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Publication Date

1979-04-01

Submitted to Pollution Engineering.

LBL-8935 c.
Preprint

Energy and Environment Division

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April 1979

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Prepared for the U.S. Department of Energy under Contract No. W-7405-ENG-48

LBL-8935 c.2

INDUSTRIAL WATER DISCHARGES AND STATIONARY SOURCE PARTICULATE EMISSIONS

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Introduction

Recent legislation designed to prevent the deterioration of our environment has led to a surge of interest in analytical chemistry. There has been a surge both in the development of analytical instrumentation and in the promulgation of guidelines that prescribe permissable levels of pollutant emission. This situation has resulted in the need for many people to make decisions about the purchase of analytical instruments.

A choice must be made first between the numerous techniques which may be used to make a certain measurement. After determining which technique is to be used, the analyst must decide which of the many commercially available instruments he will purchase. Manufacturers invariably have several models of similar instruments from which to choose and differences between these models and those of other manufacturers are often unclear. Even after this selection has been made, it is essential that the analyst understand the principles of operation of the instrument and the potential interferences caused by his particular sample type.

To aid laboratories in choosing among the techniques and instruments currently available for the determination of industrial discharges, a survey of instrumentation used for analysis and monitoring of environmental pollutants was undertaken in 1971.

For the past eight years the Survey of Instrumentation for Environmental Monitoring has described instrumentation used to analyze air and water quality, radiation emissions and biomedical impacts. It has grown from four looseleaf binders to seven, including AIR (Gases, 2 binders and Particulates, 1 binder), WATER (2 binders), RADIATION (1 binder), and BIOMEDICAL (1 binder) with over 8000 pages and more than 5000 volumes in circulation.

This paper contains condensed excerpts from the Survey illustrating the variety of information which is included.

Water Discharges

The same increase in national productivity that has led to an increase in the standard of living is now threatening to lower that standard because of environmental pollution. With the goal of achieving water clean enough for recreation, and for the protection and propagation of wild life, legislation has been passed to eliminate, eventually, the discharge of pollutants into the national water system. The approach is to allow the discharge of various pollutants by specific industries and require control technologies to be used to maintain discharge of these pollutants below specific levels. These restrictions are enforced by the requirement that a permit be issued before discharges are permitted (National Pollutant Discharge Elimination System).

The effluent guidelines and standards for 42 industrial categories have been published in the Code of Federal Regulations.[1] Each category is broken down into subcategories and guidelines are given for these more than 400 specific operations (e.g. pharmaceutical mnaufacture is divided into fermentation products, extraction products, chemical synthetic products, mixing and formulation, and research). Table I[1] lists the 42 major categories with the pollutants whose discharge is allowed.

Different effluent levels are allowable depending on the following:

1) the industrial subcategory

2) the control technology required (i.e., best conventional technology, best available technology economically achievable)

3) whether or not it is a new source (new sources are more severly regulated than existing sources)

4) where the effluents are discharged (effluent levels discharged into publicly owned treatment works may be different from direct discharges into navigable waters).

Because of the more than 400 subcategories and the many possible conditions of effluent emission for each, a table displaying the effluents associated with each condition would be too large for publication here. Pollutants which may be discharged by industries in the major categories are listed in Table I. In many cases, the associated pollutants are the same for all subcategories of the major categories. Exceptions to this are also indicated in the table. For details that pertain to a specific industry, the Code of Federal Regulations[1] should be consulted. Because the promulgation of effluent guidelines is an ongoing process,[2] the EPA should be contacted for the latest information.[3]

The abbreviations used in the Table refer to methods of pollutant detection described in the Code of Federal Regulations.[4] The following less obvious symbols are defined as follows

BOD5 - biochemical oxygen demand - 5 day test
Cl residual - this test measures the chlorine remaining after a specified contact time
CN - cyanide
COD - chemical oxygen demand
Cr(VI) - this test determines the concentration of chromium in the +6 state
fecal coliform - this test is a measure of the number of bacteria of fecal origin
NH_3(N) - nitrogen present as ammonia
NO_3(N) - nitrogen present as nitrate
organic N - nitrogen present as part of an organic species
PCB - polychlorinated biphenyls
Ra226 - the isotope of radium whose atomic weight is 226 gm/mole
TKN - total Kjehldal nitrogen (organic nitrogen plus ammonia nitrogen)
TSS - total suspended solids.

