Choosing Optimum Management Strategies

Pollution Control Systems

EPA Technology Transfer Seminar Publication

EPA-625/3-77-008

CHOOSING OPTIMUM MANAGEMENT STRATEGIES

ENVIRONMENTAL PROTECTION AGENCY • Technology Transfer

MAY 1977

ACKNOWLEDGMENTS

This seminar publication contains materials prepared for the U.S. Environmental Protection Agency Technology Transfer Program and has been presented at Technology Transfer design seminars throughout the United States.

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INTRODUCTION

Although plant managers neither can nor should become pollution control experts, they must have access to basic information on the subject.

This publication, therefore, is addressed to managers and supervisors who have some responsibility for their plant's pollution control measures but for whom this represents only a part of their overall concerns. The general manager, for example, is usually drawn into pollution control planning because profitability may be affected. The production supervisor, who must maintain the plant's operating schedules, may also share in selecting, installing, and operating the pollution control system. Even the treasurer may be involved, because of the impact of pollution control decisions on cash flows, relationships with lending institutions, and tax considerations. Other administrative employees are also likely to share in pollution control planning and operation.

Capital spending decisions require managerial expertise and may involve complex sets of variables. Normally, these variables are the fairly standard ones that underlie any calculated entrepreneurial risk. Some of the same considerations enter into decisions about pollution control; for instance, cost-effective alternatives for materials and design.

But managers should be aware that there are some unique considerations affecting their decisions about pollution control. An obvious one is that a pollution control system is one of the few capital investments a plant may make that in no way contributes to efficiency or profitability. However, it also represents one of the few capital outlays eligible for government-sponsored benefits to ease financial strain.

What are the special factors that make management's decisions on pollution control conspicuously different from decisions about other capital expenditures? We have identified five:

1. The decision-making process is subject to an externally imposed deadline.

   For normal capital expenditures, a long period of deliberation is not unusual. Moreover, the actual commitment can be put off if more critical needs arise or if more favorable financial conditions are expected later.

   In stark contrast stands the issue of pollution control. The laws and regulations almost invariably include fixed deadlines for compliance, and these, in turn, impose quite rigid deadlines for making decisions and purchases.

There are highly publicized instances of postponements of such deadlines, sometimes through industry persuasion, sometimes through litigation. But more often, government insists on timely compliance by industry.

2. Pollution control equipment is generally foreign to a plant's production technology.

While management is highly knowledgeable about its manufacturing equipment and the technology for enhancing productivity and improving product quality and appeal, its understanding of waste control is often elementary. Since modern pollution control equipment can be quite sophisticated, management may face delicate selection and trade-off considerations, especially if a decision is made to keep equipment expenditures low.

3. Performance of the new equipment must ultimately satisfy a third party: the government.

Most plant managers have had experience with new equipment that did not quite meet all the purchase requirements. When this happens, it is not unusual to work out a compromise with the equipment supplier—a reduction in the purchase price or some other concession—with management guided only by the plant's best interests.

How different the situation when pollution control equipment is involved! A third party, the government regulatory agency, will hold management to the performance standards in the regulations, meaning that a whole area of management freedom is eliminated.

4. A plethora of regulations may apply.

The usual parameters of management decisions, such as quality and cost-effectiveness, may seem classically simple when a plant starts to deal with pollution control. The regulations governing the capital-expenditure commitments and those covering the performance of control equipment can originate from different levels of government; sometimes several levels of regulations appear simultaneously. There is also the ever-present possibility that controlling one pollution problem will spark another. Efforts to deal with water pollution have given rise to odor problems; control of air pollution, in turn, has often led to a water pollution problem. Thus, the plant may suddenly find itself bound by regulations governing new types of pollution.

5. Special tax treatment and financing sources may be available.

Fortunately, the special circumstances affecting capital expenditures for pollution control are not all unfavorable. The government has established a whole set of laws and regulations specifically aimed at pollution control expenditures that provides especially favorable tax treatment and financing arrangements.

The suggestions that follow are not mere theoretical considerations; rather, they have been applied in working plants and found useful. They are presented here from a managerial viewpoint to aid managers and supervisors in conducting pollution control programs in their own companies. Our goal is to provide information and guidance in a practical, common-sense form. In keeping with this, we will cite actual case histories, on the theory that while it is good to learn from one's own mistakes, it is even better to learn from someone else's.

Chapter II

THE APPLICABLE LAWS AND REGULATIONS

HISTORY AND EVOLUTION OF ENVIRONMENTAL REGULATIONS

Pollution control requirements are of surprisingly ancient vintage. The first known statute regulating air pollution was enacted more than 700 years ago—in 1273. Moreover, it appears that private lawsuits relating to pollution preceded this statute by several hundred years.

These so-called private nuisance actions, which can still be invoked today (see page 15), may have been somewhat effective in protecting a single landowner from a nearby source of pollution. However, they proved much less satisfactory in protecting the general public from diverse sources of pollution. The civil action of "public nuisance," therefore, evolved to allow municipal officials to sue to abate or halt a nuisance that affected the public at large. Eventually legal theories that developed around the public nuisance law were codified in many jurisdictions as statutes or ordinances. They provided criminal, as well as civil, sanctions against perpetrators of nuisances to the general public.[a]

The United States adopted this English regulatory scheme, based on private and public nuisance doctrines, and also evolved a statutory scheme dividing responsibilities among different levels of government: federal, state, and even county or local.

In this particularly American system, smaller jurisdictional entities are normally expected to resolve their own problems, especially in matters involving "police power" (i.e., public safety and health). Larger entities become involved only if these efforts are inadequate. Generally, this is the pattern that has prevailed in pollution control.

Among the present methods of control, regulation of different pollutants developed by differing paths. Air pollution, for example, is regulated primarily by the states; the federal government exercises mainly oversight authority. Water pollution, on the other hand, is subject to more pervasive federal regulation, though the states play a nearly equal role, incidentally causing frequent overlapping. Solid waste disposal and noise pollution may be state regulated, but they are more commonly controlled by local governments, if at all; the federal government plays a comparatively small part in their control.

For water pollution control, the first federal assistance was finally offered in 1948 through the Water Pollution Control Act after it was recognized that the problem could

[a]Interestingly, moral as well as environmental offenses were frequently included in the regulation of public nuisances.

not be resolved on the state level. Federal involvement was then expanded through the Federal Water Pollution Control Act (FWPCA) of 1946 and again through the 1972 Amendments to that Act. At that point, the federal government effectively assumed overall responsibility.

A similar pattern evolved in air pollution control. The first federal response to deteriorating air quality came with the enactment of the Air Pollution Control Act of 1955. The subsequent Clean Air Act (CAA) of 1963 provided for increased federal support of state and local efforts. The Clean Air Act was amended twice in 1965 to establish specific federal emissions standards for motor vehicles and to require the issuance of air quality criteria. The Air Quality Standards Act of 1967 further increased federal involvement. Finally, the 1970 Amendments to the Clean Air Act required the states to establish specific plans to reduce air emissions, provided a method of setting nationwide standards for new sources of pollution, severely restricted certain hazardous emissions, and required even more stringent restrictions on emissions from motor vehicles.

In the regulation of solid waste disposal, the federal government at first provided technical assistance and modest financial assistance to state and local governments in accordance with the Solid Waste Disposal Act of 1965, as amended by the Resource Recovery Act of 1970. The Resource Conservation and Recovery Act of 1976, signed into law on October 21, 1976, further amended the Solid Waste Disposal Act. It required the Environmental Protection Agency to set nationwide standards for the handling, transportation, and disposal of hazardous solid wastes; to issue permits for operators of hazardous-waste disposal facilities; and to fund research and development in waste reduction, waste disposal, and resource recovery technology. Planning assistance to the states is predicated on their phasing out open dumps over a 5-year period.

REGULATORY AGENCIES

Now, how are these environmental laws administered? They are administered by executive agencies at federal, state, and local levels. The primary federal agency, the Environmental Protection Agency (EPA), administers and enforces the Clean Air Act, the Federal Water Pollution Control Act, the National Environmental Policy Act, the Solid Waste Disposal Act, and other environmental statutes. Other federal agencies may have input into environmental matters, but these are secondary to EPA and they affect environmental regulation to a lesser degree. Some of the other agencies are the Occupational Safety and Health Administration (OSHA), the Energy Research and Development Administration (ERDA), the Federal Energy Administration (FEA), the Nuclear Regulatory Commission (NRC), the Department of the Interior, and the U.S. Army Corps of Engineers.

At the state level, environmental laws may be administered by one or more state agencies. For example, in Maryland two entirely separate agencies control air pollution and water pollution. Three basic types of state environmental agencies have been identified by the Council of State Governments:

- The health department. This is where most states originally placed responsibility for pollution control programs. While environmental matters may become stepchildren to broader public-health considerations, the size of such a department can provide economies of scale and act as a buffer against budget slashing.

- The mini-EPA. This is a separate department responsible for all or almost all pollution control programs. There are fewer policy conflicts here than in a health department, but coordination of pollution control with other environmental objectives may be more difficult.

- The environmental superagency. Here are found pollution control and all other environmental responsibilities, such as conservation and resource management. The superagency tends to be larger than the mini-EPA, with a correspondingly stronger voice in state government. It also fosters an integrated approach to environmental affairs, since conservation and natural resource management responsibilities may be coordinated with pollution control objectives.

These state agencies implement federal statutes as well as state environmental laws, which are frequently more stringent than comparable federal ones.

Local governments sometimes also regulate pollution; indeed, some have enforcement authority specifically delegated by the state; and most have zoning, nuisance, and noise-control ordinances. Cities that enforce air pollution codes commonly have some type of enforcement agency for that purpose. Zoning decisions are generally made by a zoning board. Other ordinances are usually enforced as criminal laws; local police detect and apprehend violators, and the district attorney prosecutes them in the name of the city or state.

The courts are the mechanism through which pollution control is accomplished when voluntary compliance cannot be obtained. The courts may set fines or criminal penalties for violations of the law (after a trial, of course). They award damages or issue injunctions in nuisance actions. They hear appeals from agency determinations and also hear citizen suits brought against the agencies or against industry under provisions for such suits contained in environmental laws.

After centuries of quiescence, in the past decade the courts have become an active force in pollution control. Their interpretations of the new environmental laws have even caused enforcement agencies to become more vigorous in controlling certain forms of pollution than the legislatures that enacted those laws may have intended.

INTERPRETATION OF THE LAWS

Managers who attempt to interpret environmental regulations without a strong background in both the law and the technology of environmental control do so at their own peril. Obviously, environmental laws and regulations are no less complex and no more self-explanatory than any other form of bureaucratic prose.

Even regulations that appear to be clear on their face can have serious pitfalls lurking in the verbiage. Certain words or phrases with accepted meanings in ordinary speech may assume substantially different significance in a law or regulation. Lawyers refer to these as "words of art." Such words of art are sometimes, but not always, defined in the regulation in which they appear. Absence of a definition does not mean that a term is not a word of art.

One other precaution: Environmental regulations frequently specify testing procedures that are acceptable for determining compliance with emissions or effluent limits. Testing methods may be buried in appendices to the control regulations, or they may be described in a special portion of the regulations devoted solely to testing methods. Often a testing method is specified by name and/or number only with a reference to a standard technical manual in which the mechanics of the test procedure are described.

If a particular test method is specified in the regulations, the enforcement agency will not accept compliance tests made by other methods, even if the nonspecified procedure is more accurate and shows the facility to be well within the effluent or emission limits.

REGULATION OF WATER POLLUTION

The Federal Water Pollution Control Act divides sources of water pollution into three categories and subjects each to a different method of regulation. The categories are existing sources, new or modified sources, and sources of toxic pollutants, whether existing or new.

Moreover, there is a further regulation, applicable to both new and existing sources, which requires appropriate pretreatment when effluents are discharged into publicly owned treatment plants. Although the states retain considerable authority in regulating water pollution, the federal government's role is also considerable and may lead to a great deal of overlapping enforcement. Let us see how regulations work in already existing sources of pollution.

EXISTING SOURCES

For existing sources of water pollution containing no toxic substances, the Federal Water Pollution Control Act requires the achievement of "best practicable control technology" (BPT) by July 1, 1977. FWPCA further requires the more stringent "best available control technology" (BAT) by July 1, 1983.

It is important to note that, although the Act speaks of "best . . . technology," EPA translates this into numerical limits on the volume or concentration of pollutants that a regulated source may discharge. The source may use any control technique (including a change in processing methods) to meet these numerical limits.

EPA has attempted to set effluent limits on a number of industrial categories, thereby in effect numerically defining for those industries what is meant by BPT and

BAT. Such limits have been subject to much litigation, since the Act is somewhat ambiguous as to whether EPA may set effluent limitations on existing sources or may set only nonbinding guidelines. As the lower courts have not yet reached a consensus on this issue, it will probably be resolved eventually either by a Supreme Court ruling or by a clarifying amendment from Congress.

There are, then, three methods of translating the statutory requirements of BPT and BAT into numerical limitations on existing sources of pollution:

- EPA sets effluent limits that are binding on the entire industrial category.
- EPA sets guidelines for effluents that will generally be applied to the entire industrial category, but will leave some room for flexibility by the enforcement agencies.
- Each source negotiates with the enforcement agency an individual definition of BPT and BAT. (The agencies themselves, of course, frequently use informal guidelines internally to set a negotiation range.)

EPA has delegated authority to 27 states to negotiate and enforce effluent limits on individual sources. However, the authority to set nationwide effluent limitations and guidelines for industrial categories cannot be delegated. In practice there are three combinations of federal and state authority over existing sources of water pollution:

- When EPA has not delegated authority to the state, and the state has no permit requirements of effluent limits of its own, only EPA regulations apply. In this case, since EPA sets limits only on discharges to surface waters (e.g., rivers and lakes); discharges to underground waters (e.g., quarries and wells) are not regulated.
- When EPA has not delegated authority to the state, but the state has its own permit requirements and/or effluent limits, then both state and federal regulations apply. Thus, two permits may be required for surface discharges. For underground discharges a state permit, based on state effluent limits, may be required.
- Where EPA has delegated authority to the state, only one set of effluent limits and permit requirements applies, and it may apply to both surface and underground discharges.

Effluent limits, regardless of which agency imposes them, may be more stringent than BAT for certain sources that discharge into heavily polluted waters. A goal of the FWPCA is that all surface waters be suitable for fishing and swimming by 1983. If EPA foresees that a water body will not reach that goal, it may impose limits even stricter than BAT, although economic factors must still be considered.

NEW OR MODIFIED SOURCES

The FWPCA requires EPA to set new-source performance standards (NSPS), covering 27 listed industrial categories and such other categories as EPA deems appropriate. These standards are similar to effluent limitations set by EPA for existing sources, and they apply uniformly to all new sources throughout the United States, with little left to the discretion of enforcement agencies. NSPS are required to reflect the "best available demonstrated control technology"—similar to the 1983 BAT requirement for existing plants. EPA may delegate enforcement authority over NSPS to the states, but they may not set standards.

