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TEST PLAN

DEFLAGRATION STUDIES ON WASTE TANK 101-SY

PHASE I. LABORATORY FLAMMABILITY STUDIES OF MIXTURES
OF HYDROGEN, NITROUS OXIDE, AND AIR

by Kenneth L. Cashdollar, Isaac A. Zlochower, and Martin Hertzberg

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MASTER

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JUL 2 1991
WINK FARM PROJECT OFFICE

Phase I. Laboratory Flammability Studies of Mixtures of Hydrogen, Nitrous Oxide, and Air started on May 29, 1991 and will end on June 30, 1992. A detailed description of the tests to be performed is in the Interagency Agreement.

This Test Plan contains the following sections:

- I. Key technical personnel and organization charts.
- II. General time schedule for tests.
- III. Test chambers, detailed test procedures, and output documentation.
- IV. Calibration of equipment and quality assurance.

KEY TECHNICAL PERSONNEL AND ORGANIZATION CHARTS

The work described in this Test Plan will be conducted by the Fires and Explosion Group of the Pittsburgh Research Center of the U.S. Bureau of Mines. Organization charts of the Pittsburgh Research Center and of the Fires and Explosions Group are in appendix A. Resumes of the key personnel who will supervise and conduct the research are listed in appendix B.

GENERAL TIME SCHEDULE FOR TESTS

The detailed lists of tests of the mixtures of hydrogen, nitrous oxide, and air are listed in tables 1-5 in the Interagency Agreement. Tables 1 and 2 are for two ratios of hydrogen to nitrous oxide diluted with air. We will measure the maximum pressures and rates of pressure rise for the undiluted mixtures and then the amount of air to dilute each mixture below the lean flammable limit. Table 3 is for similar data for hydrogen in air. Table 5 lists a specific run with a mixture of hydrogen, nitrous oxide, nitrogen, and air. Table 4 deals with the lean flammable limits of various mixtures. We will do the tests listed in table 4 and any other additional tests that are necessary to characterize the lean flammable limits of the hydrogen and oxidizer mixtures. There will also be a limited number of tests to evaluate the effects of water vapor at a temperature of 54°C. In addition to the tests listed in the tables, we will do some preliminary tests on hydrogen and nitrous oxide mixtures inerted with argon. All of these experimental tests should be completed within six months after approval of the Test Plan. The exact order of the tests will be determined as the work proceeds.

TEST CHAMBERS, DETAILED TEST PROCEDURES, AND OUTPUT DOCUMENTATION

The tests will be conducted in two Bureau of Mines chambers: one with a volume of 20 L and one with a volume of 120 L. The 20-L chamber is a near-spherical vessel that can be used for the testing of either gases or dusts. It has a pressure rating of 20 bar (300 psig) and is described in the publications in appendixes C and D. The 120-L chamber is a spherical vessel used for the testing of gases. It has a pressure rating of 69 bar (1000 psig) and is described in the publication in appendix D. The flame propagation criteria used for the lean flammability limit measurements in the two chambers are also listed in appendix D. Instrumentation for the chambers will include two pressure transducers to measure the explosion pressure and, at least for some runs, a fine thermocouple to measure the explosion temperature.

Data will be recorded using a high speed analog-to-digital (A/D) board in a personal computer (PC). It can sample several data channels at speeds greater than 20 kHz per channel. In addition, the data will also be recorded on a high speed strip chart recorder. The direct data will include the starting pressure, maximum explosion pressure, maximum rate of pressure rise, and maximum temperature (if the thermocouple is used). In addition, the explosion temperature will be calculated from the maximum explosion pressure using the ideal gas law, the maximum burning velocity will be calculated from the maximum rate of pressure rise, and the fraction of hydrogen burned will be calculated from the final pressure after the explosion products have cooled. Gas samples will also be collected from some of the tests.

The general testing procedures are:

1. Standard Bureau safety precautions will be followed. For example, no smoking or open flames are permitted in the test area.
2. When changing gas cylinders, the gas feed lines to the chamber must be thoroughly flushed before the start of the tests.
3. Tests of hydrogen at near stoichiometric concentrations will be made in the 120-L chamber. The chamber will be located in a bomb-proof and will be operated remotely from the observation room.

The detailed procedures for each test (for either chamber) are:

1. Evacuate the chamber to ≤ 0.01 bar (≤ 0.1 psia).
2. Add hydrogen by measuring the partial pressure in the chamber with a sensitive pressure transducer (0 to ~ 20 psia).
3. Add the other gases by partial pressures.
4. Mix the gases with an internal fan. (First, the mixing time necessary for each chamber will be determined by sampling at various time intervals while the gases are mixing.)
5. Collect sample of initial test mixture if desired. (Samples will be collected from the initial tests to confirm the partial pressure mixing procedure. Later, mixtures will be spot checked.)
6. After mixing, the initial pressure before the test should be ~ 1 bar.
7. After turning off the fan, delay 30 sec so that the gas mixture is quiescent before the test. (If the test is to be made under turbulent conditions, leave the fan on.)
8. If using electric spark ignition, charge the capacitor to the proper voltage. If using chemical ignitor, remove the shunt and connect the leads.

9. Push "start" button to begin test and data acquisition.
10. After test, collect gas sample of products if desired. (This may be difficult if the final chamber pressure is significantly below atmospheric due to the condensation of water vapor.)
11. Record the starting pressure, maximum explosion pressure, maximum rate of pressure rise, and maximum thermocouple temperature (if used) in the daily data notebook. The pressure data recorded by the PC can also be compared to those from the strip chart recorder.

An example of the computer output data for a test run is in appendix E. This is typical of the data that will be produced for each test run. In addition to the hard copies that we send you, we can also make the data available to you on floppy disks, along with a computer program to display the data. The data for each run will also be recorded in a daily notebook.

CALIBRATION OF EQUIPMENT AND QUALITY ASSURANCE

The primary check of the calibration of the entire test system will be repeat tests of standard mixtures of gases (e.g., 10% methane in air or 20% hydrogen in air). These calibration tests will be run at least once a week during the testing. These tests will assure that there are no changes in the entire system, including test chamber, gas measurement and mixing procedures, pressure transducers, and PC data acquisition and analysis system. The data compared for these calibration tests will include maximum pressure and maximum rate of pressure rise.

