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Environmental Protection Technology Series

INSTRUMENTATION FOR MONITORING THE OPACITY OF PARTICULATE EMISSIONS CONTAINING CONDENSED WATER

Environmental Sciences Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

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INSTRUMENTATION FOR MONITORING THE OPACITY OF PARTICULATE EMISSIONS CONTAINING CONDENSED WATER

by

Milos Tomaides
Interpoll, Inc.
St. Paul, Minnesota 55113

Contract No. 68-02-2225

Project Officer

William D. Conner
Emission Measurement and Characterization Division
Environmental Sciences Research Laboratory
Research Triangle Park, North Carolina 27711

ENVIRONMENTAL SCIENCES RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711

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ABSTRACT

The objectives of the program were to develop and field test instrumentation and methodology for monitoring the opacity of particulate pollutants in stationary source emissions containing condensed water. The scope of work required that the instrumentation be capable of discriminating between the condensed water which is not a pollutant and the particles that are pollutants.

An instrument has been developed for on-stack operation which continuously extracts and measures the opacity of a representative sample of the particulate effluent. By increasing the sample temperature, the condensed moisture is vaporized and the opacity of the remaining solid particles is measured with a high precision optical transmissometer.

The instrument has been tested while monitoring the effluent of an expanded perlite furnace and the effluent from a wet scrubber of a sludge incinerator. Comparative tests have been performed on the instrumentation with a conventional across-stack transmissometer opacity monitor to show correlation of both instruments on a source without a condensed water interference problem.

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ACKNOWLEDGMENTS

The project team wishes to give special recognition to Mr. K. G. Ford, a member of the project technical team. He diligently handled a major share of the instrument design and its field testing.

We would also like to express our appreciation to the managerial and supervisory staff of each plant where the instrumentation was tested. Their assistance and cooperation contributed significantly to the efficiency of this project.

Also greatly appreciated is the personal interest and assistance of Mr. Phillips W. Smith, President of Lear Siegler, Inc., Engelwood, Colorado, who gladly loaned the optical transmissometers required for the field testing of the instrumentation.

Finally, we would like to thank Mr. William D. Conner, the Project Officer, for his guidance and numerous suggestions throughout the course of the program.

SECTION 1

INTRODUCTION

When the temperature of stationary source emissions are below the dew point of the water vapor in the emissions, measurement of the in-stack opacity of the particulate pollutants by standard across-stack transmissometer instrumentation is not possible due to interference from condensed water. To monitor the opacity of the particulate pollutants in such emissions, e.g. sources with wet scrubber particulate controls, methodology and instrumentation are needed to discriminate between the condensed water which is not a pollutant and the particulates that are pollutants.

EPA, being aware of such a need, requested under this contract the development and field testing of the instrumentation and methodology which would meet the following requirements:

1. Monitor only the opacity of the particulate pollutants in the emission

2. Exclude from the measurement any opacity due to the presence of condensed water which is not a pollutant

3. Be designed for continuous on-stack operation

4. Meet performance drift specifications required for conventional across-stack transmissometers (Federal Register, Vol. 39, No. 177, September 11, 1974)

5. Be designed to measure a representative sample of the effluent (this is particularly important in the case of extractive methods).

The report which follows covers a sixteen-month program which included design and construction of related instrumentation and its field testing. The results of the program are summarized in Section 2 of this report.

Recommendations for practical application of the results of this program are presented in Section 3.

Section 4 of this report covers the information about the design and operating parameters of the tested instrumentation. Also described in this section is the auxiliary equipment required for the operation of the instruments.

Description of the two test sites which were selected for the field tests is presented in Section 5. Since the management of the companies at which the instruments were tested preferred that the companies remain anonymous, the company identities and specific locations have been omitted from this report.

The test procedures and data collection and reduction applied during the course of the field testing are described in Section 6.

Results of the laboratory and field tests are described and summarized in Section 7. Also presented in this section is a summary of reliability of the instrumentation tested.

SECTION 2

CONCLUSIONS

In the course of conducting this program, we have had the opportunity to evaluate the performance of the developed instrumentation under various operating conditions. Based upon this experience, the results of the activities performed under this program are summarized as follows:

a. The instrumentation consisting of an in-stack heated sampling probe and out-of-stack sample conditioning module is capable of removing both the condensed moisture and reentrained moisture from the aerosol sample by evaporation before its opacity is read by a transmissometer

b. For the range of particle sizes and flow conditions tested, the sampling-conditioning probe was removing a fairly representative sample of the aerosol flow

c. The comparative tests between an on-stack transmissometer and optical module transmissometer with dry effluent gas flow suggest that the optical module underestimates the true dry particulate matter opacity by about 2 to 7 percent of the true opacity

d. The equipment is rigid enough to meet EPA drift specifications for transmissometer opacity monitors

e. The design of the instrumentation tested is too complicated, which would result in too high a market price. The instrument can be simplified for normal use when the operational flexibility, which was required on the prototype, is not essential.

f. The sampling-conditioning probe is not necessary when the effluent flow is well mixed, with negligible stratification, and when only freshly condensed moisture must be removed from the sample. A single sampling point, heated, stainless steel probe will perform satisfactorily.

g. The probe of the design tested should be used primarily when large droplets of reentrained moisture are present. This probe should always be used in the upward flow with the inlet opening facing the flow, or in the horizontal flow, the probe should be located vertically.

h. The optical analyzing module should be installed tilted from the vertical direction to prevent contamination of the reflector by large particulate agglomerates which may enter the module under certain conditions

i. The instrument is capable of continuously monitoring the true opacity of the solid particulate matter in stacks of up to 6 feet in diameter. For larger stack diameters, with stratified aerosol flow conditions, the probe tested is not applicable.

SECTION 3

RECOMMENDATIONS

The instrumentation developed and tested under this program is capable of measuring the opacity of particulate matter in the presence of condensed moisture. However, the field tests indicate that some design changes may further improve its performance. The recommended design considerations are summarized as follows:

a. All the instrumentation which comes into direct contact with a gas sample should be constructed from a better grade stainless steel to eliminate corrosion problems

b. The particulate opacity is affected primarily by small particles which are usually distributed homogeneously within the gas flow. For this reason, a single point sampling probe rather than a complicated slot-shaped probe will perform satisfactorily in most practical applications.

c. The probe should always be heated and in difficult applications equipped with a manually or automatically operated wiper to facilitate an occasional cleaning of the interior and also exterior probe walls

d. The gas sample should preferably be introduced into the middle of the length of a cylindrical conditioning module rather than into its end. As a result, the conditioning module can be positioned horizontally instead of vertically to eliminate contamination of the transmissometer reflector with large particles or agglomerates.

e. The residence time required for proper operation of the sampling and sample conditioning equipment should be checked for each application

f. When the sampling probe and sample conditioning module are installed, the probe and module temperatures should be increased to a magnitude beyond which no decrease in the measured opacity of the analyzed aerosol sample would occur. The temperature should not be increased to the extent where droplets of higher boiling point condensibles are also evaporated because these are already pollutants.

g. A final test on the effectiveness of the equipment for removal of condensed moisture should be performed after equipment installation. A recommended approach is to place a 47 mm filter holder inside the sample-conditioning module through one of the transmissometer ports. After placing a glass fiber analytical filter in the holder (Gelman Type AE) and after sealing off the transmissometer port through which the filter holder is connected to a vacuum pump, the conditioning module is activated. At the time when the module reaches a steady state of operation, the vacuum pump is turned on and the flow through the filter holder adjusted to about 50 percent of the sample flow through the module. After sampling for a period of time, the filter is removed and weighed. The filter weight is also determined after it is conditioned in a dessicator. By comparing these filter weights with its initial weight before sampling, the presence of condensed moisture in the sample flow can be determined.

SECTION 4

INSTRUMENTATION

The instrumentation developed under this contract consists basically of a sampling interface and a sample conditioning module. The purpose of the sampling interface is to extract a representative sample of the aerosol flow, heat the sample, and supply the sample into a sample conditioning and testing module on a continuous basis. By raising the aerosol sample temperature during its transport through the sampling interface probe into the conditioning module, condensed moisture is eliminated and a high precision optical transmissometer, which is mounted on the conditioning module, is used to measure the opacity of solid particles alone. The conditioned aerosol sample is then returned back into the main gas flow.

During the course of the project, an idea of using the Lear Siegler RM41P stack probe equipped with two high temperature, flat, electrical heaters at the probe's inlet slot was also tested. It was anticipated that the heaters may remove condensed moisture from the aerosol stream before it enters the sensing area of the probe.

The instrumentation and equipment developed and tested under this contract are described in more detail in this section.

PRINCIPLE OF OPERATION

The wet gas transmissometer system is shown schematically in Figure 1. It consists of an in-stack sampling-conditioning probe (1), out-of-stack optical analyzing module (3), optical transmitter and receiver (2), optical reflector (6), and an air flushing system (4,5,7).

A sample of the flow of emissions enters the sampling probe (1) through a slot-shaped inlet. The probe is heated and the condensed moisture evaporated inside the probe before the sample enters an optical analyzing module (3). Special design provisions are made, as described further, to prevent condensation inside the optical module and to protect the inside walls of the optical module and optics from being contaminated. The conditioned sample flows downward through the module and is returned back into the stack through an ejector-deflector (7). The returned sample is partly diluted by flushing air (4). For this reason it is deflected horizontally inside the stack by an ejector-deflector (7) to minimize its effect on the main stack flow in the vicinity of the stack sampling probe inlet. The conditioned sample which flows through an optical module (3) is continuously monitored using an optical transmissometer (2 and 6).

The schematic of the sampling-conditioning probe is shown in Figure 2.

