



GE Power Generation

cc: ~~B.H. Rodriguez~~
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February 23, 1993

Mr. Charles D. Garing
City of Lakeland- Larsen Power Plant
2002 U.S. Hwy. 92 East
Lakeland, Florida 33801

Subject: Air Permit Modification for Humidity Correction Formula

Dear Chuck:

Attached you will find a copy of Mr. Ron Pavris' letter and report on the above subject matter.

If I can be of any further assistance please, do not hesitate to call me at (813) 286-4829.

Leo Molina
Manager-Engineering Services

Att.

cc: Al Dodd/COL ←
D. Shultz/B&V
L. Webb/B&V

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THE DEVELOPMENT OF CONTROL ALGORITHMS FOR
CONTROLLING NO_x ON GE HEAVY-DUTY GAS TURBINES

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R.E. Pavri
Schenectady, NY
November, 1988

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I. INTRODUCTION

Since the early 1970's, with the promulgation of the Clean Air Act, all gas turbine manufacturers installing machines in the USA have had to develop and implement methods to control NO_x emissions from their turbines. The method most widely used is diluent (water or steam) injection in the flame zone of the combustor. To meet the New Source Performance Standards (NSPS), (Ref.1) simple methods were developed which relied on controlling the direct diluent injection as a function of fuel flow rate. As the codes became progressively more stringent, controls algorithms had to be developed to minimize the effect of diluent injection on hardware integrity, combustion stability, and other emissions.

The purpose of this document is to describe the basis of GE's control algorithm and how it is used in conjunction with the turbine instrumentation to limit NO_x to a specified limit.

II. BACKGROUND

In any combustion process involving air, oxides of nitrogen (NO_x) are formed. NO_x formed from oxidation of free molecular nitrogen in the combustion air or fuel is called thermal NO_x. For a given combustion system, thermal NO_x is primarily a function of combustor residence time and the adiabatic flame temperature of the fuel which is the temperature reached by burning a theoretically correct mixture of fuel and air in an insulated vessel.

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Since the early 1970's, with the promulgation of the Clean Air Act, all gas turbine manufacturers installing machines in the USA have had to develop and implement methods to control NOx emissions from their turbines. The method most widely used is diluent (water or steam) injection in the flame zone of the combustor. To meet the New Source Performance Standards (NSPS), (Ref.1) simple methods were developed which relied on controlling the direct diluent injection as a function of fuel flow rate. As the codes became progressively more stringent, controls algorithms had to be developed to minimize the effect of diluent injection on hardware integrity, combustion stability, and other emissions.

The purpose of this document is to describe the basis of GE's control algorithm and how it is used in conjunction with the turbine instrumentation to limit NOx to a specified limit.

II. BACKGROUND

In any combustion process involving air, oxides of nitrogen (NOx) are formed. NOx formed from oxidation of free molecular nitrogen in the combustion air or fuel is called thermal NOx. For a given combustion system, thermal NOx is primarily a function of combustor residence time and the adiabatic flame temperature of the fuel which is the temperature reached by burning a theoretically correct mixture of fuel and air in an insulated vessel.

The following general relationships exist between diffusion flame combustor operating conditions and thermal NOx production:

- NOx increases directly with fuel/air ratio
- NOx increases exponentially with combustor inlet air temperature
- NOx increases approximately as the square root of combustor inlet pressure
- NOx decreases exponentially as the total moisture of the combustion air increases, either because of specific humidity of the inlet air, steam injection, or water injection.

The current industry accepted method for abating thermal NOx formation is to reduce the combustor flame temperature by introducing a thermal heat sink into the flame zone. Water or steam are extremely effective at achieving this goal within limits. A penalty in overall efficiency must be paid for the additional fuel required to heat the water or steam to combustor temperature, although gas turbine output is enhanced because of the additional mass flow through the turbine. There are practical limits to the amount of water or steam that can be injected into a standard single fuel nozzle diffusion flame combustor before operating problems develop. The practical limits are determined by:

- Combustor dynamic pressure oscillations
- Carbon monoxide emissions
- Combustor operating stability
- Combustor flame blow-off and/or blow-out (flame extinguished)

Dynamic pressure oscillations occur in all diffusion flame combustors and are produced by the combustion process. Dynamic pressures can be defined as pressure oscillations within the combustor. These dynamic pressures can couple with the combustor acoustic mode and be amplified, thus causing increasing mechanical wear rates of the combustion system hardware. Injection of water or steam to reduce NOx will further increase the dynamic pressure oscillations. (Ref.2). Dynamic pressure limits have been empirically established by field measurement and parts' life experience for GE machines. Exceeding these dynamic pressure limits will impact the recommended maintenance intervals for the combustor hardware.

As more and more water or steam is added to the combustor, a point is reached at which a sharp increase in carbon monoxide is observed. This sharp increase in CO indicates that the combustor efficiency is beginning to decrease. On liquid fuels, as more diluent is injected, CO will begin to increase leading to combustor stability problems and if enough diluent is injected, the flame will be extinguished. On gaseous fuels, once a sharp increase in CO begins because of high diluent injection, further increases also lead to the flame being extinguished.

III. NOx CONTROL TO NSPS LEVEL

In September 1979, the EPA promulgated the NSPS for stationary gas turbines for NOx emissions. By then, GE had developed the diluent injection method of controlling gas turbine exhaust NOx to proper levels as dictated in the NSPS. This diluent is injected into the flame zone of the combustor which reduces the flame temperature and hence, thermal NOx.

The NSPS NOx code as per Subpart GG of 40CFR60 (Ref. 2) but written in British units is:

$$NOx_a = 75(13652/Y) + F \quad \text{III-1}$$

NOx_a = Allowable NOx in PPMVD @ 15% O₂

Where Y = Manufacturers' rated Heat Rate (HR) in Btu/KWH

F = Allowance for fuel bound nitrogen

It also required that the measured NOx, after HR adjustment, be adjusted to ISO standard day conditions by the following ambient condition correction factor (correct form).

$$NOx_{iso} = NOx_{obs} \left[\frac{P_{ref}}{P_{obs}} \right]^{0.5} e^{19(H_{obs} - .00633) \left[\frac{288}{T_{amb}} \right]^{1.53}} \quad \text{III-2}$$

Where:

NOx_{iso} = emissions of NOx at 15 percent oxygen and ISO standard ambient conditions.

NOx_{obs} = measured NOx emissions at 15 percent oxygen, PPMV.

P_{ref} = reference combustor inlet absolute pressure at 101.3 kilopascals ambient pressure, PSIA.*

P_{obs} = measured combustor inlet absolute pressure at test ambient pressure, PSIA.*

H_{obs} = specific humidity of ambient air at test, lbs. water/lbs. air.

e = transcendental constant (2.718).

T_{amb} = temperature of ambient air at test, °K

* The units on pressure terms are not defined in Ref. 1. They may be different than PSIA but must be consistent for both terms.

For the MS6001B, MS7001EA and MS9001E, the HR correction increases the allowable NOx to the 90-100 PPMVD range. The amount of steam injection to meet these levels of NOx on a typical MS6001B on natural gas or distillate oil fuels is shown in Figure 1.

The ISO adjustment allows the measured, raw NOx value from a gas turbine exhaust to be either above or below the required value. For an MS6001B on natural gas, the required NOx with HR adjustment is 95 PPMVD. On a day with ambient temperature of 100°F, 60% relative humidity and a normal barometric pressure of 14.7 PSIA, the required NOx with ISO correction is 74 PPMVD. If the ambient temperature is 80°F with relative humidity of 20% and again a normal barometric pressure of 14.7 PSIA, the required NOx is 105 PPMVD.

As discussed earlier, diluent injection can have detrimental effects on gas turbine operations. Even though the ISO adjustment can require the measured raw NOx to be below the required value, the amount of steam/water injection to meet it is relatively low and experience has shown it to have minimal effect on other turbine operating parameters. Consequently, a simple algorithm was developed to control only the injected steam/water into the combustor as a function of fuel flow rate. A single control line of diluent (steam/water) injection flow rate vs. fuel (gas/oil) flow rate was developed. Figure 2 shows a typical control curve for a standard MS6001B for NOx control to the NSPS level for steam injection with gas fuel. In algebraic form, this curve is:

$$S_r = m(F - F_o) + S_{min} \quad \text{III-3}$$

S_r = Required steam flow, lbs/sec

F = Fuel flow, lbs/sec

F_o = Fuel flow offset, lbs/sec

m = Steam/gas slope

S_{min} = Minimum steam flow, lbs/sec

$$S = S_r + S_o \quad \text{III-4}$$

S = Actual steam flow, lbs/sec

S_o = Steam flow offset, lbs/sec

See Figures 2 and 5 for the definition of fuel flow offset. The steam flow offset is the minimum controllable steam flow. This is set by valve tolerances and control instrument sensitivity. A typical value of S_o is 0.3 lbs/sec. Once this curve is adjusted (if necessary) after the field test, demonstrating compliance is relatively simple. It only requires that actual diluent injection flow be higher than that called for by the curve at the measured fuel flow. A dedicated controls routine in the gas turbine control system has a standard "Wet Low NOx Display" which helps the customer in keeping records to demonstrate compliance. A brief description of Wet Low Nox Display is given in Figure 3.

IV. NOx CONTROL FOR MORE STRINGENT NOx CODES (e.g., NOx = 42 PPMVD @ 15% O₂)

As the NOx codes, in Japan and California, became more stringent in the early 1980's, it became apparent that a more complex control mechanism would be necessary to meet the lower NOx emissions limits (e.g. 42 PPMVD @ 15% O₂) and yet strike the balance to maintain the turbine hardware integrity and keep CO emissions manageable.

Figure 1 also shows the estimated steam injection required to meet NOx = 42 PPMVD @ 15% O₂ (no corrections) on gas and NOx = 65 PPMVD @ 15% O₂ (no corrections) on oil for a typical MS6001B. At or below this level of NOx, the effect of diluents entering the combustion reaction zone from any source on combustor dynamics, stability, flame blow-off, turbine hardware life, and CO emissions cannot be neglected as it could at the higher NSPS level. Starting with the sale of MS6001B to Crown-Zellerbach (now Gaylord Container Corp. in Antioch, California) in late 1981 (commercial operation December, 1982), a new control algorithm was developed to control the diluent injection into the combustor. In essence, this algorithm accounts for all sources of diluent(s), viz.

1. Direct combustor head-end steam or water injection
2. Water vapor as inlet humidity that enters the gas turbine compressor inlet
3. Power augmentation steam (if present) added to the compressor discharge.

IV A. ALGORITHM DERIVATION

The technical basis of the non-NSPS NOx control algorithm is the NSPS ISO correction, viz:

$$\frac{NOx_{iso}}{NOx_{obs}} = \left[\frac{P_{ref}}{P_{obs}} \right]^{0.5} \cdot e^{19(H_{obs} - .00633) \left[\frac{T_{amb}}{288} \right]^{-1.53}} \quad (1)$$

Within the usual range of ambient conditions, the pressure correction term is usually 5% or less and is neglected. With this assumption and using T_{amb} in °R, equation (1) becomes:

$$\frac{NOx_{iso}}{NOx} = e^{19(H - .00633) \left[\frac{T_{amb}}{519} \right]^{-1.53}} \quad (2)$$

Where NOx = NOx_{obs}; H = H_{obs}

$$\text{Now } \frac{T_{amb}}{519} = 1 + \frac{T_{amb} - 519}{519} \quad (3)$$

$$\text{Then } \left[\frac{T_{amb}}{519} \right]^{-1.53} = \left[1 + \frac{T_{amb} - 519}{519} \right]^{-1.53}, \text{ which by series expansion}$$

$$\approx 1 - \frac{1.53}{519} (T_{amb} - 519)$$

$$\approx 1 - .00295 (T_{amb} - 519) \quad (4)$$

Expressing temperature in °F, Equation (2) then becomes:

$$\frac{\text{NOx}_{\text{iso}}}{\text{NOx}} = e^{19(H-.00633) [1-.00295(\text{Tamb}-59)]} \quad (5)$$

The natural logarithm of Equation (5) gives:

$$\ln \frac{\text{NOx}_{\text{iso}}}{\text{NOx}} = 19 (H-.00633) + \ln [1-.00295(\text{Tamb}-59)] \quad (6)$$

Since the term .00295 (Tamb -59) is of the order of ± 1 , and the $\ln[1-.00295 (\text{Tamb} -59)]$ is also of the order of ± 1 , Equation (6) simplifies to:

$$\ln \frac{\text{NOx}_{\text{iso}}}{\text{NOx}} = 19 (H-.00633) -.00295 (\text{Tamb} -59) \quad (7)$$

Equation (7) shows the variation in NOx due to changes in the ambient temperature and humidity.

As discussed earlier, injecting any diluent into the flame of a diffusion flame combustor exponentially reduces thermal NOx (Ref 2). Figure 4 shows the effect of steam/water injection on thermal NOx for typical GE heavy-duty gas turbines. In mathematical form, these curves could be written as:

$$\text{RNOx}_s = e^{-m_s (s/F)} \quad \text{for steam injection} \quad (8)$$

$$\text{RNOx}_w = e^{-m_w (w/F)} \quad \text{for water injection} \quad (9)$$

Where:

- RNOx = Ratio of $\frac{\text{NOx with diluent injection}}{\text{NOx without diluent injection}}$
- S = Steam flow, lbs/sec
- F = Fuel flow, lbs/sec
- W = Water flow, lbs/sec
- m_s = Slope of the steam injection line
- m_w = Slope of the water injection line

Since energy is required to vaporize liquid water, it is a more effective diluent in lowering the combustion temperature, than steam and $m_w > m_s$

In logarithmic form, Equations (8) and (9) become:

$$\ln \text{RNOx}_s = -m_s (s/F) \quad (10)$$

$$\ln \text{RNOx}_w = -m_w (w/F) \quad (11)$$

Equations (10) and (11) show the variation in NOx due to steam and water injection respectively.

Equating Equations (10) or (11) to (7) shows the necessary variation in injected steam or water as the ambient humidity and temperature deviates from humidity = .00633 lbs water/lbs dry air and 59°F (standard reference conditions).

