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Development of Measurement Techniques for Fugitive Emissions from Process and Effluent Streams

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May 1979

Development of Measurement Techniques for Fugitive Emissions from Process and Effluent Streams

by

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FOREWORD

This report summarizes the work completed by TRC - THE RESEARCH CORPORATION of New England under EPA Contract Number 68-02-2133, "Development of Measurement Techniques for Fugitive Emissions from Process and Effluent Streams."

The results of three major research and development tasks assigned under the task-level-of-effort contract are presented in detailed summaries. Two additional major research and development tasks, for which separate reports have been published, are summarized by abstracts of their reports. Twenty two assigned service area and documentation and publication tasks are briefly summarized.

The effort was sponsored by the Process Measurements Branch of the Industrial Environmental Research Laboratory at Research Triangle Park, North Carolina. Dr. Robert M. Statnick and D. Bruce Harris directed the effort as Project Officers. Henry J. Kolnsberg was the Project Manager for TRC. Gordon T. Brookman, Dr. Robert E. Kenson, and Roland L. Severance served as Task Managers.

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SECTION 1

INTRODUCTION

Fugitive emissions are defined as those pollutants introduced into the atmosphere or into ground or surface waters without first passing through some stack, duct, pipe or channel designed to direct or control their flow. They are generated from a wide variety of industrial process sources, ranging from small, single-point sources such as process equipment leaks to large, area sources such as material storage piles. Their physical and chemical characteristics are varied, including airborne particulate matter, gases and vapors; and waterborne suspended solids and dissolved gases, liquids, and solids. Their one common characteristic, their lack of containment, makes both the assessment of the environmental impact and the control of the fugitive emissions considerably more difficult than the assessment and control of point-source emissions.

The initial step in establishing controls for fugitive emissions is the determination of the emission strength of the various sources and their impact on the environment. Determinations of specific fugitive emission concentrations, distributions and physical or chemical characteristics usually cannot be made with the recognized standard sampling and measurement techniques presently in use. Special measurement techniques must be developed and verified to obtain data that will be universally accepted as baseline information for the establishment of control systems and limitations for industrial fugitive emissions.

Three general measurement techniques, related to the size or nature of the fugitive emissions source, have been developed for airborne emissions. The quasi-stack technique utilizes a temporary hood to capture the emissions from a small source and transport them to a duct for measurement using standard stack-sampling methods. The roof monitor technique uses the structure enclosing sources as a capture hood and measures the flow and concentration of the emissions from all sources within the structure as they pass through a roof monitor or similar vent to the atmosphere. The upwind-downwind technique measures the emission concentrations in the ambient atmosphere, utilizing recognized diffusion equations in mathematical models to back-calculate source strength from the differences in concentrations. These techniques are very general and require modification and adaptation for almost every specific site/source combination. Additional techniques for waterborne emissions, both general methods and site-specific modifications, are also needed.

This report summarizes the work completed by TRC - THE RESEARCH CORPORATION of New England under EPA Contract 68-02-2133, "Development of Measurement Techniques for Fugitive Emissions from Process and Effluent Streams" toward the fulfillment of these needs. The contractual effort was conducted from December 1975 to December 1978 for the Process Measurements Branch of the EPA's Industrial Environmental Research Laboratory at

Research Triangle Park, North Carolina. Dr. Robert M. Statnick was the EPA Project Officer for the first half of the contract and D. Bruce Harris was the EPA Project Officer for the concluding half. Henry J. Kolnsberg was the Project Manager for TRC.

The objective of the contract was to provide measurement methodologies for airborne and waterborne fugitive emissions that would be applicable to environmental assessment and control technology development projects related to the stationary source energy and industrial process programs of the Agency. The contract provided a continuing program of evaluation, development, testing and field adaptation of existing and proposed measurement techniques and programs in a 20,000 man-hour task-level-of-effort format.

The contract effort consisted of 27 individual tasks, divided into three general work areas. Five Research and Development tasks required about 13,700 man hours of effort, 12 Service tasks about 1,400 man-hours and 10 Documentation and Publication tasks about 1,900 man-hours. An additional 1,400 man-hours were expended in the technical management of the contract.

The Research and Development tasks included:

Task 02 - Evaluation of Non-Point Source Waterborne Emissions

Task 03 - Study of Remote Sensing Methods Applicability to Fugitive Emissions Measurement

Task 04 - Evaluation of Surface Runoff at Integrated Iron and Steel Plants

Task 05 - Design of a Fugitive Assessment Sampling Train

Task 07 - Preliminary Investigation of Techniques for the Determination of Hood Capture Efficiency

The Service tasks were:

Task 20A - Evaluation of a proposed no-duct quasi stack measurement technique

Task 20D - Preparation of alternative measurement approaches for emissions from a coke quench tower

Task 20E - Preparation of a sampling program for fugitive emissions from a coal cleaning facility

Task 20H - Assistance in the preparation of a guideline on particulate fugitive emissions

Task 20I - Critical review of a feasibility study of source identification from ambient air monitoring

Task 20J - Preparation of a measurement program for particulate matter emissions from iron ore loading operations

Task 20L - Review of a test plan for ambient monitoring of fluidized bed coal combustor emissions

Task 20M - Review of a sampling plan for fugitive emissions from petroleum refineries

Task 20N - Critique of a proposed plan for the measurement of mining particulate matter emissions

Task 20P - Preparation of a conceptual roof monitor measurement approach for an open hearth shop

Task 20R - Critique of exposure profiling technique for particulate matter fugitive emissions

Task 20U - Consultation and assistance to an EPA contractor in sampling refinery hydrocarbon fugitive emissions

The Documentation and Publication tasks included:

Task 20B - Preparation of a guideline for fugitive emissions measurements

Task 20C - Preparation of a summary of airborne fugitive emissions measurement techniques

Task 20F - Preparation of papers for symposium presentations

Task 20G - Preparation of a summary of fugitive emissions work completed under IERL contracts

Task 20K - Preparation of a bibliography of research program abstracts

Task 20Q - Study to determine the need for a technical manual for the measurement of industrial process water flows

Task 20S - Preparation of a chapter on fugitive emissions measurements for a Level 1 environmental assessment procedures manual

Task 20T - Preparation and presentation of a paper on fugitive emissions measurement for an EPA Symposium

Task 20V - Preparation and presentation of a paper on the development of the fugitive assessment sampling train for an EPA Symposium

Task 06 - Organization of the Second Symposium on Fugitive Emissions: Measurement and Control.

The work completed in each of these tasks is described in this report along with the conclusions and recommendations resulting from the completed efforts. Only abstracts of the final reports for Tasks 02 and 04, which were published as separate documents, are included.

SECTION 2

RESEARCH AND DEVELOPMENT TASK DESCRIPTIONS

TASK 02 - EVALUATION OF NON-POINT SOURCE WATERBORNE EMISSIONS

A full description of this task is contained in Sampling and Modeling of Non-Point Sources at a Coal-Fired Utility, EPA-600/2-77-199, September 1977. The report abstract is quoted as follows:

> The report gives results of a measurement and modeling program for non-point sources (NPS) from two coal-fired utility plants, and the impact of NPS on receiving waters. The field measurement survey, performed at two utility plants in Pennsylvania, included measurement of overland runoff from NPS and river sampling upstream and downstream of each plant site. NPS sampled were stormwater runoff and leachate from coal storage piles and runoff from impervious areas such as parking lots and roofs which were covered with dust fallout from coal and ash handling operations. A mathematical model was developed to simulate both the quantity and quality of industrial NPS pollution and its impact on receiving waters. Field data indicated that NPS pollution from utilities had little impact on the two rivers, compared to the impact from sources upstream of each site. Modeled results compared to field measurements within a factor of 4 for both the quantity and quality of stormwater runoff and its impact on the quality of the receiving waters. Field survey results indicate that, for a cost-effective program, sampling must be supplemented with modeling (the modeling results indicate that the developed model can be used with a minimum of field data to successfully simulate industrial NPS pollution and its impact on receiving waters for the utility industry).

TASK 03 - STUDY OF REMOTE SENSING METHODS APPLICABILITY TO FUGITIVE EMISSIONS MEASUREMENT - JUNE 1976

Large scale programs to assess the environmental impact of fugitive air emissions from industrial sources, using basically research type fugitive emissions measurement strategies, have proven to be costly and limited in accuracy. In many cases, the cost of measuring the fugitive emissions from only one major source in a complex, multiple-emissions-source process can exceed the cost of all sampling required to define the point source emissions from the process.

The complexity of many proposed fugitive emission measurement methods means that the time consumed in equipment preparation, setup and calibration is substantial and precludes their application for survey-type fugitive emissions testing. Some quick, accurate, and potentially low-cost method is needed. Remote sensing of the fugitive emissions would be ideal, since most remote systems are self-contained and do not necessarily require access to the emissions source.

Four remote sensing techniques have been identified as potentially useful for fugitive emissions measurement. They are:

1. Tunable Laser Method
2. Lidar Method
3. Long Path Transmissometer Method
4. Time-Lapse Photography Method

The objective of this task was to review the capabilities of these four sensing methods. Each method was reviewed separately with regard to its principle of operation, limitations, and application to fugitive emission measurement.

Remote Sensing of Fugitive Gaseous Emissions Using Laser Infrared Spectroscopy

The use of laser systems for gaseous air pollution detection and monitoring has advanced greatly over the past few years due to improvements in both laser technology and signal processing techniques. Because almost every gaseous air pollutant has characteristic absorption bands at middle infrared frequencies (2.5-25μm), tunable infrared laser systems have been successfully used for pollutant monitoring in several recent studies. Such devices have found application in point sampling, in in situ source monitoring, and in ambient air measurement of CO and NO.

Among those lasers which are capable of emitting infrared radiation are parametric oscillators, spin-flip Raman lasers, gas lasers, and semiconductor diode lasers. The use of a combination of these lasers makes possible complete coverage of the infrared absorption band regions between 0.63 and 34μm. Compared to conventional infrared instrumentation, the laser system usually has better sensitivity and specificity because of the high intensity, narrow spectral bandwidth, coherence, small beam diameter, and the small directional divergence offered by the laser.

