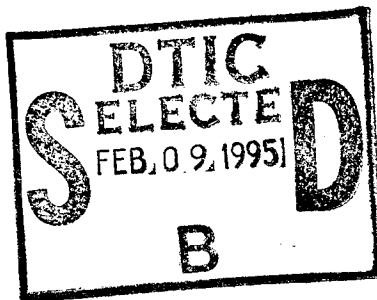




**US Army Corps
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Construction Engineering
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USACERL Special Report FF-95/02
November 1994

Industrial Instrumentation for Quality Assurance

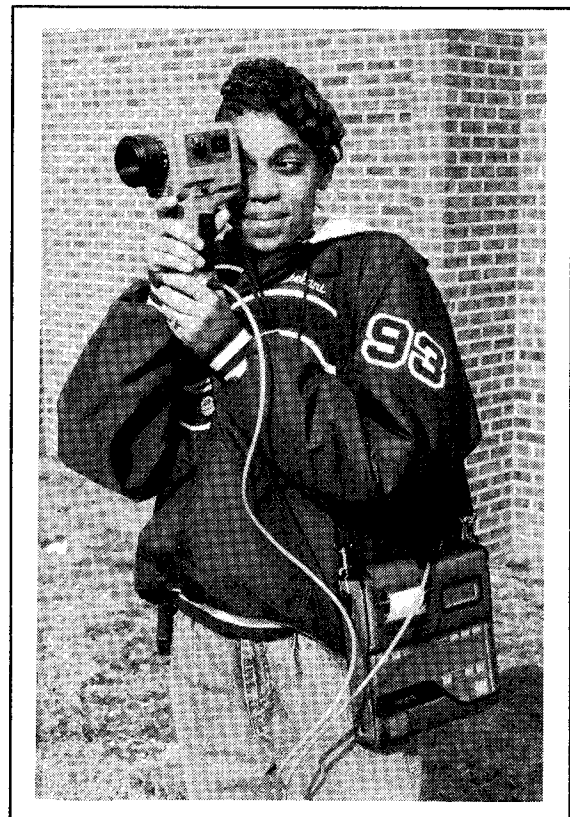
Catalog of Systems Available for Army Real Property Quality Assurance Applications

by
James H. Johnson
Mark J. Poskin

As the U.S. Army downsizes and many experienced personnel leave the service, installation Directorates of Public Works (DPWs) must fulfill their mission with lower operating budgets and less technical personnel. A key DPW function significantly affected by this trend is the quality assurance (QA) program.

Previous work by the U.S. Army Construction Engineering Research Laboratories (USACERL) identified a number of industrial instrumentation systems that could help verify field judgments made by QA inspectors. The equipment was field tested by DPW personnel, monitored and evaluated by USACERL, then transferred to U.S. Army Center for Public Works (USACPW) to establish an equipment bank of sensor/measurement instrumentation. The equipment bank allows installation DPWs to use and evaluate various systems without the expense of buying them.

This report comprises a catalog of the sensor/measurement systems available in the USACPW equipment bank, plus some scheduled for acquisition. Listings are organized according to QA application. Each listing includes a product description, price range, indication of technical skill required for using the system and interpreting its output, and description of operating principle. A list of vendors is included in an appendix.



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Foreword

This study was conducted for the U.S. Army Center for Public Works under Project 4A162784AT41, "Military Facilities Engineering Technology"; Work Unit SB-A52, "Quality Inspection via Condition Monitoring." The technical monitor was Robert Hohenberg, CECPW-FM.

The work was performed by the Facility Management Division (FF) of the Infrastructure Laboratory (FL), U.S. Army Construction Engineering Research Laboratories (USACERL). Alan W. Moore is Chief, CECER-FF, and Dr. David M. Joncich is Acting Chief, CECER-FL.

LTC David J. Rehbein is Commander and Acting Director of USACERL, and Dr. Michael J. O'Connor is Technical Director.

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1 Introduction

Background

As the U.S. Army downsizes and many experienced personnel leave the service, installation Directorates of Public Works (DPWs) must fulfill their mission with lower operating budgets and less technical personnel. A key DPW function significantly affected by this trend is the quality assurance (QA) program.

The installation's QA program ensures that the Army "gets what it pays for" in real property maintenance activity (RPMA) services performed by private-sector contractors. When the Army contracts for RPMA services, the quantity and quality of the delivered service must be verified. Although service contractors usually are required to maintain a quality control (QC) program, QA surveillance by the Army is necessary to verify and document the contractor's performance.

Historically, key QA inspections have been performed by journeyman craftsmen who used their eyes and ears to collect operating data on essential equipment such as electric motors or refrigeration systems. Today's inspectors must make supportable, reproducible QA judgments on the basis of less experience. To be successful, inspectors need tools that can reliably measure and document the factors being inspected. In addition, innovative technologies may produce Army installations that feature intelligent buildings, self-correcting utility systems, and automated service systems. Such buildings and systems will require more technically advanced, detailed, accurate, and timely methods of inspection. Not even highly experienced inspectors will be able to rely solely on their eyes and ears when inspecting such advanced systems.

Previous work by the U.S. Army Construction Engineering Research Laboratories (USACERL) identified a number of industrial instrumentation systems useful to DPW inspectors (Johnson, James H., and M.J. Poskin, *Investigation of Sensor/Measurement Systems for Army Installation Quality Assurance Applications*, Special Report FF-93/14 [USACERL, September 1993]). Such systems can enhance any inspector's capabilities by providing operational data not available by looking or listening.

From the broad array of new, more portable, rugged, cost-effective industrial instrumentation becoming available, USACERL selected candidate systems for field test by DPW personnel. This work verified the suitability of commercially available industrial sensor/measurement systems to the development of more effective QA inspection techniques. The equipment used in the field tests was later moved to the U.S. Army Center for Public Works (USACPW) to establish a "lending library," or equipment bank, of sensor/measurement instrumentation. Since that time, more instrumentation has been added to the equipment bank and more are scheduled for acquisition. The creation of this equipment bank enables installation DPWs to use and evaluate various systems without the expense of buying them.

USACERL was tasked by the USACPW to publish a catalog of instrumentation for installation DPW personnel.

Objective

The objective of this work was to create a catalog that identifies industrial-type instrumentation that has been field-tested, evaluated, and obtained (or planned for inclusion) into the USACERL instrumentation equipment bank.

Approach

Instrumentation identified by USACERL and DPW customers as potentially useful was obtained, field tested, and incorporated into a "lending library," or equipment bank.

Instrumentation in this catalog is divided into four broad application categories: (1) machinery, (2) buildings and structures, (3) utilities, and (4) habitability. Each category is reviewed in a separate chapter. For each category, a list of typical applications is provided, followed by descriptions of available instrumentation that is appropriate for that application.

The instrumentation features described in this catalog are derived from the manufacturer's releases or brochures. Models and descriptions will change with time. The catalog presents this instrument data, when available, in six areas of interest to the DPW:

1. Description
2. Price Range

3. Operating Skill or Training Level Required
4. Interpretive
5. Operating Principle
6. Source.

The description discusses the physical attributes of the instrument, including accessories. Because prices of these systems fluctuate widely, price ranges are given instead of the list price. The price ranges used in the catalog are as follows:

PRICE RANGE (\$)	DESCRIPTOR
less than 500	Very Low
501 - 800	Low
801 - 1500	Moderate
1501 - 5000	Moderately High
5001 - 8000	High
8001 - 10,000	Expensive
more than 10,000	Major Purchase

Next, the skill or training level required for the QA user to operate the instrument is given. Also provided is the level of interpretive ability necessary to understand the test results. These ratings range from little to no experience, to high levels of expertise, depending on the complexity of the test results. The operating principle, when not self-evident from the product description section, is provided for those who want to know the basis of the system's operation. Sources for acquiring the various sensor/measurement instruments are also included.

To promote technology transfer and feedback from the field, Appendix A includes a survey form on which DPW users may offer comments or suggestions about the systems listed in the catalog. Appendix B includes the names and addresses of system manufacturers. An alphabetical index of the systems follows Appendix B. This index can help users quickly locate the first page reference to instruments listed more than once. A complete description of the instrument is only given the first time it appears.

Scope

The versions of equipment described in this catalog are certain to be upgraded or superseded over time. This document is not an up-to-the-minute listing of the latest technology, but is intended as a sourcebook to help DPW personnel identify and borrow sensor/measurement technology that may enhance QA inspections. The exact equipment described here may not be available from the USACPW equipment bank over

time. However, an equivalent or upgraded device in the same category should be available from the equipment bank or a commercial supplier.

Mode of Technology Transfer

Feedback from the DPW on instrumentation/procedural merit for QA and inspection uses is invited (see Appendix A.) The catalog is intended to be a DPW permanent reference for identifying and requesting specialized instruments from the USACPW equipment bank for tryout or productive application.

2 Instrumentation for Machinery

Machine Vibration Measurement Applications

- Measure mechanical vibration, bearing vibration/shock shaft alignment at various points on operating machinery to detect:
 1. shaft misalignment
 2. rotor misalignment
 3. stator problems
 4. mounting errors/loosened anchor bolts
 5. faulty or missing bearings/gaskets
 6. improper tension in belts, chains, etc.

- Measure, monitor, or detect vibration levels and other degradation trends in motors, drives, and pumps.

- Monitor noise and vibration levels from duct, filter, exhaust fan and forced air systems.

- Locate and measure stress vibrations, water-hammer, and other noisy or destructive conditions in piping systems.

Hand-Portable Vibration Measurement Systems

Metrix Vibration Meter Model 5160DV

Description: A hand-held, battery-powered instrument used to measure vibration displacement and velocity over the frequency range of 10 to 1000 Hz. The probe, pickup, signal conditioner, and meter are all contained in an integral enclosure with eight meter-selector positions ranging in intensity. Accessories—leather carrying case, batteries, extension probe, shaft rider fork, instruction manual.



Price Range: Low

Operating Skill or Training Level Required: Low

Interpretive Ability Required: Low

Operating Principle: A piezoelectric quartz crystal accelerometer produces a voltage when compressed by the movement of an attached reference mass. The voltage is proportional to the oscillation of the reference mass caused by the vibration. The signal is conditioned for both velocity and displacement readings. For shaft alignment measurements, a specially designed shaft rider fork attachment rests on the rotating shaft. Shaft misalignment results in levels of vibration proportional to shaft speed.

Source: Metrix Instruments Co.

Kernco Vibration Monitor Model 41A10

Description: A hand-held, battery-powered unit used to measure the root-mean-square (RMS) value of vibration velocity in inches* per second (ips). A 5 ft oil-resistant rubber cable connects the processor to a small vibration transducer. Readings are displayed

* U.S. standard units of measure are used in this report. A table of metric conversion factors may be found on page 59.

in a large red LED crystal window. Accessories—5 ft cable, vibration transducer, followup form, magnetic base, probe and carrying case.

Price Range: Low

Operating Skill or Training Level Required: Moderate

Interpretive Ability Required: Technician Level

Operating Principle: Vibration transducer

Source: Kernco Instruments Co.

Vibration Measurement and Analysis Systems

Kernco Clipboard Vibration Analyzer

Description: A portable, battery-powered vibration analyzer contained in a 9.5 × 14 in. lightweight aluminum clipboard housing. The meter displays an LCD readout of displacement, velocity acceleration within a range of 0-200 miss, ips, or G's, with +/- 5 percent accuracy. Accessories—accelerometer sensing equipment, pickup cable, magnetic pickup clamp, pencil probe, batteries, battery charger, instruction manual.

Price Range: Moderate

Operating Skill or Training Level Required: Senior Technician

Interpretive Ability Required: Must read charts

Operating Principle: Accelerometer

Source: Kernco Instruments Co.

IRD Vibration Analyzer Model 828

Description: A hand-held, battery-powered device used to measure and log vibration (acceleration, velocity, and displacement). Large visual LCD indicates time-waveform, spectrum probability analysis in graphic and numerical form, and automatically evaluates these data for machine condition judgment. Large keypad for easy entry and a magnetic accelerometer probe accompany the instrument. Accessories—magnetic accelerometer probe, probe cable, batteries, carrying case, instruction manual.