Equating (10) to (7):

$$-m_s \left(\frac{s}{F} \right) = 19 (H - .00633) - .00295 (T_{amb} - 59) \quad (12)$$

$$\text{or } \frac{s}{F} = \frac{.00295 (T_{amb} - 59) - 19 (H - .00633)}{m_s} \quad (13)$$

Similarly, equating (11) to (7):

$$\frac{w}{F} = \frac{.00295 (T_{amb} - 59) - 19 (H - .00633)}{m_w} \quad (14)$$

Lab and field tests have shown that the typical value of $m_s = 1.06$ and $m_w = 1.58$ for GE heavy-duty gas turbines. Substituting $m_s = 1.06$ in Equation (13) gives:

$$\frac{s}{F} = .0028 (T_{amb} - 59) - 17.95 (H - .00653) \quad (15)$$

Adding Equation (15) to the NSPS control curve (Equation III-3) gives:

$$S_R = m (F - F_o) + F [.0028 (T_{amb} - 59) - 17.95 (H - .0063)] + S_{min} \quad (16)$$

Equation (16) shows how the required steam injection must vary with ambient humidity and temperature to hold NOx at a preset value, e.g., 42 PPMVD @ 15% O₂.

For those turbines where power augmentation steam is present, its contribution towards NOx abatement must be accounted for. The general form of Equation (16) reads:

$$S_R = m (F - F_o) + F [.0028 (T_{amb} - 59) - 17.95 (H - .0063)] + S_{min} - q S_p \quad (17)$$

Where S_p = Power augmentation steam flow, lbs/sec
 q = Fraction of power augmentation steam flow entering the flame zone.

Equation (17) is THE algorithm that is used to control the steam injection flow on all GE heavy-duty gas turbines that must meet NOx levels less than the NSPS.

Note that the actual steam flow is higher than required steam flow from Equation (17) by the steam flow offset, S_o .

For water injection, the equation is:

$$W_R = m' (F - F_o) + F [.0019 (T_{amb} - 59) - 12 (H - .0063)] + W_{min} - q (ms/mw) S_p \quad (18)$$

$$\text{and } W = W_R + W_o \quad (19)$$

W_R = Required water flow, lbs/sec

W_{min} = Minimum water flow, lbs/sec

W = Actual water flow, lbs/sec

W_o = Water flow offset, lbs/sec

Other terms are the same as for steam injection.

The algorithm for steam injection is shown in the graphical form in Figure 5a-5c. Figure 5a shows the very strong effect of humidity on a high ambient temperature day. On cold days, e.g. 30°F, where the specific humidity is very low, the ambient humidity effects are negligible, Figure 5b. The ambient temperature effects are quite sizable and are shown in Figure 5c.

All GE manufactured gas turbines come equipped with documentation on control specifications which show in detail (among other things), the NOx control algorithm. The specification shows the algorithm in controls language, and Figure 6 compares the algebraic terms of the algorithm with the controls language terms and also shows typical values of the constants.

IV B. Special Instrumentation

Since the NOx control algorithm needs inputs for turbine inlet humidity and temperature, all GE gas turbines that control NOx to these levels are equipped with:

- Inlet humidity sensor.
- Inlet temperature sensor.

Included in the Appendix A are typical arrangement drawings which show the standard locations of these sensors. Appendix A also contains literature on the humidity sensor describing the scientific principle behind it. Specifications on the inlet temperature sensor are also included.

IV C. Demonstrating Compliance

It is important to recognize that the NOx control algorithm is no longer a single curve but a family of curves depending on the ambient conditions. However, demonstrating compliance is still straightforward. Appendix B shows the steps necessary to demonstrate compliance.

The GE control system "Wet Low NOx Display" again helps the customer's record keeping on showing continuous compliance. The required steam/water flow is now compensated for ambient humidity and temperature.

IV D. Field Experience

Starting with the Crown Zellerbach (now Gaylord Container Corp.) MS6001B which began commercial operation in 1982 in Antioch, California, there are 48 GE gas turbine units operating, installed or shipped (as of the end of 1988) that control NOx using this algorithm. All these units have to meet stringent NOx codes with either water or steam injection. Some units also have power augmentation steam. A list of these units is given in Appendix C.

The field experience, mostly in California, has clearly proven that the algorithm works in maintaining the NOx at or below the required value. Appendix D includes actual data, as reported to the local air district, demonstrating continuous compliance with the permit NOx limit over a number of different ambient temperature conditions and humidity.

REFERENCES

1. Code of Federal Regulations, Title 40, Article 60, Subpart GG.
2. E.J. Walsh, "GE Heavy-Duty Gas Turbine Multiple-Combustion System" GER 3435A.

EFFECT OF STEAM INJECTION ON NO_x CONTROL

MS6001B/STANDARD COMBUSTION SYSTEM

<u>NO_x</u> (PPMVD)	<u>GAS</u>	<u>OIL</u>
	<u>S/F</u>	<u>S/F</u>
NSPS		
95	.4	—
94	—	.88
42	1.16	—
65	—	1.20

NO_x IN PPMVD @ 15% O₂

S = STEAM FLOW LBS/SEC

F = FUEL FLOW LBS/SEC

FIGURE 1

TYPICAL

PG6541(B)
STEAM INJECTION COMPLIANCE CURVE
EPA 75 PPMVD NO_x (NSPS)

Notes: 1. Control Curve set 1000 lb/h above Compliance Curve

2. To adjust curve to site elevation multiply Heat Consumption and Steam Injection by the altitude correction factor $\left(\frac{\text{site bar. press.}}{14.7 \text{ psia}} \right)$ and redraw curve.

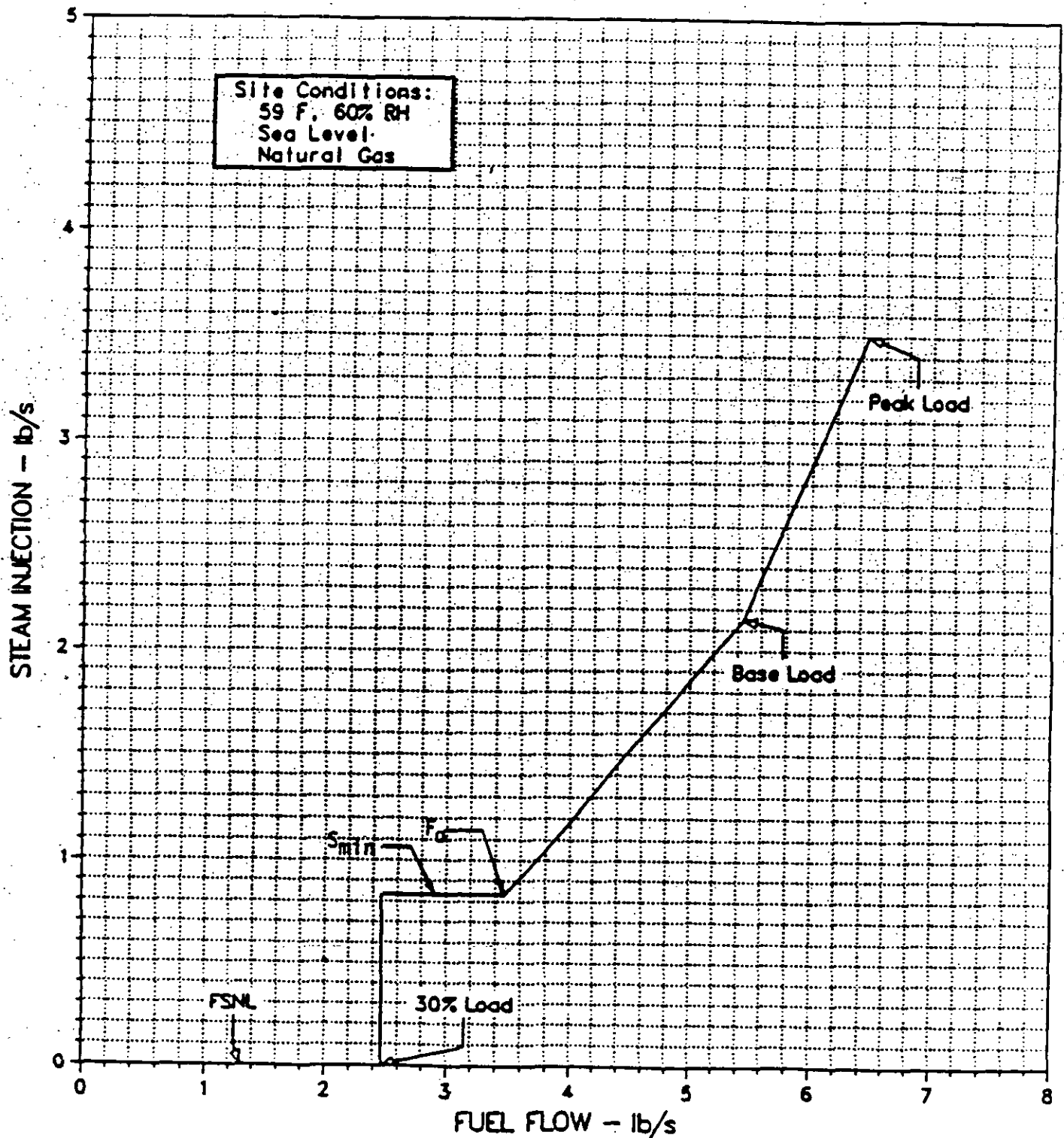


FIGURE 2

a. NET LOW NOx DISPLAY

DATA LIST 07 displays the data required to verify the compliance with low nitrous oxide emission regulations.

This data list consists of the hourly average and the minute averages.

Each set of data, which is displayed on one line, consists of the following:

- Date and Time of the average calculation
- Average Fuel Flow: for example, GAS FUEL LBS/SEC
- Average Injection Flow: for example, STEAM LBS/SEC
- Average Actual Injection to Fuel Ratio: labeled ACTUAL RATIO
- Average Required Injection to Fuel Ratio: labeled REQUIRED RATIO
- Average Ambient Temperature: DEG F or DEG C

1. The minute average is the average of the inputs during each minute and is calculated when:

- the NET LOW NOx control is enabled.

DATA LIST 07 displays the last 10 sets of minute averages with the latest data at the top of the list.

2. The hourly average is the average of the last 60 minute averages and is calculated each minute when:

- NET LOW NOx control is enabled and
- Qty. 60 minute averages have been accumulated.

DATA LIST 07 displays the last calculated hourly average which consists of one set of data.

- Net Low NOx Display

DATA LIST 07					
NET LOW NOx DATA			14 MAR 84 20:29:26		
HOUR AVERAGE TIME	GAS FUEL LBS/SEC	STEAM LBS/SEC	ACTUAL RATIO	REQUIRED RATIO	AMBIENT TEMP°F
14 MAR 84 20:29:00 MINUTE AVERAGES TIME	5.000	1.000	0.200	0.190	75
	GAS FUEL LBS/SEC	STEAM LBS/SEC	ACTUAL RATIO	REQUIRED RATIO	AMBIENT TEMP°F
14 MAR 84 20:29:00	5.000	1.000	0.200	0.190	75
14 MAR 84 20:28:00	5.000	1.000	0.200	0.190	75
14 MAR 84 20:27:00	5.000	1.000	0.200	0.190	75
14 MAR 84 20:26:00	5.000	1.000	0.200	0.190	75
14 MAR 84 20:25:00	5.000	1.000	0.200	0.190	75
14 MAR 84 20:24:00	5.000	1.000	0.200	0.190	75
14 MAR 84 20:23:00	5.000	1.000	0.200	0.190	75
14 MAR 84 20:22:00	5.000	1.000	0.200	0.190	75
14 MAR 84 20:21:00	5.000	1.000	0.200	0.190	75
14 MAR 84 20:20:00	5.000	1.000	0.200	0.190	75