Three fundamental monitoring techniques are available with laser systems: remote heterodyne detection, resonance fluorescence, and direct absorption. Remote heterodyne detection is a completely passive, single-ended technique in which characteristic infrared emission lines from a gaseous pollutant are detected by heterodyning them with tunable laser radiation of the same wavelength. The technique of resonance fluorescence is an active one making use of absorption and subsequent re-radiation of laser light. This method, however, appears most useful for only a few atoms and molecules. Direct absorption of laser radiation offers the greatest versatility of the three schemes. This technique was therefore considered for the quantitative remote measurement of gaseous fugitive emissions from industrial sources.

Principle of Operation--

The measurement of air pollutant concentration by attenuation of laser infrared lines depends upon finding coincidences between laser lines and pollutant absorption lines. When infrared radiation of a resonant frequency of a molecule impinges on the molecule, radiant energy is absorbed by that species. The intensity of the absorption is proportional to the concentration of the absorbing species and to the path length, as described by the Lambert-Beer Law:

$$P_t = P_o \exp(-\alpha'_o CL)$$

where

P_t is transmitted power

P_o is initial power

α'_o is the absorption coefficient of gas

C is gas concentration

L is path length

Thus, measurement of the transmitted power will provide the concentration of the absorbing species if the other parameters are known.

Instrumentation used for infrared absorption techniques must include a source of radiation and a detector together with associated optics. One possible arrangement consists of the source and detector virtually side by side and requires the use of a reflector to return the radiation to the detector. A second possibility puts the detector and source at opposite ends of the measurement path. Both are considered long-path techniques.

Limitations--

Although long path laser infrared systems look promising for measurement of fugitive emissions, there are several critical problems which need to be considered:

Interferences--One very serious problem in infrared spectroscopic studies is that of interferences from atmospheric CO_2 and water vapor. This is an ever-present difficulty, for each contains strong absorption bands in the infrared region of the spectrum. Water completely blanks out the far infrared and absorbs strongly in the middle region between 5.5 and 7.5μm. Fortunately, most of the major pollutants contain at least one strong absorption line or band from 3-15μm so that it may be possible to work around the CO_2 and water vapor lines and bands using high resolution instrumentation.

Temperature Effects--Because semiconductor diode lasers can be tuned by varying their temperature, they are sensitive to changes in temperature and must be cooled to liquid nitrogen temperatures when in use. This can be accomplished by use of a closed-cycle cooler and liquid-nitrogen-cooled detectors. The detector must be refilled with liquid nitrogen every ten hours.

Distance Effects--Long optical paths are generally needed to bring bands of low-concentration pollutants to detectable levels. The path length required depends on pollutant concentration, the strength of the absorption bands, and system sensitivity. Successful work has been done over paths less than 1 km.

Quantitative/Qualitative Considerations--

Long path remote sensing techniques are capable of measuring only the average concentration of a pollutant over the optical path between the transmitter and the receiver. Pollutant concentrations that can be detected over a 1 km path, assuming that a 5% signal change is detectable, range as low as 0.02 ppm for C_2H_4 with a CO_2 laser.

Although qualitative applications of this technique have not been reported in the literature, it seems that such applications could be successful. Although the entire spectrum cannot be scanned with a single radiation source (because no laser is yet tunable over the whole range), several lasers set on the most probable pollutant absorption wavelengths could be used over the path to be measured. A signal change, which would indicate the presence of an absorbing pollutant, would only need to be calibrated to make the measurement quantitative as well.

Application to Fugitive Emissions--

No reports of the use of infrared laser techniques to measure fugitive emissions have been made to date. Using the absorption technique described above, CO, NO, SO_2 and ethylene have been successfully measured from open sources, in ambient air and in in situ situations. Considering these results, it appears that the application of such techniques in the measurement of fugitive emissions would be successful provided that:

(a) The emitted plume is large enough to permit the use of long paths if the pollutant concentration is low,

(b) It is possible to install a retroreflector or detector on the far side of the plume,

(c) The pollutant to be measured has an infrared absorption band outside a CO_2 or water absorption band,

(d) Any aerosol backscatter is accounted for.

In addition to these limitations, several considerations should be kept in mind:

(a) The fugitive source that is being measured must be well defined.

(b) Only the average concentration over the path can be determined.

(c) The uncontrolled environment may cause optical scintillations which could reduce sensitivity compared to controlled laboratory situations.

(d) Vibrations and misalignment could cause problems.

Remote Sensing of Fugitive Particulate Emissions Using Lidar

Lidar has been used successfully for air pollution detection since its development in 1963 for meteorological use. Its utility stems from its ability to remotely detect particulate matter in the atmosphere at distances up to 30 km. The lidar technique also has the advantage of being independent of external sources of electromagnetic radiation because it is an active system. Lidar systems have been used in the delineation of cloud layers, determination of upper atmosphere density and temperature profiles, determination of smoke plume opacity and in the remote measurement of transport, diffusion and relative particulate concentration profiles of clouds of particulates.

Principle of Operation--

The principle of lidar operation is very similar to that of conventional radar. In both systems a pulse of energy is transmitted and scattered by objects in the atmosphere. A small fraction of this pulsed energy is scattered in the backward direction, detected and measured as a function of the range at which the scattering occurred.

The difference between the two systems is the type of energy source. Lidar systems utilize laser radiation of wavelengths somewhere between the far infrared and the near ultra-violet portion of the electromagnetic spectrum, operating at much shorter wavelengths than conventional radar systems. This characteristic gives lidar the capability of detecting very small objects such as atmospheric particles. Conventional radars would totally overlook objects of this size.

The laser energy associated with lidar systems is highly monochromatic, essentially coherent and concentrated in very short high-powered pulses. This energy is directed by refracting or reflecting lens systems in a beam signal. A suitable receiver lens system then collects the energy back-scattered by the molecules and particulates within the beam. An energy sensitive transducer (normally a photomultiplier tube) detects this back-scattered energy which is then displayed on an oscilloscope as a function of range.

Return signals may be photographed or magnetically recorded. The use of magnetic video disc memory provides an input to more sophisticated analysis procedures such as automatic data input for computer processing. This is a key feature of sophisticated lidar systems.

The general lidar equation of the received signal is:

$$P_r = \frac{P_t \, C \tau \beta 180 \, A}{8 \pi r^2} \exp \left(-2 \int_0^r \sigma(r) dr \right)$$

where

P_r = power received from range r

P_t = transmitted power

C = velocity of light

τ = pulse duration

$\beta 180$ = volume backscattering coefficient of the atmosphere at range r

A = effective receiver aperture

σ = extinction (attenuation) coefficient at range r

All the values of this equation are known values of the system except the volume backscattering coefficient (β180) and the extinction coefficient (σ).

The volume backscattering coefficient (β180) of the atmosphere at range r is defined as the ratio of the amount of energy backscattered from a defined unit volume to the amount initially received. It is a measure of the effectiveness of the scatterers as a target. The extinction coefficient (σ) is defined as the attenuation of a pulse traveling to a point r and back to the receiver. It accounts for all the interactions that extract energy from the laser beam.

The magnitude of β180 and σ depend upon the wavelength of the incident energy and the number, size, shape and refractive properties of the illuminated particles per unit volume. These particles can consist of true particulate components or an aerosol.

Limitations on Method--

Although lidar systems look promising for the measurement of fugitive particulate emissions, there are several critical parameters which need to be considered:

Particle Size--Lidar systems can detect scattering from particles larger than 1/10 of the wavelength of the light source. For example, the ruby laser, commonly used in laser radar systems, operates at a wavelength of 0.694μm and can theoretically detect scattering particles greater than 0.07μm in diameter. This theory however applies only for "clear" and stable atmospheric conditions. Small particles such as those in aerosols can therefore in reality be uncounted because of background effects not due to the aerosol itself.

Distance Effects--There are short and long range distance limitations with the use of lidar systems. Short range limitations are a function of the unit's transmitter/receiver optical system geometry. The intersection of the transmitter beam and the receiver field of view can create a false peak in the receiver system, thereby masking valid scattering return signals. The short range limitation for the lidar system used in a recent study was approximately 300 meters. Closer than this, false signals predominated over scattering return signals.

Long range distance limitations are a function of the power of the laser source and the composition of the scattering medium. The more power a laser source has, the farther the signal will travel before it is completely attenuated. Conversely, the larger the scattering particles and the denser the scattering medium the shorter distance the laser signal will travel before it is completely attenuated. Typical lidar systems used for meteorological observation have long range distance limitations of about 40 kilometers.

Time Limitations--The time required to make one complete observation of a dispersing fugitive cloud depends upon the number of cross sections of the emission cloud that are made and the number of vertical lidar shots per cross section. These two factors depend on the size of the fugitive cloud. The Stanford Research Institute lidar study group has stated that each vertical scan of 20-30 lidar shots requires 2-5 minutes. A set of three vertical scans or cross sections, therefore, requires 10-15 minutes.

Each plume cross section observation must be calibrated for the following three factors in order to obtain contours of relative particulate concentrations:

1. Range effect
2. Log-amplifier transfer function
3. Pulse-to-pulse variation in transmitted power

Location Effects--Another limitation to the use of lidar systems is the testing location. The direction of the transmitted beam should be perpendicular to the centerline of the plume or fugitive cloud in order to obtain maximum return power. This is an important factor because lidar systems detect backscattered signals which may be relatively small. Any plan to measure fugitive emissions with a lidar system should include several test sites that are located perpendicular to the most frequent wind directions.

Qualitative/Quantitative Considerations--

Lidar systems have primarily been used for qualitative applications. There are two factors which limit the use of lidar systems for quantitative applications; reducing the lidar equation to one unknown and accounting for multiple scattering effects.

The lidar equation defines the received power of the lidar systems as a function of range in terms of two variables; the backscattering coefficient and the attenuation coefficient. The lidar equation must be reduced to one variable if the return signal is to generate quantitative information. This may be done by independently determining the value of one of the variables or by assuming that a specific relationship exists between the two variables.

Independent determination of one of the variables requires specific measurements or qualifying assumptions. The measurements required may include particle shape, refractive index, density and particle size distribution. Independent measurements, qualifying assumptions and assumptions relating backscatter coefficient to attenuation coefficient all place limitations on the accuracy of any quantitative results attained.

Multiple scattering effects must also be considered when attempting to obtain quantitative information from the lidar equation. Multiple scattering can produce responses in the lidar receiver system that are greater than expected and indicate misleading high quantitative amounts. Multiple scattering effects occur to the greatest extent during turbulent meteorological conditions. Lidar testing is normally done through stable atmospheres where multiple scattering effects are considered negligible. The degree to which this assumption is valid limits the accuracy of quantitative results.

