

A Survey of Methods and Instrumentation for
THE ANALYSIS OF BENZENE IN THE WORKPLACE AIR

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Prepared by

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SUMMARY

A study of methods and instrumentation for the determination of benzene vapor in air at concentrations of concern from an occupational health standpoint was undertaken under the sponsorship of the National Institute for Occupational Safety and Health, and provides the basis for this report.

A brief introduction to the problems of benzene toxicity, measurement and control is provided in Part One of this report. Part Two is devoted to the description and evaluation of methods and instrumentation. The Appendix contains lists of references from the literature and from private communications, lists of instrument manufacturers, and brochures and data sheets on selected instruments.

Conventional sampling, monitoring and analytical methods and equipment are described and their capabilities and limitations are discussed and compared, including brief descriptions and evaluations of ancillary equipment for readout and alarm. Some new instruments having special relevance to this determination are described, some promising new techniques are discussed, and the applicability of some older but little used methods are re-examined.

All methods and instrumentation known to the author have been considered, and other methods of possible but undetermined relevance also have been investigated. The wide variety of circumstances and the unforeseeable combinations of mixed gases and vapors which may exist in various situations render any firm findings of optimal procedures or instrumentation impossible. The information presented herein is intended to provide a basis for the rational selection of practical methods and instrumentation for specific applications.

For situations in which the use of benzene is recognizable, infrequent, and in small quantity, no special control equipment or analytical instrumentation may be justified, and worker safety may in large degree depend upon proper education relative to the hazard involved and to good ventilation practices, and requirements for adequate ventilation capability. Probably the judicious use of gas detector tubes can provide evaluation of hazard during unusual or non-standard operations.

Assuming that industry must share responsibility for its own compliance with reasonable standards, for operations involving large quantities of volatile materials with significant benzene content, continuous monitoring instrumentation may be required. For this purpose continuous monitoring may be supplemented with frequent sampling and laboratory analysis, or automatic, programmed gas chromatographs may be employed--perhaps time-shared with process control analyses.

For agency surveillance purposes, the applicability of non-specific or semi-specific portable monitors, the collection of air samples for laboratory analysis, or the need for gas chromatographic on-site analysis must necessarily depend upon the knowledge and judgment of the hygienist.

A SURVEY OF METHODS AND INSTRUMENTATION
FOR THE ANALYSIS OF BENZENE IN THE
WORKPLACE AIR

PART ONE

INTRODUCTION

This study was performed under the sponsorship of the National Institute for Occupational Safety and Health, in accordance with the provisions of the Public Occupational Safety and Health Act of 1970--under which NIOSH has responsibility for the development of criteria for standards relating to occupational exposures to chemical and physical agents. This study is one of a series relating to the substances which constitute the major occupational health hazards. In the words of the authorizing contract, "The promulgation and enforcement of standards and regulations having legal status will require simultaneous issuance of specifications of measurement methods to be used to determine the extent of compliance. The selections of methods, therefore, represent decisions of considerable importance which NIOSH must be prepared to justify and defend."

Benzene Toxicity

The toxicity of benzene, by respiration or by skin contact, has been recognized for many years, but its chronic effects, in particular, have been underestimated in the past. A brief description of benzene toxicity is provided by Elkins (3):

"The narcotic action of benzene is greater than that of corresponding aliphatic hydrocarbons but is of minor importance compared to its chronic effects. A single severe exposure to benzene is apparently no more serious than a similar exposure to many other solvents. In fact, serious aftereffects are less probable than with most of the organic halogen compounds, for example.

However, any concentration of benzene vapor sufficient to cause even the slightest symptom of narcosis is far too high for continued exposure, and the condition should be immediately corrected.

Benzene poisoning is evidenced mainly by blood changes, which eventually develop into anemia. The typical picture, a marked decrease in white cell count, is found when the exposure has been severe and relatively short. If a more moderate exposure over a longer period of time has been incurred, any of numerous blood changes can occur.

If the absorption of benzene is permitted to continue, a condition is eventually reached in which the blood-forming mechanism is no longer capable of supplying sufficient white blood cells, and death from an infection predisposed by this condition follows. Often the hemopoietic system fails to recover when the absorption of benzene is stopped, and the victim may succumb to some infection, such as influenza, with symptoms typical of benzene poisoning, months or even years after contact with benzene has ceased."

Despite growing awareness of the severity of the problem, evidences of a continuing hazard are not lacking (48, 89, 96, 101, 145, 158, 175, 185, 303).

Benzene Standards

The maximum permissible concentrations of benzene for air exposure have reflected the growing recognition of benzene's high toxicity (114, 145). The cumulative effects of continued or repeated low-level exposures are difficult to assess (114, 153, 174), and the assessment is complicated by the fact that most exposures are to mixed solvents of which benzene is not the only toxic component (83).

Permissible concentrations in air set by different governments and different agencies have varied widely, but all have been repeatedly lowered as the evidence has mounted. The lowest concentration of benzene in air considered hazardous in 1929 was 1500 ppm (372). Twenty years ago the officially designated permissible concentrations in air varied from 35 ppm in Massachusetts to 755 ppm in Wisconsin, with the American Standards Association (ASA) recommendation at 100 ppm, and that of the American Industrial Hygiene Association (AIHA) at 25 ppm (8). American standards have tended to be less rigorous than those of other industrial nations, the limits in the U.S.S.R. (1967) and Czechoslovakia (1969) being 6 and 16 ppm, respectively.

The Threshold Limit Values adopted by the American Conference of Governmental Industrial Hygienists for 1970 (and continued in 1971) specify 25 ppm benzene as both the TLV and the Ceiling limit (30). The American National Standards Institute (ANSI, formerly ASA) recommendations, reducing the TLV to 10 ppm and setting a Peak limit of 50 ppm (38, 114), were officially adopted by the United States government in August 1971 (373). These limits are defined as follows:

TLV: The maximum permissible time-weighted average concentration to which any worker is exposed, averaged over a normal 8-hour day, for a 40-hour week.

Ceiling: The maximum concentration to which a worker can be exposed for an unlimited period, consistent with the TLV average.

Peak: The absolute maximum concentration to which a worker can be exposed, time-limited to no more than 10 minutes and not more than once per work shift.

The new TLV is barely above the threshold of odor detectability--4 to 5 ppm (374), thus, if in the future increased medical evidence dictates an even lower TLV, we will find that odor alone offers inadequate protection.

The refreshing concept of expressing integrated exposure as such has been promoted by Sherwood (47, 174, 329). He proposes a total weekly exposure limit of 5000 ppm-minutes, equivalent to a time-weighted average of 10.4 ppm for a 40-hour week--in close agreement with the new United States TLV.

Benzene Production and Use

Benzene is produced chiefly as an alternative product of the petroleum industry, of which Enjay, Commonwealth Petrochemical, Shell, Gulf, Monsanto, Phillips, Standard of Indiana, Dow, Texaco, and Mobil are the largest producers, with a combined 1967 production of nearly 800 million gallons (375). Approximately 16% of the production derives from coal, yielding a total production in 1969 of 1185 million gallons (43), up 18.5% from the 1968 production. Thus benzene is second only to ethylene as a hydrocarbon intermediate. In addition, in 1967, production of the homologs toluene, p-xylene, and o-xylene were 759, 850 and 1628 million gallons, respectively (43).

Benzene is consumed chiefly (87%) by conversion to intermediates-- chiefly styrene, cyclohexane, phenol, aniline, and maleic anhydride (375)-- for the manufacture of polymers. The other 13% is used mostly in the manufacture of detergents and pesticides, etc. and of relatively small amounts of solvents, paint-remover formulations, rubber cements, artificial leathers, and paints and lacquers. Perhaps surprisingly, the paint industry consumed only 800,000 gallons of benzene in 1970, as compared to 55 million gallons of toluene and 45 million gallons of xylene (375).

The increased use of the benzene homologs and derivatives, and of other less toxic substances, is a direct result of the increased recognition of the benzene hazards and a concerted effort to find safer substitutes.

Thus, despite the high and increasing production of benzene, its use as such is decreasing, and its conversion into less toxic homologs and derivatives is frequently accomplished by the petrochemical producers, by controlled closed-system processes, rather than by the manufacturers of plastics, detergents, and pesticides. (This probably accounts for the failure of these manufacturers to respond to our inquiries, and for the statement "no benzene use" from one large manufacturer. However, no petrochemical company personnel responded substantively--except three European respondents (235, 329, 339)!)

Although no longer a major component of common solvents, paints, or lacquers, benzene is still present in high proportions in some paint-remover products. It also is present in gasolines at 1 to 5%, and thus constitutes a health hazard in some gasoline transfer operations, in addition to the explosion hazard. Thus, while nearly all benzene is converted in large-scale operations, its hazard under these circumstances is well controlled, and perhaps the greatest health hazard from benzene occurs in small shops with inadequate ventilation, no monitoring capability, and little or no recognition of the hazard.

Monitoring Factors and Philosophy

With increasing concern for the environmental hazards associated with industrial processes, it must be assumed that industry will be called upon to participate in policing its own environmental impact, and that responsibility for monitoring the workplace air will be accepted by industrial management,

and not left entirely to the regulatory agencies. Monitoring instrumentation then can be designed or selected to meet the needs of specific processes and individual situations, with better effect and perhaps at lower cost than for instrumentation used by agency personnel for a wide variety of surveillance functions. While analytical instrumentation of nearly any degree of sensitivity, specificity and precision can be assembled or developed with sufficient funding, the problem of achieving adequate protection at costs commensurate with the size and profitability of an individual operation is often difficult.

The ideal of a simple, sensitive, and specific direct-reading instrument is seldom achieved, and certainly not yet in the case of benzene. Simple concentration-sensitive instruments appropriate for benzene suffer from lack of specificity, and the sensitivity is usually marginal or inadequate at TLV levels. The only relatively simple highly-sensitive detector--the flame ionization detector--is indiscriminately sensitive to all hydrocarbon vapors--and benzene is frequently encountered as a minor constituent in a mixed organic solvent. Moreover, because in most instances its vapor pressure is higher than those of the other solvents present, its relative concentration in air may be several times its fractional content in the liquid, and conversion factors from "total hydrocarbons" to "benzene" are not always consistent, even for a specified process, solvent and workplace. Non-specific monitors are, however, not without value, since they can establish patterns of readings which may correlate with process operations, and warn of off-standard conditions when this pattern is broken.

However, for many operations involving potential benzene hazard, even simple instrumentation may prove difficult to justify operationally, as well as economically, in the absence of personnel capable of properly maintaining, calibrating, and operating the instrument--and interpreting its readings. Thus, in many instances, chief reliance for worker protection must still rest upon the availability of knowledgeable occupational or public health personnel, upon ready availability of surveillance and analytical services, and upon a thorough and aggressive educational program.

PART TWO

I -- SUMMARY EVALUATIONS

This investigation into the available methods and instrumentation for the analysis of benzene in the workplace air has brought to light two newly developed instruments not previously reported in the literature for this determination*, has perhaps brought into sharper view the potential application of a number of emerging techniques**, and brings renewed emphasis to employment of a known but little-used method***. Even more clearly, however, it points out that there is as yet no simple, inexpensive, specific instrumentation for unambiguous benzene determination at any level, and only a small number of less ideal instruments with sensitivity adequate for TLV-level direct vapor-in-air analysis.

Of necessity, capital and operational costs will determine to a large extent the applicability of any instrument to a given situation. In all cases, and especially for small operations--in which the greatest hazards are likely to exist (303), operational complexity and instrument maintenance and calibration present additional problems which may become barriers to effective monitoring and worker protection.

For the small operation--e.g. the family antique-restoring shop--even a portable combustible-gas-analyzer of requisite sensitivity may be difficult to justify economically or operationally, in view of the knowledge and judgment required for valid interpretation. In such situations it may be wise to require or recommend at least a gas detector tube kit, but perhaps major reliance for safe operation must rest upon worker and operator education and upon the availability of analytical services from the public agencies.

* Flame emission photometry and second-derivative UV spectrophotometry, plus possibly IR filter spectrophotometry.

** See Section IX (e.g. tunable filters, tunable lasers, optical multi-channel analysers).

*** Ultra-violet photometry, by mercury lamp source, selective sensing, or bandpass filters, including dual-wavelength.

In the larger operations, especially where benzene is produced, converted, or handled in large quantities, requirements for rigorous monitoring and perhaps for the installation of continuous monitoring instrumentation may be well justified.

An evaluation of what appear to be the most practical methods and instrumentation for sampling, analysis, and both spot and continuous monitoring for benzene is given below.

A. SAMPLING

The preferred sampling method will vary with the sampling conditions and with both the type and location of the analytical instrumentation or laboratory.

1. Personal samplers

There appears little doubt that the personal sampler, worn by the worker and located in the breathing zone, constitutes the most valid method for measuring integrated exposure to respiratory poisoning. Any inconvenience imposed by these devices seems more than offset by their ability to experience the same gradients and transient effects encountered by the worker--such as when briefly descending into a sump to recover a dropped wrench. It also appears to be the general consensus that the adsorptive column, particularly the activated charcoal column (193, 132, 162, 157) is the preferred collection medium for integrated-exposure samples, at least in the United States, although hydrophobic gas-chromatograph column-packing materials may eventually prevail (87). Pre-packed, pre-conditioned charcoal tubes designed for this use have just become commercially available (Table 3F-26) at less than \$1 each. Since these tubes are sealed units with break-off tips, like gas detector tubes, they can be stored indefinitely for immediate use.

Recovery of benzene from these tubes by desorption with CS_2 can vary from 90 to 100% (193, 162), but by establishing a standardized procedure (time, temperature, solvent volume, sample load) reproducibility probably can be held to $\pm 3\%$ --adequate for industrial hygiene purposes. Measurement of the benzene content of these samples normally is by gas chromatography (GC), but UV spectrophotometry also can be used, especially if no other aromatics are present in the sample.

New personal sample pumps are being marketed to meet HEW specifications for pulse-dampened 8-hour constant-flow operation, by means of voltage regulation, as well as the Bureau of Mines "intrinsically safe" criterion. These units, however, are much heavier than the best non-regulated personal samplers, of which one (Table 3C-5)--while subject to slow-down with battery discharge--measures pump strokes to record total volume in terms of equivalent time at the calibrated flowrate, yielding a valid total volume value, if not a true time-weighted average.

2. Samples for Remote Analysis

Samples for determination of integrated exposure at a fixed sampling point can be obtained in the above manner, except that pump weight is no longer a factor, and often line-powered pumps can be used. For stationary samplers, the solid column has little advantage over the impinger or bubbler except with regard to ease of transportation to the remote laboratory. In both cases, the measured sample is in the liquid phase, sample recovery for low total-sample collection is perhaps better for the bubbler than for the column, and the desorption period (30 to 200 minutes) is eliminated. Only the solvents used are different, and while the less volatile alcohols used in bubblers may be less desirable than CS₂ for GC separation--especially with flame ionization detectors, when UV measurements are employed the column advantage in transportability may be more than offset by elimination of the desorption step.

Collected whole-air samples permit direct GC injection by syringe or (preferably) by sample loop (without the bother and delay of solvent desorption) with 95% or better sample recovery for storage periods up to a few days, especially for large samples.

For small samples (e.g. under 1 liter) greater loss in sample recovery is incurred by the increased surface-to-volume ratio; however sample losses at less than 1/2% per day were observed in one study (not benzene) with 4 oz. (120 ml) bottles (186). Benzene losses, though higher, may be acceptable and predictable for short-term storage. A cushioned carrying case was devised for the gas sample bottles used in the above study, permitting shipment by common carrier. With the advent of expanding molding foams, carrying cases can be custom fabricated to fit any shape, and permit the safe shipment of samples in any shape of bottle, gas bulb, or syringe.

Samples collected as whole-air substantial volume, in Teflon sampling bags, can be used to flush and fill multiple gas bulbs or bottles at a more convenient location, or can be used as a source for "loading" adsorbent columns or solvent-filled impingers or bubblers, for remote analysis. Teflon and Tedlar gas sampling bags are more expensive than those of the other materials (see Table 3-F), but yield higher recovery, and can be used repeatedly, if thoroughly flushed and conditioned between uses.

3. Sampling for On-site Analysis

For nearby on-site analysis, column or impingers shall be best for integrated long-term samples, but integrated whole-air samples also are possible. For either long or short-term sampling, bag samples can be introduced directly into a GC sampling valve, with almost 100% recovery for minimum storage time and moderate bag size. Gas-tight syringes also are quite convenient for grab samples, for direct injection (1 to 10 ml), or for flushing and filling a sample loop (e.g. 50 ml syringe for 2 ml loop).

The methods for remote sampling also can be used for close-coupled analysis.

4. Continuous Sampling

Most portable survey instruments employ integral pumps which perform continuous sampling, drawing a stream of air through a hose or probe to a concentration-sensitive detector. Air flow is not critical, but should be adequate to flush out the effects of past samples and to provide a fresh sample to the sensor within a period comparable to the response time of the instrument.

Continuous monitors of fixed installation also usually are provided with an integral pump of suitable performance. Most pumps can contaminate the air by loss of lubricant plasticizers, so most pumps must be placed down stream from the detector--sometimes causing the detector to operate at below-ambient and perhaps fluctuating pressure, resulting in an erroneous or irregular concentration reading. The metal bellows pumps can be either up or downstream from the sensor, and can be arranged so as to minimize pressure transients in the detector.

* * * * *

The problems, methods, and equipment for sampling are more fully discussed in Section III.

B. METHODS OF ANALYSIS -- COLLECTED SAMPLES

1. Colorimetric Analysis

Laboratory analysis for benzene content in air by the "butanone" method (see Section IV) begins with a nitration step which can be performed at the time of collection--by placing the nitrating mixture in a bubbler or impinger, or by subsequent nitration of a whole-air sample. The color intensity is a measure of the benzene concentration, and can be measured photometrically or by visual comparison with standards.

Unless selective chemical filters were used to separate the sample fractions (1), toluene and xylene, etc., will interfere with ~1:1 benzene equivalence.

Because of the chemical operations, the analysis is relatively slow. It can be performed, however, with a minimum of laboratory facilities.

In laboratories equipped with a suitable photometer, it may be usefully employed, but purchase of this instrument solely for benzene analysis probably would not be justified.

2. UV Spectrophotometry

The "standard" methods for benzene analysis employ UV spectrophotometry to measure benzene in a liquid solvent (31, 39, 40).

Analytical samples can be obtained by collection of benzene from the air on a silica gel column and elution by iso-octane (31), or by direct absorption by the solvent in an impinger or bubbler. This method does not resolve benzene from toluene, xylenes, and other substances absorbing at or near 254.5 nm. A minimum air sample of 25 liters is necessary to detect benzene at the TLV level (10 ppm), and correspondingly larger samples are necessary for determining sub-TLV concentrations.

For adequate liquid samples to permit distillation and chemical treatment, benzene and toluene can be determined separately in mixtures containing the higher homologs and derivatives (40).

The method requires only normal laboratory facilities and a simple spectrophotometer (such as the Beckman DU) and average skill for total aromatic evaluation, but high technical skill and computational competence are required for the separate determination of benzene and toluene. While reasonably rapid for routine analyses of multiple samples, the latter method is time-consuming and expensive for small and intermittent sample loads.

Laboratories possessing a spectrophotometer suitable for this determination and available for the work load involved may find this method practical, but probably would not be justified in procuring this instrument specifically for benzene determination, since the gas chromatograph is better for this purpose and can be procured at comparable cost.

3. Gas Chromatography

The specificity obtainable by means of gas chromatography and the high sensitivity possible with the flame ionization detector have made this the most universally applied analytical instrument, and it is now the preferred instrument for benzene determination. By proper selection of chromatographic column and operating parameters, almost any mixture of vapors and gases can be fully resolved. Measured air samples can be inserted from flowing streams or from static bag samples by means of a sampling valve, or syringe air samples can be injected directly into the column. Liquid samples obtained by means of air stripping methods also can be injected by microsyringe. This ability to yield high resolution and high sensitivity (e.g. 0.01 ppm) from many sample forms, with little or no pretreatment and with high and consistent efficiency, renders the gas chromatograph unequalled as a laboratory tool for industrial hygiene analysis.

Quantitative evaluation of the substances resolved on the chromatograph column requires a separate conversion factor for each substance versus the corresponding peak height or area on the chart trace chromatograph. Variations in these factors can occur with slight changes in operating parameters or detector performance, or with the manner or skill with which the sample is injected. For valid evaluation of sample concentrations, especially where variable sources are involved, substantial technical skill and judgment are

required. Similarly, considerable technical skill is required for the selection and control of proper operating parameters, and for instrument calibration and maintenance.

Instrument cost can vary from under \$500 for the simplest syringe-injection model of low sensitivity (w/o recorder) to several thousand dollars for precisely controlled, high-sensitivity instruments with switchable columns. An instrument suitable for most industrial hygiene purposes, for manual operation, complete with gas valves and recorder, can be purchased and equipped for about \$2000.

Gas operating costs for a typical GC instrument with flame ionization detector could be as low as 13¢/hr (using the large cylinders), or even 2¢/hr for instruments using a passive detector.

C. PORTABLE SURVEY INSTRUMENTS

No portable monitor specific for benzene has been developed, and although much added selectivity may be achievable by means of selective chemical filters to remove or differentiate between interfering compounds, full confirmation of this possibility is not at hand.

1. Combustible Gas Detectors

Two such instruments--one conventional and established, employing a platinum filament sensor, and one very new and employing a metal oxide sensor, are listed below as representative of the best of this type of instrument.

TABLE C-1
COMBUSTIBLE GAS DETECTORS -- PORTABLE

	<u>C1-1</u>	<u>C1-2</u>
Ref. No.	5A-1	5A-2
Manufacturer	FIGURE 5 GasTech (M63)	FIGURE 6 Bacharach (M16)
Model	1024	CSS-P
Weight	8 lb 8 oz	4 lb 10 oz
Price	\$650	\$431
Sensitivity, MDC/f.s.	<10/100 ppm	<20/1000 ppm
Interferences	All combustible gases (incl. CO, NH ₄ , H ₂ S)	
Maintenance	Minimal	Low (Requires periodic filament replacement)
Skill required:		
Operation	Low	Low
Maintenance	Med.	Med.
Interpretation	Med. High	Med. High
Operating Cost:	Power & maintenance only (rechargeable battery in CSS-P)	

2. Total Hydrocarbon Detectors (FID)

Only one instrument of this type is known which can be considered truly portable.

TABLE C-2

TOTAL HYDROCARBON DETECTOR

Ref. No.	<u>5B-1</u> FIGURE 8
Manufacturer	Century(M31)
Model	OVA-98A
Weight	9 lb (shoulder strap)
Price	\$2800
Sensitivity, MDC/f.s.	0.2/10 ppm $\frac{1}{4}$ scale, 1% f.s. (log)
Interferences	All hydrocarbons (not CO, NH ₄ , H ₂ S)
Maintenance	Medium high Flame detector requires cleaning.
Skill required	
Operating	Low
Maintenance	Normally low, expert on breakdown
Interpretation	Med. High
Operating Cost:	Power and maintenance + <5¢/hr (hydrogen) (if refilled from large cylinder)

3. UV Photometry

The use of the mercury vapor detector as a device for measuring benzene (which is considered an interferent in mercury vapor monitoring) is not new (28, 278), but in the opinion of the author, has not been fully employed. Mercury interference can be eliminated by means of the built-in filter for normal zeroing. While subject to interference from the benzene homologs and derivatives and some ketones, and from ozone, ammonia, and some other inorganic gases, it is insensitive to most hydrocarbons and alcohols and halogenated solvents, and is more sensitive to benzene than most combustible gas detectors. (See Section VI).

Two mercury vapor meters are listed below, with estimated benzene sensitivities tabulated.

TABLE C-3

UV PHOTOMETERS -- MERCURY VAPOR DETECTORS

Ref. No.	6A-2	6A-1
		FIGURE 12
Manufacturer	Bacharach(M16)	A.P.T.C.(M11)
Model	MV-2 Sniffer	Mercometer
Weight	6 lb	22 lb
Price	\$660	\$1184
Sensitivity, MDC/f.s.	8/160 ppm	2/160 ppm (digital)
Interferences	aromatics, ozone, ketones, NH ₄ , SO ₂	
Maintenance	Low Periodic change of charcoal and gold filters.	
Skill required:		
Operation		Low
Maintenance		Med.
Interpretation		Med.
Operating Cost:	Power & maintenance only	

4. Infrared Spectrometer (MIRAN)

A new instrument with promise of applicability to benzene analysis is now available--but not yet developed for this application (see Section VII-B). It appears to be physically suitable for portable monitoring (FIGURE 16), and adequately sensitive, but is not yet available in the necessary spectral region for avoiding interference from water vapor, CO, and other common gases.

5. Gas Chromatography

No truly portable flame ionization GC instrument is currently on the market, since all require external gas supply bottles, and no portable thermal conductivity GC currently available has adequate sensitivity. The situation is both deplorable and correctible.

A sensitive portable instrument is both needed and attainable. See Section VIII and Section IX for discussion of this problem.

D. CONTINUOUS MONITORS

In addition to the well established non-specific monitors in common use, several new monitors are now available with promising but unproved capabilities, plus the well-proven but expensive process gas chromatographs, of which low-cost models are beginning to appear. A few examples of each type will be presented for comparison of general characteristics.

1. Combustible Gas Analyzers

These monitors are widely used for measurement of explosion hazard, are sensitive to all combustible gases, and are useful in industrial hygiene measurements chiefly to warn of unusual conditions which may be accompanied by toxicological hazard.

TABLE D-1

COMBUSTIBLE GAS ANALYZERS

Ref. No.	<u>5A-9</u>	<u>5A-10</u>	<u>5A-16</u>
	FIGURE 7		
Manufacturer	Sieger(M137)	Sieger	Control Inst.(M40)
Model	1810	1310	A1CCS5
Size	6½x11x8½(15#)	7x19x14(30#)	19x9-x16(16#)
Price	\$975	\$3130/4 ch.	\$520/channel 1 - 5 channels
Sensitivity,MDC/f.s.	25/250 ppm	25/250 ppm	40ppm/10% LEL
Interference	All Combustible gases		All Comb. gases
Maintenance	Low		
Skill required			
Operation	Low		
Maintenance	Medium		
Interpretation	Med.-to-high		
Operating Cost:	Power and maintenance only		

2. Total Hydrocarbon Analyzers

Like the portable THCA instruments, these are sensitive to all hydrocarbons, but not to CO and ammonia, etc. They yield a record of total HC vapor concentration at very low levels, on a continuous sampling basis--unlike the more specific gas chromatographs which employ the same sensor.

TABLE D-2

	<u>TOTAL HYDROCARBON ANALYZERS</u>		
Ref. No.	<u>5B-3</u>	<u>5B-6</u>	<u>5B-9</u>
	FIGURE 9	FIGURE 10	FIGURE 11
Manufacturer	Gow-Mac(M65)	P.A.I.(M120)	M-S-A (M102)
Model	23-500	30-100	Total HC
Size	12x15x14(35#)	14x16x14½(35#)	19x 12x13(30#)
Sensitivity,MDC/f.s.	0.05/0.5 ppm	0.05/5 ppm	0.1/ 1 ppm
Interference	all hydrocarbons		
Maintenance	medium to high		
Skill required			
Operation	medium		
Maintenance	medium		
Interpretation	medium to high		
Operation Cost:	Power and maintenance + < 5¢/hr (hydrogen)		

3. UV Photometers

One simple instrument is available at low cost having adequate sensitivity, and with selectability better than the preceding, but interferences similar to those of the mercury vapor meters--though less sensitivity to ozone and SO₂. Other, dual-beam instruments provide improved interference rejection, at higher cost.

TABLE D-3

UV PHOTOMETERS

Ref. No.	<u>6A-5</u>	<u>6A-6</u>	<u>6A-7</u>
	FIGURE 13		FIGURE 14
Manufacturer	Honeywell(M73)	DuPont(M47)	Peerless(M87)
Model	UHV-15 SP	400	209
Size	8x36x8 (45#)	61x12x5+ (85#)	24x8x13 (40#)
Price	\$795	\$4790	\$4300
Sensitivity,MDC/f.s.	2/10 ppm	4/100 ppm	2/50 ppm
Interferences	aromatics, ketones, NH ₄ , SO ₂ , ozone		
Maintenance	Low	Medium to High	
Skill required			
Operation	- - - - - Low	- - - - -	- - - - -
Maintenance	Low	Medium	Medium
Interpretation	- - - - - Medium	- - - - -	- - - - -
Operating Cost:	Power & maintenance only		

4. Flame Emission Photometer

This instrument has quite good sensitivity and good selectivity for benzene--even relative to toluene (12:1), with rejection of most other common interferences.

Performance is based only on the vendor's claims.

TABLE D-4

FLAME EMISSION PHOTOMETER

Ref. No.	<u>6C-1</u>
Manufacturer	Nuclear Corp. (M108)
Model	Benzene Vapor Detector (special)
Size	12x 18x 12 (35 lb), plus gas bottle
Price	\$3000
Sensitivity, MDC/f.s.	1 ppm/200 ppm
Interferences	Toluene (~1:12), xylenes (~1:20)
Maintenance	Medium to high
Skill required	
Operation	Low to medium
Maintenance	Medium to high
Interpretation	Low to medium
Operating cost:	Power and maintenance + ~5¢/hr

5. Second Derivative UV Spectrophotometer

This new technique provides high specificity and sensitivity on a continuous sample, but at medium to high cost--depending upon whether one or more components are to be measured--which is an important "plus".

The performance assessment is based not only on claims, but upon spectra obtained on mixed benzene and homologs for the author's evaluation.

TABLE 5-D

2d Deriv. UV SPEC.

Ref. No.	<u>7A-1 & 7A-2</u>
	FIGURE 15
Manufacturer	Spectrometrics of Fla.(M138)
Models	IV & III
Size	56 x 22 x 14½ (125#)
Price	\$4300 \$12,500 (multi-component)
Sensitivity	0.5 ppm or less/ variable f.s.
Interferences	Toluene rejection 40:1; xylenes 100:1
Maintenance	Medium to high (electro-mechanical functions)
Skill required	
Operation	Low
Maintenance	Medium to high
Interpretation	Low (direct concentration)
Operating Cost:	Medium to high--power and maintenance only

6. Gas Chromatographs--Process and Environmental, etc.

The gas chromatograph does not measure a flowing sample, but samples the stream repetitively (if automatic and programmed) for "batch" analysis. The fully automatic process and environmental instruments have special circuitry to measure the chromatographic peak heights or areas and to convert these data to a running record (chart or printout) in arbitrary units or in direct concentration. Because of the high cost of these instruments, their application to occupational health monitoring can be justified most easily if the instrument is time-shared with process control.

Some monitoring instruments designed originally for environmental monitoring, with lesser capabilities in some cases and with "demand" start instead of automatic programmed operation, and/or chromatographic trace readout without peak evaluation--at lesser cost.

TABLE D-6

(page 1 of 2)

AUTOMATIC GAS CHROMATOGRAPHS

Ref. No.	<u>8B-1</u>	<u>8B-4</u>	<u>8B-7</u>
Manufacturer	Antek(M10)	Byron(M28)	P.A.I. (M120)
Model	40-IPC-X	400	Special
Size	12x16x12 (25#)	22x13x15(70#)	14x16x14½(55#)
Price	\$2655 (man.)	\$4350(man)	\$3445(man)
Sensitivity, MDC/f.s.	0.1/1 ppm	1/10 ppm	0.05/5 ppm
Interferences	- - - - -	none - - - - -	- - - - -
Maintenance	Medium to high (FID)		
Skill required			
Operation	- - - - -	low - - - - -	- - - - -
Maintenance	- - - - -	medium to high - - - - -	- - - - -
Interpretation	- - - - -	medium - - - - -	- - - - -

Operation Cost: on preceding instruments-- power and maintenance
 plus carrier and FID gases @ <15 ¢/hr

TABLE D-6 (cont'd)

(page 2 of 2)

AUTOMATIC GAS CHROMATOGRAPHS

Ref. No.	<u>8C-1</u>	<u>8C-8</u>	<u>8C-14</u>
	FIGURE 18		
Manufacturer	Beckman(M21)	Arcas(M14)	Baseline(M165)
Model	6800 Spec.	500 Series	1000
Size	17x40x20(200#)	(see Table 8C-8)	6x11x12 (18#)
Price	~\$7500 fully programmed	~\$5000 programmed	<\$2000
Sensitivity,MDC/f.s.	0.05/ 1 ppm	not stated	5/100 ppm
Maintenance	- - - -	medium to high	- - - -
Skill required			
Operation	- - - -	low to medium	- - - -
Maintenance	med. high	low to med.	low to med.
Interpretation	Low	Low	Low to med.
Operating Cost:	Power and Maintenance -- plus <25¢/hr	< 5¢/hr	< 5¢/hr

II -- SOURCES AND PROCEDURES

In order that the reader may assess the scope and limitations of the foregoing evaluations and the collected data and observations which follow, it may be helpful to describe the investigator's background, the sources of information employed, and the extent of inquiry involved.

The investigator's past experience had been largely in analytical instrumentation design, development, and application, mostly during employment for 23 years on the A.E.C. Hanford project (senior research scientist). Although this experience was related to chemical separations of radioactive materials, it included spectrophotometry, calorimetry, and other physical methods, as well as analytical instrumentation for radiochemical measurements. Although some experience had been gathered in the design of radioactivity monitors for environmental protection, no prior experience had been gained in the field of industrial hygiene. An intensive indoctrination in industrial hygiene methods and procedures therefore was appropriate.

A. PRELIMINARY STUDY

As preparation for making the necessary evaluative judgments and recommendations on available and potentially available instrumentation methods and techniques, an extensive study was undertaken with regard to both the latest and the older methods of sampling and analysis, as well as those most commonly in practice today. Some attention also has been given to the toxicological aspects of benzene and its homologs and related compounds.

The 15 books listed (Appendix A, Table A-1) constitute the bulk of those studied, other books examined having been found largely redundant or inapplicable. In general, of course, the material found in books is either elementary or outdated, but it serves to give a more rounded understanding of the problem and of the basic principles involved in many of the instrument methods in current use. In particular, M.D. Jacobs' excellent text (6), although in many respects now outdated, provides a clear and detailed picture of the classical methods of sampling and analysis--much of which is still applicable; and the later compendium by A.C. Stern et al. (1,5) is also broadly applicable and brings into focus many methods and instruments of more recent development.

Many interesting and sometimes applicable instrumental methods are described or referenced in the governmental publications listed in Table A-2. The bibliography (21), especially, would have been of inestimable help if it had been received earlier, and in any event added several hitherto unknown sources of pertinent information. The Los Angeles County publications (16, 17) were referred to by a number of our respondents as their "standard methods".

A number of "standards" and general information publications were obtained from the various professional societies and associations (Table A-3), and are especially useful in selecting methods with legal status and industrial acceptance. Unfortunately, by the time a method becomes accepted to this extent, it generally has been superseded in practice by a newer method exploiting a more recent state of the art.

B. CURRENT TECHNOLOGY

Several pertinent journals and trade periodicals were rather thoroughly perused, especially the more recent and current issues, and 178 articles therefrom have been referenced as applicable to some aspect of benzene-in-air analysis (Tables A-4, A-5, and Addenda, P. A-21).

A number of outstanding persons in the industrial hygiene field, authors of current articles of interest, chairmen and members of selected professional committees, and persons recommended to our attention were contacted by telephone or letter, and in general responded with pertinent and substantial information, resulting in 33 of the 157 "private communications" referenced in Table A-6.

About 900 "instrument users' survey" inquiries were mailed to various federal, state, county, and city public health agencies, to military, A.E.C., and NASA installations, to members of the American Industrial Hygiene Association, and to petroleum refiners, detergent, plastics, and paint manufacturers, and others believed to be involved with benzene production and processing.

Of the 12% response received, very few were from companies believed to be the major producers or users of benzene, and some of those who did respond denied any involvement with benzene, or gave noncommittal replies. Disappointingly, no reports of any installed continuous monitoring instrumentation for benzene analysis for occupational health reasons were received from any source.

Over half of those responding reported no involvement with benzene analysis, or urinalysis only, and it is reasonable to assume that this is also true of a greater fraction of those who did not respond at all. Of those responding who have had experience with benzene-in-air as an occupational health hazard, 40% use only gas detector tubes, and very few of these indicated any dissatisfaction with them.

Thus, only about 3% of those surveyed contributed information on instrumental methods of analysis. However, this statistically scanty population of only about 30 working hygienists included some of the most knowledgeable experts in the field, supplemented by those directly contacted by personal letter. Many of the respondents from both groups gave exceedingly helpful and sometimes quite extensive counsel, and all this was supplemented by the accumulated experience of these and other workers, as reported in the technical literature.

C. INSTRUMENT MANUFACTURERS

Over 800 inquiries were sent to instrument or equipment manufacturers, seeking by means of a very broad survey form--and in some cases by personal letter--to uncover unsuspected new instruments and methods, and to discover otherwise unknown sources of the established types of instrumentation, as well as to obtain comparative specifications on all instruments. All instrument manufacturers considered reasonably likely to produce applicable instrumentation, including peripheral equipment such as pumps, flowmeters, recorders, etc., were surveyed. In addition to those known to contribute to industrial health instrumentation, names were obtained from advertisements in technical magazines, listings under "New Products", etc., references in technical articles and reviews, and (chiefly) from "directory" issues of technical magazines: Chemical Engineering "Environmental Engineering Desk Book" (June 21, 1971), Analytical Chemistry "1971-72 Laboratory Guide" (July, 1971), Environmental Science and Technology "1971-72 Pollution Control Directory" (September 1971), Instruments and Control Systems "1972 Buyers' Guide", Science "Guide to Scientific Instruments 1971-72" (November 1971), Instruments and Control Systems 44, No. 7, 69 (1971) "Strip Recorder Survey", and Electronic Design 19, No. 25, 48 (1971) "Focus on Industrial Chart Recorders". Manufacturers selected for inquiry were those listed under one or more categorical headings such as "gas analyses", "analytical instruments", etc.

Of the 250 manufacturers responding to our survey--many only after the second or third inquiry, about one-third replied that they could offer nothing applicable in any way to benzene determination, or sent data sheets or brochures leading to this conclusion. Several who so responded were known by us to offer applicable instrumentation, but this was not known to their own sales people or clerical help who replied. Undoubtedly others who mistakenly believe they offer no applicable instrumentation have been overlooked, but these cases usually involve general-purpose or peripheral equipment not specific for benzene or not suitable for routine monitoring.

The 171 manufacturers considered to be suppliers of applicable, potentially applicable, or related instrumentation are listed in Table B-1 of Appendix B. The listings in this table are to some degree clarified by the fold-out LEGEND (Table B-1a) preceding the listings, and by the fold-out Category index (Table B-2), following. This index refers to a catalog file containing the material received from the manufacturers listed in Table B-1, plus pertinent survey forms and correspondence, filed by instrument type and application. (The file accompanies copy #1 of this report--delivered to the sponsor.)

Those manufacturers giving negative response are listed in Table B-3, and those who chose not to respond (not including those who finally responded to repeated inquiries) are listed in Table B-4.

The remarkably poor cooperation received from some manufacturers--especially some of the well-established firms, in contrast to the excellent cooperation received from others--especially some of the smaller organizations, may be indicative of the zeal with which these companies will accommodate their customers, both private and regulatory. For this reason a record of the numbers and kind of inquiries made, and the adequacy of the response received, has been included in Table B-1 (following company name). The rating symbols are explained in Table B-1a. Whatever significance this rating may possess must be evaluated not only from the rating itself but also from the need for data, as indicated by the number and types of products involved.

D. PRODUCT LISTINGS

All products of reasonable direct or potential applicability to the determination of benzene in the workplace air are listed according to their function and specificity in the tables at the end of each of the following sections or sub-sections, and are discussed by type in text preceding the tables.

Perhaps some instruments have been omitted which the reader feels should have been included. More likely, some of those included will be considered of little or no practical applicability to occupational health activities. Subjective judgments had to be made, and the investigator chose to err more in the direction of too much than too little, relying on the reader's judgment and knowledge, and his willingness to read the qualifying descriptions in the text.

All listings in the section tables are cross-indexed by manufacturer, and all sectional listings are indicated in Table B-1.

NORTHWEST environmental and preventive

HEALTH SERVICES

Currently we are engaged in a study* of analytical methods and instrumentation for the determination of benzene vapor concentration in air from an industrial hygiene standpoint, as a basis for establishing improved methods and instrumentation.

Unquestionably those laboratories and agencies involved in the day-to-day operations pertaining to occupational hygiene and public health responsibilities constitute our most valuable source of practical information and knowledgeable judgement on available instrumentation and methods. Conversely, these same agencies and laboratories stand to benefit substantially from a wide-range compilation of the accumulated experience in even one of the many specialized fields in the occupational health domain. Therefore, we feel justified in asking you and your staff to cooperate in our study by sharing with us your knowledge and experience relative to our immediate problem: the determination of benzene vapor concentration in air in the industrial environment.

In particular, we are asking you to give us your evaluation, both "absolute" and comparative, on all the methods and instruments used by your laboratory (now or in the recent past) for the above determination. Although commercially available instruments are of major concern, especially in view of anticipated expansion of monitoring activities by inexperienced personnel, any "shop made" instruments or modifications or in-house methods which you have found to be superior to commercial instruments or standard methods, or supplementally useful, also are of extreme interest. Similarly, suggestions for improvements or new approaches will be most welcome.

The enclosed questionnaire may be used as a guide in preparing your evaluation, but it need not be adhered to if you find it limiting or otherwise unsuitable. Moreover, we are not asking for a unified consensus or "average" evaluation on any instrument, feature, or method, but rather the full expression of all viewpoints of those involved in the actual determinations and data evaluations. Wherever we may have failed to ask an appropriate question, we hope that you will nevertheless provide the pertinent information.

* Supported by the Health Services and Mental Health Administration, Department of Health, Education, and Welfare, pursuant to the Williams-Steiger Act, Public Law 91-596.

Please prepare a separate critique for each instrument or method, on separate sheets. We will gladly supply additional forms on request, or you may reproduce the sample enclosed. An early reply will be most helpful.

Thank you for your cooperation in helping us to achieve what we hope will be a comprehensive, valid, and useful evaluation.

Sincerely,

A handwritten signature in cursive script, appearing to read "U. L. Upson".

U. L. Upson

Principal Investigator

INSTRUMENT USERS' SURVEY
Benzene Vapor Concentration In Air Analysis

Submitted by _____ (organization or individual)
_____ (address)

Prepared by _____ (individual) Date _____ 1971
Telephone (____) ____ - ____ Extension _____

SUBJECT

(Sampler, portable instrument, plant monitor, personal mon., lab method, etc.)
INSTRUMENT NAME _____ MODEL NO. _____
MANUFACTURER _____ Country of origin _____

SAMPLING FUNCTIONS

Measured volume, timed flow, etc. (please state) _____
Bag, Bellows, syringe, diaphragm pump, etc. - - _____
Manual, 120 v 60 Hz, battery (state NEDA#), etc. _____
Precision of sample volume (observed standard deviation) ± _____ %
Reliability of method (1 to 5)* _____, of this instrument/model (1 to 5)* _____
Rating of method (1 to 5)* _____, rating of this instrument (1 to 5)* _____
Details, comments & suggestions** _____

continued on p. ____

COLLECTION, FIXATION, CONCENTRATION

Equipment employed (impinger, column, bubbler, etc.) _____
Medium (silica gel, iso-octane, ethanol, etc.) _____
Rating of method (1 to 5)* _____, rating of this instrument (1 to 5)* _____
Details, comments & suggestions** _____

continued on p. ____

CHEMICAL OPERATIONS, DESORPTION, etc.

Purpose of operation _____
Automatic, laboratory, etc. _____
Method, reagents used, etc. _____
Rating of method (1 to 5)* _____, rating of this instrument (1 to 5)* _____
Details, comments & suggestions** _____

continued on p. ____

* Rating code: 1) poor, 2) below average, 3) average, 4) above average, 5) superior, n.o. = no opinion. Please rate the method vs. other methods, the instrument vs. other instruments employing the same general method.

** Please state the advantages and disadvantages relative to other instruments similarly employed (e.g. portable vs. portable) as well as overall, giving trade names and model nos. Point out special features, conveniences or deficiencies, and suggested improvements or alternative new instrumentation. Please use additional numbered sheets for extended comments, and so indicate.

HEALTH SERVICES

The Occupational Safety and Health Act of 1970, which became effective on April 28th of this year, greatly expands the requirements for pollution monitoring equipment of all kinds. A better understanding of present and attainable instrumentation capabilities will be needed by industry and by the regulatory agencies to monitor and maintain safe working conditions and environmental quality.

Currently we are engaged in a study* to help clarify and define one aspect of this very large problem--the measurement and control of atmospheric pollution of the workspace by benzene. Our task is to evaluate all available methods, equipment, and instrumentation relating to the determination of benzene vapor concentration in air, including every step from sampling to readout and every type of instrument from personal exposure monitors to automatic continuous recording analyzers. To accomplish this task fully we need the help of every manufacturer of products relating to this problem.

If your company produces equipment or instrumentation applicable to any phase of the determination of benzene vapor concentration in air, we offer you the opportunity to present your products' capabilities for inclusion in this investigation--by filling out the enclosed questionnaire for each product and model, in as much detail as possible. Additional questionnaires will be furnished gladly on request, or you may reproduce the enclosed questionnaire.

Please adhere to the specified units and nomenclature (e.g. ppm, liters/min, etc.) to simplify comparative evaluation, and please include all requested information applicable to each product. We believe that you will want your products to be included in this study, and we hope you will assign one of your most competent and knowledgeable people to this task, and will assign it immediate priority.

Please also include any comments, suggestions or descriptive statements you feel to be pertinent; and please enclose with the questionnaire, or send under separate cover, two copies each of any specification sheets, brochures, or catalogs, etc. which depict and/or more fully describe your products.

Thank you for helping us to make this study truly inclusive and indicative of the current state of the art, and for giving it your prompt attention.

Sincerely,



U. L. Upson
Principal Investigator

* Supported by the Health Services and Mental Health Administration, U. S. Dept. of Health, Education, and Welfare.

DIVISION OF ENVIRONMENTAL HEALTH / 805 GOETHALS DRIVE / RICHLAND, WASHINGTON 99352 / PHONE

(A Subsidiary of Hanford Environmental Health Foundation)

(509) 948-0188

PROPRIETARY PRODUCTS SURVEY
Benzene Vapor Concentration In Air Analysis

NAME OF MANUFACTURER (or Importer): _____

ADDRESS: _____

If imported, state manufacturer's name
and country of origin _____

(Please make a separate report on each product)

PRODUCT NAME _____

Model number _____

FUNCTION (e.g.: sampler, personal monitor, portable
monitor, lab. instrument, component, etc.) _____

AIR MOVER

Power (manual, battery NEDA No., 115v 60Hz, etc.) - - _____ (state)

Max. continuous battery operation (minimum)

Rechargeable (type) _____, built in charger? - - - - - _____ (yes, no)

Flowrate range, minimum to maximum - - - - - _____ to _____ liters/min

Flowrate stability - - - - - \pm _____ % at _____ liters/min for _____ hrs.

Flow Totalizing (measured or timed) - - - - - _____ (state)

Pump type (piston, bellows, diaphragm, fan, etc.) - - - - - _____ (state)

Comments* _____

Continued on p. _____

COLLECTION AND CONCENTRATION

Collector (bag, tube, impinger, column, etc.) - - - - _____ (state)

Medium (iso-octane, ethanol, silica gel, etc.) - _____ (state)

Minimum collection period for \pm 25 ppm benzene detn. - - - - - _____ minutes

" " " " \pm _____ ppm (best) - - - - - _____ minutes

Collection period timing (manual or automatic) - - - - _____ (state)

Efficiency of collection - - - - - _____ \pm _____ %

Comments* _____

Continued on p. _____

INTERMEDIATE OPERATIONS

Function of operation(s) (devel. color, desorb, etc.) _____ (state)

Reactants, solvents, diluents, etc. - - _____ (state)

Operation performance (manual, semi-auto., auto.) - - _____ (state)

Total operating period/detn., typical - - - - - _____ minutes

Timing (automatic, manual) - - - - - _____ (state)

Comments* _____

Continued on p. _____

* Please use separate numbered sheets for additional information

ANALYTICAL MEASUREMENT

Mode (e.g. color, color length, UV-Hg lamp, UV spec., IR spec., GC, mass spec., polarograph, etc.) _____ (state)
Minimum detectable concentration (2 x standard deviation) - - - - _____ ppm benzene
Interferences (ppm to yield same reading as 5ppm benzene)
Toluene - - - - - _____ ppm
Xylenes - - - - - _____ ppm to _____ ppm
Mercury - - - - - _____ ppm
Ozone - - - - - _____ ppm
Other: _____ ppm
_____ ppm
Recovery from poisoning or overexposure (explain below) - - - - _____ min.
Zero-set in contaminated atmosphere (explain below)
Comments* _____

Continued on p. _____

READOUT, RECORD, ALARM

Readout mode (e.g. meter, digital, etc.) - - - - - _____ (state)
Readout units (direct ppm benzene, linear factor, chart conversion, table, graph, etc.) - - - - - _____ (state)
Highest range full-scale concentration - - - - - _____ ppm benzene
Lowest range full-scale concentration - - - - - _____ ppm benzene
Printout (none, strip chart, tape printer, etc.) - - - - - _____ (state)
Alarm (none, fixed-level trip, adjustable trip) - - - - - _____ (state)
Output (switch closure, 5 volt, 1 ma, etc.) - - - - - _____ (state)
Reset (manual, automatic, both) - - - - - _____ (state)
Comments* _____

Continued on p. _____

SPECIAL FEATURES: _____

Continued on p. _____

COMPONENTS - - items adaptable to this kind of instrumentation, incorporated in similar instruments, or accessory thereto, but not covered in above form.

List and describe, and show application to benzene detn. on separate sheet. p. _____

DIMENSIONS:

	Weight	Width	Depth	Height
Main instrument chassis	_____ lbs.	_____ in x	_____ in x	_____ in
_____	_____ lbs.	_____ in x	_____ in x	_____ in
_____	_____ lbs.	_____ in x	_____ in x	_____ in

PRICES:

Basic instrument (state exclusions) _____ \$ _____ FOB
Options: _____ @ \$ _____
_____ @ \$ _____

DELIVERY: Days after receipt of firm order, typical _____, maximum _____

Please complete and return at your earliest convenience to:
U. L. Upson, Northwest Health Service, 808 Swift, Richland, WA 99352
THANK YOU

NORTHWEST environmental and preventive
HEALTH SERVICES

We understand that your organization handles benzene in significant quantity and therefore is concerned with the problem of personnel exposure, so probably you have in your plant fixed, portable and/or personnel monitors for the detection and measurement of benzene vapor concentration in air, and trained personnel who use them routinely.

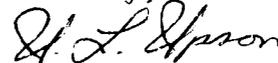
Currently we are engaged in a study* of analytical methods and instrumentation for the determination of benzene vapor concentration in air from an industrial hygiene standpoint. In order for our evaluation to be truly valid, it must incorporate the experience and best judgment of those in the field who use benzene vapor monitoring instruments and methods on a day-to-day basis. Therefore we are asking you to encourage your people to cooperate with us in our study by giving us their frank opinions of the methods and instruments they use. Hopefully our study will lead to better methods and improved instruments, to the benefit of all.

The enclosed questionnaire may be used as a guide in preparing your evaluation, but it need not be adhered to if you find it limiting or otherwise unsuitable. Moreover, we are not asking for a unified consensus or "average" evaluation on any instrument, feature, or method, but rather the full expression of all viewpoints of those involved in the actual determinations and data evaluations. Wherever we may have failed to ask an appropriate question, we hope that you will nevertheless provide the pertinent information.

Please prepare a separate critique for each instrument or method, on separate sheets. We will gladly supply additional forms on request, or you may reproduce the sample enclosed. An early reply will be most appreciated.

Thank you for your cooperation in helping us to achieve what we hope will be a comprehensive, valid, and useful evaluation.

Sincerely,



U. L. Upson
Principal Investigator

ULU/dac

Enclosure: Q-U

* Supported by the Health Services and Mental Health Administration, Department of Health, Education, and Welfare, pursuant to the Williams-Steiger Act, Public Law 91-596.

III--SAMPLING

A. SAMPLING REQUIREMENTS

Sampling of the workplace air for industrial hygiene purposes must be considered with respect to the needs for determining both "acute" and long-term exposures relative to the designated Peak, Ceiling and Time-Weighted Average (TLV) values, which for benzene are now 50, 25 and 10 ppm, respectively. Sampling for peak and ceiling concentrations requires either continuous sampling (with continuous measurement), continual repetitive short-term sampling, or short-term sampling during the known peak period--as determined by other measurements or by process operations (e.g. solvent transfer, vessel venting, etc.).

Discrete "peak" samples should be collected in a period of sufficiently short duration to avoid averaging maximum concentrations with lesser levels preceding or following the peak, but must be of sufficient duration and sample volume to average out minor inhomogeneities (such as those due to local turbulence, door openings, etc.) and to provide an adequate sample for the desired analytical precision. In the past, the latter consideration has been a major factor, and a minimum sampling period of 15 minutes has been considered advisable, with sample volumes of 5 to 10 liters typical. With the more sensitive, more specific, and more direct methods and instrumentation now available, shorter and more frequent sampling is possible, yielding potentially better resolution of the concentration vs. time profile.

With the development of environmental and process monitors which automatically sample and analyze the ambient air (and/or process streams) continuously or at regular and frequent programmed intervals, a continuous record of the measured concentrations can be obtained. From such instruments (e.g. Tables 7A & 8C), the peak concentrations can easily be observed, and can be utilized to provide alarm and control functions. The time-weighted average concentration can be determined from the time-concentration data either electronically and automatically or by recorder or manual integration of the chart record. Instruments yielding digital concentration printout at regular intervals (see Table 8B-4) allow easy

arithmetic averaging--either by computer or by office calculator. In large installations, or where the major capital and operating costs can be charged to "production" for instruments time-shared between process and health monitoring functions, such instrumentation should find acceptance. The air monitoring functions of a time-shared process monitor can guard against process upsets, control ventilation to insure legal compliance, and provide an adequate record thereof.

However, most operations involving potential benzene hazard probably are too small or the hazard is too infrequent to justify continuous automatic monitors, at least of the types specific for benzene, and sampling will need to be performed manually on a routine, spot-check, or "demand" basis. This will be particularly true in the case of compliance monitoring by government agency personnel. For these applications portable concentration-sensitive instruments can serve to indicate general concentration levels and signal the need for grab samples. The latter can be collected as gaseous, dissolved or adsorbed samples, obtained manually or by manually-initiated mechanical sampling (e.g. by sampling valve).

In the absence of a continuous record of the concentration of benzene in the workplace air, total integrated exposure of personnel and the time-weighted average concentration can be determined by continuous (or programmed repetitive) cumulative sampling, and subsequent analysis of the collected sample. Such analyses indicate past exposure and thus warn of past occurrence of hazardous conditions but, being retrospective and "historical", serve no direct preventive function.

Methods for both short and long-term sampling are described below.

B. SAMPLING PROCEDURES

1. Short-term Sampling

Sampling for the measurement of instantaneous concentrations in air takes on two general forms: a) continuous sampling for direct instrumental concentration measurement, and b) collected samples for subsequent analysis of the concentration or of a measured aliquot.

For "instantaneous" real-time measurement of the benzene concentration the workplace air, continuous sampling and concentration-sensing detectors would be ideal. However, since benzene is most often present only as a minor component of the air-borne vapor, and since no simple, specific direct-reading instruments are available for most situations*, collected samples often must be obtained. Also, if only infrequent sampling is necessary, if a continuous-sampling monitor is normally adequate but a more specific analysis or greater sensitivity is occasionally required, or if the analysis must be performed at a different location, some form of "grab" sample will be required.

a. Continuous Sampling

Instruments which measure concentration directly require only that a valid sample be delivered to the detector, with no requirement of sample volume measurement, and they present a "real time" indication of the total concentration in the sample of those constituents to which that detector is sensitive. Direct sampling instruments which take a measured sample from a sample stream also require only that a fresh and representative sample be delivered to the secondary sampling point. In these instruments a

* Combustible gas analyzers, total hydrocarbon analyzers, and photometers are non-specific (or class-specific) instruments, and in the past have constituted the only available practical continuous, direct-reading concentration-sensitive devices available. Newly developed instruments with fairly high specificity (See Tables VI-C, VII-A & VII-B) and state-of-the-art advances with potentially high specificity (Sec. IX) may significantly alter the situation.

measured sample is processed and analyzed to determine the amount of the component of interest in that sample, the original concentration being calculable from this value. For benzene-in-air analysis, programmed bench or process gas chromatographs with sample loop valving exemplify this technique.

Since gaseous samples change concentration with pressure in accordance with Boyle's law, high pressure drops and variable flow in the sampling system should be avoided. Thus, where high flows are necessary to obtain a valid sample, instrument bypass may be necessary so that instrument sample flow can be adjusted to allow operation at near-ambient pressure.

The sampling system, whether for direct-concentration or batch-analysis instruments, should neither adsorb or otherwise extract the component(s) of interest from the sampled air (e.g. when the concentration rises above that to which the system is equilibrated) nor contribute to the sample stream (e.g. when the concentration drops below the preceding level). To minimize such memory effects, the sampling system should avoid a high surface-to-volume ratio and extended sample residence time within the sampling system.

Portable instruments yielding direct concentration-dependent readings (e.g. combustible gas detectors, flame ionization, hydrocarbon analyzers, and mercury vapor detectors) generally employ small pumps which provide continuous sampling through a hose and/or probe. Usually the hoses and probes are short and do not present large surfaces to produce "memory" problems. However, stainless steel tubing and Teflon or Teflon-lined hoses are preferred--polyethylene, polyvinylchloride, neoprene and rubber-lined hoses being progressively less desirable in this respect when aromatics are present.

Continuous monitors frequently include integral air movers appropriate for the type of detector employed, or suitable external pumps are supplied or specified by the manufacturer. Usually the major requirement is only that the pump reliably supply an adequate flow to present a fresh sample to the sensor with reasonable delay.*

* For instruments employing the flame ionization detector (FID)--in which the flowrate directly influences the detector output--the sampling rate must be closely regulated to maintain instrument calibration. A suitable integral pump may be provided by the manufacturer, and a flow-limiting orifice or other flow-control equipment usually is included.

Since automatic monitors tend to be large and best adapted to fixed and protected locations, remote sampling usually is employed; and since they often are expensive, they often are provided with sequential multi-point sampling, or with several remote sensors.

(1) Remote sampling

With remote sampling the problems of valid samples and system memory may be substantial, and system design, materials and flow rates become significant. With long sample lines, the required flow is determined by the total volume of the sampling system and by the desired response.

A short residence time is required to maintain a fast instrument response to concentration changes at the sampling point. Thus, for long tube runs, optimum response of the monitor to changes in sample concentration may require both high linear flow rate and more than minimum tube diameter--e.g. $\frac{1}{2}$ -inch or greater vs. $\frac{1}{4}$ -inch O.D.--to reduce the surface-to-volume ratio and memory effect. Also, the tube material should be neither itself absorbent to the measured constituents, nor susceptible to the accumulation by corrosion of porous or reactive surfaces or tube constriction. Long plastic tubing has been used successfully for some gases (159), but where long sample lines are involved either stainless steel tubing, or, if otherwise practical, plastic tubing of a larger bore (to compensate for increased absorption effects) and a correspondingly higher pump rate should be employed. Care also must be taken to avoid outside runs and cold traps which may collect condensed solvent or water vapor.

The monitor itself may tolerate a much lesser flow rate (e.g. 0.2 LPM) than that required for good sampling (e.g. 6 LPM). In such situations, either the instrument can be equipped with a separate pump to draw a low-flow sample from the high-flow stream, or the main pump can be located upstream from the monitor and its output largely vented, to yield the requisite net sample stream.

(2) Multi-point sampling

Where instrument costs are high and several locations require routine sampling, one monitor may be time-shared among the several sample lines. In such installations all sample lines should be kept active between sampling periods, to avoid condensation and corrosion and to insure a fresh sample. One large pump can be employed to "keep alive" all the unsampled lines (to a sequential sampling valve designed for this application), and a separate pump provided to draw the time-selected sample through the monitor. The sequential valves generally available through industrial hygiene supply house are not designed for continuous remote multi-point sampling, but suitable valves are available from the manufacturers of process control monitors (Table 8C) (see Section VIII, p.7).

(3) Remote sensors

Some combustible gas monitors employ remote diffusion sensors with individual electronic modules, rather than sequentially valving flow samples from the different sampling points. The remote detector has several advantages:

- 1) No pumping is required, and no pumping failures can occur,
- 2) All sampling points are monitored continuously,
- 3) All monitors function independently, and failure of one component disables only one monitor,
- 4) Sample stoppage and detector flooding by condensate or ice in the sample line is eliminated,
- 5) Cross-contamination in the sequential valve and line-memory are avoided.

The necessity to run electrical conduits to the sampling locations, instead of pipe or tubing, presents a disadvantage both in cost and inflexibility, and the capital cost also is higher. Also, should the need to change sampler locations arise, it is more difficult to relocate electrical-conduit fixtures than to divert or extend metal tubing.

b. Collected Short-term Sampling

Collected (grab) samples may be required for spot check surveillance of the work environment, for routine programmed time or space profile data, or "on demand" at times of process upset, solvent transfer, or other operations of potential unusual hazard. The samples may be taken for immediate instrumental or laboratory analysis, for delayed analysis, or for transport to a remote facility for analysis.* They may be collected as gaseous samples, by solution in a liquid solvent (by impinger, bubbler, or scrubber) or by adsorption on solid surfaces (e.g. silica gel or activated charcoal, etc.).

(1) Whole-air samples

The problems of static whole-air sampling are not just those of measurement and containment. Greases or other lubricants and plastics in contact with the sample can contribute to the sample or absorb it. There is some migration of solvent vapors into most materials and through thin plastic sheets, and there is some loss of condensible vapors, such as benzene, to any surface. For all these reasons, minimum sample contamination or loss will be associated with large samples having low surface-to-volume ratios--and thus least convenient to store and transport. With care in the selection, cleansing and conditioning of materials and surfaces, however, even with small containers, discrepancies between the original and as-analyzed sample concentrations can be kept within limits adequate for industrial hygiene purposes. In general, in the experimental studies of these effects in plastic bags, bottles, and syringes, recoveries have ranged from 80 to 100%, depending upon storage time, container size and type, material, and the individual experimenter (63, 80, 178, 189, 134, 186, 221). For any given method, size, material, and storage period, results probably can be corrected within $\pm 3\%$. Recoveries of over 95% have been reported after storage from five to seven days for all the above forms of containment (134, 178, 186, 189).

* Remote analysis may in fact be necessary, where sampling is distant from the "home office," especially if gas chromatographic (GC) separation is involved. While no such prohibition was known to U. S. air carrier personnel contacted, nor found in the basic regulations, Sherwood (329) states that no pressurized gases are permitted on European airliners, thus debarring the use of portable GC instruments under some circumstances.

Several investigators (81 and others) have reported that the container should first be conditioned by exposure to a pre-sample (or pre-standard) of the same composition as to be stored, to bring the surface into equilibrium with that concentration (which seems eminently logical), but in some studies the data fail to show any significant differences between conditioned and unconditioned surfaces (80). An intensive study of surface effects for all types of containers and materials should be undertaken to establish optimum sampling procedures and equipment for whole-air samples. In general, however, it is a wise procedure to flush all bags, syringes, gas bottles, etc. thoroughly before final filling with the analytical sample.

Plastic gas-sampling bags are widely used as whole-air containers (188, 189, 221, 222, 293, 320, 338), and are available in a number of materials (171). Teflon FEP, Tedlar, and Mylar have been found most suitable for aromatic vapors (78, 80, 81), while somewhat greater loss rates have been observed for Saran and Scotchpak bags (60, 173). Recovery of aromatics appears to be less complete than for most gases and vapors, and extended storage is not recommended (78).

Unmeasured collection of air samples in plastic sampling bags can be accomplished in many ways--e.g., by means of pumps, fans, bulbs, bellows, etc., or by self-filling methods (84, 338). Sampling bags can be obtained with septum holders and valves installed on opposite sides (Table 3F-12, 13, 14) and can be filled by simply pulling apart the sides of the deflated bag with the valve open (304) (with minimum sample contamination if a rubber glove is worn on the valve hand). Caplan (222) uses a small "flashlight" fan to fill the sampling bag, with which he then fills a "breath tube" (from which he samples by hypodermic syringe to obtain GC aliquots). Conventional air sampling pumps can be used, but care must be taken to select a non-contaminating pump (such as the metal bellows pump Table 3A-6) for downstream collection, since most sampling pumps are designed for upstream sampling, in which pump contamination effects have no significance.

The small diaphragm pumps designed for home aquarium aeration (Table 3A-1,3) are suspect because of possible vapor absorption or release by the elastomer diaphragm, but the actual effects for benzene vapor at sub-TLV to above-Peak levels should be determined before rejecting these inexpensive and reliable units.

Measured samples can be obtained by means of timed constant-flowrate sampling pumps, or from hand pumps such as used for gas detector tubes, modified for output flow--with the same problem of possible sample contamination by seals and gasketing materials. This problem can be overcome by enclosing a deflated sample bag in a rigid, gas-tight container which is then exhausted to inflate the bag with ambient air (80). Measured samples also can be obtained by calibrating the volume of standard bags at full inflation to predetermined fullness. This requires so little actual pressure that syringe samples extracted therefrom are not significantly in error (72).

Measured samples (e.g. for GC injection) can be taken from bag samples by syringe through an installed septum, or the bag itself can serve as a septum and can be re-sealed with mending tape. Bag samples also are used to fill evacuated flasks, or to flush and fill flow-through gas bottles and sampling valve loops.

For installations at which a gas chromatograph is located in the plant area, or sufficiently close for sampling lines, air samples can be drawn directly through a sampling valve (see Sec. VIII, p. 7) and inserted into the GC without additional handling (221, 293, 304, 305, 338).

If the sample is to be analyzed remote from the sampling point, or is to be stored before analysis, a flask, gas bottle or syringe may be filled directly from the ambient air, and compactly packed for transportation or storage. Small (4 oz.) "French square" bottles with screw-on caps modified to provide a septum seal have proven quite satisfactory (196).

Perhaps the most convenient method of sampling for GC determination is by gas-tight syringe, which permits direct injection of the air sample into the GC column. This is particularly useful for immediate on-site analysis, but the sealed syringes also can be transported and/or stored for later analysis. High-precision gas-tight syringes are available in sizes from a few micro-liters to 100 ml (Table 3F-18 to 25). Volumes in the 1 to 10 ml range probably yield the optimum compromise between sensitivity and resolution loss due to flow disturbance--depending on GC flow parameters. Inexpensive disposable plastic syringes may prove adequate for industrial hygiene measurements, if sample recovery is found to be reasonably high and repeatable.

(2) Stripped-air samplers

Most commonly, grab samples as well as time-averaged samples are still taken by stripping methods in which the air samples are passed through liquid solvent or solid adsorbent to remove and concentrate the constituents of interest, and the stripped air returned to the environment. Liquid stripping employing UV-transparent solvents (e.g. iso-octane, ethanol, methanol, cyclohexane, etc.) (85) in impingers (138, 139) or bubblers (65, 191) was preferred when UV spectrophotometry was the most specific available method, and is still in wide use, both in the U. S. (234, 287, 306, 320, 339) and abroad (267). Similarly, impingers and bubblers are used to obtain liquid samples for direct gas chromatograph (GC) injection (135, 147, 292, 334, 343, 349). The most common current method, according to our respondents, is that of adsorption in an activated charcoal (82, 179, 184, 192, 222, 231, 259, 279, 348) or silica gel (74, 77, 90, 95, 106, 144, 187, 235, 330) column, with subsequent elution by liquid solvent, for both UV and GC analysis. Of the solid adsorbents, activated charcoal is favored by American hygienists, most of whom use the P.H.S. method of White, Taylor, Mauer and Kupel (193, 132), optimizing the procedures of Reid and Halpin (162), Fraust and Hermann (98), and Otterson and Guy (157). In this method, the charcoal column is eluted with CS_2 , to which the flame ionization detector (FID) is insensitive, making the method especially adaptable to GC analysis by FID/GC.

Three of the six respondents from laboratories in Europe--Sherwood (329), De Gesero (235), and Turner (339)--use silica gel and elute with an alcohol, as do a considerable number of Americans; and another, Cox (230) now employs a freeze trap, but looks favorably upon a GC column-packing, Poropak Q, which (like charcoal) has less water hold-up than silica gel. Sherwood (329) prefers silica gel in some measure because of the high toxicity of CS_2 , and says that he has no trouble at all storing and transporting samples in capped dry silica gel columns. He also reports (176) finding both charcoal/ CS_2 and thermal desorption of silica gel to be incomplete, and ethanol better than propanol for elution of silica gel. He observes the temperature rise of the gel on addition of the alcohol as evidence of reserve adsorptive capacity. De Gesero, on the other hand, adds isopropanal at once and transports the samples in stoppered flasks, to equilibrate enroute to the laboratory. Possibly mixed-solvents would yield faster, more complete, or smaller-volume elution (184, 187).

Thermal desorption of a collected sample by flash heating offers freedom from the bothersome solvent desorption procedure, and is well suited to automatic instrumentation. Direct freeze-trap collection of condensible vapors for flash injection into a gas chromatograph (94, 109, 230, 276) appears to have lost favor because of water vapor problems; and thermal desorption methods now usually employ silica gel as the collection medium (154), as in the proprietary concentrators (Table 3F-1,2,3).

It would appear that the much greater convenience of a solid-adsorbent column weighs heavily in its favor over the liquid-solvent impinger/bubbler method. Not only are the liquid-sorbent devices more difficult to handle, especially if worn as a personal sampler by an active worker, but transfer and evaporation losses are likely to be greater. For quick grab samples taken not too distant from a gas chromatograph, however, and directly injectable without a long (e.g. 2-hour) and bothersome desorption period, liquid bubbler samples should prove quite advantageous.

Although the literature is filled with accounts of 10-liter or greater samples concentrated by bubblers or columns, such volumes appear no longer to be necessary or wise (see 2. par 3, below). Modern gas chromatographs with flame ionization detectors can determine the benzene concentration of an air sample of only 1 or 2 ml to less than 0.1 ppm, and the newer thermal conductivity detectors are sufficiently sensitive to detect 1-3 ppm benzene in a 5-ml sample, or less than 1 ppm with d-c amplification. Such samples can be obtained on flow sample streams by gas sampling valves, or for grab samples by gas syringe injection. Up to 50 ml gas injections have been used (136). The sample recovery from small gas syringes after transportation and storage from a remote sampling site is not yet fully established, and quite possibly adsorbent column collection is best, even for short-term sampling. It should be adequate to load the columns for this purpose by means of a few 100-cc strokes of a gas-detector-tube pump, with no need for continuous **pumping**, flow calibration, and timing. Pre-purged activated charcoal columns (132) are now commercially available at modest cost in sealed units (Table 3F-26), like gas detector tubes, and can be used with the same pumps. Micro-columns for low-volume samples may permit near-total injection of the eluate (368).

2. Long Term Sampling

An air sample collected at a uniform continuous rate, or as frequent uniformly-spaced equal increments, will have the average composition of the sampled air for the period sampled, and thus will be a measure of the average air contamination level to which the workers have been exposed. Such samples are collected at fixed locations in the workplace breathing area and/or-- often with much greater validity--by means of personal samplers (Tables 3C and 3F) worn by the workmen, with the sampler intake as near as practical to the breathing zone (77a, 106).

The collection media are the same as those employed for short-term sampling (above), but because of the need for greater capacity the stripping methods generally are preferred over whole-air sampling. This has been necessary in the past because of the need to collect or strip large samples (10 liters or more) to obtain adequate analytical precision, but this restraint need not apply today. For example, if sample recovery from syringe samples is proved to be consistently high and repeatable, a pulse-motor-driven syringe, or a "door closer"-type orifice-regulated spring-loaded syringe can be employed to obtain long-term whole-air samples adequate for GC analysis, even as a personal (worker-worn) sampler. For fixed-station samplers, a micro-pump can be used to fill a plastic bag (e.g. 1 liter/8-hr @ 2 ml/min - see 3C-8), with no requirement for calibrated sampling rate or measured volume, so long as the rate is sufficiently uniform for valid averaging. In this manner the measured sample can be taken by syringe or sample loop (valve), and the bag can provide reserve sample for duplicates or re-runs. Similarly, a rigid container can be used, and the sampling rate regulated by means of the rate of change of pressure (M15), with either an evacuated flask or a pressurizing pump, or the method of Conner and Nader can be employed (80).

For both solid and liquid air-stripping sampling, care must be taken not to exceed the capacity of the stripping material to retain the collected sample (106). This is well recognized in liquid bubbler-impinger applications, and frequently 2 or 3 units are connected in series to insure against significant losses. The problem is less recognized in the case of solid adsorbents. It must be understood that these adsorbent columns are not reservoirs that can be filled until they overflow, but are actually long-retention-time chromatographic columns from which any adsorbed sample eventually will emerge

even if subsequent flow is of pure air, and it will be displaced and expelled by gross quantities of any more-firmly-adsorbed (longer-retention-time) constituent--such as water vapor. For this reason, activated charcoal and Poropak Q, which are less hydrophylic than silica gel, are preferable for long-term sampling.

The problems of flowrate uniformity and calibration are not inconsiderable if air concentrations are highly variable, so that a precisely constant sampling rate may be necessary to obtain a representative sample. Line-powered pumps with adequately uniform flowrate are available (see Table 3-A), and recently battery-powered personal samplers have been greatly improved by voltage regulation (Table 3C-1). For fixed installations, the method of pressure-gradient flow regulation used in relatively large-scale industrial samplers (M15) may be applicable.

Ordinarily ball-float rotameters (Table 3-E) are used to adjust sample flow rates and to provide a visual check of the need for readjustment, rendering the analyses highly subject to human error. Mechanical flow controllers (Table 3E-7) are available for non-personal installations, and flow meters which provide an electrical signal are easily adapted to flow control or warning (Table 3E-8, 9, 10). Even rotameters can be provided with optical or capacitative or magnetic sensors to signal non-standard flow -- but none of these devices is easily adaptable to the personal sampler. One such device (Table 3C-5), however, provides a pump stroke totalizer to indicate integrated volume in terms of equivalent time at the nominal flow rate. This compensates for any slow-down with time in the total sample value, but not for the progressively lesser weight given to end-of-shift sampling. The new voltage-regulated models coming on the market (e.g. 3C-1) avoid this "droop" and should eliminate the need for flow re-adjustment.

C. SAMPLING EQUIPMENT

The problems at sampling are necessarily closely related to the types and quality of the available equipment, as has been indicated in the foregoing discussion. Some equipment, however, has been touched on only lightly if at all, and some may merit further consideration. Table 3 lists a number of typical items used in sampling for industrial hygiene purposes, but is by no means all-inclusive, either in its scope or within each type of equipment. However, it should serve to indicate the variety of items available, and some possible sources thereof.

1. Pumps

The available line powered pumps (Table 3-A) generally are intended mainly for monitoring for particulate matter--often determined by the weight change of a filter. Thus they usually have higher flow rates than now required for most vapor-concentration monitors (unless for "keep alive" of multiple lines) and higher than tolerable (without sampler by-pass) for long-term collection. Except for the metal bellows pumps--and possibly the small diaphragm units, they are limited to "vacuum" upstream sampling by lubricant and/or graphite contamination of their effluents. The larger battery-operated pumps (Table 3-B) are useful (or essential) for "field" sampling, but suffer more variable flow.

The small, light-to-medium weight "personal" pumps (Table 3-C) are adapted to 8-hour battery operation (with filters--and, in the new and heavier models, with impingers or absorber columns), either as site monitors or worn by the workers. The new voltage-regulated models can be expected to replace the older models, if not because of better performance per se, then because they are being built to meet H.E.W. Specifications which the older models don't meet.

A combination digitally-controlled pump, adsorption column, and thermal GC injector is listed in Table 3-F.

2. Sequential Gas Samplers

A few gas sampling units and valves are available a) for sequentially passing the same sample stream through a number of impinger or bubblers to obtain a time profile, b) for sequentially contacting a stream with different reagents for different analyses, or c) for sequentially drawing samples from several points--each through its own collector.

The units offered the industrial hygiene market (Table 3-D, typical) appear to be designed for "stake-out" field monitoring, rather than for continuous multi-point monitoring. Valves for the latter purpose are available from process control instrumentation channels.

3. Flowmeters

A few typical rotameters, a diaphragm controller, a turbine flowmeter, and a number of thermal flowmeters, are listed as representative of the devices available, in Table 3-E.

4. Concentrators, Collectors, Traps

A number of sample collection items, self-explanatory, are listed in Table 3-F. Not mentioned heretofore are the double-ended gas sampling bulbs (Table 3F-15, 16, 17) which can be filled by pump flushing or by transfer from a bag sample, and from which GC samples can easily be extracted via a side-arm septum. Probably most important is the recent availability of sealed, pre-filled and conditioned charcoal columns (3F-26) for use in sampling by the "PHS" method (132,193).

TABLE 3-A

(page 1 of 3)

LINE-POWERED AIR SAMPLING PUMPS

<u>Ref. No.</u>	<u>3A-1</u>	<u>3A-2</u>	<u>3A-3</u> FIGURE 2	<u>3A-4</u>
Mfg. &/or Vendor	Oscar (M109) Byron (M28)	SKC (M136)	Gow-Mac(M65)	Science Pump (M130)
Model Number	2000 Spec.	224	59-100	Komhyer A-1000****
Material Type Drive	not stated diaphragm vibrator	Neoprene diaphragm synch.mtr.	Neoprene diaphragm vibrator	Teflon essentric synch.mtr.
Vacuum Max. Flow	n.s. 0.2 LPM(est.)	n.s. 0.2 LPM	3" Hg 0.5 LPM	2" Hg 1 LPM**** (non-adj)
8-hr Stability Life	n.s. 5 yr*	±5% n.s.	±5% 1500-3000h	±2% 5-10,000 hr
Features	low cost, long life, for GC use	fully enclosed in case w/handle, "zero leak" check valves	for GC use with Gow-Mac models	all-Teflon 15% glass fiber reinforced
Size, WxHxD (in)	4x5x4	6¼x8¼x8	3x3x6	2x3½x4½
Weight	2 lb	5 lb	2 lb	2 lb 2 oz
Delivery	n.s.*	2-4 wks	1-2 wks	n.s.
Price	\$12-15	\$255	\$23	\$188

Notes:

* Aquarium pump, modified for vacuum; guaranteed "to Year 2000".

**** Model A-150 available for 0.15 LPM ±1.5%, 2x2½x2½, 8 oz, \$149.

TABLE 3-A (cont'd.)

(page 2 of 3)

LINE-POWERED AIR SAMPLING PUMPS

<u>Ref. No.</u>	<u>3A-5</u>	<u>3A-6</u>	<u>3A-7</u>	<u>3A-8</u>
Mfg. &/or Vendor	FMI (M59)	FIGURE 1 Metal Bellows (Cole-Parmer) (M98/M36)	Cole-Parmer (M36)	Bendix NEI (M104)
Model Number	Lab Pump RRP-1A*	MB-21** (7065-2)	Dyna-vac 7062	Bantam 19102
Material Type Drive	ceramic/carbon piston 1/30 HP,sh.p.	stn.stl. bellows 1/40 HP,sh.p.	n.s.*** diaphragm ind. mtr.	carbon vane n.s.
Vacuum Max. Flow	21" Hg 0.825 LPM	13" Hg 6.2 LPM**	14" Hg 6.5 LPM	15" Hg 13 LPM
8-hr Stability Life	±1% n.s.	n.s. n.s.	n.s. n.s.	n.s. n.s.
Features	pos. displ. micrometer adj. flow to 0.01 sccm (add \$30), reversible, ss body	corrosion proof, non- contaminating	direct drive, high speed for smooth flow	portable case w/built-in flowmeter & valve. ****
Size, WxHxD (in)	10¼x4+x5	6½x3½+x4½	6¼x3½+x4½	5½x6x11½
Weight Delivery	ca 7 lb 1-2 wks	5½ lb 2-4 wks	n.s. 1-3 wks	n.s. n.s.
Price	\$165*	\$66	\$56***	\$215

Notes:

- * Valveless action; also available in 6 & 12 v dc models.
- ** Also available 11 LPM @\$71 to 42 LPM @ \$105.
- *** Available w/ball-bearing motor @ \$66 & in stn. stl @ \$90 & \$101.
- **** With air-sampler filter holder, adapts to impingers, columns, etc.

TABLE 3-A (cont'd.)

(page 3 of 3)

LINE-POWERED AIR SAMPLING PUMPS

<u>Ref. No.</u>	<u>3A-9</u>	<u>3A-10</u>	<u>3A-11</u>	<u>3A-12</u>
Mfg. &/or Vendor	(M36) Cole-Parmer	Bendix NEI(M104)	Bendix NEI (M104)	Radeco (M124)
Model Number	Duraire 7054	Sentry 25121	Air S. Kit 25004	Gen. Purpose M31
Material Type Drive	n.s. diaphragm 1/10 HP,sh.p.	graphite piston n.s.	graphite piston 1/3 HP	n.s. turbine 9/16 HP,sh.p.
Vacuum Max. Flow	25" Hg 42 LPM*	22" Hg 28 LPM	26 Hg 68 LPM	5" Hg 300 LPM****
8-hr Stability Life	not stated n.s.	n.s. n.s.	n.s. n.s.	n.s.**** n.s.
Features	w/retractable handle, noise-dampened; attractive die-cast alum. body	portable case built-in automatic timer (5-60 min), flowmeter & valve**	built-in flowmeter & valve, rectangular case	built-in flowmeter & valve, rectangular case w/handle
Size, WxHxD (in)	7½x5x7½	7x10x16	10x19x13½+	8-x11x8½
Weight Delivery	13½ lb 2-4 wks	n.s. n.s.	n.s. n.s.	20 lb n.s.
Price	\$60*	\$318	\$309	\$155****

Notes:

- * Vac-pressure model, w/valves & regulators @\$83.
- ** Built-in filter holder--adaptable to columns, etc.
- **** Model CF750A w/built-in elapsed-time meter, ±2% regulated @ 50-200 LPM--\$265.

TABLE 3-B

(page 1 of 2)

BATTERY-POWERED AIR SAMPLING PUMPS (non-personal)

<u>Ref. No.</u>	<u>3B-1</u>	<u>3B-2</u>	<u>3B-3</u>	<u>3B-4</u>
Mfg. &/or Vendor	Science Pumps (M130)	FMI (M59)	Bendix NEI (M104)	Bendix NEI (M104)
Model Number	Komhyer D 200	Lab Pump RRP-1B	Telematic 2110-5	Air Sampler 15003
Material Type Battery	Teflon eccentric 6v DC external*	ceramic/carbon piston 6 or 12v. DC external**	n.s. n.s. 8.4v. Ni-Cad rechargeable	n.s. n.s. 6.3v. Ni-Cad rechargeable
Vacuum Max. Flow	3" Hg 2.15 LPM (non-adj.)	19" Hg 0.8 LPM	n.s. 5 LPM	19" Hg 18 LPM****
8-hr Stability Life	$\pm 1\frac{1}{2}\%$ 5000 hr*	$\pm 2\%$ n.s.	n.s. n.s.	n.s. n.s.
Features	all-Teflon 15% glass reinforced	pos. displ., micrometer adj. flow (add \$30), reversible	intrinsically safe, built-in automatic timer, attache case style	built-in flowmeter, shoulder-strap case
Size, WxHxD (in)	2x2 $\frac{1}{2}$ x3	10 $\frac{1}{4}$ x4x5	6 $\frac{1}{2}$ x5-x3 $\frac{1}{2}$	10x4x9
Weight	5.5 oz*	7 lb**	n.s.	n.s.
Delivery	n.s.	1-2 wks	n.s.	n.s.
Price	\$92*	\$165**	\$195***	\$466****

Notes:

- * 750 hr motor brush life; battery not included.
- ** Battery not included.
- *** Battery & charger included (\$135 without).
- **** Designed for filters but adaptable to columns, etc.; batteries included.

