUTH COAST AIR BASIN in tons SO_x/day[a]

TARGET	ALLOWABLE EMISSIONS
1. Achieve California Sulfate Air Quality Standard of 25 micrograms/cubic meter over a 24 hour averaging time.	149
2. Violate California Sulfate Air Quality Standard 3-5% of the time.	238
3. No additional controls with an above average natural gas supply.	335
4. No additional controls with a low natural gas supply.	421

[a]See Hahn (1981b) for the basis of these calculations. Sulfur oxides emissions are measured as tons of SO_2 equivalent.

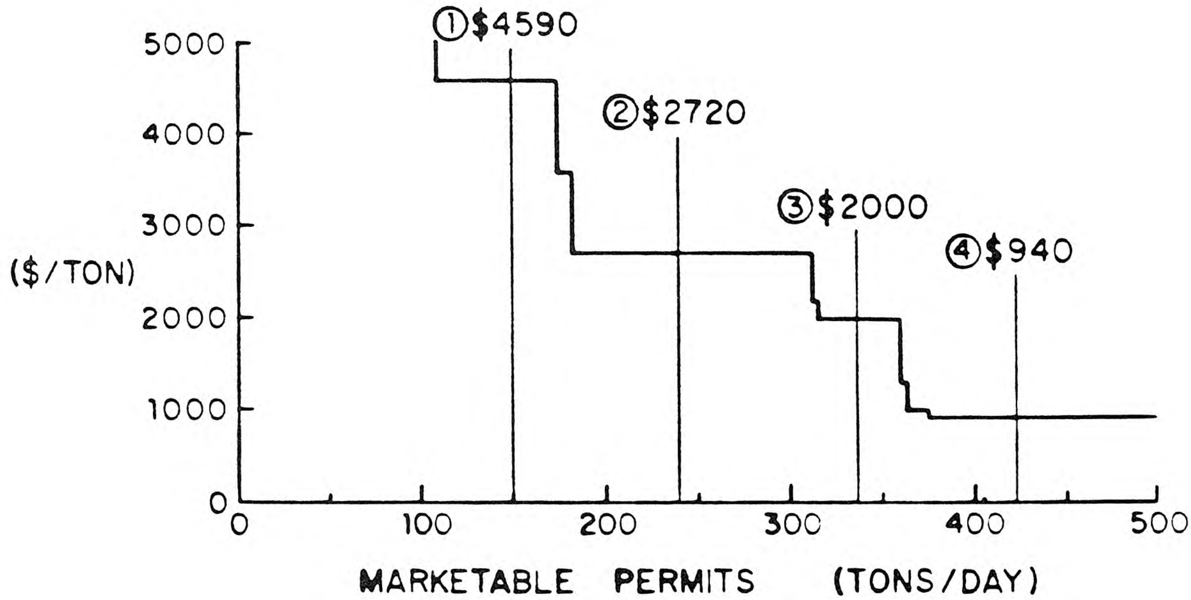

FIGURE 1

The Demand for Permits with Low Availability of Natural Gas

Simulations have also been made under the assumption that it is possible to make linear combinations of the discrete abatement alternatives that make up the step function. This represents the other extreme possibility, and produces the lowest abatement cost function that is consistent with observed cost data. This simulation produces estimates of equilibrium prices of permits that are about twenty percent lower than the prices depicted in Figure 1.

The four vertical supply constraints in Figure 1 correspond to the four air quality targets presented in Table 1. The market price of a permit is drawn next to each intersection. Thus, for the first case in which the California sulfate standard is met, the point estimate for the price of a permit is 4,590 dollars. From this graph, it is also possible to calculate two other potentially interesting numbers. The annual abatement cost for any level of air quality can be computed by integrating the area under the demand curve and to the right of the air quality target. The amount of money which could conceivably change hands in a permit market can be calculated by multiplying the number of permits issued by the equilibrium price. The significance of these numbers is discussed below.

The price of an emissions permit is highly sensitive to the availability of natural gas and to the choice of an air quality target. Table 2 shows the equilibrium price of a permit with alternative assumptions about air quality standards and the availability of natural gas. Table 2 exhibits two interesting features. First, it can be seen that the price of a permit can vary by an order of magnitude depending on the assumptions concerning natural gas supply and the air quality target. This is made especially apparent in Figure 2, which shows the effect on the demand for permits of a change from low to high availability of natural gas. Second, a comparison of the first two columns indicates that a fairly small change in air quality standards cause a substantial change in the price of a permit. This reflects the fact that the marginal cost of sulfur oxides abatement changes at the upper end of the air quality spectrum.

The total annual cost of abatement varies considerably both as a function of the natural gas supply and the air quality target. The data are presented in Table 3. The estimates of abatement cost do <u>not</u> include abatement equipment installed prior to 1977. Consequently, the changes in abatement cost between different categories are probably the most meaningful figures. Even without estimates of some abatement equipment in place, abatement costs are in the hundreds of millions, except for the case in which natural gas is in plentiful supply.

The most important point to be derived from Table 3 is that the availability of natural gas has a marked effect on the cost of reducing SO_x emissions. The only difference between the situations of low and high natural gas supply is that the latter substitutes natural

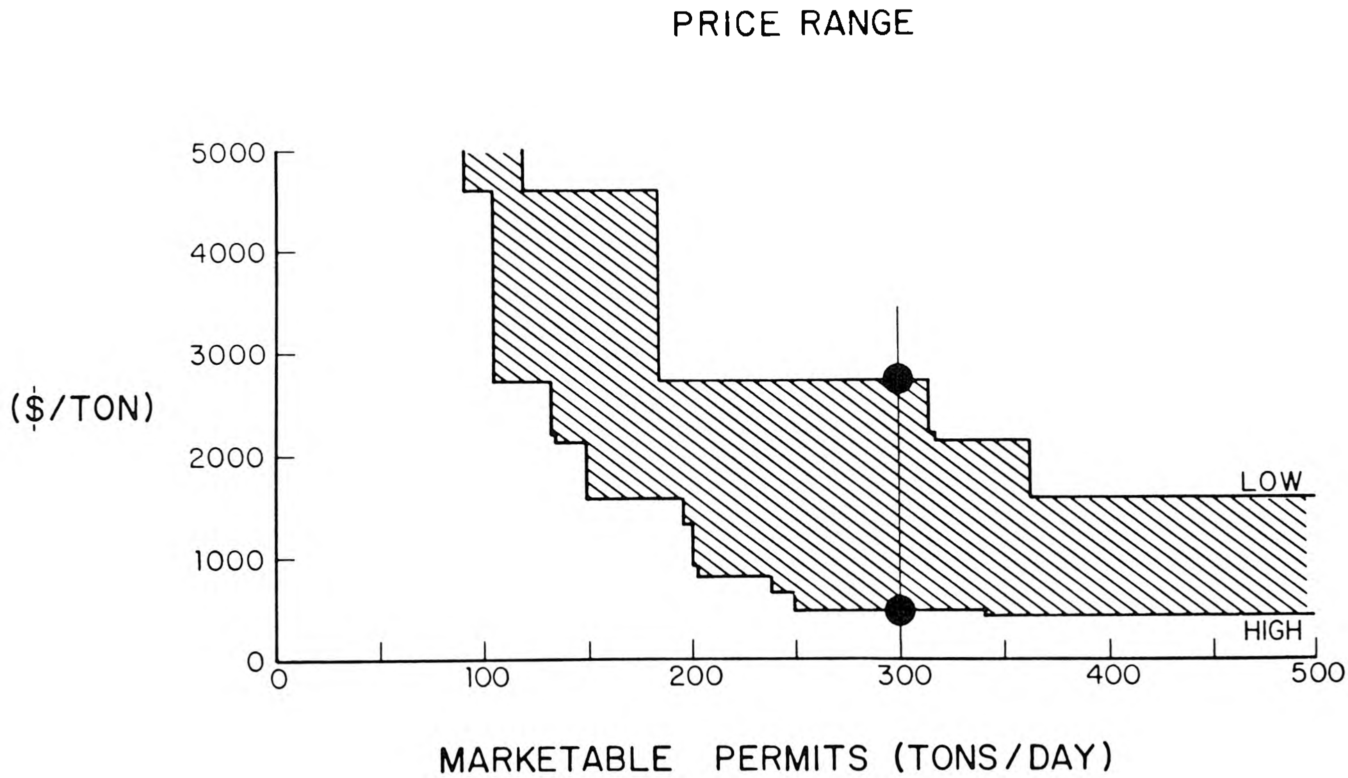

FIGURE 2

Sensitivity of Demand for Permits to Availability of Natural Gas

TABLE 2

PRICE SENSITIVITY ANALYSIS

NATURAL GAS SUPPLY	AIR QUALITY TARGET			
	1	2	3	4
Low	4,590[a]	2,720	2,000	940
Historical	2,720	2,000	940	810
High	1,320	650	470	420

[a]All prices in \$ 1977. A permit entitles the user to emit one ton of SO_x for one day.

TABLE 3

ANNUAL ABATEMENT COSTS
(in millions of 1977 dollars)

NATURAL GAS SUPPLY	AIR QUALITY TARGET			
	1	2	3	4
Low	684	576	487	447
Historical	400	315	280	252
High	112	83	66	53

gas for 100 million barrels of residual fuel oil. Dividing the difference in abatement costs between the two cases by the difference in the amount of oil used yields an average cost saving per barrel-equivalent of natural gas between 4 and 6 dollars, depending on the air quality target. The cost savings result from the substitution of natural gas for high-sulfur fuel oil, rather than using low-sulfur oil or extensive abatement investments to meet emissions targets.

Another way of illustrating the critical importance of the natural gas supply is to ask what firms would be willing to pay for having natural gas substituted for one barrel of residual fuel oil. Assume that the marginal value of natural gas equals the full marginal cost of burning residual fuel oil. The full cost includes the price of a barrel of oil plus the cost of emitting or abating the associated sulfur oxides. Performing the calculation for all twelve cases reveals that firms would be willing to pay anywhere from 107 percent to 130 percent of the price of the residual fuel oil for an equivalent BTU amount of natural gas.

The last point which the analysis of the competitive case raises is the magnitude of the sums of money which could conceivably change hands if a market were to be implemented in a way that caused all permits to be sold, such as a public auction. Define the total annualized value of the permits as the number issued multiplied by the annual price people are willing to pay to hold a permit for one year. (This price is obtained by multiplying the data in Table 2 by 365.) For the twelve cases examined here, the total annual value of the permits varies between 65 and 250 million dollars, and in most cases is comparable to the corresponding annualized abatement costs. This may have considerable political significance. The initial allocation of permits, establishing the baseline from which trades are made, is an implicit allocation of a considerable amount of wealth -- indeed, the magnitude of the wealth inherent in the permits is likely to be large in comparison to the efficiency gains from a permits market. Consequently, the principal focus of the political debate over alternative market designs is likely to be wealth distribution, not efficiency.

A second equity issue of some importance is the magnitude of these costs in relation to the total costs -- and long-term economic viability -- of industry. The industry studies in Appendix F address this question for each major source category. The general conclusion is that the <u>viability</u> of industry is not at stake; however, these costs are not insubstantial, and will not be accepted easily. The resistance to TEP will, of course, be substantially greater if the permits are sold by the state, with the state keeping the revenues.

DOES FINE-TUNING PAY?

The preceding analysis deals with the case in which emissions permits are freely tradable throughout the airshed, with no account taken of the differences among sources in the impact of emissions on ambient air quality. In practice, a fine-tuned permits market would be difficult to implement; however, the outcome of such a system, assuming it could be implemented, can be simulated in the same fashion as the case of a competitive market for geographically unspecified permits. The results of these simulations are shown in Table 4.

Column (1) lists six alternative levels of total emissions to be allowed in the airshed. Column (2) shows the annual abatement costs for achieving these levels, assuming a competitive permits market and low availability of natural gas. The low natural gas case was selected because it generates the highest abatement costs and, therefore, is likely to produce the maximal benefits from fine-tuning.

Associated with the competitive distribution of each of the emissions levels in Column (1) is a set of the average concentrations of sulfate particulates during the year at each of the seventeen air quality monitoring sites used in the simulation. Suppose that instead of setting a limit on total emissions, regulators issue permits to pollute at each receptor point equal to the pollution that would result from the competitive equilibrium in the emissions permit market, as calculated from the air quality model reported in Chapter 2. Each source of emissions would then need to acquire separately permits for the pollution its emissions caused at every measuring station. Because geographical location matters in affecting measured air pollution, this approach could produce additional rearrangements of emissions -- and some increase in total emissions -- that resulted in lower abatement costs but did not reduce air quality at any measuring station. Column (3) shows the costs associated with the competitive equilibrium distribution of emissions under this system.

Finally, suppose regulators are concerned only with air quality at the worst measuring station, and that they create permits for each station that allow pollution at every monitoring station to equal the pollution measured at the worst station under the competitive equilibrium distribution of emissions permits in Column (1). This would allow further trades and increases in emissions as long as air quality did not deteriorate at the location with the worst pollution, and did not force some other station to have its air quality deteriorate beyond the level at the worst-case station. The abatement costs associated with the competitive equilibrium distribution of these permits is shown in Column (4).

The result of these simulations is that defining permits in terms of pollution, and geographically differentiating the permits for each monitoring location, has relatively little effect on the efficiency of the market. The differences in annual abatement costs under the three systems vary from zero to four percent of the total, amounts that are surely small compared to the difficulties of trying to implement a more complicated system.

TABLE 4

ABATEMENT COSTS AND MARKET ARRANGEMENTS[a]

(1) Baseline Emissions Target (Tons/Day SO_2 Equiv)	(2) Costs for Single Market In Emissions Permits	(3) Costs for Equivalent Multiple Air Quality Markets	(4) Costs for "Adjusted" Multiple Air Quality Markets
150	682	682	682
200	614	606	594
250	565	557	545
300	515	513	505
350	476	473	464
400	455	448	436

Note: Assumes "low" natural gas availability.

[a]Costs represent annual abatement costs in millions of 1977 dollars.

There are two qualifications to the basic result that a finely-tuned system may not be warranted on the basis of cost savings. First, it should be noted that air quality is measured in terms of average annual concentrations. A shorter averaging time could produce a different result. Second, the result speaks to the present. Calculations are based upon the abatement possibilities and emissions inventories of existing firms in their current locations. Changes in the economic structure of the airshed conceivably could alter the pattern of emissions such that a more complicated system would provide substantial benefits. This is not a likely problem, for emissions already tend to be concentrated at the western central edge of the air basin. In any case, at present, there does not appear to be a serious loss in efficiency associated with adopting the simplest approach of making emissions permits freely transferable throughout the airshed.

THE EFFECTS OF MARKET POWER

Thus far, the analysis has been restricted to the case in which firms act as price-takers in the permits market. One potential problem with a marketable permits system is that one or a few firms may be able to manipulate the market to their advantage and, in the extreme, destroy its efficiency advantages over standards. This problem cannot be dismissed lightly for the case at hand.

The source producing the highest rate of emissions is an electric utility. Table 5 shows the estimated share of total emissions that it would produce under the competitive market allocation, which ranges between one-fourth to one-half of the permits. Whether this will, in fact, allow the firm to exercise significant market power depends on how the market is organized and operates. For purposes of analysis, we will assume that this sizable market share allows the firm to exercise market power.

The market power of the firm with the largest market share could manifest itself in several ways. It is not even clear without further specification of the details of the design of the market whether a firm with market power will act as a monopolistic seller of permits or as a monopsonistic buyer. Here we will analyze a case that appears plausible in its initial conditions, yet extreme in the assumption about the strength of market power. We assume that the firm in question initially will be given fewer permits than it is expected to want to hold after the market in permits is opened. This is consistent with present policies that tend to require utilities to adopt abatement methods having higher marginal abatement cost than is common for most other industries. Thus, we assume that the utility will be the <u>only</u> purchaser of permits; that is, the initial distribution of permits is such that the utility will be able to exercise maximal market power. In such a market, the equilibrium price will equal the marginal abatement cost of the sellers of permits, but not of the monopsonistic buyer. In purchasing permits, the monopsonist will take account of the fact that as it increases its

TABLE 5

MARKET SHARE OF THE LARGEST PERMIT HOLDER UNDER COMPETITION

NATURAL GAS SUPPLY	AIR QUALITY TARGET			
	1	2	3	4
Low	31	43	45	41
Historical	32	43	48	48
High	23	29	40	47

TABLE 6

MARKET SHARE OF THE LARGEST PERMIT HOLDER UNDER MARKET POWER

NATURAL GAS SUPPLY	AIR QUALITY TARGET			
	1	2	3	4
Low	20	31	37	41
Historical	32	40	33	44
High	23	25	39	32

TABLE 7

PERMIT PRICES UNDER MARKET POWER

NATURAL GAS SUPPLY	AIR QUALITY TARGET			
	1	2	3	4
Low	2,720[a]	2,000	1,000	940
Historical	2,720	1,000	650	470
High	1,000	470	420	210

[a]All prices are in \$ 1977. A permit entitles the user to emit one ton of SO_x per day.

purchases of permits, it will drive up their price. Hence, it will buy fewer permits at a lower price than would be the competitive, cost-minimizing solution. In other words, the monopsonist will abate too much in relation to other firms, and the latter will have lower marginal abatement costs than the former. To the monopsonist, some additional, uneconomic abatement will be worthwhile because of its depressing effect on the price paid for the permits that it acquires from other firms. A full exposition of the problem of market power in permits markets is contained in Appendix C.

Table 6 shows the simulated market share of the firm holding the most permits, assuming that it achieves the profit-maximizing monopsony. A comparison of Tables 5 and 6 illustrates the additional abatement that the monopsonist will undertake if it has market power. The two tables also reveal one other interesting fact. The market share of the largest firm is highest at an intermediate natural gas supply and does not differ much between high and low gas supply. This reflects the fact that at the extremes natural gas is either used sparingly or extensively by almost all industrial sources, while the intermediate case reflects the fact that utilities will be among the last to be allowed to switch to gas from low-sulfur fuel oil under the current scheme for gas allocations.

The decrease in market share is typically accompanied by a decrease in the price of a permit. This can be seen by comparing Table 7 with Table 2. As in the competitive case, the permit price still varies by an order of magnitude over different assumptions about the air quality target and the supply of natural gas.

Although the differences between the competitive and monopsonistic case appear large, whether they cause a major loss of efficiency in achieving abatement targets remains an open question. The appropriate measure of inefficiency is neither price nor market share, but the differences in total abatement costs under the two situations. If at the competitive equilibrium all firms face a fairly flat marginal abatement cost over a wide range of emissions reductions, a large shift of emissions from the monopsonist to the rest of the firms might entail relatively little loss of efficiency. As can be seen in Figure 1, all of the choices of alternative ambient air quality standards happen to fall within relatively flat portions of the demand curve for permits, and therefore in areas in which the abatement cost function obeys essentially constant marginal costs. Calculations of the efficiency loss of market power were made in each case, and the loss was determined to be relatively small, ranging from zero to ten percent depending upon the particular combination of assumptions about natural gas supplies, ambient air quality standards, and the method used for estimating the abatement cost functions.

Nevertheless, a conclusion that market power will not severely undermine the operation of the market is not warranted at this time. The estimated loss in efficiency due to market power is quite sensitive to small changes in the cost functions. The inexactness in

TABLE 8

PAST AND PROJECTED "MARKET SHARES" OF SULFUR OXIDES EMISSIONS BY SOURCE TYPE FOR THE SOUTH COAST AIR BASIN OF CALIFORNIA[1]

1973 Emissions		1980 Projection Low Natural Gas Scenario	
Source Type	% of Total Emissions[2]	Source Type	% of Total Emissions
Utility	28	Utility	31
Mobile Sources	16	Mobile Sources	27
Utility	11	Utility	10
Oil Company	8	Oil Company	4
Steel Company	7	Coke Calcining Company	4
Oil Company	3	Oil Company	4
Coke Calcining Company	3	Steel Company	3
Oil Company	3	Oil Company	3
Oil Company	2	Oil Company	2
Oil Company	2	Oil Company	2

[1]These figures are based on the 1974 definition of the South Coast Air Basin which was subsequently revised.

[2]Emissions are rounded to the nearest percent.

Source: Calculations by Hahn (1981a) based on Cass (1978 and data used to compile Appendix E to this report.

abatement costs available to us, and the possibility of technological change and the entry of new sources makes the permits market potentially vulnerable to this problem. Consequently, considerable thought must be given to the possibility of building in protections against monopsonistic market power into the tradable permits system.

THIN MARKETS

The final potential source of market failure is that transactions will be too infrequent to convey meaningful price signals to polluting firms, to make relatively easy the acquisition of permits for entry and expansion of polluting facilities, and to allow a firm to avoid the expense of organizing the market and engaging in extensive bilateral negotiation every time it desires to make a trade. This is an especially difficult design problem to get a firm grip on in advance of operating the market, for the indicators of the extent of market transactions are so crude. One measure is the number of firms accounting for existing and expected emissions.

In Los Angeles ten companies account for approximately 85 percent of the sulfur oxides emissions under current standards, assuming mobile sources are assigned to the oil refiners operating in the airshed. This is shown in Table 8, which indicates the share of emissions accounted for by the major sources. The mobile source emissions would be allocated to oil refineries in a permits market, since controlling the sulfur content of fuel is by far the cheapest and most effective way to reduce mobil source emissions. What these data indicate is a potential problem of market thinness. Most major industrial polluters emit relatively small amounts of sulfur, so that the market for small quantities of permits is likely to be reasonably well-functioning; however, a major expansion or entry of an oil refinery, an offshore oil terminal, or an electric utility generation facility would be especially difficult to accommodate because so few sources have sufficient numbers of permits to be potentially significant sellers to the new source. This is also true of offsets and banks in current EPA policy. For a major new source, there are very few potential partners for an offset trade.

A second problem in anticipating the extent of a problem of market thinness is that the available data probably underestimate the possibilities for transactions. A substantial source of demand and supply in the market for permits will be factors that are not measurable in advance. Examples are innovations in abatement technology, entry, exit, contraction and expansion of polluting entities, and opportunities for more efficient abatement methods that may be known to existing sources but that have not yet appeared in the public domain (e.g., process changes).

In Los Angeles, the problem is even more difficult because the local air pollution control authority has explicitly adopted the policy of attempting to write standards in inverse order of their costs per unit abatement. Thus, with few exceptions, the standards in place are the least expensive abatement methods available, and the pending standards are the least expensive remaining possibilities. Consequently, most of the demand for trades, and the gains from a permits market, are unlikely to be measured using existing cost information. Therefore the extent to which the thinness of the market is a potential problem is likely to be overstated. For example, given historical natural gas supplies and no abatement methods other than those whose costs are known publicly, the annual cost savings from a competitive reallocation of the emissions permits that are currently in place is estimated to save only about $20 million per year in abatement costs, which is about 7 percent of the total. This indicates a strong possibility of a thin market, indeed; however, it is sure to be an underestimate of the potential savings, and hence the desire to trade.

INITIALIZING THE MARKET

The major design criteria for a tradable emissions permit market are: equity in the distribution of permits initially; sufficient early transactions to produce a stable price for permits that is close to the long-run equilibrium to encourage rational long-term investment planning; and attainment of an equilibrium price and distribution of permits that is close enough to the competitive case to assure attainment of air quality objectives at lower costs than can be obtained by alternative regulatory approaches. A major design feature that affects the extent to which a permits market satisfies these criteria is the method for starting up the market.

The most attractive method for the initial allocation is an auction mechanism. This provides a thick market (all permits are transacted in the initial distribution) and, because all polluters are placed on the same side of the market, it minimizes the likelihood of monopolistic imperfections. The mechanics of the proposed mechanism are as follows. Each source would be asked to write down the number of permits it would seek to purchase at each of several prices. The firm would be free to choose as many price gradations as it wanted. It could write down one price-quantity pair (e.g., X tons per day at any price up to $Y per ton). It could provide a step function of several jumps, such as X tons per day for prices between $Y and $Z ($Y larger), and X+W tons for prices below $Z. Or, it could bid a continuous demand function for permits. Permits would then be allocated to the highest bidders at the quantities requested, descending down the price bids until the permits were completely allocated. The price at which permits are traded can be determined in either of two ways. First, among the bids not receiving any permit allocations, the highest unsuccessful bid can be the price of all permits (e.g., the allocation mechanism is a second-price auction). This process is theoretically preferrable, but somewhat complicated to understand. Alternatively, the lowest successful bid can be the price (e.g., a first price auction). We have examined the performance of the zero-revenue, first-price auction by using small group experiments. The experimental evidence that it does work efficiently is reviewed in Appendix D.

The main difficulty, of course, with the straightforward auction process is that it generates considerable revenue for the state, and therefore may be politically infeasible. As a matter of economic analysis, a permits auction is an attractive source of revenue, for the sale of emissions permits is one of the few ways available to the state to collect taxes in a way that contributes to, rather than detracts from, economic efficiency. As a matter of political feasibility, alternatives to a revenue-generating method need to be explored because, by avoiding the creation of a new tax on business, they stand a greater chance of winning the support of industry to the idea of TEP. This suggests a method of "grandfathering" permits on the basis of some inventory of emissions.