To date, NSPS have been issued for 40 industrial categories and a number of subcategories. NSPS for water pollution sources have generally been promulgated for the same industrial categories that have existing effluent limitation guidelines. Standards for new sources in industries without NSPS are determined on a case-by-case basis.

TOXIC WATER POLLUTANTS

FWPCA gives EPA authority to set effluent standards for toxic water pollutants. These standards are also set by category of industry, and EPA may even place a total ban on such discharges where appropriate. Unlike other regulatory provisions in this Act, enforcement authority is not delegated to the states; but the states may set and enforce their own toxic standards, which may be even stricter than EPA's.

To regulate a toxic effluent EPA must first list the pollutant as toxic, then set effluent limitations on it for appropriate industrial categories (the primary sources). Industries that discharge a listed pollutant for which no standards have been set are regulated on a case-by-case basis.

PRETREATMENT

Both new and existing sources of water pollution have the opportunity under the FWPCA to use publicly owned water treatment facilities, circumstances permitting. To do so, the industry must pretreat the effluent to make it compatible with the treatment capabilities of the public facility.

EPA establishes nationwide pretreatment standards for industrial categories, similar to other limits, such as NSPS and toxic pollutants. In fact, all these sets of standards are often published simultaneously by EPA. EPA cannot delegate the setting and enforcement of pretreatment standards to the states, but states may set their own pretreatment standards, as long as these are consistent with EPA's. Local governments and regional authorities may also set pretreatment standards for treatment works that they own and/or operate.

Since publicly owned facilities generally treat only settleable solids and organics, users of these facilities must pretreat their effluent for those substances that are subject to standards. Users of a public facility must, of course, pay user charges, and they may also be required to contribute to construction costs if a new or expanded treatment facility must be built.

It should be noted that the use of publicly owned facilities is completely optional on the part of the discharger. The decision as to whether or not to pretreat is based primarily on economic, rather than legal, considerations.

PERMIT SYSTEMS

Cutting across all water pollution controls is a system of permits that forms the basis for virtually all compliance and enforcement activities. The FWPCA established the basic permitting scheme, the National Pollutant Discharge Elimination System (NPDES). An NPDES permit issued by EPA is required to discharge pollutants into virtually any body of surface water. In issuing these permits, EPA sets the specific effluent limits on an individual source. If there are existing limitations or guidelines, then these are made part of the requirements imposed by the permit. If none of these apply, then BPT and BAT for the individual source will be determined by negotiation between the discharger and the authority issuing the permit. These are translated into numerical limits in the permit.

EPA has delegated permit issuance and enforcement authority to 27 states. These states may require NPDES permits for discharges to either surface or subsurface waters. The states, with or without delegated authority, may also require operating permits and permits to construct new sources or to modify those already existing.

There is an interesting feature of this permit system. Obtaining a permit is, in itself, an essential prerequisite to the right to discharge any pollutant, regardless of how small the volume or concentration of the discharge may be. Therefore, unless and until a source has obtained such a permit, its operations are in violation of the law for that reason alone, even if effluents from the source comply with all applicable limitations of BPT and BAT.

REGULATION OF AIR POLLUTION

Sources of air pollution also fall into three main categories: existing sources, new or modified sources, and sources of hazardous pollutants, whether new or existing. Federal and state responsibilities are quite differently apportioned in the three categories. In air pollution control there is nothing analogous to pretreatment or the permit system (NPDES) which apply to water pollution.

EXISTING PLANTS

Air pollution emissions from existing sources of nonhazardous pollutants are regulated by state governments, with federal back-up enforcement by the EPA. The Clean Air Act (CAA) required that each state develop an implementation plan (SIP) for regulating air pollution. EPA determined if the plan was sufficiently stringent to enable the state to attain the national ambient air qualtity standards in a timely fashion; if not, EPA substituted appropriately stringent requirements of its own in the SIP.

There is no consistency in regulatory schemes among the states; some states have different standards for different regions within the state; others do not. Some states regulate emissions that others ignore (NO_x and hydrocarbons, for example). Some states set special emission limitations for certain industrial categories; others have only a general emission limit. Not all states that select specific industrial categories for special regulation choose the same categories. Certain pollutants may be subject to more than one standard within a particular state; for example, particulates may be simultaneously subject to a mass emissions limit, a visible emissions limit, and a fugitive dust limit.

Because regulations vary so greatly from state to state, management must carefully study the laws and regulations of the state in which a particular plant is located before embarking on an air pollution control project for that plant. Experiences of plants in other states should be relied upon only with appropriate caution.

NEW OR MODIFIED SOURCES

The Clean Air Act empowers EPA to establish national standards of performance for certain categories of industrial sources, much as the FWPCA does for new sources of water pollution. These standards (NSPS) apply to sources constructed or modified after EPA's publication of proposed standards for that category. (The critical modifications that bring existing facilities within NSPS regulation are described at length in EPA regulations.)

EPA does not issue permits to construct, but it must be notified prior to new construction or modification extensive enough for NSPS to apply. EPA may delegate regulation to the states if state regulations are sufficiently stringent and the state agency can demonstrate the capacity to enforce the regulations. Some states have new-source regulations independent of EPA's; in those states, both state and federal regulations must be satisfied. In addition, many states require permits to construct or modify a source of air pollution. Local governments (particularly those with SIP enforcement authority) may also require construction permits for new or modified sources.

Although NSPS for 24 industrial categories have already been published by EPA, others are being considered. Since NSPS are generally more stringent than existing-source standards, it is usually to a firm's advantage to begin construction or modification of a plant prior to the publication of proposed new-source standards for its industry. Construction is deemed "begun" by the letting of contracts; so if it is discovered that NSPS for a contemplated plant are under consideration by EPA, substantial savings may be obtained by pushing ahead with construction commitments to beat the NSPS effective date.

Approval for construction of a new source does not depend solely on that source's ability to meet any applicable NSPS. Even if a new source meets its NSPS, or if no NSPS apply to that source, construction still may not be permitted. This anomalous situation is due to the current uncertainty over the Act's prohibition of degradation of air quality in "clean air" areas (those already surpassing the national secondary ambient air quality standards). Construction in "dirty air" areas (those not likely to meet the secondary ambient air quality standards by the deadline date) may also be prohibited. The entire topic of construction of major sources of air pollution (minor sources have generally been exempt from this controversy) is undergoing considerable change through EPA regulations, court decisions, state agency actions, and congressional attempts to amend the CAA to resolve the uncertainties.

The current state of affairs (subject to much uncertainty) is that a new source may be constructed in "dirty air" areas only if an equivalent amount of pollution is reduced as an offset in the same area. The offset is separate from the emissions reduction already required under the SIP. New sources in clean air areas may only "use up" defined increments of the area's margin above the secondary ambient air quality standards. The application of these rules varies so greatly from area to area that a straightforward formulation of their effect is not possible. State air officials should be consulted to discover their interpretation of these rules and to negotiate the required offsets or increments.

HAZARDOUS AIR POLLUTANTS

The Clean Air Act further empowers EPA to set national emissions standards for hazardous air pollutants (NESHAP). Designed with a safety margin, these standards are analogous to toxic-effluent standards for sources of water pollution. No source may be constructed or modified in violation of a national emissions standard for hazardous air pollutants; nor may an existing source violate the standard, but EPA may grant 2-year waivers for compliance. Unlike the situation that applies to toxic effluents, EPA may in this case delegate enforcement authority to the states, but it retains standard-setting authority. States, however, may independently set standards for pollutants not regulated under NESHAP, or set stricter standards for those that are.

To date, EPA has designated only asbestos, beryllium, and mercury as hazardous. Permit requirements are not affected by NESHAP regulation; therefore, states may require special operating permits for sources emitting certain pollutants, though EPA does not. Rather than limit emissions, NESHAPs may define operating practices and specific control techniques. These are mandatory and strictly enforced by both EPA and the states.

ANCILLARY LAWS AND REGULATIONS

Although air and water pollution controls are by far the most commonly encountered environmental problems for industries, there are other legal issues that may arise and unexpectedly cause severe problems. The more common of these issues are environmental impact, land use, solid waste, noise, occupational safety and health, and nuisance laws.

ENVIRONMENTAL IMPACT STATEMENTS

The National Environmental Policy Act (NEPA) requires preparation of an extensive environmental impact statement (EIS) prior to the irrevocable commitment of resources to any major federal action having a significant impact on the human environment. While NEPA applies to private enterprise only on the rarest occasions, it has spawned several state laws, known as "little NEPAs." If a state has a little NEPA, it may require its own EIS before state or local government will grant a permit to construct a new industrial plant or to substantially modify an existing one. The plant manager should be sure to find out if the state has such an act when a new or modified plant is to undergo construction, and if the act applies to private construction or governmental permits allowing private construction.

LAND USE LAWS

State land use laws and local land use or zoning ordinances have an impact on the siting decision for a new plant and may affect the expansion or modification of an existing plant. Where the zoning or land use laws allow construction or modification, permits to construct may be required; where they do not, exceptions, variances, and amendments may be available for certain sites.

SOLID WASTE LAWS

Many states have laws regulating the methods of storage, collection, transportation, and disposal of solid wastes and sludges. (These are frequently generated in large quantities by air and water pollution control equipment.) Local and regional solid waste authorities may also have pertinent ordinances or rules. Besides the obvious impact that these regulations have on industrial solid waste management practices, they may also become a significant factor in the choice of air and water pollution control equipment. Disposal of collected wastes from some types of control equipment may be much more difficult and costly than waste disposal from alternate methods. State and local solid waste disposal regulations should be understood thoroughly before management makes an irrevocable commitment to any particular pollution control device.

Under the federal Resource Conservation and Recovery Act of 1976, EPA issues regulations pertaining to the storage, transportation, and disposal of hazardous solid wastes and requires permits for operators of hazardous-waste handling or disposal facilities.

NOISE REGULATIONS

There are no federal noise regulations for industrial activities in general, only noise standards for certain types of equipment. Few states have noise laws, but those that do may significantly affect certain industries: most existing state laws have noise standards that vary by time of day and by type of use of adjoining property. Local governments frequently have noise ordinances, particularly within city or town limits. The plant manager should be aware of noise laws or ordinances and take steps to comply with them as with air and water pollution laws.

OCCUPATIONAL SAFETY AND HEALTH

The federal Occupational Safety and Health Act (also called the Williams-Steiger Act), administered by the Occupational Safety and Health Administration (OSHA), sets standards within the workplace for worker exposure to health hazards (such as chemicals, airborne pollutants, and noise exposure) as well as safety hazards (such as lack of railings, unsafe equipment, and slippery floors). The manager should determine if OSHA has issued exposure limits for any contaminant likely to be found in any workplace within the plant and check to see that noise exposure limits and safety requirements are met. OSHA has the authority to fine noncomplying firms. Some states have occupational safety and health laws in addition to those set down by OSHA, and OSHA enforcement may be delegated to the states. These state laws and regulations should be examined in the same fashion as the federal law.

THE LAW OF NUISANCE

The common law (i.e., court-made law based on precedent) of private nuisance, still in effect in most states, permits a landowner to recover for a lessening in the usefulness of his/her property. In addition, some states have private nuisance statutes setting specific grounds for recovery by injured parties (not necessarily landowners). Under private nuisance law an injured party may recover damages from a polluting plant, even if that plant is meeting all other applicable environmental regulations.

Public nuisance statutes (at the state level) or ordinances (at the local level) are quasi-criminal in nature. They provide for fines and equitable relief (injunctions) against the nuisance, sometimes even prison sentences for repeated violators. Private parties can recover damages against public nuisances only if they can show extraordinary economic damages not suffered by the public at large. Public nuisances may include air and water pollution, noises, odors, vibration, and even eyesores and other aesthetic blight.

Air and water pollution control laws have obviated much of the need for public nuisance actions against polluters, but the aggrieved private citizen living near an industrial plant can still present a significant threat as a potential litigant against that plant. Good public relations and amicable compensation of local residents affected by plant emissions can avoid costly lawsuits.

Chapter III

RELATIONS WITH OUTSIDERS

CONSULTANTS

Many companies will not have the in-house expertise to carry out a pollution control program. The question often, therefore, is not whether an outside consultant or plant personnel provide the more efficient result, but whether the needed investment in personnel training is more cost efficient than hiring an expert consultant.

A consultant should be familiar with all pertinent laws and regulations and their enforcement; the various control options and their performance capabilities, limitations, and cost attributes; and the problems (with appropriate solutions) encountered in the practical integration of pollution control technology with plant processes.

Whether you should hire a consultant or not depends essentially on two operational characteristics: (a) the extent to which plant personnel is trained and experienced in technologies found in pollution control, and (b) the likelihood that the same or similar pollution problems will be encountered again at this plant or in others that the company owns.

The first of these characteristics largely determines the cost of additional training to enable plant personnel to accomplish the task with results equivalent to those of a consultant. The second determines the future use that can be made of the acquired skills. The two characteristics together influence the approach management should take.

If the initial job is large and the type of work is likely to continue, then you may wish to consider hiring permanent staff. If, on the other hand, you decide that time and cost of training and the subsequent use of the acquired capability do not merit training either your own personnel or staff additions, a consultant is called for. If your personnel work closely with a consultant, it is not unlikely that, after completion of the first project, some of the skills and knowledge of the consultant will be assimilated by your staff, thereby improving their skills to the point where subsequent projects might be adequately handled in-house or with a minimum of consulting assistance.

Let us say you have decided that the present state of training and the subsequent needs for new skills are such that it is more cost efficient to obtain the services of a consultant. The problem is then where to find a consultant and how to choose among several candidates.

LOCATING A CONSULTANT

Finding a consultant is considerably different from finding suppliers. Suppliers often act in a consulting capacity in that they will offer solutions for some of your problems or recommend improvements on their equipment and systems. If, however, you desire a broad spectrum of unbiased ideas you cannot rely solely on recommendations of suppliers. A supplier is most skilled in his own equipment or in equipment having features that compete with his product. He, therefore, may not have the desired technical breadth. There is also an unavoidable built-in bias in favor of his equipment. Suppliers advertise in magazines and may use direct mail and sales visits.

Consultants, on the other hand, rarely advertise in trade media, but may place professional cards in journals and technically oriented magazines. Many consultants are professional engineers; in fact, many jurisdictions require engineering consultants to be licensed by the state. Often the code of ethics of the professional engineer forbids advertising except for professional cards, much as in the case of lawyers and doctors (though recent Supreme Court decisions found advertising bans to be illegal restraints of trade).