All pollutants are classified as either conventional, toxic or non-conventional. Conventional pollutants include BOD, TSS, and pH (others could be proposed soon).[5] There are 129 priority pollutants that appear on the toxics list in the Federal Register.[6] They also appear in a recent issue of Pollution Engineering.[7] Non-conventional pollutants are those that are neither toxic or conventional, (i.e., NO_2^-, P, oil and grease). Best conventional pollutant control technology will be required for conventional pollutants by July 1, 1984. Best available technology economically achievable will be required for toxic and non-conventional pollutants by the same date.[5] In the meantime different technologies and different levels have been promulgated depending on the industrial process.

There can be no question of the determination of Congress to improve the quality of the nation's waters within the next five years. This attitude of the government will without doubt encourage the development of new pollution control technologies and new monitoring instrumentation. Time will tell how successfully pollution engineers and instrument manufacturers will be in meeting the challenge.

Stationary Source Particulate Emissions

There are at least three reasons why it may be important to monitor stationary source particulate emissions: 1) to safeguard workers from occupational exposure 2) to assess performance of industrial operations and 3) and to limit environmental pollution by adherence to the regulations of the Environmental Protection Agency. An excellent description of air sampling instrumentation with emphasis on protection of the worker has recently been published by the American Conference of Government Industrial Hygienists.[8] Here, we will be primarily concerned with particulate monitoring carried out for the second and third reasons.

The Environmental Protection Agency has promulgated two methods for assessing the extent of particulate emissions from stationary sources. One method (gravimetric method) requires that a portion of the stationary source gases be passed through a filter and the mass of the particulate contained in a known volume of gas be determined gravimetrically. The other method (opacity method) is an estimate of the particulate loading in a gas stream that is obtained by measuring the extent to which the intensity of a light beam is decreased. The gravimetric method is difficult and somewhat time consuming because:

1) Many samples must be taken because a single sample may not accurately represent the particulate content of the gas being sampled either because of lack of homogeneity, or because of non-isokinetic sampling.
2) Frequently small masses are involved, and much effort is required to obtain meaningful weights of the filter before and after sampling because of handling difficulties.
3) Errors caused because of the absorption of water vapor by the filter during sampling must be avoided.
4) Static charge must be removed from the filter before weighing.

The approved manner of carrying out the sampling and weighing procedure is described by the Environmental Protection Agency.[9] (Method 5 "Determination of Particulate Emissions from Stationary Sources").

The opacity method derives from the simple idea that the smaller the fraction of light transmitted through the gas, the higher the quantity of particulate matter. The transmission (T) is the ratio of transmitted light intensity (I) to the incident intensity (I_0) that is $T = I/I_0$ and the opacity (0) is defined as $0 = I-T$. Since light scattering depends on the size and composition of the scattering material, it is difficult to determine a direct relationship between opacity and particulate mass. However, opacity measurements are used as indicators of change in emission output and opacity standards have been established for many industrial operations. Particulate and opacity standards for new stationary sources that have been taken from the Code of Federal Regulations[10] are listed in Table II. This reference should be consulted in order to be sure of compliance with regulations of the Environmental Protection Agency.

In order to increase the probability of valid opacity measurements, the Environmental Protection Agency has published a list of performance specifications[11] that should be met by opacity measuring instruments also known as transmissometers. These specifications are listed in Table III. The calibration error is determined by comparing the transmissometer reading with filters of known opacity. A total of five nonconsecutive readings should be made for three different filters. Zero drift is determined by taking readings at 24 hour intervals during a 7 day test period. Calibration drift is obtained by an opacity reading of the same filter every 24 hours. Response time is determined by inserting the highest opacity filter and noting the time required for the reading to reach 95% of the final value. Also the time required for the reading to return 95% of the distance toward zero when the filter is removed is noted. Both of these time periods should be less than 10 seconds.