In a grandfathered system, regulators would make an initial allocation of permits, and then would rely on the inefficiencies of this allocation to generate incentives for a market to form. Three methods for initially distributing the permits are considered. One would base permit distribution on emissions as they existed prior to recent attempts to control them, with perhaps some additional provision for firms that have entered the airshed or expanded capacity since that time. The second would base the initial allocation on the emissions allowed under current standards. The third would base the distribution of permits on the projected equilibrium that would result from a competitive, perfectly efficient market in permits. Any other method that is based upon historical emissions performance raises the objection that people who were early to comply with regulation would be punished for cooperating. Any method that is not based on emissions raises the objection that it is arbitrary, and in any case is more vulnerable to becoming bogged down in a contest between competing claims for redistributing wealth that have nothing to do with air pollution policy.

Basing the initial distribution on the projected competitive equilibrium has a serious defect in terms of efficiency of the permits market. To the extent that the initial distribution succeeded in finding the competitive equilibrium, it would also succeed in avoiding the necessity for any transactions among present sources. Only in the case of new sources or expansions of existing facilities would a demand for trades arise. Thus, a relatively speedy attainment of a stable, competitive price for permits would be least likely under this mechanism. Indeed, much the same problems as confront the current banking and offset policies could be expected: a slow development of the market owing to the difficulties of finding trading partners and negotiating a price.

A second difficulty with the strategy of distributing the permits on the basis of the estimated competitive equilibrium is that it may be more vulnerable to legal challenges and delays. The method for simulating the competitive equilibrium is to minimize estimated abatement costs for the entire airshed, a calculation that is based on numerous estimates of costs for each category of sources at all feasible levels of abatement. This is tantamount to setting new source-specific standards for the entire region. Because the cost estimates on which the equilibrium allocation would be based are admittedly inexact, they are vulnerable to challenge as being insufficiently precise to support a regulatory decision, just as existing source-specific standards are often challenged -- and changed or delayed -- on the basis of their estimated costs and effectiveness. If any single estimate of costs or efficiency abatement that was used in simulating the competitive equilibrium was successfully challenged, it would undermine the entire initial allocation of permits, and, hence, the implementation of the system.

The other seeming attractive alternatives on equity grounds are to base initial allocations on preregulatory emissions or current standards. One possibility of the former is the emissions inventory of 1973, while an estimate of the latter is a projection of the 1980 inventory. Both are shown in Table 8.

A major difficulty with a system based on precontrol emissions is that for one important source -- oil refineries -- the methods that they would adopt today with no regulation would produce far less emissions than the best methods of 1970. A method based on precontrol emissions would, in any event, end up giving most of the permits to oil companies, who would then probably sell them in large quantities and high profit to public and municipal utilities. This does not seem to be very acceptable politically.

Allocations based on either precontrol or historical emissions have another undesirable property. They appear to stack the deck in favor of monopsonistic behavior by the firm with the largest share of permits. In 1973 and 1980, this firm accounted for 28 and 31 percent of emissions, respectively, as contrasted with a projection of 44 percent under competition, assuming current regulations and historical natural gas availability. Thus, one would expect the largest firm to be a purchaser of permits -- and a very large purchaser if the competitive outcome is to be achieved. In either case, in order to achieve the competitive result, the firm with the largest market share must account for nearly all purchases of permits (nearly everyone else would be a seller), and therefore face powerful incentives to engage in monopsonistic purchasing practices.

The dilemma in organizing the permits market is that there is a seeming inconsistency in getting the single largest source of emissions to engage in transactions so as to get the market started quickly on a course that provides stable price signals to firms making abatement and location decisions, and in preventing the market from being manipulated. Several possibilities emerge for attacking this problem.

One approach is to use different methods for the largest emissions source and other sources for making the initial distribution of permits, allocating to the potential monopsonist something like the competitive equilibrium estimate while using the historical basis for allocating permits to others. This would probably produce a situation in which the largest source was not a participant in the early stages of the market; however the remaining sources would have an incentive to engage in trades, and would be more likely to produce a competitive outcome.

A second approach is to make a distinction between the most important sources as a group and the remaining sources, allocating permits initially so that all of the former are equally interested in acquiring more permits, while all of the latter want to sell. Thus, each of the half-dozen most important sources of emissions could be allocated a number of emissions permits that falls short of the estimated competitive equilibrium by the same absolute amount, while the other firms could be given permits that exceeded their estimated equilibrium amount by some proportion that is consistent with the first allocation. In such a situation, the largest source of emissions would hold the largest number of permits, but would not account for an especially large fraction of the transactions on its side of the market.

A third approach is to allocate only some fraction of the permits on the basis of historical or projected emissions, and let the state auction the rest. All firms could, say, be allocated 80 or 90 percent of their projected equilibrium emissions, and the remaining permits would be sold. This has the objection that, like an emissions tax, the state ends up collecting revenues, so that the costs of the system to polluters exceed their abatement costs; however if the fraction of permits sold were small enough, the efficiency gains to industry in rationalizing abatement control strategies would offset the revenues lost to the auction.

A final possible approach is to use an auction process that redistributes auction revenues to the firms that participate in the market. In order to produce an efficient outcome, the method for determining the rebate to a firm must not depend on its actions in the auction. One process, the Zero Revenue Auction, that generates no net revenue and that has attractive incentive properties is as follows. Each firm would receive a provisional initial allocation, based upon one of the criteria discussed above (historical emissions, current standards, expected competitive equilibrium). All sources would be required to offer their entire allocation for sale. Each firm would then report its demand curve for permits, as described above in the standard auction. The sum of the demand curves would be used to calculate the market-clearing price for the fixed total quantity of permits for the entire market. This price would then be used to calculate the final allocation of permits to each firm, according to its demand curve. Firms would make a gross payment to the state equal to the market price times their final allocation, and would receive a gross revenue from the state equal to the market price times the initial allocation. The net financial effect on each firm would be the market price times the difference between its initial and final allocation; the net financial effect on all firms taken together would be zero.

The initial allocation of permits, whatever the baseline emissions used for grandfathering, would not have to be equal in magnitude to the amount of baseline emissions. That is to say, the market can be initialized at a level of emissions that is substantially different than the total baseline emissions on which the allocation is based. Whatever the choice of a baseline for grandfather, the allocation would proceed as follows. The ratio of target emissions to the baseline emissions would be calculated. Each firm would then receive a provisional allocation of permits equal to this ratio times its baseline emissions. New or expanded sources since the date of the baseline would receive allocations based upon actual emissions when their operations began. In short, each source would provisionally receive a <u>share</u> of the new emissions ceiling equal to its <u>share</u> of the baseline emissions.

We have designed a small group experiment to test the performance of the Zero Revenue Auction. A description of this experiment is contained in Appendix D. Pilot tests of this procedure have been undertaken, and the results are encouraging. The pilot test reached the competitive equilibrium -- that is, it performed efficiently.

The discussion thus far has dealt with the issue of setting up the market initially. If permits were to be perpetual, and if the state were to play no further role in facilitating efficient transactions, the initialization process would be the only concern. But in practice, market operations are also an important design issue. Briefly to summarize the discussion in Chapter 1, the state has an interest in: (1) constructing a market institution in which changes in total emissions can be made to accommodate new information about the costs and benefits of abatement, (2) making it easy for firms to buy or sell permits in response to changes in abatement technology, and (3) facilitating the entry, exit and expansion of businesses in the region by assuring a regular permits market.

The problems of pure grandfathering in an ongoing market are the same as in market initialization. In a grandfathered system in which businesses must organize their own permits market, trades are difficult to consummate and, hence, will be infrequent. The result is an inefficient market that is not sufficiently responsive to new technologies or new sources. Moreover, regulators will face procedural hurdles in altering the ceiling on emissions since there will be no regularized, periodic repermitting activity.

The most promising solution to this problem is to give permits a fixed life, and to reallocate permits when the old ones expire according to the same process that was used for the initial allocation. As with the initial allocation, the most efficient process is an auction; politically, the Zero Revenue Auction may be more attractive than an auction that raises revenues. The reallocation would proceed as follows. The state regulatory authority would establish a new target level of emissions, based upon current information about the relationship between emissions and air quality, the effects of pollution, and the costs of further abatement. The ratio of new to expiring permits would be calculated, and each holder of expiring permits would receive a provisional allocation of new permits equal to this ratio multiplied by its holdings of expiring permits. Then, as in the initial allocation, everyone seeking new permits would submit bids (in the form of demand curves), which would be used to allocate the new permits, collect revenues, and make compensating disbursements.

The considerations that should go into selecting the frequency of these auctions and the life of a permit are as follows. One is the investment planning horizon of sources of pollution. While this varies as interest rates change, for most companies it is in the range of five to ten years. To encourage businesses to make the proper decisions from an efficiency perspective in trading off investments in pollution equipment versus changes in operating methods, permits with lives exceeding five years are necessary.

A second consideration is the frequency with which major sources of emissions might want to enter the region. Construction of a major new industrial facility requires substantial time, so that a continuous market is not necessary. But ten years is surely too long to wait for a market to develop. Two or three years would be a more realistic frequency for the permits auction.

Finally, the time for readjusting emissions and air quality targets must also be considered. Proceedings to change environmental quality targets are protracted because they require gathering and evaluating evidence and satisfying due process requirements. At present, these kinds of policy changes appear to take place about once per decade. But in a world in which regulators are not preoccupied with setting source-specific standards, reviews of overall policy objectives would receive greater attention, and might be altered more frequently. In any case, the time between changes in emissions ceilings can reasonably be expected to be longer than is necessary to accommodate entry, expansion and technological change, but shorter than the investment planning horizon of business.

To accommodate these diverse requirements, one possible approach is to have permits of a relatively long duration, but to have only a fraction of them expire at any given time. For example, suppose that the initial allocation of permits separated them into three categories: one-third with a nine-year life, one-third with a six-year life, and one-third with a three-year life. At the end of three years, the expiring permits would be replaced by new permits with a nine-year life. Eventually, the system would have nothing but nine-year permits, one-third of which expired every three years. At each expiration date, regulators would establish a trade-in ratio of new for expiring permits, although substantial changes would not be expected to occur very frequently. Businesses seeking long-term investments would have the stability of long-term permits to match that commitment. Potential entrants and expanding firms would have relatively frequent markets in which to acquire necessary permits.

Of course, there is no magic in the details of the procedure described above. More or less frequent markets could be arranged, and some variability could be introduced in the life of a permit. But the general guidelines that must be followed to produce an efficient system are the following:

(1) Permits that last for on the order of five to ten years;

(2) Markets that occur every two or three years; and

(3) A large enough fraction -- a third to a half -- of the permits expiring at each date so that the auction market will have many participants and will not be monopolized.

If this approach is adopted, permits of different vintages can be expected to have different annualized values. Longer lived permits are more valuable because of the certainty in terms of future emissions that they secure. In advance of operating the market, there is no reliable way to guess what this difference in value would be. Moreover, to auction three vintages of permits simultaneously in initializing the market is probably unduly complicated. The best solution would be to give every firm an equal number of permits of each vintage in the initial auction, and let subsequent trades among businesses readjust the allocation to accommodate different attitudes about securing future emissions. The exact form of the bids in the auction, then, would be to write down a willingness to pay for a portfolio of permits of different vintages that add up to the total emissions permitted in the first year.

Between formal auctions, businesses could still negotiate trades. Of course, all trades would be reported to the regulators, along with statements about the new levels of emissions to be obtained by each trading partner. The regulatory agency would maintain a file of all current holdings of permits of each vintage, thereby facilitating the identification of trading partners by a business seeking to negotiate a deal, much as the case with the proposed emissions reduction banks. Indeed, regulators could facilitate the intervening market by maintaining a register of firms willing to buy or sell permits, with the quantities and prices at which they seek to trade.

The process described above can also be orchestrated to produce a phased reduction in total emissions from current levels to the ultimate target. This would be done by announcing long in advance that at each expiration date, the number of new permits would equal some predetermined fraction (less than one) of the expiring permits. For example, in the context of the nine-year permits mechanism described above, the initial allocation could be for 300 tons per day, a slight reduction from current emissions. This quantity would be divided into three vintages, each accounting for 100 tons per day. If the state then announced that as each vintage expired, the number of new permits would be exactly half of the number of expiring permits, the state could then be assured of reaching the AAQS for sulfate particulates in nine years.

The last issue of importance in structuring the market is the development of a role for brokers in emissions permits. In an efficient market operation, it is quite likely that some permits would be held by intermediaries who lease their use. Because the quantity of sulfur emitted is dependent on the fuel that is burned, unanticipated events in fuels markets can have a significant effect on whether fuel burners are in compliance with emissions requirements. Different sources can be expected to have different attitudes about the risk of interruption of low-sulfur fuel supplies. Some, like utilities, will need to keep fuel use up regardless of fuel market conditions and overall environmental constraints, while others will be able to make quick adjustments. These differences will lead to a market demand for interruptable permits -- that is, leases for the use of permits that can be cancelled with short notice. One can expect that permits brokers -- either firms holding permits that they normally do not use but might want to use in an emergency, or completely independent companies that hold permits and sell contingent claims on their use -- will develop to accommodate this demand.

There is nothing inherently wrong with this development; indeed it is probably necessary for utility participation in a permits market. But it poses one problem to regulators. If permits are freely transferred on short notice among sources of pollution, regulators may have difficulty keeping track of exactly who is emitting what, and whether all current emissions are covered by permit holdings. The solution to this problem is a reporting requirement -- and a regulatory clearinghouse for information about permit holdings that operates quickly and accurately. Permit holders would be required to report all permit transactions immediately, and prior to the transfer of emissions between sources. The reporting lead time should not be long, or else the possibility of developing an effective contingent claims market for permits will be undermined. Given the nature of fuel delivery contracts and inventory policies of major sources, a lead time of a week or so would seem to be sufficient.

GENERALIZING THE BASIC APPROACH

Even if the formation of a tradable emissions permit market is found to be an attractive policy option for one particular pollutant in a specific locale, the issue still remains as to the generalizability of the result. Will a detailed air quality model always be required for each application? Will new cost estimates need to be developed for each case? In short, will regulators need to undertake an in-depth analysis similar to the one discussed here in order to ascertain whether a market solution is appropriate for a particular problem?

Certainly, some analysis will always be required in thinking about making the transition from "command and control" regulation to a market approach; however, it is likely that as experience with incentive-based options such as markets increases, the level of analysis needed for potential new applications will decrease.

Specifically, what are the critical components with which a regulator should concern himself before considering a market scheme? One is the approximate costs of regulation incurred by the agency and by industry. A second would be monitoring and enforcement capability. A third important element would be knowledge about the sources of emissions, and a fourth would be an understanding of the relationship between source emissions and measures of environmental quality.

The first point to observe about this list of requirements is that in a general way it is common to the development of a rational environmental policy of any kind. A regulator needs to have some idea of the relationship between emissions and pollution in order to develop a set of standards, tradable emissions permits, or effluent taxes that accomplishes the objectives of environmental policy. Moreover, regulators need to know the pre-regulation pattern of emissions and the abatement opportunities available to each major source in order to set standards or taxes that will achieve environmental objectives in a cost-effective manner. Finally, all policies must be consistent with the ability of the regulator to monitor emissions and pollution, and to enforce any method of achieving its goal.

Nevertheless, the informational requirements may differ in their details for implementing a system of tradable permits. One reason is that a positive case needs to be made to convince political actors -- regulators, regulated businesses, environmentalists, and the public at large -- that a change in regulatory methods is worth trying. This is the source of the belief that the initial implementation of a tradable permits system will require a well-documented study of its likely performance, but that subsequent implementations will require less information if the initial program succeeds.

Even so, a market approach may still require a different combination of analysis and data than other approaches. The reason is that the important regulatory decisions in implementing and maintaining a market system are somewhat different, leading to different evidentiary requirements if a regulatory authority's decisions are to withstand legal and political attacks. A case in point would be the establishment of a baseline emissions inventory upon which to make the initial distribution of permits. Because potentially large implicit wealth transfers are involved, participants in the process to set up a tradable permits system could be expected to take an active interest in establishing a baseline, leading an agency to make a greater commitment of resources to this issue than would otherwise be the case. By the same token, agency expenditures for identifying best control technologies could be reduced, because the agency would no longer need to establish legally defensible source-specific standards. In a world with tradable permits, the key regulatory decisions are the initial allocation of the permits, the establishment of total emissions limits, and the determination of an ambient air quality standard. Regulatory resources would tend to be redirected towards these issues, and away from studying problems of specific sources.

In the meantime, many air pollution problems are less well understood than SO_x in Los Angeles. The auction mechanism described above has several features that are suited to the case of poor information. First, the periodic auction is the best way to protect against market imperfections owing to either market concentration or market thinness. Second, the concept of having some of the permits expire every two or three years is especially appropriate when the relationship between emissions and air quality is poorly understood, because the process by which expiring permits are converted into new ones allows the regulator continually to adjust the number of permits (and hence air quality). Of course, the more uncertain are regulators about the emissions to air quality relationship, the greater is the degree of variability in the number of permits that they would desire. One method for achieving greater potential for variability is to have two types of permits: long-term (perhaps ten years or longer) and short-term (as short as one year). A high proportion could be assigned to the short-term category and therefore varied in quantity from year to year. A second use of short-term permits would be to facilitate an economically efficient, gradual approach to achieving the ultimate air quality objective. Regulators could announce a strategy to reissue short-term permits at some ratio of new to expiring permits that is less than one, thereby gradually winding down the total emissions in the area. The process could be based upon an emissions target that is established before the system begins to operate (assuming the relationship between emissions and air quality is known well enough to make this feasible), or the winding down process could be open-ended, with regulators announcing a fixed percentage reduction in short-term permits until ambient air quality standards are achieved (or changed).

The preceding arrangements still leave unsolved one potential failing of a market in permits: the possibility of localized effects from a single or a few sources that elect to buy a large number of permits rather than to abate. Because this result in the context of a permits market is a consequence of a cost-minimizing process of reducing emissions, the appropriate response to the problem may be to allow some degree of localized violations of air quality standards. Nevertheless, in the context of existing air pollution regulation, rather than regulation seeking to make some sort of optimal trade-off between benefits and costs, the ambient air quality standard is an inflexible policy objective.

If enough firms contribute to a localized effect, one possible solution is a system of multiple permits markets. This would require a formal regulatory determination of the coefficients relating emissions to air quality for the relevant sources and localized pollution hot spots. As long as the number of these localized problems is relatively small, requiring firms to participate in only a few markets, this approach may prove workable. But it would require a substantial evidentiary burden on the regulators in defining the permits, the markets, and the mathematical relationship of sources to each. In the absence of good information about the relationship between emissions and air quality, regulators may not be able to sustain such findings legally, or may be able to do so only after a long legal battle.

A second, probably more fruitful approach is to set up a permits market, but to overlay minimum standards on the sources that are suspected of having important localized pollution effects. Only very large sources or sources emitting at or near ground level can be expected to cause a violation of ambient air quality standards all by themselves; hence regulators could deal on a case-by-case basis with these sources. The idea would be to let the permits market allocate emissions, but to set an upper bound on the number of permits that could be held by some specific sources or a lower bound on stack heights. These standards would be set according to the same procedural and evidentiary requirements that apply to the present source-specific regulatory standards; however, the process of implementing them would not need to delay the implementation of a general permits market. The long legal process to set an upper bound on a particular source could be underway while the market operated, and could be directed only at the major sources that in equilibrium were observed to hold a greater number of permits than the proposed upper bound.

In the case reported here, for example, attention was focused entirely on the effect of SO_x emissions on particulate sulfates because the Los Angeles airshed is in compliance with standards for SO_2 concentrations. As discussed in Chapter 2, SO_2 emissions undergo chemical reactions and transportation in the atmosphere to become sulfates. Thus, at any given location, SO_2 pollution is more likely to be the result of a nearby source of SO_2 emissions, whereas particulate sulfates are more likely to be the result of emissions from numerous sources, including some at a relatively great distance. In Los Angeles, compliance with SO_2 standards at stationary sources generally only requires that major sources install tall enough smokestacks so that by the time SO_2 reaches the ground it has been adequately dispersed in the atmosphere to satisfy maximum atmospheric concentrations. The adoption of an emissions market for sulfur oxides in Los Angeles as a means for controlling sulfate pollution would most assuredly be done in the context of a continued requirement of an adequate stack height for major stationary sources of SO_2 emissions. This observation has quite general applicability, for it is commonly the case that a single source of emissions produces several different kinds of pollution: a nearby effect for which it is the only source, and more distant effects that involve interactions with other sources. Markets are well suited for dealing with the latter case, but only within the context of maximum permissible concentrations at the point of emissions in order to avoid exceeding the limits for localized effects. At the extreme, for cases in which localized effects are the binding constraint on emissions for most of the important sources, a tradable permits system could have limited value.

Another situation in which tradable permits may be less attractive is in the case of very complex pollution problems in which several types of emissions interact to form a variety of pollutants, often in nonlinear and even nonmonotonic ways. An example is photochemical smog, which is the product of chemical reactions involving, among other things, numerous hydrocarbon compounds and oxides of nitrogen (NO_x). For different combinations of emissions in the atmosphere, smog can be either increased or decreased by increasing emissions of NO_x. More generally, the specific kinds and geographic distribution of numerous emissions can be very important in determining the severity of pollution, given a constant level of total emissions for NO_x and hydrocarbons. For the case of photochemical smog, the unpredictable secondary effects of markets could lead to unpredictable worsening of pollution due to a major transaction or even through a reduction in the total number of permits for a particular type of emissions. Of course, whether this is likely to be a problem for any particular choice of tradable emissions permits is an empirical question; however, the analytical problems associated with demonstrating the desirability of a market for dealing with the components of photochemical smog are substantially greater than the problems that must be solved for tackling SO_x emissions.

Any of the preceding systems — numerous short-term permits, some standards overlaying the market for permits -- creates uncertainty among emissions sources in picking an optimal abatement strategy, or indeed in being willing to experiment with a change in the regulatory system for controlling emissions. Uncertainty about the future state of regulatory stringency affects the selection of abatement methods by a regulated entity -- both the total amount abated, and the choice among capital-intensive technologies versus changes in operating procedures. In general, uncertainty should make firms somewhat more reluctant to abate at all, and somewhat more likely to adopt more flexible abatement methods that allow relatively inexpensive adjustments in emissions as policy changes occur.

One good argument for a stable regulatory policy is to create a more certain decisionmaking environment for regulated firms. But if long-term goals cannot be very accurately stated, either because the benefits of improved air quality are uncertain or because the relationship between emissions and air quality is poorly understood, regulatory policy will produce a more efficient result if this uncertainty is transmitted to businesses by the regulatory system. A system that does not specify the long-run emissions goal, but that makes some measured change in emissions over time (and that is ambiguous about the ultimate stopping point), will be more efficient if it encourages more flexible abatement methods. Consequently, although the politics of the situation may prove intractable, a design criterion for situations in which the amount of emissions to be allowed in an area is unknown ought to be to construct a permits system that conveys this uncertainty to polluting entities. An example would be a process in which the number of permits was reduced by some prespecified fraction each time the permits were reissued until air quality objectives were achieved.

With all the caveats in mind, the research to date on the Los Angeles sulfate problem indicates that tradable emissions permits are a promising alternative to command and control regulation. None of the major sources of market imperfections appear to be so intractable that they cannot be overcome by an intelligently designed market institution. Hence, because of the other beneficial incentive effects of the system, tradable permits for sulfur oxides emissions in Los Angeles appear attractive. Moreover, the analytical issues associated with researching the question of the feasibility of a permits market have also proved to be tractable, suggesting that the same methods might be fruitfully applied to other pollution problems.

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CHAPTER 4

SOME LEGAL ASPECTS OF TRADABLE EMISSIONS PERMITS FOR AIR POLLUTION IN SOUTHERN CALIFORNIA

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INTRODUCTION

This paper discusses some of the legal aspects of a program of tradable emissions permits (TEP) for air pollution in Southern California.[1] The program in question would be limited -- initially, at least -- in two respects: (1) it would apply only in the South Coast Air Quality Management District (SCAQMD); (2) it would apply only to emissions of sulfur oxides (SO_x). The limitations are explained by the fact that the program, if it went forth at all, would do so only on an experimental basis; it would be an effort to learn more in practice about alternative air pollution control techniques that have, thus far, enjoyed considerable discussion but little experience.

BACKGROUND

Command-and-control regulation has been the mainstay of governmental intervention regarding environmental problems, air pollution included. As the name perhaps implies, the command-and-control approach typically proceeds by imposing rigid standards on individual pollution sources (for example, standards requiring that sources meet specified emission limitations or use specified abatement technologies, or both), backed up by sanctions designed to ensure that each source complies fully with the rules applicable to it. At least within categories of like sources, command-and-control regulations tend not to differentiate among polluters in terms of their marginal costs of control; rather, equal amounts of cleanup are required of all sources within a category. As a result, the aggregate costs of reaching a given level of emissions abatement are higher than necessary. Moreover, because the command-and-control approach requires sources only to meet, not go beyond, the mandated standards, there is little or no incentive to take cost-effective steps to reduce emissions even more, or to develop innovative new control technologies. (There might be some incentive to develop control techniques that make it cheaper to achieve the required standards, but it will be a weak one if the source in question believes -- not unreasonably -- that use of the new technology will lead eventually to a tightening of standards.)