How then do you locate potential consultants skilled in your problem area? Here are a few suggestions:

- Some states and EPA regional offices maintain lists of available consultants. It is first wise to ascertain requirements for listing. In some instances, an applicant must meet certain requirements before he is listed; in others, a consultant gets on the list by simply stating that he wishes to be listed.
- Readers' abstracts normally available in libraries can help you locate consultants; for example, Applied Science and Technology Index, Pollution Abstracts, Selected Water Resources Abstracts, and Solid Waste Management Abstracts and Excerpts from the Literature.
- If an author is frequently identified with a subject, he may be qualified to consult, or he may recommend people who are available and appropriately qualified.
- Another way of finding a consultant is to contact your professional or trade association for leads.
- Certain journals and magazines list consultants, sometimes arranged by geographical regions with their specialties noted. Some of these publications are the Journal of the Air Pollution Control Association, Environmental Science and Technology, and Pollution Engineering.

After you have found a number of potential consultants, you may have to conduct an initial "geographical" screening. You normally will have to pay the consultant's travel expenses, and most consultants include part or all of the time "away from the office" in their fee. You may, therefore, be paying relatively unproductive fees if long travel times are involved. Generally, if you have more than about four names, you should be able to adjust the field of candidates by eliminating those consultants located at appreciable distances from you.

People are reluctant to question professionals about job fitness. How many people do you know who select doctors or lawyers by interview? Most often a client-professional relationship is initiated via another professional, or by suggestion from a patient or client who liked the service the professional supplied. In the case of selecting consultants, this reticence to interview can be often overcome by using a reporting form with which professional engineers and architects are generally familiar (e.g., Form 255 used by the federal government.) Or you may write the consultant that you are attempting to select a consultant for services, describing in full the problem you wish him to undertake, and requesting that he provide completed forms, together with his fee structure. This method of initial contact will often overcome the face-to-face dilemma and keep options open.

When you receive the data, examine it to ascertain how much past consulting work the applicant has done on your particular type of problem or on closely related problems. Determine how extensive his experience has been on a particular activity listed on the form. Consultants sometimes do not differentiate between the total job and their contributions. You should specifically ask for his job breakdown in the cover letter.

Once you have the names and projects the consultant cites, you can contact the clients noted. Look for experience as well as training. A person with extensive technical training and empathy with your problem may not serve you best; after all, you probably have people on your staff with good technical competence and high enthusiasm. What you are looking for is a consultant who, by virtue of training and experience on a number of jobs with problems similar to yours, can bring pertinent experience to bear on your problem in a cost-effective fashion.

WORKING WITH A CONSULTANT

After you have decided on the consultant and have a service arrangement, you will want to have a kickoff meeting. Key plant personnel with whom the consultant would be expected to collaborate should be at the meeting. Plant personnel can sometimes view the consultant as a threat, especially if they feel that they should have been assigned the work and the decision to hire a consultant was not theirs. The kickoff meeting, therefore, should assure everyone that the project has the blessings of top management and that results will reflect the degree of cooperation between plant personnel and the consultant. A division of responsibilities should be made clear.

The extent to which the consultant will be used and the ground rules of the consultant-client relationship should be thoroughly aired within the company management prior to this first meeting, so that the division of responsibilities and duties can be worked out at the meeting.

The areas in which a consultant can contribute cover the entire spectrum of a pollution-control program. Starting with the emissions survey, the consultant could develop conceptual designs, prepare bids and specifications, evaluate proposals, assist in letting subcontracts and purchase orders, and, if called on, follow through the installation process. In many fields, consultants are brought in only to present spot information on a particular topic. In pollution control, however, it is not unusual to find consultants involved from the conception of the project through the initial operation of the system. In some instances, the consultant is assigned overall technical and performance responsibility for the job.

To properly fulfill his duties, a consultant probably will need access to production figures, raw material information, and process details. Best results are obtained when plant personnel are candid and give complete data to facilitate the consultant's work. Sometimes the consultant may receive information that the company considers confidential.

The problem for the company is that the consultant-client relationship does not receive the same legal protection as the attorney-client relationship. Because information that a client divulges to a consultant is not privileged, the consultant may be required to testify to what a client has disclosed to him. The consultant may not, however, divulge such information to some third party without a legal compulsion to do so; such disclosure would violate the implied contractual terms of the agency relationship between the consultant and client, subjecting the consultant to liability for damages the disclosure causes. Explicit agreements not to divulge confidential information are frequently included in consulting contracts, however. Your company lawyer can frame an appropriate agreement.

ATTORNEYS

It is a rare company indeed that does not use the services of an attorney with some regularity. In deciding which pollution control measures to take (negotiating compliance schedules with regulatory agencies, interpreting pollution control and administrative regulations, drawing up sales contracts), the company's attorney frequently provides assistance unavailable from nonlegal advisers and performs tasks that management is generally incapable of. Not all lawyers, however, are equally competent in solving pollution control problems.

As the fields of law have become increasingly complex, the natural tendency of the legal profession has been to specialization. Although any attorney is theoretically qualified to answer legal questions in any field of law, those legal advisers most often relied upon by businesses have specialized in taxation, corporate law, securities regulation, labor law, and contracts. Since environmental law is every bit as complex and specialized as those fields, ordinarily it will be to the company's advantage to engage an attorney specializing in environmental law for comprehensive advice. Not only will the specialist be able to answer questions with less preparation and research (thus saving the client money), he/she will also be more conversant with the control technology required and will have extensive contacts with the regulatory agencies. In this field, as in most other professions, there is no substitute for experience.

To a certain extent the functions of the consultant and the attorney may overlap. Both should understand the applicable regulations; both deal regularly with the enforcement agency. When a company hires a consultant in pollution control, that consultant may assist the company's regular attorney in performing those tasks requiring specialized knowledge. Bid packages, for example, should contain provisions for acceptance tests equivalent to the state enforcement agency's compliance testing procedures. While a business attorney may not realize this, a consultant would alert the attorney to include such provisions in the bid package and sales contract.

If the technical work is to be done by in-house staff, an attorney experienced in pollution control should be retained to assist management. (The attorney ordinarily used, even staff counsel, may have the necessary experience, of course.) Many of the attributes described for consultants hold also for environmental lawyers, except for technical expertise in designing, installing, and testing the pollution control equipment. Just as the consultant should be chosen to complement the company's in-house technical and management capabilities, the lawyer should be chosen to complement in-house legal and management capabilities.

LOCATING AN ATTORNEY

If management decides to retain an environmental lawyer, the next problem is how to find one. Some sources are suggested below:

- Most county bar associations have Lawyer Reference Services, which match potential clients with participating local attorneys. Attorney listings are usually classified by specialities or fields of interest.
- The company's staff counsel or business lawyer may be able to recommend a specialist or to find one through contacts not available to management.
- Most large law firms have at least one attorney knowledgeable in environmental matters.
- The environmental agency may informally advise a company of some environmental lawyers with whom they deal. (It is highly unlikely that the agency has a formal list of lawyers or will recommend one, but they may give out the names of several as a personal favor.)
- Professors of environmental law at law schools may have private practices themselves.

In rural areas with small bar associations it is possible that none of these methods may turn up a properly qualified individual. Therefore, an attorney from another area may be obtained or a consultant hired to assist nonspecialized counsel. Distances from the nearest environmental lawyer and consultant may determine which option is more cost effective. The consultant should be brought in only to provide regulatory and management assistance at a cost lower than that for a full range of technical and management assistance.

Assessing the qualifications of an attorney is difficult, especially for a nonlawyer. It is possible to request the attorney to quote an hourly rate and roughly estimate the total number of hours that will be required to complete the necessary work. Attorneys will not tell you who their clients are, however, since this information may not be divulged. Although the question is seldom asked by prospective clients, attorneys may discuss the types of cases in which they have experience.

Any information disclosed to an attorney by a client is absolutely privileged; such information cannot be obtained from the attorney by discovery procedures in civil litigation, by subpoena, or by testimony in court. One significant tactical advantage in having an attorney rather than a consultant deal with regulatory agencies, then, is the protection given information divulged to the expert.

REGULATORY AGENCIES

An important aspect of pollution control efforts involves the relationship of the company to the regulating agency. This relationship can range from total cooperation to a formal adversary position. The stance your company should take can only be decided by company management.

INTERPERSONAL RELATIONS

Enforcement authorities in general have some flexibility in interpreting regulations and particularly in determining schedules for achieving compliance. Agreement on areas where some discretionary latitude is available is enhanced if the company presents carefully thought-out arguments based on technical and economic facts. General gripes about, for example, the "ecological movement" or the "outrageous costs involved" will not be nearly as persuasive as a rational, substantiated argument lucidly presented.

As in many interpersonal relations, your frame of mind often permeates the discussions and affects results. If you assume the regulatory authority has singled you out for arbitrary and capricious enforcement, it would not be surprising to see the matter end up in adversary proceedings. If your attitude is that the best course is a cooperative one, if you expect the authority to react rationally to accurate and persuasive technical and economic arguments, then the chance is better that the discretionary finding will be equitable. Of course, if this cooperative approach does not yield satisfactory results, appeal rights and other remedies can be sought.

ADMITTANCE TO THE PLANT

Personnel from EPA and state enforcement agencies should be given access to the plant, its grounds, and the required records. Refusing such access to authorized inspectors can only create needless ill will. Moreover, EPA can issue orders or obtain a court order to admit its inspectors. Violating such an EPA order may result in a fine; violation of a court order is contempt of court. Refusing access to state inspectors may also result in fines, court orders, or loss of operating permits.

VOLUNTARY COMPLIANCE VS. DELAY

Management should not wait passively for enforcement actions to be instituted before taking measures to correct pollution problems. While it may be tempting to delay such expenditures as long as possible, or to gamble that an inspection will not occur, such benefits as may accrue could ultimately prove to be false economy. When compliance must be achieved under the threat of enforcement actions, costs can go up dramatically with shortened times for contracting, construction, debugging, etc. Conversely, efficiencies and economies can be realized by moving at a more leisurely pace, in advance of pressures from enforcement agencies.

Such advance measures also create a more favorable impression of the company within the agencies, among the company's own employees, and even with the general public. This is more than a triumph of style over substance, since the resulting good relations with the enforcement agencies may provide actual substantive benefits.

CONSENT ORDERS

A consent order or compliance schedule (the two terms are often used interchangeably) is an agreement negotiated between a government agency and a regulated company. The company agrees to take specifically detailed steps to correct some violation of the agency's regulations. In return, the agency agrees to forebear prosecution for those violations so long as the company meets the commitments it made in the consent order. Technically, a consent order is an administrative order issued by a regulatory agency; it usually includes a compliance schedule specifying goals or milestones and dates. Compliance schedules may also be included in NPDES permits and state operating permits, both for air and water.

While consent orders can provide significant benefits for both the agency and the polluter, the manager should be aware of some dangers they present if their import is imperfectly understood. A company that is in the midst of an agency enforcement action or investigation may be tempted to make optimistic promises in a consent order just to achieve a temporary respite from the agency's "heat." Succumbing to this temptation, without fully understanding the effect of such a consent order, can have serious repercussions.

Violations of the terms of a consent order, or failure to meet the goals of a compliance schedule in a timely fashion, gives the enforcement agency separate grounds for prosecution, quite independent of, and in addition to, the underlying violation on which the order was based. Moreover, since the consent order typically describes specific remedial actions to be taken, the company's failure to adhere to this consent order is comparatively easy to determine and to prove in court. Therefore, defense against a resulting prosecution becomes correspondingly more difficult.

These potential legal consequences of consent orders should not deter management from entering into them; but they should be carefully negotiated from a position of great knowledge about the available control options, particularly their technological capabilities, their costs, and the time constraints on design and construction of the control systems. Management should determine the least-cost control method that will enable the plant to meet all applicable regulations, then obtain time estimates from the equipment vendors, and only then negotiate a consent order with the enforcement agency, being adequately armed with the information necessary to strike a fair bargain. This methodology reinforces the advisability of initiating a voluntary compliance program rather than delaying and awaiting enforcement action.

APPEALS

Appeal procedures are available to test the legality, constitutionality, and rationality of agency rulings and orders. Generally the agency will have internal review procedures providing at least one, sometimes two or three, levels of appellate review. Consent orders are generally not reviewable, since they are mutually agreed upon and are considered to be a hybrid between an order and a contract. Administrative appeals may be heard by a higher ranking bureaucrat, an appeals board, or an administrative law judge.

Once administrative appeals and rehearings have been exhausted, appeals to state or federal courts are permitted by various administrative procedure acts, state and federal constitutions, and common-law principles.

It is important to note dealines for filing appeals. These deadlines are strictly enforced, so appeals must be filed within the time limit provided or the right to appeal will be lost.

If an order is being discussed with an agency to have the agency modify its terms, the manager should file the appeal before the time limit expires. If the rehearing is not granted or the negotiations ultimately fail to solve the company's problem, the right to appeal will then not be precluded; if the negotiations are successful, the appeal may be dropped. As a matter of tactics, filing the appeal may also encourage the agency to negotiate a settlement more quickly (before the appeal must be heard).

OVERLAPPING JURISDICTIONS

Overlapping between the jurisdictions of different agencies dealing with pollution control is not rare. For example, in states which have not been delegated the authority to issue NPDES permits, obviously they must be obtained from EPA. However, these same states also have the right to require their own discharge permits and to enforce their own effluent limitations. Situations can also arise in which compliance with regulations for one kind of pollution violate others. Meeting an air pollution regulation, for example, may result in the violation of a solid waste disposal regulation.

Accordingly, care must be exercised. Problems arising from such causes should be brought promptly to the attention of the cognizant regulatory agencies.

Chapter IV

THE POLLUTION CONTROL PROGRAM

MANAGEMENT TIMING

Industrial management is accustomed to calendars of events that are time oriented, such as entry into new markets, when to adjust inventories, when to act on tax matters, etc. A prime example of such an activity, pollution control management, involves three important time-oriented factors:

-- initiating a pollution control program;

-- meeting mandated deadlines; and

-- handling delays in system acquisition.

Management usually has some freedom in choosing its day of decision. For this reason, arguments are often advanced for delaying a company pollution control program until the last minute. Aside from the vain hope of escape, or at least a temporary respite from enforcement, it may be argued that public pressure may reduce the regulations in severity and enforcement. Another argument (with some analytical base) relates the decision to alternative investments—if financial commitments for pollution control are delayed, the same funds could be invested in an interest-bearing account or a capital alternative which would produce an important return on investment. In practice, however, there are countervailing arguments in favor of initiating a program at an early stage.

That there is any management leeway owes its existence to the time required in the administrative process. It takes an appreciable amount of time to formulate regulations, and additional time to contact industries and initiate enforcement actions. This time varies from several months to perhaps one or two years. During this interval, management is aware of the impending necessity of pollution control investment and has the freedom to act or not to act. There are five important aspects, discussed below, that should bear on management's decision.

The first is that plans can be initiated at an early stage, while capital funds are withheld until the technical requirements are sufficiently reliable to specify and buy equipment and enforcement is imminent.