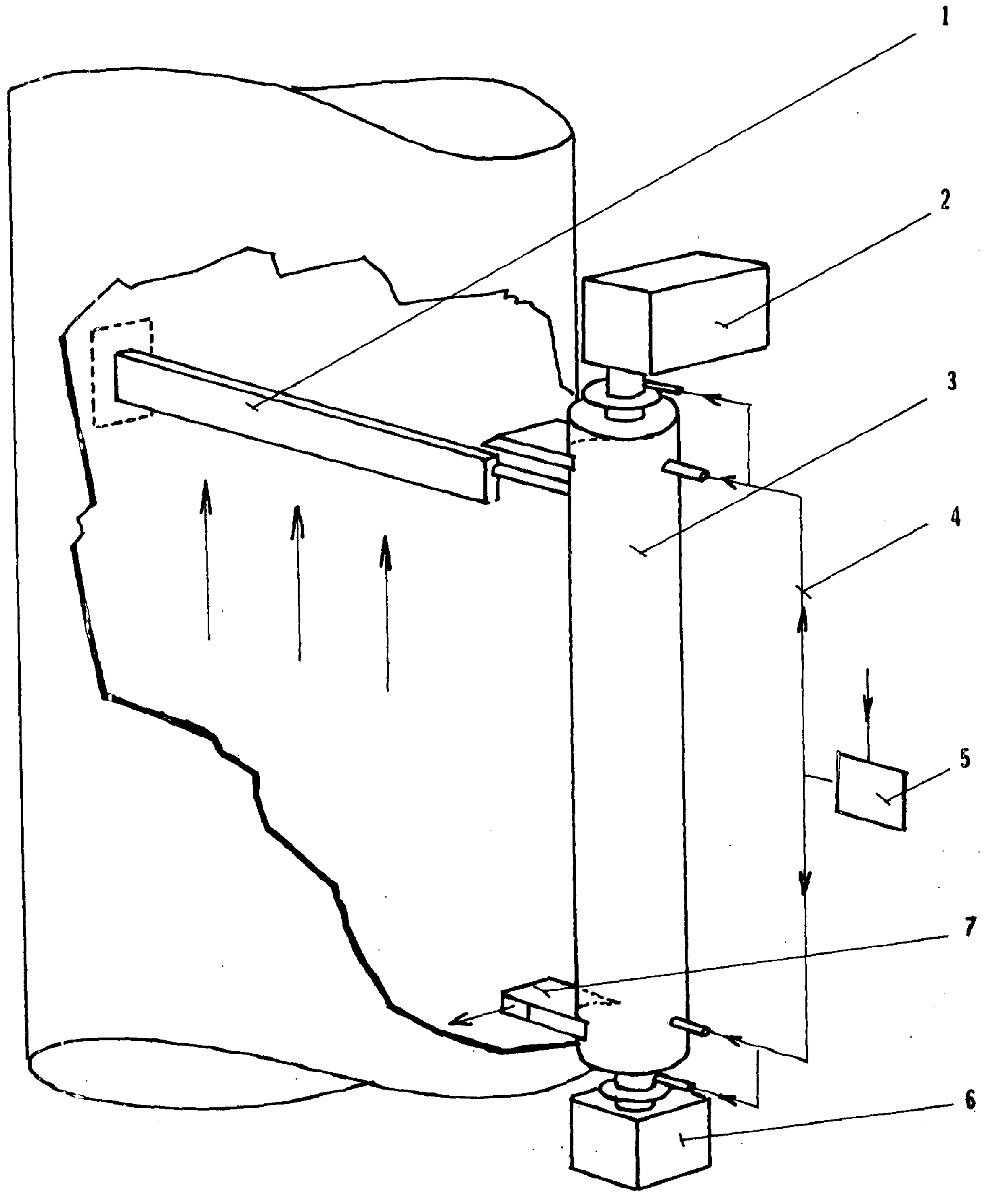
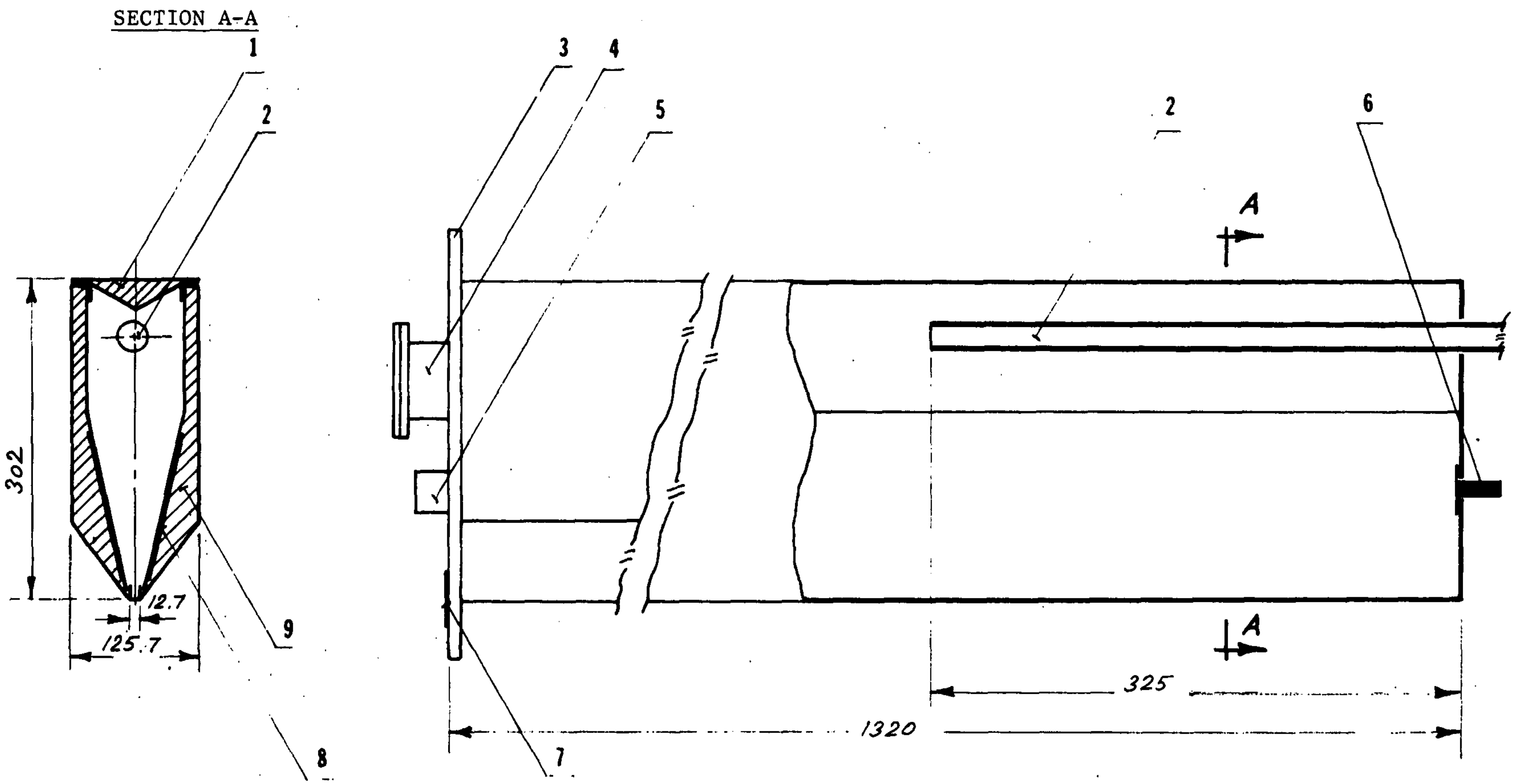


Figure 1. Schematic of the wet gas transmissometer system



All dimensions in mm.

Figure 2. Schematic of the sampling-conditioning probe

The probe is of a nearly rectangular cross section with heated inside walls (7). The probe has a narrow-slot sample inlet along most of its length. The heated inside walls (7), which serve as a radiant infrared heater, are insulated (8) on the outside to minimize probe heat losses. On one side, the probe is closed with a plate (3) which is used as a flange to seal the stack port after the probe is inserted in place. The other probe end is plugged with an end plate sealed in the probe open end. This plate has an opening for inserting a stainless steel sample pipe (2). The conditioned sample leaves the sampling probe through the sampling pipe (2) and enters the optical module. The probe is positioned in place by an alignment pin (6) on one side of the stack and by a flange plate (3) bolted to a stack port (not shown) on the opposite side of the stack. Other major parts of the probe are a control opening (4) through which sampling pipe (2) can be cleaned and also a thermocouple junction box (5) to which thermocouples, which measure the stack temperature and the heater wall temperature, are connected. When the probe is not in use, the slot-shaped inlet can be closed by sliding a prism-shaped plug through an opening (7).

The optical analyzing module is shown schematically in Figure 3. The module is of a cylindrical shape. A two-way beam optical transmissometer system is mounted on the ends of the module with the transmitter and receiver mounted on the top flange (1) and the reflector mounted on the bottom flange (21). The conditioned sample enters the module through a stainless steel pipe (5). A small amount of this sample flows upwards through an opening (4) into a rectangular ejector (2) and is returned back into the stack together with the transmitter-receiver purge air flow using an ejector flat air jet (3). In this way the dilution of the conditioned sample in the transmissometer sensing volume by the purge air is eliminated. A major portion of the conditioning sample flows downward through the module and is removed at the module bottom by an ejector (18) and returned back into the stack. The inside walls of the module are heated with surface heaters (7,9,13,16,20) to prevent any condensation. The optical reflector mounted on flange (21) is protected from being contaminated with a flat air jet-ejector system (18,19).

FLOW MODEL STUDY

With the main dimensions of the optical analyzing module selected and after calculating the size of the upper and lower ejectors, an actual size plexiglass model of the analyzing module was constructed. The model was then used to evaluate the sample flow patterns inside the module and to finalize the best geometry of the air ejectors.

For this purpose the air was supplied into the ejectors from two separate 750 mm w.g. (29.5 in. w.g.), 1.4 m^3/min (49.5 cfm) blowers of adjustable speed to vary the flow through the individual ejectors. The amount of the purge air from the transmissometer transmitter-receiver and from the transmissometer reflector was also simulated using a third blower. By adjusting the amounts of the upper and lower ejector air, a negative pressure inside the analyzing module was established so that the room air was flowing into the module through the sampling pipe (5) as shown in Figure 3.