For the foregoing reasons, among others, there has been considerable interest of late in alternatives to the traditional regulatory approach. The alternatives -- under consideration or in some instances in actual operation -- owe a substantial debt to years of unrelenting argument by economists that market-like approaches represent the most promising methods of controlling pollution problems. The classic alternative offered by economists has been the emission fee -- a charge assessed against a source for each unit of pollution it emits. The charge, computed in various ways depending on the details of the approach (computed, for example, so as to reflect the social costs of each unit of pollution emitted, or so as to achieve a predefined ambient quality goal), is designed to control pollution-intense activities by fixing an appropriate price. A related approach, marketable permits, fixes quantity instead. With marketable permits, an ambient goal is first specified; then the total pollution load it implies is divided up into a number of permits to pollute which are sold (or otherwise distributed) to polluters and which are thereafter freely transferable. A source must have a permit for each unit of pollution it emits. Because pollution control is costly, and because sources may not legally pollute without permits, the permits will command a positive price similar (if not identical) to the charge imposed under the emission fee approach.

Emission fees and marketable permits are both responsive to the central shortcomings of command-and-control regulation. Each technique encourages sources that can control at relatively low cost to control more (thus avoiding payment of some fees or use of some rights) than sources with higher control costs; in consequence of this, the aggregate costs of any given level of control tend to be minimized. Both techniques give sources continuous incentives to control further than they would under command-and-control regulation, and to develop efficient technologies by which to do so.

Command-and-control regulation is, as we shall see, typified by the Clean Air Act -- the present federal air pollution legislation -- and by state and local laws and regulations adopted in California to carry out (or go beyond) the requirements of the federal program. The alternative approach to be discussed here would reflect an application of the marketable permits discussed above.

GENERAL LEGAL CONSIDERATIONS AND CONCLUSIONS

Unhappily, the general approach of marketable pollution permits has not received the attention given by legal analysts to the related technique of emission fees; it stands, therefore, on rather unsure footing.[2] This is a relatively minor problem, though, for several reasons. First, the considerations mentioned in the literature in support of emission fees provide equal foundation for marketable permits. Moreover, the body of constitutional doctrine with which designers of either approach must be concerned is, as shown below, very accommodating. Second, and related to the first point, recent developments at the state and federal levels of government generally reflect sympathy for market-like approaches. Several states have used incentive programs and these have withstood legal attack. (These programs did not involve air pollution control, but this is beside the point at least insofar as constitutional considerations are concerned.) The federal government has developed and is using several control techniques (e.g., bubbles and offsets) to deal with air pollution in particular, and these techniques are remarkably similar in approach to the notion of marketable permits. There has been no serious suggestion that the techniques suffer any constitutional infirmity.

A way of summarizing the foregoing remarks is to say that there is no general constitutional barrier to a TEP program -- a conclusion that will be expanded (but only slightly) in subsequent discussion. This is not to say that particular issues of constitutional law do not arise; in fact they do. For example, federal and state prohibitions on the taking of property without just compensation may come into play, depending on how a TEP program is designed and implemented. Similarly, California constitutional doctrine especially might foreclose enforcement techniques that would probably be permitted under federal law (we shall consider ways to avoid this problem). These and several other matters have little or nothing to do with a TEP program generally; they have rather to do with particular ways of implementing such a program. As of yet, no specific form of program has been settled upon. Indeed, the specific form of program (if any) eventually selected for implementation necessarily depends to considerable degree on legal considerations. It is best, then, to proceed on an issue-by-issue basis, considering the central elements of any TEP program and the legal constraints that might bear on the choice of approach regarding each of the elements. But this issue-by-issue discussion, to be pursued below, should not mask the conclusion stated here -- that the general approach of TEP is constitutionally acceptable.

This is not to say that the approach is legislatively acceptable. The Clean Air Act, as it presently stands, probably forecloses reliance on anything but a very limited TEP program for SO_x emissions in the SCAQMD. The same is probably true of state legislation and local rules. The federal constraint is more serious, however, because appropriate amendments to the Clean Air Act (if necessary) would probably be more difficult to obtain than amendments at the state and local levels.

We have, thus far, arrived at two overarching conclusions: (1) the TEP approach, generally speaking, is constitutionally acceptable -- constitutional problems will arise, if at all, only in several particulars of program design; (2) the TEP approach, unless severely limited, is probably impermissible under applicable legislation -- the federal Clean Air Act especially. The next section develops these two points; the section after that takes up some particular questions of program design on an issue-by-issue basis.

CONSTITUTIONAL AND LEGISLATIVE PROVISIONS GOING TO THE GENERAL ACCEPTABILITY OF TEP

Constitutional Provisions

Would anything in the federal constitution, or in the constitution of California, forbid a move from command-and-control regulation of SO_x emissions to a TEP program aimed at these pollutants? The answer is almost certainly no. We are discussing here the basics of constitutional law, and for the propositions in question one need not even cite chapter, much less verse. The governing principles are clear, and have been for at least 40 years.

To begin with the issue of general regulatory authority, Congress, under its constitutional power to regulate interstate commerce, may control interstate and intrastate air pollution. That conclusion is beyond question. So is the conclusion that California may, pursuant to the inherent police power of all states, regulate air pollution to promote the public health, safety, welfare, and morals.

The regulatory powers of Congress and of California are not, of course, unlimited, but the limitations to be mentioned here would not foreclose regulation through TEP. Both the federal government and the state must act in accord with requirements of due process and equal protection of the laws. (The federal government is obliged to do so by the fifth amendment of the United States Constitution, and the state by the fourteenth amendment. The state constitution has similar requirements of its own, but for our purposes federal and state views on due process and equal protection, under either constitution, are the same.) Neither due process nor equal protection, however, places any significant constraint on a federal or state TEP program for SO_x emissions.

Turning first to due process requirements, it is worth noting that in the realm of so-called economic regulation (the case here, as opposed to governmental regulation of such "fundamental" interests as the right to marry and procreate) federal and state governments are given great freedom -- indeed, virtual license. Due process requires nothing more than that the means of regulation chosen bear a rational relation to a legitimate end -- here, the end of regulating commerce or promoting public health and safety through air pollution controls. So long as a regulation has that rational basis, and is not unreasonable, arbitrary, or capricious, it survives due process review. Lest those tests sound less than perfectly permissive, bear in mind that an economic regulation is presumed to be constitutional, and anyone challenging it must prove otherwise. The burden of proof is almost impossible to carry. If any state of facts -- known, inferable, or even hypothetical -- would support the legislative action, the action stands. If the matter is debatable, as it almost always is, the government is free to decide that action is necessary, and to choose the means by which to intervene.

In light of these principles, and considering the advantages demonstrated by economists to inhere (at least in theory) in incentive approaches to air pollution control, there is no question that the federal or state government could adopt a TEP program free of due process concerns. The United States Supreme Court has not invalidated an economic regulation on due process grounds since the Depression. Whether or not the same can be said of the California Supreme Court, it is clear that the court's current views coincide with the generalization above.[3] The same is true of the courts of other states, which have rejected due process arguments in recent cases upholding incentive approaches to environmental and related problems -- e.g., bottle deposits to control litter, cigarette taxes to defer smoking cigarettes with high nicotine and tar content.[4] Finally, the legal literature on incentive approaches to environmental control -- primarily emission fees -- concludes that due process requirements do not present a real concern.[5]

What has been said of due process may also be said of equal protection. Once again, in the area of economic regulation, there need be only a rational basis -- broadly read -- for any system of classification or differentiation adopted by the legislative body.[6] There would be no problem, then, in limiting TEP to SO_x emissions, or even to SO_x emissions from particular important sources. As explained elsewhere in this report, there are a number of reasons why SO_x might lend itself to TEP in ways that other pollutants do not (e.g., linearity of relationships, availability of models, breadth of effects). One study of the legal aspects of emission charges, an approach closely related to TEP, concludes:

> [C]harges plans do not appear to be in any danger from equal protection claims. In particular, those designed to apply to one parameter only of an environmental problem (e.g., . . . sulfur dioxide), or to reach only the worst sources, would very likely survive equal protection challenges under federal and state constitutions.[7]

Due process and equal protection are not the only matters of constitutional law that might arise in connection with adoption of a TEP program; the others, however, are best examined in the issue-by-issue discussion of particular TEP elements. Before turning to that discussion, some legislative provisions have to be considered.

Legislative Provisions

Congress has, since 1970, played a dominant role in air pollution control. In that year it enacted legislation establishing demanding requirements not only for pollution sources but for states as well; in 1977 the legislation in question was amended in various ways of relevance here. Taken together, the 1970 and 1977 legislation (now called the Clear Air Act) requires, among other things, that all states achieve (by deadlines extending to 1987) ambient air quality standards established by the United States Environmental Protection Agency (EPA). In addition, (1) states -- or areas within states -- that meet or surpass the federal ambient standards must adopt measures designed to prevent significant deterioration of air quality, and major stationary sources constructed in such areas must, among other things, employ the best available control technology (BACT); (2) states -- or areas within states -- that do not meet the federal ambient standards must adopt measures to correct conditions in such nonattainment areas, and major stationary sources constructed in such areas must, among other things, comply with the lowest achievable emission rate (LAER) (moreover, existing sources in such areas must upgrade their control technology as "expeditiously as practicable"); (3) major sources constructed in either kind of area, if they are subject to new source performance standards (NSPS) promulgated by the EPA, must at the least comply with the emission limitations set by those standards.

For present purposes, item number (2) of the requirements listed above can be ignored, because the SCAQMD complies with the national ambient air quality standards related to SO_x.[8] By virtue of meeting those standards, however, the District is a so-called PSD (prevention of significant deterioration) area, and this brings into play the BACT standards mentioned in (1) above. The NSPS mentioned in (3) also apply. BACT and NSPS establish minimum performance standards for individual sources.[9] To the extent these standards apply, then, reliance on a TEP program is limited by present federal law: a source subject to the standards would have to comply with them no matter how many permits it held. (This does not mean that there is no room for TEP, even as to sources subject to BACT or NSPS; examples to the contrary are discussed below. It does mean that a full-blown TEP program does not appear to be authorized by the Clean Air Act, though there are counterarguments -- again to be considered below. If a full-blown program cannot be pursued, then not all of the economies made possible by the TEP approach will be realized: some sources will be controlling to a degree inconsistent with cost minimization.)

We said above that the TEP approach is constrained by federal BACT and NSPS requirements -- to the extent those requirements apply. Explaining the extent of application is cumbersome. The following remarks try to put the situation in a nutshell.

1. NSPS are promulgated by the EPA on a pollutant-by-pollutant, category-of-source-by-category-of-source basis. We can say that a source is "on list" when a standard is prescribed for a given pollutant from a source of the size and type in question. Once on list, sources thereafter constructed (or modified)[10] are subject to the prescribed standard. The EPA has promulgated NSPS which, I presume, are of relevance here. There are, for example, SO_2 standards for fossil fuel fired steam generators, electric utility steam generating units, sulfuric acid plants, petroleum refineries, and primary copper, zinc, and lead smelters.

2. The BACT requirement applies to major facilities[11] constructed or modified in PSD areas (such as the SCAQMD, in the case of SO_x). A modification is defined for purposes of this requirement in the same way as it is defined for purposes of NSPS. A modified (but not a new) source can escape the BACT requirement, however, and also other preconstruction review requirements applicable to PSD areas, if it offsets increases resulting from the modification by equal or greater reductions elsewhere in its operations, so that there is no emissions increase in the aggregate. This is known as the "bubble" approach. If the source in question were "on list," however, it would still be subject to NSPS (the bubble is not permitted with regard to NSPS).

In addition to the federal requirements sketched above, there are a series of local (SCAQMD) performance standards which, like the federal ones, apply on a source-by-source basis, and which, again like the federal standards, are relevant here because they set emission limitations for SO_2. There are, for example, SCAQMD SO_2 standards for sulfur recovery plants, sulfuric acid plants, fossil fuel fired steam generating plants, petroleum refineries, and so on. Some of these local standards are largely under state and local (as opposed to federal) control. The Clean Air Act generally permits state and local governments to control existing stationary sources in any way they choose consistent with the achievement and maintenance of ambient air quality standards. Put another way, if we assign a given abatement burden to existing sources, state and local authorities can allocate that burden among the sources as the authorities see fit. (If state and local standards are made part of the state's SIP -- state implementation plan -- then changes in the standards may require federal approval, but the approval should be granted so long as the changes are consistent with the overall control strategy required of the area in question.) As to these standards, then, it should be possible to switch to a TEP approach: marketable permits in an amount consistent with the aggregate emissions represented by the present standards would simply be issued, and the source-by-source standards abandoned. Other of the local standards, however, implement federal NSPS and BACT requirements, and these could not be replaced by TEP as a matter of local discretion. Rather, the Clean Air Act itself would have to be amended, for as we saw the act as it stands sets emission limitations that establish minimum performance standards for individual sources. To repeat our earlier conclusion, then, the act presently appears to foreclose full-scale reliance on TEP.

Having said this much, we should consider several arguments that might be advanced in support of the permissibility of applying TEP to all sources (of SO_x) despite the apparent prohibitions of the Clean Air Act.

1. One study of the legal aspects of economic incentives for pollution control, by Irwin, concludes that there is some basis for incentive programs (presumably including TEP) under the Clean Air Act,[12] but the conclusions are of little help to us here; in fact, they simply confirm what was said above. Thus, while Section 111 NSPS are not discussed, Section 112 hazardous pollutant standards are, and the conclusion is that Section 112 does not authorize economic incentives as a control technique. The reasons given -- essentially that Section 112 contemplates source-by-source emission limitations only -- apply equally to NSPS under Section 111, for, as we saw above, that section also appears to contemplate minimum source-by-source levels of control. (The same is true, of course, of PSD requirements.)

The Irwin study argues that Section 110 of the Clean Air Act does permit economic incentives as an approach to control, and one can readily agree. The scope of permission is limited, however. Section 110 requires states to prepare SIPs to achieve federal ambient air quality standards, and authorizes the EPA to do so in instances of state default. It is reasonably clear that economic incentives can be used as part of an SIP, but not as a substitute for NSPS or BACT source controls. Thus incentives could be used to control SO_x emissions from existing sources. This is the same conclusion we reached earlier.[13]

2. Putting aside certain exceptions, not relevant here, regarding motor vehicle emissions, Section 116 of the Clean Air Act permits states to adopt air quality and emission standards of their own, provided such standards are at least as demanding as otherwise applicable federal standards. Might this section permit a state or locality to opt for TEP rather than federal source-by-source requirements, so long as the degree of control achieved by TEP in the aggregate is equal to or exceeds those federal requirements? Common sense might suggest an affirmative answer, but the act quite clearly says otherwise. Section 116 provides in part

> that if an emission standard or limitation is in effect under an applicable implementation plan or under Section 111 or 112, [states and localities] may not adopt or enforce any emission standard or limitation which is less stringent than the standard or limitation under such plan or section.

The reference to Section 111 in this language incorporates NSPS, and the reference to implementation plans incorporates the BACT requirements imposed on PSD areas (under Section 110, SIPs for attainment areas must make provision for PSD programs, including the BACT standards for major new or modified sources). As explained earlier, NSPS and BACT express minimum requirements for individual sources. A full-scale TEP program would contemplate that some sources would exceed these minimum requirements. Thus such a program is not authorized by Section 116.

This reading of the Clean Air Act is confirmed by the ASARCO case, holding that source modifications that result in increased emissions bring NSPS into play even if the increased emissions are fully offset by reductions elsewhere in the source.[14] If a single plant cannot escape NSPS by arguing that its aggregate emissions have not increased, then it is abundantly clear that a group of sources cannot do so by arguing that their emissions have not increased.[15]

3. Section 405 of the Clean Air Act directs the EPA, in conjunction with the Council of Economic Advisors, to "undertake a study and assessment of economic measures for the control of air pollution. . . ."[16] The question arises whether this section might authorize the EPA to approve a full-scale TEP program for SO_x emissions in the SCAQMD, at least on an experimental basis. The answer, it appears, is no.

Section 405 combines two proposals -- one from the Senate calling for study of financial penalties as a means to encourage more effective NO_x controls, and one from the House pertaining more broadly to economic measures that might supplement the present regulatory approach or serve as a means to control presently unregulated problems.[17] The Senate proposal (now contained in Section 405(f) of the act) is limited, then, to emissions of no concern to us here, and in any event quite clearly contemplates some sort of emissions tax or charge. The House proposal (now contained in Sections 405(a)-(e) of the act) is more general, but nothing in its brief legislative history suggests other than what comes out of a straightforward reading of the text of Section 405 itself -- namely, that Congress had in mind economic approaches that might serve as supplements to (not substitutes for) present regulatory controls in the act, and economic approaches that would aim at problems not controlled at the present time. (Section 405(c) leaves some very slight room for a more optimistic assessment.) A TEP program for SO_x emissions falls into neither category. Moreover, nothing in the language of Section 405 or its legislative history provides credible support for the idea that Congress intended to authorize pilot projects, much less projects that would in effect sanction even temporary significant departures from requirements -- like NSPS and BACT standards -- explicitly stated elsewhere in the act. In any event, Section 405 requires that the studies called for be concluded within two years after enactment of the provision -- that is, by August 1979. Even if Section 405 otherwise authorized a TEP experiment, then, it would do so no longer.[18]

<u>Summary and Some Further Observations</u>

A TEP program as a means of air pollution control would not appear to suffer any general constitutional infirmities; however, particular constitutional constraints -- to be considered below -- do bear on program design and implementation. The legislative picture is different: present federal, state, and local provisions -- because they set minimum standards for individual sources -- would limit the range within which TEP could operate. Some of the state and local provisions are of less concern than the federal ones, because they are matters of state and local discretion and could be changed if California authorities were enthusiastic about TEP. (EPA approval of these changes would probably be necessary, but presumably would be granted.) Other state and local provisions, however, implement requirements set pursuant to the Clean Air Act. With regard to these, changes could be approved by the EPA only if approval would be consistent with the act. Approval of a full-scale TEP program for SO_x emissions in the SCAQMD, it appears, would be inconsistent with the act, and thus unlikely to be forthcoming; if forthcoming, approval would be vulnerable to successful legal challenge from environmentalists or regulated firms, both of which are likely to be unenthusiastic about TEP. It appears, then, that amendment of the Clean Air Act would be necessary to authorize a full-scale TEP program. At the least, such an amendment would probably entail a good deal of time and trouble; the chances of success are uncertain.

None of the foregoing should be taken to suggest that some sort of TEP program could not go forward, though it would require some changes in state and local law, and probably EPA approval. The choice of means for controlling existing stationary sources of pollution is largely in the hands of California authorities.[19] Even as to new sources, some of these (unhappily, the least significant ones) are likely not to be on the NSPS list, or likely not to be of sufficient size to be covered by the BACT requirements of the PSD program. As to all such sources, TEP would appear to be acceptable as the primary means of control. Moreover, TEP would have <u>some</u> advantages even as to sources subject to the minimum requirements of NSPS and BACT. New or modified sources subject to such standards, for example, might in fact be capable of higher degrees of control, and TEP could provide incentives to reduce emissions beyond the regulatory standards. A firm using BACT would still be emitting pollutants for which it would have to hold permits, and this would move the firm to control further if the cost of doing so were less than the cost of permits that would otherwise have to be held. Similarly, sources that could do no better than BACT could still induce higher levels of control in the aggregate by purchasing permits from other sources, not subject to BACT, that were in fact able to manage degrees of control that went beyond the BACT standards. But the converse does not follow: Even if BACT or NSPS requirements were very expensive for some sources subject to those standards, the sources could not avoid the standards (and promote efficiency) by purchasing permits. It is in this fashion that present federal requirements appear to foreclose full-scale reliance on TEP and thus make it impossible to realize some of the economies of the approach.

SPECIFIC ISSUES

It is time to turn to some particular issues, taking them up in an order that corresponds, at least roughly, to the order in which they would arise in designing, implementing, and enforcing a TEP program.

Enabling Legislation

As we saw above, present federal law probably does not authorize a full-scale TEP program, even as an experiment; thus federal legislation, in the form of an amendment to the Clean Air Act, is a necessary or at least prudent step. Whether state legislation would be required is less clear; the present state statutes might be read to authorize a TEP program, promulgated either by the California Air Resources Board (ARB) or the SCAQMD (a change in SCAQMD regulations would, in any event, be needed). Even if not required, however, specific state legislation would be desirable: it would remove any doubt as to whether the ARB or the SCAQMD has been delegated authority to implement a TEP program; it could provide standards and guidelines to help protect the ARB or SCAQMD against charges that program adoption or implementation were abuses of agency discretion.[20]

Ideally, federal and state legislation enabling a TEP program should be limited to the SCAQMD.[21] The question considered here is whether such legislation, restricted to one geographic area, is constitutionally permissible.

Under both the federal and state constitutions, this question appears to involve two aspects. The first is general to both constitutions, and requires that we return briefly to the issue of equal protection. The argument might be made that the federal or state legislative body, in limiting the legislation in question to one particular area, has made a classification that violates equal protection of the laws.[22] Our earlier discussion suggests that such a contention is unlikely to be taken seriously. It would be plainly rational to begin a new approach to environmental control on an experimental basis, to limit the experiment to a single area, and to choose the area in question by reference to the severity of its pollution conditions, the abilities of its control authority, and its access to relevant information.[23] On the last point, the very fact that the study of which this paper is a part has developed the information necessary to run a TEP experiment only in the SCAQMD provides of itself strong support for the conclusion that there is nothing arbitrary in authorizing the experiment for the SCAQMD alone.

The second aspect of a legislative provision limiting TEP authority to the SCAQMD is treated slightly differently under federal and state constitutional law. At the federal level there is a principle of equality between the states. At one time, this principle might have supported an argument by some state other than California that Congress, in giving a TEP option to the latter that it withheld from other states, had treated the states in an unequal and constitutionally forbidden manner. Assuming such an unlikely challenge were made (and it appears that it could only be made by a state, as opposed to some dissatisfied individual or group), it would meet with no success today. In South Carolina v. Katzenbach, the United States Supreme Court limited the equality principle, holding that it "applies only to the terms upon which States are admitted to the Union, and not to the remedies for local evils which have subsequently appeared."[24]

The facts of the Katzenbach case are suggestive: The Voting Rights Act of 1965, which created new remedies for discrimination in voting, contained a formula that confined the remedies to a small number of states and political subdivisions that, the legislative history disclosed, Congress had particularly in mind because of their record of substantial voting discrimination. It was this singling out to which South Carolina objected, claiming a violation of the equality principle. In rejecting that claim for the reason noted above, the Court held that the act "was a permissible method of dealing with the problem." "In acceptable legislative fashion, Congress chose to limit its attention to the geographic areas where immediate action seemed necessary."[25]

This language certainly supports the sort of limiting approach already used by Congress in air quality legislation -- the formula in the 1967, 1970, and 1977 acts that had (and still has) the effect of permitting waivers of the new motor vehicle preemption provision in California[26] -- so long as there is a rational basis for the limitation. But the Katzenbach case can be read to go further, allowing Congress to explicitly limit legislation to named areas or even a single named area -- so long, again, as it has a rational basis for doing so. And we have already noted that limiting a TEP experiment to the SCAQMD would be a sensible way to proceed.

At the state level, the constraint of concern here is expressed differently, because of a number of provisions in the California Constitution requiring uniform operation of general laws and prohibiting special legislation. The outcome, though, should be the same. "These provisions . . . do not prevent classification by the Legislature, nor do they require that statutes operate uniformly with respect to persons or things which are in fact different." Moreover, "it is clear that the test for determining the validity of a statute where a claim is made that it unlawfully discriminates against any class is substantially the same under the state prohibitions against special legislation and the equal protection clause of the federal Constitution."[27] If we were correct in concluding that a TEP program for the SCAQMD would survive an equal protection challenge under the United States Constitution, then it should fare just as well under the state constitution.

Defining Pollution Permits

By defining pollution permits I mean determining the total number of permits to be available in a given period (e.g., per year) and determining the "contours" of individual permits -- determining, that is, precisely what a permit allows its owner to do. (What amount of pollution may be emitted per permit? Over what period? To whom may rights be transferred?) These, I think, are primarily design not legal problems. The only legal requirements appear to be the loose one of due process (discussed earlier) and the somewhat tighter ones imposed by federal and state legislation.

We have already discussed the problem of the minimum source-by-source requirements found in present law. Assume now either that our conclusions regarding those requirements are incorrect, or that the necessary amendments have been realized. Still a constraint remains, having to do with ambient air quality standards. The total number of permits and when and where they can be used must all be consistent with achieving the various federal and state ambient air quality standards that bear on our problem. I assume this means that some kind of model or models must be developed and used, and they must show in a reasonably convincing (not arbitrary or irrational) fashion that the total number of permits and the rules governing how they can be used and traded by individual sources, must reveal a scheme that, in principle anyway, will achieve each of the relevant ambient standards (peak, average annual, etc.).

Presumably we have the necessary models and the capability to translate them into a suitable definition of rights and rules governing their use and exchange. It would be the agency's burden to justify the accuracy of the models and the sufficiency of the evidence on which they are based.[28] If the agency could not do so, its program might be invalidated on any number of grounds: inconsistency with ambient standards; arbitrary and capricious action; denial of due process. A similar fate could befall the program if the agency action is based on enabling legislation that itself adopts faulty models, though here, perhaps, there would be more deference to the legislative (as opposed to the administrative) judgement, at least as regards a challenge based on due process.

In fact, I anticipate that the definitional problem might not be too difficult. This is so not simply because we have good models available, but also because we are dealing with a pollutant regarding which the federal (and perhaps some of the state) ambient standards have been met. We should already have, then, a good picture of the maximum total pollution load that can be tolerated. We need only assume, in addition, that permits are controlled in such a way as not to exceed that total, and that unlawful hotspots are avoided.

