Chapter 6
CEM System Procurement, Installation, and Start-up

Purchasing a CEM system should be a step-wise, methodical process. As we have discussed in this handbook, many options must be considered and many decisions must be made before a system actually comes on-line. The manager of the CEM project must assimilate and understand the information available on these options, review that information objectively, and choose the options that best meet the project objectives. Many pitfalls exist: one can rely too heavily on the experience of others, become deluded by aggressive advertising, be led astray by low cost factors, or enter the process with decisions already made. As stated earlier, the goal is to choose the best system for the intended application. Achieving this goal reflects on both the technical and the management skills of the project manager.

Several central factors should be considered in the program developed to accomplish this goal (White, 1995a). They are:

1) The design should meet regulatory requirements and be consistent with plant operating requirements.

2) The materials, components, and techniques should be both reliable and durable under the constraints of ambient and effluent gas conditions, and operating conditions.

3) The system should be easy to use, serviceable, and cost-effective in its long term operation.

4) The risks associated with existing and new technologies applied to monitoring non-criteria pollutions should be minimized.

These factors apply equally to extractive, in-situ, or parametric systems. They apply to systems that are either commercially available or to research systems under development. Cost is always a constraint, but in the field of continuous emission monitoring, cost is not necessarily related to system quality or performance. Evaluations should first be made on a technical basis to determine whether the proposed systems can meet both the regulatory and technical criteria. Costs should then be normalized between those acceptable options so that cost comparisons are made between equivalently performing systems (Brown, 1992). Nevertheless, some risk will be associated with applying existing or innovative techniques to monitoring non-criteria pollutants. If the technique is inappropriate to the application, costs associated with the initial resource investment and noncompliance with monitoring requirements must be considered. These issues will be discussed in more detail later in the chapter.

The selection of a monitoring system should be conducted in a systematic manner (Kopecky, 1979), following established project management procedures in place at the company. Although these procedures may differ from company to company, typical CEM evaluation programs follow approximately ten basic steps. These steps are:

1) Defining the project scope
2) Reviewing the regulations and process requirements
3) Assessing the site
4) Reviewing monitoring options
5) Evaluating vendor options
6) Preparing and transmitting a request for proposal
7) Reviewing bids and awarding contracts
8) Installing the system
9) Approving (certifying) the system
10) Implementing a QA/QC program and operating the system

An example flow diagram that incorporates these steps is given in Figure 6-1.

This process can be lengthy. One author estimated that a typical CEM project will take approximately 40 weeks from inception to certification (Passmore, 1991). Each of these steps will be discussed in detail in the following sections.

6.1 Defining the Project Scope

A CEM project most commonly begins with the assignment of a project manager, usually a project engineer, to develop a technical specification for the

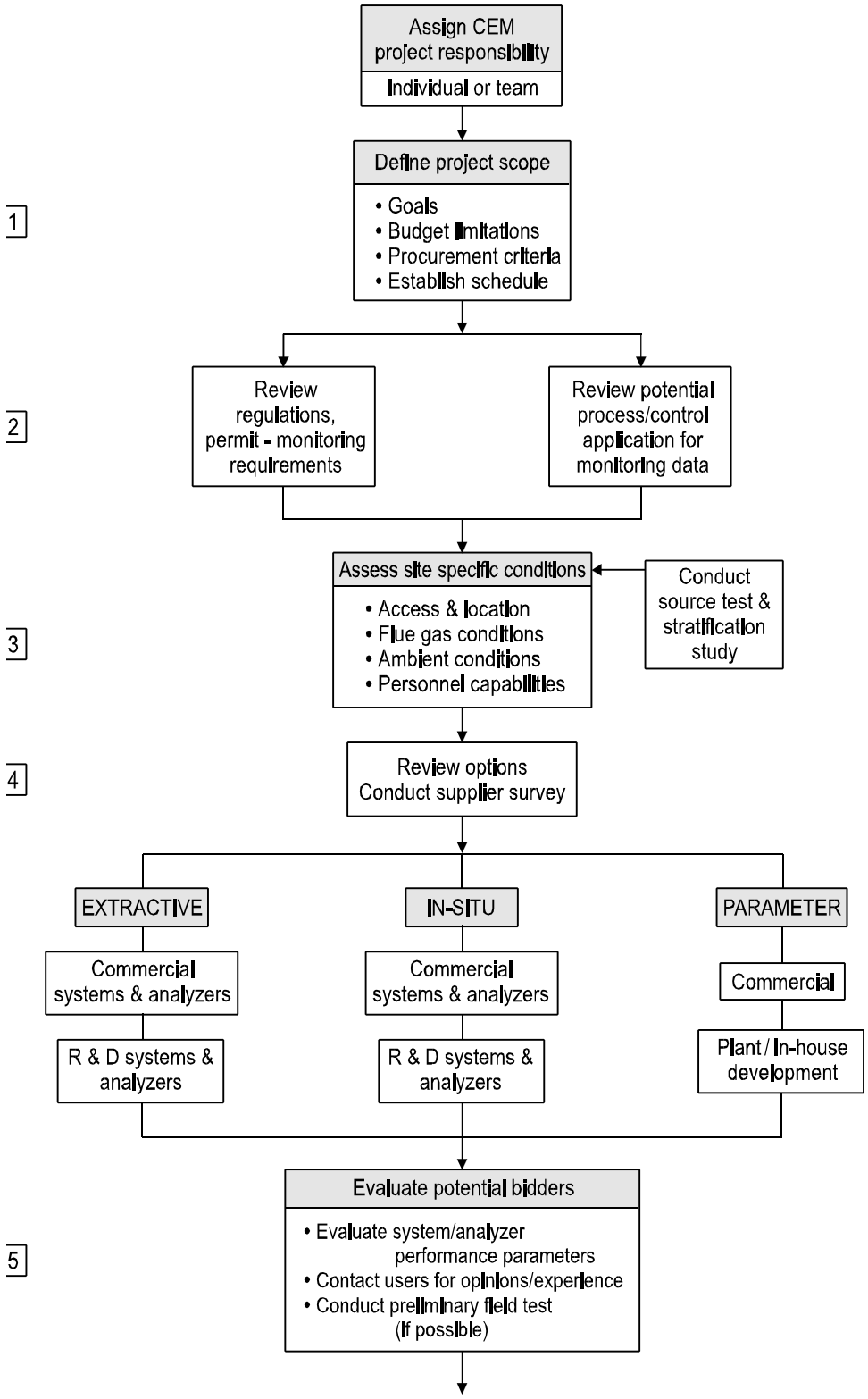

Figure 6-1. Example flow diagram for CEM system selection and implementation.

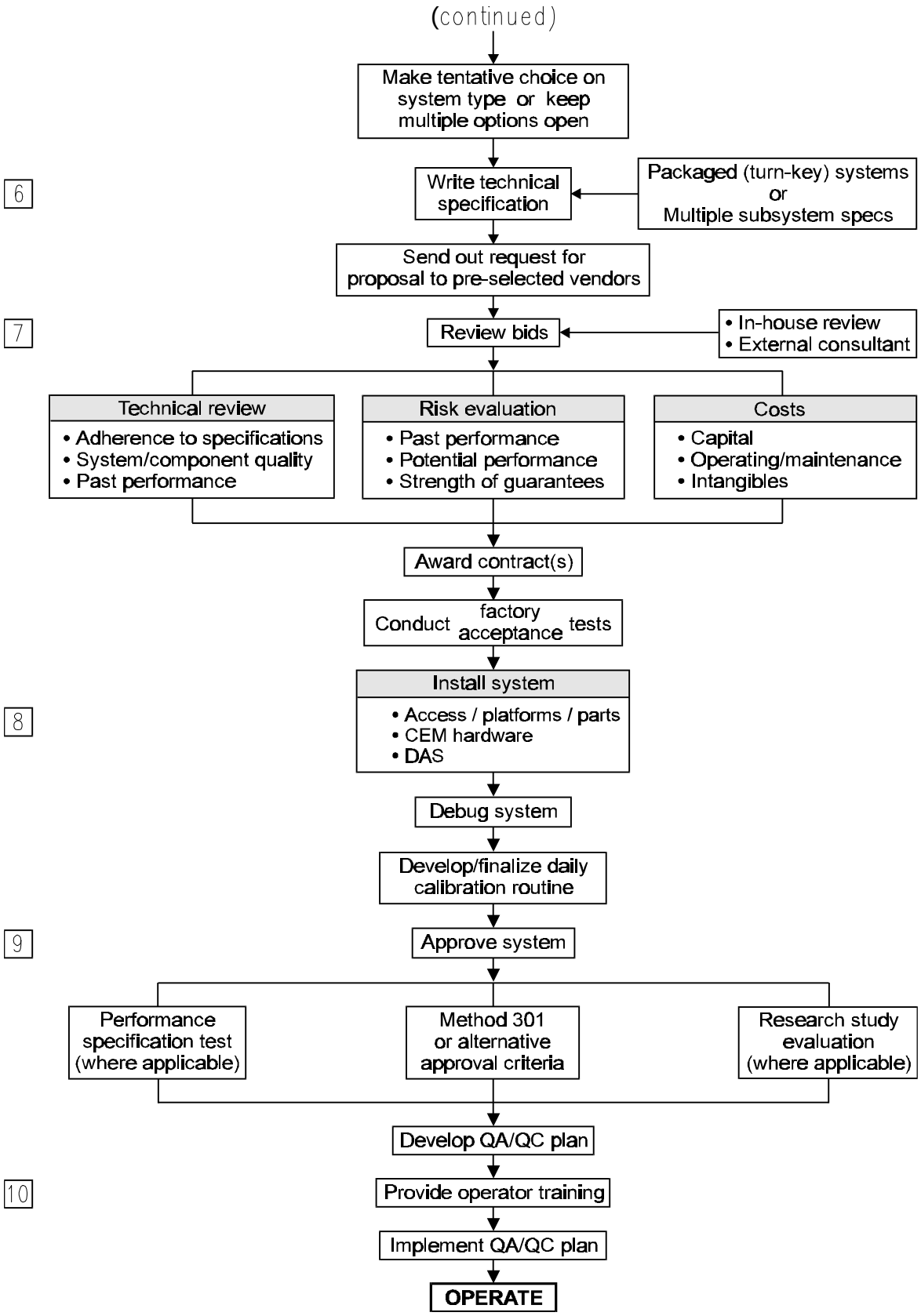

Figure 6-1. Continued

proposed system. Today, most project managers will assemble a team to assist in reviewing regulations and technology, preparing the technical specification, and evaluating the bids received. Instrumentation and control supervisors, technicians, and other plant personnel can be invaluable contributors to this process. The team should also include purchasing personnel, environmental personnel, and, where necessary, legal counsel.