In addition to the above electronic stability requirements, transmissometers must be only sensitive to the wavelength region between 400 and 700 nm and must have a limited field of projection and field of vision (< 5 degrees). The wavelength restriction is necessary because the infrared absorption of water vapor and carbon dioxide will cause errors in all regions except 400-700 nm. The larger light scattering effects in the ultraviolet region also indicate it should be avoided. The restricted projection field and viewing field is to lessen the effects of scatter in the visible spectral region and the effects of ambient light. The EPA also requires frequent zero and span checks so that an instrument malfunction will be quickly detected. This procedure will point out such problems as electronic drift due to line voltage changes, phototube drift because of temperature changes, light intensity drift with aging, and degradation of optical alignment caused by deformation of the stack.

Manufacturers have come up with some ingenious approaches to preserve optical alignment during stack distortion:

1) a probe is attached to one side of the stack. This probe consists of a pipe with a light source mounted on the end that is inserted into the stack and a photodetector on the other end -- the photodetector remains outside the stack. Slots are cut into the probe such that stack gases flow between the light source and detector.

2) a breech pipe extends through the stack and slots are cut through the pipe.

3) a breech rod extends through the stack and rigidly holds the detector and light source; the gases below the rod are monitored.

4) collimated optics with a retro-reflector are arranged to minimize light losses due to stack distortion. This avoids the use of breech rods or pipes. A double-pass approach continuously corrects for variations caused by temperature, line voltage lamp aging and electronic aging. This approach depends upon having both the light source and photodetector on the same side of the stack and is illustrated in Fig. 1.[12]

With this configuration beam splitting devices and choppers can be used to monitor changes in intensity of the light source and drift in photodetector response. Auxiliary light sources and mirrors have been incorporated into some of these configurations so that zero and span calibration can be carried out easily or, in some cases, automatically. Air blowers are used to keep windows clean, and separate photodetectors are sometimes used to monitor light transmission through the windows and thus indicate the presence of dirt on the window surface. Pulsed light sources are sometimes used to prevent error caused by ambient light in the stack. Although these seen to be good solutions to the most serious of the opacity measurement problems, the potential buyer should talk to users of these instruments to evaluate their actual performance. The various manufacturers of transmissometers are listed in Table IV along with special instrumental features that allow a preliminary comparison to be made. The cost that appears in this table is the base cost and does not necessarily include all of the options listed in the read out column.

Since the relationship between opacity and mass concentration is so dubious, one might wonder why measure opacity at all? The rationale for requiring most stationary sources to adhere to opacity standards is set forth by the EPA.[13] Opacity monitoring is intended not to measure mass but to verify on a day-to-day basis that control eqipment is operating properly. As such, opacity standards (in %) for each source category are set so they are less restrictive than the applicable mass standard. The EPA argues that a full source test for mass emissions is too expensive for routine monitoring for compliance, and the necessity to schedule such a test 2 weeks or longer in advance provides ample opportunity for those inclined to cheat by reducing the power to their control equipment until the test begins or leaving repairs to the last minute. Opacity standards are therefore established at a level requiring proper operation and maintenance of the control equipment, as a kind of warning or alarm level indicating non-compliance.

However, it must be pointed out that the opacity provisions are independently enforceable standards, just like the mass standards, and that it is not necessary to show that the mass standard has been violated to support enforcement of the opacity standard.[13]

Recent efforts to improve particulate monitoring techniques have been reported at a symposium sponsored by the EPA/IERL process measurement branch.[14] The goal is to produce a more accurate, less expensive, easier to use instrument that puts out time resolved data. It was verified that transmissometers produce reliable mass data if the particulate matter has constant physical and chemical properties. It may be possible to combine particle size data with opacity data to obtain a reliable mass measurement. An instrument has been described that provides particle size data in hot stack environments. This instrument measures the near forward scattering of a laser beam by the stack emissions.[14] Other new techniques (i.e., charge transfer, light backscatter and beta ray attenuation) were also discussed at this symposium. Given time, it is certain that ongoing work in this field will improve the monitoring process.