Price Range: High

Operating Skill or Training Level Required: Moderate

Interpretive Ability Required: High

Operating Principle: A quartz crystal accelerometer produces a voltage when compressed by the movement of an attached reference mass. The voltage is proportional to the amplitude of the oscillation caused by the applied vibrating mass. Vibration spectrum analysis differs from shock pulse in that it identifies amplitude measurements at various relevant frequencies. A frequency spectrum is displayed on a screen indicating states of deterioration and their responsible component (each motor component having a different identifying frequency).

Source: IRD Mechanalysis, Inc.

Hand-Held Bearing-Vibration Measurement Systems

Kernco Bearing Condition Indicator Model 54AIO

Description: A lightweight, battery-powered, hand-held meter used for evaluating the condition of ball or roller bearings in machinery. Designed to ignore the normal range of machine vibrations, this meter displays only the high-frequency vibration normally associated with faulty gears or bearings. The housing and probe are contained in one integral unit measuring 2 in. square by 7 in. long with a color-coded meter, and a test switch located on top of the unit. Accessories—4 in. pencil probe, carrying case, clipboard with pad, 9 volt battery.

Price Range: Low

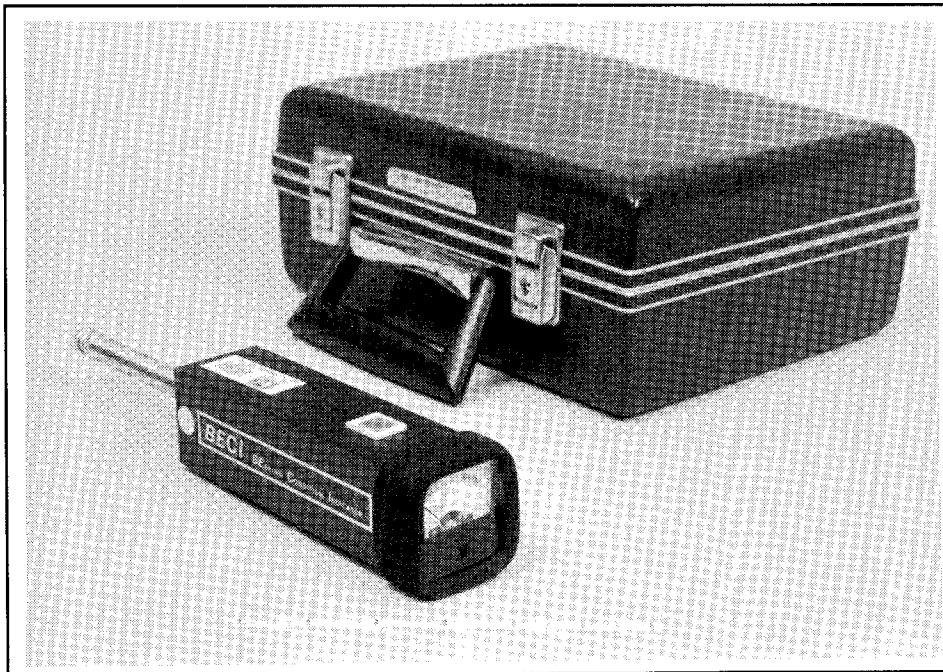
Operating Skill or Training Level Required: Low

Interpretive Ability Required: None

Operating Principle: Accelerometer

Source: Kernco Instruments Co.

Vitec Bearing Condition Indicator (BECI)



Description: A lightweight, battery-powered, hand-held meter used for evaluating the condition of ball or roller bearings in machinery. Designed to ignore the normal range of machine vibrations, this meter displays only the high-frequency vibration normally associated with faulty gears or bearings. The housing and probe are contained in one integral unit measuring 2 in. square by 7 in. long with a meter, and a test switch located on top of the unit. Accessories—4 in. pencil probe, carrying case, clipboard with pad, 9 volt battery.

Price Range: Moderate

Operating Skill or Training Level Required: Low

Interpretive Ability Required: Low

Operating Principle: The operating condition of roller or ball-type motor bearings is directly influenced by bearing lubrication, quality of installation, and bearing age. Vibrations normally associated with faulty gears or bearings are of a higher frequency than common machine vibrations. A quartz crystal accelerometer attached to a reference mass produces a voltage when compressed by the movement of the reference mass. The voltage is proportional to the amplitude of oscillation caused from the applied vibrating mass. A special internal quartz accelerometer detects these high

frequency vibrations while ignoring normal machine vibrations. A direct needle readout on a simple 1-5 scale indicates relative bearing condition.

Source: Vitec, Inc.

Bearing Shock Sensing and Analysis Systems

Kernco Bearing Analyzer Model 54AI1

Description: This hand-held, battery-powered pistol-like instrument analyzes shock pulses (stress waves) generated by operating rolling-element bearings. It can be used in three different modes of operation: Bearing Condition Mode (displays information on the mechanical condition of the rolling element), Shock Value Mode (displays raw shock pulse information for trending), or Tone Generator Mode (enables the user to listen to shock pulse patterns emitted by bearings). Bearing shock waves, when properly interpreted, give the best advance warning of imminent bearing failure. Accessories—batteries, 25 followup forms, earphone, carrying case, operating manual.

Price Range: Moderate

Operating Skill or Training Level Required: High

Interpretive Ability Required: Engineer Level

Operating Principle: Accelerometer

Source: Kernco Instruments Co.

Kernco Bearing Analyzer BEA-53

Description: A lightweight, battery-powered, hand-held meter used for evaluating the condition of ball or roller bearings in machinery. Designed to ignore the normal range of machine vibrations, this meter displays only the high-frequency vibration normally associated with faulty gears or bearings. The housing and probe are contained in one integral unit measuring 2 in. square by 7 in. long with a meter, and a test switch located on top of the unit. Accessories—4 in. pencil probe, carrying case, clipboard with pad, 9 volt battery.

Price Range: Moderate

Operating Skill or Training Level Required: Low

Interpretive Ability Required: High

Operating Principle: A piezoelectric quartz crystal transducer produces a voltage when compressed by the movement of an attached reference mass. The voltage is proportional to the amplitude of the oscillation and to the shock wave created by the roller bearing compressing the bearing raceway. Shock pulse meters are mechanically tuned to operate at a frequency of 32 kHz, thereby ignoring normal machine vibrations. Output signals are in decibels (dB), either digitally displayed or acoustically emitted through headphones.

Source: Kernco Instruments Co.

Shaft Alignment Vibration Measurement and Analysis Systems

— *Metrix Vibration Meter Model 516ODV (see Index)*

Magnetic Field Measurement Applications

- Measure the magnetic flux density around electric motors as a predictive maintenance tool for detecting signs of wear and potential failure.
- Detect, track, and identify high flux outputs from high-voltage areas, power plants, transmission lines, transformers generators when this flux energy may interfere with other sensitive equipment.

Walker Scientific Gaussmeter Model MG-4D

Description: A portable, battery-powered, hand-held gaussmeter is provided with precalibrated probes for measuring dc and ac (RMS) magnetic fields. The Hall-effect measuring system is housed in a small (2 × 3 × 6 in.) hardened plastic box. The device consists of an attachable probe, a large LCD readout, calibration switch, three range switches (100 gauss to 10,000 gauss). Accessories—general-purpose transverse probe, 6 ft probe extension cable, batteries, carrying case, manual.

Price Range: Low

Operating Skill or Training Level Required: High

Interpretive Ability Required: High

Operating Principle: Based on the Hall Drift Effect, the device measures magnetic field densities. A flat chip conductor in the probe produces a small horizontal current. When a magnetic field passes perpendicular through this chip, the Hall drift current phenomenon is produced. The voltage of this current is measured and scaled to read directly in gauss units.

Source: Walker Scientific, Inc.



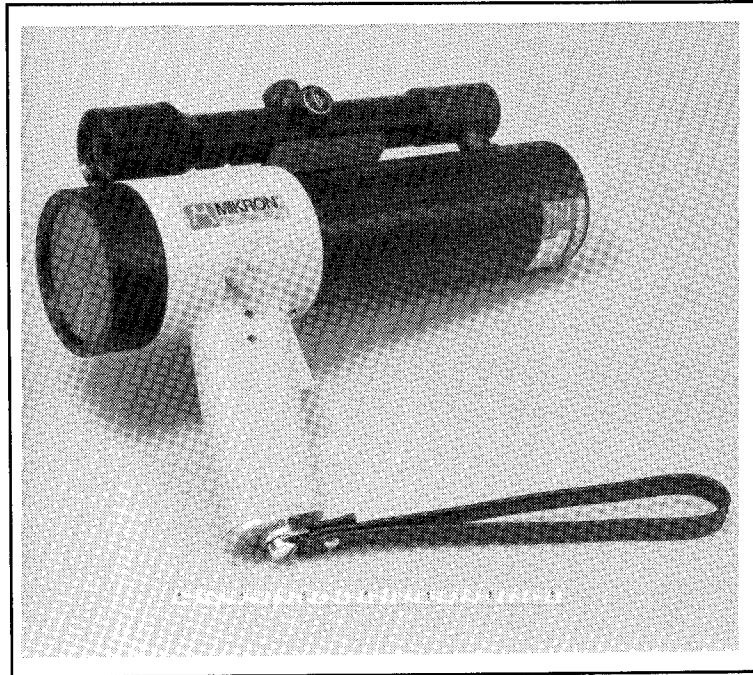
Operating Temperature Measurement Applications

- Detect overheated pumps, motors, compressors and generators.
- Detect overheated rotary shafts and generator blocks.
- Detect overheated steam and hot-water pumps, motors, compressors, heat exchangers, boilers, distribution lines, or other steam processing equipment.
- Detect high shaft temperatures indicating possible misalignment.

Non-Contact Temperature Measurement Systems

Mikron Portable Infrared Thermometer Model M56P

Description: A hand-held, pistol-like device made of brazed and painted aluminum, consisting of an optical tube, telescopic sight, IR window, temperature scale, emissivity/power controls, battery compartment. The instrument is used to make remote surface temperature measurements from 0-700 °F from up to 16 ft away. Accessories—carrying case, safety wrist strap, batteries, battery charger, output cable, emissivity book, and instruction manual.



Price Range: Moderate

Operating Skill or Training Level Required: Low

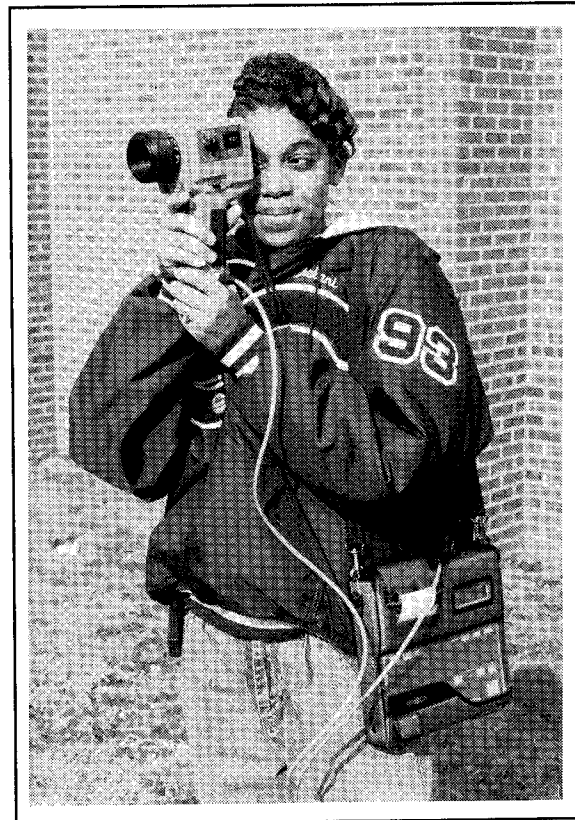
Interpretive Ability Required: Moderate

Operating Principle: Measures electromagnetic radiation generated by any material of a temperature above absolute zero (-273 °C). Device is based on the principle of the thermistor bolometer: two matched metal elements—one exposed to the source of radiation, the other shielded—are connected in a bridge circuit where an electrical potential is realized. The measure of electrical potential is proportional to amount of radiational energy on the exposed element. With a built-in amplifier and signal conditioner, a direct-scaled motor surface temperature (in both Fahrenheit and Celsius) is provided.