The project scope should be defined at an initial meeting. In this meeting, a decision should be made whether the CEM system will be used solely to meet agency requirements or if it also will be used as input for plant operations control. The implementing rules, the required pollutant measurements, and the data acquisition and reporting requirements should be discussed so that the project team will have an understanding of the purposes of the project. The project manager should have gained enough initial understanding of source monitoring options so that the advantages and disadvantages of extractive, in-situ, or parameter monitoring can be discussed. The estimated budget and procurement criteria as well as the project schedule also should be discussed at this time.

6.2 Reviewing the Regulations and the Process

After the planning stage, the monitoring regulations should be reviewed in detail. This is important to establish the system design criteria for the technical specification. Particular points to focus on are:

- Monitors required, based on how the data are to be reported (see Appendix E of this manual).
- Are parameter surrogate or predictive systems allowed?
- Are time-shared systems allowed?
- Daily calibration techniques allowed (e.g., are Protocol 1 cylinder gases required or are reference spectra or gas cells allowed?).
- Instrument span (range) requirements.
- Sampling, analyzing, and recording frequencies.
- Drift, relative accuracy, and availability requirements.
- Recording and reporting requirements

The requirement for a CEM system may have come through a permit, a state rule, or a federal rule. In some cases more than one rule may require a CEM system. Conflicts between specifications may arise from multiple monitoring requirements. Such conflicts should be resolved with the regulating agency before preparing the request for proposal. Also, many states have developed CEM guideline documents (Nazzaro, 1986, Seidman, 1990). These incorporate essentially de-facto requirements that are often referenced to in the permit. The state should be contacted early in the project to determine if such guidelines have been published and if they must be met by the installed system.

The applicability of a CEM system to both monitor process operations and to provide data for operations control should also be investigated at this time. For example, many companies are now using NO_x monitoring data to allow operators to adjust load in accordance with the plant NO_x control program. VOC monitors may be used to track the efficiency of a catalytic convertor or to monitor loss of product in process operations. Predictive emission monitoring systems have proven extremely useful to monitor; and control many chemical process operations often the regulatory emissions data are merely an extra benefit from the model. However, one must be careful in designing a system for both regulatory and process application. The process monitoring requirements may be either more or less stringent than the regulatory requirements and finding a system to satisfy both at reasonable cost may be difficult.

6.3 Assessing the Site

The plant site and flue gas characteristics should be reviewed next. A suitable location for the CEM system already may have been identified; however, its advantages and disadvantages should be examined carefully. The EPA has established siting criteria for monitoring systems that are very flexible (USEPA, 1996). The intended location(s) should be evaluated for the following:

- Can a representative sample or measurement of the actual flue gas emissions be obtained at the location?
- Is the site accessible?
- Are ambient and physical conditions at the site suitable for monitoring instrumentation?

Sample representativeness is often the biggest issue in monitor siting (EPRI, 1993, Jahnke, 1994). One problem is that flue gas can be stratified, having high and low pollutant concentrations over different areas of the measurement cross-section. Another problem is the presence of non-parallel or swirling (cyclonic) flow, which affects the measurement of flue gas velocity. These problems can be identified by conducting a stratification study, measuring gas concentrations and flow angles over the cross-section at the tentative monitoring location. If the gas is found to be stratified and the location is still viewed as the best available, sampling options will be affected. In-situ path monitors or multiple point sampling systems may be necessary to obtain averaged measurements over the cross-section (Jahnke, 1994).

Flue gas characteristics should be either measured or estimated. This information may be obtained from prior stack test reports and/or from process data. Particularly important for the instrument vendor and the system design are:

- Flue gas temperature and static pressure
- Pollutant gas concentrations (average and range during upset, or other conditions)
- Moisture percentage/presence of water droplets
- Particulate loading and particulate or precipitate carry-over at upset conditions
- Flue gas velocity

Hot metal stacks or flues, excessive vibration, weeping brick stacks after wet scrubbers, should also be noted.

Ambient conditions at the candidate locations should be evaluated. The effects of cold or hot weather, pressure variation at high elevations, sunlight, lightning, entrained dust, or duct gas leaks or stack down-wash on exposed instrumentation and probes should be examined. These issues are critical in the continuing performance of in-situ systems, but can be less of a problem for extractive system instrumentation housed in environmentally controlled shelters.

Another factor that should be considered in the choice of systems is the manpower capability at the facility. Personnel will be required to perform preventive and corrective maintenance on the system after it is certified. Manpower at appropriate skill levels must be available to meet these maintenance demands if high system availability is to be achieved.

6.4 Reviewing Monitoring Options

Sufficient information should be available by this part of the process to begin an evaluation of the various monitoring options. One of the first decision points will be whether to focus on extractive, in-situ, or parameter monitoring systems. Each has its own advantages and disadvantages - again, one must remember that the evaluation should concentrate on determining the best system for the application. This chapter contains guidance for that evaluation, providing flow charts and comments on the application specific features of various systems designs. However, many exceptions also exist. Due to the practically infinite permutations between process units, control devices, flue gas characteristics, and personnel resources, no fool-proof scheme can bedeveloped for monitor selection. In the end, the merits of each option must be considered in terms of the application.

In general, extractive systems provide the most options and are the most flexible in meeting sampling challenges, particularly for HAPs monitoring. In-situ systems can provide low maintenance options when only a few target compounds are required to be monitored. Parameter monitoring systems can offer both monitoring and process control capabilities. For these or other reasons, decision makers may have an initial interest in one type of system over another. Upon further examination, a first preference may not lead to a system suitable in meeting the project goals. The following sections contain flow diagrams that can aid in determining the suitability of various options.

6.4.1 Extractive Systems

Extractive monitoring is the most developed of the three monitoring techniques. It can be a “brute-force” approach to monitoring in the sense that extractive system components can be modified or replaced until some combination of hardware and operating conditions is found that can deliver a viable sample to an analyzer. This is where most HAPs monitoring development programs start. As more experience is gained in extracting and measuring specific compounds, the systems may be simplified.

Figure 6-2 is an example flow diagram for selecting between the various extractive system options.

6.4.1.1 Basic Issues

In the first gate for entry into extractive systems, one should consider three basic issues. If an interest exists in time-sharing one set of analyzers among

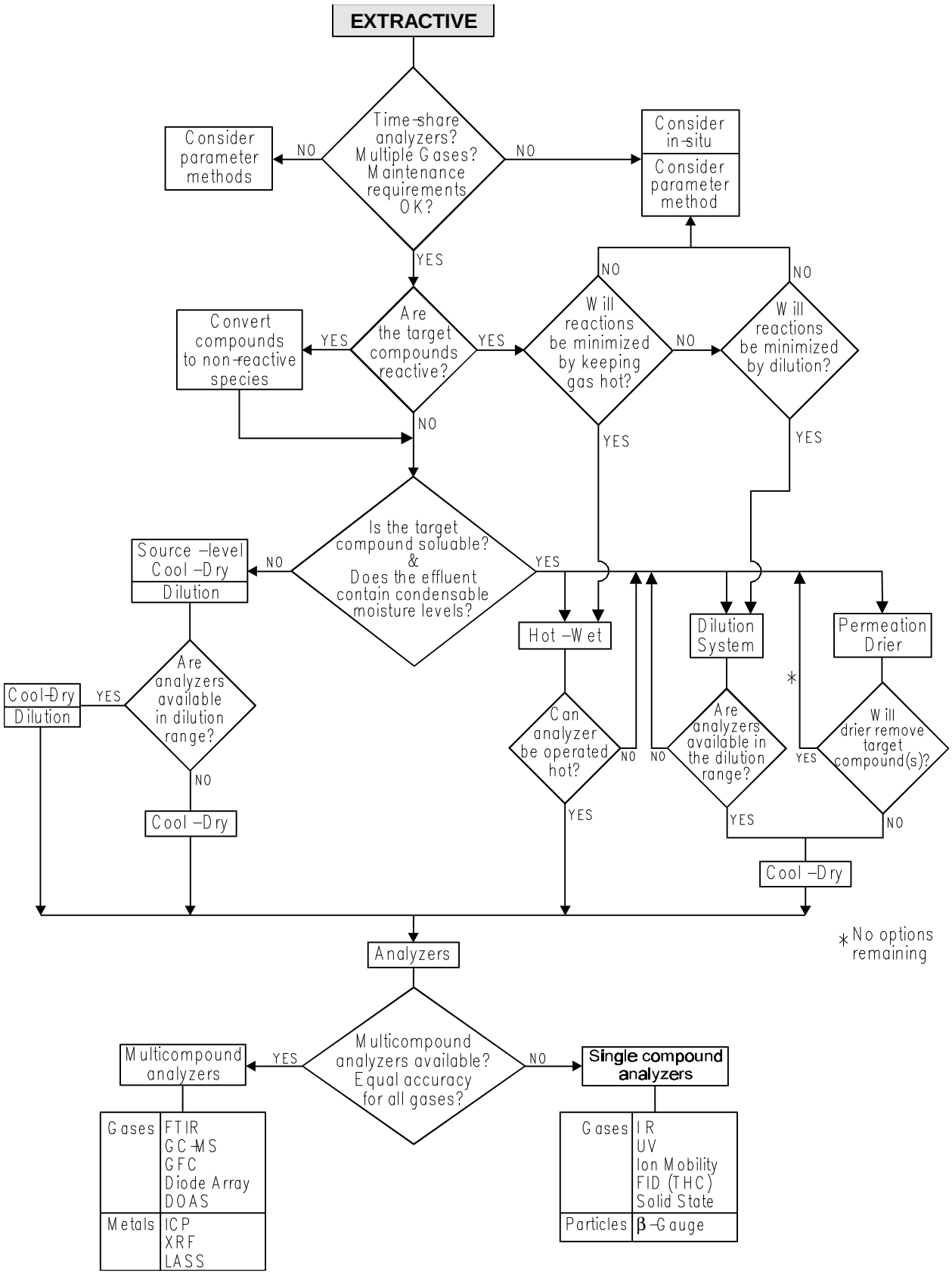

Figure 6-2. Selection considerations for extractive systems.

several units, extractive systems, not in-situ, are appropriate. If the user requires or desires to monitor several gas species, more multi-gas analyzers are available commercially for extractive systems than for in-situ systems. Lastly, extractive systems require more maintenance than either in-situ or parametric systems. These basic issues should be considered when choosing the system. A summary of other technical issues discussed in more detail in Chapter 3 follows.