Application to Fugitive Emissions--

Lidar as a remote sensor of fugitive emissions would find best application where particulate emissions or aerosols would normally be measured by upwind-downwind networks. Lidar shows promise of being more accurate than the usual upwind-downwind techniques although no application to fugitive emission measurements has been documented.

Proven Fugitive Emission Applications--The Stanford Research Institute conducted a program in May and October of 1968 which utilized a lidar system to remotely track the dispersion of the effluent from tall stacks at a generating station. Although emissions from a stack cannot be considered a fugitive source, the technique used to measure them can be almost directly applied to the measurement of fugitive emissions.

The program consisted of several studies. One study remotely tracked the stack plumes for distances up to 20 kilometers. The most common distance reported was 3 kilometers. Each observation was made at a single point located as close to perpendicular to the plume as possible and consisted of 20-30 vertical lidar shots for each of as many as 3 azimuth angles.

The study also attempted to obtain quantitative data by making corrections for attenuation, computing return signals on the basis of scattering theory and by making independent particle size measurements. A short series of measurements showed a close agreement with calculated values from power plant data and wind speed.

In obtaining this type of quantitative data, several limiting factors were apparent. First, the size distribution and the optical properties of the particulates were assumed to be spatially uniform. Second, multiple scattering was considered to be negligible. Third, considerable effort was necessary to correct for attenuation.

Remote Sensing of Fugitive Particulate Emissions Using Transmissometers

In the measurement of stack emissions, transmissometers have been utilized as continuous monitors of plume opacity near the stack outlet. Response curves of particulate emission rate versus opacity have made it possible to continuously monitor particulate emissions as a function of the measured opacity. If a roof monitor is considered as a large cross-sectional area stack, a transmissometer ought to be applicable to quantitatively monitoring the roof monitor fugitive particulate emissions.

Principle of Operation--

Transmissometers are devices that measure the attenuation of visible light across a fixed path in relation to some characteristic of the path that tends to change light transmittance. The most common example is a transmissometer used to measure the opacity of suspended particulate matter emissions from a stack.

While the principal application of such devices is to measure and record stack plume opacity, they can be used as indicators of particulate mass concentrations in the stack. The application of interest here is to measure particulate mass concentration across the relatively long paths normally required to encompass fugitive emissions.

The transmittance (T) of a particulate cloud is related to opacity (O) as:

$$T = 1 - O$$

The optical density (D) of a cloud is related to transmittance as:

$$D = \log 1/T$$

In general, for any given type and thickness of particulate cloud the concentration of particulates is directly related to optical density or the log of 1/T. The relative optical density of a cloud of particulates at a given concentration and optical path length is strongly influenced by particle size and index of refraction, acceptance angle of the transmissometer and other variables. Much work has been done over the years in developing relationships between the transmittance (or opacity) of an aerosol cloud and its particle concentration. The most useful equation relating particle concentration and several particle variables to opacity is:

$$c_m = \frac{Kp}{L} \log 1/T$$

where

c_m = particle mass concentration,

K = specific particulate volume divided by the aerosol attenuation coefficient,

p = particle density,

L = path length through aerosol cloud,

T = transmittance through aerosol cloud.

Limitations--

Although transmissometers can be considered for the measurement of fugitive particulate emissions, there are several problem areas:

Uniformity of Particulate Composition--Because of the strong dependence of response of the transmissometer to particle size and refractive index, there can be serious problems in quantifying roof monitor fugitive emissions. If the emission source or sources within the building have variable particle size and/or refractive index emissions, the transmissometer readings may not give valid mass emission results unless special calibration procedures can be established for the specific conditions involved.

Path Length of Light Beam--Obtaining sufficient signal strength at the receiver to register the full range of opacity may impose limitations on the path length over which the light beam can be transmitted. This must be experimentally determined using an emission source similar, in terms of particle size and refractive index, to that being measured. The maximum path length can then be calculated from opacity versus light path length test results.

Uniformity and Representativeness of Roof Monitor Emissions--If the emissions flow out of the roof monitor is not uniform, problems may be encountered in using a fixed path and geometry transmissometer to establish the average emissions from the roof monitor in any given time period. A second set of transmissometers mounted perpendicular to the primary set might be required in such cases to establish the relative uniformity of emission flows from the roof monitor.

Mechanical Vibration--Since alignment of the source and the sensor of transmissometers is critical to the determination of the opacity of the emissions, vibration can be a serious problem in their use on roof monitors. Severe vibrations can be experienced in roof monitors as the result of craneway movements or thermal plumes from high temperature operations.

Application to Fugitive Emissions--

No published reports have been located describing the application of transmissometers to fugitive emissions measurement.

For a transmissometer to be successfully applied to the measurement of particulate fugitive emissions, data must be obtained regarding the physical characteristics of the particles and the constancy of their characteristics over the measurement period. In general, transmissometers could best be used on fugitive emissions from processes that generate particulates of constant physical properties.

Transmissometers might also be used in an upwind-downwind configuration if particle characteristics remain constant and it is possible to obtain a reliable relationship between particle concentration and the extinction coefficient. Several transmissometer beams could be arranged to intercept the fugitive particulate plume at various elevations. Wind velocity measurements at each elevation would permit computation of the particulate material flux at several levels.

Remote Sensing of Fugitive Particulate Emissions Using Time-Lapse Photography

Time-lapse photography has been used in a wide variety of studies to identify and monitor pollution resulting from natural and man-made causes. The main advantages of time-lapse photographic measurement are: Action is stopped and a permanent record provided; changes in emissions generation and flow direction over relatively long time periods are detected and discretely identified.

Principle of Operation--

In time-lapse photography a series of discrete still photos are made at a predetermined time interval on motion picture film and projected at standard speeds to reduce the time span of the action. Events occurring over extended periods of time can then be viewed in short periods or stopped entirely for analysis.

Time-lapse photography can effectively be employed to trace the path of a dispersed plume, indicate changes in the size of a plume, and determine if visible emissions are emitted from a specific site over a specific period of time, without long-term visual observation. It is also theoretically possible to relate the optical density of the filmed image to the opacity of a fugitive cloud. The opacity can in theory also be related to a mass emission rate. To date this has not been accomplished successfully. Image density measurements can be made at this time by commercially available densitometers, but no technique has been developed to relate such density measurements to plume opacity or particulate concentration.

Limitations--

Time-lapse photography techniques have certain limitations for the measurement of fugitive emissions. They are only applicable to visible emissions. This mandates that they be used only to measure particulate emissions of high opacity. They can ordinarily be used only during daylight hours. They cannot be used during adverse weather conditions such as rain, snow, fog, etc., because of visibility and contrast problems.

Application to Fugitive Emissions--

Purdue University is currently conducting a study for the National Science Foundation to measure trace metals in the environment. One portion of the program is involved in a preliminary study of fugitive emissions from coke pushing operations at a steel plant along Lake Michigan. This study was conducted during the summer and fall of 1975 and attempted to quantify emissions primarily through the use of hi-volume samplers in the fugitive emission plume. Photographs of the emission plume were used to determine the time periods in which the sampler was within the plume and to define the shape of the plume. Stop-motion analysis of the film was utilized.

Conclusions and Recommendations

While each of the four methods reviewed showed some promise of adaptability as a useful tool for the measurement of airborne fugitive emissions, no single method may be used as a general technique for the assessment of all types of emissions to the atmosphere. Each could, with considerable developmental effort, be used to measure either gaseous or particulate emissions, but not both.

Interviews with users and manufacturers of the various devices studied indicated that no significant efforts were being made or planned for their development as remote fugitive emissions monitors. Most of those interviewed could not provide even a rough idea of the amount of developmental effort that might be required to adapt their devices to the intended purpose or offer any estimates as to the probability of the success of such efforts.

In light of these facts, it was recommended that no further effort be expended on the investigation or on the development of a remote sensing technique at this time under this task. It was suggested that TRC and IERL/RTP maintain an awareness of further developments in remote sensing techniques and devices and resume the effort if such developments indicate a reasonable probability of successfully adapting a technique to the measurement of fugitive emissions.

TASK 04 - EVALUATION OF SURFACE RUNOFF AT INTEGRATED IRON AND STEEL PLANTS

A full description of this task is contained in Assessment of Surface Runoff from Iron and Steel Mills, EPA-600/2-79-046, February 1979. The report abstract is quoted as follows:

> The report presents the results of a program whose objective was to assess whether surface runoff from iron and steel mills is an environmental problem. Included is a compilation of existing data available before this program, results of information gathered from plant tours, and results of a field survey at two fully integrated mills on tidal rivers. Data collected at the two sites indicate that the coal and coke storage piles and the coal and coke handling areas have the highest potential for contaminating stormwater. The data also indicate that TSS runoff concentrations are typical of urban runoff concentrations while TDS values are approximately one to two times the typical urban runoff concentrations. From plant tours it was found that stormwater controls which presently exist within the steel industry are limited. The only system specifically designed for stormwater control exists at Armco's Houston Works where coal piles have been diked as a control measure for both fugitive air emissions and stormwater runoff. Some mills collect stormwater runoff with process wastewater for subsequent treatment at a terminal plant. Those methods which are applicable to the industry include rainfall detention ponding rings for flat roofs, swirl degritters, and retention basis or sedimentation ponds.
>
> TRC concluded that, with the exception of runoff from coal and coke storage areas, stormwater runoff is not a problem when compared to point source control.

TASK 05 - DESIGN OF A FUGITIVE ASSESSMENT SAMPLING TRAIN (FAST)

This task, which could not be completed within the time limitations of this contract, has been transferred to a new contract, number 68-02-3115, for continuation. A detailed report on the design, fabrication and testing of the sampling system will be prepared under the new contract. A brief summary of the work completed on the task is presented below.

Discussions between TRC personnel and the EPA Project Officers resulted in a target design specification for an ideal sampling train as the development starting point. This ideal sampler was described as being able to obtain, from the ambient air in the vicinity of an industrial fugitive emissions source, a 500-milligram sample of suspended particulate matter and a similar-sized sample of organic vapors in an eight-hour sampling period. The particulate matter sample would be separated into respirable (smaller than 3 micrometer) and non-respirable (larger than 3 micrometer) fractions. The sample sizes were selected to correspond to the then-considered minimum for complete analysis including bioassay. The sampler was also to be self-contained and portable; it would require minimum power and, using commercially available components wherever possible, cost less than $10,000 to fabricate in the prototype version.