A final design problem relates to enforcement, discussed more generally later. Permits should be defined in a way that is consistent with abilities to monitor compliance. We would not, that is, want to assign characteristics to permits that could not be adequately measured. If, for example, monitoring technology allows us only to know a rate per day, permits should not be defined in terms of rate per hour. (I assume this point is sufficiently plain that my utter unfamiliarity with monitoring capabilities does not obscure what I'm trying to say.)

To conclude this section, we might note a general guiding principle: the definition of permits, regarding both legislative and due process constraints, should not have to be any more precise than the source standards of present law; it should, though, be just as precise.

Distributing Pollution Rights

The question of distribution concerns who gets how many permits. Again, I think the problem is primarily one of design, not legality. Any scheme with an arguably rational basis should suffice. So long as permits are defined in a way consistent with the discussion in the last section, it should be permissible to distribute them by auction, by giving them to existing sources on the basis of any rational plan (e.g., in accord with a source's present emissions, in accord with the existing or a projected SIP, in accord with the competitive equilibrium, or in accord with some amount based on but less than the competitive equilibrium, in order to avoid strategic problems in the market; we might add here, though, that distributions based on a projected competitive equilibrium should have behind them a convincing account of how the equilibrium was determined).

The foregoing conclusions are based on our earlier discussion of due process, and on the following points that can be taken as guiding principles.

1. Permits can be grandfathered -- distributed to existing sources. Programs that favor existing firms over new entrants are commonplace, not only in the air pollution field but in related areas (e.g., land use) as well. In the case of air pollution control, for example, all of the following programs favor existing sources relative to future ones, and have never been thought to be invalid for that reason: the federal offset program for nonattainment areas can be, and often is, implemented in a way that in effect assigns property rights to existing sources, from which new entrants must, essentially, purchase rights to pollute; federal new source performance standards

set more demanding emission limitations for new sources than those generally applicable to existing sources; under the federal bubble approach, existing sources can avoid NSPS in making modifications, whereas new sources must comply with NSPS. In the land use area, zoning programs typically allow nonconforming land uses to continue if they existed prior to enactment of the zoning legislation, at least for a time (the so-called amortization period); a broad array of growth controls imposed by zoning and other land use regulations have been upheld even though they favor owners of developed land over owners of undeveloped land.[29] More generally, both the United States Supreme Court and the California Supreme Court have endorsed the broad principle of grandfathering in regulatory programs, so long as there is a rational basis for the approach.[30]

2. Regulated entities need not be treated on a perfectly consistent basis, so long as there is a rational basis for unequal treatment. For example, the fact that any particular method of distribution would end up costing some sources more than others (including costing some existing sources more than other existing sources) is not a basis for invalidating the method, at least if it cannot be shown that the method of distribution is meant to be discriminatory and for reasons having no relation to the public interest. There is, in short, no requirement that a pollution control program cost all sources the same.[31] Generally speaking, virtually any method of distributing marketable permits (except some very perverse methods designed to subsidize inefficient firms) will end up favoring sources with relatively low control costs,[32] and this of itself should be considered an acceptable -- indeed, commendable -- aim.

3. Even if a particular method of distribution has the effect of putting some existing firms out of business, or of forbidding entry to some firms, this does not make the method vulnerable to attack so long as it has a rational basis. We have already seen that federal, state, and local governments can establish reasonable controls on air pollution, and we have argued that there should be no general constitutional objection to implementing these controls through marketable permits (because the approach has a rational basis).

It is clear that otherwise reasonable regulatory controls are not invalid simply because they may put some firms out of business; the same conclusion should follow for marketable permits.

In Union Electric Co. v. EPA,[33] the United States Supreme Court considered the issue whether technological or economic infeasibility provided grounds for challenging EPA approval of an SIP. The Court held in the negative, against the contention of petitioner, a major utility, that because it could not possibly comply it would have to close down certain of its facilities. In reaching its conclusion, the Court referred to remarks from the Senate committee acknowledging the real possibility that some plants might be put out of business.[34]

The Union Electric case was relied upon in a recent decision of the Pennsylvania Supreme Court that considered an issue similar to that under discussion here. In Pennsylvania Department of Environmental Resources v. Pennsylvania Power Co.,[35] the Department ordered the utility to limit its emissions of particulates and SO_2, and when the utility failed to comply, initiated an action for civil penalties. Penalties were imposed, but subsequently overturned in part (the SO_2 penalties) by an intermediate court on the ground that compliance with the emission limitation was technologically impossible: the intermediate court held that under such circumstances the penalties would be unconstitutional.

The Supreme Court of Pennsylvania reversed this decision. The Department, it held, was legislatively empowered to establish technologically impossible standards; indeed, the court took note that in enacting the federal legislation underlying the Pennsylvania standards -- the Clean Air Act -- Congress explicitly acknowledged that its effect might be to put some firms out of business. And this acknowledgment, the court said, was "condoned" by the United States Supreme Court in Union Electric.[36] The Pennsylvania court went on to say that to some degree the issue of technological impossibility was left by Congress to the states, so long as ambient standards are met. It then cited a number of Pennsylvania cases upholding authority to shut down plants that could not comply with technologically impossible standards. The court said:

> Thus Pennsylvania has recognized that technological impossibility will not provide a license to continue in an industrial activity which falls below the designated air quality standards. This judgement is consummate with the clearly expressed congressional intent, and its constitutional propriety has been recognized by the U. S. Supreme Court. Union Electric Co. v. EPA, supra.[37]

Given its view that a firm could lawfully be forced out of business for noncompliance with technologically impossible standards, the Pennsylvania court upheld civil penalties as an alternative (indeed, preferred) sanction. The penalties keep firms alive but give them time and incentives to develop new control technologies.

Implicit in the decision in the Pennsylvania Power case is the idea that the penalties imposed there would be upheld even if they had the effect of forcing a firm out of business. If a firm may be directly shut down, surely it may be pushed to closure by an incentive system which, though designed to stimulate technological development and keep firms alive, has the effect of forcing termination of marginal firms. And if civil penalties may permissibly have this effect, the same should follow for TEP. The Pennsylvania Supreme Court would, I think reach this conclusion in light of its decision in Pennsylvania Power. I trust the Supreme Court of the United States and that of California would concur.

4. One of the few papers addressing the legality of transferable permit systems for pollution control asks the following question:

> [S]uppose an existing discharger had to close shop because he could not afford a sufficient number of marketable effluent permits sold at auction. Could he successfully sue to enjoin the . . . system on the ground that, as applied to him, it was in effect an unconstitutional "taking" of his property without compensation, in violation of due process rights guaranteed to him under the Fifth Amendment?[38]

The paper answers in the negative, but largely for a reason that is of no help to us here.[39] Still, one can agree with the conclusion on several grounds. First, the taking issue is implicitly rejected by those decisions, discussed in point (3) above, upholding the constitutionality of reasonable pollution controls that have the effect of forcing some firms out of business.

Second, air pollution is a nuisance like activity, and harsh regulation -- even prohibition -- of such activities has (for better or worse) almost always survived the taking challenge.[40] To sell permits at auction should no more work a taking than would reasonable control regulations that happened to be beyond the means of a particular source.

Third (and putting aside cases where the government actually occupies an owner's property, or transfers title to the property to itself), the taking issue generally becomes a significant one only when government regulation forecloses virtually any use of an owner's property -- makes it worthless or at least forecloses any reasonable return (even here, a taking is avoided if the property in question was being used in a nuisance-like fashion). That would probably not occur in our case, for the TEP program would not foreclose other uses of the property, though it might result in substantial losses of value in some instances.[41]

If, then, a TEP program for Southern California relied on auctions to distribute permits, the foregoing considerations suggest that no insurmountable taking problem should arise. Having said that, I admit to being uncomfortable with the conclusion. "Nuisances" or not, the fact is that polluting firms are a very important part of the economic base of the Los Angeles area, and any court would pause before endorsing a program that could have deeply disruptive effects.[42] Then, too, it is one thing to make entrants compete for permits, and another to make existing firms do so.[43] Moreover, TEP would be a novel approach, a new regime, and courts would probably be especially concerned to protect existing interests from the possibly severe effects of a seemingly bold social experiment. Surely, though, legislators would be sensitive -- probably more so -- to these same considerations. As a political matter, then, auctions -- at least as the sole means of TEP distribution -- are probably unlikely. Such a political judgment could well represent as well a cautiously wise approach in terms of constitutional law. This is not to say, though, that auctions could not be relied upon in part,[44] or gradually phased in as the sole means of distribution; each of these latter approaches would lighten the impacts of auctions and thus the concern with taking problems.

5. If we turn from distribution to what might be called redistribution of permits under a TEP program, we see another way in which the taking issue can arise, and again it is a difficult issue on which to reach any firm conclusion. Suppose a firm doing business under a TEP regime has 100 permits each of which allows the firm to emit X amount of pollution per day for one year. During the year in question the SCAQMD determines that the total number of permits outstanding is too large to realize achievement of the ambient air quality standard. May the District simply cancel an appropriate number of outstanding permits, or must it purchase them?

To simplify a difficult problem, assume that enabling legislation clearly provides for cancellation, and that it specifies standards by which to "spread" cancellation on some equitable basis among firms. Assume too that the determination that too many permits are outstanding is based on good evidence, reasonable models, and so forth. Assume, in other words, that all the general due process and equal protection concerns discussed earlier have been satisfied here, and the only issue is whether a permit under TEP is some sort of property right that cannot simply be cancelled.

One way to get at that issue is to first consider how it would be resolved if the permit in question were a traditional operating permit issued to a polluting firm on condition that it meet the emission limitations, etc., established by a regulatory program. Can the terms of the permit subsequently be changed? For example, can emission limitations be made more stringent?

Our earlier discussion -- in particular, that concerning changes in pollution control regulations that might force some firms out of business -- has already suggested that the answer is yes, and this does indeed seem to be the case. The regulations could be changed unless the firm has a vested right, and it appears that permits issued under the police power as part of a regulatory program do not confer vested rights; the permit is accepted subject to the power of the government to impose further regulations in the public interest.[45]

Does the situation change if marketable permits are substituted for regulatory standards? I simply am not sure, and I have not found any authorities more pertinent than those already discussed. The easiest case would arise if permits were initially distributed to existing firms free of charge, and one of these firms later complained when some of its permits were cancelled. Here, the firm should be regarded as in essentially the same position it would occupy in a regulatory regime, and in that regime -- presumably -- cancellation would be permitted. Even here, though, the firm could argue that transferable permits gave rise to expectations and were more "property like" than an operating permit under a regulatory regime.

The harder case, of course, arises if permits are auctioned, or if the complaining firm purchased some or all of its permits from another firm; the complaining firm could argue that it made substantial expenditures in reliance on an expectation created by the permits that they were indeed licenses to pollute, not subject to cancellation without compensation. The obvious response is that even in a regulatory regime firms make investments based on permits, yet we have presumed that the terms of those permits could be changed. With TEP, though, the total investment (by firms which have purchased permits) will typically be larger. Moreover, there may in a court's view be something about marketable permits that makes them more "property like," more like vested interests.[46]

One answer to our problem may be to have the permits, or the legislation behind them, specify that they are subject to cancellation under certain conditions.[47] The difficulty is that this may create uncertainty and impede operation of the TEP market. On the other hand, firms might simply have faith, as they presently must, in the legislative body's good judgement in making alterations in the established control program.

Another answer to the cancellation problem might be that, as a matter of good policy, compensation <u>should</u> accompany cancellation of permits. This would enhance the market by making permits reliable; it would discipline authorities in considering changes. It would also be expensive, however, and if permits were not auctioned at the outset (and this is likely), there would be no convenient revenues with which to fund compensation. Moreover, the argument that a compensation requirement would discipline government decision processes is not very compelling if the level of government insisting on tighter controls is not the level footing the bill. Given the existing pattern of federal mandates and state execution, this situation could easily arise.[48]

Enforcement

We come now to the most difficult (perhaps the only difficult) issue addressed in this paper, having to do with matters of enforcement in instances of violations of the TEP system. Typically, violations will consist in sources polluting in excess of their permits. The question is what might be done about such cases. Two general issues arise. The first concerns the mode of enforcement; the second concerns proof of violations. We shall take these up in turn.

1. Were the TEP system to rely on the traditional means of enforcing regulatory statutes, no difficult legal problems would arise. A small handful of enforcement techniques has been in such long and regular use that the question of constitutional acceptability is beyond doubt. Moreover, though they may not be perfect, these techniques are easily adapted to a TEP system. Thus the legislature could, with ample federal and state precedent, provide that acts of pollution-sans-permits would make sources subject to civil fines,[49] criminal sanctions, or injunctions.[50] All of these, though, would be imposed through the judiciary, and one might like to go further; court actions -- criminal proceedings in particular -- entail a number of procedural protections for defendants that, taken together, can make for a very inefficient system of sanctions. Could one, then, give direct enforcement authority to administrative officers, with only limited judicial review to protect against arbitrary action -- review, that is, short of a full-scale trial on the merits? On the federal level the answer to this question is clearly in the affirmative. On the state level, one cannot be quite so confident. Local air pollution control districts are empowered to deal with a violator by revoking its permit after a hearing,[51] and I presume that revocation is not subject to de novo judicial review; districts may also issue abatement orders.[52] Permit revocations and abatement orders are, of course, sanctions "whose consequences may be drastic. . . . May the legislature instead give the administrator the power to utilize an economic sanction of lesser severity? Specifically, may it authorize the administrator to impose a money penalty when he deems this an appropriate means of law enforcement?"[53]

One would think that the greater power to revoke a permit would include the lesser power to impose a milder economic sanction, yet in many states, California apparently included, this is not clear.[54] Civil administrative penalties might be attacked in California on several overlapping grounds -- unlawful delegation of legislative authority, separation of powers, denial of the right to a jury trial in civil actions, denial of the right to procedural protections accorded criminal defendants. A good deal of research has left me more or less unenlightened regarding how receptive the California Supreme Court would be to such challenges, but I am inclined to be hopeful that it would follow the federal lead, and that of a few state courts,[55] and reject each of them.

The federal picture can be gathered quickly from brief mention of two recent decisions by the United States Supreme Court. In the first, Atlas Roofing Co., Inc. v. OSHRC,[56] the Court rejected a challenge that administrative penalties imposed pursuant to OSHA denied the seventh amendment right to jury trial in suits at common law.[57] The seventh amendment, the Court held, does not extend to adjudication of new statutory public rights created by Congress. In the second case, United States v. Ward,[58] the Court held that an administrative penalty imposed under the Federal Water Pollution Control Act was civil and did not trigger protections afforded by the Constitution to criminal defendants (e.g., right against self-incrimination, right to jury trial).

2. Let us turn now to the matter of proving violations of the TEP System -- in particular, polluting without permits. If good monitoring technology exists, the problem is a simple one: the enforcement agency could simply rely on monitoring reports and compare these to inventories of permits per source in order to determine the degree of noncompliance, if any, and appropriate sanctions could then be imposed. Self-reporting of permits purchased and amounts of pollution emitted could be required and, if the legislative form of the sanction (e.g., some formula) makes it possible, sources could also be required to compute and remit fines based on their violations.[59] Spot checks and other auditing procedures would be needed to assure accurate reporting.[60]

Proof of violations is obviously more difficult if good continuous monitoring technology does not exist, but the problem is not insurmountable. This, at least, is the conclusion of the only treatment of the subject I have found -- that by Anderson et al.[61] That study surveys the state of the art in monitoring technology (as of about 1977) and concludes that direct continuous monitoring techniques do not exist for all cases. The study suggests, though, that there are satisfactory alternatives -- proportional sampling, materials balance (suitable, it appears, for determining SO_x emissions from power plants), and -- of greatest interest here -- estimation. The following quotation summarizes the study's remarks on the estimation approach:

> Where satisfactory techniques for actually measuring discharges, either directly or indirectly, are unavailable, or where the available techniques impose expenses that are unduly burdensome in relation to the size of the enterprise being monitored, it may be necessary to simply estimate the quantities in question. There are probably many cases in which the degree of accuracy achieved by estimation would be satisfactory to both the charging authority and the discharger; and it may be used in preference to direct measurement even where relatively inexpensive direct monitoring techniques are available. For example, the Ruhr basin water associations . . . limit their monitoring to a periodic sampling and fairly crude laboratory analysis of a discharger's effluent. The samples are taken only infrequently from any given plant; and in practice many, if not most, of the dischargers are satisfied to pay fees based on estimates of the quantity and strength of their discharges derived from various measures of plant activity.

> Estimation may also be the only feasible monitoring procedure in the case of very small dischargers, such as automobiles or domestic oil burners, or in the case of nonpoint sources such as feedlots or strip mines. Estimates may frequently be tied to some measure of the activity of a discharger. In the Czechoslovakian system . . . , for example, the amount of BOD discharged by a brewery is estimated according to a formula which includes the number of employees (to take into account the use of sanitary facilities), the number of kegs and returnable bottles washed, the number of kegs and bottles filled (to take into account spillage), and the total quantity of beer produced. Coefficients for each of these parameters have been developed empirically and are applied uniformly to all breweries. Any individual plant has the option to demonstrate that process changes or treatment facilities have reduced the amount of BOD in its effluent below the estimated value and thereby receive a reduction in the charges payable. It should be possible in most cases to develop a set of parameters and coefficients like these which will enable the charging authority to estimate the quantities of air or water pollutants discharged by a given plant using a given production method with a fair degree of accuracy.
>
> Estimation is probably best used in conjunction with other techniques, principally sampling, which can serve to augment and verify the figures developed by estimation. It may in fact be the most attractive of all the monitoring techniques. First, once the estimation formulas have been developed, applying them to determine the amount of the charge due is virtually costless. And so long as the formulas are reasonably accurate, the estimation approach would not be subject to challenge as being arbitrary. If, as would usually be the case, the discharger may reduce the charges payable by demonstrating that its discharges are less than the estimates, the discharger is free to make the economic choice between potential savings on charges and the expense of installing monitoring equipment which would produce a more accurate, and presumably lower, indication of the quantities being discharged. The same economic principles will operate to provide a badly needed incentive for the development of new, less expensive, and more accurate monitoring instruments.[62]

In closing, we might make two observations suggested by the Anderson study. First, the monitoring problem should not be any greater obstacle to a reasonably effective TEP system than it is to a regulatory regime; both require measurement of discharges.[63] Second, perhaps the problem should be considered an easier one in the TEP context, if a sanction based on the value of noncompliance by the firm can be devised. Such a sanction -- paying the price of a permit divided by some detection probability -- might be less severe from the firm's point of view than a typical regulatory sanction (e.g., large fine, revocation of permit).[64] Given this, courts should be willing to tolerate less precision in the means used to prove violations -- especially if the source is free to submit more accurate information.

FOOTNOTES

1. Most issues relating to income taxation -- e.g., whether a taxable gain (or loss) would be realized upon sale of a TEP -- are not considered here. Some of the constitutional law of taxation may, however, be relevant (at least by analogy) to questions concerning the distribution of permits.

2. There are several papers on the legal aspects of marketable pollution permits; none of them is very satisfactory for our purposes. See R. deLucia, "An Evaluation of Marketable Effluent Permit Systems," Sec. 7 (EPA-600/5-74-030, September 1974); R. Anderson et al. (of Mathtech, Inc.), "An Analysis of Alternative Policies for Attaining and Maintaining a Short-Term NO_2 Standard," Sec. 7.6 (prepared for the Council on Environmental Quality); R. Kerr, "An Air Rights Market and the Legal Precedents Favoring Its Implementation" (unpublished, undated). The deLucia paper discusses several of the constitutional issues we shall address, but not in a thoroughgoing fashion. The paper does concur, though, with our conclusion that marketable permits suffer no general constitutional infirmity. The Mathtech paper's legal "analysis" is nothing more than a one-page summary of deLucia. Kerr's paper is more substantial. By and large, its concern is to show that approaches analogous to marketable pollution permits already exist (e.g., transferable water and development rights). Kerr calls these analogies "precedents"; a number of relevant constitutional issues are not discussed. Kerr also argues that the Clean Air Act -- particularly its offset and prevention-of-significant-deterioration provisions -- contains "precedents" for marketable pollution permits. If he means by this that the act <u>authorizes</u> such permits on a substantial scale, then I disagree with him -- as we shall see.

3. See, e.g., <u>Metromedia, Inc. v. City of San Diego</u>, 26 Cal. 3d 848, 610 P.2d 407 (1980), prob. juris. noted, 49 U.S.L.W. 3270 (U.S. Oct. 14, 1980) (billboard controls). As indicated, the United States Supreme Court recently granted review in the <u>Metromedia</u> case. This no doubt reflects the first amendment issues of commercial speech involved in that case but not present in our context. Put aside those issues, and the Court would no doubt regard the controls upheld in <u>Metromedia</u> as entirely unexceptionable.

4. See the discussion in W. Irwin, "Economic Disincentives for Pollution Control: Legal, Political and Administrative Dimensions," Sec. 5 (EPA-600/5-74-D26, July 1974) (hereinafter Irwin). While Irwin's discussion notes some cases contrary to the generalizations in the text, these clearly do not represent the mainstream.

5. See the literature cited in Irwin, _supra_ note 4, at 38 n.1.

6. For a recent application of this principle by the United States Supreme Court in a case involving economic regulation, see _Minnesota v. Clover Leaf Creamery Co._, 15 E.R.C. 1473 (U.S., 1981), upholding state legislation banning retail sale of milk in plastic nonreturnable containers.

7. F. Anderson et al., "Environmental Improvement Through Economic Incentives" 122 (1977) (hereinafter Anderson). See also Soper, "The Constitutional Framework of Environmental Law," in _Federal Environmental Law_ 20, 73-74 (E. Dolgin and T. Guilbert eds. 1974):

> For the most part, legislative regulation of environmentally harmful activities of individuals or business concerns should not be vulnerable to claims that others, "similarly situated," have not been dealt with equally harshly. In this respect, . . . environmental regulation resembles economic regulation and should similarly require only a rational relationship to a legitimate legislative objective in order to withstand attack on equal protection grounds. Familiar principles in this context -- a statute is not invalid under the Constitution because it might have gone farther than it did; a legislature need not "strike at all evils at the same time"; "reform may take one step at a time, addressing itself to the phase of the problem which seems most acute to the legislative mind" -- should operate to provide wide leeway for legislative initiatives. Recent cases that have considered the issue in the environmental context have had little trouble rejecting the equal protection argument.

8. The SCAQMD has not achieved the California sulfate ambient standard, nor -- perhaps -- the state's SO_x ambient standard. These state standards, more demanding than the federal requirements, have not been made part of California's state implementation plan (SIP). Accordingly, state and local officials believe, failure to meet the state standards does not make the SCAQMD a nonattainment area for federal purposes. (The Los Angeles County Superior Court recently invalidated the state ambient standards for SO_2 and sulfates. _Western Oil and Gas Association v. California State Air Resources Board_, Los Angeles Superior Court No. C246284. The decision has no particular bearing on our discussion.)

9. Section 165(a)(4) of the Clean Air Act, regarding BACT in PSD

areas, prohibits construction of major sources unless "the proposed facility is subject to the best available control technology for each pollutant subject to regulation under this Act emitted from, or which results from, such facility." Section 111(e), regarding NSPS, states that "it shall be unlawful for any owner or operator of any new source to operate such source in violation of any standard of performance applicable to such source." BACT is at least as strict as NSPS, and may be more demanding.

10. "Modified" denotes physical changes in a source, or changes in its methods of operation, which increase the amount of pollutants emitted.

11. A major facility is (1) a source that emits or has the potential to emit 100 or more tons per year of any pollutant _if_ the facility is on a list of 28 source types specified in Section 169(1) of the Clean Air Act (e.g., iron and steel mills, copper smelters, fossil fueled steam electric plants of more than 250 million BTUs per hour heat input, petroleum refineries, etc.); _or_ is (2) any other source with the potential to emit 250 or more tons per year of any pollutant.

12. See Irwin, _supra_ note 4, at 72-75. Irwin's study was written prior to passage of the 1977 amendments to the Clean Air Act. The 1977 amendments provide little if any additional support for the TEP approach.

13. Federal courts have invalidated reliance on pollution dispersal techniques (tall stacks) and intermittent controls as means to achieve ambient air quality standards, because they do not reduce the total amount of pollutants eventually released into the atmosphere. See M. Jaffe et al., "Legal Issues of Emission Density Zoning" 19-20 (EPA-450/3-78-049, September 1978). Since a TEP program would reduce the total pollution load, it should present no problem in these terms -- unless the courts conclude that there must be emission limitations applicable to _each source_. Such a conclusion would be inconsistent with the generally accepted view that Section 110 of the Clean Air Act permits use of such economic incentives as emission fees, unless the notion is that emission fees and similar approaches are to be used only as supplements to source-by-source emission controls. In my view this is an unduly narrow and unlikely reading of Section 110.