Source: Mikron Instruments Co.

Minolta/Land Cyclops 330 IR Temperature Viewer and DP-C2 Data Processor

Description: The Cyclops 330 gun-style temperature sensor and DP-C2 data processor comprise a compact, multi-functioned system of great value for making remote temperature readings. This ac- or battery-powered system can be used either to measure absolute temperature or the difference between a measured temperature and a user-specified temperature. The data processor can store up to 1,000 readings in memory, which can be sorted into as many as 50 data pages for statistical calculations. Data can be output to an external computer or printed on an integrated thermal dot printer. The printer can print data as numbers or as a simple dot-based analog graphic. The unit also has an internal timer for use in making periodic, unattended remote temperature measurements.



Price Range: Moderately High

Operating Skill or Training Level Required: Moderate

Interpretive Ability Required: Moderate

Operating Principle: Uses the principle of the thermistor bolometer to measure the infrared radiation generated by any material. Two matched metal elements—one exposed to the source of radiation, the other shielded—are connected in a bridge circuit, where an electrical potential is realized. The level of electrical potential is proportional to amount of infrared energy received by the exposed element.

Source: Land Infrared

Raytek Raynger Model PM-5 Non-Contact Thermometer

Description: A durable, hand-held, battery-powered device used for remote surface temperature measurement within a range of 0-1600 °F from distances up to 10 ft. Readings are digitally displayed with a +/- 1 percent accuracy stored in a built-in

datalogger for future output to a computer. Accessories—built-in datalogger, belt-loop pouch, batteries, instruction manual.

Price Range: Moderate

Operating Skill or Training Level Required: Low

Interpretive Ability Required: Moderate (1 day training)

Operating Principle: IR radiation is produced by any object with a temperature above absolute zero (-273 °C). IR is electromagnetic radiation with a wavelength between 0.75 μm and 1,000 μm , which is beyond the visible spectrum (invisible).

Source: Raytek, Inc.

Telatemp LCD Reversible Temperature Decals

Description: Simple paste-on temperature-sensitive decals.

Price Range: Low

Operating Skill or Training Level Required: Low

Interpretive Ability Required: Low

Operating Principle: Advanced LCD technology allows custom reversible decals to change color at selected temperatures in one-degree increments. Continuous surface temperature monitoring from -10 °F to 200 °F is provided. To detect when a temperature rises and stays above its critical calibrated tripping point, a message appears on the decal in black against a green background. When the surface cools, the decal returns to being completely green, and the message disappears.

Source: Telatemp Corporation

Infrared Imaging Systems

Inframetrics Thermal Imaging Radiometer Model 522

Description: A portable, 12 v battery-powered black-and-white or color thermal imaging system designed for evaluating relative temperature differences in static and dynamic thermal targets. The system is capable of converting invisible infrared

radiation into quantified heat pattern pictures within a range of -20 °C to 1300 °C to be viewed on color video monitors and recorded on a VCR. The Model 522 package C is equipped with line scan/isotherm measurement modes, a hand-held radiometric computer, 8 selectable color palettes, a 4:1 optical zoom feature, VCR, battery pack, and a field-transport cart for onsite applications. Accessories—scanner, control electronics, 5 in. color video monitor, power supply/charger, HHC with program module, high-temperature filter, Polaroid® camera with photo shroud, VCR, operating manual, a two-wheel transporter cart.

Price Range: Major Purchase

Operating Skill or Training Level Required: High

Interpretive Ability Required: High

Operating Principle: See Description

Source: Inframetrics, Inc.

Infrared Combined Systems

Agema Thermovision 470 Infrared Thermal Measurement and Imaging System

Description: A field-portable, thermal imaging and measurement system capable of detecting overheated areas in power lines and substations, refractory installations, blast furnaces, circuit-breaker boxes, generators, etc. The camera produces real-time IR images and stores these images to a built-in 3.5 in. floppy disk drive. Agema offers two software packages for analyzing the images recorded on diskettes. Accessories—thermovision scanning camera with 40-degree lens, monochrome 1.5 in. viewfinder, shoulder strap and pad, monopod adapter, portable rechargeable battery, battery charger, battery cable, operating manual transport case.

Price Range: Major Purchase

Operating Skill or Training Level Required: Moderate

Interpretive Ability Required: High

Operating Principle: IR radiation is produced by any object with a temperature above absolute zero (-273 °C). IR is electromagnetic radiation with a wavelength between 0.75 μm and 1,000 μm , which is beyond the visible spectrum (invisible). Thermography scanning equipment can be used to detect IR radiation temperature distributions caused by flaws or inconsistencies with different impedances to heat flow in material or component targets. Thermographic imagers use quantum detectors that convert IR radiation to voltage signals, which in turn can produce thermographic pictures for viewing on a video display. IR imagers can also identify "hot spots" on electrical connectors or operating machinery. Considerable expertise is required to interpret these images, unless the images are enhanced with a color graphics software program.

Source: AF Infrared, Inc.

Hughes Probeye IR Viewer Model 1650

Description: A field-portable, argon-cooled, battery-powered, infrared viewer used to detect overheated areas in electrical, HVAC, steam, and other power distribution and generation equipment. The operating temperature range is 0-100 °C. IR images are stored by a Polaroid camera or other recording system. Accessories—two argon cylinders, pressure gauge, cylinder wrench, 1.5 wan rechargeable batteries, AC battery charger, safety strap assembly, carrying case, and instruction manual.

Price Range: Major Purchase

Operating Skill or Training Level Required: High

Interpretive Ability Required: High

Operating Principle: IR radiation is produced by any object with a temperature above absolute zero (-273 °C). IR is electromagnetic radiation with a wavelength between 0.75 μm and 1,000 μm , which is beyond the visible spectrum (invisible). Thermography scanning equipment can be used to detect IR radiation temperature distributions caused by flaws or inconsistencies with different impedances to heat flow in material or component targets. Thermographic imagers use quantum detectors that convert IR radiation to voltage signals, which in turn can produce thermographic pictures for viewing on a video display. IR imagers can also identify "hot spots" on electrical connectors or operating machinery. Considerable expertise is required to interpret these images, unless the images are enhanced with a color graphics software program.

Source: Flir Systems, Inc.

Internal Machine Inspection Applications

- Locate leaks, cracks, holes, corrosion, buildup, blockage, or other internal surface anomalies in water pump casings, water/wastewater distribution lines, and water/wastewater storage tanks.
- Inspect power generation plants, transformers, conduit cable pipes and trays, and electrical generators for corrosion or obstructions.
- Inspect and identify through-wall piping systems, especially in older structures, and in-wall water channels and pools behind wall structures.

Boscopes

Zibra Labs Milliscope Model 20.150.00

Description: A portable, hand-held, rigid borescope used to perform nondestructive inspection of very small or inaccessible areas. An ultrathin (1 mm) optical insertion shaft with fiber-optic illumination provides a cameralike instrument to inspect difficult-to-reach areas. The system can be hooked up to a color video monitor for improved viewing, or to a still camera for documentation. Accessories—mirror tube model MT24.150 and LS-BX rechargeable light source.

Price Range: Moderate

Operating Skill or Training Level Required: Moderate

Interpretive Ability Required: High

Operating Principle: See Description

Source: Emco Sales and Distribution, Inc.

Machida 8mm Flexible Borescope Model FBA-8-100

Description: A field-portable, battery-powered, large-diameter borescope used for remote visual inspection in hard-to-reach areas. An 8 mm heavy-duty polyurethane over-steel-cable houses the imaging bundle and light source tubes attached to an eye-

piece. A single 15-handed articulation control knob adjusts the rotating end of the cable, allowing the operator to select the image needed in the inspection area. A 150 w halogen lamp and battery pack are worn over the shoulder and attached to the borescope cable to direct light through the cable. Accessories—150 w portable battery-powered light source model RH-150B, 19 v Ni-Cad battery, battery recharger, rubber eyepiece shield, light guide plug adapter, carrying case, and instruction manual.

Price Range: High

Operating Skill or Training Level Required: Low

Interpretive Ability Required: High

Operating Principle: A bundle of light-transmitting fibers is inserted into a small, predrilled hole in the masonry permitting visual inspection of interior cavity.

Source: Machida, Inc.

Video Probes

Optronics S-1 Borescopic Video Inspection and Documentation System

Description: A field-portable, ac- or battery-charged video borescope system consisting of a half-inch diameter miniature CCD color camera attached to a 10 ft flexible fiber optic cable. The cable is attached to the monitor and VCR to produce real-time color images of the areas being inspected. Accessories—half-inch diameter CCD color video camera, 8 in. high-resolution color video monitor, built-in 8 mm VCR, 10 ft video head cable, and 6-hour rechargeable battery pack.

Price Range: High

Operating Skill or Training Level Required: Moderate to High

Interpretive Ability Required: High

Operating Principle: See Description

Source: Optronics Engineering, Inc.

Welch Allyn Video Probe 2000 Flexible Borescopes

Description: The Video Probe 2000 is a fiberscope that uses a CCD at the tip of a small, flexible viewing device attached to a 16 mm fiber-optic tube of varying length. The fiber-optic tube is connected to a computer and color video monitor to produce video images of the areas being inspected. Accessories—video processor VPII Deluxe, 13 in. color video monitor, and computer keyboard.

Price Range: Major Purchase

Operating Skill or Training Level Required: Low

Interpretive Ability Required: High

Operating Principle: A flexible fiber-optic cable with an attached CCD color camera at the tip produces real-time video images on a high resolution color video monitor. Areas inspected can be videotaped.

Source: Welch Allyn Video Division, Inc.

IT Series 161000 MI-II Video Image Processing System

Description: A field-portable, ac or battery-powered video image processing and borescopic system used for remote visual inspection within large cavities and large internal diameters of pipes and cylinders. The large video mouse (LVM) is a compact (4 in. x 14 in. long) remote visual instrument containing a high-resolution color camera, illumination, and four separate remote-controlled motor drives for scan, focus, and zoom. An umbilical cord containing all necessary cables for operation is available in various lengths up to 90 ft. Accessories—built-in color video monitor, camera control, VHS recorder, light-source, measurement/data keyboard, external 12 VDC battery pack, aluminum case with cover, and instruction manual. (Use with IT 164000 Large Video Mouse.)

Price Range: Major Purchase

Operating Skill or Training Level Required: Low

Interpretive Ability Required: High

Operating Principle: A flexible fiber-optic cable with an attached CCD color camera at the tip produces real-time video images on a high resolution color video monitor. Areas inspected can be videotaped.

Source: Instruments Technology, Inc.

3 Buildings and Structures

Building Strain Measurement Applications

In-Situ Building Measurement Tasks

Sharples Portable Strain Viewer

Description: A hand-held, battery-powered device used to inspect toughened window glass used in multilevel buildings. The inspector is able to view stress patterns in glass from inside the building. By projecting a light onto a window and looking through the instrument's viewing aperture, the inspector can determine if toughened stress patterns are present in the glass.

Price Range: Very Low

Operating Skill or Training Level Required: High

Interpretive Ability Required: High

Operating Principle: The device projects a beam of light through glass, and senses any distortions of the light that may indicate stress patterns in the glass

Source: Sharples Stress Engineers, Ltd., Preston, Lancashire, United Kingdom

Structural Materials Measurements

Spectronics Lamp Model B1B-120B

Description: A hand-held, ultraviolet (UV) lamp with an anodized aluminum housing and contoured rubber pistol grip contains a 120 w high-intensity, bulb with built-in ballast and 8 ft heavy-duty power cord. The ballast eliminates the need for an external transformer, reducing the bulk and weight while maintaining the power. The 120 w long-wave UV lamp (365 nm) produces maximum intensity, in either a concentrated spot or broad beam, for detecting low-level fluorescence in dimly lit areas. An attached, vinyl-clad, stainless steel heat-guard stand makes operation safer and

protects the bulb from mechanical shock damage. Accessories—120 w bulb with built-in ballast, HGS-129B heat guard/stand, filter, 8 ft power cord, starter assortment pack for water, gas, oil, and refrigerant leaks, UV-absorbing eyeglasses.