6.4.1.2 Reactive Gases/Condensable Gases

The tendency of target gases to react or decompose before analysis is a primary consideration when selecting a monitoring approach. Two gases may coexist in the flue gas, but when extracted and cooled they may react. The resultant compounds may not be representative of the target pollutants and, in some cases, may form a precipitate that plugs the system. An organic compound may react with the oxygen in the dilution air of a dilution system, or a compound may catalytically decompose on the probe, tubing, or pump surfaces. Other compounds may be unstable and decompose merely on standing. Where the sampling system perturbs the gases or particles being measured, a representative sample may not be obtained and other monitoring techniques may need to be considered.

The next consideration should be whether the gases being measured are condensable or soluble. Gases like hydrochloric acid, ammonia, formaldehyde, and methanol will drop out along with water in any chiller of a dry-extractive system. Other gases with varying water solubilities may be partially lost to the condensate. If the gases are not condensable, a dry-extractive system would offer a greater range of options in selecting analytical techniques. Of course, dilution systems can be used for non-condensable gases, but the choice of analyzers may be limited to those that are sensitive enough to measure at the lower, diluted concentrations. If the gases are condensable, hot-wet source level systems, permeation dryers, or dilution systems can be used. Dilution systems are preferable here if analytical techniques are available at low ranges. Hot-wet systems require greater maintenance, since parts and materials degrade faster at elevated temperatures. Nafion permeation driers will lose some polar compounds such as ammonia, alcohols, and organic acids, but are acceptable for others, such as the halogenic acids, inorganic acids, and aldehydes (1995, Permapure).

6.4.1.3 Multi-gas vs Dedicated Analyzers and Analytical Methods

The next decision addresses the type of analytical system to be used. If a number of gas species are to be analyzed, multi-component analyzers such as gas-chromatographs, gas chromatography coupled with mass spectrometry (GCMS), or FTIRs may be considered. However, one should evaluate the sensitivity of the analyzer to each of the species analyzed. The analyzer may be able to measure one gas to a 1 ppm level, but other gases only to a 10 ppm level. A separate analyzer may be required to measure the diluent gases (O_2 or CO_2) since the percent level concentrations of these gases may not be consistent with the lower ranges necessary for the pollutant gases.

Caution is warranted when selecting multi-component analyzers. The analyzer previously may not have been applied to a similar process or to a flue gas with similar characteristics. In such cases, the CEM project may not be straightforward and may require some initial research and development work.

Multi-component analyzers utilize techniques such as Fourier transform infrared spectroscopy, GCMS, differential optical absorption spectroscopy, and gas filter correlation (for a limited range of pollutants) for monitoring organic compounds. For metals monitoring, inductively coupled plasma, x-ray fluorescence, and laser spark spectroscopic techniques are under development.

Single component analyzers employ electro-optical, electro-chemical, and other techniques. Differential optical absorption, ion-mobility spectroscopy, fluorescence spectroscopy, and electrochemical methods typically are used. Flame ionization detectors monitor total hydrocarbons, beta gauges can measure the flue gas particulate loading.

If multi-component analyzers are not available, or if single component monitors with better applications experience are found on the commercial market, a collection of single component analyzers may be more appropriate. Single component analyzers are, in general, optimized for that component and may offer greater sensitivity and interference rejection than can multicomponent systems. Unfortunately, very few single-component analyzers have been developed for monitoring air toxics or HAPs. Not that they could not be developed, but the commercial market is small and instrument manufacturers usually do not make analyzers that have no market.

The analytical techniques have been discussed in greater detail in Chapter 3 of this handbook. At this point, an extension of the flow chart is difficult since many factors are involved in choosing the analytical method. One must evaluate the instrument response time, drift, and precision specifications, interference rejection capability, stage of development, ruggedness, cost, and so on. Some familiarity must be gained with the technologies used to monitor toxic gases and Chapter 3 should be reviewed.

6.4.2 In-situ Systems

In-situ systems were developed as an alternative to extractive systems where maintenance levels became unacceptable. Plugging, leaks, and corrosion eventually will occur in even the best designed extractive system, but often these problems can be avoided if the gas is measured without extracting it in the first place. In-situ instruments that require only 50 to 60 hrs of preventive maintenance a year are available commercially (Karpinsky, 1995). Unfortunately, at this point, these instruments have been developed primarily for the monitoring of criteria pollutants. Therefore, the first question that must be asked is whether an analyzer has been developed that can measure the pollutants of interest. Figure 6-3 is an example flow diagram that illustrates points to be considered for decision-making for in-situ systems.

6.4.2.1 Siting Considerations

If a pollutant can be monitored by the in-situ technique, some site specific questions need to be addressed before proceeding. The first and most obvious question is whether an interest exists in timesharing the system between multiple ducts or stacks. If so, go back to extractive systems. Time-sharing a spectrometer might be feasible in path systems using fiber-optic cables, but no known applications of this technique exist. Other barriers to the use of in-situ systems pertain to the capability of the monitor to operate at the chosen duct or stack location.

Siting for in-situ systems is important since limits to environmental conditions are encountered that even the best of systems cannot withstand. Exposure to temperature extremes may limit an instrument's application. Although the instrument may have an internal heater to maintain temperature if it gets too cold, the instrument may not have an internal cooler to reduce the temperature if it gets too hot. Lightning can be a problem. An exposed in-situ monitor mid-way up a stack makes an excellent lightning rod. Excessive vibration also may be a problem. This factor often is pointed out as a disadvantage in in-situ systems, however, techniques have been developed to minimize both the effects of vibration and lightning on in-situ instrument systems.

Flue gas characteristics certainly limit the application of in-situ systems. High gas temperatures (> 500 °F) affect molecular infrared light absorption characteristics. Hot-metal stacks will emit infrared radiation and reduce the sensitivity of in-situ infrared analyzers. In addition, cycling stack temperatures can distort untempered probes, or cause misalignments in poorly designed path systems. Electro-optical in-situ analyzers require a certain amount of light to reach the detector after it traverses its optical path in the stack. If particulate levels are high, or if high levels of water droplets or other aerosols are present, the intensity of the light may be too weak to afford good signal to noise levels. Opacity levels common to most flue gas exhausts (< 20% opacity) do not present a problem for most in-situ monitoring applications.

The monitoring location for the in-situ system must be accessible. Duct or stack locations accessible by catwalks or stairs are ideal. Systems located in the annulus between chimney and flue and accessible by man-lift have traditionally been preferred but may now require confined space entrance permits due to OSHA regulations. Sites accessible only by ladder, requiring a safety harness, are not ideal. The rule-of-thumb is: if no one is willing to go up and service the system in the middle of winter, find another location or purchase some other system.

6.4.2.2 Flue Gas Stratification Issues

Flue gas stratification can be a major problem in obtaining representative flue gas measurements. Stratification is the uneven distribution of pollutant, diluent, or particulate concentrations over the area of the sampling cross-section. Air in-leakage, combining ductwork, mixing or combining effluent streams, duct geometry, and flue gas physical properties can cause pollutants in the gas to stratify. The flue gas velocity can also vary over this cross-section; in the case of non-parallel cyclonic (swirling flow), its direction can vary also. Cyclonic flow presents one of the most challenging sampling problems. Selecting an alternate sampling site is usually more prudent than attempting to measure flow under cyclonic conditions.

Three approaches can be taken to minimize stratification effects. One is to install a path in-situ system, where a measurement is made on a line across the stack. The measurement represents a line average, not an area average, but the average measurement

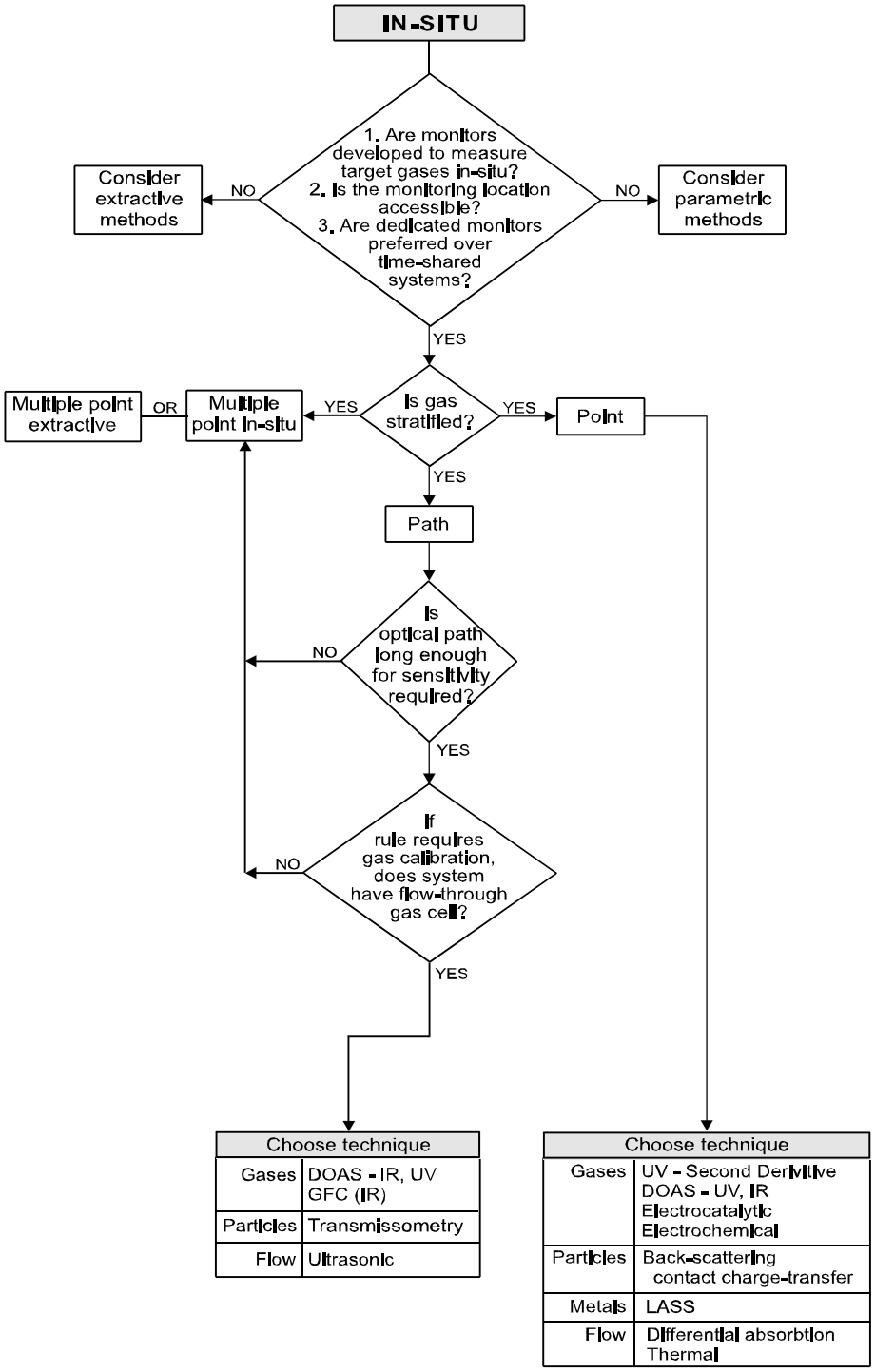

Figure 6-3. Selection considerations for in-situ systems.

can be more representative than a single point measurement under varying stratification conditions.