A heavy white smoke was generated at the sampling pipe inlet by mixing

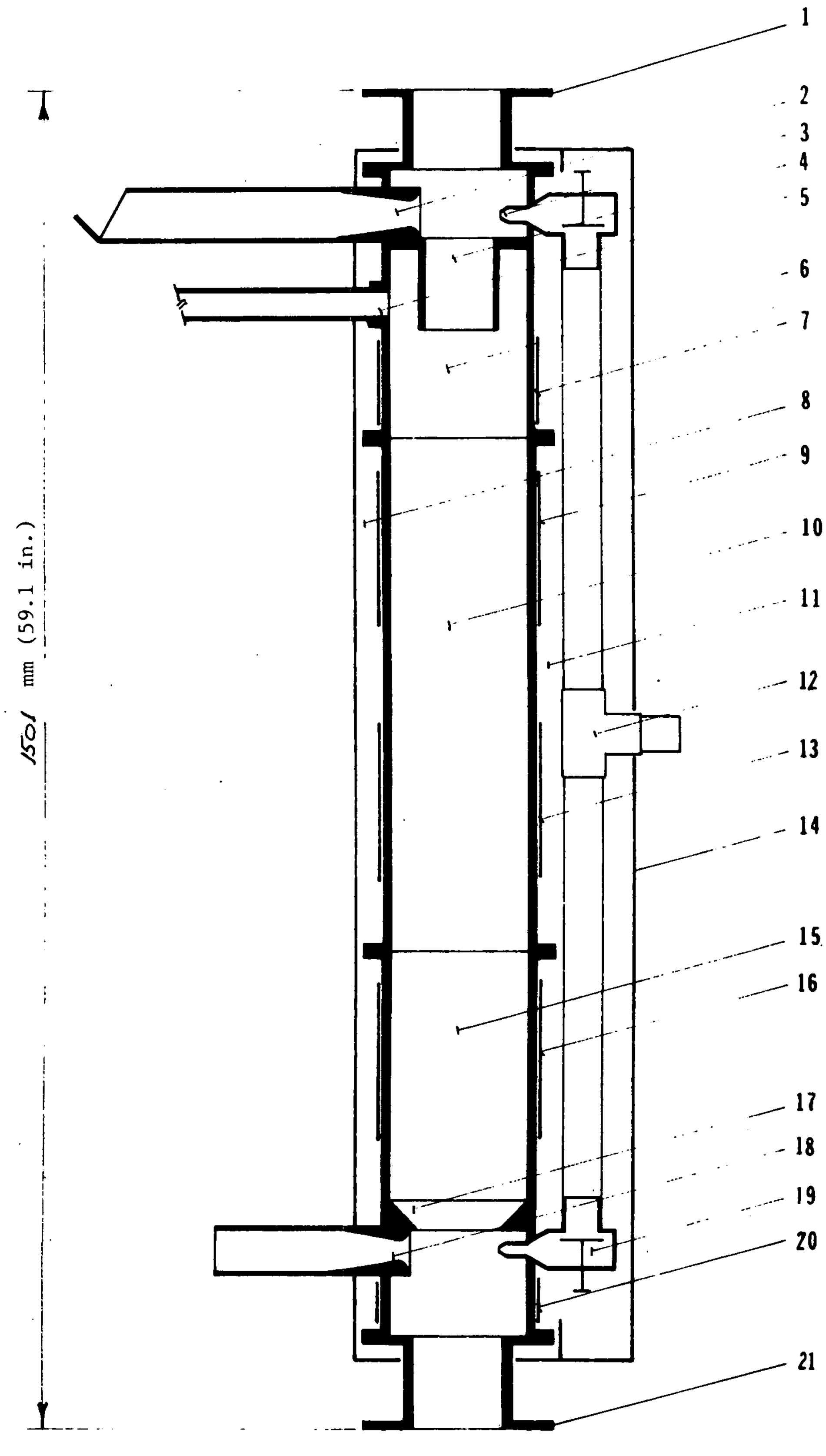


Figure 3. Schematic of the optical analyzing module

an air flow saturated with ammonia vapor and another flow saturated with hydrochloric acid. The reaction between these vapors results in a white smoke. With the smoke entering the module and using an intensive side illumination of the plexiglass model, the flow patterns within the model were easy to see.

The optimal performance of the module was determined for the parameters presented in Table 1. Under these conditions the smoke flow through the module was nearly parallel with the module length with only minor disturbance at the very top of the module. The optical path through the sample was 1000 mm (39.37 in.).

FINAL DESIGN

Based upon the plexiglass model test of the optical analyzing module, the design of the sampling-conditioning probe and of the optical module could be completed.

The design of the sampling-conditioning probe is basically identical with that one shown in Figure 2, except that the top section (Figure 2, Part #1) of the probe was made removable. With this section removed, the gas can flow freely through the probe between the heated inside walls. It was intended to test this flow-through mode of operation and use a portable Lear Siegler RM41P transmissometer to monitor the opacity inside the sampling-conditioning probe. For the measurement, the probe of the portable transmissometer is inserted through the control opening of the sampling-conditioning probe (Figure 2, Part #4).

The design of the final optical analyzing module and its support on the stack corresponds to the schematic drawing shown in Figure 3. The module is made of black anodized aluminum and consists of the top, middle, and lower

TABLE 1. FLOW PARAMETERS FOR OPTIMAL PERFORMANCE OF THE OPTICAL ANALYZING MODULE

Sample flow rate	85 l/min	(3 acfm)
Average outlet velocity in the top ejector	90 m/min	(300 fpm)
Top ejector flow rate	590 l/min	(20 acfm)
Average outlet velocity in the bottom ejector	450 m/min	(1500 fpm)
Bottom ejector flow rate	1330 l/min	(47 acfm)
Purge air transmitter	420 l/min	(15 acfm)
Purge air reflector	420 l/min	(15 acfm)

sections which are all bolted together to form a cylindrical chamber. The inside diameter of the module is 152.4 mm (6 in.) and its total length, including the transmissometer mounting flanges, is 1501 mm (59.1 in.). The length of the module section along which the sample opacity is measured is 1000 mm (39.37 in.). This facilitates easy calculation of the turbidity coefficient of the measured aerosol.

Considering the flow conditions presented in Table 1, the sample residence time in the probe is about 15 seconds and it is about 13 seconds for the module.

As shown also in Figure 3, the optical analyzing module is insulated with a layer of about 25.4 mm (1 in.) fiberglass insulation and is enclosed in a cylindrical stainless steel shield (14). The piping for the ejector air supply (12) is also enclosed within this shield. Both ejector nozzles are equipped with screw adjustable dampers for an independent adjustment of both ejectors.

AUXILIARY EQUIPMENT

All auxiliary equipment required for the probe and module operation was placed in a sheet metal container. The container is 762 mm (30 in.) high, 762 mm (30 in.) wide, and 610 mm (24 in.) deep. It is mounted on swivel casters for easy transportation. The top wall of the box is hinged to form a cover with two strip chart recorders located underneath. The front wall forms a door which is hinged too. There is a panel behind this door on which all the readout and control instruments are located. Specifically, they are: (a) two independent transmissometer readouts, one for the optical analyzing module transmissometer and the other one for an in-stack transmissometer; (b) thermocouple selector switch and temperature readout; (c) temperature controls for the probe heaters and for the module heaters; and (d) flowmeters and speed controls for three high pressure air blowers (in-stack transmissometer flushing air, module transmissometer flushing air, and ejector supply air). This control module was interconnected with flexible hoses and cables with the instruments mounted on the stack. A photograph of the module is shown in Figure 5 of this report.

MODIFIED RM41P OPACITY PROBE

Lear Siegler stack probe type RM41P was modified by attaching two high temperature flat heaters to one side of the probe slotted inlet as shown in Figure 4. Each of the heaters was 76 mm (3 in.) wide, 355 mm (14 in.) long, and 6.4 mm (1/4 in.) thick. They were attached to the probe with three steel pipe clamps to assure the rigidity of the assembly. The portion of the probe sample inlet slot which was exceeding the length of heaters was shielded with an aluminum foil. The intention was to evaluate how much condensed steam can be removed from the sample gas flow before it enters the probe sensing volume while the probe is placed in the wet gas stream.

