PD-ABQ-489

WORLD ENVIRONMENT CENTER

UKRAINE

ENERGY CONSERVATION/WASTE MINIMIZATION DEMONSTRATION PROJECT

AT

NIZNEDNIPROVSKY PIPE MANUFACTURING PLANT

IN

DNIPROPETROVSK

Progress Report No. 1

USAID/WEC COOPERATIVE AGREEMENT NO. ANE-0004-A-00-0048-00

World Environment Center
419 Park Avenue South, Suite 1800
New York, NY 10016

MARCH 1998

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Project Description: Reduction of natural gas consumption

Project Type: Energy Conservation/Waste Minimization Project

Country: Ukraine

Industrial Sector: Steel

Dates: December 18-19, 1997

Funding Source: United States Agency for International Development

Participants: Niznedniprovsky Pipe Manufacturing Plant & World Environment Center

Project: Improvement in combustion efficiency of Reheat Furnace at Wheel Manufacturing Facility

Business Development:

B

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I. INTRODUCTION

In September 1995, an amendment was added to the United States Agency for International Development's (USAID's) and World Environment Center (WEC's) Cooperative Agreement No. ANE-0004-A-00-0048-00 to include Ukraine as one of the additional countries to receive WEC's technical assistance, training and information dissemination services related to urban and industrial pollution control.

WEC activities in Ukraine are implemented in two stages as follows:

Stage I – includes a number of **Energy Conservation/Waste Minimization Demonstration Projects** (EC/WMDP) implemented at various large industrial plants. The main goal of this stage is to *demonstrate* to these enterprises the beneficial aspects of a Waste Minimization/Energy Conservation Program. Through the *demonstration projects*, an effort is made to encourage enterprises to incorporate such programs into the permanent policy of plant management. The intent is, among other things, to demonstrate that pollution prevention and energy conservation programs are not just additional expenses, but help to achieve *good business* results. A number of demonstration projects were established at selected enterprises in the Donetsk, Dnipropetrovsk and Lviv regions. Some of them are already completed; others are underway.

Stage II – of WEC programs in Ukraine, called the **Impact Program** (IP), is presently being initiated. The intent of this stage is to *disseminate to a much wider audience* energy conservation and waste minimization concepts, which will ultimately lead to the introduction of an *Environmental Management System.*

Under Stage I, one of the plants selected is the Pipe Manufacturing Plant "Niznedniprovsky", in Dnipropetrovsk, which was visited by WEC's team from December 18-19, 1997 to identify facilities where the demonstration project would be performed. This report presents the results of the visit.

II. EXECUTIVE SUMMARY

A WEC team consisting of Dr. Raymond L. Feder, WEC staff consultant and Mr. Joel Hoffner, consultant-specialist, visited the Nizhnedniprovsky Pipe Manufacturing Plant in Dnipropetrovsk, Ukraine in December 1997 to select an Energy Conservation/Waste Minimization Demonstration Project that has the potential to achieve significant reductions in energy consumption and in associated air emissions from the plant processes.

The Nizhnedniprovsky Pipe Manufacturing Plant consists of an Open Hearth Steelmaking Shop, five Pipe Mills, one Wheel Mill and one Ring & Tire Facility. The Plant occupies approximately 240 hectares of land. Steelmaking capacity is approximately 4,000,000 metric tons per year, but is currently operating at 30% of the capacity. The plant produces seamless and welded pipe, forged wheels, rings and tires.

A previous visit by a WEC team in November 1997 identified four potential projects. In the course of discussions and review during the December visit, one project was selected for implementation as the demonstration project.

Project C3, Wheel Plant Rotary Hearth Furnace Combustion Control Improvements, was selected because it has the greatest potential for obtaining the anticipated monetary and environmental benefits, and is potentially the least complicated to install and to operate.

The selected project, C3, specifies an in-situ oxygen probe and a permanently installed aspirating carbon monoxide analyzer for use in one reheat furnace at the Wheel Facility (See Appendix C). The use of these instruments is expected to reduce fuel consumption in the furnace by at least 2% and decrease scale generation by at least 5%. The cost of this instrumentation is expected to be in the range of $25,000 to $30,000.

This project (C3) will reduce annual natural gas consumption by at least 265,000 Nm^3 with an annual monetary benefit estimated at $24,000 based on a unit value for natural gas of $90/1000$Nm^3$.

Additional savings of about $3,500 per year are expected from a reduction in scale formation as a result of improved temperature control in the reheat furnace.

In addition to monetary benefits, this project will reduce environmental emissions such as carbon dioxide by 520 tons per year and nitrogen oxide emissions by 0.5 tons per year. These reductions will be of significance since the Pipe Plant is located in the city of Dnipropetrovsk, a densely populated area.

Specifications are being developed for the selected instrumentation.

III. FINDINGS

Dr. Raymond Feder of the World Environment Center, Mr. Joel Hoffner of E&E Corporation, and Dr. Gregory Shmatkov, WEC in-country coordinator, visited Nizhnedniprovsky Pipe Manufacturing Plant in Dnipropetrovsk, Ukraine on December 18 and 19, 1997 (See Appendix A). The purpose of the visit was to review four previously identified candidate projects that had the potential to achieve significant reductions in energy consumption and associated air emissions from the plant processes and to select one project for implementation.

The Nizhnedniprovsky Pipe Manufacturing Plant consists of an Open Hearth Steelmaking Shop, five Pipe Mills, one Wheel Mill and one Ring & Tire Plant. The Plant occupies approximately 240 hectares of land. Steelmaking capacity is approximately 4,000,000 metric tons per year but is currently operating at 30% of the capacity. The plant produces seamless and welded pipe, forged wheels, rings and tires.

The Open Hearth Steel Pipe Shop produces bottom-poured round ingots from four 250 ton furnaces. The energy source for the Open Hearth is approximately 70% natural gas and 30% mazut (residue oil). Ingots are inspected and the surface is prepared prior to reheating and rolling in the pipe and wheel mills. The Open Hearth Shop is currently producing 60,000 tons of steel per month.

Ingots are sliced into blanks before reheating at the Wheel Plant. Rotary hearth furnaces are used at the Wheel Plant and #4 Tube Mill to bring the blanks or ingots to rolling temperature. The furnaces are normally fired with natural gas unless the supply is low, then mazut is fired to supplement the gas. The Wheel Plant is currently running at about 30% capacity. The #4 Pipe Plant is at about 85% of full production capacity.

Process steam is produced in two Boiler Houses. Process steam is normally 250°C at 12 atmospheres. Heated water is produced in one Boiler House that recovers heat from the Open Hearth flue gas. The steam boilers are normally fired with natural gas unless the supply is low, then mazut is fired. Use of mazut is an unusual occurrence.

In general, the Plant is well maintained and clean. Control panels in #4 Pipe Mill and the Wheel Plant were observed to be in excellent conditio

Management and technical staff are very much interested in making improvements to their energy consumption and air emissions. The low production levels result in poor utilization of the steelmaking and rolling mill equipment, except for #4 Pipe Plant where production levels are high. Relatively inefficient operations and high-energy consumption are natural results of the low production level.

IV. ENVIRONMENTAL & ENERGY ISSUES & PROJECT OPPORTUNITIES

A. Energy Reduction Techniques

The following generic types of projects have produced energy and air emission reductions in steel production facilities worldwide. WEC team visits in November and December to Nizhnedniprovsky Pipe Manufacturing Plant focused on identification of these types of projects as the basis for an Energy Conservation Demonstration project:

- Improved efficiency of fuel combustion processes in coke ovens, blast furnaces, open hearth furnaces, basic oxygen steelmaking furnaces, soaking pits, billet and bloom reheat furnaces, heat treating, and steam producing boilers. This category of projects reduces fuel consumption and reduces generation of carbon monoxide and nitrous oxides in air emissions. Improved fuel combustion also reduces iron oxide formation and associated solid wastes that require treatment or disposal.

- Introduction of maintenance technologies that uncover pending failures of machinery or advanced wear of refractory lining in heat intensive processes. Early discovery of problems avoids catastrophic failures and attendant disruptions to production processes which, in turn, cause abnormal energy losses and temporary inefficiency in air emission control systems.