One strain gauge pressure transducer (0-20 psia) will be used to measure the mixing of the gases by partial pressures. Two strain gauge pressure

transducers (0-200 or 0-300 psia) will be used for all flammability tests. Each of these transducers has a calibration check built in by the manufacturer (appendix F). The transducers will be checked each day with their built-in calibration before the start of the gas tests. In addition, the Bureau has a dead weight tester (appendix G) as a primary pressure standard. This will be used to check the calibration of the two transducers once at the start and once at the end of the testing program. The calibration data will be recorded in the daily notebook.

The computer program will print out the data for each pressure transducer (appendix E). It will also compare the data from the two transducers and will display the average of the two on the summary data sheet if the data agree to within 5%. If the two transducers do not agree to within 5% for a run, they will both be checked with their built-in calibration shunt. If the calibration is incorrect, it will be corrected or the transducer will be replaced.

For at least some of the tests, a platinum-rhodium thermocouple will be installed in the chamber to measure the explosion temperature as a function of time. The temperature will be calculated from the measured voltage by an equation that matches the data in standard thermocouple reference tables, such as those in the Omega Engineering Temperature Measurement Handbook.

The gas samples will be analyzed by standard gas chromatography (GC). The GC will be calibrated daily with a Matheson primary standard gas (appendix H) or the equivalent. The GC will be used to analyze gas samples from the hydrogen, nitrous oxide, nitrogen, and air cylinders used to produce the gas mixtures for the tests. In addition, the GC will be used as necessary to measure gas samples from the test chambers before the runs to verify the

mixture concentrations. After the runs, gas samples analyzed by GC could determine the products of combustion.

Appendix A:

[illegible]

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PITTSBURGH RESEARCH CENTER

FIRES AND EXPLOSIONS

Michael J. Sapko - Research Supervisor

Beth L. Gilmore - Secretary
Belle L. Liebert - Staff Assistant
John C. Edwards - Research Physicist
Aldo Furno - Physical Scientist (Retired)
Linda L. Chasko - Clerk Typist
Tracy L. Gates - Clerk Typist

FIRE HAZARDS - Group Supervisor

LAZZARA, Charles P. - Supervisory Research Chemist

BASIC COMBUSTION - Group Supervisor
HERTZBERG, Martin - Supervisory Research Chemist

Conti, Ronald S. - Electronics Engineer
Leong, John C. - Electronics Technician
Miron, Yael - Chemical Engineer
Mura, Kenneth E. - Physical Science Technician
Perzak, Frank J. - Research Chemist
Ryan, Mark W. - Fire Prevention Engineer
Smith, Alex C. - Research Chemist

Cashdollar, Kenneth L. - Research Physicist
Green, Gregory M. - Physical Science Technician
~~Radvansky, George J.~~ - ~~Physical Science~~ Technician
Thomas, Richard A. - Engineering Technician
Zlochower, Isaac A. - Research Chemist

FULL-SCALE MINE RESEARCH - Group Supervisor

Bazala, Eugene M. - Physical Science Technician
Cortese, Robert A. - Electronics Engineer
Greninger, Nevin B. - Chemical Engineer
Jackson, Kenneth W. - Electronics Technician
Lipscomb, Randy - Physical Science Technician
Ward, Jack A. - Electronics Technician
Weiss, Eric S. - Mining Engineer

FIRE PROPAGATION & DETECTION - Group Supervisor
LITTON, Charles D. - Supervisory Physical Scientist

Cohen, Anna F. - Research Physicist
Corry, John - Physical Science Technician
DeRosa, Maria I. - Industrial Hygienist
Egan, Margaret R. - Research Chemist
Franks, Robert A. - Electronics Engineer
Friel, Gene F. - Chemical Engineer
Hwang, Charles C. - Mechanical Engineer (FM)
Morrow, Gerald S. - Electronics Technician
Opferman, John J. - Electronics Technician

IMPLEMENTATION OF COAL DUST/ROCK DUST REGULATIONS - Group Supervisor
~~COURTNEY, Welby G.~~ - ~~Supervisory Research Chemist~~

~~Cheng, Lung~~ - ~~Mechanical Engineer~~
Nagy, Frank - Physical Science Technician
Pro, Richard W. - Physical Science Technician

JUNE 1990

Bureau of Mines subcontractors:

SSI:

Gas analyses by gas chromatography

Machining

Keystone Computer Resources:

Computer programming

Appendix B: Key Personnel

MICHAEL J. SAPKO

Education:

M.S., 1976, Chemical Engineering, University of Pittsburgh, Pittsburgh, PA

B.S., 1972, Chemical Engineering, University of Pittsburgh, Pittsburgh, PA

Experience:

January 1990 - present

Research Supervisor, Fires and Explosions Group, Pittsburgh Research Center, U.S. Bureau of Mines.

April 1983 - January 1990

Supervisory Chemical Engineer, Fires and Explosions Group, Pittsburgh Research Center, U.S. Bureau of Mines.

April 1972 - April 1983

Chemical Engineer, Fires and Explosions Group, Pittsburgh Research Center, U.S. Bureau of Mines.

Throughout his career with the Bureau of Mines, he has conducted and supervised research relating to coal mine fire and explosion safety. His principal research areas have included the fundamental aspects of ignition processes, flame propagation, and flame detection and the mechanisms of solid, liquid, and gas combustion reactions.

Author or coauthor of more than 50 publications and numerous presentations.

National and international consultant on fires and explosions.

Has served on committees that were responsible for establishing standards relevant to coal mine health and safety and on committees that investigated various industrial explosion problems.

Holds several patents in the area of mine fire and explosion extinguishment.

Memberships:

The Combustion Institute

Society for Mining, Metallurgy, and Exploration

EuropEx: European Information Center for Explosion Protection

MARTIN HERTZBERG

Education:

Ph.D., Chemistry, 1959, Stanford University, Stanford, CA.

Certificate in Meteorology, 1954, U.S. Naval Postgraduate School,
Monterey, CA.

B.A., cum laude, 1949, New York University, University Heights, NY.

Experience:

1970 - Present

Supervisory Research Chemist, Fires and Explosions Group, Pittsburgh
Research Center, U.S. Bureau of Mines.

Group Supervisor for the program on Explosion Hazard Testing and
Evaluation of Mineral and Industrial Dusts and Gases and for a
complementary fundamental research program on Thermochemical Pyrolysis
Mechanisms and Microscopic Structure Studies. Research results are used
in analytical evaluations of explosion hazards in mining and other
industries. The laboratory scale program also provides guidance for the
cost effective use of the Bureau's full scale Mine Test Facilities.

Internationally recognized expert on combustion and fire explosion
research, publishing papers in the 15th, 16th, 18th, 19th, 20th, 21st,
22nd, and 23rd Symposia (International) on Combustion.