Price Range: Very Low

Operating Skill or Training Level Required: Low

Interpretive Ability Required: Low

Operating Principle: For cracks, flaws, or other anomalies on surfaces or welds, a fluorescent liquid penetrant is sprayed onto the surface after inspected area is cleaned with a solvent remover. Liquid penetrant seeps into minute surface openings by capillary action. The excess penetrant is wiped away and a developer solution is applied. The area is then inspected with a hand-held portable high-intensity ultraviolet (UV) lamp. Cracks and surface flaws are easily identified by their bright glow. For refrigerant leak detection, a fluorescent dye is added to the freon system through a mist infuser attached to the test manifold. The fluorescent dye mixes with the refrigerant and is given time to circulate through the compressors, valves, coils, and tubing. The high-intensity ultraviolet lamp is then shone over these surfaces; minute leaks are identified by a bright yellow-green glow.

Source: Spectronics Corporation, Inc.

Building Material Condition Measurement Applications

- Measure or monitor the strength, quality, durability, thickness, moisture content, permeability, and density of concrete, masonry and mortar, wood, and metal.
- Locate cracks, flaws, subsurface voids, delaminations, or other anomalies in concrete, masonry and mortar, wood, and metal.
- Inspect the condition of metal welded connections.
- Determine the presence and location of reinforcing metal.
- Detect or measure the thickness and extent of oxidation buildup and corrosion in water and wastewater piping and sewage tanks, reinforcing steel, and other metal structures.

- Inspect the condition of inner grout in masonry and mortar.
- Measure the adhesion bond strength in laminated wood.

Strength Measurement Systems

James PPR Meter (Windsor Probe)

Description: The Windsor Penetrometer System is a portable pneumatic-driven device used for testing the strength of homogeneous materials up to 24,000 psi.

Price Range: Moderate

Operating Skill or Training Level Required: Low

Interpretive Ability Required: High

Operating Principle: A spring-loaded hammer fires a steel pin into the concrete surface; a needle micrometer measures the depth of penetration. The depth is inversely proportional to the compressive strength and durability of the concrete.

Source: James Instruments, Inc.

James H-Meter Rebound Hammer

Description: This is a hand operated, instrumented, test hammer (3.5 lb) that uses the Schmidt Rebound method to measure the quality and strength of concrete.

Price Range: Low

Operating Skill or Training Level Required: Low

Interpretive Ability Required: High

Operating Principle: A spring-driven mass strikes the concrete surface; rebound distance is measured and recorded on a calibrated scale.

Source: James Instruments, Inc.

James M-Meter (Concrete Maturity Meter) Model M-3004

Description: A 6-channel microprocessor instrument that measures actual temperatures of the maturing concrete by means of a disposal sensor inserted in the freshly placed concrete. An analytical interpretation provides a "maturity number" on the M-Meter display panel.

Price Range: High

Operating Skill or Training Level Required: Moderate

Interpretive Ability Required: High

Operating Principle: Disposable probes inserted into freshly-placed concrete; elapsed time is measured internally and integrated with temperature.

Source: James Instruments, Inc.

Quality, Uniformity, and Durability Measurement Systems

The same devices listed above under "Strength Measurements" may be used, plus the following:

James V-Meter

Description: This is a low-frequency ultrasonic test system for coarse-grain materials (wood, concrete, ceramics, refractories, and plastics/laminates). Direct reading of pulse velocity measurement accurately identifies basic characteristics (or changes in these characteristics) for these materials.

Price Range: Moderate

Operating Skill or Training Level Required: Low to moderate

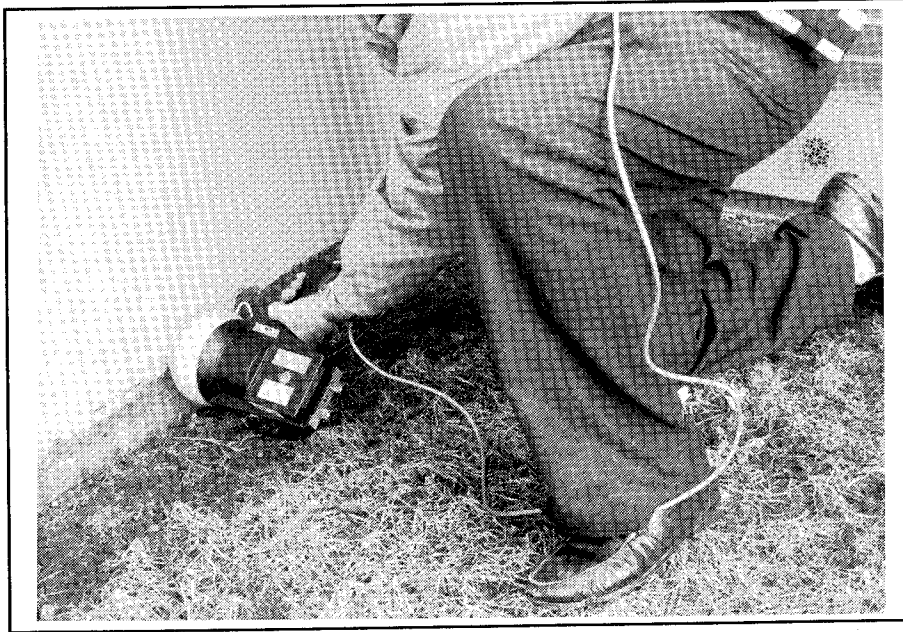
Interpretive Ability Required: High

Operating Principle: Ultrasonic energy is pulsed through a concrete, masonry, or wood sample. The velocity of the pulse is measured and is proportional to the thickness, density, and elasticity of the tested material. Variable velocity measurements indicate

internal voids, delaminations, or anomalies caused from decay, moisture, and/or the lack of inner grout. Separate transmitting and receiving transducers are required.

Source: James Instruments, Inc.

Spatial Dynamics M600 Concrete and Cement Tester



Description: A large hand-held, battery- or AC-powered device used for making relative nondestructive measurements of curing maturity, moisture content, mixture ratio, voids, and trapped moisture in both cured and uncured concrete. A patented antenna concentrates microwave energy up to a depth of 24 in. into the material to be tested and compared to standard reference materials. Readings appear on a digital readout in coefficient of reflection units. Accessories—rechargeable battery pack, earphone, power cord, carrying case, and an instrumentation manual.

Price Range: High

Operating Skill or Training Level Required: Moderate

Interpretive Ability Required: High

Operating Principle: Patented antenna emits low-level microwave energy into the concrete, masonry, or wood. The dielectric properties are measured by comparing the signal it produces with the reflected signal. Variable readings indicate internal discontinuities. High readings indicate areas of moisture.

Source: Spatial Dynamics Applications

Others

Other systems useful for measuring structural strength, described under other headings, include:

- *Zibra Labs Milliscope Model 20.150.00 (see Index)*
- *Machida 8mm Flexible Borescope System Model FBA-8-100 (see Index)*
- *Optronics S-1 Borescopic Video Inspection and Documentation System (see Index)*
- *Welch Allyn Video Probe 2000 Flexible Borescopes (see Index)*
- *IT Series 161000 MI-II Video Image Processing System (see Index)*

Thickness Measurement Systems

All of the systems listed below, described under other headings, can be used for thickness measurements:

- *James V-Meter (see Index)*
- *Spatial Dynamics M600 Concrete and Cement Tester (see Index)*
- *Zibra Labs Milliscope Model 20.150.00 (see Index)*
- *Machida 8mm Flexible Borescope System Model FBA-8-100 (see Index)*
- *Optronics S-1 Borescopic Video (see Index)*
- *WA Video Probe 2000 (see Index)*
- *IT System (see Index)*

Moisture Content Measurement Tasks

James Moisture Meter

Description: A palm-size (0.5 lb) meter that measures the dielectric constant of concrete, mortar, brick, stone, wood and paper materials in a water-free or moisture laden condition. (The dielectric constant of water is many times greater than the materials that contain water.) Thus, the moisture meter digitally reads out the percentage of free moisture behind walls of typical structural materials (even when covered with decorative panels).

Price Range: Moderate

Operating Skill or Training Level Required: Moderate

Interpretive Ability Required: Moderate

Operating Principle: Based on electrical capacitance, measures the dielectric constant (permisivity) of concrete or wood within its magnetic field. The water content of the material is read directly as percentage of moisture.

Source: James Instruments, Inc.

Others

— *Spatial Dynamics M600 Concrete and Cement Tester* (see Index)

Permeability Measurement Tasks

James Poroscope

Description: A field-test system (6 lb) used to determine air or water permeability of concrete. A small amount of air/water is injected into a molded test hole plug and the permeability readout on a digital meter.

Price Range: Moderate

Operating Skill or Training Level Required: Low

Interpretive Ability Required: Low

Operating Principle: Based on "Figg Technique," a hole (40 mm deep × 10 mm in diameter) is drilled into the concrete surface. A specially molded silicone plug is pushed into the hole leaving a sealed void 20 mm high × 10 mm diameter. A hand-operated vacuum pump and steel hypodermic needle compresses air into ale void. The time required for the vacuum to fall from -55 kPa to 50 kPa is a measure of the air permeability of the concrete (Figg number). The same test is conducted for water permeability.

Source: James Instruments, Inc.

Metal Detection and Location Systems

James HR Rebar Locator

Description: This hand-held rebar locator is for concrete but also signals any ferrous base material (pipes, flues, wire, or sheets) embedded in concrete, masonry, or wood). Identification is good to a depth of up to 10 in.

Price Range: Low

Operating Skill or Training Level Required: Low

Interpretive Ability Required: Moderate

Operating Principle: Presence of steel affects the magnetic field induced by the probe. The closer the probe is to the imbedded steel, the greater the effect. Identifies the size, position, and depth of embedded rebar. It will locate any ferrous-base material, including rebar, wire, pipe, shed metal, conduit, etc., embedded or placed in another nonferrous material.

Source: James Instruments, Inc.

Others

Other systems that can be used for metal detection, listed under other headings, include:

- *Zibra Labs Milliscope Model 20.150.00* (see Index)
- *Machida 8mm Flexible Borescope System Model FBA-8-100* (see Index)
- *Optronics S-1 Borescopic Video* (see Index)
- *WA Video Probe 2000* (see Index)
- *IT System* (see Index)

Corrosion Detection and Measurement Systems

Panametrics Digital Ultrasonic Corrosion Gauge Model 26DL

Description: A hand-held, battery-powered instrument used to measure the thickness of metals ranging from 0.02-10 in. in thickness and within a temperature range of -5 to 900 °F. Automatic probe recognition offers compatibility with a family of dual transducers. An internal datalogger allows up to 2000 thickness readings to be stored

for future computer downloading capabilities. Accessories—internal datalogger, transducer probe, 6-V rechargeable Ni-Cad battery pack, battery charger/AC adapter, test block, RS-232 interfacing cable, coupler, carrying pouch, carrying case, demonstration floppy disk, and instruction manual.

Price Range: Moderate

Operating Skill or Training Level Required: Low

Interpretive Ability Required: Low

Operating Principle: Pulsed ultrasonic, compressional waves are induced into the tested metal sample regular timed intervals. When the pulses encounter a reflecting surface some or all of the energy is reflected back. The proportion of energy reflected back is monitored and measured and is proportional to the remaining thickness of uncorroded metal. This measurement is for pipes and tanks which are not easily accessible. Both the receiving and transmitting transducers are contained in one probe. With its built-in microprocessor, a low skill level is sufficient to operate and interpret the readings.

Source: Panametrics, Inc.

James Corroscan

Description: Based on electrical potential, a silver chloride half-cell is connected to an exposed section of rebar and to a water-saturated "Delrin Wheel" to complete the circuit. The wheel rolls along the surface parallel to the embedded rebar. The potential difference between the electrode of the half-cell and the rebar is related to the probability of corrosion of the embedded rebar.

Price Range: High

Operating Skill or Training Level Required: Moderate

Interpretive Ability Required: Moderate

Operating Principle: See description above

Source: James Instruments, Inc.