TABLE 3-B

(page 2 of 2)

BATTERY-POWERED AIR SAMPLING PUMPS (non-personal)

<u>Ref. No.</u>	<u>3B-5</u>
Mfg. &/or Vendor	RAC (M125)
Model Number	Midget A.S. 2312-B*
Material Type Battery	carbon vane 12v lead*
Vacuum Max. Flow	not stated 15 LPM
8-hr Stability Life	n.s. n.s.*
Features	built-in flowmeter, shoulder strap case
Size, WxHxD (in)	10x3 $\frac{1}{2}$ x7 $\frac{1}{4}$
Weight	5 $\frac{1}{2}$ lb
Delivery	1-2 wks
Price	n.s.

Notes:

- * Line-powered model #2312-A also available; both come complete with impinger; battery is carried in separate case (7 $\frac{1}{2}$ lb, 13 lb total), operates 1 hr at 15 LPM/charge; also operates from automobile cigarette lighter socket; brush life 300 hours. (No response to inquiries, proof not returned)

TABLE 3-C

(page 1 of 2)

PERSONAL SAMPLER PUMPS (all w/Rechargeable Battery)

<u>Ref. No.</u>	<u>3C-1</u>	<u>3C-2</u>	<u>3C-3</u>	<u>3C-4</u>
	FIGURE 3			
Mfg. &/or Vendor	Bendix NEI (M104)	Bendix NEI (M104)	Bendix NEI (M104)	M-S-A (M102)
Model Number	Personnel C115 (new)	Micronair "6-Volt" (new)	Micronair	Monitaire 92813/14
Material Type	not stated diaphragm	n.s. piston	n.s. piston	n.s. diaphragm
Battery Cap. Life	2 AH (n.s.v) 8 hr @12"	n.s. (6v) 8 hr	n.s.(3.75v) 8 hr	n.s. (6v)**** 7 hr
Delta P Max. Flow	17" H ₂ O 5 LPM ²	n.s. 4 LPM**	n.s. 2.5 LPM***	n.s. 4.7 LPM, or 0.94 LPM
8-hr Stability Flowmeter	<-2% 1-5 LPM	n.s. range n.s.	<-5% 1.0-2.0 LPM	n.s.**** (see above)
Features	automatic voltage regulation holds flow constant,* built-in bat. tester	needs flow re-adj. @ 4hr.	not 8 hr for column, or impinger	interchange- able flowmeter tubes for dual range, protected flowmeter
Size, WxHxD (in)	5½x6½x2½	3¼x6½x2¼	6¼-x3¼x2¼-	2x4x4¼+
Weight	3 lb	24 oz	18 oz	19 oz
Delivery	1-3 wks	1-3 wks	1-3 wks	2-4 wks
Price	\$350	n.s.	n.s.	\$121****

Notes:

All models this page Bureau of Mines approved, chargers not included.

* Pulse damped, meets Bureau of Mines & HEW specifications, supersedes C110, holds constant flow 8 hr without re-adjustment.

** Lightweight models, require flow re-adjustment 8 hr.

**** Line operation on 16-hr charge setting, faster charge also available; stability claimed superior by some respondents cf. other available in 1971; pulse-damped model for column and impinger applications, to meet HEW specifications, in development.

TABLE 3-C

(page 2 of 2)

PERSONAL SAMPLER PUMPS (all w/Rechargeable Battery)

<u>Ref. No.</u>	<u>3C-5</u>	<u>3C-6</u>	<u>3C-7</u>	<u>3C-8</u>
Mfg. &/or Vendor	Casella(M160) Willson (ESB)	SKC (M136)	SKC (M136)	SKC (M136)
Model Number	GP. Personal C	Life Guard 222-2000	Life Guard 222-1	Life Guard 222-2
Material Type	synthetic diaphragm	- - - - -	not stated diaphragm	- - - - -
Battery Cap. Life	0.9AH(7.5v)* 10 hr (filter)	- - - - -	n.s. (3v) 8 hr	- - - - -
Delta P Max. Flow	6" @ 2LPM 3 LPM	- - - - - 2.0 LPM (non-adj)	- n.s. - - - 1 sccm (non-adj)	- - - - - 2 sccm (non-adj)
8-hr Stability Flowmeter	B/M 0.5 to 5 LPM (separate)*	- - - - -	Bureau of Mines approved none	- - - - -
Features	built-in timer, no flowmeter built-in, speed-governed motor	- - - - -	regulated voltage $\pm 0.025v$ ($\pm 0.8\%$) "zero leak" check valves stainless steel case	- - - - -
Size, WxHxD (in)	3 $\frac{1}{2}$ x5x2 $\frac{1}{4}$	- - - - -	3 $\frac{1}{2}$ x6 $\frac{1}{2}$ x1-3/4	- - - - -
Weight	1 lb 5 oz	- - - - -	2 lb 4 oz	- - - - -
Delivery	1-5 wks	- - - - -	n.s.	- - - - -
Price	\$170*	\$225	\$235	\$235

Notes:

All models this page Bureau of Mines approved, chargers not included.

- * Current model (also 6v DEAC 5/900 battery, older model?).
pulse-damped model to meet HEW specifications in development;
absorption tube and holder, personal \$17, static \$19.

TABLE 3-D
SEQUENTIAL GAS SAMPLERS

<u>Ref. No.</u>	<u>3D-1</u>	<u>3D-2</u>	<u>3D-3</u>
Mfg. &/or Vendor	RAC (M125)	Bendix NEI (M104)	Bendix NEI (M104)
Model Number	PV 2340 (H)*	SQ-12 3500-10**	SAS-24 24008
No. of inputs	12	12	24
Flow (max.) Flow (req'd)	15 LPM 1 to 5 LPM	28 LPM** not stated	n.s. n.s.
Programmer: Per sample Total cycle	$\frac{1}{2}$ to 23 /4 hr 3/4 to 288 hr	10 m to 5 h 24 hr	n.s. 48 hr
Pump Size (in) Weight	12x17 $\frac{1}{4}$ x12 30 $\frac{1}{2}$ lb	use separate pump**	integral 1/15 HP carbon vane pump***
Impinger case Size, WxHxD (in) Weight	5 $\frac{1}{4}$ x14x12 16 $\frac{1}{2}$ lb	11 $\frac{1}{4}$ x26x8 $\frac{1}{2}$ n.s.	18x12x12 $\frac{1}{2}$ n.s.
Delivery	1-2 wks	n.s.	n.s.
Price	\$740*	\$720**	\$925***

Notes:

- * Heated impinger-case available @ \$n.s.; impingers & columns not included.
- ** Separate heater available; separate pump #1750-50 @ \$n.s. (see ref. 199).
- *** Also available without pump, @ \$740; switch assembly only, #24063 @ \$475.

TABLE 3-E

(page 1 of 3)

FLOW METERS, GAS (Typical)

<u>Ref. No.</u>	<u>3E-1</u>	<u>3E-2</u>	<u>3E-3</u>	<u>3E-4</u>
Mfg. &/or Vendor	Gilmont Cole-Parmer (M36)	NEI (M104)	RAC(M125)	Dwyer (M48)
Model Number	Cal & Cor. E-7x60(3234)	Dual Scale** 8200 series	Dual Scale** AD series	Visi-Float VFB(4" scale)
Type Form	rotameter shielded tube	rotameter plastic block	rotameter plastic block	rotameter plastic block
Min. Range	1-260 sccm*	0.3-2 LPM	0.5-6 LPM	0.2-4 LPM
Max. Range	0.2-12 LPM*	10-84 LPM	5-25 LPM	4-40 LPM
No. Ranges	3	6	2	5
Precision	±2% (est.)	±10%	±10%	±3%
Control Valve Mounting	micrometer pipe mtd.	needle stand	needle stand/plate	SS needle pipe mtd
Size WxDxH (in)	n.s.	n.s.	n.s.	~2x2x7
Weight	n.s.	n.s.	n.s.	n.s.
Delivery	n.s.	n.s.	n.s.	2-4 wks
Price	\$100	n.s.	n.s.	\$17

Notes:

- * Arbitrary scale and correlation chart.
- ** Other scale in standard cubic feet per hour (SCFM).

TABLE 3-E

(page 2 of 3)

FLOWMETERS, GAS (Typical)

<u>Ref. No.</u>	<u>3E-5</u>	<u>3E-6</u>	<u>3E-7</u>
Mfg. &/or Vendor	(Schutte & K.) Sci. Gas (M131)	Fisher (M56) Alltech (M4)	Brooks (M27)
Model Number	FM 175 *	Alltech Prec'n 4040	Controller*** 8900 series
Type Form	rotameter tube & frame	rotameters (3) tube & frame	rotameter*** tube & frame
Min. Range	3-33 sccm		0.37-1.3LPM***
Max. Range	4-42 LPM	single	24-63 LPM
No. Ranges	16	1	6***
Precision	±2%(1% sp)	n.s.	±3% std(1%sp)
Control Valve	needle	needle (3)	needle
Mounting	panel/bench	panel**	pipe mtd.
Size WxDxH (in)	2x2x9	n.s.	3x3.10
Weight	not stated	n.s.	n.s.
Delivery	n.s.	stock	2-4 wks
Price	\$46 - \$110	\$187	\$19-\$162***

Notes:

- * 175 mm scale; panel or bench mtg.; brass, SS, Monel, PVC in aluminum case.
- ** Three-meter assembly for GC: air 20-400 ml/min, carrier gas (uncal.) 76 divs, hydrogen 10-100 ml/min; also available bench mtg.-\$225.
- *** Integrally mounted flowmeter and controller, available in alum, brass and 316 SS; flow data are for 250mm scale Sho-rate flowmeter, 150 mm also available; flowmeters and controllers available separately.

TABLE 3-E

(page 3 of 3)

FLOWMETERS, GAS (Typical)

<u>Ref. No.</u>	<u>3E-8</u>	<u>3E-9</u>	<u>3E-10</u>
Mfg. &/or Vendor	Flow Tech.(M58)	Brooks (M27)	Tech. Inc.(M164) Versatronics
Model Number	Omiflo* FTM/LFA	Mass Flowmeter 5800 Series**	MFG Series MFG-01 (typ.)
Type Form	turbine 2-piece	thermal 2-piece	thermal 2-piece
Min. Range	10-150 sccm	0-10 sccm	100 sccm***
Max. Range	1000-10,000 LPM	0-5 LPM (air)	800 scfm
No. Ranges	6 (decade)	9	11 (preselect 1)
Precision	±0.2%	±0.2%	±2%
Control Valve	not included	not included	none
Mounting	pipe/panel	pipe/panel	in-line
Size WxDxH (in)	1½x3x3 (sensor)	3½x2½x1½	1½x2½x3
Weight	not stated	n.s.	n.s.
Delivery	n.s.	2-4 wks	n.s.
Price	\$1390	\$420	\$970***

Notes:

- * See File A-4 for full details, remote readout.
- ** Similar instruments available from CGS/Datametrix (price n.s.), Flow Corporation (price n.s.), Thermal Instrument Corp. (\$1150), & Hastings-Raydist (price n.s.)
- *** Flow, price and dimension for linear (±0.4%) model 0-100 sccm; prices to \$1085 w/size; dual range \$1460 to \$1575; non-linear "NL" series \$595, dual \$850, all sizes.

GAS COLLECTION AND CONCENTRATION DEVICESCONCENTRATORSRef. No.SKC Inc. (M136)

3F -1	Model No. 215--Absorption-desorption unit, 8-second thermal desorption, designed for GC use. With concentrator tube, mini-dewar, manifold--	\$750
3F -2	Model No. 216--As above, for remote collection in concentrator tubes, thermal injection--	\$650
3F -3	Model No. 219--"Air Check" system utilizing No. 216, portable sampling station with digitally-controlled metering pump and rechargeable battery, 4 asst'd traps, control assembly, concentrator-desorber, tools, instructions--	\$1950

TUBE HOLDER--for gas detector tubes (or columns)

(see footnote 3C-5, also 3F-26)

Mine Safety Appliances Co. (M102)

3F -4	Cat. No. 92943--Single-tube holder assembly--	\$ 7.00
3F -5	Cat. No. 93481--Multiple-tube holder assembly--	\$23.00

IMPINGERSMine Safety Appliances Co. ("Monitaire" accessories)

3F -6	Cat. No. 93470--Connector assemble for midget impinger--	\$1.45
3F -7	Cat. No. 92947--Adapter and midget impinger--	\$2.90
3F -8	Cat. No. 93495--Tubing for midget impinger--	\$0.45

NEI (Bendix) (formerly Unico) (M104)

3F -9	Cat. No. 7209--Midget impinger--bubbler, 25 ml--calibrated 5 ml to 25 ml, 1mm nozzle, for sampling at 2.8 LPM @ 12" H ₂ O vacuum--	\$10.50
3F-10	Cat. No. 1450-10--Micro-impinger (spill proof), 2 ml, for sampling at 0.57 LPM--	\$17.50

Research Appliance Company (RAC) (M125)

3F-11	Cat. No. 2277-1--Midget impinger-bubbler, 30 ml--calibrated 0-30 ml, for sampling at 2.8 LPM--	\$n.s.
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GAS SAMPLING BAGSAlltech Associates (M4)

3F-12 Teflon gas bags--2-mil FEP Type A, w/1/8 in wide seals;
19 standard sizes: 3x3 in. (50 ml) @ \$10.52 to
36 x 48 in. (180 L) @ \$86.64; 10x12 (3½ L) @ \$14.04
Septum and Swagelok fittings supplied or installed.

Chapman Industries, Inc. (M33)

3F-13 "Fepline" sampling bags, 10-mil Teflon and 2-mil Tedlar.
17 standard sizes, 6x6 in to 60x67 in--\$n.s.
Halkey-Roberts valve and Swagelok fittings supplied
or installed.

Fluorodynamics, Inc. (M61) Sales by Antek (M10)

3F-14 "Chemton" sampling bags, 10-mil Teflon FEP and 2-mil Tedlar
10 standard sizes from 6x6 in (0.7 L) @ \$11.78 FEP and
\$10.25 Tedlar to 60x60 in (450 L) @ \$243 FEP and
\$128 Tedlar; 12x12 (4 L) @ \$19 FEP and \$15 Tedlar.
Halkey-Roberts valve and Swagelok fittings supplied or
installed.

GAS SAMPLING BULBSAlltech Associates (M4)

Double ended, with 2 stopcocks and side-arm septum.

3F-15	Cat. No. 7014 - 125 ml capacity--	\$16.75
3F-16	Cat. No. 7015 - 250 ml capacity--	\$19.50
3F-17	Septa for above, pkg. of 12--	\$ 3.60

SYRINGES, GAS-TIGHT (typical)Alltech Associates (M4) - Hamilton Syringes

3F-18	Model 1001* - 1.0 ml, 10 ul/div.	\$19
3F-19	Model 1002* - 2.5 ml, 50 ul/div.--	\$20
3F-20	Model 1005* - 5.0 ml, 100 ul/div.--	\$20
3F-21	Model 1010 - 10.0 ml, 200 ul/div.--	\$20
3F-22	Model 1020 - 20.0 ml, 1 ml/div.--	\$25
3F-23	Model 1030 - 30.0 ml, 1 ml/div.--	\$30
3F-24	Model 1050 - 50.0 ml, 5 ml/div.--	\$35

* Also available from Anal. Instr. Dev. (M9), and others.

Carle Instrument (M30)

3F-25	Cat. No. 6546 Gas Collector Kit, 10 ml syringe, tubing clamp--	\$ 4
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CHARCOAL COLUMNS (for use with PHS method, Refs. 132, 193)**Barnebey-Cheney (M19)

3F-26	Cat. No. TQS--Contamination Collection tube--10/\$ 7.50 100/\$70
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** M-S-A and NEI also will supply in late 1972.

TABLE 3-G

TRAPS AND DRIERS (typical)

Ref. No.

Alltech Associates (M4)

3G -1	Cat. No. 8122--Charcoal Traps, 120 cc	\$38.00
3G -2	Cat. No. 8123--Charcoal Traps, 400 cc	\$76.00
3G -3	Cat. No. 8124--Refill kit, 400 cc	\$ 4.50
3G -4	Cat. No. 8125--Gas Purifier (5A+Drierite), 120 cc	\$42.00
3G -5	Cat. No. 8128--same, 400 cc	\$84.00
3G -6	Cat. No. 8132--Refill kit, 400 cc	\$ 8.50
3G -7	Cat. No. 4002--Oxy-Trap column, ¼" tubing w/fittings (reduces O ₂ to 0.1-1.0 ppm in GC carrier gas)--	\$49.50

Cole-Parmer (M36)

3G -8	Cat. No. 7193--Drying column, indicating Drierite only approximately 750 cc--	\$20.00
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SKC Inc. (M136)

3G -9	Cat. No. 237-120--Trap w/¼" Swagelok fittings, 120cc	\$41.50
3G-10	Cat. No. 237-400--Same, 400 cc--	\$83.75
3G-11	Cat. No. 236--Pre-filled, disposable, color-indicating trap, filled with charcoal and indicating molecular sieve (Hylar M)--	3/\$39.50
	Filler materials for #237 traps (400cc each)	
3G-12	Drier: Molecular sieve & Drierite-#237-101--	\$ 7.95
3G-13	Hydrocarbon: High-activity charcoal-#237-102--	\$18.50
3G-14	Universal: 3-layer trap filling-#237-103--	\$14.00

Lemaire Instrument Co. (M89)

3G-15	Mercury trap, disposable, 12 mm D x 35 mm L.--	10/\$ 5.00
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IV -- CHEMICAL ANALYSIS

A. LABORATORY METHODS

All of the methods of benzene analysis involving chemical reactions are based on the formation of colored benzene derivatives, and therefore are most accurate as "instrumental methods" in the final quantifying step. However, if no spectrophotometer or photometer is available, concentrations can be estimated by visual comparison with standards freshly prepared by the same procedure (6).

Most of the earlier methods used in industrial hygiene measurements were based on the conversion of benzene to m-dinitrobenzene and subsequent detection and evaluation of that compound or of a secondary derivative. The benzene vapor can be nitrated directly in the collecting impinger, bubbler, scrubber, or gas bulb, using a nitrating mixture of equal volume of concentrated sulfuric and fuming nitric acids. Subsequent standing and/or heating ensures complete nitration, and any of several methods of color development and measurement can be employed following neutralization (3, 4, 6, 7, 8, 10, 18, 10, 115).

The most common procedures employ reaction of m-dinitrobenzene with methyl ethyl ketone (MEK) or other ketones to produce a violet color of intensity proportional to the concentration of the benzene derivative (4, 6, 18, 19). Measurement can be made by comparison with fresh standards by means of a spectrophotometer, or by a photometer using the #53 filter (3); but visual comparison is adequate for most purposes. The MEK (or "Butanone" or "Bureau of Mines") method has been modified for gas bulb collection and analysis of multiple samples (18) and is in current use by some laboratories (204, 234, 306). The Dolin modification is claimed to be specific for benzene in the presence of its homologs and some derivatives (6).

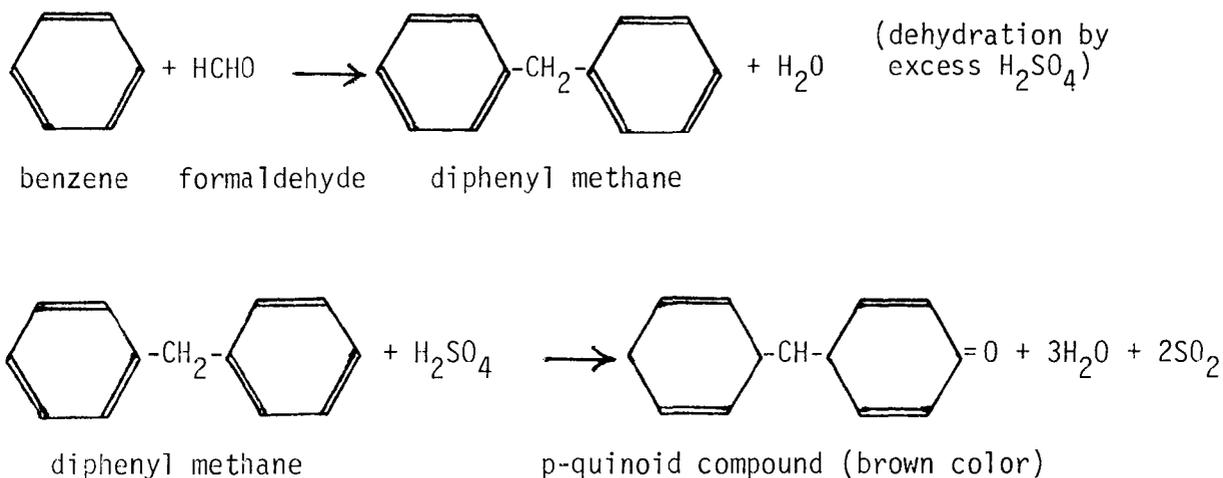
The sulfuric acid-formaldehyde reaction with benzene produces a brown colored compound which has been used as a wet-chemistry method, but this reaction is now employed chiefly in benzene-toluene-xylene gas-detecting tubes (see B below). Methods involving ferric ion reactions also have been used (6).

Direct measurement of benzene in a transparent solvent by UV spectrophotometry (Sec. VII-A) without prior chemical reaction (11) has largely replaced the above methods (77, 90, 144, 306³²⁰), and has been accepted as "standard by" the American Industrial Hygiene Association (31), the American Society for Testing and Materials (40), and the American National Standards Institute (39). Gas chromatography (Sec. VIII) is now largely replacing all photometric methods, but both the colorimetric and spectrometric methods still serve a useful function for the small laboratory or for infrequent need.

A gravimetric non-specific method for hydrocarbon vapors has been reported (103a), in which a measured volume of air sample is dried and passed through a tared column of activated charcoal and evaluated from the weight increase. While probably not generally useful, this method could serve to confirm other measurements--such as by gas detector tubes.

B. GAS DETECTOR TUBES

Although a number of benzene-sensitive chemical reactions have been proposed for use in color-indicating gas detector tubes (45, 115, 129), the established benzene-detecting tubes commercially available in this country (Table 4) all employ the same reaction (282):



These chemicals are adsorbed upon a granular silica gel packing, and packed in a small-bore glass tube which is fusion sealed until use, at which time the tips are broken off. In some tubes a "pre-cleanse layer" is employed to strip out the benzene homologs, to make the tube substantially specific for benzene, but this reduces their accuracy. The tubes generally are sold as being accurate to $\pm 25\%$ of the measured concentration, but studies have shown that none in fact meet this criterion with 95% confidence (64), and the benzene-specific types do not even meet a $\pm 50\%$ (95% C.L.) criterion.

Most tubes are length-of-stain type in which a specified volume of air is pumped through the column at an orifice-regulated rate (unfortunately different for each manufacturer, so that the proprietary pumps are not interchangeable), and the amount of benzene in the specified air volume is indicated by how far the colored portion of the column extends from the air-input end. Each set of tubes is accompanied by a calibration scale or chart, the accuracy of which depends largely upon the uniformity and packing density of the silica gel particles and any physical or chemical changes since calibration--from

either vibration or aging. Shelf life is stated as one or two years*, but in reality is very dependent upon storage temperature, and can be significantly increased by refrigeration. The sensitivity range can be increased by increasing the air volume by a factor of 2 to 10, reducing the indicated concentration accordingly, but also imposing a somewhat corresponding reduction in accuracy.**

The Dräger benzene tubes employ a color comparison technique rather than length-of-stain. The concentration of benzene in the sampled air is measured by the total volume (number of 100 cc pump strokes) necessary to cause the sensitized column to match a reddish-brown comparison layer. The calibration is nominally linear up to 15 strokes, with color-match equivalent to ~25 ug benzene (e.g. 6 strokes = 0.6 liter @ "13 ppm" = $0.6 \times 13 \times 3.2 = 25$ ug).

Although length-of-stain measurement is easier to read than a rather subjective color match and is generally preferred, since individuals vary in their ability to discriminate between subtle changes in color or intensity, several respondents to our inquiries favor the Dräger tubes.

Another manufacturer (M42) has privately announced (227) the marketing of a new benzene-specific detector tube (Table 4B-6), and an established distributor, now reorganized (M1), is introducing a new Japanese product line (Table 4B-7).

The Kitagawa and M-S-A pumps are positive displacement cylinder pumps with indexed piston shafts, and the M-S-A pump also has three selectable orifices (on a turret) to provide different flow rates for different applications. The Dräger pump is a bellows pump with a "calibrated" chain stop to produce 100 cc per stroke, and can be fitted with a stroke counter.

Although detector tubes are of limited sensitivity, specificity and reliability, their low cost, ready availability, easy storage, and simplicity of operation render them still a valuable asset for quick survey or instrument confirmation. They may offer the only practical means of health monitoring equipment for many small operations (16,167).

A list of the available detector tubes applicable to benzene detection, and of the corresponding pumps, is presented in Table 4.

* At ambient temperature. Respondent (332) claims only 6 mos. reliable life.

** Study (106) reports erroneous results with extended sampling time.

TABLE 4
GAS DETECTOR TUBES & TEST KITS

Ref. No.Mine Safety Appliance Com. (M-S-A) (M102)***

4A-1	Pump--100 ml (25 ml inc.), 4 orifices (turret), No. 83499--	\$68
4A-1a	Kit--Pump, parts, case (13x10x2½), No. 83500--	\$82
4A-1b	Kit--Pump, parts, case (19½x13½x4-3/4), No. 83498--	\$90
4A-2	Kit--Pump (bulb), case (plus 12 tubes), No. 08-93118--	\$60

4B-1	Detector tube*--Length-of-stain vs scale, 2-200 ppm benzene (or toluene, xylene, or high CO), 2 yr shelf life (ambient)**, No. 93074--	12/\$35
------	---	---------

NEI (Bendix) (M104))Matheson Gas Products) Kitagawa (Japan) FIGURE 4

4A-3	Pump--100 ml (10 ml inc.) single prec'n orifice, NEI #400--	\$65
4A-3a	Kit--pump, access., case-w/sh.straps, NEI #400, Math. #8014--	\$75

4B-2	Detector tube*--Length-of-stain vs scale, 10-310 ppm benzene (or toluene, xylene, hexane), 1 yr shelf life**, NEI #118A--	5/\$4
------	---	-------

4B-3	Detector tube--Same as above except specific for benzene, 25-345 ppm, 1 yr shelf life**, NEI #118B--	10/\$6
------	--	--------

SKC, Inc. (M136))National Mine Service Co.) Dräger (Germany)

4A-4	Pump (bellows)--100 ml/stroke - SKC #802, NMS/Dräger #31--	\$57
4A-4a	Kit--Pump, pouch, steel case - NMS/Dräger #31/21--	\$90
4A-4b	Kit--Pump, pouch, case, stroke counter - SKC #801--	\$108

4B-4	Detector tube 0.05*--Color match vs comparison layer (count pump strokes to match), 15-420 ppm benzene (or toluene, xylene, naphthalene), 2 yr shelf life guar.** Dräger #CH24801--	10/\$9
------	---	--------

4B-5	Detector tube 5/a--As above except specific for benzene @ 5-40 ppm, (pre-cleanse layer removes 90% toluene and 95% xylene), 2 yr shelf life guaranteed**, Dräger #6718801--	10/\$8
------	---	--------

* Only the tubes indicated by asterisk were found to be accurate within ±50% @95% confidence level over the range 20 to 160 ppm benzene (Ash and Lynch--ref. #64).

** The shelf life of all tubes is extended by refrigerated storage.

*** The bulb pump (#08-93119) in the M-S-A Aromatic Hydrocarbon Detector kit is not recommended because of volumetric inaccuracy.

TABLE 4

(page 2 of 2)

GAS DETECTOR TUBES & TEST KITSRef. No.Devco Engineering (M42) (mfg. not stated)

(new product as of 3/72, per letter, Conti (226))

4A-5 Kit w/bellows pump, case, 10 tubes approximately \$100

4B-6 Detector tubes--length-of-stain, specific for benzene
(pre-cleanse layer for toluene, xylene, naphthalene, etc.)
15 to 400 ppm range--tube price not stated.Acme Products--A.T.O (M1) Gastec (Japan)

(new, sole-distribution product)

4A-6 Kit w/piston pump, pouch \$45

4B-7 Detector tube--length-of-stain (integral scale),
12-800 ppm benzene (or toluene, etc.) 10/\$5

V -- INSTRUMENTAL ANALYSIS -- NON-SPECIFIC

A. CATALYTIC COMBUSTION DETECTORS -- COMBUSTIBLE GAS ANALYZERS

1. Principle of Operation

All hydrocarbon gases and vapors and other combustible gases will burn in air at concentrations above a certain critical level, depending upon their composition. This level is called the lower flammability or lower explosion limit (LFL or LEL). (There is also an upper limit based on air deficiency.) In the presence of an ignition source and a catalytic surface, both of which can be provided by a heated platinum wire*, combustible vapors will be ignited at any concentration, even in the low parts per million range; and treatment of the platinum surface with certain materials makes it a more effective catalyst. If combustible gases or vapors are present in the air surrounding a heated platinum filament, heat from the catalytic combustion of these vapors will be absorbed by the filament and will raise its temperature in proportion to the concentration of the combustible gas. Since the resistance of platinum is proportional to its temperature, the resistance of the platinum filament is a measure of its temperature and of the concentration of the combustible gas. The change in resistance due to this combustion is measured by the unbalance produced in an electrical bridge circuit in which the active filament is compared to a reference filament which is either a) non-catalytic or b) surrounded by an inert atmosphere.

2. Instrument Limitations

The combustible gas analyzer is simple to operate, low to moderate in cost, and fairly dependable. It is an extremely useful instrument if combustibility per se is the property of interest. Its universal sensitivity to all combustible gases become a disadvantage in monitoring for specific vapors, and its usual sensitivity--more than adequate for detecting explosion hazard--is marginally adequate at best for industrial health monitoring.

* Other metal filaments or catalytic beads, etc. also are used. One instrument (5A-1) employs a heated metal-oxide catalyst.

Combustible gas analyzers (CGAs) employing platinum catalysts are considered generally to have greater sensitivity than other types of CGA detectors, but they suffer from the fragility of the fine platinum filaments, especially in portable instruments. All CGAs suffer from eventual depletion of their catalytic efficiency, in varying degree, and platinum filaments are subject to poisoning from Freons, other halogenated compounds, silicones, and heavy-metal organics such as tetraethyl lead. Thus they are not suited for applications in which these substances may be present.

Trace amounts of catalyst poisons in a combustible vapor, which may not seriously incapacitate an instrument at normal vapor levels, may produce serious errors if the vapor level (and hence the poison concentration) undergoes a high-level excursion. Thus, CGA instruments should be recalibrated following each high-scale reading, as well as at routine intervals. Intermittently used instruments should be calibrated before each use.

3. Selectivity and Sensitivity

The CG detector is sensitive to any combustible gas (if mixed with adequate air for combustion), and thus can yield no real measure of any given combustible component unless the composition of the total combustible-gas air burden is known and has been evaluated in terms of that constituent. Benzene vapor determination by CGA thus suffers interference from all organic vapors plus carbon monoxide and ammonia, if present in concentrations at all comparable to or greater than the benzene concentration.*

However, even under this handicap, if the fraction of benzene contribution to the total "combustible gas" measurement is known to be fairly constant under normal operating conditions, and if the actual concentration of benzene under these conditions has been determined by specific analysis

* If low-toxicity combustible vapors such as ethanol or acetone (TLV=1000) are present, concentrations well below their TLV would give a falsely high reading (on an instrument calibrated for benzene) despite the fact that the instrument is less sensitive to these vapors than to benzene. In the cases of carbon monoxide and ammonia (TLV = 50 ppm), however, the 5:1 difference in TLV is offset by an opposite and equal or greater difference in sensitivity, so that an above-TLV reading in terms of benzene would indicate a real hazard, whether the reading were due to benzene, CO, NH₃, or any mixture of these.

(e.g. gas chromatography) to be well below 10 ppm, under most circumstances the approximate benzene vapor level can be estimated with some validity within the "normal" range of "combustible gas" readings. Any marked change in this reading thus would be a warning of abnormal operating conditions and a signal to take corrective action and to initiate appropriate sampling and analysis.

Generally these instruments are employed for explosion-hazard monitoring, and are calibrated in terms of "% LEL" of the specified gas of major hazard potential. Instruments for which only 100% LEL full-scale sensitivity is claimed are not included in Table 5-A (even though they may be capable of higher sensitivity), since they would not detect benzene at TLV levels. A number of more sensitive CG instruments are listed in Table 5-A.

Some models have scales of 0 to 10% LEL, for which a minimum significant (5% f.s.) reading of 0.5% LEL corresponds to ~70 ppm benzene on an instrument calibrated for benzene, toluene, hexane, pentane or gasoline. A few still more sensitive plant monitors are available with full-scale readings of 1,000, 500 and 200 ppm, with detection limits probably about 50, 25 and 10 ppm, respectively. The most sensitive Pt-filament portable instruments have minimum full-scale readings of 200 to 1,000 ppm, but a new metal-oxide catalyst instrument (5A-1, see FIGURE 5) claims a full-scale reading of only 100 ppm and a projected detection level less than 10 ppm, the 8-hr time-weighted-average limit for benzene.

Thus, CG detectors are marginally useful for direct measurements at benzene TLV concentrations, but can be extremely useful at the higher levels attendant upon an "incident", or for detecting abnormal conditions in air containing mixed vapors at sub-TLV concentrations for their normal compositions. These instruments have the advantage of great simplicity and fairly short warm-up (10-40 minutes). They require little maintenance and little skill to operate, but readings must be interpreted with caution and intelligence.

4. Instrument Types

Portable instruments with integral pumps and drawn sample detectors are available in lightweight units with "sniffing" probes or hoses which can be used to sample sumps, floors and other areas not adequately monitored by

fixed-sampler plant monitors. A number of portable instruments are listed in Table 5A, Sec. I and illustrated in FIGURES 5, 6 & 6a. The battery-operated models can be used in outdoor or remote locations.

Plant CG monitors are available with two types of detector heads. The "pump type" or "drawn sample" head is located in or close to the control chassis, and air is pumped to the detector through lines from one or more sampling locations. The detector and alarm system are time-shared via a sequential sampling valve. "Diffusion type" heads are installed at the sampling locations and connected to the control chassis electrically, with individual or time-shared control and alarm circuitry. The relative merits of these operational modes are discussed under Continuous Sampling, Sec. III.p. 3.

A number of combustible-gas plant monitors with either drawn-sample or diffusion heads are listed in Table 5A, Sec. II, and one model is illustrated in FIGURE 7.

5. Operation, Maintenance, and Calibration

Operation is by direct-reading dial (portable) or recorder trace (usually stationary), which usually is calibrated in terms of a single component of interest. Suitable equivalence correction must be applied for other combustible gases in the atmosphere.

Platinum filament monitors will require detector element replacement at intervals from a few weeks to a year or more, depending upon the accumulated exposure, shock, etc. Metal-oxide elements require less frequent replacement.

Portable instruments should be checked and calibrated before each use, but fixed installations yielding consistent low-level readings normally need recalibration only once a shift or less, depending upon required sensitivity and operating conditions. Recalibration is indicated following any substantial high-level reading, or following the presence in the sample of any substance likely to "poison" the catalyst.

Instrument zero is adjusted either by use of "zero gas" air, or by inserting a charcoal filter in the input line. Upscale calibration usually is in terms of a single-component calibration gas, frequently methane, with suitable correction for the gas composition being monitored (see Sec. X).

TABLE 5-A

(page 1 of 5)

SEC. I--COMBUSTIBLE GAS DETECTORS, PORTABLE

<u>Ref. No.</u>	<u>5A-1</u>	<u>5A-2</u>	<u>5A-3</u>	<u>5A-4</u>
	FIGURE 5	FIGURE 6	FIGURE 6a	
Mfg. &/or Vendor	Johnson Div. GasTech(M63)	Bacharach(M16)	Bacharach(M16)	M.S.A. (M102)
Model Number	U.S.G.D. 1024	CSS-P 503-005	Gastron 282	C.G.A. 40
Power	115v/60 Hz	rechg.bat.**	rechg.bat.***	8 D-cell****
Detector type	metal oxide	Pt filament	Pt filament	Pt filament
Min. Det. Conc.	<10ppm	<20ppm**	<50ppm	~100ppm
Min. range	0-100ppm*	0-1000ppm	0-500ppm	0-10%LEL
Max. range		0-100%LEL	0-25% gas	0-100%LEL
No. ranges	1	2	3	2
Stability	10ppm/24hr	±5%/30d	100%/hr	±5%/30d
Response time	5-10 sec.*	6 sec	2 sec	n.s.
Sampling	2 LPM cont.	int. pump**	int. pump	bulb pump
Recorder output	0-10.25,50, 100 mv	option**	none	none
Alarm	option	option**	audible	none
Features	built-in filter for zero set, 10' hose, halogenated HC's OK	options available tube and probe, compensated (silicone resistant)**	pistol-grip light(2#6oz) built-in alarm, direct sample (no hose)	built-in filter chamber, 5 ft hose, carrying strap
Size WxHxD (in)	11x7x7	3x6x8	8x3½x3, +grip	5x6x4
Weight	8½ lb	6 ¾ lb	4 lb 10 oz	6 lb
Delivery	4 wks	1-6 wks	1-4 wks	1-3 wks
Price	\$650	\$431**	\$728	\$175

Notes:

- * Mid-scale = ~25 ppm., 10-minute warm-up.
- ** 8-hr min. charge; some users claim 10 ppm MDC; uncompensated Model 500-001 available at \$397; continuous monitor/alarm models available.
- *** Batteries in belt case (2 lb 4 oz); 2-minute warm-up time; outfit in attache-style case.
- **** 10-11 hr operation per set of batteries.

TABLE 5-A

(page 2 of 5)

SEC. I--COMBUSTIBLE GAS DETECTORS, PORTABLE

<u>Ref. No.</u>	<u>5A-5</u>	<u>5A-6</u>	<u>5A-7</u>	<u>5A-8</u>
Mfg. &/or Vendor	Erdco(M53) "Tox-ex"	Sieger(M137) Smith-Jessee	Scott-Davis (M133)	Erdco(M53) "Tox-ex"
Model Number	05 HCS	608	Vapotester D-16	Transportable 08 GA-SP****
Power	D-cell &EV225	D-cell(C4)	D-cell	115v/60 Hz
Detector type Min. Det. Conc.	Pt filament ~100 ppm	Pt filament ~100 ppm	Pt filament ~100 ppm	Pt filament 25-50 ppm
Min. range	0-10%LEL	0-10%LEL	0-10%LEL	0-500ppm****
Max. range	0-100%LEL	0-100%LEL	0-100%LEL	0-100%LEL
No. ranges	2	2	2	2
Stability	not stated	2% f.s.	±1%/h(cont)	n.s.
Response time	1 sec.	1-3 sec	3 sec	3-4 sec
Sampling	diff'n head	diff'n head	bulb pump	cont. pump
Recorder output	none	none	none	none
Alarm	audible	none	none	audible
Features	built-in alarm, electrically differentiates methane/ benzene, etc.	Battery test, simple operation, convenient hose storage	built-in dryer, 5-foot sample line	long-life pump, cont. opn. 50 ft. hose & probe
Size WxHxD (in)	9x3-x3½+hd1	7½x3½x5	6x3x6	33½x30x22
Weight	2 lb 8 oz	5 lb	4 lb	320
Delivery	6-8 wks	4-6 wks	8 wks	6-8 wks
Price	\$125	\$185**	\$196	\$3650****

Notes:

* 6 hr min. on dry cells, Hi-Cad bat. & charger; bulb pump & hose provided for spot monitoring(3 sec. response @ 25 ft.); long-life filaments.

** 4-6 hr cont. duty; carrying case \$22.50

**** Transportable unit on casters, std. model 0-1000 ppm, long-life filaments.

TABLE 5-A

(page 3 of 5)

SEC. II--COMBUSTIBLE GAS DETECTORS, FIXED

Ref. No.	5A-9	5A-10	5A-11	5A-12
	FIGURE 7			
Mfg &/or Vendor	- - - - -	- - - - -	Sieger - - - - -	- - - - -
	- - - - -	- - - - -	Smith-Jesse, Inc. (M137) - - - - -	- - - - -
Model Number	- - - - -	- - - - -	Gas Alarm - - - - -	- - - - -
	1810	1313	1310	1330
Power	- - - - -	120/240v, 50/60 Hz	or 24vdc	- - - - -
Detector type	Pt filament with impregnated catalysts (diffusion)			
Min. Det. Conc.	- - - - -	- - - - -	25 ppm	- - - - -
Min. range	- - - - -	- - - - -	250 ppm	- - - - -
Max. range	- - - - -	- - - - -	1-1200 ppm	- - - - -
No. ranges	- - - - -	- - - - -	1 (preselect)	- - - - -
Stability	- - - - -	- - - - -	±2% full scale	- - - - -
Response time	- - - - -	- - - - -	1-3 sec.	- - - - -
Sampling	- - - - -	- - - - -	diffusion head (remote)	- - - - -
Recorder output	- - - - -	optional (add \$108/channel)	- - - - -	- - - - -
Alarm	- - - - -	meter, light, 5A contacts or slave relays	- - - - -	- - - - -
Features	single channel, meter	1-3 chan. per bin, single meter	4 to 8 chan. per bin, readout	4 to 8 chan. mixed LEL & ppm by selector switch
Size WxHxD (in)	6½x11+x8½	7x19x14	7x19x14	7x19x14
Weight	15 lb	- - - - -	30 lb	- - - - -
Delivery	- - - - -	- - - - -	6 to 8 weeks	- - - - -
Price	\$975	2ch.-\$2060**	4 ch.-\$3130	e.g.\$2660

Notes:

- * optional 24v battery-supply model available (1810 only)
- ** At \$740 plus \$660/ch. (1 alarm level) or \$780/ch. (2 alarm levels)
- *** At 4/3130 plus \$660/ch. (1 alarm level) or \$780/ch. (2 alarm levels)
- **** LEL modules at \$330 and \$450/channel, resp.

TABLE 5-A

SEC. II--COMBUSTIBLE GAS DETECTORS, FIXED

Ref. No.	5A-13	5A-14	5A-15	5A-16
Mfg. &/or Vendor	Erdco Engineering Corp. (M53) - - - -Tox-ex - - - -		Control Instruments (M40)	
Model Number	- - - CGA Series 04CGA-SP	- - - 010CGA-SP	- - CCS Series A1CC1	- - - A1CCS5
Power	- - 115v/60 Hz - - -		- 120/240v,50/60 Hz	
Detector type	- - - Pt filament - - -		- - Pt filament - - -	
Min. Det. Conc.	- - - ~25 ppm - - -		- - 40 ppm - - -	
Min. range	- - - 0-500 ppm* - - -		- - 0-10%LEL - - -	
Max. range	- - - 0-100%LEL - - -		- - 0-100%LEL - - -	
No. ranges	- - - 2 - - -		- 1 (preselect) - - -	
Stability	- - - not stated - - -		- - - n.s. - - -	
Response time	- -varies w/line run - - -		- - 5 sec - - -	
Sampling	- remote sample flow head -		drawn or diffusion -	
Recorder output	- - - standard - - -		- 0-1 volt (std) - - -	
Alarm	- audible + 5A contacts -		audible + 10A DPDT- -	
Features	single chan.* 2 to 8 chan.** automatic or manual purge for zero adjust high-temp fil.,non-poisoning constant voltage for stability long-life non-pulsing pump rack mounting option		single chan. 5 ch./bin - - purge option - - modular plug-in units versatile controller malfunction warnings two-level alarm option rack mounting option	
Size WxHxD (in)	36x24x9	42x30x9	7x3 ¹ / ₂ x8 ¹ / ₂ ***	19x8-3/4x16***
Weight	n.s.	n.s.	8 lb	16 lb
Delivery	- - - 6-8 wks - - -		- - - 2 weeks - - -	
Price	\$2149*	8/\$3555**	\$520	\$520/ch.

Notes:

- * 0-1000 ppm standard; seq. sampling opt.; single-channel exp.-proof \$3656.
- ** Eight-channel explosion-proof \$5625
- *** Module's 7x3¹/₂ hor. or vert.; various cabinet options include std. relay rack mtg; explosion-proof mtgs. available extra.

TABLE 5-A

(page 5 of 5)

SEC. II--COMBUSTIBLE GAS DETECTORS, FIXED

<u>Ref. No.</u>	<u>5A-17</u>	<u>5A-18</u>	<u>5A-19</u>	<u>5A-20</u>
Mfg. &/or Vendor	Devco Engineering (M42)			
Model Number	- - - 5001-SP	Combustible Gas/Vapor Detection Systems 5002-SP	- - - 5003-SP	- - - 5004-SP
Power	- - - - - 115/240v,60 Hz - - - - -			
Detector Type	- - - - - Pt filament - - - - -			
Min. Det. Conc.	- - - - - approx. 50 ppm - - - - -			
Min. Range	- - - - - 0-1000 ppm (spec)- - - - -			
Max. range	- - - - - 0-100% LEL - - - - -			
No. ranges	- - - - - 1 (preselect) - - - - -			
Stability				
Response time	- - depends on tube run (ca. 2 sec. w/diff. head) - -			
Sampling	flow head(502) flow or remote diffusion head(501)			
Recorder output	- - - - - as required - - - - -			
Alarm	- - - - - as required - - - - -			
Features	rack-mount or bench, single channel*, flow only	rack-mount, 5-ch/bin 7x19 panel, self-contained pumps in drawn-sample (flow head) models.	expl-proof single chan. wall-mtg.,	NEMA-12 wall-mtg., single channel
Size WxHxD (in)	24x8x18	19x7x14	12x12x10	18x20x8
Weight	30 lb	10 lb/ch	50 lb	50 lb
Delivery	n.s.	n.s.	n.s.	n.s.
Price	\$1000**	ca~\$750/ch**	\$1200**	\$750**

Notes:

* Optional Model 5001-nTS w/sequential sampling: 2 to 8 points, 5001-2TS @ \$1500 (200 lb) to 5001-8TS @ \$3500 (300 lb)

** Plus detector heads: 501 @ \$75 (5 lb) (10x3x4); 502 @ \$150 (10 lb) (10x8x8)

B. FLAME IONIZATION DETECTORS -- TOTAL HYDROCARBON ANALYZERS

1. Principle of Operation

In the flame ionization detector (FID), the sample is fed into a hydrogen flame and carbon ions are produced in the flame approximately in proportion to the number of hydrocarbon molecules "consumed" times the number of carbon atoms per molecule.* For each charged ion, a free electron is produced, and these are collected on a positively charged electrode and conducted to "ground" through an electrometer which measures the extremely small current thus produced. For a given hydrocarbon gas or vapor at constant flow, the electrometer current is a direct measure of the volume percent concentration, since the number of molecules per unit volume of a gas or very dilute vapor is proportional to its volume percent concentration.

Unlike the catalytic detector, this detector does not sense carbon monoxide, thus eliminating a serious source of interference in combustible gas analysis in some applications. The FID also can tolerate gases which would poison the platinum catalyst of a CGA, making it the preferred instrument in such applications, quite apart from its other characteristics. Primarily, however, the FID is used, either alone or as a gas chromatograph detector, because it is 2 to 3 orders of magnitude more sensitive than CGA or thermal conductivity detectors.

2. Operating Requirements

Since the FID/electrometer combination is essentially a "carbon atom count rate meter", it responds not only to the concentration of hydrocarbon atoms in the air sample entering the flame, but also and equally to the flow rate of the sample, within operating limits. Thus the sample flow must be precisely controlled, as also must the hydrogen flow.

* Each carbon atom in saturated aliphatic and aromatic compounds has unity ion-production weight. Olefinic carbon atoms have a carbon number of 0.95, and acetylenic carbons 1.3. Oxygen in the molecule has a negative "carbon number" of -1.0 in ethers, and lesser negative effect in alcohols. Nitrogen has a small negative value in amines, and halogens also have minor effects.

In the Total Hydrocarbon Analyzer (THCA), the sample air is also the burner air, and (except for calibration gases) no cylinder gases other than hydrogen are required.* For maximum sensitivity and reliability, the hydrogen used should be lower in hydrocarbon content than the required detection level in the air.

Normally the effect of the HC content of the fuel gas is electrically "bucked out" to yield zero reading during calibration against "zero gas" air. For fixed installations in continuous operation, a hydrogen generator (Table 8D-8) may be justified, thereby providing an ultra-pure hydrogen supply at minimal operating cost.

3. Instrument Types and Features

Commercially available total hydrocarbon analyzers all have drawn-sample detector systems, since hydrogen and high-voltage supplies are required by the sensors and the electrometer is more reliably located close to the detector. While it may be possible to equip a plant THCA with multiple input lines and sequential valving as for CGA instruments, the difficulties in maintaining a flame with interrupted or fluctuating air input (during valving) make this impractical; and FID monitors customarily are installed as single-input units (FIGURES 18 & 19).

One small bench-top model (5B-7) features an optional "selective combustor" accessory which provides programmed catalytic selective oxidation of hydrocarbons to yield separate measurements of total HC, methane, and zero-HC. For benzene analysis, this accessory would be of significant value in analyzing atmospheres in which methane is a major hydrocarbon component, as well as to provide a zero reference without the need for "zero gas." (For this latter purpose alone, a simpler combustor would serve as well, as also would a charcoal filter.)

* In contrast, in FID gas chromatographs, in which the sample is delivered to the flame by inert carrier gas (usually helium), pure air must be provided to support the flame, in addition to hydrogen and the carrier gas. Because of its much higher flow rate and the necessity that it be substantially free of hydrocarbons, the air supply to an FID/GC may constitute its major operating cost.

With one notable exception (5B-1), instruments which are labelled by the manufacturer as "portable" are not actually hand-portable as compared to leak detectors and CGA and mercury survey instruments. During operation they must be stationary on a bench or cart, with hydrogen supply attached. These instruments might more accurately be called semi-portable or bench models, as opposed to panel-mounted plant monitors.

4. Sensitivity and Selectivity

Relative to catalytic combustion detectors, the FID is a selective detector only in that it is insensitive to non-hydrocarbon combustible gases such as hydrogen, carbon monoxide and ammonia--which may or may not be an advantage in any given application. Otherwise its applicability to benzene-in-air analysis is subject to the same restraints and limitations as for CGA instruments when other hydrocarbons are present in the sampled air.

The FID instrument is, however, much more sensitive than the CGA. The sensitivity of the FID can be as low as 0.001 ppm, but in practical applications is limited by the detector noise level and by hydrocarbon impurities in the hydrogen supply, which cannot be entirely zeroed out on a long-term basis. The commercial Total HC analyzers listed in Table 5-B have stated or estimated minimum-detectable-concentration (MDC) sensitivities varying from 0.003 ppm (5B-9) to 1 ppm (5B-1 & 5B-2). Minimum full-scale sensitivities and MDC's frequently are expressed in terms of ppm methane (carbon number 1), and are reduced 6-fold for benzene on a volumetric ppm basis. The listed MDC's are believed to reflect this factor, since benzene sensitivity data were requested, but this may not be true in all cases.

5. Operation, Maintenance, Calibration

Hydrogen consumption by an FID total HC analyzer typically will be between 0.05 and 0.1 SCFH (25 to 50 ml/min), at a cost of 2¢/hr to 60¢/hr, depending upon the grade, cylinder size, and quantity purchased.

The burner requires routine cleaning--depending upon the application, and must be monitored against "flame out" and cessation of operation. Almost all instruments have at least a flame-out indicator light, some also are equipped with audible alarms, and some have automatic fuel shut-off valves to eliminate explosion hazard.

The effect of the slight hydrocarbon content in the fuel gas is electrically "bucked out" during calibration against "zero gas" air in lieu of the atmosphere air sample. Similarly, up-scale sensitivity is checked against a calibration gas, such as methane in air, and instrument readout adjusted accordingly. Normally calibration should be necessary routinely only once a shift, or following any change in fuel supply or any burner cleaning or adjustment.

C. OTHER NON-SPECIFIC DETECTORS

Several other non-specific detectors which are used successfully in other applications were considered with regard to possible applicability to benzene vapor detection. At the present state of development, none appears to have significant advantages in sensitivity or cost compared to standard catalytic-combustion and FID detectors. There is some possibility that some of these instruments are capable of improved sensitivity, types 5C-1 and 5C-2 in particular, and if so they may find greater application.

TABLE 5-B

(page 1 of 3)

TOTAL HYDROCARBON ANALYZERS

<u>Ref. No.</u>	<u>5B-1</u>	<u>5B-2</u>	<u>5B-3</u>	<u>5B-4</u>
	FIGURE 8		FIGURE 9	
Manufacturer	Century(M31)	Ecologic(M49)	Gow-Mac(M65)	Scott/Davis(M133)
Model Number	Org.Vap.Anal. OVA-98A	Tot.HC Anal. 6000	Tot. HC Anal. 23-500	Tot. HC Anal.
Power Application	bat. (8 hr)* portable	115/230,50/60 semi-port.	115v,50/60Hz bench	115v,50/60 semi-port.
Min. Det. Conc.	0.2 ppm	0.1 ppm	0.05 ppm	0.1 ppm
Min. Range	1-10ppm $\frac{1}{4}$ sc.	0-1 ppm	0-0.5 ppm	0.5 ppm
Max. Range#	10,000ppm f.s.	0-5000 ppm	0-5000 ppm	0-5000 ppm
No. Ranges	1(4 dec. log)	4	3	6
Stability	5%/24 hr	$\pm 0.1\%$	$\pm 10\%$	$\pm 2\%/24$ hr
Response	2 sec	2 sec	5 sec	2-3 sec
Sampling	2 LPM (int.)	int. pump	ext.(opt.)***	external
Fuel Supply	8 hr (int.)	20 hr (int.)	external	15-20 h (int.)
Flame-out	aud/vis	lamp	lamp indic.	indicator
Recorder Output	0-5 volt	0-1,0-50mv	0-1, 0-10 mv	n.s.
Alarm	var.pitch	option**	none	audible****
Features	fully port. int. calib. 5 ft. hose and probe*, charcoal filter*	built-in calib. gas, built-in rotameter removable handle & rack mtg.	selective combustor accessory,*** fail-safe flame	calibration stability not flow dependent, adj. alarm set point
Size WxHxD (in)	8 $\frac{1}{2}$ x4 $\frac{1}{2}$ x11 $\frac{1}{2}$ +	12x18x10	12x15x14	12x11x21
Weight	9 lb	38 lb	22 lb	35 lb
Delivery	2-6 wks	4-6 wks	4-6 wks	12 wks
Price	\$2800*	\$1500**	\$1600	\$1520****

Notes:

- # By Range switch at "Min. Range" sensitivity.
- * Rechargeable 12v (charger \$15); meter at probe; charcoal filter \$10
- ** Alarm output @\$150
- *** Sampling pump @\$23; programmed selective combustor @\$595 yields separate values of zero, methane, total HC. (14x12x7, 30 lb): sample by-pass valve \$25.
- **** 2 ppm f.s. on 5 mv recorder; alarm option @\$n.s.; opt. rack mounting.

TABLE 5-B

(page 2 of 3)

Ref. No.	TOTAL HYDROCARBON ANALYZERS			
	5B-5	5B-6 FIGURE 10	5B-7	5B-8
Manufacturer	Bendix (M24)	P.A.I. (M120)	Scott Research (M134)	Beckman(M21)
Model Number	Tot. HC An.	Tot. HC Mon. 30-100	Tot. HC An. 116	F.I. Anal. 400
Power Application	115v/60 Hz semi-port.	115v/60 Hz semi-port.	115v,50/60 Hz semi-port.***	115v/60 Hz bench/panel
Min. Det. Conc.	0.05 ppm	0.05 ppm	0.05 ppm	0.003 ppm
Min. Range	0-1 ppm	0-5 ppm	0-1 ppm	0-0.2 ppm
Max. Range#	n.s.	0-10% ppm	0-10%	0-200 ppm
No. Ranges	1	9	11	4 (decade)
Stability	"zero drift"	±1%	±1%	n.s.
Response	6 sec	1 sec**	2 sec	½ sec
Sampling	int. pump	4-5 LPM (int.)	option	pump(opt.)****
Fuel Supply	external	external	external	external
Flame-out	none	indicator	shut-off (5v) (std)	lamp(std)****
Recorder Output	0-1, 0-10 mv	0-5 mv	0-100 mv	10mv to 50(std)
Alarm	none	optional	optional	optional****
Features	sample rotameter, opt. rack mounting	stabilized flow and electrometer	sintered filters in all gas lines. htd. det., direct read	sintered filter on gas lines, flame arrestor, electronic zero & span, temp. control
Size WxHxD (in)	19x10x20	14x16x14½	19x8-3/4x14	7½x8¼x21
Weight	40 lb	35 lb	45 lb	55 lb
Delivery	4-6 wks	6-12 wks	4-6 wks	1-4 wks
Price	\$1750	\$1850**	\$2050	\$1990

Notes:

- # By Range switch at "Min. Range" sensitivity
- ** Instrument + sampling system response 10-20 sec (typ); alarm, flame-out shut-off, automatic relight & expl.-proof housing options.
- *** Also rack mount or explosion-proof housing
- **** Pump @\$100; Flame-out ckt. & alarm \$55; 4-20/10-50 ma @ \$80, panel mtg w/door \$75

TABLE 5-B
TOTAL HYDROCARBON ANALYZERS

<u>Ref. No.</u>	<u>5B-9</u>	<u>5B-10</u>
	FIGURE 11	
Manufacturer	M-S-A (M102)	Scott-Davis (M133)
Model Number	Total HC	Cont. Mon. 11-6500
Power Application	115v/60 Hz panel mtg.	115,50/60 Hz fixed station
Min. Det. Conc.	0.1 ppm	0.1 ppm
Min. Range	0-1 ppm	0-5 ppm
Max. Range#	0-300 ppm	0-5000 ppm
No. Ranges	8	6
Stability	1%/24 hr	±2%/24 hr
Response	1 sec	2-3 sec
Sampling	pump (opt.)*	external
Fuel Supply	external	external
Flame-out	light*	indicator
Recorder Output	option	0-25 mv
Alarm	option	audible
Features	sintered filters on gas lines, stabilized zero, pot. calibration	calibration stability not flow dependent, adj. alarm set point.
Size WxHxD (in)	19x12x13-	19x42x12
Weight	30 lb	120 lb
Delivery	12-20 wks	12 wks
Price	\$2023	\$2760

Notes:

* Integral pump @ \$105; flame-out shut-off & alarm @ \$158

TABLE 5-C

OTHER NON-SPECIFIC DETECTORS

5C-1. Flame-Thermal Detector (M40/FFA & M133/6800)

In these detectors the combustible gas is ignited by a flame (as in the F.I.D.), and its concentration is measured by means of the associated temperature rise (as in the catalytic-combustion detector). It gains freedom from catalytic poisoning by silicones, halogens and heavy metals at the expense of the added complexity and expense of a flame and fuel, but operates on low-cost propane instead of ultra-pure hydrogen. It is very stable and tolerant of varying ambient temperature and humidity. The commercial instruments found, however, had inadequate full-scale sensitivities of 100% LEL.

5C-2. Selective Catalytic Combustion (M122/Selcom Model 10C-2)

In this detector selective catalysts are used to differentiate between hydrocarbon and carbon monoxide, and a separate passive temperature sensor is used to measure the effect of the combustible components, as in the flame-thermal detector, again losing the simplicity of the platinum filament bridge circuit. An MDC of 20 ppm hexane is reported for the commercial instrument (plus the ability to measure CO separately), and about twice that concentration is indicated for benzene.

A new portable model 11 with separate HC and CO readout is in development and will sell at about \$1,000.

5C-3. Gas Density Detector (M65/11-373 & M120/29-100)

This detector is sometimes used to add the advantage of detector selectivity to gas chromatographic resolution, and sometimes alone. It is not sufficiently sensitive for low concentrations of benzene vapor in air.

5C-4. Thermal Conductivity Detectors (M16/SA65-A & M65/21-200, M95/8013, 23)

This detector operates similarly to the platinum-filament combustible gas monitor--except without catalytic combustion, the gas of interest cooling the filament instead of heating it--depending on its thermal conductivity. Usually the instrument is used as a leak detector, and in this use has good sensitivity to gases with thermal conductivities markedly different from that of air (e.g. hydrogen and helium). It has relatively poor sensitivity to benzene vapor in air. More importantly, all other vapors interfere and mixed gases may counteract each other.

5C-5. Alpha Ionization (M91/GA600B & M102/BillionAire)

These detectors measure the effect of the "contaminant" in the gas stream upon the ion current produced by a radioactive alpha source. In monitoring ambient atmospheres, non-differential instruments would be subject to excessive interferences from slight variations in the concentrations of the more prevalent air constituents, including water vapor. A differential instrument comparing the sampled air with air passed through an activated charcoal filter would yield a continuous real-time measure of the charcoal-adsorbed constituents, but probably would be neither sufficiently sensitive nor sufficiently stable for the purpose at hand. Sensitivity can be increased by chemical reactions, etc. which produce aerosols or particles, believed not feasible here.

VI -- INSTRUMENTAL ANALYSIS -- SEMI-SPECIFIC

A. UV PHOTOMETERS

1. Principles of Operation

Ultraviolet absorption spectra are more often associated with ionic and inorganic characteristics than with organic molecules, but the benzene structure has resonances at these frequencies which can serve to differentiate aromatic from aliphatic compounds. However, the UV absorption spectra of benzene and its homologs, while simpler than the IR spectra, are sufficiently complex and overlapping that these compounds can be separately evaluated only by high-resolution spectrophotometry. (see Sec. VII-A & Sec. IX-A-2)

In photometry, low resolution techniques involving band-pass filters, narrow-band or line-emission sources, or relatively narrow-band sensors are employed. These techniques yield some specificity to spectral regions and absorption bands, but not resolution of individual absorption peaks.

By coincidence, the principal emission line from a low pressure mercury vapor lamp is at 253.7 nm wavelength, and the most intense benzene absorption peak in that region centers at about 255nm. There are other emission and absorption peaks which overlap for benzene and the other light aromatics, so a mercury lamp photometer is fairly sensitive to benzene, toluene and xylene vapors in the beam path, although much less so than to mercury vapor. Ozone and SO₂ also absorb in this region more strongly than benzene, and NO₂ and acetone yield lesser but significant response. Most of these interferents, if present, can be removed by chemical filters, probably with some loss of aromatic vapors, too.

Benzene has much more intense absorption peaks at about 185 and 200 nm which are even more suitable for monitoring, but which require other means of wavelength selection. This selection can be achieved by means of an energy-selective detector or by employing a narrow-bandpass filter. Measurements at these wavelengths are less susceptible to interference from ozone and SO₂, both of which may be present in the air at concentrations comparable to that of benzene. (However, since the ozone and SO₂ TLVs are 0.1 and 5 ppm, respectively, it may be well to include them in the reading.)

2. Instrument Types and Features

Most UV photometers employ a mercury lamp source, and most of these are designed for mercury vapor detection--for which they are most sensitive (6A-1, 2, 3, 4, 8, & 113).

One commercially available gas photometer (6A-5) employs a broad-band (argon lamp) source and a narrow-band detector peaking at about 205 nm. Some (6A-6 and 6A-7) employ dual-beam two-wavelength bandpass filters.

Measurement of two wavelengths yields different ratios for different absorbents, and can be used to identify a pure substance or to resolve, to some extent, a two-component mixture, as discussed below (55c).

Gas photometers have the advantage of being concentration-sensitive instruments--hence no requirement except a fresh sample is imposed upon the sampling system, and they tend to make up in simplicity for lack of specificity. Specificity in some applications is much better than obtained with the CGA or THCA, and sensitivity, depending on the model, may be adequate in many applications. The capital cost is low to moderate, and operating costs are negligible.

The mercury vapor monitor is calibrated in terms of mercury vapor concentration, with a typical minimum range of 0.2 mg Hg/m^3 full scale. This corresponds to about 160 ppm full scale for benzene (262), and an estimated 400 ppm full scale for toluene and xylene. A gold-wire mercury trap is included in most monitors to permit setting zero in mercury-laden air, and could be switched in to check for mercury interference when monitoring for aromatics. Similarly, a slip-on charcoal filter would permit zero setting in the presence of aromatics and most interfering gases.

3. Specificity and Sensitivity

While a single-wavelength instrument will not resolve benzene, toluene and xylene fractions in a mixed-solvent vapor, it will be substantially insensitive to most aliphatic hydrocarbons and alcohols, and will have reduced sensitivity to ketones. The 205 nm instrument (6A-5) is relatively insensitive to SO_2 or ozone.

If the sampled air contains only two major components, a two-wavelength measurement, with proper calibration, will roughly resolve the mixture. The mercury lamp photometer, for example, is about three times more sensitive to benzene than to either toluene or xylene, and the selective sensor photometer (6A-5), is about equally responsive to benzene and toluene, but twice as responsive to the xylenes. For a two-component system of low-level benzene in toluene, for example, two-instrument monitoring might yield a valid approximation of the % benzene in the solvent vapor, as well as of the total vapor concentration in air.

To illustrate this thesis, we can investigate a hypothetical example, with some appropriate but unverified assumptions:

1. Assume that the solvent is toluene with a nominal 1% benzene content; but that the vapor composition is typically 5% benzene, owing to its greater volatility.

2. Assume that the UV continuous monitor (205 nm) has equal sensitivity to benzene and toluene at 100 ppm full scale; and that the mercury meter (254 nm) has full scale readings for benzene and toluene of 160 ppm and 400 ppm, respectively, with scale calibration for 0.2 mg Hg/m³ f.s.

3. Assume that for the purpose of this exercise the toxicities of benzene and toluene are additive, at individual TLVs of 10 ppm and 200 ppm, respectively.

4. Assume that the UV monitor alarm level is set at 50 ppm--an appropriate and not over-safe level, i.e. 50% full scale.

Then the composite TLV is $1/(0.05/10 + 0.95/200) = 102.5$ ppm (total), comprising 5⁺ ppm benzene and 97⁺ ppm toluene, and (at 50 ppm total concentration) the benzene fraction can increase to 15% without exceeding a safe level.

$$\frac{15(50)}{10} + \frac{85(50)}{200} = 96\% \text{ TLV (composite)--at apparent } <50\% \text{ TLV}$$

Case A: Assume that the total benzene + toluene concentration reaches just 50 ppm, and that the benzene fraction is 5% of this or 2.5 ppm. The UV monitor will read 50 ppm, initiating an alarm, and the mercury meter reading will be:

$$\frac{5(50)}{160} + \frac{95(50)}{400} = 13.4\% \text{ f.s. or } 0.027 \text{ mg/m}^3 \text{ "equiv. Hg" reading}$$

Case B: Assume 50 ppm total benzene + toluene, but an increase in the benzene fraction to 16% or 8 ppm. The mercury meter reading will than be:

$$\frac{16(50)}{160} + \frac{84(50)}{400} = 18.5\% \text{ f.s. or } 0.037 \text{ mg/m}^3 \text{ reading}$$

This difference of about 5% of full scale may not be sufficient to justify any firm judgment about vapor composition, but might well indicate the need for a grab sample and analysis. Thus, if a mercury monitor were "red lined" at (in this example) 15% f.s. or 0.03 mg/m^3 , any mercury meter readings above "red line" at UV monitor "alarm" levels of about 50 ppm would call for a grab sample and analysis; but "below red line" readings would indicate normal benzene vapor fractional concentration, and signal only corrective action.

Since the open-gap mercury monitor (6A-3) is calibrated at 0.1 mg/m^3 full scale (80 ppm benzene or 200 ppm toluene), it also should be possible to construct a drawn-sample instrument with equal sensitivity, perhaps with a longer cell. Dual-beam photometry, as in the digital unit (6A-1), also should provide greater sensitivity. Moreover, if the benzene TLV is taken at 25 ppm or at some intermediate concentration for alarm-level purposes, the difficulties in this evaluation are correspondingly reduced. (Note: See also sub-chapter 4, following.)

A similar approach to that of employing two instruments with different relative sensitivities to two components is possible in one instrument currently available (6A-7). This instrument employs two (or four) narrow-bandpass filters, either on separate streams or for two components of a single stream. The single-component instrument recommended by this manufacturer (@ 262.5 nm) would suffer interference not only from the benzene homologs but also from NO_2 and SO_2 , if present. Both of these, however, are of toxicity comparable to benzene.

It appears that in view of their semi-specific response and their ability to measure benzene concentration at or below 10 ppm, more attention should be given to UV photometers for preliminary survey and continuous monitoring applications. The cost of the stationary monitor (6A-5), its simplicity and

freedom from maintenance*, and its sensitivity to ± 2 ppm benzene, all combine to recommend this instrument for continuous monitoring applications in which constant surveillance is needed but an automatic dedicated GC or process GC is not warranted.

The known commercial UV monitors and mercury detectors are listed and described in Table 6-A.

4. Laboratory Photometers and New Developments

Laboratory photometers are low-cost instruments often found in laboratories, but generally are not adaptable to gas samples. If the effort has been taken to collect liquid solvent samples, much more precise determinations are obtainable on spectrophotometers which can resolve and identify the peaks of interest, and which also are found in most laboratories.

An exception to the general inapplicability of laboratory photometers to benzene determination may be available in the recently developed dual-wavelength photometer developed by Karasek (120) and marketed by Pharmacia (M113). The instrument as currently marketed was designed to measure liquid samples only, but apart from this and the dual-wavelength feature it appears to be identical with the L.D.C. Mercury Monitor (6A-8), also developed by Karasek and co-workers (122, and 269).

By fitting a gas cell such as used on the mercury monitor on the dual-wavelength UV photometer of similar design, it should be possible by means of the dual-beam measurements at both 254 and 280 nm to determine not only the concentration but also the composition of a two-component mixture (as described above), but with both much better sensitivity and much better resolution. The price data were not sent with the brochure on this instrument, although requested, but a gas cell model might be expected to cost about \$2500. The sensitivity is not given for a gas cell, since none is offered, but an MDC of 0.1 ppm benzene is estimated (as for 6A-8).

* The Honeywell UVH-15 monitor (FIGURE 13) was developed for detecting ammonia leaks in apple storage warehouses in the Yakima Valley, and is reported to be sensitive and reliable.

Another possibility in a UV photometer for benzene determination is a modification of an oxygen monitor manufactured by Dasibi Corporation. In response to a telephone inquiry regarding the applicability of their instrument to benzene determination, the company undertook some experimental work. The following is from a letter for Lloyd Bowman, President:

"This instrument would have a range of 0.1 to 25 ppm. It would be equipped with special filtering devices to remove ozone, NO₂, SO₂, and mercury. It would contain an alarm which is adjustable and can be set over the entire range of the instrument. The accuracy we anticipate is 10% (±). The instrument operates on the principle of UV absorption. This requires no wet chemicals reagents, or gases to operate."

No further information was given, and no price was indicated.

TABLE 6-A

(page 1 of 2)

SEC. I -- UV PHOTOMETERS, PORTABLE

<u>Ref. No.</u>	<u>6A-1</u>	<u>6A-2</u>	<u>6A-3</u>	<u>6A-4</u>
Manufacturer	A.P.T.C. (M11)	FIGURE 12 Bacharach (M16)	Beckman (M21)	Sunshine (M140)
Model Number	Mercometer 2006-1 (SP)	MV-2 Sniffer 23-7205**	M.V. Meter K-23	Vapor Det. 38 D
Power	115v/60 Hz*	rechg. bat. (8hr)	115v/60 Hz***	115v/60Hz****
Optics	dual-beam	single-beam	single-beam	single-beam
Min. Det. Conc., Hg Est'd Benzene MDC	0.01 mg/m ³ 2 ppm	0.01 mg/m ³ 8 ppm	0.01 mg/m ³ 8 ppm	0.01 mg/m ³ 8 ppm
Min. Range, Hg Max. Range, Hg No. Ranges	0-0.2 mg/m ³ 0-2000 mg/m ³ 4	0-0.2 mg/m ³ 0-1.0 mg/m ³ 2	0-0.1 mg/m ³ 0-1 mg/m ³ 2	0-0.3 mg/m ³ not stated 1
Stability Response	½%/24 hr 0.3 sec	±5%/30d ≤5 sec	*** not stated	"extremely" ≤1 sec
Sampling Recorder Output Alarm	pump(int.) 0-20 mv none	fan(int.) none none	gap*** none option	pump(int.) option**** option****
Features	2-4 digit readout*.	regulated voltage, built-in filter & calib'n.	meter readout.	attached 5' hose, built-in filter.
Size WxHxD (in)	9½x12x11	4½x11½-x4¼+	4½x13x8½	5x17x4
Weight	22 lb	6 lb	7 lb	8 lb
Delivery	1-3 wk	2-6 wk	1-3 wk	1-3 wk
Price	\$1184	\$660	\$895	\$895

Notes:

- * Rechargeable battery pack @ \$365 (40 lb); BCD output @ \$50; designed & calibrated for discrete Hatch and Ott samples.
- ** Supersedes #571-002. Charger \$28, carrying case \$39; Model SMV, cont. monitoring system, available.
- *** Calibrate before each use; closed cells available (requires external pump).
- **** Available in explosion-proof model 38E @ \$1495; alarm and control model 38F @ \$1425; rack or panel mtg. options; battery model in devel.

TABLE 6-A (cont'd)

(page 2 of 2)

SEC. II -- UV PHOTOMETERS, FIXED

Ref. No.	6A-5	6A-6	6A-7	6A-8
	FIGURE 13		FIGURE 14	
Manufacturer	Honeywell(M73)	DuPont(M47)	Peerless(M111)	LDC(M87)
Model Number	G. & V. Det. UVH-15-SP	Photo. Anal. 400	209	Merc. Mon.
Power	115,230,60 Hz	115v,60 Hz	115v,60 Hz	115v,60 Hz
Selectivity by UV Source	Sensor	Filter	Filter	Lamp
Optics	Argon lamp	Hg lamp	not stated	Hg lamp
Sensor	single-beam (185-225 mm)	dual-beam phototubes	chopped d.b. thermistors	dual-beam not stated
Min. Det. Conc.	2 ppm*	4 ppm	2 ppm	<0.1 ppm
Min. Range	10 ppm*	200 ppm	0-50 ppm	2 ppm
Max. Range	50 ppm*	4000 ppm	0-5%	****
No. Ranges	1 (preselect)	n.s.	4	6
Stability	±10%/24h	1 ppm/h	2%/24h	n.s.
Response	not stated	6 sec	<5 sec	n.s.
Sampling	pump*(int)	pump(int)	option***	external
Recorder Output	0-10 mv	0-10 mv	0-10 mv	standard
Alarm	5A-3PDT	1A-SPDT	option***	n.s.
Features	re-zero alarm (manual re-zero).	automatic or manual re-zero.	internal mech'l std'z'n.	Lab instr., recorder included.
Size WxDxH (in)	8x36x8	61x12x5 1/8**	24x8x13	****
Weight	45 lb	85 lb**	40 lb	n.s.
Delivery	4-6 wk	6-12 wk	6-12 wk	n.s.
Price	\$795*	\$4790	\$4300	\$1790

Notes:

- * For open cell & blower;30-in closed cell & diaphragm pump @ \$895
- ** Expl.-proof add \$650; power supply 12x16x6½ (45 lb); control station 12½x4½x9 (12½ lb); zero gas for auto. zero;
- *** Sample module (pump, filter, flowmeter)--\$500; alarm \$100 to \$300
- **** Calibrated in optical density (5 ub/m² Hg f.s.); two units.

B. IR FILTER PHOTOMETERS AND NDIR MONITORS

Benzene exhibits a number of fairly strong absorption peaks in the infrared spectrum which can be utilized for benzene determination. Unfortunately, however, not only the benzene homologs but also many other organic and inorganic gases and vapors absorb in the same or closely adjacent spectral regions, often more strongly than benzene. Thus specificity for benzene requires either a highly specific detector, or additional measurements to provide interference correction data.

1. Two-Wavelength Filter Photometer

One manufacturer (M111) offers a dual-beam filter photometer (6A-7, 6B-7) which is supplied to measure 2 or 4 gases, or fewer gases at 2 or 4 wavelengths, in either the IR or UV regions. It is possible that by dual-wavelength (or 4-wavelength) characterization of a single gas stream, a useful degree of specificity can be attained in the IR, although the UV region appears more promising (55c). Possibly measurements in both regions would be most effective. These questions can be resolved only by experimental measurements, but the manufacturer has not yet undertaken such a study.

Another two-wavelength IR photometer has been developed for NASA as a carbon dioxide sensor (26), and not inconceivably might be adapted to benzene detection. This novel device achieves chopped-beam stability with no-moving parts, the two filtered solid state sources being alternately switched on and off by a multivibrator switching circuit. No data were given on other applications, and the possibility of operating in the far-IR region best for benzene is not indicated.

2. NDIR MONITORS

Non-dispersive infrared (NDIR) photometers are used to measure benzene concentration in process controls, where benzene is the predominant constituent, but they are marginally useful for benzene-in-air in the presence of water vapor, carbon monoxide, carbon dioxide and other inorganic or organic gases and vapors (110, 112, 143).

Most NDIR photometers gain specificity by employing the Luft detector, which comprises a microphonic sensor filled with the gas of interest and a segment wheel or revolving mirror which exposes the sensor to broad-band IR beams alternately through the sample cell and through a reference cell. The gas in the sensor is heated only by the wavelengths to which it is resonant, and these wavelengths are selectively absorbed by the same gas in the sample cell, reducing the heating of the sensor gas during that half-cycle. The pulsating pressure in the sensor thus produces an a-c signal which is proportional to the concentration of the sensor gas in the sample cell.

Even considering the many benzene absorption peaks, and the many other substances which therefore interfere, the Luft type IR photometer might prove a useful device for benzene if a benzene-filled detector could be employed. However, condensible vapors do not yield stable detectors, and aromatic vapors appear to be worse than others, so a non-specific substitute gas (e.g. methane) would have to be employed, reducing sensitivity ten-fold, and specificity even more. Other NDIR monitors employ bandpass filters and non-specific detectors, and although inherently less sensitive may be more appropriate for benzene.

In some applications in which a total concentration value may be of interest, or where NDIR monitors are already at hand, some value may be obtained by such a monitor, especially if used only to indicate trend, and supplemented by other and more specific methods. For this reason a number of such monitors are listed in Table 6-B, although not recommended for new installations.

The NDIR detector, while not appropriate for benzene, is employed in environmental monitors to detect carbon monoxide, for which this method is sensitive and fairly specific. This capability is utilized in the CCIR (chromatograph-combustion IR) instrument developed by the Air Pollution Control District, County of Los Angeles (16, 17). In this instrument all hydrocarbons are catalytically oxidized to CO after GC partitioning, and are measured as CO by an NDIR detector. The NDIR sensor also is employed in a number of automobile exhaust analyzers, some of which also measure hydrocarbons by catalytic oxidation to CO. Two such instruments (6B-9, 6B-10) are listed in Table 6-B, but are judged inapplicable to occupational hygiene measurements.

TABLE 6-B

(page 1 of 1)

"NDIR PHOTOMETERS"

(not recommended)

<u>Ref. No.</u>	
6B- 1	Beckman(M21)--Infrared Analyzer, Series B Models IR-215B, 315B and 415B for laboratory, plant and explosion hazard installations. Luft-type detectors. Minimum range 0-500 ppm (prices not stated).
6B- 2	Bendix(M24)--UNOR Infrared Gas Analyzers Model UNOR 2, Luft detector, process-control type, stable fast response. Minimum range 0-300 ppm, \$2500, (not supplied for benzene).
6B- 3	Infrared(M78)--NDIR Gas Analyzer Model 1000, one or more channels, automatic monitor. Minimum range 0-1000 ppm, \$2500 to \$4000.
6B- 4	Intertech(M81)--Carbon Monoxide Monitoring/Sampling System Model URAS-2, Luft detector, adaptable to benzene sensitivity. Minimum rang 0-100 ppm, \$7500.
6B- 5	JASCO(M83)--NDIR Analyzer-Filter type Model PAX--Benzene MDC 2 ppm @ 100 ppm f.s., w/PMT sensor. Air Mover, recorder, digital readout, alarm options, \$8100.
6B- 6	M-S-A(M102)--Luft-type Infrared Analyzer (LIRA) Model 200, process-control type, fully-engineered. Minimum range 0-300 ppm, \$2750 to \$3665.
6B- 7	Peerless(M111)--Gas Analyzer-Filter type (FIGURE 14) Models for 1 to 8 components. Dual beam with chopper and filters, digital or recorder readout, auto. zero; Minimum range 0-50 ppm (NO & NO ₂ interfere), \$3000 to \$4500.
6B- 8	Anacon(M7)--Moisture Analyzer Model 206, for H ₂ O in liquids, but adaptable to gas streams and other wavelengths, \$6750.
6B- 9	Ecologic(M49)--Infrared Carbon Monoxide Analyzer Model 5500, portable, drawn-sample unit, dual-beam w/chopper, possibly adaptable, \$875.
6B-10	Commercial Electronics(M38)--Allen CO/HC Analyzer Model 15-02, for auto. exhaust analysis, possible adaptable. Minimum range 0-1000 ppm, \$295.

C. FLAME EMISSION PHOTOMETER

In this detector the sample constituents are excited in a hydrogen flame similar to that in an FID (Total HC) or flame-thermal detector, but instead of measuring the ion production or temperature change, the light emission due to excitation is measured. Since various excited atoms or pyrolysis fragments have characteristic emission wavelengths, the detector can be made semi-specific by spectrophotometric measurement. This feature is sometimes employed to augment the resolution of gas chromatography, but also can be employed without prior separation. One manufacturer (M109) has offered such an instrument for benzene vapor detection.

The method has a special advantage for benzene analysis in that greater C_2 emission is obtained from benzene than from its homologs or derivatives, yielding x12 discrimination against toluene and probably even more against xylene, ethylbenzene, etc. (Flame ionization, on the other hand, weights the molecules approximately proportional to their carbon number.) It yields a continuous, real-time readout which can be expressed in terms of ppm benzene --in this case with much greater validity than in the previously discussed instruments.

The instrument has the disadvantage that it requires a flame detector and consumes a considerable amount of fuel, optimally about 400 ml/min (308). This is more nuisance than expense, however, since the hydrogen can be the cheapest available grade (Extra Dry) since the common impurities do not contribute to the benzene emission peak. As a portable instrument using a refillable lecture bottle, the instrument will operate over two hours at about 70¢/hr. As a fixed instrument supplied by a standard 1C cylinder (200 SCF @ \$11), it will operate about ten days at less than 5¢/hr. Hydrogen also can be supplied by an electrolytic generator (Table 8D-8 & 8a).

The commercial instrument is further detailed in Table 6-C.

TABLE 6--C

FLAME EMISSION FILTER PHOTOMETER

<u>Ref. No.</u>	<u>6C-1</u>
Manufacturer	Nuclear Corp.(M108
Model	Benzene Vapor Detector
Power	115v/60 Hz
Min. Det. Conc.	1 ppm
Min. Range	0-200 ppm (typical) (non-linear response)
Max. Range	single range (selectable)
Stability	not stated
Response	5 sec (90%)
Sampling	internal pump (std)
Recorder Output	option
Alarm	option
Features	Handle
Size WxDxH (in)	12x18x12
Weight	35 lb (plus gas bottle)
Delivery	8 to 12 wk
Price	\$3000

VII -- INSTRUMENTAL ANALYSIS -- SPECIFICA. UV SPECTROPHOTOMETER

Several of the older methods of benzene analysis employ spectrophotometry to evaluate the benzene content of a transparent solvent, obtained either in a bubbler or impinger or by elution of a silica gel or charcoal adsorbent (see p. VII-2). However, the strong absorption bands of the benzene compounds in the UV spectrum have been utilized for the direct determination of benzene vapor in air only by photometric methods--with correspondingly low specificity (Sec. VI-A). The fairly complex and overlapping UV absorption spectra of benzene and its homologs and derivatives make the resolution of the conventional mixed-vapor spectrum too difficult and detailed to be easily adaptable to routine monitoring, except possibly by computer techniques.

1. Continuous UV-Spectrophotometric Monitor

Recently a new instrumental technique has been developed which permits the resolution of single absorption peaks almost independent of interferences from adjacent peaks due to other constituents (254, M138). This technique, called "second derivative spectrometry," involves the rapid optical scanning of a small spectral increment (~ 2 nm) to obtain (electro-mechanically and optically) the second derivative (curvature) of the absorption spectrum. This function can be obtained with either a fixed or scanning center-line wavelength, to yield either a concentration record vs. time or a spectral scan. With this instrument spectral peaks often can be identified and measured, if different in peak shape, even if only of minor intensity relative to "interference" peaks. Discrimination against even the benzene homologs is remarkably good (see Table 7-A).