ACKNOWLEDGMENT

This work was supported by the Energy and Environment Division of the Department of Energy.

REFERENCES

1. 40 CFR 401 thru 461 available from the Superintendent of Documents of U. S. Government Printing Office, Washington, D. C. 20402
2. See, for example Fed. Reg. 43(164) 37570-37607 (Aug. 1978) (see Ref. 1 for procurement.
3. Director, Effluent Guidelines Division, Office of Water Planning and Standards, U. S. Environmental Protection Agency, Washington, D. C. 20460, (202) 426-2571.
4. 40 CFR 136 (see Ref. 1 for procurement information).
5. "Modifying the NPDES" Environ. Sci. Technol. 12(9) 1002 (1978).
6. Fed. Ref. 43(164) 4108 (Feb. 1978) (see Ref. 1 for procurement.)
7. "EPA Effluent Guidelines Division List of Priority Pollutants for B.A.T. Revision Studies," Poll. Eng. 9(12) 40 (1977).
8. American Conference of Government Industrial Hygienists, "Air Sampling Instruments for Evaluation of Atmospheric Contaminants" Fifth edition. Published by the American Conference of Government Industrial Hygienists, P.O. Box 1937, Cincinnati, OH 45201
9. United States Environmental Protection Agency, 40 CFR 60, Appendix A, Method 5. (See Ref. 1 for procurement).
10. Reference 9, Section 60.40 through Section 60.275.

11. Reference 9, Section 60, Appendix B, Performance Specification 1.

12. "Application Engineering Handbook", Brochure # 101A, 2nd edition Dynatron Inc., 1978 available from Dynatron Inc., Barnes Industrial Park, Box 745, Wallingford, CT 06492

13. Fed. Reg. 39:9308 (March 8, 1974) available from Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.

14. "Particle Sampling and Measurement" Environ. Sci. Technol. 12(8) 881 (1978).

Table 1. Pollutants Associated with Various Industries

Point source category	Number of subcategories	Allowed discharges or parameters which may be changed
Dairy Products processing	12	All subcategories - BOD5, TSS, pH
Grain Mills	10	All subcategories - BOD5, TSS, pH
Canned and Preserved fruits and vegetables	8	All subcategories - BOD5, TSS, pH
Canned and Preserved seafood	33	All subcategories - TSS, pH, oil and grease; 7 subcategories - BOD5 and 3 - debris larger than 0.5 inches
Sugar Processing	8	Two subcategories may not discharge pollutants into navigable waters; all others BOD5, TSS and pH; one subcategory - coliform and high temperature
Textile Industry	7	All subcategories - BOD5, COD, fecal coliform, and pH; six subcategories - phenol, color, S, and Cr.
Cement Manufacture	3	All subcategories - TSS and pH; two subcategories - temperature
Feedlots	16	15 subcategories may not discharge pollutants into navigable waters; one subcategory may discharge BOD5 and fecal coliform
Electroplating	6	24 separate pollutants are listed; consult 40 CFR 413 to relate subcategory to pollutant
Organic chemicals Manufacture	2	BOD5, TSS, pH, COD

(continued)

Table 1. (continued)