Subsurface Void and Delamination Detection Tasks

- *Spatial Dynamics M600 Concrete and Cement Tester (see Index)*
- *James E-Meter (see Index)*
- *James V-Meter (see Index)*

Inner Grout Condition Evaluation

- *James V-Meter (see Index)*
- *Zibra Labs Milliscope Model 20.150.00 (see Index)*
- *Machida 8mm Flexible Borescope System Model FBA-8-100 (see Index)*
- *Optronics S-1 Borescopic Video (see Index)*
- *WA Video Probe 2000 (see Index)*

Density Measurement Tasks

- *James V-Meter (see Index)*

Measuring Adhesive Bond Condition (Laminated Wood)

- *Inframetrics Thermal Imaging Radiometer Model 522 (see Index)*
- *Agema Thermovision 470 Infrared Thermal Measurement and Imaging System (see Index)*
- *Hughes Probeye IR Viewer Model 1650 (see Index)*

Crack, Flaw, and Anomaly Detection Tasks

Spectronics High Intensity Black Light Lamp Model B1B-120B

Description: A hand-held, ultraviolet (UV) lamp with an anodized aluminum housing and contoured rubber pistol grip contains a 120 w high-intensity, bulb with built-in ballast and 8 ft heavy-duty power cord. The ballast eliminates the need for an external transformer, reducing the bulk and weight while maintaining the power. The 120 w long-wave UV lamp (365 nm) produces maximum intensity, in either a concentrated spot or broad beam, for detecting low-level fluorescence in dimly lit areas. An attached, vinyl-clad, stainless steel heat-guard stand makes operation safer and protects the bulb from mechanical shock damage. Accessories—120 w bulb with built-in ballast, HGS-129B heat guard/stand, filter, 8 ft power cord, starter assortment pack for water, gas, oil, and refrigerant leaks, UV-absorbing eyeglasses.

Price Range: Very Low

Operating Skill or Training Level Required: Low

Interpretive Ability Required: Low

Operating Principle: For cracks, flaws, or other anomalies on surfaces or welds, a fluorescent liquid penetrant is sprayed onto the surface after inspected area is cleaned with a solvent remover. Liquid penetrant seeps into minute surface openings by capillary action. The excess penetrant is wiped away and a developer solution is applied. The area is then inspected with a hand-held portable high-intensity ultraviolet (UV) lamp. Cracks and surface flaws are easily identified by their bright glow. For refrigerant leak detection, a fluorescent dye is added to the freon system through a mist infuser attached to the test manifold. The fluorescent dye mixes with the refrigerant and is given time to circulate through the compressors, valves, coils, and tubing. The high-intensity ultraviolet lamp is then shone over these surfaces; minute leaks are identified by a bright yellow-green glow.

Source: Spectronics Corporation, Inc.

Measuring Weld Condition

— *Spectronics High Intensity Black Light Lamp Model B1B-120B (see Index)*

Insulation Condition Measurement Applications

- Detect areas of heat loss due to poor insulation properties as indicated by building enclosure surface temperature drops.
- Detect moisture-damaged insulation in walls, floors, ceilings, and roofs.

Infrared Imaging Systems

— *Inframetrics Thermal Imaging Radiometer Model 522 (see Index)*

Infrared Combined Systems

- *Agema Thermovision 470 Infrared Thermal Measurement and Imaging System (see Index)*
- *Hughes Probeye Infrared Viewer Model 650 (see Index)*

Roofing Inspection Applications

- Locate areas of heat loss, roofing insulation, or membrane damage using IR imaging.
- Identify and locate moisture infiltration into roofs using microwave detection methods.

Heat-Variance Detection (Infrared Imaging) Systems

- *Inframetrics Thermal Imaging Radiometer Model 522 (see Index)*
- *Agema Thermovision 470 Infrared Thermal Measurement and Imaging System (see Index)*
- *Hughes Probeye Infrared Viewer Model 650 (see Index)*

Moisture Damage Evaluation Tasks

- *Inframetrics Thermal Imaging Radiometer Model 522 (see Index)*
- *Agema Thermovision 470 Infrared Thermal Measurement and Imaging System (see Index)*
- *Hughes Probeye Infrared Viewer Model 650 (see Index)*
- *Spatial Dynamics M600 Concrete and Cement Tester (see Index)*

Paint and Coating Evaluation Applications

- Visually inspect and measure the number of coatings, the type of individual film thicknesses substrate conditions of paints and other protective coatings applied to all materials.
- Measure the thickness of nonconductive coatings on any ferrous or nonferrous substrate.
- Measure or verify the applied quality of paint.
- Measure the tensile adhesion strength of protective coatings in pounds per square inch (psi).

Identifying Coating Number and Type

Tooke Gauge Mark IV

Description: A portable, hand-held instrument which accurately (but destructively) measures the thickness of each coat in multicoat paint systems applied to any surface. The device cuts a small v-grooved incision into the paint surface and the coating cross-section is observed through an integral 50x power microscope. Observation indicates possible intercoat contamination, entrapped air, voids, underlying rust or mill scale, pin-holes, poorly adhered coats, coating embrittlement and thicknesses. Accessories—three cutting tips, batteries, spare bulb, and leather carrying case.

Price Range: Low

Operating Skill or Training Level Required: Low

Interpretive Ability Required: Low

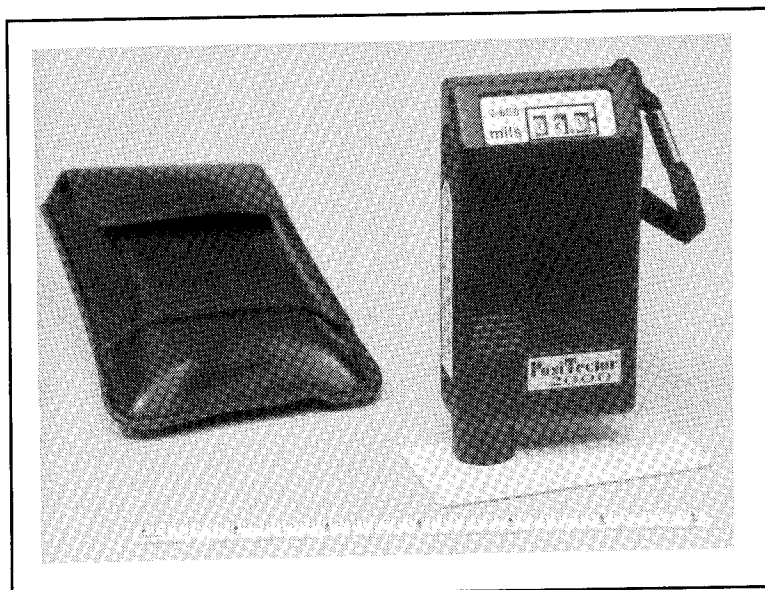
Operating Principle: A beveled cutting edge inscribes a small V-groove incision into the protective coating down to the substrate. Visual examination is made through an illuminated microscope (10X) with an equipped reticle (scale) in the eyepieces to measure the number and thickness of protective layers.

Source: KTA-TATOR, Inc.

Coating Thickness Measurement (on Ferrous Base)

Positector 2000 Coating Thickness Gauge

Description: A small hand-held, battery-powered device used for measuring the thickness of nonmagnetic coatings (paint, enamel, plastic, galvanizing, metalizing, plating, phosphating, etc.) with a ferrous backing. The gauge is palm size, durable, and ready to use without switching. Measuring 4 x 2 x 1 in. and



made of a durable, hardened plastic, the positector works when held normal (perpendicular) to any positioned surface. It is adjustable to unusual substrates, and the reading is unaffected by aging or reasonable shock, temperature, and vibration environments. Accessories—(0-60 mils) with tungsten carbide probe tip, 9-volt battery, set of sample thickness standards, and leather case.

Price Range: Very Low

Operating Skill or Training Level Required: Low

Interpretive Ability Required: Low

Operating Principle: A ruby-tipped probe contains a magnet wrapped in an energized coil of a known magnetic field strength. The more coatings over the ferrous substrate (i.e., the farther the magnet is from the ferrous substrate), the weaker the field. The magnetic field strength is proportional to the coating thickness.

Source: DeFelsko, Inc.

Positest Coating Thickness Gauge Model FM

Description: A hand-held, magnetic detection device used to measure thicknesses of nonmagnetic coatings on steel within a range of 0-80 mils. The instrument features a tungsten carbide tip for long wear, v-grooves in the probe housing for correct positioning, and an explosion-proof housing. Accessories—leather case, wrist and neck straps, and laminated instruction card.

Price Range: Very Low

Operating Skill or Training Level Required: Low

Interpretive Ability Required: Low

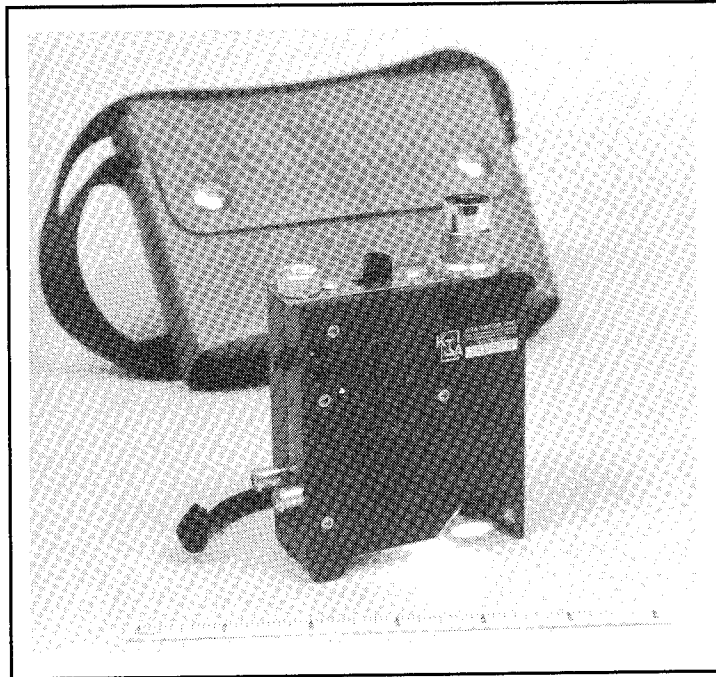
Operating Principle: Similar to the Positector 2000.

Source: DeFelsko, Inc.

Paint and Coating Thickness Measurement (All Surfaces)

Tooke Gauge Mark III Model OG232

Description: A portable, hand-held instrument which accurately (but destructively) measures the thickness of each coat in multicoat paint systems applied to any surface. The device cuts a small v-grooved incision into the paint surface and the coating cross-section is observed through an integral 50x power microscope. Observation indicates possible intercoat contamination, entrapped air, voids, underlying rust or mill scale, pin-holes, poorly adhered coats, coating embrittlement and thicknesses. Accessories—three cutting tips, batteries, spare bulb, and leather carrying case.



Price Range: Very Low

Operating Skill or Training Level Required: Low

Interpretive Ability Required: Low

Operating Principle: A beveled cutting edge inscribes a small V-groove incision into the protective coating down to the substrate. Visual examination is made through an illuminated microscope (10X) with an equipped reticle (scale) in the eyepieces to measure the number and thickness of protective layers.

Source: KTA-TATOR, Inc.

Others

— *Tooke Gauge Mark IV* (see Index)

Quality of Applied Paint

USACERL Portable Paint Test Kit

Description: This product was developed by the U.S. Army Construction Engineering Research Laboratories (USACERL) in response to paint testing problems in quality assurance maintenance activities. The kit, whose contents fit into a briefcase, evaluates drying time, hiding power, appearance, gloss, adhesion cleanability properties of most oil-based and latex paints.

Price Range: Very Low

Operating Skill or Training Level Required: Moderate

Interpretive Ability Required: High

Operating Principle: The kit includes a series of simple physical-property tests, to be interpreted by the user.

Source: U.S. Army Construction Engineering Research Laboratories (1-800-USACERL)

Measuring Paint and Coating Adhesion Strength

KTA-TATOR Pneumatic Adhesion Tester

Description: A silicone test plug is adhered, with high strength epoxy, to the surface. Compressed air is applied to the adhered plug until the test poundage is reached or the plug detaches the coating from the surface. Tensile adhesion pulls are evaluated in pounds per square inch (psi).