- Practices and technologies to maximize the effective utilization of production facilities. Idle facilities, especially those that are run intermittently, experience higher energy and power consumption than facilities producing at full capacity. Proper scheduling of facilities, in times of low production, can have dramatic impact on energy consumption and associated environmental emissions.

B. Plant Observations

The Plant is taking steps to reduce energy. Examples of these steps are as follows:

- The installation of a vacuum degasser will allow shutdown of the heat treatment furnaces in the Wheel Plant. These furnaces removed entrapped hydrogen; the degasser will now ensure that hydrogen levels are low.

- The Wheel Plant is shutdown approximately one-half of each month and the furnace temperatures are reduced. The shutdown strategy is good and minimizes (but doesn't eliminate) wasted gas.

- Improved optical emission pyrometers have been installed in the Wheel Plant rotary hearth furnace and temperature control (plus fuel consumption) has improved.

- Excess oxygen analyzers have been used in the steam boilers with success; however, the quality of the equipment was poor and maintenance costs were too high for continued use.

All data regarding fuel consumption in the Plant is in kilograms of equivalent fuel. This standard is based upon 7000 kcal/ Nm^3 for equivalent fuel. To convert the gases used in the Plant to equivalent fuel, multiply consumption (Nm^3) of natural gas by 1.14. All gas values are referenced to +20 Centigrade and 760mm of mercury pressure.

The nominal calorific value of natural gas is 8000 kcal/Nm^3 but varies widely from 7990 to 8400 kcal/Nm^3. The cost of natural gas is $90/1000 Nm^3.

C. Energy Conservation Project Opportunities

Plant personnel and WEC representatives identified four projects for consideration during the visit in November. Each had good potential and were worthy of evaluation. The candidate projects are summarized in the following paragraphs.

C1. Open Hearth Flue Gas Carbon Monoxide Control Improvements

Carbon monoxide (CO) is generated in the steelmaking process. Carbon monoxide is captured by the flue gas system. The flue gas system uses an after-burner to combust the carbon monoxide. The combustion is not always complete and some CO continues to the electrostatic filters. CO may undergo combustion in the filters or may be emitted to the air. On the average, the amount of CO emitted is within regulation limits (less than 1%), however, control of CO combustion can be improved.

This project requires an in-line carbon monoxide analyzer to continuously detect the level of CO in the flue gas stream in the ductwork following the after-burners. The Plant task is to integrate the CO analyzer into the air supply controls for the after-burner. Increased levels of CO cause the controller to increase the air supply to the after-burner.

C2. Steam Boiler Combustion Control Improvements

One Boiler House that generates steam consists of six boilers at 20 tons/hour; one boiler at 40 tons/hour; one boiler at 50 tons/hour and one boiler being rebuilt to 50 tons/hour. Process steam is normally 250°C at 12 atmospheres but currently the delivered temperature has dropped to 212°C. The 20 ton/hour boilers are generally less efficient than the other boilers. The 20 ton/hour boilers consume approximately 1,500 to 1,600 Nm^3 of natural gas per hour.

Boiler controls are reasonably modern and consist of PID fuel-air ratio control and PID steam pressure control. The controls are well maintained.

Combustion efficiency varies as the calorific value of the natural gas varies and as the operating conditions vary. Fuel air ratio control does not currently use evidence of combustion efficiency to trim the air. Oxygen analyzers were used in the past with good results but the equipment quality was poor. Excess oxygen has been found to be as high as 10%.

This steam boiler combustion improvement project requires an in-line oxygen analyzer in the flue gas stack for one 20 ton/hour boiler. Also provided are additions to the PID controls as required to integrate the oxygen readings into the control system. The oxygen levels adjust the fuel air ratio control to improve combustion efficiency. The Plant task is to integrate the oxygen analyzer and additions to the PID controllers into a control system that improves combustion and reduces fuel consumption.

C3. Wheel Plant Rotary Hearth Furnace Combustion Control Improvements (This project has been selected for implementation)

In the Wheel Plant, sliced wheel blanks are heated to a rolling temperature of 1250°C to 1270°C in a rotary hearth furnace. The nominal production capacity of the furnace is approximately 45 tonnes per hour (approximately 400,000 tonnes per year). The furnace and wheel plant is currently producing 7,000 tonnes per month.

The furnace has five zones, designated zones #1 thru #5 starting at the delivery end of the furnace. There are a total of 62 burners in the furnace. Combustion gases flow counter to the flow of wheel blanks and exit to a stack in zone #5.

Normally, the furnace is fired with natural gas. The average gas consumption is 106 to 270 kg/ton (3.6 to 9.3 Mbtu/ton) of steel heated. Mazut is used only when gas is short in supply.

Each zone has microprocessor fuel air ratio control and temperature setpoint control. Temperature in each zone is sensed by new optical pyrometers which sight through ports in the furnace wall. There are eight microprocessors and six pyrometers. A project is currently underway that will link all microprocessors to a supervisory level PC which will

direct the furnace heating pattern depending upon the product size, weight and grade produced.

It is important to control the furnace atmosphere to minimize scale loss. However, the scale that is produced must be loose. To accomplish this, zones 3,4 and 5 are set to run lean (with excess air of 4% to 6%). These zones have an oxidizing atmosphere that promotes formation of loose scale. Zones 1 and 2 are set to run rich (with excess fuel and CO at 5%). These zones have a reducing atmosphere that ceases formation of scale prior to delivery of the blank.

Accurate control of combustion conditions is important to the scale formation process and the efficiency of combustion. Excess carbon monoxide generation in zones #1 and #2 can result in CO emissions from the flue gas stack.

This project requires a carbon monoxide sensor for zone #2 and an excess oxygen sensor for zone #5 (See Appendix C & D). The two sensors are integrated into the current microprocessor controls by the Plant. Proper settings for CO in the delivery zones and excess oxygen in the entry zones is determined through experimentation and trials.

C4. #4 Pipe Mill Rotary Hearth Furnace Combustion Control Improvements

In the Pipe Mill, ingots are heated to a rolling temperature of 1220°C in a rotary hearth furnace prior to piercing of the blank. The nominal production capacity of the furnace is approximately 30 to 50 tons/hour (approximately 360,000 tons/year). The furnace and pipe mill is currently producing 20,000 tons/month.

The furnace has three zones. Combustion gases flow counter to the flow of ingots and exit to a stack in the entry.

Normally, the furnace is fired with natural gas. The average gas consumption is 78 kg/ton (2.7 Mbtu/ton) of steel heated. Mazut is used only when gas is short in supply.

Each zone has out-dated analog fuel air ratio control and temperature setpoint control. Temperature in each zone is sensed by optical

pyrometers which sight through ports in the furnace wall. The fuel air ratio is set at 12.5 to 1 - a highly oxidizing atmosphere.

Accurate control of the atmosphere is important to the scale formation process and the efficiency of combustion.

This project requires new microprocessor controls and optical pyrometers for three zones of the furnace. The Plant integrates the controls and pyrometers into an effective control system which minimizes excess oxygen and maximizes combustion efficiency. Proper settings fuel air ratios and temperatures in the zones is determined through experimentation and trials.

V. CONCLUSIONS AND RECOMMENDATIONS

The four candidate projects were reviewed by Nizhnedniprovsky Pipe Manufacturing Plant management and WEC and were discussed during the December plant visit. Of the four possible projects, the Wheel Mill Rotary Hearth Furnace project C3 is now recommended for the following reasons:

- Current fuel consumption in the furnace is 3 to 4 times world class standards and can significantly be reduced by application of proven technology.

- The project is expected to reduce natural gas consumption by at least 265,000 m^3/yr or 2% of present usage with attendant reduction in cost of about $24,000/yr. The potential for higher savings is very probable.