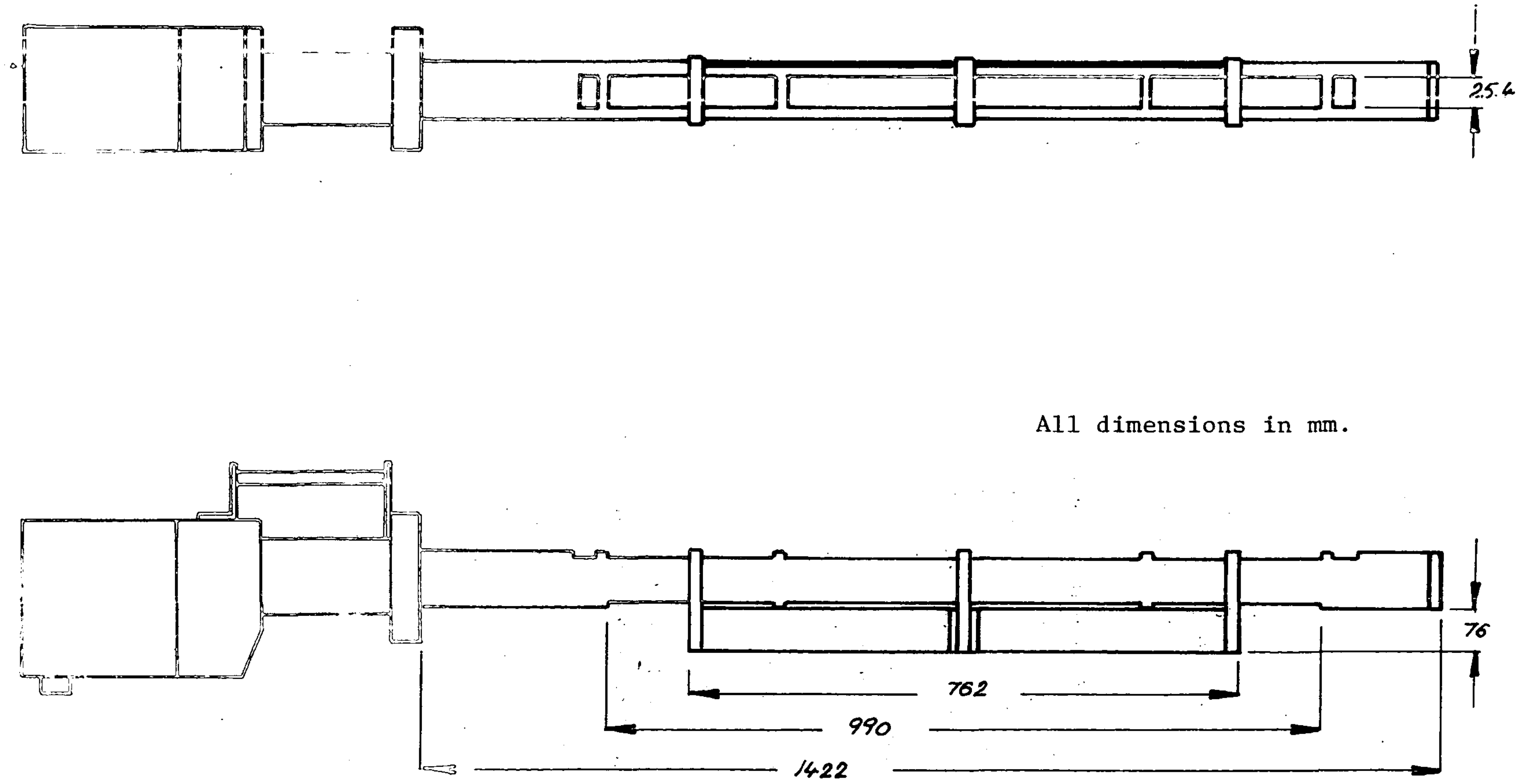


Figure 4. Modified Lear Siegler RM41P opacity probe

SECTION 5

TEST SITES

As called for in the Scope of Work, the instrumentation developed under this contract was supposed to be tested in the field. The first phase of the tests required was a comparative test of the instrumentation with a conventional across-stack transmissometer opacity monitor to show correlation on a source without a condensed water interference problem. This phase was followed by a performance test of the instrumentation at a plant known to have a condensed water interference problem. The test was to be for a period of at least thirty (30) days. The performance test was to include an analysis of instrument stability and a comparison of opacity measurements by the instrument with and without the condensed water in the stack effluent. The first test location was on the stack of an expanded perlite furnace. During the tests at this site, it was found that the droplets present in the flue gas are truly condensed moisture in its origin. The droplets were very fine and relatively easy to control by our instrumentation.

For this reason, a decision was made at the conclusion of the perlite furnace tests to test the instrumentation at another location with large water droplets. This new location was downstream from a scrubber at a sludge incinerator with a large quantity of reentrained moisture carried by the flue gas flow.

These two test locations are described in this section.

SITE #1 - EXPANDED PERLITE PLANT

An expanded perlite plant located in Minneapolis was used as the first site in the experimental program. The plant manufactures insulation blocks made of expanded perlite. The raw perlite, which has a high moisture content, is rapidly heated on a traveling grate by pulling direct flame through the layer of material. During this process, the moisture is released nearly instantaneously from the individual perlite particles, which results in a large increase of their porosity. The effluent gas leaves the furnace through a brick stack of approximately 2.1 m (7 ft) by 2.1 m (7 ft) cross section. The stack is 12 m (40 ft) tall. The wall is 0.3 m (1 ft) thick. The effluent gas temperature ranges from 49^{o} C (120^{o} F) to 60^{o} C (140^{o} F) at the stack exit. The moisture condenses shortly before the gas exits the stack which results in a heavy steam plume even at relatively high ambient air temperatures.

Because the condensation is caused primarily by mixing cool ambient air with moisture saturated flue gas, the amount of condensation can be controlled up to a certain extent. For this purpose, a sheet metal extension was constructed and placed on the stack top as shown in Figure 5 and Figure 6.

The sheet metal stack extension is approximately 2.6 m (8.5 ft) long and has inside dimensions of 2.1 m by 1.2 m (6.76 ft by 4 ft). Special stack reinforcement brackets were installed at the crown of the stack to which the stack extension is attached. A catwalk was constructed on three sides of the stack exit for instrument servicing purposes. The steel stack extension has a horizontal slot-shaped damper in its lower portion across its longer side (2.6 m). This damper was kept closed during the period of testing when no condensation in the gas stream was desired. With the damper opened, a special baffle located upstream of the damper on the stack inside wall created slightly negative pressure at the damper location. As a result, the ambient air entered the stack extension through the damper, which resulted in condensation of moisture.

As shown in Figure 5 and Figure 6, the on-stack transmissometer was located approximately in the middle of the length of the stack extension. The optical path of this transmissometer was 1.46 m (57.5 in.). The sampling-conditioning probe was located parallel to the light beam of the on-stack transmissometer with the inlet slot into the probe in a close proximity to the light beam. The brick stack is located along one side of the production building, which has a flat roof at the elevation of only 1.6 m (5.25 ft) below the stack exit. The transmitter of the on-stack transmissometer and the optical analyzing module were located on the stack to face the roof to facilitate their maintenance and servicing.

SITE #2 - WASTEWATER TREATMENT PLANT

The instrumentation was also tested on the downstream side of a wastewater sludge incinerator located in St. Paul, Minnesota. The sludge is burnt in a multiple-hearth incinerator which is fired on natural gas. The gas flame is utilized to augment the self-sustained incinerator flame. The off-gas is treated in an impinger plate wet scrubber which is followed by an I.D. fan. The gas continues to flow from the fan through a straight, horizontal, round duct of 711 mm (28 in.) I.D. and enters the bottom of a stainless steel stack. The on-stack transmissometer and the optical analyzing module were located in the horizontal duct section as shown in Figure 7.

A straight piece of duct approximately 3 m (118 in.) long preceded an on-stack transmissometer. The stack sampling-conditioning probe of the equipment tested was located with the inlet slot parallel to the light beam of the on-stack transmissometer within close proximity. Using this arrangement, the on-stack transmissometer was analyzing the portion of the gas flow which was subsequently flowing into the probe itself. This arrangement reduced the possible adverse effect of the flow stratification. The optical analyzing module was again mounted vertically on the side of the breaching duct.

Because the flow at this test location was horizontal, the sampling-conditioning probe had to be turned 90 degrees to accommodate for this condition. For this reason, the sampling probe port had to be modified compared