Co-editor of *Industrial Dust Explosions*, STP 958, ASTM, 1987.

Several patents on ionization smoke detection and optical detection.

Expert consultant to EPRI, DOE, and NRC on hydrogen combustion safety issues in nuclear reactors; and to EPRI and MSHA on safety in coal-firing systems in power and cement plants.

1964 - 1970

Principal Research Scientist, Atlantic Research Corporation, Alexandria, VA, where research was performed on solid propellant combustion kinetics, mass spectra of exothermic compounds, radiometry of infrared flares, chemiluminescence, ignition, flammability, and high power lasers.

Memberships:

The Combustion Institute
American Chemical Society

Honors:

Foreign Visiting Scholar, National Center for Scientific Research, Orleans, France, Summer 1988.

Phi Lambda Upsilon (Chemistry Honorary), 1957.

Honors Cooperative Student, Stanford-Lockheed, 1956-1959.

Phi Beta Kappa, 1949.

KENNETH L. CASHDOLLAR

Education:

M.S., Astronomy, 1973, The University of Wisconsin, Madison, WI.

B.S., Physics, magna cum laude, 1969, Dickinson College, Carlisle, PA.

Experience:

1973 - present

Research Physicist, Fires and Explosions Group, Pittsburgh Research Center, U.S. Bureau of Mines. Principal areas of research include both laboratory and large-scale explosion hazard testing and the development of instrumentation for explosibility testing.

Project Leader for the program on Hazard Testing and Evaluation of Mineral Dusts and Gases.

Author or coauthor of over 50 papers on dust and gas explosions and on instrumentation for explosibility testing.

Chairman of the Symposium on Industrial Dust Explosions, sponsored by ASTM, Bureau of Mines, and NFPA, Pittsburgh, PA, June 10-13, 1986.

Co-Editor of *Industrial Dust Explosions*, (proceedings volume from the Symposium on Industrial Dust Explosions), STP 958, ASTM, 1987.

Designed 20-L explosibility test chamber and personal computer based, high-speed data acquisition system.

Patent for a Multichannel Infrared Pyrometer.

Memberships:

The Combustion Institute

American Physical Society

Optical Society of America

SPIE - The International Society for Optical Engineering

Vice-Chairman of ASTM Committee E27 on the Hazard Potential of

Chemicals, Vice-Chairman of subcommittee E27.04 on Flammability,

Chairman of subcommittee E27.05 on Explosibility and Ignitability

of Dusts

EuropEx: European Information Center for Explosion Protection

Honors:

Special Honors in Physics, Dickinson College, 1969.

Sigma Pi Sigma (Physics Honorary), 1969.

Phi Beta Kappa, 1969.

Listed in American Men and Women of Science, Who's Who in Optical Science and Engineering, and Who's Who in Frontier Science and Technology.

ISAAC A. ZLOCHOWER

Education:

Ph.D., Chemical Physics, Jan. 1966, Columbia University, New York, N.Y.

B. S., Chemistry, magna cum laude, June 1959, Brooklyn College, New York

Experience:

1982 - present

Research Chemist, Fires and Explosions Group, Pittsburgh Research Center, U.S. Bureau of Mines. Project Leader for the basic research program on thermochemical pyrolysis mechanisms of explosible dusts and extinguishants.

1981 - 1982

Physical Scientist, Environmental Control Group, Pittsburgh Research Center. Project Scientist on the Mine Fire Control program.

1970 - 1981

Research Associate, Fiber Glass Division, PPG, Ind., Pittsburgh, PA. Project Leader for fiber glass research in plastics, cement, and elastomer reinforcement. 2 patents on acid resistant glass fibers.

1967 -1970

Research Chemist, Enjay Additives Div., Exxon Research & Dev. Corp.,
Linden, N.J., Project Chemist on cold-flow additives for diesel fuels.

1965 - 1967

Research Associate, School of Mines, Columbia University, New York, N.Y.
Postdoctoral Research on Microemulsions.

Honors:

New York State Regents Fellow, undergraduate and graduate.

Honors in chemistry - Brooklyn College

Best In-house publication award, Pittsburgh Research Center, 1988.

Qualifications:

Well rounded education and research experience in chemistry. Expertise in
combustion and explosion phenomena, and in performing thermodynamic
calculations on explosible and inerted mixtures.

GREGORY M. GREEN

Education:

A.A., Mining Technology, 1983, West Virginia Northern Community College,
Wheeling, WV

Experience:

1986 - present

Physical Science Technician, Fires and Explosions Group, Pittsburgh
Research Center.

Four years of experience in dust and gas explosion testing.

Experienced in the use of the PC based high-speed data acquisition
system for the 20-L test chamber.

Operator of the Bureau's scanning electron microscope.

Appendix C:

Printed Name

Appendix D:

Point number

Appendix E:

90/11/07 14:46:48

20-L CHAMBER, PITTSBURGH RESEARCH CENTER, BUREAU OF MINES
Summary Report - Test Number 900505

Fuel: HYDROGEN H2

2nd Gas : NITROUS OXIDE N2O

Concentration: 12.1 %

Concentration: 12.1 %

Ignitor : 138 J,

Remainder Gas: air

P1 Smoothing 3, 11

Dispersion Time: 0.000 c

Pressure at Ignition: 14.7 psia

Total Delay Time: 0.122 sec

P max: 76.1 psia at 0.10 s

Ignition time: 0.540 s

Pressure Ratio: 5.15

Max dP/dt: 1273.9 psi/s at 0.08 s

Kg : 23.95 bar m/s

Mixing: fan mixing

Sample Rate: 2000 Hz

<CR> - continue

F3 - print screen

Pressure Transducer 1

900505

Max pressure 76 at 0.64 sec

Press. at ignition 14.7

Max dP/dt 1274 at 0.62 sec

ign = 0.540 s

dly = 0.122 s

Appendix F:

Viatran

PRODUCT BULLETIN NO. 53

Model 218
Pressure Transducer

Output : 0-5V DC
Pressure Ranges : 0-5 thru 0-15,000 PSI
Supply Input Voltages: 12V, 24V, 28V, or ± 15 V DC
Type : 4-wire

The Model 218 utilizes field-proven single element strain gage technology coupled with DC signal conditioning to provide 0-5V DC signal in ranges of 0-5 thru 0-15,000 PSI G, A, V, or D. With standard compensated temperature limits of -30°F to $+180^{\circ}\text{F}$, the Model 218 will suit the majority of applications without special installation procedures.