Another approach is to use multiple probes or monitors to sample at several points on the cross-section. This technique has been used in monitoring stratified flow in ductwork by placing a grid of thermal sensors at measurement points defined by EPA Method 2. Sometimes, increasing the number of sampling points from one to just two or three can greatly improve the representativeness of the measurement.

In situations where the stratification pattern is stable over varying process load or operating conditions, a single point in-situ monitor or extractive system probe may be suitable if a point representing the average cross-sectional concentration or velocity can be found. Detailed solutions to these problems are treated elsewhere (Jahnke, 1994 Chapter 2 and references therein).

6.4.2.3 Path In-situ Monitor Considerations

If the decision-making process has led this far to path in-situ monitors, two other factors must be considered. First, for small diameter ducts or stacks, the sensitivity of the instrument may be limited. At low concentrations and short pathlengths, too few pollutant molecules will be present to absorb much light energy. The instrument detector may not be sensitive enough to see very small changes in the returning light energy and the sensitivity of the instrument will suffer. Longer path-length options might be considered, such as measuring across the stack at an angle (Reuter-Stokes, 1995), measuring lengthwise down the duct or stack, or even pulling the flue gas into a longer by-pass tube to make a hybrid in-situ/extractive system.

The second important issue regarding path in-situ systems is a regulatory one. In the United States, many CEM regulations require the use of calibration gases for daily calibration (see for example, 40 CFR 75 Appendix B). This has been addressed in path in-situ systems by using a flow-through gas cell (Carman, 1993). Problems do arise when certified standards are not available or are not available at appropriate concentrations. Other means for performing calibration checks have been developed that use reference spectra or sealed gas cells containing pollutant gases of known concentration. These techniques are used commonly in European instrumentation and are accepted by the European Community. The use of reference spectra is convenient, especially for monitoring air toxic compounds where reliable cylinder gas standards are not available. If one desires to use these alternate calibration techniques, the agency should be consulted first.

6.4.2.4 Analytical Methods

The analytical techniques utilized in point and path in-situ systems are similar to those used in extractive systems, although the number of applicable techniques is limited due to in-situ system design constraints. Chapter 3 contains detailed discussions of the various techniques.

For in-situ gas monitoring systems, the differential optical absorption spectroscopy offers the greatest flexibility for monitoring air toxic organic compounds. Spectrometer systems, tuned lasers, or various filtering methods that distinguish between different light wavelengths in the IR or UV range have all been employed in path monitoring systems. Spectrometer systems offer the advantage of monitoring a number of compounds simultaneously. Tuned lasers, optical filters, and gas filter correlation techniques are somewhat limited, but still may monitor from 1 to 8 compounds at a time. On the other hand, transmissometry is the only path in-situ monitoring technique available for particulate matter.

More analytical options are available for point in-situ systems. In addition to the electro-optical methods typically used for monitoring gases, electro-analytical methods can be employed as well. Electro-chemical or electrocatalytic sensors can be supported at the tip of a probe for direct, in-situ measurements. Particulate matter may be monitored by the techniques of light scattering and contact charge transfer, whereas metals can be measured in-situ by laser spark spectroscopy. Flow can be monitored by a variety of differential absorption and thermal techniques.

6.4.3 Parameter Monitoring Systems

Parameter monitoring stands as a distinct alternative to the use of sampling and analytical hardware of traditional CEM systems. Parametric techniques offer some distinct advantages, but also suffer some disadvantages that are not overcome easily. These issues are discussed in more detail in Chapter 4 of this manual. Figure 6-4 contains a process for choosing parametric systems when they are required or are being considered as a monitoring option.

The first major decision point associated with parametric systems is whether the permit or regulation allows its application for meeting the monitoring requirement. Parameter surrogate monitoring is specified in a number of the NSPS and may be specified in Title V operating permits. Parameter

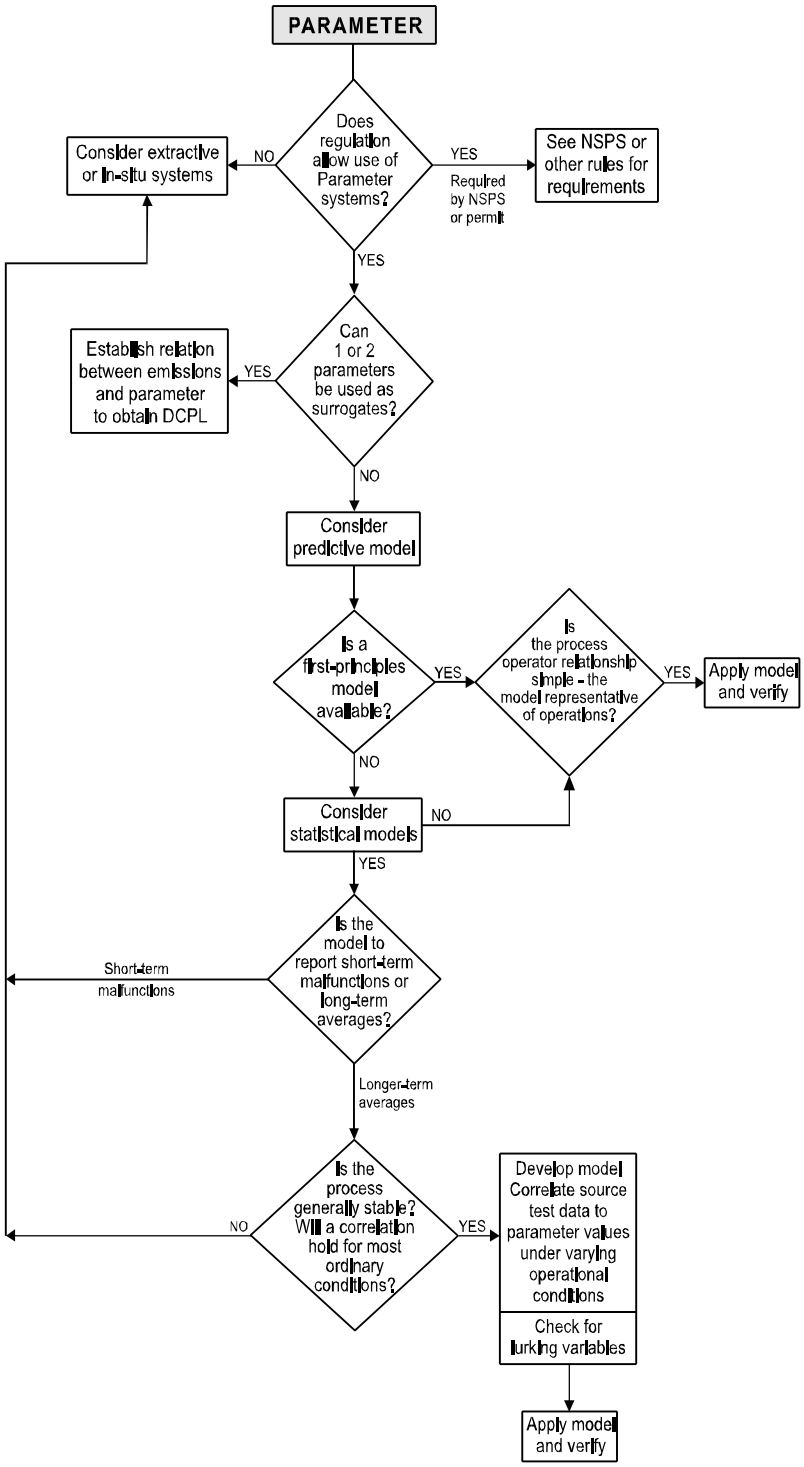

Figure 6-4. Considerations for parameter monitoring systems.

monitoring is also acceptable in the proposed CAM program.

The simplest approach to using operational parameters in emission monitoring is as a surrogate for the actual emissions. If a clear relationship can be established between emissions and one or two parameters such as pressure drop, temperature, etc., a parameter value (the DCPL - direct compliance parameter limit) may be acceptable as a de facto emissions standard. If this is not acceptable in meeting agency requirements, then a predictive model may be developed.

As discussed in Chapter 4, two types of predictive models are used: the first principles or phenomenological models and statistical models. Both models may provide additional insights into process operations. Models should be tested and verified. If they fail verification, one may always return to CEM analytical hardware.

Simple statistical models can be developed in-plant, by consultants, or companies that specialize in their development. If the model is to be used for compliance with short term emission exceedances, excessive correlation testing may be required to model all the conditions under which an exceedance might occur. This testing may be very difficult to perform or prohibitively expensive. If, however, longer term averages are to be reported or the data will be used to report adherence to emission limitations, the model may not have to be as robust.

The statistical model should be developed under varying operating conditions and also evaluated for the effects of parameters or conditions not included in the model. The final model should be robust, having an accurate solution for each set of operating conditions. Models can cross-check themselves, but all models should be re-verified periodically.

6.4.4 New Market Products and Systems under Research and Development

Figures 6-2 and 6-3 are flow diagrams for evaluating monitoring approaches that are, in general, commercially available, or where some previous similar experience exists in their application. In evaluating new market products or newly developed techniques, following such a diagram may be difficult if little is known about the system limitations. For such new systems, an alternative flow diagram is suggested, Figure 6-5.

In this approach, the pollutant properties are considered first, the analyzer capabilities are evaluated, and then the sampling system options are reviewed. This evaluation approach proceeds from the analyzer to system selection rather than the approach given in Figures 6-2 and 6-3, from the system type to the available analyzers.