- The project has the additional benefit of $3500 from reducing scale generation and attendant solid waste disposal implications, both environmental and cost. In addition to the anticipated total annual benefits of $27,500 resulting from reduced usage of natural gas and reduced formation of scale, this project will have environmental benefits through reduction of CO_2 generation by 520 tons/yr and nitrogen oxide generation by 0.5 tons/yr. These emissions reductions are important since the Pipe Plant is located in Dnipropetrovsk, a densely populated area.

- Estimated cost of equipment is approximately $27,000 with a payback period of approximately 1 year based on fuel savings and scale reduction.

- The existing control system for the furnace is modern and can accommodate additional sensors reasonably easily.

- The sensors and controls will be integrated into a PC-based supervisory control system thereby facilitating the capture of furnace performance data which can be used to demonstrate the improvements achieved.

VI. PAYBACK AND COST INFORMATION

The Wheel Plant Rotary Furnace heats sliced wheel blanks to a rolling temperature of 1250°C to 1270°C. Furnace zones 3, 4 and 5 are targeted to run with excess air of 4% to 6%. Zones 1 and 2 are set to run with excess fuel and CO at 5%. The furnace is currently heating from 5,000 to 7,000 tons of steel per month. The average gas consumption ranges from 106 to 270 kg/ton (3.6 to 9.3 Mbtu/ton) of steel heated.

The furnace is fired with natural gas. Accurate control of the furnace atmosphere is important to the scale formation process and the efficiency of combustion. Excess carbon monoxide generation in zones #1 and #2 can result in CO emissions from the flue gas stack and wasted unburned fuel. Excess air in zones 3, 4 and 5 causes generation of nitrous oxides and wastes fuel to overcome the cooling effect of the excess air.

The actual calorific value of the natural gas fluctuates considerably. It is supplied from two deposits in Russian Federation that have different compositions. The actual delivered calorific value is not known, but has been found to vary between 7990 and 8400 kcal/Nm^3. The cost of natural gas is $90/1000 Nm^3.

The fuel air ratio is set based upon an assumed gas composition, therefore, the ratio is often in error as the gas composition fluctuates. Gas and airflow rate measurement errors also contribute incorrect fuel air ratio deviations. The current control system does not detect and therefore can not adjust fuel air ratio to compensate for varying fuel composition or erroneous flow rate measurements. This results in poor combustion efficiency and generation of unwanted nitrous oxides and carbon monoxide in the flue gas.

Excess air variations of 2% and carbon monoxide variations of 3% have been measured with portable instruments over very short periods of time. Changes in the calorific value of natural gas require a proportional change in the amount of air required for complete combustion. For example, the natural gas at 8400 kcal/Nm^3 requires 6% more combustion air than natural gas at 7990 kcal/Nm^3. The excess air, over

and above the amount required for combustion, reduces the net heating value of the gas by approximately 4% and causes proportionally higher fuel consumption per ton of steel heated.

The proposed gas analyzers will measure combustion products and provide input to the furnace control system such that the setpoint fuel air ratio is maintained even as the fuel composition varies and flow errors occur. Based on the information provided by the plant, it is reasonable to assume that fuel savings of at least 2% can be attained and as high as 4% may be possible.

Implementation of this project will result in a decrease in annual costs for natural gas of $24,000 to $45,000. The lower figure is based upon an anticipated fuel reduction of 2% per ton of steel produced; a cost of natural gas of $90 per 1000 Nm^3; an average steel production rate of 5,000 tons per month; gas consumption at 160 kg/ton of steel; and a conversion rate of 0.73 kg/Nm^3 for Russian natural gas. The higher figure is based upon an anticipated fuel reduction of 4% per ton of steel produced; a cost of natural gas of $90 per 1000 Nm^3; an average steel production rate of 7,000 tons per month; gas consumption at 110 kg/ton of steel; and a conversion rate of 0.73 kg/Nm^3 for Russian natural gas.

In addition to energy reductions, scale loss due to excessive oxidation in the furnace will reduce by 5%. Reduced scale loss results in reduced annual steelmaking costs of $3,000 to $4,000 based upon normal scale loss of 1% in the furnace; a reduction in that scale loss by 5%; production rate of 5,000 to 7,000 tons per month; ingot value of 420 hrivnia per ton and scrap value of 250 hrivnia per ton. Ingot and scrap values were provided by the plant.

This project will reduce annual natural gas consumption 265,000 Nm^3 to 508,000 Nm^3. The savings in natural gas consumption also results in a reduction of greenhouse gases, specifically carbon dioxide. Combustion of natural gas produces approximately 1 cubic meter of carbon dioxide for each cubic meter of natural gas burned. Implementation of this project will decrease generation of carbon dioxide by 520 tons to 1,000 tons/year.

These reductions in emissions of CO_2 and nitrogen oxides are important environmental benefits since the Pipe Plant is located within

Dnipropetrovsk city. WEC project costs are associated with the purchase of a carbon monoxide analyzer (most probably a sampling type) with appropriate enclosures and interface to the furnace control computer and an in-situ oxygen analyzer with appropriate enclosures and interface to the furnace control computer (See Appendix C). It is assumed that the plant will undertake the costs of electrical, mechanical, and piping installation of the analyzer as well as the computer programming required to cause adjustments to the fuel air ratio control. All electrical panels, transformers, circuit breakers and wiring will be provided by the plant. All mechanical brackets, furnace modifications, sampling pipe (including water cooling if required) will be provided by the plant. On this basis, WEC costs are estimated to range from $25,000 to $30,000.

VII. IMPLEMENTATION PLAN AND SCHEDULE

March 1998	-	Issue Trip Report and Recommendations
April 1998	-	Submit Equipment Quotations to USAID for Approval
May 1998	-	Issue Purchase Order for Equipment
August 1998	-	Delivery of Equipment to JFK for trans-shipment to Ukraine
September 1998	-	Installation of Equipment
October 1998	-	Operation of Equipment and Evaluation of Operating Data

VIII. APPENDICES

APPENDIX A – DETAILS OF PLANT VISIT

I. Date of Visit: December 18 – 19, 1997

II. Attendance at Meetings

Meetings at the Niznedniprovsky Pipe Manufacturing Plant were attended by the following personnel in December 1997:

For World Environment Center:

R. L. Feder, Staff Consultant
J. Hoffner, E & E Corporation
G. Shmatkov, WEC in-country Coordinator
V. Zirka, Translator

For Niznedniprovsky Pipe Manufacturing Plant:

Mr. Vladimir K. Gooliy - First Deputy Director General (Vice Director)
Mr. G. Skobelkin - Deputy Chief Power Engineer
Mr. A. Fomenko - Deputy Chief of the Control & Measuring Devices and Automation Shop
Mr. Terentiev - Chief of the Control and Measuring Devices and Automation Shop
Mr. V. Danilov – Chief of Heat Engineering Shop
Ms. L. Aprosinenko – Chief of the Ecology Laboratory

In addition to the above personnel, the following Niznedniprovsky personnel were met in November 1997:

Mr. A. Kozlovsky – General Director of the Plant
Mr. Vladimir Syplenko – Chief Engineer
Mr. V. Rykov – Chief Mechanical Engineer
Mr. V. Kirsanov – Manager of the Engineering Center
Mr. V. Gudanets – Chief Power Engineer
Mr. V. Chernyavsky – Deputy General Director of Environment
Mr. A. Scheblykin – Chief of Sector of Control and Measuring Devices and Automation Shop

APPENDIX B – DOCUMENTS RECEIVED

I. BUSINESS CARDS

JSC NIZNEDNIEPROVSKY TUBE-ROLLING PLANT

Vladimir K.
GOOLIY
VICE-DIRECTOR

21, STOLYAROVA STR.,
DNEPROPETROVSK,
320000, UKRAINE

TEL. [illegible]
FAX [illegible]
TELEX 148217 STAN

II. DRAWINGS, STATISTICS AND BROCHURES

- Wheel Plant Furnace Cross-Section Drawing
- Wheel Plant Furnace Design Specifications
- Wheel Plant Furnace Production Statistics for August, September, October and November 1997
- Wheel Plant Furnace Combustion Gas Measurements for November 5, 1997; November 17, 1997 and December 18, 1997
- Niznedniprovsky Pipe Manufacturing Plant Brochures