14. The "bubble," that is, is not permitted. See _ASARCO Inc. v. EPA_, 578 F.2d 319 (D.C. Cir. 1978). The D.C. Circuit's recent decision in _Alabama Power Co. v. Costle_, 13 E.R.C. 1993 (1979) (permitting bubble under PSD provisions) is arguably inconsistent with its earlier ruling in the ASARCO case and may suggest that the latter will be overturned, at least as to NSPS in clean areas. See Note, "The EPA'S Bubble Concept After _Alabama Power_",

32 Stan. L. Rev. 943 (1980). In any event, new (i.e., unmodified) sources will still be subject to NSPS.

15. Could TEP be applied on top of NSPS and BACT, so long as sources subject to those standards at least comply with them? Anderson, supra note 7, at 133, worries that the answer might be no:

> The language chosen by Congress [in Section 116] leaves us with some lingering doubt that Congress intended to do more than authorize states to set higher standards than those which the state would have had to impose for the minimal satisfaction of the federal scheme. Congress did not prohibit the creation of a separate regulatory mechanism, such as supplementary charges, but neither did it appear to contemplate more than the possibility of stricter state applications of the standards and procedures within the framework specified in detail in the federal legislation.

I think this concern is unfounded.

16. Section 405 is reproduced in full in the Appendix.

17. See S. Rep. No. 95-127, 95th Cong., 1st Sess. 106-08 (1977); H.R. Rep. No. 95-294, 95th Cong., 1st Sess. 341, 447-48 (1977). See also the Conference Report, H.R. Rep. No. 95-564, 95th Cong., 1st Sess. 187 (1977).

18. At least two other sections of the Clean Air Act provide for research programs, but I doubt that either would authorize the sort of TEP experiment contemplated here -- despite their authorization of demonstration projects. See Sections 103, 104. I have not looked into the legislative history of these provisions.

19. Remember, though, that modification of existing sources can bring NSPS and BACT into play.

20. In California Hotel and Motel Association v. Industrial Welfare Commission, 25 Cal. 3d 200, 211-12, 599 P.2d 31, 38 (1979), the California Supreme Court summarized the approach to be taken by California courts in judicial review of legislative acts by administrative agencies in the state. Agency action will be upheld if (1) the agency acted within the scope of its delegated authority, (2) used fair procedures, and (3) acted reasonably. Regarding the last point, agency action will be upheld unless arbitrary, capricious, or lacking in evidentiary support. The courts scrutinize agency action to ensure that the agency "has adequately considered all relevant factors and has demonstrated a

rational connection between those factors, the choice made, and the purposes of the enabling statute." (The Los Angeles County Superior Court employed the foregoing standards to overturn California's ambient SO_2 and sulfate standards in the decision discussed in note 8 supra.)

21. The information needed to implement a TEP experiment probably does not exist as to other areas at this time; to permit other areas to go forth, then, would be to invite apparent failure of the experiment. This is one reason to limit TEP; another is that, given its novelty, it should be contained both to facilitate effective study and to limit any problems that might develop. Still, areas denied TEP authority might complain that they lose an advantage made available to the SCAQMD; and sources (or environmentalists) in the SCAQMD might claim that they are being subjected to regulatory burdens (or regulatory "decontrol") not found in other areas in the state. Challenges like these have to be anticipated.

22. The legislative limitation might be explicit, authorizing only the SCAQMD to adopt a TEP program; or it might authorize any area to use TEP so long as the area meets certain requirements, and then specify requirements that only the SCAQMD could meet (e.g., population requirements). The federal Clean Air Act has used the latter approach to free California, but only it (until passage of the 1977 amendments) from federal preemption of emission standards for new motor vehicles. As we shall see, either approach is probably acceptable.

23. Recognition of the value of limited experiments conducted in areas well qualified to undertake the experiments was one reason for freeing California from the preemption provisions mentioned in note 22 supra. See Currie, "Motor Vehicle Air Pollution: State Authority and Federal Pre-Emption," 68 Mich. L. Rev. 1083, 1090 (1970).

    We might note at this point the United States Supreme Court's observation that "the Equal Protection clause relates to equality between persons as such rather than between areas. . . . Territorial uniformity is not a constitutional requisite." Salsburg v. Maryland, 346 U.S. 545, 551-52 (1954). See also McGowan v. Maryland, 366 U.S. 420, 427 (1961). Still, it appears that territorial distinctions must have a rational basis. We have argued that such a basis would plainly exist in our case.

24. 383 U.S. 301, 328-29 (1966).

25. Id. at 328.

26. See note 22 supra.

27. County of Los Angeles v. Southern California Telephone Co., 32

Cal. 2d 378, 388-89, 196 P.2d 773, 780-81 (1948). See also Rainey v. Michel, 6 Cal. 2d 259, 270, 57 P.2d 932, 937 (1936) ("It has been consistently held that an act of the legislature applicable to one class only, when that class is reasonably the subject of classification, is a general law, and is not in conflict with any of the provisions of the state Constitution prohibiting special legislation."). In Stout v. Democratic County Central Committee, 40 Cal. 2d 91, 251 P.2d 321 (1952), the court invalidated, as unconstitutional special legislation, a measure aimed at "any city and county" (which could only be San Francisco, the only city and county in California). The court, however, was not formalistic; the measure was invalidated not because it singled out one area, but because the singling out had no conceivable rational basis. See also Solvang Municipal Improvement District v. Jensen, 111 Cal. App. 2d 237, 241, 244 P.2d 492, 494 (1952), upholding a special legislative act when it involved "none of the evils against which the Constitution affords protection."

28. See the discussion in Silver, "Problems in Attempting to Translate Statutory Standards into Emission Limitations under Air and Water Pollution Control Legislation," 22 Vill. L. Rev. 1122, 1130-32 (models for derivation of controls), 1132-37 (underlying tests and measurements) (1976-77).

29. See, e.g., Ellickson, "Suburban Growth Controls: An Economic and Legal Analysis," 86 Yale L. J. 385 (1977). Growth controls are not uniformly upheld; a main ground for their invalidation, through -- that they are intended to exclude low income and minority consumers of housing -- is of no concern to us here.

30. See, e.g., New Orleans v. Dukes, 427 U.S. 297 (1976), upholding a city ordinance prohibiting pushcart food vendors from operating in the French Quarter of New Orleans, but exempting vendors who had been in business for at least eight years. The opinion suggests, though, that the rational basis for the classification was that eventually all pushcarts would be phased out of business. This should not, however, be the only rational basis. To give permits to existing sources but force new entrants to purchase them would serve the legitimate public ends of inhibiting growth in sources, minimizing disruption to the economic base of the community, and easing administration; it would also reflect the likelihood that new sources are in a better position than existing sources (who would have to retrofit) to adapt in an efficient manner to the new permits regime. On the California law, see, e.g., Hunter v. Justice's Court, 36 Cal. 2d 315, 223 P.2d 465 (1950) (exempting working oil fields from newly enacted oil well spacing law); Accounting Corp. v. State Board, 34 Cal. 2d 186, 208 P.2d 984 (1949) (discrimination against new entrants must have some relation to the public interest; to discriminate against some regulatory targets solely because they are new is unacceptable).

State tax cases, involving principles analogous in some ways to the regulatory cases discussed above (taxes can be used for regulatory purposes), are not terribly enlightening. See, e.g., Stevens v. Watson, 16 Cal. App. 3d 629, 94 Calif. Rptr. 190 (1971) (upholding preferential tax assessment treatment to nonprofit golf courses of 10 acres or more that had been operated for at least two years; one rationale for the decision was that the tax scheme discouraged premature development of urban land and encouraged preservation of open spaces). Compare In re Fassettl Cal. App. 2d 557, 69 P.2d 865 (1937), (invalidating a municipal license fee, similar to a municipal tax, and other burdensome regulations on persons operating hog ranches on premises they had not occupied for at least a year prior to enactment of the regulations).

31. See, e.g., Portland Cement Association v. Ruckelshaus, 486 F.2d 375, 388-90 (D.C. cir. 1973), cert. denied, 417 U.S. 921 (1974).

32. Of course, some methods of distribution may end up favoring sources with low control costs more than would other methods of distribution.

33. 427 U.S. 246 (1976).

34. The Court did not give explicit constitutional blessing to such a result, but this was clearly implied. The implication was softened, though, by the Court's noting that issues of infeasibility could be raised at other stages (than approval of the SIP) -- in an application for a variance, for example, or in enforcement proceedings. The Court did not, however, hold that consideration of infeasibility was constitutionally required at these stages.

A case clearer in its implications, although arising in a slightly different context, is EPA v. National Crushed Stone Association, 49 U.S.L.W. 4008 (U.S. Dec. 2, 1980), holding that the EPA, in setting 1977 effluent limitations pursuant to the Federal Water Pollution Control Act, need not authorize variances for companies unable to meet the standards.

> In the High Court's view, the 1977 standards were to be more demanding than that: if point sources in poor financial health are unable to comply with the effluent limitations, they have no alternative but to cease operations. Although not fully comfortable with the prospect of numerous plant closings, the Court saw that Congress had foreseen the likelihood of such impacts and judged them a necessary cost of exerting minimum controls over discharges of pollutants into the nation's waters.

"Comment," 10 Environ. L. Rptr. 10215 (1980).

Needless to say, the Supreme Court would hardly have held as it did if plant closings were a constitutionally unacceptable result.

35. 416 A.2d 996 (1980).

36. 416 A.2d at 999.

37. 416 A.2d at 1001. See also Northwestern Laundry v. Des Moines, 239 U.S. 486, 491-92 (1916):

> So far as the Federal Constitution is concerned, we have no doubt the State may by itself or through authorized municipalities declare the emission of dense smoke in cities or populous neighborhoods a nuisance and subject to restraint as such; and that the harshness of such legislation, or its effect upon business interests, short of a merely arbitrary enactment, are not valid constitutional objections. Nor is there any valid Federal constitutional objection in the fact that the regulation may require the discontinuance of the use of property or subject the occupant to large expense in complying with the terms of the law or ordinance.

38. See deLucia, supra note 2, at 135-36.

39. The deLucia paper is concerned with water pollution, and relies on the federal navigation servitude to dismiss the taking question. See id. at 137. It is worth noting, though, that deLucia also concludes that an auction of rights that had the effect of putting a firm out of business would survive an equal protection challenge. "Auctioning off scarce resources is a nondiscriminatory way of allocating them." Id. at 138.

40. See, e.g., J. Dukeminier and J. Krier, Property 1135-38 (1981).

41. The most thoroughgoing discussion of the taking issue in a context roughly similar to ours is found in Jaffe et al., supra note 13, at 25-44. Jaffe and his colleagues address the legal issues of emission density zoning, a control technique that limits total emissions from units of land rather than from sources. After reviewing a large number of taking cases, the authors conclude that while generalization from state to state is difficult, the trend is in a direction that would uphold emission density zoning. We might add here that the California Supreme Court has been among the most liberal in upholding government

regulations in the face of taking allegations.

42. TEP, of course, might not have such effects if the number of permits auctioned were close to the amount of pollution presently being emitted.

43. It is not clear in the discussion by Jaffe et al., notes 13 and 41 supra, whether the authors contemplated application of emission density zoning to land already devoted to industrial (polluting) uses. There is a long tradition in zoning -- some think it is constitutionally required -- to free pre-existing land uses from subsequently enacted zoning ordinances, at least for a time. Sometimes these nonconforming uses are simply permitted to go unregulated; more often they are subject to amortization techniques that allow them a specified period within which to conform with the zoning regulations or cease operations. If an auction system were to be used for TEP, perhaps the latter, phasing-in technique would provide a good approach.

44. E.g., distribute 90 percent of the rights to existing firms and auction the remainder.

45. For state cases, see e.g., Rosenblatt v. California State Board, 69 Cal. App. 2d 69, 158 P.2d 199 (1945); Castleman v. Scudder, 81 Cal. App. 2d 737, 185 P.2d 35 (1947), both involving occupational licensing.

On the federal level, cases involving broadcasting licenses are instructive. See, e.g., the early (but still, I think, viable) case of Federal Radio Commission v. Nelson Brothers Bond and Mortgage Co., 289 U.S. 266 (1933), involving termination of a broadcasting license. In upholding the action, the court said (id. at 282):

> That the Congress had the power to give this authority to delete stations, in view of the limited radio facilities available and the confusion that would result from interferences, is not open to question. Those who operated broadcasting stations had no right superior to the exercise of this power of regulation. They necessarily made their investments and their contracts in the light of, and subject to, this paramount authority. This Court has had frequent occasion to observe that the power of Congress in the regulation of interstate commerce is not fettered by the necessity of maintaining existing arrangements which would conflict with the execution of its policy, as such a restriction would place the regulation in the hands of private individuals and withdraw from the control of Congress so much of the field as they might choose

> by prophetic discernment to bring within the range of their enterprises.

Though I am quite confident that our analysis of the cancellation issue in the context of a regulatory regime is correct, the fact is that the cases are not perfectly consistent regarding what is a vested right. See, e.g., Vicent Petroleum Corp. v. Culver City, 43 Cal. App. 2d. 511, 111 P.2d 433 (1941) (oil drilling permit not property right but only a privilege, and can be revoked); Trans-Oceanic Oil Corp. v Santa Barbara, 85 Cal. App. 2d 776, 194 P.2d 148 (1948) (oil drilling permit was a vested right and could not be revoked).

46. Even assuming that marketable permits were property interests that could not be cancelled without compensation, it should not follow that the permits could not be redefined in a way that reduced their value but did not make them worthless. Government regulations that diminish property value are commonly upheld against taking challenges. See the text at note 41 supra.

    I have not pursued a line of argument that would run as follows: transferable permits issued by the state represent a contractual commitment upon which permits owners are entitled to rely, such that changing the terms of the commitment in a substantial way would violate the Constitution's mandate (Article I, Section 10) that a state shall not pass laws impairing the obligation of contracts. I doubt that permits would be viewed as "contracts." Moreover, it is open to considerable doubt in any event whether the state could contract away its permits, in essence, to exercise the police power in the future. Cf. L. Tribe, American Constitutional Law 470-73 (1978).

47. It is interesting to note that the federal legislation in the Nelson Brothers case, note 45 supra, did not provide for cancellation, though the Court regarded language authorizing refusal of licenses or their renewal as extending to cancellation.

    I leave aside whether cancellation would require, as a matter of due process, any procedures beyond those normally required in altering a regulatory regime (e.g., notice and comment).

48. We should note here a matter related to the foregoing discussion. A TEP program should provide for what might be called "temporary cancellations" during emergency episodes. In other words, permits and the legislation behind them should provide, just as the present regime of regulation does, that under certain alert conditions special control requirements apply. I see no legal problem whatsoever in putting such a regulatory overlay on top of a TEP program.

49. Design of such a fine may not be a simple matter if the idea is somehow to equate the expected value of the fine to the value to the source of violating the TEP system (polluting without a permit), at least in the case of violations by firms that make up, individually, a large part of the demand for permits. The expected value of the fine to the firm is the magnitude of the fine times the probability the fine will be imposed (the violation detected). Assume a 75 percent probability of detection. The fine should then be about one and one-third times as large as the value to the firm of polluting without a transferable permit. The latter value, presumably, is the market value of a permit on a given day. Assume a firm that is a heavy polluter, and thus a heavy purchaser of permits. When it participates in the market, permits trade at $2,000, when it does not participate, permits trade at $1,000. The firm decides on a given day, when it would need 10 permits (costing $20,000), to purchase (or use) none. Thus, permits on that day trade at $1,000 each. If the fine is based on the market value of permits on the day of violation (because this measures the economic value of noncompliance to the violating firm) divided by the probability the fine will be imposed, the firm, if caught, will pay a fine of roughly $13,400 for not using permits that would have cost it $20,000! The fine would be $1,340 per violation because that number times 75 percent equals roughly $1,000 ($1,005).

The foregoing problem was suggested to me by Dr. Robert Hahn, and I do not know how realistic it is. Moreover, maybe I have put it in the wrong way. There are at least two ways to respond to the problem (if it exists). One might base the fine on an estimate of the amount permits would have commanded if the firm had participated in the market (or on an estimate of the control costs saved by the firm, though I am not sure this is a relevant number). Alternatively, one might use the ordinary method of permitting a fine up to, say, $5,000 per violation, leaving it to the court to settle the amount. This latter alternative would be overkill in some cases, underkill in others, and in any event would vary as a function of the judge imposing it. There then arise problems of unfairness, over- and under-compliance, and perhaps general disutility. See Levinson, "Deterring Air Pollution Through Economically Efficient Sanctions: A Proposal for Amending the Clean Air Act," 32 Stan. L. Rev. 807, 813-14 (1980).

50. For federal precedents see, e.g., Section 113 of the Clean Air Act (civil actions for injunctive relief and civil penalties up to $25,000 per day of violation; criminal fines and imprisonment for certain violations). For state precedents, see, e.g., the following sections of Calif. Health and Safety Code (West 1979 and Supp.) (air pollution): 42400 (violations of statutory provisions and of state or local rules are misdemeanors); 42401 (civil penalties up to $6,000 per day of violation for violating

abatement orders issued by state or local authorities); 42402 (civil penalties up to $500 per day of violation for violating emission limitations and state and local regulations); 42403 (civil penalties to be recovered through civil actions in courts of competent jurisdiction); 42453 (judicial proceedings to enforce abatement orders).

51. See, e.g., Calif. Health and Safety Code Section 42309.

52. See, e.g., id. Section 42450. These, though, are enforced through judicial actions for injunctive relief and may, then, be more cumbersome. See id. Sections 42452-42454. Ultimately, of course, the courts cannot be avoided if the violator is recalcitrant -- a civil or criminal action or contempt proceeding will be inevitable. The idea behind an efficient enforcement system is to limit significant judicial involvement to such extraordinary instances, rather than to make it a routine part of the process.

53. Gellhorn, "Administrative Prescription and Imposition of Penalties," 1970 Wash. U.L.Q. 265, 271. I presume Gellhorn has in mind penalties that would be subject only to limited judicial review to see that the administrative decision was supported by substantial evidence and not arbitrary or capricious. This, as we shall see, is the federal model.

54. California Health and Safety Code Sections 43211-43213 appear to empower the Air Resources Board to impose and collect specified civil penalties in certain cases involving motor vehicle emissions. The sections do not specify the enforcement mechanism other than to say the ARB shall "enforce" the provisions. I have no idea what the statutes contemplate or what the Board does.

55. See, e.g., City of Waukegan v. Pollution Control Board, 57 Ill. 2d 170, 311 N.E.2d 146 (1974) (upholding, against challenge based on separation of powers, legislation giving pollution control board discretion to impose civil fines). See also K. Davis, Administrative Law of the Seventies Section 2.13 (1976).

56. 430 U.S. 442 (1977).

57. The unlawful delegation argument has been a dead letter at the federal level for some time.

The structure of the OSHA penalty system reveals the limited role typically played by courts in reviewing administrative penalties. An inspector imposes the penalty. If the alleged violator wishes to contest it, he has a right to an evidentiary hearing before an administrative law judge. The judge's decision is an appealable order subject to review by the full OSHRC. If review is granted, the OSHRC decision on the penalty becomes final unless the violator seeks judicial review in a court of appeals. In the event of judicial review, the OSHRC findings on questions of fact are conclusive if supported by substantial evidence. If the violator fails to pay the assessed penalty, provision is made for a collection action in federal district court in which neither the fact of the violation nor the propriety of the penalty may be retried. Thus a violator never gets a jury determination of the facts constituting the violation.

58. 48 U.S.L.W. 4926 (U.S. June 27, 1980). The tests used by the Supreme Court to distinguish between civil and criminal penalties are obscure and to some degree wrong-headed. For discussion see Levinson, _supra_ note 49, at 821-24. See also Lundermann, "Constitutional Aspects of Economic Law Enforcement," _4 Harv. Environ. L. Rev._ 41 (1980). There are California cases suggesting that the legislative designation of a penalty as civil is conclusive, but I do not take these seriously. See, e.g., _Madonna v. State of California_, 151 Cal. App. 2d 836, 312 P.2d 257 (1957).

Note that the Court in _Ward_ held that the penalty did not trigger the self-incrimination clause. Hence the legislation under review could constitutionally require, as it did, that violators report their violations -- so long as they were immunized from criminal prosecution for the facts reported.

Assume that the California Supreme Court would hold administrative civil penalties unconstitutional as a matter of state law. The federal Clean Air Act, in its Section 120, provides for a civil administrative (noncompliance) penalty, and it could be amended to extend to a TEP system. The EPA could then enforce the penalty. Section 120 provides at present that the EPA may delegate its powers under the noncompliance penalty to the state. Assuming state agencies could not, as a matter of state law, impose such penalties otherwise, could they do so in the event of a delegation from the EPA? Scant authority indicates that the answer might be yes. Cf. _Eden Memorial Park Association v. Department of Public Works_, 59 Cal. 2d 412, 380 P.2d 390 (1963).

59. This technique would protect against claims of an unlawful delegation of _legislative_ power to the agency. In fact, I believe some discretion could be granted to the agency, so long as the enabling legislation indicated standards to be considered in setting the penalty. The agency, of course, would still be exercising powers of a _judicial_ sort -- it would, for example, be determining facts. But agencies commonly do this today -- for example, in revoking permits. That the sanction is a money penalty rather than revocation of a permit should make no difference.

60. If the sanctions for polluting without permits were civil (as

opposed to criminal), a self-reporting requirement would not infringe upon the right against self-incrimination. A failure to report, or to report accurately, could be subjected to criminal sanctions; probably, though, information in or growing out of the self-report could not be used against a reporting source in a criminal case, except for prosecutions for giving false reports. See United States v. Ward, note 58 supra. A number of provisions in California's air pollution legislation permit or require monitoring and self-reporting (e.g., Calif. Health and Safety Code Sections 41511, 42303, 42304, 42700, 42705, 42706), prohibit false statements (Section 42303.5), and provide for inspfalse statements (Section 42303.5), and provide for inspections and fees to cover inspection expenses (Sections 41510, 41512, 42707).

61. Note 7 supra. The Anderson book is concerned with emission fees, but the discussion is equally applicable to transferable permits. The parts of the book bearing on proof of violations and summarized briefly in the balance of this paper are found at pp. 90-106 and 138-43. I add two comments: (1) Proof of violations is easier with a civil than with a criminal sanction because the government's burden of proof is substantially lower in the first instance than it is in the second. Moreover, proof should be an even simpler matter if administrative civil penalties can be and are used, because the format of an administrative proceeding is more relaxed than the format of a civil trial: the rules of evidence are likely to be less demanding, for example, and the absence of a jury should make it easier to deal with such relatively complex matters as sampling techniques, assumptions underlying emission estimates, and so forth. (2) Statistical techniques may be used to prove violations (as we shall see, Anderson et al. make this point). They may be clumsy at times, but they are used -- and sucessfully. An instance has to do with cases involving racial discrimination of various sorts -- in jury selection, in housing, in employment. I have not gone into the literature on this matter, however, and I do not know if doing so would prove helpful.

62. Id. at 103-04. See also id. at 93: "Presumptions can be established that bias the system toward a higher rather than a lower charge where there is . . . uncertainty. . . ." Firms should then be free to overcome these presumptions, if they choose, by coming forth with a more accurate means of measurement.

63. See id. at 101-02.

64. Cf. id. at 188.

APPENDIX

Section 405 of the Clean Air Act

SEC. 405. (a) The Administrator, in conjunction with the Council of Economic Advisors (hereinafter in this section referred to as 'the Council'), shall undertake a study and assessment of economic measures for the control of air pollution which could --

(1) strengthen the effectiveness of existing methods of controlling air pollution,

(2) provide incentives to abate air pollution to a greater degree than is required by existing provisions of the Clean Air Act (and regulations thereunder), and

(3) serve as the primary incentive for controlling air pollution problems not addressed by any provision of the Clean Air Act (or any regulation thereunder).

(b) The study of measures referred to in paragraph (1) of subsection (a) shall concentrate on

(1) identification of air pollution problems for which existing methods of control are not effective because of economic incentives to delay compliance, and

(2) formulation of economic measures which could be taken with respect to each such air pollution problem which would provide an incentive to comply without interfering with such existing methods of control.

(c) The study of measures referred to in paragraph (2) of subsection (a) shall concentrate on

(1) identification of air pollution problems for which existing methods of control may not be sufficiently extensive to achieve all desired environmental goals, and

(2) formulation of economic measures for each such air pollution problem which would provide additional incentives to reduce air pollution without --

(A) interfering with the effectiveness of existing methods of control, or

(B) creating problems similar to those which prevent alternative regulatory methods from being used to reach such environmental goals.

(d) The study of the measures referred to in paragraph (3) of subsection (a) shall concentrate on

(1) identification of air pollution problems for which no existing methods of control exist,

(2) formulation of economic measures to reduce such pollution, and

(3) comparison of the environmental and economic impacts of the economic measures with those of any alternative regulatory methods which can be identified.

(e) In conducting the study under this section, a preliminary screening should be made of the problems referred to in subsections (b)(1), (c)(1), and (d)(1) and economic measures should be formulated under subsections (b)(2), (c)(2), and (d)(2) in the most promising cases, giving special attention to structural and administrative problems. In formulating any such measure which provides for a charge, the appropriate level of the charge should be determined, if possible, and the environmental and economic impacts should be identified.