An extensive computerized literature search and review was conducted in the hope of obtaining sufficient information on ambient concentrations of industrial fugitive emissions as particulate matter and organic vapors to prepare a realistic system design specification for the system, designated the Fugitive Assessment Sampling Train (FAST). While this search and review revealed almost no data on ambient concentrations, it did provide a wealth of information on emission rates from a wide variety of industrial processes. A series of calculations based on recognized atmospheric diffusion equations for a range of atmospheric, topological and wind conditions were then performed to relate the published emission rates to ambient concentrations. These calculations indicated that an ambient concentration of 200 micrograms per cubic meter can be found within 100 to 500 meters of sources emitting between 0.6 and 23 kilograms per hour--a range covering about 90 percent of the industrial sources for which data is available.

This 200 microgram per cubic meter concentration was used to determine the sampling rate required to obtain a 500 milligram sample in an eight-hour period of 5.2 cubic meters per minute (184 CFM) as the initial system design parameter. A Roots lobe-type vacuum blower, capable of moving the required volume of air against a pressure drop of about 10 cm Hg, was selected as the particulate sampling prime mover. A system of drive belts and pulleys was utilized to operate the blower at the required 3800 RPM from a three horsepower drive motor. The drive system also provides enough flexibility to adjust the speed and the sampling rate up to about 20% if required.

To provide for the separation of the particulate matter sample into respirable and non-respirable fractions, an Air Correction Design 6UP Sanitary Cyclone Separator was selected. Its design capacity of 6.3 cubic meters per minute (222 CFM) provides a D_{50} at about 2 micrometers at a pressure drop of about 0.6 cm Hg. The cyclone was selected as preferable to filter- or impactor-type collectors since the sample is removed from the sampling streams and minimizes the degradation in sampling rate or effectiveness caused by the deposition of particulate matter on flow-through filters or impactor plates.

Consultations with Mr. Kenneth Cushing of the Southern Research Institute, under contract to the Process Measurements Branch in the area of particulate matter sampling, indicated that Reeves-Angel 934AH glass fiber filter material would be about 99.95% effective in collecting the fraction of the particulate matter sample down to about 0.3 micrometers passed through the cyclone. A circular format was selected for the filter material to provide the most even distribution of the sample on the filter surface and minimize the pressure drop buildup. A circular filter holder was designed to accommodate a 929 square centimeter (1 square foot) filter, limiting the pressure drop across the unloaded filter to 3.7 cm Hg. A louvered inlet section was also designed to reject particles larger than 100 micrometers to complete the particulate matter sampling section of the train.

To provide stable samples of airborne organic vapor emissions, it was decided to utilize an adsorbent resin in a removable canister that could be easily transported from the sampling site to a laboratory for extraction and analysis of the sample. Dr. Philip Levins of Arthur D. Little, Inc., under contract to the Process Measurements Branch in the organics sampling area, provided consultation to TRC on the resin. The best available resin, XAD-2, which is almost 100% effective in retaining organic vapors C_6 and higher, was determined to require a canister containing about 75 kilograms to provide a 500-milligram sample. This was prohibitive from the standpoints of size and cost, and the design criterion was revised to obtain the minimum sample required for a Level 1 assessment of 14 milligrams. This sample size requires only 2.1 kilograms of resin and a sampling rate of only 0.14 cubic meters per minute (5 CFM). A canister was designed and an oil-less Gast vacuum pump selected to draw the sampling stream from the main stream after the particulate matter is removed.

The system design was reviewed and approved and procurement and fabrication efforts started. At this time, the EPA's Health Effects Research Laboratory suggested that an additional size fraction of the particulate matter sample be included to help in the assessment of the inhalable (less than 15 micrometer) portion of the emissions. It was decided to add a battery of six single stage Sierra Instrument impactors to the system to effect this additional fractionation betweeen the inlet and the cyclone. These impactors were designed to provide a D_{95} for 15 micrometer particles at the system sampling rate with a pressure drop of only 0.05 cm Hg, and could therefore be added without affecting the system design.

The final system design is shown schematically in Figure 1. Design flow rates and pressure drops for each system element are shown enclosed in brackets. Samples retained by each element are shown in parenthesis.

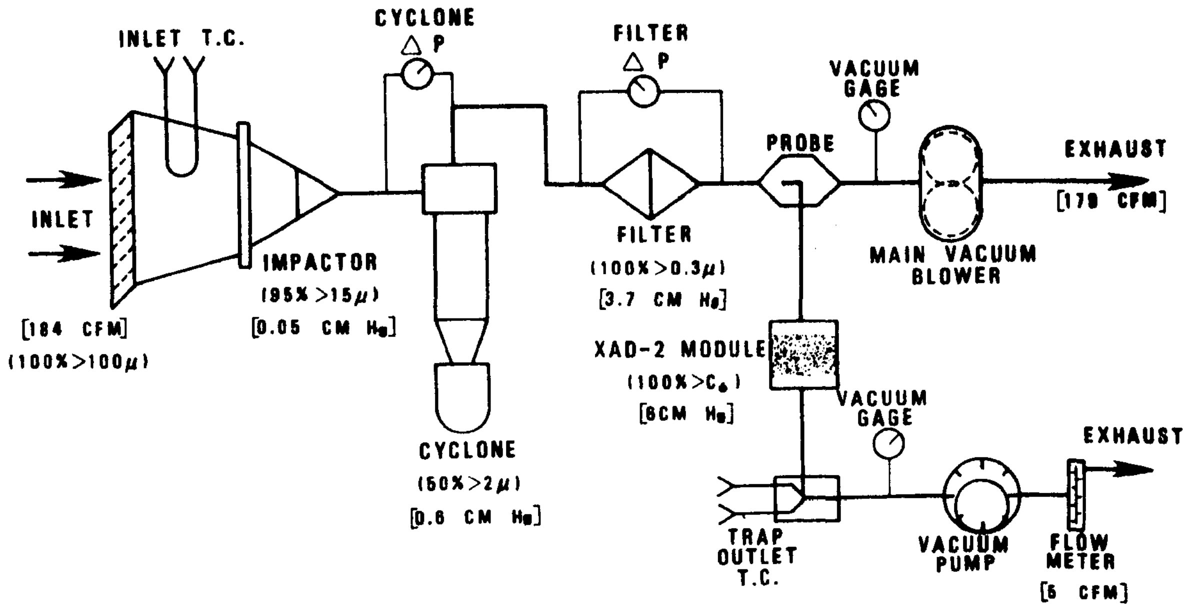

Figure 1. Fugitive assessment sampling train design operating condition

The procured and fabricated elements of the prototype system were then loosely packaged onto a space frame about 75 cm (2.5 feet) square by 183 cm (6 feet) high to allow easy access to the elements during development testing. The main sampling blower and the organic vapor sampling pump were separately mounted to improve the system's portability and permit the location of the blower and pump exhausts away from the sampling inlet.

After a successful operational test and a few modifications to the system were completed at TRC, the FAST was shipped to the Southern Research Institute's laboratory for calibration testing of the particulate sampling section. Tests were run by Southern using monodisperse ammonium fluorescein aerosols provided by their vibrating orifice aerosol generator at 3, 10 and 15 micrometers. The test results for the cyclone, shown in Figure 2 as points plotted on the manufacturer's design curve, are in very good agreement. The test results for the impactor, also shown in Figure 2, indicate good agreement with the design curve for smaller particles but are considerably lower than expected for the 15 micrometer particles of major concern.

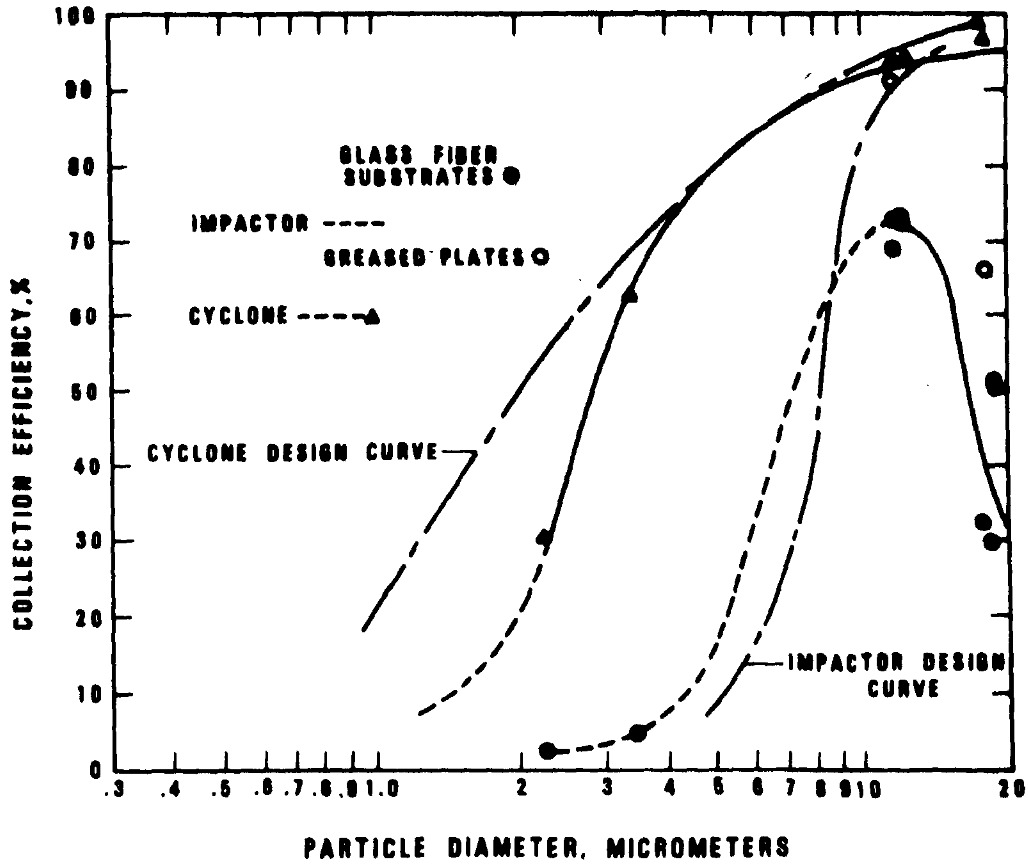

Figure 2. Collection efficiency as a function of particle diameter for the FAST impactor and cyclone

Since it was felt that this discrepancy was caused by bouncing of the larger particles off the glass fiber substrate used in the impactors, a test was run using a grease substrate in an attempt to reduce the bounce. This resulted in a slight improvement in performance, but not to a level considered satisfactory for further development. A joint effort by TRC and Southern Research has been initiated to design and fabricate an elutriator to replace the impactor as the 15 micrometer fractionator. It is expected that the elutriator, envisioned as a battery of parallel settling chambers, will replace and perform the functions of both the inlet louvers and the impactors.