FIGURE 3

TYPICAL CURVE OF
 NO_x ABATEMENT WITH DILUENT INJECTION
GE HEAVY DUTY GAS TURBINES

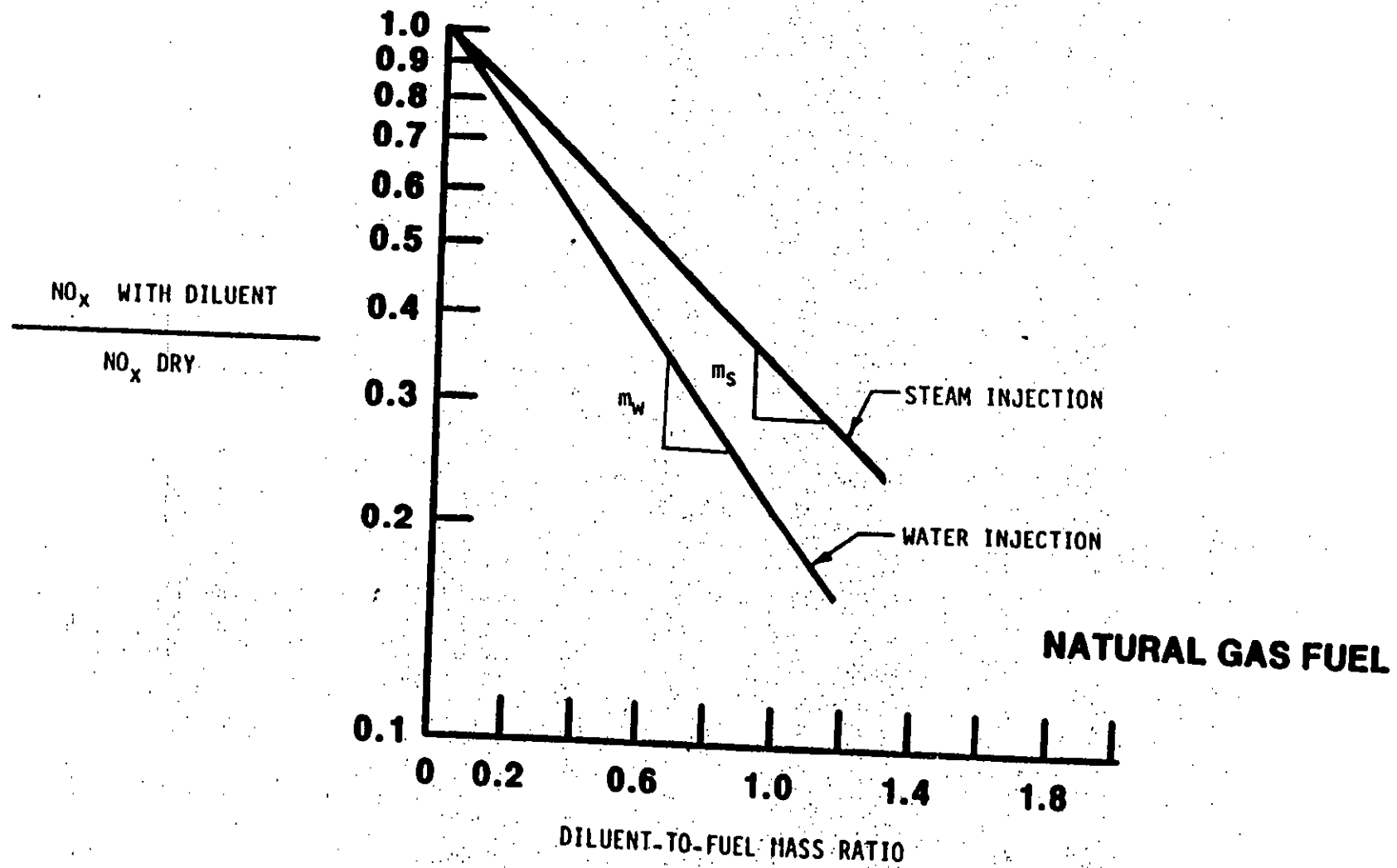


FIGURE 4

TYPICAL

GENERAL ELECTRIC - PG6541(B) GAS TURBINE STEAM TO FUEL FLOW SCHEDULE

STEAM INJECTION TO LIMIT NO_x TO 42 PPMVD @ 15% O₂

FUEL: NATURAL GAS
ELEVATION: SEA LEVEL

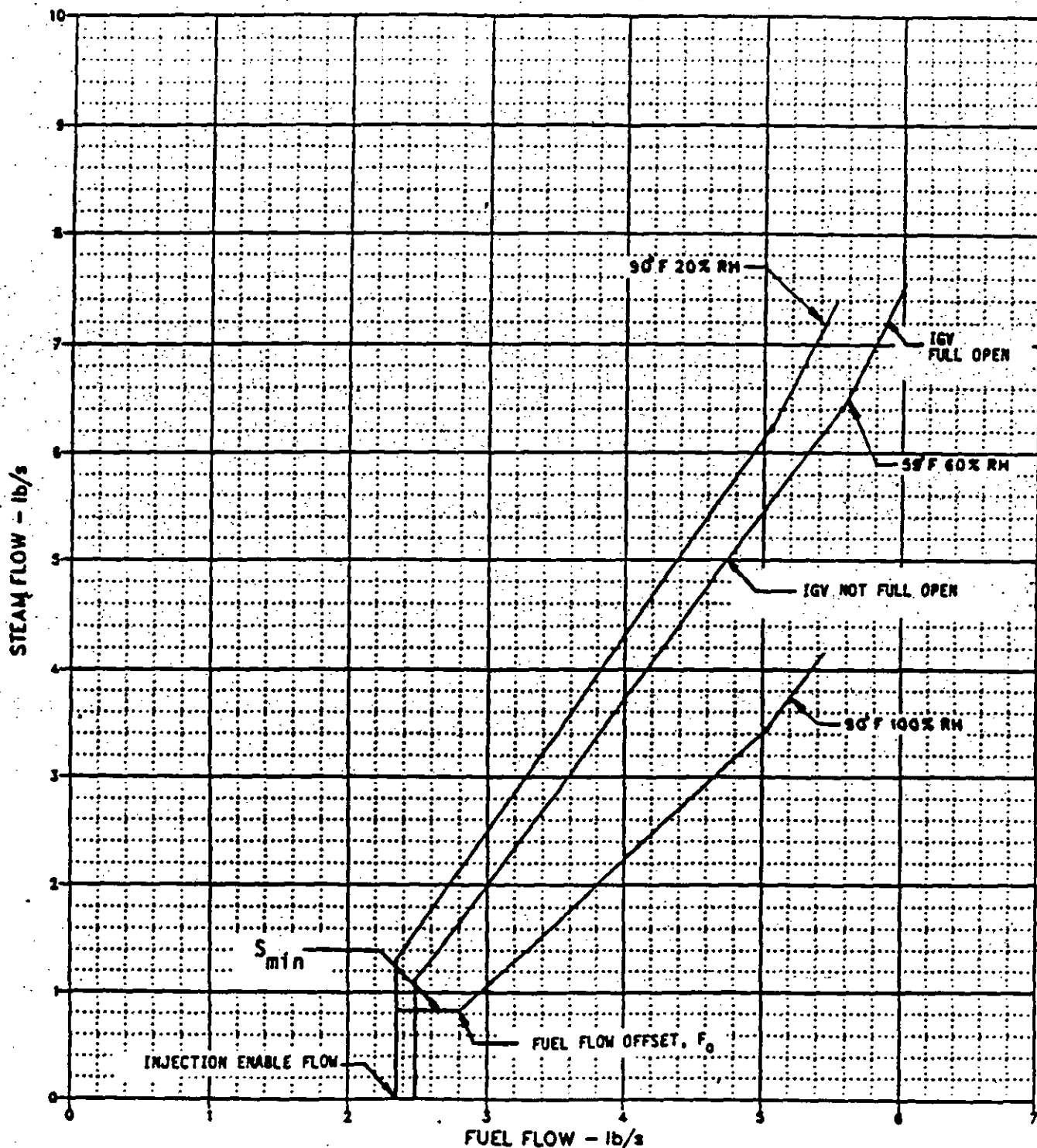


FIGURE 5a

TYPICAL

GENERAL ELECTRIC - PG6541(B) GAS TURBINE STEAM TO FUEL FLOW SCHEDULE

STEAM INJECTION TO LIMIT NO_x TO 42 PPMVD @ 15% O₂

FUEL: NATURAL GAS
ELEVATION: SEA LEVEL

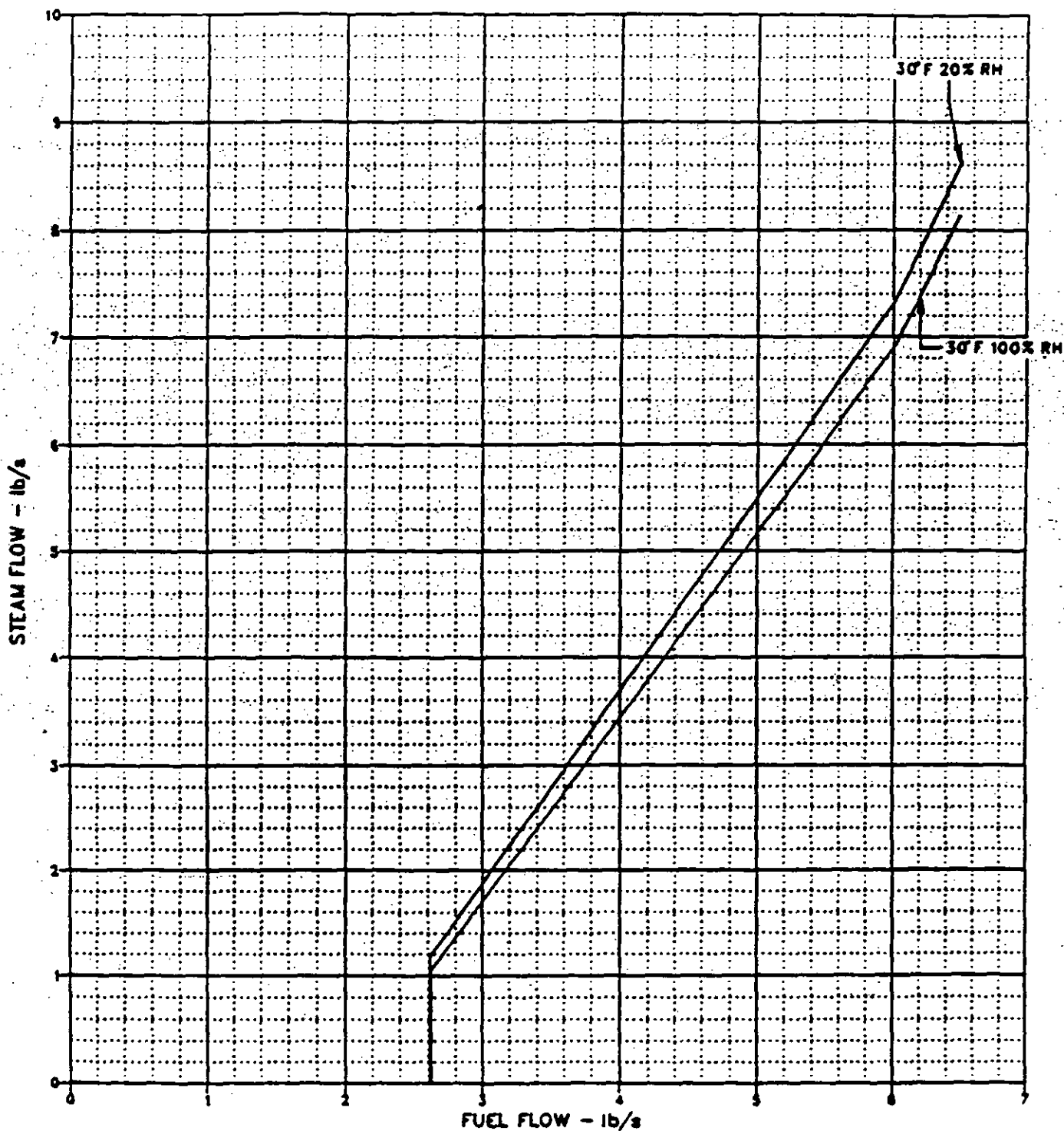


FIGURE 5b

TYPICAL

GENERAL ELECTRIC - PG6541(B) GAS TURBINE STEAM TO FUEL FLOW SCHEDULE

STEAM INJECTION TO LIMIT NO_x TO 42 PPMVD @ 15% O₂

FUEL: NATURAL GAS
ELEVATION: SEA LEVEL

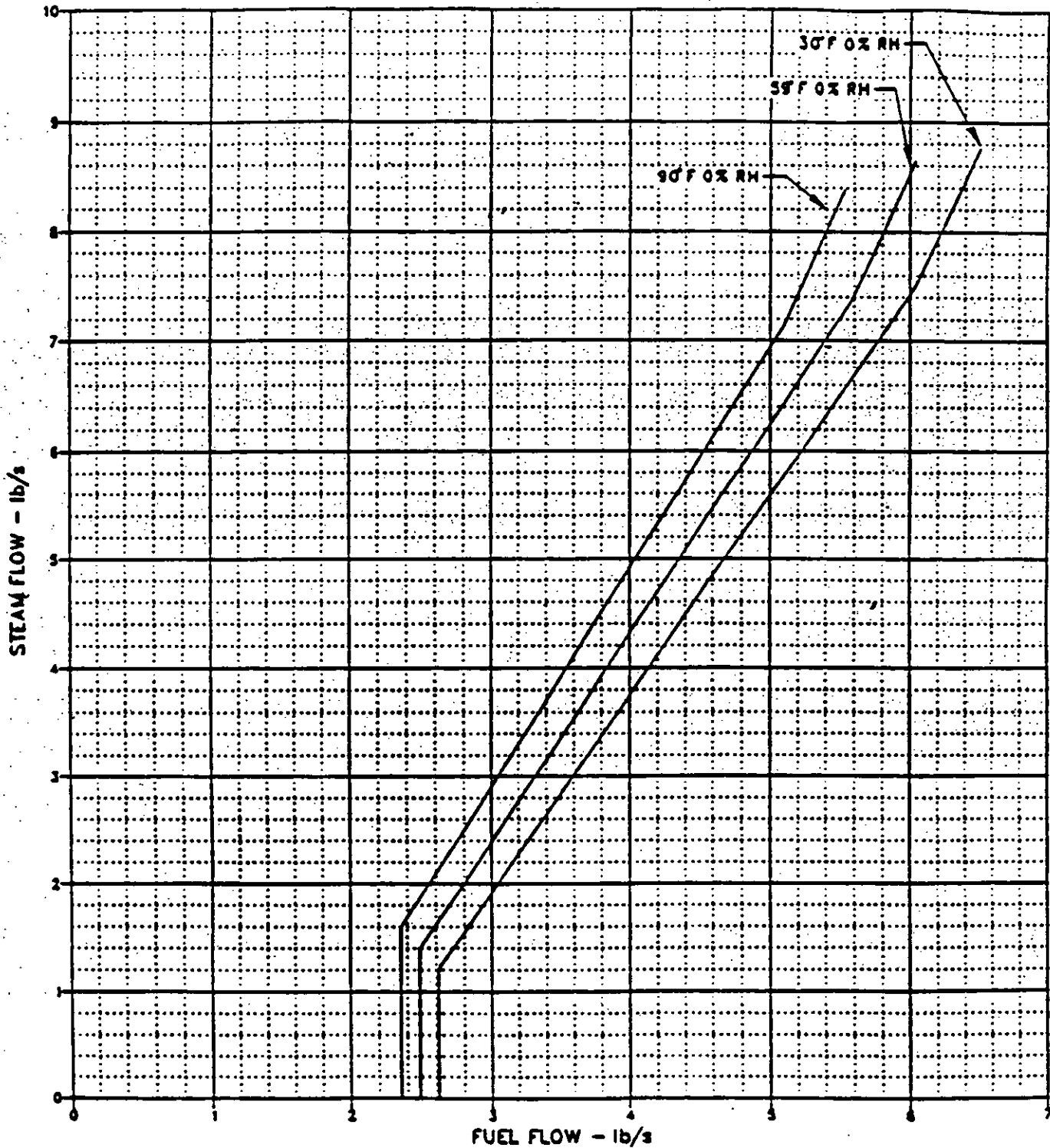


FIGURE 5c

STEAM INJECTION FLOW REFERENCE
ALGORITHM: MK4_WQRV1_01 STM/INJ

REQUIRED STEAM FLOW IS SCHEDULED AS A FUNCTION OF FUEL FLOW, WITH COMPENSATION FOR AMBIENT TEMPERATURE (CTIM), SPECIFIC HUMIDITY (CMHUM), AND IF USED, POWER AUGMENTED STEAM FLOW (WQKn_A).

THE EQUATION FOR THE REQUIRED STEAM FLOW USED IS BASED ON:

$$SR = [F-F_0]m + F[.0028(T_{amb}-59) - 17.95(H-.0063)] + S_{min} - q(Sp)$$

IN MKIV, THIS BECOMES:

$$WQR = [FQT - WQKn_B]WQKn_K + FQT[WQKn_T(CTIM-59F) - WQKn_H(CMHUM - 0.0063)] + WQKn_N - (WQKn_A) WQJA$$

WHERE: FQT = F, TOTALIZED GAS FUEL FLOW (LB/SEC)
CMHUM = H, SPECIFIC HUMIDITY (LB WATER/LB AIR)
CTIM = T_{amb}, AMBIENT TEMPERATURE (DEG F)
WQR = SR, STEAM FLOW REF. (LB/SEC)

NOTE: WQKn_*, WHEN n=0; GAS FUEL < LK83WK1 SELECT L83WK0
WQKn_*, WHEN n=1; GAS FUEL > LK83WK1 SELECT L83WK1

INITIAL CONTROL SPEC SETTINGS ARE PREDICTED FOR THE ALLOWED EMISSIONS LEVEL. AS EMISSIONS TEST DATA IS AVAILABLE, CONSTANTS SHOULD BE READJUSTED TO COMPLY WITH REQUIREMENTS. HOWEVER, IN THE INTEREST OF MINIMIZING GAS TURBINE MAINTENANCE COSTS, INJECTION CONTROL CURVES SHOULD BE SET TO REDUCE EMISSIONS NO MORE THAN 10% BELOW ALLOWABLE.

x

WATER INJECTION FLOW REFERENCE
ALGORITHM: MK4_WQRV1_01 H2O/INJ

REQUIRED WATER FLOW IS SCHEDULED AS A FUNCTION OF FUEL FLOW, WITH COMPENSATION FOR AMBIENT TEMPERATURE (CTIM), SPECIFIC HUMIDITY (CMHUM), AND IF USED, POWER AUGMENTED STEAM (WQKn_A).