(f) Within one year after the date of enactment of this Act, the Administrator shall complete a study and report to the Congress on the advantages and disadvantages (including an analysis of the feasibility) of establishing a system of penalties for stationary sources on emissions of oxides of nitrogen and make recommendations regarding the establishment of such a system. Such study shall determine if such a system will effectively encourage the development of more effective systems and technologies for control of emissions of oxides of nitrogen for new major emitting facilities, or existing major emitting facilities, or both. In any case in which a proposed penalty system is recommended by the Administrator, the report should include --

(1) a recommendation respecting the appropriate period during which such system of penalties should apply, and the appropriate termination date or dates for such system, if any, taking into account --

(A) the time at which adequate technology may reasonably be anticipated to be available to control oxides of nitrogen for that category of facilities,

(B) the degree to which such technology can be expected to be used on such facilities, and

(C) the Administrator's authorities to require the use of such technology, and

(2) recommendations respecting the compilation of

records by facilities subject to such penalties for purposes of determining the applicability and amount of such penalty.

(g) Not later than two years after the date of the enactment of this section, the Administrator and the Council shall conclude the study and assessment under this section and submit a report containing the results thereof to the President and to the Congress. Interim reports on specific pollution problems and solutions recommended shall be made available to the President and the Congress by the Administrator whenever available.

CHAPTER 5

THE EFFECTS OF PUBLIC UTILITY REGULATION ON THE EFFICIENCY OF A MARKET FOR EMISSIONS PERMITS

James M. Gerard

INTRODUCTION

Tradable emissions permits (TEP) are one example of incentive-based approaches to controlling environmental pollution. The key to the effectiveness of these proposals is their ability to channel the quest for profits into achieving a given amount of abatement of pollution at minimum costs to society. In the case of a market for emissions permits, the efficiency of the policy depends on whether the market is competitive and whether each polluter seeks to minimize the sum of abatement costs and expenditures on permits, given its rate of output.

Electric utilities pose a special problem in the implementation of TEPs. Electric utilities using fossil fuels are often a major source of the most difficult-to-control air pollutants, and are therefore likely to be an important factor in a permits market. Electric utilities are also subjected to extensive regulation of their prices, investments and profits by public utilities commissions. Economic regulation is basically a set of rules and procedures for deciding whether a particular cost element can be passed on to customers, and if so, how. Consequently, how a utility will act in a market for emissions permits, and what abatement strategies it will adopt, are affected by the way that utilities regulators treat expenditures on permits for purposes of rate making.

This paper explores how economic regulation of utilities affects their response to TEPs. After laying out a general description of the public utility regulatory process, the paper turns to a detailed analysis of how key decisions about the treatment of TEP expenditures for rate-making purposes will affect the decisions by utilities about how, if at all, they will participate in a permits market.

The Utility Regulatory Process

Public utility regulation proceeds by separating the costs incurred by a regulated utility into four general categories. First, some activities of the utility may not be regulated. All costs attributable to these activities must be excluded from the process of calculating the revenue requirements of regulated activities. Second, some costs that are attributable to regulated activities may nevertheless be branded as wasteful by the regulators, and thereby excluded from the revenue requirements of regulated activities. Third, some costs are classified as capital investments. These costs are to be spread out over time, and so only a fraction are allowed to be recovered in any one year. At the same time, the regulated firm is allowed to earn profits on these expenditures. Fourth, some costs are classified as operating expenses. They may be recovered in their entirety in the year in which they are made, but may not enter into the calculation of the profits that the firm may earn. Regulation then proceeds to set prices of regulated services so that the allowed costs of the third and fourth type, including a reasonable profit on capital investments, will exactly equal total revenues.

The scheme for classifying allowed costs as either operating or capital expenses is more complicated than one might expect. Operating expense treatment is afforded all of the "support equipment, material, and services" sustaining the operation of utility plant in public service. Included in this classification are: general and administrative expenses, maintenance (including replacement parts and service contracts), advertising, taxes, insurance, depreciation allowances, and fuel expended in the production of electricity -- fuel stocks held in storage are an element of working capital, part of the rate base. Capital expenses are "nonrecurring plant investment" for the purpose of providing regulated service.

How a cost element is classified affects the willingness of a regulated business to bear it. Most obvious is the importance of the distinction between allowed and disallowed costs. If regulators indicate the slightest possibility of disallowing a cost element on the belief -- correct or incorrect -- that it is unnecessary or wasteful, utility managers would be unwise to incur it and risk the financial health of the company.

Another important distinction is the separation between capital investments and operating costs. An attractive feature of classifying a cost as a capital expense is that it can then enter into calculating the allowed profits of the firm. But there are unattractive features as well. Because capital costs determine allowed profits, regulators fear that these costs are more likely to be padded and hence scrutinize them somewhat more carefully. By contrast, many elements of operating costs are subject to automatic adjustment clauses whereby changes in these costs are automatically passed through into the price structure of the utility with little or no regulatory review. In addition, the fact the capital expenditures <u>can</u> cause higher allowed profits does not mean that they <u>will</u>. If the allowed rate of return on capital investments is lower than the cost of raising new funds on capital markets, it is disadvantageous to the firm to undertake new capital investments. In the 1970s, both of these effects were important in affecting the incentives of utilities with respect to environmental policies. Both contributed to a general preference for low-sulfur fuel over capital investments in abatement equipment as a means to reduce sulfur emissions at electric generation facilities.[2]

The presence of public utility regulation also affects incentives through the effects that it has on the translation of risks into the financial structure of the regulated utility. As implied above, the structure of cost accounting in the regulatory process makes capital investments somewhat more risky to the firm than operating expenses. In addition, the so-called "common carrier" or "public service" doctrine also affects risks. According to this principle, regulated utilities must provide service on demand at regulated (presumably remunerative) rates. Regulatory officials, while scrutinizing whether service is provided in an efficient manner, are willing to let firms pass through costs associated with making the probability extremely low that demand will exceed capacity. The result of this process is that regulated utilities are risk-averse with respect to their abilities to serve their customers, but risk-taking with regard to costs, relative to behavior that would be expected in the absence of regulation. To illustrate the point, utilities tend to prefer "cost-plus" contracts for constructing new generation facilities, or even to act as their own architect/engineer/contractor, rather than to engage in "fixed price" contracts.[3] The reason is that if a regulated utility experiences an unanticipated but unavoidable cost increase, it is likely to be able to pass most of it on to ratepayers through a price increase, whereas no such opportunity exists for a construction firm operating on a fixed price contract. Consequently, the fixed price contract will include a substantial risk premium to reward the construction firm for bearing the risk. This gives the utility an incentive to adopt a contracting form (cost-plus) or alternative arrangement (self-contracting) that allows ratepayers to bear the risk but lowers the expected cost of the investment to the utility.

The preceding discussion all bears importantly on the likely response of a utility to the implementation of tradable emissions permits. The issues of concern to the regulated utility will be:

1. Are permits an allowable cost?

2. If so, are they capital costs or operating expenses?

3. How, if at all, will the presence of a permits market affect the ability of the utility to satisfy its public service obligation?

4. How will a permits market affect the financial risks of the utility business, and who will bear these risks?

As it turns out, there is no simple answer to most of these questions. The implications of marketable permits for the financial condition of a utility depends crucially on two related issues: how the permits are defined and the market for them is set up, and to what particular cost category expenses for permits are assigned. These issues are related because the former decision can affect the latter one.

TEPS AND ELECTRIC UTILITIES: A REGULATORY CASE ANALYSIS

The remainder of the paper deals with the disposition of the TEP within the accounts system of the regulated firm. Economic analyses are not usually concerned with the niceties of accounting practice, but in this instance, some attention must be given to these issues. The allowed profit rate of the regulated firm is a well-defined quantity, expressed as a percentage of the value (defined by some fixed standard) of capital assets of the firm meeting certain tests for admissibility as public utility investments. The purchase of a TEP endows a firm with a valuable conditional property right, a right somewhat analogous to those enjoyed by owners of more conventional kinds of property (land and water, for example). Proceeding by analogy in the disposition of various classes of real and intangible property (citing California rate hearings for the most part), it is possible to say a great deal about how the TEP may finally be viewed by utility regulators. This, in turn, will allow an analysis of the effect of particular regulatory rules on the utility's choices over TEPs versus abatement.

EMISSIONS PERMITS AS "PRIVATE" PROPERTY

The regulation of air pollution is, of course, a classic example of a social response to a common property problem. Uncoordinated private exploitation of a common pool resource will in general lead to a suboptimal allocation of its use, because competing private interests lack the incentive to take into account the social costs each imposes on the others. In the existing legal framework, the State is empowered to modify or constrain exclusive private control over various classes of property, including (but not limited to) use rights for common pool property such as air and water. To use the terminology of Calabresi and Melamed [1972], the State is faced with the problem of settling and enforcing an <u>entitlement</u> that defines the limits of private rights, and hence, the extent of public property. The two major dimensions of the public policy issue are the decision on where to draw the dividing line between public and private rights, and the method for allocating entitlements. Generally, both equity and efficiency considerations enter the policy debate, since different allocations of entitlements imply different distributions of wealth and common property use.

Within this broad and quite informal outline of property rights, where might the tradable emissions permit fit? A fully detailed legal analysis of the emissions permit is not within the scope of this study;[4] it is sufficient merely to sketch the asset-like properties of the TEP from the perspective of a utility regulator. The prevailing permits system for air quality regulation recognizes de facto rights to use the airshed, but heavily qualifies them. First, the permits are generally nontransferable although changes in regulation during the late 1970s, the so-called "controlled trading options," allow some highly regulated transfers (see Noll [1981]). Second, they are conditional on the polluter's adherence to a set of fixed performance or input standards. Third, they are subject to revision at any time through an administrative process.

The purest form of the TEP approach weakens the immediate influence of government over use rights by limiting government control to the specification of a total, airshed-wide emission ceiling (along with the authority to set the expiration dates of the individual permits which sum up to the ceiling amount). Once the emissions permits are created and allocated, they are freely tradable (subject to verification) between polluting firms.

Even a pure TEP program can be designed so that the local air quality control authority can respond to adverse changes in air quality by adjusting the number of permits. For example, the air pollution control authority can retain the power to change the ceiling on total emissions by giving permits a fixed life and then by failing to renew some of the permits as they expire. While any given emissions ceiling is in force, a simple property rule can hold for trades between polluters (i.e., rights can be transferred between firms at the market rate of compensation). Under this system, emissions permits can be viewed as intangible capital assets which, depending on the allocation mechanism in use, may undergo periodic adjustments in value, but which meanwhile grant to a firm a share of the allowed emissions level established within the airshed.

In some cases, regulators may be concerned that very large sources will create localized "hot spots" -- e.g. local areas where ambient air quality standards are not satisfied because of a high concentration of the area's ceiling on total emissions. A practical solution to this potential problem is to give regulators the authority to constrain the distribution of TEPs through the market by setting maximum emissions standards for a few large sources. Alternatively, regulators could establish a secondary market for permits in the "hot spot" area. Local emissions would be required to satisfy a ceiling that solved the problem of the hot spot, and for firms contributing to the hot spot the more localized, secondary permits would be the binding limit on emissions. In either case, the permits still are qualified rights of access to the airshed much as in the present system, except that only in exceptional cases will the rights actually be qualified by source-specific or other special regulatory interventions. Once again, permits are an intangible capital asset for the period in which they are valid.

EMISSIONS PERMITS IN PRACTICE: MARKET DESIGN ISSUES

The comparative advantages of tradable permits over source-specific pollution regulation have been the subject of a long and thorough theoretical investigation.[5] Unfortunately, the transition to real markets and real firms is certain to involve considerations which to some degree upset the tranquil picture offered by theory. Generalizations about market design do not come easily; each airshed has its own set of potential problems. Are the emissions for which permits are to be created concentrated in the hands of relatively few firms, or dispersed among many? What about the spatial distribution of emissions? Do localized "hot spots" exist, or does the pollutant flow more or less uniformly over the airshed? Given the abatement technologies of polluting firms, is it likely that the volume of trades will be too low to establish a meaningful price? If so, how can more frequent trading be stimulated?

In the context of a particular market implementation, different approaches to design issues imply different definitions of permits. Permits may be defined by setting the spatial boundaries of the market or markets,[6] the length of time permits remain valid, and the rules governing the initialization and continuing operation of the market. Particular choices among market design alternatives have an important bearing on how firms (especially regulated firms) view the TEPs as assets.

Investigations of regulated firm behavior typically take the form of attempts to draw inferences about the firm's optimal response to a particular institution (such as a factor market) given a set of regulatory rules. Here, another degree of freedom exists: different kinds of permits, because they are different kinds of assets from the point of view of the utility rate-making, can lead to different patterns of factor choice by the utility. The task at hand is to determine which of these possible market organizations best reinforce the flexibility and efficiency of air quality control, given the response of the regulated sector. To accomplish this task requires the following: a general statement of the different ways of defining tradable permits, an analysis of the relationship between these definitions and the status of TEPs as private property, and an analysis of how the status of TEPs as private property affects their treatment as allowable costs by utility regulators.

In establishing a program of tradable emissions permits, policymakers face a number of important issues concerning the definition of a permit. First, they must decide on the lifetime of permits. Generally speaking, permits may be defined to have <u>fixed</u>, <u>perpetual</u>, or <u>indeterminate</u> duration. Policy makers must also decide the extent to which the property right in permit is "vested" -- that is, immune to a taking without the payment of fair compensation. This is bound up in the specification of the privileges and powers the permit confers on its owners, along with the subsequent reaction of the courts to attempts (by government agencies, for example) to diminish these rights without compensation. As far as emissions permits are concerned, the prospects for securing full compensation in the event of cancellation by governmental _fiat_ appear dim indeed; the rights are created solely as part of a program for the control of air quality, long recognized as an appropriate area for government regulation of economic activity. Reductions of emissions rights by pollution control authorities are thus likely to be viewed by the courts not as a taking, but as a routine exercise of the police power.[7] In any event, given some resolution of the taking issue which allows a TEP program to go forward, it is possible that a spectrum of permits of varying lifetimes would be created, along with a standardized process of permit renewal, thereby affording air quality regulators flexible control over emissions in the short, medium and long run.

A second market design issue affecting the asset qualities of TEPs is the mode of initialization of the market. Most of the discussion of market initialization has concerned two alternatives: _auctions_ and "_grandfathering_" (although again, it is not unlikely that the program actually adopted will involve a mixture of both.) If the emissions permits are auctioned, policymakers must also decide on the disposition of the revenues from the sale. The state can keep the revenues or, if the distributional (and political) effects of this large wealth transfer are unacceptable, can redistribute the auction revenues to participating firms.[8] The grandfathering option entails an allocation of emissions rights to firms at zero cost, based either upon historical emissions shares or a projection of the shares of emissions at or near the market equilibrium.[9] Once the initial shares have been allocated, subsequent trades occur at prices established within the market.

Although the two methods of initialization can yield similar market equilibria, the courts may not be disposed to view auctioned and grandfathered permits on an equal footing as property. James E. Krier has argued that firms making sizable expenditures on auctioned permits would do so with the expectation that the purchase secures a certain stream of benefits, and therefore, firms would maintain, these benefits could not be arbitrarily interrupted or reduced without due compensation. On the other hand, a court might not be as compelled by such an argument if the rights had initially been distributed _gratis_.[10] Krier finds the courts in some disagreement over the necessary attributes of "compensable" rights.

Finally, there are two major alternatives for organizing the continued operation of the market. The government may take a _passive_ role, functioning merely as a price information exchange and leaving the details of market function to the private sector, or the government may become a more _active_ participant, enforcing regular auctions at which firms must offer some fraction of their permits for sale. The determination of how the market is to be run matters from the standpoint of market efficiency -- different methods will have different properties in terms of the stability of the market price and the transactions costs of the market. As was true for market initialization, the government may intervene in continuing market operations either through purchases and sales of permits or by periodically requiring that existing permits be traded in for new ones, perhaps at trading ratios that are not unity.

EVIDENCE AND METHODOLOGY

In the analysis of the likely treatment of tradable emissions permits by public utility commissions, the available data takes the form of impressions and judgments of regulators and utility employees, standard accounting practice guidelines, and transcripts of rate case decisions. Some care must be taken in interpreting this kind of data. Public utilities commissions are administrative agencies which derive their authority from legislatures, subject to the body of law which has developed subsequent to Munn v Illinois (1877) 94 US 113. As such, Utilities Commissions themselves are not bound by a rule of stare decisis.[11] Commissions have considerable freedom to roll with the economic seas, as long as decisions are not arbitrary or capricious. It is therefore dangerous to draw ironclad conclusions about the rate-making status of a given type of property, based upon the facts of particular rate cases.

ADMISSIBILITY OF TEPS FOR RATE-MAKING PURPOSES

At the opening stage of the rate-making process, the utility will request a rate adjustment to offset expenditures on TEPs; regulators will then have to establish rules for the their treatment. The first test applied to a newly-proposed utility "element of value" is "admissibility for rate-making purposes." The determination of admissibility is logically prior to the classification of the element's components as additions to the rate base (the capital investments of the utility on which the regulated rate of profit may be earned) versus simple treatment as current expenses. Invariably, California rate cases quote Section 216 of the Public Utilities Code:

> "Public utility" includes every common carrier, toll bridge operation, pipeline corporation, gas corporation, electrical corporation . . . , where the service is performed for or the commodity delivered to the public or any portion thereof.

A project, venture, or element of value must be deemed a "public utility" in order for the regulated firm to seek rate relief. The public utility classification subsumes all "electric plant," defined as including:

> all real estate, fixtures and personal property owned,

> controlled, operated, or managed in connection with or to facilitate the production, generation, transmission, delivery, or furnishing of electricity. . . . [Cal. P.U.C., Section 217]

The broad application of Sections 216 and 217 in resolving the admissibility question is tempered by one further consideration: the property or venture must be "dedicated to public use" or alternatively, "used and useful in the public service."[12]

A utility may retain property which is "used but not useful" -- that is, private property of the utility not dedicated to direct public service. For example, Southern California Edison Company is in the salmon business -- as part of its overall management plan for the streams feeding into its hydroelectric generating system north of Los Angeles. The earnings, if any, from such nonutility property are recorded "below the line," i.e., accrue directly to shareholders, but so do all costs incurred. Because by definition nonutility property is divergent from the utility's main line of service, commissions generally restrict nonutility holdings to de minimus, or nearly negligible, levels.

This brings regulators to an initial, important determination: are TEPs to be given full "public utility" status, or, like the fishery management expenditures, are they to be exempted from regulation by the commission? If Section 217 of the Public Utilities Code is narrowly interpreted, the domain of regulation must be restricted to the set of activities performed by the utility in the public interest -- the generation and provision of electricity. Toward this end, the most frequently-adopted regulatory rate-making standard, known as cost of service regulation, establishes a rate schedule designed to cover all prudent costs directly associated with the utility's public purpose: operating costs plus a provision for a fair return on capital devoted to public service.[13] In recent years, however, the boundaries of cost-of-service regulation have blurred considerably. The enactment of the Public Utilities Regulatory Policies Act (PURPA), PL 95-617, in 1978 formally signalled a major change in course for electric utility regulation -- away from policies aimed at supporting the rapid expansion of electrification, towards consolidation and conservation. The changes in regulatory philosophy implied by PURPA, along with the body of previously-established environmental quality control legislation (such as the Clean Air Act), have resulted in an overhaul of the cost-of-service criterion. Utilities commissions have extended the process of regulatory review beyond the direct costs of electricity generation, giving increased attention to the treatment of externalities from electricity production such as pollution and exhaustible resource depletion, in rate design.

There is ample evidence that utility expenditures on tradable permits within a properly-implemented TEP program would be ruled admissible, within the evolving regulatory regime just described, as public utility investments. It has long been regulatory practice to admit pollution control expenditures to public utility status; utilities commissions routinely grant rate relief for expenditures devoted to mandated emissions control equipment (usually, long-lived capital equipment designed to remove pollutants from power plant exhaust gasses) or to input controls (for example, authorization to burn "cleaner," more expensive fuels). In the present framework of pollution regulation, an order for a particular emissions reduction is transmitted from the local, state or federal pollution control authority to the utility. The commission enters the process at the final step, by reviewing and authorizing the expenditures committed by the utility. On a case-by-case basis, the commission rules on whether the utility followed prudent management and engineering practice in complying with the pollution control order. The commission also monitors the initial and ongoing costs of compliance, attempting to ensure that the costs are "reasonable" -- presumably, in comparison with costs of similar controls previously installed by other utilities.

Although the commission itself has little to say in the negotiations leading to a mandated change in the utility's emissions, it does retain full control over the treatment of pollution control expenditures in the utility's accounts. The policy of the California P.U.C. has been to include pollution control equipment in the rate base on an equal footing with all of the other components of "electric plant." When, in a 1977 rate case, California's largest electric utility asked for special, accelerated rate recovery of pollution control expenditures, the commission denied the request.[14] In so doing, the commission plainly expressed its view that a generating facility was not to be considered as electric production plant plus pollution abatement plant, each with its own method of cost recovery, but instead that the the two in combination comprised a single, integrated electric system for rate-making purposes.

Utility regulators have recently demonstrated their willingness to rule favorably on the admissibility of emissions reduction credits (ERCs), which, as will be seen in the next section, represent the closest analogy to tradable emissions permits. ERCs are created as part of the "controlled trading" program for nonattainment areas set forth in the 1977 Clean Air Act amendments, and subsequent EPA interpretive rulings. Firms which make a certifiable emissions reduction below the actual emissions rate allowed for a given source by the State Implementation Plan (SIP) can qualify part of the reduction as an ERC.[15] Once the reduction has been verified, a firm can use the ERC to offset emissions resulting from plant expansion in the nonattainment area; alternatively, the firm can either "bank" the ERC, reserving it for future use, or transfer it to another firm by sale or lease, subject to the rules of the particular air quality control region. The cost of creating an ERC is the cost of the pollution control equipment installed, or the process change made, in order to bring about the qualifying reduction. The crucial difference of concern to regulators between the ERC and the routine purchase of required emission controls is that the former involves an emissions reduction below whatever emissions "baseline" is currently enforced for the class of sources in question. Therefore, the regulators' problem in reviewing the utility's acquisition of ERCs (or, of TEPs) becomes more complex: to the relatively straightforward cost-monitoring task within the command-and-control regime is added a neccessity for the consideration of cost efficiency -- i.e., what is the utility's cost-minimizing combination of abatement activities and emissions credit trades? By and large, regulators seem prepared to take up these new problems and issues. Very recently, a series of discussions were held between the California P.U.C. and a large northern California utility concerning the environmental impact of a proposed major generating station in the San Francisco Bay area.[16] Although plans for the power plant were subsequently shelved for an indefinite time, the utility was advised that any properly-registered ERCs obtained in connection with the project would be treated as utility property. Another, more publicly-documented indication of the status of ERCs is offered by a 1979 Federal Energy Regulatory Commission (FERC) order,[17] which allows a utility to claim the depreciation and amortization benefits on pollution control equipment installed on the facilities of an outside firm for the purpose of creating an ERC. The drift of these regulatory decisions is clear -- both the initial investment and the cost recovery streams associated with ERCs stand an excellent chance of being consistently ruled admissible for rate-making purposes.

Moreover, there is little doubt that a well-defined, closely-administered TEP air quality control program would pass the "dedication" test. Presumably, before the commission would review a utility's plan for participation in a TEP program, the program itself would have the force of law as part of the implementation of Federal and State pollution control regulation. To the extent that the TEP program could be shown to be effective in pursuing air quality goals while minimizing control costs, it would be consistent with the utility regulator's overall concern (under the expanded cost-of-service criterion) with economically-justified investment directed at meeting existing environmental regulations. According to the customary equity consideration applied by utilities commissions in the treatment of utility property devoted to public service, the costs and benefits of the program should be apportioned fairly to ratepayers and shareholders alike;[18] this can only happen if the utility's participation in the program is deemed a public utility under Section 216.

The fact that firms outside the regulated sector would also be participating in the permits market raises no special problems. Public utilities frequently transact within markets (such as real estate) where they compete with nonregulated firms. But once a piece of property becomes a public utility, a component of "electric plant," certain strictures on the transferability of the property are imposed. In particular, utilities are forbidden to sell, lease, or in any way encumber property devoted to the service of the public without explicit commission authorization.[19] This sanction, which might seem at first glance to contribute to higher transaction costs for regulated firms, is not as restrictive as it appears. As a practical matter, the utility may circumvent the formal process by internally transferring the property to a nonutility account, and then disposing of the property as it wishes.[20] All property accounts of the utility are audited during general rate hearings; upon completion of the audit the commission can disallow any improper transfers. In the case of emissions permits, where fairly regular transactions might occur, it is likely that the commission would hand down an order detailing documentation requirements and guidelines for utility-involved TEP transfers, and then allow the utility a good deal of latitude in specific decision-making.

PROPERTY RIGHTS ANALOGIES TO TEPS IN UTILITY ACCOUNTS

The preceding section offered a tentative conclusion on the admissibility of TEPs drawn from the following argument: pollution control equipment and expenses, along with presently-existing controlled-trading emissions "rights," have been granted public utility status; therefore, given the intimate connection between the utility's TEP inventory and the level of abatement activity, a like status is appropriate for TEPs. Assuming that TEPs will be brought under the purview of public utility regulation, our next concern is obvious: might not the specialized accounting methodology applied to regulated firms, in and of itself, contribute to systematic distortions of a utility's incentives to hold TEPs? As a first step, it is useful to explore similarities and differences between the kinds of assets implied by the alternative TEP definitions discussed in Section B and assets routinely appearing in public utility accounts. The results of this exercise will be far from clear-cut; the TEP cannot be neatly pigeon-holed as an exact analogy to any particular class of utility property. Nevertheless, attempting to place the prospective TEPs within the utility accounts via analogy to established utility assets helps to illuminate the central regulatory issues in need of resolution, and, in addition, provides corroborating evidence in support of the conclusion on admissibility.