APPENDIX C- DESCRIPTION OF TYPICAL RECOMMENDED INSTRUMENTATION

I. Non-Dispersive Infrared Gas Analyzer

II. Zirconium Oxide Flue Gas Oxygen Analyzer

IR7000

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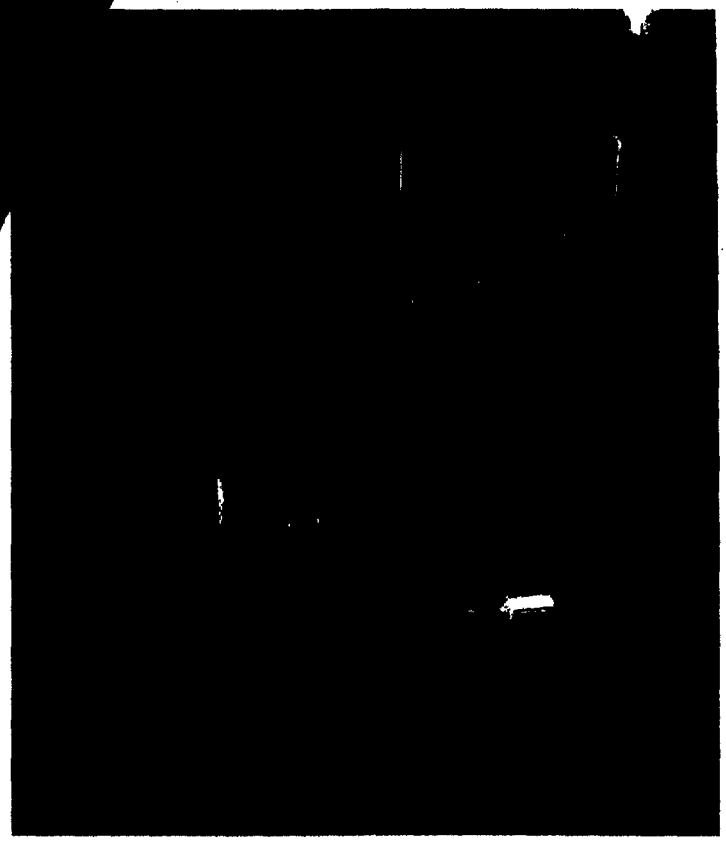
Gas Analyzers



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gas interference.

hrough the four front
ntrol calibration gas
frequency, active chart
low alarm conditions, as
well as manual zero and span calibrations. All operator settings are protected by battery backup.

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Standard Features

- User selected auto-zero, auto-span calibration
- Linearized instrument range, eliminating need for separate instruments to achieve full scale span
- Closed sample path is not exposed to ambient air eliminating the need for periodic purging
- 4 selectable chart recorder ranges
- Modular design for easy maintenance
- Configured to accommodate an optional oxygen channel
- Low power requirements. No heat build up and therefore no premature failure of components.
- No moving parts associated with the optical bench. No chopper motor required.
- No "tuning" required with optics unlike competitive NDIR methods
- The signal from the detector is digitized making signal processing reliable and flexible
- Thorough self-diagnostics software package
- Easy set up and interface

Applications

- Chemical and petrochemical processes
- Combustion and flue gas processes
- Pulp and paper
- Vapor recovery systems
- Enhanced oil recovery
- Air separation
- Metals, ceramics and heat treating atmospheres
- Land fill gas power stations
- Emissions testing (part of the mobile stations)
- Carbon dioxide scrubber efficiency
- $CO/CO_2/C_2H_4$ monitoring in oxyhydrochlorination process in EDC manufacturing

Model Designations

IR7000	Panel / rack mount
IR7010	Split architecture (analysis unit - explosion proof)
IR7000P	Portable
IR7000T	Trace gas
IR7000D	Dual Bench

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TELEDYNE ANALYTICAL INSTRUMENTS

A business unit of Teledyne Electronic Technologies

SENSORS ○ ANALYZERS ○ SYSTEMS ○ SCIENTIFIC SOLUTIONS

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Specifications

Measuring method:	NDIR single beam
Gas measured:	User specified
Measuring range:	Per application
Response time (T90):	User selectable typically 15 - 60 seconds for nominal flow rates
Display:	Vacuum fluorescent
Alarms:	High and low limit, user selectable
Analog output:	Selectable 1,5, or 10 volts; optional isolated 4-20mA current loop
Analog ranges:	4, each with adjustable full scale; selectable auto range
Cal valve actuation:	Isolated triac control. Rated maximum load: 0.6 amp at instrument voltage
Power source:	120/240 VAC, 50/60Hz (Portable model includes rechargeable batteries - minimum 6 hours continuous operation)
Power consumption:	50 watts/channel
Materials in sample flow path:	Glass, gold, buna-n, lexan, epoxy, sapphire, 304 stainless steel
Sample flow:	0.2 to 2.0 liters/minute (Trace gas — 5.0 - 10.0 liters/minute) (Portable — internal sample pump)
Sample temp:	-10° to +50°C
Sample condition:	Non-condensing, particulate free
Warm-up time:	Usable in 60 minutes. Optimum operation in 3 hours.
Ambient conditions:	Operating: -10° to 50°C (non-condensing) Storage: -10° to 80°C (0° to 50°C for oxygen sensor)
Dimensions:	
Rack mounted and dual bench:	22.5" L x 17.1" W x 5.25" H 571mm L x 447mm W x 133mm H (suitable for 19" rack)
Portable:	20.0" L x 8.5" W x 5.25" H 508mm L x 216mm W x 133mm H

Weight:

Rack mounted:	38 lbs (17.2kg)
Portable:	19 lbs (8.6kg)

Standard Ranges - IR7000 / IR7000P

Gas*	Typical Low Range*	Typical Hi Range*
CO	0-100 to 0-1000ppm	0-10% to 0-100%
CO_2	0-30 to 0-300ppm	0-5% to 0-50%
SO_2	0-50 to 0-500ppm	0-10% to 0-100%
NO_2	0-100 to 0-1000ppm	0-10% to 0-100%
N_2O	0-100 to 0-1000ppm	0-10% to 0-100%
CH_4	0-300 to 0-3000ppm	0-10% to 0-100%
Propane	0-100 to 0-1000ppm	0-10% to 0-100%

Resolution:	0.1% of full scale
Repeatability:	+/-0.1% of full scale
Noise:	+/-0.1% of full scale
Accuracy:	+/-0.3% of full scale determined on maximum range only and is absolute for all other ranges

High Sensitivity Ranges - IR7000T

Gas*	Range	Range	Accuracy
CO	0-5 to 0-50ppm	0-20 to 0-200ppm	+/-0.25ppm or better/24 hrs
CO_2	0-2 to 0-20ppm	0-20 to 0-200ppm	+/-0.1ppm or better/24 hrs

Resolution:	0.01ppm
Repeatability:	+/-0.25% of full scale
Noise:	+/-0.1% of full scale
Accuracy:	+/-0.5% of full scale determined on max range only; is absolute for all other ranges.

* Four outputs are available from minimum to maximum: Example CO offers 0-5, 0-10, 0-25, 0-50ppm, all represented as 0-1V output

* At maximum range and constant ambient conditions

Other gases available by request

Options

- ○ 0-25% Electrochemical oxygen channel
- ○ RS-232 interface

If you would like more information on any product in the IR7000 series, please don't hesitate to contact your local representative or Teledyne.

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Warranty

Instrument is warranted for 1 year against defects in material or workmanship

NOTE: Specifications and features will vary with application. The above are established and validated during design, but are not to be construed as test criteria for every product. All specifications and features are subject to change without notice.