6.5 Evaluating Potential Bidders

After the site characteristics and monitoring options have been evaluated, information should be obtained on potential suppliers and bidders for the project. Potential bidders may include CEM system integrators, instrument manufacturers, data acquisition system (DAS) vendors, computer software firms, and environmental consulting/contracting companies. Many of these companies will exhibit at trade shows and advertise in trade journals. Lists of instrumentation companies and CEM system integrators are given in trade journal “Buyer’s Guides,” but these lists generally are not very discriminating.

Once contacted, vendors will send literature, call, visit, and market. Although marketing calls may seem onerous, they can provide a means for assessing both the applicability of the vendor’s approach and the capabilities of the vendor. On the other hand, the vendor who understands the requirements and limitations early in the proposal process, can deliver a better product in the end.

At this point in the monitoring system selection process, the project manager and team should concentrate on screening the assembled list of potential vendors to those that meet project selection criteria (Brown, 1992). These initial criteria should include an evaluation of:

- System capability in meeting regulatory requirements
- System capability in meeting plant process/control needs
- Suitability of the system for operation at the plant, at the intended location, and under plant operating conditions.

Contractual requirements such as bid bonds, warranties, guarantees, and other commercial aspects should be discussed before a formal bid solicitation. Preliminary cost estimates, maintenance costs, and vendor service capabilities also may be important screening issues.

To help in this part of the process, the team should contact other users of monitoring systems, preferably users in the same or similar industries. Here, the

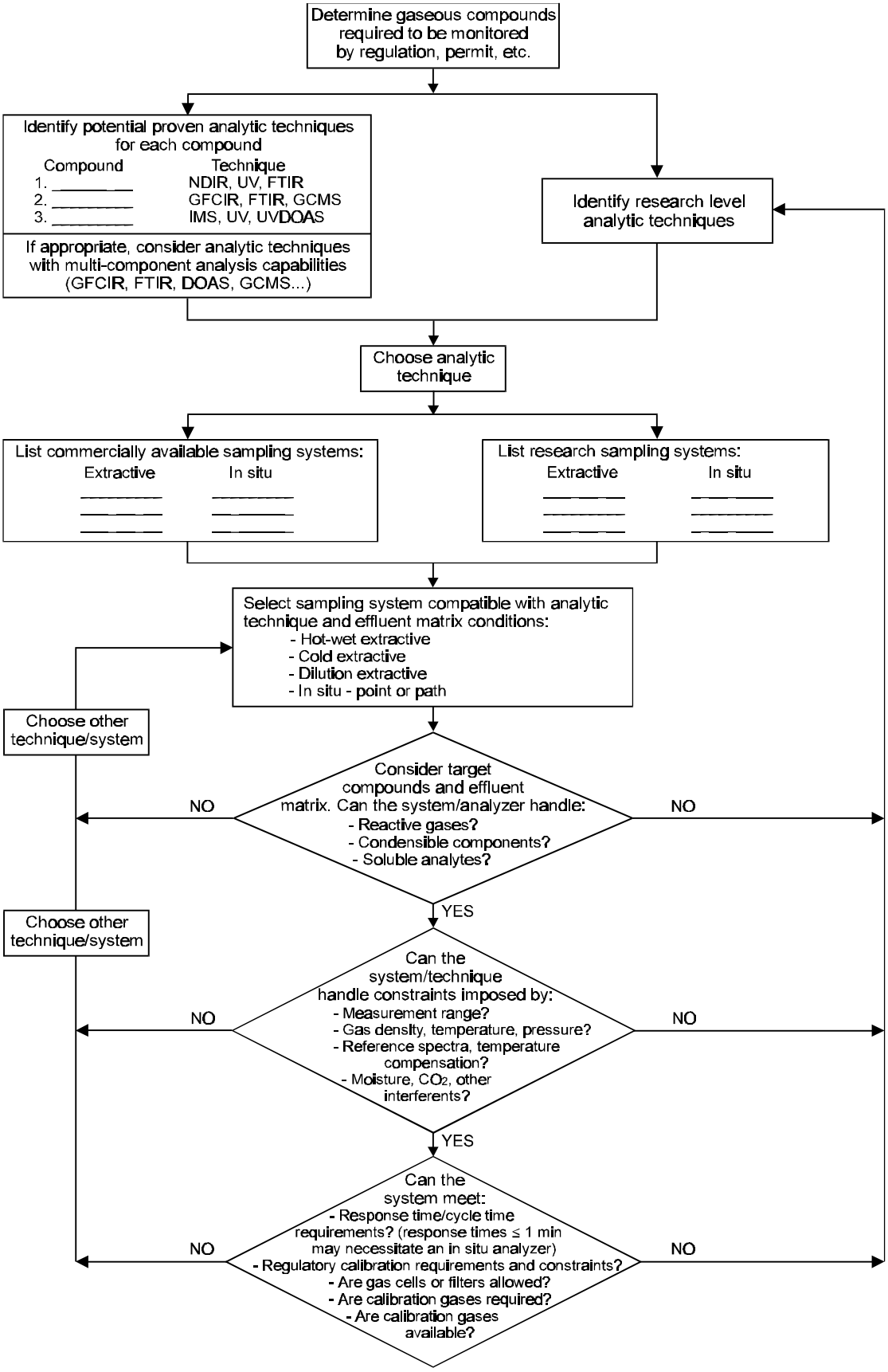

Figure 6-5. Alternative approach to monitoring system decision-making.

industry network becomes useful. The opinions and experience of others can be extremely helpful in maintaining objectivity when evaluating the claims of the various suppliers. However, as a cautionary note, be aware that the experience of others is based on specific applications and may not be appropriate to the current project. Industry networks can fool themselves by reaching an overall consensus - everyone agreeing that only one specific approach is the correct approach. A project manager conducting a more objective evaluation may end up in the position of deviating from the "conventional wisdom," and find difficulty in justifying a different, but more appropriate technology to management.

When a corporate office is planning to purchase a number of monitoring systems for company facilities, management often desires to standardize, having one vendor supply identical systems to all of the plants. However, prudence should be shown by first purchasing one system, evaluating the system technically, and evaluating the performance of the vendor in terms of response and service before committing to a corporate-wide purchase. Another approach is to invite vendors to demonstrate equipment during a short-term field trial. A field trial will be particularly appropriate if the source conditions at the trial are similar to those of the intended application. Vendors are becoming hesitant in participating in such programs since they are costly, do not necessarily reflect actual equipment performance, and may offer no return if the system is not selected. However, if an instrument manufacturer has developed a new analytical method or monitoring technique, it must be field demonstrated before it can hope to have any market acceptance. The manufacturer will be eager to obtain the cooperation of a plant to help in proving the system. Many good system applications have resulted from such developmental work.

The screening process should identify at least three, but preferably more, potential bidders. If company policy is to accept the lowest bidder, then only vendors that can provide a product that the plant can live with should be put on the bidder's list. If the company requires that all requesting or potential bidders be included on the list and that no prior discrimination is allowed (as is the case in some municipal facilities), then this entire exercise is useless.

6.6 Writing the Bid Specifications

The purpose of performing an initial vendor screening is to simplify the writing of the technical specification. As a result of the evaluations conducted on the available technologies (Step 4 of this strategy) the project manager may have decided initially to focus on extractive or in-situ systems. However, a vendor may have later pointed out the merits of predictive monitoring systems. Options still can be kept open in the technical specification by incorporating a set of uniform criteria that either technique can satisfy.

After a consensus has been reached by the CEM project team, a detailed technical specification can be prepared. In most cases, the team will not have to start from ground zero and develop an original document since model and example specifications are often available. The Electric Power Research Institute has developed a model Request for Proposal package for CEM systems required under 40 CFR 75, the acid rain program (EPRI, 1993). The package includes an example transmittal letter, suggested terms and conditions, and a guideline technical specification. The package can be modified easily for other monitoring programs and serves as a good starting point. Technical specifications also tend to circulate within the networks of a given industry and technical specification packages frequently can be "borrowed" from someone else. Vendors also offer bid packages to "assist" potential clients in their monitoring programs. However, these packages are usually self-serving, being written in a manner to exclude competing technology or competitors. The company itself may have standard specification requirements and the monitoring specification may have to be tailored to meet the criteria of the contracts department. Whichever route is chosen, the specification should provide a basis for the purchaser to obtain the system desired and a basis for legal action if it is not satisfactory after installation.

A typical CEM system specification incorporates the following (from Jahnke, 1993):

1) Purpose. A brief statement of where the CEM system will be installed, the number of units that will be monitored, and statement of the regulatory requirements applicable to the installation.

2) Scope of Work. An outline of hardware, software, and services to be provided by the vendor. This section may include a basic system configuration, list of the number of analyzers required, data acquisition/control requirements, and may specify brand-names of analyzers or components if desired. Vendor furnished services may include complete system engineering, installation, and start-up, if desired.

3) Equipment and Services Provided by Others. A listing of equipment and services that the vendor is not expected to supply. This may include equipment or supplies such as elevators, ports,

catwalks, platforms, electrical supplies, foundations, or calibration gases. Services supplied by plant personnel or others may include system installation, wiring, or certification.

4) Description of Operating Conditions. A description of environmental and stack gas conditions at the sampling locations. Diagrams of sampling ports and access conditions should be provided here or referred from here to the appendix of the specification. Flue gas characteristics such as moisture content, velocity, and temperature, and the expected composition and concentrations of pollutants in the flue gas should be supplied. This information is critical to the vendor for the design of the system.

5) Design Criteria and Construction. A detailed description of the system on which the bid is to be prepared. The intent is not to provide all design data, but to provide the vendor with an understanding of the system requirements from both regulatory and operational aspects. Design requirements include adherence to standards, codes, and regulations. They also include specifications for instrument range, drift, and response time. They may include specifications for sample conditioning, interfacing with other plant systems, and data acquisition requirements and reporting formats.

   This section will constitute the bulk of the specification. However, care must be taken not to "over-specify" the system. The vendor must be allowed leeway in the design to use his own experience in CEM systems for the job. If the requirements are too stringent, either no one will bid on the system or they will be ignored in the systems offered.

6) Vendor Furnished Services. A listing and description of services desired from the vendor. These may include, total project management, installation, training, performance testing, or ongoing maintenance services.

7) Inspection and Testing. A listing of certification guarantees and warranties expected from vendor. These may include factory checkout and certification provisions, performance specification test guarantees, and system availability requirements.

8) Equipment Delivery Requirements. A statement of progress report requirements, delivery dates, and shipping requirements.

9) Engineering Data and Documentation. A listing of required system documentation. This should include accurate system schematics and wiring diagrams, operating manuals, maintenance instructions, and DAS operating instructions and documentation.