Consider, then, four common types of utility assets with varying degrees of similarity to TEPs. The first, the (electric) <u>franchise right</u>, is a utility-specific element of intangible property which sets forth the contract between the utility and the municipalities or counties it serves. Next, we look at various types of real property <u>leases</u> as a means of comparison to the important class of TEPs having fixed duration. Finally, we take up the special problems of common-pool property by examining land-water rights, and, as mentioned previously, <u>emissions reduction credits</u>.

Franchise Rights

Black's Law Dictionary defines a "franchise" as an agreement giving the transferee the right to distribute, sell, or provide goods, services, or facilities within a specified area.[21] Here, the term refers to a bilaterally-negotiated agreement of exclusive dealing between a political subdivision such as a municipality and a public utility. Before the utility may exercise its franchise right with a municipality, it must obtain from the utilities commission a certificate of public convenience and necessity, authorizing the utility to expand its service area subject to the practices and rate schedules deemed prudent by the commission. Nevertheless, the franchise contract, as an instrument of regulation, predates the centralized regulatory authorities now in place in most states. Before the creation of state utilities commissions, municipalities were largely left to their own devices in dealing with local monopolies providing electric service. Individual cities and towns sought to mitigate the effects of monopoly pricing by by authorizing utility service through franchise contracts which specified that an annual consideration (either in cash or services such as road paving) be granted to the municipality by the utility. As the local electric monopolies expanded and began to interconnect, the abuses and inefficiencies of the pure franchise system gradually gave way to the central coordination of state public service commissions.[22] The vestigial franchise contract which remains today is limited to the specification of the right-of-way granted the utility by the municipality. The utility is allowed free access to streets, gas mains, transmission lines, and other equipment within city limits; in return for this privilege the utility pays the city government a set fee (usually, an initial payment for the grant of the franchise and an annual payment of a fixed percentage of the gross revenues of the utility in the franchise area). The analogy between franchise rights and emissions permits lies in the fact that both can be viewed as the granting of a right-of-way by an agency of local government. In the case of emissions permits, the right-of-way pertains to the use of the airshed.

If TEPs are to be treated analogously to franchise rights, then their cost is admissible for rate-making purpose. Historically, utilities commissions have drawn a careful distinction between the value of a franchise to a utility and the value of a franchise right in rate-making purposes. The value to the utility of a franchise may run into the tens of millions of dollars -- in the form of direct additions to revenues, together with required capacity increases. But this value is admissable as a cost only to the extent it is actually paid -- and is judged reasonable by the regulators. Without these stipulations, public utility regulation could not prevent monopoly prices, for the value of the monopoly franchise could be set equal to the potential for monopoly profits and entered as an allowable cost in setting utility rates. Consequently, the franchise right is viewed for rate-making purposes as merely an operating permit, or more precisely, an operating contract. For reasons discussed below, this sharply limits the allowed value claimable by the utility for the right itself. Limitations notwithstanding, the franchise right has always been regarded as an element of utility property.[23]

Franchise rights, like TEPs, are transferable, although not, it must be admitted, without some difficulty. Direct transfers of franchises between investor-owned utilities are quite rare; much more common is the sale or lease of publicly-held systems to private ones, or conversely, the condemnation of an investor-owned utility's property under franchise by a municipality wishing to convert to a publicly-owned system.[24] In either case, a hearing must be convened in order to place a value on the tangible and intangible utility property to be transferred. When private property is converted to a public use (for instance, when the municipality acquires some portion of the property of the privately-held utility), the generic name for the takeover is eminent domain. The adjudicator of such a proceeding (the Commission) may profess to adhere to a valuation standard expressed in ideal market terms, as in:

> As the measure of value of the properties to be valued, the Commission has used the concept of the highest price, estimated in terms of money, that a willing buyer would pay to a willing seller for the property if exposed for sale on the open market, where each is under no unusual pressures of time or circumstance and each has knowledge of all the uses and purposes to which the property is best adapted. . . . [Southwest Water Co. 74 Cal. P.U.C. 193 (1972), p. 194]

Nevertheless, the final determination of value remains somewhat arbitrary.[25]

The duration of franchise rights varies considerably from state to state. For example, in Florida franchises must have a fixed term of no greater than thirty years, while other states allow rights of indeterminate or even perpetual duration (such as many in force in California). Although the allowed lifetimes of franchise rights differ, very few have relatively short durations (say, 5 to 10 years). The reason for this holds equally for franchise rights and fixed-term TEPs: both kinds of rights in a sense "secure" long-term investments in fixed capital. That is, the franchise right guarantees that the utility may extend service, with the requisite rights-of-way, to a municipality for a permit sufficient to justify a long-term capital investment, and that the utility's property may not be confiscated by the municipality without the payment of fair compensation. Similarly, the utility's stock of TEPs would secure a controlled right of access to the airshed -- and without this right, the utility cannot produce electricity (assuming that nonzero electricity production implies nonzero production of pollution).[26] If a large fraction of the utility's TEPs have short lifetimes, the utility's incentive to invest in fixed abatement capital may be chilled, as the utility attempts to keep its emissions inventory flexible in anticipation of short-run changes in the price and number of available permits. Strictly speaking, this comparison assumes that TEPs may be cancelled or diminished in value without compensation only when they expire. As stated in the previous section, the air pollution control authority need not operate under this constraint, but if they do not, the effect will be to reduce the attractiveness of long-term investments in abatement equipment.

The franchise right is in essence another type of operating permit or license, but by virtue of its standing as a contract, it is also recognized as an element of intangible utility property. This dichotomy is reflected in the accounting treatment of the franchise right, as can be seen in a recent decision on a San Diego Gas and Electric application seeking to exercise electric franchise rights in the city of Lemon Grove, California.

> The Commission shall have no power to authorize the capitalization of the franchise involved herein . . . or the right to own, operate, or enjoy such franchise . . . in excess of the amount (exclusive of any tax or annual charge) actually paid to the State or to a political subdivision thereof as the consideration for the grant of such franchise. . . . [SDG and E Applic. 58894, Decision 90876 (1979), p. 3]

So, the consideration actually paid in granting the right, the negotiation and documentation fee, (in the Lemon Grove case, all of $137.50) was added to the rate base, while the annual charges assessed (again, for Lemon Grove, 2 percent of gross annual receipts collected from within-city operations) were to be expensed.

If regulators were to treat TEP´s analogously to franchise rights, a major implication would be the effect on the transferability of permits. Transfers of franchises are regulated by the commission *a priori*, in contrast with most utility-involved property transfers. The commission seeks to prevent competition for franchises in order to prevent municipalities from capturing the potential monopoly profit making in an exclusive franchise. Commissions also seek to maintain consistency among utilities in the valuation of intangible and seldom-marketed property. Competition would upset this aim by causing the price of a franchise to most nearly reflect its value as a right of access to a market. Consequently, by direct policy intent there is very little connection between the franchise fee and the value of the benefits actually provided to the utility by the municipality.[27]

The policy of regulators to inhibit competition has important implications if TEPs are treated analogously to franchise rights. The efficiency of a tradable emissions permit system depends explicitly upon the price of a permit being an accurate measure of marginal abatement costs at all sources. A free, competitive market for permits supplies this correspondence; the commission should not intervene in the valuation process to hold down the price of permits in the rate base of the utility. Thus, although the analogy between TEPs and franchise rights has several points in its favor, it is apparent that it presents some major problems because of the treatment of franchise transfers.

Leases

One conclusion emerging from the synopsis of the legal issues bearing on the emissions permit market was that emissions permits are not likely to "ripen" into perfect (vested) property rights; the air pollution control authority can construct a system that enables it to cancel or diminish the amount of emissions permits without paying full compensation. Given this, a natural inclination is to liken TEPs to contractual agreements where, for example, a right of use of some asset transfers between two parties, without the necessary transfer of a full property right in the asset. Particularly in the case of emissions permits with finite, determinate lifetimes, therefore, various kinds of lease contracts may serve as promising analogies.

For the problem of establishing a system of use rights to the airshed, the air pollution control authority or a private broker can act as a lessor, and the polluting firms such as the utilities as lessees.

A somewhat complicated process is used in the classification of the lease as either capital or operating. The general procedure can be summarized as follows. The lease contract is subjected to four tests which seek to establish the extent to which effective ownership of the leased asset transfers to the lessee. If the lease passes any one of the tests, it is ruled capital, and may therefore contribute to the allowed profits to the utility. If the lease fails all four of the tests, it must be treated as operating. The tests are:[28] (i) Does title to the leased property transfer to the lessee at the end of the lease term? (ii) Does the lease contain a bargain purchase option?[29] (iii) Is the lease term 75 percent or more of the economic life of the asset? and (iv) Is the present value of the minimum lease payments greater than or equal to 90 percent of the fair value of the asset?

Referring again to the previous discussion of the attributes of TEPs of fixed duration, these questions can be answered tentatively. The key issue is whether the asset being leased is the permit or the airshed. If the latter, then the answer to all questions is probably "no." Air pollution regulators are not likely to convey permanent title to the airshed. Moreover, because the airshed is an asset with a perpetual life, no fixed-duration permit could pass the 75 percent test, and only permits of very long duration could pass the test relating to 90 percent of the present value.

Alternatively, the lease could pertain to the permit, not the airshed, either through an agreement with the state or, more likely, through a transaction with a permits broker. Here the state would hold a perpetual title to the airshed, for which it had issued to a broker a use permit valid for some fixed period of time. The broker in turn would lease the use of the permit to the utility. As long as the lease arrangements passed any of the four tests with respect to the permit, then the permit could be regarded as a capital expense.

One further lease criterion, in addition to a positive test for capital status, must be satisfied in order that the capital lease ruling can be made -- the lease must be noncancelable. According to the system of financial accounting standards, a lease is by definition noncancelable if it is cancelable only under the following circumstances: (i) the occurrence of some totally unforseen or remote contingency; (ii) by expressed permission of the lessor; (iii) if the lessee agrees to enter into a new lease with the same lessor; or (iv) by a provision in the lease whereby the lessee agrees to pay a "sufficiently large" penalty charge in the event of cancellation.[30] It is evident that these cancelability criteria are designed, for the most part, with the lessor's interest in the lease contract in mind. But if the experience to date with external offsets and emission reduction credits is any indication, a leading issue in the implementability of the TEP market is likely to be the degree to which the security of the lessee's right can be guaranteed. Nevertheless, the technical definition of noncancelability seems flexible enough that the pollution control authority could conceivably assign emissions rights under any combination of operating or capital lease terms.

A lease contract can be written such that lessees may transfer leases freely among themselves. An assignable lease either explicitly allows between-lessee transfers, or else is ". . . simply a lease silent as to the lessee's right to transfer his interest."[31] Of course, the polluting firms could also sublease their emissions permits. Applied to TEPs, this would enable a utility to hold permits it might need but did not normally use, allowing others to use them on an interruptable basis. This would protect the utility against interruptions in the supply of low sulfur fuel that would force an increase in emissions (and hence permits used) if service is to continue.

It is not necessary for the lessor to prespecify a fixed annual sum as the lease payment. In the mineral lease, the lessee is assigned the right to work a mine or oil deposit in return for a rental payment based on the value of the resources extracted. Similarly, the "lease payment" to the government in the TEP program could take the form of a given percentage of the market value of the TEPs, as revealed by regularly-held auctions -- a system which would be compatible with the periodic auction market alternative.

Land/Water Rights

Up to this point, we have not directly examined the consequences of the statement which began Section A -- linking the problem of implementing the TEP market to the problem of allocating common pool property. This section is primarily concerned with the analogy between TEPs and different types of water rights; the word "land" appearing in the section title above refers to the fact that, in both legal doctrine and utility accounting, land and water rights are inextricably bound together. In addition, both land and water rights have uniformly been regarded as vested property rights and hence as qualifying for treatment as capital costs by utility regulators. The following exposition is intended to explore the underlying issues of economic resource allocation at the expense of legal exactitude and voluminous case citations; for the latter, a number of excellent references already exist.[32]

In California and much of the western United States, water rights law is a complex amalgam of English common law, mining law and customs, and the subsequent work of state courts and legislatures. By "water right" we may mean either a right to the actual "corpus" of the water (as in the utility's use of water in power plant cooling towers), or a right of use of natural streamflows (for example, to furnish the energy input to hydroelectric generating stations). We will focus on the second definition of the term in what follows.

English common law defines water rights as part and parcel of the title to the land riparian (i.e., directly adjoining) a watercourse.[33] Under the riparian doctrine, each riparian landowner is endowed with the perpetual right to use the water flowing past his land, but no part of the flow of the watercourse may be diverted for use on nonriparian lands. Because the water right is inseperable from the adjoining real property, the riparian right is fully vested. In practice, the pure riparian system of allocation works well only along watercourses having a relatively constant volume of flow sufficient to satisfy the present and prospective need of all established riparian users.[34] For this reason, the western United States, with water scarcity and influential groups of nonriparian water users, has developed another type of water right. For the same reason, riparian rights are also largely an irrelevant concept in air pollution control, for it implies a system whereby all polluters would have a vested, nontransferable right to pollute.

As western water rights become more highly valued, a new set of rules gradually emerged. It provided for water rights which could be separated from abutting land rights and attain an independent status as vested property rights -- appropriative water rights.[35] The appropriative doctrine directed that riparian rightholders could claim only the amount of water that they could put to "reasonable and beneficial" use, and that any surplus water could be allocated to appropriative users. The appropriative and riparian rights were deemed to coexist within the same body of water.

Appropriative rights are a much better-defined property right than their riparian counterparts. The appropriative right (as formalized in California by the Water Commission Act of 1913), specifies the point of diversion from the watercourse, the approximate quantity of flow to be diverted, and a clear priority ranking among claims to be used in resolving disputes in times of scarcity.[36]

Several features of appropriative rights are important for the purposes of drawing the analogy to TEPs. One is that appropriative rights are subject to registration uncertainty, or some vagueness in their actual long-term claims to the asset in question, in this case water. Unlike riparian rights, appropriative rights are forfeited in the event of nonuse and can be superseded by claimants with superior rights. Thus, a riparian rightholder may activate a heretofore, unused claim at any time, at the expense of junior appropriators. State water projects and municipalities may also acquire and hold for future use sizable, high-priority rights to surface waters, which may subsequently be exercised without compensating the displaced appropriators.[37] The analog to this uncertainty in a TEP program arises from the likelihood that, at least for a time, portions of the command-and-control regulatory framework will underlie and interact with the tradable permits system. The possibility that emissions permits can be confiscated without notice could be fit into the appropriate rights schema if the order and conditions of confiscation were clearly established for all permit holders.

A second, more important type of uncertainty in the allocation of water rights (or any right in common property, for that matter) arises from <u>third-party effects</u>. A third-party effect is simply an externality created by a legal bilateral transfer of property rights in a common pool resource. On a watercourse, for example, an appropriative rights transfer resulting in a change of the point of diversion may effect the flow of water to downstream users uninvolved in the negotiations leading to the exchange -- and, of course, the bilateral transfer price will in general fail to reflect any diminution of downstream rights. In California, the courts have routinely enjoined such transfers;[38] not surprisingly, the actions of the courts, along with the high information and negotiation costs borne by prospective buyers and sellers, have combined to bring market activity in water rights to a virtual standstill. Of course, more limited kinds of water rights transfers do occur. Water users may exchange water through <u>contract</u> rights, which allow for a well-defined use of a specific quantity of water, without full transfer of a property right.[39]

In two other states, Utah and Washington, water regulators have experimented with fixed-term permits for surplus water.[40] The parallels between these permits and the assets we have considered as analogies to TEPs are of some interest. It is important to emphasize that the water permits are created by state agencies to facilitate an allocation of water that is in the public interest. As fixed-term entitlements devoted to this public purpose, the water permits are not vested rights.[41] The state agencies recognize the tradeoff (discussed above in the franchise right and lease analogies) between regulatory flexibility and user security in the selection of an optimal permit lifetime. The Utah water code allows the duration of the permit to be tailored to needs of particular projects; Washington's sets a fixed 50-year term.[42] Both states provide an option for automatic renewal of a permit when it expires. The permits are tradable in principle, but again, the possibility of third-party effects are likely to constrain free exchange.

How important are third-party effects likely to be in an emissions permit market? In general, changes in the geographic pattern of emissions can be expected to affect the amount and pattern of harmful pollution. But the importance of this phenomenon varies considerably according to the chemical properties of the emissions, differences in meteorological and topographic characteristics among airsheds, and so on. In the case of sulfate air quality control in the Los Angeles basin, the pattern of sulfate concentration over the basin is not very sensitive to changes in the spatial distribution of major emissions sources.[43] Nevertheless, the spatial pattern of emissions does have some effect, and if courts were as scrupulous in applying third-party considerations to block transfers in air rights as they are in appropriative rights, the consequence would be a highly constrained and probably insignificant market. Consequently, a decision by public utility regulators to classify emissions permits analogously to water rights for rate-making purposes runs some risk if the analogy is picked up by the courts.

Controlled Trading and Emissions Reduction Credits

The emissions reduction credit (ERC) was mentioned above as the closest available analogy to the TEP; the reader may therefore have been a bit puzzled about the amount of attention given the other, less perfect analogies above. The reason for our reliance on franchises, leases, and water rights as comparison assets is that ERCs and the other components of the "controlled trading" program have yet to gain wide acceptance by polluting firms as instruments of air quality control, and consequently, the impact of ERCs on utility accounting and rate-making has been minimal and somewhat uncertain. Controlled trading is the name given to the EPA's tripartite program for the creation of a constrained market for air pollution entitlements within an air quality control region. This section traces the correspondence between ERCs and TEPs and, in so doing, reveals the extent to which the TEP program may share the implementation problems encountered by the incentive-based control strategies presently allowed within the Clean Air Act.

The heart of controlled trading is the offset concept. Major new polluting facilities may be constructed within nonattainment areas if the entrant firm can arrange to offset its new source emissions with verifiable emissions reductions obtained from already-existing firms. Thus, firms can, with certain important limitations, circumvent the restriction of having to install uniform abatement technologies on all new sources.[44] A second liberalization of uniform source-specific control regulations, closely related to offsets, is the "bubble" policy, promulgated by EPA in 1979. A "bubble" is a subregion of an airshed which contains a number of discrete emissions sources. Instead of setting a fixed emission control for each source, the bubble policy establishes an upper emissions limit for the entire subregion, and then allows any combination of individual source emissions (again, subject to certain constraints) that sum to an amount less than the emissions ceiling. As originally defined, a bubble could extend only over multiple sources within a facility of a single firm. The policy was subsequently expanded to allow multi-firm, multi-plant bubbles. Emissions permit markets operate within large multi-plant bubbles (in the case of a multiple markets TEP program), or quite possibly, within a bubble extending over an entire airshed.

The emissions reduction credit and the emissions reduction "bank" represent the means of exchange in an incentive-based pollution entitlement system. The idea behind the ERC was that firms would have an incentive to reduce their emissions beyond the requirements of the law if the residual emissions reduction could be "credited to the firm's account" for future use or for sale to other firms. In theory, an emissions reduction bank would also protect a firm's identified, verifiable reductions below the mandated "baseline," since any feasible reductions not banked could be confiscated by the state, via a SIP revision, as part of the state's showing of reasonable further progress towards attainment.

As noted in the last section, a major reason for the rather sluggish activity in controlled trading to date[45] is the pollution entitlement analog to what was called "registration uncertainty." Just as the security of appropriative water rights and fixed-term water permits may be threatened by the coexistence of the partially-conflicting riparian doctrine, the reliability and certainty of marketable emissions permits as assets is constrained by the continued reliance of air quality regulators upon the original source-specific approach of the 1970 Clean Air Act. The dictates of command-and-control regulation limit the efficiency gains from a marketable entitlement system in a number of important ways. Incentive-based programs notwithstanding, the major burden of moving an air quality control region towards attainment is borne by the enforcement of nondecentralized technical standards such as "reasonably available control technology" (RACT).[46] For new sources in nonattainment areas, for whom the offset policy was ostensibly designed, the inflexible technical requirements are much more strict: new entrants must reach the so-called "lowest achievable emissions rate" (LAER),[47] and offsets cannot be used as part of the demonstration of this standard. Similar criteria sharply limit the potential cost savings to firms attempting to use multi-plant bubbles.[48] In addition, the rules governing the registration of ERCs within emissions banks have tended to confirm the suspicion that air pollution entitlements would not be viewed as vested property rights.[49]

It is beyond the scope of this paper to discuss in detail the alternative policies by which an air quality control region may be "weaned" gradually from command-and-control pollution regulation, while simultaneously implementing a system based on TEPs (see instead Noll [1981] and Hahn [1981]). For the present purpose, the importance of the ERC lies in its close similarity to the TEP as an asset; ideally, the latter is the former stripped of the transactions costs arising from the source-specific alphabet soup of regulatory constraints which now exist. The ERC is emerging in application as an indeterminate-lifetime, imperfectly-vested right to emit, from within a well defined geographic area, a fixed quantity of a given pollutant into the airshed. Therefore, to the extent that utility regulators have considered ERCs as potential utility property, they have confronted nearly all of the important issues germane to a similar determination for TEPs.

An issue of immediate interest is how much can be said about the rate-making status of ERCs. First, note that in an important sense, there actually exist two kinds of ERCs: there are ERCs which have been banked and are available for sale, and there are ERCs created in the course of an offset transaction where a source's emissions have been reduced below the SIP baseline. If a firm buys a banked ERC, it gains an intangible asset, while paying the purchase price plus any negotiation costs incurred. On the other hand, if the firm qualifies for an ERC through an offset transaction, the ERC itself is created for merely the costs of verification and registration with the air pollution control authority -- the investment undertaken to bring about the ERC in this case is completely <u>tangible</u> (the pollution abatement equipment installed on a polluting facility somewhere in the bubble, for example). Therefore, to anticipate the next section slightly, two ERCs of equal size, obtained by the two methods outlined above, are not likely to be perfect <u>after-tax</u> substitutes for each other, even in a perfectly competitive market for ERCs. A similar situation, albeit without the costs imposed by the source-specific constraints on offsets, will prevail in the firm's decision whether to purchase a TEP or undertake further abatement.

Second, there is some evidence that, at least in California, regulators have earmarked ERCs for the rate base. In the ill-fated negotiations mentioned above concerning the San Francisco Bay Area power plant, ERCs obtained by the utility as part of the facility's complex emissions offset proposal were to be included in the pollution control bond issue with the rest of the abatement capital devoted to the project.[50]

TEPS AND THE REGULATORY ACCOUNTS: CASE EVIDENCE

This study attacks the question of the utility's impact on an emissions permit market through a two-stage process. The first stage, for which the last four sections have supplied the groundwork, deals on a general level with the placement of the TEP within the utility accounts system, and with the closely-related issue of the valuation of TEPs for rate-making purposes. The aim of this accounting review is the identification of any systematic differences which may exist in the way regulated and unregulated firms view TEPs as valuable assets.

The following sections, motivated by the asset analogies developed above, suggest alternative ways of incorporating TEPs within the accounts structure of the regulated utility. We will also consider one further issue -- the extent to which a utilities commission may view the utility's participation in the TEP program as an experimental or pilot venture. For electric utilities, the late seventies and early eighties has been a period of great interest in advanced and alternative technologies. Until recently, all of these new technologies have dealt directly with the production of electricity: oil shale, coal gasification, geothermal, active/passive solar, cogeneration, and so on. In 1978, directives stemming from the enactment of PURPA called for the design of new conservation programs, which also had an effect on electricity production, but in a more indirect fashion. Each of these new programs and technologies has posed difficult regulatory problems. Utilities commissions have had to balance the prospect of increasing the riskiness of utility returns against allowing investors an unreasonable margin of insulation from risk (through approval of wholesale rate base treatment for unproven production facilities and conservation programs, thereby saddling ratepayers with undue financial burdens). An initially unproven TEP program, even more tenuously related to electricity production, cannot expect to escape all scrutiny along these lines. Again, a growing rate case literature will be examined for indications of uniform principles applied in modifying the rate-making treatment of alternative technologies.

Utility Accounts I: Original Cost Rate Base and Operating Expenses

The most general guidepost in the determination of the allowed revenue for regulated utilities is the concept of "fair return on fair value," first expressed in the landmark case Smith v Ames 169 US 466 (1898). As time progressed, the controversy over the status of utility expenditures as capital or operating expenses was largely resolved by the introduction of the Federal Power Commission's Uniform System of Accounting, which served as a model for the account systems of many state Commissions. Even as utility accounting grew more refined and standardized, however, the courts resolutely edged away from the establishment of a precise definition of "fair value." By 1944, in FPC v Hope Natural Gas Co. 320 US 591, the break with the idea of standardized rate-making was complete; Justice Douglas wrote for the majority, "It is not the theory but the impact of the rate order that counts. If the total effect of the rate order cannot be said to be unjust and unreasonable, judicial inquiry under the act is at an end." Thus, utilities commissions were free to employ any "fair and proper" methodology in fixing a value for the utility's investment in public service. In at least one case, a state commission took this freedom quite literally, dispensing with the notion of a rate base altogether -- a course of action which the state court quickly countermanded.[51]

If the rate base remains as a fixture in the process of setting the utility's "revenue requirements," what alternative measures of fair value have evolved? At present, most commissions rely on one of two methods for assigning a dollar value to the rate base: <u>original cost</u> or <u>reproduction cost</u>. Original cost, the standard in California, is simply the nominal cost of procurement or construction of each element of the rate base, at the time the element is first devoted to public service. At any moment in time, therefore, the original cost value of the rate base is the sum of the actual cost outlays made on each component of electric plant, without regard to a component's vintage (and consequently, without regard for the movement of price indices between vintages). Adjustments to the original cost rate base (in the form of improvements to or unanticipated deterioration of property) are also recorded at original cost. Provided that the utility's accounting system is sufficiently detailed, original cost closely approximates what accountants commonly refer to as "book" cost.