Regional Offices

Tokyo, Japan **81-33-239-9090**

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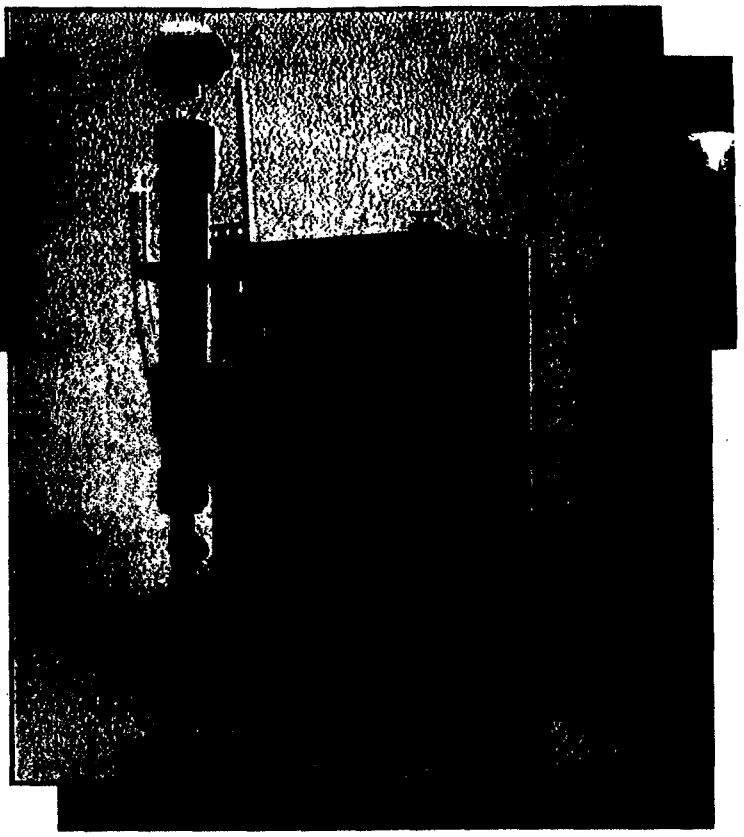
Series 9000 Flue Gas Analyzer Systems



Optimizing combustion efficiency and minimizing exhaust emissions are vitally important for proper operation of every industrial process that burns fuel. From clean-burning natural gas furnaces to "dirty" coal-fired kilns, Teledyne's versatile Series 9000 systems are ideal for a wide range of flue gas monitoring applications. Standard systems are available for monitoring: Oxygen (O_2), carbon monoxide (CO), carbon dioxide (CO_2) and/or combustible gases. And customized systems can be provided to suit your exact specifications.

All Series 9000 Systems utilize continuous-duty extractive sampling methods that pull sample from the stack and provide near-line monitoring of the flue gas content. Simple, reliable air aspirators or rugged sampling pumps are part of a complete Series 9000 sampling system. Teledyne can provide all the accessories you need for an effective flue gas analysis system—including probes, preconditioners and sample lines for even the most difficult flue gas applications.

Methods of Analysis

Oxygen. All Series 9000 systems feature oxygen analysis using Teledyne's patented* Micro-Fuel Cell. This reliable sensor is a sealed electrochemical transducer with no electrolyte to change or electrodes to clean, so it is virtually maintenance-free. Because it has an absolute zero, no zero gases are needed for calibration. And air (20.9% O_2) is used for span purposes.

Combustibles. A low-temperature catalytic bead sensor provides reliable measurement of total combustibles in the Models 9700 and 9750. Standard range of analysis is 0-5% CH_4 equivalent (other ranges available).

Carbon monoxide (CO). Two methods of CO analysis are available. The low-cost Models 9100 and 9150 use a long-life, disposable electrochemical sensor that provides all the accuracy and reliability required for most applications.

*U.S. Patent numbers 3,429,796 and 3,767,552

A non-dispersive infrared analyzer is an alternative approach to CO monitoring that is employed in the Model 9300. This infrared analyzer is a dual-path, single source device that uses optical techniques to eliminate potential interferences. The analyzer features a solid-state vibration-resistant detector, for accurate and reliable operation. An automatic zero circuit provides excellent long-term stability.

Carbon dioxide (CO_2). Optionally available in the Model 9300 is a CO_2 analysis. Standard range of this analysis is 0-20% CO_2 (others available). An infrared analyzer is used to measure CO_2, and it provides the same outstanding features and performance as the Model 9300's CO infrared analyzer.

Sampling Systems

Simple air aspirator. For cleaner-burning applications (such as natural gas-fired burners), very little sample conditioning is needed to prepare flue gas for analysis. The Models 9150, 9600, and 9750 systems are ideal for such clean applications. These systems use a simple sampling design that includes an air-operated jet pump to pull flue gas sample to the analyzer. The system also cools the sample below ambient, thus removing condensables and lowering the sample dewpoint to prevent condensation inside the analyzer.

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Pumpless system. For applications with positive pressure flue gas, a water-washed sample system can be provided without a pump. This system offers the same features as the water-washed peristaltic pump system, except it uses neither an eductor nor a pump.

Rugged peristaltic pump. For dirtier flue gas applications (such as heavy oil-and coal-fired furnaces), the Models 9100, 9300, 9500 and 9700 incorporate a water-washed sampling system that pulls flue gas to the analyzer and prepares it for analysis. The heart of this system is a unique peristaltic pump, which is specifically designed for efficient operation pumping the gas/water mixtures created by the water-washed sampling system. This system complements the pump and removes particulates and acids from the flue gas. Drying of the sample is unnecessary. The system is cost-effective and contains no critical orifices, sample blending or processing which might contribute to increased maintainence or downtime. The result: A steady flow of clean flue gas to the analyzer.

Typical Applications

- Flue gas and process analysis
- Boiler — power and processes
- Firebox — processes
- Stacks (e.g., reduced crude heaters, cracking heaters and CO boilers)
- Thermal cracking processes
- Asphalt processes
- Catalytic reformers
- Regeneration of catalysts
- Open hearth furnaces
- Electric furnaces
- Soaking pits
- Slab reheat furnaces
- Cement and lime kilns
- Alumina kilns and calciners
- Glass-making processes
- Heat treating and annealing furnaces
- And virtually any hydrocarbon-based combustion exhaust

Series 9000 Model Designations

Model No.	Gases Measured	Sample System
9150	O_2 and CO	Air aspirator*
9600	O_2 only	Air aspirator*
9750	O_2 and combustibles	Air aspirator*
9100	O_2 and CO	Peristaltic pump**
9300	O_2 and CO (CO_2 optional)	Peristaltic pump**
9500	O_2 only	Peristaltic pump**
9700	O_2 and combustibles	Peristaltic pump**

*These air-aspirated systems use a reliable eductor for sampling flue gas from natural gas fired-furnaces, light oil burners, and other clean-burning combustion applications.

**These rugged water-washed systems use a peristaltic pump for sampling flue gas from heavy fuel oil furnaces, coal-fired burners, cement kilns, and other dirty flue gas applications.

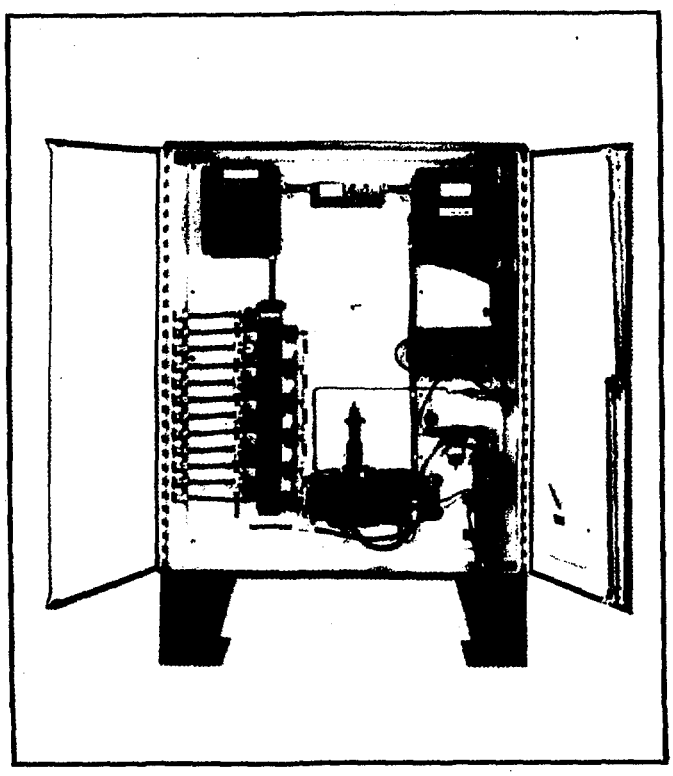
Special Configurations and System Options

Remote control unit. All Series 9000 systems are available with a separate control unit that can be remotely mounted in a control room, instrument shed or other convenient location. In this configuration, the system's analysis section—which includes the sampling system and gas sensor(s)—can be mounted on or near the flue gas stack. This configuration can simplify certain installations and helps achieve minimal sample lag time.