Second, process changes can frequently be employed which will reduce the cost of needed control equipment, and in some industries may even be sufficient to meet regulations. In the past, process changes lacked appeal in part because of the federal Internal Revenue Code, which, although permitting amortization of a pollution control system within 60 months, irrespective of the asset depreciation range of the equipment, did not accord process changes the same advantage. The tax code further reduced the appeal of rapid amortization by making rapid amortization and the investment tax credit mutually exclusive. In 1977, for the first time, the revised tax code permits an industry to take rapid amortization and, at the same time, one half of the investment tax credit. Process changes qualify under the new law for rapid amortization, making such changes more attractive from a tax standpoint.

Process changes, however, often require a long lead time. They can be highly involved from an engineering point of view; or the specific change may appear superficially uncomplicated, but it may cause subsequent problems in process operations. For example, take the case of changing from solvent coatings to water base coatings: coefficient of rolling friction of the finished coating would be altered, and this could impair the mechanical movement of the container or coated material in the production lines. Therefore, although process changes are attractive, they often require considerable study time to ensure that the changes do not bring about deleterious side effects and that equipment and tax savings potentials are fully realized. If a company refrains from initiating a program until it has been cited for a violation, the process change alternative may not be a viable route.

Third, in addition to allowing more time to study the choice of a process change or control equipment, an earlier start offers a longer period for personnel training. This training can be of greater extent and depth; training can be better fitted into the employees' schedules, and employees can be better trained to collaborate with consultants or other outsiders (see Chapter III).

Fourth, a careful cash flow analysis should be made. The cost of equipment and services sometimes escalates faster than the net-of-interest income minus taxes plus operation expenses. This can be seen from Figure 1, which shows increases in the type of costs that would be encountered in pollution control systems, either control equipment or process changes, over the period 1972-76. In three of these years (the exception is 1973), an analysis of acquisition costs would indicate that purchase of the needed control equipment would be preferable to delaying purchase and then investing the funds in a short-term interest account. Where operating expenses due to energy and materials costs are appreciable, however, escalating acquisition-cost effects are much less forceful in the decision process.

It can be argued that the comparison should be made with an alternative capital investment, since the return on investment may be greater than the interest income minus taxes. However, the short time span available to management (usually less than two years) would effectively mean a comparison between simultaneous rather than alternative capital investments for pollution control and another capital investment.

Fifth, control regulations, rather than getting easier with time, often get stiffer. Although there are some instances where regulations became less strict, as in water regulations for the plating industry, this is an exception to the general rule. Each industry should assess the direction the relevant regulations are moving in, but definitely it should not be assumed that they will get easier with time.

Index	Price Index	Percent Increase Over Preceding Year			
Bureau of Labor Statistics Wholesale Prices and Price Index	June 1972	June 1973	June 1974	June 1975	June 1976
General Purpose Machinery and Equipment	122.7	3.7	17.3	19.4	6.6
Pumps & Compressors	124.2	2.8	15.7	26.8	5.7
Electrical Machinery & Equipment	110.6	1.9	7.0	16.4	3.6
Motors, Generators	123.3	4.5	7.0	26.6	8.9
Chemical Engineering					
Plant Cost	136.5	5.9	14.0	9.7	6.2
Equipment, Machinery	135.4	5.0	20.8	12.3	6.5
Engineering & Supervision	111.9	16.0	2.3	5.9	7.5
	4th quarter 1972	4th quarter 1973	4th quarter 1974	4th quarter 1975	2nd quarter 1976
Marshall & Swift Equipment Cost Index	336.7	3.8	10.5	16.7	4.0
Survey of Current Business	June 1972	June 1973	June 1974	June 1975	June 1976
Dept. Commerce Construction Cost Composite Index	137	10.2	14.6	9.8	4.7
American Appraisal Co.					
Construction Cost Ave. 30 cities	1367	11.3	5.5	6.5	7.3
Atlanta	1545	13.5	4.3	2.2	5.9
Boeckh Construction Cost Index	May 1972	June 1973	June 1974	May 1975	May 1976
Ave. 20 cities - Commercial & Factory Buildings	144.2	7.7	12.2	7.7	9.3
Engineering News Record	June 1972	June 1973	June 1974	June 1975	June 1976
Construction Cost	1726.15	13.6	3.8	11.1	6.2
Building Cost	1038.43	9.5	8.3	6.9	7.5
Engineering News Record	Labor Cost Indexes				
Common Labor	3437.63	8.5	6.2	13.1	5.8
Skilled Labor	1629.94	5.8	7.1	7.9	7.6
Bureau of Labor Statistics Employment & Earnings					
Contract Construction	$5.97	6.4	5.0	7.6	5.8
Special Trade Construction	6.42	2.2	8.8	5.9	5.3
Electrical Work	7.02	6.0	4.0	6.3	8.1

Figure 1. Price Increases Based on Certain Indices

As an example, take the new source performance standards for air pollution. For plants modified or newly constructed so that they have a potential of emitting more uncontrolled emissions than heretofore, the new codes are generally stiffer than the average of the regulations in state implementation plans. This tendency toward tougher regulations is also evidenced by the methodology the government uses to select, from a great many possible industries, those for which new source performance standards (NSPS) should be developed. As these standards take a considerable amount of technical and economic study, only about six industries can be covered per year. One criterion that EPA applies in its choice of industries is the improvement in air quality that a new regulation would bring, as compared to the specifications of the average state regulation. Therefore, plant management can generally be assured that the regulations of the NSPS will be more strict than the regulations faced by a plant constructed or modified before the promulgation of the standards. If a new plant or modifications are contemplated, it generally would benefit management to initiate construction prior to the date a new source performance standard is promulgated.

The foregoing discussion assumed that management had some latitude with regard to timing. We now turn to the problem of meeting mandated deadlines. There are at least three unique deadlines that call for pollution control strategies:

-- deadlines for filing appeals;

-- deadlines for advising of tests and filing of permits and reports; and

-- deadlines for special tax treatment.

Compliance and abatement orders, or stipulations set in a permit, can be issued by state, local, and federal levels of government. These issuances, hereafter referred to as orders, frequently contain a statement as to the right of appeal and the appeal deadlines. In other instances, the order may merely state that it is made pursuant to a particular regulation; and, in this case, the appeal period would be set forth in that regulation. There is no leeway in these matters: An appeal must be made within the deadline specified in the regulation, or the right of appeal is forfeited.

Regulations frequently call for performance tests to prove that the process has been adequately controlled. The regulations may require notification of state or federal personnel so that they can view the performance-testing operation. For instance, under most new source performance standards, the company must notify the EPA regional office 30 days prior to the acceptance test. If an acceptance test depends on weather and production needs, such as in some batch processes, there may be uncertainty as to whether the test will take place on the date scheduled. If this is the case, the regional office should be notified of a proposed date, with a notation that conditions may make it necessary to alter the stated date, and that the date will be reconfirmed when the test date draws nearer. If the test is conducted without providing for government oversight, the test results may not be approved.

The tax laws also may require that certain actions be taken within a prescribed period. For instance, the coverage afforded by a small business loan to finance an air pollution compliance investment depends on the date the federal government and the state acted with respect to air pollution control. As another example, for a contractor who financed a pollution control program initially from working capital, there is a deadline date with respect to his ability to refinance these expenditures. The investment tax credits and rapid amortization provisions also have effective dates that may affect management choice.

Next, we turn to the problem of handling delays in the receipt and installation of equipment. This is, of course, not a new problem for management. The unique aspect with respect to pollution control is that delays in receipt and installation of control equipment may result in fines assessed by state or local regulatory officials. Consequently, there is a greater need for reducing delays and protecting the company if delays do occur.

A realistic delivery schedule for equipment and installation is the first step in protection. By early initiation of a pollution control program, as previously advocated, there is a good chance the compliance deadline will be appropriately longer (with a safety margin) than the proposed delivery period. However, this built-in safety feature has a practical limit. The next recourse is to include contract provisions that protect the company if the program is not completed within the specified period.

As one approach, the supplier can be offered a financial incentive to perform on time. The strongest incentives come from provisions that impose pre-agreed financial penalties for delays. This usually takes the form of a "liquidated damages" clause. Under such a clause, a given slippage in delivery means that a pre-agreed amount of money becomes due from the supplier to the company, usually as a deduction from the original purchase price. Unfortunately, there are two serious problems that beset liquidated damage clauses. First, they are not looked upon favorably by the courts, and therefore frequently end up to be legally unenforceable. Second, suppliers are generally extremely reluctant to agree to such clauses—they do not want to waive in advance their right to rely on whatever legitimate excuses they may have, if and when delivery delays occur. Moreover, damage clauses are really not so good as timely delivery. Therefore, whether or not such clauses are agreed to, additional techniques can and should be used in every case.

There are three principles that can minimize the risk of delays in equipment delivery and installation:

-- contractual emphasis;

-- intensive purchasing follow-up; and

-- strict adherence to company obligations.

At the time of contract signing, the general contractor and/or the principal suppliers must be impressed with the necessity for timely delivery. To that end, clauses should be included in the contract which (a) clearly state that time delivery is an of-the-essence feature of the contract, and (b) bind the supplier to pay any fines that may be imposed by regulatory agencies if the equipment is not installed and properly working on the compliance date. Such clauses should not be hidden under the general terms and conditions of a contract or purchase order, but should be conspicuously set out in the contract document; they should be further emphasized in a covering letter and in verbal exchanges noting the presence of these provisions.

Intensive follow-up action after purchasing can keep the company informed as to the scheduled pace of production for the various pieces of equipment. Periodic checks for confirmation of shipping dates should be made, and written correspondence should be directed to key officers of the supplier if delays are indicated. In this connection, it is wise to expressly provide, in the original contract, that the company shall have the right to check on such production progress, including the right to physically inspect the production sites if it is so desired. Without such contract provisions, the supplier would be under no obligation to provide information that is necessary for the company to assess progress.

Production schedules also can have processing stages which require the purchaser to take certain actions before the supplier can proceed to the next stage. For instance, the company must frequently approve supplier's drawings, choose among various technical alternatives, and provide certain services as, for example, gas, power, water, compressed air, and test facilities. These requirements should be scrupulously adhered to, because any slight delay in company performance of its responsibilities could be seized upon as justification for a contractor or supplier delay, and perhaps as the basis for an added-cost claim. If verbal approvals are given, they should, without fail, be promptly confirmed in writing, with the verbal date of approval stated in the confirmation. Again, provision should be made in the original contract for these specific obligations of the company, so that misunderstandings—which usually lead to delays—cannot arise. Likewise, to avoid the conflicts that classically arise when verbal transactions are relied upon, the contract should clearly provide that the supplier is entitled to respond only to written approvals.

TURNKEY VS. COMPANY INTEGRATION

A turnkey contract, as defined in Dictionary of Scientific and Technical Terms (McGraw-Hill, 1974), is

> A contract in which an independent agent undertakes to furnish for a fixed price all materials and labor, and to do all the work needed to complete a project.

This approach has a higher appeal for pollution control than for other capital buying. There are three reasons why this is so: (a) the technology involved is generally foreign to the company's normal production interests; (b) the performance of the system must satisfy a third party (the government); and (c) there are generally several very different control strategies with complicated trade-offs to be considered.

The goal in turnkey operations is to place the responsibility for system performance on one party and/or to reduce the time drain on company personnel. The turnkey contractor obviously will adjust his price to reflect the added risk he must assume.

In a true turnkey operation, a single contractor assesses the company process, determines the control system needed, and obtains, installs, and acceptance tests the system. Subcontractors may be used, but the turnkey contractor retains the responsibility for performance and has complete management and technical authority.

While this concept of a total turnkey operation is appealing, because it theoretically does not divert management's attention and carries little risk, it is difficult to implement. A potential contractor cannot afford to pre-analyze the regulations involved and your process and effluent problems without remuneration, and, without such data, he cannot estimate the cost to supply and install a turnkey operation covering the necessary performance and warranty provisions. On the other hand, the company would like to have several turnkey proposals. There are two ways out of this Alphonse-Gaston act. One way is to offer small contracts to several potential turnkey contractors, where the funded effort would result in development of the needed data plus a turnkey proposal for the necessary control system. This approach is utilized by the federal government in its so-called two-step procurements, and less frequently in the commissioning of sculpture and buildings.

Another approach is to compromise the concept of total turnkey by dividing the work into two stages, the first including what will be defined later in this chapter as the "conceptual design," which leads to the "procurement package." The second stage is a turnkey operation based on the procurement package. The concept of a true turnkey obviously is compromised, since one party prepares the concept design and procurement package and another undertakes to supply and install a system based on the procurement package. There has been a split in authority and risk, but only at one point.

The two-stage arrangement is the most common approach to turnkey contracting found in pollution control programs in all but the largest installations. While there is some compromise of performance responsibilities with a resulting risk, it considerably lessens the problem of divided responsibilities as compared to the situation where a number of contractors are involved, all separately controlled by the plant.

If a company feels it has the management capabilities and the available staff time, there is no reason why the control program could not be handled in-house, with company personnel responsible for specification, engineering, equipment, and installation. If several such programs are envisioned, the first can serve as a training base for future procurements. If such training and experience would bring no, or little, future benefits, the assumption of risk and staff time involved in an in-house effort may tip the scales in favor of a turnkey operation.

THE CONCEPTUAL DESIGN

The conceptual design consists of five parts:

1. A delineation of the regulation(s) that must be met;

2. A report of the effluent flow and contaminant(s) loading as a function of process conditions (results of a survey);

3. A process flow sheet showing pertinent process operations, raw materials consumed, fuels used, utilities available, etc.;

4. Accurate plan and elevation views showing location of existing buildings and pertinent equipment, with preferred location(s) for any end-of-line control equipment; and

5. A description of likely process or end-of-line control strategies with a general description of their advantages and disadvantages.

The conceptual design does not solve problems. Its purpose is to accurately define the problems and preview some solutions—in other words, the cornerstone of a good control strategy. It forms the basis of a procurement package which is used in securing proposals and as an aid in evaluating the proposals received.

DELINEATING THE REGULATIONS

A thorough understanding of the regulations—which ones apply, what they mean, how they affect a particular plant—is a prerequisite to developing the conceptual design. Without this understanding, the potential for mistakes is high. This may seem obvious, but a few examples may serve to underline the importance of this point. Below are five known cases in which company resources were wasted because the regulations were misunderstood, either through incomplete discovery or improper interpretation:

Case 1

Air pollution control equipment was purchased under a guarantee based on regulations in the supplier's state. After installation, it was found not in compliance with the requirements in the buyer's state. Thus the control equipment worked as guaranteed, but could not meet the applicable requirements. The matter went through costly litigation.

Case 2

A wet scrubber system was purchased by a plant's management because it had been successfully used to control air pollution at a similar sister plant in another state. After the system was installed, it was discovered that the planned wastewater discharge from the system to an abandoned quarry was forbidden by state regulations, even though this same practice was perfectly acceptable in the state where the model plant was located. Additional water processing was required before discharge, including pH conditioning, flocculation, and settling processes, making the system's total capital and operating costs higher than other equipment choices open to management before they made their unfortunate purchase.