The output signal for the instrument possesses two important characteristics: 1) it is directly related to the total mass of the resonant gas in the absorption path (for small concentrations), and 2) it is independent of fluctuations in the intensity of the excitation light (UV) source, yielding a high signal-to-noise ratio. The sensitivity thus obtained is two to three

orders of magnitude higher than by conventional spectrophotometry, yielding detection levels below 1 ppb for some gases, and well below 1 ppm for benzene vapor.

This instrument is further described in Table 7-A. (FIGURE 15).

2. Laboratory Spectrophotometry

No effort has been made to evaluate laboratory spectrophotometers operating in the UV, UV-Vis, Vis, or IR regions, since these usually are general-purpose instruments valued more for their versatility than for their routine application to a specific determination. In general, where fast or routine or highly specific or extremely sensitive determination of benzene concentration is required, one of the other instruments will do a better job--especially the gas chromatograph.

However, it must be recognized that many laboratories will not have a frequent need for benzene analysis, and may not have justification to procure a gas chromatograph for this or other analyses--although this likelihood grows more remote daily. In many laboratories there may be no GC instrument available, or none not already dedicated to a different problem, or none fitted with a suitable column, while a perfectly good UV-Vis spectrophotometer lies idle on the bench much of the time. In such cases, the well-established methods of UV absorption analysis (31*, 39*, 40*, 45, 90, 105, 144, 197) should prove quite adequate for the occasional need. Even the older colorimetric methods of analysis (6), such as the "butanone method" (3, 6, 18, 19, 20), are still in use (204) and no doubt are quite adequate for occasional or even a substantial number of analyses. While those methods resolve benzene and its homologs only with difficulty if at all, they should still find considerable applicability in the small laboratory (130, 131, 276).

Since most laboratories have such a spectrophotometer on hand, or in any event probably would not purchase one solely for benzene analysis, and considering the great number and wide variety of instruments on the market, no listing of these instruments has been included in this report.

* standard methods of AIHA, ANSI and ASTM

TABLE 7-A

Ref. No.	7A-1	FIGURE 15	7A-2
Manufacturer	Spectrometrics of Florida (M138)		
Model Number	Single-component IV		Multi-component III
Power	- - - - - 115v/60 Hz		- - - - -
Optics Sensor	- - - - - single-beam, d ² phototube		- - - - -
Min. Det. Conc.*	- - - - - 0.005 to 0.5 ppm		- - - - -
Toluene Disc. Factor**	30:1 @ 259nm	to	40:1 @ 242nm
Xylene Disc. Factor**	100:1 @ 252nm	to	100:1 @ 242nm
Stability Response	- - - - - claimed very good 3min/point		- - - - - 7min/4 peaks
Sampling Recorder Alarm	- - - - - built-in pump - - - - - included - - - - - optional (extra cost)		- - - - - - - - - - - - - - -
Features	- - - - - multi-component model - monitors O ₂ to check performance, - ruggedized & simple for long-term - - - - - unattended operation		- - - - - - - - - - - - - - -
Size (in)	56x22x14½		56x22x14½
Weight	125 lb		125 lb
Delivery	6-9 wk		10-14 wk
Price	\$4300		\$12,500

Notes:

* Data supplied by vendor. Highest sensitivity stated only for multi-component model, hence probably includes interference correction, both 0.05 and 0.5 stated for single-component models.

** Discrimination factors were calculated by U. L. U. from scans specially run by vendor (254); Note: sensitivity at 259 nm higher than at 242 nm.

B. INFRARED SPECTROPHOTOMETRY

Until very recently practically all industrial infrared instrumentation has been of the non-dispersive type, relying upon the selective sensing properties of the Luft detector (Sec VI-B). Dispersive IR spectrophotometry has been used in the laboratory to derive absorption spectra from which the composition of complex mixtures and even basic knowledge of molecular structure can be deduced. It has also been used for routine laboratory analysis (35, 45, 71, 79, 145a, 165, 181), especially before the advent of gas chromatography, but is now less widely employed (99). The method is potentially specific, but not wholly so in practice, depending upon interferences present and complexity required for corrections. Prism optics for the infrared region involve either high losses or sensitive materials, and in general dispersive IR has not been an attractive field for the development of "practical" instrumentation.

The announcement in late 1971 and 1972 of a new line of instruments (FIGURE 16) (M159) based on a different concept has altered this picture significantly, although the exact applicability of these instruments to TLV-level benzene-in-air analysis is still obscure. The new instruments employ a circular variable-wavelength filter (CVF) to yield the effect of dispersive optics with greater simplicity and reliability and higher optical efficiency. Thus, as in a conventional spectrophotometer, the sample absorption spectrum can be scanned vs. wavelength to yield a graphic representation or, alternatively, the instrument can be set to "ride" a selected absorption peak to yield a concentration record vs. time. In the case at hand, the instrument could be set to monitor a selected benzene absorption peak on a routine basis, and employed in the scan mode for verification (or identification of interfering constituents) only on the occasion of abnormal peak-monitor readings.

Specificity for benzene relative to its homologs is not obtainable at the wavelength (3.25 μm) for which sensitivity data have been submitted (281), but interference from ozone, CO, and CO₂ can be eliminated. Further work to seek a more selective peak is currently underway (356).*

The relatively high cost of this instrument (\$4000) may militate against it in favor of more specific instrumentation (e.g. GC) for many

* See footnote page VII-5.

applications. However, the new instrument has a number of favorable characteristics. In many cases it may be adequately specific--depending upon the interferences present. In the scan mode it provides an easy means for comparing the vapor composition with "normal," and a possible means for determining the vapor composition. In the "ride" mode it can provide a continuous record of measured concentration. It is simple and inexpensive to operate. The instrument is nominally a hand-portable monitor, but can be obtained for in-plant installation, and in an explosion-proof version.

A two-wavelength model employing fixed-bandpass filters is currently under development. This instrument could easily be adapted to either separate records on two peaks or to single-peak plus peak-ratio output, yielding data on stream composition as well as concentration--for an interference-wise two-component sample. This instrument will be commercially available in 1973.

A tabulation of information on the presently available instrument is given in Table 7-B.

A novel two-wavelength IR filter photometer with possible applicability (26) is described in Sec. X-3. The two-gas or four-gas filter photometer described in Sec. VI (6A-7, Figure 14) also borders on spectrophotometry, if narrow-bandpass filters are used.

- * Late communication (4-7-72) (356) states:
"Our present filter cuts off just below the intense long wavelength band of benzene. A long wavelength filter will allow analysis for benzene with only slight interference from toluene or xylenes."

TABLE 7-B

INFRARED SPECTROMETRIC ANALYZER

<u>Ref. No.</u>	<u>7B-1</u>
	<u>FIGURE 16</u>
Manufacturer	Wilks(M159)
Model	MIRAN Portable Gas Analyzer (<u>M</u> inature <u>I</u> R <u>A</u> nalyzer)
Power	115/230v, 50/60 Hz (or converter from 12v DC)
IR Source	Nichrome-wire-wound ceramic rod
Optical Aperture	f1.5
Measuring Mode	Single-beam (dual-beam in development)
Path Length	3/4 meter to 20 meter, adjustable number of passes
Detector	pyro-electric
Spectral Range	2.5 to 14.5 micro-meters (3 discs)
Min. Det. Conc.	0.1 ppm
Gain Range	75:1 (plus x1, x5 and x20 scale expansion)
Stability	$\pm 1\%/24\text{ hr}$ solid state electronics
Response	0.3, 1 and 4 sec (90%), selectable
Sampling	external pump (not included)*
Recorder Output	0-1v
Alarm	none (can provide on recorder)
Size WxHxD (in)	27x11x6 $\frac{1}{2}$ plus cell
Weight	30 lb
Delivery	4-6 wk
Price	\$3950*

* An ambient air analyzing model now (4-7-72) available @ \$4350.

C. POLAROGRAPH

Polarography is cited in some early references on benzene analysis, and has excited considerable interest elsewhere*. It appears to have gained less attention here (200), but at least one industrial continuous polarograph (developed by R. A. Hagstrom and I. A. Capuano at Olin Matheson) has been reported (116).

Inquiry was made relative to an automated polarograph currently being advertised (M118), but no instrument directly applicable to benzene-in-air analysis appears to be immediately available. (See also Section IX, D)

*Bibliography of Polarographic Literature.

- #3966. Ministry of Chemical Industry--Sector Standard of Analysis of Atmosphere for Noxious Matter: No. 2 Determination of Benzene in the Atmosphere, Standard No. 69-8112, Dr. E. Kucera, Pracovni Lekarstvi 5, 159 (1953).
- #4900. Roubal, J., and Zdrzil, J.--Prumyslove ovzdusi: I. Urcovani par benzenu a jeho homologu ve vztahu k benzinovym param. (Industrial Atmosphere. I. Determination of Benzene and Its Homologues in Relation to Benzine Vapours.). Pracovni Lekarstvi I., 26, (1949).
- #5620.05
Stepanenko, E. M.--Polarographic Determination of Vapors of Benzene and its Homologs in Air. Trudy Nauch. Sessii Leningrad. Nauch.-Issledovatel, Inst. Gigieny Truda i Prof Zabolevanii, Posvyashchen. Itogam Raboty za 1956, Leningrad 273-3 (Pub. 1958). C. A. 55, 1297 (1961).

D. MASS SPECTROMETRY

Mass spectrometry is a powerful adjunct to the other analytical techniques when simple knowledge of molecular or ionic (or pyrolysis fragment) weight is needed to resolve otherwise similar sample constituents. It also can be applied without prior separation in situations in which no weight ambiguity is involved (164). This generally is true of benzene-containing solvent vapors, and an automated MS instruments is available which readily adapts to this determination (M156). It can either scan the spectrum or "ride" a selected peak.

Although this instrument should prove ideal in that it would provide a continuous and unambiguous record of the vapor concentrations in air of benzene and/or associated solvents, the cost of such instrumentation could be justified only if primarily used for one or more other functions, and time-shared for air analysis.

Some performance data on this instrument are given below. (See also Sec. IX, D). (Other MS manufacturers failed to respond to our inquiries.)

TABLE 7-D
MASS SPECTROMETERS, PROCESS & ENVIRONMENTAL

<u>Ref. No.</u>	<u>7D-1</u>
Manufacturer	U.T.I.(M151)
Model	Q30
Power	115v/60 Hz
Min. Det. Conc.	1 ppm
Min. Range	0-10 ppm
Max. Range	0-100%
Stability	High
Sampling	pump (included)
Recorder	strip chart (included)
Alarm	(via recorder switch)
Features	Concurrent multi-component analysis (w/programmed readout and alarm optional) Oscilloscope for test and readout (standard)
Size WxHxD (in)	23x64x32
Weight	400 lb
Delivery	not stated
Price	\$18900

VIII -- GAS CHROMATOGRAPHY

A. OPERATING PRINCIPLES

The gas chromatographic technique is the most universally applicable of all instrumental methods of chemical analysis, both for quantitatively determining substances present in a sample at extremely low concentrations or as a tool for elucidating the composition of extremely complex mixtures--for example, those natural vapors emitted by plants and animals of which we otherwise are aware only as odors. Contrary to this highly qualitative function, the gas chromatograph is basically a non-specific instrument, in that in very large degree it employs as sensors either non-specific detectors or those whose specificity is only for a broad group of compounds (51, 52, 55a).

The outstanding virtue of the gas chromatograph lies in the ability of the chromatographic column to separate the compounds of a mixture and present them to this non-specific detector in a reproducible time sequence. The identity of the substance producing each detector response, or peak, thus is related to the period between the moment of sample entry into the column and the moment of its emergence--as indicated by maximum detector response. The height of the peak (or more properly its true area), as displayed on a recorder chart, is a measure of the quantity of that substance in the sample.

In this instrument an inert carrier gas--usually helium or hydrogen, sometimes nitrogen, and occasionally purified air--flows through the chromatographic column at a uniform rate, passing through the detector at the column exit. Adsorptive material in the column, usually as a "stationary phase" liquid or wax coating on porous packing material, or on the walls of a correspondingly longer (to obtain equivalent surface) open-bore or capillary column, is chosen to have graded attraction to the compounds of interest in a given determination and, insofar as possible, to have negligible adsorptive effect on other fractions.

The sample is injected into the upstream end of the column, either as a gas or dissolved in a volatile liquid (with dissimilar adsorption properties), by syringe or by valve, and is carried through the column by the inert carrier gas. In a suitable column, the components of interest will have graded

adsorption on the column surfaces, and thus will have graded "retention time" between injection and detection, and are identifiable on the detector record on that basis, relative to the retention times of pure standards under identical conditions. The retention time is dependent, for a given column and sample substance, on both carrier gas flowrate and column temperature, so both parameters must be precisely controlled.

The detector output usually is recorded on a strip chart as a series of peaks representing the successively emerging components, the heights of the peaks* being a measure of the amount of that component in the sample. On automated process or environmental monitors, or by added instrumentation on some laboratory instruments, the peaks for each component are separately computed and the data presented digitally, or as a succession of bar graphs, or as separate step-function "trend" records for each component.

* For a given column and detector at fixed operating parameters, the area under the peak is, ideally, a true measure of the quantity of each component, but because of differences in detector sensitivity to different components a different area-to-sample quantity factor applies to each peak. Moreover, area integration in itself involves difficulties and errors, and in many cases peak height measurement serves equally well or better as an index to component quantity.

B. COMPONENTS AND FUNCTIONS

1. GC Detectors

Any device which will respond to the presence of an "impurity" in the carrier gas stream will serve as a GC detector. The two most common detectors are the thermal conductivity detector (TCD) and the flame ionization detector (FID). The thermal conductivity detector is electrically similar to the platinum-filament combustible gas detector (Sec. V-A), except that (as in the leak detector, Table 5C-4) the filament is non-catalytic and is cooled by the gas in proportion to its thermal conductivity--rather than heated by combustion. The flame ionization detector is the same as that used in the Total Hydrocarbon Analyzer (Sec. V-B), and is sensitive only to hydrocarbon compounds (53, 54, 73).

The TCD, though not specific, is selective to the extent that it is most sensitive to those gases and vapors whose thermal conductivities differ most greatly from that of the carrier gas by which it is transported to the detector. Thus, the sensitivity of a TCD/GC to a given substance depends not only upon the thermal conductivity of the substance, but also upon that of the carrier gas employed. Since helium and hydrogen have very high thermal conductivities, and no other gases or vapors are comparable in this respect, these gases are most often used as carriers in TCD/GC instruments.*

Since benzene has a relative thermal conductivity (RTC) of 0.45, and helium and hydrogen have RTC's of 5.8 and 7.1, the TCD is about 20% more sensitive to benzene than to methane (1.45). Thus the TCD also responds strongly to water vapor (TCD \ll 1) which is present to some extent in all ambient air, and therefore water vapor must either be removed from the sampled air or separated from the components of interest by the chromatographic column.

Thermal conductivity detectors vary in their sensitivities by differences in construction which affect both their response to sample changes and their response to spurious effects ("noise"). Detector output stability, and hence minimum detectable concentration, is affected by inadequate temperature control. Sensitivity and resolution are affected by cell volume, since the cell volume of a GC detector corresponds to the "slit width" of the spectrometer and determines the limit of peak resolution in much the same way. Improved detectors now on the market are capable of sensitivities to benzene concentrations down to 1 ppm at the detector. Some have noise levels low enough to permit amplification to yield 1 mv output at 0.1 ppm or less, and full-scale sensitivities of less than 100 ppm before amplification are possible. A few such detectors and amplifiers are listed in Table 8-D. These premium items are not normally provided in "standard" instruments. Amplification at $\times 10$ should provide noise levels well below 5% f.s. in the best units, yielding

* In the leak detector the same effect is employed with opposite "polarity," the instrument, zeroed on air, being most sensitive to hydrogen and helium and nearly insensitive to carbon monoxide, which has a thermal conductivity of 0.97 relative to air.

less than 1 ppm minimum detectable concentrations for 2 to 5 ml sample loops. These sensitivities are presently available only in process and large laboratory TCD/GC instruments having precise temperature control (e.g. 8C-9). Some manufacturers decline to quote maximum sensitivity data, in view of the many factors involved in a given application.

Flame ionization detectors (described in Sec. V-B.1) are extremely sensitive to hydrocarbon vapors, especially in dual-flame differential models which balance out impurities in the operating gases and thus "see" only the sample. Sensitivity to fractional ppb have been reported for laboratory instruments, and some field instruments have full-scale sensitivities of 0.1 ppm or less. As in the case of thermal conductivity detectors, sensitivity numbers are supplied reluctantly if at all by some FID/GC manufacturers, in view of the wide variety of circumstances possibly involved. A 10 ppm f.s. sensitivity (for 2-5 ml air samples) should prove adequate for most occupational hygiene purposes, and should be easily attainable with all FID/GC instruments.

The insensitivity of flame ionization detectors to non-hydrocarbon gases and vapors can be helpful in situations in which the sampled atmosphere contains much greater concentrations of inorganic gases, carbon dioxide or water vapor than of the hydrocarbon, since these constituents might have residual "trailing edge" interference with the peaks of interest if measured with a TCD (73).

Many other detectors have been developed (53, 54), mostly to enhance overall sensitivity, usually at the cost of complexity and operator skill requirements (See IX-A.3.), to obtain adequate sensitivity to substances otherwise difficultly detectable or to obtain resolution between co-emerging peaks by selective measurement (55b, 82, 141, 241, and 360).

Some of these other techniques may prove superior to the TCD in sensitivity and selectivity, without the complexity and gas requirements of the FID. A new piezoelectric detector developed by King, Gibbons and Karasek (122, 123, 124, 125 & 126) and currently under commercial development (M87) shows much promise.

In this detector the sensitive element is a quartz crystal which is incorporated in an oscillator circuit, and the oscillator frequency varies with any change in mass or pressure on the crystal surface. By coating the crystal

with an adsorptive material such as used in GC columns, the oscillator frequency will be changed whenever a substance having affinity for that surface passes through the detector, and this change is a measure of the amount of material so adsorbed and of its concentration in the gas stream.

2. Chromatographic Columns

The sensitivity of a detector cannot alone be considered the measure of sensitivity of a GC instrument, since the sample constituents may be either concentrated or diluted while undergoing partition as they migrate through the column.

In a column prepared to ignore the true gases (e.g. N_2 , O_2 and CO_2) and to partition aromatic fractions, for example, the true gases in an air sample inserted into the carrier stream by a sampling valve or syringe will flow through the column at the same rate as the carrier gas, and the "air peak" indicated by the (TCD) detector will be a measure of this transit period or "response time" of the instrument. Any material which is adsorbed on the "stationary-phase" coating or solid adsorbent column packing material will be delayed in its progress through the column, and the more strongly it is adsorbed the greater this delay. In this manner the different constituents which are so adsorbed form into bands which move down the column (like an elastic string of fuzzy overlapping beads, growing more distinctly separated as they proceed down the column, and farther apart at their increasingly more intense centers as the slower components continue to fall behind) until each band is completely separated from the others. Depending upon the carrier gas flow rate, the nature of the column, and the column temperature, the volume of gas which each band occupies as it enters the detector may be either greater or smaller than the volume of the original air sample.

With a well-selected long column and a slow gas flow (see Sec. IX-A.1.), each peak may be considerably more concentrated than was its fraction of the original air sample; but with "work horse" instruments designed and operated to yield a rapid analysis cycle, sample dilution is likely to occur. Consider, for example, a 2 ml air sample injected into a carrier gas stream flowing at 20 ml/min, and assume (for a given flowrate, temperature and column) all the components of interest will be measured within a 3-minute period, with

each component well separated from the others and emerging over about a 30-second period. Then the total volume occupied (at graded concentration) by each component is about 10 ml, and the average concentration of that component in the detector (over the 30-second period) will be only 20% that in the original sample. If the concentration at the center of the band is 3 times the average concentration, the peak concentration measured by the detector will be only 60% of that which would have been measured, for that component alone, in a Total Hydrocarbon Analyzer (but in that instrument, of course, it could not have been measured alone). Thus flow rate, column partitioning efficiency, and detector volume as well as detector sensitivity, all affect the overall instrument sensitivity (62, 91, and 104).

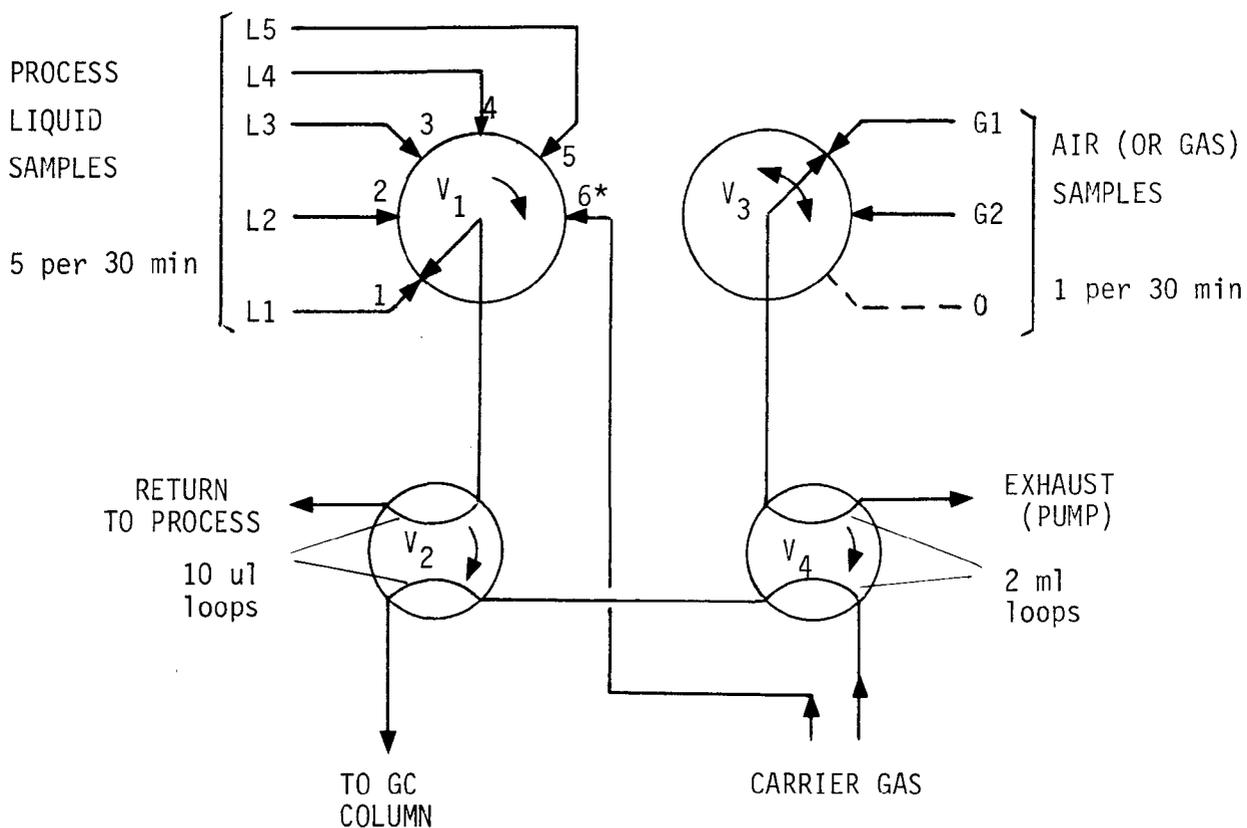
3. Sample Injection

Samples can be injected into the gas stream as microliter liquid samples (with a micro syringe--as for liquid-sorbed long-term samples), by direct injection with a gas-tight syringe (typically 1 to 10 ml), or by a gas sampling valve. In the later device a small length of tubing, the "sample loop" (which may be a few microliters to several ml in volume) is first filled by a drawn-sample stream. When the valve is switched this loop is inserted into the carrier gas stream, and the slug of air sample is swept into the column. This method can easily be automated. Moreover, because it is almost instantaneous and because it simply substitutes a volume of air sample for an equal volume of carrier gas, the sampling valve yields better resolution than syringe injection, which spreads the injection over a longer period and disturbs the gas flow by the volume added.*

Sampling valves can be combined with sequential input-selecting valves to permit atmospheric samples to be alternated with process-control gas or liquid samples, on a time-shared basis. The figure below illustrates an example in which the atmospheric air is sampled once every six 5-minute cycles (i.e. every 30 minutes), the other 5 cycles being devoted to liquid "process" samples. In this illustration the air samples are alternated between two sampling points, each of which would thus be sampled once per hour. An alternative 3-point (or multi-point) sampling system is suggested (by input "0"). Such a system would involve correspondingly longer intervals between

* See addendum, p. VIII-11.

SHARED-TIME MULTI-POINT SAMPLING SYSTEM
(TYPICAL)



- V₁ -- SEQUENTIAL SAMPLING VALVE (liquid 6-position)
- V₂ -- GC SAMPLING VALVE (10 uL loops, 180°/step)
- V₃ -- SEQUENTIAL SAMPLING VALVE (gas - e.g. 2-position)
- V₄ -- GC SAMPLING VALVE (2 mL loops, 180°/step)

* -- PROGRAM STEP NUMBER

PROGRAM (Typical): V₁ & V₂ @ 5-min/step (V₁ lags V₂)
 V₃ & V₄ @ 30-min/step (V₃ lags V₄)
 V₃ & V₄ lag V₂ (STEP #1)

EXAMPLE: The air sample trapped in V₄ at the end of period #6 will be analyzed during immediately succeeding period #1, while sample L1 is filling V₂ via port #1 of V₁. During period #6 the relevant loop of V₂ is flushed with carrier gas to prevent contamination of the air sample from V₄.

samples from a given point. The example given is merely illustrative of the wide range of time-sharing arrangements possible, and of the feasibility of incorporating industrial health monitoring functions into a process control instrument.

C. INSTRUMENT TYPES & FEATURES

Gas chromatographs are available in an ever-growing number of types and models by an expanding manufacturing capability, as the analytical capabilities of these instruments and their applicability to old and new problems become apparent. Nearly all of the smaller or more simple or more industry-oriented and automated instruments employ one or the other of the two well-tested detectors--TCD and FID, though some gas density detectors (Table 5C-3) are employed in process control analyses which benefit from this characteristic.

Few TCD instruments currently available for industrial use are adequately sensitive for benzene determination at TLV Levels--though probably they could be made so with care and effort, at prices comparable to FID models. Both the need for a sensitive simplified GC analyzer and the technology for producing one exist. In particular, there is a real need for an adequately sensitive, easily portable, rough-and-ready model, either battery or line operated (see Sec. IX-1).

1. Portable GC Instruments

Currently there appears to be one instrument on the market which meets most of the above criteria (Figure 17) (M95, 8A-5). Unfortunately, its sensitivity to benzene, is only about 1000 ppm fullscale for the standard instrument. However, the instrument is easily portable and is the only such instrument which operates fully assembled, as carried. A battery-operated, portable (42 lb) FID model (8A-9) with sensitivity below 0.1 ppm comes to something over \$4200 complete with gas supply.

Some lighter weight but less sturdy instruments are available in both TCD and FID models with capability for automatic air-sampling operation--in the scan mode) (8A-1 to 4); and there is a sturdier but less versatile series (8A-6 to 8) at similar cost (\$1300 to \$2000, with gases and recorder).

(Note: A new instrument (8C-14) was added to the tables as a "process" instrument, since it is so employed in current applications. Its low weight and modest cost also qualify it as a "portable" or "bench" instrument.)

2. Bench Models

FID scan-output models with programmed or "demand" automatic operation run over \$4000, compared to similar manual models at nearly 50% less; and an automatic model with trend memory output sells at \$4500 to \$6500 with 3-peak memory and bar-graph readout (8B-4).

An interesting and inexpensive "special" (8B-7) by a process analyzer manufacturer (M120) consists of a Total Hydrocarbon Analyzer with an added column and valve front end, sensitive to 0.05 ppm at under \$3600 for manual operation.

3. Continuous Monitors

Fully automatic process analyzers with automatic sampling and both bar-graph (peak summing) spectra for each sampling period and a trend record on each component--all custom assembled to customer specifications, are difficult to price, but most run about \$10,000 and up. However, one manufacturer (M120) offers a 2-stream, 8-component TCD model at under \$5000, a 2-stream, one-component FID model for under \$7500, and an 8-stream, one-component FID model for under \$8400. Sensitivity to ± 1 ppm by TCD is claimed.

"Environmental" or "Air Quality" GC monitors are now being produced as standard items at around \$8000 for 3 to 5 component models especially designed to measure CO, CH₄, and Total Hydrocarbons. Modification to measure the aromatics involves only slight additional cost.

4. Special-Purpose Instruments

Special-purpose instruments have been developed for specific, otherwise difficult analyses--as for pesticide traces in ground water, foods, etc.--and are not easily applicable to other determinations.

One interesting "special" is an instrument designed to "sniff out" explosives, or those who have handled explosives, in airport loading lines

(M76, 50, 354). This instrument is totally automatic after receipt of a "start" signal, and can detect and alarm on the vapors of the specified explosives in the parts per trillion range.

D. SENSITIVITY ENHANCEMENT

It appears highly desirable to be able to detect sub-ppm levels without the complexity and problems of an FID. Apart from possible improvements in the sensitivities of well-developed detectors like the TCD, or the commercial emergence of new flameless detectors such as the piezoelectric crystal, improved sensitivity can be obtained from existing instruments employing current state-of-the-art TCD's.

Directly improved output from these models requires operation at the lower output voltages associated with lower concentrations, easily obscured by electrical "noise" unless great care is observed in both detector and electronics design, and in the temperature control of the detector and column. For portable and industrial instruments, this care, at added cost, should be worthwhile. Stable low-noise solid-state d-c amplifiers at moderate cost are available as plug-in units suitable for inclusion in the circuits of these instruments, or as recorder pre-amplifiers; and microvolt recorders also are available for upgrading the sensitivities of existing instruments, where detector noise levels permit.

Sensitivity also can be enhanced by sample concentration, either prior to injection or between the column and the detector. Preconcentration can be accomplished by a direct coupled concentrator (Table 3F-1, 2 & 3), by a tandem column in the GC similarly operated, or by stripping sample collection as for time-weighted-average samples (368). Concentration just prior to detection can be accomplished by using hydrogen as the carrier gas, with a known fraction of helium mixed with the hydrogen either within the supply bottle or by precision dynamic mixing at the GC entry. By means of a palladium diffusion apparatus (8D-7), the hydrogen can be removed from the carrier stream, leaving the sample concentrated in the small fraction of helium remaining as a carrier.

E. GC ACCESSORIES

A number of catalogs, brochures and data sheets have been accumulated relative to GC sampling valves, columns, packing materials, etc., as well as on integrators, "peak pickers", detectors, and concentrators--some of which have been referred to herein. These materials are included in the files accompanying Copy #1 of this report, under categories I-6, I-7 and I-8 (see Appendix B-2).

The major items of interest are listed and briefly described in Table 8-D.

Addendum (to "Sample Injection", p. VIII-6):

Sample injection also can be effected by sample adsorption on an internal "stripping" column--with desorption by backflush flow, or on an external column (132,193,87, 220,230)--with thermal desorption directly into the GC column (or by conventional solvent elution and syringe injection).

Both methods permit a large air sample to be concentrated on the pre-column over an extended period, and then relatively quickly injected into the GC. Commercial accessories are available for both close-coupled and remote-sampling sorption and thermal desorption (Table 3F-1, 2, 3). Thermal "flash" desorption, however, requires a significant time (e.g. ~8 sec.), and does not ordinarily yield as good GC resolution as direct on-column injection (102).

TABLE 8-A

SEC. I--GAS CHROMATOGRAPHS, PORTABLE

(page 1 of 5)

Ref. No.	8A-1	8A-2 (See FIGURE 21)	8A-3	8A-4
Manufacturer	- - - - -	Carle Instr. (M30)	- - - - -	- - - - -
Model Number	Basic 6500	Basic 6500G	Basic 8004**	Basic 9000
Power	- - - - -	115v, 60 Hz	- - - - -	- - - - -
No. Columns	2	3	2	2
Detector	micro-therm.	micro-therm.	sens. m-t	diff. FID
Sample Valve	option	standard	option	option
Sampling	- - -	external, by syringe	or pump (w/valve)	- - -
MDC (2 ml)	<100 ppm	<100 ppm	10 ppm	0.1 ppm
Min. Range (2 ml)	3000 ppm	3000 ppm	300 ppm	0-3 ppm
Attenuation	- - x1, x5, x25, x100, x500	- - -	- - -	1,2,5 x 5 dec.
Recorder Output	- - - - -	0-1.0 mv*	- - - - -	- - - - -
Gas Supply	- - - - -	external	- - - - -	- - - - -
Operating Gases	He	He	He	He, H ₂ , Air
Features	- - -	simplicity, low cost, carrying case	- - -	- - -
Size WxHxD (in)	- - - - -	13 x 17 x 5	- - -	14x18x7
Weight	- - - - -	29 lb	- - -	39 lb
Delivery	- - - - -	n.s.-	- - -	n.s.
Price-B	\$ 415	\$ 595	\$ 790	\$1085
C	\$1245	\$1290	\$1623	\$1915

Prices: B--basic instrument, C--with sampling valve and 11A-7 recorder

Note: These instruments were designed chiefly as simplified educational units, yet suitable for field use. By the addition of pumps, electrical valve actuators, and programmers, they can be adapted to automatic operation, but only in scanning mode--not alarm and control. Gas bottles, regulators, etc. not included in size, weight and prices.

* Models 6500 T and 9001, with 0-10mv output, @ \$465, and \$1095(B).

** Other models of 8000 series are less sensitive, lower cost.

Optional accessories:

Sampling valve--	\$135	valve actuator--	\$140-150
Switching valve--	\$125	valve programmer--	\$295-325
Back-flush valve--	\$125	valve oven--	\$145

TABLE 8-A

SEC. I--GAS CHROMATOGRAPHS, PORTABLE

(page 2 of 5)

Ref. No.	8A-5	8A-6	8A-7	8A-8
	FIGURE 17			
Manufacturer	Matheson (M95)	- - - - -	Gow-Mac (M65)	- - - - -
Model Number	Portable GC 8430	Junior 69-050	69-140	Std. FID 69-750
Power	115v/60 Hz	- - - - -	115v/60 Hz	- - - - -
No. Columns	2*	1	2	1
Detector	TDC	dual TDC	4 fil TDC	FID
Sample Valve	option	- - -	option #180-130 @ \$225	- - - - -
Sampling	external	- -	syringe, or pump (opt.) @ \$25	- - -
MDC (2 ml)	10 ppm	4 ppm	1 ppm***	0.05 ppm
Min. Range (2 ml)	0-1000 ppm	0-200 ppm	0-100 ppm	0-0.5 ppm
Attenuation	x1 to x512(10)	- x1 to x512 (10 @ x2) -	-	n.s.
Recorder Output	0-1, 0-5 mv	- - 0-1 to 0-10 mv - -	- -	0-1 mv
Gas Supply	Internal	- - - - -	external	- - - - -
Operating Gases	helium (int)	- - He or N ₂ (ext)	- -	He, H ₂ , air(ext)
Features	portable, operates with cover closed	-	educational models rugged portable cases (open to operate)	n.s. n.s.
Size WxHxD (in)	12x16x13	8x9 ¹ / ₄ x8 ¹ / ₂	9x11x14	13x12x16
Weight	25 lb	10 lb	16 lb	25 lb
Delivery	not stated	- - - - -	2 to 4 wk	- - - - -
Price B	\$ 650	\$ 380	\$ 645	\$1095
C	\$1545	\$1325	\$1590	\$2040

Prices: B-Basic instrument; C-w/sampling valve and 11A-7 recorder

Notes:

- * Non-std. coln. for max sensitivity; heated sample valve (1 ml) @ \$200
 *** Model 100 w/2-filament TDC @ \$595 (2 ml MDC = 2 ppm)

TABLE 8-A

SEC. I--GAS CHROMATOGRAPHS, PORTABLE

(page 3 of 5)

<u>Ref. No.</u>	<u>8A-9</u>	<u>8A-10</u>
Manufacturer	Anal. Inst. Div. (M9)	
Model Number	- - - Portable GC 511	- - - 512
Power	rechg. Ni-Cd & 115v chgr.*	
No. Columns	1	1
Detector	FID	micro-therm.
Sample Valve Sampling	opt. w/1,2&5ml loops @ \$325* syringe or ext. pump w/valve	
MDC (2 ml)	0.05 ppm	75 ppm
Min. Range (2 ml)	0.1 ppm	0-500 ppm
Attenuation	- - - not stated - - - -	
Recorder Output	- - 0-4 volts - - - -	
Gas Supply	- - - internal - - - -	
Operating Gases	He, H ₂ , air	helium
Features	fully-portable, self- contained power and gases for min. 8 hr operation	
Size WxHxD (in)	- - - 18x10x15 - - - -	
Weight	- - - 42 lb - - - -	
Delivery	- - - n.s. - - - -	
Price-B	\$3300	\$2950
C	\$4100	\$3750

Prices: B--basic instrument; C--with sampling valve and 11A-2 recorder

Notes:

- * Back flush valve \$328; switching valve \$400;
Models 521 & 522 for 115v/60 Hz and ext. gases @ \$2700 and \$2350;
Models 531 & 532, rack-mount, @\$2500 & \$2150.

TABLE 8-A

SEC. II--GAS CHROMATOGRAPHS, BENCH

(page 4 of 5)

Ref. No.	8A-11	8A-12	8A-13	8A-14
Manufacturer	Beckman(M21)	Gow-Mac(M65)	- - -	Dohrmann - - -
Model Number	GC-2A	Std GC 69-550	IDC GC 15C-3	Auto-C GC 2460
Power	115v,50/60 Hz	115v/60 Hz	- - 115v/60 Hz	- - - -
No. Columns	2	2	2	2
Detector	4-fil TDC	4-fil TDC	4-fil TDC	FID****
Sample Valve	1 ml (std)*	option**	ext. option	ext. option
Sampling	ext. pump	pump (opt)**	n.s.	n.s.
MDC (2 ml)	not stated	1 ppm	5 ppm	0.05 ppm
Min. Range (2 ml)	n.s.	0-100 ppm	n.s.	n.s.
Attenuation	n.s.	1-512 (10)	1-1024	1-1024
Recorder Output	0-1 mv	0-10 mv	0-1 mv	0-1 mv
Gas Supply	external	ext.	ext.	ext.
Operating Gases	He	He	He	He, H ₂ , Air
Features	compact, simple operation *	compact, low-cost, versatile	versatile, compact low-cost	prog. temp., automatic cycle
Size WxHxD (in)	27½x9x19½	17x12x14	13¼x15½x15½	20x27x17
Weight	90 lb	37 lb	70 lb	125 lb
Delivery	n.s.	2-4 wks	4 wks	4 wks
Price-B	\$2800	\$ 875	\$1400	
C	\$3495	\$1795	\$2200	\$2200

Prices: B--basic instrument; C--with sampling valve and 11A-7 recorder

Notes:

- * 5 ml and 10 ml loops available; requires 500W Sola transformer
- ** Ext. pump @ \$23, sample valve \$225
- *** Sample valves @ \$n.s.; & switching v. \$n.s.; back flush v. \$n.s.
- **** TCD available; flow sampling options \$n.s.

TABLE 8-A

SEC. I--GAS CHROMATOGRAPHS, BENCH

(page 5 of 5)

<u>Ref. No.</u>	<u>8A-15</u>	<u>8A-16</u>	<u>8A-17</u>
Manufacturer	Hewlett-Packard (M72)		SKC (M136)
Model Number	- - - 5700 Series 5711A	- - 5712A	Mini-mite 200
Power	- - 115/230, 48-66 Hz -		115v/60 Hz
No. Columns	- one (quick change) -		1
Detector	dual FID	dual TCD	FID
Sample Valve Sampling	- - - - option* - - - external pump(or injection)		option*** external***
MDC (2 ml)	0.005 ppm	~1ppm (est'd)	n.s.
Min. Range (2 ml)	- - - not stated - -		n.s.
Attenuation	28(x10 ⁻⁶)	2 ⁸	1to10 ⁴ x1to10 ²⁴
Recorder Output			n.s.
Gas Supply	- - - external - - -		ext.
Operating Gases	He, H ₂ , air	He	He, H ₂ , air
Features	Extremely high stability repeatable retention time digital temperature control automatic oper'n options		wide range, increased sens. by conc'n.
Size WxHxD (in)	22½ x 18½ (incl. det) x 19		n.s.
Weight	- - - - 85 lb - - -		n.s.
Delivery	- - - - n.s.- - - -		n.s.
Price-B	\$2995	\$2550	\$1350
C	\$3690	\$3245	

Prices: B--basic; C--w/pump; valves, recorder 11A-7; A--programmed oper'n.

Notes:

- * Sampling valve \$350, heated \$475 plus temp. control \$250
- *** Use with concentrators & ext. sampling valve (see 3F-1, 2, & 3) to obtain direct air sampling.

TABLE 8-B

SEC. II--GAS CHROMATOGRAPHS, SEMI-AUTOMATIC

(page 1 of 2)

Ref. No.	8B-1	8B-2	8B-3	8B-4
Manufacturer	- - - - -	Antek Inst. (M10)	- - -	Byron (M28)
Model Number	40-IPC-X	140-IPC-X	110-IPC-X	HC Spec.Anal. 400
Power	- - - - -	115v/60 Hz	- - - - -	115v/60 Hz
No. Columns	1	1	1	1
Detector	FID	FID	TCD	FID
Sample Valve	- - - - -	option*	- - - - -	standard
Sampling	- - -	syringe or pump (opt.)*	- - -	int. pump
MDC (2 ml)	- - -	0.1 ppm - - -	25 ppm	1 ppm
Min. Range (2 ml)	- - -	1.0 ppm - - -	0-500 ppm	0-10 ppm
Attenuation	- - - - -	x1-1024(11 step)	- - - - -	x1to x100(5)
Recorder Output	- - - - -	0-1 mv - - -	- - - - -	0-10 mv****
Gas Supply	- - - - -	external-	- - - - -	external
Operating Gases	- - -	He, H ₂ , air	- - -	helium
Features	- - - - -	fully-automatic	- - - - -	automatic
	- - - - -	operation capability	- - - - -	5-min. cycle
	- - - - -	5-min. cycle	- - - - -	rack mtg.
	- - - - -	semi-portable	- - - - -	semi-port.
Size WxHxD (in)	12x16x12	- - -	19x20½x11½	- - -
Weight	25 lb	70 lb	70 lb	22x13x15 70 lb
Delivery	- - - - -	4-6 wks	- - - - -	2-6 wks
Price-B	\$1195	\$1995	\$1995	
C	\$2655	\$3455	\$3455	\$4350-\$6450
A	\$3250	\$4050	\$4050	

Prices: B--basic; C--w/pump; valves, recorder 11A-7;
A--programmed operation (added to C)

Notes:

* Sample valve & pump system \$765; LDC-3200 recorder standard @\$485.

**** Recorder not included; instrument provides digital or analog values of 3 selected peaks; memory options permit holding one or all 3 peaks for parallel print out, computer input, or analog. Minimum price includes auto. zero and bar-graph presentation, single or continuous cycling.

TABLE 8-B

SEC. II--GAS CHROMATOGRAPHS, SEMI-AUTOMATIC

(page 2 of 2)

Ref. No.	8B-5	8B-6	8B-7	8B-8
Manufacturer	H-W (M69)	Tracor (M149)	P.A.I. (M120)	Nuclear Corp (M108)
Model Number	Elect. Orsat 500-1 (500-2)	Analyzer 350 F	Analyzer Special*** (see 5B-5)	Benzene GC Special****
Power	115v/60 Hz	115v/60 Hz	115v/60 Hz	115v/60 Hz
No. Columns	1 (2)	1	1	1
Detector	TCD & CG	FID	FID	FID
Sample Valve	not stated*	10 port(std)**	Special***	standard
Sampling	built-in pump	pump (std)		int. pump
MDC (2 ml)	n.s.*	n.s.**	0.05 ppm	n.s.****
Min. Range (2 ml)	n.s.*	n.s.**	0-5 ppm	n.s.****
Attenuation	(in recorder)	n.s.	5 ppm to 10%	x1 to 5x10 ⁷
Recorder Output	n.s.*	0-1 mv	0-5 mv	0-1 mv
Gas Supply	none req'd	ext	ext	ext
Operating Gases	none	He, H ₂ , air	He, H ₂ , air	H ₂ , air****
Features	air carrier automatic 3-min. cycle	precolumn (could serve as stripper)**	low-cost, sensitivity	Designed for submarine use. Can be fixed or port.
Size WxHxD (in)	17x7x17	19x12x24	14x16x14½	21½x18x15
Weight	25 lb	60 lb	55 lb	75 lb
Delivery	n.s.	12-18 wks	10-16 wks	n.s.
Price-B	\$995 (\$1095)	\$5275**	\$2850***	n.s. (PRI)
C	\$1800 (\$1900)	\$5970**	\$3545***	
A		\$10,420**		

Prices: B--basic instrument; C--with sampling valve and 11A-7 recorder;
A--programmed operation (added to C)

Notes:

- * Brochure received, data incomplete after repeated inquiries
- ** Not offered except as CO, CH₄, Total HC monitor; but like Byron, Beckman & Bendix monitors could be modified for benzene determination.
- *** Special gas chromatograph offered by PAI--by equipping their Total HC FID monitor with a sampling valve and column, 9-step attenuator.
- **** Custom-built item for benzene, methane, trichlorethene, Me chloroform, freons, vinylidene chloride and "Total HC;" uses compressed air or ambient with optional purifier. ("n.s." information left incomplete on proof sheet), 24-step attenuator.

GAS CHROMATOGRAPHS, ENVIRONMENTAL & PROCESSRef. No.

8C-1	<u>Beckman(M21) Air Quality Chromatograph, Model 6800</u>	<u>FIGURE 18</u>
	Operation--	fully automatic, unattended.
	Sampling--	ambient air sampling by integral pump. (optional grab sampling by bag, syringe, etc.)
	Min. Range--	0-1 ppm CO, CH ₄ & total HC (std.) (plus ethylene & acetylene--add \$980)
	<u>Special</u> --	0-0.5 ppm benzene, toluene, ethylbenzene, m+p-xylene, o-xylene, total HC--any 1 to 5.
	Attenuator Ranges--	x1 to x8000 (2 x4 steps)
	Analysis Rate--	4, 6 or 12 analyses/hr (selectable)
	Linearity/Repeatability--	±1%/±½% f.s.
	Zero Drift--	none (automatic compensation)
	Calibration--	automatic, daily
	Operating Gases*--	hydrogen (70 ml/m), air (350 ml/m)
	Gas cost--	approx. \$3.00/day*
	Outputs--	1) 0-10 mv for scan or bar graph recorder (also available on front panel for test) 2) 0-5 v continuous for each component for trend recording, computes, etc.
	Recorders--	Modified, bar graph or scan--add \$900 3-pen, trend or scan--add \$902
	Power--	107-128v/50-60 Hz
	Size, WxHxD (in)--	17x40x20
	Weight--	200 lb
	Delivery--	4 to 8 wk
	Prices--	Standard CO, CH ₄ , THC-- \$7350 5-channel--(see above)-- \$8330 Special--benzene(+ up to 4 other) \$7350 & up
8C-2	<u>Beckman(M21) Process Chromatograph</u>	
	Custom-designed, w/features and capabilities as required--	
	e.g. single-channel @	~\$7000 & up (depending on features)
	3-channel @	~\$7000 & up (depending on features)

* not including zero gas and calibration gases.

GAS CHROMATOGRAPHS, ENVIRONMENTAL & PROCESSRef. No.8C-3 Bendix(M24)Environmental Chromatograph

Operation--fully automatic, unattended

Sampling--ambient air by integral pump

Min. Range--0-5 ppm CO, CH₄, total HC
(3 channels, other gases special order)

Attenuator Ranges--x1,x2,x5,x20

Analysis Rate--12 analyses/hr

Linearity/Repeatability--±2%/±1%

Zero Drift--none (automatic correction)

Calibration--automatic, 3 std., daily

Operating Gases*--hydrogen (**ml/min),

Gas cost--approx. \$ **/day

Outputs: 1) 0-10 mv (-1 mv, 0-1v) scan voltage

2) 0-**v continuous for each component

Recorders--for scan, bar, trend (not included)

Power--120v/60 Hz

Size, WxHxD(in)-- 24x72x36

Weight 250 lb

Delivery 4 to 7 wks

Price, Standard-- \$6850

8C-4 Bendix(M24)Process Chromatograph

Custom-designed, w/features and capability as required--

Price range--single-channel @ \$7000-9000

3-channel @ \$10,000-13,000

*not including zero gas and calibration gases

**incomplete data, proof not returned.

GAS CHROMATOGRAPHS, ENVIRONMENTAL & PROCESSRef. No.Applied Automation(M12) Process Gas Chromatograph

Custom-designed, w/features and capabilities as required; choice of peak-height or area evaluation; FID or amplified TCD sensing; auto zero (std); versatile programming and output options; computer interfacing available. Requires 40-50 psi air.

- 8C- 5 Model 102 System--Digital programming (256 to 2048 sec. cycle), Analyzer--35½"x25"x16½"; 75 lb; protected location Programmer--19"x8 3/4"x11"--(rack mounting). Delivery--45 to 90 days; Price--\$6500 to \$8500.
- 8C- 6 Model 12--Punched disc programming
1 to 5 components in 1 to 4 streams
Analyzer--19"x57"x22", 100 lb, weather pump.
Programmer--19"x12½"x19", 55 lb (rack mounting).
Delivery--45 to 90 days; Price--\$6500 to \$8500.

Arcas(M14) Process Gas Chromatograph FIGURE 19

Modular units selectable to yield features and capabilities required. Amplified TC, FID, auto zero, automatic operation, applications and sampling for most compounds of interest. Computer compatible. Programmer can also be used to control automated Arcas Laboratory Chromatograph (not listed).

Analyzer--34"x34"x18",
Programmer--400--10"x12"x20"; 500--7"x7"x20".
Weight--approximately 200 lb

- 8C- 7 Price range, w/recorder:
Multi-stream: Series 400--\$5000 to \$10,000
Single-stream: Series 500--\$4500 to \$10,000

M-S-A(M102) Gas Chromatograph

- 8C- 9 Model 650--Modular units, as above, compact (20"x33"x12½", 115 lb).
Price range, w/recorder approx. \$10,000, (tentative product).

GAS CHROMATOGRAPHS, ENVIRONMENTAL & PROCESSRef. No.Process Analyzers (P.A.I.) (M120) Process Gas Chromatographs

- 8C-10 Model 26--223-4--One or two-stream analyzer, low cost, compact, modular--up to 6 components.
Price range, w/recorder ~\$4000 to \$9000
Typical: Complete TCD system for 2 streams and 8 measured components, Price--\$4820.
- 10a Complete FID system for 2 streams and one measured component, Price--\$6820.
- 8C-11 Model 26-212A--3 to 8 streams, 1 to 9 components
Versatile; many sampling, analysis and readout options.
Price, w/recorder \$7000 and up.
Typical: Complete FID system for 8 streams and one measured component, Price--\$7670.

Thermco (M147) Process Gas Chromatograph

- Standard models for N₂, H₂, He, A, and O₂, but none currently for benzene, etc., claim ±1 ppm for TC detector
- 8C-12 Semi-portable automatic analyzer on wheels
(38"x62"x27" + cylinders, 400 lb), Price--\$3850.
- 8C-13 Fixed automatic monitor (36"x72"x30", 800 lb), Price--\$13,000

Baseline Instruments (M165)

- 8C-14 Model 1000--Low-cost, single stream gas analyzer w/analog built-in recorder w/programmed alarm & control set point activation. Amplified TCD MDC ~5 ppm. Ambient or heated column. Small size (6"x11"x12"), 18 lb, 2-6 wk delivery
Price--\$1820.

GC DETECTORS AND ACCESSORIESDETECTORS, Micro-katharometers (typical)

	<u>Mfg/Vendor</u>	<u>Type</u>	<u>Model</u>	<u>Vol.</u>	<u>Res.</u>	<u>D-P-S No.</u>	<u>Price</u>
8D-1	Gow-Mac(M65)	filament	Hex-nano 10-952	140 uI	32 ohm	20,000	\$ 130
8D-2		thermistor	10-939	19 uI	8K ohm	not stated	\$ 130
8D-3	Antek(M10)	Pt. fil.	Micro-K MK. 158	2.6 uI	~20 ohm	15,000*	\$ 400
8D-4	Trienco(M150)	Pt. fil.	NanoVolume	20 nI	20 ohm	n.s.**	\$ 255

DETECTOR SYSTEM (TC)

Yields 1 ppm sensitivity with standard type of TC detector.

8D-5 P.A.I.(M120) TC detector, amplifier, integrator \$1525

AMPLIFIER

8D-6 SKC (M136) Dynatron 341 Detector Multiplier

Low-noise d-c amplifier for TC detectors, 20x amplification yields 20x increased sensitivity with low-noise, low-drift detector system. All solid-state, chopper-stabilized, noise-rejecting, over load-protected. Built-in output attenuator--can drive 1, 5, 10 mv recorders.

\$ 395

GC CONCENTRATOR

8D-7 Trienco (M150) No. 910-PC, ProTran Concentrator

Hot palladium diffusion/oxidation apparatus removes hydrogen from mixed gas carrier, e.g. 99% H₂, 1% He---to give 100:1 concentration factor, 100x sensitivity; or He can be added between column and concentrator.

(Note: impurities in hydrogen also will be concentrated)

\$ 747

(See also collectors/concentrators 3F-1, 2, & 3)

Notes:

* 20 uv/ppm (at the detector)

** Nano volume permits concentration of H₂ carrier by Pd diffusion to yield up to 1000x sensitivity (see 8D-8), 20 uv/ppm.

TABLE 8-D

(page 2 of 4)

GC DETECTORS AND ACCESSORIESHYDROGEN GENERATOR

- 8D- 8 Trienco (M150) No. 911-PHG, ProTran, Hydrogen Generator
Electrolytic generator and Pd diffusion/oxidation to produce continuous supply of hydrogen for FID, or for carrier with nano-TCD. (0-150 ml/min @ 0-100 psig). Low water loss and auto-fill, safe, non-contaminating. \$ 950
- 8D- 8a Milton Roy (M166) No. ERD-150
150 ml/min - unit (cf. 8D-8 re explosion hazard) \$ n.s.

HEATLESS MC DRYER/FRACTIONATOR (Skarstrom) (M163)

- 8D- 9 Model 8F200 (See ref. 127)

GC, PROGRAMMERS, VALVE ACTUATORS, VALVE OVEN (typical)

- 8D-10 M-S-A (M102) Model 525, Chromatograph Programmer \$ n.s.
(tentative product)
Ten-channel stepless program by pencil-marking transparent disc; e.g. for injection (sample valve), column switching attenuator switching, auto-zero, etc.
- 8D-11 Carle (M30) Model 4100
Two-function; 5, 15, 30 or 60-minute cycle \$ 295
- 8D-12 Model 4150 Valve Minders
As above except 4 functions \$ 325
- 8D-13 Model 4200 Valve Actuator
Models for 4-position and 8-position valves, accessories \$140-\$150
- 8D-14 Model 4301 Valve Oven
For broad line of Carle valves \$ 145

PEAK PICKERS (typical)

- 8D-15 Bell & Howell (M22) Model 19-418, Chromatograph Signal "Peak Picker"
"Sample-and-hold" on most-positive input since reset; drift <-0.05% f.s./min. \$ 173

GC DETECTORS AND ACCESSORIESINTEGRATORS

8D-16	Mechanical ball-and disc integrators--require visual chart reading and human interpretation, usually procured with strip-chart recorders and manufactured either by recorder mfg. or, more often, by Disc (M44).	approx. \$ 800
8D-16a	<u>Disc Instruments (M44), Model 610</u> Automatic digitizer/printer	\$ 895
8D-17	<u>Esterline-Angus (M54) Model 70D7, Electronic Chart Integrator</u> For use with E.A. Speed Serve II recorders (11B-2); produces readout similar to mechanical integrators.	\$ 750
8D-18	<u>Hewlett-Packard (M72) Option 035, Electronic Chart Integrator</u> Full scale baseline adjustment, front panel baseline set, integrates + and - peaks. Fits Hewlett-Packard No. 7123 A/B recorders only. Read-out similar to 8D-16 above.	\$ 750
8D-19	<u>ISCO (M80) Model 950, Electronic Digital Integrator</u> Digital and recorder output, 5-digit printer included, automatic noise filtering.	\$1985
8D-20	<u>Vidar (M153) Autolab 6300 Digital Integrator</u> Auto peak detector, baseline corrector, recorder output 10 digit printer (3 digit time, 7 digit area). Retention Time/Total Area option.	\$2200 add \$ 600
8D-21	<u>Hewlett-Packard (M72) Model 3373B, Electronic Digital Integrator</u> Automatic tangent baseline correction, choice of manual and automatic operating modes. Recorder and digital outputs for time shared on on-line computer system.	\$2550
8D-21a	<u>Built-in Digital Printer (for above only)</u> Prints out 4 digits of time (fixed point) and 5 digits of area (floating point)	\$ 600

GC DETECTORS AND ACCESSORIESINTEGRATORS (cont'd.)

8D-22	<u>Infotronics (M77) Model CRS-208, Electronic Digital Integrator</u>	\$2200
8D-22a	8-digit w/auto. peak sensing-BCD output	
	Retention time option	\$ 300
8D-22b	Baseline correctors	\$ 300
8D-22c	Printer (7-digit)	\$ 500
8D-23	<u>Problematics (M119) Model CDA-100A, Digital Integrator</u>	
	Computerized, yields elution time, corrected and normalized % area, or direct concentration.	\$6950

IX -- POTENTIAL NEW METHODS & INSTRUMENTATION

A. GC IMPROVEMENTS

The gas chromatographic technique is sensitive and versatile, but to achieve optimum sensitivity and selectivity requires careful adaptation to any given analysis. Except for process chromatographs custom-designed and installed in dedicated in-plant service, this ideal is rarely achieved, and is seldom even approached in the kind of small, simple instrumental system needed for routine in-plant analysis. A competent analyst can modify most general-purpose GC instruments to yield adequate selectivity for a given analysis by careful selection of column and flow parameters.

Generally, for industrial hygiene measurements, sensitivity is no problem with a flame ionization detector; but the pure-air requirements of FID/GC instruments, added to their fuel and carrier gas consumptions and the general inconvenience of a flame detector, make search for a simpler alternative highly attractive. For industrial health survey and monitoring applications, a portable instrument of the type represented by the new Matheson Model 8430 (FIGURE 17, Table 8A-5)--but with ± 1 ppm or better sensitivity--is greatly needed. Such instruments appear to be well within the capabilities of the present state of the art (283), and manufacturers should be encouraged to provide them. Explicit specifications should be developed for each specific application, for guidance of the manufacturers. Some suggestions for GC development follow.

1. Columns

For an instrument dedicated to benzene-in-air determination, the stationary phase of the column can be selected to optimize separation of the C_6 - C_9 aromatics at flow rates to yield a rapid determination--e.g. 5-min scan; but unless the purchaser specifies the optimum material or at least carefully states his problem he will receive a more widely applicable but less optimum column in a new GC instrument. It is wise to have one or more wide-range columns on hand to permit "screening" runs to see what is

present in the air from time to time, and 2- or 3-column instruments with column-switching valves can provide increased versatility.

Good stationary-phase materials for light aromatics are known and easily specified, but optimum column conditions for fast, routine analysis are not likely to be achieved this easily, and "standard" columns and operating parameters for specific applications and vapor compositions should be established on the basis of experimental optimization studies. Many new developments are yet to be investigated in detail. Solid materials in particular should be considered, since they avoid the problem of "phase" migration out of the column and into the detector on prolonged operation (68, 146, 230). Lanthanum chloride on Graphon (76), cobalt phthalocyanine on carbon black (97), bonded-phase aryl substances on silica ("benzyl porosils") (140), dendritic salt supports (172), "Carboseive" (369, M141), and other new substances should be evaluated relative to the various more common "Carbowax on Chromosorb" combinations (68, 235, 311).

Perhaps more significantly, open-tube columns should be thoroughly investigated for this kind of application, since these columns give high resolution with high speed and low gas flow (111, 149), in both the SCOT (support-coated open tube) (117) or PLOT (porous-layer open tube) (150a) variations. Capillary columns also operate at low flows and have been used in benzene determination with good sensitivity and high resolution (283); but they impose longer transit times than open tube or packed columns. Carrier gas flow rates of 2 or 3 ml/min are possible with open-tube columns, reducing gas consumption ten-fold, which is especially important in portable instruments. Moreover, low flow rates in SCOT or PLOT columns permit concentration of the sample during partitioning, whereas sample constituent concentration may be reduced in high-flow packed columns (see Sec. VIII-2). Low flow and small samples require micro-volume detectors, however, and these are not usually supplied as standard equipment (see below).

2. Carrier Gases

Helium is the preferred carrier gas in most GC applications. It is inert to the FID, provides nearly as much TCD sensitivity as hydrogen, and is available with lower HC impurities. Its use, however, constitutes an essentially irrecoverable loss of a very limited natural resource. Air or nitrogen carrier can be used with the FID or with the piezoelectric detector, but with the TCD only with great loss in sensitivity. The promising piezoelectric detector (see below) could operate without cylinder gas of any kind by employing ambient air carrier and an air purification train--perhaps only charcoal filters. Similarly, if a cyclic air purification system (127, 177a) were to be employed for FID combustion air, it also could provide air carrier, and thus eliminate the labor and expense of buying and changing air cylinders.

Hydrogen carrier yields maximum possible sensitivity with thermal conductivity detectors, and hydrogen also could be used with FIDs specially designed for that purpose (see below). Pure hydrogen can be generated at the instrument by electrolysis (Table 8D-8), or impure hydrogen can be purified by palladium diffusion. Also, a 10% helium-90% hydrogen carrier gas can be concentrated ten-fold prior to detection by palladium diffusion to remove the hydrogen (Table 8D-7), and similarly 100X concentration would be obtained by a 1%-helium-in-hydrogen carrier. The accompanying sample concentration extends sensitivity accordingly, but in each case the impurities are concentrated to the same degree, so pre-column hydrogen purification by diffusion may also be necessary. Steam as the carrier gas has been suggested (152), but no advantage is readily apparent for the present problem.

With any carrier gas, column, and detector combination, the sensitivity and resolution will vary with gas flow rates (102), and optimum flow rates should be established for the recommended instrumentation for each determination.

3. Detectors

Low-noise thermal conductivity detectors are now available which can reliably respond to benzene concentrations below 1 ppm, if temperature stability is adequate. By employing output amplification, low-level concentrations can be recorded with standard recorders. Micro-volume TCDs (Table 8-D) thus could be used with open tube columns to provide a portable TCD/GC instrument using only a lecture-bottle carrier gas supply for ample operating life (~ 200 hr). It seems reasonable that a micro-FID unit also could be devised for use with a hydrogen-carrier system, employing the carrier as fuel (e.g. 2 ml/min carrier + 2 ml/min pure hydrogen to prevent flame-out) with greatly reduced air requirement (e.g. 50 ml/min). In this manner even an FID/GC instrument could be made easily portable.

Perhaps even more promising is the piezoelectric sorption detector now under development (122, 123, 124, 125, 126, 269, 304, M87). In this instrument a piezoelectric quartz crystal is coated with a sorptive stationary phase. This crystal is the frequency-controlling element in an oscillator circuit, and any "loading" caused by sample adsorption on the coating reduces the oscillator frequency. A zero-beat heterodyne circuit employing a similar but isolated crystal provides an output frequency proportional to the loading mass on the sorptive layer, easily converted to a digital or analog output signal. With this detector adequate sensitivity may be obtained without the need for a sensitive and trouble-prone flame detector, or for gases other than the carrier gas. Also, by proper coating selection, the detector may be made preferentially sensitive to the compound(s) of interest, and perhaps insensitive to others (e.g. air and water vapor).

Another high-sensitivity detector employs photo-ionization (rather than flame ionization), by means of conventional glow-discharge ionization or by micro-wave excitation (141, 141a, 49, 86, 100, 146, 148, 161, 164, 182, M132). While this technique has great value in some very-low-concentration applications, and is being developed for process GC and portable GC models (161 and 241), it appears to involve more equipment and operator skill than desirable for industrial health applications.

A fluorescence GC detector developed for the analysis of polynuclear arenes in the gas phase has recently been reported (75), combining a GC column with a spectrofluorometric detector. The applicability of this technique to our problem is not apparent, and this development is not in the direction of reduced complexity.

The flame emission detector, in which the photoemission due to a specific sample component is selectively measured by a fixed-wavelength sensor, gives increased specificity at the cost of slightly greater complexity than the FID, and is valuable in some cases of difficult GC separation (308, M108). It does not appear necessary or justified for benzene-in-air industrial hygiene measurements in any foreseeable situation.

4. Amplifiers

Although amplification is used with TC detectors in process GC instruments in the petroleum industry, no laboratory or portable instruments were found to provide this advantage. With adequate temperature control of the valving, column and detector to stabilize the baseline, 10x amplification will yield 100 uv full-scale sensitivity on a standard 1 mv recorder and will render 10 to 20 uv peaks easily measurable. With the better TC detectors yielding 20 uv/ppm, this corresponds to 0.5 to 1 ppm sensitivity at the detector--or from about 0.2 ppm to 2 ppm sensitivity in the sample, depending upon column dilution or concentration. Although MDCs as high as 100 ppm are stated for some TCD/GC instruments, other manufacturers claim ± 1 to 2 ppm sensitivities without amplification. MDCs well below 1 ppm therefore should be attainable without resorting to flame ionization detectors.

A few recorders are available with 100 uv full scale sensitivity, but the amplification could more easily and cheaply be incorporated in the GC circuit. LSI and discrete operational amplifiers and instrument amplifiers are available in plug-in form at moderate cost, and could easily be incorporated in many TCD/GC instruments, yielding a ten-fold sensitivity increase with quite tolerable noise and drift. (Most manufacturers questioned had not yet considered this capability.) For existing instruments, at least one stabilized amplifier is available as a separate unit, at higher-than-necessary but acceptable cost (Table 8D-6).

5. Combination Instruments -- GC/MS, GC/IR

Added specificity in the resolution of complex spectra of multi-component samples can be obtained by employing a non-destructive GC detector to separate and indicate "group" peaks, and a mass spectrometer (556, 82, 360, M172) or IR spectrometer (M21, M43) to resolve the peak components. As for the flame-emission and fluorescence GC detectors, this approach is not required here, and would be of little value and considerable expense (316) in any foreseeable situations involving only benzene hazard.

B. OPTICAL METHODS

1. Multichannel Analyzer

A very recent and entirely fresh approach to spectrophotometry may well lead to automatic instrumentation yielding specific determinations of the separate components of a mixed sample (121, 269, 367, and M139). In this instrument, instead of sequentially scanning the light intensity over the selected spectral range by means of a narrow slit, the entire spectrum is projected onto the face of a vidicon TV camera tube and scanned at a millisecond rate by an electron beam, using standard video techniques. Thus wavelength is converted to time on a millisecond scale (as opposed to minutes by conventional methods), and changes in sample concentration can be followed on a real-time basis. Data handling techniques used in nuclear spectrometry and digital computers permit easy closed-interval integration of spectral absorption peaks and the resolution of component concentrations.

As presently announced, the spectral range is from 300 to 1100 nm, and hence not applicable to the aromatic peaks in the 250-270 nm UV region. However, the present instrument employs a standard vidicon tube designed for the visual spectrum, and special tubes can be developed to extend the sensitive range farther into the UV spectrum, as has been done for multiplier phototubes, if the demand develops.

2. Tunable Lasers and Tunable Filters

Tunable lasers offer the promise of very high spectrophotometric resolution at the source rather than by "white light" dispersion by prisms or gratings, or by narrow-bandpass filters (276). The chief advantage of the laser is the extremely narrow bandwidth of the emitted light, which is essentially monoenergetic and coherent. Tunable lasers have somewhat increased effective bandwidth because of drift or jitter in the controlling parameter (e.g. temperature), but are still very nearly monoenergetic. Thus the laser output can be tuned to "ride" on the exact center of a selected absorption peak, yielding an absorption-sensitive device which is essentially blind to off-peak absorptions and hence to interference from adjacent but not fundamentally overlapping peaks. Even so, the IR spectrum is so crowded with multiple peaks of related substances, true gases and water vapor, that the peak to be measured must be chosen with care. The UV spectrum is somewhat less crowded, and is free of interference from CO, CO₂ and water vapor.

Tunable CO₂ lasers operate in the visible to near-IR region, and as such are not able to utilize any benzene absorption peak which is free from CO, CO₂, water, or other aromatic interference (212, M66). In a rapidly developing technology, it seems probable that mid-IR tunable lasers will be developed in the near future. It is less probable that the prices of such equipment will be reduced enough to make this approach truly attractive for most applications.

The situation with regard to UV lasers is more promising (361, 362, 363, M166), but price is still a problem. A recently announced tunable dye laser operates over the range 265 to 340 (or 420) nm, which is very close to the benzene peaks at 262.5 and 254.9, and covers some lesser benzene peaks and peaks of toluene and the xylenes (289, M34). New advances in solid-state detectors may lead to simplified instrumentation (26a). Although not presently incorporated into operating instruments suitable for routine monitoring, and not presently economically competitive, this technique should be carefully watched for technical and/or economic break-throughs which may bring it into contention.

Exciting possibilities for improved instrumentation are suggested by the recent development of an electronically-acoustically tunable optical filter (TOF) which appears to have most or all of the advantages of the dye cassette tunable laser, plus the potential for significantly reduced cost (371, M170). It can be excited by a laser (as is the tunable dye cassette) or by a suitable wide-band light source, and emits a conversion beam of only 0.1 to 0.5 nm bandwidth in the 250 nm region (0.1 to 0.3 nm in the visible). While the current cost of this instrument is in the range of \$13000 - \$15000 (depending on spectral range), the price is expected to drop to about \$2000 - \$4000 for production models (357).

If the price barrier can be overcome for either the tunable laser or the tunable filter, or for any other precisely selectable "line" source in the 255 nm region, a practical, specific, direct-reading, real-time benzene monitor will be achievable.

3. Two-wavelength Measurements

Two-wavelength or multiple-wavelength measurements can yield concurrent data on the various interfering constituents of a sample, leading to determination of the concentrations of most or all of these constituents (55c), either by instrumental computation of simultaneous equations, or by charts, graphs or equations applied by the analyst (see also Sec. VI-A-3 & 4 and Sec. VI-B-1). Simple instruments employing electronic beam-chopping can eliminate moving mechanical parts (261). This approach warrants further development.

In a similar way, a gas sample can be characterized by any two (or more) measurements by different instruments (e.g. a combustible gas analyzer and a mercury detector) which yield different relative response to the two (or more) components of interest. A study of these capabilities seems well warranted.

4. UV Photometers

UV photometry (see Section VI-A) is presently available in at least three plant monitors and in several mercury vapor detectors, but appears to be capable of further development, both by more careful design of conventional instruments (49) and by greater employment of existing models to more precisely ascertain their capabilities and limitations.

5. Other Optical Techniques

Raman and laser Raman spectroscopy (23, 128, 188, M21, M168) have been suggested (276) and are being employed in environmental measurements (336). Although the spectra are less complex than with absorption IR (2), the instrumentation appears to be complex and expensive (317). Correlation spectrometry, in which the sample spectrum is compared with a "mask" of the desired component spectrum, has been applied to air pollution studies involving sulfur dioxide (23, 66). An interferometer developed for pollution measurement and operating in the IR region is being tested for multi-component smog analysis (364). It is claimed to be able to distinguish between ozone, CO, and water, and to measure very small amounts of ammonia, methane, acetylene, ethylene, and many other substances, by means of a long-path beam through the in-situ atmosphere. The feasibility of applying any of the above methods to benzene-in-air determination has not been evaluated in this study, but is not considered to be high at this time.

Other techniques with undetermined feasibility for practical application include fluorescence spectrometry (75, 170, 352, 365, M112), Hadamard-transform spectrometry (55), and Fourier-transform spectrometry (276, M43). Fluorescence spectroscopy is especially useful for the determination of trace levels of polynuclear aromatic substances in micro-particulate samples, and has been applied to gaseous samples (75), but does not appear to be advantageous for benzene-in-air analysis (352). Like the photographic emission spectrometer and the new optical multichannel analyzer, the transform techniques view the entire spectrum simultaneously rather than by time-vs-wavelength scanning. These methods employ multiplex instruments and require computer decoding to interpret the matrix data obtained. For these reasons and the high cost involved, especially in Fourier-transform spectrometry, they appear inapplicable to routine monitoring.

C. CHEMICAL SUBTRACTIVE METHODS

By parallel or sequential selective subtraction of various chemical groups from the sampled air, considerable functional specificity can be obtained with inherently non-specific sensors such as the combustible gas, flame ionization and thermal conductivity detectors. The measurement of benzene in the presence of aliphatic and higher aromatic substances appears feasible by this technique; but although specific methods have been reported (1, 61, 108), they do not appear to have gained widespread acceptance. This technique warrants further investigation, especially in terms of programmed automatic instrumentation.

D. OTHER POTENTIAL METHODS

The plasma chromatograph offers a relatively simple method for measuring the mass of organic molecules (366). The technique may prove useful in monitoring situations such as those in which benzene is to be measured in the presence of normally interfering substances without chromatographic separation, if adequate resolution is obtainable and the plasma chromatograph can be made less expensive, more reliable, or simpler to operate and maintain than the GC. These characteristics have not yet been established.

Polarographic methods may be applicable for impinger-bubbler samples or for automated vapor-trapping liquid sampling (200, M118) (Sec. VII-C), and have been developed for continuous monitoring (116). Condensed-phase vapor samples may be more amenable to IR analysis than gaseous samples (165). Chemiluminescent methods are useful in a number of air monitoring applications (169, M134) and are under development for benzene and other organic compounds (342, M23). A method called "electromolecular propulsion" was announced in two magazines (not noted), but an inquiry to the manufacturer (M72) brought no explanation of the method. The manufacturer states, "we have resolved mixed methylnaphthalenes in our 'pocket lab' in less than 15 seconds." One manufacturer of scanning electron microscopes (355, M101) suggests benzene analysis by that instrument following a particle-forming reaction of some kind.

Coulometry does not appear to be particularly suitable for benzene analysis, but if primarily employed for other determinations might also provide useful input on the reduction potential of the atmospheric organic vapors--perhaps on a shared-time basis (190). Similarly, fuel cells and electrolytic sensors may contribute supplementary information (M13, M52, M148). Ion production by catalytic oxidation on a platinum filament also is possible. This would not be as sensitive as the FID, since the ion yield is low, but might be made semi-specific, since the yield is variable with structure (196). The Macor, which employs a metallo-organic solid-state surface, has been developed for semi-specific response to a number of gases and vapors, but has not yet been developed for aromatics (M167). It is offered as a monitoring sensor in a permeation tube calibration gas device (Table 10B-7).

An undeveloped method with possible feasibility would involve color development by chemical reaction, as in the Matheson (M95) carbon monoxide detector, with photometric measurement and alarm. In addition to the reaction used in gas detector tubes (Sec. IV), other color reactions are known which might prove more suitable (6, 20, 45, 115, 129).

E. CALIBRATION IMPROVEMENTS

Studies should be undertaken to evaluate and standardize methods for both zeroing and calibrating the various types of survey instruments, since these procedures are essential to the validity of the instrument readings. The effectiveness and capacity of simple charcoal filters for obtaining zero-air and clean operating air (180) should be firmly established (or disproved), and calibration procedures involving pre-calibrated bottle gases or simple, fool-proof static dilutions should be determined and standardized.

Although permeation or diffusion tubes can be made for any desired level of standard, and can be provided at certified levels, not all applications will justify procuring the required equipment. However, it seems likely that a micro-ampoule containing about 20 μ l of liquid benzene could be used with a squeeze bottle and breaker such as used for methane ampoules (Table 10A-3) (FIGURE 23), eliminating the need to employ micro-syringes. A brief study should be undertaken to confirm or deny the validity of such a method.

Information was received (just before going to press) that one vendor (M 16) has announced a static dilution method and equipment similar in operation to its LEL calibration kit (Table 10A-3) (FIGURE 23), but employing a collapsible bag, to yield sustained flow sufficient for flow monitor calibration. Developments of this type should be encouraged and fully evaluated.

* * * * *

A list of selected potential instrumentation is provided by Table 9.

TABLE 9

POTENTIAL INSTRUMENTATION FOR BENZENE ANALYSIS

GC DETECTORS

- 9A-1 Piezo-electric (M87)
 A method of "loading" a quartz-crystal oscillator (as in micro-balance), and measuring loading by beat frequency vs. unloaded crystal (as in quartz thermometer), by coating crystal with selected stationary hose. Selective response and high sensitivity, without flame, vacuum, or gases.
- 9A-2 Photo-ionization--glow discharge
 Ion collection as in FID, very sensitive, high sensitivity to benzene, toluene; none to water, methane.
- 9A-3 Photo-ionization--microwave
 Extremely sensitive--requires He or Ar, vac. pump., NW generator.

OPTICAL MULTICHANNEL ANALYZER (M139)

- 9B-1 Promising if extendable to 250nm region. Permits digital interference correction by nuclear spectrum-stripping or other computer techniques.

TUNABLE LASERS (M34) (M66) (M166)

- 9B-2 IR Spectrometry--High resolution, peak-riding,
 single peak or multi-peak w/auto. compensation. Currently too limited wavelength range and too expensive. (212)(276)
- 9B-3 UV spectrometry--Probably more selective than IR, if
 tunable laser range can be extended to 250 nm--needs lower cost.

TUNABLE FILTER (371, M170)

- 9B-4 Newly announced instrument (See text).

CHEMILUMINESCENCE (M23) (M134)

- 9D-1 Specific or group-specific analytical instrumentation adaptable to benzene analysis, in development.

ELECTRO-MOLECULAR PROPULSION (M68)

- 9D-2 Method under development--not explained--which purports to yield resolution of like substances quickly in an inexpensive "pocket lab".

PART TWO

X -- CALIBRATION METHODS & EQUIPMENT

For any instrument to yield reliable readings and to ensure confidence in the data obtained, regular and sometimes frequent calibration is essential. Calibration must be made at zero (or low) concentrations to correct for zero drift (and sometimes for correctible interferences), and at full (or high) scale to adjust sensitivity or range.

Some automatic environmental or process control instruments incorporate programmed or "demand" automatic zero and range-adjust standardization functions, but generally these procedures must be performed by the operator, and thus the reliability of the data obtained will in large degree depend upon the skill and regularity with which these functions are performed.

In some cases calibration may be performed by injection of a gas (or liquid) into the instrument input, or by the introduction of static samples. In most instruments considered herein, a measured or flowing gas sample is required, and enough standard gas must be provided for a long enough time to ensure total displacement of the previous sample. Even a gas syringe, which has nominally zero volume at full travel, should be flushed with several volumes of the standard gas before injection into the measuring instrument. Optical absorption instruments and GC sampling valves can be flushed adequately and filled with a standard gas static sample. For this purpose a sample bag filled with the standard gas is convenient. Squeeze bottles also may be used with instruments requiring moderate sample volumes.

In all standardization procedures employing intermediate containment (i.e. bottles, bags, or syringes), the container should be "conditioned" by adequate prior exposure to gas of substantially the same composition and concentration as the standard to be used, to establish gas-to-surface equilibrium conditions (81).

Methods for obtaining standard gases are described below.

See Sec. IX-E.

A. INSTRUMENT ZERO-SET

Zero-set adjustment is usually made by introducing "zero gas" or "zero air" into the instrument in lieu of the normal sample. Air and inert gases of very low and known impurity content are available in compressed-gas cylinders for this purpose. An equally suitable zero gas can be produced at the instrument if all substances in the ambient air which are to be measured (not necessarily all substances to which the instrument is sensitive!) can be removed by filtering or other treatment. In fact, it would be ideal if only the substance of greatest interest--in this case benzene--could be preferentially removed, and the non-adsorbed interferences then zeroed out electrically. This would render an inherently non-specific instrument functionally specific. This ideal is substantially achieved in the mercury monitors, which employ a gold mesh filter to remove mercury vapor (by amalgamation) without affecting such interferences as benzene and toluene, and with negligible or no effect on ozone, SO₂ and NO₂. Thus, even if these vapors and gases are present and are "seen" by the mercury monitor, they can be zeroed out electrically, rendering the immediately subsequent net readings specific for mercury. Similarly but less ideally, an activated charcoal filter can be used to zero a benzene-monitoring instrument of any kind (127), with varying effect on the interferences--depending upon both the instrument and the interferences involved, but with equal or greater validity than by use of a true zero gas (180).

B. INSTRUMENT CALIBRATION

1. CALIBRATION GASES

Valid up-scale instrument calibration--i.e. "sensitivity," "range," "gain," or "attenuation" adjustment--requires the introduction of a standard sample with a known concentration of the vapor of interest (i.e. benzene), or a known concentration of a stand-in gas whose benzene equivalence is known for the given instrument. Because of the tendency of condensible vapors such as benzene to condense or adsorb on surfaces, it frequently is more practical to substitute a true gas whose benzene equivalence is known or can be determined by independent analysis.

The benzene equivalence of simple hydrocarbons can easily be calculated for FID measurement from the carbon numbers, and thermal conductivity equivalences also are calculable. For any given CGA instrument, the equivalence may be obtainable from the manufacturer, or in any case can be determined experimentally. However, the calculated FID or TCD equivalence of two gases will not be valid relative to GC peak heights, since peak shapes will vary with retention time. Also, the retention time for benzene is more accurately measured than estimated from that of another substance. Thus, for GC instruments, the substitution of standards is not recommended for primary standardization, although it may be satisfactory for calibration re-check to confirm normal operation.*

Cylinders of compressed calibration gases are commercially obtainable at ppm levels for methane, propane, hexane and other hydrocarbons, singly or in mixtures, in nitrogen or air. One vendor (M131) has stated the ability to provide a benzene-in-air calibration gas at 5 ppm, in selected cylinders. Aerosol pushbutton-can calibration and zero gases also are available, and are convenient for field check calibrations (M134, 10A-2).

Calibration gases also can be prepared in the laboratory or in the field. For environmental and industrial health instruments measuring in the parts-per-million range or lower, the preparation of standards for instrument calibration at operating levels requires extreme dilution. For maximum accuracy, dynamic dilution systems must be employed to overcome surface

* A standard gas mixture containing both a stable true gas (e.g. hexane) for quantitative standardization and benzene for retention time standardization also could be used. (ULU)

adsorption equilibrium effects. However, for many industrial health purposes, static dilution methods yield adequate accuracy and precision.

2. Static Dilution Methods

Static dilution methods involve the simple dilution of a known quantity of the standard substance in a known volume of air or inert gas. A kit for the dilution of methane to 1.2% in air (for calibration of GCA instruments at 22% LEL) is commercially available (M16, 10A-3). Extraction of 1 ml of this standard by hypodermic syringe, and re-dilution by injection into a 1 liter (nominal) air-filled bottle, yields a standard of 10-12 ppm methane--depending upon actual bottle volume. This would be equivalent to about 2 ppm benzene to an FID instrument, and to higher concentrations to other detectors--the exact equivalences to be determined, at least once, by independent direct calibrations. Static dilution benzene standards can be prepared by similar injection of liquid benzene into a plastic bottle, gas bulb (3F-16) or glass jug (224) (e.g. 20 μ l into 1.1 liter air = 5 ppm benzene). Similarly, standard gases can be prepared by injecting benzene into a gas sampling bag (63), with measured air dilution by means of a hand pump such as used for gas detection tubes--e.g. 100 ml/stroke. Septa for injections can be installed in plastic bottles or bags, and air valves can also be installed in sampling bags. In all such methods, care must be taken that the dilution air is free of hydrocarbons or other measureable substances. Cylinder zero gases or air filtered through activated charcoal or column packing should be used unless the ambient air is known to be pure at the preparation location.

In all static dilutions there will be some loss of the standard to adsorption on the vessel walls, and this effect will vary with the wall material, the wall surface properties, and the surface-to-volume ratio of the container. There are indications that with Teflon bottles or bags, and with glass jugs of 1 gallon or more capacity, the effect is quite tolerable (63, 198, 224), and studies on sampling bags (for sampling) seem to indicate that losses are generally under 5%, and much less for vessels or bags "conditioned" by pre-exposure to the same concentration (60, 63, 78, 80, 81, 178, 189).