Separate technical specifications may be written for various subsystems. Frequently, a separate specification is written for the data acquisition and handling system. Special precautions are necessary to ensure that the two systems are fully compatible (see Chapter 5).

Services such as training, maintenance, and performance testing should be requested to be bid separately as options. Costs for these services should also be bid separately since they tend to be quite variable between bidders. Separating services from the system technical specifications will assist in the evaluation process and will offer more flexibility in subsequent negotiations.

A set of technical specifications normally will be accompanied by a set of "Standard Terms and Conditions" prepared by the company contracts department. This document will include legal requirements for insurance, limits of liability, remedies, disputes, etc.

After a draft bid package has been prepared, it should be circulated to other departments within the company before it is released (Brown, 1992). Legal departments, computer systems, purchasing, and various engineering departments may wish to provide input or comment on areas of their particular concern. The package should then be revised appropriately, finalized and issued. If not already having done so, bidders should be allowed the opportunity to visit the site and observe plant conditions and operations to better design a proposed system. Approximately four weeks should be allowed for bidders to respond to the Request for Proposal.

6.7 Reviewing the Proposals and Making a Decision

Reviewing proposals objectively is difficult since, by the time proposals are received, members of the CEM team will have some preconceived idea about what will be the "best" system or who will be the "best" vendor. However, the decision should be based on a systematic evaluation of the proposal following objective criteria established before the RFP, keeping in mind that the quality of the proposal will often be indicative of the quality of the work.

6.7.1 Areas for Review

Three principle areas need to be reviewed on a preliminary basis after receipt of the proposals (Figure 6-6).

These areas include a technical review, an evaluation of risk (especially for new systems for new applications), and cost. This review is preliminary because, despite all good intentions in drafting clear, concise, and explicit technical specifications, one vendor will offer oranges and another will offer apples. One usually must obtain further information, clarify exceptions, and normalize equipment costs and services to make valid comparisons.

6.7.1.1 Technical Evaluation

In the technical review, a determination should be made whether the system will meet all regulatory specifications and any additional specifications given for the plant application. Most proposals will state that all specifications are met; however, corroborating information should be provided so that the review team may verify such statements.

Technical Review
Adherence to Technical Specs.
System/Component Quality
Proposal Quality
Risk Evaluation
Past Performance
Potential Performance
Strength of Guarantees
Costs
Capital
Maintenance
Intangibles

Figure 6-6. Areas for proposal review.

The system and component quality should be evaluated. A proper evaluation here may require prior knowledge on the part of the team members, or a reliance on the experience of others who have purchased similar systems or instrumentation. System quality may be difficult to evaluate for newly developed analyzers. The frequent lack of experience of entrepreneurial instrumentation companies in stack monitoring applications is a factor that must be considered in the review.

The best proposals are those that are written specifically for the plant application. The worst consist of a price quote and a collection of vendor trade literature. Most proposals will fall somewhere in between these extremes, generally towards the lower end of quality. Not that better proposals can't be written, but when a vendor sales or project manager has to respond to numerous proposals, few receive the attention that is desired. However, if a vendor really wants the job, enough care and time will be put into the proposal to show that a good system can be provided for the application. Ultimately, well-prepared proposals have greater success in being awarded.

6.7.1.2 Risk Evaluation

The evaluation of risk in a CEM program is not simple. Frequently, the results of important decisions are not known until much later in the implementation of a monitoring program. An untested assumption or a faulty decision early in the development of a monitoring program may affect many subsequent steps. The project manager must recognize the risk associated with critical decisions and understand the impact of unfavorable outcomes on both the immediate task and subsequent activities.

The primary risk associated with selection of a monitoring approach or specific equipment is that the selected system will not perform acceptably. When a general failure occurs, the investment of resources (time for internal personnel, subcontracted services, and capital expenses) produces neither benefit nor compliance with applicable monitoring requirements. An entire system may need to be replaced or new regulatory requirements may need to be negotiated.

The project manager must focus on the specific issues of the particular monitoring application. Past performance of similar systems may provide a limited basis for evaluation of risk. Contractual conditions, warrantees, and performance guarantees can draw attention to specific issues and may also provide some recourse for the purchaser if performance proves to be unacceptable. However, to minimize risk of unacceptable performance is always better than to rely on the threat of litigation.

Because of the importance of CEM data to source compliance programs, the CEM project manager must consider how inaccurate, imprecise, or non-representative monitoring data affects source operation and con-

trol equipment costs. The risks and costs associated with inaccurate data must be weighed against the cost for more reliable monitoring results. Achieving the appropriate balance between these risks and costs becomes more crucial as emission levels approach the applicable limit. One may expect that a source operating well within the applicable limits will be willing to accept a greater level of uncertainty in the monitoring data. In this case, the source operator may be able to choose more economical alternatives over more accurate data. On the other hand, a source with a minimal compliance margin will place greater value on accurate monitoring data and may be able to justify the greater expense associated with achieving higher levels of performance. Costs associated with modification of process or control equipment and operational costs due to changes in source operation and maintenance practices necessary to meet emission limitations are considered "compliance costs" for the applicable standard. Such costs should not be attributed to the monitoring program. Similarly, the risks associated with non-compliance with emission standards also must be considered separately even though such problems might be detected only by means of the monitoring program.

The proper balance between risk and cost will depend on the monitoring approach and many source-specific factors. This balance must be determined on a case-by-case basis. Two examples of risk evaluation are provided below:

6.7.1.2.1 Example 1 - PEM System Risk Assessment. Consider the selection of a PEM system relative to a conventional CEM system for the measurement of gaseous pollutants. In this approach, hardware expenses are mostly eliminated and the initial capital outlay for the PEM system may approximate the cost of the CEM system DAHS. As compared to the CEM system approach, additional comparative emissions testing is required to develop either the "first principals - phenomenological" PEM system or the "statistical - inferential" PEM system. Thus, an investment occurs in direct costs (i.e., planning and engineering time for company personnel or similar subcontract services by consultants or vendors). PEM system performance tests involving comparisons with independent emissions measurements may be required soon after the model is established. A similar test may have to be repeated on a periodic basis as a QA procedure.

To assess the risk associated with a PEM system approach, estimates must be made of the initial model development cost, initial confirmation performance test cost, and subsequent periodic QA test cost. These are the expected costs that will be incurred in all PEM system applications. In addition, the potential costs associated with unfavorable outcomes must be considered. The likelihood that the PEM system will fail either the initial or subsequent tests and the potential costs of retesting must be assessed. Also, the likelihood that the initial model development effort will need to be repeated either because of repeated failures of performance tests or because of fundamental changes in the fuel, raw materials, process, or control device function must be considered.

The ultimate cost of the PEM system will be very sensitive to the risks discussed in the previous paragraph. The relationship as shown in Figure 6-7 is suggested as a method of estimating the cost of the PEM system.

The consistent application of arbitrary estimates or ranges of the likelihood of various outcomes in the above relationship will assist the decision maker in assessing the overall cost for the PEM system. An example of such an analysis is shown in Figure 6-8. Prudence dictates assigning higher risk factors to industries or applications where little previous experience has accumulated. Higher risk factors should be assigned to applications within agency jurisdictions where strict monitoring regulations or QA requirements may be adopted.

6.7.1.2.2 Example 2 - CEM System Risk Assessment. The likelihood that a CEM system will perform acceptably will depend to a great extent on the pollutants or compounds to be measured. Opacity, SO_2, and NO_x CEM systems are now considered to be very reliable for many applications. However, the development status of CEMS for non-criteria pollutants spans a very wide range. For example, "total hydrocarbon monitors" employing FIDs have been installed at certain sources in the United States for a number of years. CEM systems for Hg are available from several manufacturers, but issues related to calibration standards and reference test method procedures are being resolved. Monitors for other metals (e.g., "multi-metals CEM systems") are beginning to become available commercially. The project manager must recognize that the likelihood of a general failure of the monitoring system to perform acceptably is very significant until commercially available systems are installed and experience is gained at a substantial number of facilities.

For commercially available CEM systems, risks can be minimized by careful consideration of each step in the CEM program implementation. The selection of a CEM measurement location is a key aspect in the development of a monitoring program and is an example of a

$$\$LC(N) = [\$IM + (1 + P_1)\$T_P][1 + P_3 + P_4] + N[M(1 + P_2)\$T_{QA} + \$O\&M] \qquad \text{Equation 6-1}$$

Where:	$\$LC(N)$	=	Lifetime cost for N years
	$\$IM$	=	Initial model development cost (including software, hardware, installation, and development test costs)
	$\$T_P$	=	Performance test cost
	$\$T_{QA}$	=	Periodic quality assurance test cost
	$\$O\&M$	=	Annual PEM system operation and maintenance costs (exclusive of periodic quality assurance tests)
	N	=	Years of expected operation
	M	=	Number of periodic QA tests required per year
	P_1	=	Likelihood of performance test failure (range of 0 to 1)
	P_2	=	Likelihood of periodic QA test failure (range of 0 to 1)
	P_3	=	Likelihood model must be redeveloped because of model failure during expected useful life of PEM system (range of 0 to 1)
	P_4	=	Likelihood that a new model must be developed because of fuel, process, or control equipment changes during expected useful life of PEM system (range of 0 to 1)

Figure 6-7. Cost estimation method for PEM system.