All stainless steel construction of both pressure cavity and housing assures the maximum protection

against corrosion and environmental contamination during normal operation. Electrical connection is made through a standard six pin screw-type connector. Viatran's unique calibration circuit facilitates field calibration without a pressure source.

The Model 218, through many years of varied application and dependable service, has proven itself in severe industrial environments.

Dimensions

Specifications

Pressure Ranges	0-5, 10, 15, 20, 25, 30, 50, 75, 100, 200, 350, 400, 500, 750, 1000, 1500, 2000, 3000, 4000, 5000, 7500, 10,000, and 15,000 PSI gage, absolute, vacuum, differential.	Ripple	Not Applicable
Differential Base Pressure	2000 PSI Maximum	Circuit Protection	Not Applicable
Measure and Fluids	Any fluid compatible with 17-7 PH, 17-4 PH, 303 SS and Buna N O-rings standard. Alternate materials available optionally. Differential units require a clean, dry gas as a reference medium.	Insulation Resistance	Better than 1000 megohms at 50V DC
Supply Voltage	Model 218-12 12V DC = 2V DC Model 218-24 24V DC = 4V DC Model 218-28 28V DC = 4V DC Model 218-15 = 12V DC to = 18V DC	Proof Pressure	1 1/2 times rated range (15,000 PSI maximum). M5 provides increased overpressure capability.
Regulation	Less than $\pm 0.1\%$ FSO over supply voltage range.	Burst Pressure	5 times rated range (20,000 PSI maximum)
Output Signal	0-5V DC. M18 provides 0-10V DC	Long-Term Stability	Better than $\pm 0.25\%$ FSO over 6 months.
Load Impedance	500 ohms nominal	Resolution	Infinite
Static Error Band	Better than $\pm 0.4\%$ of calibrated span, including errors due to linearity, hysteresis and repeatability. M19 provides improved accuracy.	Position Sensitivity	Mounts in any position with no effect on zero.
Combined Zero & Span Temperature Effects on Accuracy	Less than 2% FSO per 100°F. M11 provides improved temperature performance.	Response Time	Less than 1 millisecond to reach 90% of full scale.
Operating Temperature Limits	-50°F to $+200^\circ\text{F}$	Frequency Response	2 KHz for 0-5 PSI range extending up to 40 KHz for 0-15,000 PSI range
Range Adjustment	$\pm 10\%$ FSO	Shock & Vibration	Less than 0.25" WC per G in plane normal to diaphragm. Negligible error in remaining two planes.
Range Calibration Signal	100% FSO calibration circuit operated by shorting pins 5 (E) and 6 (F)	Pressure Capsule Material	303 SS, 17-4, 17-7 SS and Buna N O-rings. Includes materials wetted by process fluids. Alternate materials available optionally.
Range Calibration Signal Accuracy	Better than $\pm 1.0\%$ FSO. Exact pressure-to-output correlation data provided on calibration data card shipped with unit.	Process Pressure Port (HI)	1/4" NPT female. M2 provides alternate pressure port.
Zero Adjustment	$\pm 10\%$ FSO screwdriver adjustable	Reference Pressure Port (LO)	1/4" NPT female, differential pressure units only.
Interaction Between Zero & Span	Less than $\pm 1.0\%$ FSO over full adjustment range.	Electrical Connection	WK6-32S. M1 provides alternate connectors.
		Mounting	May be supported by process piping or supplied with optional mounting bracket A1
		Enclosure	High quality stainless steel. All electrical components protected against adverse environmental conditions.
		Nameplate	Stainless steel, welded to transducer body.
		Weight	22 ounces nominal (623.7 grams)

Ordering: Specify model, input voltage, and pressure range and indicate modifications or accessories required. Refer to Catalog No. 88 for details.

High Output Pressure Transducer Model P21 E Type

three terminal operation from dual power supplies

Features:

- ranges 0-15 psi through 0-15,000 psi absolute, gage and vacuum
- compatible with most liquids and gases
- output signal 0-5 VDC standard
- excitation ± 12 to ± 15
- three accuracy classes — 0.15 - 0.5 - 1.0
- static and dynamic measurements
- field adjustable zero and span
- temperature compensated

DESCRIPTION:

The P21E type was specifically designed to operate with excitation being supplied by dual power supplies (± 12 to ± 15) with the output signal referenced to ground or power supply common; however, this unit will also operate with a single power supply and will produce a phantom ground. When operating from a single supply either the power supply low or signal low may be grounded, but not both.

The P21E type includes all the necessary electronics including an instrument amplifier to provide a high level output signal (0 to 5 VDC is standard). These units have internal potentiometers to adjust the zero and span settings (these potentiometers are behind plugs).

P21E types are available in three accuracy classes and prices to match various requirements. All are carefully tested, compensated and calibrated with NBS traceable standards to assure compliance with specifications. A certificate of calibration is supplied with each unit giving the exact sensitivity of that unit.

The P21E type pressure

transducers employ a four-arm strain gage bridge bonded to the reference or non-wetted side of a stainless steel diaphragm. This diaphragm type pressure sensor is machined from 17-4 PH stainless steel bar so that there are no joints or pockets in the stressed areas near the diaphragm. This construction yields a highly reliable transducer with long life and with low errors due to hysteresis and non-repeatability. The stainless steel pressure cavity of the P21 transducers has a low volume that is highly corrosion resistant to most liquids and gases. There are no adhesives, plastics or O-rings used in the P21's pressure cavity.

The P21E type can be provided in virtually any pressure range between one atmosphere and 15,000 PSI in any desired units. All P21's may have a vacuum applied to their pressure port and will indicate this with a negative output signal. In addition to the usual true gage (relative) reference types, the P21 is available for sealed gage, absolute, compound, vacuum and wet-dry measurements. Consult factory application engineers for help with your requirements.

Circuit Diagram

3-wire circuit

Dimensions

7/16 20 UNF straight thread for O-ring seal with 1/4 in. O.D. tube fittings.