Case 3

An air pollution control system was purchased under a supplier guarantee that the system would meet the state regulations where the plant was located. After installation, it was discovered that the emission source was also covered by the federal new source performance standards (NSPS). Extensive modifications were necessary to meet the more stringent requirements. The sum of the original equipment costs plus modifications, if known prior to management selection, would have resulted in a different equipment choice.

Case 4

An installed air pollution control system was tested by a company based in another state. After testing, the results were disallowed by state reviewers because the testing company had followed the state regulations of its home state, which permitted different methods and test equipment, rather than the ones specified by the state in which the client's plant was located. The test had to be repeated with the plant paying for the additional testing.

Case 5

A new plant was located at a certain site because it was assumed the plant wastes could be discharged directly into the municipal sewer. The site had been chosen in part because the plant had a high hydraulic load and the costs of on-site treatment versus direct discharge to an existing sewer system swung the decision to the selected location. It was later discovered that, under federal procedures, the plant's effluent was not compatible, industrial sewer rates were higher than contemplated, and recourse to total on-site treatment was necessary. (Pretreatment and sewer rates were higher, and the wastes were incompatible with the municipal sewer plant operation.) Had a proper investigation been made of the regulations regarding compatible/incompatible wastes, several other sites with more favorable labor or transportation rates, which were outweighed at the time by the supposed water-treatment advantages, would probably have been selected.

POLLUTION SURVEYS

After the regulations have been assembled, and those pertinent to your problem studied and understood, the next step in developing a conceptual design is a survey of the effluents produced by the plant—the pollution survey. The objective is to identify pollution sources that contribute to waste loads, together with the effect of process variables on the waste stream created by these sources.

Pollution control systems for both air and water are usually designed for worst process conditions, i.e., greatest flow, highest levels of and most toxic contaminants. Steps that reduce flow or lower contaminant levels are therefore attractive up to a point where further reduction is more expensive than installing a given size or efficiency control device. In some instances, effluent reduction is a viable way of meeting regulations without recourse to control devices.

If pollution peaks in plant processes are encountered, either in flow or concentration, it usually pays to analyze process adjustments that will reduce the load. These conditions are somewhat analogous to the role of peak-demand charges in a plant's electrical expenses—they are of short duration, but have a pronounced effect on costs.

A necessary first step is to quantify a plant's present flows and pollutant load. Plants usually keep detailed records on such matters as production rates, rejects, and material costs, but may not have adequate data on flows and pollution loading. This missing data must be supplied by a pollution survey. The identification of pollution sources is usually straightforward. Characterizing the contribution of the various sources with respect to process variables is much more difficult; the alternative is to do it or to risk serious future problems. Process effluent variables, such as type of pollutant, concentration, and changes in volume or temperature of plant conveying stream (gas or hydraulic load), could cause control upsets if not recognized and planned for in the control strategies. Such upsets (failure to perform because of overload) may cause one or more of the following:

-- failure of the control system to control the process effluent in accordance with the regulations;

-- reduction in production throughput;

-- upstream effluent problems caused by undesirable mixing (water) or "puff-back" (air); and

-- increases in maintenance costs.

Who is to perform the survey? As a practical matter, candidates are limited to plant personnel, an outside consultant, or a prospective supplier. The alternatives have advantages and disadvantages that management must evaluate in light of the company's particular needs and capabilities. Here are some pros and cons to consider:

- A survey by company personnel is advantageous because company personnel possess better knowledge of the process through experience; and if special equipment or skills are not required, costs compared to hiring consultants are likely to be less. The disadvantages are that: (a) company personnel may not know what factors are important to the subsequent selection and successful operation of the control process, and may therefore not optimally match the survey to the needed design data; and (b) if special skills or extensive test equipment are required, the costs may be higher than hiring a consultant.

- A survey by an appropriate consultant has two advantages: (a) the consultant has better knowledge of the types of data needed to select the proper control system from the variety of possible approaches; and (b) the final recommendations result from broad experience with a number of approaches, and there is no inherent reason for the opinions of consultants to be biased. There are also two disadvantages: (a) the survey expense is likely to be higher than having the survey performed by plant personnel or prospective supplier, unless very special skills or equipment are involved; and (b) the plant might rely too heavily on the consultant.

- A survey by a prospective equipment supplier has these advantages: (a) it is less expensive than a survey by plant personnel or consultants, unless very special skills or equipment are involved; and (b) a supplier knows what process factors are important with respect to its own equipment design and selection. There are two disadvantages: (a) the supplier has a probable bias towards his own products; and (b) the supplier may not perform a thorough analysis unless reasonably assured of the equipment order.

Once a survey is made, the manager should examine the results carefully before committing the company to a control strategy. He should remember that the goal is to smooth out and reduce total flow, which will save on control expenses and reduce the likelihood of future upset problems. There are a number of data checks and balances that should be utilized.

The manager should ask that the data be presented in both graphical and tabular form. For example, graphs showing flow and pollution load on the vertical axis and time on the horizontal axis give a quick feel for peak conditions; the accompanying tabular format allows examination of quantitative data without having to read constantly from the graph. It is also good practice to look at the original data sheets as well as the data presentation, to make sure the presentation is a faithful reproduction of what was measured (more on this later).

It is good practice for the manager to arm himself with a few benchmarks, which he can use in assessing the accuracy of the data given in the survey. This serves as a rough data check and keeps the involved technical people on their toes. For example, suppose a graph indicating total fluid load is fairly constant or gently undulating with time; in this case, the measurement accuracies submitted in the survey can sometimes be checked in rough fashion by comparing the flow for the period tested with past water use charges (for the billing period, gallon usage divided by the same time interval with nonworking days eliminated). Likewise, gas flows reported in the survey may have been obtained from velocity traverses; such flow data can be compared with rough figures obtained from a fan manufacturer by telling him the rpm of the fan, the gas temperature, the system pressure drop, and the fan model number.

Another important point to check is sampling efficiency. Was the survey conducted over a sufficiently long period of time so that long-term changes are reported? At the same time, were individual test periods short enough to resolve peaks? To get a rough feel for long-term variations in water flow, list water use charges (and sewer charges separately, if available) by month over a representative period, say on the order of a year. If there are time-span differences in the billing periods, the figures should be adjusted. In addition, you can discuss likely differences in flow and contaminant loadings over time with plant operating personnel. If, for example, it is decided that a month is a sufficiently long period to make observations, the next question is how frequently the waste streams are to be sampled.

Collecting twenty-four-hour composite samples is an approach to getting what, in effect, is the value that would be obtained if all of the wastewater were collected over a 24-hour period, mixed thoroughly, and a resulting or composite sample taken. These composite samples are often called for in water regulations, and should be reported in a wastewater survey. It is also important to have a "grab" sample of the wastewater, representing conditons at that instant. The government-issued NPDES permit will probably be based on both a daily maximum value and a 30-day-average value. This means the survey and subsequent controls must work together to meet both these values. NOTE: The EPA Methods Manual (the bible on conducting wastewater surveys) recommends that, for technical-sampling reasons, only grab samples should be used for oil and grease pollution; composite samples are not acceptable.

How accurate should the survey strive to be? This accuracy question essentially consists of two parts. The first is a statistical measure, called sampling error. This error comes about because the flow is "sampled," and is related to how frequently, where, and at what intervals the samples are taken. It is somewhat analogous to the science of quality control, which can be accomplished by statistically sampling production. To reduce this sampling error, you may wish to seek the services of someone with statistical experience to assist in the survey design, even if the actual survey is to be conducted by your own personnel.

The other part of the accuracy question is measurement error. This includes inherent or equipment-based errors and subsequent storage, transportation, and analysis of specimens. The latter errors can be controlled by proper equipment selection and sample handling techniques. Note that survey accuracy costs money, and the accuracy required in the survey should be commensurate with the job of control equipment selection. Since control costs for equipment and operation go up in definite increments, survey accuracy need be no better than the smallest necessary increment in equipment cost and operation for various equipment capacities.

In determining the survey accuracy needed, you must have a fair understanding of equipment costs related to the parameter you wish to measure. A comparative example is given in Figures 2 and 3. Figure 2 is a curve for capital cost for direct flame incineration. An error of ±20% in gas flow, at 5,000 scfm, would correspond to a cost-span difference in installed price of about $13,000. In the case of an adsorption system, as shown in Figure 3, the same error of ±20% at 5,000 scfm would cover about $37,000. At 30,000 scfm, the same ±20% error would have cost-span differences of, respectively, $17,000 and over $110,000. This information is presented in tabular form below:

	5,000 SCFM	30,000 SCFM
Direct flame (Primary and secondary heat recovery)	$13,000	$ 17,000
Adsorber	$37,000	$111,000

These are sizable sums, which could roughly be cut in half with a ±10% error in measurement. In this case, the savings in installed cost would probably outweigh the costs to attain the higher accuracy.

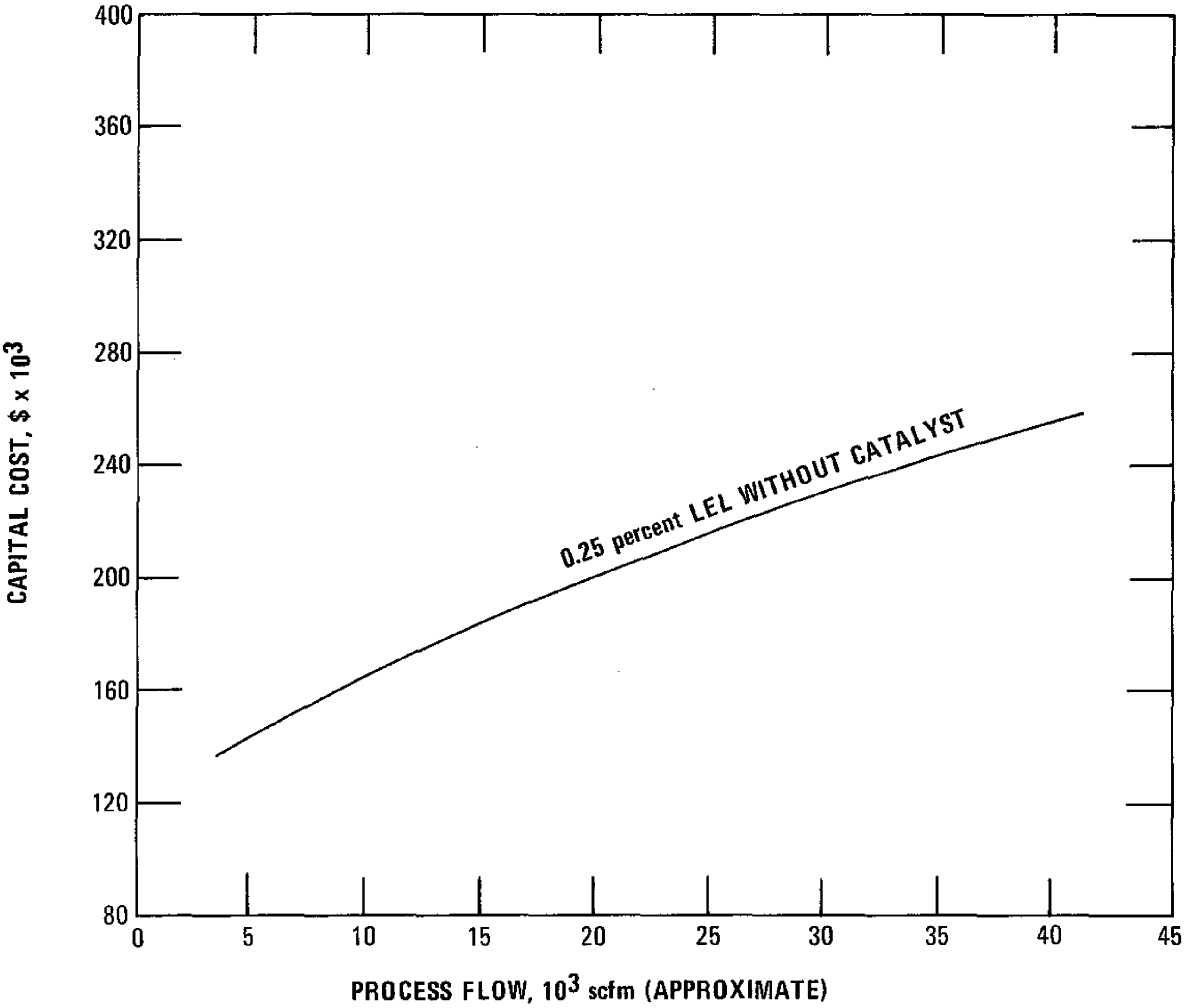


Figure 2. Capital Cost for Direct Flame Incinerators with Primary and Secondary Heat Recovery (70 - 300°F process gas inlet)

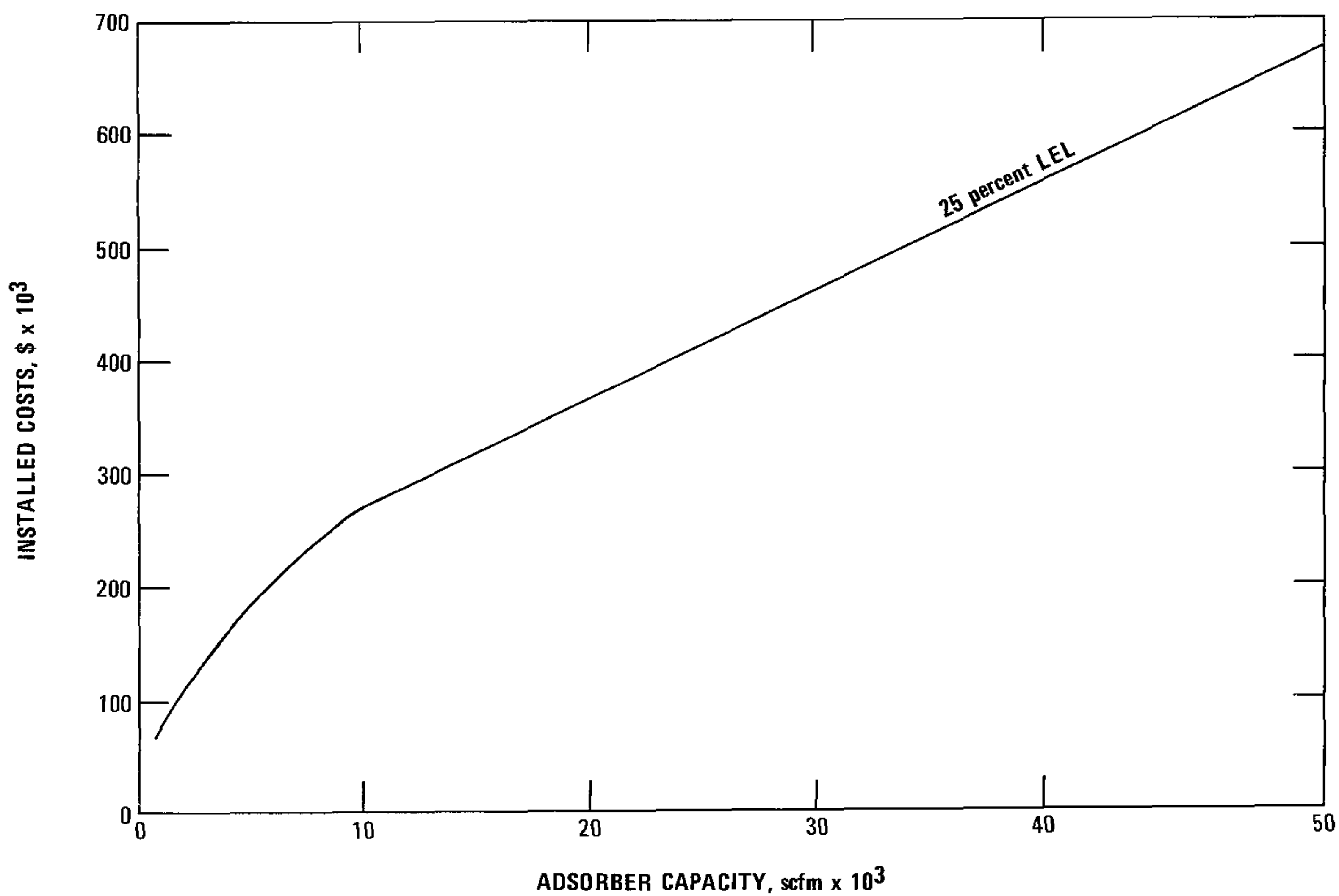


Figure 3. Estimated Installed Adsorption System Cost

As illustrated by this example, the accuracy requirement of the survey is heavily dependent on the way equipment costs are affected by any resulting inaccuracies. This leads to the problem of multiple safety factors. If several steps are involved in arriving at a final effluent or process description, and the steps are carried out by independent parties, there is a considerable propensity to accumulate safety factors. Management unknowingly may even add an overall safety factor to the result. Steps in data acquisition should therefore be clearly listed and any safety factors applied should be noted. Such safety factors are often inserted to compensate for possible inaccuracies in the reported data.