THE EQUATION FOR THE REQUIRED WATER FLOW IS BASED ON:

$$WR = [F-F_0]m' + F[.0019(T_{amb}-59) - 12(H-.0063)] + W_{min} - q(m_s/m_w)Sp$$

IN MKIV THIS BECOMES:

$$WQR = [FQT - WQKn_B]WQKn_K + FQT[WQKn_T(CTIM-59) - WQKn_H(CMHUM - 0.0063)] + WQKn_N - WQJA(WQKn_A).$$

WHERE: WQR = WR, REQUIRED WATER FLOW (LB/SEC)
FQT = F, TOTALIZED FUEL FLOW (LB/SEC)
CMHUM = H, SPECIFIC HUMIDITY (LB WATER/LB AIR)
CTIM = T_{amb}, AMBIENT TEMPERATURE DEG F

NOTE: WQKn(n)_ : n=0 (GAS OR MIXED FUEL L83WK0)
WQKn(n)_ : n=1 (LIQUID FUEL ONLY SELECT L83WK1)

FIGURE 6a: ALGORITHM DEFINITION

NAME		TYPICAL VALUE		UNITS	DESCRIPTION
MKIV	ALGEBRAIC	6001B	7001EA		
WQKO_A	q	0.265	0.265	##	POWER AUG. STEAM CORRECTION
WQKO_B	Po	2.200	5.470	#/SEC	FUEL FLOW OFFSET
WQKO_E		1.80	4.910	#/SEC	INJECTION ENABLE FLOW
WQKO_H		17.950	17.950	##/H	HUMIDITY CORRECTION COEFF.
WQKO_K	ms	1.700	1.6120	RATIO	STEAM/GAS SLOPE
WQKO_N	Smin	1.000	3.110	#/SEC	MINIMUM INJECTION FLOW LIMIT
WQKO_T		0.0028	0.00280	/P	AMB. TEMPERATURE CORRECTION COEFF.
WQKR3	So	0.300	0.300	#/SEC	ADJ. STEAM FLOW OFFSET

NOTES

1. These values are typical. Each unit in the field has its site specific values.
2. The MKIV algorithm includes protective limiting values for maximum and minimum on many parameters as well as logic switching points.
3. The water/gas slope changes depending on the position of the inlet guide vanes (2 values of the slope). Values of these constants differ depending on the slope.

FIGURE 6b: TYPICAL VALUES FOR STEAM INJECTION

NAME	ALGEBRAIC	TYPICAL VALUE		UNITS	DESCRIPTION
		6001B	7001BA		
WQKO_A	$q(\text{mg/m}^2)$	0.1778	0.1778	##	AUG STM RATIO INTO FLAME
WQKO_B	F_o	2.20	5.470	#/SEC	FUEL FLOW OFFSET
WQKO_E		1.80	4.900	#/SEC	INJECTION ENABLE FLOW
WQKO_H		12.000	12.000	##/H	HUMIDITY CORRECTION COEFF.
WQKO_K	m'	1.334	1.1700	RATIO	WATER/GAS SLOPE
WQKO_N	W_{\min}	1.000	1.000	#/SEC	MINIMUM INJECTION FLOW LIMIT
WQKO_T		0.00190	0.00190	/F	AMB. TEMPERATURE CORRECTION COEFF.
WQKR3	W_o	0.300	0.300	#/SEC	ADJ. WATER FLOW OFFSET

NOTES

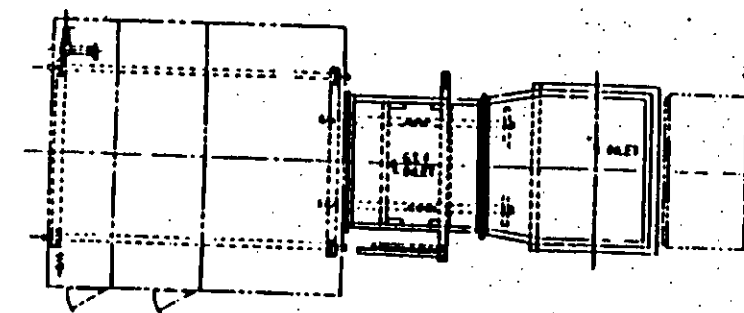
1. These values are typical. Each unit in the field has its site specific values.
2. The MKIV algorithm includes protective limiting values for maximum and minimum on many parameters as well as logic switching points.
3. The water/gas slope changes depending on the position of the inlet guide vanes (2 values of the slope). Values of these constants differ depending on the slope.

FIGURE 6c: TYPICAL VALUES FOR WATER INJECTION

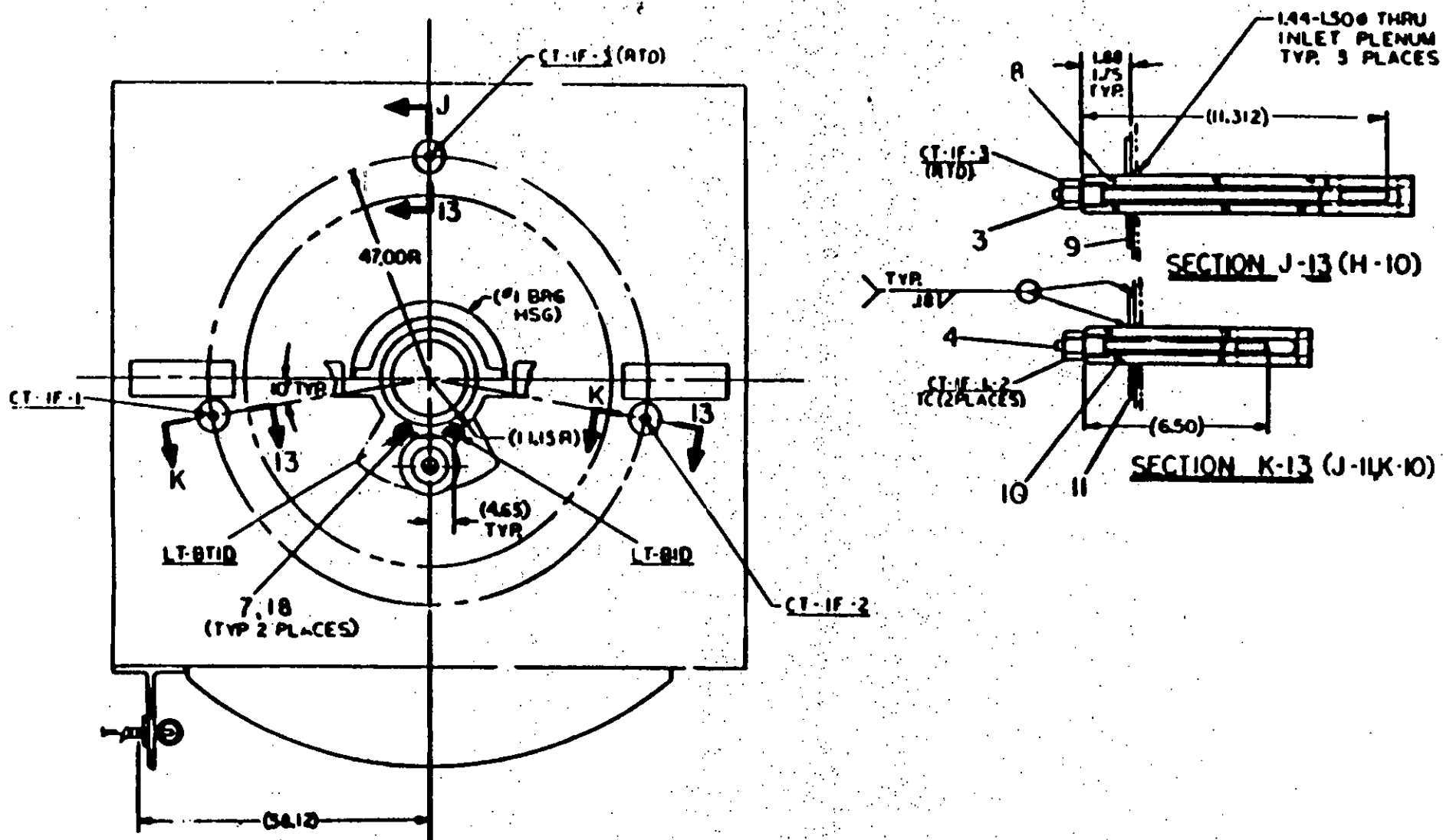
APPENDIX A

INLET HUMIDITY & TEMPERATURE SENSORS

STANDARD LOCATIONS & SPECS.



Item	Part No.	Qty.
1	101-2440	1
2	101-2441	1
3	101-2442	1
4	101-2443	1
5	101-2444	1
6	101-2445	1
7	101-2446	1
8	101-2447	1
9	101-2448	1
10	101-2449	1
11	101-2450	1
12	101-2451	1
13	101-2452	1
14	101-2453	1
15	101-2454	1
16	101-2455	1
17	101-2456	1
18	101-2457	1
19	101-2458	1
20	101-2459	1
21	101-2460	1
22	101-2461	1
23	101-2462	1
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25	101-2464	1
26	101-2465	1
27	101-2466	1
28	101-2467	1
29	101-2468	1
30	101-2469	1
31	101-2470	1
32	101-2471	1
33	101-2472	1
34	101-2473	1
35	101-2474	1
36	101-2475	1
37	101-2476	1
38	101-2477	1
39	101-2478	1
40	101-2479	1
41	101-2480	1
42	101-2481	1
43	101-2482	1
44	101-2483	1
45	101-2484	1
46	101-2485	1
47	101-2486	1
48	101-2487	1
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373	101-2812	1
374	101-2813	1



TURBINE INLET
(Looking from front).

FIGURE A2: STANDARD ARRANGEMENT FOR INLET TEMPERATURE SENSOR

Infrared System Detects Condensation, Icing Conditions

Instrument uses infrared bandwidth with selective absorption properties to give fast, accurate dew point measurements

E. J. Stefanides, Central States Editor

Sterling Heights, MI—A new anti-ice and absolute moisture control system protects gas turbines and large antennas from condensation and ice. This system uses an infrared method of dew point measurement that is very accurate and insensitive to the effects of contamination, ambient light, and environmental temperature excursions. Its method of operation is based on the fact that certain bands within the infrared spectrum are absorbed by water. There is in fact

one band, the 935 nanometer band, whose absorption is exclusively limited to water. The system generates and detects moisture by generating and monitoring infrared energy of this band's wavelength.

The system is a patent-protected development of the Environmental & Process Controls Company. It includes an electronic controller, a sensor unit, and a connecting cable. The sensor generates conditions that cause a moisture film to be produced then dissipated; and mea-

sures the temperatures at which the moisture appears and disappears. It also measures ambient temperature. The electronic controller contains logic for control of the sensor and interpretation of the temperature data. It also provides for digital display of the temperatures, and furnishes a relay contact-type output signal. The output signal activates ancillary equipment, which provides the actual protection against formation of condensation or ice.

The sensor is a box-like structure with an air opening that includes a thermomodule, a Light Emitting Diode(LED), a phototransistor, and two matched thermistors. The thermomodule contains a solid-state thermocooler and one of the two thermistors. The hot side of the thermocooler is fixed to the sensor housing, and uses the housing as a heat sink. The cold side is equipped with a reflective surface that is part of the infrared optical system. The thermistor is embedded beneath this attached reflective surface, and measures its temperature. The other thermistor is either installed

Sensor contains infrared monitoring system with LED and phototransistor, and thermomodule with reflective surface.