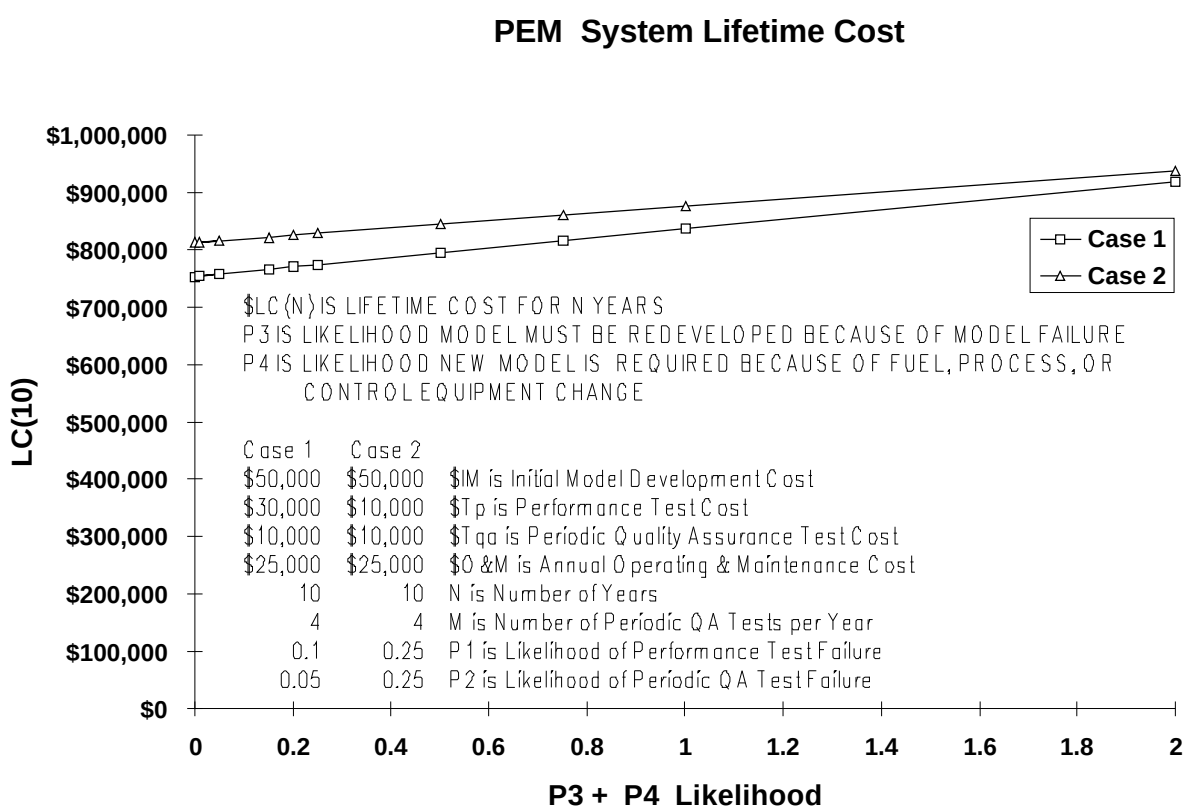

Figure 6-8. Analysis of PEM system lifetime cost for two example cases.

decision that affects many subsequent steps. Selecting a tentative monitoring location early in the planning phase of a monitoring program to specify emission and environmental conditions is very important for potential vendors. Furthermore, the costs for access to the monitoring location (ladders, elevators, platforms, sample ports, etc.) and providing support utilities may be greater than the capital cost for the monitoring equipment. Flue gas (or flow) stratification at a measurement location can affect the representativeness of monitoring data substantially. In evaluating a tentative monitoring location, the following must be considered: 1) the availability of alternate monitoring locations, 2) the cost to relocate a monitor if the tentative location is later found to be unacceptable, 3) the likelihood of pollutant, diluent, or flow stratification at the location and the reliability of indications that it may exist, 4) the likelihood that a failed relative accuracy test would have to be repeated and the costs for retesting, 5) the cost associated with potential delays in the approval process of the CEM system, and 6) the practicality and cost associated with performing a stratification test before finalizing the location selection or prior to performing the relative accuracy test. The risks and costs associated with all of these factors must be balanced during the planning effort.

Assessment of risk for the initial acceptance test and subsequent QA checks and audits is also important. The cost of the initial acceptance test is usually substantial. A well planned and executed test can be a thorough evaluation of CEM system performance and the adequacy of the calibration procedure. A poorly performed test may result in failure to meet specifications, even for the best designed and implemented monitoring program, resulting in a costly retest and substantial delays. A poorly performed test also can allow a flawed CEM system design or improperly applied CEM system to be accepted when it should not. This outcome avoids immediate retesting but leaves the facility with an unreliable monitor. Unfortunately, this situation may continue for many months until the underlying problems are identified by subsequent QA audits or other activities.

In planning the initial and subsequent tests, the following must be balanced: 1) the level of preparation and oversight for the test and the associated costs, 2) the qualifications and capabilities of the test team, 3) the likelihood that the CEM system will fail a test and the cost for retesting, 4) the likelihood that the test will not detect an important performance problem affecting either regulatory requirements or contractual guarantees, and 5) the cost associated with potential delays in the approval process resulting from a failed test.

Other QA risk criteria to consider are: 1) the likelihood or expected frequency of daily drift check failures, 2) likelihood of periodic QA test failures and the need for retests, 3) expected and/or guaranteed CEM availability, 4) availability of replacement parts and service from the vendor, and 5) the supplier's response time to provide service or replacement parts/monitors. These factors will affect the on-going operating cost for the monitoring program and they will affect the risk associated with satisfying minimum data availability requirements of the regulatory agency.

Evaluating the risks associated with a CEM system or PEM system monitoring program requires the likelihood and impact of unfavorable outcomes of various decisions and events. Considering the downside risks can help to focus attention on the most critical issues and may be helpful in preventing negative possibilities from turning into actual experiences.

6.7.1.3 Cost Evaluation

In addition to the initial capital expense for the purchase of a monitoring system, other start-up costs are associated with engineering, selection, purchase, installation, and performance testing of the monitoring system. Recurring or ongoing costs for the operation, maintenance, quality assurance, recordkeeping and reporting associated with the monitoring program also must be considered. The costs that will be incurred at a particular facility will depend on many factors and will differ greatly between facilities. The pollutants to be monitored, the type of monitoring approach selected, the monitor installation location and conditions, and many other source-specific factors will affect the cost of the monitoring program.

All of the costs that may be expected should be taken into account in the cost evaluation of competitive monitoring proposals. In most cases, the majority of costs that will be encountered over the life of the monitoring equipment will not be represented in a monitor equipment vendor's proposal. Many other external and source-specific factors over which the vendor or equipment supplier has little control need to be considered. Nevertheless, all of the expected costs should be projected and considered in conjunction with each vendor's cost proposal and technical approach. This is necessary both 1) to evaluate different proposals on a consistent basis, and 2) to determine the total cost of the monitoring program for the affected facility. Much experience has shown

that the proposal offering the lowest initial purchase price is not necessarily the least cost approach over the CEM program lifetime.

Costs must be evaluated over the useful life of the equipment or on another basis that accounts for both initial and ongoing costs. The average life of a CEM system is likely to vary between five and ten years depending on the type of equipment used and the monitoring application. The distribution of these costs between capital outlays for initial equipment purchases, facility modification costs, software purchases, subcontracted support services, and internal costs for engineering/planning, purchase, operation and maintenance, reporting, recordkeeping, and administrative support will vary for each particular monitoring application. A checklist is provided in Appendix F which may be helpful in evaluating some of these costs. The checklist is offered as a guide to encourage thinking about CEM program costs in a comprehensive manner.

6.7.2 A Matrix Evaluation Technique

A common technique used in evaluating proposals is to prepare a matrix of various evaluation factors and to assign a maximum possible score to each factor. For example, each listed item in Figure 6-6 could be used as an evaluation criteria and assigned a maximum score of 10. The matrix would then be composed of 9 criteria evaluated for each proposal received (Figure 6-9).

Each returned proposal is scored and the total scores for each category (technical, risk, cost) are obtained. Each member of the evaluation team should complete the matrices for each vendor independently. Then, they should meet as a committee and reach a scoring consensus on each evaluation criteria. Each member should justify his or her score until agreement is reached. The use of an outside consultant or CEM expert from another company to provide an independent, objective review of the proposals also may be helpful.

6.7.3 Normalizing the Issues

The proposal review may identify the best system for the application, but frequently many questions and issues are raised that require clarification. One vendor may have drawn exception to numerous specifications, whereas another may have agreed to all of the specifications. Another may have proposed an inferior conditioning system, but a superior analyzer. A service contract of one may have proposed 12 trips in a year including expenses,

	BID 1	BID 2	BID 3	BID 4
TECHNICAL REVIEW				
• Adherence to Technical Specs.				
• System/Component Quality				
• Proposal Quality				
RISK EVALUATION				
• Past Performance				
• Potential Performance				
• Strength of Guarantees				
COSTS				
• Capital				
• Maintenance				
• Intangibles				

Figure 6-9. Simplified example matrix evaluation.

whereas another offered 8 trips plus expenses. Another may have a superior system but misunderstood the data acquisition system criteria. Often, another round of evaluation will be necessary to bring the proposals to a stage where they can be compared on a uniform basis. This can be achieved by listing all exceptions and questions and requiring a response from the vendor suitable for review within one to two weeks. For large projects, bringing the vendors to the plant to review their proposals and clarify outstanding issues may be necessary.

All costs should be normalized so that equivalently performing systems would be purchased for the stated quotations. Some costs may have to be adjusted up or down if equivalent services are not offered by the vendors. Intangible issues also need to be considered and factored into the risk rankings. These intangibles include an assessment of the stability of the company (its ability to provide parts and service five years or ten years from the equipment purchase), its ability to honor guarantees, the likelihood of the company being sold, the probability of the only person who knows anything leaving, etc.

By this time, the project team should have determined which proposals are technically acceptable and have ranked the proposal costs. Depending upon company policy or pre-established guidelines, a contract may be awarded to the lowest bidder of those technically acceptable, or technical/cost considerations may be weighted. For example, the project team may agree initially that technical factors will contribute 80% in the final evaluation and costs 20%, or vice versa. On the other hand, after all this analysis has been done, it may be thrown out and the award decision based on subjective opinions that a favored vendor is the only vendor that can develop a successful operating system for the application. If the latter approach is taken, company resources have been wasted.

An evaluation can be objective and systematic, or subjective. An ostensibly systematic evaluation can also be distorted and biased to achieve a desired end. However the decision is made, the company must understand that plant managers, plant engineers, and technicians will have to work with the system for many years into the future. The choice of systems will be considered a good choice for all concerned if it meets the three criteria discussed in the introduction to this chapter:

1) The design meets regulatory requirements and is consistent with plant operating requirements.

2) The materials, components, and techniques are reliable and durable under the constraints of ambient and flue gas conditions, and operating conditions.

3) The system is easy to use, serviceable, and cost-effective in its long term operation.

6.8 Installing the System

After the contract is awarded, construction will begin on the system. This will take several months, depending upon parts availability and the vendor's backlog. Few vendors have systems that can be provided "off-the-shelf," since most begin construction after receipt of an order. A typical time to fabricate and deliver the CEM system can take from two to four months (Passmore, 1991, Ferguson, 1991, Retis, 1992). Installation and construction will take four to six weeks, as will start-up and certification. Thus, at least 8 months lead time should be planned.

Depending upon the size of the project and the project budget, conducting a factory acceptance test (FAT) before the system is shipped may be desirable. This requires some member of the project team to visit the vendor and evaluate the performance of the system on the shop floor. An excellent checklist has been developed by EPRI (EPRI, 1993) for conducting such an evaluation.