Price Range: Moderate

Operating Skill or Training Level Required: Low

Interpretive Ability Required: Low

Operating Principle: See Description

Source: KTA-TATOR, Inc.

4 Utilities

Water/Wastewater Quality Applications

- Monitor pH levels in plant and operations water supplies for maintaining proper acidity levels.
- Test drinking water for lead, fluoride, calcium, etc. content from supply areas and other various locations (i.e., sinks, drinking fountains) in buildings with older plumbing systems.
- Verify cold, safe, good-tasting drinking fountain water.
- Monitor and measure calcium and iron levels in water, wastewater, and storm drainage piping.
- Analyze and test effluent discharge from wastewater treatment plants for maintaining regulated standards.
- Test feed and cooling water for calcium content in boilers, chillers, heat exchangers.

Water Testing Systems

Hanna Instruments Water Test

Description: A hand-held, battery-powered instrument which provides quick and reliable measurement of four variables in water analysis: pH (0-14 pH), oxidation reduction potential (ORP) (+/- 1000 mV), conductivity (0-1990 S), and temperature (0-60 °C). The instrument is made of a lightweight, durable plastic construction measuring 9 in. high, and has a direct LCD readout. Preliminary pH and conductivity calibration are necessary before each measurement. An instruction manual is included.

Price Range: Very Low

Operating Skill or Training Level Required: High

Interpretive Ability Required: Moderate

Operating Principle: Reads parts of free hydrogen per million (pH) electrolytically.

Source: Kernco Instruments Co.

Hanna Piccolo pH Meter Kit

Description: A hand-held, battery-powered instrument used to measure pH levels in liquids on a direct LCD readout (0-14pH) with automatic temperature compensation with a +/- .01 pH accuracy. Preliminary pH calibration is necessary before each measurement. Accessories—basic 2 calibration solutions, calibration screw-driver, pH electrode, plastic storage case, batteries, and instruction manual.

Price Range: Very Low

Operating Skill or Training Level Required: Moderate

Interpretive Ability Required: Moderate

Operating Principle: Reads parts of free hydrogen per million (pH) electrolytically.

Source: Kernco Instruments Co.

Hanna All-In-One pH/Temperature Gauge Model HI 8414

Description: A hand-held, battery-powered instrument used to measure both pH and temperature with Automatic Temperature Compensation (ATC) in liquids. Preliminary pH calibration is necessary before each measurement. Accessories—meter, general-purpose plastic body refillable single junction electrode, carrying case, instruction manual, and battery.



Price Range: Very Low

Operating Skill or Training Level Required: Moderate

Interpretive Ability Required: Moderate

Operating Principle: See Description

Source: Kernco Instruments Co.

Hellige Aqua Analyzer Colorimeter Series 952

Description: A portable, tabletop electronic device used to analyze water samples for certain chemical levels. Measuring 7 × 4.5 × 6.5 in. and made of painted anodized aluminum, this instrument is a fully contained abridged spectrophotometer with built-in rotatable discs containing eight permanent glass filters. The instrument also contains a regulated power supply, a lamp that produces a controlled beam of light, a photocell, an amplifier system, and a digital readout. Accessories—22 different test kits, 6 specimen tubes, tube rack, and user's manual.



Price Range: Moderate

Operating Skill or Training Level Required: Needs specialist

Interpretive Ability Required: Very High

Operating Principle: Light beam bends proportionally to concentration of target ion in specific reagent solution.

Source: Orbeco Analytical Systems, Inc.

Electrical Power Quality Applications

- Check purging (i.e., power surges and fluctuations) in sensitive electronic equipment including computer, microwave, radio and satellite systems.
- Detect and monitor high magnetic flux outputs from high-voltage areas, power plants, transmission lines transformers, generators when this flux energy may interfere with sensitive surrounding equipment.
- Provide energy management analysis of operating HVAC systems for determining peak power demands and consumption.
- Measure and monitor voltage, ohms, and amperage of any energized conductor.
- Detect overheated or malfunctioning electrical transformers, power switching panels, transmission lines, circuit breakers, switch gear boxes, and other major interior and exterior electrical supply and distribution interfaces.

Electrical System Power Analysis Tasks

AEMC True RMS Power and Demand Analyzer Model 3950

Description: This fully programmable, high-accuracy unit measures, displays, and records electrical values critical for analyzing demand and consumption on both balanced and unbalanced systems. Data are displayed on an alphanumeric LCD, and stored in memory for output to printer or computer via an RS232-C interface. The unit is usable on single and three phase, 3 or 4 wire systems to measure voltage rms, amperage rms, Wattage, VA, phase, power factor, and frequency (Hz). Accessories—carrying case, ac supply or rechargeable internal battery, and an instruction manual.

Price Range: Moderate

Operating Skill or Training Level Required: High

Interpretive Ability Required: High

Operating Principle: See Description

Source: AEMC Instruments

Amprobe ACD-10 Digital Clamp-On Amp/Ohm/Volt Meter

Description: At only 6.75 in. long, this hand-held, portable instrument measures ac current, voltage, and resistance. It can measure voltage ranging from 0-750 VAC, current from 0-300 amps, and resistance from 200-40,000 ohms. Readings are displayed on a large (0.5 in.) LCD. The unit is internally protected up to 550 VAC of overvoltage, and the clamping jaws open up to 31 mm. Accessories—9 volt battery, wrist strap, removable belt clip, carrying case, and instruction manual.

Price Range: Very Low

Operating Skill or Training Level Required: Moderate

Interpretive Ability Required: Moderate

Operating Principle: See Description

Source: Amprobe Instrument Co.

Electrical System Temperature Measurement Tasks (Non-Contact)

The systems listed below, described under other headings, can make non-contact temperature measurements from electrical system components:

- *Mikron Portable Infrared Thermometer Model M56P (see Index)*
- *Raytek Raynger Model PM-5 Non-Contact Thermometer (see Index)*
- *Telatemp LCD Reversible Temperature Decals (see Index)*

Electrical System Operating Temperature Infrared Imaging Systems

- *Inframetrics Thermal Imaging Radiometer Model 522 (see Index)*

Electrical System Operating Temperature Infrared Combined Systems

The systems listed below, described under other headings, can make non-contact temperature measurements from electrical system components:

- *Agema Thermovision 470 Infrared Thermal Measurement and Imaging System (see Index)*
- *Hughes Probeye IR Viewer Model 1650 (see Index)*

Utility Line Location Applications

- Locate water, wastewater, electrical, telephone, TV cable, computer cables, natural gas, steam, and storm sewer lines.
- Identify and locate underground gas storage tanks, vessels, and distribution lines without digging or disturbing the soil.
- Locate and trace energized conductors (i.e., wires, conduit, cable trays) from their respective receptacle boxes or breaker panels through walls, floors, and ceilings without interrupting the power.

Line Location Systems

Heath Locating System Model LS-800

Description: A field-portable, battery-powered device used to locate underground pipes, cables, and other utility-type structures. A 4 lb transmitter box is set on the ground while the hand-held receiver provides audio and visual indicators to guide the operator to the exact location of the utility line being traced. A lock indicator assures the operator that the receiver is locked onto the signal and a depth indicator button produces a direct LCD readout of the depth in inches of the utility line. Accessories—transmitter, receiver, cable/grounding kit, batteries, carrying case, and instruction manual.

Price Range: Moderate

Operating Skill or Training Level Required: Moderate

Interpretive Ability Required: High

Operating Principle: Measures reflectivity of pipe to em waves.

Source: Heath Consultants, Inc.

Amprobe Current Tracer Model CT23-10B

Description: A hand-held, battery-powered probe and stationary transmitter used for safe tracing of energized conductors on 6-600 volt circuits without turning off power or interrupting electronic equipment. This device is capable of tracing any energized conductor, neutral line or ground line from any location within a facility back through main distribution panels, transformers, and switch gear boxes. Without interrupting power, one can locate circuit breakers, feeder lines, panel boxes, neutral and ground lines, short circuits, conduit, and branch lines within any electrical system. Accessories—P-23 probe, T-23 transmitter, T-10 transmitter, PT-23 pigtail connector, 600CK voltage converter, CC6-CT case, and instruction manual.



Price Range: Low

Operating Skill or Training Level Required: Low

Interpretive Ability Required: Low

Operating Principle: The device detects overlaid frequencies on the active electrical line being traced.

Source: Amprobe Instrument Co.

Fluid Leak Detection Applications

- Detect a leaking pressurized gas to very small quantities, using ultrasonic methods.

- Detect leaks in forced air, duct, filter, and exhaust fan systems.
- Locate invisible in-line steam leaks and hot spots at building interfaces, fittings, and equipment connection points through audible ultrasonic amplification or infrared imaging.
- Locate buried steam line leaks without unnecessary excavation.
- Detect natural gas or other combustible gas leaks in storage, distribution areas and at connection points.
- Detect liquified petroleum gas (LPG) and propane gas leaks in containment and distribution areas.
- Detect and locate underground liquid gas leaks from storage vessels and/or distribution line and measure the resulting soil contamination.
- Locate fuel leaks, cracks, holes, or other anomalies in gas engines, fuel pump casings and lines, and any other enclosed circulatory fuel systems.
- Detect and provide warning for high methane gas concentrations in wastewater treatment plants and underground facilities.
- Detect and locate freon and refrigerant gas leaks, cracks, holes, or other anomalies in any enclosed circulatory refrigeration systems.

Measuring Pressurized Air and Other Gases

Ultraprobe 2000

Description: A hand-held, battery- or ac-powered ultrasound-generation device for detecting pressure and vacuum leaks (air, methane, oxygen, etc.) in HVAC and other mechanical equipment. By scanning the test area with an ultrasonic receiver, the operator can listen through a pair of headphones for rushing sounds that indicate a leak. The closer the device is to the leak, the louder the rushing sound. The instrument's *fixed band frequency mode* reduces background noise interference, allowing the device to be used in noisy environments. Accessories—rubber focusing probe, stethoscope probe, extension probe kit, battery recharge kit, Ni-Cad rechargeable battery pack, deluxe industrial headset, aluminum carrying case, and instruction manual.

Price Range: Moderate

Operating Skill or Training Level Required: Moderate to High

Interpretive Ability Required: Moderate

Operating Principle: See Description

Source: UE Systems, Inc.

Amprobe ULD-100 Ultrasonic Leak Detector

Description: An ultrasonic receiver usable on working systems alone or on tested systems as part of the Ultraprobe 2000 method.

Price Range: Moderate

Operating Skill or Training Level Required: Low

Interpretive Ability Required: High

Operating Principle: When any pressurized gas, steam, or water passes through a small opening greater than 10 (-5) ml/second, ultrasonic sound is created. Because ultrasound comprises any sound above 20 kHz, it cannot be heard by the human ear. The Amprobe ULD-100 converts this ultrasound into an audible frequency.

Source: Amprobe Instrument Co.

Steam Measurement

The following systems, described separately under other headings, can be used to make steam measurements:

- *Ultraprobe 2000* (see Index)
- *Amprobe ULD-100 Ultrasonic Leak Detector* (see Index)
- *Inframetrics Thermal Imaging Radiometer Model 522* (see Index)



- *Agema Thermovision 470 IR Thermal Measurement and Imaging System* (see Index)
- *Hughes Probeye Infrared Viewer Model 650* (see Index)

Detecting Combustible Gases

Kernco Wall-Mounted Gas/Vapor Detector Model 51A24

Description: A wall-mounted combustible and toxic gas detector is contained within a rustproof NEMA 11 housing and powered by 110 volts. Measuring 7 in. x 5 in., the unit can detect as low as 1 PPM of some gases and will provide both a visual and audible alarm and contains a relay contact output for remote sensing. The unit weighs approximately 2 lb and has a sensor life of 50,000 exposures.