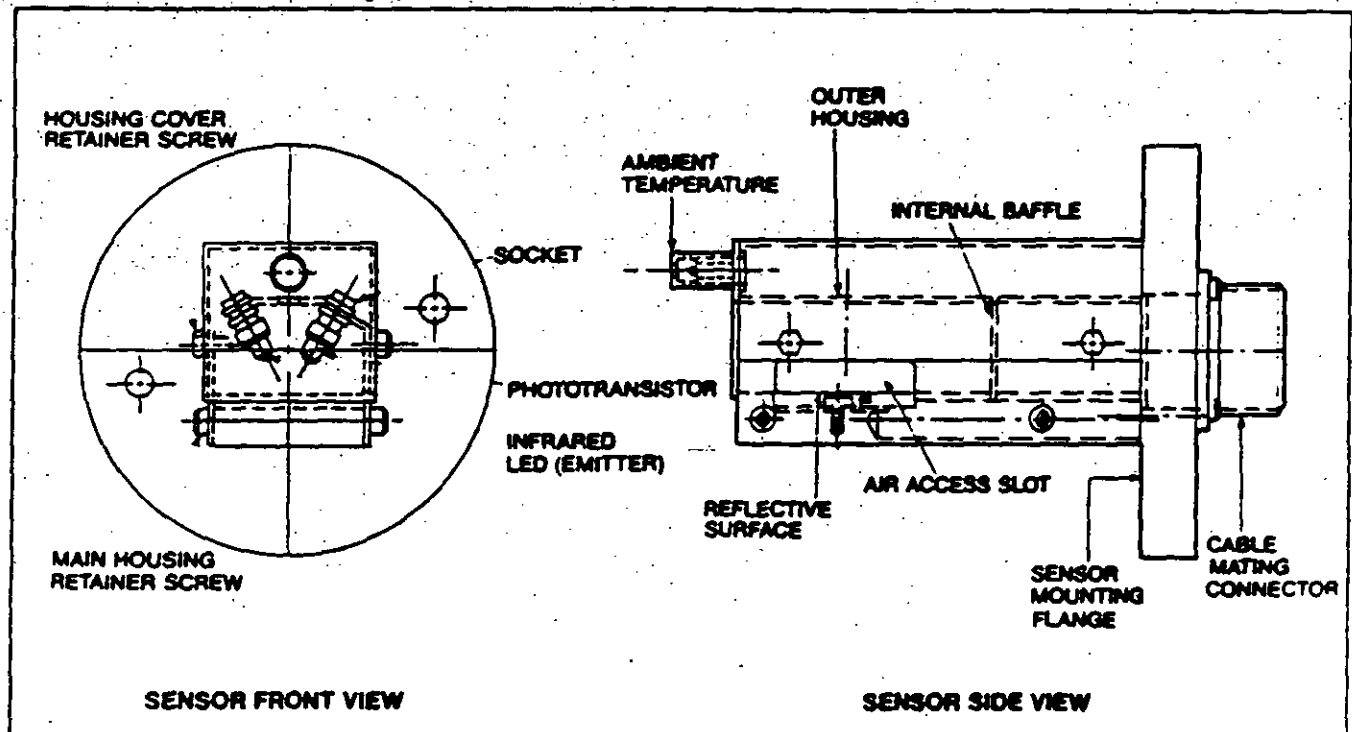


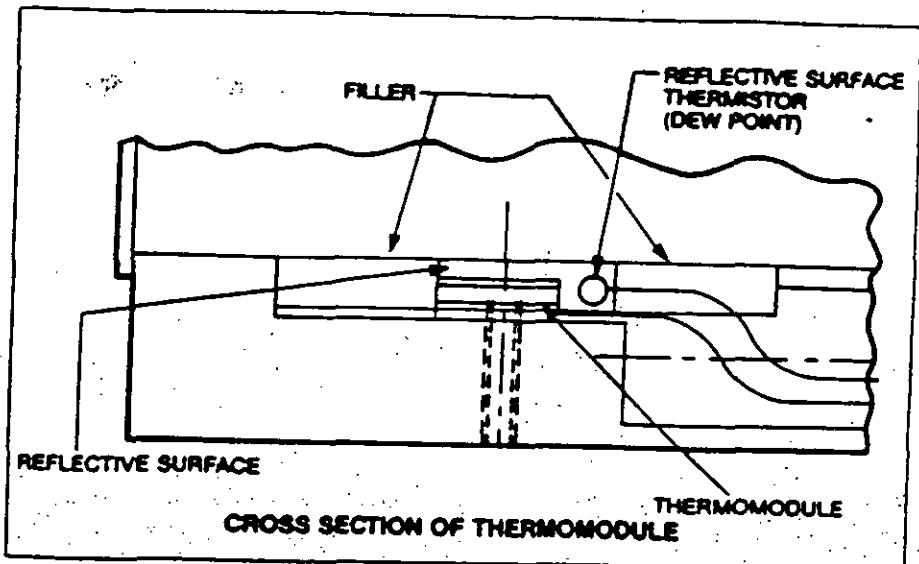
FIGURE A3: INLET HUMIDITY SENSOR

on the exterior of the sensor housing, or when possible, is mounted on the surface of the protected equipment.

The LED and photo transistor are selected to and applied in a manner that causes them to operate in the 935 nanometer band. They are located in the housing, and are inclined at 30-deg angles to and are focused on the reflective surface. This arrangement is such that virtually all the infrared energy emitted by the LED is reflected to and impinges on the phototransistor.

In operation, the thermomodule in the sensor is turned on by the electronic logic within the controller. Its activation produces a chilling effect, which causes a thin film of dew or condensation to accumulate on the attached reflective surface. The thin film of moisture absorbs all of the infrared energy emitted by the LED. This absorption eliminates reflection of any infrared energy to the phototransistor, causing it to be turned off. The turnoff signal informs the electronic controller that moisture is present on the reflective surface.

The phototransistor's turnoff signal, indicating the presence of moisture, produces two related actions. It activates the circuit that receives input from the reflective surface's embedded thermistor, causing it to



Thermomodule allows chilling and heating of reflective surface, has embedded thermistor.

begin monitoring the temperature of that surface. Also, it stops flow of current to the thermomodule, thereby allowing warming of the reflective surface.

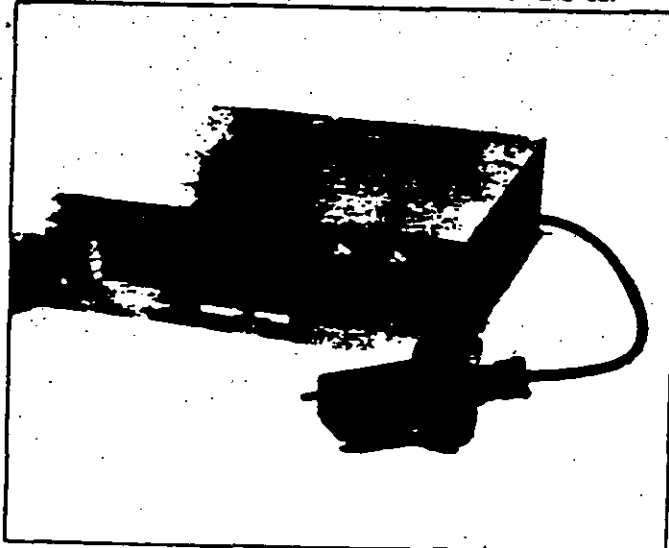
As the reflective surface warms, its moisture film is quickly dissipated, causing the phototransistor to turn back on. This turn on signal also produces two related actions. It causes the thermistor circuit's monitoring of the reflective surface's temperature to be temporarily terminated. Also, it causes current to flow to the thermomodule, producing a chilling effect for the next measuring cycle.

The monitoring of the tempera-

ture of the reflective surface furnishes the data for the dew point determination. The dew point is taken as an average of the temperatures at which moisture appears and disappears. The difference between these two temperatures is usually less than 0.5F; so a very accurate, high-resolution dew point temperature measurement is obtained.

The instrument's second thermistor circuit measures ambient or surface (of the protected equipment) temperature. The dew point temperature and ambient or surface temperature measurements, are available within the instrument in both digital and analog form. The

System detects conditions that cause condensation and ice.



Sensor's solid-state components generate/dissipate moisture film.

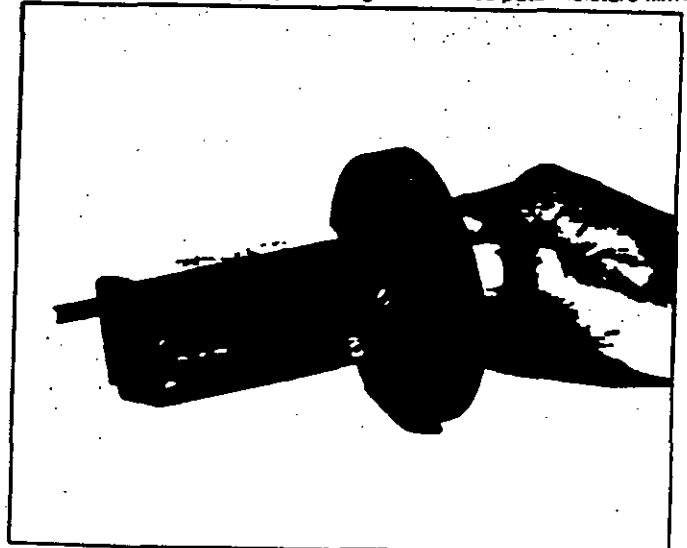


FIGURE A3 (Continued)

INFRARED SYSTEM

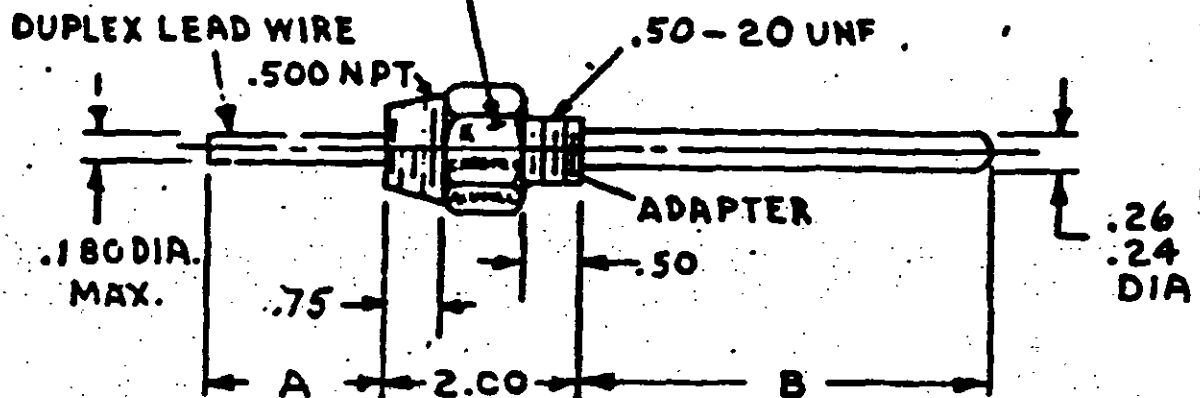
digital form allows their selectable readout on an LED digital display unit on the front panel of the controller. The analog form allows their use by logic that provides control and alarm functions. The instrument also includes circuitry for digital storage of the two readings, and for output of these readings and control signals to a computer or other microprocessor-based control unit.

In systems used for protection against ice, detection of conditions that cause formation of ice is obtained from data processing provided by a pair of comparator circuits. One circuit compares the ambient temperature to a reference signal that corresponds to the 41F ambient temperature, at which ice formation becomes a threat. This circuit is activated by an ambient temperature of 41F or less, and arms the second comparator circuit. The second circuit compares ambient and dew point temperatures, and is activated when dew point temperatures are 4F lower than ambient temperature. This activation provides warning and control outputs, which indicate that conditions for formation of ice exist. The control signals activate devices that protect against ice, and are provided by a control relay built into the controller.

The controller logic also provides for generation of a dry cycle. It is used at startup and periodically to remove moisture or ice from the reflective surface. During the dry cycle, the polarity of current supplied to the thermocooler is reversed to heat the reflective surface. To facilitate readout and control functions during this interval, the previous temperature readings are stored in the controller's memory. Additional details . . . Contact Environmental & Process Controls Co., 35523 Dunston Dr., Sterling Heights, MI 48077, 313-979-4512.

FIG. #1

STAMP DWG. PART & REV. NOS.,
TYPE & CALIBRATION, MFG, AND
DATE ON THIS SURFACE.

**REQUIREMENTS:**

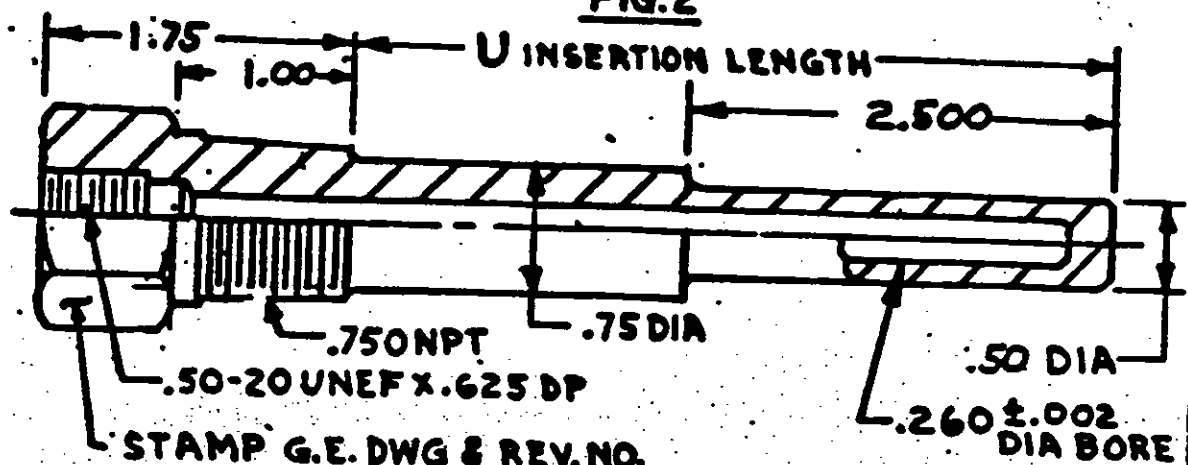
1. Thermocouple must be of swaged construction using #321 or 347 STN. Steel sheath, inert high temperature insulation (MgO or approved equal) Chromel-Alumel thermocouple wires, ISA calibration "K", B & S #22 gage or larger.
2. Lead wires shall be Chromel-Alumel B & S #18 gage or larger stranded thermocouple wire with insulation good for 1000° F service ISA calibration "K", Chromel-yellow (+), Alumel-red (-), with hot junction insulated.
3. Splice between thermocouple & lead must be protected from mechanical damage due to abrasion & lead wire stresses.
4. Adapter to be of .875 Hex Stainless Steel.
5. Thermocouple & well P1 thru 60 to be provided as one unit.
6. Insulation resistance between the sheath and either wire of the T/C shall not be < 5 megohms using a 100 volt megger.

This may be purchased from: Lewis Engineering Co.
550 Spring St.
Naugatuck, Conn. 06770
or

Meco Inc.
1401 South Marshall
Paris, Illinois 61944
' or equal

FIGURE A4: INLET TEMPERATURE SENSOR

FIG. 2



STAMP G.E. DWG & REV. NO.
AND FIG. NO. ON HEX.
SIMILAR TO STD. SERIES W602 (LEWIS ENG. CO.)
MATERIAL 304 STAINLESS STEEL.

APPENDIX B

DEMONSTRATING COMPLIANCE FOR NO_x LESS THAN NSPS

To check-out the NOx control algorithm and certify the gas turbine for proper compliance requires several steps.

1. Gas Turbine Start-up and Check-out

The first step is go through all the start-up checks and have the unit up and running. The turbine must be checked out for proper operation up to full load. This step usually requires several weeks.

2. Diluent Injection System Check-out

The steam/water injection system needs to be checked before injection into the turbine. For water injection, most of the equipment is usually on a skid and must be checked for proper calibration, feedback, etc.

If the turbine is equipped with steam injection, the steam generator has to be up and running. All steam lines must be blown out, traps checked and controls set.

3. Instrumentation Calibration

All instrumentation must be properly calibrated. This includes exhaust thermocouples, inlet humidity and temperature sensors, all flow meters (fuel and diluent) etc.

4. Software Checks

The software needs to be checked for proper feedback commands, set points, etc. One way to do this is to type in representative values of the parameters and checking the output.

5. Set-up and Check-out of Emissions Equipment

The emissions test vendor is charged to perform this function. Depending on the contract, the vendor is hired by GE or the customer.

This step requires setting up and calibrating the emissions measurement trains as specified in the permit. Special protocol has to be followed in gathering the sample exhaust gas, processing it and its measurement to the required accuracy.