3. Dynamic Dilution Methods

a. Exponential Dilution

The exponential dilution flask method of Lovelock (141a) employs a flask of known volume with a continuous (small) flow rate through the vessel and thorough mixing to achieve equilibrium. When a known (small) amount of gas or volatile material is introduced into the vessel, the concentration in the vessel, and in the outflow gas, diminishes exponentially at a rate dependent upon the ratio of flowrate to vessel volume

$$C = C_0 e^{-Ft/V}$$

where C_0 is the calculated initial concentration, S/V. Thus the instantaneous concentration can be calculated at any integrated flow, Ft. The system requires an accurate soap film flowmeter and a sampling valve or septum to permit extracting a sample at the selected time and concentration. The listed commercial systems (Table 10-D) provide a septum for syringe sampling and all other necessary components (except a stop watch).

b. Steady-state Dynamic Dilution

Until recently dilution systems employing the continuous mixing of gases of prepared vapor-in-gas mixtures have been the only means for the accurate preparation of low-level concentrations*-especially below 1 ppm concentration. In these systems dilution air is thoroughly purified by combustion, drying and filtering, and accurate mixing is achieved by means of precision metering of pressure-regulated streams (70) (Table 10C-1).

While this method may still be the most accurate, provided that primary gas standards of the requisite composition and accuracy are obtainable, it requires a fairly complex system and a trained operator. The availability of pre-diluted gases from the compressed gas vendors, and the emergence of permeation and diffusion tube systems which permit the generation of standard gases of condensible vapors, tend to make this method impractical except for large laboratories having sufficient need to justify the necessary equipment and trained personnel.

* steady-state sustained supply.

c. Permeation and Diffusion Tubes

Following the early work of Altshuller and Cohen (59) with diffusion tubes and that of O'Keefe and Ortman (155, 156) with permeation tubes, methods and equipment for the use of these techniques to produce low-concentration standard gases have developed rapidly (70, 103, 142, 163, 168, 224, 291, 314), and several calibration systems of this type are now being marketed (Table 10-B).

These devices utilize a "package" source for both gases and volatile-liquid vapors, and operate on the bases that for a specified vapor or gas at a fixed temperature there is a fixed and reproducible rate of diffusion through a given capillary orifice, or of permeation (per unit area) through a given porous material. Diffusion tubes yield higher emission rates, other factors being equal, and thus are used for low-volatility compounds. Permeation tubes with porous walls are favored for most applications. For reduced emission, permeation wafers sealed into one end of a non-porous tube are employed. The three types of sources complement each other and together provide an extremely wide range of emission rates for a wide range of substances.

Permeation tubes usually consist of a length of Teflon tubing (typically about 10 cm long) filled with the liquid (or gas) of interest and closed at both ends with non-porous plugs. The rate of emission of vapor from such a tube is proportional to the porous area (active length times effective circumference), is an inverse function of tube wall thickness, and--within certain constraints--increases predictably with increasing temperature. To a lesser degree, insofar as this affects surface concentrations, emission rate also varies with the rate of flow of the diluting gas (142). Above a minimum flow rate, concentration in the output gas is inversely proportional to gas flow rate.

Equipment is now commercially available with the necessary gas flow control and measurement and with controlled-temperature tube chambers. Such equipment is capable of producing a wide range vapor concentrations in the output stream. Systems with pre-purification also can produce zero gas, and some systems can be used for dynamic gas dilutions of externally supplied gases. Several available systems contain chambers which can accommodate up to 3 (or even 6--10B-15) tubes, and thus can produce a multi-component standard gas.

The concentration of each component is determined by the surface area and wall thickness of each tube, by the porosity of the tube material to that vapor, and by the selected temperature and air flow rate common to the system.

The systems can be left "on" so that equilibrium conditions are maintained, and thus provide an ever-ready source of calibration gas until tube exhaustion. Tube life depends upon tube capacity and emission rate. Typically, a tube containing 5g benzene and emitting 10 ug/min will last about 200 days, yielding 10 ppm at 300 ml/min gas flow or 3 ppm at 1 LPM.

Permeation or diffusion tubes for benzene and its homologs are now available from at least three commercial sources (M9, M50 & M99) and can be expected to become available from others. These tubes can be obtained "certified," or for customer calibration. Emission rates in the ranges 10 ppm benzene @ 1500 ml/min nominal (48 ug/min), 0.1 to 1 ug/min, and 0.4 ug/min-cm have been estimated by various vendors on the basis of current production tubes for other gases, or from experimental measurements. One vendor (M50) offers a system that includes a sensor which monitors system output and indicates the concentration digitally in ppm, and can be adjusted to yield the desired concentration. This firm will soon (12/72) market a hand-held calibrator with a built-in 6-month supply.

INSTRUMENT CALIBRATION PRODUCTSA. CALIBRATION GASES

10A-1	Cylinder Gases (11 SCF to 200 SCF)	
	Zero gases--air, N ₂ , H ₂ , He, etc.--	200SCF @ \$ 80
	Hydrocarbon gases--e.g. hexand in N ₂ --	200SCF @ \$ 90
	(Aromatic HC's not standard--see text)	
	Sources (typical): Air Products (M3)	
	Matheson Gas (M95)	
	Scientific Gas (M131)	
	Scott Research (M134)	
	<u>Scott Research (M134)</u>	
10A-2	Push-button Cans	
	Zero gases (3 L) @ \$5 to \$7; HC gases @ \$7 to \$9	
	<u>Bacharach (J-W) (M16)</u>	
10A-3	Ampoule/Dilution Kit, Combustible Gas (FIGURE 23)	
	Yield 22% LEL methane--too high for ppm scales,	
	but can be secondary standard for further dilution.	
	550-075 Kit complete--	\$ 6.45
	550-076 Ampoules	12/ \$ 2.90

B. PERMEATION AND DIFFUSION TUBES & EQUIPMENTAnalytical Instrument Development, Inc. (M9)

10B-1	Permeation tube--Benzene, calibrated & certified (75 ⁰ C)--	\$ 29
10B-2	Diffusion tube (customer fills & calibrates)--	\$ 15
10B-3	Model 303--Calibration system, single-chamber, 3-tube, for ext. gas supply & measurement, 0-2 LPM--	\$ 475
10B-4	Model 305--Calibration system, as above, with scrubber & rotameter, for control at analyzer--	\$ 725
10B-5	Model 307--Calibration system--precision flow control--	\$ 845
10B-6	Model 309--Calibration system, with dynamic dilution capability--	\$ 965

INSTRUMENT CALIBRATION PRODUCTSB. PERMEATION AND DIFFUSION TUBES & EQUIPMENT (cont'd)Electro/Mass Laboratories (M50)

10B- 7	Model M510--"DIAL-A-PPM", digital, differential detector reads gas stream before and after permeation chamber, yields digital ppm readout of added component (thermistor TCD). Benzene tubes available. Precision flow and temperature control. 14"x5"x14" 27 lbs.--	\$2425
10B- 8	Model B210--"Permatron", digital, same as above except digital ppb readout of added component (MACOR or EC detector). 19"x5"x14" 22 lbs.--	\$2625
10B- 9	Model D200--Calibration System, precision rotameter, dynamic dilution capability, precision flow control (orifice), single chamber. 11"x13"x10" 18 lbs.--	\$ 695
10B-10	Hand-held Calibrator--with 6 months supply (in development, available 12/72)--	n.s.

Metronics (M99) "Dynacal"

10B-11	Permeation Tube--benzene 50-100 ng/min--	\$ 35*
10B-12	Permeation Tube--toluene 10 ng/min--	\$ 35*
10B-13	Model 300--Air Analyzer Calibrator, DYNACALIBRATOR. Electronically-controlled temperature device, built-in electronic-drive gas pump with precision control--200 ml/min to 4 LPM, internal scrubbers for zero air and purge gas, flowmeter, solid-state proportional temp. controller, stainless steel solenoid valve for two-mode operation--	\$1975

Monitor Labs (M103)

10B-14	Permacal Model 8500 Calibrator--3-tube parallel, with built-in filters for zero air-- (Benzene permeation tubes not yet available)	\$ 800
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Tracor (149)

10B-15	Permeation Tube Calibration System Permeation flow, dilution flow, zero gas flow, separately measured; scrubber; up to 6 tubes; 5 ppb to 10 ppm by permeation; 0-1 ppm to 10% by dilution-- (Tubes and automatic calibrator also available)	\$1990
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* Certification @ \$25 per temperature point.

INSTRUMENT CALIBRATION PRODUCTSC. EXPONENTIAL DILUTION FLASKSKC (M136)

10C-1	Cat. No. 209-115--250 ml flask & system	\$ 265
10C-2	Cat. No. 030-250--250 ml flask only	\$ 105
10C-3	Cat. No. 210-115--500 ml flask & system	\$ 285
10C-4	Cat. No. 030-500--500 ml flask only	\$ 107

D. DYNAMIC GAS DILUTION SYSTEMNEI-Bendix (M104)

10D-1	Precision dilution system for preparing low concentrations of calibration gases in purified dry or humidified air. Complete with valves and gauges. Mounted on Formica panel. 8' x 4' x 1" -- (see also 10B-6 and 10B-9)	\$3000
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E. SOAP FILM FLOWMETERS

(for calibrating dilution systems and rotameters)

Carle Instruments (M30)

10E-1	Cat. No. 6670--10 ml capacity--	\$ 10
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Dohrman (M45)

10E-2	Part No. 877080--(capacity n.s.)--	\$ 15
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SKC (M136)

(2, 10, 50, 100, 150, 500, 1000 & 2000 ml sizes)

Tripod mounted

10E-3	Cat. No. 311-10--10 ml capacity, plain--	\$ 30
10E-4	Cat. No. 311-100--100ml capacity, plain--	\$ 33
10E-5	Cat. No. 300-1000--1000 ml capacity, plain--	\$ 64
10E-6	Cat. No. 313-1000--1000 ml cap. water jacketed--	\$ 96
10E-7	Cat. No. 302-- <u>Field Calibration Flowmeter</u> Complete portable unit, simplified operation--	\$ 185

PART TWO

XI -- STRIP CHART RECORDERS

A. RECORDER APPLICATIONS

Because of their rectilinear record and greater versatility, only strip chart recorders have been considered in this study, although circular chart recorders are in widespread use for recording slowly changing parameters, usually with 24-hour charts which are changed daily and stored for reference. Strip chart recorders are used in two quite different ways with the instrumentation covered in this report:

- 1) for providing a time record of the readings of continuous monitors,
- 2) for displaying the spectra produced by scanning instruments which measure one sample parameter as a function of another.

1. Time-Record (Trend) Recorders

For direct-reading continuous monitors such as combustible gas analyzers, total HC analyzers, UV or NDIR photometers, and other devices providing a "real time" or delayed-real-time output indicating the measured parameter, usually a slow chart rate and slow pen response are desired in order to produce a steady record. The slow chart rate also provides a time scale such that present readings can easily be compared with past performance, and minimizes the expense of chart paper and its handling and storage. Chart speeds of 1"/hr or less are typical.

Most real-time monitors provide an output of 0-10 mv or more, often even in the voltage range, so that sensitivity requirements for recorders for this service are generally moderate, and pen response of 2 to 5 seconds full scale usually is adequate.

Usually panel or rack-mounted "industrial" single-range, single-speed recorders are employed for this application, especially in permanent installations. Laboratory recorders often have sufficient versatility to provide the sensitivities and chart rates required, and may be employed for temporary or intermittent real-time monitoring. Some recorders are sufficiently sensitive and versatile for "laboratory" designation, yet adequately reliable for continuous operations.

2. Scan Recorders

The other, quite different application of strip chart recorders is to portray the intensity vs. time spectrum of scanning instruments such as a spectrophotometer or gas chromatograph, in which the time axis represents not real time relative to the sampled medium but an instrument variable such as wavelength or relative chromatographic mobility. In these applications the pen response must be adequate to follow the output of the instrument, which may be rapidly changing, and the chart speed must be adequate to visually separate these pen traces so that peak shapes as well as peak heights are easily discernible. Thus, pen speeds of 1 second or less full scale and chart speeds of 1"/min or greater are required.

In most scanning applications, scans are initiated manually "on demand", operation is intermittent, and the recorder chart drive operates only during the scan. In automatic "continuous" monitors the repetitive scans are at programmed intervals, and chart motion may or may not be stopped between scans (depending upon "off time"). In multi-point sampling instruments the recorder may be time-shared by all the inputs, or (more often) separate records are provided for each input. Thus, while the more versatile "laboratory" or "bench" or portable recorders are most often used with scanning instruments, one or more single-range panel or rack-mounted recorders may be employed.

To provide a scan which reads from left to right, a right-hand zero scale and slide-wire circuit are required, available on several models; and a "live zero" (e.g. -0.05/0/+1.0 range) permits the base line to be centered on zero without "bottoming" (e.g. 11A-7, FIGURE 21). Roll charts are standard for panel-mounted and rack-mounted recorders, and for most strip chart recorders, but some portable and laboratory recorders use fan-fold paper, or offer this option. For "continuous" (i.e. programmed) monitors, a take-up roll obviously is necessary; but for manually-initiated scans the chart often is removed for study and/or filing, and the take-up roll may be omitted (e.g. 11A-7). In these applications a tear-off bar and a writing platen (for chart notations, peak labelling, etc.) are desirable features, and in some vertical-chart recorders a tilt-out platen adds convenience. Flat-bed recorders often are preferred for laboratory applications because of ease of notation, but they are awkward to carry and are unprotected in exposed locations.

The decision to use a wide or narrow chart will be determined by the relative value given to size and weight, legibility and resolution, and capital cost. The chart costs do not vary greatly with chart width, but fan-fold chart paper is nearly twice as expensive as roll-chart paper, and requires more frequent (but easier) replacement.

B. RECORDER TYPES

1. Portable Recorders

Portable recorders are required for use with portable monitoring or surveying instruments; and if the monitor is fully portable and battery operated, the recorder also should be battery powered. Several battery-powered recorders are available and are listed in Table 11-A. Only two provide the 1 mv f.s. sensitivity usually employed with TCD gas chromatographs, but one very versatile model (FIGURE 20) includes a 2mv f.s. range which may be adequate, especially with detector amplification.

In many temporary spot monitoring or survey applications, line-powered portable recorders will be most satisfactory, with both capital and operating costs generally lower than for battery-operated equivalents. Some "portable" instruments are basically high-quality laboratory or "system" recorders in special cabinets, and thus are suitable for continuous monitoring applications, as well as for typical "portable" use.

2. Bench Recorders

The term "bench recorders" has been applied here to laboratory or general-purpose recorders having cases and conformations which offer some degree of protection against drip and splash--as opposed to flat-bed recorders--and thus are suitable for some in-plant locations as well as for laboratory use. In many cases these same models are available in rack-mounting cabinets or with brackets for this purpose, and thus are suitable for permanent installation.

Many instruments which might be considered either "industrial" or "bench" recorders are available, but only those providing 1 mv or less full scale sensitivity, suitable for TDC-GC use, are listed here (Table 11-B). These recorders also are available with lesser sensitivities.

3. Card Chart Recorders

A special type of recorder which records on Keysort cards is available in two known models (Table 11-C). These may be advantageous in scanning applications in which the scan records are stored for future reference or for legal evidence of compliance or non-compliance--by either the industrial or regulatory agency.

4. Flat-Bed Recorders

Although these recorders are available with a wide variety of sensitivities, chart rates and special features, and are preferred by many chemists for laboratory applications, they are judged by this writer to be unsuitable for most monitoring and survey applications. They are difficult to carry except by means of a separate case or pouch. Although sometimes provided with a flexible or rigid (sometimes transparent) cover, they are generally unprotected in operation and thus not suitable for use in locations exposed to the weather or to splash, drip, spray or dust. For those who prefer this type, a number of such recorders are listed in Table 11-D.

5. Panel-Mounted Recorders

These instruments commonly are used for time-record purposes, but also are available with sensitivities, response, and chart rates suitable for scanning applications. The housings usually are adequate to protect against normal plant conditions, including a protective cover-door. Usually they are offered only as dedicated single-range, single speed recorders. Most models are also available in two-pen and multi-point versions.

The listings in Table 11-E have been limited to typical single-pen "basic" models. Special features such as input amplifiers, alarm and control contacts, re-transmit slide wires, etc., are at extra cost, and the many custom variations available are beyond the scope of this study.

TABLE 11-A

(page 1 of 5)

STRIP CHART RECORDERS, PORTABLE

<u>Ref. No.</u>	<u>11A-1</u>	<u>11A-2</u>	<u>11A-3</u>	<u>11A-4</u>
Mfg &/or Vendor	Cole-Parmer (M39)	FIGURE 20 Esterline(M54)	L.D.C. (M87)	Instr. C. (M79)
Model Number	Mark VII 8341	Port-a-Graph T 171B	ServoGraphic 310/310B***	400
Power Chart Width	ac/bat* 4"	ac-dc/bat** 150mm(6")	ac or dc*** 4"	ac/bat**** 4"
Min. Range, f.s.	10 mv	2 mv	1mv (10 mv)	5 mv(10mv,std)
Max. Range, f.s.	200 mv	50 volt	1 volt (10v)	100 mv (200v)
No. Ranges#	6	14	1 (4)***	cont.
Accuracy	½%	½%	½%	½%
Response, f.s.	¾ sec	½ sec	½ sec	3 sec
Zero Adjust	100% f.s.	100% f.s.	100% f.s.	100% f.s.
Input Impedance	10 megohm	2 megohm	inf. @ bal.	10 megohm
Writing	ball point	cap. cart.	fiber,disp.	ball point****
Min. Chart Rate	1 in/hr	20mm/hr	1 in/hr	¼ in/hr
Max. Chart Rate	5 in/hr	360mm/min	15 in/min	3 in/min
No. rates#	1 (5)	12	1 (2)***	1 (16)
Cover Door	std.	no	opt.	std.
GC Use	some	most	yes	no****
Features	fully-port., built-in charger, enclosed.	fully-port., built-in charger, carry case, accessories.	no handle, fan-fold paper ac <u>or</u> dc.	fully-port., enclosed built-in charger, D-cell.
Size, WxHxD (in)	7-x8½x10	12½x9½x6½	6½x5x9	7-x8½x10½
Weight	17 lb	8 lb	not stated	17 lb
Delivery	not stated	1-2 wk	n.s.	2-3 wk
Price	\$850	\$300	\$405	\$750

Notes:

Switchable, or (by interchange)

* 115v, 60 HZ, chgr. & Ni-Cd std.; No. 8340, 12 range, 16 speed, line only @ \$710

** 115v, 60 Hz std.; 8 D-cells (8h); Ni-Cd (12h) \$48; 12 v auto adapter \$30
Ext. 12v source (310B)--add \$85; 4-span input \$75; 2-speed \$20

*** 115 v, 60 Hz & Ni-Cd (200hr) std.; inkless (N/C); line only \$585; panel mtg. \$10, 2-speed drive \$25; alarms \$70; GC available mid-72.

TABLE 11-A (cont'd)

(page 2 of 5)

STRIP CHART RECORDERS, PORTABLE

<u>Ref. No.</u>	<u>11A-5</u>	<u>11A-6</u>	<u>11A-7</u>	<u>11A-8</u>
Mfg &/or Vendor	W-M (M155)	W-M (M155)	FIGURE 21 (Westronics) Carle (M30)	Esterline(M54) ISCO (M80)
Model Number	EPR Series EPR-2T	EPR Series EPR-2TC	Basic GC 6700***	ISCO 610****
Power Chart Width	ac/bat* 150mm (6")	115v, 60 Hz 150mm (6")	115v, 60 Hz*** 5"***	115v, 60 Hz 4½" cal (6")
Min. Range, f.s.	5 mv	1 mv	1.1 mv***	100 mv (0.2 ma)
Max. Range, f.s.	100 volt	25 volt	(ext. atten.)	
No. Ranges#	14	14	1	cont. (cur.)
Accuracy	½%	½%	½%	1%
Response, f.s.	0.3 sec	0.3 sec	½ sec	not stated
Zero Adjust	100% f.s.	100% f.s.	mechanical	100% f.s.
Input Impedance	2 megohm	2 megohm	100 Kohm	(10K source, max.)
Writing	cap. pen	cap. pen	cap. pen	cartridge
Min. Chart Rate	20 mm/hr	20 mm/hr	1 in/min std	¾ in/hr
Max. Chart Rate	180 mm/min	360 mm/min	not stated	12 in/min
No. Rates#	6	6	1	10
Cover Door	no	no	std.	no
GC Use	some	yes	yes	no
Features	fully-port., built-in charger.	portable (lin op.).	tilt-out platen, tear bar, <u>no take-up roll.</u>	special purpose, limited use.
Size, WxHxD (in)	12½x9½-x6½	12½x9½-x6½	9½x8½x14½	10x8½x10½
Weight	13½ lb	13¼ lb	17½ lb	31 lb
Delivery	1-3 wk	1-3 wk	1-3 wk	n.s.
Price	\$780	\$750	\$695	\$745

Notes:

- # Switchable, or (interchange)
- * Bats.(not incl.)6 D-cell (8h), Ni-Cd (15h), alkaline (24h); reroll adapter \$10
- *** Modified Westronics S5E, -0.05 mv to +1.05 mv, rt. hand zero; 230v/50Hz opt. also available w/10" chart, #6800 @ \$925, bench or rack mtg.
- **** Int. ampl'r for current input, intended for that application. See 11B-2.

TABLE 11-A (cont'd)

(page 3 of 5)

STRIP CHART RECORDERS, PORTABLE

<u>Ref. No.</u>	<u>11A-9</u>	<u>11A-10</u>	<u>11A-11</u>	<u>11A-12</u>
Mfg &/or Vendor	Instr.C. (M79) Mast (M94)	PSC (M117)	YSI (M161)	H-P (M69)
Model Number	Mast 725-3S(A)	Series 701 GP 701-5	80 A***	Lab & System 7127 A
Power Chart Width	115v, 60 Hz 4"	115/230v 60Hz 4"	115/230v 50/60 2.31"	115/230v, 60 Hz 10"
Min. Range	10 mv	1 mv**	10 mv (1uA)	1 mv (single)
Max. Range	100 mv	1 v	500 v (50 mA)	100 v (opt.)
No. Ranges#	1 (2)	1 (3)	5+ 4:1 cont.	19 (opt.)
Accuracy	½%	½%	2%	0.2%
Response, f.s.	¾ sec	½ sec	1 sec	½ sec
Zero Adjust	100% f.s.	100% f.s.	400% f.s.	200% f.s.
Input Impedance	*	inf. @ bal.	1 megohm	inf. @ bal.
Writing	ball point*	nylon (disp.)	pressure	cap. or disp.
Min. Chart Rate	¼ in/hr (std)	1 in/hr	1 in/hr	1/4 in/min
Max. Chart Rate	48 in/min	15 in/min	30 in/hr	(1/hr)****
No. Rates#	1 (16)	1 (6)**	1 (8)	4 (totl)
Cover Door	yes	no	yes	option
GC Use	no	yes	no	yes
Features	built-in alarm options	no handle light wt. fan-fold chart	inkless, reliable, noisy	many options & accessories, versatile
Size, WxHxD (in)	7x11½x10½+	6x4x10	11x6x5	17½x9-x8¼
Weight	26 lb	5 lb	9 lb	24 lb
Delivery	n.s.	2-3 wk	2-3 wk	n.s.
Price	\$680	\$375	\$450	\$1150****

Notes:

Switchable, or (interchange)

* Max. source imp. 50 K ohm; alarm--int. add \$245, ext. add \$80

** 10 mv & 1 volt @ \$315 & \$275; 2-speed add \$35; 4-colors ink

*** Model 81 A, dual-ch. @ \$695; both use Rustrak recorder w/preamp

**** With GC module option, others available, 0.1 mv f.s. (add \$100), handle \$25 and door \$50, servo-actuated pen, detector selector switch; also rack mtg.

TABLE 11-A (cont'd)

STRIP CHART RECORDERS, PORTABLE

<u>Ref No.</u>	<u>11A-13</u>	<u>11A-14</u>	<u>11A-15</u>	<u>11A-16</u>
Mfg &/or Vendor	Houston (M75)	- - -L & N (M88)	- - -	Honeywell(M73)
Model Number	Omnigraphic 10	- - - Speedomax XL 610	- - - XL 600	Elektronik 193 Portable
Power Chart Width	115/230v 50/60 10" cal. (12)	- - 115/230v, 60 Hz 250mm (9 7/8")	- - -	115v, 60 Hz 6"
Min. Range	1 mv (10uA)	1 mv	0.1 mv	0.5 mv (0.1)
Max. Range	100 v (100mA)	1250 mv	100 v	100 volt
No. Ranges#	6+ (6)*	9	20	1 (19)
Accuracy	1/4%	1/4%	1/4%	1/4%
Response, f.s.	1/2 sec	<1 sec	<1/3 sec	<1/2 sec
Zero Adjust	200% f.s.	- - -±100%	f.s. - - -	160% f.s.
Input Impedance	inf. @ bal.	50 K (min)	10 Meg (min)	inf. @ bal.
Writing	fiber (disp.)	- - capillary pen	- - -	jewel tip
Min. Chart Rate	3 in/hr	1 in/hr	1 in/hr	6 in/hr
Max. Chart Rate	20 in/min	80 in/min	600 in/min	60 in/min
No. Rates#	5	- single (2-20 opt.)**	-	1 (10 opt.)****
Cover Door	std	- plastic dust cover	-	none****
GC Use	yes	- - - - yes	- - - -	yes
Features	volt-ohm -ammeter, versatile.	Tilting writing platen & tear-off bar, multiple options.		tilting platen, multiple options.
Size, WxHxD (in)	17 1/2 x 11 1/4 x 9-	- - 18 x 9 x 11-	- - -	9-x9-x10 1/2+
Weight	34 lb	- - - 25 lb-	- - -	20 lb
Delivery	1-2 wk	4 wk	8 wk	2-4 wk
Price	\$995	\$935	\$1085	\$750

Notes:

- # Switchable, or (interchange)
- * Also 1-100K ohms; rack mtg. opt. N/C, also lin-log model 11 @ \$1245
- ** Chart options--2-sp. add \$25, 10-sp. add \$160; opt. rack mtg. N/C.
- **** 19 range model add \$275, 10-speed add \$100; plastic cover supplied; rack mtg. opt.

STRIP CHART RECORDERS, PORTABLE

<u>Ref No.</u>	<u>11A-17</u>	<u>11A-18</u>
Mfg &/or Vendor	- - - Rustrak (M128)	- - -
Model Number	200 Series 288	400 Series 400
Power	- - - 120 v, 60 Hz	- - -
Chart Width	- - - 2 5/16 inch-	- - -
Min. Range	0-10 mv	0-25 mv**
Max. Range	0-500 v	0-100 mv
No. Ranges#	1 (preselect)	1 or variable**
Accuracy	±2% f.s.	±0.5%
Response, f.s.	1 sec	1 sec
Zero Adjust	none	option**
Input Impedance	1000 ohm/v (galvanometer)	10K to 1 megohm** (amplifier)
Writing	- inkless, pressure-sensitive paper -	-
Min. Chart Rate	1/32 in/hr	1/2 in/hr
Max. Chart Rate	480 in/hr	240 in/hr
No. Rates#	- - - one (preselect)	- - -
Cover Door	- - - - - yes	- - - - -
GC Use	- - - - - no	- - - - -
Features	Dual-trace and dual-channel options, Extended view options, portable & rack options, controller option, event marker option.	
Size, WxHxD (in)	3 3/4x5 3/4-x4+	3 3/4-x5 3/4-x6
Weight	3 lb	4 lb
Delivery	- - - - 2-8 wk	- - - -
Price	\$99.50 - \$114.50	\$239 + amplifier

Notes:

- # Switchable, or (interchange)
- ** Basic range 0-100 mv @ 1 megohm; plug-in amplifiers: 1-25 mv @ 10Kohm - \$145, 1-50 mv @ 10Kohm, ±5x offset - \$150, 25-100 mv @ 1 megohm - \$75.

TABLE 11-B

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STRIP CHART RECORDERS, BENCH

<u>Ref. No.</u>	<u>11B-1</u>	<u>11B-2</u>	<u>11B-3</u>	<u>11B-4</u>
Mfg. &/or Vendor	Dohrman(M45)	Esterline(M51)	Health(M71)	H-P(M72)
Model Number	Lab. Series R-100*	Speed-ServoII L1101S	EU-205-B	Dedicated 7123****
Power Chart Width	115v, 60 Hz 11"(12)	115v, 60 Hz 10"(11")	115/230v 50/60 10"	115/230v 60 Hz 10"
Min. Range f.s. Max. Range f.s. No. Ranges#	1 mv 0.5 volt 1, opt. 6*	½ mv 100 mv(100v) 1(12)**	1 mv 500 volts 18	1 mv 100 volt 1 (11)
Accuracy Response f.s. Zero Adjust Input Impedance	0.3% f.s. ½ sec 100% f.s. ½ megohm	¼% 0.3 sec 110% (12x)f.s. 20 megohm	0.19. ½ sec 15x f.s. inf.@bal.	0.2% ¼ 100% f.s. 1 megohm
Writing Min. Chart Rate Max. Chart Rate No. Rates#	cap. pen* ½ in./min 10 in/min 2, opt. 5*	disp. cart. ¾"/hr 60"/min 1(2,5,10)	disp. cart. 0.2"/hr 30"/min 23	disp. cart. 1"/hr (30m) 6"/min(150m) 1 (2,6)
Cover Door GC Use	none yes	option yes	none yes	none yes
Features	simple & compact, desirable options*,	tilt platen, multiple options, rack mtg.	digital chart drive, push-button select, tilt platen,	fixed 45 ⁰ platen, rack mtg. option.
Size, WxHxD(in) Weight Delivery	16x5x15 26 lb 4 wk	17½x9-x16 40 lb 6 wk	17½x8½-x13+ 40 lb n.s.	17x3½x19½ 42 lb n.s.
Price	\$880	\$935**	\$675***	\$900****

Notes:

Switchable, or (interchange)

* Model RSC-1200, 6 range, 5 speed, add \$100; 10-sp. add \$100;
rack mtg, deduct \$100** Door avail. only on rack mtg. cab.; dual span \$25, multi-span \$100,
5-sp \$50. Also available 5" wide (See 11A-8)

*** Rack mtg. \$25, retransmit slide wire \$60, metric transport \$45

**** 5-inch model deduct \$55, Rt. hand zero N/C; 2-speed 4:1 chart drive \$25;

TABLE 11-B

(page 2 of 3)

STRIP CHART RECORDERS, BENCH

<u>Ref. No.</u>	<u>11B-5</u>	<u>11B-6</u>	<u>11B-7</u>
Mfg &/or Vendor	Honeywell(M73)	Kipp & Zonen Enraf-Nonius(51)	LDC(M87)
Model Number	Elektronik 194 Lab	Micrograph BD5	Series 280 2801
Power Chart Width	115v, 60Hz 10"	115/230v50/60 20 cm(8")	115/230v 50/60*** 10"
Min. Range f.s.	0.5 mv(0.1)*	20 μ v (20nA)	1 mv
Max. Range f.s.	100 volt	100mv (0.1mA)	10 volt
No. Ranges#	1 (19)	12 +(12)	1 (5,12)
Accuracy	$\frac{1}{4}$ %	$\frac{1}{2}$ %	$\frac{1}{2}$ %
Response f.s.	$\frac{1}{2}$ sec	0.6 sec	1 sec
Zero Adjust	160% (12x)f.s.	100% f.s.**	100% f.s.
Input Impedance	inf. @ bal.	1 megohm	inf @ bal.
Writing	Jewel tip	n.s.	disp.fiber
Min. Chart Rate	6"/hr	1 mm/min	1"/hr
Max. Chart Rate	60"/min	1000 mm/min	15"/min
No. Rates#	1 (10 opt.)*	10	1 (2,4)
Cover Door	option	none	none
GC Use	yes*	yes	yes
Features	tilt-out platen.	elect. rewind tilt.platen extreme sensitivity & stability.	low cost, rack mtg. option.
Size, WxHxD(in)	18-x8 $\frac{1}{2}$ -x13	17 $\frac{1}{4}$ x13 3/4x11 $\frac{1}{2}$	n.s.
Weight	35 lb	47 lb	n.s.
Delivery			
Price	\$965	\$1730	\$540***

Notes:

Switchable, or (interchange)

* Spec. 0.5 & 1 mv cards for GC; multi-span (see 11A-16), rack/panel, disappearing door \$50.

** Automatic $\pm 300\%$ f.s. suppression \$235;

*** Also 12v dc ext. model; writing platen \$15.

TABLE 11-B

(page 3 of 3)

STRIP CHART RECORDERS, BENCH

<u>Ref. No.</u>	<u>11B-8</u>	<u>11B-9</u>	<u>11B-10</u>
	FIGURE 22		
Mfg &/or Vendor	- - Westronics (M158)	-	YEW(M162)
Model Number	S11E*	LS11D**	Series 3040 3046-610
Power	- - - 115v, 60 Hz	- -	110v, 60 Hz
Chart Width	- - - 11" (12+)	- -	240 mm
Min. Range	- - - - 1/2 mv	- - -	1/2 mv
Max. Range	10v	100v	100v
No. Ranges#	1	1 (16)**	17***
Accuracy	1/4%	1/4%	0.3%
Response f.s.	1 sec*	1 sec	3/4 sec
Zero Adjust	±2%	±100% f.s.	100% f.s.
Input Impedance	- inf.@bal.	(50k unbal.)	1 megohm
Writing	cap.pen,disp.res. or ballpt.		SS pen
Min. Chart Rate	- - -	1/2"/hr	2 cm/hr
Max. Chart Rate	- - -	120"/hr	60 cm/min
No. Rates#	1 (2,5,10 opt)	5 (10 opt)	8***
Cover Door	yes (lock) disappearing		none
GC Use	yes	yes	yes
Features	- - tilt-out platen	-	versatile,
	- - tear-off bar	- -	low cost
	rack mtg.	**	
Size, WxHxD(in)	18-x8 1/2-x13 1/2	20 1/2-x9 1/4-x16 1/2	17 1/2-x8-x11 1/2
Weight	35 lb	50 lb	31 lb
Delivery	6 wk	6 wk	
Price	\$860*	\$1115	\$855***

Notes:

Switchable, or (interchange)

* 1/2 sec response + 10-speed \$100. Also 5" model (see 11A-7)

** Overhead door, front-panel controls: 3 selectable input, std., optional 16 span and 10 speed.

*** Single range, single sp. \$745

TABLE 11-C

CARD CHART RECORDERS

11C-1	<u>L & N (M88) Infotrak No. 11502</u>	
	Chart--	5x8 Keysort Card
	Style--	panel mounting, or portable w/kit (opt.)
	Single Range--	0-0.9 mv (to 120 mv) -- or current
	Accuracy--	½%
	Zero Adjust--	-25% to + 125% f.s.
	Response (99%)--	1 second
	Chart Speeds--	½ to 60 min/card or 1 to 12h/card
	Pen Type--	capillary
	Power--	115v, 60 Hz
	Size, WxHxD(in)--	7x7x19
	Price--	\$900 for mv ranges \$760 for voltage and current ranges
11C-2	<u>FLUIDYNE (M60) Servographic</u>	
	Chart--	5x8 Keysort Card OR 5" roll chart
	Style--	Flat-bed bench cabinet
	Single Range--	10 mv*
	Accuracy--	½%
	Zero Adjust--	100% f.s.
	Response f.s.--	not stated*
	Chart Speeds--	1"/min plus one other
	Pen Type--	disposable fiber tip
	Power--	115/230v 50/60 Hz
	Size, WxHxD(in)--	not stated
	Price--	\$625

Notes:

* 1 mv span @ ½ sec f.s. model available

TABLE 11-D
STRIP CHART RECORDERS, FLAT BED (typical)

<u>Ref. No.</u>	<u>Mfg.</u>	<u>Model</u>	<u>Chart Width</u>	<u>Sens.</u>	<u>Basic Price</u>
11D- 1	Beckman(M21)	100500	10"	x	\$1160
		93500	5"	(10mv)	690
11D- 2	Dohrman(M45)	SC1200	11"	x	980
11D- 3	Gow-Mac(M65)	70-210	10"	x	595
11D- 4	Heath(M71)	EU-20B	10"	(10mv)	225
11D- 5	Hitachi(M82)	QD 15	10"	x	1155
11D- 6	Houston(M75)	7	5"	xx	910
		3200-50/7	10"	x	1145
11D- 7	Lab.Data Control(M87)	320*	5"	x	485
		330	10"	x	538
11D- 8	L & N(M88)	XL680	10"	x	780
11D- 9	Linear Instr.(M90)	112	5"	x	395
11D-10	LKB(M92)	6530	8"	(2mv)	1040
11D-11	London(M93)	REC51**	10"	xxx	1210
11D-12	Matheson(M95)	8500***	7 7/8"	x	635
11D-13	McKee-Pedersen(M96)	MP-1027	10"	x	595
11D-14	Photovolt(M114)	Microcord44	10"	xx	1200
11D-15	PSC(M116)	702	5"	x	425

Notes:

x 1 mv full scale model; xx 0.5 mv f.s.; xxx 0.1 mv f.s.

* 10 mv LDC 320 also sold as Carle 7200 @ \$465; see also 11A-3.

** GC module available @ 0.1 mv f.s. (Radiometer/Copenhagen).

*** Formerly sold as Unicorder 20 (made in Japan)

TABLE 11-E

STRIP CHART RECORDERS, PANEL MOUNTING

(see also panel and rack options, Table 11-B)

<u>Ref. No.</u>	<u>Mfgr.</u>	<u>Model</u>	<u>WxHxD</u>	<u>Base Price</u>
11E- 1	Bailey(M17)	Type SR/11	4-x7-x20	\$ 410 ^y
11E- 2	Barber-Colman(M18)	8000*	18x14-x13	995
11E- 3		8700	18x16x13	1 200
11E- 4		RD Series**	9-x10½x13+	760
11E- 5		C4 Series	6x6x22	365
11E- 6	Beckman(M21)	2550	6x7-x21¼	406
11E- 7	Bell & Howell(M22)	18-301A	6-x8+x15-	630
11E- 8		18-302A	6-x8+x15-	450
11E- 9	Bristol(M26)	CR-1PH553	no data***	940
11E-10		other		780
11E-11	Foxboro(M62)****	NRE-6	6x7x24	n.s.
11E-12		ERB Series	13x15x11½	
11E-13	Hitachi(M82)	VKP35/VKB35	12x13x18(est.)	n.s.
11E-14		PR33	~17x9x18(est.)	n.s.
11E-15	Honeywell(M73)	112 Line	14½x10+x13½+	1 000
11E-16		111 Line	9½x10+x13½+	850
11E-17	L & N(M88)	Type H/S	11x12x13	800
11E-18		Type W	15x12x13	970
11E-19		Type M	7x7x19	650 (mv) 395 (V&A)
11E-20		or 7x7x13		
11E-21	MFE(M100)	M-12/12B ^x	3½+x5½x6½	250
11E-22	Robertshaw(M126)	223/224 ^{xx}	7-x7-x20+	250
11E-23	Taylor(M142)	Series 1300J		
11E-24		Series 1310J		
11E-25	Texas(M145)	FS01N	11x12+x21	740
11E-26		FL01W	18-x12-x12½	965
11E-27	Weather Measure(M155)	ET Series ^{yy}	13x14½x11½+	750
11E-28	West(M157)	FS	19x12½x12¼	935

Notes:

- * Special Chromacorder model for gas chromatographs, 1 mv f.s. to 50 mv (5),
60"/hr, right hand zero, tear bar
- ** Kit available for portable use
- *** No response, limited info. from magazine listing
- **** Manufactured by Yokogawa

- x Rustrak-type, portable case \$25, rack mounting \$50
- xx Force-balance solenoid motor, min. range 0-20 mv.

- y Requires enclosure and power supply;
2 and 3-pen recorders, controllers available
- yy 4 mv f.s. (std.) to 1 mv f.s. (amp'r opt.), opt. alarm and control.

XII -- DIGITAL DEVICES

Brochures and data sheets have been collected, but not extensively, on a number of digitizers, printers, computer interfaces, etc., which may find application in large scale monitoring, when combined as part of a process control instrumentation system. No attempt has been made to classify or evaluate this material. The material collected is filed under categories M-4 and M-5 in the catalog file which accompanies copy #1 of this report. Table 12 is a listing of items included in these folders.

XIII -- ALARM & CONTROL DEVICES

No listing of devices for alarm and process or ventilation control is included in this report, since such instrumentation must be selected according to the needs of each installation.

In general, signal outputs which can drive a recorder also can serve to activate alarm and control equipment, either by direct comparison of the output signal with the selected alarm-level voltages, or by means of switches or transmitting slidewires mounted in the recorder. Many of the continuous-monitor-type instruments listed herein have alarm capabilities built in, and the others can achieve it via the recorder output signal.

Similarly, digital instruments can generate alarm and control signals by digital comparison, or--if computer coupled--by computer interrogation.

TABLE 12-A

(page 1 of 1)

DIGITAL DEVICES (FILE M-4)

<u>Ref. No.</u>	<u>Manufacturer</u>	<u>Model</u>	<u>Function</u>
12A- 1 12A- 2	Beckman(M21)	Auto-Pro 3500 Model 3115	Digital Plotter Printer
12A- 3 12A- 4	Consolidated Controls(M37)	Model 50GP Model 50GP16	Digital Indicator and Data Logger Digital Printer
12A- 5	Disc Instrument(M44)	Model 610	Automatic Printer (for GC integration)
12A- 6	Doric Scientific(M46)	Digitrend 210	Data Logger
12A- 7 12A- 8	Esterline Angus(M54)	Model P-500 Model D2020	Digital Printer Data Acquisition System & Computer Interface
12A- 9 12A-10	Keltron Corp.(M85)	Model DM400 Model DM500	Digital Printer Digital Printer
12A-11 12A-12	MFE(M100)	Model DPC11E/M Model DPA6/12	Digital Ticket Printer Digital Printer
12A-13	Westronics(M158)	Model 7100	Digital Data System

TABLE 12-B

(page 1 of 1)

MISCELLANEOUS DATA DEVICES (FILE M-5)

<u>Ref. No.</u>	<u>Manufacturer</u>	<u>Model</u>	<u>Function</u>
12B- 1	Adams-Smith(M2)	Model 100	Instr. Interface (for Wang 700 calc'r)
12B- 2		Series 200	Instr. Interfaces
12B- 3	Beckman(M21)	Auto-Pro 1000	Automation Data Center
12B- 4		Auto-Pro 3210	Acoustic coupler (telephone interface)
12B- 5		Auto-Pro 3200	On-line switchbox
12B- 6		Auto-Pro 3111	Intercoupler
12B- 7		Auto-Pro 3109	Intercoupler
12B- 8	Brush (Gould)(M64a)	620 System	Data Acquisition
12B- 9	Canberra(M29)	Quanta	Computer Analyzer Systems
12B-10	CLC Corp.(M35)	Model SER-20	Environ. Recorder
12B-11	Fluidyne(M60)	7000 Series	Interfaces for Wang 700/720
12B-12	Hewlett-Packard(M72)	Model 3360A	GC Data Processing System
12B-13	Infotronics(M77)		Decoder/Controller
12B-14	Tetrahedron(M144)	Data Manager	Magnetic-type data recorder

APPENDIX A

LITERATURE CITATIONS AND STUDY REFERENCES

TABLE A-1 TEXT AND REFERENCE BOOKS

1. Altshuller, A.P., in
"Air Pollution, Vol. II" (A. C. Stern, Ed.),
2d Ed., Academic Press, New York, 1968, pp. 115-129.
2. Biffin, F.M., and W. Seaman,
"Modern Instrumentation in Chemical Analysis",
McGraw-Hill, New York, 1956.
3. Elkins, H.B.,
"The Chemistry of Industrial Toxicology",
2d Ed., John Wiley, New York, 1959.
4. Goldman, F.H., and M. B. Jacobs,
"Chemical Methods in Industrial Hygiene",
Interscience, New York, 1953.
5. Hendrickson, E.R., in
"Air Pollution, Vol. II" (A. C. Stern, Ed.),
2d Ed., Academic Press, New York, 1968, pp. 3-50.
6. Jacobs, M.B.,
"The Analytical Chemistry of Industrial Poisons,
Hazards, and Solvents",
2d Ed., Interscience, New York, 1949.
7. Jacobs, M.B.,
"The Chemical Analysis of Air Pollutants",
McGraw-Hill, New York, 1952.
8. Jacobs, M.B., and L. Schefflan,
"Chemical Analysis of Industrial Solvents",
Interscience, New York, 1953.
9. Mellon, M.G. (Ed.),
"Analytical Absorption Spectroscopy",
John Wiley, New York, 1950.
10. Ruch, W.E. (Ed.),
"Chemical Detection of Gaseous Pollutants",
Univ. of Michigan Press, Ann Arbor, Michigan, 1966.
11. Stewart, C.P., and A. Stolman,
"Toxicology Mechanisms and Analytical Methods",
Vol. II, Academic Press, New York, 1960.
12. Stolman, A., et al.,
"Progress in Chemical Toxicology",
Vol. II, Academic Press, New York, 1965.
13. Strafford, N., et al. (Eds.),
"The Determination of Toxic Substances in Air",
Heffer, Cambridge, 1956.
14. Yaffe, C.D., D. H. Byers, and A. D. Hosey (Eds.),
"Encyclopedia of Instrumentation for Industrial Hygiene",
Univ. of Michigan Press, Ann Arbor, Michigan, 1956.
15. McCabe, L.C.,
"Air Pollution - Proc. U.S. Tech. Conf. on Air Pollution",
McGraw-Hill, New York, 1952.

TABLE A-2 GOVERNMENT PUBLICATIONS

16. "Air Pollution Source Testing Manual" (R. G. Holmes, Ed.),
Los Angeles County Air Pollution Control District,
Los Angeles, 1965.
17. MacPhee, R.D., and M. Kuramoto,
"Recommended Test Methods for Organic Solvents and
Vapors (Rule 66)",
Los Angeles County Air Pollution Control District,
Los Angeles, 1968.
18. Siegel, J., and W. J. Burke,
"Industrial Air Analysis",*
N.Y. State Dept. of Labor, Div. of Ind. Hyg. and Safety Stds.,
New York, 1948, pp. 20-21.
19. Schrenk, H.H., S. J. Pearce and W. P. Yant,
U. S. Bureau of Mines, Report of Investigation No. 3287, 1935.
20. "Benzene; Toluene and Xylene; Styrene (Methods for the Detection
of Toxic Substances in Air)",
Ministry of Labour, London, England, 1966.
(Abstract only, Ref. 21-#04219-D)
21. "Hydrocarbons and Air Pollution: An Annotated Bibliography",
Parts I and II, Natl. Air Poll. Control Adm. Publication,
No. AP-15, U.S. Dept. of H.E.W., 1970.
Abstracts of references: 20, 60, 66, 74, 81, 91, 99, 101, 103a,
104, 109, 115, 129, 130, 131, 137, 143, 146, 147, 155, 167, 171,
179, 180, 181, 183, and 196.
22. "1969 Inventory of Air Pollution Monitoring Equipment Operated by
State and Local Agencies", PB-198 329, U.S.E.P.A.
Research Triangle Park, NC, 1971.
23. Lieberman, A., and D. Schipma,
"Air-pollution-monitoring Instrumentation: A Survey",
NASA-SP-5072, NASA Technology Utilization Div.,
Washington, D.C., 1969.
24. "Testing Methods and Techniques - A Compilation",
NASA-SP-5931 (01), NASA Technology Utilization Div.,
Washington, D.C., 1970.
25. "Gas Chromatograph Sample-Transfer Valve",
Tech. Brief 71-10474, Technology Utilization Office, NASA, Code KT,
Washington, D.C., 1971.
26. "Minature Carbon Dioxide Sensor",
Tech. Brief 71-10536, Technology Utilization Office, NASA, Code KT,
Washington, D.C., 1971.
- 26a. "Increasing the Response of PIN Photodiodes to the Ultraviolet",
Tech. Brief 72-10053, Technology Utilization Office, NASA, Code KT,
Washington, D.C., 1972.

* Also: N.Y. State Ind. Bull. 18, 17 (1939)

TABLE A-3 ASSOCIATION AND SOCIETY PUBLICATIONS

27. Silverman, L.,
"Industrial Air Sampling and Analysis",
Ind. Hygiene Assoc., Pittsburgh, 1947.
28. Silverman, L., et al.,
"Air Sampling Instruments",
3d Ed., Am. Conf. Govt'l. Ind. Hygienists, Cincinnati, 1966.
29. Silverman, L., E. M. Adams, and E. W. Gilliland,
in "Air Sampling Instruments",
Am. Conf. Govt'l. Ind. Hygienists, Cincinnati, 1960.
30. "Threshold Limit Values for Airborne Contaminants, and Intended
Changes. Adopted by ACGIH for 1970",
Am. Conf. Govt'l. Ind. Hygienists, Cincinnati, 1970.
31. "Benzene",
Analytical Abstracts (series), Amer. Ind. Hygiene Assoc.
Cincinnati, 1965.
32. AIHA-ACGIH Jt. Comm. (Respirators),
"Table of Sorbents for Contaminants Listed in ACGIH 1970
Threshold Limit Values",
Amer. Ind. Hyg. Assoc. J. 32, 404, (1971).
33. ACGIH-AIHA Jt. Comm. (Detector Tubes),
"Direct Reading Gas Detecting Tube Systems",
Amer. Ind. Hyg. Assoc. J. 32, 488 (1971).
34. AIHA Hygenic Guide Series: Benzene,
Amer. Ind. Hyg. Assoc. J. 31, 383 (1970).
35. "Infrared Absorption Spectroscopy",
AIHA (Analytical Guides: Suppl. II - IR Spec.),
Amer. Ind. Hyg. Assoc. J. 32, 412 (1971).
36. "Cleaning Our Environment, The Chemical Basis for Action",
(Incl. Supplement), American Chemical Society,
Washington, D.C., 1969.
37. Levy, A., and S. Miller,
"Final Technical Report on the Role of Solvents in
Photochemical Smog Formation",
Tech. Div. Report No. 99, National Paint, Varnish, and
Lacquer Association, Inc., Washington, D.C., 1970.
38. "Acceptable Concentrations of Benzene",
ANSI Standard Z37.4 (1969), Amer. Natl. Stds. Inst.,
New York, 1969.
39. ANSI Standard Method Z11.70 (1951), Amer. Natl. Stds. Inst.,
New York, 1960. (See ASTM D 1017-51, Ref. No. 40)
40. "Standard Method of Test for Benzene and Toluene by Ultraviolet
Spectrophotometry",
ASTM Designation: D 1017-51, Am. Soc. Testing Mat.,
New York, 1960. (Also ANSI Standard Z11.70-1951)
41. "Sampling Atmospheres for Analysis of Gases and Vapors",
ASTM Designation: D 1605-60 (1967),
Am. Soc. Testing Mat., New York, 1967.
42. "Project Threshold",
ASTM Committee D-22,
Am. Soc. Testing Mat., Philadelphia, 1971.

TABLE A-4 -- FEATURE ARTICLES, REVIEWS, ETC.

(see also Addenda, page A-21)

43. 1970 Chemical Production Data,
Chem. Engr. News 49, No. 36, 12A (1971).
44. Heylin, M.,
"Special Report--Pollution Control Instrumentation",
Chem. Engr. News 49, No. 7, 78 (1971).
45. Mueller, P.K., E. L. Kothny, L. B. Pierce, et al.,
"Analytical Reviews--Air Pollution",
Anal. Chem. 43, No. 5, 1R (1971).
46. Hochheiser, S., F. J. Burmann and G. B. Morgan,
"Atmospheric Surveillance--The Current State of Air
Monitoring Technology",
Environ. Sci. Tech. 5, 678 (1971).
47. "Simplified Monitoring of Acute and Chronic Hazards of
Benzene Exposure" (staff)
Ind. Hygiene News Report 14, No. 8, 1 (1971).
48. Huffman, D.,
"Deadly Benzol Still With Us",
Monitor, Aug. 1971, 7,
Ind. Comm. of Ohio, Div. of Safety and Hygiene,
Columbus.
49. Hell, A.,
"Radiation Sources for Optical Spectroscopy",
Anal. Chem. 43, No. 6, 79A (1971).
50. "Explosives: Portable Detecting Device",
Chem. Engr. News 49, No. 27, 9 (1971).
51. Heines, Sister Virginia,
"Chromatography--A History of Parallel Development",
Chem. Tech. 1, 280 (1971).
52. Ettore, L. S.,
"The Development of Chromatography",
Anal. Chem. 43, No. 14, 20A (1971).
53. Hartmann, C.H.,
"Gas Chromatography Detectors" (Review),
Anal. Chem. 43, No. 2, 113A (1971).
54. Villalobos, R.,
"Process Gas Chromatography Detection Systems" (Review),
Chem. Eng. Progr. 64, No. 4, 55 (1968).
55. Decker, Jr., J.A.,
"Hadamard-Transform Spectrometry: A New Analytical Technique",
Anal. Chem. 44, No. 2, 127A (1972).
- 55a. F. W. Karasek,
"Marcel Golay - Scientist/Inventor",
Research/Development 22, No. 10, 30 (1971).
- 55b. F. W. Karasek,
"GC/MS/Computers",
Anal. Chem. 44, No. 4, 32A (1972).
- 55c. T. J. Porro,
"Double-Wavelength Spectroscopy",
Anal. Chem. 44, No. 4, 93A (1972).

TABLE A-5 -- TECHNICAL PAPERS

(see also Addenda, page A-21)

56. Altshuller, A.P., and T. A. Bellar,
"Gas Chromatographic Analysis of Hydrocarbons in the
Los Angeles Atmosphere",
J. Air Poll. Control Assoc. 13, 81 (1963).
57. Altshuller, A.P., T. A. Bellar and C. A. Clemons,
"Concentration of Hydrocarbons on Silica Gel Prior to Gas
Chromatographic Analysis",
Amer. Ind. Hyg. Assoc. J. 23, 164 (1962).
58. Altshuller, A.P., and C. A. Clemons,
"Gas Chromatographic Analysis of Aromatic Hydrocarbons at
Atmospheric Concentrations Using Flame Ionization Detector",
Anal. Chem. 34, 466 (1962).
59. Altshuller, A.P., and I. R. Cohen,
"Application of Diffusion Cells to the Production of Known
Concentrations of Gaseous Hydrocarbons",
Anal. Chem. 32, 802 (1960).
60. Altshuller, A.P., A. F. Wartburg, et al.,
"Storage of Vapors and Gases in Plastic Bags",
Int. J. Air Wat. Poll. 6, 75 (1962).
(Abstract only, Ref. 21-#01983-H)
61. Andreatch, A.J., and R. Feinland,
"Continuous Trace Hydrocarbon Analysis by Flame Ionization",
Anal. Chem. 32, 1021 (1960).
62. Annino, R., J. Franko, and H. Keller,
"Mixed Carrier Gases in Chromatography--A Source of Error",
Anal. Chem. 43, 107 (1971).
63. Apol, A.G., W. A. Cook, and E. R. Lawrence,
"Plastic Bags for Calibration of Air Sampling Devices--
Determination of Precision of Method",
Amer. Ind. Hyg. Assoc. J. 27, 149 (1966).
64. Ash, R.M., and J. R. Lynch,
"The Evaluation of Gas Detector Tube Systems: Benzene",
Amer. Ind. Hyg. Assoc. J. 32, 410 (1971).
65. Axelrod, H.D., et al.,
"New Bubbler Design for Atmospheric Sampling",
Anal. Chem. 43, 1916 (1971).
66. Barringer, A.R.,
"New Instrumentation and Techniques for Pollution Monitoring",
Air and Water Pollution Conference, Sacramento, California, 1967.
(Abstract only, Ref. 21-#04881-D)
67. Bellar, T.A., M. F. Brown, and J. E. Sigsby, Jr.,
"Determination of Atmospheric Pollutants in the Part-Per-
Billion Range by Gas Chromatography",
Anal. Chem. 35, 1924 (1963).
68. Bellar, T.A., and J. E. Sigsby, Jr.,
"Evaluation of Various Silica Gels in the Gas Chromatographic
Analysis of Light Hydrocarbons",
Environ. Sci. Technol. 1, 242 (1967).

TABLE A-5 TECHNICAL PAPERS (cont'd)

69. Bellar, T.A., J. E. Sigsby, C. A. Clemons and A. P. Altshuller,
"Direct Application of GC to Atmospheric Pollutants",
Anal. Chem. 34, 763 (1962).
70. Blacker, J.H., and R. S. Brief,
"A Dilution System for Preparing Dynamic Gas Concentrations",
Amer. Inc. Hyg. Conf., Toronto, May 1971, (abstract only),
Amer. Ind. Hyg. Assoc. J. 32, No. 5, Abstract p. 56 (1971).
71. Boettner, E.A., and R. C. Dallos,
"Analysis of Air and Breath for Chlorinated Hydrocarbons by
Infrared and Gas Chromatographic Techniques",
Amer. Ind. Hyg. Assoc. J. 26, 289 (1965).
72. Boubel, R.W.,
"Pressure-Volume Characteristics of Plastic Bags",
Amer. Ind. Hyg. Assoc. J. 26, 318 (1965).
73. Braman, R.S.,
"Flame Emission and Dual Flame Emission--Flame Ionization
Detectors for Gas Chromatography",
Anal. Chem. 38, 734 (1966).
74. Buchwald, H.,
"Activated Silica Gel as an Adsorbent for Atmospheric Contaminants",
Occup. Health Rev. 17, 14 (1965).
(Abstract only, Ref. 21-#01023-D)
75. Burchfield, H.P., R. J. Wheeler and J. B. Bernos,
"Fluorescence Detector for Analysis of Polynuclear Arenes by
Gas Chromatography",
Anal. Chem. 43, 1976 (1971).
76. Cadogan, D.F., and D. T. Sawyer,
"Gas Chromatographic Studies of Surface Complexes Formed by
Aromatic Molecules with Lanthanum Chloride on Silica Gel and
Graphon",
Anal. Chem. 43, 941 (1971).
77. Campbell, E.E., and H. M. Ide,
"Air Sampling and Analysis with Microcolumns of Silica Gel",
Amer. Ind. Hyg. Assoc. J. 27, 323 (1966).
- 77a. Chatterjee, B.B., M. K. Williams, et al.,
"The Location of Personal Sampler Filter Heads",
Amer. Ind. Hyg. Assoc. J. 30, 646 (1969).
78. Clemons, C.A., and A. P. Altshuller,
"Plastic Containers for Sampling and Storage of Atmospheric
Hydrocarbons Prior to Gas Chromatographic Analysis",
J. Air Poll. Control Assoc. 14, 407 (1964).
79. Comberlatti, J.R.,
"Application of Rapid Infrared Spectrometry to Air Pollution
Research",
Anal. Chem. 43, 1497 (1971).
80. Conner, W.D., and J. S. Nader,
"Air Sampling with Plastic Bags",
Amer. Ind. Hyg. Assoc. J. 25, 291 (1964).

TABLE A-5 TECHNICAL PAPERS (cont'd)

81. Confer, R.G., and R. S. Brief,
"Mylar Bags Used to Collect Air Samples in the Field for
Laboratory Analysis",
Air Eng. 7, 34 (1965).
(Abstract only, Ref. 21-#03971-D)
82. Cooper, C.V., L. D. White and R. E. Kupel,
"Qualitative Detection Limits for Specific Compounds Utilizing
Gas Chromatographic Fractions, Activated Charcoal and a Mass
Spectrometer",
Amer. Ind. Hyg. Assoc. J. 32, 383 (1971).
83. Cropper, F.R., and S. Kaminsky,
"Determination of Toxic Organic Compounds in Admixture in the
Atmosphere by Gas Chromatography",
Anal. Chem. 35, 735 (1963).
84. Curtis, E.H., and R. H. Hendricks,
"Large Self-Filling Gas Sampling Bag",
Amer. Ind. Hyg. Assoc. J. 30, 93 (1969).
85. Dambrauskas F., and W. A. Cook,
"Methanol as the Absorbing Reagent in the Determination of
Benzene, Toluene, Xylene, and Their Mixtures in Air",
Amer. Ind. Hyg. Assoc. J. 24, 568 (1963).
86. Dodd, H.C.,
"Direct Sample Injection into a Helium-Ionization Gas Chromatograph",
Anal. Chem. 43, 1724 (1971).
87. Dravnieks, A., et al.,
"High Speed Collection of Organic Vapors from the Atmosphere",
Environ. Sci. Technol. 5, 1220 (1971).
88. Elkins, H.B.,
"Maximum Allowable Concentrations of Mixtures",
Amer. Ind. Hyg. Assoc. J. 23, 132 (1962).
89. Elkins, H.B., E. M. Comproni, and L. D. Pagnotto,
"Industrial Benzene Exposure from Petroleum Naphtha: II",
Amer. Ind. Hyg. Assoc. J. 24, 99 (1963).
90. Elkins, H.B., L. D. Pagnotto, and E. M. Comproni,
"The UV Spectrophotometric Determination of Benzene in Air Samples
Adsorbed on Silica Gel",
Anal. Chem. 34, 1797 (1962).
91. Esposito, G.G., and M. H. Swann,
"Determination of Aromatic Content of Hydrocarbon Paint Solvents
by Gas Chromatography",
J. Paint Technol. 38, 377 (1966).
(Abstract only, Ref. 21-#03991-D)
92. Ettre, L.S.,
"Application of Gas Chromatographic Methods for Air Pollution
Studies",
J. Air Poll. Control Assoc. 11, 34 (1961).

TABLE A-5 TECHNICAL PAPERS (cont'd)

93. Farrell, T.J.,
"Re: Criteria for Judging Acceptability of Analytical Methods",
Anal. Chem. 43, 156 (1971).
94. Feldstein, M., and S. Balestrieri,
"The Detection and Estimation of Part Per Billion Concentrations
of Hydrocarbons",
J. Air Poll. Control Assoc. 15, 177 (1965).
95. Feldstein, M., S. Balestrieri, and D. A. Levaggi,
"The Use of Silica Gel in Source Testing",
Amer. Ind. Hyg. Assoc. J. 28, 381 (1967).
96. Forni, A., E. Pacifico, and A. Limonta,
"Chromosome Studies in Workers Exposed to Benzene or Toluene or
Both",
Arch. Environ. Health 22, 373 (1971).
97. Franken, J.J., C. Vidal-Madjar, and G. Guiochon,
"Gas-Solid Chromatographic Analysis of Aromatic Amines, Etc.",
Anal. Chem. 43, 2034 (1971).
98. Fraust, C.L., and E. R. Hermann,
"Charcoal Sampling Tubes for Organic Vapor Analysis by Gas
Chromatography",
Amer. Ind. Hyg. Assoc. J. 27, 68 (1966).
99. Freedman, R.W., and H. W. Lang,
"A Comparison of Infrared and Gas Chromatographic Methods for
Determination of Methane in Mine Air,"
Report No. RI-7179, Bureau of Mines, Washington, D.C., 1968.
(Abstract only, Ref. 21-#16620-D)
100. Freeman, R.R., and W. E. Wentworth,
"Helium Photoionization Detector Utilizing a Microwave Discharge
Source",
Anal. Chem. 43, 1987 (1971).
101. Girard, R., F. Tolot, and J. Bourret,
"Benzene Hydrocarbons and Serious Blood Diseases",
Arch. Mal. Profess. 31, 625 (1970). Abstract only.
(Abstract #1310: Ind. Hyg. Digest 35, No. 12, 24 (1971).)
102. Grant, D.W., and A. Clarke,
"A Systematic Study of the Quantitative Effects of Instrument
Control on Analytical Precision in Flame Ionization Gas
Chromatography",
Anal. Chem. 43, 1951 (1971).
103. Hales, J.M., D. A. Snyder, and J. L. York,
"A Method for Obtaining Dilute Mixtures of Gases",
Amer. Ind. Hyg. Assoc. J. 32, 299 (1971).
- 103a. Hettche, O., and H. VanBecker,
"Method For the Gravimetric Trace Analysis of Hydrocarbon Vapors".
(Abstract only, Ref. 21-#07373-D)

TABLE A-5 TECHNICAL PAPERS (cont'd)

104. Hill, R.L., and J. M. Sonley,
"A Four-Channel Chromatograph for Rapid Gas Analyses",
Lab. Pract. 17, 55 (1968).
(Abstract only, Ref. 21-#09365-D)
105. Houghton, J.A., et al.,
"Practical Applications of Analysis by the Ultraviolet
Absorbance Method",
Amer. Ind. Hyg. Assoc. J. 25, 380 (1964).
106. Ingram, W.T.,
"Personal Air-Pollution Monitoring Devices",
Amer. Ind. Hyg. Assoc. J. 25, 298 (1964).
- 106a. Innes, W.B.,
"Selective Catalytic Combustion Sensors for Reactive Organic
Analysis",
AIHA Paper No. 71-1088. Joint Conf. on Sensing of
Environmental Pollutants, Palo Alto, California,
November 8-10, 1971.
107. Innes, W.B., and A. J. Andreatch,
"Hydrocarbon and Carbon Monoxide Analysis by the Selective
Combustion Method",
Environ. Sci. & Technol. 4, 143 (1970).
108. Innes, W.B., W. E. Bambrick, and A. J. Andreatch,
"Hydrocarbon Analysis Using Differential Chemical Absorption
and Flame Ionization Detectors",
Anal. Chem. 35, 1198 (1963).
109. Iritani, T., and Y. Morishita,
"Quantitative Determination of Benzene, Toluene, and Xylene
in Solvent and in Air by Gas Chromatography",
Japan J. Ind. Health (Tokyo) 2, 56 (1960).
(Abstract only, Ref. 21-#04143-D)
110. Jackson, M.W.,
"Analysis for Exhaust Gas Hydrocarbons--Nondispersive Infrared
Versus Flame-Ionization",
J. Air Poll. Control Assoc. 11, 697 (1966).
111. Jacobs, E.S.,
"Rapid Gas Chromatography Determination of C₁ to C₁₀ Hydrocarbons
in Auto Exhausts",
Anal. Chem. 38, 43 (1966).
112. Jacobs, M.B., M. M. Braverman, and S. Hocheiser,
"Continuous Determination of Carbon Monoxide and Hydrocarbons
In Air by a Modified Infrared Analyzer",
J. Air Poll. Control Assoc. 9, 110 (1959).
113. Jacobs, M.B., and R. Jacobs,
"Photometric Determination of Mercury Vapor in Air Mines and
Plants",
Amer. Ind. Hyg. Assoc. J. 26, 261 (1965).
114. Jones, A.R., and R. S. Brief,
"Evaluating Benzene Exposures",
Amer. Ind. Hyg. Assoc. J. 32, 610 (1971).

TABLE A-5 TECHNICAL PAPERS (cont'd)

115. Kachmar, E.G.,
"Determination of Benzene, Toluene, and Xylene Simultaneously Present in the Air",
U.S.S.R. Literature on Air Pollution and Related Occupational Diseases 7, 143 (1962).
(Abstract only, Ref. 21-#06661-D)
116. Karasek, F.W.,
"Modern On-Line Process Analysis and Control",
Research/Development 20, No.2, 34 (1969).
117. Karasek, F.W.,
"Chromatographic Speed and Efficiency",
Research/Development 20, No. 3, 32 (1969).
118. Karasek, F.W.,
"Table Top Raman Spectroscopy",
Research/Development 20, No. 6, 32 (1969).
119. Karasek, F.W.,
"Analytical Tools in Process Automation",
Research/Development 20, No. 12, 68 (1969).
120. Karasek, F.W.,
"The UV Dual Monitor",
Research/Development 22, No. 12, 23 (1971).
121. Karasek, F.W.,
"Optical Multichannel Analyzer",
Research/Development 23, No.1, 47 (1972).
122. Karasek, F.W., and K. R. Gibbins,
"A Gas Chromatograph Based on the Piezoelectric Detector",
J. Chromat. Sci. 9, 535 (1971).
123. King, Jr., W.H.,
"Piezoelectric Sorption Detector",
Anal. Chem. 36, 1735 (1964).
124. King, Jr., W.H.,
"Using Quartz Crystals as Sorptive Detectors-Pt. 1",
Research/Development 20, No. 4, 28 (1969).
125. King, Jr., W.H.,
"Using Quartz Crystals as Sorptive Detectors-Pt. 2",
Research/Development 20, No. 5, 28 (1969).
126. King, Jr., W.H.,
U.S. Patent 3,427,864, Feb. 18, 1969.
127. King, Jr., W.H.,
"Generation of Clean Air to Permit Gas Chromatography Without Cylinders",
Anal. Chem. 43, 984 (1971).
128. Koenig, J.L.,
"Laser Raman Spectroscopy",
Research/Development 20, No. 6, 18 (1969).

TABLE A-5 TECHNICAL PAPERS (cont'd)

129. Kol'kovski, P.,
"A New Color Reaction for Vapors of Certain Aromatic Hydrocarbons",
Zh. Analit. Khim. 22, 456 (1967).
(Abstract only, Ref. 21-#08490-D)
130. Konosu, H.,
"Determination of Organic Solvent Vapor-Air Mixtures by a Non-Dispersive Ultraviolet Gas Analyzer and Examination of Precision",
Govt. Chem. Ind. Res. Inst. (Tokyo) 62, 257 (1967).
(Abstract only, Ref. 21-#07386-D)
131. Konosu, H., and Y. Mashiko,
"Design of a Non-Dispersive Ultraviolet Gas Analyzer and Its Application to Quantitative Measurement of Traces of Toxic Gases and Vapors in Air",
Kogyo Kagaku Zasshi 68, 1868 (1965).
(Abstract only, Ref. 21-#028861-D)
132. Kupeř, R.E., and L. D. White,
"Report on a Modified Charcoal Tube",
Amer. Ind. Hyg. Assoc. J. 32, 456 (1971).
133. Laitinen, H.A.,
"Analytical Chemistry in Environmental Science--1. The Meaning of Zero",
Anal. Chem. 43, 497 (1971).
134. Lang, H.W., and R. W. Freedman,
"The Use of Disposable Hypodermic Syringes for Collection of Mine Atmosphere Samples",
Amer. Ind. Hyg. Assoc. J. 30, 523 (1969).
135. Levadie, B., and J. F. Harwood,
"An Application of Gas Chromatography to Analysis of Solvent Vapors in Industrial Air",
Amer. Ind. Hyg. Assoc. J. 21, 20 (1960).
136. Levadie, B.,
"The Determination of Organic Vapors in Air by Gas Chromatography Using a Direct Injection Method",
Amer. Ind. Hyg. Assoc. J. 21, 322 (1960).
137. Lewis, R.J., R. Smith, and P. Baker,
"An Analysis of Instrument Downtime for a Large Air Monitoring Network",
60th Am. Mtg. Air Poll. Control Assoc., Cleveland, 1967.
(Abstract only, Ref. 21-#07885-D)
138. Linch, A.L.,
"The Spill-proof Microimpinger",
Amer. Ind. Hyg. Assoc. J. 28, 497 (1967).
139. Linch, A.L., and M. Corn,
"The Standard Midget Impinger--Design Improvement and Miniaturization",
Amer. Ind. Hyg. Assoc. J. 26, 601 (1965).
140. Locke, D.C., J. T. Schemermund, and B. Banner,
"Bonded Stationary Phases for Chromatography",
Anal. Chem. 44, 90 (1972).

TABLE A-5 TECHNICAL PAPERS (cont'd)

141. Lovelock, J.E.,
"A Photoionization Detector for Gases and Vapours",
Nature 188, 401 (1960).
- 141a. Lovelock, J.E.,
"Ionization Methods for Analyzing Gases and Vapors",
Anal. Chem. 33, 162 (1961).
142. Lucero, D.P.,
"Performance Characteristics of Permeation Tubes",
Anal. Chem. 43, 1744 (1971).
143. Luft, K.F., G. Kessler, and K. H. Zoner,
"Non-Dispersive Infrared Gas Analysis With the Unor Apparatus",
German. Chem. Ingr. Tech. 39, 937 (1967).
(Abstract only, Ref. 21-#08592-D)
144. Maffett, P.A., T. F. Doherty and J. L. Monkman,
"A Direct Method for the Collection and Determination of Micro
Amounts of Benzene or Toluene in Air",
Amer. Ind. Hyg. Assoc. J. 17, 186 (1956).
145. Magnuson, H.J., et al.,
"Industrial Toxicology in the Soviet Union--Theoretical and
Applied",
Amer. Ind. Hyg. Assoc. J. 25, 185 (1964).
- 145a. Manning, Robert J.,
"Application of a Small Infrared Spectrophotometer in
Pollution Analysis",
American Laboratory (July, 1971).
146. Matsumura, Y.,
"The Adsorption Properties of Active Carbon. Preliminary Study
on Adsorption of Various Organic Vapors on Active Carbon by Gas
Chromatography",
Ind. Health (Japan) 3, 121 (1965).
(Abstract only, Ref. 21-#04648-D)
147. Matsumura, Y., and R. Soda,
"Gas Chromatographic Analysis of Atmospheric Pollutants in
Industries",
Bull. Natl. Inst. Ind. Health 4, 44 (1960).
(Abstract only, Ref. 21-#04206-D)
148. McCormick, A.J., C. S. Tong, and W. D. Cooke,
"Sensitive Selective Gas Chromatography Detector Based on
Emission Spectrometry of Organic Compounds",
Anal. Chem. 37, 1470 (1965).
149. Mon, T.R.,
"Preparation of Large Bore Open Tubular Column for Gas
Chromatography",
Research/Development 22, No. 12, 14 (1971).
150. Morris, R.A., and R. L. Chapman,
"Flame Ionization Hydrocarbon Analyzer",
J. Air Poll. Control Assoc. 11, 467 (1961).

TABLE A-5 TECHNICAL PAPERS (cont'd)

- 150a. Nikelly, J.G.,
"Evaluation and Applications of Porous Layer Open Tubular
Columns Made by the Dynamic Method",
Anal. Chem. 44, 625 (1972).
151. Nomiyama, K., and M. Minai,
"Studies on Poisoning by Benzene and its Homologues: 12",
Ind. Health (Japan) 8, 31 (1970).
152. Nonaka, A.,
"Gas-Solid Chromatography of Organic Compounds Using Steam
as the Carrier Gas",
Anal. Chem. 44, 271 (1972).
153. Novak, J., and V. Vasak,
"Discussion of the Interpretation of Threshold Limit Values",
Amer. Ind. Hyg. Assoc. J. 27, 555 (1966).
154. Novak, J., V. Vasak, and J. Janak,
"Sorpton on Gas Chromatography Column Materials",
Anal. Chem. 37, 660 (1965).
155. O'Keefe, A.E.,
"Permeation Standards for Trace Gas Analysis,"
Presented at the 152nd Meeting, New York, 1966.
(Abstract only, Ref. 21-#11270-D)
156. O'Keefe, A.E., and G. C. Ortman,
"Primary Standards for Trace Gas Analysis",
Anal. Chem. 38, 760 (1966).
157. Otterson, E.J., and C. U. Guy,
"A Method of Atmospheric Solvent Vapor Sampling on Activated
Charcoal in Connection With Gas Chromatography",
Trans. of 26th Ann. Mfg. A.C.G.I.H., 37 Philadelphia (1964),
(pre-delivery copy from E. J. Otterson, author).
158. Pagnotto, L.D., H. B. Elkins, H. G. Bugsch, and J. E. Walkley,
"Industrial Benzene Exposure from Petroleum Naphtha: I",
Amer. Ind. Hyg. Assoc. J. 22, 417 (1961).
159. Parker, D.R., and L.W. Brewer,
"Techniques for Remote Sampling of Gases",
Amer. Ind. Hyg. Assoc. J. 32, 475 (1971).
160. Parkinson, G.S.,
"Benzene in Motor Gasoline--An Investigation into Possible
Health Hazards in and Around Filling Stations and in Normal
Transport Operations",
Ann. Occup. Hyg. 14, 145 (1971).
161. Price, J.G.W., D. C. Fenimore, D. G. Simmonds, and A. Zlatkis,
"Design and Operation of Photoionization Detector for GC",
Anal. Chem. 40, 541 (1968).
162. Reid, F.H., and W. R. Halpin,
"Determination of Halogenated and Aromatic Hydrocarbons in
Air by Charcoal Tube and Gas Chromatography",
Amer. Ind. Hyg. Assoc. J. 29, 390 (1968).

TABLE A-5 TECHNICAL PAPERS (cont'd)

163. Reynolds, W.D., and J. G. Green,
 "A Highly Accurate Calibration Instrument for Specific Air
 Pollution Monitors",
 162nd National Amer. Chem. Soc. Mtg.,
 Washington, D.C., Sept. 1971 (preprint).
164. Robinson, C.J.,
 "Low-Resolution Mass Spectrometric Determination of Aromatics
 and Saturates in Petroleum Fractions",
Anal. Chem. 43, 1425 (1971).
165. Rochkind, M.M.,
 "Infrared Analysis of Multicomponent Gas Mixtures",
Anal. Chem. 39, 567 (1967).
166. Rushing, E.D.,
 "Gas Chromatography in Industrial Hygiene and Air Pollution
 Problems",
Amer. Ind. Hyg. Assoc. J. 19, 238 (1958).
167. Sakamoto, H., and T. Kozima,
 "Reliability of Measurement of Evaporated Benzene Homologue
 Concentrations With the Benzene-Detection Tube",
Japan J. Ind. Health (Tokyo) 3, 419 (1961).
 (Abstract only, Ref. 21-#04742-D)
168. Saltzman, B.E., W. R. Burg, and G. Ramaswamy,
 "Performance of Permeation Tubes as Standard Gas Sources",
Environ. Sci. Technol. 5, 1121 (1971).
169. Santini, R.E., and H. L. Pardue,
 "Dual Detector Chemiluminescence Spectrophotometer",
Anal. Chem. 42, 706 (1970).
170. Sawicki, E.,
 "Fluorescence Analysis in Air Pollution Research",
Talanta 16, 1231 (1969).
171. Schuette, F.J.,
 "Plastic Bags for Collection of Gas Samples",
Atmos. Environ. 1, 515 (1957).
172. Schwartz, R.D., R. G. Mathews, J. E. Rountree and D. M. Irvine,
 "Evaluation of Dendritic Salt as a Support for Gas-Liquid
 Chromatography",
Anal. Chem. 43, 2000 (1971).
173. Sherwood, R.J.,
 "Evaluation of Exposure to Benzene Vapour During the Loading
 of Petrol", (internal report) (to be published) (preprint)
 Esso Europe Inc., London, (1971).
174. Sherwood, R.J.,
 "The Monitoring of Benzene Exposure",
 Amer. Ind. Hyg. Assoc. Conf., Toronto, 27 May 1971.
 (to be published) (pre-print)
175. Sherwood, R.J.,
 "Occupational Hygiene in Aromatics Plants",
Ann. Occup. Hyg. 14, 125 (1971).

TABLE A-5 TECHNICAL PAPERS (cont'd)

176. Sherwood, R.J., and F. W. G. Carter,
"The Measurement of Occupational Exposure to Benzene Vapour",
Ann. Occup. Hyg. 13, 125 (1970).
177. Sherwood, R.J., and S. G. Perry,
"A New Approach to Field Determination of Specific Volatile
Organic Substances--Application to Benzene in Hydrocarbon
Mixtures",
Ann. Occup. Hyg. 11, 241 (1968).
- 177a. Skarstrom, C.W.,
"Heatless Dryer",
U. S. Patent No. 2,944,627.
178. Smith, B.S., and J. O. Pierce,
"The Use of Plastic Bags for Industrial Air Sampling",
Amer. Ind. Hyg. Assoc. J. 31, 343 (1970).
179. Smith, S.B., and R. J. Grant,
"A Non-Selective Collector for Sampling Gaseous Air Pollutants-
Final Rept",
Research and Development Dept.,
Pittsburgh Coke and Chemical Co., 1958.
(Abstract only, Ref. 21-#03425-D)
180. Smith, W.D.,
"The NRL Total Hydrocarbon Analyzer",
in NRL-6491, Naval Research Lab.,
Washington, D.C., 1967.
(Abstract only, Ref. 21-#08519-D)
181. Steger, E., and H. Kahl,
"The Analysis of Gaseous Air Contaminations by Infrared
Spectroscopy",
Germ. Chem. Tech. 21, 483 (1969).
(Abstract only, Ref. 21-#14470-D)
182. Taylor, H.E., J. H. Gibson, R. K. Skogeboe,
"Determination of Trace Impurities in Argon by Microwave-
Induced Excitation",
Anal. Chem. 42, 876 (1970).
183. Tighe, J., R. B. Engdahl, and E. J. Center,
"Direct Infrared Spectral Analysis of Contaminants in the
Atmosphere (A Preliminary Study)", (1953).
(Abstract only, Ref. 21-#04631-D)
184. Turk, A., J. I. Morrow, S. H. Stoldt, and W. Baecht,
"Enhanced Desorption of Atmospheric Samples From Activated
Carbon",
J. Air Poll. Control Assoc. 16, 383 (1966).
185. Van Haaften, A.B., and S. T. Sie,
"The Measurement of Phenol in Urine by Gas Chromatography
as a Check on Benzene Exposure",
Amer. Ind. Hyg. Assoc. J. 26, 52 (1965).
186. Van Houten, R., and G. Lee,
"A Method for the Collection of Air Samples for Analysis by
Gas Chromatography",
Amer. Ind. Hyg. Assoc. J. 30, 465 (1969).

TABLE A-5 TECHNICAL PAPERS (cont'd)

187. Van Mourik, J.H.C.,
"Experiences with Silica Gel as Adsorbents",
Amer. Ind. Hyg. Assoc. J. 26, 498 (1965).
188. VanderKolk, A.L.,
"Sampling and Analysis of Organic Solvent Emissions",
Amer. Ind. Hyg. Assoc. J. 28, 588 (1967).
189. VanderKolk, A.L., and D. E. VanFarowe,
"Use of Mylar Bags for Air Sampling",
Amer. Ind. Hyg. Assoc. J. 26, 321 (1965).
190. Wartburg, A.F., A. W. Brewer and J. P. Lodge, Jr.,
"Evaluation of a Coulometric Oxidant Sensor",
Int. J. Air Wat. Poll. 8, 21 (1964).
191. Wartburg, A.F., J. B. Pate and L. P. Lodge, Jr.,
"An Improved Gas Sampler for Air Pollutant Analysis",
Environ. Sci. Technol. 3, 767 (1969).
192. West, P.W., B. Sen, and N. A. Gibson,
"GLC Analysis Applied to Air Pollution",
Anal. Chem. 30, 1390 (1958).
193. White, L.D., D. G. Taylor, P. A. Mauer, and R. E. Kupel,
"A Convenient Optimized Method for the Analysis of Selected
Solvent Vapors in the Industrial Atmosphere",
Amer. Ind. Hyg. Assoc. J. 31, 225 (1970).
194. Whitman, N.E., and A. E. Johnston,
"Sampling and Analysis of Aromatic Hydrocarbon Vapors in
Air: A Gas-Liquid Chromatographic Method",
Amer. Ind. Hyg. Assoc. J. 25, 464 (1964).
195. Williams, I.H.,
"Gas Chromatographic Techniques for the Identification of
Low Concentrations of Atmospheric Pollutants",
Anal. Chem. 37, 1723 (1965).
196. Woods, F.J., M. E. Umstead, and J. E. Johnson,
"A Study of the Ionization Produced by the Catalytic Combustion
of Hydrocarbons",
NRL Rept. 6316, Washington, D.C., 1965.
(Abstract only, Ref. 21-#00060-D)
197. Yamamoto, R. K., and W. A. Cook,
"Determination of Ethyl Benzene and Styrene in Air by
Ultraviolet Spectrophotometry",
Amer. Ind. Hyg. Assoc. J. 29, 238 (1968).
198. Zdrojewski, A., and J. L. Monkman,
"A Simple Gas Dilution Apparatus",
Amer. Ind. Hyg. Assoc. J. 30, 650 (1969).
199. Zdrojewski, A., and J. L. Monkman,
"A Modification of the Gelman Sequential Sampling Valve",
Amer. Ind. Hyg. Assoc. J. 30, 652 (1969).
200. Zuman, P.,
"Polarography in Organic Chemistry",
Chem. Engr. News, 3/18/68, p. 97.