Price Range: Low

Operating Skill or Training Level Required: Low

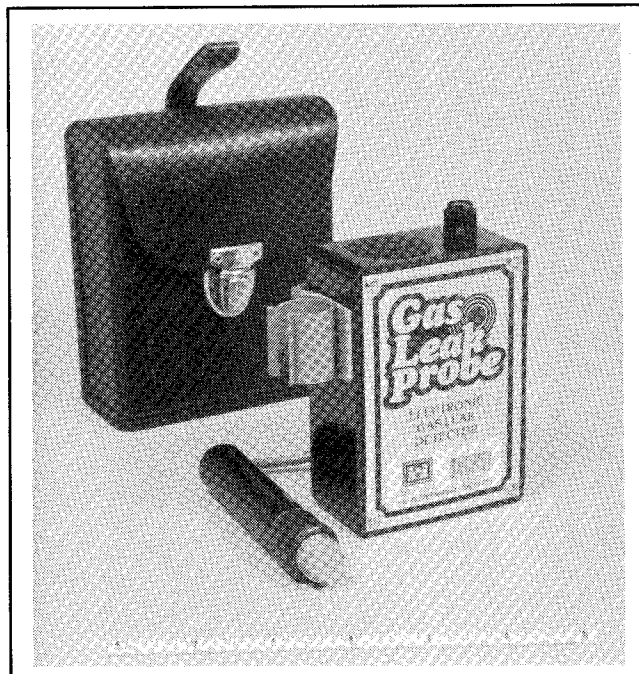
Interpretive Ability Required: Low

Operating Principle: See Description

Source: Kernco Instruments Co.

Quantum Instruments Electronic Gas Leak Probe Model BT-45

Description: A portable, battery-powered, hand-held instrument used to detect and locate the source of any combustible gas leak. Made of hard plastic and anodized aluminum, the unit measures 4 x 3 x 1 in. with a rubber and stainless steel screen probe tip connected to a 16-in. rubber-coated cord. The power and sensitivity control knob are located at the top of the unit to control the audible "beep" rate used to flag the detection of combustible gases. Accessories—probe, earphone, carrying case, battery, and instruction manual.



Price Range: Very Low

Operating Skill or Training Level Required: Low

Interpretive Ability Required: Low

Operating Principle: An internal ceramic heater burns minute levels of any combustible gas present in the air. The rise in temperature within the ceramic heater triggers the change in electrical capacitance of a capacitor. Change in capacitance increases the beeping rate of the audible alarm from a "normal" rate to a very fast rate, indicating the presence of a combustible gas.

Source: Quantum Instruments, Inc.

Heath Porta-Fid II Flame-Ionization Gas Leak Detector

Description: A hand-held, battery-powered device used to measure small quantities of combustible substances. The flame-ionization principle allows a controlled amount of fuel gas to be mixed with the air sample being measured. The air sample is drawn into a chamber by a small electric pump where the ionization process occurs and where the ionization rate is electrically measured and converted into ppm (parts per million) of the sample being measured. The device draws a 700 cc per minute sample, has an analog meter, emits a pulsating alarm when gas is detected, and provides a meter readout of 0-5000 ppm. Accessories—fuel cylinder holder, rechargeable battery, telescopic probe assembly, 2 fuel cylinders, transfiller, regulatory system, battery charger, 100 extra filters, storage case, and an instruction manual.

Price Range: Moderate

Operating Skill or Training Level Required: Moderate

Interpretive Ability Required: Moderate

Operating Principle: See Description

Source: Heath Consultants, Inc.

Others

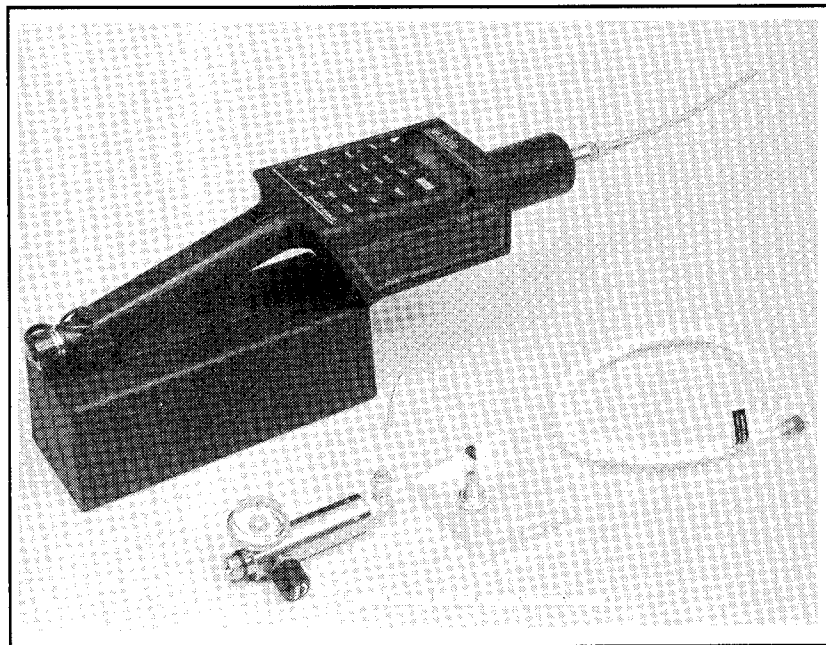
The systems listed below, described separately under different headings, can also be used for detecting combustible gases:

- *Ultraprobe 2000* (see Index)
- *Inframetrics Thermal Imaging Radiometer Model 522* (see Index)
- *Agema Thermovision 470 IR Thermal Measurement and Imaging System* (see Index)
- *Hughes Probeye Infrared Viewer Model 650* (see Index)

Detecting Volatile Organic Compounds (VOCs)

Photovac MicroTIP Air Analyzer MP-1000 ML-2000/IS-3000

Description: This unit is one of the lightest volatile organic compound (VOC) monitoring devices available (5.25 lb). Using a photo-ionization detector (PID), the MicroTIP provides immediate determination of contaminant levels over a range of 0.1 to 2000 ppm. A built-in datalogger provides recording and downloading capabilities for 12 hours of data. Simple instructions and reading are visible on an LCD panel. Accessories—carrying case, calibration kit, analog cable, printer cable, three-meter sample line, and rechargeable snap-on battery pack.



Price Range: Moderate

Operating Skill or Training Level Required: Low to Moderate

Interpretive Ability Required: Moderate

Operating Principle: See Description

Source: Photovac International, Inc.

Others

The two systems listed below may also be used for detecting VOC leaks:

- *Amprobe ULD-100 Ultrasonic Leak Detector (see Index)*
- *Spectronics High Intensity Black Light Lamp Model B1B-120B (see Index)*

Detecting Refrigerants and Halogens

TIF 5000 Halogen Leak Detector

Description: A lightweight, hand-held unit with a flexible probe for detecting gaseous halogen.

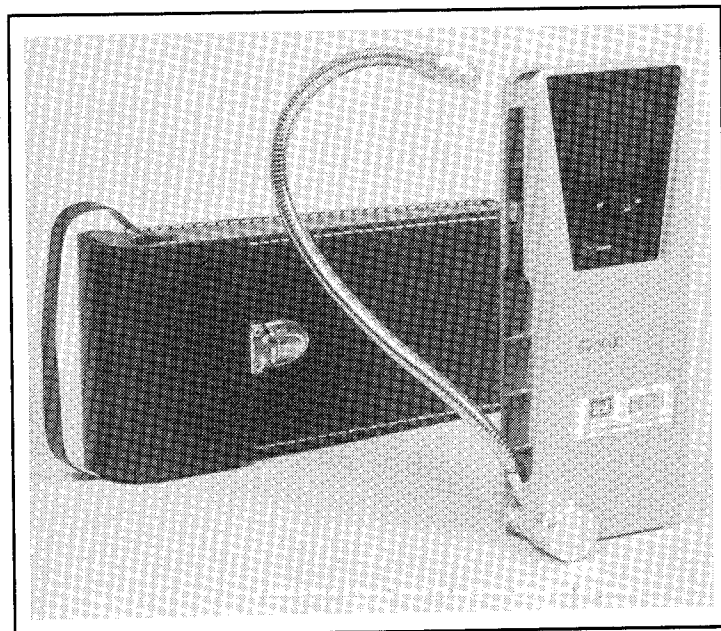
Price Range: Moderate

Operating Skill or Training
Level Required: Low

Interpretive Ability Required:
High

Operating Principle: Based on electrical capacitance, air passes through a nonconducting liquid film. If halogen gas is present, it is absorbed onto the film and an electrical current passes through the film. A semipermeable membrane, wrapped around an electrode, accepts only halogen ions to the negative pole cathode. The conductance created is an indication of the halogen gas present.

Source: TIF Instruments, Inc.



Kernco Halogen Leak Detector Model 51A38

Description: A hand-held device used to detect halogen leaks as small as 0.5 ounce per year. Powered by two C batteries, measuring 8 × 3 in., and containing a 12.5 in. probe. The instrument automatically recalibrates each time it is turned on. The instrument emits a beep signal that will increase in speed and frequency as the leak source is approached. Accessories—spare sensing tip, sensing tip protector, six filter cloths, batteries, carrying case, and instructions.

Price Range: Very Low

Operating Skill or Training Level Required: Low

Interpretive Ability Required: Low

Operating Principle: See Description

Source: Kernco Instruments Co.

Liquid Gas Detection

— *Photovac MicroTIP Air Analyzer MP-1000ML-2000/IS-3000* (see Index)

Energy Management Measurement Systems**Kernco Combustion Efficiency Analyzer Model 48A12**

Description: A field-portable, battery- or ac-powered analyzer kit used to measure thermal efficiency and profile flue emissions from a gas-operated boiler or furnace. The instrument gives continuous readout on two displays. One digitally monitors flue temperature and oxygen concentrations, and the other provides an analog display of carbon monoxide levels. Accessories—aluminum case, extraction probe, connection cable, water trap, gel cell battery, air filter, ac adapter/charger, and instruction manual.

Price Range: Moderate

Operating Skill or Training Level Required: Moderate

Interpretive Ability Required: High

Operating Principle: Since thermal efficiency is related to excess oxygen present in flue gases, oxygen is measured with a free-oxygen sensor and a built-in thermocouple for temperature measurement. The amount of oxygen in the flue relative to its temperature can provide an indication of thermal efficiency.

Source: Kernco Instruments Co.

5 Habitability

Air Quality Measurement Applications

- Measure and monitor outdoor and indoor air temperature/ humidity levels and log for future analysis.
- Monitor flow levels from forced-air, duct, filter, and exhaust fan systems.
- Verify the HVAC cooling system meets performance specifications for flow, temperature, humidity control and filtration.
- Carefully monitor HVAC effectiveness in sensitive environments (i.e., cool, clean air is supplied to hospital patient and clean rooms, laboratories, computer rooms and certain storage areas).

Air Flow Measurement Systems

Kernco Digital Anemometer Model 20D13

Description: A hand-held, battery-powered instrument used to measure air velocity within a range of 35-6000 FPM. Operated by a single pushbutton and powered by one 9-volt battery, the reading is averaged over a 6-second period with a +/- 2 percent accuracy. The instrument measures approximately 10.5 x 4.5 in., and weighs 10.3 oz. Accessories—carrying case, battery, and instruction manual.