It should be noted that, when several inaccuracies are involved in a computation, it is likely that the errors will have a tendency to offset each other. At the opposite extreme, the worst possibility is that each error would be in the same direction. For example, if five separate errors are involved, the resultant error E_R then would equal the sum of the individual errors $E_a + E_b + E_c + E_d + E_e$. This situation is quite rare where the errors E_a through E_e are due to independent causes, because in that case there is only a rather small chance that all five errors are in the same direction. The contrasting condition, that the errors will cancel out completely and produce a zero E_R, is also quite rare. The resultant error E_R that has the highest probability of occurrence is:

$$E_R = \left(E_a^2 + E_b^2 + E_c^2 + E_d^2 + E_e^2\right)^{1/2}$$

This expected error is considerably smaller than the worst possibility given by a straight addition of the errors. Bear this in mind in application of an overall safety factor.

Another possible pitfall that management should be aware of involves the tinkering with data. This tinkering can be quite innocent. Rounding off numbers, for instance, can introduce errors if the numbers are small and several arithmetic operations are to be performed. For example, consider the simple case of adding four numbers that are rounded to the next whole number.

A	B
Rounding the sum	Rounding and summing
9.5	10
9.7	10
11.6	12
8.8	9
39.6 or 40	41

A 2.5% difference results. The correct technique is A.

The tinkering can also be of a more complex type with perhaps a psychological basis. As illustrated in Figure 4, the original data might first be "tidied up" by a test technician, by eliminating a few far-out points; and then the project engineer might come along and remove a few more. The result is a rather neat pattern for the data. This process might yield different practical results, as can be seen by the fitted curves in Figure 5. Data points should only be discarded if it is possible to demonstrate that some equipment or method aberration was involved. NOTE: To check on data validity, integrity of calculations, and error treatment, ask to see the original data. If a single line is shown (hopefully, the result of regression analysis), the correlation factor should be stated or the 90 - 95 percent confidence factor lines should be indicated.

PROCESS DESCRIPTION

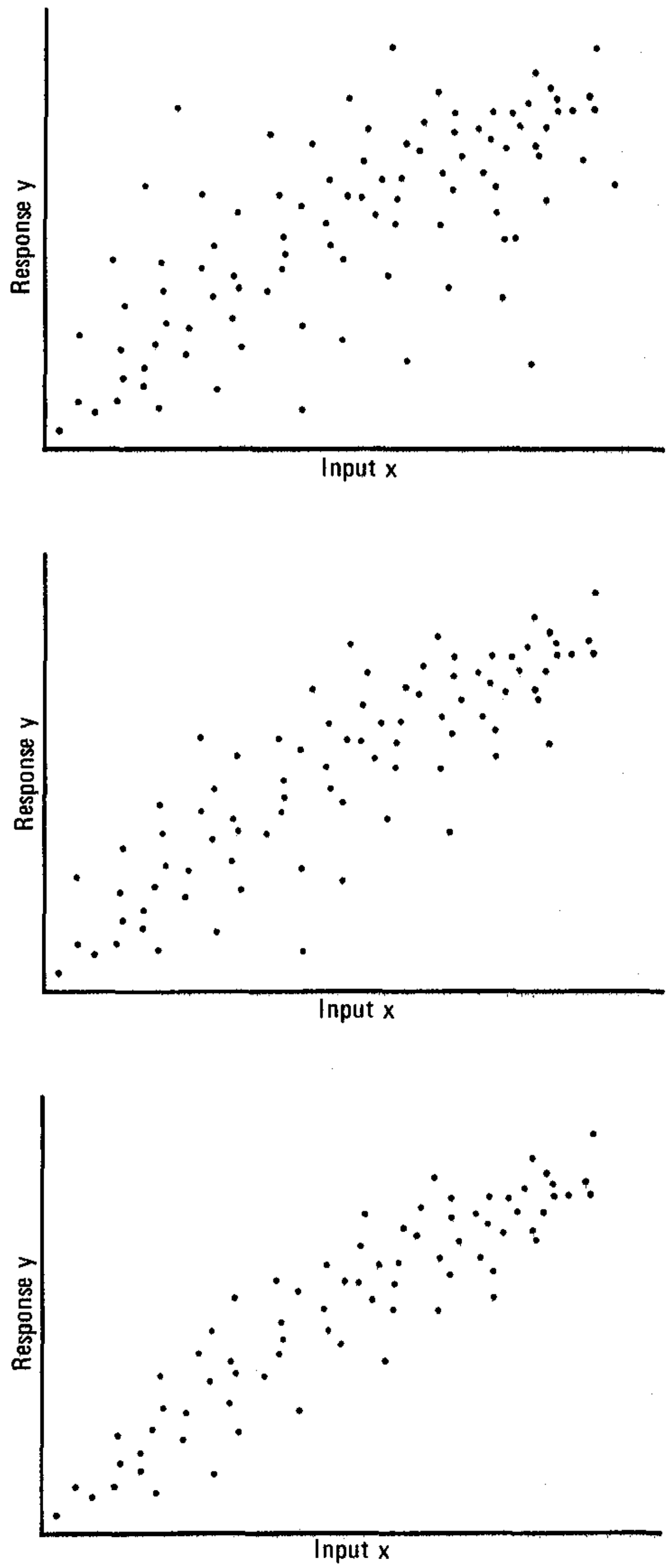
A process description is an integral part of the conceptual design. Simple line drawings with appropriately labeled blocks representing equipment may be used. The drawing should be uncluttered so that process data, such as description of material, production rate, temperatures, volumes, etc., are shown over the operating ranges to be encountered. Service utilities, such as plant air (cfm and psig), electricity (voltage and phase), and gas (cfm and psig) should be noted.

PLANT DRAWINGS

Scale plan and elevation views of the plant, if not already available, should be prepared. These will enable the equipment needed to be properly fitted into the plant structure. The company's choice of control equipment locations should be indicated on these plans. Even if these plans are fairly new and you have good confidence in their accuracy, the bid package and contract should state (in a prominent place, not buried) that the contractor is responsible for verifying all field locations. He should do this prior to final signing of the contract.

In allocating space for control equipment, a balance of space and efficiency must be sought. Plant space is valuable, perhaps even precious, so the tendency is to squeeze in the control equipment. The offsetting considerations are difficulty of maintenance, if the equipment innards are not accessible, and added motive costs. For example, short radius bends in confined spaces add pressure drops. In turn, these pressure drops result in greater energy costs for the movements of a given amount of air.

A rather technical example will illustrate this point. In a gas conveying system, a 90° elbow that has a radius equivalent to 1 1/4 duct diameter has a 55% static pressure loss. For example, if the velocity pressure is 1.126", there will be a .62" w.g. pressure drop. If the radius is permitted to be 2 1/2 x duct diameter, the loss would be .25" w.g., resulting in a .37" w.g. difference. If the system has three such elbows, the total drop is 1.11" w.g. If it also has transition sloping into a duct at 45°, the pressure drop here is .41"; but if there were room to enter at 15°, the loss is only .32", a difference of .09". These two adjustments account for 1.2" w.g. A general rule of thumb is that, for every 2" reduction in pressure drop, 14 brake horsepower is saved at the fan; this actually varies with the fan and motor, but is acceptable for

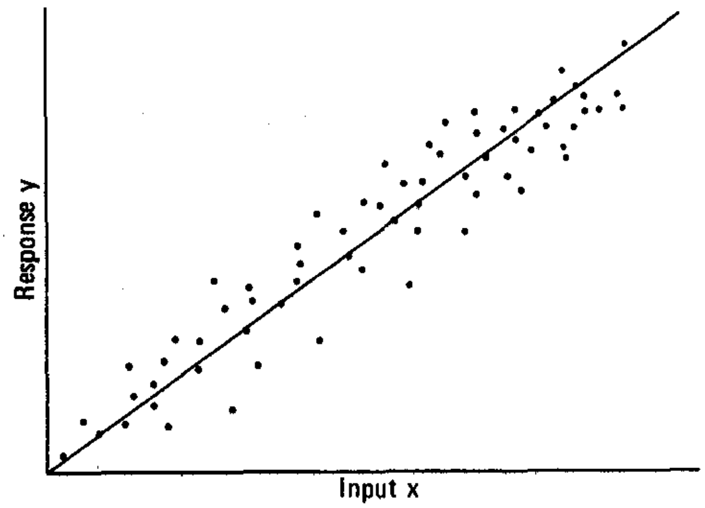


Test technician's original data plot

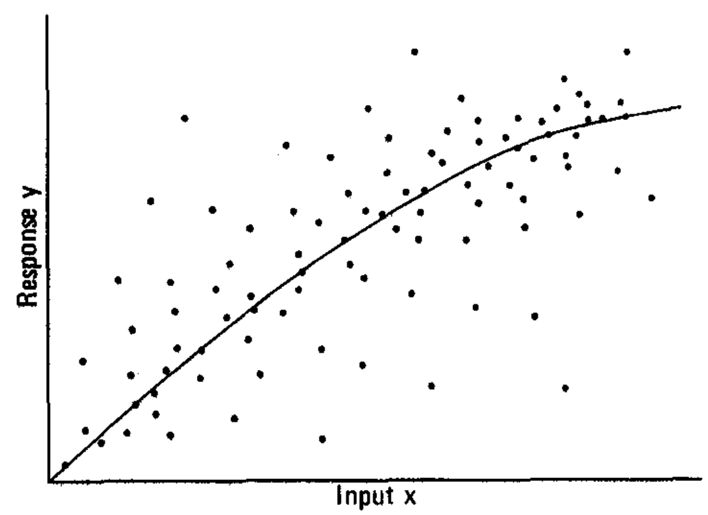
A few points removed by the engineer

Further cleanup by the project engineer

Figure 4. Data Tinkering – "Cleanup"



Regression line for "cleaned up" data



Regression line for original data

Figure 5. Results of "Cleanup"

general discussion. The operation savings for a two-shift, seven-day-week operation would be on the order of $14\,\text{hp} \times \frac{1.2}{2} \times .746 \left[\frac{\text{kW}}{\text{hp}}\right] \times 5840\ \text{hr/yr} \times \$.04/\text{kWh} = \$1{,}464/\text{yr}$ savings.

PROCESS OR END OF LINE STRATEGIES

The fifth element of the conceptual design calls for data on various control strategies. The data should include acquisition and operating costs, limitations, advantages, and side effects. Although this is the last topic discussed in this section, it should be one of the first to receive attention in developing the conceptual design.

Sources of this information are varied. EPA, through its technology transfer activity, is a good source; so are the economic portions of guideline information documents at EPA and the supporting documents for NSPS. For information on air pollution control devices, a good source is the Industrial Gas Cleaning Institute. Various trade and industry organizations have developed excellent data for their members, and it is often available at a slightly higher cost to interested nonmembers.

THE PROCUREMENT PACKAGE

Many small companies do not prepare a formal request for quotations, what we call a procurement package. They often call in likely suppliers, show them the plant area, and verbally describe the problem. This method is hard to resist: it appears easy (no hard thought in formulating a procurement package) and inexpensive. In reality, it is often a more expensive procedure, since it involves repetition. Comparing the accumulated bids is especially difficult. More importantly, errors can creep into the procurement process, and perhaps become critical in the performance period. While preparation of an effective procurement package is no panacea for avoiding these costs and performance problems, it is a giant step in the right direction.

In addition, there are some secondary benefits worth mentioning. The package can be sent to the home office of the contractor, so that reliance on several steps of communication (plant-to-representative-to-home office) is avoided. Suppliers, when in receipt of what is obviously a carefully thought-out bid request, also tend to extend their best effort in responding—they feel that they have been presented with a bona fide sales prospect, that the company is not merely on a "fishing" expedition.

We have seen unbelievably casual treatment of procurement for pollution control systems. In one instance, a wet collector was supplied in response to a bid request handwritten on one sheet of tablet paper. The system failed performance tests and was woefully undersized. Fortunately, the supplier of the unit was also a supplier of other equipment to the firm, and, because the firm was a valued customer, a compromise settlement was reached. Another company, after several false procurement starts (they were fishing), provided process and waste data to a supplier's representative in a phone booth and the data was relayed to the home office on an application form filled in by the representative during the phone conversation. A fundamental mistake—using acfm (actual cubic feet per minute) instead of scfm (standard cubic feet per minute)—resulted in a violent puff-back at equipment turn-on, creating a local plant fire. Many changes were made in the system over the next six months (the mistake was not found), but the performance attained was only marginal. Litigation followed.

Legal protection is yet another reason to prepare a sound procurement package. In this case, contract clauses can help form the basis for subsequent legal remedies, if this is ever needed. Failure to perform on the part of a contractor is sometimes remedied by providing that the buyer shall be entitled to damages—for instance, to recover the difference in cost between the defaulting contractor's quotation and that of the next highest bidder for a comparable system. Having a carefully prepared procurement package can help considerably, if it is ever necessary to establish that another bidder was presenting a "comparable system."