A field test of the FAST has been planned at a coke oven battery, where the system will be tested simultaneously with two Battelle mega-vol samplers and a standard hi-vol sampler in the measurement of emissions from coke pushing operations. This test, to be run prior to the fabrication and installation of the elutriator, should provide sufficient data for continued development of the cyclone and filter sections as well as an initial indication of the effectiveness of the adsorbent canister train design.

It is expected that the FAST will require some modifications and a repeat of the calibration and field testing cycle after the addition of the elutriator. Verification tests of the total system will be performed after the modifications and additions have been completed and an operating procedures manual will be prepared and published for the final version.

The efforts to date in the development of this Fugitive Assessment Sampling Train have been quite successful and encouraging. The completion of the planned effort wil provide a useful tool for rapid, reasonable assessments of fugitive particulate matter and organic vapors from a wide variety of industrial sources.

TASK 07 - PRELIMINARY INVESTIGATION OF TECHNIQUES FOR THE DETERMINATION OF HOOD CAPTURE EFFICIENCY

Hooding has been used for many years as an effective means of collecting open source emissions such as fumes, gases, dust and particulates, so that they may be transported to a control device for proper treatment to reduce the amount of pollutants discharged into the atmosphere. Most of the previous work with hoods and hooding systems has been directed toward the control of small industrial process emissions. The objective of this task was to perform a preliminary investigation of methods to measure the capture efficiency of hoods for large process emission source control.

The eventual goal of this effort and subsequent efforts indicated by the preliminary investigation is to produce a technical manual on hood capture efficiency measurements that will describe the techniques that may be employed to determine hood efficiencies.

A comprehensive literature search was conducted to determine the state-of-the-art in hood capture efficiency measurements. Through discussions with individuals concerned with hood capture efficiency measurements in the Environmental Protection Agency, the National Institute of Occupational Safety and Health, industry, and research organizations, a number of processes where the measurement of hood efficiency could be important were identified. The techniques currently being used to determine the efficiencies of capture hoods for some of these industrial processes were investigated in an attempt to formulate a basic set of specifications that could be applied to a general technique. New techniques identified during the study were also analyzed on this basis.

Literature Search

An exhaustive literature search was performed using the System Development Corporation (SDC) computerized data banks, along with literature searches performed by the University of Connecticut Health Center and the

EPA library service. Data bases covered included NTIS, Pollution, Compendex, APTIC, Toxicology, MEDLARS and the Library of Congress.

Before scanning the data bases, a search strategy was formulated whereby a list of key word identifiers, with major and minor categories, was generated. These identifiers were fed into each data base, starting with very general categories and working down to specific identifiers. The computer then searched its files and printed the titles of those articles which contained those key words in the title or abstract. Typical key word identifiers used in this search included: HOOD, CAPTURE, EMISSIONS, EXHAUST, DESIGN, EFFICIENCY, ENCLOSURE, AIR POLLUTION, VENTILATION, FUME, COLLECTION, TESTING, AND PERFORMANCE EVALUATION. By using these identifiers individually and in various combinations and permutations, as well as keying in certain categories of articles not to be accessed, major articles and reports on hood capture efficiency measurements were located. The search into each data base was usually considered complete when the same articles or group of articles was accessed by using two or three different groupings of key words. Subsequent to the literature search, phone calls were made to the authors of the more pertinent articles to attempt to trace secondary references and to discuss their knowledge of the state-of-the-art of hood capture efficiency measurements.

Thirteen primary references were found in the open literature which could apply to measuring hood capture efficiency. The bulk of the material found in the literature dealt with a variety of emission measurement techniques, but contained little information on hooded processes or the efficiencies of hoods.

ADDITIONAL INVESTIGATIONS

Since the information obtained through the literature search was so sparse, additional information was obtained by directly contacting knowledgeable individuals identified in the search or in previous professional contacts as having an interest in, or concern with, hood capture efficiency measurements.

Telephone contacts and personal interviews with ten individuals, four from academic or research organizations, four from industry, and two from the EPA; resulted in the identification of nine measurement techniques potentially applicable to the problem and a number of industrial processes that could require capture efficiency measurements as part of a program to improve the control of their emissions.

These techniques and processes were reviewed in detail and reduced to a list of four techniques that could provide measurements with acceptable error limits and five processes representative of the problems that might be encountered in the general application of the techniques. The measurement techniques are:

1 - Tracer techniques
2 - Multi-point probes
3 - Physical modeling
4 - Optical measurements

The processes are:

1. Metallurgical coke production
2. High alloy electric furnace steel production
3. Electrolytic smelting of aluminum
4. BOF steel production
5. Rubber tire production

The techniques and their possible applications to the processes are described in the section following.

Measurement Methods Applications

Tracer Methods--

Tracer studies have already been conducted for industrial hygiene tests of hood and ventilation system capture efficiency. Nitrous oxide has been used as a gas tracer to determine the air change efficiency of an operating room ventilation system, determined by measuring the rate of decay of nitrous oxide in the operating room air. Uranine dye released through a nebulizer has been used as a particulate tracer to measure the effectiveness of an auxiliary air hood in a chemical use laboratory. In this application, auxiliary air is used to increase the air dilution inside a vent hood to more rapidly dissipate toxic fumes. Any fumes not captured by the hood could leave the hood through the hood face area where the operator stands. Air samples were taken in the hood face with and without auxiliary air. The hood face sample was assumed to be the uncaptured emissions, and the hood capture efficiency was thereby calculated from the weight of uranine dye released in the hood and the hood face sample weight. This hood capture efficiency method appears attractive for application to larger air pollution emission sources.

Scale-up of the tracer technique to large emission sources would require that uncaptured emissions be sampled at several different locations around the hood face. The larger area within which the escaped tracer must be sampled can increase the errors in the hood capture efficiency measurement unless a very complex sampling network is set up. Costs and error limit constraints would have to be examined on a case-by-case basis to calculate the most cost-effective configuration for a hood capture efficiency test. Another limitation is the temperature stability of the tracer. For high temperature processes, Freon or sulfur hexafluoride gas and uranine dye or dioctyl phthalate particulate tracers would not be suitable. High temperature tests would be limited to the use of more stable materials, such as helium, titanium chloride and zinc sulfide as tracers.

Tracers offer some distinct advantages over other hood capture efficiency methods in that background concentrations of the actual air contaminant do not interfere with the efficiency measurements. Most of the tracers used for such tests are detectable at far lower concentrations than most air contaminants. This can increase the accuracy of the hood capture efficiency measurements even where tracer concentrations are low as a result of the distance from the hood to the sampling point or the large face area of the hood where they are released. The tracers become diluted with tracer-free air as they travel further from the hood or when they encounter large volumes of outside air at the face of a large hood. Since most tracers can be accurately measured in the parts per billion range while most pollutants can only be measured in the parts per million range, it is possible to measure a tracer added at a concentration as much as three orders of magnitude lower than that of the pollutant emitted and have the same measurement accuracy.

A basic procedure for a tracer test would be as follows:

1. Background measurements are taken of the tracer concentration before any tracer gas is released in the area.

2. The tracer is introduced uniformly into the emission source. The time period and rate of addition are measured.

3. A sample of the air captured by the hood is taken in the duct leading from the hood at a point where flow is generally uniform in the duct. Tracer concentration and total gas flow are measured for a definite time interval.

4. Over the same time interval, the hood face concentration of uncaptured tracer and the flow of air away from the hood are measured.

5. Background measurements of tracer concentrations are taken after release of the tracer gas has stopped.

6. The mass flow rates of tracer in the duct and around the hood face are calculated. This data is used to determine hood capture efficiency.

7. The test is repeated as required to determine the accuracy and precision of results.

Application of tracers to sources of interest for hood capture efficiency measurements would include:

Source	Characteristics	Tracer
1. Metallurgical Coke Production	Hot, short time interval high volume flow through large hood area. Fume, particulates & gases released.	Helium or titanium chloride
2. High Alloy Electric Furnace Steel	Hot, short time interval high volume flow through large hood area. Fume, particulates & gases released.	Helium or titanium chloride
3. Electrloytic Aluminum Smelting	Hot, continuous low volume flow through large hood area. Fume, particulates & gases released.	Helium or zinc sulfide
4. BOF Steel Production	Hot, short time interval high volume flow through large hood area. Fume, particulates released.	Helium or titanium chloride
5. Rubber Tire Production	Warm, short or long time interval low volume flow through small hoods. Fume, particulates & gases released.	SF_6, Freons, uranine dye or dioctyl phthalate

The tracer method is given the highest ranking of the four possible hood capture efficiency measurement methods.

Multipoint Probe Methods--

Multipoint probe methods have already been applied with some success to the determination of hood capture efficiency for large scale processes. Recent EPA studies on the capture of emissions from coke pushing operations using coke-side sheds have shown that there are deficiencies in the pushing system design that allow some particulate and fume emissions to escape at the ends of the sheds. Tests were performed using EPA method 5 particulate test trains traversing the shed leakage points during pushing operations. Tests at two coke ovens showed the utility of the method. At the same time as these tests were conducted, the particulate and fume captured by the shed were measured using an EPA method 5 train traversing the duct leading from the shed to a stack or control device. The success of these tests demonstrates that this method can be applied to significant emission sources where hood capture efficiency measurements would be needed to define the potential degree of control of the source in question.

In comparison to the tracer-method, which can use a similar sampling method and network, the multipoint probe method suffers from two disadvantages. The first is that a direct measurement of the pollutant in question can be less sensitive and accurate than that of a tracer. The second is that the background levels of pollutant within the plant atmosphere can be significant enough to cause appreciable errors in direct measurement.