Price Range: Low

Operating Skill or Training Level Required: Low

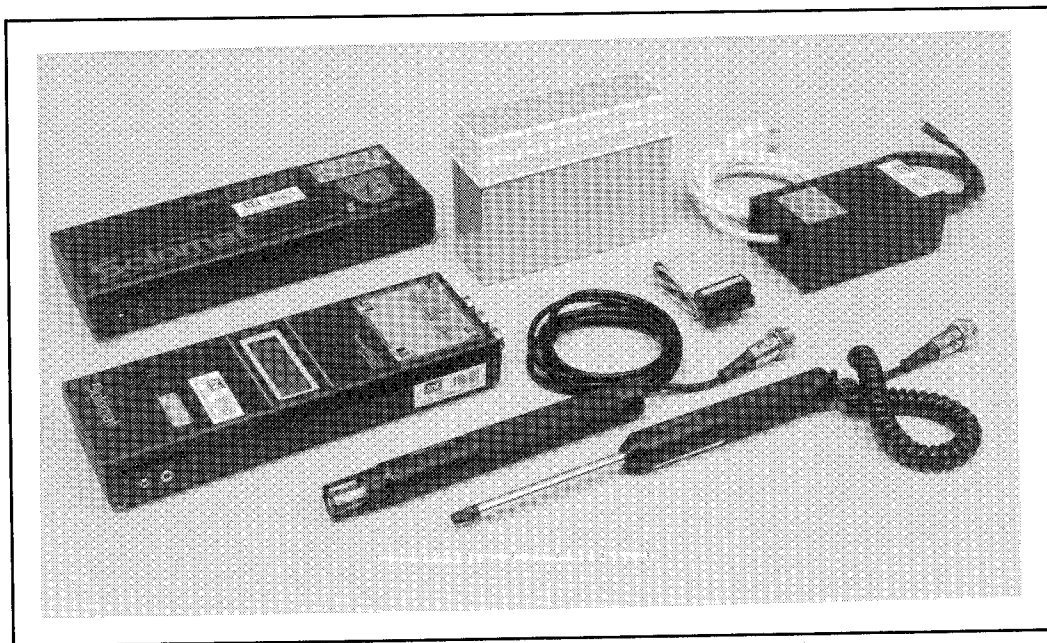
Interpretive Ability Required: Low

Operating Principle: The rotational speed of an air driven 3-in. propeller (vane anemometer) is taken directly proportional to the true air speed. A built-in microprocessor provides a digital readout of the air speed in feet per minute.

Source: Kernco Instruments Co.

Air Flow, Temperature, and Relative Humidity Measurement Systems

Solomat Deluxe MPM 2000 Multi-Probe Meter



Description: A hand-held, portable, multifunctional instrument capable of measuring air temperature, air speed, water and air pressure, relative humidity, RPM, pH, oxygen and ion, content, conductivity, and voltage/frequency measurements. Measuring 1.5 x 3.5 x 7 in., and made of impact-resistant ABS plastic, this microprocessor has 20 detachable modumeters and an array of probes to create a highly specific instrument. Accessories—2016 multichannel modumeter, data storage memory pack, 226-RH thermo-hygro probe, 127-MS hot-wire anemometer probe, EX4 logger cable, EX8 interface cable, DC3e battery pack, and AA3/1 charger/adaptor.

Price Range: Moderate

Operating Skill or Training Level Required: Moderate

Interpretive Ability Required: Moderate

Operating Principle: To measure air flow, a thermistor sensor monitors the cooling down effect caused from air passing by a very fine heated wire (hot-wire anemometer). The amount by which the hot wire is cooled is directly proportional to the air speed. With the Solomat microprocessor, a direct readout of air speed is obtained.

To measure air temperature, the instrument uses the principle of resistance temperature. A 100-ohm platinum disk (resistance temperature detector, or RTD) is electrically charged. As air passes across the disk, the electrical resistance of the platinum is measured and is inversely proportional to the air temperature. With the Solomat microprocessor, a direct readout of temperature in Fahrenheit or Celsius is provided.

To measure relative humidity, a thin polymer and bronze film sensor responds to water vapor in the air. The amount of water vapor on the film sensor affects the electrical capacitance of the bronze capacitor. The amount of change in electrical capacitance is inversely proportional to the relative humidity of the air. With the Solomat microprocessor, a direct digital readout of relative humidity is provided.

Source: Solomat, Inc.

Toxic Contaminant Detection Systems

— *Kernco Wall-Mounted Gas/Vapor Detector Model 5 IA24* (see Index)

Pest Detection Systems

— *Spatial Dynamics M600 Concrete and Cement Tester* (see Index)

Metric Conversion Factors

1 in.	=	25.4 mm
1 ft	=	0.305 m
1 sq ft	=	0.093 m ²

Appendix A: Field Survey of Potential QA Instrumentation Test Sites

MEMORANDUM For Catalog Readers:

SUBJECT: Evaluation of Field-Portable QA Measurement/Detection Devices for Support of Inspection-Related Activities

1. USACERL is evaluating field-portable, commercially-available intelligent sensor/measurement devices for supporting Quality Assurance (QA) inspection activities. We wish to track the use of intelligent inspection equipment for improving the accuracy and reproducibility of many DPW inspection tasks as well as improve the timeliness and effectiveness of the data captured.
2. Attached is a list of QA equipment to be made available from USACERL to any requesting DPW on a time-limited loan basis. The list identifies the supplier and describes the functional uses of each of the supplied systems. Also attached is a 1-page reply form. It is requested that you support our inquiry by completing this form and returning it to:

USACERL
ATTN: CECER-FFI (James Johnson)
P.O. Box 9005
Champaign, IL 61826-9005

3. For any questions or concerns regarding this inquiry, feel free to contact USACERL POC: James Johnson (Principal Investigator) at (217) 352-6511 or (800) USA-CERL. A prompt reply will be greatly appreciated.

DPW REPLY FORM

QUESTIONNAIRE:

a. Please list inspection-related equipment that your office currently uses or plans to purchase.

b. Please list systems that you would like to acquire for tryout purposes (from this catalog or other sources).

c. Check the maintenance services you feel are of importance to your existing or planned inspection/maintenance needs.

- 1. FACILITY STRUCTURAL DETERIORATION _____
- 2. PLANTS AND EQUIPMENT STATUS _____
- 3. UTILITIES GENERATION _____
- 4. UTILITIES DISTRIBUTION _____
- 5. HABITABILITY STANDARDS _____
- 6. MECHANICAL SYSTEM ASSESSMENTS _____
- 7. ROTARY MOTOR MEASUREMENTS _____
- 8. VISUAL INSPECTION AIDS _____
- 9. INFRARED INSPECTION SYSTEMS _____
- 10. LEAK DETECTION SYSTEMS _____
- 11. PROTECTIVE FINISH ASSESSMENTS _____

d. If inspection instrumentation related to the areas of maintenance service that you checked above were available to your installation on a 15-day loan basis, would you be interested in evaluating these inspection devices for your specific needs?

YES _____ NO _____

INSTALLATION(S) SUPPORTED: _____

NAME/ORGANIZATION: _____

Appendix B: Suppliers of Sensor/ Measurement Systems

These companies are the suppliers of the sensor/measurement systems used in the USACERL QA monitoring systems study and are not necessarily recommended as a future acquisition source for these types of instrumentation. The list is a reference and provided for additional information purposes only.

1. **AF Infrared**
2608 West Lincoln Highway
Merrillville, IN. 46410
(Tel.) 219-736-0202
2. **Amprobe Instrument**
630 Merrick Road, PO Box 329
Lynbrook, NY. 11563
(Tel.) 516-593-5600
3. **DeFelsko, Inc.**
410 Cedar Street
Ogdensburg, NY. 13669
(Tel.) 1-800-267-0607
4. **Emco Sales and Distribution**
88 Bartley Road
Flanders, NJ. 07836
(Tel.) 201-927-2900
5. **Flir Systems, Inc.**
16505 SW 72nd Avenue
Portland, OR. 97224
(Tel.) 503-684-3731
6. **Heath Consultants, Inc.**
1809 Riley Road
New Castle, IN. 47362
(Tel.) 317-521-2068
7. **Inframetrics, Inc.**
12 Oak Park Drive
Bedford, MA. 01730
(Tel.) 508-670-5555
8. **Instruments Technology**
P.O. Box 381
Westfield, MA. 01086
(Tel.) 413-562-3606
9. **IRD Mechanalysis**
6150 Huntley Road
Columbus, OH. 43229-1074
(Tel.) 614-885-53769.
10. **James Instruments, Inc.**
3727 Kedzie Avenue
Chicago, Illinois 60618
(Tel.) 800-426-6500
11. **Kernco Instruments Company**
420 Kenazo Avenue
El Paso, TX. 79927
(Tel.) 800-325-3875
12. **KTA-TATOR, Inc.**
115 Technology Drive
Pittsburgh, PA. 15275
(Tel.) 412-788-1300

13. **Land Infrared**
2525 Pearl Buck Road
Bristol, PA. 19007
(Tel.) 215-781-0700
14. **Lenox Instrument Company**
265 Andrews Road
Trevose, PA. 19053
(Tel.) 215-322-9990
15. **Machida, Inc.**
40 Ramland Road South
Orangeburg, NY. 10962-2698
(Tel.) 800-431-5420
16. **Metrix Instrument Company**
1711 Townhurst Drive
Houston, TX. 77043
(Tel.) 713-461-2131
17. **Mikron Instruments Company**
445 West Main Street
Wyckoff, NJ. 07481
(Tel.) 201-891-7330
18. **Nucleus Corporation**
25880 Commerce Drive
Madison Heights, MI. 48071
(Tel.) 313-399-3610
19. **Olympus Instruments**
1800 Sandy Plains Rd, Suite #307
Marietta, GA. 30064
(Tel.) 800-537-1882
20. **Optronics Engineering**
175 B Cremona Drive
Goleta, CA. 93117
(Tel.) 805-968-3568
21. **Orbeco Analytical Systems, Inc.**
185 Marine Street
Farmingdale, NY. 11735
(Tel.) 516-293-4110
22. **Panametrics, Inc.**
221 Crescent Street
Waltham, MA. 02254
(Tel.) 800-225-8330
23. **PCB Piezotronics**
3425 Walden Avenue
Depew, NY. 14043-2495
(Tel.) 716-684-0001
24. **Princeton Gamma-Tech, Inc.**
568 Weddell Drive, Suite #1
Sunnyvale CA. 94089
(Tel.) 408-734-8124
25. **Quantum Instruments Inc.**
1075 Stewart Avenue
Garden City, NY. 11530
(Tel.) 516-222-0611
26. **Raytek, Inc.**
1201 Shaffer Road, Box 1820
Santa Cruz, CA. 95061-1820
(Tel.) 800-227-8074
27. **Savi Technology, Inc.**
350 Cambridge Avenue, Suite #50
Palo Alto, CA. 94306
(Tel.) 415-328-4323
28. **Sharples Stress Engineers Ltd.**
Preston, Lancashire, U. K.
29. **Solomat Instrumentation Division**
652 Glenbrook Road
Stamford, CT. 06906
(Tel.) 800-932-4500
30. **Spatial Dynamics Applications**
42 Washington Drive
Acton, MA. 01720
(Tel.) 508-263-7704
31. **Spectronics Corporation**
956 Brush Hollow Road, POB 483
Westbury, NY. 11590
(Tel.) 800-274-8888

- 32. TEC**
PO Box 22996, Lexington Drive
Knoxville, TN. 37933-0996
(Tel.) 615-675-1241
- 33. Telatemp Corporation**
PO Box 5160
Fullerton, CA. 92635-0160
(Tel.) 800-321-5160
- 34. TIF Instruments Inc.**
9101 NW 7th Avenue
Miami, FLA. 33150
(Tel.) 305-757-8811
- 35. TSI Incorporated**
500 Cardigan Road
PO Box 64394
St. Paul, MN. 55164
(Tel.) 612-490-2807
- 36. UE Systems**
12 West Main Street
Elmsford, NY. 10523
(Tel.) 800-223-1325
- 37. Walker Scientific Inc.**
Rockdale Street
Worcester, MA. 01606
(Tel.) 508-852-3674
- 38. Welch Allyn Video Division**
4341 State Street Road
PO Box 220
Skaneateles Falls, NY. 13153
(Tel.) 315-685-4100

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USACERL DISTRIBUTION

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ATTN: CEHEC-IM-LH (2)
ATTN: CEHEC-IM-LP (2)
ATTN: CERD-L

CECPW 22310-3862
ATTN: CECPW-FM (20)

INSCOM
ATTN: IALOG-I 22060
ATTN: IAV-DPW 22186

USA TACOM 48397-5000
ATTN: AMSTA-XE

US Army Materiel Command (AMC)
Alexandria, VA 22333-0001
ATTN: AMCEN-F
Installations: (19)

FORSCOM
Forts Gillem & McPherson 30330
ATTN: FCEN
Installations: (23)

TRADOC
Fort Monroe 23651
ATTN: ATBO-G
Installations: (20)

Fort Belvoir 22060
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