Specifications — Model P21 E Type

PRESSURE RANGES 0-15, 25, 50, 100, 150, 200, 300, 500, 750, 1000, 1500, 2000. Other ranges and units may be 2500, 3000, 5000, 10000, 15000 PSIG, PSIA, PSIV or PSIS available

INDIVIDUAL CHARACTERISTICS

		P21EA	P21EB	P21EC
FULL SCALE OUTPUT	VDC (field adjustable)	0 to 5.0 $\pm$ 0.025	0 to 5.0 $\pm$ 0.05	0 to 5.0 $\pm$ 0.1
ZERO BALANCE	% FSO Maximum (field adjustable to zero)	$\pm$ 1.0	$\pm$ 2.0	$\pm$ 2.0
STATIC ERROR BAND	% FSO (nonlinearity, hysteresis, and nonrepeatability)	$\pm$ 0.15	$\pm$ 0.50	$\pm$ 1.0
NONREPEATABILITY	%FSO	0.1	0.1	0.2
THERMAL EFFECTS	%FSO/100°F % FSO/50°C	$\pm$ 1.0	$\pm$ 2.1	$\pm$ 5.0 typical
OPERATING TEMPERATURE RANGE		- 65 to + 250 °F - 54 to + 125 °C	- 30 to 180 °F - 35 to + 80 °C	0 to 160 °F - 20 to + 70 °C

COMMON CHARACTERISTICS

COMPENSATED TEMPERATURE RANGE 0 to + 160°F
- 20 to + 70 °C
EXCITATION $\pm$ 12 to $\pm$ 15 VDC
EXCITATION REGULATION 1% FSO
RESOLUTION Infinitesimal
PROOF PRESSURE 2x rated pressure or 20,000 PSI,
whichever is less
BURST PRESSURE 4x rated pressure or 25,000 PSI,
whichever is less
LIFE Over 10 million cycles between zero and
rated pressure
FREQUENCY RESPONSE Flat to 2500 Hz

MATERIAL Sensing cavity 17-4 PH stainless steel
Housing 304 stainless steel
PRESSURE FITTING 7/16-20 UNF-2B straight thread
for o-ring seal with 1/4 in. tube fittings (SAE type)*
ELECTRICAL CONNECTOR Bendix PTIH-10-6P or
equivalent
NOISE 10 millivolts p-p
OUTPUT CURRENT 5 milliampere maximum
CURRENT CONSUMPTION 35 milliampere typical
ACCELERATION EFFECT, STATIC 1 mv/g
WEIGHT 6 oz.
SOURCE INDEPENDANCE less than 50 ohms
CAVITY VOLUME, less thread 0.02 cu. in.

HOW TO ORDER:

Specify the model, pressure range, units and type (gage, absolute, sealed gage, differential, or vacuum)

List any options or modifications.

Include any accessories as a separate item. Note that mating electrical connectors are not included with transducers and should be ordered as a separate item if required.

For special application, please consult the factory.

*The standard pressure fitting on the P21 is the SAE straight thread O-ring type with 7/16-20 thread. This fitting can be interfaced with many Parker and Swagelok fittings as well as those of many other companies so that connections may be made in almost any situation. Trans Metrics stocks many of these fittings for your convenience. The P21 can also be provided with a 1/4-18 NPT internal pipe thread, MS 33649 internal straight thread fluid connection, or the MS 33656 external 37° flare tube fitting for 1/4 o.d. tubing.

5325 Naiman Parkway, Solon, Ohio 44139

Phone 216/248-2229

Telex/TWX 810-427-2059, Cable: Transmtrx Soln

P21E Printed in U.S.A. 9/85

Appendix G:

Consolidated Electrodynamics Corporation CEC

Primary Pressure Standard #6-201

GENERAL DESCRIPTION

A. INTRODUCTION

The Primary Pressure Standard (Fig. 1A) is a high-accuracy pneumatic dead-weight tester used for measuring gas pressure. It is a true primary instrument in that it uses as its references the fundamental quantities of mass, length, and time. The 6-201-0001 is ideally suited for accurately calibrating other pressure-measuring instruments. Both gage and absolute pressure measurements may be made.

B. PRINCIPLE OF OPERATION

The simplicity of the principle of operation of the 6-201-0001 is apparent in the schematic diagram shown in Fig. 1B. The gas whose pressure is to be determined is admitted through Port A. When this pressure causes the piston (P) with its weights (W) to rise to a point of equilibrium, balance is achieved. Since the effective diameter (d) of the piston-cylinder combination and the weight of the piston, plus the added weights, are accurately determined, the total weight (lbs) divided by the effective area (sq in π) provides the actual pressure in pounds per square inch. Friction between the piston and cylinder is negligible in the 6-201-0001, as their surfaces are polished to a microfinish and the piston is rotated on an air film during operation, thereby reducing static friction to a minimum.

C. APPLICATIONS

The 6-201-0001 Primary Pressure Standard represents the latest development in pressure-measuring devices. Some of the several possible applications are listed below. The user will undoubtedly discover additional applications not given here.

1. Calibration of absolute and gage-type pressure-measuring instruments.
2. Checking mercury manometers.
3. Calibration of CEC Electromanometer Secondary Pressure Standards.

A unique feature of the 6-201-0001 is its capacity for direct calibration of absolute type transducers. The chamber within the cover glass (see Fig. 1A) can be easily evacuated for this purpose. The pressure drop across the piston-cylinder area is thus referenced essentially to zero absolute pressure rather than ambient pressure. It is for this reason, principally, that the motor drive (Item 2, Fig. 3) is provided; as rotation of the piston could not be

TYPE 6-201-0001 PRIMARY PRESSURE STANDARD

FIG. 1A

SCHEMATIC - TYPE 6-201-0001 PRIMARY PRESSURE STANDARD

FIG. 1B

TYPE 6-201-0001 SET-UP FOR CALIBRATION WITH
TYPE 6-003-0001 CALIBRATION PRESSURE CONTROLLER

FIG. 2A

TYPE 6-201-0001 SET-UP FOR GAGE CALIBRATION

FIG. 2 B

TYPE 6-201-0001 SET-UP FOR ABSOLUTE CALIBRATION

FIG. 2 C

accomplished by hand. A typical system for absolute calibrations is shown in Fig. 2B. In Fig. 2A is shown a typical system for calibrating gage-type transducers.

D. SPECIFICATIONS

1. Operational Characteristics

- a. Accuracy: 0.015%* of reading
- b. Pressure ranges: 0.3-1.5, 0.3-5, 1.5-15, 1.5-50, 15-150, 15-500
- c. Resolution: Better than 0.002% of reading
- d. Temperature range: 60°F to 100°F
- e. Standard ambient temperature: 75°F
- f. Humidity: 0 to 80% of relative humidity
- g. Thermal coefficient of sensitivity: -0.0012% of reading/°F
- h. Power requirement: 105-125 volts, 60 cps, 10 watts to the motor through a momentary contact manual switch

2. Mechanical Characteristics

- a. Size: 10 1/2" long, 8 1/2" wide, and 7 1/2" high nominal
- b. Weight: Approximately 22 pounds complete
- c. Mounting: Three leveling screws in tapped holes in base may be used as intended or replaced for more permanent installation.
- d. Finish: Dark blue painted base, medium blue painted case, glass cover
- e. Electrical connection: A detachable 3-prong cord set is supplied to match a standard Cannon connector in the instrument base.
- f. Pressure connection: Under side of piston pressurized from standard 1/4" Swagelok fitting in the base. Case vented to atmosphere (gage pressure) or evacuated (absolute pressure) through a fitting capable of receiving a standard 1/2" I. D. vacuum pump hose.
- g. Fluids applicable to parts: Clean, dry, noncorrosive gases only.