Multipoint sampling. A number of systems are available for monitoring more than one sampling point. Pump-driven multipoint systems can monitor as many as twelve sample points on a time-shared basis. An adjustable sequencer and integrated valve assembly is included to automatically control sampling from one point to the next. These systems can be customized to satisfy unique application requirements.

Special enclosures. Several enclosure options are offered with Series 9000 systems. Purged enclosures can be provided to satisfy certain hazardous area requirements. Insulation, steam-or electric-heating, cooling, protective roofing, special materials (such as fiberglass) and special paint are available for extreme ambient conditions. Many systems can be provided in free-standing enclosures (standard with the Model 9300).

Explosion-proof housings. Series 9000 systems are also available in explosion-proof housings for use in hazardous areas.



Multipoint analysis systems monitor up to twelve flue gas streams on a time-shared bases. These cost effective systems are optional for Models 9100, 9300, 9500 and 9700.

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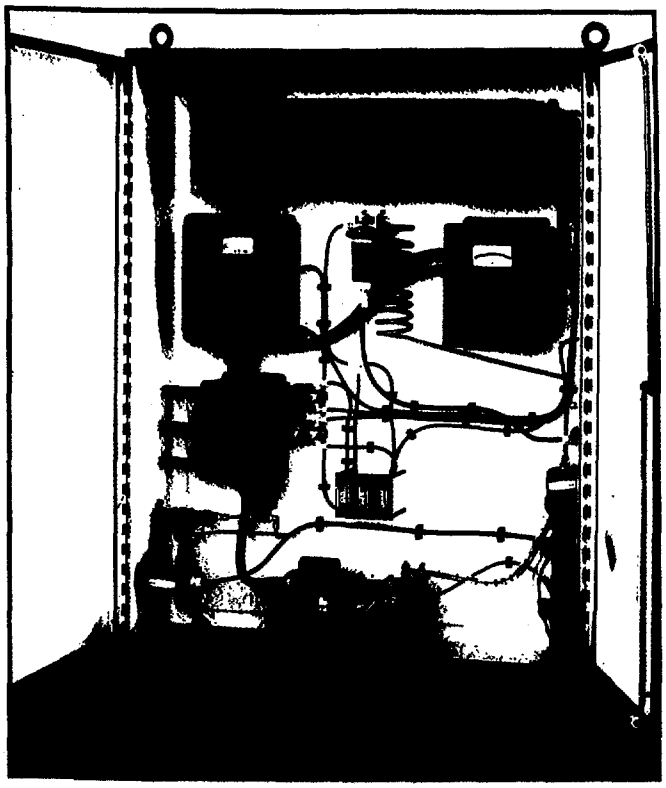
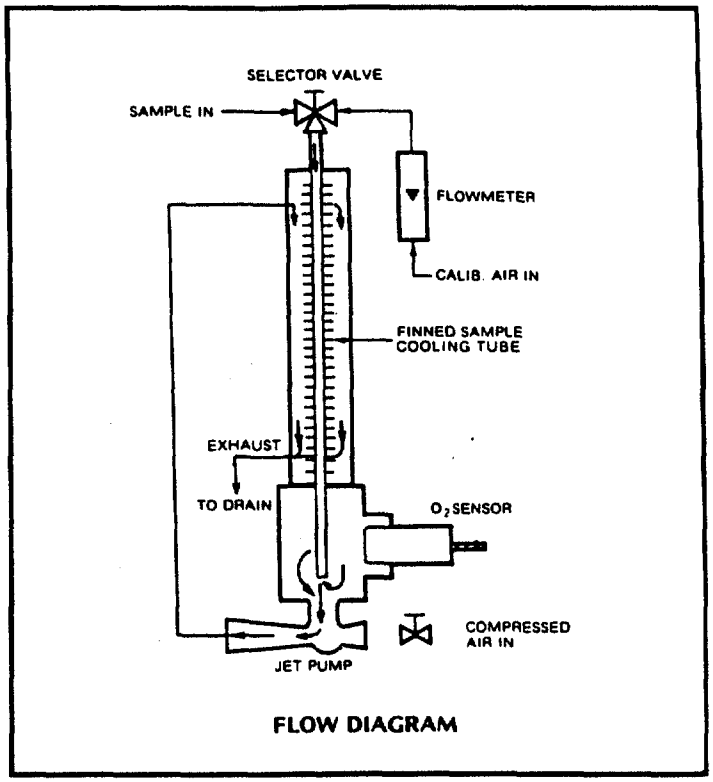
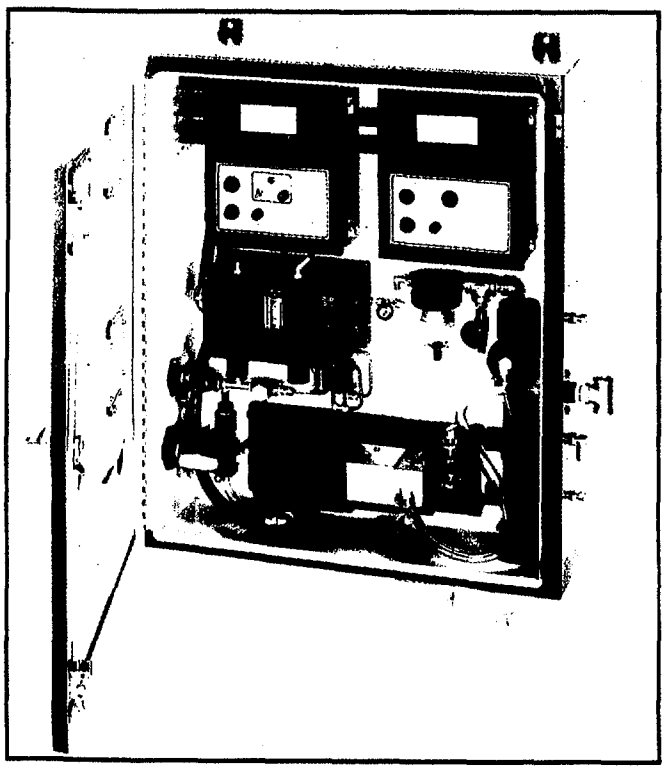


Model 9300 system uses infrared analysis for monitoring CO and CO_2 (optional). O_2 analysis is also included with the standard 9300 system.



This simple, effective air aspirator system is used with many Teledyne flue gas analyzers and is ideal for sampling from natural gas-fired combustion and other clean-burning applications.



Model 9100 CO and O_2 analyzer system uses a water-washed sampling system driven by a unique peristaltic pump designed specifically for handling dirty flue gas.

"Split version" Model 9150/SV CO and O_2 analyzer system features an air-aspirated analysis section—which can be mounted on or near the flue gas stack—and a separate control unit, for convenient remote mounting.