TABLE A-6 -- PRIVATE COMMUNICATIONS (excluding manufacturer inquiries)

(see also Addenda, page A-21)

201.	Adams, D. F. (ASTM D-22)	Washington State University
202.	Allington, John R.	Instrumentation Specialties Co.
203	Anderson, Darrell E.	Minnesota Dept. of Health
204.	Baliff, Jack & Robert Ratajack	New York State Dept. of Labor
205.	Bart, M., J. Eisen, and J. Heacock	California Dept. of Ind. Relations
206.	Bartlett, Dr. Jay P. (AIHA)	San Francisco
207.	Baucom C. D.	North Carolina State Board of Health
208.	Beaman, R. J.	Procter & Gamble
209.	Beck, E. C.	Swift & Company
210.	Behr. Jr., Byron C.	Byron Instruments, Inc.
211.	Bellino, Vincent A.	Lacz Associates
212.	Bernard, Burton	GTE-Sylvania, Electro-Optics
213.	Beutner, Heinz P.	Arthur D. Little, Inc.
214.	Bobalk, M. W.	National Lead Company of Ohio
215.	Bovee, H. H.	Univ. of Wash. Dept. Environ. Health
216.	Boyle, John P.	U. S. Department of Labor (Dallas)
217.	Bradbury, Howell G.	Fort Worth Public Health Dept.
218.	Britt, Eugene H.	NASA, Langley Research Center
219.	Burkhardt, Howard L.	Idaho Department of Health
220.	Campbell, E. E.	Los Alamos Scientific Lab.
221.	Campbell, Mason W.	Boeing Company (Seattle)
222.	Caplan, Knowlton J.	Univ. of Minn. Div. Environ. Health
223.	Carter, George T.	NASA, Kennedy Space Center
224.	Cieplinski, Edward W. (ASTM E-19)	Analytical Instrument Development Inc.
225.	Cohen, Robert S.	Dover Chemical Corporation
226.	Comberiati, Joseph R.	Bureau of Mines (Morgantown)
227.	Conti, Frank	Devco Engineering
228.	Corley, J. P.	Battelle Northwest (Richland)
229.	Cosand, M. E.	San Bernadino County Health Dept. (CA)
230.	Cox, R. A.	A.E.R.E. (Harwell)
231.	Crable, John V.	Nat. Inst. For Occ. Safety and Health (Cincinnati)
232.	Cropper, Walter V. (Director)	ASTM (Philadelphia)
233.	Crupi, Thomas	Massachusetts Dept. Labor & Ind.
234.	Deacon, A. E.	Kansas State Dept. of Health
235.	DeGesero, R. A., P. W. Klaren & A. Roelse	Dow Chemical (Nederland)
236.	Deufler, William L.	Mecklenbury County Health Dept.(NC)
237.	Devlin, Thomas H.	Baltimore County Dept. of Health (MD)
238.	Dickinson, Calvin L.	Velsicol Chemical Corp.
239.	Douglas, Darrel D.	Oregon State Board of Health
240.	Emery, E. E. (ASTM D-19)	Youngstown Steel

TABLE A-6 PRIVATE COMMUNICATIONS (cont'd)

241.	Fenimore, D. C.	Texas Research Institute of Mental Sciences
242.	Fenlason III, Robert W.	Wm. Beaumont Gen. Hosp.(El Paso)
243.	Foderaro, John & A. J. Ferrugiario	Frankford Arsenal (PA)
244.	Forby, L. P.	Douglas United Nuclear (Richland)
245.	Foster, F. J.	Philco/Ford (CA)
246.	Freeman, R. R.	Texas Research Institute of Mental Sciences
247.	Garcia, Leroy L.	New Mexico Environ. Improvement
248.	Garland, B. I.	Fulton County Health Dept. (GA)
249.	George J. H. B.	Arthur D. Little, Inc.
250.	Giever, P. M. (Chm. ASTM Comm. D-22)	Walden Research Corporation
251.	Goodman, W. G.	Alaska Dept. of Health & Welfare
252.	Gregory, E. G. & W. D. McCrary	Nevada Dept. of Health, Welfare and Rehabilitation
253.	Habermeyer, John G.	Ames Research Center (Moffett Field)
254.	Hager, Robert N.	Spectrometrics of Florida, Inc.
255.	Hanemann, Sheldon J.	Louisiana State Dept. of Health
256.	Hatton, Jack F.	California Div. of Ind. Safety
257.	Hebblethwaite, R. L.	Florida State Div. of Health
258.	Hertlein II, Fred	Pearl Harbor Naval Shipyard
259.	Herwig, Jr., Lee C.	Edgewood Arsenal (MD)
260.	Hickey, W. C.	ICI American Inc.
261.	Hintgen, George W.	City of Dallas Public Health Dept.
262.	Houser, Edwin A.	Beckman Instruments, Inc.
263.	Hoxie, Donald C.	Maine Dept. of Health & Welfare
264.	Hurst, T. L.	Kerr-McGee Corporation
265.	Innes, W. B.	Purad Incorporated
266.	Jaworshi, H. E.	Detroit Bureau of Occ. Health
267.	Johansen, Inger	Denmark State Institute for Occupational Hygiene
268.	Junod, T. L. & Donald E. Miller	NASA, Lewis Research Center
269.	Karasek, F. W.	University of Waterloo (Canada)
270.	Kary, Kenneth H.	North Dakota State Dept. of Health
271.	Keigher, Donald J.	NASA Industrial Safety Branch (DC)
272.	Koontz, Harry R. & Harold M. Erickson	Riverside County Dept. of Health (CA)
273.	Kratel, R.	World Health Organization (Geneva)
274.	Kurvink, Donald G.	South Dakota State Dept. of Health
275.	Kusnetz, H. L.	Shell Oil Company (Houston)
276.	Laitinen, H. A.	University of Illinois
277.	Lake, James W.	Space Nuclear Systems Office (Jackass Flats)

TABLE A-6 PRIVATE COMMUNICATIONS (cont'd)

278.	Lange, Arthur E.	Vermont Div. of Ind. Hygiene
279.	Largent, Edward J.	U.S. Dept. of Labor, OSHA (Chicago)
280.	Larkin, William J.	AEC Nevada Operations Office
281.	Lavery, Donald	Wilks Scientific Corporation
282.	Leichnitz, Kurt	Dragerwerk Chemical Div. (Germany)
283.	Levadi, Benjamin (ASTM D-22)	Vermont Department of Health
284.	Levy, Arthur	Battelle Memorial Institute (Columbus)
285.	Levy, Morton L.	Crobaugh Laboratories
286.	Lewis, David T.	Maryland Bureau of Ind. Hygiene
287.	Linch, A. L.	E. I. duPont deNemours & Co. (Deepwater)
288.	Lipera, Joe	Univ. of Calif., Lawrence Radiation Laboratory (Livermore)
289.	Lockhart, Wayne	Chromatix
290.	Love, James E.	NASA Flight Research Center (Edwards)
291.	Lucero, Daniel P.	Electro-Analytical Transducer Corp.
292.	Marcie, Frank J.	USAF Environ. Health Lab.(Kelly AFB)
293.	Maykoski, Robert T.	USAF Eviron. Health Lab. (McClellan AFB)
294.	McNab, Warren	BASF Wyandotte Corporation
295.	Metz, F. I.	Midwest Research Institute
296.	Meunier, J. J.	The Bendix Corp. (Kansas City)
297.	Miller, Jr., Alfred M.	Sinclair Koppers Company
298.	Miller, W. R.	Maryland State Dept. of Health
299.	Moroz, William J.	Center for Air. Environ. Studies (Pennsylvania State Univ.)
300.	Norback, Bruce A.	USAF Hospital Edwards AFB (CA)
301.	O'Keefe, Andrew E.	EPA, Research Triangle Park (NC)
302.	O'Neill, Hugh J.	IIT Research Institute
303.	Otterson, Edward J.	Wisconsin Dept. of Health & Social Services
304.	Parks, Robert E.	Antek Instruments, Inc.
305.	Pendergrass, John A.	3M Company (St. Paul)
306.	Pierce, Louis B.	California Dept. of Public Health
307.	Popper, Felix	Hampshire Chemical Div., W. R. Grace & Company
308.	Prager, Manfred J.	Nuclear Corporation of America
309.	Ramaley, Thomas R.	Industrial Commission of Arizona
310.	Ramirez-Ledesma, J.	University of Puerto Rico
311.	Rapp, D. E.	Dow Chemical Company (MI)
312.	Rees, H. D.	Pinellas County Health Dept. (FL)
313.	Resnick, Harold	Appalachian Lab. for Occupational Respiratory Diseases (WV)

TABLE A-6 PRIVATE COMMUNICATIONS (cont'd)

314.	Reynolds, W. D.	Electro/Mass Laboratory
315.	Riley, Edward A.	University of Notre Dame
316.	Robinson, C. J.	American Oil Company
317.	Robinson, J. W.	Louisiana State University
318.	Romer, L. A.	Westinghouse (Idaho Falls)
319.	Rossano, Jr., A. T. (ASTM D-22)	University of Washington
320.	Salazar, Alfredo	Aerojet Liquid Rocket Company
321.	Santillanes, Simon O.	Albuquerque Dept. of Environ. Health
322.	Schiltz, J. O.	The Bendix Corporation (Kansas City)
323.	Schorzman, M. H.	Madigan General Hospital (Tacoma)
324.	Schultz, Neil B.	Union Carbide Corp. (Oak Ridge)
325.	Scotfield, Francis (ASTM D-22)	Nat'l Paint, Varnish & Lacquer Assoc.
326.	Scott, R. H.	Battelle Northwest (Richland)
327.	Scribner, Jonathan W.	Alaska Dept. of Environ. Conservation
328.	Shaul, Robert S.	Maryland Dept. of Health & Mental Hygiene
329.	Sherwood, R. J.	Esso Research Centre, Abingdon, England
330.	Shoemaker, William E. (AIHA)	Bryn Mawr, PA
331.	Speicher, H. W.	Westinghouse (East Pittsburgh, PA)
332.	Spohnheimer, L. N. & Robert Staggs	AEC Ames Laboratory (Iowa)
333.	Swann, M. H.	Aberdeen Proving Ground (MD)
334.	Taloff, Paul	University of California (Davis)
335.	Tanaka, Shiro	Pennsylvania Div. of Occ. Health
336.	Tannenbaum, Harvey	Edgewood Arsenal (MD)
337.	Temer, Dan J.	New Mexico Environ. Impr. Agency
338.	Thompson, R. L. & D. L. Nist	Pan-Amer. Environ. Health Lab. (Kennedy Space Center)
339.	Turner, D.	The British Petroleum Co., Ltd. (Middlesex)
340.	Vander Kolk, Alvin L.	Michigan Bureau of Ind. Health & Air Pollution Control
341.	Vaughan, H. L.	Mississippi Div. of Occ. Health
342.	Vennos, Spyros	Bendix Environ. Science Div.
343.	Wallace, James D.	Rocket Propulsion Lab. (Edwards AFB)
344.	Welty, C.	AEC Operational Safety (DC)
345.	Weinstock, Ivan L. (Publisher)	Occupational Hazards (DC)
346.	Whitson, T. C.	Industrial Hygiene Dept. (Oak Ridge)
347.	Wilhelmsen, Mack	AEC (Idaho Falls)
348.	Willens, Nathan	Illinois Department of Labor
349.	Willson, F. M.	Continental Oil Company
350.	Wyatt, George L.	U.S. Dept. of Labor, OSHA (Atlanta)
351.	Zatek, J. E.	Mine Safety Appliances Company

ADDENDA

(Late Additions and Oversights)

TABLE A-6

352.	Berlman, Isadore B.	Hewbrew University of Jerusalem
353.	Bowman, Harry M.	Industrial Health Foundation
354.	Linenberg, Amos	Hydronautics - Israel Ltd.
355.	Hodgkin, Norman M.	Micrographics
356.	Wilks, Jr., Paul A.	Wilks Scientific Corp.
357.	Fitzgerald, John	Isomet Corporation
358.	not used	
359.	not used	

TABLE A-4 and A-5

360. Karasek, F. W.,
"Flow and Vacuum: Keys to GC/MS Interfacing",
Research/Development 22, No. 9, 52 (1971).
361. "Lasers and Electro-Optics" (staff),
Ind. Research 14, No. 2, L1 (1972).
362. "Lasers and Electro-optics" (staff),
Ind. Research 14, No. 3, L1 (1972).
363. "Compact Laser Design" (staff),
Electromech. Design 16, No. 2, 7 (1972).
364. "Instruments" (staff),
Ind. Research 14, No. 3, 24 (1972).
365. Sawicki, E., and H. Johnson,
"Characterization of Aromatic Compounds by Low-Temperature
Fluorescence and Phosphorescence"
Microchem. J. 8, 85 (1964).
366. Karasek, F. W.,
"A Drift-Mass Spectrometer",
Research/Development 21, No. 12, 25 (1970).
367. "Optical Multichannel Analyzer Uses Electronic Scanning",
Research/Development 22, No. 9, 78 (1971).
368. Chromatography--Microcolumn Separation Aids GC",
Ind. Research 13, No. 10, 33 (1971).
369. "Chromatography--Separating Compounds With a Little Carbon",
Ind. Research 13, No. 13, 33 (1971).
370. "High Resolution Filter Replaces Optics in Spectrometer",
Research/Development 22, No. 11, 60 (1971).
371. "Tunable Optical Filter Light Source",
Chem. Engr. News 50, No. 14, 16 (April 3, 1972).

ADDENDA (cont'd)

372. Henderson, Y., and H. H. Haggard,
ACS Monograph No. 35 (1927),
Also Report No. PHS-185 (1929).
373. Rules and Regulations, Title 29 - LABOR,
Chapter XVII - OSHA (DOL), Part 1910,
Occupational Safety and Health Standards.
374. Byrd, J. F., and A. H. Phelps, Jr. in
"Air Pollution, Vol. II" (A. C. Stern, Ed.),
2d Ed., Academic Press, New York, 1968, p. 325.
375. Chemical Economics Handbook,
Organic Chemicals, A-B, 618.5020,
Stanford Research Institute (1969).

APPENDIX B

TABLE B-1a-- LEGEND FOR TABLE B-1

REF. NO. -- Assigned reference number, M series.

MANUFACTURER/DISTRIBUTOR -- Name of firm, address, telephone number, and name or person(s) contacted, if known.

Responsiveness of manufacturer to inquiries (coded, upper right)

Code: NDI No direct inquiry made
*** Superior cooperation and response
** Adequate response
* Inadequate response
x No response to inquiries; information obtained by other means (ads, readers' cards, etc.)
(n) Number of written inquiries
t() Telephone inquiries (number)
PRC Proof returned completed
PRI Proof returned incomplete
PNR Proof not returned
PNS Proof not sent

MODEL -- Manufacturer's (or distributor's) name and/or number

DESCRIPTION

Cat.: Categorical classification (see Table B-2) and location of catalogs and descriptive material in Categorical File.

Table: Location of detailed description of instrument model.

Features: Stated description or coded listing of functional features.

System functions code--included or (optional)

- | | |
|--|----------------------|
| 1. Automatic continuous or repetitive sampling | 4. Recorder printout |
| 2. Remote sampling | 5. Alarm and control |
| 3. Remote sensing | 6. Digital output |

Environmental capabilities code

- | | |
|---------------------------------------|--|
| a. Explosion-proof | d. Laboratory use only |
| b. Weather and spray-down proof | e. Battery operated (otherwise line powered) |
| c. Requires protected plant locations | |

APPENDIX B

TABLE B-1 -- MANUFACTURERS & PRODUCTS

(page 1 of 30)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*		
			Cat.	Table	Features
	ACCO (see Bristol, M26)				
M1	Acme Products Div., A-T-0, Inc. **t(1) South Haven, MI 49090 (616) 637-2121 Lou Rodenhouse, Dennis Browner	not stated	B-1 B-3	4B-5 4A-6	gas detector tubes & kit
M2	Adams-Smith ** (1) P.O. Box 363 PNS Needham, MA 02192 (617) 449-2050 Harry E. Adams	100 Ser. 200	M-5	12B-1 12B-2	computer interfaces
M3	Air Products & Chemicals, Inc. ** (1) Specialty Gas Dept. PNS 733 W. Broad Street Emmaus, PA 18049		L-3	10A-1	calibration gases, carrier gases, H ₂ , O ₂ , air
M4	Alltech Associates, Inc. ** (2) 202 Campus Drive PNS Arlington Heights, IL 60004 (312) 392-2670	4040 4110-46 7014 1705-50 700/7000 4002 8122	A-4 A-5 A-5 A-6 A-6 I-7 I-7 I-7	3E-6 3F-12 3F-15 3F-18, 24 n.l. 3G-7 3G-1 n.l.	rotameters sampling bag sampling bulbs gas syringes liq. syringe oxy-sorb gas purifier columns, pkgs., & fittings
M5	American Instrument Company ** (2) 8030 Georgia Avenue PNS Silver Springs, MD 20910 (301) 589-7336 Samuel Greenberg	GC-3BF -4BPF -45APF	I-4	n.l.	lab GC
M6	AMICON Corporation ** (1) Scientific Systems Div. PNS 21 Hartwell Avenue Lexington, MA 02173 (617) 862-7050	CEC 1	I-7	n.l.	liq. eluate concentrator

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*		
			Cat.	Table	Features
M7	Anacon, Incorporated 30 Main Street Ashland, MA 01721 (617) 881-3000 Walker Ciak, G.E. Stackhouse	** (3) PNS 206SP	F-5	6B-8	IR moisture N/A
M8	Analabs, Incorporated 80 Republic Drive North Haven, CT 06473 (203) 288-8463 Gene W. Critzer	** (2) PNS CeraBeads	I-7	n.l.	GC column packing
M9	Analytical Instrument Development, Inc. 250 South Franklin Street West Chester, PA 19380 (215) 692-4575 Edward W. Cieplinski	9301-0011 511 512 303to309	A-5 I-2 I-2 L-2 L-2	3F-15 8A-9 8A-10 10B-1 10B-2 10B-3 to -6	gas syringe port. GCS 4c,e calibration permeation & diff. tubes systems
M10	Antek Instruments, Incorporated 6005 North Freeway Houston, TX 77022 (713) 869-3683 Robert E. Parks, V.P.	*** (4) PRC 140-IPC-X 310-IPC 40-IPC-X	I-3 I-3 I-6	8B-1 8B-2 8D-3	semi-P. GCs 1,2,4,c
M11	Anti-Pollution Technology Corp. 937 South Washington Avenue P.O. Box 1013 Holland, MI 49423 (616) 392-1492 Tom Dooley, Project Engineer	*** (7) t(1) PRC 2006SP	F-3	6A-1	digital mercury monitor
M12	Applied Automation, Incorporated (Phillips Petroleum Subsidiary) Pawkuska Road Bartlesville, OK 74004 (913) 336-0250 R.T. Curby, R.E. Wightman	** (3) t(4) PRC 102	I-1	8C-5	process GC 1,2,4,5,a,b

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*			
			Cat.	Table	Features	
M13	Applied Electrochemistry, Inc. 735 North Pastoria Avenue Sunnyvale, CA 94086 (408) 732-7880 Joseph Weissbart	** (3) t (1) PNS	K-3	n.1.	electrolytic cell N/A	
M14	The Arcas Company 2040 Kipling Houston, TX 77006 (713) 529-5768 John Chapman	*** () t (1) PNR	400 + 500 I-1 I-7	8C-b n.1.	process GC 1,2,4,5,a,b valves	
M15	ARCCO Instrument Company, Inc. 7144 East Condor Street Los Angeles, CA 90022 (213) 685-7491 J.W. Dunn	** (2) t (1) PNS	A-4	n.1.	gas sampler N/A	
	Avco/Everett Research Lab (see M166)					
M16	Bacharach Instrument Company 625 Alpha Drive Pittsburgh, PA 15238 (412) 782-3500 F.T. Counsell 2300 Leghorn St. Mountain View, CA 94040 (415) 967-7221 P.H. Luft	** (5) t (3) PRC	19-0246 CD-800 CS-700 CSS-P G, H 282 SA-65A US 455L MV-2 550-075	A-6 C-1 C-1 C-2 C-2 C-2 E-4 F-3 F-3 L-3	n.1. n.1. 5A-2 n.1. 5A-3 5C-4 n.1. 6A-2 10A-3	syringe plant CGA port. CGA " " " " leak detector Hg monitor Hg monitor calib. kit
M17	Bailey Meter Company (sub. of Babcock & Wilcox) Wickliffe, OH 44092 (216) 9435599	** (2) PNS	SR/52 SC	M-1 M-1	11E-1 11E-2	recorders b or c
M18	Barber-Colman Company Industrial Instruments Div. 1300 Rock Street Rockford, IL 61101 (815) 877-0241 Roger C. Buck	* (2) t (3) PNS	8000 RD R	M-1 M-1 M-1	11E-3 11E-4 11E-5	recorders b or c

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*		
			Cat.	Table	Features
M19	Barnebey-Cheney 835 North Cassady Ave. Columbus, OH 43216 (614) 258-9501 Jerry Hartman Baseline Industries, Inc. (see M165)	***t(2) PNS TQS	A-5	3F-26	charcoal & columns
M20	Bausch & Lomb Analytical Systems 820 Linden Avenue Rochester, NY 14625 (716) 232-6000 Charles Lermond, E.E. Duke See also Houston Instruments (M75)	** (2) * (2) PNS 200-UV 505 600 VOM 10 VOM 11	G-3 G-3 G-3 M-2 M-3	n.1. 11A-13 11A-13	UV-VIS spec. UV-VIS spec. UV-VIS spec. see Houston see Houston
M21	Beckman Instruments, Incorporated Process Instrument Div. 2500 Harbor Boulevard Fullerton, CA 92634 (714) 871-4848 E.A. Houser, R.L. Chapman, L. Braun, M. Johnston (see also Table 12)	*** (9) t(4) PRC 400 K-23 IR-18A IR-20A IR-215B -315B -415B 6800 GC 2A GC-M GC-55,-65 GC-72-5 30 series 700 2550 100500 93500 610	D-1 F-3 G-3 G-3 F-5 I-1 I-1 I-3 I-4 I-4 I-4 I-8 K-3 M-1 M-3 M-3 M-4	5B-9 6A-3 n.1. n.1. 6B-1 8C-1 8C-2 8A-11 n.1. n.1. n.1. n.1. Sec.IX 11E-6 11D-1 11D-1 n.1.	THCA Hg monitor lab IR lab IR NDIR environ. GC 1,2,4,5,c process GC 1,2,4,5,c bench GC lab GCS " " integrators laser Raman recorder " " printer
M22	Bell & Howell Electronic & Instruments Group 360 Sierra Madre Villa Pasadena, CA 91109 (213) 796-9381	** (2) PRC 19-418 18-301A 18-302A	I-8 M-1 M-1	8D-15 11E-7 11E-8	peak picker recorder "

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*			
			Cat.	Table	Features	
M23	Bendix (see also NEI) Environmental Science Div. 1400 Taylor Avenue Baltimore, MD 21204 (301) 825-5200 Dr. Spyros Vennos	X(1) PNS	K-3	Sec. IX	chemi-lumin- escence	
M24	Bendix Corporation Process Instruments Div. Drawer 477 Ronceverte, WV 24970 (304) 647-4358 Oliver Cano, Sr. Sales Engr.	**t(1) *(3) t(2) PNR	CDS-1500 Total HC UNOR II Envir. Chrom Process GC 2300	C-1 D-1 F-5 I-1 I-1 I-4	n.l. 5B-5 6B-2 8C-3 8C-4 n.l.	CGA FID monitor 1,2,4,5,c NDIR 1,2,4,5,c 1,2,4,5,c a (opt.) lab GC
	Bendix-Unico (see NEI, M104)					
M25	Bowers Instrument Co. 2600 Monroe Street Wilmington, DE 19802 (302) 762-4171 John C. Bowers, Pres.	** (1) PNS	100	I-5	n.l. medical GC	
M26	Bristol Division of ACCO 40 Bristol Street Waterbury, CT 06720 (203) 756-4451	** (2) PNS	CR-1, PH553	M-1	11E-9, 10 recorder	
M27	Brooks Instrument Division Emerson Electric Company 407 West Vine Street Hatfield, PA 19440 (215) 368-2000	*(3) t(2) PNS	Sho-Rate 8900 5800	A-4 A-4 A-4	n.l. 3E-7 3E-9 rotameter controller mass f'meter	
	Brush Instruments (see Gould, M64a)					
M28	Byron Instruments, Incorporated 520½ South Harrington Street Raleigh, NC 27601 (919) 832-7502 Byron C. Behr, Pres.	*** (3) t(1) PNR	400SP	A-1 I-3	3A-1 8B-4 aquar. pump auto. GC 1,2,4,5,6,c	

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*			
			Cat.	Table	Features	
M29	Canberra Industries 45 Gracey Ave. Meriden, CT 06450 (203) 238-2351 Steve Johnson	** (1) Quanta	M-5	12B-9	computer systems	
M30	Carle Instruments, Incorporated 1141 East Ash Avenue Fullerton, CA 92631 (714) 979-9900 Bill Butz	*** (3) t (4) PRC	6546 6500 6500G 8000 9000 1000, 1150 2011, 2020 2800 4100, 4150 4200 4301 4400, 5511 5520, 8030 8031, 8032 6670 6800 6700 7200	A-5 I-2 I-2 I-2 I-2 I-6 I-7 I-7 I-7 I-7 I-7 I-7 L-1 M-1 M-2 M-3	3F-25 8A-1 8A-2 8A-3 8A-4 n.1. n.1. 8D-11, 12, 13 8D-14 n.1. n.1. n.1. n.1. n.1. 11A-7f 11A-7 11D-7f	syringe TCD/GC TCD/GC TCD/GC FID/GC GC detectors GC access GC access " " " " " diln. eq. recorder " "
	Cary Instruments (see M168)					
M31	Century Systems Corporation P.O. Box 133 Arkansas City, KA 67005 (316) 442-4500 Guy C. Amey	*** (2) t (1) PRC	OVA-98A	D-2	5B-1	port. FID total HC
M32	CGS/Datametrics 127 Coolidge Hill Road Watertown, MA 02172 (617) 924-8505 Sydney Locke	** (1) PNS	1000	A-4	3E-9f	mass flowmeter
M33	Chapman Industries, Incorporated Avondale, PA 19311 (215) 268-2252	** (1) PNS	GC	A-5	3F-13	sampling bag

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*			
			Cat.	Table	Features	
M34	Chromatix 1145 Terra Bella Avenue Mountain View, CA 94040 (415) 969-1070 Dr. Wayne Lockhart	** (2) t (2) PNS	1000SP	K-1	Sec. IX	tunable lasers
M35	CLC Corporation 119 The Great Road Bedford, MA 01730 (617) 275-9486	** (1) PNS		M-5	n.1.	environ. recorders
M36	Cole-Parmer Instrument Company 7425 North Oak Park Avenue Chicago, IL 60648 (312) 647-0272 D.J. Lisack	** (2) PRC	7062 7064 BB 7054-2,3,4 7065-2,4 3234 7193 8341	A-1 A-1 A-1 A-1 A-4 I-7 M-2	3A-7 n.1. 3A-9 n.1. n.1. 3G-8 11A-1	pump " " " rotameter drying column recorder
M37	Coleman Instruments Division of Perkin-Elmer 42 Madison Street Maywood, IL 60153 (312) 345-7500 See also Perkin-Elmer, M112	** (2) PNS	EPS-3T 111	G-3 G-3	n.1. n.1.	UV-VIS-NIR lab spec. " "
M38	Commercial Electronics Incorporated 880 Maude Ave. Mountain View, CA 94040 (415) 969-1910	** (2) t (1) PNS	15-02	F-6	6B-10	auto exh. analyzer
M39	Consolidated Controls (sub. of Condec Corp.) Bethel, CT 06801 (203) 743-6721 or El Segundo, CA 90245 (213) 722-5301	** (2) PNS	50GP 50GD 16	M-4 M-4	12A-3 12A-4	data logger printer

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*			
			Cat.	Table	Features	
M40	Control Instruments Corporation 5 Oxford Road North Caldwell, NJ 07006 (201) 226-9366 Jim Schaeffer	** (2) t (1) CGS	C-1	5A-15,	CGA	
		PRC	E-1	16 5C-1	CGA	
M41	Dasibi Corporation 3223 North Verdugo Road Glendale, CA 91208 (213) 248-1354 Lloyd Bowman, Dick Horak	** (3) t (1) 1003	F-2 K-3	Sec. IX	modified O ₂ monitor (UV photo- meter)	
		PNS				
	Davis Instruments (see Acme, M1) (and Scott-Davis, M133)					
M42	DEVCO Engineering Incorporated 36 Pier Lane West Fairfield, NJ 07006 (201) 228-0321 Frank Conti	** (2) t (2) G.D.T.	B-1	4A-5	gas detector tube	
		PRC	5000 ser.	C-1	5A-17, 20	CGA
M43	Digilab, Incorporated (sub. of Block Eng., Inc.) 237 Putnam Avenue Cambridge, MA 02139 (617) 868-4330 Louis Hyatt	** (2) PNS	K-3	Sec. IX	fourier trans.spec.	
M44	Disc Instrument, Incorporated 2701 South Halladay Street Santa Ana, CA 92705 (714) 549-0343 John McDowell	** (2) PNS	Ser.200	I-8	8D-16	integrator
			Ser.300	I-8		integrator
			610	M-4	8D-16a	printer
M45	Dohrmann Division Envirotech Corporation 1062 Linda Vista Avenue Mountain View, CA 94040 (415) 968-9710 Mark V. Christensen	** (2) t (1) 15C-3	I-3	8A-13	bench GC	
		2460	I-3	8A-14	" "	
		PRC	877080	L-1	10E-2	soap film flowmeter
			R-100	M-1	11B-1	recorder
			SC1200	M-3	11D-2	"
			S-X	M-3	n.l.	"
	S-Y	M-3	n.l.	"		

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

TABLE B-1 -- MANUFACTURERS & PRODUCTS

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*		
			Cat.	Table	Features
M46	Doric Scientific Corporation 7601 Convoy Court San Diego, CA 92111 (714) 277-8421 Drägerwerk, AG (Lübeck, Germany) See National Mine Service Co.	** (1) PNS Digitrend 210	M-4	12A-6	scan alarm
M47	Du Pont Instrument Products Division 1007 Market Street Wilmington, DE 19898 (302) 774-2421 C.G. Dell	** (2) PRC 400	F-1	6A-6	UV photo- meter
M48	Dwyer Instrument, Incorporated P.O. Box 373 Junction Indiana 212 & US 12 Michigan City, IN 46360 (219) 872-9141 R.A. English	** (2) PNS RM VFB	A-4 A-4	n.1. 3E-4	rotameter "
M49	Ecologic Instrument Corporation 597 Old Willets Path Haupauge, NY 11787 (516) 582-4110 Dick Gabriel	** (1) t (1) PRI Total HC 6000	D-2 F-6	5B-2 n.1.	FID monitor 1,4,5,c NDIR
M50	Electro/Mass Laboratories 1563 Gwen Drive Baton Rouge, LA 70815 W.D. Reynolds, Pres.	** (2) PRC M510 B210 D200 Hand-held	L-2	10B-7 to -10	permeation tube systems
M51	Enraf-Nonius 130 County Courthouse Road Garden City Park, NY 11040 (516) 741-0430	** (1) BD5,6	M-3	11B-6	20 UV f.s. recorder
M52	EnviroMetrics, Incorporated 13311 Beach Avenue Marina Del Rey, CA 90291 (213) 821-4918	** (1) t (1) PNS "Faristor"	K-3	Sec.IX	fuel cell

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*		
			Cat.	Table	Features
M53	Erdco Engineering Corporation 136 Official Road Addison, IL 60101 (312) 543-6733 E.M. Nesvig, V.P.	** (2) t (1) PNR 05HCS 08CGA 04CGA-SP 010CGA-SP	C-2 C-1 C-1 C-1	5A-5 5A-8 5A-13 5A-14	port. CGA semi-port. CGA CGA CGA
M54	Esterline Angus Div. of Esterline Corporation P.O. Box 24000 Indianapolis, IN 46224 (317) 244-7611	*** (3) t (3) PRC 70D7 L11015 E T171B D-500 D-2020	I-8 M-1 M-1 M-2 M-4 M-4	8D-17 11B-2 n.1. 11A-2 12A-7 12A-8	integrator recorder " port. rec. (bat. or ac) printer data aq.
M55	Fischer & Porter Company 775 Warminster Road Warminster, PA 18974 (215) 675-6000	X (2) PNS 51-1320 series	A-4 M-1	3E-6 n.1.	rotameter recorder
M56	Fisher Scientific Company 711 Forbes Pittsburgh, PA 15219 (412) 391-1330 Harry A. Mink	* (3) PNS 11-102, etc.	I-4	n.1.	lab GCs
M57	Flow Corporation 127 Coolidge Hill Road Watertown, MA 02172 (617) 924-8505	** (1) PNS 800	A-4	3E-9f	mass flow- meter
M58	Flow Technology, Incorporated 401 South Hayden Road Tempe, AZ (602) 967-8601 Edward R. Palomaa	** (2) PNS FTM ser.	A-4	3E-8	turbine flowmeter
M59	Fluid Metering, Inc. - FMI 48 Summit Street P.O. Box 507 Oyster Bay, NY 11771 (516) 922-3480	** (1) PRC RRP-1A RRP-1B	A-1 A-1	3A-5 3B-2	pump "

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*		
			Cat.	Table	Features
M60	Fluidyne Instrumentation 470 27th Street Oakland, CA 94612 (415) 444-2376	** (2) PNS 192	M-2	11C-2	Keysort recorder calculation interfaces
		700/720	M-5	12B-11	
M61	Fluordynamics, Incorporated Diamond State Industrial Park Neward, DE 19711 (302) 368-2511 D.J. Connally Sales: Antek Instruments, Inc.	** (2) PRC Chemton	A-5 &-6	3F-14	sampling bags
M62	Foxboro Company Newport Avenue Foxboro, MA 03025 (617) 543-8750 D.L. Washburn Gastec Company (Japan) (see Acme, M1)	** (2) NRE-6 ERB ser.	M-1	11E-11	recorder
			M-1	11E-12	recorder
M63	GasTech Incorporated Johnson Instrument Division 2560 Wyandotte Street MountairView, CA 94040 (415) 967-6794 Ken Johnson, Carl Mazzuea	*** (1) t (4) PRC 1024	C-2	5A-1	port. GCA
M64	General Monitors Incorporated 3019-T Enterprise Costa Mesa, CA 92626 (714) 540-4895 Thomas H. McKerlie	** (2) PNR 175 188	C-1		plant GCA
			C-1		" "
M65	Gow Mac Instrument Company 100 Kings Road Madison, NJ 07940 (201) 377-3450 Robert Mathieu, A.E. Lawson, Jr.	*** (3) t (4) PRC 59-100 23-500 21-100 11-373 69-050 69-100 69-140 69-750 69-550	A-1	3A-3	pump
			D-1	5B-3	FID monitor c
			E-4	n.1.	leak detector
			E-3	5C-3	gas density detector
			I-2	8A-6	bench GC
			I-2	8A-7f	" "
			I-2	8A-7	" "
I-2	8A-8	" "			
I-3	8A-12	FID/GC			

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*		
			Cat.	Table	Features
M65	Gow Mac Instrument Company (cont.)	Hex-Nano 10952 10939 12100 (FID) 70-210	I-6 I-6 I-6 M-3	8D-1 8D-2 n.1. 11D-3	micro-TCD FID recorder
M66	GTE Sylvania Electro-Optics Organization Mountain View, CA 94040 (415) 966-2312 Burton Bernard	** (1) PNS 950	K-1	Sec. IX	IR tunable laser
M67	Guild Corporation P.O. Box 217 Bethel Park, PA 15102 (412) 921-1670 Lloyd V. Guild	** (1) PNS trap	I-7	3G-9	charcoal trap
	Gulton Industries, Inc. (see Rustrak and West Instr. Companies, M128, and M157)				
M68	Haber Instruments, Incorporated c/o Cyclo Sciences, Inc. 434 Bergen Boulevard Palisades Park, NJ 07650 (201) 947-7477 Dr. Norman Haber, Pres.	** (1) PNS	K-3	Sec. IX	"electro-mol. propulsion
M69	Harvey-Westbury Corporation (sub. of NY Testing Labs) 81 Urban Avenue Westbury, NY 11590 (516) 334-7770 Sales: Roydon Enterprises Hastings-Raydist (see M171)	X(3) t(1) PNR 500-2	I-3	8B-4	semi-p. GC 1,4,c

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*		
			Cat.	Table	Features
M70	Hays Corporation 742 East Eighth Street Michigan City, IN 46360 (219) 872-5561 Lyle K. Barnes	** (1) PNS 646	C-1	n.1.	CGA
M71	Heath Company Benton Harbor, MI 49022 (616) 983-3961	** (2) PNS EU-205-5 EU-20BN 701	M-3 M-3 G-3	11B-3 11D-4 n.1.	lab recorder flat bed recorder UV-VIS spec.
M72	Hewlett-Packard Company Avondale Division Route 41 Avondale, PA 19311 (215) 268-2281 or 1501 Page Mill Road Palo Alto, CA 94304 (415) 493-1501 Ben Butler	** (3) t (1) PRC 700 ser. 5711,12 5750 B 7670/71 3370 B 3373 B spec.opt. 7123 opt.035 7143 A 7127 A 3360 A	I-4 I-4 I-4 I-7 I-8 I-8 M-4 M-1 I-8 M-1 M-2 M-4	n.1. 8A-15, n.1. n.1. n.1. n.1. 8D-21 8D-21a 11B-4 8D-18 n.1. 11A-12 n.1.	lab GCs bench GCs lab GCs auto samp. integrator integrator printer recorder integrator recorder printer
	Hitachi, Ltd. (see Japanese Products, M82)				
M73	Honeywell, Incorporated Apparatus Controls Division 2701 Fourth Avenue South Minneapolis, MN 55408 (612) 332-5200 Thomas Cebulla, Wm. Croseley	*** (5) t (1) PRC UVH-15SP	F-1	6A-5	UV monitor 1,2,4,5,b a (opt.)
M74	Honeywell, Incorporated Industrial Division 1100 Virginia Drive Fort Washington, PA 19034 (215) 642-1300	** (2) t (1) PNS 15,16 111,112 193 194	M-1 M-1 M-2 M-3	n.1. 11E-15, 16 11A-16 11B-5	recorder " port. rec. bench rec.

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*			
			Cat.	Table	Features	
M75	Houston Instrument Div. of Bausch & Lomb, Inc. 4950 Terminal Avenue Bellaire, TX 77401 (713) 667-7403 John McWade	** (2) t (1) PNS	13 10 11 3000 3200-50/7	I-8 M-2 M-2 M-3 M-3	11A-13 11A-13f 11D-5 11D-5	integrator recorder leg rec. flat bed rec
M76	Hydronautics, Incorporated Pindell School Road Laurel, MD 20810 (301) 776-7454 Norman Shapira, Amos Linenberg (Israel)	** (3) PNS	103ASP	I-5	n.1.	spec. purp. GC
M77	Infotronics Corporation 8500 Cameron Road Austin, TX 78753 (512) 454-3521 See also Dohrman Div.	** (1) t (2) PNS	CRS-204 CRS-208	I-8 I-8	n.1. 8D-21	integrator "
M78	Infrared Industries, Incorporated Electro-Optics Division P.O. Box 989 Santa Barbara, CA 93102 (805) 684-4181	** (1) PNS	1000 NDIR	F-6	6B-3	NDIR
M79	Instrument Corporation of America 1949 Greenspring Drive Timonium, MD 21093 (301) 252-9220 Tom Cochran	** (2) t (1) PRC	400 500	M-2 M-2	11A-4 11A-4f	battery rec. line rec.
M80	Instrument Specialties Company 4700 Superior Lincoln, NB 68504 (402) 434-0231 John R. Allington	** (2) PNS	UA-4 224 950 610	F-4 F-4 I-8 M-2	n.1. n.1. 8D-19 11A-8	laser UV spec " " " integrator recorder

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*			
			Cat.	Table	Features	
M81	Intertech Corporation 19 Roszel Road Princeton, NJ 08540 (609) 452-8600 Albert R. Piratzky	** (1) PRC	URAS-2	F-5	6B-4	NDIR
M82	Japanese Products (Hitachi) 51 Cliff Ave. New Rochelle, NY 10801 (914) 636-8830	** (1) PNS	QD 15	M-3	11D-5	recorder
M83	Japan Spectroscopic Company, Ltd. Kitahachioji-Kojodanchi Hachioji, Japan 0426 (42) 9225 H. Iwamizu	** (2) PNS	PAX-10	F-5	6B-5	NDIR
M84	JEOL (Analytical Instruments) 235 Birchwood Avenue Cranford, NJ 07016 Johnson Instruments (see GasTech, M63) Johnson-Williams Products (see Bacharach Instrument Co., M16)	X (2) PNS		K-3	Sec. IX	laser Raman
M85	Keltron Corporation 225 Crescent Street Waltham, MA 02154 (617) 894-0525 Kipp & Zonen (see Enraf-Nonius, M51)	** (1) PNS	DM-400 DM-500	M-4 M-4	12A-9 12A-10	digital printer
M87	Laboratory Data Control P.O. Box 10235 Riviera Beach, FL 33404 (305) 844-5241 John West	** (4) t (4) PNR	Ser. 1200 PZ spec. PZ det. 2801 301 310/31013 320 330	F-3 I-2 I-6 M-2 M-2 M-2 M-3 M-3	6A-8 Sec. IX Sec. IX 11B-7 n.1. 11A-3 11D-7 11D-7	merc. mon. GC (in dev.) (in dev.) recorder recorder port. rec. flat bed recorder "

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*			
			Cat.	Table	Features	
M88	Leeds & Northrup Company Sunneytown Pike North Wales, PA 19454 (215) 643-2000 J.U. Eynoms	** (2)	W	M-1	11E-18	recorder
		t (1)	M	M-1	11E-19	"
		PRC	H/S	M-1	11E-17	"
			11502	M-2	11C-1	card chart recorder
			XL600	M-2	11A-15	recorder
			XL610	M-2	11A-14	"
			XL680	M-3	11D-8	flat bed rec
	XL683	M-3	n.1.	" " "		
M89	Lemaire Instruments, Inc. 3800 North Virginia Street Reno, NV 98503 (702) 322-8080 Neil Mallory	** (3)	Spec.	F-3	n.1.	merc. mon.
		t (1)	2000	I-7	3G-12	merc. trap
M90	Linear Instruments Corporation 2930 East Grace Lane Costa Mesa, CA 92626 (714) 546-6776 Frank A. Thomas	** (1) t (1)	112/222	M-3	11D-9	recorder
M91	Lion Precision Corporation 60 Bridge Street Newton, MA 02195 (617) 969-4710 Peter S. Vail	** (2) PNS	GA600B	E-5	5C-5	alpha ion. gas detector
M92	LKB Instruments, Incorporated 12221 Parklawn Drive Rockville, MD 20852 (301) 949-6510	** (2) PNS	6530	M-3	11D-10	recorder
M93	The London Company 811 Sharon Drive Cleveland, OH 44145 (216) 871-8900	** (2) PNS	REC51	M-3	11D-11	recorder

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

TABLE B-1 -- MANUFACTURERS & PRODUCTS

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*		
			Cat.	Table	Features
M94	Mast Development Company 2212 East 12th Street Davenport, IA 52803 (319) 326-0141 Mr. Shanklin	** (3) 725-3	M-1	n.l.	recorder
		t (2) 725-3CS	M-2	11A-9	"
		PNS 304	M-5	n.l.	recorder calibrator
M95	Matheson Gas Products 932 Paterson Plank Road East Rutherford, NJ 07073 (201) 933-2400 R.L. Sharp, Larry Fleur	*** (2) 8014	B-3	4A-30	gas detector tube
		t (6) 810-11	K-3	Sec. IX	colorimeter co detector
		PNR 8013	E-4	5C-4	TC det.
		8430	I-2	8A-5	port. GC
			L-3	10A-1	calib. gas, carriers, etc.
M96	McKee-Pedersen Instruments P.O. Box 332 Danville, CA 94526 (415) 937-3630 J.E. Meinhard Associates (see M167)	** (2) MP-1027	M-3	11D-12	recorder
		PNS MP-1886	G-3	n.l.	lab spec.
M97	Meloy Laboratory, Incorporated 6631 Iron Place Springfield, VA 22151 (703) 354-4450 Donald G. Baer	** (2) SH202 PNR	D-1	n.l.	S&HC mon. (FPD&FIL)
M98	Metal Bellows Corporation 20977 Knapp Street Chatsworth, CA 91311 (213) 341-4900 Larry Barrett or 1075 Providence Highway Sharon, MA 02067 (617) 668-3050 Paul D. Sullivan	*** (3) MB-21	A-1	3A-6	pump
		t (2) MB-41	A-1	3A-6f	"
		PRC MB-110	A-1	3A-6f	"

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*				
			Cat.	Table	Features		
M99	Metronics Associates, Inc. 3201 Porter Drive Palo Alto, CA 94304 (415) 326-5632 David L. Williams	300 Dyncal	** (2)	L-2	10B-11	perm. tube	
			t (1)	L-2	10B-12	" "	
			PRC		10B-13	calibration	
M100	MFE (Mechanics for Electronics) 340 Fordham Road Wilmington, MA 01887 (617) 658-5500	M-12/120 DPC 11E	** (1)	M-1 M-5	11E-19 n.1.	recorder ticket printer	
M101	Micrographics 3855 Birch Street Newport Beach, CA 92660 (714) 540-8494 Dr. Norman M. Hodgkin	n.s.	*(1) **t (1) PNS	K-3	n.1.	electron microscope	
	Milton Roy Co. (see M169)						
M102	Mine Safety Appliances Company 201 North Braddock Pittsburgh, PA 15028 (412) 241-5900 J.E. Zatek, W.V. Dailey, J.D. Sherwin	92780	** (5)	A-2	3C-2	pumps and	
		92790	t (5)	A-2	3C-3	charger	
		92813	PRI	A-2	3C-4	pumps	
		92814		A-2			
		93460		A-2			carry case
		94312		A-2			
		83499		B-3	4A-1	hand pump	
		83500		B-3	4A-1a	pump kit	
		83498		B-3	4A-1b	" "	
		08-93118		B-1	4A-2	arom. kit	
		-93074		B-1	4B-1	det. tube	
		40		C-2	5A-4	port. CGA	
		Total HC		D-1	5B-9	FID mon. 1,2,4,5,c	
		Billion- aire		E-5	5C-5	alpha ion'n	
LIRA 200, 202		F-5	6B-6	NDIR			
650		I-1	8C-9	process GC (no data)			
525		I-7	8D-8	GC program			

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*			
			Cat.	Table	Features	
M103	Monitor Labs, Incorporated 10451 Roselle Street San Diego, CA 92121 (714) 453-6260	** (2) PRC	L-2	10B-14	perm. tube calibrator	
M104	National Environmental Instruments, Inc. 1865 Post Road P.O.Box 590, Pilgrim Station Warwick, RI 02888 (401) 738-3710 Robert J. Kohn, Pres. Robert Allebaugh, Sales Mgr. George C. Butts, Tech. Sr. Mgr.	*** (6) t (4) PNR	19102 25121 25004 2110-5 15003 C115 Micronair 3500-10 24008 24063 8200 ser. 7209 1450-10 118A,B 400 2450 GA-1 2600	A-1 A-1 A-1 A-1 A-1 A-2 A-2 A-3 A-3 A-3 A-4 A-5 A-5 B-1 B-3 C-2 C-2 L-1	3A-8 3A-10 3A-11 3B-3 3B-4 3C-1 3C-2,3 3D-2 3D-3 n.l. 3E-1 3F-9 3F-10 4B-2,3 4A-3, 3a n.l. n.l. 10D-1	pump " " " pump w/meter pers. pump " " seq. valve " " valve rotameter impinger " gas tube pump kit CGA CGA gas dilution system
M105	National Instrument Laboratories, Inc. 12300 Parklawn Drive Rockville, MD 20852 (301) 881-2800	** (1) t (2) PNS	69-3L	A-4	n.l. gas flow controller (upstream)	
M106	National Mine Service Company 3000 Koppers Building Pittsburgh, PA 15219 James E. Ellison	** (1) t (4) PRC	31 31/21 CH24801 6718801	B-3 B-3 B-2 B-2	4A-4 4A-4a 4B-4 4B-5 pump kit " " gas detector tube " "	
M107	Nuclear-Chicago (sub. of G.D. Searle & Co.) 2000 Nuclear Drive Des Plaines, IL 60018 (312) 298-6600	** (2) t (1) PNS	53-20,-40	I-4 I-5	n.l. n.l. lab GC S.P. GC	

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*			
			Cat.	Table	Features	
M108	Nuclear Corp. of America 2 Richwood Place Denville, NJ 07834 (201) 627-4200 Dr. Manfred J. Prager	** (4) PRC	Spec.	F-7	6C-1	benzene detector semi-auto GC
			Spec.	I-1	8B-8	
M109	Oscar Enterprises 1216 Fifth Street Berkeley, CA 94710	NDI	2000	A-1	3A-1	aquarium pump
M110	Packard Instrument Company, Inc. 2200 Warrenville Road Donners Grove, IL 60515 (312) 969-6000	** (2) PNS	406,407	I-4	n.1.	lab GC
			409,420	I-4	n.1.	" "
M111	Peerless Instrumentation 512 Main Street Westbury, NY 11590 (516) 997-5959 Paul Maas	** (5) t(1) PNR	209,409	F-1	6A-7	2-wavelength UV mon. 1,2,4,5,c
			209 IR	F-5	6B-7	IR mon.
M112	Perkin-Elmer Corporation (& Coleman) 702 Main Avenue Norwalk, CT 06852 (203) 762-1000 Tom Porro, Walter Slavin L.A. Hurlbut	** (4) t(1) PNS	111	G-3	n.1.	lab UV-VIS spec.
			Spec.	J-2	n.1.	mass spec.
			203 MPF-2A,3	K-3	Sec.IX	spectroflu.
M113	Pharmacia Fine Chemicals, Inc. 800 Centennial Avenue Piscataway, NJ 08854 (201) 469-1222 Philips Electronics Instruments (see Pye Unicam, Ltd., M123)	** (1) PNS	UV mon.	F-4	Sec.IX	2-wavelength UV
M114	Photovolt Corporation 1115 Broadway New York, NY 10010 (212) 989-2900	** (2) PNS	43	M-3	11D-14	flat bed recorder
			44	I-8	n.1.	integrator

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*		
			Cat.	Table	Features
M115	Photron Instrument Company 6516 Detroit Avenue Cleveland, OH 44102 (216) 281-7020		M-1 M-3	n.1.	recorder
M116	Precision Scientific Company (sub. of GCA Corp.) 3737 West Cortland Street Chicago, IL 60647 (312) 227-2660 Chester A. Warner	68799	I-3	n.1.	bench GC
M117	Precision Standards Corporation Graphic Instrument Division 1701 Reynolds Avenue Santa Ana, CA 92705 (714) 546-0431	GP701 GP702	M-1 M-2 M-3	n.1. 11A-10 11D-15	recorder " "
M118	Princeton Applied Research Corp. Box 565 Princeton, NJ 08540 (609) 942-6835 Jud B. Flato	174	H-1	Sec.IX	automatic polarograph
M119	Problematics 223 Crescent St. Waltham, MA 02154	CDA-100A	I-8	8D-23	digital integrator
M120	Process Analyzers, Inc. 6400 South West Freeway Suite 400 Houston, TX 77036 (713) 782-0820 Ulpidio "Bill" Bonett	30-100 29-100 26-223 26-212A TDB	D-2 E-3 I-1 I-1 I-6	5B-6 5C-3 8C-10, 10a 8C-11 8D-5	FID mon. GD det. process GC " " TC detector
M121	Prolabo 12 Rue Pelee 75 Paris XI, France 355-90-00	05 910.12	G-3	n.1.	lab spec.

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*		
			Cat.	Table	Features
M122	Purad, Incorporated 724 Kilbourne Drive Upland, CA 91786 (714) 985-2012 W.B. Inne Pure Gas Equipment Co. (see M163)	** (2) PRC 10	E-2 K-1	5C-2 Sec. IX	selective comb. det.
M123	Pye Unicam, Ltd. York Street Cambridge, England (0223) 58866	** (1) PNS 104 1000 1800	I-4 G-3 G-3	n.1. n.1. n.1.	lab GC UV-VIS-IR lab spec.
M124	Radeco, Incorporated P.O. Box 23162 Pleasant Hill, CA 94523 (415) 939-6602 Radiometer-Copenhagen (see London Co., M93)	** (1) PNR M31 HC28B CF750A	A-1 A-1 A-1	3A-12 n.1. n.1.	pump " "
M125	Research Appliance Company Allison Park, PA 15101 (412) 486-0500 Elmer Fleck Riken Denshi Co., Ltd. (see Temtron, M143)	** (1) PNR 2312-A, B PV 2333-A AD, PV, F 2277-1	A-2 A-3 A-3 A-4 A-5	3B-5 3D-1 n.1. 3E-3 3F-11	pump seq. valve " " rotameter impinger
M126	Robertshaw Controls Company 1701 Byrd Richmond, VA 23226 (703) 282-9561	** (2) PNS 221/222 223/224	M-1 M-1	n.1. 11E-2c	recorder "
M127	Roydon Enterprises 366 North Broadway Jericho, NY 11753 (516) 433-9522 Sales: Harvey-Westbury	* (2) t (1) PNS See Harvey- Westbury			air carrier GC

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*		
			Cat.	Table	Features
M128	Rustrak Instrument Division of Gulton Ind., Inc. PNS Municipal Airport Manchester, NH 03103 (603) 623-3591	288	M-3	11A-17	low-cost recorder high-Z rec.
		400	M-3	11A-18	
M129	Sargent-Welch Scientific Company *(2) 7300 North Linden Avenue PNS Skokie, IL 60076 (312) 677-0600 S.P. Dodd		M-3	n.1.	recorder
M130	Science Pump Corporation ***(2) 1431 Ferry Avenue PNS Camden, NJ 08104 (609) 963-7700	A-150	A-1	3A-4f	pump
		A-1000	A-1	3A-4	"
		D-200	A-1	3B-1	"
M131	Scientific Gas Products, Inc. ***(2) 513 Raritan Center PNS Edison, NJ 08817 (201) 225-1-00 E. Vanzo		L-3	10A-1	gases rotameter (set)
			A-4	3E-5	
M132	Scintillonics, Inc. P.O. Box 701 Fort Collins, CO 80521 (303) 482-4752	HV 15A	K-2	Sec. IX	microwave generators
M133	Scott-Davis Instruments ***(4) Scott Aviation Div., A-T-O, Inc. t(2) Box 751 PRC Charlottesville, VA 22902 (703) 973-5366 J.P. Barker	3700	C-1	n.1.	CGA
		3800	C-1	n.1.	CGA
		8600	C-1	n.1.	CGA
		D-16	C-2	5A-7	port. CGA
		23-500	D-2	5B-4	semi-port. FID mon.
		11-6500	D-1	5B-10	FID mon.
6800	E-1	5C-1	FTO mon.		
M134	Scott Research Laboratories, Inc. ***(3) Route 611 t(2) Plumsteadville, PA 18949 PRC (215) 766-8861 J.R. Story	116	D-1	5B-7	semi-port. FID
		125SP	K-3 L-3	Sec. IX 10A-1& 2	Chemilumin. cal.-gas
	Sieger Gasalarm (see Smith-Jesse, M137)				

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*		
			Cat.	Table	Features
M135	Sigma Instruments (Canada), Ltd. 55 Six Point Road Toronto, Ontario, Canada (416) 239-8161)	NSK	M-1	n.1.	recorder
		NSQ	M-1		"
		NST	M-1		"
M136	SKC (sub. of Guild..Products for Science) P.O. Box 8538 Pittsburgh, PA 15220 (412) 921-4344 Lloyd V. Guild, Pres. See also Guild Corp.	224	A-1	3A-2	pump
		** (3) 222	A-2	3C-6,7	pers. pump
		PNR 801	B-3	4A-4	hand pump
		802	B-3	4A-4b	pump kit
		200	I-3	8A-14	bench GC
		236,237	I-7	3G-9	traps
				to-14	
		215,16,19	I-7	3F-1,2	concentrators
				&3	
		341	I-7	80-6	amplifier
		253	I-7	n.1.	coln. cond.
		209,210	L-1	10C-1	diln. flask
				to-4	
	300to313	L-1	10E-3	soap film	
			to-6	flowmeter	
	302	L-1	10E-7	field flow- meter	
M137	Smith-Jesse, Inc. (Sieger,Ltd.) 500 South Hauser Boulevard Los Angeles, CA 90036 (213) 931-9451 N.D. Jesse	1800	C-1	n.1.	CGA mon.
		t(3) 1810	C-1	5A-9	" "
		PRC 1303	C-1	n.1.	" "
		1313	C-1	5A-10	" "
		1310	C-1	5A-11	" "
		1330	C-1	5A-12	" "
		608-P	C-2	5A-6	port. CGA
		1900	C-2	n.1.	" "
		Spectra (see Chromatix, M34)			
M138	Spectrometrics of Florida, Inc. (ABA Industries) P.O. Box 517 Pinellas Park, FL 33565 (813) 546-3571 Dr. Robert Hager, Forrest C. Douglas	IV	G-1	7A-1	std. diff.
		t(3) PNR			7A-2

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*			
			Cat.	Table	Features	
M139	SSR Instruments Company 1001 Colorado Avenue Santa Monica, CA 90404	** (1) PNS	K-3	Sec. IX	optical multi-ch. analyzer	
M140	Sunshine Scientific Instruments, Inc. 1810 Grant Avenue Philadelphia, PA 19115 (215) 673-5600 Barry Sunshine	** (2) t (2) PRC	38D	F-3 6A-4	merc. mon.	
M141	Supelco, Incorporated Supelco Park Bellefonte, PA 16823 (814) 359-2732 W.R. Supina Sylvania (see GTE, M66)	** (2) PNS	SP-1000	I-7 n.1. I-7 Sec. IX	drying tube packed colns, fit- tings, etc. carbosieveB	
M142	Taylor Instrument Co. Process Control Div. Sybron Corp. 95 Ames Street Rochester, NY 14601 (716) 235-5000 Technology, Inc. (see M164)	* (2) PNS	1300 J 1310 J	M-1 M-1	11E-23 11E-24	recorder "
M143	Temtron Electronics Limited (Riken Den.) P.O. Box 2273, Terminal A London 12, Ontario, Canada (519) 455-9340 N.L.W. Lawrence	** (1)	TO series B-16	M-3 M-2	n.1. n.1.	flat bed recorder
M144	Tetrahedron Associates 7605 Convoy Court San Diego, CA 92111 (714) 277-2820	** (1) PNS		M-5	n.1.	"data mgr."
M145	Texas Instruments, Inc. Digital Systems Division P.O. Box 66027 Houston, TX 77006 (713) 494-5115 Dan Carter, Chuck Newman	** (2) PNS	FS01N FLO4W	M-1 M-1	11E-25 11E-26	recorder "

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*			
			Cat.	Table	Features	
M146	Thermal Instrument Company 41 Terry Drive Trevose, PA 19047 (215) 355-8400 Fred J. Curran	** (1) PNS	59,62	A-4	3E-9f	thermal flowmeter
M147	Thermo Instrument Corporation P.O. Box 309 LaPorte, IN 46350 (219) 362-6258 Robert D. Richardson	*(2) t(2) PNR		I-1	8C-12 8C-13	semi-port. GC GC mon. 1,2,4,5,c a,b (opt.)
M148	Thermo-Lab Instruments, Inc. 1308 William Flinn Highway, Rt.8 Glenshaw, PA 15116 (412) 487-1400 D.A. Sayles	** (3) PNS		K-3	Sec. IX	fuel cell (CO ₂ mon.) N/A
M149	Tracor, Incorporated 6500 Tracor Lane Austin, TX 78721 (512) 926-2800 Kenneth O. Mahler See also Westronics	*(5) PNR	350F MT-160 550	I-1 I-3 I-4 L-2	8B-6 n.l. n.l. 10B-15	semi-auto. GC 1 (opt.) 2,4,5,c bench GC lag GC calibrator concentrator
M150	Triangle Environmental Corporation 518 West Cabarrus Street Raleigh, NC 27605 (919) 833-4614 UNICO (see NEI, M104)	** (1) t(1) PRC	910 PC 911-PHG	I-6 I-7 I-7	8D-4 8D-7 8D-8	H ₂ generator GC detector
M151	Uthe Technology International (UTI) 670 Almanor Avenue Sunnyvale, CA 94086 (408) 738-3301 H.U.D. Weisandanger	** (2) PRC	UTI-Q30 100B	J-1 J-2	7D-1 n.l.	mass spec. (component)

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*		
			Cat.	Table	Features
M152	Varian Aerograph 2700 Mitchell Drive Walnut Creek, CA 94598 (415) 939-2400 Fred Baumann, Richard H. Thompson Versatronics (see M164)	** (4) PNS 1420,1440	I-4	n.1.	lab GCs
M153	Vidar (Autolab) 77 Ortega Avenue Mountain View, CA 94040 (415) 961-1000 Ed Zube	** (2) PNS 6300 System IV	I-8 I-8	8D-20 n.1.	integrators "
M154	Wallace & Tiernan Div. Pennwalt Corp. 25 Main St. Belleville, NJ 07109 (201) 759-8000	X (1) Xt (2) n.s.	A-4	n.1.	flowmeters
M155	Weather Measure Corporation P.O. Box 41257 Sacramento, CA 95841 (916) 481-7565	** (2) t (1) PNS EPR-10A-M EPR-2TB EPR-2TC EPR-2T ET ser.	M-2 M-2 M-2 M-2 M-1	n.1. n.1. 11A-6 11A-5 11E-27	port. rec. " " " " (battery) "" recorder
M156	Waters Associates 61 Fountain Street Framington, MA 01701 (415) 392-8560	** (1) PNS	I-7	n.1.	GC packing
M157	West Instrument Division of Gulton Industries 3860 North River Road Schiller Park, IL 60176 (312) 678-6400 Dan Niccikowski	** (2) t (1) PNS FS	M-1	11E-28	panel mtg. recorder

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*			
			Cat.	Table	Features	
M158	Westronics, Incorporated (sub. of Tracor, Inc.) 3605 McCart Street Fort Worth, TX 76110 (817) 926-2621 Raymond E. Knitter, Jr.	*** (3) t(5) PRC	S5E	M-2	11A-7f	panel mtg.
			S11E	M-3	11B-8	recorders
			LS11B	M-3	n.1.	lab rec.
			LS11D	M-3	11B-9	" "
			7100	M-4	12A-13	digital data system
			RAD1-3	M-4	n.1.	digital indicator
			UV-2	M-5	n.1.	input mod.
			PF-3	M-5	n.1.	" "
			MSU-L60	M-5	n.1.	switching unit
			MVS A&B	M-5	n.1.	mv. source
M159	Wilks Scientific Corporation 140 Water Street South Norwalk, CT 06854 (203) 838-4537 Dr. Donald S. Lavory, Paul Wilks, Jr., Pres.	*** (4) t(2) PRC	MIRAN	G-1	7B-1	port. IR spec.
M160	Willson Products Second and Washington Reading, PA 19603 (215) 376-6161 M.F. Shields Y-Lab (see Laboratory Data Control, M87)	** (2) t(1) PRC	CassellaC	A-2 A-5	3C-5 3C-5f	pers. pump tubeholders
M161	Yellow Springs Instrument Co., Inc. P.O. Box 279 Yellow Springs, OH 45387 (513) 767-7242	** (2) PNS	80A 81A 8470	M-2 M-2 M-2	11A-11 11A-11f n.1.	port. rec. " " " "
M162	Yewtec Corporation (Yokagawa) 1995 Palmer Avenue Larchmont, NY 10538 (914) 834-3550 ZAP Electronic Associates, Inc. Sales for Process Analyzers, Inc. (M120) (continued)	** (3) PNS x(2)	3046-610	M-3	11B-10	recorder

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

LATE ADDITIONS TO TABLE -- OUT OF SEQUENCE

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*			
			Cat.	Table	Features	
M163	Pure Gas Equipment Co. 1445 Strongs Road Copiague, NY 11727	NDI	HF200	I-7	8D-9	heatless fractionator
M164	Technology Incorporated Versatronics Instr. Div. 1825 Webster St. Dayton, OH 45404 (513) 223-8600	** (2)	ML series MFG ser.	A-4 A-4	3E-10 3E-10	mass flow-meter " "
M165	Baseline Industries, Inc. 3024 Valmont Road Boulder, CO 80302 (303) 447-9703 Mr. Spongberg	**t(2)	1000	I-1	8C-14	small process GC
M166	Avco/Everett Research Lab. 2385 Revere Beach Parkway Everett, MA 02148 (617) 389-3000	X(1)	C5000	K-1	n.1.	UV laser
M167	J.E. Meinhard Associates P.O. Box 9 Tustin, CA 92680 (714) 544-3811	*t(2)	Spec.	1NA	n.1.	Macor
M168	Cary Instruments (a Varian subsidiary) 2724 S. Peck Road Monrovia, CA 91016	NDI	83	K-3	Sec.IX	laser Raman
M169	Milton Roy Co. 5000 Park St., N. St. Petersburg, FL 33733 (813) 544-2581	X(1)	ERD-150	I-7	8D-8a	hydrogen generator
M170	Isomet Corp. 103 Bayer Drive Oakland, NJ 07436 (201) 337-3811 John Fitzgerald, Michael Imbert	t(2)	devel.		n.1.	tunable filter (UV)

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

REF. NO.	MANUFACTURER/DISTRIBUTOR	MODEL	DESCRIPTION*		
			Cat.	Table	Features
M171	Hastings-Raydist P.O. Box 1275 Hampton, VA 23361	*(1) U series	A-4	3E-9f	mass flow-meter

* See LEGEND (Table B-1a) preceding and Table B-2 following this table (foldouts)

TABLE B-2 -- INSTRUMENT CATEGORIES

Characterization by type and function, used for classification in Catalog File C (Categorical) and for reference in Table B-1, column FILE.

- | | |
|--------------------------------------|---|
| A. SAMPLERS & ACCESSORIES | G. SPECTROPHOTOMETERS |
| A-1 Pumps | G-1 Plant UV spectrophotometers |
| A-2 Personal samplers | G-2 Plant IR spectrophotometers |
| A-3 Sequential samplers | G-3 Laboratory spectrophotometers |
| A-4 Flowmeters | H. POLAROGRAPHYS |
| A-5 Impingers, columns, bags, etc. | I. GAS CHROMATOGRAPHS |
| A-6 Syringes, etc. | I-1 Environmental monitors
and process analyzers |
| B. GAS DETECTOR TUBES, ETC. | I-2 Portable GC instruments |
| B-1 Length-of-stain tubes | I-3 Bench GC instruments |
| B-2 Stain-intensity tubes | I-4 Laboratory GC instruments |
| B-3 Tester kits | I-5 Special GC analyzers |
| C. COMBUSTIBLE GAS MONITORS | I-6 GC detectors |
| C-1 Plant monitors | I-7 GC valves & accessories |
| C-2 Portable monitors | I-8 Peak integrators and
"peak pickers" |
| D. FID TOTAL HYDROCARBON MONITORS | J. MASS SPECTROMETERS |
| D-1 Plant FID monitors | K. POTENTIAL NEW METHODS |
| D-2 Portable FID monitors | L. CALIBRATION EQUIPMENT |
| E. OTHER NON-SPECIFIC INSTRUMENTS | L-1 Dilution equipment |
| E-1 Flame, thermal detector | L-2 Permeation tubes, etc. |
| E-2 Selective catalytic combustion | L-3 Calibration gases |
| E-3 Gas density | M. READOUT DEVICES |
| E-4 Thermal conductivity | M-1 Plant analog recorders
(strip chart recorders) |
| E-5 Alpha ionization | M-2 Portable analog recorders |
| F. PHOTOMETERS | M-3 Laboratory analog rec'rs |
| F-1 Plant UV monitors | M-4 Digital devices |
| F-2 Portable UV monitors | M-5 Miscellaneous |
| F-3 Mercury monitors | |
| F-4 Laboratory UV instruments | |
| F-5 Plant non-dispersive IR monitors | |
| F-6 Portable NDIR monitors | |
| F-7 Flame emission | |

FOLD OUT FOR USE WITH TABLE B-1

TABLE B-2 -- INSTRUMENT CATEGORIES

Characterization by type and function, used for classification in Catalog File C (Categorical) and for reference in Table B-1, column FILE.

A. SAMPLERS & ACCESSORIES	G. SPECTROPHOTOMETERS
A-1 Pumps	G-1 Plant UV spectrophotometers
A-2 Personal samplers	G-2 Plant IR spectrophotometers
A-3 Sequential samplers	G-3 Laboratory spectrophotometers
A-4 Flowmeters	
A-5 Impingers, columns, bags, etc.	H. POLAROGRAPHYS
A-6 Syringes, etc.	I. GAS CHROMATOGRAPHS
B. GAS DETECTOR TUBES, ETC.	I-1 Environmental monitors and process analyzers
B-1 Length-of-stain tubes	I-2 Portable GC instruments
B-2 Stain-intensity tubes	I-3 Bench GC instruments
B-3 Tester kits	I-4 Laboratory GC instruments
C. COMBUSTIBLE GAS MONITORS	I-5 Special GC analyzers
C-1 Plant monitors	I-6 GC detectors
C-2 Portable monitors	I-7 GC valves & accessories
D. FID TOTAL HYDROCARBON MONITORS	I-8 Peak integrators and "peak pickers"
D-1 Plant FID monitors	J. MASS SPECTROMETERS
D-2 Portable FID monitors	K. POTENTIAL NEW METHODS
E. OTHER NON-SPECIFIC INSTRUMENTS	L. CALIBRATION EQUIPMENT
E-1 Flame, thermal detector	L-1 Dilution equipment
E-2 Selective catalytic combustion	L-2 Permeation tubes, etc.
E-3 Gas density	L-3 Calibration gases
E-4 Thermal conductivity	
E-5 Alpha ionization	M. READOUT DEVICES
F. PHOTOMETERS	M-1 Plant analog recorders (strip chart recorders)
F-1 Plant UV monitors	M-2 Portable analog recorders
F-2 Portable UV monitors	M-3 Laboratory analog rec'rs
F-3 Mercury monitors	M-4 Digital devices
F-4 Laboratory UV instruments	M-5 Miscellaneous
F-5 Plant non-dispersive IR monitors	
F-6 Portable NDIR monitors	
F-7 Flame emission	

FOLD OUT FOR USE WITH TABLE B-1

APPENDIX

TABLE B-3

MANUFACTURERS -- NEGATIVE RESPONSE TO INQUIRY

Air Pollution Industries, Inc.	Englewood, NJ
American Gas & Chemicals, Inc.	New York, NY
Amstro Corporation	Fairfield, NJ
Andersen-2000, Inc.	Salt Lake City, UT
API Instruments Company	Waltham, MA
Astro Ecology Corporation	Houston, TX
Avco Corporation	Tulsa, OK
Baird-Atomic, Inc.	Bedford, MA
Bausch & Lomb, Inc.	Rochester, NY
BIF, Sub. of General Signal Corp.	Providence, RI
Billings & Gussman, Inc.	Waltham, MA
E. D. Bullard Company	Sausalito, CA
Cambridge Instrument Co., Inc.	Ossining, NY
Combustion Equipment Assoc. Inc.	New York, NY
Compact Air Samplers	Dayton, OH
Computer Instruments Corp.	Hempstead, NY
Del Electronics Corp.	Mt. Vernon, NY
Delta Scientific Corp.	Lindenhurst, NY
Dresser Industries, Inc.	Connersville, IN
Eberline Instrument Corp.	Santa Fe, NM
Eclipse Fuel Engineering Co.	Rockford, IL
Electrodyne	Sharon, MA
Elnik Instruments, Inc.	Lodi, NJ
Engelhard Minerals & Chemicals, Corp.	Newark, NJ
Carlo Erba S. p. A.	Milano, Italy
Fisher Controls Co.	Marshalltown, IA
Forma Scientific Products	Marrietta, OH
Gam Rad, Inc.	Detroit, MI
General Electric Co.	Daytona Beach, FL
General Electric Co.	Philadelphia, PA
General Electric Co.	Schenectady, NY
Gerstemslager Co.	Wooster, OH
Roger Gilmont Instruments, Inc.	Great Neck, NY
Gilson Medical Electronics, Inc.	Middleton, WI
Gould Inc., Brush Division	Cleveland, OH
Hallikanien Instruments	Richmond, CA
Hasting-Raydist (M171)(Table B-1)	Hampton, VA
E. Vernon Hill Incorporated	San Francisco, CA
Houston Atlas, Inc.	Houston, TX

TABLE B-3 (cont'd)

MANUFACTURERS -- NEGATIVE RESPONSE TO INQUIRY

IMI Div., Becton, Dickinson & Co.	Newport Beach, CA
Instrumentation Laboratory, Inc.	Lexington, MA
International Chemical & Nuclear Corp.	Oakland, CA
Kahl Scientific Instrument Corp.	El Cajon CA
Kollmorgen Corporation	Attleboro, MA
Lab-Line Instruments, Inc.	Melrose Park, IL
Laboratory Equipment Corp.	St. Joseph, MI
E. Leitz, Incorporated	Rockleigh, NJ
Luft Instruments, Inc.	Lincoln, MA
3M Company	St. Paul, MN
Marine-Electro-Mechanical, Inc.	Wickliffe, OH
Martek Instruments, Inc.	Newport Beach, CA
MCB Manufacturing Chemists	Norwood, OH
McMillan Electronics Corp. (MEC)	Houston, TX
Meteorology Research, Inc.	Altadena, CA
Micromeritics Instrument Corp.	Norcross, GA
Millipore Corporation	Bedford, MA
Nester/Faust Manufacturing Corp.	Neward, DE
Nicolet Instrument Corporation	Madison, WI
Nuclear Supply and Service Company	Washington, D.C.
OCLI Instruments	S. Norwalk, CT
Olin Chemicals	Stamford, CT
Permutit Company	Paramus, NJ
Photron Instrument Company*	Cleveland, OH
Pollution Control-Walther, Inc.	Birmingham, AL
Pollution Monitors, Inc.	Chicago, IL
Reactor Controls, Inc.	Oak Ridge, TN
Rigaku Denki Co., Ltd.	Chiyoda-ku, Tokyo, Japan
Rohde & Schwarz Sales Co.	Passaic, NJ
Royco Instruments, Inc.	Menlo Park, CA
Sara-Sonic Co.	San Francisco, CA
Scientific Glass Blowing Co., Inc.	Houston, TX
Scientific Industries, Inc.	Mineola, NY
Scintillonics, Incorporated	Fort Collins, CO
Simpson Electric Company	Chicago, IL
Singer	Parsippany, NJ
Sloan Thechnology Corp.	Santa Barbara, CA
Soltec Corporation	N. Hollywood, CA
Staplex Company	Brooklyn, NY
Stoelting Company	Chicago, IL

TABLE B-3 (cont'd)

MANUFACTURERS -- NEGATIVE RESPONSE TO INQUIRY

Technicon Instruments Corp.	Tarrytown, NY
** Teledyne Analytical Instruments	San Gabriel, CA
Thermo Electric Co., Inc.	Saddle Brook, NJ
Thermo-Systems, Inc.	St. Paul, MN
Theta Sensors, Inc.	Orange, CA
Tipptronic	Chagrin Falls, OH
United Sensor & Control Co.	Watertown, MA
Universal Oil Products Corp.	Darien, CT
Westinghouse Electric Corp.	Elmira, NY
Westinghouse Electric Corp.	Pittsburgh, PA
Carl Zeiss, Incorporated	New York, NY

* See Table B-1. Product described in response to inquiry not applicable.
Applicable instrument advertised.

** See Table B-4 Telmar.

APPENDIX

TABLE B-4

MANUFACTURERS -- NO RESPONSE TO INQUIRY

(Excluding those listed in Table B-1 on basis of advertisements only.)