*For ranges of 15-150 and 15-500 psi the accuracy is 0.025% of reading.

PART II

OPERATING INSTRUCTIONS

A. INITIAL SET-UP

NOTE: The Type 6-003-0001 Pressure Calibration System provides a convenient factory available set-up for use with the Type 6-201-0001 Pressure Standard. Refer to the Operation and Maintenance Manual of the Type 6-003-0001 Pressure Calibration System for proper instructions in its use with the Type 6-201-0001 Primary Pressure Standard.

1. Remove the Primary Pressure Standard from its container and place it on a flat, firm surface at the operating site. Using the knurled leveling screws, level the instrument so that the bubble in the spirit level is in the center of its circle.
2. Select the appropriate piston-cylinder combination for the desired pressure range. (See Part III, Pressure Table.) Using the spanner wrench provided, tighten the piston or cylinder down until an air-tight seal is made with the "O" ring in the adapter. See "Precautions", Section C.
3. Attach the power cable to the receptacle at the base of the instrument and to a 105-125 volt, 60-cycle power source.
4. Connect the pressure line (DO NOT apply pressure at this time) to the instrument lower male fitting labeled (+).

If absolute pressure measurements are to be made, connect the vacuum line to the upper male fitting labeled (-).

Leak-free connections are essential if accuracy is to be maintained. When making connections to the pressure and reference ports of the Primary Pressure Standard, care should be taken to avoid twisting the fittings and thus causing a loss of seal.

5. Before making absolute measurements, during which the chamber within the cover glass is evacuated, apply a thin coat of vacuum grease to the ring gasket on which the cover glass rests.
6. Select the appropriate weight set for the pressure range desired and place the required weights on the piston cylinder as shown in Fig. 4. Also see Section B, 4 of Part II.

Note that the pressure stop swings to one side to allow placing of the weights. Be certain that the pressure stop is returned to its position above the weights before applying pressure to the instrument.

ITEM NOMENCLATURE
(SEE PART LIST FOR P/N)

- 1 POWER CABLE
- 2 MOTOR & CLUTCH ASS'Y
- 3 BASE
- 4 GASKET "O" RING
- 5 ADAPTER
- 6 GASKET "O" RING
- 7 GASKET
- 8 CASE
- 9-10 PISTON & CYLINDER
- 11 WEIGHTS
- 12 GASKET
- 13 COVER-GLASS

TYPE 6-201-0001 PRIMARY PRESSURE STANDARD, EXPLODED VIEW

FIG. 3

7. Place the cover glass in position as shown in Fig. 1A. The cover glass should always be in the position shown even when making gage measurements, as it shields the weights against air currents which may affect instrument accuracy.

B. OPERATION

NOTE: It is mandatory that the pistons, cylinders, and weights be thoroughly cleaned before operation of the unit (see Part II, C PRECAUTIONS, 4).

1. Feed air pressure into the instrument until piston and weights rise to approximately 1/8 inch from the pressure stop. Maintain the pressure at this level.

2. Depress motor starter button to rotate piston and weights. When the piston has reached proper speed, the motor will automatically disengage and the piston (or cylinder) will spin freely. The time required to reach proper speed before disengaging will vary with the number of weights being used.

3. Weights may be added or removed to obtain range of pressures for the measurements desired (see Part III, Pressure Table).

4. Six pressure ranges are currently available. These are shown below with the appropriate piston-cylinder combinations and weight sets required. The values of the weight sets are such that equal increments of 1% full-scale can be measured starting with the lowest pressure point indicated in the table below.

<u>PRESSURE RANGE</u>	<u>INCREMENTS</u>	<u>PISTON-CYL NO.</u>	<u>USE &</u>	<u>WEIGHT SET NO.</u>
0.3 - 1.5 psi	0.015 psi	6-001-0001		6-002-0001
→ 0.3 - 5 psi	0.05 psi	6-001-0001		6-002-0002
1.5 - 15 psi	0.15 psi	6-001-0002		6-002-0001
→ 1.5 - 50 psi	0.50 psi	6-001-0002		6-002-0002
15 - 150 psi	1.50 psi	6-001-0003		6-002-0001
→ 15 - 500 psi	5.00 psi	6-001-0003		6-002-0002

The lower limit of each range is determined by the weight of the piston or cylinder, whichever is the item lifted by the incoming air pressure. In the two lowest ranges, where the largest diameter piston-cylinder is utilized, the cylinder is the suspended, revolving member. This is piston-cylinder combination No. 6-001-0001. The weight of this cylinder is 6.00 ounces which provides a minimum pressure measurement of 0.3 psi.

LEVELING THE 6-201-0001 PRIMARY PRESSURE STANDARD

FIG. 4

In the four highest ranges, the piston is the suspended, revolving member. This is piston-cylinder combination No. 6-001-0003, and the weight of the piston is 3.00 ounces, providing a minimum pressure measurement of 15 psi.

Using the weight sets provided, the pressure may be varied in 1% increments over the range.

Piston-cylinder combinations have the following dimensions:

PISTON-CYLINDER NO.	NOMINAL DIAMETER	AREA
6-001-0001	1.26 in.	1.25 sq in. $\pm 0.01\%$
6-001-0002	0.400 in.	0.125 sq in. $\pm 0.01\%$
6-001-0003	0.126 in.	0.0125 sq in. $\pm 0.02\%$

Weight sets are supplied in the following combinations:

WEIGHT SET NO.	WEIGHT VALUE & NUMBER OF WEIGHTS
6-002-0001	(9) 0.3 oz $\pm 0.005\%$
	(9) 3.0 oz $\pm 0.005\%$
	(9) 1.0 oz $\pm 0.005\%$
6-002-0002	(1) 4.0 oz $\pm 0.005\%$
	(1) 7.0 oz $\pm 0.005\%$
	(9) 10 oz $\pm 0.005\%$

The 4- and 7-ounce weights in Weight Set No. 6-002-0002 provide a means for easily making pressure measurements not possible with the 1- and 10-ounce weights (see Part III, Pressure Table).