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Features

- Easy to install
- Easy to service and maintain
- Low price
- Cost-effective operation
- Convenient off-stack access
- Multipoint monitoring capability
- Air calibration (for O2 analysis)
- Optional automatic calibration
- Adjustable response time
- Systems for very clean and very dirty flue gas
- Rugged, reliable, durable
- Off-stack installation not exposed to harsh flue gas environment
- Optional "split version" can be installed on-stack or at other remote locations

Options

- 100 or 220 VAC, 50 or 60 Hz
- Special ranges
- Digital meters
- Alarm setpoints and relay contacts
- 1-5, 4-20 or 10-50 mADC output(s)
- Isolated output(s)
- Water or steam eductor (for 9150, 9600 or 9750)
- Purged, heated or cooled enclosures
- Thermal insulation fiberglass enclosures
- Separate analysis section and remote-mounted control unit ("split versions")
- Multipoint systems
- Explosion-proof housings
- Free-standing enclosures (std for 9300)
- Sample probes, external preconditioners
- Air blowback for sample lines
- Custom-designed systems

Specifications*

Oxygen Analysis

Ranges: 0-5, 0-10, 0-25% O_2
Sensitivity: 0.5% of full scale
Accuracy: ±2% of full scale at constant temperature ±5% of full scale throughout operating temp. range
Response Time: 90% of full scale in 45-60 seconds
Signal Output: 0-1 VDC or less (mADC and isolated outputs optional)
Sensor: Class A-3 Micro-Fuel Cell

Combustibles Analysis

Range: 0-5% methane (CH_4) equivalent
Sensitivity: 0.5% of full scale
Accuracy: ±0.2% combustibles
Response Time: 90% in less than 15 seconds
Signal Output: 0-1 VDC or less (mADC and isolated outputs optional)
Calibration: Span gas 4.0-4.8% CH_4 in nitrogen
Sensor Type: Low temperature catalytic bead

Carbon Monoxide Analysis

Range: 0-500, 0-1000 ppm CO
Sensitivity: 2% of full scale
Accuracy: ±2% of full scale at constant temperature
Response Time: 90% of full scale in 45 seconds
Signal Output: 0-1 VDC or less (mADC and isolated outputs optional)
Calibration: With certified gas (700-900 ppm CO in air or nitrogen, or 350-450 ppm CO in air or nitrogen)
Sensor: Class F-1R electrochemical

Infrared Analysis (Model 9300)

Gases Measured: CO, CO_2, or both
Range(s): 0-500 ppm to 0-20% CO standard. Options include second CO range and/or CO_2 measurement up to 0-20% CO_2.
Response Time: 90% of reading in less than 30 sec.
Zero Drift and Diurnal: Corrected by automatic zero
Repeatability/Accuracy: ±2% of full scale
Linearity: ±2% of full scale
Signal Output: 0-1 VDC or less (mADC and isolated outputs optional)
IR Optical Bench: Dual path, single source, modular construction (no optical adjustments)
Detector: PbSe (solid-state photoconductor)
Sample Cell: Rigid PVC, sapphire windows

Typical System

Operating Temperature Range: 0° C to 50° C (optional auxiliary heating available for use in below-freezing ambient temp.)
Operating Power: 115 VAC, 60 Hz, single phase (other voltages optionally available)
Air Supply: Compressed air regulated to 5-25 psig. 2 SCFM typical for aspirated systems
Water Supply (for water-washed systems only): 10-100 psi, 0.25 - 1.5 gallons/minute
Sample System Materials: Selected for high resistance to corrosion in flue gas application, e.g., organic plastics, 316 stainless steel, etc.
Readouts: Integral analog meter(s)

*Specifications subject to change without notice.

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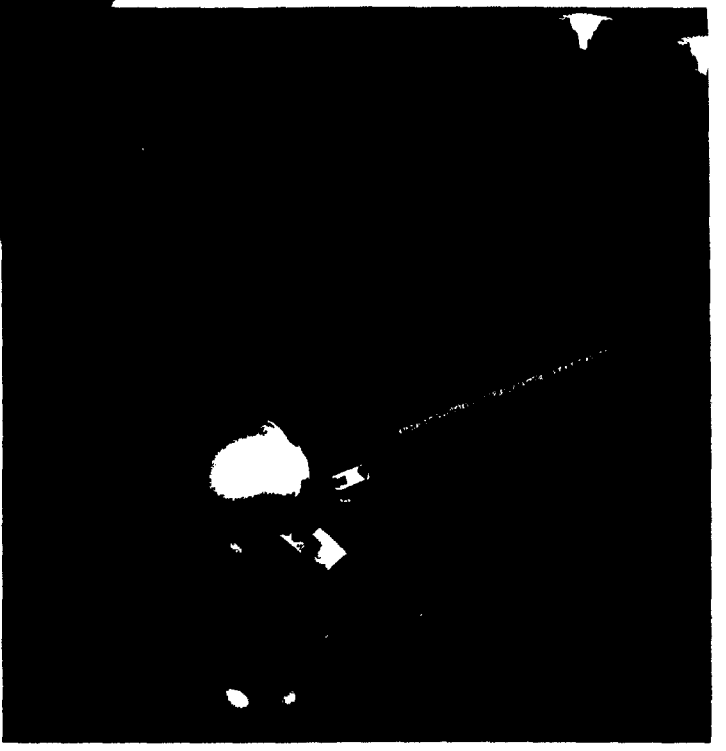
9060

as Oxygen Analyzer



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stic Features

s programmable
-purge outputs as a
standard. The user can program the cal/purge sequence
to an alarm relay for external indication. The 9060 has
also been designed with a probe diagnostic loop to
continuously monitor for probe impedance to ensure
the sensor is functioning properly. The electronics
self-calibrates all inputs every minute.

Easy Interface

The Model 9060 provides two isolated 4-20mADC linearized control signal outputs. One is dedicated to the O_2 signal and the other is user selectable from thirteen other variables. In addition, an RS-232 / RS-485 printer / computer interface capability is provided. One general diagnostic alarm and three field selectable alarms with switching are provided standard.

Additional Features

An integral automatic reference pump is provided as standard. This pump draws atmospheric air and delivers it to the zirconium sensor as reference air in lieu of customer supplied instrument air. If the operator desires, the pump can be bypassed and instrument air, at a flow of 50cc/min can be delivered to the sensor as required.

Applications

- *Gas, oil, pulverized coal and black liquor boilers*
- *Cement, lime and ceramic kilns*
- *Refinery process heaters and furnaces*
- *Blast furnace ovens*
- *Soaking pit and heat treating furnaces*
- *Thermal cracking furnaces*
- *Catalyst regeneration*
- *Asphalt processes*
- *Utility boilers*

Series 9060 Zirconium Oxide Sensors / Probes

Model 9060H	Heated probe design for typical stacl gas applications
Model 9060UH-LT	Unheated probe design (with 253M/ sheath)
Model 9060UH-HT	Unheated probe design (with alumir ceramic sheath). Suited for high ten applications.
Model 9060UH-C	Unheated probe design (with proprieta sheath for corrosion resistance). Suited for corrosive / acid gas conte applications.
Model 9060H-EX	Heated probe design for extractive applications.

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Specifications

Range of Output 1: Field selectable from the following
Linear: 0-1% to 0-100% O_2

Output 2: Can be applied to the optional second sensor input or to one of the following selectable variables:

Log oxygen	O_2 deficiency	Probe EMF
Carbon dioxide	Efficiency	Stack temperature

Display Choice

O_2 deficiency	Probe EMF	Date - time
Carbon dioxide*	Efficiency*	Stack temperature
Probe temperature	Sensor impedance	Ambient temperature
Run hours and date since last service		

**Calculated values*

Accuracy and Repeatability: +/-1% of actual measured oxygen value with a repeatability of +/-0.5% of measured value.

Response Time: 90% in less than 4 seconds - typical

Inputs

- One or two zirconia oxygen probes or sensors
- Stack or spare thermocouple, type T, J, K, R, S, or N
- Main flame safety interlock (for heated probes only)
- Purge pressure switch
- Dual fuel selector
- Remote alarm acknowledge

Outputs: Two linearized isolated 4-20mADC signals

Alarms: Common alarm relay with 20 alarm functions and three programmable alarm relays for low, very low and high O_2, probe temp. low, calibration error, pump failure and horn.

Computer / Printer Communications: RS-232 or RS-485 for connection of a computer terminal or printer for diagnostics of the analyzer, probe, sensor or combustion appliance.

Purge and Calibration Check: One purge and two calibration check output relays to operate, solenoid valves.

Reference Gas Pump: Integral diaphragm pump delivers atmospheric air to the ZrO_2 sensor, or customer can supply their own instrument air (50cc/min) for reference purposes.