One of the most common problems noted during factory acceptance tests is that the data acquisition system software is not completed (Porter, 1990). Although the system hardware may be fully functional, an essential subsystem basically will be nonoperable. Caught between contract requirements and regulatory deadlines, this scheduling failure is often overlooked, with the expectation that the DAS will be ready sometime during the on-site installation. Approving the FAT without the data acquisition system will be the beginning of trouble in the CEM program. Nonadherence to contractual conditions at this point can lead to further exceptions and delays during installation.

Installing the system will require the cooperation of plant personnel, the vendor, and either plant or subcontracted construction engineers. Platforms may have to be constructed, ports installed, and electrical cables run to the sampling site. These activities may be handled by the plant or the vendor, although vendors often prefer not to be responsible for these construction activities. Major problems can develop at this stage if the construction engineers are not fully informed about the purposes of the CEM system and the vendor's installation requirements. A port in-

stalled at a 45° angle may not align with one on the other side, the analyzer cabinet door may bump into the scaffolding hand rail when opened, or no support is provided for the sampling line or electrical cables. Adequate communication will prevent such problems from developing.

The installation of the system will be relatively straightforward. Debugging the system will not be straightforward, particularly for newer systems developed for the measurement of HAPs. Unanticipated interferences, electrical stability, and calibration drift problems are common in the initial stages of operation. Since the daily calibration check routines for HAPs monitors may differ from the traditional usage of calibration gases, the routines themselves may have to be fine-tuned. A daily calibration instability of greater than 2.5% of span may be indicative of a site-specific installation problem. The problem must be investigated and resolved. Calibration stability should be achieved before proceeding with system certification or other approval procedures.

6.9 Approving/Certifying the System

Certification and approval methods for non-criteria pollutant monitoring systems are discussed in detail in Chapter 7 of this manual. The traditional "performance specification test" certification procedures incorporate the "relative accuracy test," which compares the continuous monitoring measurements to those obtained using an EPA reference method. Performance specification test procedures have proven to be an excellent means for certifying monitoring systems for criteria pollutants. However, validated methods exist for only about 40 of the 189 air toxics materials listed under Title III of the Clean Air Act and these for only a very limited range of sources. This lack of appropriate test methods limits the application of similar testing procedures for these monitoring systems.

Other approval mechanisms can be considered by the environmental control agency. The Method 301 validation criteria (see Chapter 7) are applicable for short-term test methods, but involve an extensive validation program on a site-specific basis only. Alternative methods have been proposed that incorporate laboratory evaluations with field tests conducted at representative "challenging" applications (Peeler, 1996). Proposed laboratory tests include checks for calibration stability, response time, interference rejection, and linearity. Field tests include techniques such as analyte spiking, direct calibration checks, and sampling system bias tests. Similar methods have been used by Kinner (Kinner, 1996) for FTIR applications in cement kilns.

In other cases, such as for metals (as vapor or as particulate matter combined or uncombined), reference methods may not produce data sufficiently precise to compare to monitoring system data. Calibration standards may not be available or may have to be specially generated. Special spiking procedures may also have to be developed. The limited experience in these techniques with certain materials can transform an intended validation program into a research study. Attention then must be paid to all facets of the validation program. The experimental research design must determine the representativeness of the sample measured as well as the precision and accuracy to which it is measured.

Approval methods also are necessary for parametric monitoring systems (parameter surrogate or predictive). Where validated reference methods are not available alternatives must be considered.

6.10 Implementing the QA/QC Plan and Operating the System

Certification or approval of a monitoring system provides no guarantees that the system will continue generating accurate and precise emissions data. An implemented quality assurance (QA)/quality control (QC) program is necessary if data quality is to be maintained (Jahnke, 1993: EPRI, 1993; Scott, 1995; Carlyle, 1995). A quality assurance plan should be prepared prior to certification and implemented immediately thereafter. Effective programs include standard operating procedures for daily calibration, preventive maintenance, training, and periodic audits. When the quality control functions are being performed routinely, the monitoring system then can be viewed as being operational.

REFERENCES

Aldina, G.J. 1993. “Continuous Emissions Monitoring, WTE Style,” *Solid Waste & Power*, pp 32-38.

Brown, V.V. 1992. “Selecting New Continuous Emission Monitors PG&E's Experience.” Paper presented at the *Air & Waste Management Association Meeting*, Kansas City, MO. Paper 92-120.04.

Carlyle, T.E. 1995. Quality Assurance Plans for Continuous Emission Monitoring systems: Compliance with 40 CFR Part 75. *Acid Rain & Electric Utilities - Permits, Allowances, Monitoring & Meteorology.* Air & Waste Management Association. Pittsburgh, PA. pp. 589-593.

Carman, T.A., Anadi, R.S. 1993. A Multi-component, Across-Stack, NDIR Analyzer Meets On-Line Cylinder Gas Audit Requirements of a CEMS. *Continuous Emission Monitoring - A Technology for the 90's*. Air & Waste Management Association, Pittsburgh, PA. pp 373-382.

DeWees, W.G., Steinsberger, and Buynitzky, W.D. 1994. "EPA Method 301 Validation of a Source Measurement Method for Title III Polar Volatile Organic Compounds (PVOCs)." Paper presented at the *Air & Waste Management Association Meeting*, Cincinnati, OH. Paper 94-TA27.04.

Electric Power Research Institute. 1983. *Con-tinuous Emission Monitoring Guidelines.* Report No. EPRI CS-3723. Palo Alto, CA.

Electric Power Research Institute. 1988. *Continuous Emission Monitoring Guidelines - Update*. Report No. EPRI CS-5998. Palo Alto, CA.

Electric Power Research Institute. 1993. *Continuous Emission Monitoring Guidelines - 1993 Update, Volume 2*. Report No. EPRI TY-102386-V2. Palo Alto, CA.

Ferguson, A.W. and Cochran, J.R. 1991. Continuous Emission Monitoring -- "Getting Your Act Together to Ensure 1990 Clean Air Act Compliance." Paper presented at the *Power-Gen '91 Conference,* Tampa, FL.

Jahnke, J.A. 1993. *Continuous Emission Monitoring.* Van Nostrand Reinhold. New York, NY.

Jahnke, J.A. 1994. *An Operator's Guide to Eliminating Bias in CEM Systems*. EPA 430-94-016.

Kinner, L.L. and Peeler, J.W. 1996. Development of Fourier Transform Infrared (FTIR) Spectrometry and Gas Filter Correlation Infrared (GFC-IR) Instrumental Test Method Protocols for the Portland Cement Industry.

Kopecky, M.J. and Rodger, B. 1979. Quality Assurance for Procurement of Air Analyzers. *ASQC Technical Conference Transactions - 1979.* Houston, TX: pp 35-40.

Krooswyk, E.D. and Saliga, J.J. 1994. Recent CEMS Installations Provide Valuable Insights. *Power Engineering*. pp 35-38.

Marlatt, R.D. and Teacher, G.F. 1995. Design Criteria Manual Guides CEM Project. *Project Engineering*. August 1995. pp 59-61.

Nazzaro, J.C. 1986. Continuous Emission Monitoring System Approval, Auditing, and Data Processing in the Commonwealth of Pennsylvania. *Continuous Emission Monitoring - Advances and Issues*. Air & Waste Management Association. Pittsburgh, PA. pp 175-186.

Parrish, C. 1993. A Comparison of CEM Method 25A and Method 18 Test Results for Determining VOC and Air Toxic Emission Rates. *Continuous Emission Monitoring - A Technology for the 90's.* Air & Waste Management Association, Pittsburgh, PA. pp 165-173.

Passmore, J.G. and Brodmerkle, S.L. 1991. "A Systematic Approach to the Selection and Installation of Continuous Emissions Monitoring Systems." Paper presented at the *Power-Gen '91 Conference,* Tampa, FL.

Peeler, J.W., Kinner, L.L., and DeLuca, S. 1996. "General Field Test Method Approval Process and Specific Application for a Direct Interface GCMS Source Test Method." Paper presented at the *Air & Waste Management Association Meeting,* Nashville, TN. Paper 96-RP132.01.

Permapure, Inc. 1995. *Nafion Gas Sample Dryers*. Trade Literature. Permapure, Inc. Toms River, NJ.

Porter, T. 1990. Experience in Design, Installation, Certification and Operation of Continuous Emission Monitors at Resource Recovery Facilities. *Continuous Emission Monitoring: Present and Future Applications*. Air & Waste Management Association. Pittsburgh, PA. pp 148-161.

Retis, C.E. and Henry, R.E. 1992. Meeting CAA demands on CEM Systems. *Power Engineering.* pp 46-49.

Reuter-Stokes. 1995. Gas Analyzer Mixes in Some Solid Savings. *World Cement*.

Scott, N. 1995. The Care and Feeding of Your CEMS. *Acid Rain & Electric Utilities - Permits, Allowances, Monitoring & Meteorology.* Air & Waste Management Association. pp 589-593.

Seidman, N.L., Peeler, J.W., and Quarles, P. 1990. Developing State Guidelines for Continuous Emission Monitors. *Continuous Emission Monitoring - Present and Future Applications.* Air & Waste Management Association. Pittsburgh, PA. pp 174-180.

Tatera, J.F. 1993. A Review and Discussion of Several Design Requirements that will Impact CE systems Used in Hazardous Process Plant Environments. *Continuous Emission Monitoring - A Technology for the 90's*. Air & Waste Management Association, Pittsburgh, PA. pp 99-107.

U.S. Environmental Protection Agency. 1995. *EPA Method 301 - Field Validation of Pollutant Measurement Methods from Various Waste Media*. U.S. Code of Federal Regulations, 40 CFR 63, Appendix A.

U.S. Environmental Protection Agency. 1996. Code of Federal Regulations Standards of Performance for New Stationary Sources - Appendix B - Performance Specifications,.40 CFR 60, Appendix B. Washington, D.C.

Wagner, G.H. 1993. "Meeting Your Monitoring Requirements." Paper presented at the *Air & Waste Management Association Meeting*, Denver, CO. Paper 93-FA-164.01.

White, J.R. 1995a. Survey Your Options: Continuous Emissions Monitoring. *Environmental Engineering World.* July-August 1995. pp 6-10.

White, J.R. 1995b. Technologies for Enhanced Monitoring. *Pollution Engineering*. June 1995. pp 47-50.

Weldon, J. 1990. Emission Monitoring System Design and Cost Considerations for Resource Recovery Facilities. *Continuous Emission Monitoring: Present and Future Applications*. Air & Waste Management Association. pp 162-173.