All test vendors are quite familiar with these procedures.

6. Preliminary Emissions Test

The next step is to run a preliminary emissions test. The test must duplicate accurate operating conditions and the data needs to be gathered at the required loads specified in the permit. The diluent injection system should be in manual mode. The exhaust gases could be sampled from only one location.

During the test, the diluent flow may need to be adjusted manually to meet the required NOx.

The data to be recorded:

- a. Gaseous Emissions: NOx, CO, etc. (as required in the permit)
- b. Exhaust O₂
- c. Ambient Conditions: Temperature, humidity, pressure
- d. Machine Parameters: Output, exhaust temperature, fuel flow, steam/water flow, fuel heating valve (LHV), exhaust gas flow rate (if required)

7. Adjust Control Constants

From the new data of step 6, the required steam flow at reference conditions is calculated using the algorithm. This is the steam flow vs. fuel flow reference line that meets the permitted NOx. If the constants of the original controls setting differ from the values calculated from the test data, these constants must be readjusted.

8. Retest to Check the Adjusted Constant(s)

The adjusted algorithm must be rechecked across the load range to validate the changes. The test procedure is similar to step 6, except the controls are in auto (not manual) mode.

9. Compliance Test

The next step is to perform the official compliance test. Again, the test vendors are usually quite familiar with all the protocols and test procedures.

10. Compliance Test Report

The test vendor prepares the test report using proper procedures.

11. Continuous Compliance

The Wet Low NOx Display is available on all turbines to assist the customer in monitoring and recording the continuous NOx compliance requirement. The required diluent flow is automatically compensated for ambient humidity and temperature.

APPENDIX C

GE HEAVY DUTY GAS TURBINES OPERATING OR SHIPPED

(as of the end of 1988)

USING THE NO_x CONTROL ALGORITHM AS DESCRIBED
IN THIS DOCUMENT FOR CONTROLLING NO_x LESS THAN NSPS

SHIPPING DATE	NAME LOCATION (# UNITS)	FUEL USED	DILUENT	NOx PPMVD
<u>MS7001</u>				
1984	FLUOR/KRCC BAKERSFIELD, CA (4)	NG OIL	WTR	42 (1) 42
1986	FLUOR/SYCAMORE BAKERSFIELD, CA (4)	NG OIL	WTR	42 42
1986	GILROY FOODS * GILROY, CA (1)	NG OIL	STM	25 55
1987	FLUOR/ARCO WATSON, CA (4)	NG BUT	STM	42 65
1988	ENCOGEN SWEETWATER, TX (2)	NG	STM	42
1988	HARBOR COGEN/CHAPLIN TORRANCE, CA (1)	NG	WTR	42
1988	MIDWAY SUNSET COGEN * TAFT, CA (3)	NG OIL	WTR	25 42
1988	BASIC AMERICAN FOODS KING CITY, LA (1)	NG OIL	STM	42 65
1988	SMITH/FIRESTONE OKLAHOMA CITY, OK (1)	NG	STM	42
1988	HSPE/TENASKA PARIS, TX (2)	NG OIL	STM	42 65
<u>MS6001</u>				
1982	CROWN ZELLERBACH (GAYLORD CONTAINER) ANTIOCH, CA (1)	NG OIL	STM STM	42 65
1984	INLAND CONTAINER ONTARIO, CA (1)	NG OIL	WTR WTR	42 65
1986	CHEVRON EL SEGUNDO, CA (2)	NG BUT PROP	STM STM STM	42 65 65
1986	KAISER/GE SAN JOSE, CA (1)	NG OIL	STM STM	42 65
1986	UNIVER. ENERGY TAFT, CA (1)	NG	WTR	42
1986	CARDINAL COGEN PALO ALTO, CA (1)	NG OIL	STM STM	42 (1) 65

SHIPPING DATE	NAME LOCATION (# UNITS)	FUEL USED	DILUENT	NOx PPMVD
------------------	----------------------------	--------------	---------	--------------

MS6001 (cont.)

1987	ANR VENTURE HARTFORD, CT (1)	NG OIL	STM STM	42 62
1987	KOCH REFINARY CORPUS CHRISTI, TX (1)	NG RG	STM STM	42 65
1988	CELANESE BISHOP, TX (1)	NG OIL	STM STM	42 65
1988	ENCOGEN SWEETWATER, TX (1)	NG	STM	42
1988	EXXON CHEM CO BAYTOWN, TX (3)	NG	STM	42
1988	FINA OIL CO PORT ARTHUR, TX (1)	NG RG	STM STM	50 65
1988	ORLANDO UTILITIES INDIAN RIV, FL (2)	NG	STM	50
1988	PRITCHARD/TEXACO BAKERSFIELD, CA (1)	NG	WTR	42
1988	CAIN CHEMICAL CORPUS CHRISTI, TX (1)	NG OIL	STM	42 65

MS5001

1985	CITY OF SANTA CLARA SANTA CLARA, CA (2)	NG OIL	WTR WTR	42PPM 42PPM
1985	TURLOCK IRRIGATION DIST. TURLOCK, CA (2)	NG OIL	WTR WTR	42PPM 65PPM
1987	MOBIL TORRANCE TORRANCE, CA (1)	NG PROP	STM STM	42PPM 42PPM
1988	MERCK, SHARP, DOHME WEST POINT, PA (1)	NG OIL	WTR WTR	45PPM 45PPM

NG = Natural Gas
RG = Refinery Gas
BUT = Butane
PROP = Propane
STM = Steam
WTR = Water

* = Utilize Multiple Nozzle Quiet Combustor

(1) = Data showing continuous compliance is included in Appendix D

APPENDIX D

FIELD DATA, AS REPORTED TO THE LOCAL AIR DISTRICT DEMONSTRATING
CONTINUOUS COMPLIANCE WITH THE PERMIT NO_x LIMIT.

1. CARDINAL COGEN (MS6001B)

Attached here is the field data from Cardinal Cogen which has a MS6001B installed on the campus of the Stanford University. The emissions test was done in June 1988. This gas turbine is controlled to 42 PPMVD NOx @ 15% O₂ using the algorithm described here.

Cardinal Cogen is a special case. Their fuel contract with the supplier allows the fuel quality to vary at certain times. The customer also has a continuous exhaust monitor (CEM) installed in the stack as mandated by the BAAQMD. The customer is using the CEM to economize their plant operation by minimizing their steam injection. This is done manually..

It is important to recognize that the algorithm described here allows the customer to meet NOx compliance but not necessarily "economize" the steam flow. The Cardinal Cogen CEM provides a means to operate at the absolute minimum steam injection. If the fuel quality is significantly changing and the customer wants to optimize the steam flow manually, the constants in the algorithm have to be retuned. GE has designed an automatic system to do this which does not require retuning the constants. Such a system is in operation at several California sites.

The field data is a copy of the Emissions Report filed with the BAAQMD for the months of August and September, 1988. As is evident, the algorithm controls the gas turbine NOx below 42 PPMVD. In those few incidences (4 in 2 months) when the NOx exceeded 42 PPMVD (maximum variation is 3% or less), the cause was either the variation of the fuel gas composition or the excess occurred during start-up.

2. KERN RIVER COGENERATION COMPANY (4 X MS7001E)

This appendix also includes the field data from KRCC which has four MS7001E installed outside of Bakersfield, CA. NOx level is 140 lbs/hr (42 PPMVD @ 15% O₂) on natural gas and oil with steam injection. The data clearly shows that the NOx algorithm is controlling the gas turbines below the permit value.

Also included are the letters from Kern County Air Pollution Control District confirming that the units meet all applicable permits on the annual compliance tests for years 1987 and 1988.

Cardinal Cogen

a joint venture

Serra CoGen, Inc.

A Subsidiary of General Electric Company

Raymond Energy Inc.

A Subsidiary of Kaiser Engineers Inc.

October 13, 1988

BAAQMD
939 Ellis Street
San Francisco, CA 94109

Attn: Gale Karels

Subject: Emissions Report - August
Plant No. 1629

Dear Mr. Karels:

Attached is Cardinal Cogen's "Monthly Emissions Report" for August, 1988. This is the first monthly report submitted by Cardinal Cogen so we appreciate any comments your department may have concerning its content and format.

We realize this report is overdue and apologize for any inconvenience this may have caused BAAQMD. Our delay was caused by problems with extracting emissions data from our computer's archive storage system. We're confident this problem won't occur again.

Very Truly Yours,



Steven Mansperger
Instrument Technician

cc: A. Brush
O. Juvier
R. Paterson
F. Vilece
File 10.10

C A R D I N A L C O G E N
M O N T H L Y E M I S S I O N S R E P O R T

I. SOURCE GENERAL INFORMATION

1. Source S-5 Duct Burner and S-6 Gas Turbine
2. Address Cardinal Cogen
Building 14-105, Stanford University
Stanford, CA. 94305-4114
3. Phone Number (415) 723-3890
4. Affected Facility
5. Person Completing Report:

Steven Mansperger

Signed: 

Date: 10-13-88

This is to certify that, to the best of my knowledge, the information provided on these forms is correct and accurate.

6. Person Responsible for review and integrity of report:

Randal Peterson

Signed: 

Title: Facility Engineer

Date: Oct 13, 1988

II. CONTINUOUS EMISSION MONITOR INFORMATION

1. Manufacturer:	Horiba	Horiba	Horiba
2. Model No. :	VIA-500F	PMA200F	VIA-500F
3. Serial No. :	561749011	702008	561749012
4. Basis for Gas Measurement:		Dry	
5. Averaging Time :		6 minutes	
6. Corrected to % Oxygen :		15 %	
7. Zero/Span Values :			
	NOX	O2	CO
Zero	0 ppm	0 %	0 ppm
Span	98.55	20.9 %	94.4

8. Date of last Performance Test : 7-27-88
9. Performance Specification Test : 7-27-88
10. Total Operating Time of Source
During Reporting Period (minutes) : 20,133

CARDINAL COGEN
MONTHLY EMISSIONS REPORT

Operating Permit 304
Plant No. 16
Source S-5 Duct Burn.
Source S-6 Gas Turbi

Date	NOx Daily Ave. Emissions (Corrected ppm)	NOx Max. Hrly Emissions (Corrected ppm)	NOx Daily Mass Emissions (Lbs per Day)	Gas Turb Fuel Use Daily Ave. (SCFM)	Duct Burn. Fuel Use Daily Ave. (SCFM)	Duct Burn. Operating Time (Min.)	Stm/Fuel Ratio Daily Ave
8-17-88	40	43	1,140	7,571	872	217	1.093
8-18-88	36	38	1,046	7,589	864	186	1.120
8-19-88	36	59	967	7,044	841	66	1.154
8-20-88	37	39	1,058	7,532	835	2	1.099
8-21-88	38	40	1,099	7,600	NA	0	1.109
8-22-88	37	39	1,075	7,519	860	183	1.137
8-23-88	38	39	1,084	7,544	863	199	1.100
8-24-88	38	40	1,102	7,516	875	218	1.093
8-25-88	36	41	1,063	7,474	877	227	1.085
8-26-88	33	40	848	7,464	838	6	1.077
8-27-88	37	39	1,063	7,516	NA	0	1.078
8-28-88	38	39	1,060	7,527	NA	0	1.077
8-29-88	38	41	1,089	7,454	845	109	1.081
8-30-88	39	41	1,104	7,412	843	65	1.069
8-31-88	39	40	1,116	7,477	844	105	1.076

NOTES:

1. NOx emission limit with duct burner and gas turbine operating together is 40 ppm corrected to 15% oxygen. When the gas turbine is operating without the duct burner, this limit is 42 ppm corrected to 15% oxygen.
2. Emissions reporting starts on 8-17-88, the day written notification of Cardinal Cogen's successful completion of the Performance Specification Test was received from BAAQMD.
3. The duct burner is generally used daily between 6AM - 11 AM to meet Campus heating steam demands.

CARDINAL COGEN MONTHLY EMISSIONS REPORT

STATEMENT OF EXCESS EMISSIONS

Excess stack emissions occurred during the month of August, 1988, as listed below:

Date	Time	NOx Excess Emissions (PPM, 1 Hr. Average, Corrected to 15 % O2)	Fuel Firing		Corrective Action	Remarks
			Oil	Gas		
8-17-88	0100	42.5		x	Retuned Steam	
	1300	43.3		x	Injection Control	
	1400	42.2		x	Constants	
8-19-88	2000	38.7		x	None	Occurred at low load during startup after a unit trip. Below load injection starts.

There were no exceedences during this reporting period.

CENS CORRECTIVE ACTION REPORT

Parameter	Date & Time		Duration	Date & Time		Corrective Action	District Dispatcher Notification		
	Inoperative Condition Began			Inoperative Condition Ended			Yes/No	Date	Time
NOx Analyzer	8-25-88 @ 1700		.5 hr	8-25-88 @ 1730		Problems occurred during Zero calibration. Retuned calibration circuitry.	No		

Significant changes in the monitoring system since
the last Performance Test:

Yes ☒ No

Signed: HMY Date: 10-13-88
Title: INSTRUMENT TECH

CARDINAL COGEN
MONTHLY EMISSIONS REPORT

PLANT OPERATING RECORD
.....

Date	Time Off Line	Time On Line	Reason for Shutdown
8-19-88	1757	2155	Control System Fault

Comments : _____

Cardinal Cogen

a joint venture

Serra CoGen, Inc.

A Subsidiary of General Electric Company

Raymond Energy Inc.

A Subsidiary of Kaiser Engineers Inc.

October 25, 1988

BAAQMD
939 Ellis Street
San Francisco, CA 94109

Attn: Gale Karels

Subject: Emissions Report - September
Plant No. 1629

Dear Mr. Karels:

Attached is Cardinal Cogens's "Monthly Emissions Report" for September 1988.

Since we have not heard from you regarding the August Report, we are submitting this report in the same format.

Please notify us if you have any questions or comments.

Very Truly Yours,



Steven Mansperger
Instrument Technician

cc: A. Brush
O. Juvier
R. Paterson
F. Vilece
R. Boericke
File 10.10

C A R D I N A L C O G E N
M O N T H L Y E M I S S I O N S R E P O R T

I. SOURCE GENERAL INFORMATION

1. Source S-5 Duct Burner and S-6 Gas Turbine
2. Address Cardinal Cogen
Building 14-105, Stanford University
Stanford, CA. 94305-4114
3. Phone Number (415) 723-3890
4. Affected Facility
5. Person Completing Report:

Steven Mansperger

Signed:

Steven Mansperger

Date:

Oct 25, 1988

This is to certify that, to the best of my knowledge, the information provided on these forms is correct and accurate.