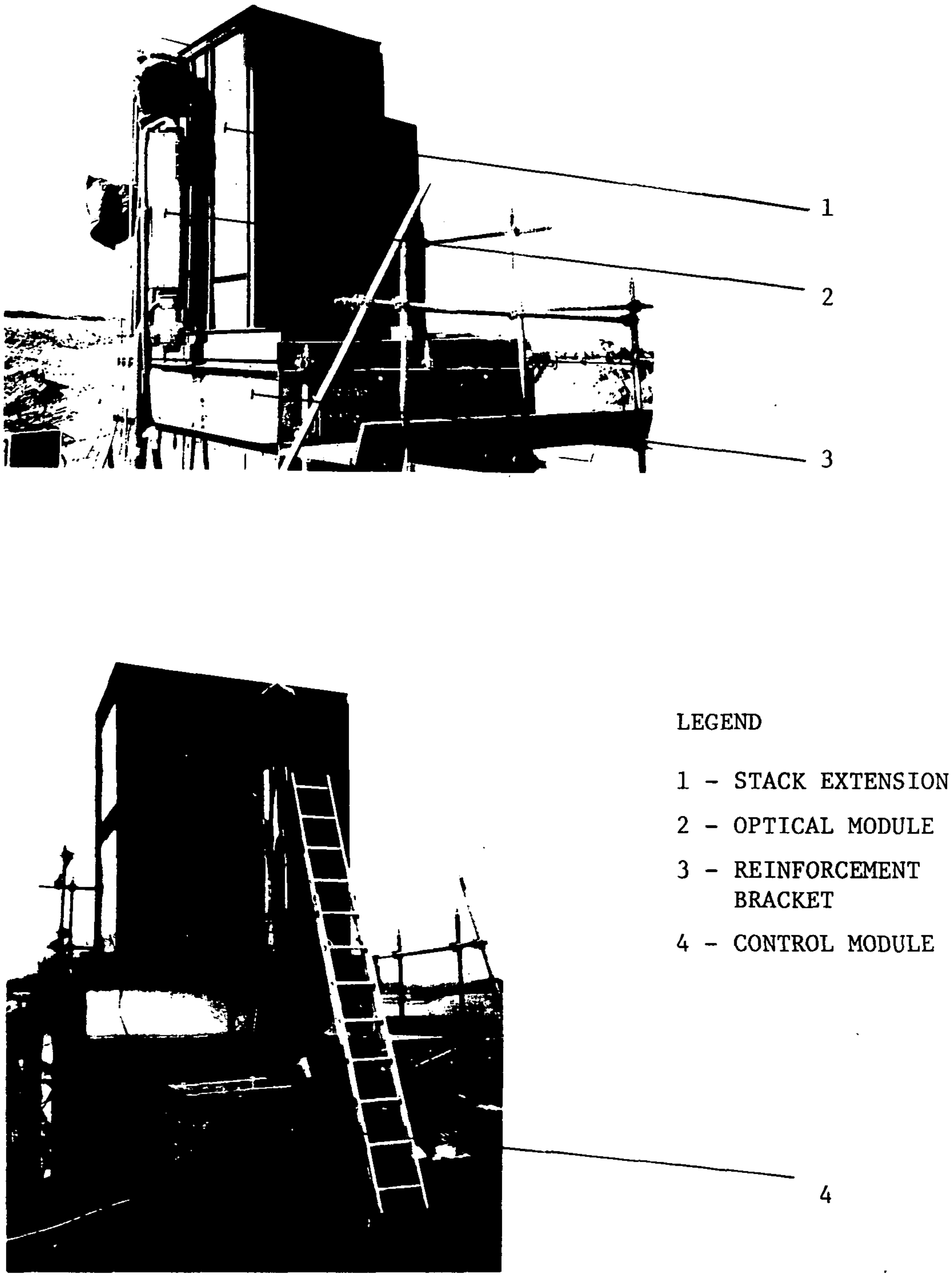


Figure 5. Test site at the expanded perlite plant

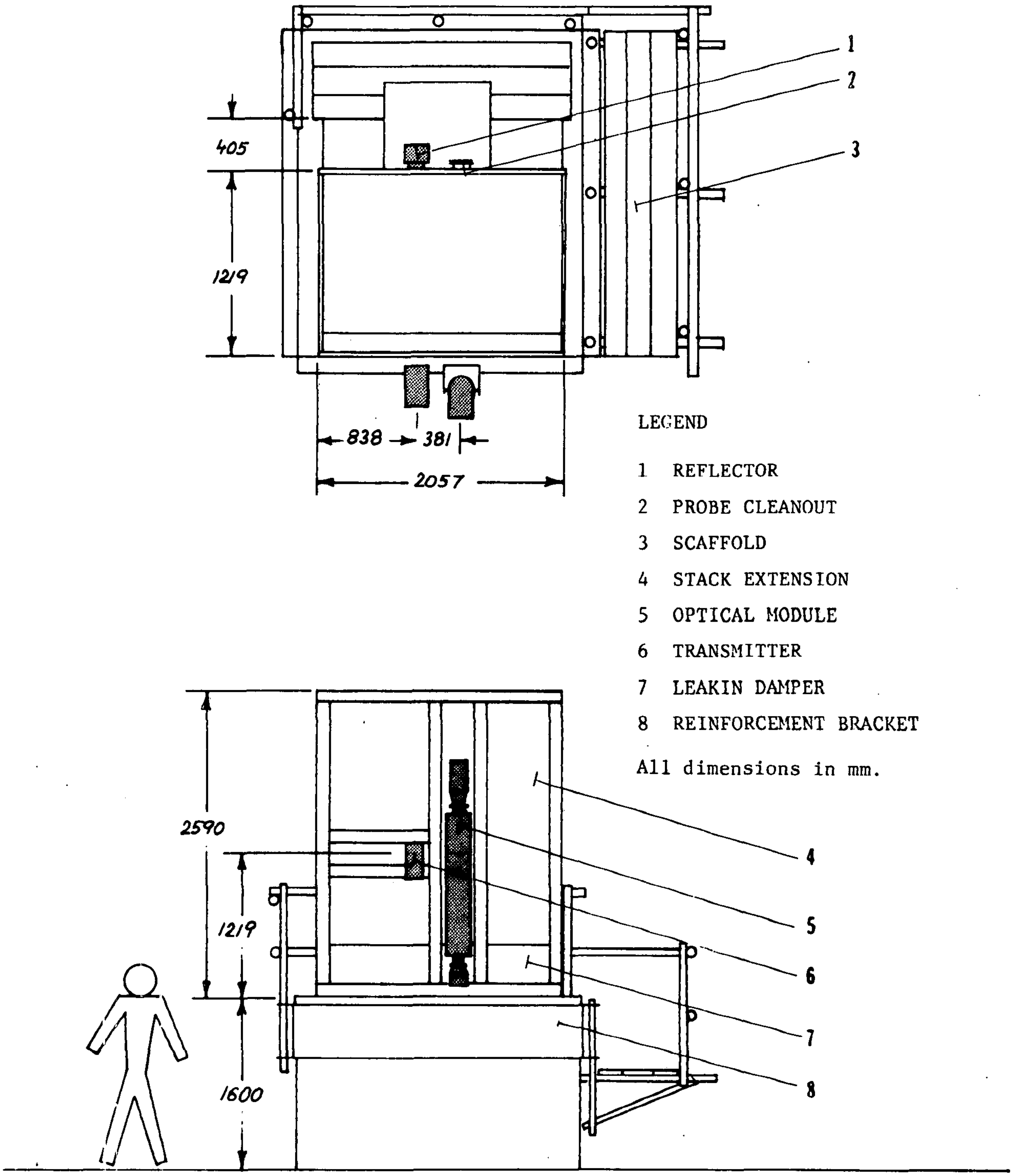


Figure 6. Schematic of the stack extension

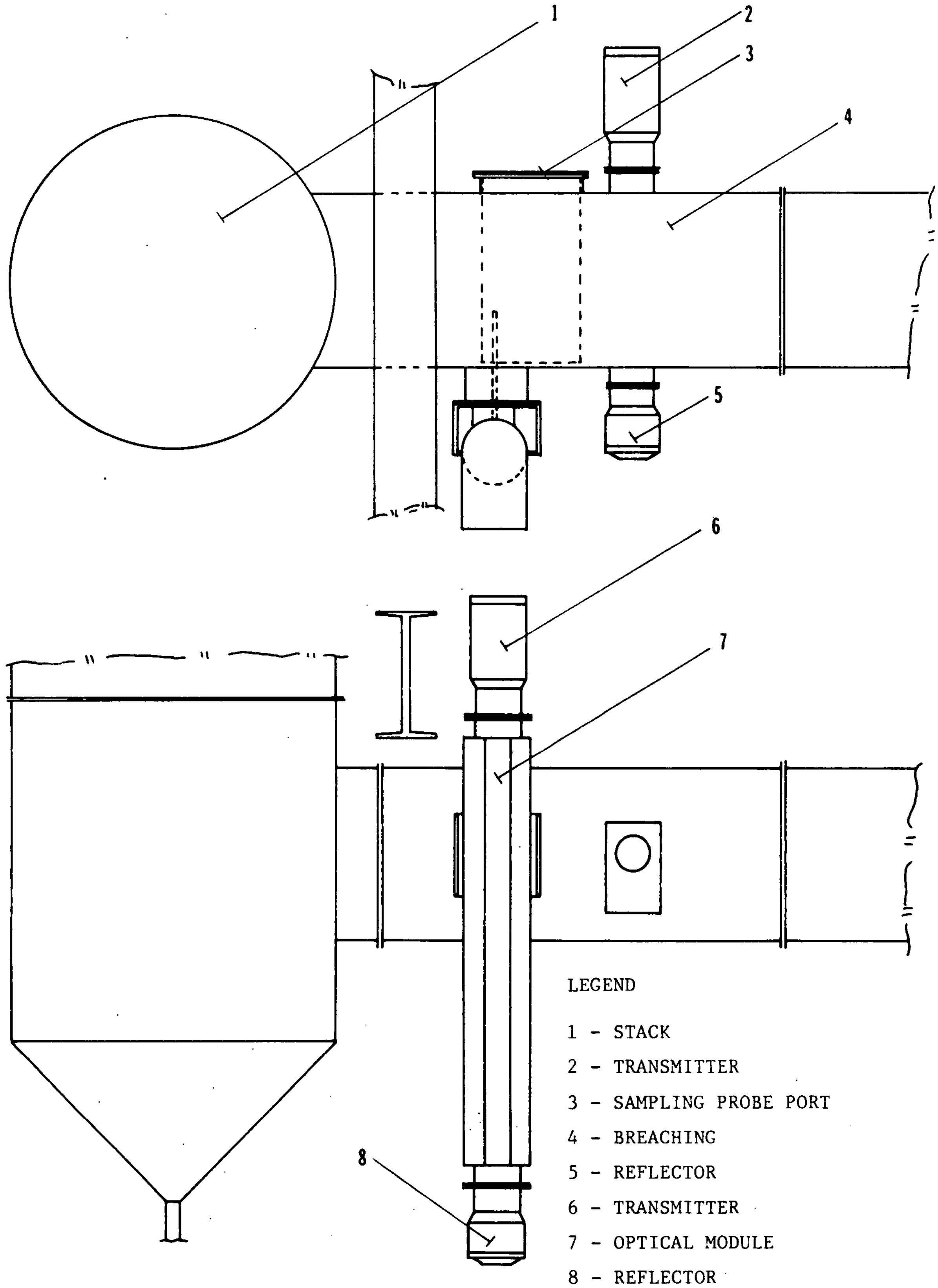


Figure 7. Schematic of the wastewater treatment plant test site

to normal use for which the probe has been designed with the probe normally located in the upward gas flow.

Compared to Site #1, the gas flow at Site #2 contained relatively large quantities of reentrained moisture from the scrubber, as well as very fine condensation droplets.

SECTION 6

TEST PROCEDURES

The primary purpose of the field tests was to establish the accuracy, repeatability, and reliability of the instrumentation when used for monitoring of the opacity of a wet gas flow. It was also anticipated that the field tests will help to locate possible drawbacks of the equipment design and help to find further improvements. For this reason, the attempt was made to design the instrumentation, as well as the auxiliary equipment, to provide for maximum flexibility in changing the operating conditions.

One of the first tasks during the instrumentation testing was to establish the correlation between the opacity of a dry aerosol flow as measured by an on-stack transmissometer and also measured with the instruments developed under this contract. These tests were directed towards finding how much error is introduced in the opacity determination by not providing an isokinetically collected sample and also by losing some particulate matter within the sampling-conditioning probe and within the optical analyzing module.

During the course of the field tests, other operating parameters of importance were: stability of the instrumentation, reproducibility of the instrument readout, operational reliability, and cleaning requirements.

The test procedures and parameters measured during the field tests are described in this section.

INSTALLATION AND STARTUP

With the instrumentation installed in a location of homogeneous particulate flow, the following procedure was usually employed for the equipment startup:

a. The sampling probe and conditioning module heaters were turned on

b. When the temperature of the interior walls was at least 20^{o} C above the temperature of the gas to be sampled, the source of the purge air for the on-stack and conditioning module transmissometers was activated

c. The conditioning module air ejectors were activated resulting in the flow of a sample through the probe and conditioning module

d. The temperature of the interior walls of the probe and of the conditioning module was increased up to the value at which no further decrease of the opacity as read on the module transmissometer occurred.

PARAMETERS MEASURED

The parameters directly related to the instrumentation operation measured during the field tests were:

a. On-stack transmissometer readout

b. Module transmissometer readout

c. Sample flow rate

d. Ejector air flow rate

e. Module transmissometer purge air flow rate

f. On-stack transmissometer purge air flow rate

g. Temperature of the stack flow

h. Temperature of the sampling probe heater

i. Sample temperature at the module inlet

j. Temperature of the module heaters

k. Temperature at the sample outlet from the module.

Besides these basic parameters, several measurements were taken which were related to the gas flow, as, for example, flue gas flow rate, its temperature, moisture content, and particle concentration.

DATA COLLECTION

The instrumentation was maintained in continuous operation at each of the two test sites. Routine servicing was done once a day, usually in the morning. Two strip chart recorders were used to continuously monitor the on-stack transmissometer opacity and the module transmissometer opacity. The charts were collected on a daily basis and processed the very same day. All the parameters listed in paragraph 2 of this section were recorded manually in a log book during the instrument servicing.