Abcor, Incorporated	Cambridge, MA
Ace Glass Incorporated	Vineland, NJ
Ace Scientific Supply Co., Inc.	Linden, NJ
Achem	New Berlin, WI
Acton Laboratories, Inc.	Acton, MA
Adam-David Company	Langhorne, PA
Advanced Acoustical Research Corp.	Bethpage, NY
Advanced Research Instrument Systems, Inc.	Austin, TX
AEI Scientific Apparatus, Inc.	Elmstord, NY
AEI Scientific Apparatus, Ltd.	Urmston, Manchester, M31220 England
Aer - O - Flo Corp.	Florence, KY
Aero Vac Corporation	Troy, NY
Aerojet General Corp.	El Monte, CA
Aerojet General Corp.	San Ramon, CA
Aerotherm Corp.	Mt. View, CA
Air Lab, Inc.	Lake Charles, LA
Air Products and Chemicals, Inc.	Allentown, PA
Aircon Corporation	Cincinnati, OH
Airflow Developments (Canada), Ltd.	Ontario, Canada
Alexander Chemicals	Chicago, IL
Alken-Murray Corporation	New York, NY
Alnor Instrument Company	Chicago, IL
Ambient Systems, Inc.	Hastings-on-Hudson, NY
American Chain & Cable Co.	Waterbury, CT
American Chemical & Refining Co., Inc.	Waterbury, CT
American Environmental Systems Co.	Long Island City, NJ
American Meter Co.	Philadelphia, PA
American Nuclear Corp.	Oak Ridge, TN
American Optical Corporation	Richmond, CA
American Standard Incorporated	New Brunswick, NJ
American Ultraviolet Company	Chatham, NJ
Amicon Corporation	Lexington, MA
Amiproducts, Inc.	New York, NY
Amperex Electronic Corporation	Hicksville, NY
Analtech, Inc.	Newark, DE
Analytic Systems Associates	Pullman, WA
Andonian Associates, Inc.	Waltham, MA
H. Reeve Angel & Co., Inc.	Clifton, NJ
Angstrom, Inc.	Belleville, MI
Applied Electro Mechanics, Inc.	Alexandria, VA
Applied Science Laboratories, Inc.	State College, PA
Aqua Test Corporation	Arlington, MA
A. R. F. Products, Inc.	Raton, NM
Aromil Chemical Company	Baltimore, MD
Ashland Oil & Refinery Co.	Ashland, KY
Atkins Technical, Inc.	Gainesville, FL
Atlantic Equipment Engineers	Bergenfield, NJ
Atlantic Research Corp.	Alexandria, VA

TABLE B-4 (cont'd)

MANUFACTURERS -- NO RESPONSE TO INQUIRY

Atlas Chemical Industries	Wilmington, DE
Atlas Electric Devices Co.	Chicago, IL
Audn Corporation	Hamburg, NY
Automated Environmental Systems, Inc.	Woodbury, NY
Automation Products, Inc.	Houston, TX
Badger Meter Manufacturing Co.	Milwaukee, WI
Baker Chemical Co.,	Phillipsburg, NJ
The Baker Company, Inc.	Biddeford, ME
Barkley & Dexter Labs, Inc.	Fitchburg, MA
Barnes Engineering Company	Stamford, CT
Baroid	Houston, TX
Barringer Research, Ltd.	Rexdale 605, Ontario, Canada
BDH Chemicals	Toronto, Ontario, Canada
Bel-Art Products	Pequannock, NJ
Belfort Instrument Co.	Baltimore, MD
Bell & Howell	Bridgeport, CT
Beltran Associates, Inc.	Brooklyn, NY
Bendix Corporation	Baltimore, MD
Bendix Scientific Instruments	Rochester, NY
Bendy Engineering Company	St. Louis, MO
Benthos, Inc.	N. Falmouth, MA
Betz Environmental Engineers, Inc.	Plymouth Meeting, PA
Betz Labs, Incorporated	Trevoze, PA
Bio-Rad Laboratories	Richmond, CA
Biospherics Incorporated	Rockville, MD
B & K Instruments, Inc.	Cleveland, OH
Black Light Eastern	Westbury, NY
Boehringer Mannheim Corp.	New York, NY
Bolt Beranek & Newman Inc.	Santa Ana, CA
Wm. R. Bradley & Associates	Tenafly, NJ
Brinkmann Instruments Inc.	Westbury, NY
Bronwill Scientific	Rochester, NY
Dayton T. Brown, Inc.	Bohemia, NY
Buchler Instruments	Fort Lee, NJ
Buell Engineering Co., Inc.	Lebanon, PA
Burrell Corporation	Pittsburgh, PA
G. F. Bush Associates	Princeton, NJ
Calbiochem	Los Angeles, CA
Calgon Corporation	Pittsburgh, PA
Calibrated Instruments, Inc.	New York, NY
Seymour Calvert Associates	Riverside, CA
Cambridge Systems, EG&G Inc.	Newton, MA
Cambridge Technology, Inc.	Needham, MA
Canalco, Inc.	Rockville, MD
The Carborundum Co.	Niagara Falls, NY
Cargille Labs, Inc.	Cedar Grove, NJ
Carter-Day Company	Minneapolis, MN

TABLE B-4 (cont'd)

MANUFACTURERS -- NO RESPONSE TO INQUIRY

Cary Instruments	Monrovia, CA
Catalytic Inc.	Philadelphia, PA
Cenco Instruments Corp.	Chicago, IL
Chatas Glass Co.	Vineland, NY
Chem Corporation Engineering	Sausalito, CA
Chem-Tec Equipment Co., Inc.	Pompano Beach, FL
Chemec Process Systems	Tappan, NY
Chemetron Corporation	Chicago, IL
Chemical Data Systems, Inc.	Oxford, PA
Chemical Research Services, Inc.	Addison, IL
Chemical Separations Corp.	Oak Ridge, TN
Chemico	New York, NY
Chemtrix, Inc.	Beaverton, OR
Chemtronics, Inc.	San Antonio, TX
Chessco Industries, Inc.	Fairfield, CT
Christie Electric Corp.	Los Angeles, CA
Chromalloy American Corp.	Hawthorne, CA
Chromalytics Corp.	Unionville, PA
Chromatronix Inc.	Berkeley, CA
Cintra Inc.	Mt. View CA
George D. Clayton & Associates, Inc.	Southfield, MI
Climatronic Corp.	Hauppauge, NY
Climet Instruments Co.	Sunnyvale, CA
Coast Engineering Laboratories	Gardena, CA
Combustion Engineering, Inc.	Windsor, CT
Commerical Testing & Engineering Co.	Chicago, IL
Commonwealth Laboratory, Inc.	Richmond, VA
Conax Corporation	Buffalo, NY
Consolidated Electrodynamics Co.	Pasadena, CA
Continental Modules, Inc.	Whippany, NJ
Control Sales, Inc.	Denver, CO
Controlled Atmosphere, Inc.	Orange, CA
Coors Porcelain Co.	Golden, CO
Core Laboratories, Inc.	Dallas, TX
Corion Instrument Corp.	Waltham, MA
Corning Glass Works	Corning, NY
Corning Laboratories, Inc.	Cedar Falls, IA
Cosmodyne Corporation	Torrance, CA
Cosmos Scientific Co.	E. Linden, NJ
Coulter Electronics	Hialeah, FL
Coulter Electronics, Inc.	Sunnyvale, CA
Edwin Cox Associates	Richmond, VA
W. H. Curtin & Company	Houston, TX
Custom Scientific	Whippany, NJ
CWC Industries, Inc.	Cleveland, OH

TABLE B-4 (cont'd)

MANUFACTURERS -- NO RESPONSE TO INQUIRY

Daniel Industries, Inc.	Houston, TX
Datex	Duarte, CA
Charles Davidoff	New York, NY
Davis Instruments (see Scott-Davis)	Newark, NJ
Dell Optics Co., Inc.	N. Bergen, NJ
Doerfer Laboratory	Cedar Falls, IA
Dragon Valves, Inc.	Norwalk, CA
Drew Chemical Corp.	Boonton, NJ
Du Pont de Nemours & Co., E.I.	Wilmington, DE
Du Pont Indstuments	Monrovia, CA
Dunn Analytical Instruments	Cambridge, MA
Durrum Instrument Corp.	Palo Alto, CA
Dustex	Buffalo, NY
Dynasciences Corp.	Chatsworth, CA
The Ealing Corp.	Cambridge, MA
Ecological Science Corp.	Miami, FL
Ecology & Environment, Inc.	W. Senca, NY
Edel Laboratories	Newark, NJ
EG&G, Incorporated	Waltham, MA
Electro-Nucleonics, Inc.	Fairfield, NJ
Ellison Instrument	New Buffalo, MI
Elron, Inc.	Edison, NJ
Engineering-Science, Inc.	Arcadia, CA
Engis Equipment Co.	Morton Grove, IL
Englehard Minerals & Chemicals Corp.	Murray Hill, NJ
Entoleter, Inc.	New Haven, CT
Enviro Control, Inc.	Washington, D.C.
Environal Engineers	Union, NJ
Environeering, Inc.	Skokie, IL
Environics, Inc.	Santa Ana, CA
Environment One Corporation	Schenectady, NJ
Environmental Consultants, Inc.	Clarksville, IN
Environmental Data Corp.	Monrovia, CA
Environmental Engineering, Inc.	Gainesville, FL
Environmental Health Laboratories	Farmington, MI
Environmental Instrument Co.	Menlo Park, CA
Environmental Metrology Corp.	Ann Arbor, MI
Environmental Quality Engineering, Inc.	St. Paul, MN
Environmental Sciences, Inc.	Pittsburgh, PA
Envirotech Systems, Inc.	Brisbane, CA
Eon Corp	Brooklyn, NY
Epic, Inc.	New York, NY
Essex Engineering Co.	Essex, CT
Excelsior Electronics Co.	Canoga Park, CA
Extranuclear Lab, Inc.	Pittsburgh, PA

TABLE B-4 (cont'd)

MANUFACTURERS -- NO RESPONSE TO INQUIRY

F & J Scientific	Monroe, CT
Farrand Optical Co., Inc.	Valhalla, NY
Finnigan Corp.	Sunnyvale, CA
First Machinery Corp.	Brooklyn, NY
Fisher Governor Co.	Coraopolis, PA
Flamort Chemical Co.	San Francisco, CA
Flexbar Machine Corporation	Farmingdale, NY
Floridin Company	Pittsburgh, PA
Flowseal Products, Inc.	Lodi, NJ
Flotec, Inc.	Lodi, NJ
Fluid Data, Inc.	Hauppauge, NY
Sidney R. Frank Group	Goleta, CA
Frederiksen Engineering Co., Inc.	Oakland, CA
Freeman Laboratories, Inc.	Rosemont, IL
FRL Incorporated	Belmont, CA
Ernest F. Fullam, Inc.	Schenectady, NY
Gaertner Scientific Corp.	Chicago, IL
Gallard-Schlesinger Chemical Mfg. Corp.	Carle Place, NY
A. Gallenkamp and Co., Ltd.	London EC2P-2ER, England
Galson Technical Services, Inc.	Syracuse, NY
Gannett Fleming Corddry & Carpenter, Inc.	Harrisburgh, PA
Garratt-Callahan Co.	Millbrae, CA
Garver-Davis, Inc.	Cleveland, OH
George W. Gates & Co., Inc.	Franklin Square, NY
GCA Technology (see Precision Scientific)	Bedford, MA
Gelber Pumps, Inc.	South Chicago, IL
Gelman Instrument Co.	Ann Arbor, MI
General Combustion, Inc.	Alliance, OH
General Electric Co.	W. Lynn, MA
General Nuclear Corp.	New York, NY
General Radio Co.	Concord, MA
General Resource Corp.	Hopkins, MN
General Tesing Labs., Inc.	Springfield, VA
Geomet, Inc.	Pomona, CA
GfG-Becorit Electronics, Ltd.	Nottingham, England
Gilford Instrument Labs., Inc.	Overline, OH
Glowall Corporation	Willow Grove, PA
GM Manufacturing & Instrument Co.	Bronx, NY
Golden Instruments, Inc.	Chicago, IL
Granville-Phillips Co.	Boulder, CO
Greiner Scientific Corp.	New York, NY
Gulf Environmental Systems Co.	San Diego, CA
Gustafson Manufacturing Corp., Inc.	Hopkins, MN

TABLE B-4 (cont'd)

MANUFACTURERS -- NO RESPONSE TO INQUIRY

H & P Equipment Co.	Weehawken, NJ
Hack Chemical Co.	Ames, IA
Hallmark Standards, Inc.	Mt. Vernon, NY
W. H. Hammond Drierite Co.	Xenia, OH
Hankison Corp.	Canonsburg, PA
Hanovia Lamp, Canrad Precision Industries	Newark, NJ
Harleco	Philadelphia, PA
Harris Laboratories, Inc.	Lincoln, NB
The Harshaw Chemical Co.	Cleveland, OH
Harshaw Chemical Co.	Solon, OH
Harvard Apparatus	Millis, MA
R. J. Harvey Instrument Corp.	Hillsdale, NJ
Health Co.	St. Joseph, MI
Heen & Flint Associates	Rochester, NY
Hellige, Inc.	Garden City, NY
Hellma Cells, Inc.	Jamaica, NY
Hemeon Associates	Pittsburgh, PA
Hercules, Inc.	Wilmington, DE
High Accuracy Products Corp.	Claremont, CA
Hills-McCanna	Carpentersville, IL
Hittman Associates, Inc.	Columbia, MD
Hoad Engineers, Inc.	Ypsilanti, MI
Hoke Inc.	Cresskill, NJ
Honeywell Test Instruments	Denver, CO
Horizon Ecology	Chicago, IL
Hotpack Corp.	Philadelphia, PA
Houston Research, Inc.	Houston, TX
Howell Instruments, Inc.	Fort Worth, TX
Hubbell, Roth & Clark, Inc.	Bloomfield Hills, MI
Huggins Labs	Sunnyvale, CA
Hughes Aircraft Co.	Culver City, CA
Hygrodynamics, Inc.	Silver Spring, MD
HYTEK International Corp.	Medina, OH
ICN Chemical & Radioisotope	Irvine, CA
I.D.Q. Inc.	Evansville, IN
Ikor, Inc.	Burlington, MA
Illumination Industries, Inc.	Sunnyvale, CA
Industrial Chemicals, Inc.	South Bend, IN
Industrial Filter & Pump Mfg. Co.	Cicero, IL
Industrial & Mill Supply Co.	Huntington Station, NY
Instra-Tech Inc.	Fullerton, CA
Instrument Development Company	Attleboro, MA
Instrumentation Associates, Inc.	New York, NY
Instrumentation Specialties Co.	Lincoln, NB

TABLE B-4 (cont'd)

MANUFACTURERS -- NO RESPONSE TO INQUIRY

International Biophysics Corp.	Irvine, CA
International Light, Inc.	Newburyport, MA
International Pollution Control, Inc.	St. Louis, MO
International Sales Associates	Langhorne, PA
Interscience	Birmingham, NJ
Ionac Chemical Co.	Watertown, MA
Ionics Research, Inc.	Monterey Park, CA
ITT Barton	
Janos Optical Corp.	Newfane, VT
Jarrell-Ash	Waltham, MA
Jet Instruments	E. Albuquerque, NM
Wm. B. Johnson & Associates, Inc.	Montville, NJ
Johnson Laboratories, Inc.	Cockeysville, MD
The Johnson-March Corp.	Philadelphia, PA
Jouan Quetin	Gambetta, 75-Paris 20 eme, France
Joy Manufacturing Company	Pittsburgh, PA
Kahn & Co., Inc.	Wethersfield, CT
Kaman Sciences Corp.	Colorado Springs, CO
Jacob Katz Associates, Inc.	Munhall, PA
Kemlon Products	Houston, TX
Kenco Associates, Inc.	Ashland, KY
Kenics Corp.	Danvers, MA
Kennedy Engineers	San Francisco, CA
Kerotest Manufacturing Corp.	Pittsburgh, PA
Wayne Kerr Co.	Southfield, MI
Kingmann-White, Inc.	Placentia, CA
Lester B. Knight & Associates, Inc.	Chicago, IL
Koehler Manufacturing Co.	Marlborough, MA
Koslow Scientific Corp.	Bergen, NJ
Laboratory Instrument Exchange, Inc.	Chicago, IL
Lachat Chemicals, Inc.	Chicago Heights, IL
LaMotte Chemical Products Co.	Chestertown, MD
R. S. Lanauer, Jr. and Co.	Glenwood, IL
Land Instruments, Inc.	Tullytown, PA
Landsverk Electrometer Co.	Glendale, CA
LaPine Scientific Co.	Chicago, IL
Leigh Instruments, Ltd.	Carleton, Ontario, Canada
LFE Corp.	Waltham, MA
Lif-O-Gen, Inc.	Luberton, NJ
Limnetics, Inc.	Milwaukee, WI
Litton Systems Company	Camarillo, CA
LND, Incorporated	Oceanside, NY
Lock & Co., Ltd.	Oldham, Lancashire, England

TABLE B-4 (cont'd)

MANUFACTURERS -- NO RESPONSE TO INQUIRY

Lockwood Greene Engineers, Inc.	New York, NY
Los Angeles Scientific Instrument Co., Inc.	Los Angeles, CA
Lovibond of America, Inc.	Albertson, NY
Ludwig Consulting Engineers	Baton Rouge, LA
Luminon, Inc.	Irvington, NJ
Macbeth Corporation	Newburgh, NY
Mack Corporation	Flagstaff, AZ
Mahon Industrial	Warren, MI
Maier, Franz J.	Rockville, MD
Manufacturers Engineering & Equipment Co.	Warrington, PA
Marathon Engineering, Inc.	Menasha, WI
Matheson Scientific Div.	Elk Grove Village, IL
McKinney, C. H., Formulators & Engineers	Louisville, KY
McPherson Instrument Corp.	Acton, MA
Med-Science Electronics, Inc.	St. Louis, MO
Megator Corporation	Pittsburgh, PA
Meletron	Los Angeles, CA
Meriam Instrument Co.	Cleveland, OH
Merrick Scale Manufacturing Co.	Passaic, NJ
Metrodata Systems, Inc.	Norman, OK
Metrolab, Inc.	San Diego, CA
Mettler Instrument Corp.	Princeton, NJ
MG Scientific Gases	Kearny, NJ
John P. Mickel Associates, Inc.	Clawson, MI
Microbeads	Jackson, MS
Microchemical Specialties Co.	Berkeley, CA
Midwest Research Institute	Kansas City, MO
Misco Scientific	Berkeley, CA
Mitco, Inc.	Grand Rapids, MI
M/K Systems Inc.	Lynn, MA
Monsanto Biodize Systems, Inc.	Great Neck, NY
Monsanto Company	St. Louis, MO
Monsanto Enviro-Chem Systems Inc.	Chicago, IL
Mopeco Div., General Cable Corp.	Denver, CO
Motorola Instrumentation & Control, Inc.	Phoenix, AZ
Municipal Equipment	Brisbane, CA
N-CON Systems Co., Inc.	Larchmont, NY
Nalco Chemical Co.	Chicago, IL
The Nappe Corporation	Pelham, NY
National Sanitation Foundation Test. Lab.	Ann Arbor, MI
National Tank Co.	Tulsa, OK
Navan Incorporated	El Segundo, CA
Nebraska Testing Laboratories	Omaha, NB
New York Testing Laboratories, Inc.	Westbury, NY
Newing Labs, Inc.	Islip, NY

TABLE B-4 (cont'd)

MANUFACTURERS -- NO RESPONSE TO INQUIRY

Norcross Crop.	Newton, MA
Norton Co.	Newton, MA
Nuclear-Chicago Corp., Texas Nuclear Div.	Austin, TX
Nuclear Equipment Chemical Corp.	Farmingdale, NY
Nuclear Measurement Corp.	Indianapolis, IN
Nuclear Research Corp.	Southampton, PA
Nucleonic Corp. of America	Brooklyn, NY
Nucleonics, Inc.	Fairfield, NJ
Nuclide Corp.	State College, PA
Nuclide Corp., AGV Div.	Acton, MA
Nupro Co.	Cleveland, OH
NUS Corp.	Rockville, MD
Oriel Optics Corp.	Stamford, CT
Orion Research, Inc.	Cambridge, MA
Ovitron Corporation	E. Stroudsburg, PA
Ozone Research & Equipment Corp.	Phoenix, AZ
Panametrics, Inc.	Waltham, MA
Particle Technology, Inc.	Sunnyvale, CA
Peabody Engineering Corp.	Stamford, CT
P/E Development Co.	Cincinnati, OH
PEDCo-Environmental Specialists	Cincinnati, OH
Pek, Incorporated	Sunnyvale, CA
Penberthy	Prophetstown, IL
John A. Pendergrass Co.	White Bear Lake, MN
Pennwalt Corp.	Philadelphia, PA
Perco Supplies	San Gabriel, CA
Perking-Elmer, Ltd.	Beaconsfield, Buckinghamshire, Engl.
Phase Separations, Ltd.	Queensferry, Flintshire, England
Philips Electronics Instruments	Mt. Vernon, NY
Phillips Manufacturing Co.	Chicago, IL
Phillips Petroleum Co.	Bartlesville, OK
Phoenix Precision Instruments	Gardiner, NY
Photobell Co., Inc.	New York, NY
Photomation Inc.	Mountain View, CA
Photronic, Inc.	Jenkintown, PA
PHy-Lab	Minneapolis, MN
Picker Corporation	White Plains, NY
Picker Medical Products	N. Haven, CT
Pitchford Manufacturing Corp.	Pittsburgh, PA
Pitchford Scientific Instrument Corp.	Pittsburgh, PA
Planchets Lab. Products	Ann Arbor, MI
Plasmadyne	Santa Ana, CA
Pollution Control Industries	Stamford, CT
Pollution Research & Control Corp.	Glendale, CA
Pollutronics, Inc.	Cleveland, OH

TABLE B-4 (cont'd)

MANUFACTURERS -- NO RESPONSE TO INQUIRY

Power Designs, Inc.	Westbury, NY
Power Engineering & Equipment Co., Inc.	Torrance, CA
Precision Sampling Corp.	Baton Rouge, LA
Precision Systems, Inc.	Newton, MA
Prenco Manufacturing Company	Madison Heights, MI
Princeton Chemical Research, Inc.	Princeton, NJ
Pro-Tech, Inc.	Malvern, PA
Process & Instruments Corp.	Brooklyn, NY
Pure Aire Corp. of America	Van Nuys, CA
Qanta/Metrix Corp.	San Carlos, CA
Quantachrome Croproation	Greenvale, NY
Quin Tron Instrument Co., Inc.	Waukesha, WI
R 2 Associates	Paughkeepsie, NY
Radiation Facilities, Inc.	Lodi, NJ
Radiation Materials Co., Inc.	Waltham, MA
Rank Precision Industries, Ltd.	London, N.W. 5, England
Recon Systems, Inc.	Princeton, NJ
Charles M. Reeder Co., Inc.	Detroit, MI
Regis Chemical Co.	Chicago, IL
REM Incorporated	Santa Monica, CA
Research Assistance Corporation	St. Louis, MO
Research-Cottrell, Inc.	Bound Brook, NJ
Research & Development Products	Berkeley, CA
Resource Control, Inc.	West Haven, CT
Resources Research Inc.	Reston, VA
RHO Scientific, Inc.	Commack, NY
Rockland Instrument Corp.	Pearl River, NY
Rockwell Manufacturing Company	Pittsburgh, PA
RoLock Incorporated	Fairfield, CT
Rotron Controls	Woodstock, NY
Milton Roy Company*	St. Petersburg, FL
Rudolph Instruments Engineering Co., Inc.	Little Falls, NJ
Rudolph Research Corp.	Caldwell, NJ
The Rust Engineering Co.	Pittsburgh, PA
Sadtler Research Laboratories, Inc.	Philadelphia, PA
Sage Instruments, Inc.	White Plains, NY
Sanda, Inc.	N. Bala Cynwyd, PA
Saxonburg Ceramics, Inc.	Saxonburg, PA
F. C. Schaffer & Associates, Inc.	Baton Rouge, LA
Schleicher & Schuell, Inc.	Keene, NH
Schmidt Instrument Co.	San Carlos, CA
Schoeffel Instrument Corp.	Westwood, NJ

* See Table B-1, M169.

TABLE B-4 (cont'd)

MANUFACTURERS -- NO RESPONSE TO INQUIRY

SciChemCo	Los Angeles, CA
Sci-Med, Inc.	Minneapolis, MI
Science Associates, Inc.	Princeton, NJ
Science Spectrum, Inc.	Santa Barbara, CA
Scientific Cell Co., Inc.	Forest Hills, NY
Scientific Glass Apparatus Co., Inc.	Bloomfield, NJ
Scientific Products	McGaw Park, IL
Scientific Systems Corp.	Baton Rouge, LA
Seismograph Service Corp.	Tulsa, OK
Shandon Scientific Co., Inc.	Sewickley, PA
Sherwood Medical Industries, Inc.	St. Louis, MO
Shimadzu Seisakusho, Ltd.	Tokyo, Japan
Sierra Research Corp.	Boulder, CO
Silver-Top Manufacturing Co., Inc.	White Marsh, MD
Sirco Controls Co.	Seattle, WA
Marcus Sittenfield & Associates	Philadelphia, PA
Snyder Teague, Inc.	Largo, FL
Eric Sobotka Co., Inc.	Farmingdale, NY
Sonford Products Corp.	Minneapolis, MN
Ivan Sorvall, Inc.	Norwalk, CT
The Southern New England Ultraviolet Co.	Middletown, CT
Southwest Research Institute	San Antonio, TX
Sparling Div., Envirotech Corp.	El Monte, CA
SpectrMetrics, Inc.	Burlington, MA
SpectroChem Laboratories, Inc.	Franklin Lakes, NJ
Spectrogram Corp.	N. Haven, CT
Spex Industries, Inc.	Metuchen, NJ
Statham Instruments, Inc.	Oxnard, CA
Steroline Systems Corp.	Santa Fe Springs, CA
Stewart Laboratories, Inc.	Knoxville, TN
Herman H. Sticht Co., Inc.	New York, NY
Ralph Stone & Co., Inc.	Los Angeles, CA
Suburban Laboratories, Inc.	Cicero, IL
Summation Electronics, Ltd.	Guildford, Surrey, England
Swift Laboratories, Inc.	Waltham, MA
Switzer, Sr., W. W.	Lafayette, CA
Syncor Products Co., Inc.	Malden, MA
Syracuse University Research Corp.	Syracuse, NY
T & T Controls Co., Inc.	Media, PA
Taylor Chemicals, Inc.	Baltimore, MD
TC Thermonetics Corp.	San Diego, CA
Tech/Ops Instruments	Burlington, MA
Technical Equipment Corp.	Denver, CO
Technicon Corp. (See M164)	Ardsley, NY
Technology/Versatronics, Inc.	Yellow Springs, OH
Teledyne Geotech	Garland, TX
Teledyne Isotopes (N.J.)	Westwood, NJ

TABLE B-4 (cont'd)

MANUFACTURERS -- NO RESPONSE TO INQUIRY

Telmar, Inc. (see Table B-3)	Columbus, OH
Tenco Hydro-Aero Sciences, Inc.	Chicago, IL
Tenneco Chemicals, Inc.	New York, NY
Testing Machines Inc.	Amityville, NY
Thermal American Fused Quartz Co.	Montville, NJ
Thermonetics Corp.	San Diego, CA
Arthur H. Thomas Co.	Philadelphia, PA
Tirco, Inc.	Deer Park, TX
Toyo Kagaku Sangyo Co., Ltd.	Tokyo, Japan
Tracerlab	Oakland, CA
Trapelo/West	Richmond, CA
TRC (The Research Corp. of New England)	Hartford, CT
Tri-Aid Sciences, Inc.	Rochester, NY
Truesdail Labs, Inc.	Los Angeles, CA
TRW Instruments	El Segundo, CA
Turfgrass Service Co.	San Diego, CA
G. K. Turner Associates	Palo Alto, CA
Ultek	Palo Alto, CA
Ultra-Violet Products, Inc. s.b. B-3	San Gabriel, CA
Unico Environmental Instruments, Inc.	Fall River, MA
Union Carbide Corp.	New York, NY
Union Carbide Corp., Instrument Dept.	White Plains, NY
United Air Specialists, Inc.	Cincinnati, OH
U. S. Nuclear Corp.	Irvine, CA
U. S. Safety Service Co.	Kansas City, MO
United States Testing Co., Inc.	Hoboken, NJ
United Technical Corp.	Concord, MA
Universal Interloc, Inc.	Santa Ana, CA
Ushio Electric Inc.	Tokyo, Japan
Valcor Engineering Corp	Kenilworth, NJ
Valentine, Fisher & Tomlinson	Seattle, WA
Valentine Instrument Co.	Vista, CA
Van Waters and Rogers	Rochester, NY
Vari-Systems, Inc.	Cleveland, OH
Varian Techtron	Walnut Creek, CA
Veeco Instruments, Inc.	Plainviews, NY
Victoreen Instrument Div.	Cleveland, OH
Victory Engineering Corp.	Springfield, NJ
The VirTis Co.	Gardiner, NY
Vortec Products Co.	Hawthorne, CA
Vulcan Laboratories, Inc.	Pontiac, MI
Vulcan-Cincinnati, Inc.	Cincinnati, OH

TABLE B-4 (cont'd)

MANUFACTURERS -- NO RESPONSE TO INQUIRY

Robert H. Wager Co., Inc.	Chatham, NJ
Walden Research Corp.	Cambridge, MA
Warner Co.	Philadelphia, PA
Waugh Controls Corp.	Van Nuys, CA
Wellman-Lord, Inc.	Lakeland, FL
Welsback Corp.	Philadelphia, PA
Wemco Instrumentation Co.	Houston, TX
Western Machinery Co. (Canada), Ltd.	Rexdale, Ontario, Canada
Western Precipitation	Los Angeles, CA
Westinghouse Electric Corp.	Pittsburgh, PA
Westinghouse Electric Corp. Comput. & Instru.	Pittsburgh, PA
Westinghouse Electric Corp. Environ. Systems	Pittsburgh, PA
Westinghouse Electric Corp.	Raleigh, NC
Weston & Stack, Inc.	West Chester, PA
Roy F. Weston Inc.	West Chester, PA
Whittaker Corp.	Los Angeles, CA
Wilkens-Anderson Co.	Chicago, IL
Will Scientific, Inc.	Rochester, NY
Winsco Data Sensors	Santa Monica, CA
Wong Laboratories	Cincinnati, OH
N. Wood Counter Laboratory, Inc.	Chicago, IL
York Research Corp.	Stamford, CT
Otto H. York Co., Inc.	West Orange, NJ
Zeeback Incorporated	Berea, OH
Zimney Corp.	Monrovia, CA
Zirconium Corp. of America	Solon, OH
Zumro, Inc.	Clayton, CA
Zurn Industries, Inc.	Birmingham, AL

CENTURY

Portable Organic Vapor Analyzer

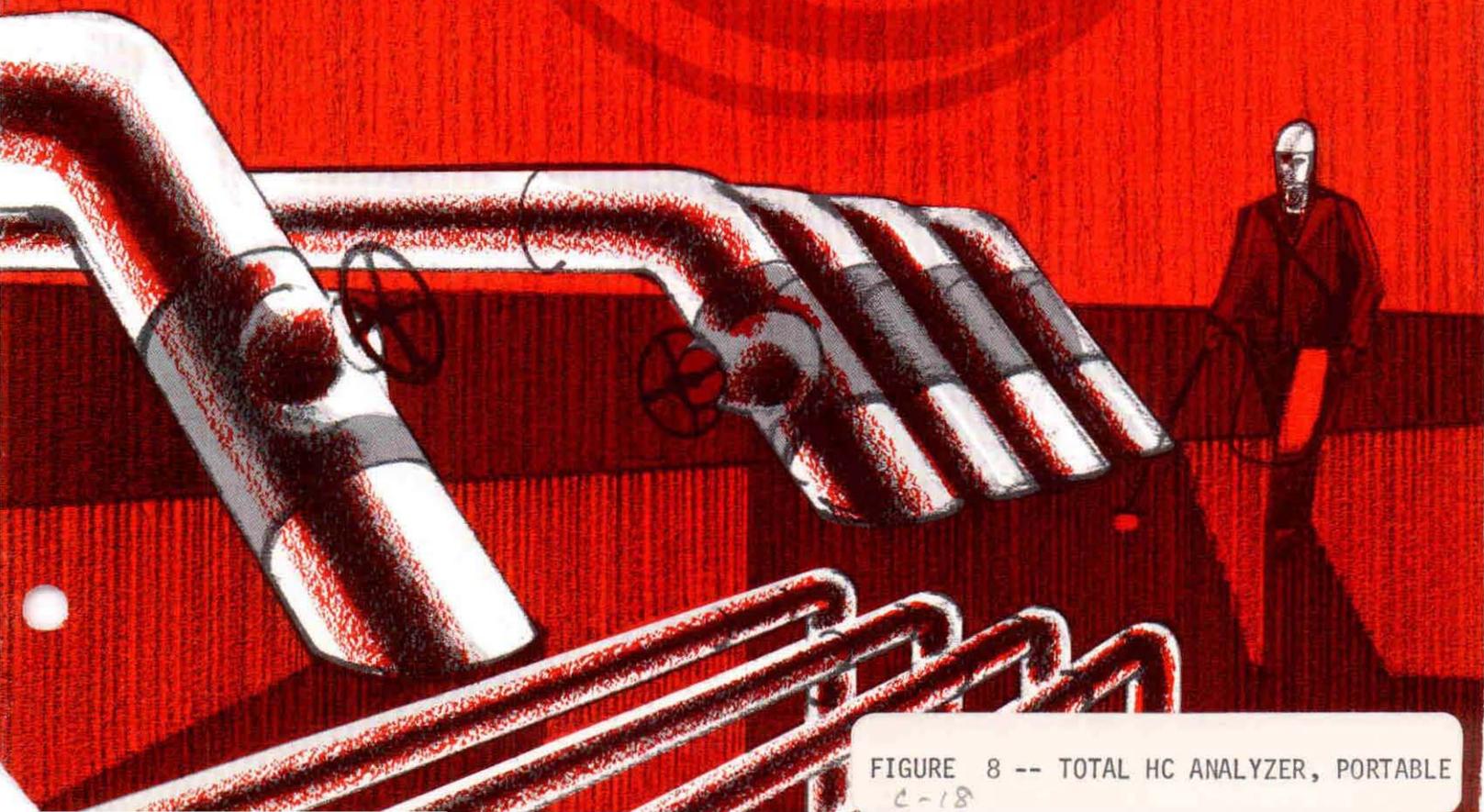


FIGURE 8 -- TOTAL HC ANALYZER, PORTABLE

C-18

CENTURY Portable Organic Vapor Analyzer

INTRODUCTION

A completely portable Organic Vapor Analyzer (OVA) is now available to detect and measure hazardous gases found in almost all industries, including manufacturing, petro-chemical, and natural gas transmission and distribution. The Century OVA is a highly sensitive instrument designed to measure trace quantities of organic materials in air. It incorporates a hydrogen flame ionization detection system which has similar analytical capabilities to those utilized in gas chromatographs. The flame ionization detector is an almost universal detector for organic compounds with the sensitivity to analyze for them in the parts per million range (V/V) in air in the presence of moisture, nitrogen oxides, carbon monoxide and carbon dioxide.

The instrument has broad application, since it has a continuous, chemically resistant air sampling system and can be readily calibrated to measure almost all organic vapors. It has a single logarithmically scaled readout from 1 ppm to 100,000 ppm or with lower maximum level, if desired. Designed for use as a portable survey instrument, it can also be readily adapted to fixed remote monitoring or mobile installations. It is ideal for the determination of many organic air-pollutants and in the monitoring of air in potentially contaminated areas.

The unique feature of the instrument is its complete *portability* which enables an entire facility to be surveyed rapidly and thoroughly. When vapors are detected, the continuous sampling feature enables the origin of those vapors to be readily traced and corrective action initiated. In most cases a qualitative analysis is not justified until the presence of potentially hazardous vapors is detected and the source of the vapors is determined. If, after locating the source, the vapors or mixture of vapors cannot be readily identified, a sample

can be taken and a qualitative analysis performed on standard laboratory equipment. However, location of the vapor source will many times reveal the type of vapor and the concentration level can then be read directly, by simply changing the instrument calibration to the predetermined setting for that particular vapor. The OVA thus enables a comprehensive survey of an entire facility to be performed rapidly and economically in contrast to ineffective and costly spot sampling techniques.

PRINCIPLE OF OPERATION

The instrument includes a detector chamber where the organic vapor being analyzed is introduced into a small hydrogen flame. Air sample is drawn into the instrument at a constant rate of nominally two (2) liters per minute through a chemically resistant line and pump. The oxygen in the air sample is used to support the small hydrogen flame.

Flames characteristically have electrical conductivity due to the presence of electrons and ions generated from the burning fuel. When even trace amounts of organic material enter the hydrogen flame, carbon-containing ions are formed and the electrical conductivity increases significantly. This change in conductivity is measured and the output is directly related to the concentration of organic materials. The exception to this phenomenon is carbon monoxide and carbon dioxide which evidently, due to their structure, do not produce appreciable ions in the detector flame. Thus, other organic materials may be analyzed in the presence of CO and CO₂.

An electric field in the chamber drives the ions to a collecting electrode which causes a current to flow into a preamplifier that is proportional to the ion collection rate. The rate of ion generation is a function of the

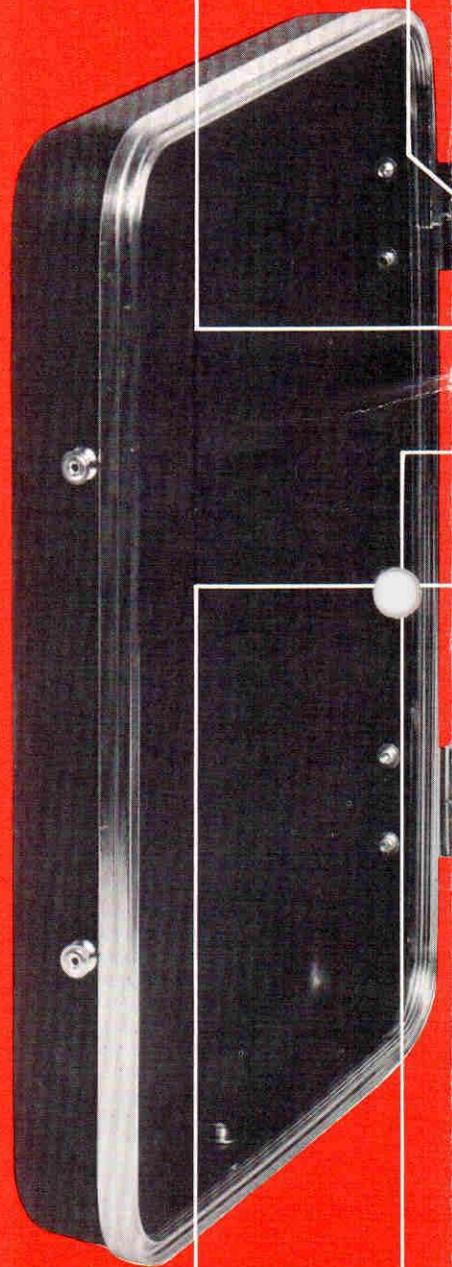
quantity and structure of the carbon compound present in the sample. The ionization current is amplified in a logarithmic electrometer preamplifier, the output of which varies as the logarithm of the input. This logarithmic feature enables measurement and readout of ionization rates over a range of up to five (5) decades (1 to 100,000) without range scaling. The output signal from the preamplifier is fed to the signal conditioning and control circuits for subsequent readout and alarm signaling.

A fuel handling system including storage tank, valves, regulators and gauges is incorporated to maintain the small hydrogen flame jet in the chamber. The instrument response is read on a hand held meter assembly or can be read out utilizing the external monitor signal. An audible detection alarm is provided which can be pre-set to any desired level and which has a frequency modulated tone which varies as a function of the signal level. The standard instrument includes an audible flame out alarm, battery test indicator and internal electronic calibration. The internal electronic calibration provides reference signals which are used in conjunction with a panel mounted gas selector adjustment to readily change the instrument calibration from one gas to another.

Since the response of the instrument is dependent upon the chemical nature of the material being analyzed, it is necessary to calibrate the device with a standard sample of that particular organic vapor. However, the approximate response of the instrument to hydrocarbons or compounds containing halogens, oxygen, or nitrogen can be *estimated* from the structure of the compounds and utilization of empirical data. The internal electronic reference signals are provided so the operator can readily recheck the instrument response from the point of ion collection to the readout meter.

This switch is used to introduce the HIGH or LOW calibration signals.

This switch turns on power to the internal pump.



A ten-turn dial readout potentiometer is used to set a predetermined calibration reference level for electronic calibration.

This switch is used to turn on all instrument electrical power except the pump power and also to display the battery charge condition.

alyzer protects you and the environment

A low pressure gauge is used to monitor the hydrogen pressure at the capillary restrictor.

This valve is used to supply or close off the hydrogen fuel to the detector chamber.

This control is used to adjust the instrument electronic calibration.

A high pressure gauge measures the pressure in the hydrogen fuel tank which is an indication of fuel supply.

This valve is used to supply or close off the fuel supply from the hydrogen tank.

This connector is used to connect the battery pack to the battery recharger assembly.

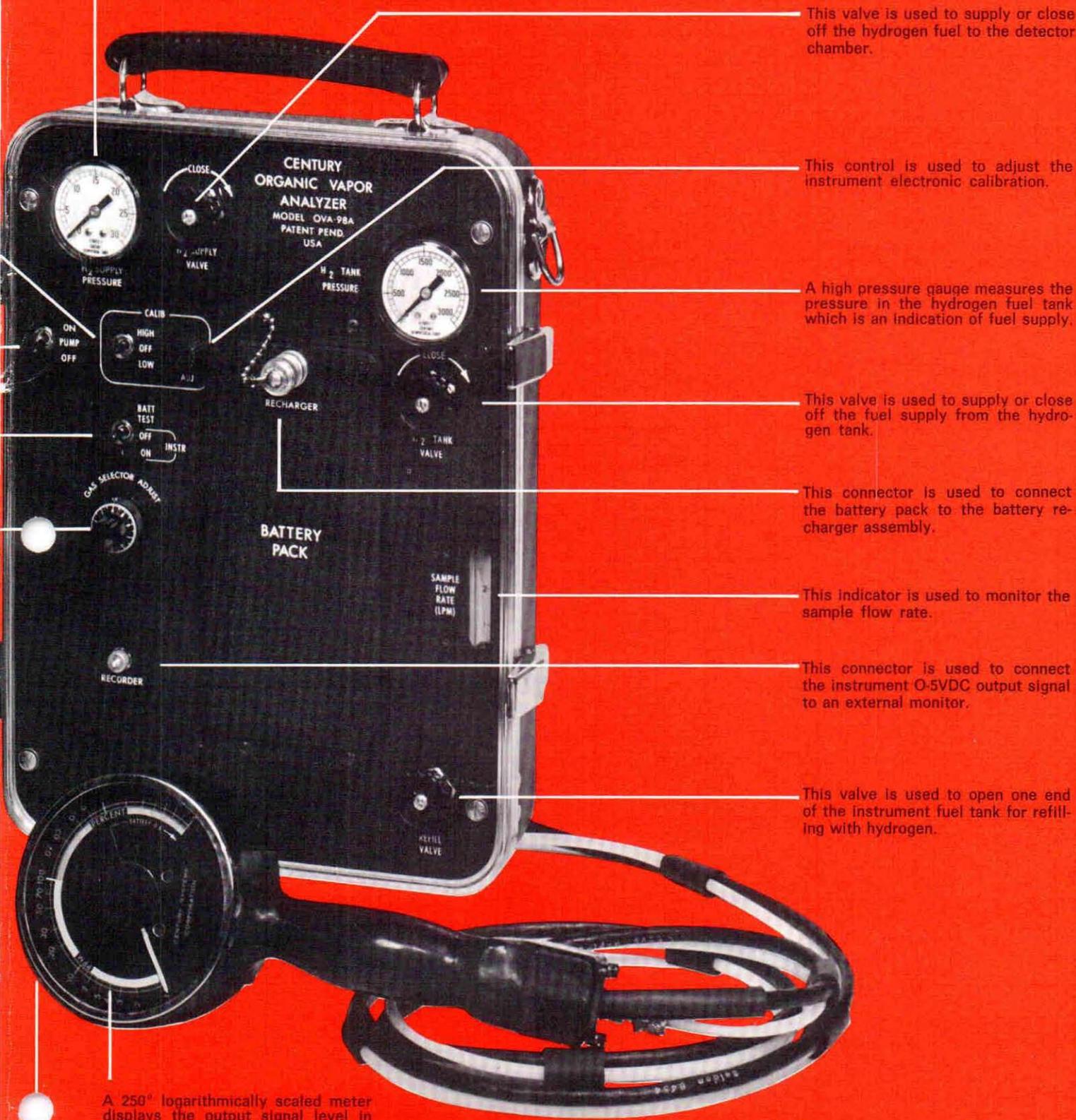
This indicator is used to monitor the sample flow rate.

This connector is used to connect the instrument 0-5VDC output signal to an external monitor.

This valve is used to open one end of the instrument fuel tank for refilling with hydrogen.

A 250° logarithmically scaled meter displays the output signal level in ppm or percent.

A potentiometer on back of meter is used to set the vapor detection level at which the audible alarm is actuated.

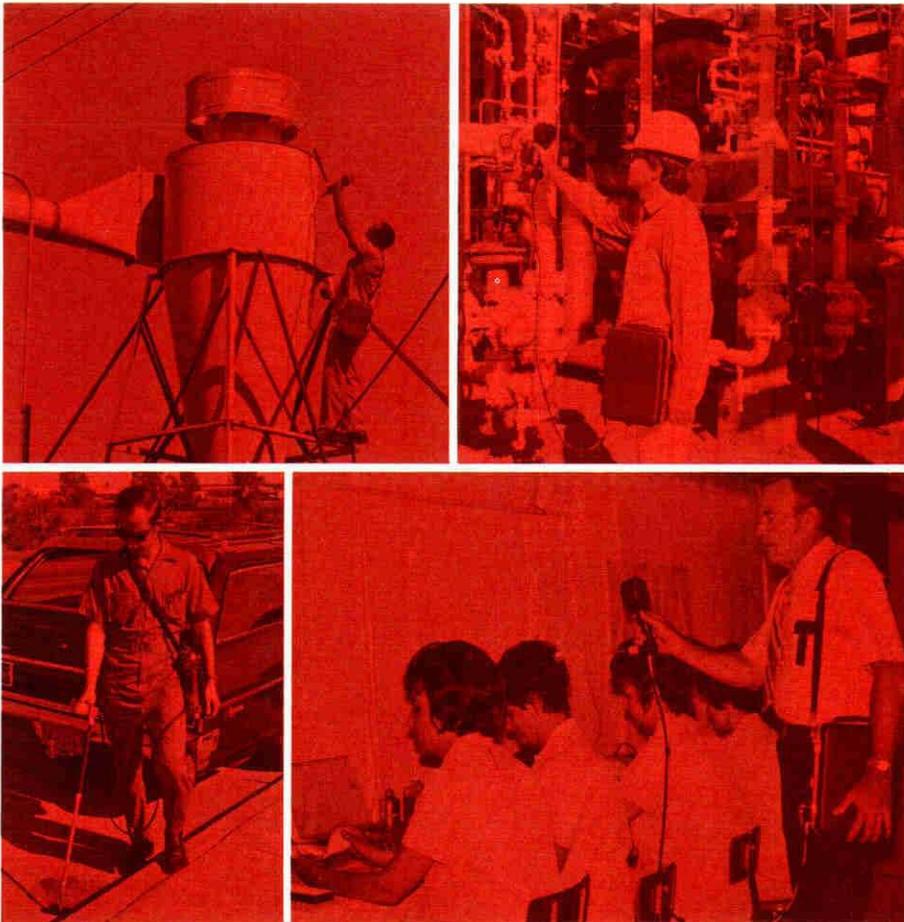


APPLICATIONS

- (1) Measurement of most toxic organic vapors present in industry for compliance with OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA) requirements.
- (2) Survey of gas distribution and transmission lines and equipment for compliance with OFFICE OF PIPELINE SAFETY (OPS) requirements.
- (3) Various measurement and monitoring applications in the air pollution field.
- (4) Leak detection in gas handling equipment.
- (5) Detecting explosive-level gas conditions in indoor and outdoor locations.
- (6) Measurement of methane in underground mines.

OTHER TYPICAL USES

- (1) Controlling and monitoring atmospheres in manufacturing and packaging operations.
- (2) Mudlogging, gas and mineral exploration.
- (3) Leak detection related to volatile fuel handling equipment.



CENTURY SYSTEMS CORPORATION

P.O. BOX 133 • ARKANSAS CITY, KANSAS 67005 • PHONE (316) 442-4500

SPECIFICATIONS

Sensitivity:	1 ppm (methane)
Response time:	Less than 2 seconds
Readout:	250° logarithmic scaled meter, various scales in the range of 1-100,000 ppm. External monitor connector.
Sample flow rate:	Nominally 2 liters per minute.
Fuel supply:	75 cubic centimeter tank of pure hydrogen at max. pressure of 2300 PSIG, fillable while in case.
Primary electrical power:	Rechargeable and replaceable battery pack, at 12 VDC.
Service life:	Hydrogen supply and battery power — 8 hours operating time minimum.
Size:	Side Pack Assembly 8 ⁵ / ₈ " wide x 11 ⁵ / ₈ " long x 4 ¹ / ₄ " deep. Probe/Readout Assembly — variable
Weight:	Side Pack Assembly — less than 9 pounds. Probe/Readout Assembly — less than 2 Pounds.
Operator requirements:	One man, one hand operation.
Detection alarm:	Frequency modulated audible alarm. Can be pre-set to desired level. Frequency varies as a function of detection level.
Flame-out indication:	Audible alarm plus visual meter indication.
Battery test:	Battery charge condition indicated on readout meter or battery recharger.
Pickup fixtures:	Variety of types for various applications.
Probe:	Telescoping adjustment over 8 inches or probe can be completely removed from Readout Assembly.
Umbilical cord:	Five (5) feet long with connectors for electrical cable and sample hose.
Filtering:	In-line disposable and permanent particle filters and optional activated charcoal filter.
Side pack case:	Molded high impact plastic case with carrying handle and shoulder strap.
Standard accessories:	1) Instrument carrying and storage case. 2) High pressure fuel filling hose assembly. 3) A.C. Battery charger.



The Gow-Mac Model 23-500 Total Hydrocarbon Analyzer is designed and engineered to continuously measure low levels of hydrocarbons normally encountered in ambient-air monitoring and automobile-exhaust analysis, as well as vapor streams. It utilizes solid-state electronics for reliability, as well as features usually found in more expensive instruments.

Principle of Operation

The Model 23-500 utilizes the flame ionization method of detection. The sample is mixed with hydrogen and burned in air. Ions and electrons formed in the flame enter a gap between two electrodes and decrease the gap resistance permitting a current to flow in the external cir-

cuit. Since the FID detector is particularly not responsive to air or water, it makes an ideal detector for air pollution analysis.

The size of the electrometer signal is in direct proportion to the number of carbon atoms in the flame at a particular instant. The low noise electrometer amplifier amplifies the small current signals from the detector and converts them to a millivolt signal to be indicated on the meter or potentiometric recorder.

The instrument measures total hydrocarbons in a range of 0-2 ppm CH₄ (methane) with a response time of several seconds up to 90% full scale. It's use with the GOW-MAC Model 13-750 Selective Combustor

makes an ideal instrument for air and emission monitoring by continuous monitoring of hydrocarbons, hydrocarbons less methane, and zero readings during the combustor cycle.

Selective Combustor Accessory

This unit consists of a combustor assembly, control module and a timer.

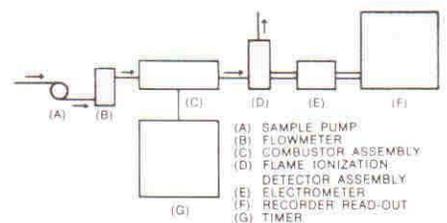


FIGURE 9 -- TOTAL HC ANALYZER, BENCH

The catalytic element is inserted in the sample train. With no power applied the analyzer reads the total hydrocarbons present in the sample. The temperature then is raised high enough to burn all of the hydrocarbons except methane. This yields a lower trace. The temperature then is raised high enough to burn all hydrocarbons present including methane. This is essentially the baseline or zero hydrocarbons. The system operates on a timed cycle of different combustion temperatures. A typical trace during such a time cycle is shown below. Note the change in other hydrocarbons (other HC) and the rather constant amount of CH₄.

Specifications

Model 23-500

Sensitivity — Full scale less than 2 ppm CH₄

Response — 90% in less than 5 seconds with by-pass regulation

Output — Recorder output terminals provided with 0-1 mV or 0-10 mV — Panel meter, 0-5 mV

Safety — Equipped with flame-out indicator light and flame arrestors on fuel and air lines

Operation — Minimum controls with pressure gauges for sample, air, fuel (H₂) included. Large meter, wide dynamic range, easily accessible for maintenance

Electrometer-Amplifier — Junction field effect transistor differential amplifier

Noise — At maximum sensitivity $\pm 2 \mu\text{V}$

Dynamic Range — 5×10^5

Flame Ionization Detector — Forced air diffusion design Linearity 1×10^6

Warranty

Workmanship and materials of Gow-Mac Instruments are of the highest commercial quality. Cells and detectors are guaranteed as to workmanship and material for 90 days; panel instruments for one year. The warranty is not valid if the user does not follow Gow-Mac's instructions for use or modifies the apparatus in any way.

Ordering Information

Instrument — Model 23-500 Hydrocarbon Analyzer

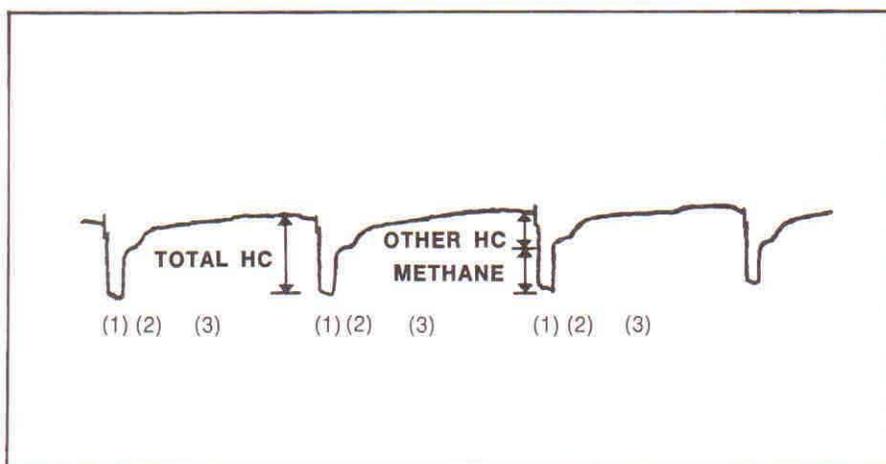
Accessories — Model 13-750 Selective Combustor complete or 13-750 Combustor only.

Pump Assembly

By-pass option

F.O.B. Madison, New Jersey

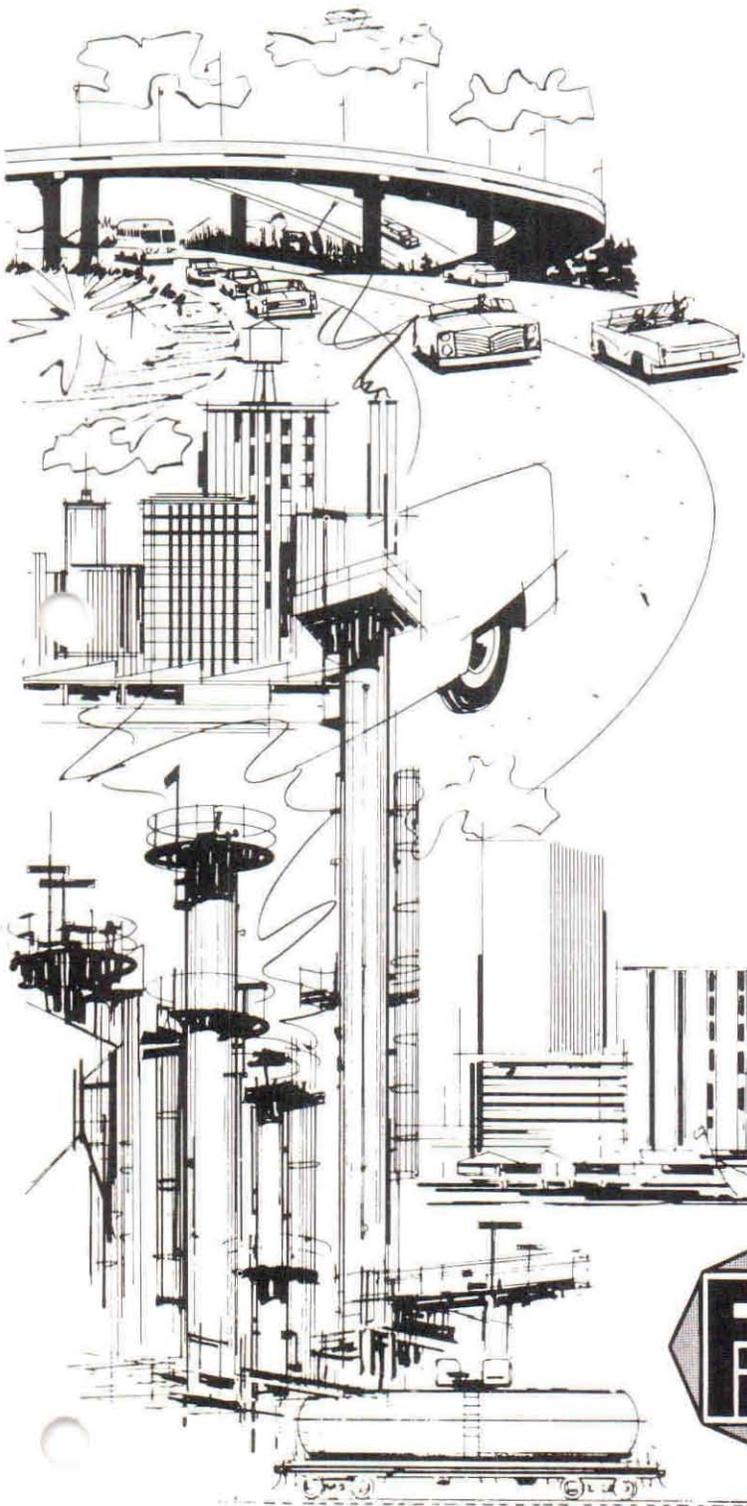
Terms: Net 30 days





Total Hydrocarbon

MONITOR



A fast, efficient, reliable instrument for monitoring hydrocarbons



PROCESS ANALYZERS, INC.

MANUFACTURERS OF ANALYTICAL PROCESS INSTRUMENTS
6400 SOUTHWEST FREEWAY, SUITE 400 HOUSTON, TEXAS 77036
TELEPHONE (713) 782-0820

FIGURE 10 -- TOTAL HC ANALYZER, SEMI-PORT



Total Hydrocarbon MONITOR

Process Analyzer's Total Hydrocarbon Monitor is truly a unique instrument, designed to be easy to use, economical, and extremely sensitive to monitoring and detecting both trace and higher levels of hydrocarbons in the atmosphere, vapors and process streams.

The detecting system is based on the ionization of carbon atoms in a hydrogen flame. Detection is specific to such carbon containing compounds as alkanes, aldehydes, alcohols, acetates, amines, aromatics, ketones, chlorinated hydrocarbons, etc.

USES

Air Pollution

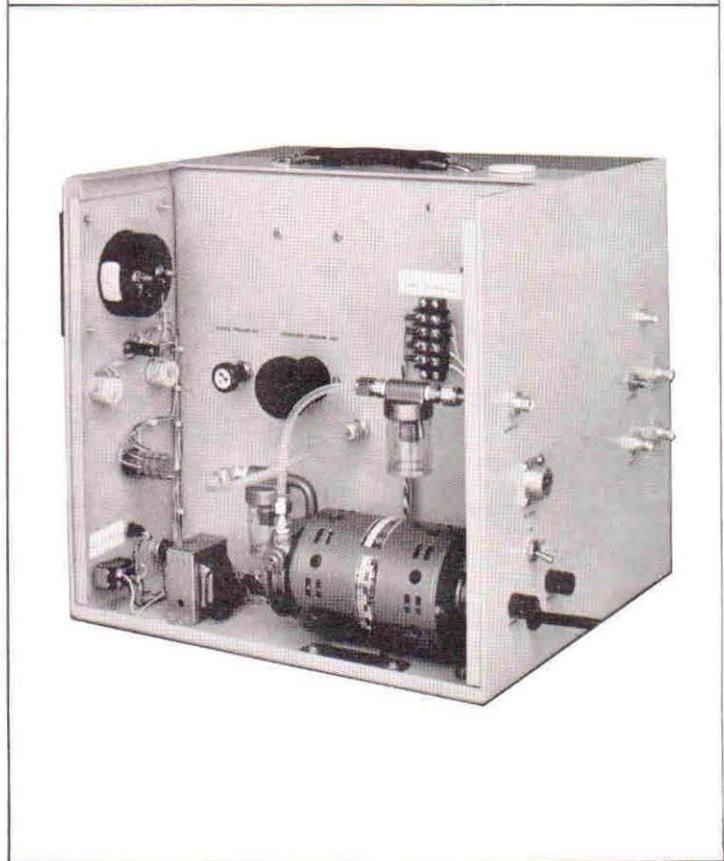
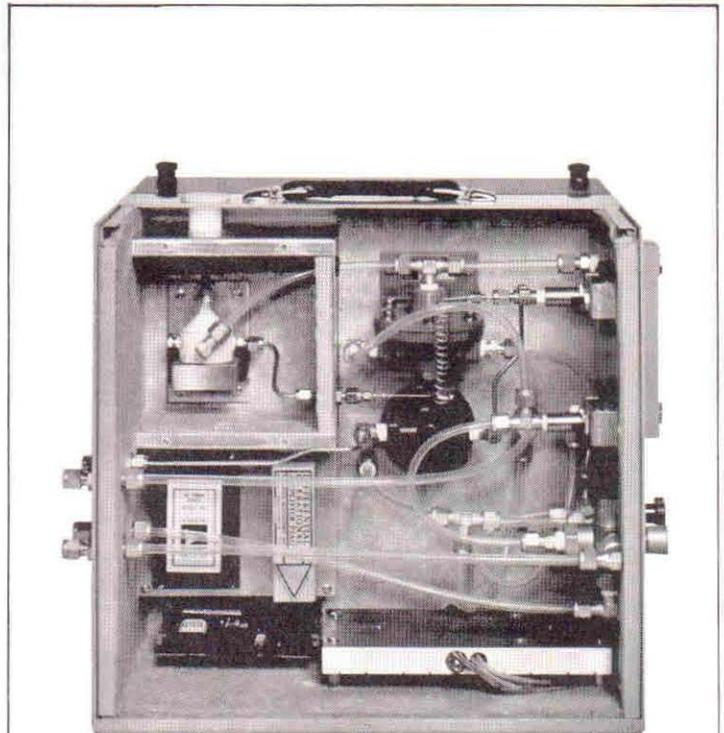
- Measuring combustion engine efficiency
- Detecting hydrocarbons in the atmosphere
- Measuring muffler and afterburner efficiency

Process Monitoring

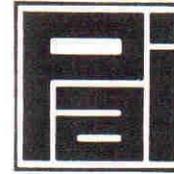
- Monitoring all types of hydrocarbon processes, including methanol converters, methane reformers and other off gases.
- Monitoring hydrocarbon content of controlled atmospheres.
- Transistor packaging
- Determining purity of inert gas streams
- Detecting hydrocarbons in "clean" atmospheres
- Monitoring gas conditions in tunnels and garages.
- Detecting dangerous natural gas leaks
- Control of solvent recovery systems
- Monitoring hydrocarbon concentrations in fuel handling areas.
- Detecting hydrocarbons in liquid and breathing oxygen.

OTHER USES

- Detecting volatile hydrocarbons in drilling muds
- Measuring "explosiveness" of swamp seepage
- Monitoring annealing and brazing atmospheres



How PAI's Total-Hydrocarbon Monitor Operates



PAI's Total Hydrocarbon Monitor is designed to be a versatile, yet easy-to-use, sensitive and efficient instrument.

Versatility is built into the instrument by the incorporation of a unique sampling and detecting system. Based on the standard theory of the ionization of carbon in a hydrogen flame, the detection system is an ion scavenging system. This allows the detector to monitor both extremely low and high levels of hydrocarbons. The entire supply of sample withdrawn from the atmosphere is exposed to the detector. The use of an extremely reliable downstream flow controller, located in a well insulated, constant temperature atmosphere, maintains a constant flow rate to the detector. A sample flow rate, ranging from 250 cc to 10,000 cc per minute, can be realistically used. This highly dynamic flow rate manifests itself, in allowing the instrument to be ultra-sensitive to low concentrations at high sample flow rates and, also permits the monitoring of relatively high concentrations, with a minimum of range attenuations, hence the lower cost.

Extra economy is also realized. As a result of the sampling system design, the only cost of operation is the power and an H_2 source. Due to the unique design of the detector, it is not necessary to maintain a specific flame temperature. As a result, a blended fuel is not necessary. The "total" design of the sample system and the detector results in an intrinsically easier instrument to operate and maintain.

The sensitivity and stability of the instrument is greatly enhanced by locating the electrometer and the flow control systems in an insulated, constant temperature atmosphere. This allows the detector to be operated at an elevated temperature, if required. By placing the most critical parts of the instrument in constant temperature zones, they are isolated from ambient conditions, thus adding another dimension to the reproducibility of the instrument.

The advanced circuitry and constant temperature effects enables the unit to be essentially drift-free, and therefore can operate for extended periods of time without need for zero reset.

OTHER PAI PRODUCTS INCLUDE:

PROCESS CHROMATOGRAPHS—single or multi stream which monitor from one to fifteen individual components.

TITRILOG II—monitors oxidizable sulfur compounds in the atmosphere, in gas streams, and in stack gases.

TITRILOG III—monitors sulfur dioxide and/or H_2S in the atmosphere.

CALORIMETER—measures the BTU content of a gas.

STACK GAS ANALYSIS—System capable of determining characteristics of stack effluent.

GRAVITOMETER—determines the Specific Gravity of various gas streams.

Total Hydrocarbon Monitor

Additional Data

The following gases are required for the calibration and subsequent operation of the PAI Total Hydrocarbon Monitor.

- Ultra-pure H₂ — Less than .1 ppm Methane desirable.
- Zero Air — Less than 1.0 ppm Methane acceptable.
- Calibration Gas — Less than .1 ppm Methane for air pollution
- For desired range

PAI's Total Hydrocarbon Monitor can also be used for the monitoring of total hydrocarbons in process streams. An explosion-proof model is also available.

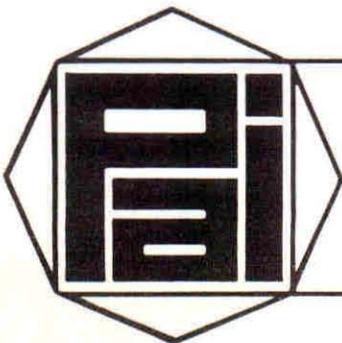
Specifications

Model 30-100 — Portable

- Zero — Manual
 - Ranges — Standard as Methane
 - 0-5
 - 0-10
 - 0-50
 - 0-100
 - other ranges available
 - Sample flow — rotometer
 - Electronics — Solid State
 - Noise Level — 1% of full scale
 - Calibration — Manual selection for zero and sample gas.
 - Ignitor — Manual
 - Power Requirements — 115 VAC 250 watts max.
 - Readout — 0-100 micro amps meter on front panel.
0-5 M.V. for potentiometric recorder.
 - Weight — 35 pounds
 - Response Time — Instrument — less than 1 second
Instrument and sampling system — typically 10-20 seconds.
- Sensitivity — 0.5 ppm carbon full scale
- Range — parts per million, as well as percent concentration, depending on analysis
- Reproducibility — $\pm 1\%$ with successive identical samples.

OPTIONAL ACCESSORIES

- Meter equipped with alarm contacts
- Multiple ranges
- 0-5 M.V. recorder
- Flame indicator
- Automatic relight
- Safety shut-off
- M.A. output
- Telemetry equipment



PROCESS ANALYZERS, INC.

MANUFACTURERS OF ANALYTICAL PROCESS INSTRUMENTS

6400 SOUTHWEST FREEWAY, SUITE 400 HOUSTON, TEXAS 77036
TELEPHONE (713) 782-0820

M-S-A TOTAL HYDROCARBON ANALYZER

... for continuous detection and measurement of trace concentrations of hydrocarbons in air, or in a variety of background gases

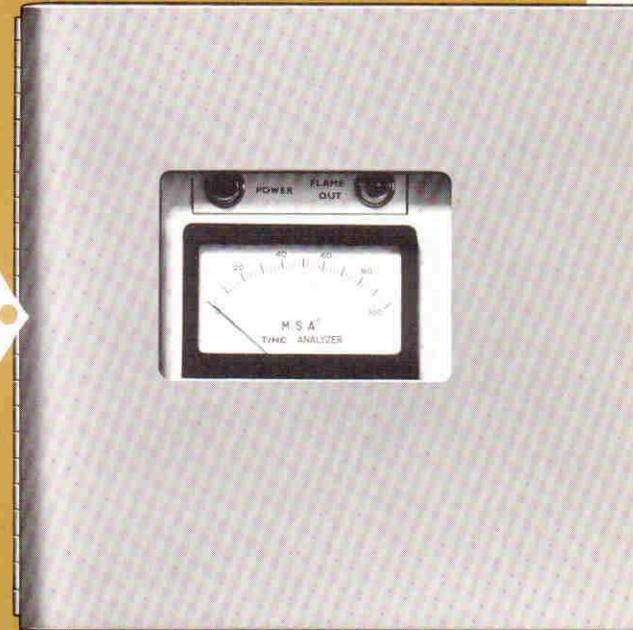


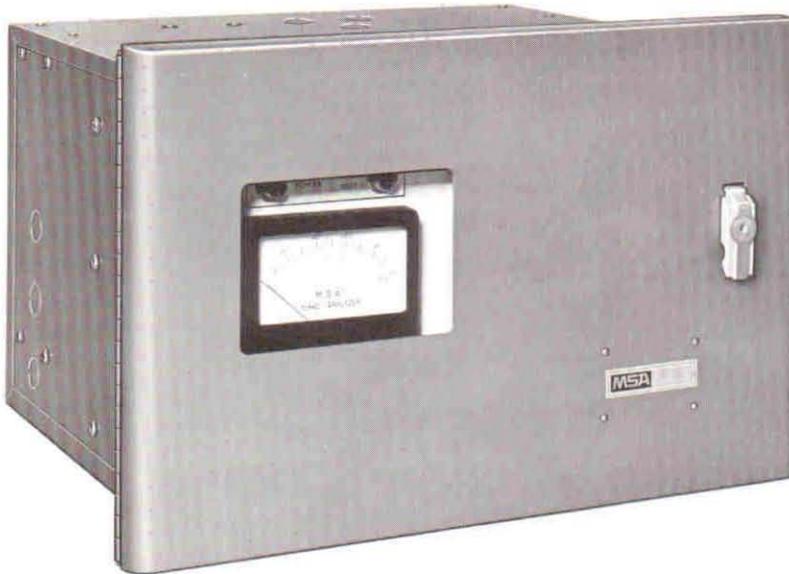
FIGURE 11 -- TOTAL HC ANALYZER, PANEL

C-25

M-S-A TOTAL HYDROCARBON ANALYZER

... accurate, sensitive, low level (ppm) gas evaluation

The M-S-A Total Hydrocarbon Analyzer is a continuous, low level (0-4ppm) monitoring instrument designed to detect and measure trace contaminants in various atmospheres. Compact, sensitive and reliable, the Analyzer finds particular effectiveness in applications as divergent as:



Air Pollution

Detecting hydrocarbons as atmospheric pollutants.

Measuring automobile exhausts for hydrocarbon emission.

Safety

Monitoring atmospheres for toxic materials (personnel protection).

Monitoring gas mains, sewers, tunnels, garages, etc., for flammable gases or vapors.

Monitoring fuel handling or storage areas for leakage.

Monitoring plants for toxic concentrations of solvents, paint vapors and the like.

Process and Industry

Leak detection in aerosol packing, storage or equipment areas.

Measuring "off gases" for hydrocarbon content and purity of inert and LOX streams.

Monitoring combustion efficiency, detecting refrigerant leakage, etc.

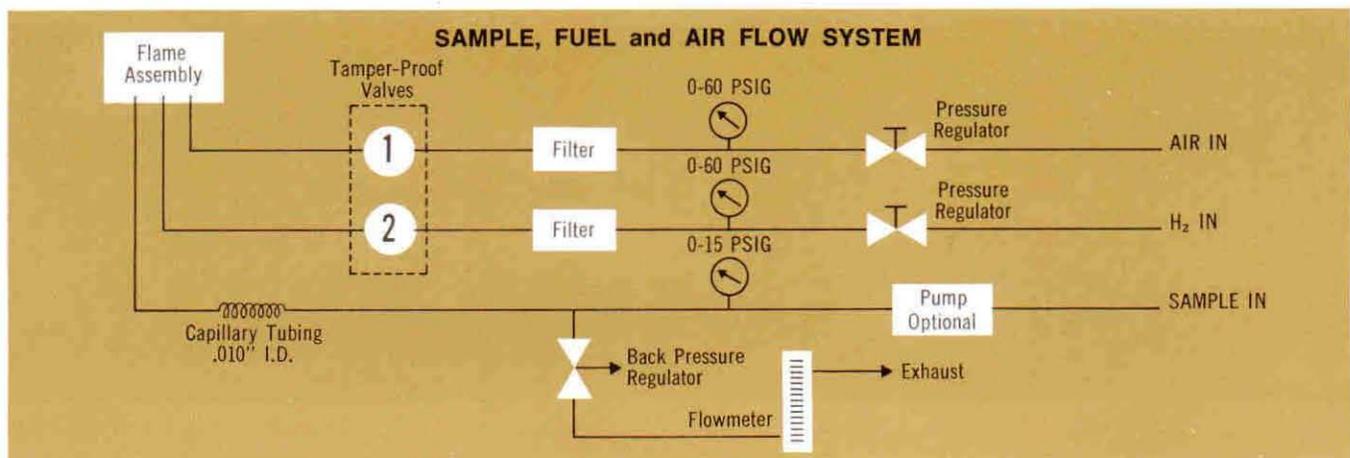
HERE'S HOW MSA'S TOTAL HYDROCARBON ANALYZER OPERATES

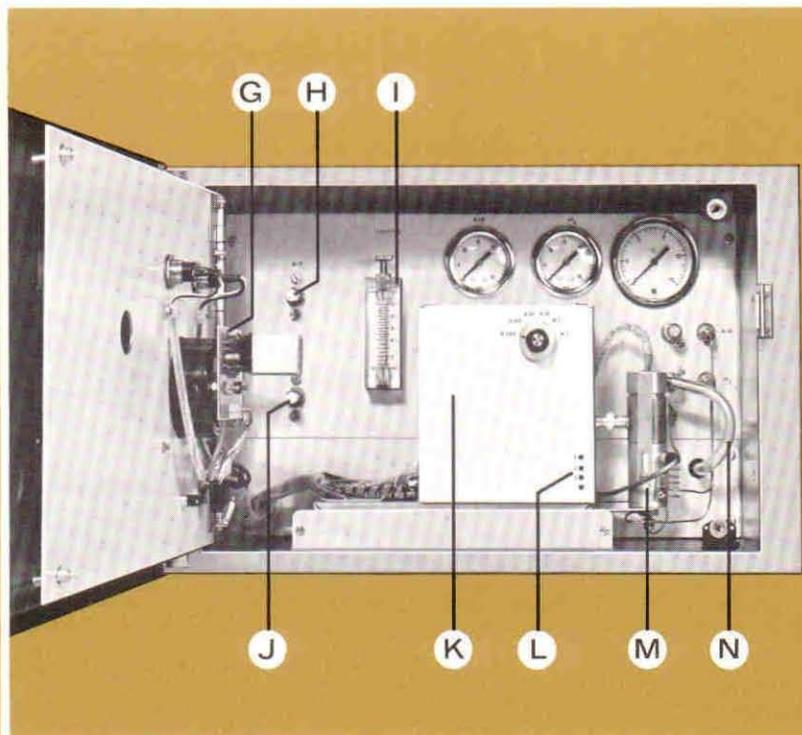
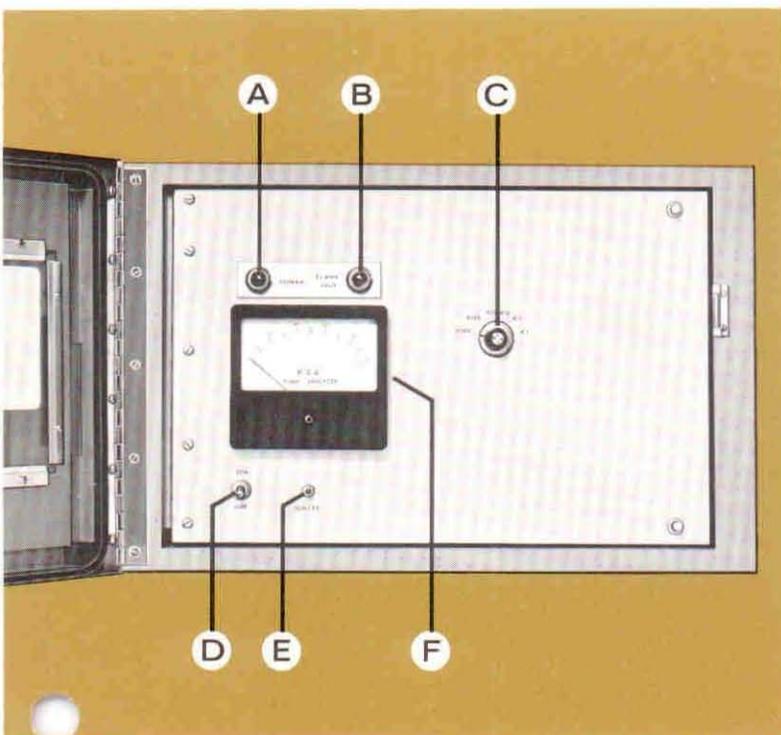
The M-S-A Total Hydrocarbon Analyzer is composed of four elements:

- Sample flow system
- Combustion gases system
- Burner assembly
- Electrometer and power supplies

Its operation is based on the ionization of carbon atoms in a hydrogen flame. Normally, a flame of pure hydrogen contains an almost negligible number of ions. Adding organic compounds—even traces—results in a large number of ions in the flame.

In the Analyzer, the sample to be analyzed is mixed with a hydrogen fuel and passed through a small jet; air supplied to the annular space around the jet supports combustion. Any hydrocarbon carried into the flame results in the formation of carbon ions. An electrical potential across the flame jet and an "ion collector" electrode suspended above the flame produces an ion current proportional to the hydrocarbon count. This is measured by an electrometer circuit whose output then provides an analysis signal for the direct reading meter, or for an optional potentiometric recorder.





M-S-A TOTAL HYDROCARBON ANALYZER...

FEATURES

Maximum Sensitivity and Accuracy—yet easy to operate

Electric Range Attenuator—with change factors of X1, X3, X10, X30, X100, X300

Stabilized Zero Setting—unaffected by range change factors

Calibrated by Span Potentiometer—more accurate than adjustment by sample flow

Solid State DC Power Supply—no batteries to recharge or replace

Sintered Metal Filters—for sample, air and fuel capillary tubing

Optional Flame-Out Alarm and Automatic Fuel Shut-Off—for maximum safety

Optional Integral Pump—for greater efficiency, convenience and performance

CHARACTERISTICS

Full Scale Range—0-4 ppm by volume, expressed as methane

Sensitivity—1% of full scale range

Response—90% of final reading in one second or less

Drift—less than 1% of full scale range per 24 hours

Noise—less than $\pm 1/2\%$ of full scale range

Reproducibility—meter graduated from 0-100 for read-out of linear analysis signal. Single turn potentiometer (trim pot) provided to match analyzer signal to potentiometer-type recorder (0-5mv, 0-10mv, 0-50mv, 0-100mv).

CONTROLS

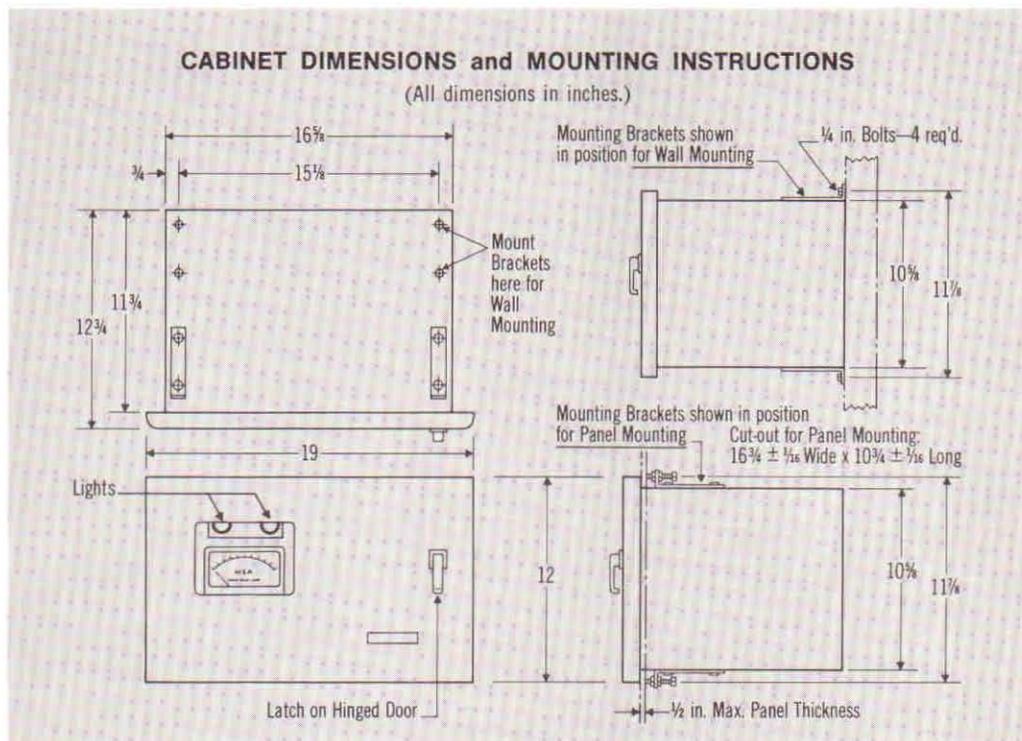
- A Pilot Light
- B Flame Out Light
- C Range Attenuator
- D On-Off Switch
- E Flame Ignition Control
- F Readout Meter
- G Flame Out Alarm Initiating Assembly
- H Air Pressure Regulator
- I Sample Flow Meter with Control Valve
- J H₂ Pressure Regulator
- K Electrometer Assembly
- L Zero Suppression and Span Controls
- M Burner Assembly
- N Burner Drain Tube

M-S-A TOTAL HYDROCARBON ANALYZER

SPECIFICATIONS

Construction—rugged, heavy gauge sheet metal cabinet with attractive lacquer finish

Weight—approximately 35 pounds



MSA INSTRUMENT DIVISION
MINE SAFETY APPLIANCES COMPANY • 201 N. BRADDOCK AVE., PITTSBURGH, PA. 15208

BOSTON • CLEVELAND • CHICAGO • PHILADELPHIA • ATLANTA
LOS ANGELES • NEW YORK CITY • PITTSBURGH • SAN FRANCISCO
DETROIT • HOUSTON • WASHINGTON, D. C. • LOUISVILLE • ST. LOUIS

Mine Safety Appliances Co. of Canada, Ltd., DOWNSVIEW, ONTARIO (METRO TORONTO)

J-W MERCURY VAPOR SNIFFER

Model MV-2

MERCURY HAZARDS

Mercury amalgamates with gold, silver, nickel, stainless steels and copper alloys. Accidental trapping of mercury can cause serious damage to vital parts in electronic equipment, reactors and delicate instruments.

Mercury is also toxic if inhaled, ingested, or absorbed through the skin or eyes. The limits of human tolerance to toxic gases are under constant review by the American Conference of Governmental Industrial Hygienists. The safe upper limit of airborne concentration for extended periods, based upon an exposure of 8 hours per day, is known as the Threshold Limit Value (TLV). The generally accepted TLV for mercury vapor is 0.05 milligrams/cubic meter of air (approximately 0.005 ppm). When mercury is exposed to air, mercury vapor concentrations considerably higher than TLV can be encountered.

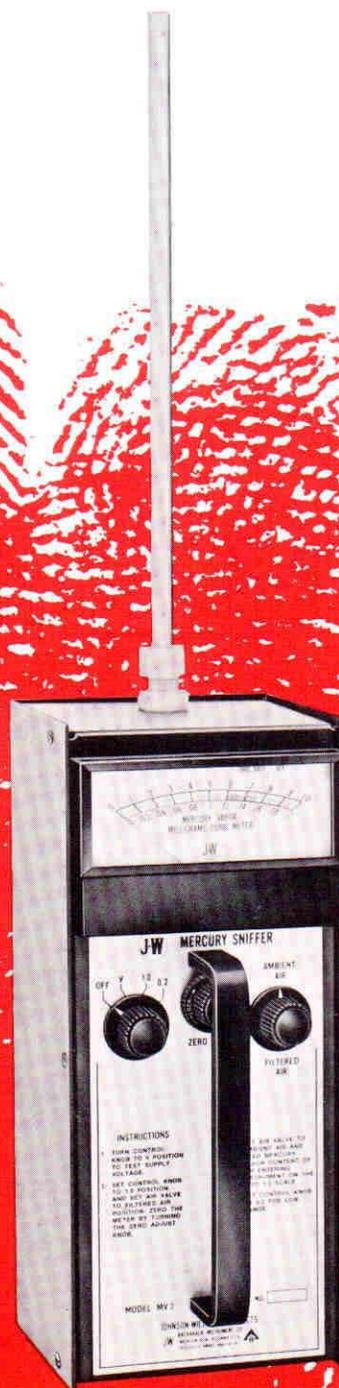


FIGURE 12 -- MERCURY VAPOR DETECTOR

J·W MERCURY VAPOR SNIFFER

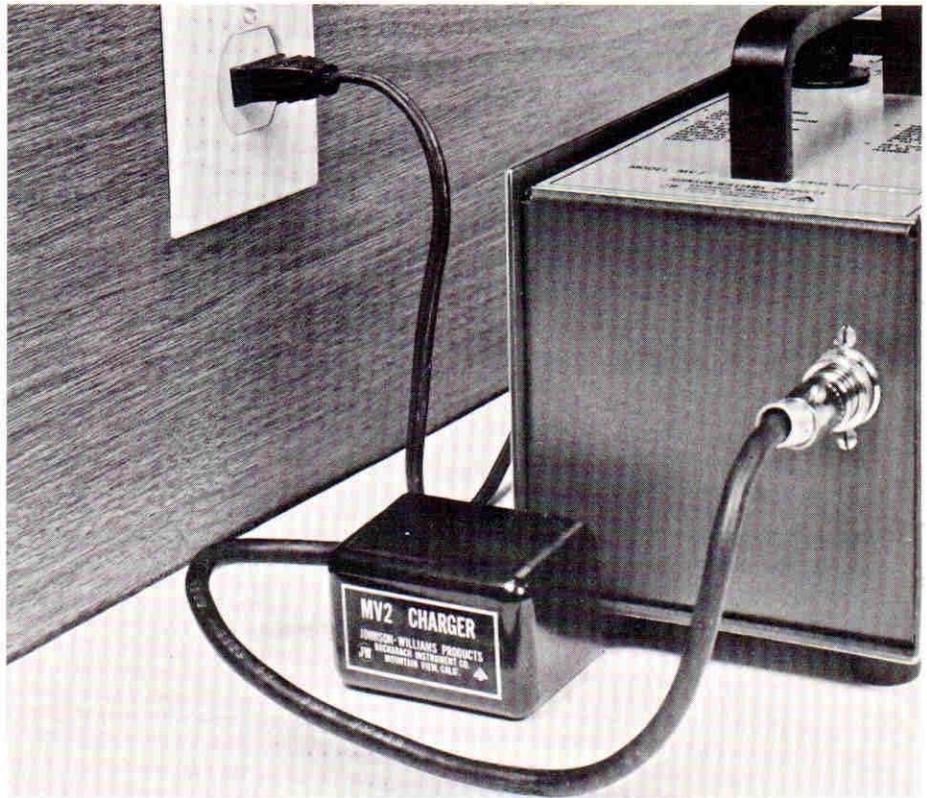
PRODUCT FEATURES

- Lightweight, battery operated—may be carried in one hand.
- 12-inch probe facilitates checking in hard-to-reach places.
- Solid-state electronics—for greater reliability.
- Dual range—low range for toxicity and contamination investigation; high range for pinpointing mercury vapor sources.
- Built-in filter—permits accurate zero adjustment, even in a contaminated atmosphere.
- Direct reading—no conversions or charts needed.
- Eliminates need for time-consuming laboratory analysis.
- Long-life UV source—for dependable operation.

DESCRIPTION

Calibrated in milligrams/cubic meter, the Model MV-2 Mercury Sniffer is a compact, self-contained and completely portable instrument. The indicating meter, controls and carrying handle are mounted in the top cover. A slip-on connection is provided in the end of the case, to accommodate an extension probe. In addition, a length of $\frac{3}{8}$ " diameter flexible tubing may be connected to the probe, for greater convenience when checking floor areas or gratings.

An advanced solid-state voltage regulator fully compensates for changes in battery voltage. An integrated circuit amplifier promotes temperature stability. The internal nickel cadmium battery is rechargeable from an encapsulated, automatic plug-in battery charger. The operating time between chargings is approximately 4 hours. Warm-up time is about five minutes and direct readings are indicated on a two-scale, easy-to-read meter. A selector switch routes the sample through an internal filter, which removes all mercury vapor and allows the meter reading to be accurately set to zero—even in a contaminated atmosphere.



OPERATING INFORMATION

The sample is drawn into the detector and through the absorption chamber, by a small motor driven suction fan, powered by the battery. All that is required to put the detector into operation is to check the battery voltage, turn the control knob to the desired range, adjust the meter zero on filtered air and then read the mercury vapor concentration from the meter.

PERFORMANCE CHARACTERISTICS

The sample is passed through an absorption chamber. A selective 253.7 milli-microns ultraviolet light source is located at one end of the chamber and, at the other end, a photoresistive element measures the intensity of radiation passing through the intervening space. The presence of mercury vapor will reduce the radiation energy reaching the photoresistive element, in proportion to the vapor concentration. The optical system is designed specifically to detect mercury, which has a strong absorption line in the ultraviolet

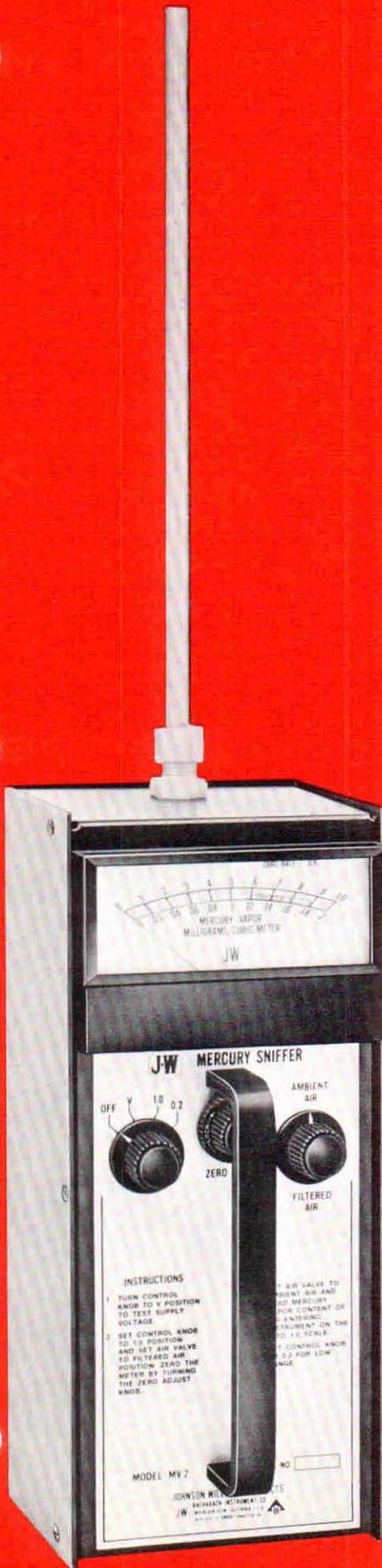
region of the spectrum.

An inverter circuit provides high voltage AC power to excite the mercury vapor UV lamp.