5. The primary pressure standard has been calibrated in CEC's laboratory at an ambient temperature of approximately 75°F. The value marked on each weight and piston-cylinder combination is based on standard gravity at 45° latitude (980.665 Cm/sec^2 or $32.174 \text{ ft/sec/sec}$ at SEA LEVEL).

At the user's location, temperature, altitude, and latitude may, of course, differ. Therefore, certain correction factors must be applied to obtain maximum accuracy. The nomograph included in this manual (Fig. 5) can be used to obtain the correction factor for these three variables. Instructions for use of the nomograph are found on the figure.

Upon obtaining the proper correction factor, the following formula should be applied:

$$P_1 = P_0 (1 + \text{Correction Factor})$$

Where

P_1 = Actual Pressure

P_0 = Indicated Pressure (according to weights and piston area)

The nomograph of Fig. 5 is based upon the thermal coefficient of sensitivity given in the specifications and in the following formula for gravity computation:

$$*g = 32.174 - 0.085 (\cos 2 \phi) - 0.000094 (h)$$

Where

g = ft/sec/sec

ϕ - latitude in degrees

h = altitude in feet

C. PRECAUTIONS

Because of the high accuracy of the 6-201 Primary Pressure Standard, mechanical tolerances are exceedingly small. All components, therefore, must be kept scrupulously clean at all times. If the following rules are diligently observed whenever handling the instrument or its components no difficulties will be experienced:

1. Keep weights clean and in their storage cases when not in use, and exercise caution in handling so that they are not dropped or scratched.
2. Install and handle pistons and cylinders with utmost care. Surfaces should be maintained free of scratches and dents. Working surfaces are microhoned and clearances measured in microinches. DO NOT touch these surfaces with dirty fabrics or corrosive materials. Perspiration from the hands may etch the polished surfaces.
3. If piston or cylinder do not rotate freely, or if a metallic rubbing sound is heard when they are rotating, stop operation of the instrument immediately. This is an indication of unclean piston or cylinder surfaces.
4. To clean piston and cylinder, wipe carefully with an optical quality cleansing tissue, such as "Kimwipes", which has been wet with a non-filming solvent** (acetone or methyl ethyl ketone are ideal). Repeat

* Ref.: National Bureau of Standards Nomograph #8, Section 11.

** These materials give off toxic vapors. Handle accordingly.

CHART I GRAVITY CORRECTION (C₁)

FIG.5

CHART II TEMPERATURE AND AIR BUOYANCY CORRECTION (C₂)

$$\text{ACTUAL PRESSURE} = \text{INDICATED PRESSURE} (1 + C_1 + C_2)$$

FIG. 5A

several times to insure cleanliness. This cleaning process should be done before each operation of the unit to assure the freedom of the surfaces from dirt, grease, or lint.

5. Be certain that the pressure stop is in the position shown in Fig. 1A before applying pressure to the instrument.

6. When making measurements, either gage or absolute, make certain that the piston or cylinder is freely floating between the pressure stop and the lower travel limit.

7. Replace the cover glass as shown in Fig. 1A when making measurements. Failure to do so may introduce errors because of air currents flowing about the weights.

8. Normal maintenance of the 6-201-0001 consists principally of maintaining its components in a condition of cleanliness at all times. To replace damaged components, consult the parts list in this manual and contact your nearest CEC office.

9. Errors in pressure measurement with this instrument can be introduced if the piston or cylinder becomes magnetized. They have been demagnetized before shipment and should normally remain so. If the parts are exposed to a magnetic field, however, they may be partially remagnetized. Therefore, as precautionary maintenance, it is recommended that pistons and cylinders be occasionally demagnetized.

D. SPECIAL INSTRUCTIONS FOR 6-001-0003

Because of the extremely small mechanical tolerances of the 6-001-0003 Piston-Cylinder Combination, special care must be taken in handling this component. A very thin film of special oil must be applied to the mating surfaces before the piston is allowed to rotate in the cylinder.

The following procedure is recommended for cleaning and lubricating the 6-001-0003 Piston-Cylinder Combination:

1. Materials Needed

- a. Methyl-Ethyl-Ketone (MEK) to be used as a cleaning agent. The final cleaning should always be done with fresh uncontaminated MEK.
- b. Lint-free, optical quality, cleaning tissue.
- c. Special lubricating oil (CEC A84309-3) supplied with instrument.
- d. Nylon short-stem brush.

e. Reagent quality-pure ethyl alcohol to be used for final rinsing.

2. To Clean and Lubricate Piston

a. Wet a clean, dry, cleansing tissue with MEK and carefully wipe the piston clean.

b. Repeat again, using fresh, uncontaminated MEK.

c. Repeat 2, a, using reagent quality-pure ethyl alcohol.

d. Apply several drops of the special oil to a clean, dry tissue, and apply a uniform film of oil to the surface of the piston.

e. Wipe the surface of the piston with a clean, dry tissue. Repeat twice, wiping as dry as possible.

3. To Clean Cylinder

a. Dip brush in MEK and scrub the cylinder several times.

b. Flush the cylinder with fresh, uncontaminated MEK. Repeat, using fresh, uncontaminated MEK.

c. Repeat 3, b, using reagent quality-pure ethyl alcohol.

d. Blow dry air or nitrogen through the cylinder until the surface is dry.

e. Do not apply lubricating oil to the cylinder surface.

E. CALIBRATION

If calibration certification is required, or for periodic recalibration, the CEC factory should be consulted.

Appendix H:

Calibration Gas Mixtures

Calibration Gas Mixtures

Matheson pioneered in the preparation and analysis of gas mixtures and today is the recognized leader in the field. Virtually every significant advance in gas mixture technology was developed in Matheson's laboratories. This dominant position is based on creative competence, a dedication to excellence, a commitment to customer satisfaction, and on a broad experience — the most important single requirement for the development and processing of gas mixtures. Matheson experience — unequalled and unsurpassed — is your guarantee of the best in existing mixtures and in formulating new mixtures to precise customer-furnished requirements.

A continuing research program supports this experience and has provided valuable information on the techniques necessary to prepare accurate, stable and economical gas mixtures.

To achieve this we use both steel and aluminum cylinders combined with a variety of internal cylinder preparations. Rely on Matheson technology to pick the right combination. Tell us what you need; we'll do the rest.