Point Source Category	Number of subcategories	Allowed discharges or parameters which may be changed
Inorganic Chemicals Manufacture	63	The information on this large number of subcategories is too varied to itemize in this table; consult 40 CFR 415.
Plastics and synthetics	21	pH
Soap and Detergent Manufacture	19	All subcategories - BOD5, TSS, pH, COD, oil and grease; 11 subcategories - surfactants
Fertilizer Manufacture	9	The following pollutants may be discharged by industries in the various subcategories: TSS, pH, P, F, NH_3(N), org. N, NO_3^-(N) consult 40 CFR 418 for details
Petroleum Refining	5	BOD5, TSS, pH, COD, oil and grease, phenols, NH_3(N), S, Cr, Cr(VI)
Iron and Steel Manufacture	26	The information on these subcategories is too varied to itemize in this table; consult 40 CFR 420
Nonferrous Metals Manufacture	8	The information on these subcategories is too varied to itemize in this table; consult 40 CFR 421
Phosphate Manufacture	6	All subcategories - TSS, pH, and total P; 4 cubcategories - F; one subcategory - with As and elemental P
Steam Electric Power Generating	4	One subcategory - TSS and pH; all others - TSS, pH, PCB, oil and grease, Cu, Fe, Cl, Zn, Cr and P

(continued)

Table 1. (continued)

Point Source Category	Number of subcategories	Allowed discharges or parameters which may be changed
Ferroalloy Manufacture	7	The most common pollutants are TSS, pH, Mn, and Cr; consult 40 CFR 424 for details
Leather, Tanning Industry	6	All subcategories - BOD5, TSS, pH, Cr, oil and grease, TKN, fecal coliform, and S
Glass Manufacture	13	All subcategories - TSS and pH; many may discharge oil, consult 40 CFR 426
Asbestos Manufacture	11	Two subcategories may not discharge pollutants into navigable waters; all others TSS and pH; two - COD
Rubber Manufacture	11	All subcategories - TSS, pH, and oil and grease. Other pollutants which may be discharged are COD, Pb, Cr, and Zn, in some subcategories
Lumber Products Processing	19	Eight subcategories may not discharge pollutants into navigable waters; BOD5, TSS, pH, COD, oil and grease, phenols, settleable solids and debris, some subcategories
Pulp, Paper and Paperboard	23	All subcategories - BOD5, TSS, and pH
Builders' Paper and Roofing	1	BOD5, TSS, pH, settleable solids
Meat Products	10	All subcategories - BOD5, TSS, pH, oil and grease, and fecal coliform; most subcategories - NH_3

(continued)

Table 1. (continued)

Point Source Category	Number of subcategories	Allowed discharges or parameters which may be changed
Coal Mining	3	All subcategories - TSS, pH and Fe; two subcategories - Mn
Offshore Oil and Gas Extraction	5	One subcategory may not discharge pollutants into navigable waters; all others - oil and grease, three - Cl residual
Mineral Mining and Processing	38	Guidelines for 17 of these subcategories have not yet been promulgated; 16 may not discharge pollutants into navigable waters; 5 - TSS and pH; one - Fe
Pharmaceutical Manufacture	5	All subcategories - BOD5, pH and COD; three - TSS
Ore Mining and Dressing	7	All subcateogires - TSS and pH; COD, Fe, Cu, Zn, Pb, Hg, Cd, CN, Al, As, Ra226, U, and Ni may be discharged by industries in various subcategories
Paving and Roofing (Tars and Asphalts)	4	One subcategory may not discharge pollutants into navigable waters, all others - TSS and pH, one - oil and grease
Paint Formulating	1	This subcategory may not discharge pollutants into navigable waters
Ink Formulating	1	This subcategory may not discharge pollutants into navigable waters
Gum and Wood Chemicals Manufacture	6	One subcategory may not discharge pollutants into navigable waters; all others - BOD5, TSS and pH

(continued)

Table 1. (continued)

Point Source Category	Number of subcategories	Allowed discharges or parameters which may be changed
Pesticide Chemicals Manufacture	5	Two subcategories may not discharge pollutants into navigable waters; all others - BOD5, TSS, pH, COD and total pesticides; $NH_3(N)$ and phenol - some subcategories
Explosives Manufacturer	2	Both subcategories - with TSS and pH; BOD5, COD, oil and grease - one subcategory
Carbon Black Manufacture	4	None of the subcategories may discharge pollutants into navigable waters
Photographic	1	pH, Ag, CN
Hospital	1	BOD5, TSS, pH