Relay Contacts: 0.5A-24 VAC, 1A-30VDC, 50VAC, or 30VDC max

Ambient Temperature: 32-122°F (0-50°C)

Connection Cable: Special cable containing shield, thermocouple compensating lead, sensor conductors and heater conductors where a heated probe or sensor is used. (optional)

Power Requirements: 120 or 240VAC, 50/60 Hz, 125VA (heated probe or sensor), 5VA (unheated probe)

Weight: 5.5 lbs

Enclosure: NEMA-4, suitable for outdoors, wall or surface mounting

Dimensions: 10.2" W x 5.1" H x 3.7" D

Accessories:
In-situ probes and sampling sensors
Class I, Div 1, Group B, C, D enclosures for hazardous areas
Probe and sensor cables
Sample aspirator (for extractive probe)
Purge and calibration check gas solenoid valves
Calibration check flowmeters

Probe Type	Probe Temperature
9060H	up to 1652°F or 900°C
9060 UH-LT	from 1292 - 2102°F or 700 - 1150°C
9060 UH-HT	from 1292 - 2552°F or 700 - 1400°C
9060 UH-C	from 1292 - 2192°F or 700 - 1200°C
9060 H-EX	up to 1652°F or 900°C (non-insitu type)

If you would like to meet with a member of the Teledyne team to discuss the Model 9060 or arrange a demonstration, please don't hesitate to contact your local representative.

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Regional Offices

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Tokyo, Japan **81-33-239-9090**

Rio de Janeiro, Brazil..... **55-21-531-1722**

APPENDIX D – PHOTOGRAPHS OF PIPE PLANT EQUIPMENT

I. Wheel Furnace Control Panel

II. Wheel Furnace Zone 5 Oxygen Analyzer Location

III. Wheel Furnace Burner Gas and Air Feed

APPENDIX D I

Wheel Furnace Control Panel

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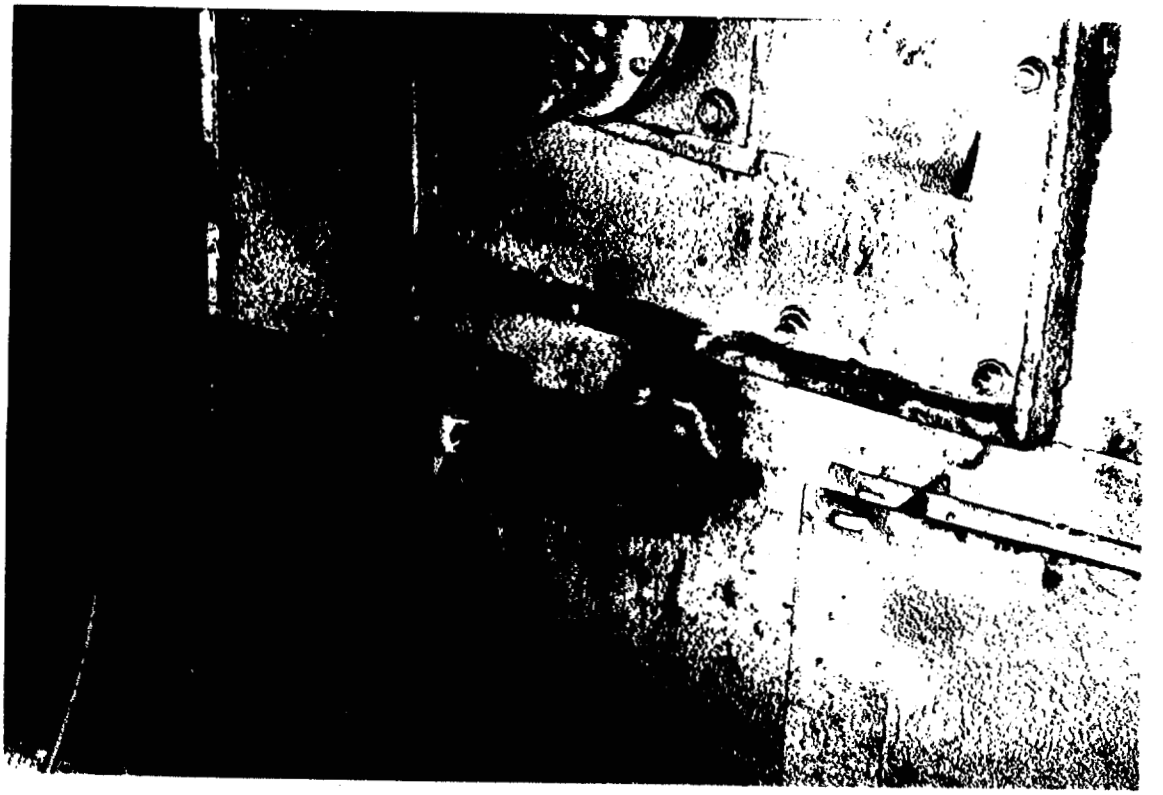
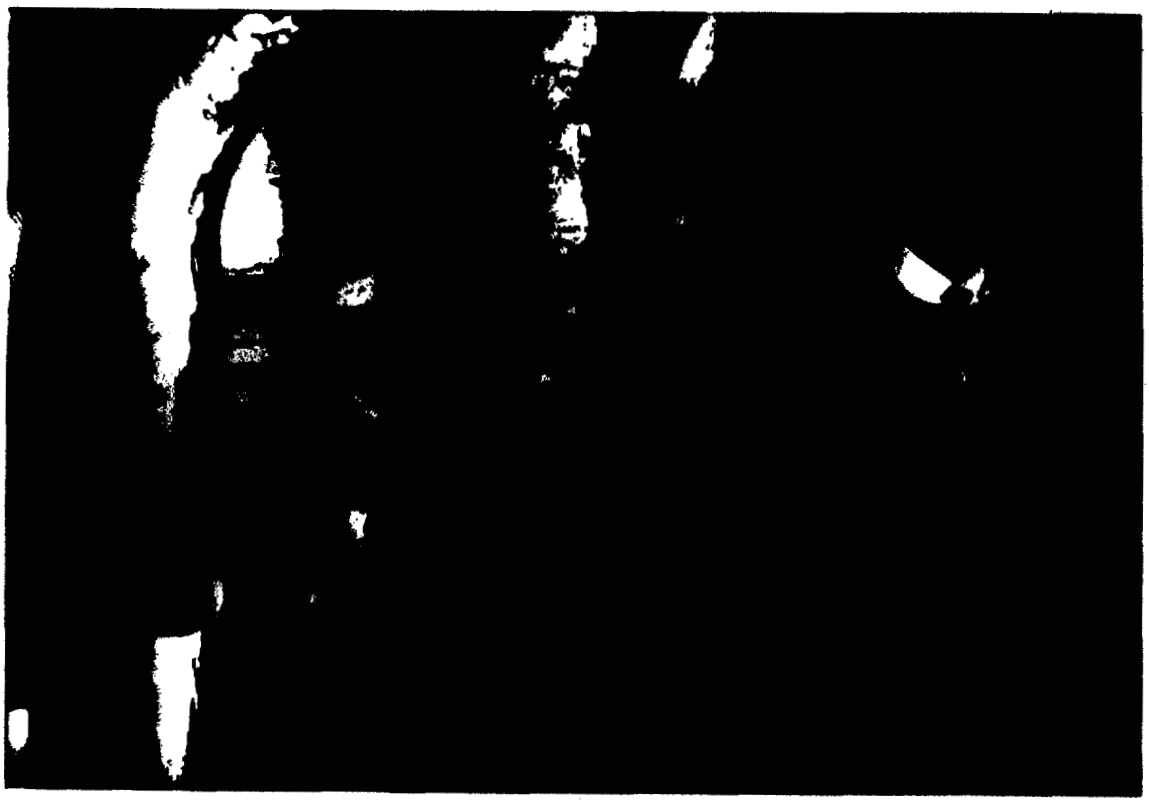
APPENDIX D II



Wheel Furnace Zone 5 Oxygen Analyzer Location

APPENDIX D III



Wheel Furnace Burner Gas and Air Feed

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