6. Person Responsible for review and integrity of report:

Randall Peterson

Signed:

Randall Peterson

Title: Facility Engineer

Date:

Oct 25 1988

II. CONTINUOUS EMISSION MONITOR INFORMATION

- | | | | |
|-------------------------------|-----------|-----------|-----------|
| 1. Manufacturer: | Horiba | Horiba | Horiba |
| 2. Model No. : | V1A-500F | PMA200F | V1A-500F |
| 3. Serial No. : | 561749011 | 702008 | 561749012 |
| 4. Basis for Gas Measurement: | | Dry | |
| 5. Averaging Time : | | 6 minutes | |
| 6. Corrected to % Oxygen : | | 15 % | |
| 7. Zero/Span Values : | | | |

	NOX	O2	CO
Zero	0 ppm	0 %	0 ppm
Span	98.55	20.9 %	94.4

8. Date of last Performance Test : 7-27-88
9. Performance Specification Test : 7-27-88
10. Total Operating Time of Source
During Reporting Period (minutes) : 42,957

CARDINAL COGEN
MONTHLY EMISSIONS REPORT

Operating Permit 30
Plant No. 1
Source S-5 Duct Burn
Source S-6 Gas Turb

Date	NOx Daily Ave. Emissions (Corrected ppm)	NOx Max. Hrly Emissions (Corrected ppm)	NOx Daily Mass Emissions (Lbs per Day)	Gas Turb Fuel Use Daily Ave. (SCFM)	Duct Burn. Fuel Use Daily Ave. (SCFM)	Duct Burn. Operating Time (Min.)	Stm/Fuel Ratio Daily Av
9-01-88	39	40	1,121	7,539	863	102	1.086
9-02-88	39	40	1,128	7,542	843	74	1.087
9-03-88	39	40	1,118	7,512	0	N/A	1.106
9-04-88	38	40	1,099	7,479	0	N/A	1.107
9-05-88	38	40	1,092	7,481	0	N/A	1.053
9-06-88	39	41	1,128	7,502	841	27	1.096
9-07-88	39	41	1,123	7,513	844	59	1.102
9-08-88	39	41	1,128	7,528	847	91	1.096
9-09-88	39	40	1,138	7,578	868	122	1.106
9-10-88	39	40	1,135	7,565	0	N/A	1.099
9-11-88	38	40	1,109	7,574	0	N/A	1.121
9-12-88	38	41	1,118	7,660	873	179	1.100
9-13-88	39	41	1,102	7,645	877	209	1.089
9-14-88	38	40	1,104	7,631	871	151	1.093
9-15-88	39	40	1,133	7,718	875	206	1.094
9-16-88	39	40	1,123	7,684	870	131	1.095
9-17-88	39	41	1,092	7,548	0	N/A	1.105
9-18-88	38	40	1,108	7,666	0	N/A	1.128
9-19-88	39	41	1,118	7,628	855	104	1.100
9-20-88	40	41	1,147	7,698	877	194	1.100
9-21-88	40	41	1,162	7,735	868	171	1.103
9-22-88	40	41	1,145	7,687	870	133	1.090
9-23-88	40	41	1,138	7,675	868	174	1.092
9-24-88	40	42	1,142	7,801	0	N/A	1.098
9-25-88	40	41	1,147	7,848	0	N/A	1.095
9-26-88	40	41	1,150	7,738	905	219	1.088
9-27-88	39	41	1,140	7,680	890	200	1.077
9-28-88	39	40	1,128	7,682	894	184	1.087
9-29-88	40	41	1,130	7,614	885	183	1.075
9-30-88	39	58	938	6,387	876	158	1.736

NOTES:

1. NOx emission limit with duct burner and gas turbine operating together is 40 ppm corrected to 15% oxygen. When the gas turbine is operating without the duct burner, this limit is 42 ppm corrected to 15% oxygen.
2. The duct burner is generally used daily between 6AM - 11AM to meet Campus heating steam demands.

CARDINAL COGEN MONTHLY EMISSIONS REPORT

STATEMENT OF EXCESS EMISSIONS

Excess stack emissions occurred during the month of September, 1988, as listed below:

Date	Time	NOx Excess Emissions (PPH, 1 Hr. Average, Corrected to 15 % O2)	Fuel Firing		Corrective Action	Remarks
			Oil	Gas		
9-26-88	1336	43		X	Returned Steam Injection Control Constants	
9-30-88	2100	73		X	None	Occurred at low load during startup after a unit trip. Below load injection starts.
	2106	55		X		

There were no exceedances during this reporting period.

CENS CORRECTIVE ACTION REPORT

Parameter	Date & Time Inoperative Condition Began		Duration	Date & Time Inoperative Condition Ended		Corrective Action	District Dispatcher Notification		
							Yes/No	Date	Time

Significant changes in the monitoring system since
the last Performance Test:

Yes ☒ No

Signed: Steven Mangano Date: Oct. 25, 1988

Title: Instrument Tech.

C A R D I N A L C O G E N
M O N T H L Y E M I S S I O N S R E P O R T

P L A N T O P E R A T I N G R E C O R D
.....

Date	Time Off Line	Time On Line	Reason for Shutdown
9-30-88	1732	2135	Control Power System Fault

Comments : _____



Kern River Cogeneration Company

Box 80478, Bakersfield, CA 93388

(805) 399-2961

Charles Myers, Executive Director

November 16, 1988

KR-2471

Mr. Edward J. Walsh
Turbine Technology Department
General Electric Company
Bldg. 53, Room 322
One River Road
Schenectady, NY 12345

Re: Air Emission Data

Dear Mr. Walsh:

Per your recent telephone conversation with Bill Hauhe of this office, attached are copies of two letters issued by the Kern County Air Pollution Control District (KCAPCD) to Kern River Cogeneration Company verifying compliance with all applicable permits for the years 1987 and 1988. Also, attached are copies of the "Monthly Stack Monitoring Report" (May, 1988 thru October, 1988) for the four (4) units located at the Kern River Cogeneration Company - Omay Hill site.

Though this is public information, we ask that you use discretion when it is disseminated. If you have any questions, contact Mr. W. E. Hauhe, Jr. at the letterhead address.

Sincerely,

C. O. MYERS
Executive Director

WEH:dmh

Attachment

cc: Messrs. F. A. Maggio (w/attachment)
M. A. Soares (w/attachment)
G. M. Thomson (w/attachment)

KERN COUNTY AIR POLLUTION CONTROL DISTRICT

1901 "H" Street, Suite 150
Bakersfield, California 93301-3199
Telephone: (805) 841-3882

LEON M. HEBERTSON, M.D.
Director of Public Health Services
Air Pollution Control Officer



June 18, 1987

Mervyn Soares
Kern River Cogeneration Company
P.O. Box 80478
Bakersfield, CA 93388

Subject: Omar Hill Annual Compliance Test
January - February, 1987

Dear Mr. Soares:

We have reviewed your annual compliance test re: Omar Hill
and find the four units to be in compliance with all applicable
permits.

Sincerely,

LEON M. HEBERTSON, M.D.
AIR POLLUTION CONTROL OFFICER

[Handwritten Signature]
Henry Mayrsohn
Manager Technical Services

HM/jb

Kern River Cogeneration Co.	
CCM	(WEN) 11/24
GUT	11/24
CCN	RWL
RWW	(MPS) MS
CALL-UP	1
COPY TO	11/24-25 MS
ROUTE	RTN
FILE	
JUN 22 '87	

KERN COUNTY AIR POLLUTION CONTROL DISTRICT

2700 "M" Street, Suite 275
Bakersfield, California 93301
Telephone: (805) 861-3682



October 14, 1988

Kern River Cogeneration Co.		
COM	AAC	
GMT	RC	
WEH	MAS	
KSL	REH	
RLI	RWW	
GLH	FRN	
COPY TO <i>MAS</i>		
FILE		
OCT 17 '88		

Mr. Mervyn Soares
Kern River Cogeneration Company
P.O. Box 80478
Bakersfield, CA 93388

Subject: Kern River Cogeneration Company

Dear Mr. Soares:

Pursuant to completion and approval of your most recent source test, we find the subject facility to be in full compliance with emission requirements.

Very truly yours,

CITRON TOY, INTERIM
AIR POLLUTION CONTROL DISTRICT

Henry Mayrsohn, P.E., Manager
Technical Services Section

HM:cm

cc: files

MAY '88K

MONTHLY STACK MONITORING REPORT
KERN RIVER COGENERATION FACILITY - KERN COUNTY, CA - UNIT 1

DAY	AVERAGE		MMBTU COMBINED	TOTAL MMBTU			TOTAL CO LBS	TOTAL WATER GALLONS	CO2 PERCENT	AVERAGES			WATER GALLONS/HR	WATER INJECTION RATIO
	GAS	OIL		GAS	OIL	COMBINED				CO	NOx	SO2		
1	1814.40	0.00	1814.40	34,348.50	0.00	34,348.50	141.70	89,304.10	3.90	8.80	0.01	119.44	0.12	2,734.40
2	980.20	0.00	980.20	22,764.10	0.00	22,764.10	126.20	77,886.20	3.80	8.80	0.01	120.22	0.12	2,302.00
3	970.20	0.00	970.20	22,401.70	0.00	22,401.70	125.18	76,886.20	3.80	8.87	0.01	127.32	0.12	2,302.30
4	904.10	0.00	904.10	17,713.40	0.00	17,713.40	143.27	80,267.40	3.80	7.90	0.01	126.70	0.12	2,500.30
5	905.10	0.00	905.10	20,001.20	0.00	20,001.20	204.20	82,804.20	3.80	8.20	0.01	126.00	0.12	2,466.00
6	1000.40	0.00	1000.40	24,000.70	0.00	24,000.70	189.21	80,800.40	3.80	7.53	0.01	121.00	0.12	2,411.70
7	901.10	0.00	901.10	20,548.40	0.00	20,548.40	165.20	77,517.20	3.80	8.00	0.01	120.20	0.12	2,320.20
8	902.70	0.00	902.70	22,505.50	0.00	22,505.50	160.11	76,426.40	3.80	8.07	0.01	127.27	0.12	2,300.30
9	972.20	0.00	972.20	20,548.50	0.00	20,548.50	160.00	76,200.20	3.80	8.07	0.01	124.24	0.12	2,300.70
10	901.20	0.00	901.20	22,501.20	0.00	22,501.20	170.27	76,100.20	3.80	7.47	0.01	122.00	0.12	2,174.70
11	902.70	0.00	902.70	22,500.70	0.00	22,500.70	206.05	76,207.20	3.80	8.41	0.01	117.11	0.12	2,170.20
12	907.20	0.00	907.20	22,972.20	0.00	22,972.20	210.21	76,002.20	3.80	8.70	0.01	116.00	0.12	2,302.00
13	970.20	0.00	970.20	14,020.50	0.00	14,020.50	125.00	44,023.40	3.80	8.00	0.01	120.00	0.12	2,242.20
14	970.40	0.00	970.40	20,200.70	0.00	20,200.70	214.00	77,700.40	3.80	8.30	0.01	121.21	0.12	2,227.00
15	904.00	0.00	904.00	22,204.40	0.00	22,204.40	200.20	76,200.10	3.80	8.20	0.01	117.01	0.12	2,175.20
16	970.70	0.00	970.70	22,226.10	0.00	22,226.10	160.10	73,002.20	3.80	7.20	0.01	120.00	0.12	2,200.00
17	901.20	0.00	901.20	22,501.40	0.00	22,501.40	154.03	77,000.00	3.80	8.10	0.01	120.00	0.12	2,204.50
18	970.20	0.00	970.20	20,470.20	0.00	20,470.20	121.50	67,007.00	3.80	8.27	0.01	122.00	0.12	2,201.00
19	901.00	0.00	901.00	20,000.20	0.00	20,000.20	140.00	76,072.00	3.80	8.20	0.01	121.42	0.12	2,194.70
20	904.00	0.00	904.00	22,007.20	0.00	22,007.20	161.24	76,002.00	3.80	8.20	0.01	120.00	0.12	2,200.00
21	902.00	0.00	902.00	22,007.00	0.00	22,007.00	160.20	77,254.00	3.80	8.70	0.01	120.00	0.12	2,210.00
22	907.00	0.00	907.00	22,970.70	0.00	22,970.70	154.05	76,222.10	3.80	8.10	0.01	119.00	0.12	2,201.20
23	907.20	0.00	907.20	22,970.00	0.00	22,970.00	164.51	76,200.20	3.80	8.44	0.01	118.42	0.12	2,201.10
24	900.00	0.00	900.00	22,112.00	0.00	22,112.00	153.00	77,201.00	3.80	8.20	0.01	120.20	0.12	2,200.00
25	900.10	0.00	900.10	22,200.70	0.00	22,200.70	150.20	77,000.20	3.80	8.20	0.01	121.17	0.12	2,244.40
26	971.10	0.00	971.10	22,200.50	0.00	22,200.50	160.01	77,070.00	3.80	8.07	0.01	121.22	0.12	2,244.20
27	970.20	0.00	970.20	20,500.20	0.00	20,500.20	154.50	76,040.10	3.80	8.70	0.01	122.24	0.12	2,202.00
28	970.00	21.00	991.00	18,700.00	900.00	19,600.00	150.45	64,070.00	3.80	8.00	0.01	112.64	0.12	2,007.00
29	904.00	0.00	904.00	22,007.10	0.00	22,007.10	154.00	76,007.00	3.80	8.44	0.01	120.00	0.12	2,200.70
30	900.00	0.00	900.00	22,040.70	0.00	22,040.70	150.04	76,200.10	3.80	8.01	0.01	120.20	0.12	2,202.20
31	904.20	0.00	904.20	22,010.70	0.00	22,010.70	120.14	76,001.20	3.80	8.00	0.01	122.47	0.12	2,210.00
MTD	971.10	0.00	971.10	600,720.70	000.00	607,542.00	5,000.00	2,247,200.20						