The measuring circuit utilizes a Wheatstone bridge, in which one arm is the photoresistive element. The amount of radiation transmitted through the absorption chamber causes a change in the photoresistive element to unbalance the bridge and deflect the meter.

PERFORMANCE DATA

A continuous indication of the mercury vapor concentration in the air being sampled is presented by the meter. The electronic circuitry is fully compensated for changes in voltage, within the limits of the battery capacity. The vapors of some organic compounds such as benzene ring compounds, halogenated hydrocarbons and particulates absorb ultraviolet light at the lamp frequency. Normally this slight interference does not present a problem.



APPLICATIONS

The Model MV-2 Mercury Sniffer is primarily used to assure safe working conditions in environments where mercury is produced, processed or stored. It has been estimated that mercury, or its compounds are used in over 80 industries, including:

- Mining and refining of cinnabar and gold and silver ores.
- Manufacture of scientific instruments—flow meters, level regulators, manometers, thermometers and barometers.
- Manufacture and repair of electrical meters, mercury arc rectifiers and dry-cell batteries.
- Mercury cell chlor-alkali plants.
- Electronic assembly—neon signs, mercury arc lamps and electronic tubes.
- Nuclear ion propulsion and research facilities.
- Manufacture of mercury compounds for treatment of fungus diseases of plants and as a preservative of textiles and wood.
- Production of marine anti-fouling agents in paint.
- Manufacture of mercury fulminate for making detonators and percussion caps.
- Pharmaceutical plants—surgical dressing and pharmaceutical compounds.
- Pulp and paper manufacture.
- Chemical, dental and hospital laboratories—Coulter counters, Van Slyke blood gas apparatus, Cantor and Miller-Abbott tubes.
- Manufacture of catalysts.

SPECIFICATIONS

Function	Surveying atmospheres for Hg concentrations considerably below and above the accepted TLV
Detector	Ultraviolet photometer
Measuring Ranges	0-0.2 and 0-1.0 mg/m ³
Sensitivity	>0.01 mg/m ³
Repeatability	±5% FSD
Battery	12 volt Ni-cad rechargeable
Battery Life	4 hours under normal usage between charge
Construction	Rugged, re-inforced metal instrument case with silver anodized front panel
Dimension	Instrument 11 ³ / ₈ " x 4 ³ / ₄ " x 4 ³ / ₈ " Probe 12" long x ³ / ₈ " OD
Weight	6 lb.

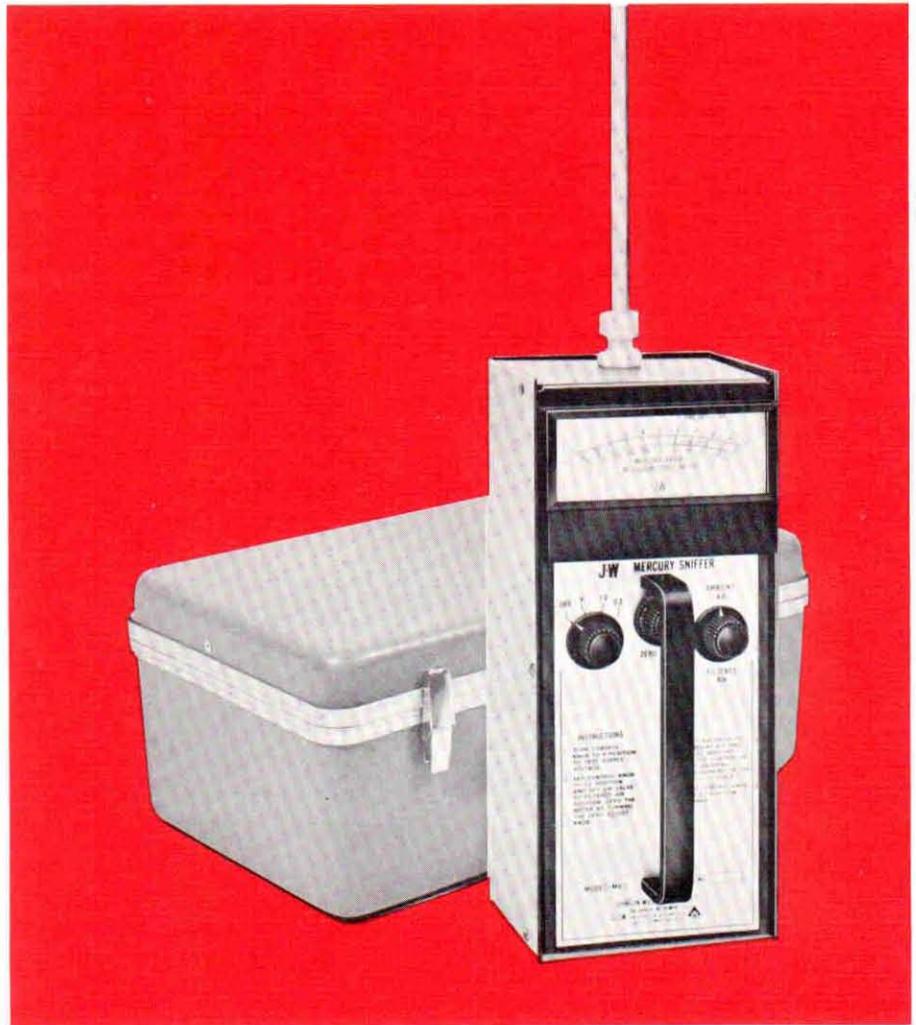
ORDERING INFORMATION

J-W Stock No.	Description
571-002	Model MV-2 complete with rechargeable battery and probe
360-220	Battery charger with cord and plug, 110 volts AC
340-186	Storage case, high impact ABS with light metal trim and foam rubber cushioning.

CONTINUOUS MONITORING SYSTEMS

Single channel and multiple channel mercury vapor monitoring systems are specifically engineered to meet individual requirements. Detection ranges can be selected to provide practical density levels for toxicity and contamination measurements. Alarm settings are adjustable. Sampling distances may be up to 500 ft. Bacharach also manufactures field and laboratory geochemical exploration instruments, for determining the mercury content of rocks, soils and plants. Details on request.

J-W and SNIFFER are registered trademarks of Bacharach Instrument Company



BACHARACH INSTRUMENT COMPANY

A DIVISION OF **AMBAC** INDUSTRIES, INC.

625 ALPHA DRIVE, PITTSBURGH, PENNSYLVANIA 15238 • 412/782-3500

Honeywell

UVH 15SP GAS & VAPOR DETECTOR

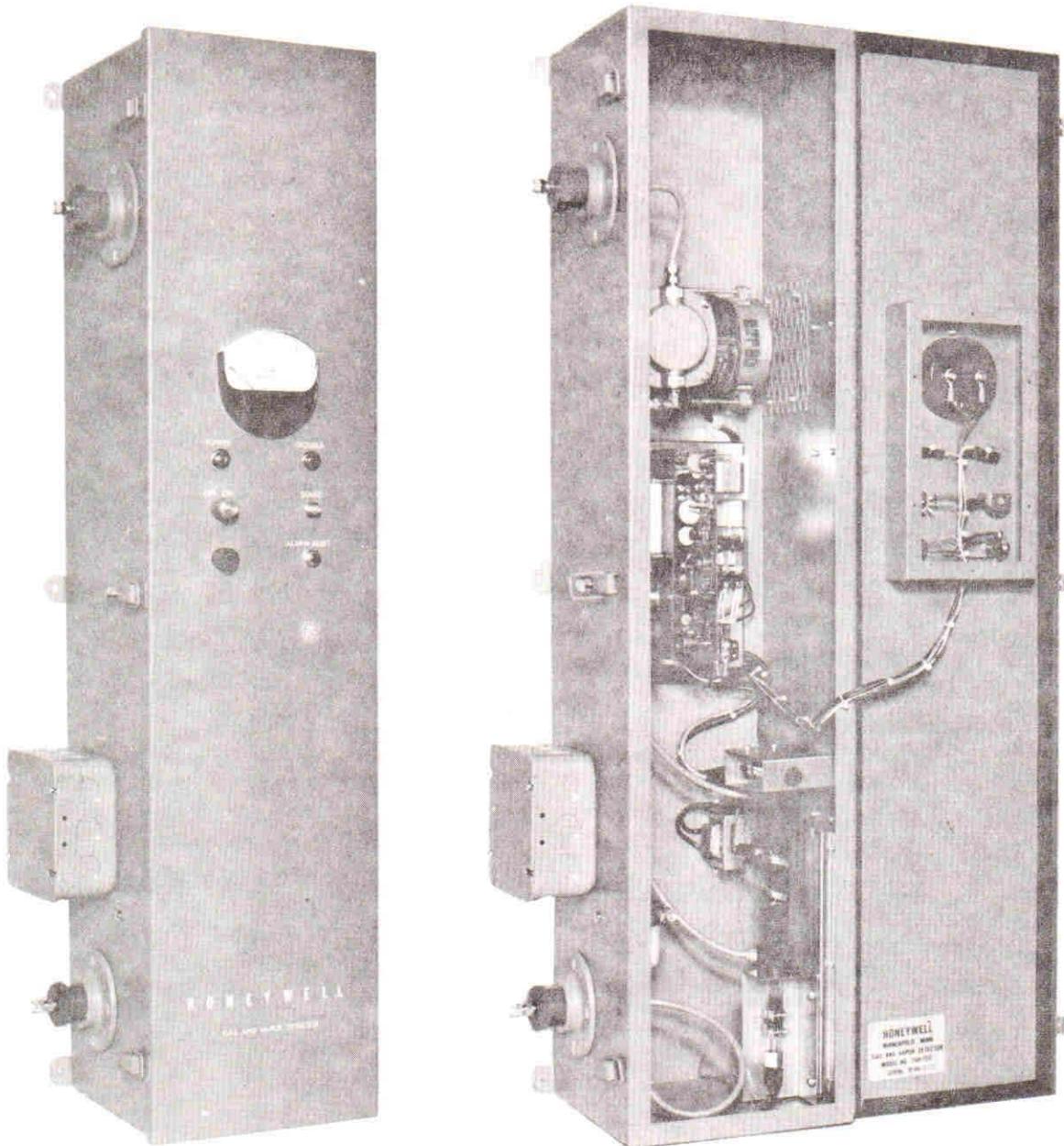


FIGURE 13 -- UV PHOTOMETER, PLANT

UVH-15S1 and UVH-15SP1 GAS and VAPOR DETECTOR

FEATURES

- Completely self-contained.
- Continuous monitoring of room atmosphere.
- Not influenced by carbon dioxide or nitrogen.
- Ultraviolet detection principle samples controlled atmosphere without conditioning it.
- Reliable solid-state circuitry for stability and maintenance-free operation.
- Standardization warning—Flashing amber light and relay for remote alarm; standardized by front panel knob.
- Rugged industrial case.
- Fail-safe—Relays de-energize to sound alarm; internal electrical failures also sound alarm.
- Readout meter for continuous indication of concentration.
- Easily attached to a recorder for a continuous and permanent record of concentration.
- Easy to install—Plant engineers, the maintenance shop, or local contractors or electricians can set it up.
- Multi-tap transformer—Input voltage is field selectable for 100, 120, 200, or 230 volts, 50 or 60 Hz.

SPECIFICATIONS

MODELS—

UVH-15SP1

Diaphragm pump with closed loop sampling. Vapors do not come in contact with internal components.

UVH-15S1

Blower Motor. Vapor passes through complete box.

INPUT VOLTAGE AND FREQUENCY—

100, 120, 200, 230 Vac, 50 or 60 Hz. Selected from a multi-tap transformer within the detector.

POWER CONSUMPTION—

60 Watts.

TROUBLE ALARM CONTACTS—

SPST, 1 Ampere.

RECORDER OUTPUT—

0 to 10 millivolts, linear; half scale equals 5 millivolt.

FINAL ALARM CONTACTS—

3PDT, 10 Amperes at 120 Vac isolated from detection circuit.

ALARM RANGE—

Half scale.

AMBIENT TEMPERATURE RANGE—

-20 to +120°F (-30 to +50°C).

BLOWER CAPACITY—

UVH-15S1 60 cfm with 0 inches of static pressure.

UVH-15SP1 1/6 cfm static pressure.

WIRING CONNECTIONS—

Terminal board in conduit box.

MOUNTING—

Lugs provided for use on wall or panel.

VAPORS DETECTED by UVH-15S1 and UVH-15SP1 GAS and VAPOR DETECTOR

You are invited to read this list. Perhaps in it you will find just the vapor you want to monitor or control. If so, drop us a line, spelling out your application. We are especially interested in the concentration (parts per million) desired to control. Note that this is only a representative list of detectable vapors; ask about other possibilities.

*Vapors or Gases	**Full Scale Sensitivity in PPM	*Vapors or Gases	**Full Scale Sensitivity in PPM	*Vapors or Gases	**Full Scale Sensitivity in PPM	*Vapors or Gases	**Full Scale Sensitivity in PPM
ESTERS		KETONES		ALKENES		MISC.	
ethyl acetate	1300	acetone	82	1-butene	102	1-nitropropane	12
amyl acetate	1050	methyl ethyl ketone	51	ethylene	1290	acrylonitrile	15
methyl methacrylate	6			1,3-butadiene	5	gasoline	15
CHLOROALKENES		ETHERS		*All concentrations are listed on a volume basis (not weight basis).			
trichloroethylene	9	ethyl ether	1160	**30" PATH LENGTH			
tetrachloroethylene	9	ACIDS		ORDERING INFORMATION ORDER FROM— 1. Local Honeywell branch office, distributor, or 2. Honeywell 1885 Douglas Drive North Minneapolis, Minnesota 55422 (In Canada, Honeywell Controls Limited 740 Ellesmere Road Scarborough, Ontario).			
HALOALKANES		acetic acid	990				
dichloromethane	540	ALCOHOLS					
chloroform	230	methanol	345				
carbon tetrachloride	140	n-butanol	140				
1, 2 dichloroethane	1030	isopropanol	630				
1, 2 dibromoethane	130	AROMATICS					
Freon 12 (CCl ₂ F ₂)	780	benzene	10				
INORGANIC GASES		toluene	10				
hydrogen sulfide	32	aniline	5				
nitrogen dioxide	190	nitrobenzene	11				
nitric oxide	1190	ALKANES					
sulfur dioxide	300	ethane	86000				
ALIPHATIC AMINES		n-heptane	13000				
n-butylamine	33	n-pentane	8800				
triethylamine	22						

PEERLESS MULTIPLE-GAS CONTINUOUS ANALYSIS SYSTEM

LABORATORY ACCURACY IN
SHOP, FIELD, AND VEHICLE USE

MEASURES UP TO FOUR
GAS CONCENTRATIONS IN
ONE SAMPLE SIMULTANEOUSLY
AND CONTINUOUSLY

ANALYZERS USE IR
OR UV OR BOTH,
DEPENDING ON
GASES MEASURED

RAPID RESPONSE AND
LOW GAS HANG-UP PERMIT
ON-STREAM USE



FIGURE 14 -- UV-IR PHOTOMETER, BENCH

APPLICATIONS

- STACK EMISSION
- EXHAUST EMISSION
- PROCESS CONTROL
- MEDICAL
- LABORATORY

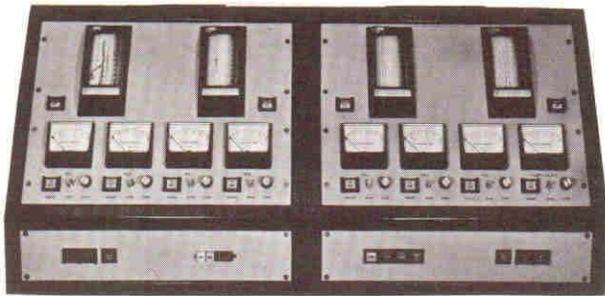
Peerless offers the following standard units and systems:

- 2-gas and 4-gas analyzers
- Long-cell analyzers (for low-concentration measurements)
- High-temperature units
- Vehicle emission analysis systems

Please fill in our "Applications Questionnaire", and we'll let you know if and how we can meet your requirements.

SYSTEMS ENGINEERING

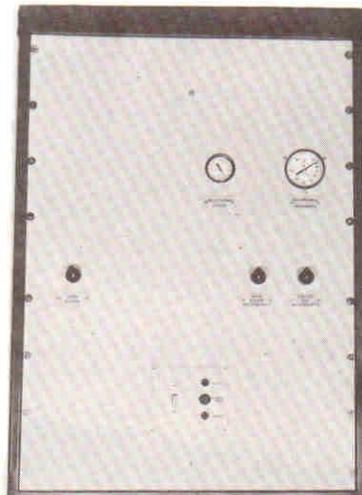
Peerless is prepared to engineer, manufacture, and install complete systems to your specifications.



REMOTE OPERATOR'S CONSOLE



ANALYZER/
MAINTENANCE
CABINET



DRYER

AUTOMATIC STACK EMISSION MONITORING SYSTEM



VEHICLE EMISSION
ANALYSIS SYSTEM
FOR FIELD USE



**PEERLESS MULTIPLE-GAS
CONTINUOUS ANALYSIS
SYSTEM**

**TWO-GAS ANALYZERS
209/210
FOUR-GAS ANALYZERS
405/406**



TWO-GAS ANALYZER 209 OR 210



FOUR-GAS ANALYZER 405 OR 406

Non-dispersive dual-beam infrared/ultraviolet analyzers for the measurement of two or four gas concentrations simultaneously and continuously in one sample.

Model	Meter Ranges	Method	
		IR	UV or IR/UV
Two-Gas Analyzer 209	Single	\$2,800	\$1,500 additional
Two-Gas Analyzer 210	Dual (1X/5X)	\$3,500	
Four-Gas Analyzer 405	Single	\$4,250	
Four-Gas Analyzer 406	Dual (1X/5X)	\$4,950	

PEERLESS INSTRUMENT CO., INC.
512 MAIN STREET / WESTBURY, N.Y. 11590
(516)-997-5959

February 1972
Prices and specifications subject to change without notice

HIGHLIGHTS

OPTICS: Rigidity of alignment assured by mounting all components directly on a heavy cast chassis.

DETECTORS: Thermistor detectors with rigidly controlled characteristics are coming off our in-house fabrication line.

CALIBRATION: Two electrically positioned mechanical calibration standards are provided for lo & hi calibrations.

PACKAGING: A sealed two-piece case provides easy access to the chassis and to the functional front panel.

GENERAL SPECIFICATIONS

STANDARD GASES

The following gases are standard: CO, CO₂, HBr, HC, HCl, NH₃, NO, N₂O, NO₂, O₃, SO₂. However, any gas with defined absorption bands in IR/UR range from 2000Å to 25 microns can be analyzed.

RANGES AND ACCURACY

Generally, 0-100 ppm full-scale for most sensitive scale, with dynamic range of 1000 available and accuracy limited by calibration gases used. (Higher sensitivities possible, but with trade-off on accuracy, response time, and/or drift.)

Standard dual-range units have 1X and 5X scales; other ratios and more scales are available as options. (A unit with two meters is also available.)

ANALOG OUTPUT SIGNALS

1 volt into low impedance. (Options are available for conversion to other analog levels, to digital, to multiplex, or to alarm signals.)

GAS SAMPLE INPUT TO ANALYZER

Flow: 0.5 to 1 cu. ft/min.

Temperature: to 200°F

ANALYZER RESPONSE TIME

Less than 1 second to 90% of reading. (Gas hang-up is low due to special sample-cell material and residual effects are minimized through use of focused optics.)

WARM-UP TIME

For most applications – 30 minutes.

For highest-accuracy applications – 2 hrs max.

STABILITY AND CALIBRATION

Zero and calibration drift < 2% per 24 hrs.

Primary calibration (using span gases) – initially and after cleaning.

Secondary calibration (1-minute procedure using internal standard):

For most applications – daily

For highest-accuracy – 2-hour intervals

ANALYZER INPUT POWER

117V, 60 Hz, 80W (typical)

AMBIENT CONDITIONS

Temperature: 32° to 100°F

Vibration: not sensitive to microphonics
(May be used in moving vehicle)

ANALYZER PHYSICAL DATA

13 x 8 x 23 inches; 40 pounds (typical). A wide range of mounting and packaging options is available.

OPERATION AND SERVICE

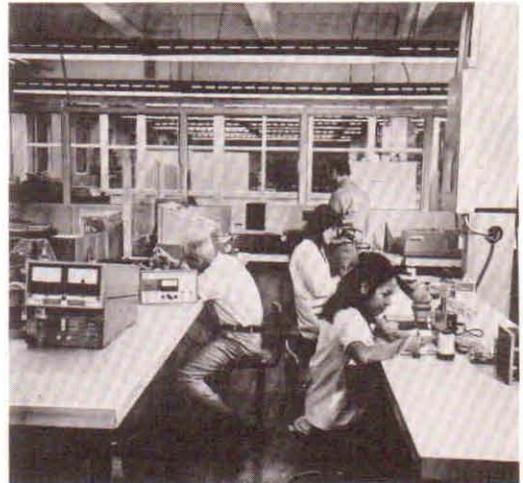
No special training required for operation or for service (½ hour once a month).

the Peerless story

Peerless Instrument is an old name that is coming up for the first time in the gas analysis instrumentation field. For over 30 years, Peerless Instrument — with major plants at Elmhurst and Westbury, New York — has been supplying precision instruments, electromechanical assemblies, and electronic controls to American industry and to the military. Typically, Peerless supplied controls for the "Nautilus", the world's pioneer nuclear-powered vessel (1954), and is now officially classified as a "Major Supplier" in this field.

In the past year, Peerless has entered the field of gas analysis instrumentation. This new line is a logical extension of the work that Peerless has long been doing. Peerless has acquired the exclusive use of several patents in the gas analyzer field, and has added in-house sintering and vacuum plating facilities for the manufacture of thermistor detectors and other IR and UV components. These have been combined with our existing know-how and facilities for designing and manufacturing optical systems, motor drives, microwelded components, and solid-state electronic controls.

Peerless not only makes the gas analyzers proper, but designs, builds, and installs complete analysis systems. Particularly in stack emission and process control applications, severe problems exist in obtaining a representative sample and in conditioning the sample prior to introducing it to the analyzer proper. Similarly, a wide variety of requirements exists at the output end: analog vs digital readouts, alarm signals, processor or computer interfacing, automatic control of analysis system, etc. Peerless solves all these problems, and delivers turn-key installations.



MICROWELDING

VACUUM PLATING

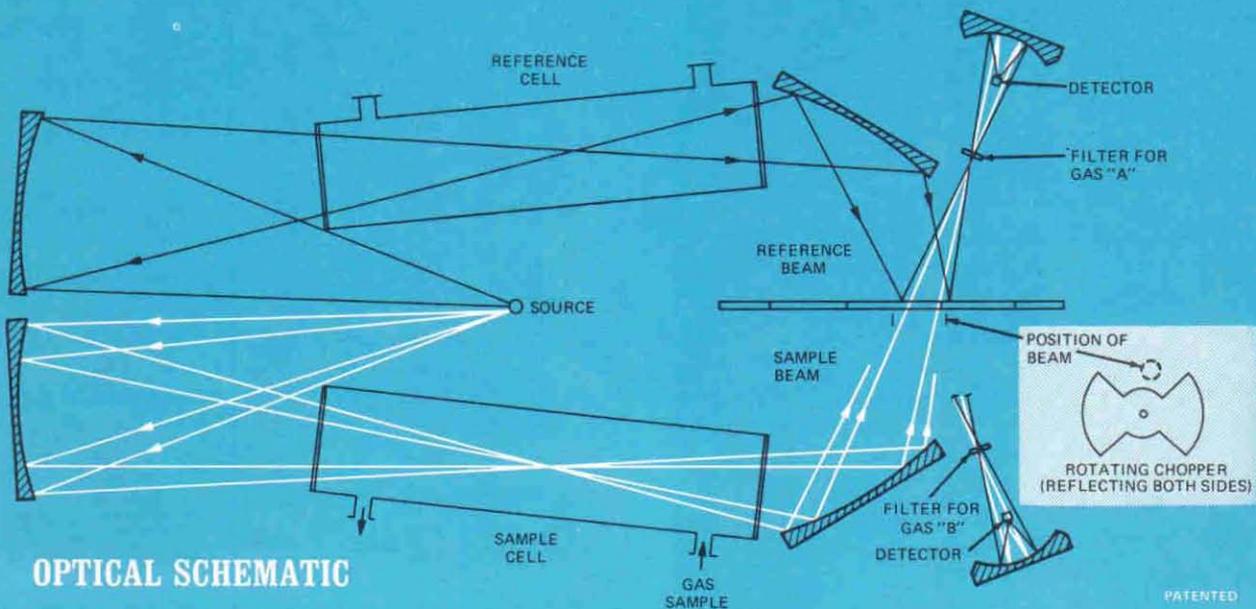


PRINCIPLES OF OPERATION

The Peerless gas analyzer is a nondispersive, dual-beam infrared/ultraviolet analyzer employing an IR and/or UV source at relatively low temperature. The energy from the source is focused (for greater efficiency) into two beams. One beam passes through a cell in which the gas sample flows. The second beam is a reference beam which passes through a zero reference cell (which contains either pure air or nitrogen).

Each beam is passed and reflected intermittently by the rotating chopper, then is focused through an optical filter and cone optics onto a thermistor detector for IR or onto a photomultiplier detector for UV. The narrow-band optical filter transmits only the specific absorption band of the gas being measured. The output of the detector is a differential pulse proportional to the IR or UV absorption of the sample gas with respect to the absorption of the reference cell.

High accuracy, efficiency, response time, and stability are attained by the use of precision focused and cone optics and solid-state electronics.



SPECTROMETRICS



of FLORIDA, INC.

Product Bulletin



MODEL III d² AIR ANALYZER

FEATURES

ANALYSIS OF MULTICOMPONENT GASES

CONTINUOUS AIR SAMPLING

ppb SENSITIVITY TO TRACE GASES

REQUIRES NO REAGENTS OR PURGE GASES

DIRECT PHYSICAL PROPERTY MEASUREMENT

OPERATIONAL SIMPLICITY

INDICATES MEASUREMENT INTERFERENCE

HIGH RELIABILITY

LINEAR OUTPUT

LOW MAINTENANCE

REAL TIME ANALYSIS

RUGGEDIZED CONSTRUCTION

WIDE MEASUREMENT RANGE OF ANALYSIS

WIDE OPERATING TEMPERATURE RANGE

FOR MOBILE VAN, FIXED STATION OR LABORATORY USE

UNATTENDED REMOTE OPERATING MODES

FIGURE 15 -- UV SPECTROPHOTOMETER (d²)

ANALYSIS OF MULTICOMPONENT GASES

The Model III d² Air Analyzer will make fast, accurate, independent measurements of sulphur dioxide, nitric oxide, nitrogen dioxide and ozone with a single instrument. No change in procedure or modification to the analyzer are required to make these four measurements. Sensitivities to these four pollutants are in the low part per billion range.

As a manually operated analyzer the Model III can also be used to measure trace concentrations of many other gases such as; ammonia, benzene, toluene, xylene, methyl ethyl ketone, and other unburned hydrocarbons; oxygenated hydrocarbons such as formaldehyde, acetaldehyde and benzaldehyde; and any other gas with sufficient absorption band strength in the ultra-violet.

DIRECT PHYSICAL PROPERTY MEASUREMENT

The Model III d² Air Analyzer is sensitive to the ultra-violet absorption spectrum characteristic of the molecular gas under analysis, a direct physical property of the gas. This sensitivity to the absorption characteristic results in an analyzer output directly proportional to the concentration of the gas. For each of the four pollutant gases being analyzed there is a pattern of absorption bands of known spectral location. These bands produce a "d² signature" whose known peak location and relative intensity provides for the positive identification of a gaseous pollutant.

HIGH RELIABILITY, LOW MAINTENANCE

The Model III d² Air Analyzer is an electro-optical instrument of extremely rugged design utilizing proven solid state electronic and optical components. No auxiliary materials are necessary for its operation such as reagents and purge gases. Maintenance is minimal and simplified by open modularized construction.

The d² spectrometer has many advantages compared to wet chemistry types of analyzers. Perhaps the most important of these is specificity of measurement. Measurement is made upon a direct physical property of the gas being analyzed, rather than upon an intermediate compound formed by bubbling the sample through a reagent, eliminating the possibility of complex reactions of other constituents of the sample producing the same intermediate compound or one that has physical properties similar to that being measured.

A Technical Bulletin describing in detail the Model III d² Air Analyzer is available. A copy may be obtained upon written request on your letterhead.

SPECTROMETRICS OF FLORIDA, INC.

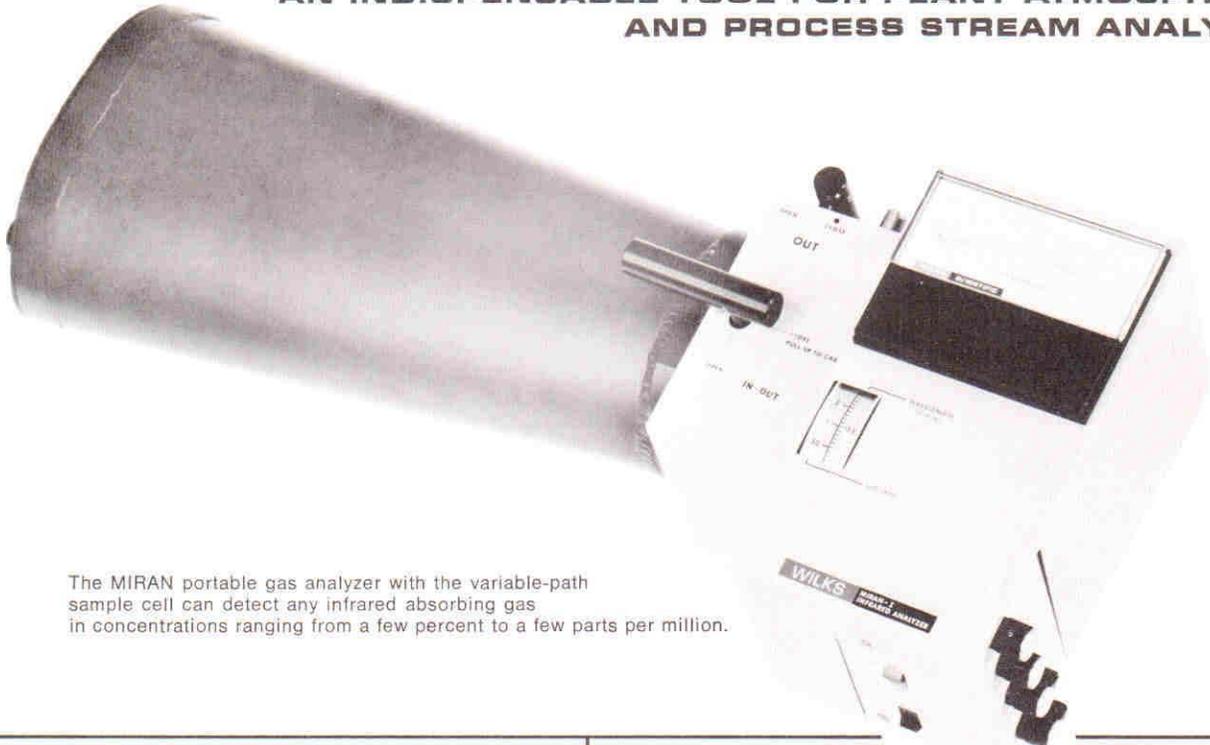
A SUBSIDIARY OF ABA INDUSTRIES, INC.

Post Office Box 517
Pinellas Park, Florida 33565

C-45

MIRAN PORTABLE GAS ANALYZER

AN INDISPENSABLE TOOL FOR PLANT ATMOSPHERE
AND PROCESS STREAM ANALYSIS



The MIRAN portable gas analyzer with the variable-path sample cell can detect any infrared absorbing gas in concentrations ranging from a few percent to a few parts per million.

FEATURES

- portable
-
- rugged construction for laboratory and field use
-
- wide sensitivity range
-
- high quantitative accuracy
-
- analyzes any gas that absorbs in the infrared
-
- short air path greatly reduces atmospheric absorption
-
- low power requirement
-
- all solid-state electronics

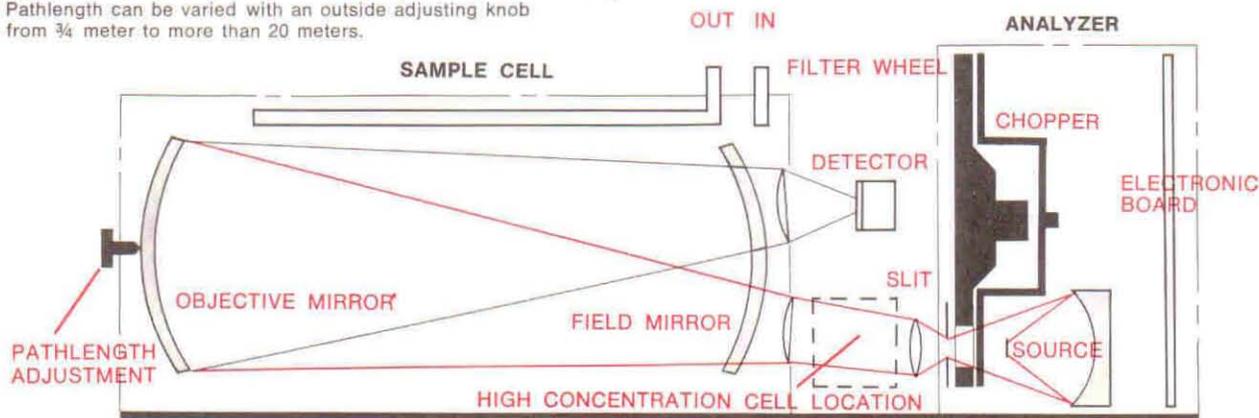
GENERAL DESCRIPTION

The MIRAN portable gas analyzer is a unique instrument for the analysis of a wide variety of gases and vapors. It can detect and measure quantitatively any gas having absorption bands in the infrared region of the spectrum over a broad sensitivity range from a few parts per million up to several percent.

The MIRAN gas analyzer has been ruggedly constructed to withstand field conditions. Because of its low power requirements of about 25 watts, it can be operated from an automobile or airplane power supply or from batteries.

The gas analyzer consists of two components — the spectrometer and the gas sampling cell. Both units together weigh less than 25 pounds. The gas analyzer has applications in the laboratory for analytical determinations, in the field for pollution monitoring, and in the plant for continuous process analysis.

The MIRAN multipass cell has exceptionally high optical efficiency. Pathlength can be varied with an outside adjusting knob from $\frac{3}{4}$ meter to more than 20 meters.



"DISPERSIVE" VERSUS "NON-DISPERSIVE" GAS ANALYZERS

The MIRAN Gas Analyzer is a dispersive instrument (DIR), which means that it can be set at any wavelength within its range (2.5 to 14.5 microns) and absorbance measured. Or, it can be used to scan through portions of the infrared spectrum.

The non-dispersive instrument (NDIR), on the other hand, looks at a broad spectral region and must be sensitized for a particular gas by means of special cells.

Thus, the dispersive instrument is a general-purpose tool, able to detect and quantitatively measure any gas having infrared absorption rather than being limited to a single, preselected gas as is the case with the non-dispersive instrument. The only limitation on the dispersive analyzer is that in situations where a number of infrared absorbing gases are present in high concentrations, it may be difficult to locate an absorption band for the gas of interest which is in a spectral region where the other gases do not absorb.

In most pollution monitoring applications, concentrations are relatively low and interference problems are at a minimum. In terms of sensitivity and quantitative accuracy, the dispersive instrument is usually superior to the non-dispersive instrument.

The variable filter spectrometer used in the MIRAN Gas Analyzer has approximately the same resolution as a prism instrument. Since it has an $f/1.5$ optical system, it has an extremely high energy throughput and, thus, can be used with a high degree of scale expansion.

The amplifier is completely solid state and the entire spectrometer (exclusive of cell) is packaged in a container 6 in. x 6 in. x 10 in. Approximately 25 watts is required to power the MIRAN spectrometer so that with a suitable inverter it may be operated off a storage battery or automobile generator.

THE VARIABLE PATH GAS CELL

A unique feature of the MIRAN Gas Analyzer is the variable path gas cell. Because the optical path can be varied from $\frac{3}{4}$ to over 20 meters, the sensitivity range of the instrument can be varied from a few percent down to a few parts per million. The ability to pressurize the cell up to 10 atmospheres adds an additional factor of 10 to the sensitivity range.

The gas cell is lined with Teflon and all components in the cell, including the mirror surfaces, are gold plated for chemical resistance.

CALCULATED SENSITIVITY FOR SELECTED GASES

Gas	Analytical Wavelength (microns)	Minimum Detectable Concentration (PPM) 20 Meter Path	Maximum Concentration 1.0 Absorbance (PPM or %) $\frac{3}{4}$ Meter Path
Cyclohexane	3.4	0.04	4000
CO ₂	4.25	0.08	7500
N ₂ O	4.5	0.03	2100
CO	4.65	1.2	8.3%
COS	4.85	0.02	1100
NO	5.3	1.5	8.2%
CH ₃ COCH ₃	5.75	0.1	4000
SO ₂	7.4	0.1	3000
Vinyl Acetate	8.2	0.06	1000
Dioxane	8.8	0.2	2100
CH ₃ CH ₂ OH	9.4	0.4	5000
NH ₃	10.75	2.2	2.1%
Freon 11	11.8	0.06	300
CCl ₄	12.6	0.05	250
CH ₂ Cl ₂	13.3	0.4	1900

APPLICATIONS

AMBIENT AIR ANALYSIS. The Williams-Steiger Occupational Safety and Health Act of 1970 requires that employers provide "safe atmospheres" for their employees. The MIRAN Gas Analyzer is an indispensable tool for the analysis of plant airs for concentration levels of practically any potentially toxic gas or vapor. The Analyzer can be taken to the area to be studied, the cell filled with ambient air by means of a small pump and both qualitative and quantitative determinations made of the vapors present.

Experience with the gas analyzer indicates that the composition of the atmosphere in a room can be surprisingly non-uniform. The ability of the MIRAN analyzer to map concentration variations within an enclosed space is unique and could well disclose hazards that would be undetected by other methods.

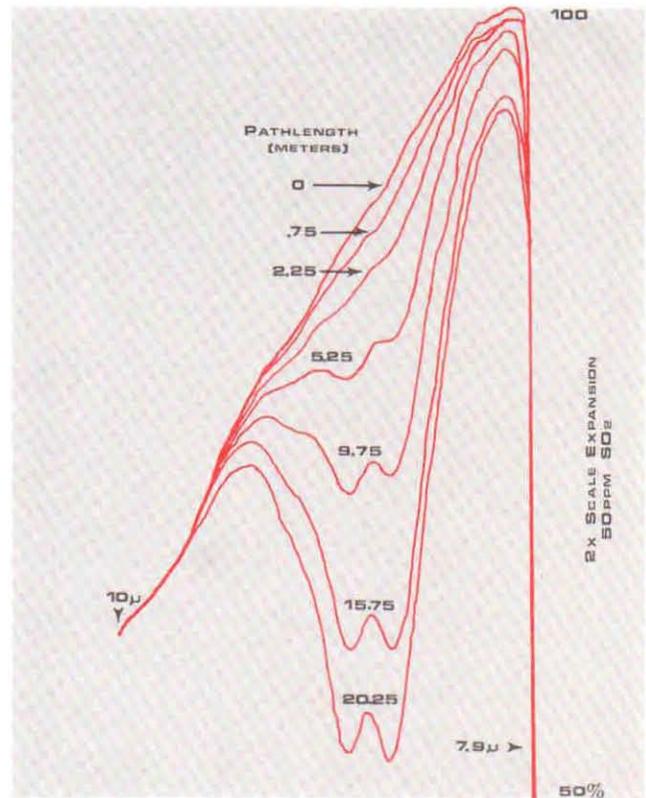
STACK GAS ANALYSIS. Here again, the Gas Analyzer is taken to the location of the stack to be monitored, stack gas is passed through a suitable filter for particulate matter and the concentrations of the different components present monitored.

PROCESS ANALYSIS. Although intended primarily for laboratory and portable use, the MIRAN Gas Analyzer can also be used for continuous monitoring of gas streams. For this application, it is generally required that the unit be installed in an explosion-proof container.

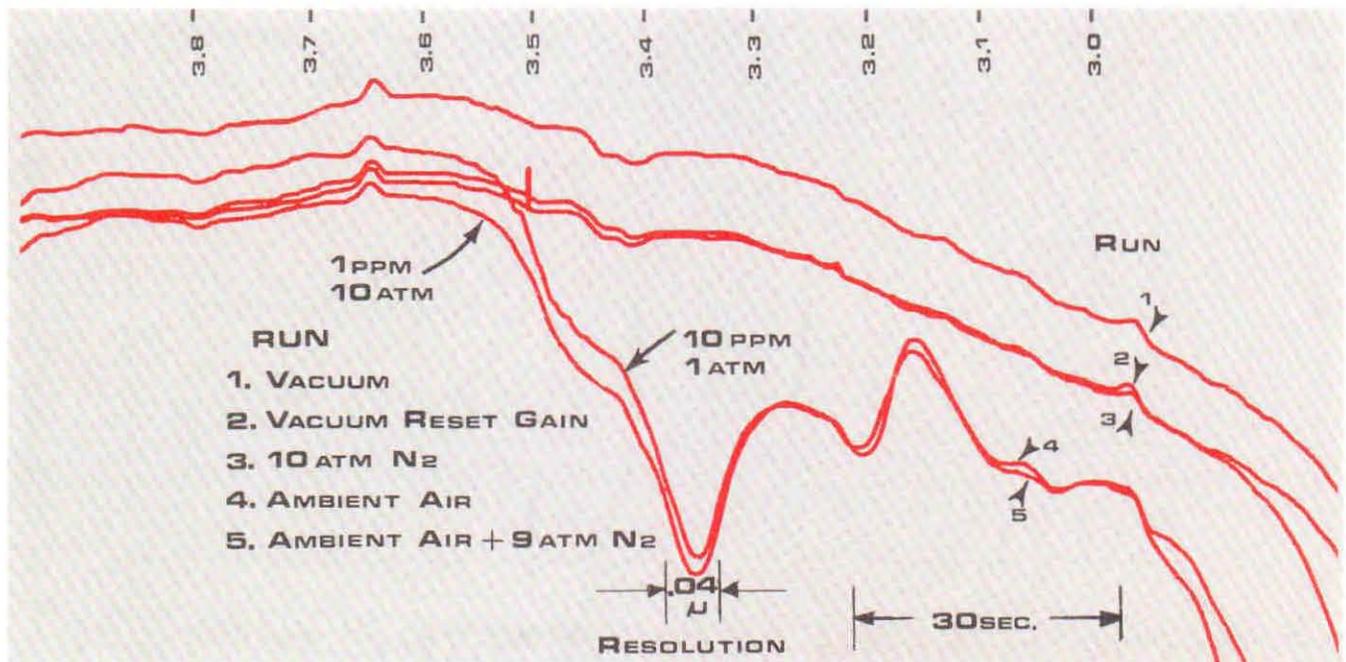
VEHICLE EXHAUST ANALYSIS. Because of its low power requirements and light weight, the MIRAN Gas Analyzer can be installed in a vehicle so that emission of CO, unburned hydrocarbons and, in some cases, NO_x compounds can be monitored under road conditions.

The MIRAN Gas Analyzer is the only portable, general-purpose gas analyzer available and it has proven to be an indispensable tool for laboratories, pollution consultants, health and insurance inspectors, and wherever gas analysis in the parts per million or low percent concentration ranges are required.

50 ppm SO₂ run at different pathlengths, 2X scale expansion, and 10 atmospheres pressure. The 817 micron SO₂ band is selected for analysis which, although weaker than the 7.4 band, is free from water vapor interference.



Ambient Air at Wilks Scientific showing contamination from isopropanol. Recording time 1.5 minutes, 1X scale expansion, path 21.75 meters. Wavelength scan is from 3.0 to 3.8 microns.

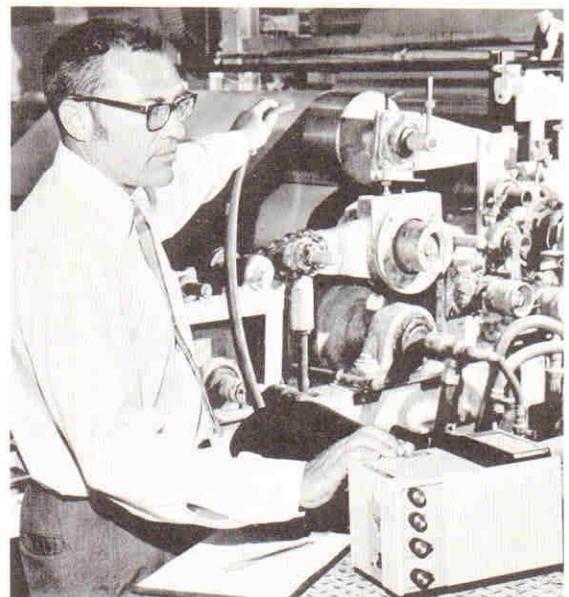




The MIRAN gas analyzer weighs less than 25 pounds . . .



Can easily be taken into the field . . .



And used for determination of vapor concentration levels in ambient air, stack monitoring and process stream analyses.

SPECIFICATIONS

SPECTROMETER

Type

Single-beam spectrometer

Wavelength Range

2.5 to 14.5 microns in three steps: 2.5 to 4.5; 4.5 to 8, 8 to 14.5 microns with small overlaps; manually set or motor driven

Approximate Resolution (0.5mm slit)

0.05 μ at 3 microns
0.12 μ at 6 microns
0.25 μ at 11 microns

Zero & Signal Level Stability

< $\pm 1\%$ drift per 24-hour period when peak-to-peak noise is less than 1%

Signal to Noise

Approximately 10,000 to 1 at 3 microns, 1mm slit, one second time constant

Photometric Accuracy

$\pm 2\%$ with integral meter; better than $\pm 0.5\%$ with strip chart recorder

Slit Settings

0.25, 0.5, 1, 2mm and closed

Time Constants

0.15, 0.6, and 2.4 seconds

Scale Expansion

1X, 2X, 5X

Gain Range

75 to 1 plus 5X scale expansion

Zero Range

+10 to -100% (multiplied by scale expansion factor)

Wavelength Drive Speed

1 minute per filter segment

Power Requirement

25 watts

Voltage

115 or 230 volts (built-in switch)

Frequency

50 or 60 Hz

Weight

25 pounds (with cell)

Dimensions

14 cm x 14 cm x 25 cm (without cell)

GAS CELL

Pathlength

$\frac{3}{4}$ meter to 20 meters or more in steps of 1.5 meters; external adjustment

Volume

5 liters

Pressure

Vacuum to 10 atmospheres; safety valve included

Inlet & Exhaust

Designed for smooth continuous flow; pressure/vacuum valves included

Finish

Teflon lined; mirrors and other internal components gold plated

Dimensions

70 cm x 28 cm x 18 cm (cell)

WILKS SCIENTIFIC CORPORATION
SOUTH NORWALK • CONNECTICUT 06856



Engineering Report

REPORT NUMBER
G-124 A

Matheson Gas Chromatograph Model 8430



FEATURES

- Thermal Conductivity Detector
- Two carrier gas needle valves
- Two self healing septums
- Temperature controller
- Ten step attenuator
- Top and bottom of unit do not separate during operation

The Matheson 8430 Chromatograph is an ideal instrument for separating gases or liquids in process analysis, schools, laboratories, and all cases where ease of transportation and price are important factors. It is a low-cost, high performance, rugged, compact unit which can perform practically all the functions of units costing twice as much.

The blue anodized aluminum case is designed to permit the addition of one or two sample valves in the oven. The upper section contains the columns, detector, injector, oven, thermometer, and sampling valves when so desired. The lower section contains the operating controls. The unit is designed to be operated without separating the two sections.

PRINCIPLE OF OPERATION

The 8430 Chromatograph uses the elution method of vapor-phase chromatography.

Prior to introducing the sample to be analyzed, the carrier gas flows through both columns at approximately

equal rates. The heated filaments constituting the thermal conductivity cell are part of a Wheatstone bridge. Both filaments are cooled at a constant rate by this carrier gas, resulting in a balanced bridge.

When introducing a fixed sample of gas or liquid into the carrier gas stream flowing through one of the two columns, this sample is washed through by the continuous flow of carrier gas. Since components in the sample will travel through the column packing at rates dependent upon individual properties, each component will emerge from the column at a different rate. As each component emerges, its molecules, mixed with the carrier gas, pass over the hot filament; the rate of heat loss is reduced and the resistance of the filament increases. This resistance change unbalances the Wheatstone bridge, resulting in an electrical signal. The amplitude of this signal depends on the change in heat loss of the filament. The output of the detector is then indicated on a recorder by a series of peaks. The area under each peak is directly proportional to the concentration of the component producing it.

The separation of sample components is achieved in the column. Consequently, the success or failure of a particular separation will depend to a large extent on the choice of column.

TEMPERATURE CONTROLLER

The unique temperature controller used in this unit permits operation at any temperature between ambient and 245°C. with a sensitivity of $\pm 0.1^\circ\text{C}$. The 300 watt heater brings the unit to proper temperature in less than 30 minutes.

SAMPLING VALVE

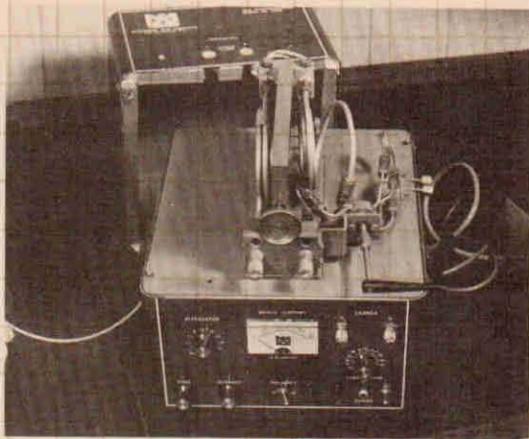
Matheson's exclusive **heated** sampling valve is one of the main accessories available. The Matheson 8430 Chromatograph is designed to permit easy installation of this valve in the oven. This sampling valve provides reproducibility of sample size of better than $\pm 0.5\%$. Its presence inside a heated oven reduces the possibility of condensation taking place within the valve. Its position at the entrance to the column improves the resolution by minimizing diffusion of the sample in the carrier stream.

ACCURATE ANALYSIS

The exceptional accuracy of the 8430 is due to its excellent temperature controller, its two high accuracy needle valves and the outstanding sampling valve.

APPLICATIONS

The 8430 Chromatograph gives the chemist an excellent tool for the analysis of gases and volatilized liquids. The potential applications of the 8430 are practically unlimited and are primarily dependent on the selection of column-packing materials.



SPECIFICATIONS

DETECTOR

Flow-through, low volume type
 Two-element thermal conductivity hot wire bridge
 Filaments 30 ohm (part 1-0600)
 Stainless Steel detector block

CARRIER GAS

Helium at 0 to 60 psi

INJECTION PORT

Two ports
 Septums: Standard 3/8" OD silicon rubber
 Direct on-column injection
 Operating temperature: to 245°C
 Sample wetted parts constructed of 316 stainless steel

OVEN

Temperature range: ambient to 245°C.
 Temperature readout: dial thermometer 0-250°C.
 High stability temperature controller: 0-100 V.A.C. proportional
 Control point accuracy: $\pm 0.1^\circ\text{C}$.

Heater wattage: 300 watts
 Temperature markings on case accurate $\pm 10\%$
 Sensor: thermistor bead
 Proportional band: * fixed

COLUMN

A: 1/4" x 6 ft. aluminum column packed with molecular sieves (5A)
 B: 1/4" x 6 ft. aluminum column packed with Poropak Q
 Adapters available for 3/16" or 1/8" columns
 Accomodation for two 1/4" x 16' columns or two 1/8" x 16' columns

GAS FLOW SYSTEM

Two high accuracy needle valves for separate control of each column
 Carrier gas inlet at the back
 Exit ports at the back
 Sampling valve inside oven (optional)

BRIDGE CONTROL

Current adjustable 150-350 ma w/off switch
 Output - 19.5 V. DC @ 150 ma
 Bridge zero adjust
 Attenuator for bridge output - 10 positions to 512
 Polarity switch
 Load regulation - 2% or better - no load to full load
 Input regulation - 0.5% for ± 10 V.A.C. variation from 110V. AC
 Ripple - 8 MVDC @ 200 ma

POWER

110V. AC - 60 Hertz (220V.-50Hz available)
 6 amp. fuse 3AG

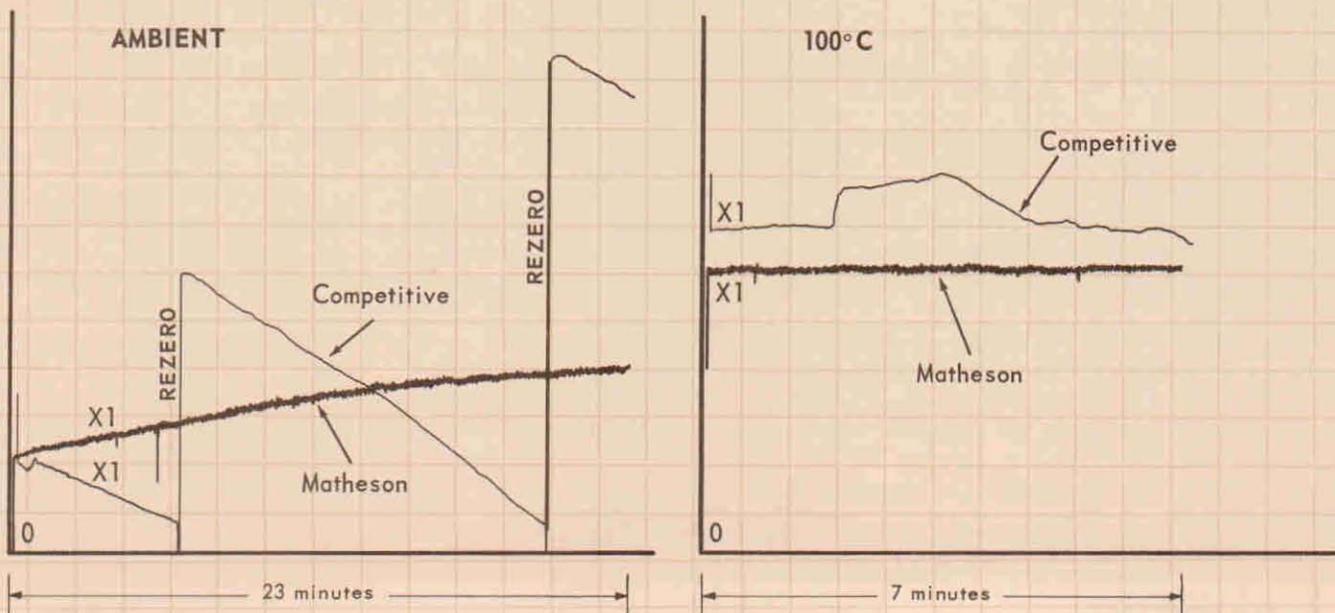
PHYSICAL

Size: 12" wide x 16" high x 12 3/4" deep
 Weight: 25 lbs.

RECORDER

0-1 or 0-5mv. potentiometric recorder required

This is a comparison between one of the most popular competitive units and the Matheson 8430 showing the steadiness of the base line.



*The proportional band is the proportion of the heater output to the difference in temperature between the oven and the selected point. The closer the temperature gets to the selected point, the smaller the heater output. This feature permits fine control of the temperature.

Price List

REPORT NUMBER

G-124 A

MATHESON GAS CHROMATOGRAPH

MODEL 8430

COMPLETE UNIT - Matheson 8430

Chromatograph \$650.00

SAMPLING VALVES - stainless steel - with

1cc. loop, bracket and 2 piece shaft - maximum temperature 175°C. Part #8430-2017 . . . 200.00

High temperature stainless steel - maximum

temperature 300°C. Part #8430-2030. 220.00

SYRINGES - 10, 20, 50 microliter w/plain

cemented needle - Part #8430-2511, 12, 15 . . 12.00

Same with plain removable needle #8430-2531,

32, 35 15.00

Same with double action cemented needle -

#8430-2521, 22, 25 16.00

Same with double action removable needle -

#8430-2541, 42, 45 19.00

ADAPTERS - stainless steel adapter 1/4" x

3/16" for 3/16" column - 300-R-4-316 4.50

Stainless steel adapter 1/4" x 1/8" for 1/8"

column - 200-R-4-316 4.30

COLUMNS - filled with Gas-Chrom S, A, P, R,

Q, chromosorb A, G, P, T, W, Silica gel, Teflon, Kel-F, Glass beads (Specify filler)

TYPE	O.D.		PRICE
Stainless Steel	1/8	3/16	1/4 \$20.00 + 2.00/ft.
Copper or Aluminum	1/8	3/16	1/4 \$20.00 + 1.50/ft.
Aluminum	3/8		1/4 \$20.00 + 2.50/ft.

For Poropak, Durapak, Porasil, Chromosorb 101, 102, 103, 104, 105 and Pennwalt Amine Packing columns, add \$1.50/ft. to above prices. If stainless steel Swagelok fittings are desired, add \$5.00/column.

REGULATORS - Carrier gas regulator - all

metal - cylinder type - model 19-580 54.60

All stainless - cylinder type - 3503-580 178.50

All stainless - line type - 3453 150.00

Component gas regulator: Contact Matheson

FLOWMETERS - Brass 621 PB w/600 tube. . . 46.20

Stainless steel 621 PS w/600 tube 70.35

RECORDER - Model 8500 635.00

Prices subject to change without notice.



MATHESON GAS PRODUCTS

A Division of Will Ross, Inc.

EAST RUTHERFORD, N.J. 07073

Post Office Box 85
Phone: (201) 933-2400

NEW YORK, NEW YORK

For direct line to East
Rutherford, dial 947-6397

MORROW, GEORGIA 30260

Post Office Box 136
Phone: (404) 478-7274

GLOUCESTER, MASS. 01930

Post Office Box 1147
Phone: (617) 283-7700

JOLIET, ILLINOIS 60434

Post Office Box 96
Phone: (815) 727-4848

CHICAGO, ILLINOIS

For direct line to Joliet,
dial 242-1321

LA PORTE, TEXAS 77571

Post Office Box 908
Phone: (713) 471-2544

CUCAMONGA, CALIFORNIA 91730

Post Office Box 608
Phone: (714) 987-4611

NEWARK, CALIFORNIA 94560

Post Office Box 188
Phone: (415) 793-2559

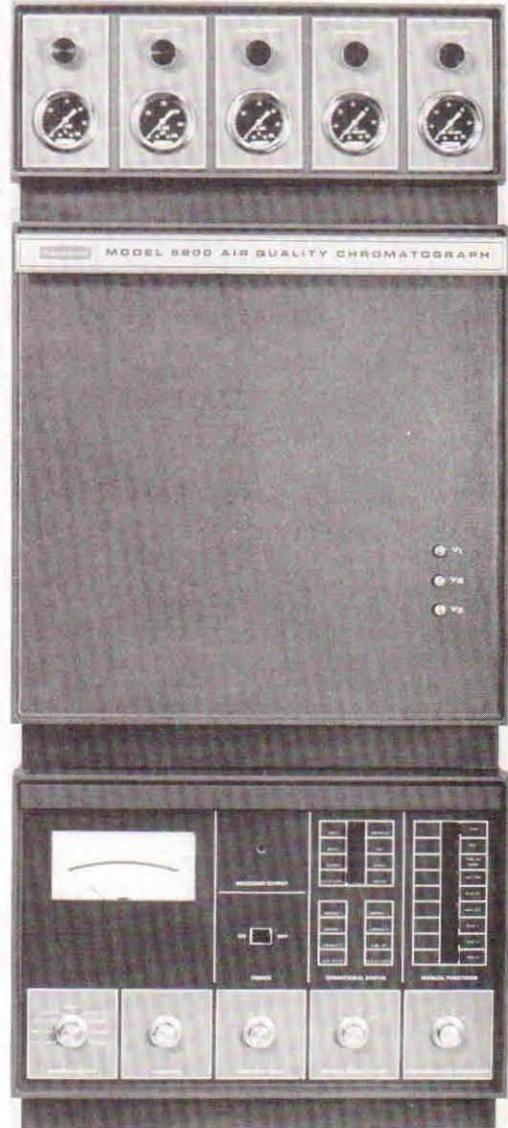
BECKMAN MODEL 6800 AIR QUALITY CHROMATOGRAPH

The Beckman Model 6800 Air Quality Chromatograph provides automatic monitoring of three atmospheric pollutants with optional capability of monitoring two additional components. The basic instrument employs a column/valving configuration to fulfill Environmental Protection Agency (EPA) requirements for ambient level monitoring of carbon monoxide, methane, and total hydrocarbons in accordance with the Federal Register, Volume 36, No. 158, August 14, 1971. Other gaseous compounds can be automatically monitored by use of appropriate column / valving configurations providing resolution of the component(s) of interest.

The Model 6800 employs a high sensitivity hydrogen flame ionization detector which provides analysis sensitivity from 0-1 ppm full scale. Multiple components are automatically monitored over individual full scale ranges from 1 ppm fs to 10,000 ppm. An electronic control section includes all circuits necessary for measuring the ionization detector signal, automatic control of all time related functions, and data reduction and presentation.

Operator controls and indicators permit simple calibration and operation. An integral test meter with selector switch permits monitoring of system operation, calibration of individual components when local recording is not employed, and rapid testing of major circuits for malfunctions.

A unique mother board/plug-in circuit board concept is designed to permit insertion of any circuit board into any location. Additional advanced design concepts include digital timing for precise instrument functions, integrated circuits for reliability, and unlimited life solid state light emitting diode indicators for elimination of maintenance associated with conventional light bulb indicators.

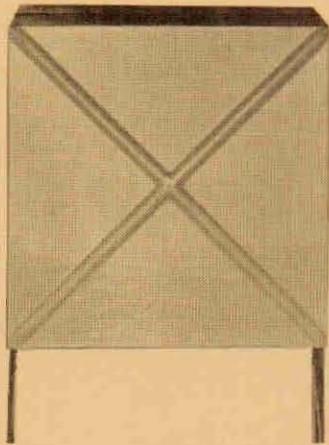


MODEL 6800

FIGURE 18 -- GAS CHROMATOGRAPH, ENVIRON.

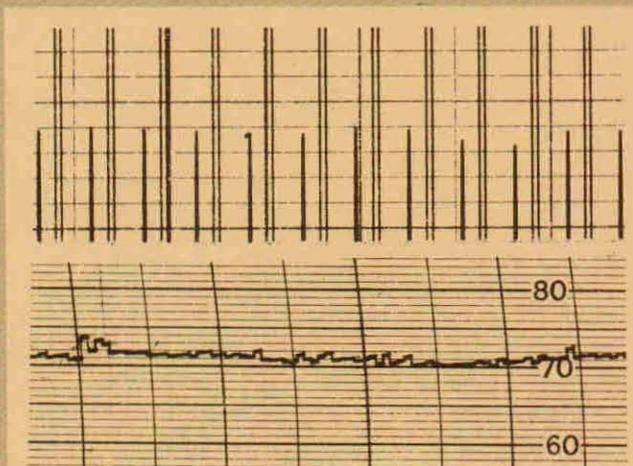
PROCESS GAS CHROMATOGRAPHS

**THE
ARCAS
COMPANY**



Actual
Instrument
Size 12"

**SERIES 400
Multi-Stream**



COMP.	TIME SEC.	AREA %	MOL. %
1	50	0.0005	0.0000
2	70	78.4356	82.9720
3	78	5.8807	5.9855
4	94	11.7821	8.4023
5	112	3.9011	2.6402

Actual
Instrument
Size 7"



**SERIES 500
Single Stream**

FIGURE 19 -- GAS CHROMATOGRAPH, PROCESS

PROGRAMMER

SERIES 400

Multi-Stream

Model CT

The programmer is designed to handle applications from simple single stream monitoring to complex multistream, multicomponent, multirange applications, and including peak picking or integrating functions in conjunction with computers. This is accomplished with "building blocks" of printed circuit plug board "functions". Plug board functions include:

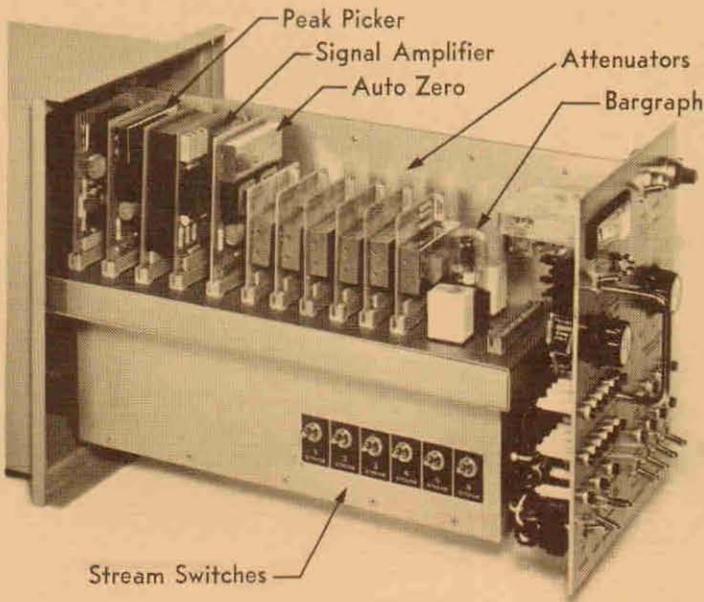
- 24 VDC power supply for TC units
- ± 15 VDC power supply
- Electronic automatic zero
- Two mode temperature controller, optionally mounted in programmer
- Attenuator relays and potentiometers
- Peak picking and memory units

Multistream units normally use a stepping switch to select the proper stream. Solid state stepping is available as an option. All signal switching is done with hermetically sealed relays and environmentally sealed switches.

Start up and programming is simplified by front panel switches which duplicate most of the programmed functions.

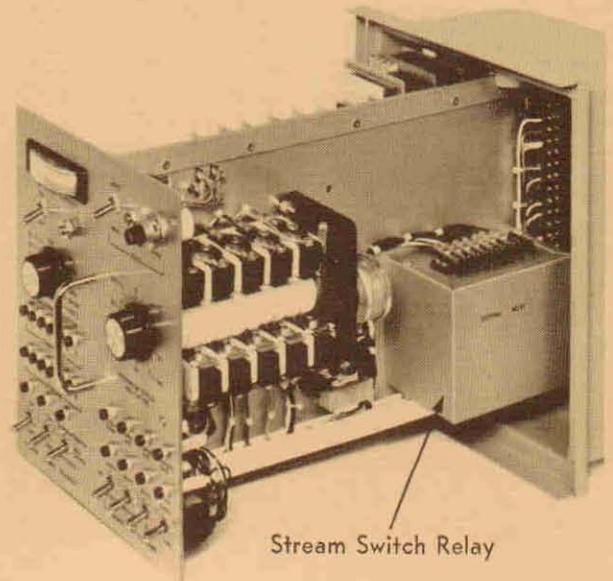
The programmer front panel is arranged for maximum utility. One glance tells the operator:

- detector current
- zero mode
- attenuation mode
- position in programmed cycle
- component and/or stream being analyzed
- position of sample and/or column switch valve



PROGRAMMER LEFT SIDE

Also visible are alarm lights which alarm and protect components in case of high temperature, air failure, or low carrier gas.



PROGRAMMER RIGHT SIDE



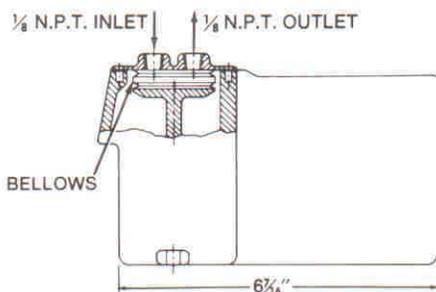
MB-21 Welded Bellows Vacuum Pump/Compressor



A PRODUCT OF
ADVANCED BELLOWS TECHNOLOGY



Patent Pending



A NEW DESIGN CONCEPT FOR A VACUUM PUMP/COMPRESSOR TO PROVIDE CONTINUOUS RELIABLE PERFORMANCE. PARTICULARLY ADAPTABLE TO CORROSIVE ATMOSPHERES AND WHERE ABSOLUTE LEAK-TIGHTNESS IS ESSENTIAL.

TYPICAL APPLICATIONS:

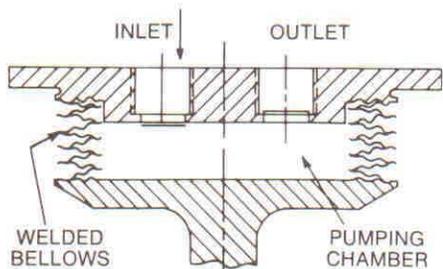
- Pollution Control and Measuring Devices
- Gas Sampling Instruments.
- Aspirating Systems For Medical Instrumentation
- Vacuum Source For Particle Counters
- Computer Peripheral Equipment

FEATURES

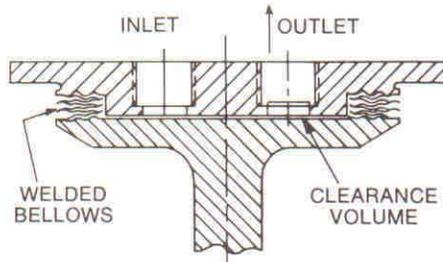
- **ABSOLUTELY NO LEAKAGE**
Hermetically sealed bellows
- **CONTAMINANT FREE**
Media is in contact with the hermetically sealed stainless steel bellows only
- **NO WEARING PARTS**
Bellows are a series of leak-tight flexures
- **CONSISTENT PUMP PERFORMANCE**
Performance unaffected by constant operation or extremes of temperature
- **CORROSION RESISTANT**
Wide choice of stainless steel for components which come in contact with media being pumped
- **COMPACT AND VERSATILE DESIGN**
Efficient operation either as a vacuum pump or as a compressor. Pump is designed for easy integration into end equipment.
- **MAINTENANCE FREE**
No lubrication or parts replacement required



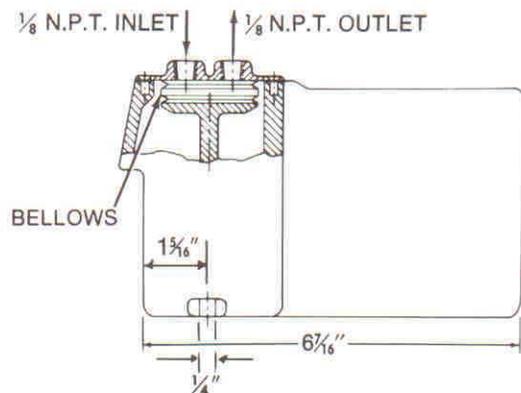
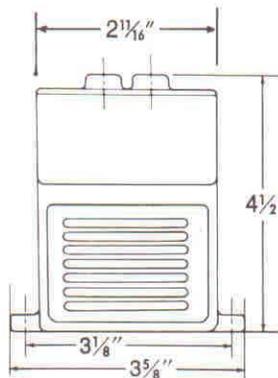
PRINCIPLE OF OPERATION



POSITION 1
BOTTOM OF STROKE

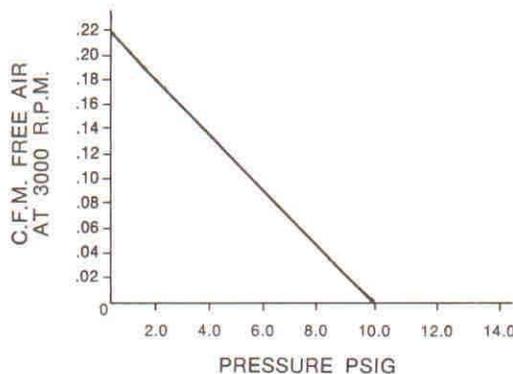
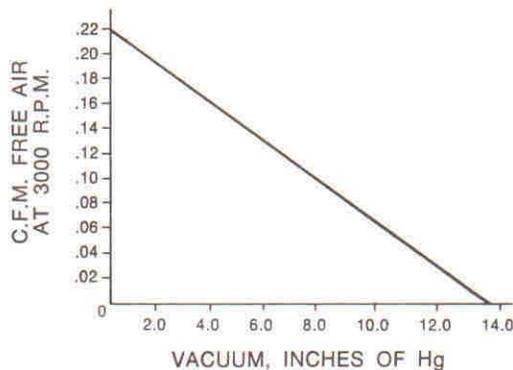


POSITION 2
TOP OF STROKE



Model No. MB-21

SPECIFICATIONS



GENERAL

VACUUM AT 0 C. F. M.	13 IN. HG
AIR FLOW	.22 C. F. M. (6.3 L.P.M.)
OPERATING PRESSURE	10 PSIG
WEIGHT	5 1/2 LBS.
OPERATING POSITION	ANY
PORT CONNECTIONS	1/8 NPT
PUMP CONSTRUCTION	

PUMP HEADER	303 ST. ST.
HOUSING BODY	ALUMINUM
VALVES	302 AND 303 ST. ST.
BELLOWS	AM 350
CONNECTING ROD	304 ST. ST.

BEARINGS	PERMANENTLY LUBRICATED BALL TYPE
----------	----------------------------------

ELECTRICAL

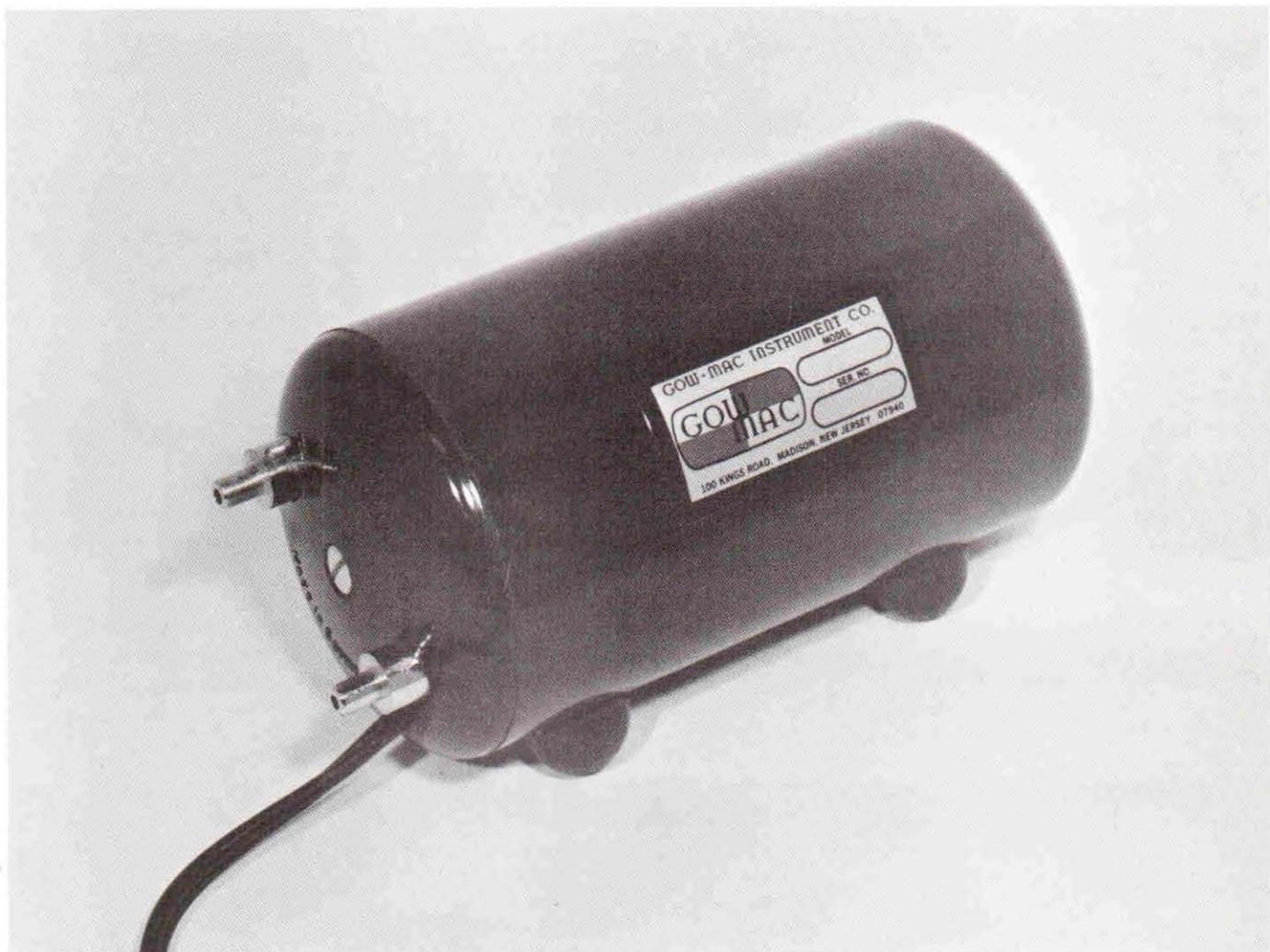
STANDARD	115 V 60 CYCLES
OPTIONAL	220V 50/60 CYCLES
CURRENT AT 115V	1.4 AMPS
POWER RATING	1/40 H.P. SHADED POLE INDUCTION MOTOR WITH BALL BEARINGS PLUS THERMAL OVERLOAD PROTECTION
OPERATING SPEED	3000 R.P.M.

METAL BELLOWS CORPORATION

EAST COAST:
1075 Providence Highway, Sharon, Mass. 02067 • 617-668-3050
TWX: 710-346-0849

WEST COAST:
20977 Knapp St., Chatsworth, L.A., Calif. 91311 • 213-341-4900
TWX: 910-494-1213





APPLICATIONS

This is a small, convenient pump which can be used for gas sample collection for a gas chromatograph. Model 59-100 is also suitable for atmospheric sampling in air pollution analysis.

Other applications: for rapid removal of solvent films in the cleaning of syringes or other tubular glassware, aeration, and where a small pump is required for intermittent service.

SPECIFICATIONS

115 V, 60 Hz, 7 W
500 cc/min at 5" Hg pressure
500 cc/min at 3" Hg vacuum
Dimensions: 3 x 3 x 6"
Shipping weight: 2 lbs.
Model 59-100 is supplied with a 6' line cord. The diaphragm is Neoprene, actuated by a vibrator.

ORDER INFORMATION

Model 59-100 \$22.50
f.o.b. Madison, N. J.
terms: Net 30

FIGURE 2 -- SAMPLING PUMP, DIAPHRAGM

BENDIX

C115 PERSONNEL MONITOR

the only air sampler with . . .

AUTOMATIC VOLTAGE REGULATION

Gives absolutely constant reading of $\pm 2\%$

Guarantees 8 hours of midjet impinger sampling

2.8 LPM ΔP 12" H₂O

Guarantees 14 hours of gravimetric sampling at

2 LPM ΔP 4" H₂O

Eliminates flow rate adjustments during sampling period.

FLOAT PULSATION ELIMINATOR

Ends float bounce for precise reading

BUILT-IN BATTERY VOLTAGE TESTER

Allows instant check of battery condition

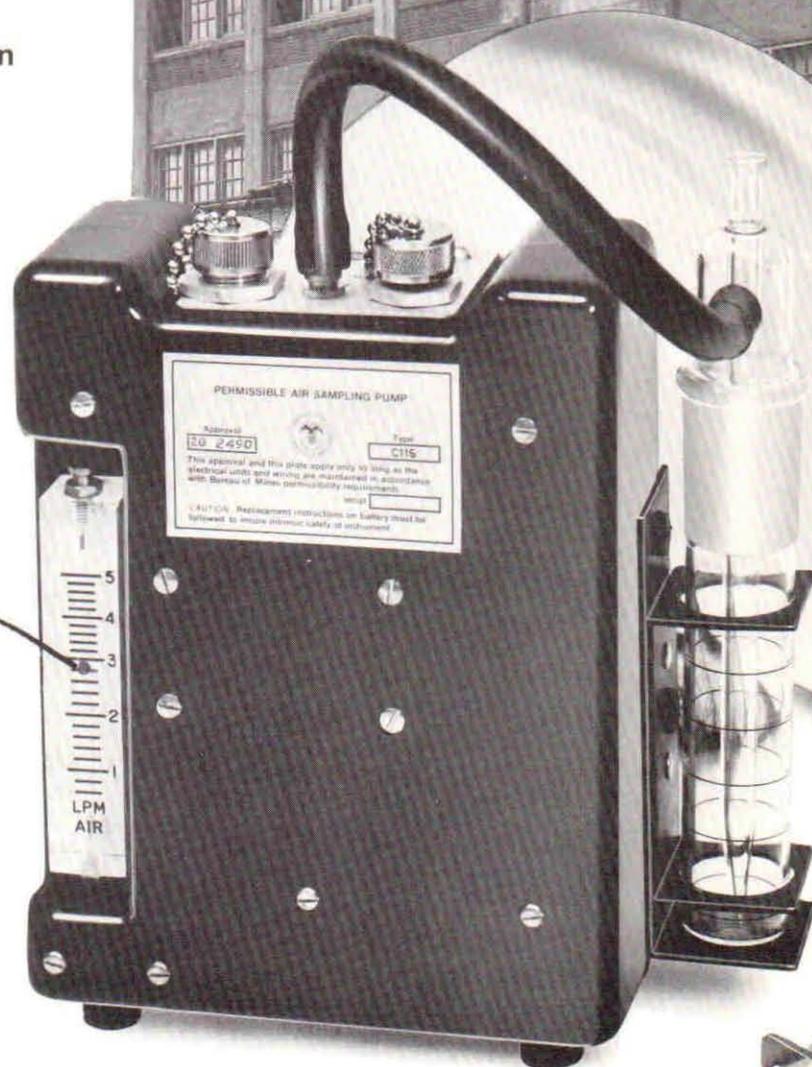
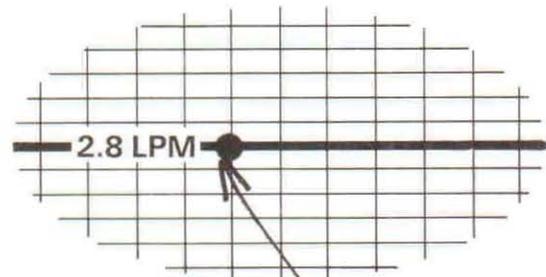


FIGURE 3 -- PERSONAL SAMPLER (PUMP)

BENDIX

C-115 PERSONNEL AIR SAMPLER

Guaranteed to collect 99% of the sample . . . exceeding the rigid requirements of and approved by the Bureau of Mines for Intrinsically Safe Operation in Explosive Atmospheres.

Bendix superiority is demonstrated in the C115 PERSONNEL MONITOR. LIGHT-WEIGHT, COMPACT and VERSATILE . . . the C115 is an air sampler offering advanced features found in no other instrument in the field and may be used with midget impingers, micro impingers, membrane filters or respirable mass samplers.

Powered by a 7.5 volt, 2 amp-hour rechargeable nickel cadmium battery, the C115 is supplied complete with a 110 volt/60 cycle battery charger. A precision diaphragm pump and hi-torque low current drain motor insures high efficiency monitoring.



Here's why the C115 can give you 99% sampling accuracy

FEATURES

- **AUTOMATIC VOLTAGE REGULATOR**
Gives absolutely constant reading of $\pm 2\%$.
Guarantees 8 hours of midget impinger sampling at 2.8 LPM ΔP 12" H₂O
Guarantees 12 hours of gravimetric sampling at 2 LPM ΔP 4" H₂O
Eliminates flow rate adjustments during sampling period
- **FLOAT PULSATION ELIMINATOR**
Ends float bounce for precise reading
- **BUILT-IN BATTERY VOLTAGE TESTER**
Allows instant check of battery condition
- **LEAD-IN-AIR ANALYSES**
Simple 3-step procedure provides accurate analysis using Bendix Inorganic Lead-in-Air Reagents.
- **TDI-MDI DETERMINATIONS**
Will provide threshold limit values from 0.01 to 0.08 PPM using Bendix reagents and color standards.

C-115 PUMP PROVIDES THE NECESSARY VACUUM FOR PRACTICALLY ANY PORTABLE GAS ANALYSIS TEST

The C-115 is designed for the collection of toxic and combustible gases, vapors, dusts, fumes, and mists which are then evaluated by various analytical techniques. Numerous Bendix portable gas detection instruments and Colorimetric Detector Tubes can be used with the Sampler. The device, therefore, can be used to collect samples of explosive gases, oxygen, ammonia, carbon dioxide, carbon monoxide, chlorine, hydrogen chloride, hydrogen sulfide, mercury vapor, nitrogen dioxide, sulfur dioxide, toluene diisocyanate, lead dust and fumes, and chromic acid mist. Dust counts can also be made, using Midget Impingers in conjunction with a microscopic analysis. Particulate sampling can be performed for radioactive dust and beryllium dust.