A reproduction cost standard is based on a determination of the money cost of acquiring or constructing the utility's property at present prices. The item-by-item cost and engineering appraisal required to do an accurate job of assessing reproduction cost is often daunting in practice; further, the method is plagued by fundamental conceptual difficulties -- e.g., what does it mean to "reproduce" today a 1925-vintage steam plant? By and large, the major difference in rate-making between the two methodologies is the point at which the attempt is made to adjust the rate base value for changes in the overall price level. The reproduction cost method seeks to internalize the adjustment within each plant account, while the original cost method fixes the rate base value and reacts to price level changes in a more aggregated way through compensatory test-year output prices, and hence, the rate of return.[52]

As a practical matter, the choice of accounting technique has not proven to be an important issue in determining the financial health of utilities. No significant difference has been found in the profitability of utilities that can be attributed to the method that regulators have used to evaluate the rate base.[53] The reason is quite simple: in states in which historical cost methods are used, firms face a compensatingly higher cost of capital. This higher cost of capital, when multiplied by a lower (historical) cost of the rate base, produces essentially the same profit.

In the case of tradable emissions permits, the choice of rate-making methods could have an effect on the incentives of the utility in acquiring permits. Suppose that a "grandfathering" procedure is used to allocate permits initially; that is, companies are told that henceforth they may trade the emissions that are implicitly allowed in existing regulations. If replacement cost concepts were used to evaluate permits for rate-making purposes, the rate base of the utility would then be adjusted to value the emissions permits at the price established for them in the market. But if original cost principles were applied, the contribution of permits to the rate base would remain at the acquisition price -- namely, zero. Consequently, in replacement cost states the immediate effect of the creation of a tradable permits system is to increase the allowed revenues of the firm by an amount equal to the profit allowed on permits, whereas in historical cost states the creation of TEP would have no immediate effect on utility revenue requirements.

Next to consider is the effect of accounting practices on trades of permits. Presumably a utility would buy permits if the savings in abatement costs exceeded the expenditures on permits, or sell permits if the revenues from the sale exceeded the additional abatement costs that were required to bring emissions into line with the new permit holdings. Suppose that the utility decides to sell permits. The question is what happens to the revenues from the sales.

In original cost states, utilities normally keep two sets of accounts: one, reflecting the depreciated original cost of the asset, is used for rate-making purposes, and a second, termed the adjustment accounts, estimates departures of the actual value of an asset from the book value for rate-making purposes. The adjustment account is the best guess of the change in the value of the property from original cost if it were to be sold. And, if the property is sold, any gains or losses represented by differences between the book value for rate-making purposes and the actual sales price, are directly applied to the revenue requirements of the firm in the year of the sale.[54] This means that ratepayers, not shareholders, reap the rewards from the sale of utility property that has experienced a windfall gain in value. For example, the California accounting procedure for land and land rights transactions states: ". . . any difference between the amount received from the sale of land or land rights . . . and the book cost of such land or land rights, shall be included in [Gains/Losses From Disposition of Utility Plant], as appropriate."[55] The latter account is one of the categories of annual revenues, the sum of which must equal the allowed costs of the firm.

In replacement cost states, the book value of the asset for rate-making purposes is normally more closely a reflection of the market price of the asset, although for a number of reasons it may depart from it. Hence, the effect of a sale of permits would be to reduce the capital value of the firm for rate-making purposes -- and to reduce revenue requirements by only the allowed profits on the permits, not the total revenues from the sale. Consequently, the sale of permits produces a cash reserve that can be used to purchase abatement equipment to reduce emissions by an amount equivalent to the reduction in permits. No such reserve is created in states that capture all of the revenue from the sales of permits for rate-reduction purposes.

The importance of these distinctions is that the original cost method of valuing permits, combined with grandfathering, blunts the incentive of the utility to participate in the permits market. All gains from sales of permits immediately go to ratepayers because the revenues are treated as windfalls.

Auction methods for allocating permits do not have this problem. If a utility acquires permits through an auction, the auction establishes the original cost of the permit. But, of course, in a standard auction the market price of the permits is also their cost to utilities -- the permits are actually sold through the auction process. The zero revenue auction, where auction revenues are returned to polluting firms in proportion to their historical emissions or some other fixed standard, would probably not be helpful to utilities because it would be likely to be treated as a windfall. If so, the revenues would then be returned to the ratepayers. Thus, revenue requirements would be reduced by the revenues from the zero-revenue auction, and then incremented by the profits allowed on the purchase of permits. The latter figure would normally be lower than the former.

Either auction process forces an immediate need for new funds, even if the total number of permits held is unchanged by the auction. In the regular auction the utility must acquire funds to buy permits, and in the zero revenue auction the firm suffers a loss in cash flow equal to the market value of the permits. In both cases the firm can then add onto its revenue requirements a profit on the market value of permits. The advantage of the auction is that it immediately forces a choice among permits, abatement equipment, and changes in operations that bring emissions in line with permit holdings. The disadvantage is the immediate effect of instituting the process on the cash flow of the utility. This is especially troublesome if the allowed rate of return is below the incremental cost of capital, as was the case for electric utilities in the 1970s and early 1980s.

The solution to the problem is relatively straightforward. Utilities could be permitted to add the implicit value of permits to the rate base at the market value. If so, the creation of a permits market would not threaten the financial position of utilities. But this is easier said than done, for the history of public utilities regulation creates a strong precedent to prevent regulated utilities from capturing windfall gains. Convincing regulators that emissions permits should be treated differently than other types of intangible property or land rights will not be an easy task.

Utility Accounts II: Amortization and Tax Effects

In this section we will focus on the mismatch between the tax treatment afforded the intangible emissions entitlement (the ERC or the TEP), and that applied to abatement capital. A recent article, Stathos and Treitman [1981], performs a first-cut tax analysis of the ERC from the standpoint of the regulated utility. Stathos and Treitman begin with a rather conservative analysis of the depreciability of ERCs. They state that the intangible purchased or perfected ERC is eligible for straight-line amortization, provided that a well defined useful life can be established.[56] In 1970 the Accounting Practices Board handed down its Opinion No. 17, specifying certain methods for handling the cost recovery of intangible assets.[57] APB recommended the following procedure:

> If the intangible asset is purchased individually, it should be capitalized and amortized over its expected useful life, using the straight-line method of amortization. (The straight-line method . . . is not required if the company can demonstrate that some other method is more appropriate.) If it is not possible to determine the useful life of the intangible, it should be amortized over a period not to exceed 40 years.[58]

Thus the APB raises an interesting normative issue -- given the specialized depreciation rules which apply to pollution abatement equipment lasting longer than one year, is there a clearly "best" method of ERC or TEP amortization, in terms of reinforcing market stability, or is the emissions entitlement market insensitive to abatement equipment accounting?

Apart from this, the intangible status of the ERC/TEP precludes it from qualifying for other tax features allowed on long-lived pollution control equipment, such as the investment tax credit.[59] It is difficult to assess the distortional effect these tax considerations might have on the emissions entitlements market. In any case, as far as pollution abatement capital depreciation is concerned, the rules which apply to regulated utilities are not dramatically different from those applying to nonregulated firms.

Interim Provisions: TEP as an Initial Experimental Venture

One of the major trends in energy policy over the last decade has been the increasing emphasis placed on diversification of generating facilities. Reasons advanced for this have included conservation of domestic fuel sources deemed in short supply (such as natural gas), and a desire to reduce the manipulability of domestic energy prices by foreign interests (either by design or as a result of political instability). Whatever the underlying motivation, the resource diversification program has not been without its problems for utility regulators. Like any firm engaging in risky R and D, electric utilities will bring on-line an experimental, high-technology production facility at a higher average cost than that of more mature technologies. Utilities, however, are not subject to the same kinds of competitive forces which act in the unregulated sector as constraints on the R and D budget. In theory, a utilities commission has the power to authorize utility R and D on a "cost-plus" basis, so that the stream of utility returns is essentially unaffected by the commercial success or failure of an experimental generating resource, at least over the term of a "demonstration period." Of course, utilities commissions do not simply rubber-stamp such a transfer from ratepayers to utility stockholders; instead, the criterion applied seeks to apportion financial risk equitably between the two groups. The regulator's desire to transmit the correct financial and innovative incentive to the utility has led to a modified system of rate-making in the case of "pilot" or demonstration programs. Several recent rate case examples will help to make clear the kinds of modifications that are made in practice.

In November of 1979, Southern California Edison Co. filed an application seeking authorization to enter a seven-year joint venture with Texaco for the purpose of demonstrating the feasibility of incorporating Texaco's coal gasification process within a combined cycle powerplant.[60] As an experimental project, the powerplant was not submitted as a planned generating resource, that is, Edison would not rely on the plant as a part of its on-line generating capacity. The combined-cycle coal plant would be considered commercially feasible if a particular capacity factor target (77 percent) was attained during the seven-year demonstration period. The utilities commission found that the plant met the initial certification requirements,[61] and supported Edison's participation. Edison proposed that its initial $25 million capital investment be included in its rate base, while the fuel and O and M expenses would flow into operating costs through Edison's existing fuel cost adjustment procedure (see Part III for details).

The commission staff took exception to Edison's guaranteed recovery of capital investment regardless of the success or failure of the project, noting that ". . . complete cost recovery over the seven-year demonstration period would unfairly burden the ratepayers and customers during that period, and also would undermine the Company's incentive to select worthwhile demonstration projects."[62] The Staff's proposed financing method reflects the regulator's concern for striking an <u>ex ante</u> balance in allocating the risk of development programs. Essentially, the staff suggested that ratepayer support for the project over the demonstration period should be limited to the value of the electricity received by the ratepayers during the period. Recovery of all other costs (including the utility's capital contribution and the rate of return on the capital invested) would be deferred until the end of the demonstration period, at which time the commission would review the performance of the plant and rule on its final rate-making status. If the plant had achieved the target capacity factor, Edison would be allowed all deferred costs, an allowance for funds used during construction, and a rate of return component. If the plant failed to reach the required performance level, Edison would be limited to a five-year amortized recovery of the deferred costs, without any return allowance or recovery of construction costs.[63] In effect then, the Commission ruled that the combined-cycle coal plant be treated as nonutility property over the term of the demonstration period, excluding it from the rate base even though such generating capacity is, under normal circumstances, clearly a rate base item.

The case of Edison's coal gas combined-cycle powerplant represents a fairly radical departure from standard rate-making practice, but it is at the same time difficult to draw any direct parallels between this case and the initial implementation of the TEP program. It has been established that experimental ventures with highly uncertain final costs and benefits may be subject to special rate-making treatment. The powerplant has one important mitigating factor in its favor, however: there is at least the possibility of the plant reaching the capacity goal and thus, beginning at some date to contribute to increased Kwh sales and offsetting revenues. Therefore, given the TEP program's deadweight status, its large and somewhat uncertain initial costs (and consequently, rate impact), it is likely that the commission would consider special handling of the account appropriate at the outset. As it happens, the California Commission has recently found itself having to deal with a similar set of problems -- the regulatory issues surrounding the establishment of a new, costly utility policy which, like a TEP program, does not directly generate offsetting revenue: conservation.

The California Utilities Commission experience with conservation programs is interesting from several standpoints. First, the commission knew that conservation measures should be adopted, but was in no position to know what kinds of programs were feasible (e.g., utility-internal measures, such as load management, versus consumer incentive programs such as rebates for installation of water heater blankets, and so on). Second, operating within this climate of uncertainty, the commission had the task of stimulating the design of conservation programs by the various utilities, while retaining control over the burden placed on ratepayers. The commission elected a strategy aimed at guaranteeing the prompt creation of conservation proposals: utilities were put on notice that a special Conservation Adjustment Account (CAA) was to be created for the purpose of accumulating the difference between accrued expenses on conservation programs and the revenues generated by periodic conservation-specific rate offsets.

In simple terms, the utilities were given a carte blanche venue to pass directly through to ratepayers all prudent expenses associated with conservation measure.[64] Utilities were free to establish conservation measures which might not turn out to be cost-effective (as long as the proposal appeared "prudent"), without fear of the expenses being disallowed at some later date. Programs judged "major" in scope, or those involving additions to the rate base, were to be considered in special applications.

In response, utilities rapidly put together quite detailed proposals (Southern California Edison's involved an initial commitment of $10.5 million) and submitted the expenditures in offset rate adjustment hearings. The utilities commission then ordered the CAA abolished and denied the requested rate relief.[65] The reason for this odd turn of events was that the commission was profoundly uncomfortable with the notion of rate-making through special offset accounts.

The object of the CAA announcement was one of "pump-priming" -- drawing out of the utilities the information which was unobservable to the commission, namely, the set of feasible conservation programs. Once the set of cost-efficient programs had been revealed, the commission rejected the piecemeal rate-making approach of the CAA, and ordered the utilities to submit all conservation expenditures for approval in the utilities' next general rate cases.[66]

Section 792.5 of the California Public Utilities Code gives the commission the authority to create special balancing accounts whenever specific changes in expense levels (associated with the creation of new programs, for example) must be passed on to ratepayers. The commission correctly restricts the use of such accounts in practice, as the conservation case shows. But, where the costs of a new program are uncertain, and where the utility's range of responses to the program is unobservable to the regulator, special rate-making procedures have been used, if only for a limited period of time. Eventually (and regulators prefer sooner rather than later), the new program becomes fully assimilated into the utility's general rate structure. When this occurs, the broader rate-making questions raised in the preceding sections of this study come into play.

Summary and Preliminary Conclusions

The purpose of economic regulation of utilities is to prevent excess profits. Elaborate procedures have evolved to identify and eliminate the sources of excess profits, whether the exercise of monopoly power or the capture of windfall gains. Utility regulators are charged with keeping utility prices as low as possible without threatening the viability of the utility company or the continuity of service.

Unfortunately, these procedures blunt the incentives of the utility to engage in cost-reducing activities. The force driving cost reduction in industry is the quest for profits. In the utility business, any gains from cost reduction will shortly accrue to ratepayers. The utility will gain only to the extent it increases its total sales -- or its political popularity.

TEP reforms are attractive because they hold the promise for cost reduction. But these prospects immediately get tangled up in the regulatory procedures that pass on cost reductions to ratepayers. The situation is compounded by the fact that TEPs are intangible assets -- a form of capital that is regarded especially skeptically by the regulatory process.

In approaching the establishment of sound utility pricing policy with respect to TEP reforms, two points should be kept in mind. First, the accounting practices for TEP can be important in determining whether utilities participate rationally in the market and help a region achieve air quality objectives at minimum cost. Second, some of the cost reductions from implementing the TEP system will inevitably be passed on to consumers, but the methods for assuring this should not destroy the willingness of utilities to participate in the permits market.

From the perspective of economic efficiency, society is better served if electricity prices go up to account for the polluting effects of electricity generation. This gives both utilities and their customers incentives to use and produce less electricity, as well as to find less polluting methods of producing it. Consequently, society should not be troubled by the fact that an appropriately implemented TEP system would lead to increased utility rates.

At the same time, utilities should face incentives to make trade-offs between abating emissions or buying permits that reflect the true opportunity costs of these alternatives. Only then will a market in permits succeed in finding the minimum cost means of achieving environmental policy objectives.

To achieve both objectives requires that the value of permits be included in calculating the revenue requirements of the utility. This can be achieved by an auction of permits, by the zero-revenue auction, or by grandfathering emissions and using replacement cost methods of valuing them. The mechanics of the zero-revenue auction can be arranged so that the revenues returned to the utility are either returned to ratepayers or retained by the utility. All of these methods cause the value of permits to be incorporated into the rate base of the utility, and hence for the utility to face the same incentives with respect to trading permits as it faces in buying and selling other assets and inputs to its production process.

Making an analogy between TEPs and leases has the additional advantage of flexibility. If permits are regarded as leased from the state, the utility can arrange to have their expense counted either as an operating cost or as a capital investment on which profits can be earned. These permits could also be subleased by the utility so as to allow the utility to have control over more permits than it currently needed, either as a means for facilitating growth or as insurance against a change in the availability of low-sulfur fuels that would require easy access to more permits if the utility were to satisfy its service requirements.

Because the details of exactly how utilities will approach a TEP market are somewhat conjectural, it makes a great deal of sense to regard any approach to incorporating permits into the rate-making process as provisional. Taking advantage of the special provisions in the law for experimental procedures for solving unusual regulatory problems seems especially attractive. If and when TEP systems are adopted and used by utilities, an experimental and highly flexible approach, based upon the leasing analogy and allowed to operate for a few years to detect its effects, appears to be the most reasonable means to try to introduce the appropriate incentives into the utility sector.

FOOTNOTES

1. Welch [1961], p. 454.

2. See Isaac [1980].

3. See Burness, Montgomery, and Quirk [1980].

4. For an in-depth analysis of the issues in constitutional and property law bearing on TEPs, see Krier [1981].

5. The theoretical background is filled in by Dales [1968], Montgomery [1972], and Teitenberg [1980]; and, in a more applied vein, by Hahn [1981], and Noll [1981].

6. The area within which permits are defined may be an entire airshed, or, as analyzed in Hahn [1981], subregions of an airshed, each with its own market.

7. Krier [1981], p. 33.

8. Noll [1981], pp. 27, 45-50.

9. _Ibid_., p. 27.

10. Krier, p. 33 and notes 45, 46.

11. Literally, "to abide by, or to adhere to, decided cases." Adherence to a rule of precedence is waived for administrative bodies such as utilities commissions. In California, this distinction was upheld in Motor Transit Company v Railroad Commission, 189 Cal. 573, 586 (1922).

12. This added requirement, seemingly trivial, is illustrated in Richfield Oil Corporation v California Public Utilities Commission, 54 Cal. 2d 419, where the court found that an exclusive contract existed between Richfiel and Southern California Edison Company for the delivery of gas to Edison's Mandalay steam generating plant, and that Richfield had not sought to extend such service to the public at large. Thus, the pipelines and related equipment involved (the operation of which would normally be regulated), were not dedicated to a public use, and were found to be exempt from commission regulation.

13. Welch [1961], p. 242.

14. _California Public Utilities Commission_ Decision 89711 [1977], p. 100.

15. For detailed discussions of the controlled trading program and

ERCs, see Richard Liroff, "Air Pollution Offsets, Trading, Selling, and Banking" (Washington, D.C.: The Conservation Foundation, 1980) and U.S. General Accounting Office, "A Market Approach to Air Pollution Control Could Reduce Compliance Costs Without Jeopardizing Clean Air Goals" (Washington, D.C.: USGAO Report PAD-82-15, 1982).

16. Interview with Jack McKenzie, Siting Engineer, Pacific Gas and Electric Company, February 18, 1982.

17. Pactex Pipeline Company, FERC Docket No. OR7810 (1979).

18. The general principle involved is discussed in Welch [1961], Chapter 5, and in the context of a recent rate hearing, in Southern California Edison Company, A59268, Brief of the Commission Staff [1980].

19. California Public Utilities Code, Section 851, amended by Section 3 of Stats. 1951, Chapter 402.

20. Interview with John Bilci, California Public Utilities Commission, February 15, 1982.

21. Black's Law Dictionary, 5th Edition (West), p. 592.

22. For background on the early state public service commissions, see Mosher and Crawford [1933], pp. 106-112.

23. "The franchise, however acquired, must be considered in determining reasonable rates for the use of property devoted to public service, otherwise it would be possible to practically destroy or confiscate its value." Spring Valley Water Company v City and Company of San Francisco, 165 Fed. 667 (N.D. Cal. 1908).

24. Pacific Gas and Electric Company, FERC Docket No. E-7777, p. 24.

25. Southwest Water Company, 74 California Public Utilities Commission 193 (1972), p. 194.

26. This raises the issue of the relative priority of the utility's emissions and service quality constraints. The utility's electricity output has to track instantaneous demand within a narrow tolerance range; demand is subject to both intra-day and seasonal fluctuations. Therefore it is likely that the utility will be authorized to hold a "reserve margin" of TEPs, and, when the margin TEPs are not in use, they may be rented to other firms on a short-term contract basis.

27. Recently, the Florida Supreme Court upheld an order by the Florida Public Utilities Commission directing that franchise fees be collected only from consumers residing in the municipality collecting the fees (the so-called direct method), rather than

spreading the franchise fees across all ratepayers. Among other things, the court cited the lack of any relationship between the value of benefits provided by the city and the franchise fee, and the lack of any set maximum amount within the franchise contract for the utility's right-of-way payment. City of Plant City et al. v Hawkins et al., 375 So. 2d 1072 (1979).

28. See Booker and Jarnigan [1979], pp. 309-310. Operating vs. capital lease status is optional to the regulated utility. On June 8, 1978, Pacific Power and Light Company, entered into a 25 year lease for a portion of the output of the Wyodak steam plant. The commission ruled that the lease met the requirements for treatment as a capital lease for rate-making purposes. However, the company elected to charge all lease expenses associated with the project to operating expenses. Moody's Public Utility Manual (New York: Moody's Investors Service, 1981), p. 1515.

29. The bargain purchase option is a payment made by the lessee to the lessor at the end of the lease term which secures title to the leased property by the lessee. The payment usually represents a sizable discount from the fair value of the property. Booker and Jarnagan [1979], p. 308.

30. Statement of Financial Accounting Standards #13, paragraph 5(f), in Journal of Accountancy, February 1977, pp. 89-90.

31. Black's Law Dictionary (West) 1979, p. 108.

32. See for example, 62 Cal. Jur. 3d, Water and Harrison Dunning, Final Report, Governor's Commission to Review California Water Rights Law, December 1978.

33. Dunning [1978], pp. 6-7.

34. Lee [1977], pp. 13-14.

35. Dunning [1978], pp. 7-9.

36. Lee [1977], p. 15.

37. Ibid., pp. 16-20.

38. Ibid., pp. 31-34.

39. Dunning [1978], p. 10. An example of a utility-involved transfer of contract rights can be found in Lee [1977], p. 58. Lee erroneously reports the transfer which took place between Pacific Gas and Electric and the Paradise Irrigation District as involving a transfer of appropriative rights. In fact, PG and E holds a pre-1914 appropriative right to divert water from the Feather River, and to convey the diverted water past two hydroelectric powerhouses. PG and E owns the canal (the Miocine

Canal) through which the water is carried to the power stations. The California Water Service (CWS) has a contract with PG and E for water in the canal, without a claim on any water rights. In the 1977 transfers mentioned by Lee, PG and E assigned CWS's entitlement to the Irrigation District for one year, and since the transfer to PID reduced the water flow past the power stations, PID paid PG and E an amount equal to the replacement power cost.

40. Archibald [1977], p. 1.

41. Ibid., p. 6.

42. Ibid., p. 4.

43. Cass [1980], specifically.

44. USGAO [1982], pp. 16-17.

45. To date, close to one thousand offset, banking, or trading transactions have taken place, but only a small fraction of these involved "external" trades between separate firms. See Wes Vivian and William Hall, "An Examination of U.S. Market Trading in Air Pollution Offsets" (Ann Arbor: University of Michigan, Institute of Public Policy Studies, March 1981).

46. See USGAO [1982], p. 14 at note 3.

47. Ibid., p. 13 at note 1.

48. Ibid., p. 17.

49. For example, in two of the most sophisticated ERC banking proposals, the Bay area bank and the (Los Angeles) South Coast AQMD Emissions Bank, rules allow for ERCs on deposit to be discounted without compensation, as required to meet NAAQS. Ibid., p. 101.

50. Interviews with John Bilci, California Public Utilities Commission, and Jack McKenzie, Pacific Gas and Electric Company, February 1982.

51. Commonwealth Telephone Company v Wisconsin Public Service Commission 71 PUR NS 65 (1947).

52. That is, since the utility's revenue requirement is calculated as original cost rate base value times allowed rate of return, the utility's allowed output prices (designed to yield the utility the allowed rate of return over a specified "test period"), can be adjusted for price level increases during each rate case.

53. Primeaux [1978].

54. Interview with Greg Johnson, California Public Utilities Commission Financial Examiner, January 30, 1982; see also, Uniform System of Accounts, Electric Utilities, FERC (U.S. Government Printing Office, Washington, D.C., 1973).

55. Uniform System of accounts, Electric Utilities [1973], pp. 101-110.

56. Stathos and Treitman [1981], p. 19.

57. See Booker and Jarnigan [1979], pp. 118-126.

58. Ibid., p. 120.

59. Stathos and Treitman [1981], p. 19.

60. Southern California Edison Company, A59268 (1979).

61. See Southern California Edison Company, A59268, Concurrent Brief of the Commission Staff, May 1980.

62. Ibid., p. 7.

63. Ibid., pp. 9-10.

64. Southern California Edison Company, A57111 (1977); Interim Opinion D87397 (1977).

65. California Public Utilities Commission, D88650 (1978).

66. Ibid., Findings and Conclusions, pp. 17-18.

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