In summary, a well-developed procurement package has all of the following advantages, and few disadvantages (see discussion of warranties for one potential disadvantage):

-- permits more contractors to be solicited;

-- elicits better responses from potential contractors;

-- aids the company by acting as a checklist;

-- facilitates the evaluation of bids;

-- serves as the basis for the contract;

-- reduces the chances of management error; and

-- aids in protecting company remedies.

CONTENTS

The procurement package should contain Elements 1 through 4 of the conceptual design. (See page 31.) It should also contain, as a minimum, acceptance-test procedures, delivery requirements, and payment schedules. It may also require performance bonds, and should establish methods for resolving disputes. Terms and conditions found in your general purchase order forms could be included. If delivery is expected to be tight, a clause should be included stating that time of delivery is of the essence.

If you are using a consultant, this is a good task assignment. You may also wish to have the company lawyer, or a specialist he designates, review the package before sending it to prospective contractors.

The procurement package should also contain general engineering specifications on such items as choice of material, finishes, wiring, and piping connections.

EVALUATION OF BIDS (AND BIDDERS)

This is the third important step in acquisition of a control system, following preparation of the conceptual design and the procurement package. It is no less important than the preceding steps, and is vital to success of the control program.

Evaluation generally takes at least one man-week of effort. If a lesser time is required, an analysis would be in order. The reason might be that too few bids were received. The reason could be positive, that contrary to general experience: (a) all the bids were complete and readily comparable; or (b) side effects and operating and maintenance costs were minimal and easily determined. However, in most cases, a superficial job of reviewing the proposals is the most likely cause. The number of possible approaches, their varying technical features, and the trade-offs among acquisition costs, operational costs, maintenance, and side effects are simply too involved to be evaluated without a thorough and capable effort, lasting considerably more than one man-week.

For example, the problem of controlling hydrocarbons can make the point clear. Control can be accomplished essentially by two means—adsorption and incineration—and these two techniques rapidly expand into several approaches based on features and economic trade-offs. The basic approaches (for stationary sources) would each have to be listed as to acquisition and annual costs. A tabular format would be effective:

Approaches	Acquisition Cost	Annual Expense
Direct Flame Incineration without heat recovery		
Direct Flame Incineration with primary heat recovery		
Direct Flame Incineration with primary and secondary heat recovery		
Catalytic Afterburner without heat recovery		
Catalytic Afterburner with primary heat recovery		
Catalytic Afterburner with primary and secondary heat recovery		
Carbon Adsorption		
Process Change A		
Process Change B		
Process Change C etc.		

Further, all of the above cost findings are affected by the operational characteristics of the plant, such as:

- -- process gas temperature;
- -- use that can be made of recovered heat;
- -- price for materials recovered;
- -- other contaminants in process gas;
- -- the LEL of process gas; and
- -- number of work shifts.

Obviously, the evaluation of proposals in this framework will take some time. It may also be the point at which you seek outside assistance.

Bid analysis must not only be sufficiently thorough, but it must proceed on a step-by-step basis. There are no hard-and-fast procedural rules, but we have found the following review procedure to be generally workable:

- Evaluate proposal coverage.
- Examine bidder's general qualifications.
- Normalize proposals.
- Determine acquisition and annual costs.

Adequate proposal coverage assures competition in terms of both price and techniques. To obtain competition as to technique, the bid responses should cover all of the techniques your conceptual design has indicated are good control strategy candidates. For example, in particulate control, your design concept might have shown that wet scrubbers, fabric filters, and electrostatic precipitators could be used. For a quarry operation, the conceptual design might have indicated a choice between (a) a wet suppression system with surfactants, or (b) a central control with outlying hoods using a fabric filter or a wet collector. The procurement package sent to potential contractors should cover the full range of techniques determined in the conceptual design, and should also request the bidder to propose any other approach that he feels offers advantages. If process changes are viable alternatives, then evaluation will proceed in parallel, because different types of suppliers and contractors are generally involved.

To develop a competitive ranking, each technique represented among the proposals received should have three or more price proposals. If technical or price gaps are found, more bidders should be solicited.

Once assured that you are considering the viable alternatives and have sufficient competition, the next step is to examine the bidder's background and qualifications. This is best done in two steps. The first step determines whether the bid should be thoroughly evaluated, as set forth later in this section. The second step is to perform a detailed screening when the bidders have been pared down to two or three. It has been said that if one wishes to study history, he should first study historians, because their works are conditioned by their experience, personality, and training. Before studying a contractor's proposal, it is likewise important to know something about the contractor and his business posture and demonstrated ability. The initial screening can be facilitated by inserting several questions into the procurement package. Three suggestions are:

- Ask for a brief company history indicating founding date, sales and earnings history, and experience in the technical disciplines involved. An annual report by a publicly owned company can be used; some privately held companies may not release earnings figures, but should provide sales figures.
- Ask for a list of clients for whom the bidder has supplied related systems. The name and telephone number of a person to contact should be included.
- State that a performance bond may be required of the successful bidder, and ask for a response to this requirement.

Answers to the above should be sufficient for the original screening and will form the basis for further detailed screening. Our concern here is the process of qualifying the final screened bidders.

A performance bond can be of some help in qualifying a bidder. Performance bonds are commonplace with government agencies. They are used less frequently in private business, but their use is rapidly increasing. If the bidder is a small company or a division of a company where this one purchase would represent a sizable fraction of its annual sales (say 10 percent or higher), or if the technology involves some factors with which the bidder has not had extensive experience, a performance bond might be requested. Such a bond does not materially lessen the chance of litigation. The main purpose is to provide a surety that, if a dispute regarding performance should occur, the financial wherewithal to affect the changes or to complete the project as contracted would be available.

Such bonds require a prospective contractor to pay a fee or premium to the surety. Such fees are generally regulated by state insurance commissions or boards. The fee, which is usually passed on to the buyer (cost included in the bid price), can range from 1 percent of the contract amount to as much as 3 percent; the higher fees are charged on accounts having more risk or requiring more administration. How the surety operates varies considerably. But before issuing a performance bond, the surety will usually investigate the technical and management capability of the applicant, the applicant's total work program, his net worth, and net working capital. The cost passed to the buyer for the performance bond is thus related to both the worth of the screening (done by the surety before bond issuance) and the face value of the bond.

The final screening should include telephone contacts and one or more visits to other installations cited in the potential contractor's proposal. It is good practice to ask a contact if he knows of any other installations, and these should also be contacted, particularly if not listed by the potential contractor. It is important to talk to several contacts at a listed plant or to several plants.

Once qualifications (the first screening) are completed, the technical and cost evaluation can continue. The next step is to normalize the bids. Even for a common control technique, it may be difficult to compare bid prices because of differences in bid formulations. For example, bidders may have different f.o.b. points, auxiliary parts may be included in some and not in others, interconnection responsibility and installation may vary. It is therefore necessary to normalize bids to a certain standard, so that price comparisons can be made. This is no different from other capital buys, except perhaps that a greater variety of techniques may have to be normalized. As a suggestion, you should normalize to what you feel should be the standard, rather than to what appears to be the most attractive bid. Otherwise, important comparisons may be missed.

Price comparisons can now be made among the bidders who seem technically qualified and financially responsible. If this involved only acquisition costs, the review would be simple enough to deserve only a brief mention. The difficulty, however, is that various techniques, because of their differing operational characteristics, have different annual costs; and these annual costs, such as energy, chemicals, replacement parts, and maintenance, can be the deciding factors. This is shown in Figure 6, which contains estimated prices for several techniques of controlling hydrocarbon emissions. This is a hypothetical installation, and we will not dwell on the cost basis and assumptions. The important things to note are: (a) the magnitude of annual costs which, in some instances, are higher than the acquisition costs; and (b) the differences in both acquisition and annual costs as a function of control type and gas volume handled. These figures are based on a two-shift, seven-day-week operation. If a 40-hour week is used, the annual cost will decrease; but, even in this situation, hydrocarbon controls require considerable attention to annual costs.

The concept of annualized costs is illustrated in Figure 7, which is a hypothetical problem in optimizing heat recovery. The extent to which heat recovery should be practiced depends on many factors, such as fuel costs, equipment acquisition costs, primary and secondary uses of recovered heat, and heat transfer efficiencies. Since these factors are unique to each plant, it is not possible to present a specific methodology for making this analysis. A general approach, however, is to analyze several levels of heat recovery as to savings in plant operational costs. To this must be added maintenance costs for the control unit plus the recovery unit. Another set of points is plotted for the annual cost associated with depreciation and interest on the acquisition costs. These two graphlines can then be added. The resultant is total annualized costs. The recovery point selected would be the smallest annualized cost corresponding to the lowest point of the dashed graph line shown in Figure 7.

The concept of annualized costs is one of two that can be used to compare costs of competing systems, the other being net present value (NPV). This method is described in the manual Choosing Optimum Financial Strategies, and is not discussed here. Both methods, however, have the common characteristic that difficulties stem from the necessity to estimate operating and maintenance costs.

Type of Control Unit	Flow Rate SCFM	Acquisition Cost $(000)	Annual Cost[2] $(000)
Direct Flame & Catalytic Incinerator (no heat recovery)	5,000	75 - 115	70 - 100 DF[5] 50C
	30,000	145 - 217	240 - 480 DF 230 - 270 C
Direct Flame & Catalytic Incinerator with primary heat recovery	5,000	94 - 130	45 - 90 DF 40 - 50 C
	30,000	185 - 275	95 - 340 DF 125 - 215 C
Direct Flame & Catalytic Incinerator with primary and secondary heat recovery	5,000	110 - 145	25 - 60 DF 20 - 40 C
	30,000	230 - 315	20 - 250 DF 60 - 185 C
Adsorber[4]	5,000	150 - 180	47 - 65 NV[3] 35 - 47 FV (15) - 40 MCV
	30,000	380 - 470	145 - 230 NV 65 - 140 FV (255) - 130 MCV

[1] Based on 2 shifts, 7 day week or 5840 hrs/yr.

[2] Based on input temperature of 70°F.

[3] NV = No Value
FV = Fuel Value
MCV = Market Chemical Value

[4] While adsorbers theoretically serve as competitors to incinerators, the applications where they can be employed interchangeably are severely limited.

[5] DF = Direct Flame, C = Catalytic

Figure 6. Operational and Capital Cost Comparisons

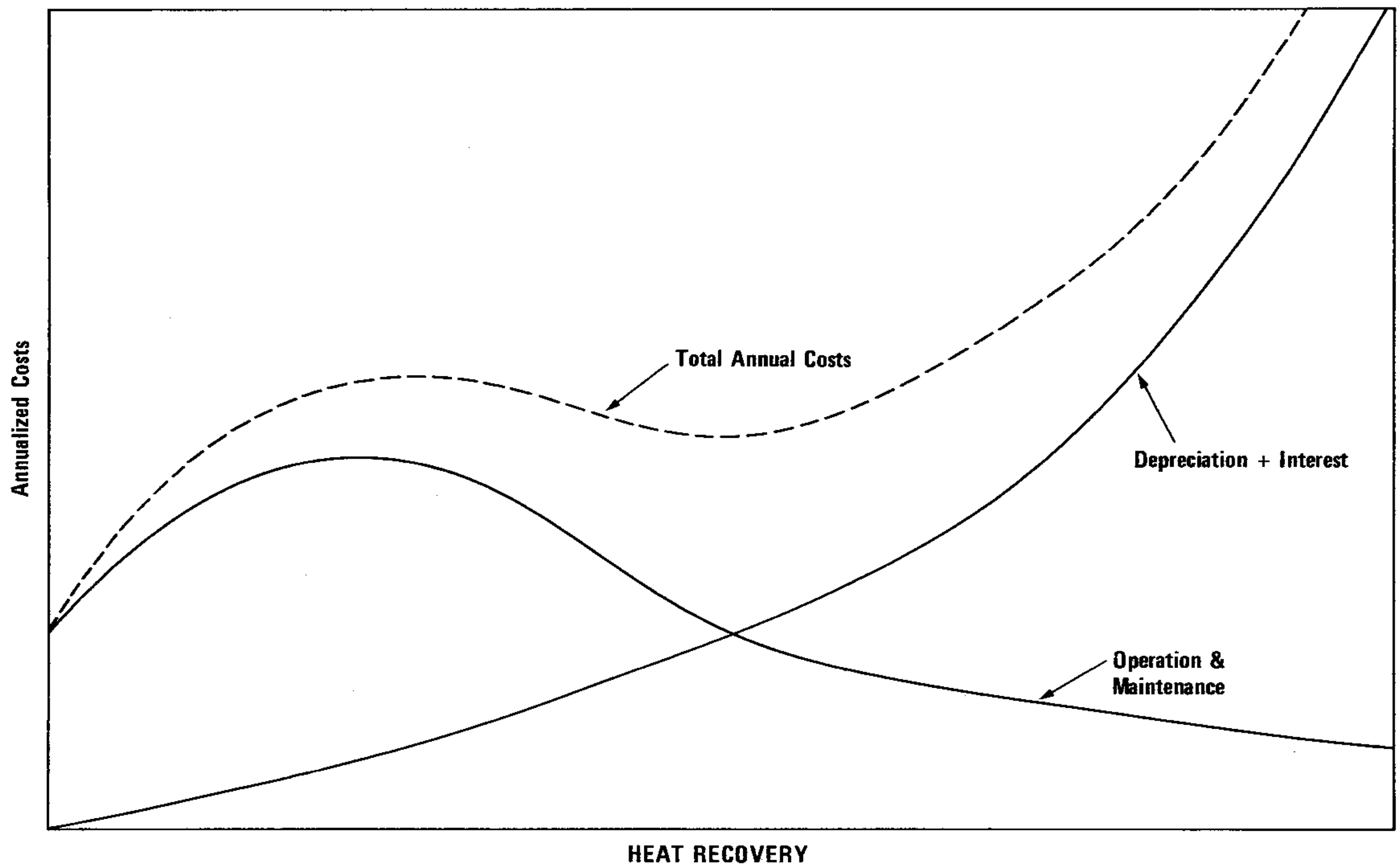


Figure 7. Optimizing Heat Recovery

Operating costs are susceptible to rather accurate analysis. The various horsepower requirements for the motors for fans, screws, air compressors, and pumps can be obtained from the contractor's proposal. These can be readily converted to annual cost by:

Annual Cost = ____ hp x .746 x ____ hrs/year operation x ____ $/kWh.

The last factor in this formula should be checked with your local power company. This check should cover historical records, but should not overlook the current rates with the added load to support the control strategy. Demand charges can have considerable effect on energy costs. There are also large variations in base load costs—a large rural user, for example, may be very low compared to a "small" user in a different area. Here, the local power company offers truly free consulting advice, and they will generally provide competent, unbiased advice.