The multipoint probe method is a direct measure of hood capture efficiency under actual operating conditions, and in that sense can be termed a more dependable method of determining hood capture efficiency than the tracer method. As with tracers, the sampling network can be complex and the cost-effectiveness of the testing method must be assessed on a case-by-case basis.

The basic test procedure would be identical to that described for tracers, except that the actual pollutant rather than a tracer would be measured.

Application of multipoint probes to sources of interest for hood capture efficiency measurements would include:

Source	Characteristics	Pollutant Measured
1. Metallurgical Coke Production	Hot, short time interval high volume flow through large hood area. Fume, particulates & gases released.	Particulates by EPA Method 5
2. High Alloy Electric Furnace Steel	Hot, short time interval high volume flow through large hood area. Fume, particulates & gases released.	Particulates by EPA Method 5 (Modified)
3. Electrolytic Aluminum Smelting	Hot, continuous low volume flow through large hood area. Fume, particulates & gases released.	Particulates by EPA Method 5
4. BOF Steel Production	Hot, short time interval high volume flow through large hood area. Fume and particulates released.	Particulates by EPA Method 5 (Modified)
5. Rubber Tire Production	Warm, short or long time interval low volume flow through small hoods. Fume, particulates & gases released.	Hydrocarbons by FID. Particulates by EPA Method 5

The multipoint probe method is given the second highest ranking of the four possible hood capture efficiency measurement methods.

Physical Models--

Physical models have been applied to the study of hood capture efficiency measurements, especially for industrial hygiene purposes. Completed studies include an investigation of a modeled mining ventilation system using methane as a quantitative tool and smoke for visual and quantitative measurements of hood capture efficiency. A scale model, low-volume, high-velocity hood system was studied using dioctyl phthalate as a tracer, its concentration being measured by a light scattering photometer. For hot processes, laboratory heating devices and titanium chloride smoke was used to follow the travel path of heated fumes from their source to a nearby capture hood. Temperature measurements were used to determine pollutant flux.

The physical modeling technique serves best as a screening test for full scale measurements rather than an end in itself. There are several dangers in using the model data to scale up to full scale hoods. The model system may have different characteristics unless all required similitudes are carefully examined. Even a single key element out of scale could distort the test results substantially. In small scale systems, the measurement techniques can physically perturb the system by introducing obstructions to flow or by diverting the flow path. Models can be very helpful in evaluating the design parameters for full scale systems. It is much more cost-effective to work out design changes to optimize emission collection on a small scale before constructing a full scale hood and attempting to measure its emission capture efficiency.

A basic procedure for a physical model test would be as follows:

1. A scale model system is constructed which retains the similitude of the key variables of a full scale system.

2. An appropriate gas, particulate or aerosol is selected to represent the pollutant of interest in the system.

3. A system is installed to present the pollutant to the hood in the same manner as in a full scale system.

4. Background readings of the scale model pollutants are taken.

5. A test is run using a probe system to capture the pollutant in the hood and on the hood face. The time interval and total pollutant release are measured.

6. Background pollutant readings are taken after pollutant release has been terminated.

7. If possible, all of the pollutant captured by the hood is collected in a control device as is all of the pollutant not captured by the hood.

8. The concentration, mass flow rate and/or total mass of collected and uncollected pollutant are measured and used to determine hood capture efficiency.

Application of physical models to sources of interest for hood capture efficiency measurements would include:

Source	Characteristics	Physical Model
1. Metallurgical Coke Production	Hot, short time interval high volume flow through large hood area. Fume, particulates & gases released.	Rectangular opening with infrared heater. Titanium chloride smoke or helium in test gas.
2. High Alloy Electric Furnace Steel	Hot, short time interval high volume flow through large hood area. Fume, particulates & gases released.	Cylinder with gas flame at bottom. Titanium chloride smoke or helium in test gas.
3. Electrolytic Aluminum Smelting	Hot, continuous low volume flow through large hood area. Fume, particulates & gases released.	Scale model probably not possible.
4. BOF Steel Production	Hot, short time interval high volume flow through large hood area. Fume, particulates & gases released.	Cylinder with gas flame at bottom. Titanium chloride smoke or helium as test gas.
5. Rubber Tire Production	Warm, short or long interval low volume flow through small hoods. Fume, particulate & gases released.	Scale model of machine & infrared heater. SF_6, Freons, zinc sulfide, dioctyl phthalate, uranine dye or titanium chloride tracer

The physical model method is considered the first step in the application of other hood capture efficiency measurement methods, and not an end in itself.

Optical Methods--

Optical methods have not yet been applied to the measurement of hood capture efficiency, but they have been applied to fugitive emissions measurement. The extrapolation from that one use to the other can be made quite reasonably. The fugitive emissions from coke oven pushing were studied using two movie cameras located on horizontal axes through the plume perpendicular to each other to define the plume size and shape and to verify auxiliary in-plume particulate measurements. Fluoride emissions from gypsum ponds have been measured using a long path infrared transmissometer with auxiliary wet chemical fluoride measurements. Optical methods are therefore applicable to both gases and particulates and would be well suited to hood capture efficiency measurement.

Optical methods require calibration by an independent measurement method and are therefore no more reliable or accurate than the calibration method. In addition, for specific sources, the backscatter of light radiation by the emissions can be so severe that no meaningful measurements can be taken. This can be true whether the optical method measures backscatter of light from the emissions or forward transmission through the emissions.

Optical methods do have the advantage of not requiring complex sampling networks and can be operated at a safe distance from hazardous areas near the source of emissions. Optical methods can also isolate specific pollutant in the source if all emissions are gaseous, and can follow the travel path of uncaptured emissions for considerable distances.

Considerable effort would be required to extend the state-of-the-art of optical methods to include their use in hood capture efficiency tests. The basic methods are applicable as they are now employed for fugitive emissions measurement, but modifications to effective ranges and sensitivities and extensive calibration efforts are required before efficiency tests can be undertaken.

A basic procedure for an optical method test would be as follows:

1. The optical monitor is set up to scan the area around the hood face. Velocity measurement devices are also set up here.

2. A calibration run is done on the optical monitor by introducing a known amount of the pollutant to be measured into its optical path and a background reading done for the pollutant of interest.

3. The pollutant is released in the vicinity of the hood, and the sampling time of the optical system determined.

4. The optical monitor scans the hood face area and a sample taken from the hood duct.

5. The calibration run is repeated and a background reading is taken.

6. The mass flow rate in the duct and around the hood face is determined from the calibrated optical measurements and the velocity traverses.

7. Hood capture efficiency is then directly calculated from mass flow rate data.

Application of optical methods to sources of interest for hood capture efficiency measurements would include:

Source	Characteristics	Optical Methods
1. Metallurgical Coke Production	Hot, short time interval high volume flow through large hood area. Fume, particulates & gases released.	Photographic plus EPA Method 5, or calibrated transmissometer.
2. High Alloy Electric Furnace Steel	Hot, short time interval high volume flow through large hood area. Fume, particulates & gases released.	Photographic plus EPA Method 5, or calibrated transmissometer.
3. Electrolytic Aluminum Smelting	Hot, continuous low volume flow through large hood area. Fume, particulates & gases released.	Infrared long path or calibrated transmissometer.
4. BOF Steel Production	Hot, short time interval high volume flow through large hood area. Fume, particulates & gases released.	Photographic plus EPA Method 5, or calibrated transmissometer.
5. Rubber Tire Production	Warm, short or long interval low volume flow through small hoods. Fume, particulates & gases released.	Infrared long path or calibrated transmissometer.

The optical monitor can be used for hood capture efficiency measurement if development work is done to adapt it from its present use in fugitive emission measurement.

RECOMMENDATIONS FOR FURTHER INVESTIGATION

The information gathered in the literature search and interviews conducted during this task, while sufficient to provide descriptions of the applicability of a few possible measurement techniques for the determination of large hood capture efficiencies, clearly indicates that no really definitive work has been completed in this area. There is not enough information to identify any single method as universally applicable or to formulate a meaningful specification for such a method. To correct these deficiencies and provide inputs to a technical manual, TRC recommends that a program be implemented to test the proposed methods to determine the most applicable method for general use and the modifications required to its application to specific source and hood configurations. The method and its modifications could then be evaluated in a series of field trials at actual process sites and the results used to prepare a technical manual describing the planning and performance of broad capture efficiency measurement programs.

SECTION 3

SERVICE TASK DESCRIPTIONS

TASK 20A - EVALUATION OF A PROPOSED NO-DUCT QUASI STACK MEASUREMENT TECHNIQUE

An evaluation was made of a measurement method proposed by another EPA contractor to determine the emission strength from an electric furnace. The method proposed to determine source strength by simultaneously monitoring the temperature and pollutant concentration at points within the furnace plume and relating the measurements to source strength through a hypothetical relationship developed in a series of laboratory-scale experiments.

The evaluation resulted in a recommendation that additional analysis of furnace plume dynamics be performed to more fully define the circumstances in which the proposed test method or a similar approach would greatly simplify emissions quantification.

TASK 20D - PREPARATION OF ALTERNATIVE MEASUREMENT APPROACHES FOR EMISSIONS FROM A COKE QUENCH TOWER

A test methodology and plan for the measurement of emissions from coke quenching towers was prepared. The test program, to provide data for the establishment of specific emission factors, was to be carried out by a contractor to another office within the EPA.

Methodologies employed in earlier attempts to measure coke quench tower emissions were reviewed and found basically ineffective. The problems involved in making measurements were defined:

- Emission period less than 3 minutes long.
- Emission velocity, temperature, and moisture content vary with time.
- Emission concentration likely to vary across tower opening.
- High water vapor and liquid droplet proportion in emissions.
- Emission exit flow likely to be skewed by tower baffles.
- Area of emission exit flow large.
- Particulates present in wide size range and as dry solids, suspended solids, and solids condensed from vapors.

The test methodology suggested utilized a modified EPA Method 5 sampling train/Aerotherm HVSS 4 CFM stack sampler with a probe designed to traverse the tower opening. A resin bed was added to collect organic species emissions. Standard sample analyses were suggested for the probable pollutants. Analyses of the various quench waters used were suggested to determine the effect of water composition on the character of the emissions.