TABLE II:[10] PARTICULATE STANDARDS[†]

Point Source Categories	Regulation Governing Mass		Regulation Governing Opacity
Fossil-Fuel Fired Steam Generator	0.18 g/million cal 0.10 lb/million Btu		20% opacity except 40% opacity for 2 min. in any hour
Incinerators	0.18 g/dscm 0.08 gr/dscf	corrected to 12% CO_2	
Cement plants kiln	0.15 kg/metric ton 0.30 lb/ton	feed to the kiln	20% opacity
clinker cooler	0.050 kg/metric ton 0.10 lb/ton	feed to the kiln	10% opacity
all other facilities			10% opacity
Sulfuric acid plants			10% opacity
Asphalt concrete plants	90 mg/dscm 0.04 gr/dscf		20% opacity
Petroleum refineries	1.0 kg/1000 kg 1.0 lb/1000 lb	of coke burn off in the catalyst regenerator	30% opacity except for 3 minutes in any 1 hour
	additional 0.18 g/10^6 cal 0.10 lb/10^6 Btu	when auxiliary liquid or solid fossil fuels are burned	
Secondary lead Smelters	50 mg/dscm 0.022 gr/dscf	blast furnace	20% opacity (blast furnace) 10% opacity (pot furnace)

(continued)

TABLE II: PARTICULATE STANDARDS (continued)

Secondary Brass and Bronze	50 mg/dscm 0.022 gr/dscf	reverberatory furnace	20% opacity (reverberatory furnace) 10% opacity (blast furnace)
Iron and Steel	50 mg/dscm 0.022 gr/dscf		
Sewage Treatment plant	0.65 g/kg 1.30 lb/ton	of dry sludge input	20% opacity
Primary Copper Smelters	50 mg/dscm 0.022 gr/dscf		20% opacity
Primary Zinc Smelters	50 mg/dscm 0.022 gm/dscf		20% opacity
Primary Lead Smelters	50 mg/dscm 0.022 gr/dscf		20% opacity
Primary Aluminum Reduction Plants			10% opacity (potroon gases) 20% opacity (anode bake plant gases)
Coal Preparation Plants thermal dryer gases	0.070 g/dscm 0.031 gr/dscf		20% opacity
cleaning equipment gases	0.040 g/dscm 0.018 gr/dscf		10% opacity
other processing and conveying equipment			20% opacity

(continued)

TABLE II: PARTICULATE STANDARDS (continued)

Ferroalloy Production Facilities (Ref. 3 for details)		
while producing silicon metal, ferrosilicon, calcium silicon, or silicomanganese zirconium	0.45 kg/MW-hr 0.99 lb/MW-hr	15% opacity
while producing high-carbon ferrochrome, charge chrome, standard ferromanganese, silicomanganese, calcium carbide, ferrochrome silicon, ferromanganese silicon, or silvery iron	0.23 kg/MW-hr 0.51 lb/MW-hr	15% opacity
dust handling equipment		10% opacity
atmospheric emission control devices		report all six minute periods of 15% opacity or greater
Steel Plants: Electric Arc Furnaces (Ref. 3 for details)		
gases from electric arc furnace control device	12 mg/dscm 0.0052 gr/dscf	3% opacity
shop during charging periods		20% opacity
shop during tapping periods		40% opacity
shop during other times		0% opacity
dust handling equipment		10% opacity

(continued)

Footnote to TABLE II.