DATA REDUCTION

The data reduction required reading the charts from the strip chart recorders. The charts from both transmissometers were first assigned a time scale. As a second step, a distinctive plateau on the recorded signal of the on-stack transmissometer was found within 30-minute increments and a corresponding point was located on the module transmissometer chart. Both opacity values were read and tabulated.

The next step was to correct the on-stack opacity reading to the optical path of the conditioning module transmissometer. The correction also had to be made for different temperatures of the stack gas flow and of the sample flow inside the optical analyzing module. The following equation has been derived for the correction of the in-stack opacity:

$$(1 - O_{COR}) = (1 - O_{ST})^{\frac{L_M(273 + T_S)}{L_S(273 + T_M)}} \qquad (1)$$

where:

O_{COR} - in-stack opacity corrected to the optical path of 1 meter and to the temperature T_M,%/100

O_{ST} - measured in-stack opacity, %/100

L_M - optical path of the module = 1 meter

L_S - optical path of the on-stack transmissometer (1.46 m expanded perlite tests)

T_S - in-stack gas flow temperature, ^oC

T_M - module gas flow temperature, ^oC

Once the in-stack opacity was corrected to the operating conditions of the sample conditioning module, a ratio of the corrected in-stack opacity and of the corresponding opacity measured on the sample conditioning module was calculated. For no condensation in the stack and no bias introduced by the module, the ratio should have been 1. The presence of condensed moisture in the stack resulted in values of the ratios larger than 1 with values of about 8 not being abnormal.

An example of the data processing form is presented in Table 2.

SPECIAL TESTS

A special test performed during the field evaluation of the instrumentation was the check on the feasibility of using Lear Siegler RM41P opacity probe equipped with high temperature heater plates for determination of opacity in the presence of condensed moisture. Another special test was to use the very same probe without heaters and locate it inside the sampling-conditioning module on which the top cover was removed as described in Section 4. These tests were short term checks, and no special data were taken during the process of this testing. The results are described in Section 7 of this report.

TABLE 2. EXAMPLE FIELD TEST DATA FORM

SUMMARY OF FIELD TEST DATA

Date: March 24, 1976

Time	Temperature °C Stack	Temperature °C Module	Opacity Stack %	Opacity Stack Corr. to 1m, Tm %	Opacity Module %	Opacity Stack Corr. / Opacity Module	Wind Speed km/hr	Amb. Temp. °C
00^{30}	38	67	0		0			
00_{60}			0		0			
01^{30}			0		0			
01_{60}			0		0			
02^{30}			0		0			
02_{60}			0		0			
03^{30}			0		0			
03_{60}			0		0			
04^{30}			0		0			
04_{60}			0		0			
05^{30}			0		0			
05_{60}			0		0			
06^{30}		67	0		0			
06_{60}		54	12	8.0	3	2.66		
07^{30}			8	5.3	2	2.64		
07_{60}			9	6.0	3	1.98		
08^{30}			9	6.0	3	1.98		
08_{60}			11	7.3	4	1.83		
09^{30}			13	8.7	6	1.44		
09_{60}			10	6.6	5	1.32		
10^{30}			15	10.0	7	1.43		
10_{60}			3	1.9	1	1.96		
11^{30}			13	8.7	6	1.44		
11_{60}			12	8.0	8	1.00		
12^{30}			13	8.7	7	1.24		
12_{60}			29	20.0	16	1.25		
13^{30}			18	12.1	9	1.35		
13_{60}			1	0.6	0			
14^{30}			9	6.0	6	1.0		
14_{60}			10	6.6	5	1.32		
15^{30}			10	6.6	5	1.32		
15_{60}			10	6.6	5	1.32		
16^{30}			10	6.6	5	1.32		
16_{60}			13	8.7	7	1.24		
17^{30}			18	12.1	9	1.35		
17_{60}			20	13.5	9	1.50		
18^{30}	38	54	20	10.7	10	1.35		
18_{60}			20	15.0	11	1.0		

SECTION 7

TEST RESULTS

The results of the laboratory and field tests of the instrumentation developed under this contract are described in this section.

LABORATORY TESTS

Before the instrumentation and the auxiliary equipment were field tested, a simplified laboratory test was performed to check the function of the individual components of the system.

The sampling-conditioning probe was inspected, and the only components which could be tested in the laboratory were the response of the thermocouples and the function of the electrical surface heaters. The range of temperatures of the interior walls in the probe was adjustable within room temperature up to 216° C (420° F) which is the maximum permissible temperature of the heaters.

The optical analyzing module was completely assembled, mounted on a stand, and hooked up to the control module. The transmitter and the reflector of the RM4 Lear Siegler transmissometer were also installed on the module and interconnected with the transmissometer readout. After checking the function of thermocouples and electrical surface heaters, the air flow through the module ejectors and the transmissometer purge air flow were adjusted to the values found to be optimal during the tests of the model of the optical module. The transmissometer readout was adjusted to zero for clean room air. The module field operation was simulated by feeding an oil smoke into the module at various quantities with all module components operating. The response of the instrument was normal, and the system was considered ready for the field tests.

EXPANDED PERLITE PLANT

The equipment was installed on the stack of the perlite plant on February 25, 1976. The regular continuous test operation started on February 27, 1976, and continued through June 4, 1976. The system was shut down during the period from May 10, 1976, through May 20, 1976, for repairs of the technological equipment. During the period from April 14, 1976, through April 21, 1976, the system was not operating because of an electronic problem on the on-stack transmissometer converter. The system was tested at this site for a total of approximately 900 hours.

During this period of time light dust deposits were cleaned three times from the edge of the slot inlet of the stack sampling-conditioning probe.

The interior of the probe did not require any cleaning. Also cleaned once was a stainless steel sample pipe through which the sample is introduced into the optical module. Light deposits of dust were cleaned three times from the upper portion of the optical module at the sample inlet location. The most common problem was that at times large agglomerates of particles released from the ducts of the technological equipment entered the sampling probe and were sucked into the optical module. The lower ejector was not powerful enough to prevent these huge agglomerates from falling on the reflector, causing erroneous reading of the transmissometer. This problem occurred on sixteen occasions and was finally nearly eliminated by mounting an orifice plate between the optical lower flange and between the flange of the reflector housing.

One of the main problems encountered during the test was a power failure on the purge blowers which caused the ejectors to fail and also resulted in no transmissometer purge air flow. During this failure, which lasted for about twelve hours, the condensed moisture contaminated the reflectors and formed an ice layer at -15° C (5° F) outside temperatures.

The equipment was exposed to very stringent conditions throughout the entire test period. The plant is operated on a two-shift basis, and the technological process is ceased at about 11:00 p.m. every day. During the early morning startup of the furnace, the moisture was condensing on all interior surfaces of the ducts and stack, as well as on the exterior surfaces of the sampling-conditioning probe.

The test period included days of very intensive moisture condensation in the stack. During these days the corrected stack opacity was up to 7.7 times higher than the module opacity. On warmer days, with the ambient temperature exceeding 4.4° C (40° F), the condensation of moisture was observed inside the stack only close to the on-stack transmissometer ports. For the outside temperatures above 10° C (50° F), no visible condensation in the gas flow was observed.

As an example of the instrument's effectiveness on removing condensed moisture, a chart of the on-stack transmissometer and module transmissometer is shown in Figure 8. As seen from this figure, the on-stack transmissometer measured very high opacities after 11:00 p.m., which is the time of the furnace shutdown. At this time the red-hot perlite located on the traveling grate is quenched with water. This results in generation of nearly pure steam with only traces of particulate matter. The quenching takes place for about an hour. The steam generated during the process flows through the stack resulting in high in-stack opacity. During the same time, a continuous sample of the steam from the stack was being removed by the sampling-conditioning probe and flowed through the optical module. The steam was effectively removed in the system as seen on the module transmissometer chart, which reads zero opacity during the whole quenching process. The sample flow through the module was maintained at 85 l/min (3 acfm). The temperatures of the interior sampling probe wall averaged about 127° C (260° F), the interior conditioning module wall about 121° C (250° F), the stack gas flow 60° C (140° F), and the sample leaving the module about 88° C (190° F).