The test plan specified the necessary pretest survey information to be obtained; the mechanical operation, manner and frequency of sampling required; and the data to be recorded. It also included an estimate of manpower and time requirements and total program costs.

TASK 20E - PREPARATION OF A SAMPLING PROGRAM FOR FUGITIVE EMISSIONS FROM A COAL CLEANING FACILITY

A sampling program for the measurement of fugitive emissions at a coal cleaning facility proposed to be built in the state of Pennsylvania was the subject of a report prepared as the initial phase of this task. The report specified the allowable emissions from such a facility under applicable Federal and State Agency regulations for both atmospheric contaminants and waterborne effluents. Principal potential sources of fugitive emissions at the proposed facility were identified, along with their typical air and water pollutants. Brief upwind-downwind air sampling and receiving body-runoff water sampling programs were described for a typical coal cleaning facility and rough cost-manpower estimates developed.

The final phase of this task was a review of a preliminary test plan prepared by an EPA contractor for the proposed Homer City coal cleaning facility. The plan was judged to be quite effective for meeting most of its stated objectives. An improved program for obtaining specific ambient measurements was suggested. It was also suggested that the test plan be revised to include measurements of opacity from specific plant sources as indicated in the proposed EPA standards cited in the Phase I report.

TASK 20H - ASSISTANCE IN THE PREPARATION OF A GUIDELINE ON PARTICULATE FUGITIVE EMISSIONS

A number of service task-type reports on particulate fugitive emissions from this and previous EPA contracts were supplied to another EPA contractor preparing a particulate guideline document. A review of that contractor's work plan resulted in a number of suggestions to facilitate the proposed effort or to readily broaden its scope.

TASK 20I - CRITICAL REVIEW OF A FEASIBILITY STUDY OF SOURCE IDENTIFICATION FROM AMBIENT AIR MONITORING

A critique of a very lengthy feasibility study of source identification from ambient air measurements, prepared by another EPA contractor, resulted in a suggestion for modifications to the report. A format was outlined, and a section-by-section list of actions suggested to make the study more readable and useful.

TASK 20J - PREPARATION OF A MEASUREMENT PROGRAM FOR PARTICULATE MATTER EMISSIONS FROM IRON ORE LOADING OPERATIONS

This task, to prepare a proposed test method for the measurement of particulate matter as fugitive emissions from an iron ore mining operation, involved a visit to the U.S. Steel Mintac mine in Mountain Iron, Minnesota, to observe the operations generating the emissions. The operation of principal concern was the loading of iron ore into rail cars by electric shovels, which generates a puff of suspended particulate matter with each shovel dumping. The puffs were observed to diffuse rapidly into the ambient atmosphere, becoming invisible after traveling no more than 10 meters even on a day with low prevailing wind speeds (estimated at 3-6 km/hr).

A method was proposed to obtain particulate matter samples from the puff as it passes a point immediately downwind of the loading operation utilizing isokinetic samplers with 37 millimeter filters. The samplers were to be suspended from poles that could be manually located near the centerline of the puff and controlled to operate only when actually in the puff. Microscopic examination of the filters would provide approximate concentration levels and particle size distributions. Two synchronized, electrically operated cameras would be utilized to obtain pictures of the puff in short intervals as it passed the sampling point, one camera aligned along the puff's path and the other normal to the path. The pictures would be analyzed to determine the size and shape of the puff. These size data, combined with the concentration data obtained from the filter analyses, would provide a good estimate of the total particle flux at the sampling point, assuming that the particle density is constant and that the distribution within the puff is reasonably close to normal.

TASK 20L - REVIEW OF A TEST PLAN FOR AMBIENT MONITORING OF FLUIDIZED BED COAL COMBUSTOR EMISSIONS

A plan prepared by another EPA contractor for an ambient monitoring program designed to determine the impact of operating a fluidized bed coal combustor on the ambient atmosphere in the Georgetown, D.C. area was reviewed under this task.

The plan was found to be generally well conceived. Suggestions were made to add an additional SO_2 sampling site and to reschedule the proposed program to shorten the required time duration and reduce the overall program cost.

TASK 20M - REVIEW OF A SAMPLING PLAN FOR FUGITIVE EMISSIONS FROM PETROLEUM REFINERIES

The objective of this task was to review and evaluate a work plan prepared by another EPA contractor for the measurement of fugitive emissions at petroleum refineries. The evaluation included a visit to a Gulf Coast refinery in the company of the contractor's personnel who were then making preparations to conduct the measurement program. The task report, based on the observations made during that visit, discussions with the contractor's personnel and our prior experience in measuring similar fugitive emissions, included a summary section quoted in part as follows:

> TRC believes the plan to be generally sound in its conception and intent. Specific recommendations are discussed in some detail in ... this Report. Those recommendations include:
>
> 1. Removal of refinery location, size, and age as "choice parameters" and the consequent restriction of choice parameters to so-called micro factors. We believe the focus should initially be on specific pieces of equipment currently in use at U.S. refineries.
>
> 2. Revision of the statistical experimental design so that within a factored "micro-type" the sampling be conducted randomly.
>
> 3. Revision of the measurement method for baggable sources to eliminate potential and, in our judgement, likely opportunities for improper bag sealing around pieces of equipment. Use of a quasi-stack method appears to be a better alternative.
>
> 4. Revision of the measurement method for certain non-baggable sources, such as the uncovered API Separators at Gulf Coast Refinery A. The emphasis here is that direct measurement, even with admitted imperfections, is to be preferred to indirect measurements combined with theoretical assumptions implicit in the mass transfer equations proposed in the Plan.

TASK 20N - CRITIQUE OF A PROPOSED PLAN FOR THE MEASUREMENT OF MINING PARTICULATE MATTER EMISSIONS

This task, essentially a follow-on effort to Task 20J described above, consisted of a critique of the measurement plan prepared by another EPA con tractor for the ore-loading operation particle sampling. The critique was delivered as a verbal discussion with the EPA project officer and was not formally documented. Its basic content is reflected in the critique prepared under Task 20R, described below.

TASK 20P - PREPARATION OF A CONCEPTUAL ROOF MONITOR MEASUREMENT APPROACH FOR AN OPEN HEARTH SHOP

This task, to develop a conceptual approach for an open hearth shop roof monitor fugitive emissions measurement program, was designed to assist another contractor to EPA Region III to quantify the fugitive emissions from the U.S. Steel Corporation's Fairless Works.

A visit to the site resulted in the preparation of an extensive report that outlined the variables affecting the generation and measurement of the fugitive emissions and proposed a measurement approach with detailed descriptions of the monitoring system principles and design, the necessary meteorological monitoring system and its associated data transmittal subsystems, and the methods proposed for data acquisition, processing, and presentation. Cost and schedule estimates were also included in the report.

TASK 20R - CRITIQUE OF EXPOSURE PROFILING TECHNIQUE FOR PARTIUCLATE MATTER FUGITIVE EMISSIONS

This task was a critique of the exposure profiling technique for the quantification of particulate fugitive emissions as developed and tested by another contractor for IERL's Metallurgical Processes Branch. The technique is basically the same as that used in the measurement of the iron ore loading operations referenced in Task 20N, above. A summary of the critique is quoted as follows:

> The exposure profiling technique described [in the] report 'A Study of Fugitive Emissions from Metallurgical Process (Integrated Iron and Steel Plants)' appears to be a viable method for estimating source strengths or emission factors from open sources of particulate fugitive emissions. Its level of accuracy, as indicated by the test results in the report, is probably commensurate with the requirements of a level 1 assessment, within a factor of 2 or 3 of the actual emissions.
>
> Both the vertical grid array of samplers, used primarily for line or large-area sources, and the two-dimensional array of samplers, used for small-areas or virtual point sources are essentially small versions of the more generally applicable upwind-downwind technique's sampling arrays or network. Designed to be used much closer to emission sources than upwind-downwind samplers, the exposure profiling technique can obtain particulate samples with a much lower ratio of background to source emission concentrations, enabling the estimation of source strength from a specific source that would be difficult or impossible to obtain using other techniques. Exposure profiling is, in general, less expensive and faster than upwind-downwind sampling in situations where both are applicable.

The technique is not as universally applicable, however, as upwind-downwind sampling. It requires site conditions that permit close access to the source and is limited to winds of moderate speed and fairly constant direction. Its proximity to the sources means that the samples will contain a high proportion of particulates larger than those normally considered suspended, thus increasing the difficulty in quantifying the suspended fraction.

The review of the exposure profiling technique leaves little doubt that the method is reasonable effective within limits. Additional testing is required to determine what those limits are and to help refine the method so that it will produce more consistent results.

TASK 20U - CONSULTATION AND ASSISTANCE TO AN EPA CONTRACTOR IN SAMPLING REFINERY HYDROCARBON FUGITIVE EMISSIONS

A meeting at RTP with three other EPA contractors and their Project Officers was held to define and discuss the problems being encountered in the sampling of hydrocarbon fugitive emissions in programs being conducted at a number of petroleum refineries. The meeting resulted in a subsequent visit to one of the refineries to observe the situation. As the result of this visit, TRC prepared a procedure for the sampling of C_6 and lighter hydrocarbons using Tedlar bags and evacuated plexiglass containers. TRC also prepared recommendations to improve sampling methods to ensure isokinetic sampling of multiphase sources.

SECTION 4

DOCUMENTATION AND PUBLICATION TASK DESCRIPTIONS

TASK 20B - PREPARATION OF A GUIDELINE FOR FUGITIVE EMISSIONS MEASUREMENTS

The preparation of a guideline for the selection of the most effective program for the measurement of fugitive emissions from industrial sources was the objective of this task. A draft of the guideline was prepared according to the original directive to include definitions and categorizations of airborne industrial fugitive emissions; descriptions of the existing techniques for their measurement; criteria relevant to the selection of measurement techniques; and baseline estimates of manpower, time requirements, and costs for typical measurement programs.

Prior to the release of this draft for EPA approval, it was decided by the EPA Project Officer to broaden the scope of the guideline to include the same information for waterborne fugitive emissions. The task was therefore deferred until the completion of the water-related Tasks 02 and 04 which were expected to provide much of the information required. The task will be resumed at a later date and will result in a guideline for measurement programs for all types of industrial fugitive emissions, both air and waterborne.