†Abbreviations used in Table:	Btu - British thermal unit, cal - calorie, dscm - dry cubic meter (s) at standard conditions, dscf - dry cubic feet at standard conditions, g - gram, gr - grain, kg - kilogram, lb - pound, mg - milligram

TABLE III[11] TRANSMISSOMETER PERFORMANCE SPECIFICATIONS

Calibration error	< 3% opacity
Zero drift (24h)	< 2% opacity
Calibration drift (24h)	< 2% opacity
Response time	10s max.
Operational test period	168 hours

TABLE IV. IN SITU OPACITY STACK MONITORING INSTRUMENTS (continued)

Manufacturer	Model	Number of passes	Attachment to stack	Type of readout	E.P.A. Specifications	Cost (kilo $)
Environmental Data Corp.	DIGA Series	double	both sides of stack	opacity, analog, digital recorder, alarm, indicator light, digitizer, auto. calib.	Yes	15 (part of multi gas monitoring system)
Fireye Division Electronic Corp. of America	FE-4 system 27 RL1 transceiver P/N 61-4183 reflector	double	breech pipe both sides of stack	opacity, Ringelmann, relay, alarm, recorder, timer	NA	0.39
	FE-5 system 44DU2 light source 47 EM4 receiver 27 PH7 control/indicator	single	both sides of stack	opacity, Ringelmann, recorder, alarm indicator lights	NA	1.41
Jacoby-Tarbox Corp.	5/D	single	both sides of stack	transmission 0-100%, turbidity 0-100%, analog, alarm, control relays, recorder	No; intended for process control	1.1
Lear Siegler Inc.	RM41	double	both sides of stack	opacity 0-100%, optical density, range switch (5), analog, alarm, status indicators† auto. calib.	Yes	4.6
Lear Siegler Inc.	RM7A	double	both sides of stack	opacity 0-100%, range switch (2) analog, recorder, alarm, control relays	Yes; except calib. error NA	2.7
Photobell Company Inc.	SMXL/AL	double	breech pipe both sides of stack	transmission, indicator lights, relay contacts	NA	1.45

(continued)

TABLE IV. IN SITU OPACITY STACK MONITORING INSTRUMENTS

Manufacturer	Model	Number of passes	Attachment to stack	Type of readout	E.P.A. Specifications	Cost (kilo $)‡
Airflow Development Ltd.	SEROP	single	probe one side of stack	0-100% obscuration, meter, recorder, data logger, alarm	NA*	5.9
Andersen Samplers Inc. (formally Joy Manufacturing Co.)	10-43	double	both sides of stack, probe optional	opacity 0-100% optical dens. 0 - ∞, analog, digital, alarm, recorder, data logger, status indicators, control relays	Yes	5.0
Bailey Meter Co.	E66-45 type UJ	single	breech pipe both sides of stack	0-100%, opacity range switch (2), meter, recorder, alarm	Yes; except calib. drift and calib. error	1.7
Controls Inc.	Series 8000	single	breech pipe both sides of stack	opacity 0-100% Ringelmann 0-5 analog, alarm, recorder	No	0.9
Contraves Goerz Corp.	400	double	both sides of stack	opacity 0-100%, optical density, 6 min integrated opacity and optical density, recorder alarm, status indicators, auto. calib.	Yes	
Contraves Goerz Corp.	401 P	double	probe, one side of stack	0-100% opacity, digital	Yes	5.5
Datatut Inc.	90AS	single (fiber optic corrector)	Breech pipe both sides of stack	Opacity 0-100%, analog, alarm, relay contacts recorder, auto. calib.	Yes	3.5
De-tic-tronic Corp.	345 P 285	single	both sides of stack	Ringlemann 0-5, indicator light, relay, recorder, alarm	NA	0.4
Dynatron Inc.	1100	double	both sides of stack, probe optical	opacity 0-100% optical dens. 0 - ∞, analog, digital, alarm, recorder 6 min. average counter timer,* auto. calib.	Yes	6.0 inc. digital display, auto span corrector

(continued)

TABLE IV. IN SITU OPACITY STACK MONITORING INSTRUMENTS (continued)