A desired sample flow is obtained by setting the flow adjust screw to an indexed position on the flow meter. Our standard instrument comes factory calibrated at 2.8 LPM and 2.0 LPM. Special air flow calibrations are available on request.

The C-115 is equipped with a tube fitting on the outlet or exhaust side of the pump. It can be used in positive pressure applications.

IMPINGER SAMPLING

The C-115 Air Sampler is designed for use with Bendix Calibrated Midget Impingers and Bubblers in sampling dust, gases, and vapors. It is the only Personnel Air Sampler on the market that guarantees 8 hours of continuous sampling at 2.8 LPM Δ P 12" H₂O.

Threshold Limit Value Determinations from 0.01 to 0.08 PPM using Bendix TDI-MDI Reagents and Color Standards (Toluene Diisocyanate/Methylene-Bis (4 Phenylisocyanate)) are accomplished with the use of the midget impinger.



RESPIRABLE DUST SAMPLER

Filter Paper Holder adapts the C115 for personnel monitoring or sampling for the detection of lead dust, radioactive particulate, beryllium and other hazardous particulates.



ANALYZER FOR INORGANIC LEAD FUMES*

Simple 3-step procedure provides accurate analysis exceeding the requirements of the "Occupational Safety and Health Act of 1970." Using Bendix Inorganic Lead-in-Air Reagents and Color Standards, measures accurately within a range from 0.02 mg./m³ to 0.4 mg./m³ of inorganic lead.

This field method for atmospheric sampling provides immediate and accurate determinations of semi-quantitative lead concentration in air throughout an entire workday. In contrast to the chemical method that could take 8 hours or more, the field method for analyzing the same number of samples requires less than 10 minutes with the C115.



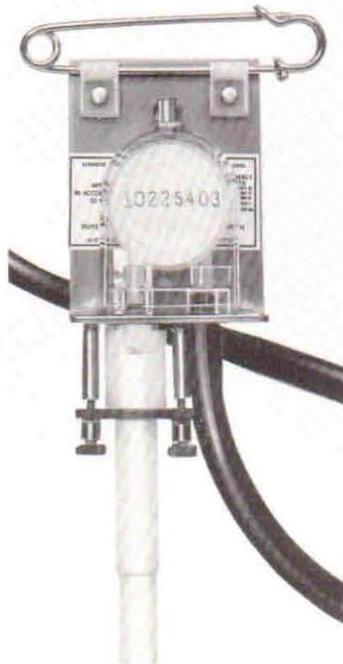
ANALYZER FOR TDI AND MDI**

The C115, when used with calibrated midget impinger, will provide Threshold Limit Value Determinations from 0.01 to 0.08 PPM using Bendix TDI-MDI Reagents and Color Standards (Toluene Diisocyanate/Methylene-Bis (4 Phenylisocyanate)).

RESPIRABLE MASS LAPEL SAMPLER

The Lapel Sampler, when used with the Bendix C115 Pump, simulates the collection characteristics of the human lung. As air is sampled, the cyclonic action of the unit separates the coarser particles of dust (those which would deposit in the upper respiratory passage) from the finer, more harmful particles which penetrate into the lung. The larger particles fall to the bottom of the tube, the finer particles are drawn to the filter assembly in the capsule, where they are trapped on a filter membrane for subsequent analysis, either weighing or counting.

Approved by the Bureau of Mines for Intrinsically Safe Operation in Explosive Atmospheres and the Environmental Health Service Bureau of Occupational Safety and Health.





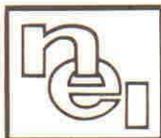
C115 ATTACHÉ UNIT 3600-18

For total convenience the C115, battery charger and all accessories fit compactly into this handsome attaché style carrying case. Case provides excellent protection for unit, while portfolio in cover is ideal for valuable reports, test papers, instruction literature and suggestions for care of unit.

Description	Part Number	Description	Part Number
C-115 Air Sampler w/Battery and Charger	3650-10	*37 mm 3-Part Plastic Filter Holder.	3600-300
C-115 Air Sampler Only	3650-05	*37 mm Membrane Filter	3600-301
Nicad Battery 7.5V	3600-31	(0.8 Micron Size).	
Battery Charger 110V 60Hz	3600-20	Filter Paper 25 mm Pkg. of 100	60692
Standard Calibrated Midget Impinger	7202	2 ft. Rubber Tubing 3/16 ID	2110-32
Impinger Holder	3600-35	Code 40/20 Inorganic Lead-In-Air	
Sampling Head Ass'y w/Cyclone,		Reagents with Color Standards for Lead	
Hose and Clip	3900-90	Dust in air evaluation (50 evaluations)	2250-10
Sampling Cassette/Capsule Assembly	3900-906	TDI/MDI Color Standards	2200-30
Filter Holder 25 mm Pkg. of 6	1107	TDI/MDI Reagents	2200-20
*Filter Holder and 37 mm Membrane	3600-309	Attaché Case w/Ethafoam Insert	3600-18
Filter (0.8 Micron Size) for Asbestos			
Dust Sampling.			

*Part Nos. 3600-309, 3600-300 and 3600-301 Filter Holder and Filter Media (0.8 Micron Size) complies with Federal Register Regulations 1910.93a for Asbestos Dust Sampling.

- * Ref. Enrique A. Quino — **Field Method for the Determination of Inorganic Lead Fumes in Air** — The Journal of the American Industrial Hygiene Association — Vol. 20, No. 2 (April 1959). Printed in U.S.A.
- **Ref. Marcali, Kalman — **Microdetermination of Toluenediisocyanates in Atmosphere** — Anal. Chem: 29, 552 (April 1957).
- K. E. Grim and A. L. Lynch — **Recent Isocyanate-in-Air Analysis Studies** — AIHA: Vol. 25 (May-June 1964).



NATIONAL ENVIRONMENTAL INSTRUMENTS, INC.

P. O. Box 590, Pilgrim Station, Warwick, R. I. 02888

Tel. (401) 738-3710

Cable NEICO TWX 710 387-1584

Distributed by:





PRECISION GAS UNICO MODEL NUMBER 400 DETECTOR

A SINGLE INSTRUMENT
FOR DETECTING TOXIC
GASES AND VAPORS

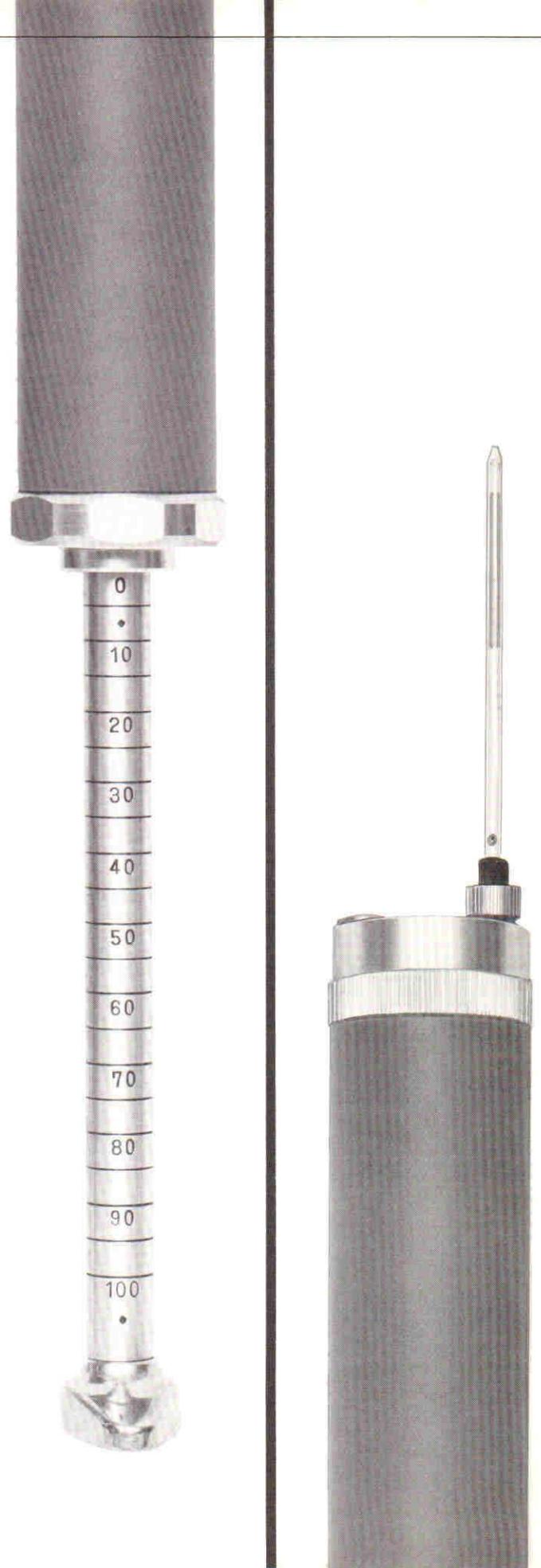


FIGURE 4 -- TESTER KIT (HAND PUMP)

BENDIX-UNICO

PRECISION GAS DETECTOR MODEL 400



Accepted as an accurate, dependable and rapid method of determining hazardous concentrations of toxic gases and vapors, the Bendix Precision Gas Detector is being used by leading industrial companies and government agencies throughout the United States. It has been tested and evaluated by government agencies, leading universities and insurance companies. All tests and evaluations have proved that the Bendix Precision Gas Detector provides reproducible and accurate results.* The Model 400 is used by more Environmental Safety and Health Engineers than any other available instrument.

To operate the Bendix Precision Gas Detector and obtain accurate and reproducible results only three easy steps are necessary.

1. Break off the tips of a fresh tube.
2. Insert tube tip marked with red dot into pump inlet.
3. Pull out the pump handle which automatically gives a 100 cc sample.

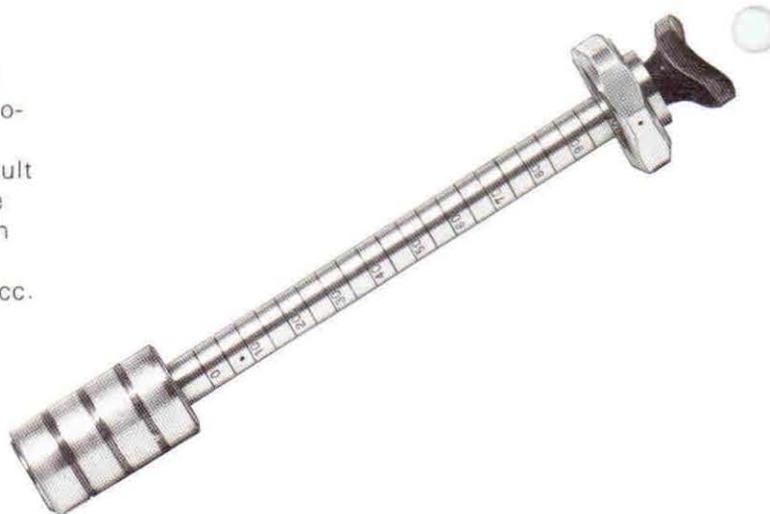
The detector tube contains a chemical reagent which absorbs and reacts to the gas or vapor being analyzed. A constant color stain is produced which varies in length according to the concentration of the material being measured. The **length** of stain is measured against a calibration chart furnished with each box of tubes.

*Users' names supplied upon request.

PUMP

The maintenance-free, lubricant-sealed pump has a solid brass, hand-honed, corrosion-proof piston. This piston provides an airtight seal even with only one atmosphere of differential pressure. This precision pump design, the result of an extensive, 15-year research program, eliminates the problems of wear, leakage and deterioration inherent with a rubber bulb or bellows or O rings. The handle of the pump is accurately calibrated and marked from 0 to 100 cc.

The thousands of 400 pumps placed in service during the past 10 years continue to perform effectively with only simple "in the field" lubrication.



SINGLE, PRECISION ORIFICE

Air samples are drawn into the Precision Pump at a fixed and reproducible rate through a single, stainless steel, limiting micro-orifice. This single precision orifice, and the design of the Detector Tubes, eliminates the chance for error over multiple orifice pumps. Since Detector Tubes are calibrated for 100 cc, there is no possibility of an error caused by selecting the wrong orifice for a given tube. The Single Orifice is precision drilled, countersunk and microscopically inspected for cleanliness, smoothness and regularity. This precise manufacturing and quality control assures that the same quantity of air is drawn into the tube each time a sample is taken.



Kitagawa DETECTOR TUBES

EVALUATIONS FOR 82 DIFFERENT GASES & VAPORS

Precision Detector Tubes are formulated with a constant reagent weight which is corrected for variations in each tube's diameter. Only finest grain or mesh size inert material, such as Silica gel, is used to insure uniform flow and distribution. Each reagent is selected so that there is a sharp and distinct color demarcation in the tube. All tubes are ready for use without prior mixing.

The Precision Gas Detector method of measuring gases and vapors by length of stain eliminates the possibility of error due to color comparison. Accurately calibrated charts are supplied for each set of tubes.

This precise sampling method and quality production techniques always assure **reproducible results.**

MODEL 100 LENGTH-OF-STAIN CARBON MONOXIDE DETECTOR

The Model 100 detector tube provides accurate measurement of Carbon Monoxide concentrations. Measuring the length-of-stain produced by CO against the calibration chart establishes the amount of Carbon Monoxide present in parts per million. Readings as low as 10 ppm can be obtained with just one pump stroke (100 ml). The entire procedure takes just 3 minutes with guaranteed accurate, reproducible results.



BENDIX-UNICO PRECISION GAS DETECTOR MODEL 400 KIT



Included in the Bendix Unico No. 400 Gas Detector Kit are the pump, metal carrying case, spare parts and operating manual. Tubes for over 82 different gas and vapor detections are available. Complete ordering information is contained on the Range Chart. Each box of tubes includes complete in-

structions, temperature corrections, measurable concentrations, T. L. V., shelf life, interferences, and quality control number.

A complete inventory of all tubes is kept in our plant for immediate shipment.

BENDIX MODEL 410 AIR FLOW INDICATOR



Bendix's Air Flow Indicator makes it possible to visually determine the directional pattern and velocity of air currents flowing from air ducts, ventilating and heating systems and chemical laboratory hoods.

The operating procedure is simple: After breaking the tips of the smoke tube, it is inserted into the aspirator bulb. The tube will emit white smoke when air is aspirated through it, making the movement and patterns of air currents clearly visible. A single tube provides 200 aspirations of smoke.

Bendix's Air Flow Indicator may also be used for rapid, absolute testing for the fit of half-mask and full mask respirators. Information on this application and use is found in the instructions included with each kit.

The kit includes 10 smoke tubes, aspirator bulb and rubber end caps, all conveniently packaged in a pocket-sized vinyl pouch. Each smoke tube is hermetically sealed and can be stored indefinitely.

PART NO.	DESCRIPTION
MODEL 400 GAS DETECTOR	
400-10	Model 400 Gas Detector Kit w/carrying case and accessories
400-15	Model 400 Precision Pump
400-20	Rubber Inlet Flange 16 each
400-30	Stainless Steel Limiting Orifice
400-55	Lubricant (Tube)
MODEL 410 AIR FLOW INDICATOR	
410-10	Air Flow Indicator Kit
410-11	Replacement Smoke Tubes



NATIONAL ENVIRONMENTAL INSTRUMENTS, INC.

P.O. Box 590, Pilgrim Station, Warwick, R.I. 02888 Tel. (401) 738-3710 Cable: NEICO



Distributed by:



THE GASTECH MODEL 1024
ULTRA SENSITIVE GAS DETECTOR

- Range 0 - 100 PPM
- Continuous or intermittent sampling
- Detects all hydrocarbons
- Readily calibrated
- Portable

NEW LEVEL OF SENSITIVITY

A new sensitivity level in a direct-indicating gas detection instrument is offered in the Model 1024. Full-scale readings of most hydrocarbons are attainable on concentrations as low as 100 ppm. Utilizing a metallic-oxide detecting element which changes its electroconductivity drastically when exposed to traces of gas, a Wheatstone bridge measurement system permits direct reading of traces of vapor below 10 ppm.

DESCRIPTION

Power is taken from the 115AC power line, with regulated voltages being applied to the sensor and bridge circuit. A built-in vibratory pump draws a sample continuously over the sensing element, with flow being indicated by a flowmeter on front panel. Circuit may be balanced to zero, using the 10-turn zero adjustment potentiometer, while sampling through the built-in charcoal filter bed to exclude unwanted background vapors. An internal coarse calibration control and a front-panel fine calibration control permit setting for direct readings on a known calibrating sample of the vapor to be tested. Readout is on a scale of approximately logarithmic distribution, with 25 ppm occurring near mid-scale. Recording of meter readings can be taken by plugging a DC multivolt recorder into jacks on rear of case.

APPLICATION

The instrument is usable on all hydrocarbon vapors, including halogenated types. It is non-specific so readings can be interpreted directly only when only one vapor can be present. Background interference due to hydrogen or CO can occur, but this effect can usually be minimized by zeroing through the charcoal filter.

SPECIFICATIONS:

Power required	:	115V 50/60 Hz at 0.2 A
Weight	:	8-1/2 lb.
Dimensions	:	11" x 7" x 7"
Recorder output	:	0 - 10, 0 - 25, 0 - 50, 0 -100 millivolts
Line cord	:	9', grounding type
Sample line	:	10', Teflon-lined
Warm-up time	:	10 minutes
Response time	:	5 - 10 seconds

ORDERING DESCRIPTION

- 1 - Model 1024 Ultra Sensitive Gas Detector complete with 10' sample line, for 115 AC power supply.

MADE BY:

Johnson Instrument Division
GASTECH, Inc.
2560 Wyandotte St.
Mountain View, Calif. 94040

FIGURE 5 -- COMBUSTIBLE GAS ANALYZER



PORTABLE GAS ANALYZERS

FOR COMBUSTIBLE GAS HAZARD AND OXYGEN DEFICIENCY TESTS

J-W SNIFFER® Model G

This dependable, economical, hand-aspirated detector is unsurpassed for convenience in testing atmosphere for explosive gas. Squeezing the SNIFFER's aspirator bulb draws vapor from test point through sampling assembly into its catalytic/Wheatstone bridge sensor. Presence of combustible gas is indicated instantly on the SNIFFER's easy-to-understand meter dial. Detachable probe-hose, optional. Analyzing circuit powered by readily obtainable "D" batteries. Size: W-4 3/8"; D-3"; H-5 3/4". Weight--approx. 4 lbs.



U.S. PATENT NO. 2,786,350



J-W SNIFFER is also available with built-in sampling pump and rechargeable battery.

J-W SENTINEL INDICATOR-ALARM

The SENTINEL automatically warns of combustible gas in the atmosphere with a penetrating sound which continues until the dangerous condition is remedied. Also has meter which shows gas concentration continuously. Transistorized electrical circuit assures trouble-free, dependable service. Loudspeaker's oscillator and analyzing circuit powered by rechargeable battery. Separate battery charger optional. Size: W-10"; D-6"; H-6". Weight--approx. 11 lbs.



Rugged construction makes SENTINEL ideal for constant use.

J-W SUPER-SENSITIVE Model SS-P

Designed for industrial hygiene work and other uses where it is essential to detect and measure minute concentrations of combustible gases and vapors, including combustible toxic vapors. Special sensor filaments, meter, high-sensitivity electrical circuit, and constant sample flow from integral pump powered by rechargeable batteries permit tests to be repeated rapidly with maintained accuracy. Two scales: 0-1.0 l.e.l. for explosibility indication, 0-1000 ppm for comparing toxic conditions with TLV ratings. Analyzing circuit and pump powered by two rechargeable nickel-cadmium batteries. Furnished with detachable probe-hose. Size: W-8"; D-3"; H-6". Wt.--approx. 6 3/4 lbs.



SENTINEL cover opens readily for easy access to controls. Convenient plug-in for battery charger located on outside of case.

J-W OXYGEN DEFICIENCY INDICATOR

Specifically made for measuring oxygen content in confined areas to determine if sufficient oxygen is present for breathing purposes, and to check oxygen content in inert atmosphere. Range 0-25% O₂. Hand-aspirated. Can be used for rapidly-repeated tests. Unaffected by most "background" gases. Detachable probe-hose for manhole tests, optional. Equipped with self-generating electrolytic cell; no batteries required. Size: W-4 3/8"; D-3"; H-5 3/4". Weight--approx. 2 1/2 lbs.



Diffusion-type detector head may be placed at a sampling location any distance up to 15 feet from SENTINEL read-out unit by using 3-wire extension cable with plug and socket, optionally available.



BACHARACH INSTRUMENT COMPANY
A DIVISION OF **AMBAC** INDUSTRIES, INC.

625 ALPHA DRIVE, PITTSBURGH, PENNSYLVANIA 15238

Bacharach **GASTRON** Combustible Gas Detector

For Hydrocarbons (Natural Gas) and Hydrogen

The Gastron locates leak sources by detecting trace quantities of combustible gas in air. It is ideal for use by gas transmission and distribution companies, chemical plants, refineries, sewage disposal plants or at any site where explosive gases may be expected.

Description

The BACHARACH Gastron is a highly sensitive, portable instrument used to detect and locate combustible gas leaks. This device will detect hydrocarbon concentrations from 50 ppm to 25% gas/air mixtures. These rugged, lightweight units contain features not available in other portable leak detectors. Continuous sampling with both visual indication and audio signal insures maximum efficiency and operator safety. A three position, thumb-operated Range Selector Switch provides three operating ranges. SEARCH, MID-RANGE, and COARSE. Rapid response and humidity compensation are additional features of both units. Low cost operation is achieved through the use of a lightweight, rechargeable battery which is designed to slip conveniently onto an operator's belt. The Gastron can be operated and maintained by non-technical personnel.

A multi-position selector switch provides operational mode selection. The Model 282 provides an ON position, a BATTERY check position, and a system OFF position. In the ON mode, both the 282 and the 310 detect combined hydrocarbons and hydrogen. The Model 310, when used in the H₂ mode, detects only hydrogen.

The Model 310 is identical to the Model 282 except that it provides an additional feature . . . hydrogen detection. The 310 will detect hydrogen concentration from 50 ppm to 5% gas/air mixtures.



Features

- High Sensitivity
- Rapid Response
- Wide Range
- Meter Readout
- Audio Signal
- Battery Powered

Applications

Protection from the hazards of leaking combustible gases is a never ending concern of not only Gas Company personnel, but of Military, Fire, Police, Water, Sewage and Waste, and Telephone personnel. Safety Engineers in factories and plants, schools, and churches find the Gastron a unique and useful safety tool.

The application of the Gastron is very clear and very broad . . . any place where combustible gases such as hydrocarbons or hydrogen are likely to be encountered.

A continuous sample of air is drawn through a sensing element where controlled catalytic combustion occurs, causing a signal to be generated which feeds both a visual and an audio indicating circuit. When gas is detected, an audio signal is momentarily interrupted and a visual indication is presented on a visual readout meter.

Special design features stabilize the visual readout meter against motion. Response and recovery after severe overloads are

Bacharach **GASTRON** Combustible Gas Detector

Models 282 and 310 Specifications are for both models unless otherwise noted.

General Specifications—

Operating Ranges

Combustible Gases

Search—0 to 500 ppm

Midrange—0 to 2½ %

Coarse—0 to 25%

Hydrogen Only

Search—0 to 250 ppm

Midrange—0 to 0.5%

Coarse—0 to 5%

Indication—Visual and Audio

Adjustments—

Zero Adjust, Indicating Meter

Motion Stability—

Suitable for hand carrying

Battery

Type—Nickel Cadmium

Capacity—4 ampere hours

Filters

Humidifier—Commercial Fiber

Dust—Fiberglass

Weight

Detector—2 lbs., 6 oz.

Battery in case—2 lbs., 4 oz.

Performance Specifications—

Sensitivity

Combustion Gases—

Better than 50 ppm

Hydrogen—Better than 10 ppm

Response Time—Less than 2 seconds

Warm-up Time—2 minutes

Water Vapor Discrimination

Dry Filter—100 to 1

Wet Filter—1000 to 1

Dust Discrimination—

Filters down to 1 micron

Temperature

Operating— -30°F to +130°F.

Storage— -60°F to 150°F.

Drift Rate—100% of scale per hr. in

"Search" range (approx.)

Detector Cell Life (Average)

100 hours (normal operation)

Ordering Information

Gastron Combustible Gas Detector,

Model 282 complete 23-7059 . . .

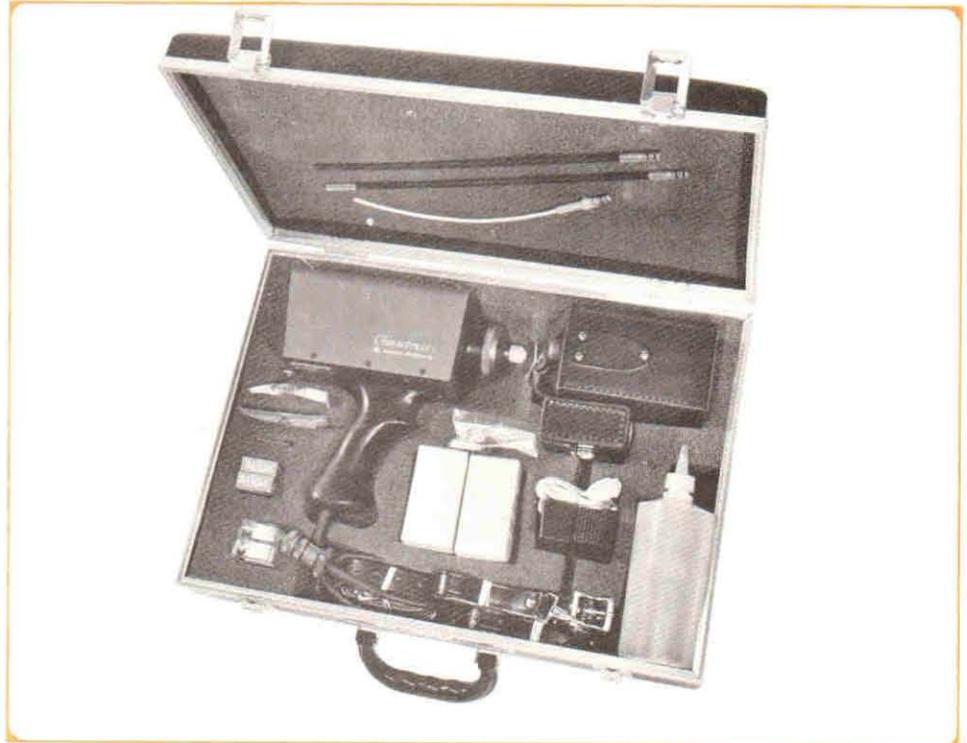
Gastron Hydrogen/Combustible Gas

Detector, Model 310 complete 23-7060

. . . Complete Kits include the model

Gastron selected, plus the following:

Carrying Case	23-7070
Probe Complete	23-7065
Calibration Kit	23-7075
Battery Charger 110V. 5060Hz.	23-0849
Battery Charger 220V. 5060Hz.	
Battery	23-0848
Battery Case (2 pin "AN" Socket)	23-7078
Accessory Case Assembly	23-7074
Instrument Shoulder Strap	23-0614
Cell Retainer Wrench	23-0636
1/16" Hex Wrench	3427
Humidifier Filters (2 boxes)	23-0632
Dust Filters (2 boxes)	23-7082
Detector Cell (1 spare)	23-7165
Earphone	23-0605
Battery Case Shoulder Strap	23-0613
Compression Sleeve & Nut Kit	23-0649



What The Experts Say

"We have had ample opportunity to perform the tests under varying and trying conditions but due to the winds we have here in the desert. At no time has the detector let us down. While we were using it daily we charged the battery every other night and found this sufficient. The fact that the instrument is self contained, with continuous operation, leaves little margin for error, even for the inexperienced."

"I have had occasion to use the bulb type sniffer and have used it against the "Gastron", and I would invite anyone to make this comparison, as they will find that the "Gastron" is considerably faster and much more accurate."

"The cooperation and fast action we received from your company in an emergency is commendable. The manhours and time saved during the emergency with the "Gastron" detector is not measurable as lives were involved."

GEORGE E. KREMSER, Chief Preventive Maintenance
Branch, Edwards AFB, California

"After using the GASTRON in the field, we highly recommend that this device be tested by other Fire Departments. We feel that it has wide application and answers an important safety requirement."

CHIEF HARRY C. MOORE, Monterey Park Fire
Department, Monterey Park, California

"It is much more sensitive than most instruments of this type and has the further advantage of taking a continuous sample of the atmosphere being tested."

"We have used production models for almost a year. We are convinced the Gastron will detect concentrations of the order of 50 ppm and that it can be used in the field by experienced workmen with only normal care in handling."

"We have found it to be a useful tool in completely paved metropolitan areas and useful in locating leaks on houselines and tracing out minute traces of gas in underground conduits. We have also used it successfully in detecting leakage on transmission lines that are inaccessible to vehicles."

ROBERT D. POMEROY, Staff Engineer,
Southern California Gas Company

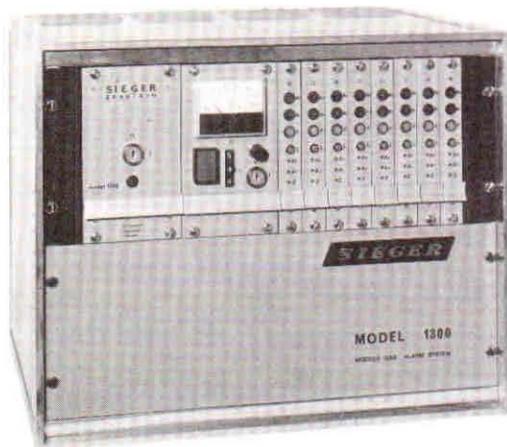


BACHARACH INSTRUMENT COMPANY

A DIVISION OF **AMBAC** INDUSTRIES, INC.

625 Alpha Drive, Pittsburgh, Pa. 15238

Phone 412/782-3500



MODEL 1300

The Model 1300 control system is a new extension to the well established SIEGER range of Gas Detection Equipment designed for continuous industrial use where plant and personnel need to be protected against potentially explosive toxic atmospheres. The system can also be applied to meet process and other control requirements.

MODULAR TRAY DIMENSIONS – Height: 7” Depth: 14” Width: 19”
WALL – TABLE MOUNTING – H-16 1/8” D-16” W-19 13/16”



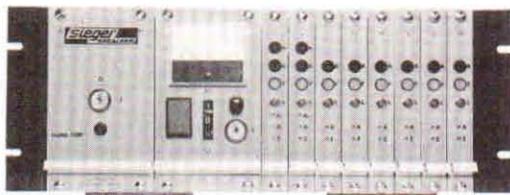
STANDARD 1300 TRAY

Fitted in wallmounting cabinet



1300 RACK MOUNTING MODULAR TRAY

NOTE: Mixture of single & two level alarms on circuit modules



A standard system consists of explosion-proof detector heads located in the danger area and connected electrically to the modular control unit installed remotely. The control unit contains fully transistorized solid state circuits in modular form together with power supply and meter modules. Integral alarm and fault signal lamps are provided, and also clean contact relays for remote alarm, fault or control requirements.

The basic modular tray is suitable for 19” rack mounting or can be provided in wall mounting cabinets as illustrated. The tray incorporates: –

- 1) A power supply module to accept 100–250V A.C. 50–60 c/s single phase mains supply, or 24 VDC. 18 VDC unit system power.
- 2) Meter module with channel selector switch, Monitoring meter scaled 0-100% of the L.E.L. and test alarm controls with key switch. A reset alarm button is also provided. A common master alarm relay – two for 2-level alarm – and a common master fault relay are incorporated as standard in the meter module, each relay having changeover contacts rated 5A 250V A.C. Independent alarm relays can also be provided.
- 3) Individual circuit modules, maximum 8 per tray, each incorporating 1 or 2 alarm signal lamps, fault lamp, test lamp button and circuit controls. Recorder outputs are also available.

- | | | |
|-------------------------|---|---|
| SIMPLE OPERATION | – | SKILLED ATTENDANCE NOT NECESSARY. |
| ACCURATE | – | ALARM LEVELS CAN BE SET PRECISELY. |
| MAINTENANCE | – | MINIMAL. NO CHEMICALS TO CHANGE. |
| ROBUST | – | PRINTED CIRCUITS – TRANSISTORIZED, SOLID STATE. |
| SENSITIVE | – | ALARM ADJUSTABLE FROM 2% TO 100% L.E.L. |
| TWO LEVEL ALARM | – | 1 OR 2 ALARM OR CONTROL LEVELS. BOTH ADJUSTABLE. |
| FLEXIBLE | – | DETECTOR HEADS IN DANGER AREA; CONTROL UNIT IN SAFE AREA. |
| RAPID RESPONSE | – | ALARM IN 1–3 SECONDS. NO ASPIRATION OF SAMPLE REQUIRED. |
| SAFE | – | EXPLOSION-PROOF DETECTOR HEADS. |

IMPORTANT FEATURES

ADDITIONAL MODELS IN THE 1300 SERIES

Model No.	No. of Channels	Range	No. of Alarm Levels	Alarm Sensitivity	Power Requirements	Type of mounting
1310	4-8 per tray	ppm*	1 or 2	from 10% scale	110-250V AC or 24V DC	rack or cabinet
1330	4-8 per tray	LEL ppm (mixed)*	1 or 2	from 2-5% LEL or from 10% scale	110-250V AC or 24V DC	rack or cabinet
1303	1-3 per tray	LEL	1 or 2	from 2-5% LEL	110-250V AC or 24V DC	rack or cabinet
1313	1-3 per tray	ppm*	1 or 2	from 10% scale	110-250V AC or 24V DC	rack or cabinet

FIGURE 7 -- COMB. GAS ANALYZER, PLANT

*Standard meter calibration:
 0 – 250 ppm
 0 – 500 ppm
 0 – 1000 ppm
 Dependent upon gas.



Multi channel systems having high sensitivity and flexibility. All detection channels operate continuously and independently. There are a variety of possibilities for grouped or independent external alarm or control signals.

DISTANCE FROM CONTROL UNIT TO DETECTOR

The detector head(s) can be situated at any distance from the control unit provided that the resistance of each lead is kept to a maximum of 1 ohm. The following table gives a guide to minimum cross sectional area required for any given length of cable.

Minimum cross sectional area conductor inches ²	Maximum allowable cable length yards
0.001	40
0.002	80
0.003	120
0.004	160
0.008	320
0.010	400

SITING AND INSTALLATION OF DETECTOR HEAD

In most cases the best position for the detector head will be obvious, according to whether the gas is lighter or heavier than air. Where there is any doubt the manufacturers will be glad to advise.

When the siting has been decided, the head can be fixed in place with two screws.

According to how the gas is most likely to impinge upon the gauze, the head may be placed in any desired position without affecting its sensitivity. However, once this has been decided the head should remain in a fixed position: any change in orientation of the sensing elements may effect a slight change in the sensitivity setting of the control unit.

A special draught deflector fitted over the detector head is provided in special circumstances, such as installation in an extract duct when the air velocity exceeds 100 ft. per minute.

TABLE OF CHARACTERISATIONS OF DANGEROUS GASES & SENSITIVITY OF SIEGER GAS ALARM SYSTEM

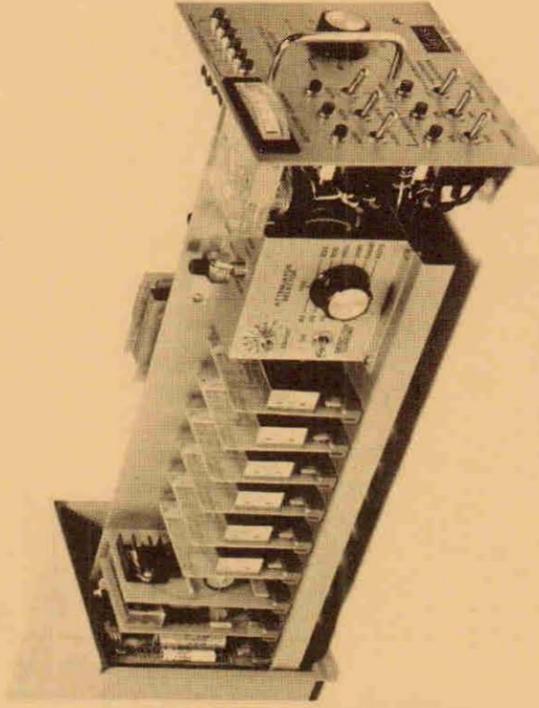
NAME OF SUBSTANCE	STATE AT N.T.P.	VAPOUR DENSITY AT 15°C. (AIR=1)	FIRE HAZARD	PHYSIOLOGICAL EFFECTS	Limits of Inflammability		MODEL 1300 Alarm Sensitivity % v/v
					Lower Limit % v/v	Upper Limit % v/v	
Acetone	Liquid	2.01	Highly Inflammable	Anaesthetic	2.5	9.0	0.25
Ammonia	Gas	0.60	Low Inflammability	Irritant	16.0	27.0	0.15
Butyl-Alcohol	Liquid	2.1	Highly Inflammable		1.45	11.25	0.07
Ethyl-Alcohol	Liquid	1.39	Highly Inflammable	Irritant	4.0	18.0	0.2
Methyl-Alcohol	Liquid	1.11	Highly Inflammable		6.0	36.0	0.3
Propyl-Alcohol	Liquid	1.87	Highly Inflammable		2.15	13.5	0.18
Benzene	Liquid	2.69	Highly Inflammable	Toxic Anaesthetic	1.4	7.5	0.07
Butadiene	Gas	1.69	Highly Inflammable		2.0	11.5	0.019
Butane	Gas	2.07	Highly Inflammable	Anaesthetic Asphyxiant	1.9	8.5	0.02
Carbon Monoxide	Gas	0.968	Highly Inflammable	Asphyxiant	12.5	74.0	0.03
Chloro-Benzene	Liquid	3.5	Highly Inflammable		1.35	7.05	0.07
Coal Gas	Gas	0.35-0.45	Highly Inflammable	Asphyxiant	5.0	31.0	0.1
Cyclo-Hexane	Liquid	2.6	Inflammable		1.22	4.81	0.07
Dichloro-Ethane	Liquid	3.1	Inflammable		6.2	15.9	0.25
Dichloro-Propane	Liquid	3.53	Inflammable		3.4	14.5	0.15
Dichloro-Methane	Liquid	2.63	Non Inflammable		15.0	—	3.0
Ethane	Gas	1.05	Highly Inflammable	Anaesthetic Asphyxiant	3.1	15.0	0.15
Ethylene	Gas	0.97	Highly Inflammable	Anaesthetic Asphyxiant	3.0	29.3	0.15
Heptane	Liquid	3.45	Highly Inflammable	Anaesthetic and Irritant	1.0	6.0	0.05
Hexane	Liquid	2.95	Highly Inflammable	Anaesthetic and Irritant	1.3	6.9	0.05
Hydrogen	Gas	0.07	Highly Inflammable	Asphyxiant	4.0	75.0	0.08
Methane	Gas	0.55	Highly Inflammable	Asphyxiant	5.0	15.0	0.25
Methyl-Ethel-Ketone	Liquid	2.25	Highly Inflammable		1.83	10.0	0.1
Octane	Liquid	3.86	Highly Inflammable	Anaesthetic and Irritant	0.8	3.2	0.05
Pentane	Liquid	2.49	Highly Inflammable	Anaesthetic and Irritant	1.4	7.8	0.07
Gasoline	Liquid	3.0-4.0	Highly Inflammable	Anaesthetic	1.3	6.0	0.07
Propane	Gas	1.56	Highly Inflammable	Asphyxiant	2.4	9.5	0.12
Sewage Gas CH ₄ CO ₂	Gas	0.7-1.0	Highly Inflammable	Asphyxiant	7.5	19.00	0.5
Toluene	Liquid	3.18	Highly Inflammable	Toxic Anaesthetic	1.3	7.0	0.06
Xylene	Liquid	3.66	Highly Inflammable	Toxic Anaesthetic	1.0	5.3	0.05

SMITH-JESSE

PROGRAMMER

SERIES 500

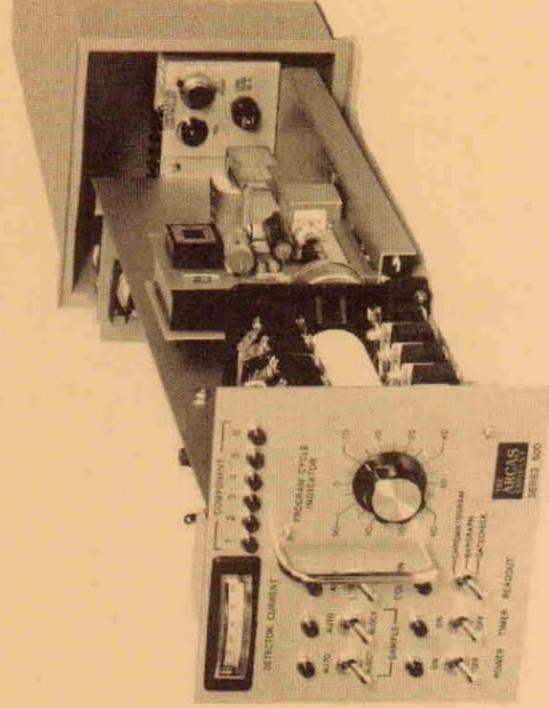
Single Stream



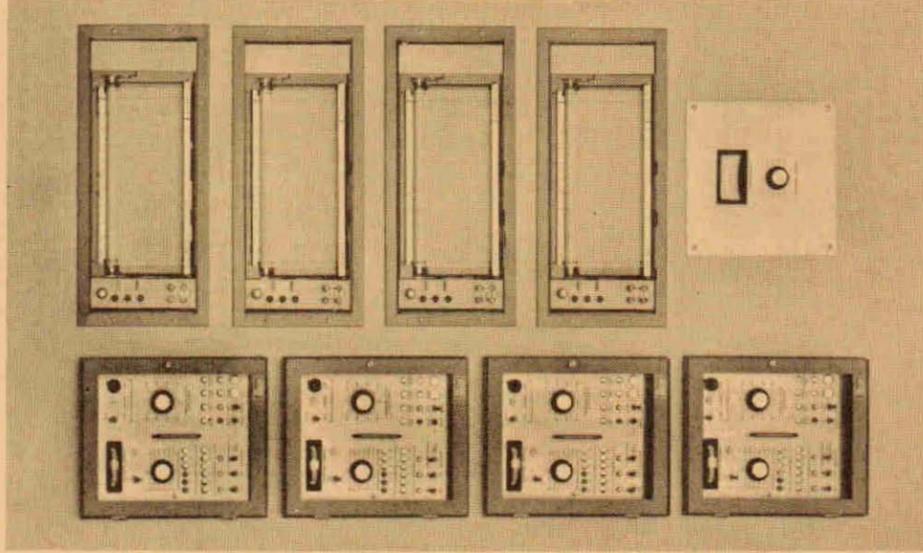
This programmer is designed to handle single stream applications from monitoring six components to peak picking or integrating functions in conjunction with computers, and/or closed loop control.

This is accomplished with "building blocks" of printed circuit plug board "functions" identical to the Series 400 Programmer.

The unit occupies only 7" x 7 1/2" or panel space, yet retains complete flexibility except for multistream applications.



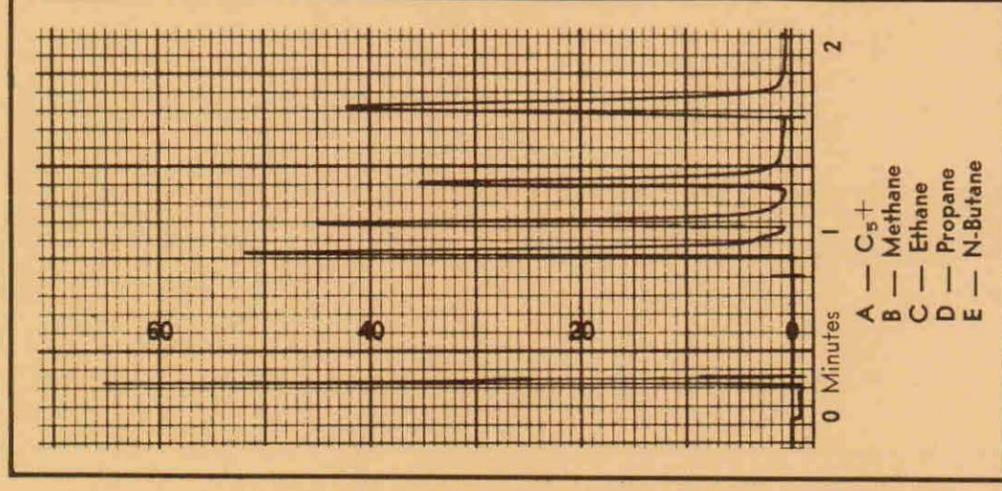
CONTRACT MAINTENANCE
APPLICATION ENGINEERING
ANALOG CLOSED LOOP CONTROL
DIGITAL COMPUTER
CONTROL APPLICATIONS



The Arcas Company - SERVICES

Complete services are available. Included are maintenance, analytical development, custom design, and panel mounting (above). Sample systems have been designed and implemented for corrosive and non-standard environments.

Complete systems capability is available for the application of computers to problems of analysis, control, and automation.



ACCESSORIES

A complete line of chromatograph and sample handling accessories is available including:

Sample Valves
Sample Probes
Regulators
Vaporizing
Pumps
Cylinder Racks
Cylinder Manifolds
Teflon Valves
Teflon Fittings
Filters
Pumps
Filaments

THE ARCAS COMPANY

2040 KIPLING

HOUSTON, TEXAS 77006

TELEPHONE: AREA CODE 713 - 529-5768

Bulletin No. 4500-1 — April 2, 1971

ANALYZER

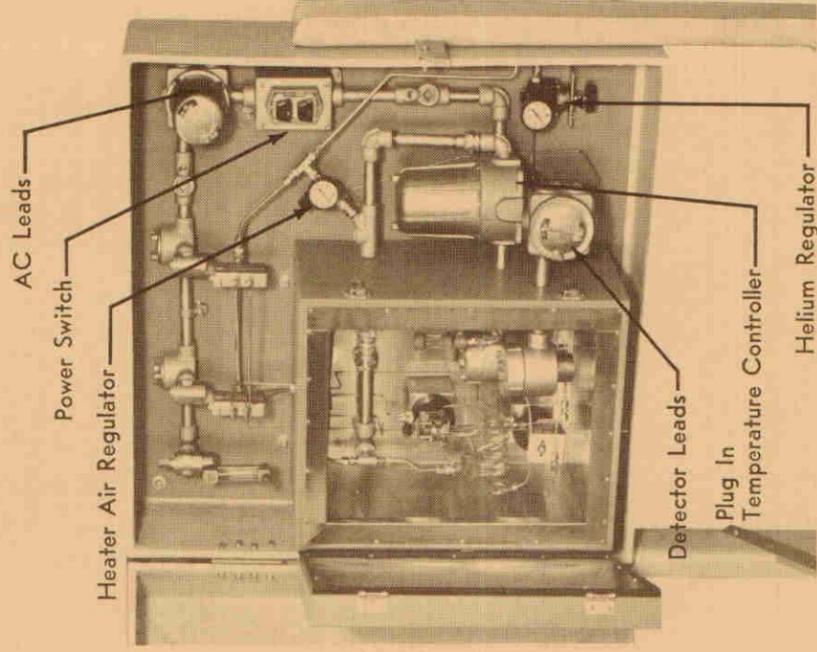
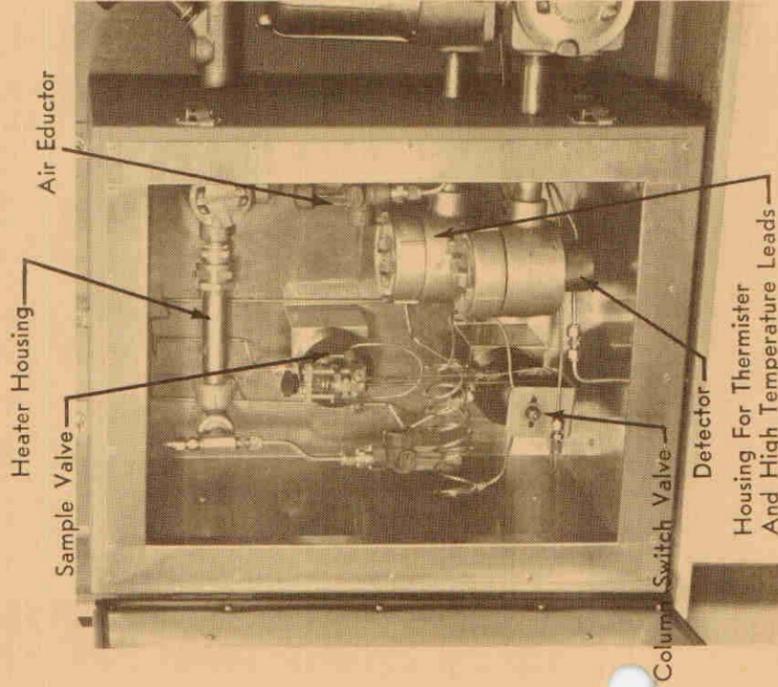
SERIES 400

The Arcas Series 400 analyzer is designed for reliability, stability, and accessibility of all components. Individual explosion proof condulets are used for most components. This makes all components quickly accessible and segregates AC from the DC signal leads. This contributes to the low noise to signal ratio required for computerized applications. The components are mounted on a fiber-

glass subpanel. This subpanel can be wall mounted in a user furnished house or can be mounted in a standard corrosion proof fiberglass weatherproof housing as shown. The house can be optionally temperature controlled. All flow rates can be adjusted external to the oven. Hydrogen and air for flame detectors are plumbed through three way diverter valves for measuring and setting.

Model B

The Model B analyzer utilizes an air bath oven with an efficient air distribution system using two eductors. This arrangement causes oven air to be circulated in approximately five seconds with a fresh air flow of two CFM. This feature, in conjunction with the proportional plus reset temperature controller yields the consistent elution times required for modern high speed computer control applications.



MODEL B

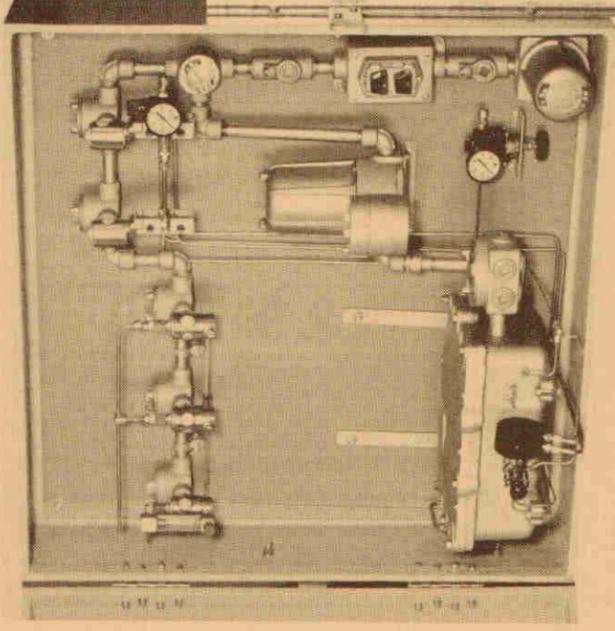
Dimensions:

Overall 36" x 36" x 18"
Oven, inside 18" x 14" x 10"

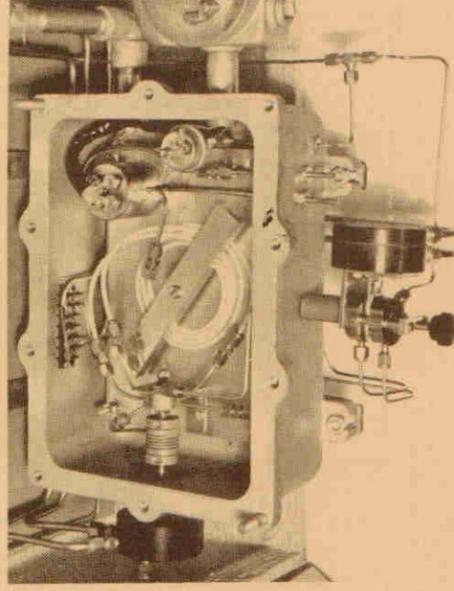
c-54

Model S

The Model S analyzer is mounted and installed the same way as the Model B. Most of the components are the same and are interchangeable. Model S differs in that the heating medium is an aluminum heat sink contained in an explosion proof conduit instead of the heated air bath. This type oven results in extremely uniform temperature, consumes no instrument air, 1/4 the power, and will stabilize the temperature within one hour after being turned on.



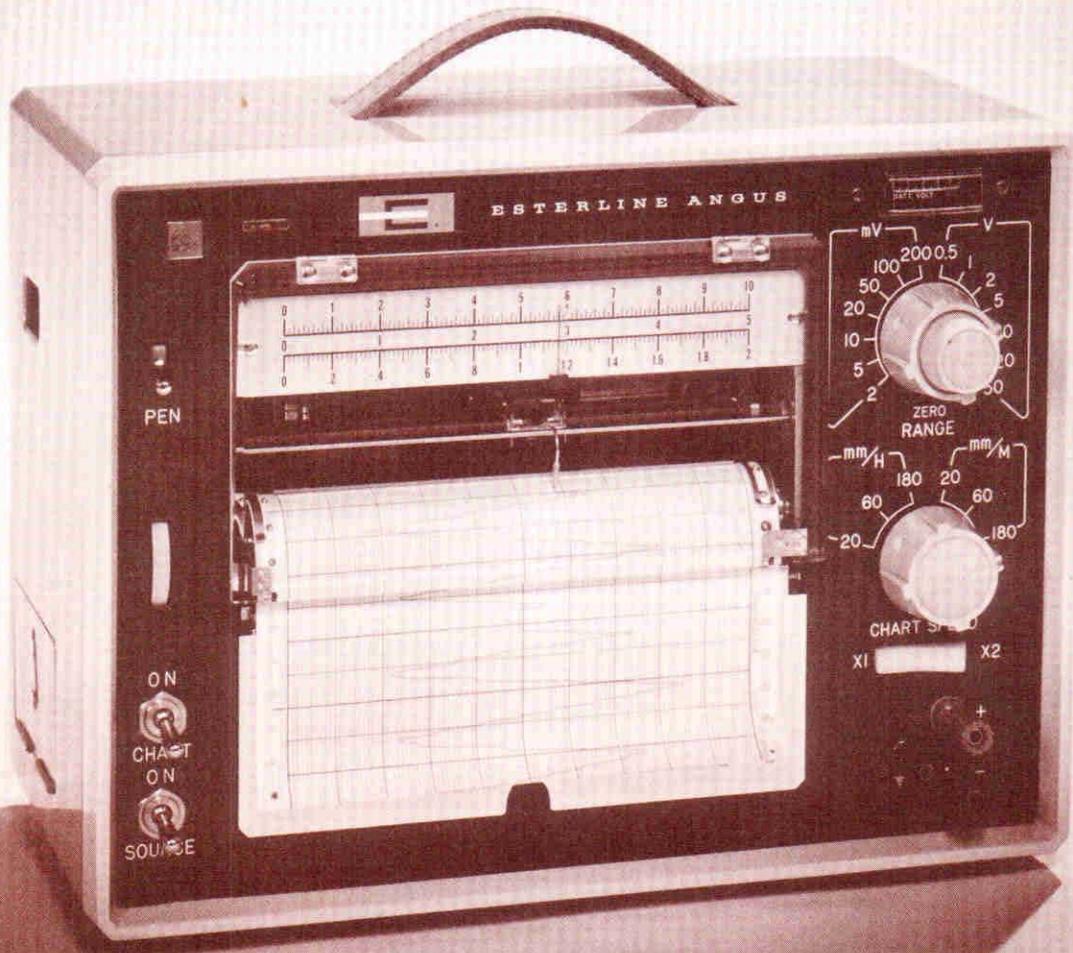
Up to three valves can be used if required. This type oven is good for conventional analyses and is especially well suited for a variety of special applications. One very useful arrangement is the placement of a liquid sample valve outside the oven with a temperature controlled flash heater between the valve and column. This technique is useful in applications analyzing a sample containing a wide range of boilers or very polar samples where a precise flash heat is required at a temperature above column temperature.



Oven Close-Up



ESTERLINE ANGUS



A Portable Battery Operated Servo Recorder Priced at \$800

Imagine a truly portable servo recorder that operates on rechargeable nickel-cadmium batteries for 12 hours, on conventional 1½ volt "D" cell batteries for eight hours or on AC indefinitely, and you have the Esterline Angus Port-A-Graph Servo.

This solid state Model T171B Recorder weighs only 15 pounds and measures 12½" wide, 9½" high and 6½" deep. Packed into this compact space are eight millivolt and six volt spans, one of the most simple rotary servo motors ever devised (only two pulleys), a 12 speed chart drive and a sliding bobbin that carries the slidewire wiper.

Wherever there's a recording job to be done, this recorder is ready to go. Especially adapted to field studies, the Port-A-Graph Servo also finds wide use in laboratories.

Uses include studies of • soil temperature • intensity of sunshine • soil moisture content • temperature of animals • acceleration and speed • fuel consumption • torque • biological, medical and chemical phenomena • water and air pollution • plant surveys • production • road roughness • wind speed and direction • atmospheric temperature • barometric pressure • nuclear or ore prospecting • radiation levels • sound level • radio propagation • intoxication.

Outstanding Features

- Entirely solid state
- Truly portable. Operates on nickel-cadmium batteries which can be recharged overnight, on 1½ volt "D" cell batteries or on conventional AC line volt-

age. Recharging unit built into recorder. Three position switch permits selection of 1.) battery operation, 2.) AC operation or 3.) recharge.

- Pen response of 1/2 second full scale.
- High input impedance (two megohms) achieved through use of first stage Field Effect Transistor input.
- Exceptional sensitivity of 2 MV full scale. Selector switch permits instant selection of any one of 14 spans ranging from 2 MV to 50 V.
- Full scale zero adjust.
- Manual pen lifter to allow indication without recording.



Lined with soft material, this optional carrying case protects the Port-A-Graph Recorder during transit. There's plenty of room to store spare charts, ink and the power cable.

- 12 switch selectable chart speeds ranging from 20 mm per hour to 360 mm per minute.
- Completely enclosed inking system.
- Multi-range scale plate. Read 0-2, 0-5 or 0-10 on one scale plate.
- Adjustable controls for gain, damping and calibration. Damping controlled through use of feedback coil.
- Linear, high turn density feedback potentiometer of excellent resolution.
- Low (2.8 VA) power consumption.



This rear view of the recorder shows the ease with which the battery pack can be removed. For AC operation or recharging, the power cable connects quickly and can be locked in place.

Specifications

Pen Response	1/2 second full span.
Accuracy	± 0.5% of span.
Input Impedance	2 megohms.
Maximum Source Impedance	10 K ohms for rated accuracy. Up to 1 megohm causes no degradation of response. Calibration adjustment may be required for input impedances above 10 K ohms.
Dead Band	0.25%
Zero Adjust	Full scale.
Chart No. S-21193	150 mm active width. No time numbers. Cross (time) line spacing at 10 mm intervals. Range 0-10, 10 major divisions, 100 minor divisions.
Ambient Temperature Range	+50 to +110°F.
Options	Carrying case, event pen (left hand 1.5 V DC), battery powered chart reroll adapter, 12 V auto battery adapter and thermocouple cold junction compensator.

Chart Speeds	12, switch selectable. 20, 60 and 180 mm per minute and hour with two times multiplier.
Scale Plate	Multiple range—0-2, 0-5 and 0-10.
Battery Life (Continuous Operation)	12 hours for rechargeable nickel-cadmium. 8 hours for 1 1/2 V "D" cells. 24 hours for alkaline "D" cells. Up to one week for 74 amp. hr. auto battery. Recorder has battery condition indicator.
Power Input	2.8 VA, 7.5 to 9 V DC and 120 V, 60 Hz or 120 V, 50 Hz.
Weight	15 pounds.
Size	12 1/2" wide, 9 1/2" high, 6 1/2" deep.
Writing System	Sealed ink supply with adjustable head. Replaceable pen point.
Spans	2, 5, 10, 20, 50, 100 and 200 MV. 0.5, 1, 2, 5, 10, 20 or 50 V.
Input Isolation	Up to 200 V DC above ground.
How to order: Specify Model T171B Recorder. \$800 price includes three charts, cartridge ink supply, one spare pen point, a lubrication kit, power cable. Batteries are not included.	

ESTERLINE ANGUS • DIVISION OF ESTERLINE CORPORATION • Box 24000 • Indianapolis, Indiana 46224

Form No. PAGC 1168A (20M)

Telephone 317/244-7611

Printed in U. S. A.

MODEL 6700 CARLE BASIC™ RECORDER FOR GAS CHROMATOGRAPHY

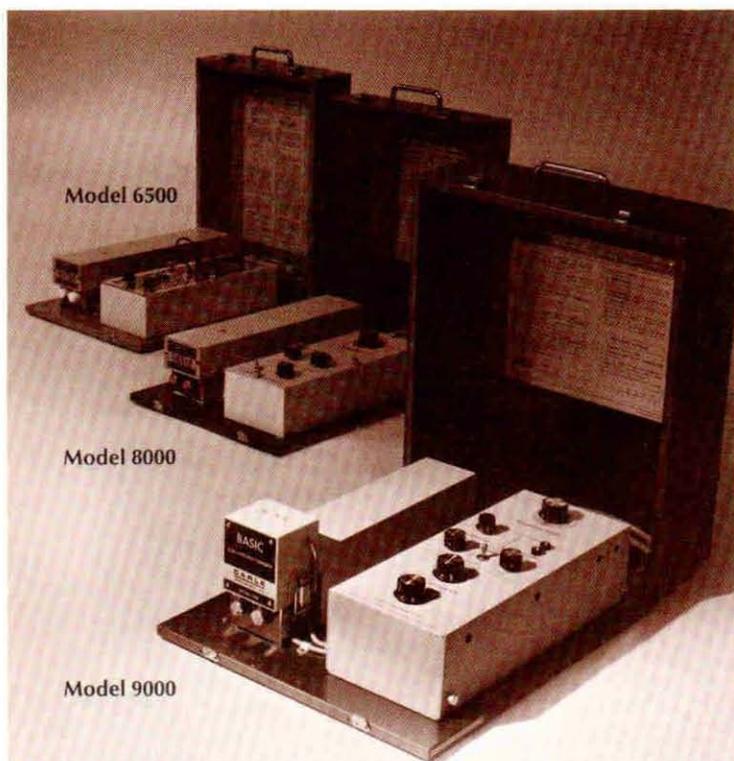
Bulletin 6700B
Revised January, 1972



CARLE
INSTRUMENTS, INC.

FIGURE 21 -- STRIP CHART RECORDER, PORT.

IDEAL FOR GAS CHROMATOGRAPHY



CARLE BASIC™ GAS CHROMATOGRAPHS

The Carle Basic™ Recorder is a specialized version of Westronics, Inc. Model 55E. Proven by over five years use with Basic Gas Chromatographs, the unit combines Westronics engineering excellence with the highest possible quality levels established by individualized Carle specifications. Sensibly priced, the Model 6700 is well-matched for use with any of the several models of Carle Basic™ Chromatographs. It is rugged, compact and convenient and has completely transistorized circuitry with a potentiometric servo system and a fast, 1/2 second pen speed.

To keep cost and ordering complexities down, the Model 6700 has been made available with an absolute minimum of unnecessary or optional features. A live right-hand zero is provided for convenience in gas chromatography applications. The tilt-up platen is easy to write on, and the reroll mechanism (not required in gas chromatography) has been eliminated. The well designed inking system offers an improved level of writing performance. This stems in part from the construction of the pen reservoir. Its direct, short flow path increases ink flow during high speed peaks. Careful matching of the pen capillary size and ink minimizes smears when the chart is turned off.

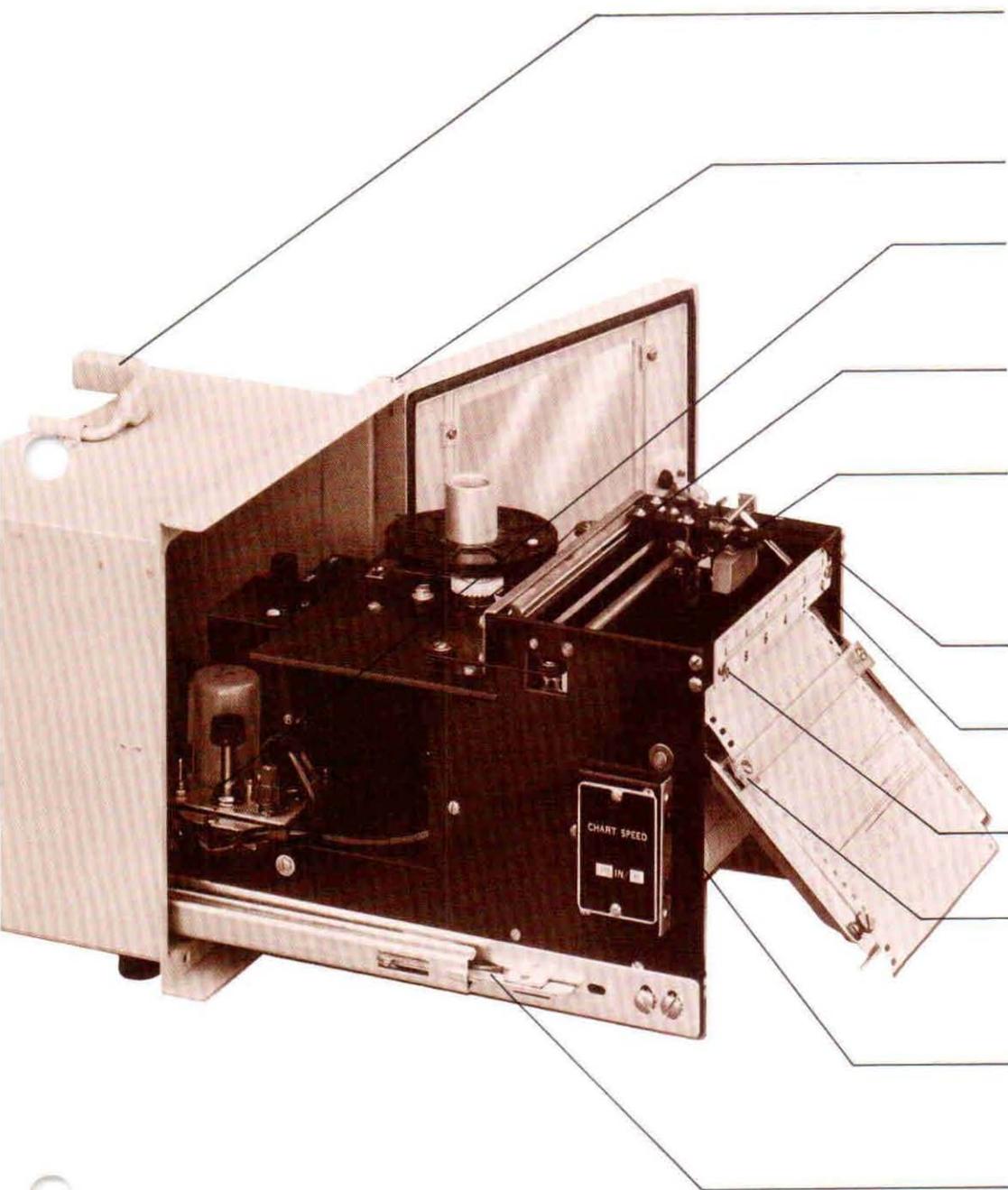
The five-inch chart records GC data compactly and accurately ($\pm 0.2\%$ readability). Reasonably priced, these charts aid in reducing costs especially in laboratories having heavy recorder use.

For more than five years, the Basic recorder has established a record of outstanding field reliability. As a companion to Carle Basic Chromatographs and as a separate unit, the Model 6700's performance level is unexcelled by much more expensive units. Backing up the Basic recorder is Westronics' nation-wide organization for on-the-spot maintenance and the complete factory service available from Carle Instruments.

SPECIFICATIONS

INPUT SIGNAL:	-0.05 to 0.0 to 1.05 millivolts DC, live zero. Input terminals isolated with respect to ground.
SOURCE IMPEDANCE:	5000 ohms.
INPUT IMPEDANCE:	Infinite at null, 20,000 ohms at maximum unbalance.
RESPONSE:	1/2 second full scale.
SLIDEWIRE:	Straight, 780 turns, $\pm 0.1\%$ linearity.
RESOLUTION:	0.1% of full scale.
ACCURACY:	± 5 microvolts.
AMPLIFIER:	All solid-state.
REFERENCE:	Temperature compensated zener diodes with separate isolation transformer.
INTERFERENCE REJECTION:	Transverse60 Hz.60 db Longitudinal60 Hz.120 db (common mode) .DC.140 db
CHART:	Translucent, 5 inch calibrated (-5) to 0 to 105%, Right zero. 5 3/4" overall width, 100 ft. rolls.
CHART SPEED:	One inch/min standard.
POWER REQUIREMENTS:	115 V $\pm 10\%$, 60 Hz, 30 watts. 230 V, 50 Hz optional.
WRITING SYSTEM:	Traveling reservoir capillary pen with manual pen lifter.

MODEL 6700 CARLE BASIC™ RECORDER SPECIFICATIONS AND FEATURES



FEATURES

Compact Size with Carrying Handle

Recorder measures only 8 $\frac{1}{2}$ in. high x 9 $\frac{3}{8}$ in. wide x 13 $\frac{1}{2}$ in. deep. Valuable bench top space is conserved and the recorder can be moved from place to place safely and easily.

Removable Door

Door hinge is spring-loaded for easy removal.

Solid-State Circuitry

Silicon-transistorized amplifier is a modular, plug-in type with a complete guard shield to provide high common mode noise rejection.

Straight Slide Wire

Electrical slidewire contact and pen are integral, preventing errors associated with mal-adjusted linkages.

Writing System

Large moving reservoir is direct-coupled to capillary pen enabling the pen system to provide reliable high speed inking. System also provides consistent inking on slow pen action. Simple manual pen-lifter.

One-Half Second Response

Full scale response of $\frac{1}{2}$ second allows accurate recording of fast peaks.

Right Hand, Live Zero

Chromatograms are recorded ready for publication. Reversed chromatograms are eliminated.

One Millivolt Span

Presentation is — 5% to zero to 105% of one mv.

Writing Platen and Tear Off Bar

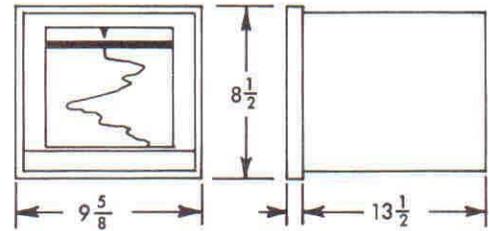
Convenience features make chart notations simple and allow easy, neat chromatogram removal. Platen is quickly raised and remains locked at 45° during operation.

Separate Chart and Power Switches

Located near the front of the chassis, but behind the door, two switches provide separate chart and power control.

Slide Out Chassis

Instrument moves in and out of case on roller slides providing quick access to all components.



Ordering Information

Prices f.o.b. Fullerton, California. Specifications and prices effective Jan. 1, 1972 and subject to change without notice.

Cat. No.	Description	Price
6700	Basic Recorder. Modified Westronics Model S5E, having span of -0.05 to 0.0 to 1.05 mv DC, $1/2$ second response, right hand zero and chart speed of one in./min. Adjustable writing platen with tear-off bar but without reroll. Includes one roll paper, accessory kit with ink supply, three-wire power cord and carrying handle. 115V, 60Hz.	\$695.00
6701	Basic Recorder. Same as Cat. No. 6700 except 230V, 50Hz.	\$715.00
6710	Chart Paper -5% to 0 to 105% , roll.	\$ 3.50

Chart Paper Discounts

Quantity	Net Price
1-4	3.50
5-9	3.25
10-24	3.00
25-	2.85

6713	Ink Black, 4 oz. bottle	\$3.35
6714	Pen Assembly	\$19.50
6715	Pen Cleaning Kit, includes suction bulb, cleaning solvent, pen cleaners.	\$10.75

Service

Complete factory service is maintained by Carle Instruments. In addition, the service organization of Westronics, Inc. is available to Basic Recorder users.

Other Carle Literature

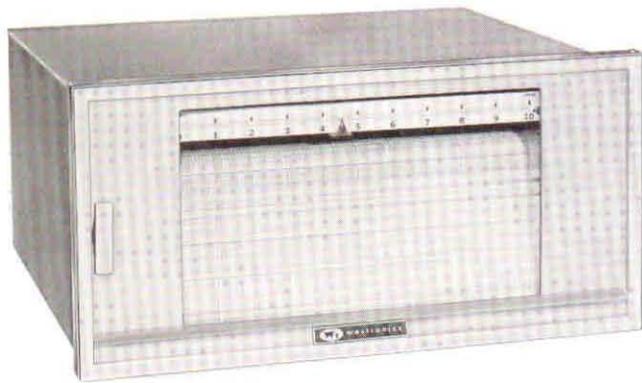
For complete information on any of the following, please write for:

- Bulletin 6000** Series 6500 Basic Gas Chromatographs for Education
- Bulletin 8000B** Model 8000 TC Basic Gas Chromatograph
- Bulletin 9000** Model 9000 FID Basic Gas Chromatograph
- Bulletin 6100** Accessories for Basic Gas Chromatographs

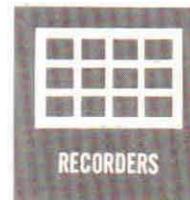
CARLE

INSTRUMENTS, INC.

1141 East Ash Avenue
Fullerton, California 92631
Phone: (714) 879-9900



**STRIP CHART RECORDER
SINGLE PEN 11"
MODEL S11E**



DESCRIPTION

The Model S11E is a single pen potentiometric strip chart recorder with a calibrated chart width of 11 inches. It provides a highly accurate record of an input variable but requires a minimum of valuable panel space. Some standard features of the S11E are noted below.

FEATURES

MINIMUM SPAN TO 1/2 MILLIVOLT - thermocouple inputs with automatic reference junction compensation, DC millivolts, resistance temperature detectors.

COMPACT SIZE - instrument case is only 8-1/2" high x 17-3/4" wide to conserve valuable panel space. Instrument may be rack or panel mounted.

QUICK CHANGE RANGE MODULE - plug-in range module allows quick change of instrument range.

TRANSISTORIZED AMPLIFIER - modular plug-in amplifier utilizes silicon transistors and complete guard shield, providing long life and high common mode noise rejection.

STRAIGHT SLIDEWIRE - the slidewire provides a direct mechanical coupling between the electrical measuring point on the slidewire and the recording pen. No linkages to a remote potentiometer to introduce error.

WRITING PLATEN - the writing platen detents positively at a 45° position to allow easy notation on the chart even while the instrument is on. A 90° detent position allows easy loading of the chart supply roll.

POWER SWITCH - instrument power switch conveniently located at the left front of the recorder chassis behind the door.

INKING SYSTEM - reliable capillary inking with large capacity reservoir. Provides consistent inking on slow or fast moving functions. A manual pen lifter is provided.

SPECIFICATIONS

INPUT SIGNAL:	DC millivolts, minimum span 0.5 millivolts full scale. Thermocouple spans with automatic reference junction compensation and resistance temperature detector with lead compensation. Input terminals isolated with respect to ground.
SOURCE IMPEDANCE:	Up to 5000 ohms standard, higher values are available.
INPUT IMPEDANCE:	Infinite at null, 50,000 ohms at maximum unbalance. 300,000 ohms optional.
RESPONSE:	1 second full scale standard, 1/2 or 3 seconds optional.
SLIDEWIRE:	Straight, 1450 turns, ±0.1% linearity
RESOLUTION:	0.1% of span.
ACCURACY:	±0.25% of span or ±5 microvolts, whichever is greater.
AMPLIFIER:	Transistorized
REFERENCE VOLTAGE:	Temperature compensated zener diodes with separate isolation power transformer.
INTERFERENCE REJECTION:	Transverse — 60 Hz — 60 db Longitudinal — 60 Hz — 120 db (common mode) DC — 140 db
CHART:	Translucent, 11 inch calibrated width, 12-3/8" overall, 100' rolls.
POWER REQUIREMENTS:	115V ±10%, 60 Hz, 30 Watts 230V, 50 Hz optional
WRITING SYSTEM:	Capillary inking with manual pen lifter.



westronics, inc.

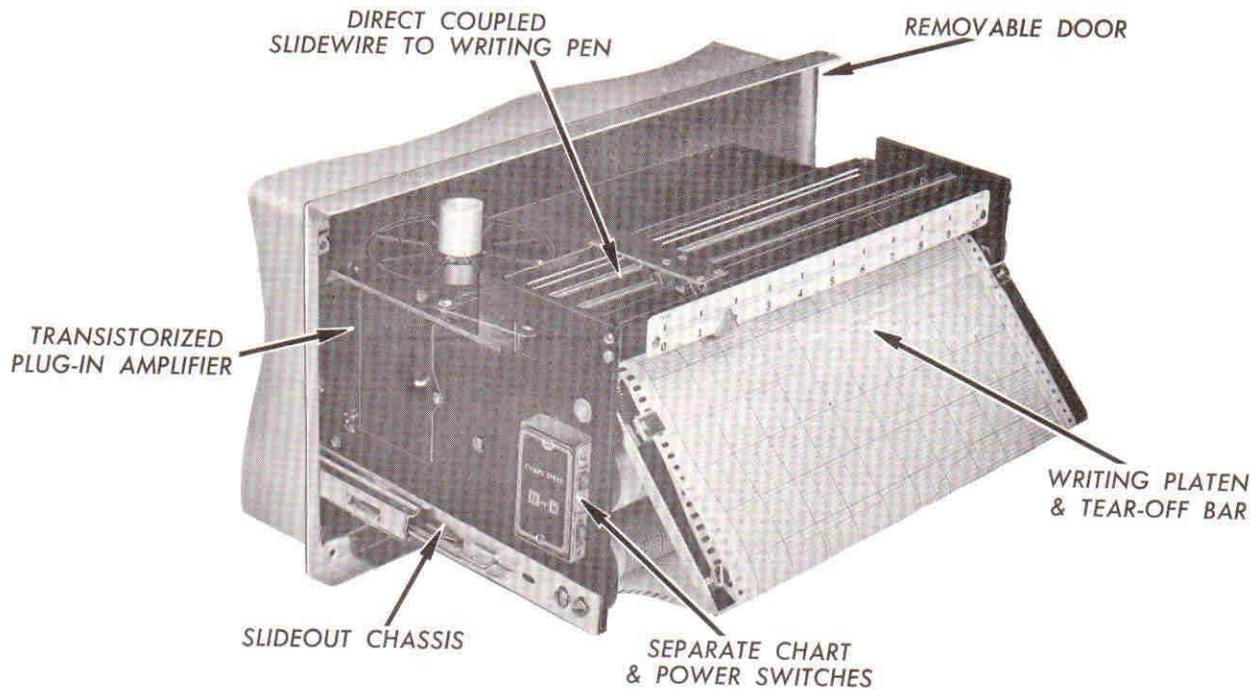
A DIVISION OF TRACOR AUSTIN, TEXAS

3605 McCart Street / Fort Worth, Texas 76110 / 817-926-2621

C-62

DATA SHEET 115.0

FIGURE 22 -- STRIP CHART RECORDER



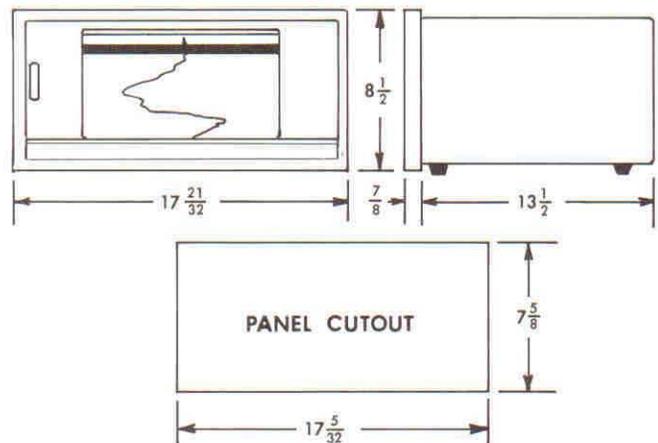
OPTIONAL FEATURES

- CHART DRIVE:** Single speed above 30 inches/hour, dual speed (2 motors electrically switched), 5 speed (1 motor with 5 speed transmission), 10 speed (2 motors electrically switched with 5 speed transmission).
- ALARM OR LIMIT SWITCHES:** Up to 6 SPDT switches rated at 5 amperes, 250 volts 60 Hz non-inductive. Individually adjustable from 0 to 100% of full scale.
- EVENT MARKER:** Left and/or right hand mounting, 115 or 28 volts, AC or DC. Indicates frequency and duration of events or functions.
- RETRANSMITTING SLIDEWIRE:** Maximum of 2 with 525 ohms, $\pm 3\%$, resistance with linearity of $\pm 0.1\%$. Other values available. Power supply for DC voltage output available.
- LOCAL-REMOTE SWITCHING:** Controls instrument power and chart from remote location.
- INTERNAL ILLUMINATION:** Incandescent illumination of chart and scale for easier readability.
- DOOR LOCK:** Prevents unauthorized use.
- CHART TEAR-OFF BAR:** Allows rapid removal of the chart paper.

UNIVERSAL WIRING:

Allows recorder to operate in conjunction with external input units to record signals from such devices as strain gages, load cells, resistance temperature detectors, or variable potentiometers. Refer to data sheets on universal input units beginning with Data Sheet 800.00.

DIMENSIONS



ORDERING INFORMATION

The recorder is provided with a standard range module, single speed chart drive (up to 30"/hour), 1 roll of standard chart paper, and accessory kit with ink supply.

When ordering, specify:

- Range:
- Chart:
- Scale:
- Chart Speed:
- Selected Options:



Gas Indicator Test Kit

Test kit consists of two boxes of ampoules and a plastic squeeze bottle—all packed in a convenient tubular container.

A SIMPLE METHOD
FOR TESTING THE
ACCURACY OF
ANY PORTABLE
COMBUSTIBLE
GAS INDICATOR



FIGURE 23 -- CALIBRATION KIT

Description

Most users of combustible gas indicators follow the practice of testing their indicators for responsiveness prior to each day's use, in order to be sure no mechanical or electrical difficulties exist which would prevent the operator from making a reliable gas test. The J-W Gas Indicator Test Kit provides a convenient field method for making a reproducible gas mixture of known composition and introducing it into the indicator. A sealed gas-filled ampoule is introduced into a plastic squeeze bottle of known volume, and breaking the ampoule releases the gas to produce a gas-air mixture of pre-determined properties.

Each ampoule is filled with methane at atmospheric pressure. Methane is used as a calibration gas because indicator response to me-

thane is more critical than response to any other gas. If the indicator has normal response to methane, it will respond normally to all other combustible gases and vapors.

Volume of the ampoule is 1.2% of the volume of the bottle, so at the accepted value of lower explosive limit for methane, 5.3%, one ampoule will make a mixture .22, or 22%, of the lower explosive limit in air. This mixture when forced into an indicator, should therefore give a reading of at least .22, or 22% l.e.l. Most indicators will read somewhat higher, depending upon the factor of safety built into the instrument.

Operation

In operation, an ampoule is inserted into the bottle which contains a metal "breaker." When shaken, the ampoule will be shattered, releasing

the gas into the interior of the bottle, and agitation of the "breaker" and the glass pieces will produce uniform mixing.

The tip of the bottle is then placed into the indicator inlet as shown and the bottle is squeezed slowly, forcing the gas-air mixture through the indicator. The reading should be at least .22 (22%) on the standard l.e.l. scale. The cap is then removed and the broken glass discarded.

Ordering Information

550-075 GAS INDICATOR TEST KIT, COMPLETE

550-076 SPARE AMPOULES—BOX OF 12 FOR TEST KIT



BACHARACH INSTRUMENT COMPANY
A DIVISION OF **AMBAC** INDUSTRIES, INC.
625 Alpha Drive, Pittsburgh, Pa. 15238 Phone 412/782-3500

B105

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