TASK 20C - PREPARATION OF A SUMMARY OF AIRBORNE FUGITIVE EMISSIONS MEASUREMENT TECHNIQUES

The initial phase of this task was a review of a chapter on fugitive emissions sampling in a Level 1 Environmental Assessment Procedures Manual prepared by another contractor for IERL/RTP. A meeting with the other contractor and their EPA Project Officer to discuss the comments made in the review led to a directive to prepare another version of the chapter. This version included summaries of measurement techniques, measurement equipment, sampling system designs, analysis methods, and data reduction for both air and waterborne fugitive emissions in a Level 1 or survey assessment. Estimates of manpower requirements for the designated assumptions of preliminary survey completion and a one-week field program were prepared.

The TRC-prepared chapter was integrated with some of the originally reviewed material by the other contractor to produce a chapter in the draft version of the document that concentrated on an ambient air assessment. A separate chapter addressed the problem of sampling liquids but made no specific reference to waterborne fugitives.

TASK 20F - PREPARATION OF PAPERS FOR SYMPOSIUM PRESENTATIONS

This task included the preparation and presentation of two technical papers relative to the measurement of fugitive emissions for the Symposium on Fugitive Emissions; Measurement and Control, held in Hartford, Connecticut, in May of 1976. The Symposium was organized by TRC for IERL/RTP under a previous contract. The papers and their published abstracts were:

Fugitive Emissions Problems in Perspective - J.E. Yocom

Primary emphasis on control of air and water pollutants has been placed on point sources. Fugitive emissions, or those emitted from non-point sources, are important contributors to environmental degradation in many areas and in relation to many types of industrial operations. Because of the potentially high cost of controlling such emissions it is important that their significance be accurately assessed.

This paper discusses many types of fugitive emissions and the methods for assessing them. Fugitive emissions are extremely site specific in respect to their measurement and control, and this paper presents examples of measurement programs that put fugitive emissions in proper perspective in relation to other source categories and other environmental impacts.

A Guideline for the Measurement of Air-borne Fugitive Emissions from Industrial Sources - H.J. Kolnsberg

The paper presents a guide for the selection of the most effective program for the measurement of airborne fugitive emissions from an industrial source. The quasi-stack, roof monitor and upwind-downwind techniques presently utilized for sampling a wide variety of air-borne pollutants are described. General criteria for the selection of the most effective sampling program, relative to characteristics of the site, process and emissions are discussed. Baseline estimates of manpower, time and cost requirements for typical measurements programs for each technique are provided.

The publication of the proceedings of this symposium and the preparation of the symposium review article that was published in the November 1977 issue of the Journal of the Air Pollution Control Association were also included in this task.

The task was completed with the publication of three Technical Manuals on the measurement of fugitive emissions by the Quasi-Stack, Roof Monitor and Upwind-Downwind sampling methods. These Manuals were prepared under previous contracts for IERL/RTP and are designed to guide environmental engineers in the utilization of the methods. Each presents criteria for the selection of the best applicable method and describes the sampling strategies and equipment, sampling system design, sampling techniques, and data reduction. Estimates of manpower and time requirements are presented for typical overall and specific measurements programs.

TASK 20G - PREPARATION OF A SUMMARY OF FUGITIVE EMISSIONS WORK COMPLETED UNDER IERL CONTRACTS

This task involved the preparation of a brief historical summary of the fugitive emissions work carried out by TRC for IERL/RTP under two previous contracts and early work on the current contract.

The summary described the results of the tasks performed under Contract Number 68-02-1815, "Development of Sampling Procedures to Determine the Emission Rate and Chemical and Physical Characteristics of Fugitive Emissions" and Contract Number 68-02-2110, "Development of Sampling Procedures - Fugitive Emissions (Particulate and Gaseous)."

The tasks under Contract Number 68-02-1815 included the identification of major industrial sources of fugitive emissions, the evaluation of samping strategies applicable to the measurement of the identified sources, the preparation of a field test procedure utilizing one of the evaluated strategies (the quasi-stack method was selected), the performance of the field program, and the preparation of a technical manual for the selected strategy.

The tasks under Contract Number 68-02-2110 included the preparation of technical manuals for the roof monitor and upwind-downwind sampling strategies; the review and evaluation of fugitive emissions data and/or proposed sampling plans and methodologies for coal storage piles, copper smelters, cattle feedlots, sand and gravel transport, abestos storage piles, and steel furnace operations; and the organization of the Symposium on Fugitive Emissions: Measurement and Control.

TASK 20K - PREPARATION OF A BIBLIOGRAPHY OF RESEARCH PROGRAM ABSTRACTS

A bibliography of research program abstracts related to the measurement or control of fugitive emissions was prepared from the most recent published compilation of such abstracts. This was EPA 600/7-76-025, published in November 1976 and listing 377 programs started in FY 1975 under the auspices of 9 different government agencies. The bibliography, intended by the project officer as an internal IERL reference, listed 74 fugitive emissions related programs and briefly summarized their fugitive emissions relevance.

TASK 20Q - STUDY TO DETERMINE THE NEED FOR A TECHNICAL MANUAL FOR THE MEASUREMENT OF INDUSTRIAL PROCESS WATER FLOWS

An extensive literature survey into the state-of-the-art of process water flow measurement indicated that no definitive document or collection of literature exists that could be used as a reference in designing a flow measurement program. Since such measurements are an important part of the assessment of the effects of process-water-borne emissions, it was recommended that a program be undertaken to develop a technical manual on flow measurement and sampling of process water streams. A program for the manual development was proposed which included a tentative outline of the manual format.

TASK 20S - PREPARATION OF A CHAPTER ON FUGITIVE EMISSIONS MEASUREMENTS FOR A LEVEL 1 ENVIRONMENTAL ASSESSMENT PROCEDURES MANUAL

A section on fugitive emissions measurements was prepared for the revised version of the Level 1 environmental assessment manual being prepared by another EPA contractor. The section expanded the section of the original version, prepared by a third contractor using the TRC inputs of Task 20C, to include applications of the FAST system and measurements of waterborne fugitives.

TASK 20T - PREPARATION AND PRESENTATION OF A PAPER ON FUGITIVE EMISSIONS MEASUREMENTS FOR AN EPA SYMPOSIUM

A paper entitled "Environmental Assessment Measurement Techniques for Fugitive Emissions" was prepared and presented at the IERL-Sponsored Symposium on Process Measurements for Environmental Assessments in Atlanta, Georgia in February 1978. The paper was published in the symposium proceedings. The abstract of the paper is cited below as published.

> The paper describes the sampling and measurement techniques currently being employed or developed to determine the impact of industrial fugitive emissions on the environment. Three general sampling techniques for airborne fugitive emissions and one for waterborne fugitive emissions as stormwater runoff are presented and evaluated with respect to their inherent accuracies and limitations. Site-specific modifications of the general techniques used in recent studies at a variety of industrial locations are described and the results of the measurement programs reviewed. Efforts toward the development of a fugitive ambient sampling train for the measurement of airborne particulate and organic emissions are summarized.

TASK 20V - PREPARATION AND PRESENTATION OF A PAPER ON THE DEVELOPMENT OF THE FUGITIVE ASSESSMENT SAMPLING TRAIN FOR AN EPA SYMPOSIUM

A paper entitled "Development of a Fugitive Assessment Sampling Train for Particulate and Organic Emissions" was prepared and presented at the IERL-sponsored Symposium on the Transfer and Utilization of Particulate Control Technology in Denver, Colorado in July 1978. The abstract of the paper is cited below as published in the symposium program.

> The measurement of fugitive emissions from sources that preclude the capture of emissions before their diffusion into the ambient atmosphere poses some unique problems. Devices designed to obtain ambient samples for area studies generally do not provide samples of particulate matter large enough for meaningful quantification and qualification analyses in a reasonable sampling period, and are usually completely non-directional in their sampling.

The paper describes a program for the development of a prototype portable Fugitive Ambient Sampling Train (FAST) designed to obtain a 500-milligram particulate matter sample in an 8-hour sampling period downwind of most industrial sources. The development of the design criteria, establishment of operating parameters, selection and design of hardware components, fabrication and initial testing of the FAST are described in detail, and the program for the qualification testing of the completed unit is outlined.

TASK 06 - ORGANIZATION OF THE SECOND SYMPOSIUM ON FUGITIVE EMISSIONS: MEASUREMENT AND CONTROL

The organization of this symposium as a forum for the exchange of information relative to fugitive emissions among the industrial, governmental and academic communities included the selection of a site, arrangement for facilities, solicitation of speakers and session chairmen, preparation of published and mail announcements, processing of registrations, management of the meeting, and publication of proceedings.

The symposium was conducted at the Greenway Plaza Hotel in Houston, Texas on May 23-25, 1977. It was attended by about 200 individuals from consulting and academic (25%), governmental (30%) and industrial (45%) organizations. Eighteen technical papers were presented and published in Second Symposium on Fugitive Emissions: Measurement and Control, EPA-600/7-77-148, December 1977.

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16. ABSTRACT The report summarizes work completed in this continuing program of evaluation, development, testing, and adaptation of existing and proposed measurement techniques for air and waterborne industrial process fugitive emissions. Results of five major research and development tasks are presented: (1) a measurement and modeling program for waterborne emissions from coal-fired utility boilers; (2) a study of the applicability of remote sensing methods to the measurement of airborne fugitive emissions; (3) a survey and measurement program to assess the environmental problems caused by runoff from integrated iron and steel mills; (4) the design and development of a fugitive assessment sampling train for particulate and organic vapor emissions; and (5) an evaluation of techniques for the determination of large hood captive efficiencies. Summaries of service area tasks related to fugitive emissions measurements include: methodology developments for emissions measurement programs at coke quenching towers, coal cleaning plants, iron ore loading operations, and an open hearth shop's roof monitors; and reviews of proposed sampling programs and methods for fugitive emissions from mining operations, petroleum refineries, and coal cleaning operations. Abstracts of three papers on fugitive emissions topics presented at EPA symposia are included.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Coal	Pollution Control	13B	21D
Measurement	Combustion	Stationary Sources	14B	21B
Industrial processes	Iron and Steel Industry	Fugitive Emissions	13H	
Leakage		Particulate		11F
Mathematical Models	Dust	Coal Cleaning	12A	
Electric Power Plants	Organic Compounds		10B	07C
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