Manufacturer	Model	Number of passes	Attachment to stack	Type of readout	E.P.A. Specifications	Cost (kilo $)
Dynatron Inc.	301	single	both sides of stack	opacity 0-100%, analog, digital alarm, counter timer*	Yes	1.5 inc. digital display, recorder
Photomation	DSM-1PP	single	both sides of stack	opacity 0-100%, Ringlemann units, analog, digital recorder alarm, control relay	Yes	2.8
Preferred Instruments	JC30F4C	single	breech rod both sides of stack	transmission, Ringlemann, indicator light, recorder, alarm	Yes; except response time NA	
Reliance Instrument Corp.	Rimcor P1X 101	single	breech rod both sides of stack	opacity 0-100%, Ringelemann units, analog, recorder, alarm control relays	Yes; except zero drift, calib. drift NA	1.3
Research Appliance Co.	RAC	double	both sides of stack	opacity 0-100%, analog, recorder, alarm, relay contacts, auto. calib.	Yes	7.2
Robert H. Wager Co. Inc.	P-6 Series	single	both sides of stack	opacity 0-100% range (2), analog	NA, intended for marine application	NA

‡Cost is base cost and does not necessarily include all the options listed in the read out column.

*NA = not available

*The counter timer totalizes the number of occurrences and total duration time that measured opacity level has been exceeded.

†Status indicators warn of malfunction of air purge system; shutters and on stack electronics. They also indicate dirty optical surfaces, and over-range operation.

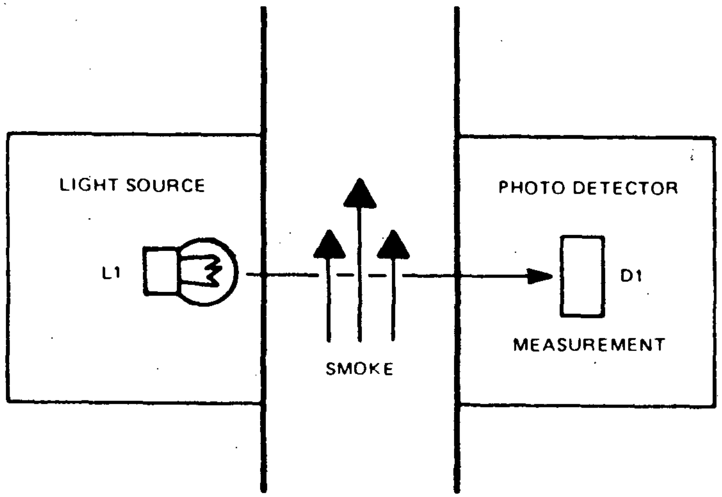

Fig. 1a. Single pass transmissometer.
(Courtesy of Dynatron Inc.
Wallingford, CT.)

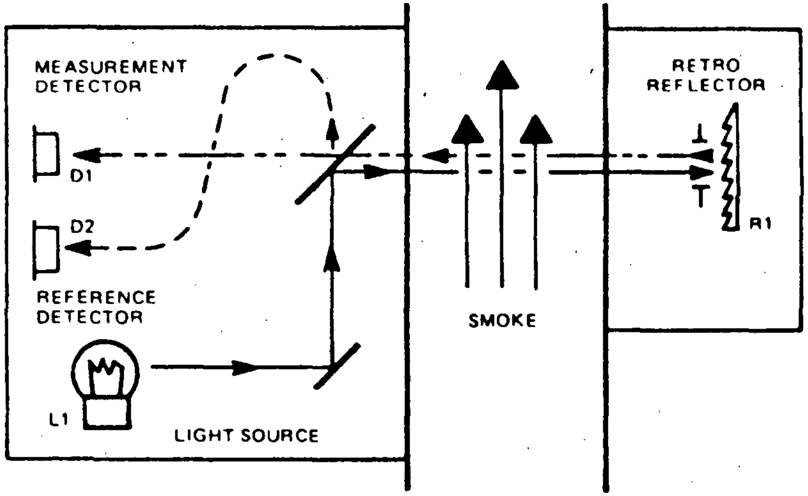

Fig. 1b. Double pass transmissometer.
(Courtesy of Dynatron Inc.
Wallingford, CT.)

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