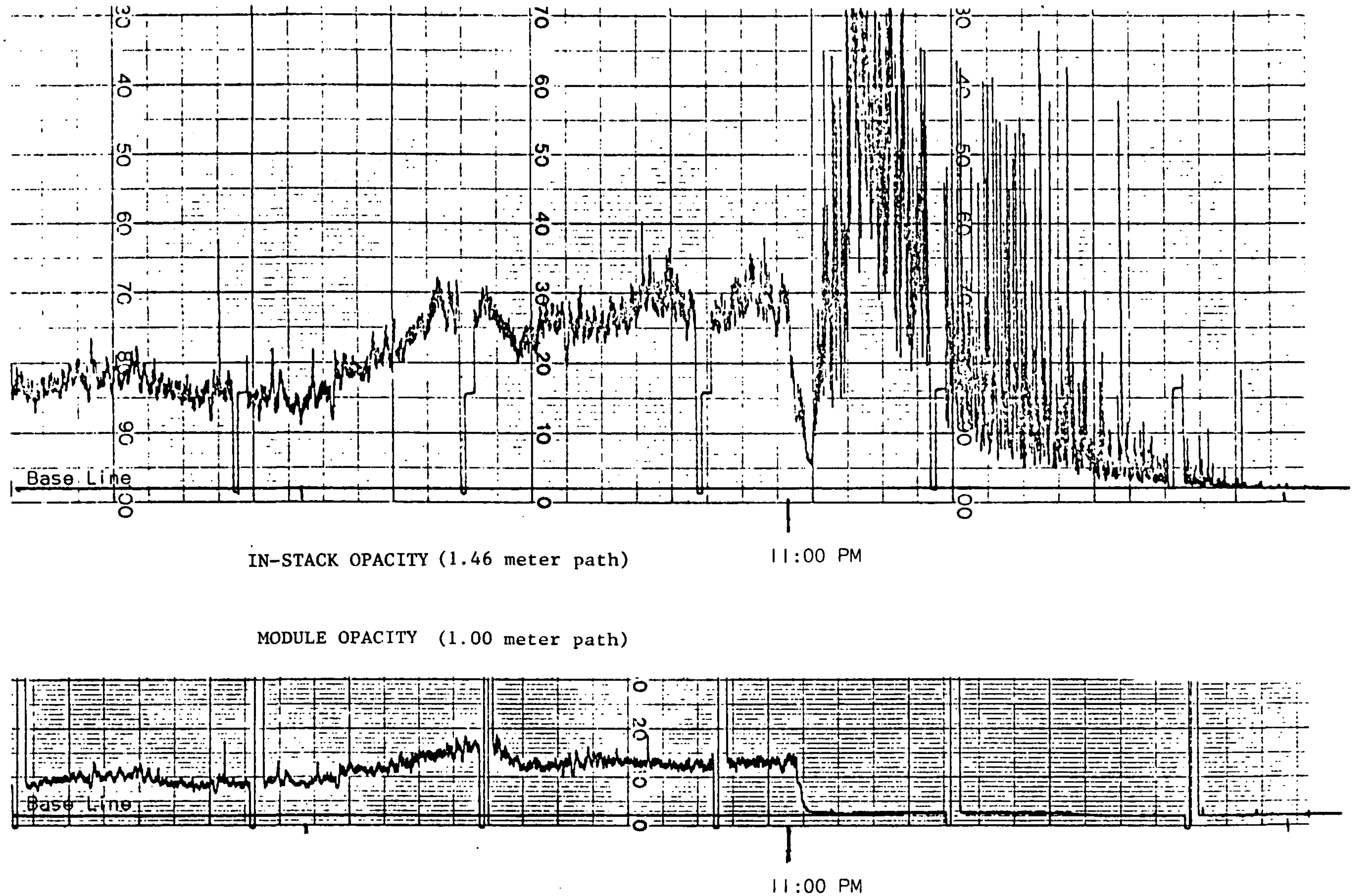


Figure 8. Sample record of the in-stack and module opacity readout

The results of the comparative tests between the on-stack opacity and module opacity have been analyzed statistically. The mean value of the ratios of the corrected on-stack opacity and module opacity for the complete test period is 1.42. The range of the ratios was from 0.96 up to 7.7. The upper limit corresponds to very intensive condensation. The corrected on-stack opacity ranged from 0 to 50 percent. The range of the module opacities was from 0 to 17 percent.

A special effort was made to manually monitor the readout of both transmissometers during several days of very warm weather when no condensation of the moisture was observed. These special tests were performed on May 21, 25, 26, 27, and 28, 1976. The test data was processed in the same manner as other data was. The ratios of the corrected stack effluent opacity and of the module opacity resulted in a mean value of 1.152. This means that the opacity measured on the conditioning module was underestimated by approximately 15 percent of the true, corrected on-stack transmissometer opacity reading. The corrected on-stack opacities were unfortunately very low, ranging from approximately 2 to 7 percent. This makes an accurate opacity determination more difficult. The standard deviation of the ratios of opacities was 0.083. The correlation coefficient for the on-stack and module opacities was approximately + 0.96 which suggests that a systematic error could have been involved during the field tests. The data sheets which document these "no condensation" tests are presented in Appendix A.

To further evaluate the agreement between the on-stack and module transmissometer readouts at higher opacity levels, a test was performed with an artificial smoke generated by burning several smoke bombs at the inlet into the I.D. fans of the perlite furnace. The smoke was a product of combustion of phosphorous compounds. The primary particles of the generated smoke are within submicron range. The test duration was several minutes and it was repeated four times. The test results are summarized in Table 3.

TABLE 3. SUMMARY OF SMOKE BOMB TESTS - SITE #1

Test #	On-Stack Opacity, Percent	Corrected On-Stack Opacity, Percent	Module Opacity, Percent	Ratio of Opacities
1	69	52.8	51	1.03
2	40	27.9	26	1.07
3	54	39.1	38	1.03
4	59	43.5	42	1.03

The agreement of opacities measured during this test was much better with the error ranging from as low as 3 percent up to 7 percent.

Two tests were also performed to determine the parameters of the expanded perlite furnace effluent. Using a velocity traverse technique, the flow rate of the gas at the stack exit was measured and was ranging from 2186 m^3/min. (77,200 acfm) to 2443 m^3/min. (86,280 acfm). The temperature of the flue gas flow was 57° C (135° F) and 66° C (150° F) respectively. The particulate concentration, which is only approximate because the sampling did not follow exactly EPA Method 5, was ranging from 134 mg/m^3wet (0.59 gr/ft^3wet) to 238 mg/m^3wet (0.10 gr/ft^3wet) although higher values were possible occasionally. The microscope analysis of the particulate sample has shown that the mass mean particle diameter is very large and was estimated at about 50 microns. The moisture content of the flue gas varies and was 10 percent by volume on the average.

WASTEWATER TREATMENT PLANT

The equipment was installed on the breaching on August 14, 1976. The regular continuous test operation started on September 16, 1976, and continued through November 11, 1976. The system was operated during this period for 24 hours a day. The instrument was down for repairs of the chopper motor of the optical module transmissometer from August 14, 1976, through September 16, 1976. The system was tested at this site for a total of approximately 1020 hours.

Major problems encountered during the test period resulted from the corrosion of the instrument material. Primarily affected were the function of thermocouples, temperature controllers of the probe and module heaters, and signal cable connectors. Maintaining proper operation of the instrument components required significant effort under these conditions. The corrosion problem developed at Site #1 because of a high content of sulfur dioxide in the effluent which resulted from burning high sulfur coal mixed with the raw perlite material. The corrosion at Site #2 was even more severe being caused by high concentrations of chlorine in the scrubbing solution.

A major functional problem was associated with the fact that the sampling probe was turned to accommodate for horizontal flow of the flue gas. This caused the large droplets and also particulate matter to be trapped inside the sampling-conditioning probe. The probe had to be cleaned mechanically about every 350 hours to maintain its proper function. On the other hand, no cleaning of the optical module was ever required.

The test conditions were really rigorous at this location with large quantities of moisture in the flue gas flow. The gas flow rate at the test location was averaging 7850 acfm wet. The flow temperature was 21° C (70° F) on the average. The moisture content was ranging from 4.5 percent by volume to as much as 18 percent by volume.

The particle concentration was ranging from 22 mg/m^3wet (0.01 gr/ft^3wet) to 84 mg/m^3wet (0.04 gr/ft^3wet). The opacity measured by the optical module (less condensed moisture) was ranging from 1.5 percent to 8 percent, respectively. At times, but very rarely, the particle concentration reached 250 mg/m^{3}wet (0.11 gr/ft^{3}wet) at the optical module opacity of about 15 percent.

One of the major drawbacks of Site #2 was a very low particulate concentration. The module transmissometer readout was below 5 to 6 percent opacity most of the time. On the other hand, it was not unusual to measure the corrected on-stack transmissometer opacity of 60 percent or more as caused by large amounts of condensed moisture.

The opacities of the on-stack transmissometer were corrected to the module conditions considering the optical path of the on-stack transmissometer to be 711 mm (28 in.) and the module transmissometer to be 1000 mm (39.4 in.). The ratios of opacities ranged from 1.6 to about 10. This means that the instrumentation never operated under no-condensed-moisture conditions.

To assess the amount of losses of particulate matter in the system, the dry flue gas flow conditions had to be created artificially by pulling dry, clean air through the incinerator which was down for repairs. The air was pulled by the I.D. fan through the scrubber without spraying the scrubbing solution. A smoke was fed into the I.D. fan inlet through an opened duct control door. The smoke was generated by a slow-burning smoke bomb identical to the test on the expanded perlite furnace. The test lasted about 7 minutes, and five readings of opacity were taken during this period of time. The results are summarized in Table 4.

It follows from the smoke test results that the accuracy of the optical module readout compared to the on-stack transmissometer is within 2 to 7 percent for the range of opacities measured.

TABLE 4. SUMMARY OF SMOKE BOMB TESTS - SITE #2

Test #	On-Stack Opacity, Percent	Corrected On-Stack Opacity, Percent	Module Cpacity, Percent	Ratio of Opacities
1	12	13.70	14	0.98
2	17	19.38	19	1.02
3	20	23.10	22	1.05
4	18	21.40	20	1.07
5	30	34.24	32	1.07

The effectiveness of the wet sample conditioning system appeared to be very good despite relatively large quantities of reentrained moisture from the scrubber and resulting from condensation. This conclusion is supported by two observations.

On September 27, 1977, the incinerator was at nearly idling condition for several hours with an insignificant amount of sludge being burnt. The on-stack transmissometer corrected opacity was over 55 percent at about 1800 hrs as double-checked visually by observing the gas flow through an opened port of the on-stack transmissometer reflector. The module transmissometer at the same time read zero opacity, and its operation was found to be normal. At 2100 hrs the incinerator was back to normal operating conditions. The on-stack transmissometer was reading corrected opacity of 85 percent and the module was reading 44 percent. The average operating parameters of the module were as follows: sample flow rate 85 l/min (3 acfm); stack flow temperature 32° C (90° F); temperature of the sampling probe interior walls 65.5° C (150° F); temperature of the module interior walls 98.9° C (210° F); sample temperature at the module outlet 65.5° C (150° F).

Another fact which indicates that the condensed moisture was being effectively removed from the sample flow was the inspection of the module interior. No particulate deposits nor any traces of moisture or marks of streaks were found inside the module even at the location where the sample impacts on the pipe baffle inside the module.

SPECIAL TESTS

The tests with the modified opacity probe, Lear Siegler RM41P, were all performed at Site #1. In these tests the Lear Siegler stack probe type RM41P has been modified by attaching two high temperature flat heaters to the probe slotted inlet as described in Section 4 of this report. The portion of the probe sample inlet slot which was exceeding the length of heaters was shielded with an aluminum foil. The probe was then tested inside a gas flow containing condensed moisture. The intention was to evaluate how much condensed steam can be removed from the sample gas flow before it enters the probe sensing volume.

The experiment failed for primarily two reasons. With the unchanged slot width, the sample flow through its sensing volume is too high and the heaters are not effective. Also, a dilution of the sample by the flushing air flow was experienced, affecting the readout accuracy.

The inlet slot width was then reduced by temporarily attaching a strip of aluminum foil along the slot. With this modification the effectiveness of the heaters has improved, but another problem has arisen. The wake turbulence downstream of the probe caused the condensed steam to enter the sensitive volume of the probe through the downstream probe slot.