It is important to note that the degree of difficulty in achieving mixture consistency increases with the number of components. There is also some inherent instability with certain components. Matheson's expertise is available to discuss your particular needs. Just ask!

To permit simple selection of the proper mixture for a specific application, Matheson mixtures are divided into the three categories described on this page.

Tighter Preparation Tolerances

Matheson is aware of certain special applications that do not require the extremely close tolerances of Primary Standards, but do require preparation tolerances exceeding those of Certified Standards. In the process control industry, for example, consistent minor component concentrations are at least as important as the accuracy of the certification. With these thoughts in mind Matheson has developed a *dynamic blending system* that delivers mixtures with tighter preparation tolerance than those listed for Certified Standards at economical prices.

Dynamic gas blending, a real time gas blending process, is a more complete gas mixing than other blending processes. This enables Matheson to produce identical gas mixtures in as many cylinders as necessary — gas mixtures in separate cylinders allows the user to connect a number of cylinders to a common manifold and/or using identical mixtures at separate locations. Think of the possibilities — assurances of consistency and elimination of re-analysis of each cylinder.

Primary Standards

Primary Standards should be used whenever you need the most accurate calibrations of an instrument, or in those applications where the knowledge of the gas concentration is critical.

Matheson Primary Standards are used wherever science requires the highest accuracy and reliability available in gas mixtures. These mixtures are precisely blended by weighting the gas components on a high load, high sensitivity analytical balance. All weights used on this balance are traceable to the National Bureau of Standards. The accuracy of weighing generally exceeds any analytical instrument accuracy. Routine quality control is used to insure the accuracy of the mixtures. Complete specifications are given on the following page.

Certified Standards

Certified Standards are the workhorses of science and industry. Applications include instrument calibration, biological, environmental and medical studies, and process simulation control and purification.

Certified Standards are calibration gas mixtures prepared by a variety of gravimetric, partial pressure and volumetric techniques. Component certification is provided through the use of NBS Standard Reference Materials, Matheson Primary Standards, certified weights, or wet chemical methods. Complete specifications are given on the following page.

Unanalyzed Mixtures

These mixtures are used in applications which do not require a mixture of accurately known composition. These mixtures are prepared by the same composition. These mixtures are prepared by the same gravimetric, partial pressure and volumetric techniques used to prepare the Certified Standards. They are not analyzed or adjusted, and the preparation tolerance cannot be guaranteed. Complete specifications are given on the following page.

Special Accuracy Mixtures

When a lack suitable standards exists or a standard proves impractical, Matheson will prepare a gas or liquid phase mixture gravimetrically on one of its many precision balances. These mixtures will not be given the Matheson Primary Standard label but they are expected to be of the highest accuracy possible.

Calibration Gas Mixtures

Calibration Gas Mixture Specifications*

Category	Range	Preparation Tolerance	Certification Accuracy
* Primary Standard	5% to 50% 500 ppm to < 5% 1 ppm to < 500 ppm	$\pm 1\%$ of Component $\pm 2\%$ of Component $\pm 5\%$ of Component	$\pm 0.02\%$ absolute or $\pm 1\%$ of the component whichever is smaller**
Certified	10% to 50% 50 ppm to < 10% 10% ppm to < 50 ppm < 5 ppm	$\pm 5\%$ of Component* $\pm 10\%$ of Component* $\pm 20\%$ of Component* 1 to < 5 ppm	$\pm 2\%$ of Component $\pm 2\%$ of Component $\pm 5\%$ of Component $\pm 5\%$ of Component

Unanalyzed Mixture

This group of mixtures is expected to have essentially the same preparation tolerance as the Certified Standard, but cannot be guaranteed as such because these mixtures are not checked by analysis.

*The values presented may vary for components that tend to be unstable or present other blending problems. Our technical personnel will be pleased to comment on your particular requirements. Certification accuracy for smaller size cylinders and/or multi-component mixtures may vary.

**Accuracies for Hydrogen and Helium components may vary from those stated due to their low molecular weight.

How to Order Calibration Gas Mixtures

Specifying gas mixtures need not be difficult, but providing us with all the pertinent information when placing your order is important. We suggest following the guide on this page if you have any questions about what information is necessary. Furnishing all the data completely will insure that the mixture is prepared according to specifications and that the order is handled expeditiously.

1. Type of Mixture, Primary Standard
Certified Standard
Unanalyzed Mixture

2. Number of Cylinders desired (see 4)
3. Cylinder size (see 4)

4. If you are not sure of the size or quantity of cylinders you need, specify the number of cubic feet, cubic meters, or other volume measurements you require and we will determine the number and size of cylinders for you.

5. Concentrations should be specified for each component in either percentages or ppm. Gases are usually prepared based on volume percent unless you specify otherwise. This chart provides a simple conversion from ppm to percent.

ppm = percent

1 = 0.0001

10 = 0.0010

100 = 0.0100

1000 = 0.1000

10000 = 1.0000

6. Preparation Tolerances—unless specified otherwise will be those designated by the 3 major categories in the table at the top of this page.

Primary Standard
Certified Standard
Unanalyzed Mixture

Often the tolerance is not important but an absolute maximum or minimum is required, particularly when the mixture is to be used as an upscale or zero reference. Knowing these requirements will help us satisfy your needs.

7. This is the place to let us know about any special requirements you have, i.e., specific impurity analysis, maximum impurity concentration, etc.

8. Specify each component by chemical name. Do not use chemical symbols, as this can lead to errors.

OR

SIMPLY CALL YOUR LOCAL MATHESON OFFICE, TELL US WHAT YOU NEED, WE'LL DO THE REST.

May 1, 1991

Burns & Roe Services
Cylinder Pad
Cochran Mill Road
Bruceton, Pennsylvania 15236

Reference P.O.#: 8273-070-REL-#99A

Gentlemen:

Below are the results of the analysis you requested, as reported by our laboratory. Results are in volume percent, unless otherwise indicated.

CYLINDER NUMBER: 390

<u>COMPONENT</u>	<u>REQUESTED</u>	<u>ACTUAL</u>
CARBON DIOXIDE, COLEMAN	12.00%	11.986%
CARBON MONOXIDE, MATHESON	1.00%	1.002%
HYDROGEN, MATHESON	5.00%	5.002%
METHANE, MATHESON	12.00%	12.025%
ETHANE, RESEARCH	1.00%	1.004%
NITROGEN, MATHESON	BALANCE	BALANCE

Sincerely yours,
MATHESON GAS PRODUCTS, INC

Wray LaFond
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WL/sad

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