MAY '88K

MONTHLY STACK MONITORING REPORT
 KERN RIVER COGENERATION FACILITY - KERN COUNTY, CA - UNIT 2

DAY	AVERAGE		MMBTU COMBINED	TOTAL MMBTU		TOTAL CO LBS	TOTAL WATER GALLONS	AVERAGES		CO ₂ PERCENT	CO		NO _x		WATER INJECTION RATIO
	GAS	OIL		GAS	OIL			CO ₂ LBS/MMBTU	CO LBS/MMBTU		LBS/MMBTU	LBS/MMBTU	LBS/MMBTU	GALLONS/HR	
1	972.10	0.00	972.10	20,962.30	0.00	20,962.30	120.23	60,353.40	0.00	0.27	0.01	121.50	0.13	2,077.20	0.70
2	944.70	0.00	944.70	21,720.00	0.00	21,720.00	122.71	70,725.20	0.00	0.21	0.01	124.00	0.13	2,004.70	0.70
3	908.00	0.00	908.00	20,400.70	0.00	20,400.70	127.00	61,900.00	0.00	0.20	0.01	122.00	0.13	2,000.00	0.70
4	940.70	0.00	940.70	14,900.00	0.00	14,900.00	120.50	61,720.00	0.00	0.20	0.01	119.00	0.13	2,000.00	0.70
5	902.70	0.00	902.70	20,900.40	0.00	20,900.40	104.20	62,251.70	0.00	0.13	0.01	120.01	0.13	2,000.00	0.70
6	904.00	0.00	904.00	20,910.70	0.00	20,910.70	107.72	61,507.00	0.00	0.27	0.01	120.27	0.13	2,000.00	0.70
7	909.00	0.00	909.00	20,900.00	0.00	20,900.00	100.00	62,223.20	0.00	0.24	0.01	119.00	0.13	2,000.00	0.70
8	900.00	0.00	900.00	20,900.00	0.00	20,900.00	104.00	62,200.00	0.00	0.24	0.01	119.00	0.13	2,000.00	0.70
9	900.00	0.00	900.00	20,901.00	0.00	20,901.00	106.71	62,413.00	0.00	0.24	0.01	119.00	0.13	2,000.00	0.70
10	900.00	100.00	1000.00	14,970.00	0.00	14,970.00	200.47	70,000.00	0.00	0.20	0.01	122.70	0.14	2,000.00	0.70
11	907.10	0.00	907.10	21,530.00	0.00	21,530.00	177.01	72,000.00	0.00	0.20	0.01	122.70	0.14	2,000.00	0.70
12	901.00	0.00	901.00	21,000.00	0.00	21,000.00	179.41	72,000.00	0.00	0.20	0.01	121.00	0.14	2,000.00	0.70
13	907.20	0.00	907.20	21,000.10	0.00	21,000.10	119.00	60,000.00	0.00	0.20	0.01	120.00	0.14	2,000.00	0.70
14	910.30	0.00	910.30	21,000.10	0.00	21,000.10	103.00	72,000.00	0.00	0.20	0.01	120.00	0.14	2,000.00	0.70
15	900.00	0.00	900.00	21,000.10	0.00	21,000.10	172.00	72,170.10	0.00	0.20	0.01	120.00	0.14	2,000.00	0.70
16	900.00	0.00	900.00	21,107.00	0.00	21,107.00	142.31	60,000.00	0.00	0.19	0.01	120.00	0.14	2,000.00	0.70
17	900.00	0.00	900.00	20,444.00	0.00	20,444.00	120.10	74,000.00	0.00	0.20	0.01	120.00	0.14	2,000.00	0.70
18	900.00	0.00	900.00	10,440.00	0.00	10,440.00	110.00	64,000.00	0.00	0.20	0.01	120.00	0.14	2,000.00	0.70
19	911.00	0.00	911.00	21,000.00	0.00	21,000.00	127.00	72,000.00	0.00	0.20	0.01	120.00	0.14	2,000.00	0.70
20	901.00	0.00	901.00	21,040.00	0.00	21,040.00	120.70	72,000.00	0.00	0.20	0.01	120.70	0.14	2,000.00	0.70
21	907.70	0.00	907.70	21,544.00	0.00	21,544.00	120.70	71,000.00	0.00	0.27	0.01	120.07	0.14	2,000.00	0.70
22	900.00	0.00	900.00	21,070.70	0.00	21,070.70	121.00	72,000.00	0.00	0.20	0.01	120.00	0.14	2,000.00	0.70
23	900.10	0.00	900.10	21,747.00	0.00	21,747.00	121.00	72,070.00	0.00	0.20	0.01	120.00	0.14	2,000.00	0.70
24	911.10	0.00	911.10	21,000.00	0.00	21,000.00	120.00	72,000.00	0.00	0.20	0.01	120.00	0.14	2,000.00	0.70
25	901.00	0.00	901.00	20,100.00	0.00	20,100.00	120.00	74,000.00	0.00	0.20	0.01	120.00	0.14	2,000.00	0.70
26	901.00	0.00	901.00	20,100.00	0.00	20,100.00	120.00	74,000.00	0.00	0.20	0.01	120.00	0.14	2,000.00	0.70
27	900.00	0.00	900.00	21,007.00	0.00	21,007.00	120.00	71,000.00	0.00	0.20	0.01	120.00	0.14	2,000.00	0.70
28	907.00	10.00	917.00	21,007.00	0.00	21,007.00	120.00	71,000.00	0.00	0.20	0.01	120.00	0.14	2,000.00	0.70
29	940.00	0.00	940.00	20,700.10	0.00	20,700.10	121.17	77,171.00	0.00	0.27	0.01	120.00	0.14	2,000.00	0.70
30	944.00	0.00	944.00	20,000.00	0.00	20,000.00	100.07	60,000.00	0.00	0.20	0.01	120.00	0.14	2,000.00	0.70
31	900.00	0.00	900.00	20,007.00	0.00	20,007.00	120.70	61,140.00	0.00	0.20	0.01	117.71	0.13	2,000.00	0.70
MTD	904.00	0.73	904.73	600,000.10	0.00	600,000.10	4,007.77	2,010,000.10							

MAY '88K

MONTHLY STACK MONITORING REPORT

KERN RIVER COGENERATION FACILITY - KERN COUNTY, CA - UNIT 2

DAY	AVERAGE GAS	OIL	MMBTU/ COMBINED	TOTAL MMBTU			TOTAL CO LBS	TOTAL WATER GALLONS	CO2 PERCENT	AVERAGE		NOx		WATER GALLONS/Hr	WATER INJECTION RATIO
				GAS	OIL	COMBINED				CO	CO	CO	CO		
1	1045.10	0.00	1045.10	25,000.70	0.00	25,000.70	104.04	91,000.00	3.00	5.10	0.00	120.00	0.12	2,000.00	0.70
2	1015.50	0.00	1015.50	25,400.00	0.00	25,400.00	101.71	85,701.00	3.00	5.75	0.01	120.00	0.12	2,000.00	0.00
3	1007.70	0.00	1007.70	24,100.10	0.00	24,100.10	141.00	83,000.00	3.00	6.00	0.01	127.70	0.12	2,000.00	0.00
4	1012.00	0.00	1012.00	10,000.70	0.00	10,000.70	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
5	1000.00	0.00	1000.00	24,000.00	0.00	24,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
6	1001.00	0.00	1001.00	24,700.10	0.00	24,700.10	100.00	81,000.00	3.00	7.00	0.01	101.00	0.12	2,000.00	0.00
7	1010.00	0.00	1010.00	24,000.00	0.00	24,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
8	1000.00	0.00	1000.00	24,000.00	0.00	24,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
9	1000.00	0.00	1000.00	24,000.00	0.00	24,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
10	000.00	0.00	000.00	25,770.00	0.00	25,770.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
11	000.00	0.00	000.00	25,000.00	0.00	25,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
12	000.00	0.00	000.00	25,000.00	0.00	25,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
13	1000.00	0.00	1000.00	10,000.00	0.00	10,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
14	007.00	0.00	007.00	25,000.00	0.00	25,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
15	004.00	0.00	004.00	25,000.00	0.00	25,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
16	007.00	0.00	007.00	25,000.00	0.00	25,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
17	1000.00	0.00	1000.00	24,100.10	0.00	24,100.10	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
18	1000.00	0.00	1000.00	21,000.00	0.00	21,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
19	000.00	0.00	000.00	25,700.10	0.00	25,700.10	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
20	000.00	0.00	000.00	25,000.00	0.00	25,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
21	000.00	0.00	000.00	25,000.00	0.00	25,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
22	000.00	0.00	000.00	25,000.00	0.00	25,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
23	000.00	0.00	000.00	25,000.00	0.00	25,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
24	000.00	0.00	000.00	25,000.00	0.00	25,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
25	000.00	0.00	000.00	25,000.00	0.00	25,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
26	007.10	0.00	007.10	25,000.00	0.00	25,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
27	1000.10	0.00	1000.10	25,000.00	0.00	25,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
28	072.10	10.00	000.00	25,000.00	0.00	25,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
29	1000.00	0.00	1000.00	24,000.00	0.00	24,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
30	1000.00	0.00	1000.00	24,000.00	0.00	24,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
31	1010.70	0.00	1010.70	24,000.00	0.00	24,000.00	100.00	80,000.00	3.00	7.00	0.01	100.00	0.12	2,000.00	0.00
MTD	1000.10	0.04	1000.70	704,474.00	0.00	704,474.00	4,704.04	2,040,000.00							

MAY '88

MONTHLY STACK MONITORING REPORT
KERN RIVER COGENERATION FACILITY - KERN COUNTY, CA - UNIT 4

DAY	AVERAGE GAS	OIL	MMBTU COMBINED	TOTAL MMBTU			TOTAL CO LBS	TOTAL WATER GALLONS	CO2 PERCENT	AVERAGE —CO—		—NOx—		WATER GALLONS/HR	WATER INJECTION RATIO
				GAS	OIL	COMBINED				LBS/HR	LBS/MMBTU	LBS/HR	LBS/MMBTU		
1	908.10	0.00	908.10	22,908.00	0.00	22,908.00	126.26	86,270.10	2.20	8.04	0.01	126.55	0.12	2,652.00	0.00
2	971.20	0.00	971.20	22,261.00	0.00	22,261.00	155.22	81,562.00	2.20	6.06	0.01	126.70	0.12	2,545.00	0.70
3	908.00	0.00	908.00	20,000.00	0.00	20,000.00	146.43	81,200.00	2.20	6.10	0.01	127.75	0.12	2,262.70	0.00
4	908.70	0.00	908.70	17,808.70	0.00	17,808.70	151.53	81,277.00	2.20	6.42	0.01	126.00	0.12	2,404.20	0.00
5	908.00	0.00	908.00	20,611.00	0.00	20,611.00	220.92	84,514.20	2.20	6.17	0.01	126.06	0.12	2,675.00	0.70
6	908.00	0.00	908.00	20,677.40	0.00	20,677.40	190.20	84,200.40	2.20	7.20	0.01	125.51	0.12	2,677.90	0.70
7	726.00	0.00	726.00	2,000.00	0.00	2,000.00	204.00	12,157.20	2.20	81.20	0.00	90.24	0.10	2,427.40	0.20
8	974.00	0.00	974.00	22,200.00	0.00	22,200.00	151.23	82,274.20	2.20	7.50	0.01	126.26	0.12	2,478.00	0.00
9	901.00	0.00	901.00	22,000.00	0.00	22,000.00	206.14	82,441.10	2.20	6.87	0.01	126.41	0.12	2,406.00	0.00
10	900.00	0.00	900.00	22,015.10	0.00	22,015.10	202.20	82,001.00	2.20	6.42	0.01	126.44	0.12	2,410.20	0.70
11	904.40	0.00	904.40	22,426.40	0.00	22,426.40	217.26	80,441.20	2.20	6.06	0.01	126.07	0.12	2,261.70	0.00
12	900.10	0.00	900.10	21,010.20	0.00	21,010.20	222.21	77,000.20	2.70	6.20	0.01	115.00	0.12	2,236.00	0.00
13	900.20	0.00	900.20	14,220.20	0.00	14,220.20	154.20	62,121.00	2.20	10.20	0.01	111.00	0.11	2,476.40	0.00
14	901.00	0.00	901.00	1,002.10	0.00	1,002.10	106.52	2,200.20	1.00	20.10	0.01	60.24	0.00	720.20	0.20
15	901.20	0.00	901.20	2,004.00	0.00	2,004.00	620.22	19,002.10	2.20	60.20	0.15	60.12	0.11	2,116.00	0.40
16	902.70	24.00	902.70	22,104.70	700.00	22,804.70	190.00	77,202.20	2.20	6.60	0.01	127.15	0.12	2,262.00	0.00
17	970.00	0.00	970.00	22,400.00	0.00	22,400.00	170.00	80,200.00	2.20	7.40	0.01	119.00	0.12	2,662.20	0.70
18	900.00	0.00	900.00	20,200.00	0.00	20,200.00	152.00	72,727.20	2.20	7.24	0.01	120.40	0.12	2,402.70	0.00
19	946.00	0.00	946.00	22,716.00	0.00	22,716.00	170.00	79,200.00	2.20	7.40	0.01	126.44	0.12	2,812.00	0.00
20	900.00	0.00	900.00	22,472.00	0.00	22,472.00	177.10	81,000.70	2.20	7.20	0.01	121.00	0.12	2,601.00	0.70
21	900.70	0.00	900.70	200.00	0.00	200.00	100.00	1,017.20	1.00	64.00	0.00	64.12	0.00	000.00	0.20
22	946.70	110.00	946.70	22,700.10	200.00	22,900.10	70.10	20,771.70	2.70	7.01	0.01	60.40	0.12	2,202.20	0.40
23	940.20	0.00	940.20	22,700.40	0.00	22,700.40	170.00	84,000.00	2.20	7.20	0.01	116.40	0.12	2,500.00	0.70
24	940.70	0.00	940.70	22,700.40	0.00	22,700.40	171.10	84,000.40	2.20	7.12	0.01	120.07	0.12	2,470.10	0.70
25	940.00	0.00	940.00	22,900.20	0.00	22,900.20	160.72	84,200.00	2.20	6.70	0.01	126.72	0.12	2,614.00	0.70
26	907.20	0.00	907.20	22,972.70	0.00	22,972.70	181.00	82,727.00	2.20	7.40	0.01	120.24	0.12	2,400.10	0.70
27	900.20	0.00	900.20	22,204.20	0.00	22,204.20	170.12	81,000.20	2.20	7.00	0.01	119.00	0.12	2,504.00	0.70
28	900.20	22.00	900.20	22,270.00	572.00	22,842.00	204.00	84,000.00	2.20	6.24	0.01	119.00	0.12	2,500.00	0.70
29	900.00	0.00	900.00	22,770.10	0.00	22,770.10	181.71	84,000.20	2.20	7.27	0.01	127.00	0.12	2,600.20	0.70
30	900.20	0.00	900.20	22,040.20	0.00	22,040.20	180.72	84,200.10	2.20	7.01	0.01	126.10	0.12	2,600.10	0.70
31	900.10	0.00	900.10	22,267.40	0.00	22,267.40	182.21	84,420.00	2.20	7.00	0.01	126.74	0.12	2,560.70	0.70
MTD	900.22	0.72	900.22	207,204.00	1,000.70	208,204.70	2,000.52	2,105,457.40							