It appears that with proper geometry of the probe slots and the flushing air outlet slots, the idea of using plate heaters to remove condensed moisture may be successful. Because this test was optional and was not included in the original program, lack of time did not allow working out details of this approach.

APPENDIX

Test Data for No Condensation Operating Conditions

SUMMARY OF FIELD TEST DATA

Site: Expanded Perlite Plant

Date: May 21, 1976

Time	Temperature °C Stack	Temperature °C Module	Opacity Stack %	Opacity Stack Corr. to 1m, Tm %	Opacity Module %	Opacity Stack Corr. / Opacity Module	Wind Speed km/hr	Amb. Temp. °C
00^{30}_{60}	71	71	9.50	6.61	6.25	1.06	12.9	17
01^{30}_{60}			8.50	5.91	6.00	0.99		
02^{30}_{60}			10.25	7.14	7.00	1.02		
03^{30}_{60}			9.00	6.26	6.50	0.96	16.6	15
04^{30}_{60}			9.25	6.43	6.25	1.03		
05^{30}_{60}			8.00	5.55	6.00	0.93		
06^{30}_{60}			7.75	5.38	6.00	0.90	12.9	14
07^{30}_{60}	71	60	9.00	6.26	6.00	1.04		
08^{30}_{60}			9.50	6.61	6.25	1.06		
09^{30}_{60}			9.50	6.61	6.75	0.98	18.5	18
10^{30}_{60}								
11^{30}_{60}								
12^{30}_{60}							14.8	21
13^{30}_{60}								
14^{30}_{60}								
15^{30}_{60}							14.8	21
16^{30}_{60}								
17^{30}_{60}								
18^{30}_{60}							14.8	22

SUMMARY OF FIELD TEST DATA

Site: Expanded Perlite Plant

Date: May 25, 1976

Time	Temperature °C Stack	Temperature °C Module	Opacity Stack %	Opacity Stack Corr. to 1m, Tm %	Opacity Module %	Opacity Stack Corr. / Opacity Module	Wind Speed km/hr	Amb. Temp. °C
00 30	38	49	5.75	3.72	3.00	1.24	0	14
60			6.00	4.15	3.25	1.28		
01 30			6.50	4.50	3.50	1.29		
60			6.50	4.50	4.00	1.13		
02 30			6.50	4.50	4.00	1.13		
60			6.25	4.33	3.75	1.15		
03 30	43	66	7.00	4.85	4.00	1.21	0	9
60			5.00	3.23	2.75	1.17		
04 30			4.75	3.07	2.25	1.36		
60			3.25	2.09	2.00	1.05		
05 30			3.50	2.26	2.00	1.13		
60			3.75	2.42	2.25	1.08		
06 30	54	77	4.00	2.58	2.25	1.15	9.4	12
60			4.00	2.58	2.25	1.15		
07 30			4.00	2.58	2.25	1.15		
60			3.80	2.46	2.00	1.23		
08 30			4.00	2.58	2.25	1.15		
60			3.00	1.44	1.75	1.11		
09 30	66	88	3.50	2.26	2.00	1.13	7.4	18
60			4.50	2.91	2.50	1.16		
10 30			3.50	2.26	2.00	1.13		
60			4.00	2.59	2.25	1.15		
11 30			3.75	2.42	2.25	1.08		
60			4.00	2.59	2.50	1.15		
12 30	77	88	4.25	2.75	2.50	1.10	12.9	22
60								
13 30								
60								
14 30								
60								
15 30							11.[illegible]	2[illegible]
60								
16 30								
60								
17 30								
60								
18 30							14.[illegible]	[illegible]
60								

SUMMARY OF FIELD TEST DATA

Site: Expanded Perlite Plant

Date: May 26, 1976

Time	Temperature °C Stack	Temperature °C Module	Opacity Stack %	Opacity Stack Corr. to 1m, Tm %	Opacity Module %	Opacity Stack Corr. / Opacity Module	Wind Speed km/hr	Amb. Temp. °C
00 30	38	38	6.25	4.06	3.50	1.16	12.9	15
00 60			5.00	3.45	2.75	1.25		
01 30			5.50	3.80	3.00	1.27		
01 60			5.00	3.45	2.50	1.38		
02 30	43	66	6.00	4.15	3.25	1.28		
02 60			5.75	3.72	3.00	1.24		
03 30			5.00	3.23	2.75	1.17	5.5	12
03 60			7.00	4.54	3.75	1.21		
04 30	54	71	5.00	3.23	2.75	1.17		
04 60			6.50	4.29	3.75	1.14		
05 30			7.00	4.62	4.00	1.16		
05 60			6.25	4.12	3.50	1.18		
06 30	66	82	5.50	3.62	3.00	1.21	7.4	13
06 60			9.00	5.97	5.25	1.14		
07 30			5.75	3.79	3.00	1.26		
07 60			7.00	4.63	4.00	1.16		
08 30	66	82	6.00	3.96	3.25	1.22		
08 60			5.50	3.63	3.00	1.21		
09 30			7.00	4.63	4.00	1.16	9.3	20
09 60			8.00	5.30	4.50	1.18		
10 30			6.50	4.29	4.00	1.07		
10 60			8.00	5.30	5.00	1.06		
11 30			8.00	5.30	4.75	1.12		
11 60			8.25	5.47	5.00	1.07		
12 30	66	77	7.75	5.13	4.25	1.21	14.8	25
12 60								
13 30								
13 60								
14 30								
14 60								
15 30							22.2	25
15 60								
16 30								
16 60								
17 30								
17 60								
18 30							12.9	24
18 60								

SUMMARY OF FIELD TEST DATA

Site: Expanded Perlite Plant

Date: May 27, 1976

Time	Temperature °C Stack	Temperature °C Module	Opacity Stack %	Opacity Stack Corr. to 1m, Tm %	Opacity Module %	Opacity Stack Corr. / Opacity Module	Wind Speed km/hr	Amb. Temp. °C
00 30	54	66	6.00	4.02	3.75	1.07	5.5	17
00 60			5.50	3.68	3.25	1.13		
01 30			5.25	3.51	2.75	1.28		
01 60			5.50	3.68	3.00	1.23		
02 30	54	71	5.25	3.51	3.00	1.17		
02 60			5.00	3.29	2.75	1.20		
03 30			4.50	2.96	2.50	1.18	0	14
03 60			4.50	2.96	2.50	1.18		
04 30	60	77	3.50	2.30	2.25	1.02		
04 60			5.00	3.29	3.00	1.10		
05 30			6.50	4.29	4.00	1.07		
05 60			7.00	4.63	4.50	1.03		
06 30	60	71	6.75	4.46	4.25	1.05	7.4	13
06 60			5.50	3.68	3.25	1.13		
07 30			5.50	3.68	3.25	1.13		
07 60			7.25	4.87	4.00	1.22		
08 30	60	77	5.25	3.51	3.50	1.00		
08 60			5.00	3.34	3.00	1.11		
09 30			5.00	3.34	3.00	1.11	24.1	23
09 60			5.50	3.68	3.75	0.98		
10 30	66	77	7.50	5.04	4.25	1.19		
10 60			7.50	5.04	5.00	1.01		
11 30			9.50	6.41	6.00	1.07		
11 60			10.00	6.75	7.00	0.96		
12 30	66	82	8.50	5.72	5.75	0.99	25.9	26
12 60			9.00	6.07	6.00	1.01		
13 30								
13 60								
14 30								
14 60								
15 30							24.1	26
15 60								
16 30								
16 60								
17 30								
17 60								
18 30							18.5	16
18 60								

SUMMARY OF FIELD TEST DATA

Site: Expanded Perlite Plant

Date: May 28, 1976

Time	Temperature °C Stack	Temperature °C Module	Opacity Stack %	Opacity Stack Corr. to 1m, Tm %	Opacity Module %	Opacity Stack Corr. / Opacity Module	Wind Speed km/hr	Amb. Temp. °C
00^{30}	49	49	9.00	6.26	6.00	1.04	20.5	16
00_{60}			8.75	6.08	5.75	1.06		
01^{30}			8.50	5.91	5.00	1.18		
01_{60}			8.00	5.55	4.50	1.23		
02^{30}	54	66	9.00	6.06	4.00	1.52		
02_{60}			8.00	5.55	4.25	1.31		
03^{30}			9.00	6.06	4.00	1.52	22.2	16
03_{60}			8.50	5.63	4.50	1.25		
04^{30}	60	71	8.50	5.63	4.00	1.41		
04_{60}			9.00	5.96	4.50	1.32		
05^{30}			9.50	6.30	5.00	1.26		
05_{60}			10.00	6.64	5.00	1.33		
06^{30}			10.50	6.98	6.00	1.16	16.7	17
06_{60}			9.00	5.96	6.00	0.99		
07^{30}			7.75	5.12	5.00	1.02		
07_{60}			8.50	5.63	5.00	1.13		
08^{30}								
08_{60}								
09^{30}								
09_{60}								
10^{30}								
10_{60}								
11^{30}								
11_{60}								
12^{30}								
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TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-77-124	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE INSTRUMENTATION FOR MONITORING THE OPACITY OF PARTICULATE EMISSIONS CONTAINING CONDENSED WATER		5. REPORT DATE August 1977
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Milos Tomaides		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Interpoll, Inc. 1996 West County Road C St. Paul, Minnesota 55113		10. PROGRAM ELEMENT NO. 1AA010 26AAM-27 (FY-75)
		11. CONTRACT/GRANT NO. 68-02-2225
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15. SUPPLEMENTARY NOTES

16. ABSTRACT

On-stack instrumentation and methodology were developed to monitor the opacity of particulate pollutants in stationary source emissions containing condensed water. The instrument continuously extracts and measures the opacity of representative samples of particulate effluent. It discriminates between pollutant particles and condensed water by increasing the temperature of the sample and vaporizing the condensed moisture. The opacity of the remaining particles is measured with any commercially available high precision optical transmissometer.

The instrument was successfully field tested on (1) the effluent from a furnace of an expended perlite manufacturing plant and (2) the effluent from a wet scrubber of a sludge incinerator. For particulate emissions containing no condensed water, opacity results measured by the new instrument compared favorably with results measured by a conventional across-stack transmissometer monitor.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
*Air pollution		13B
*Particles		07D
*Aerosols		07B
Water		13M
Chimneys		14B
*Opacity		
*Optical measurement		
Transmissometers		

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