Estimated consumption of materials should be requested in the procurement package—chemicals used in water treatment, for instance. Their cost can then be obtained from a chemicals supplier. Some chemicals have important economies of scale, and, if so, quantity discount prices could be quite different from the average price. The price used in the analysis should be the relevant one.

If natural gas, oil or coal are to be used, their projected availability as well as their costs should be analyzed. In the event your service is provided under an interruption contract, or if you feel you may voluntarily switch to an alternative fuel, that fact should be included in the bid analysis. An important observation is that fuel switching can result in changes in your gas waste stream. Changes in sulfur concentration, particulate content, and temperature excursions are commonplace. Such changes could affect the performance and operating life of the control system. NOTE: Anticipated fuel changes not only could affect control device performance and operating costs, but they might also have an impact on warranty provisions. Any such fuel switching expectations should be described in the procurement package.

Maintenance costs are difficult to estimate. Further, they can be important enough to tip the choice between control-system techniques and among feature options on a given technique. While obviously composed of labor and material, maintenance costs may, in addition, have important, less obvious costs associated with interruptions to production.

As one source of production interruption, a control system may have materials that have shorter lives than the system as a whole. This is a well-known phenomenon. Such materials might include activated carbon in adsorber systems, refractory lining in gas-conditioning portions of control devices, fabric filters in baghouses, fan belts, pump pistons, etc. Prices for these parts are readily obtainable. Often, to predict expected costs, you can rely on past maintenance history of similar equipment components. An additional approach is to examine those parts of a system where the supplier seems to be hedging on his warranty or performance provisions and the relation to processing characteristics. If a temperature must be closely controlled, particulate loading kept very low, water pressures or contaminant type tightly restricted, etc., the control operating condition is sensitive to process performance; and, where this is so, you can expect to devote correspondingly more preventive maintenance time and materials to assuring that those characteristics of your process do not exceed the tolerances noted.

Maintenance costs obviously should cover replacement of faulty or broken parts, which involves both direct labor costs as well as possibly much higher production interruption costs. Frequency of replacement, ease of replacement, and spare parts stocking costs should enter the analysis. There is wide tendency to estimate maintenance as a portion of installed system costs—such as use of a percentage rule-of-thumb figure. This approach should be avoided, since the costs of an appropriate analysis with considerably improved accuracy are usually modest with respect to the savings potential.

At this point, it should be possible to pick the "best offer" among the responsible, qualified, and normalized proposals. Before a contract is consummated you will want to assure yourself that you have

-- obtained a satisfactory warranty;

-- provided for acceptance and performance testing; and

-- established methods of resolving disputes.

A written warranty provision in a contract for pollution control systems is a practical necessity. You may have heard about implied warranties, which need not be in writing. Chief among these is the "seller's assurance of merchantability," which requires that the goods offered be of a quality at least as high as buyers can ordinarily expect in the market involved. The Uniform Commercial Code (UCC), which is in force in all states, except Louisiana, provides this type of implied warranty automatically, even if not mentioned orally or in writing, so long as the seller regularly deals with the type of goods being purchased. If the seller knows the special purpose for which equipment is to be used, another implied warranty from the UCC holds: "fitness for a particular purpose." The more the seller knows about your specific use, the tighter this warranty becomes.

However, reliance on such implied warranties in pollution control is not without problems. For example, while a baghouse can generally be used to control particulates, the seller cannot be held to be aware of a special purpose unless the buyer specifies many characteristics of both the particulates and the gas stream.

In essence, the purpose of a warranty is to establish who is at fault if the purchased system fails to operate; as a secondary objective, it also attempts to establish, or at least limit, the exposure of the parties once fault is determined. Therefore, the buyer will want to place the risk as much as possible on the seller. He can do this by describing the specific purpose for which the equipment will be used as extensively as possible. This obviously puts some risk on him, since the description of the waste stream process must be extensive and accurate. Omissions and ambiguities in the specifications leading to faulty performance might otherwise be laid on the buyer.

At the same time, the buyer wishes to establish that he is relying on the seller's expertise. If the buyer closely specifies the subject of the purchase (e.g., by specifying technical details, brand name, or patented goods), this will tend to indicate that expertise resides in the buyer, and that he is not relying on the seller's expertise in selecting the right equipment for the job.

The buyer should strive "to have his cake and eat it, too," by a two-barreled approach: (a) an extensive and accurate listing of the purpose and application of the system, and seeking a comprehensive warranty; and (b) placing a clause in a prominent place, stating in effect that the buyer is relying on the expertise of the seller and that the seller has made himself familiar with the detailed use and plant environment in which the control system will be used.

ACCEPTANCE TESTING

A unique aspect of capital acquisitions related to pollution control is the fact that the performance of the system must satisfy a third party. The performance standards can be specified by local, state, or federal regulations, or some combination of these.

Regulatory authorities carry out their function in various ways. They frequently require that performance tests be conducted by a responsible testing company and then submitted to them for review. In many instances, they require that their personnel observe the test; the purpose is to make sure that process conditions are met and that proper test methodologies and instruments are used. Some states have their own sampling teams, who may seek to duplicate results.

Acceptance testing may be complicated by multiple objectives. If you are discharging compatible waste to a sewer, there is often an acceptable range of waste load and concentration; but the fee for discharge to the sewer may be levied on either flow, or pollutant content, or a combination of both. Therefore, future costs for discharge of compatible wastes to the sewer will be dependent on how well the equipment does the job for which it was purchased. Since testing is frequently a prerequisite for acceptance by the regulatory agency, and because it is necessary to determine such future costs of operation, it is important that the full requirement for such testing be included in the contract as a condition of system acceptance prior to release of final payment and as a condition of fulfillment of some warranty provision.

The requirement for testing should specify the tests to be made, test method, process conditions under which the test is to be conducted, and name of the testing company (or provide a statement as to the general company qualifications for conducting an acceptable test). Because of overlapping jurisdictions, it may be necessary to specify more than one test for a particular pollutant. For example, a federal NSPS test and a state test may both be required for a new or modified plant. There may be differences in number of test runs required and in definitions, although the methodologies are likely to be similar: As an example, for particulate emissions from an asphalt batching plant, NSPS requires an average of results from three tests, while Pennsylvania requires only one; the Pennsylvania definition of particulates includes condensibles, while NSPS excludes them.

A word about testing expenses. Getting it right the first time can save money. Test regulations often require that tests be conducted for a minimum time duration and/or for a certain amount of gas volume; or, if you are involved in water waste, a certain number of grab samples and a certain number of composite samples must be examined for prescribed pollutants. Test requirements for air also specify that the test should be conducted under those process conditions that are likely to provide the greatest amount of uncontrolled emissions or effluents. Therefore, if you have a batch operation where the type of effluent generated varies, you will want to make sure that the day scheduled for the tests has the process conditions required by the regulations and that the process conditions persist long enough to meet the particular times, volumes, and number of samples. The company generally must provide adequate scaffolding, test points, access to process flows, etc., to facilitate the testing procedure. If the test crew arrives at the plant and the proper conditions and facilities are not available, the subsequent delay will add to the cost of the testing.

The acceptance testing contract should require that the test report be approved by the regulatory office—not the results of the test, but rather the methods employed—as a condition of payment for test services. If a test is disapproved because of improper instrumentation or methodology, the testing company should be responsible for retesting. Delays attributable to the plant would be paid for by the plant.

Testing to meet the obligations imposed by third parties, the unique aspect of acceptance testing for pollution control, can be extended to meet the interests of the other two parties concerned. In the instance where a conceptual design and/or contractor proposal shows that operating costs are high enough to exert important pressure on the acquisition decision, an additional acceptance criterion may be called for. The company may have chosen a high-cost system in terms of capital cost on the assumption that much smaller operational costs would offset the larger first costs. Where operating and maintenance costs heavily influenced the choice, the express warranty should be extended to cover this aspect of the purchase, and a satisfactory acceptance test should be agreed on. This test need not be approved by any government agency, but must satisfy the parties to the procurement contract. The savings that are often the subject of a test requirement of this type are energy, chemicals, and replaceable control parts.

Even in well-planned conceptual designs, procurement packages, and ensuing contracts, the parties to the contract may encounter differences which they cannot resolve through negotiation, so that some outside means of resolving the dispute must be utilized, i.e., through the courts or through arbitration. A relevant clause covering these matters should preferably be expressly covered in the procurement contract.

The contracting parties should agree on the particular state whose laws shall be applied in the resolution of any legal dispute arising from the contract. Please note, we are not talking here about which state to bring suit in; this is determined by other considerations. The state law to be applied by the court, once suit has been brought, can be preselected; and since state laws differ significantly in many respects, the choice of a particular state may significantly influence the ultimate outcome of the litigation. Again, because of significant differences, a company's legal advisers may be more familiar with certain state laws than others, and this, too, may influence that particular choice.

The contracting parties should agree on whether conflicts should be settled in the courts, or be submitted to arbitration. Unless the contract specifies otherwise, disputes will be resolved in the regular courts of law. This, in turn, creates both advantages and disadvantages. Among the former are standardization of procedures and of legal principles, availability of appellate procedures, provisions for pretrial discovery, and so forth. Among the countervailing disadvantages are crowded court calendars (leading to long waits), the expense of the above-mentioned pretrial and appellate procedures, public notoriety, etc.

Arbitration is in contrast to the foregoing. Rather than taking place in a regular court, it takes place before whatever group of arbitrators the contract specifies. There are even specialized organizations, e.g., the American Arbitration Association, whose services are available for this purpose. Advantages of arbitration are speed, informality, and, in many instances, reduced cost. On the other hand, there are not the safeguards of precedent, legal procedure, and appeal, which exist in court. In particular, the right of appeal is lost when arbitration is made binding, as resort to the courts by the losing party is prohibited.

The whole area of this concluding discussion—choice of law and treatment of the possibility of arbitration—is sufficiently involved and esoteric that legal advice is recommended before it is treated in the original contract.

☆ U. S. GOVERNMENT PRINTING OFFICE: 1977-757-056/5619 Region No. 5-11

METRIC CONVERSION TABLES

Recommended Units

Description	Unit	Symbol	Comments	Customary Equivalents
Length	metre	m	*Basic SI unit*	39.37 in.=3.28 ft= 1.09 yd
	kilometre	km		0.62 mi
	millimetre	mm		0.03937 in.
	micrometre	µm.		3.937 X 10^{-3}=10^3A
Area	square metre	m^2		10.764 sq ft = 1.196 sq yd
	square kilometre	km^2		6.384 sq mi = 247 acres
	square millimetre	mm^2		0.00155 sq in.
	hectare	ha	The hectare (10 000 m^2) is a recognized multiple unit and will remain in international use.	2.471 acres
Volume	cubic metre	m^3		35.314 cu ft = 1.3079 cu yd
	litre	l	The litre is now recognized as the special name for the cubic decimetre.	1.057 qt = 0.264 gal = 0.81 X 10^{-4} acre-ft
Mass	kilogram	kg	*Basic SI unit*	2.205 lb
	gram	g		0.035 oz = 15.43 gr
	milligram	mg		0.01543 gr
	tonne or megagram	t Mg	1 tonne = 1 000 kg 1 Mg = 1 000 kg	0.984 ton (long) = 1.1023 ton (short)
Time	second	s	*Basic SI unit*	
	day	d	Neither the day nor the year is an SI unit but both are important.	
	year	year		
Force	newton	N	The newton is that force that produces an acceleration of 1 m/s^2 in a mass of 1 kg.	0.22481 lb (weight) = 7.233 poundals
Moment or torque	newton metre	N·m	The metre is measured perpendicular to the line of action of the force N. Not a joule.	0.7375 ft-lbf
Stress	pascal	Pa		0.02089 lbf/sq ft
	kilopascal	kPa		0.14465 lbf/sq in

Recommended Units

Description	Unit	Symbol	Comments	Customary Equivalents
Velocity linear	metre per second	m/s		3.28 fps
	millimetre per second	mm/s		0.00328 fps
	kilometres per second	km/s		2.230 mph
angular	radians per second	rad/s		
Flow (volumetric)	cubic metre per second	m^3/s	Commonly called the cumec	15,850 gpm = 2.120 cfm
	litre per second	l/s		15.85 gpm
Viscosity	pascal second	Pa-s		0.00672 poundals/sq ft
Pressure	newton per square metre or pascal	N/m^2 Pa		0.000145 lb/sq in
	kilometre per square metre or kilopascal	kN/m^2 kPa		0.145 lb/sq in.
	bar	bar		14.5 b/sq in.
Temperature	Kelvin	K	*Basic SI unit*	$\frac{5F}{9} - 17.77$
	degree Celsius	C	The Kelvin and Celsius degrees are identical. The use of the Celsius scale is recommended as it is the former centigrade scale.	
Work, energy, quantity of heat	joule	J	1 joule = 1 N-m where metres are measured along the line of action of force N.	2.778 X 10^{-7} kw hr = 3.725 X 10^{-7} hp-hr = 0.73756 ft-lb = 9.48 X 10^{-4} Btu
	kilojoule	kJ		2.778 kw-hr
Power	watt	W	1 watt = 1 J/s	
	kilowatt	kW		
	joule per second	J/s		

Application of Units

Description	Unit	Symbol	Comments	Customary Equivalents
Precipitation, run-off, evaporation	millimetre	mm	For meteorological purposes it may be convenient to measure precipitation in terms of mass/unit area (kg/m^3). 1 mm of rain = 1 kg/m^2	
River flow	cubic metre per second	m^3/s	Commonly called the cumec	35.314 cfs
Flow in pipes, conduits, channels, over weirs, pumping	cubic metre per second	m^3/s		
	litre per second	l/s		15.85 gpm
Discharges or abstractions, yields	cubic metre per day	m^3/d	1 l/s = 86.4 m^3/d	1.83 X 10^{-3} gpm
	cubic metre per year	m^3/year		
Usage of water	litre per person per day	l/person day		0.264 gcpd
Density	kilogram per cubic metre	kg/m^3	The density of water under standard conditions is 1 000 kg/m^3 or 1 000 g/l or 1 g/ml.	0.0624 lb/cu ft

Application of Units

Description	Unit	Symbol	Comments	Customary Equivalents
Concentration	milligram per litre	mg/t		1 ppm
BOD loading	kilogram per cubic metre per day	kg/m^3d		0.0624 lb/cu-ft day
Hydraulic load per unit area; e.g. filtration rates	cubic metre per square metre per day	m^3/m^2d	If this is converted to a velocity, it should be expressed in mm/s (1 mm/s = 86.4 m^3/m^2 day).	3.28 cu ft/sq ft
Hydraulic load per unit volume; e.g., biological filters, lagoons	cubic metre per cubic metre per day	m^3/m^3d		
Air supply	cubic metre or litre of free air per second	m^3/s l/s		
Pipes diameter	millimetre	mm		0.03937 in.
length	metre	m		39.37 in. = 3.28 ft
Optical units	lumen per square metre	lumen/m^2		0.092 ft candle/sq ft

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