RIVIERA PLANT

NO_x REDUCTION TEST PROGRAM

REPORT

FPL

SEPTEMBER 29, 1996

Florida Power and Light Company
Engineering & Technical Services
700 Universe Blvd.
Juno Beach, FL 33408

FPL
Florida Power & Light Company, P.O. Box 088801, North Palm Beach, FL 33408-8801

October 7, 1996

RECEIVED
OCT 10 1996
BUREAU OF AIR REGULATION

Mr. Martin Costello
State of Florida
Department of Environmental Protection
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

RE: Riviera Power Plant NOx Emissions
Conclusion of 18-Month Study Meeting

Dear Mr. Costello:
I appreciate you and your staff taking time to meet with us to discuss Riviera power plant's final NOx limits. As per our conversation earlier today I will be sending three copies of the report. In addition I will include copies of the revised operation permit.

If you have any questions regarding this letter, please contact me at (407)625-7633.

Sincerely,

Vito Giarrusso

Vito Giarrusso
Environmental Specialist

FLORIDA POWER AND LIGHT COMPANY

RIVIERA PLANT NO_x REDUCTION TEST PROGRAM REPORT SEPTEMBER 29, 1996

INTRODUCTION

The Clean Air Act Amendments of 1990 designated Dade, Broward, and Palm Beach counties as an ozone non-attainment area. Consequently, a reduction in NO_x emissions from FPL power plants in the affected area was required using Reasonably Available Control Technology (RACT). The FDEP determined that low NO_x burner technology was RACT for FPL power plants in the tri-county area. Eight fossil steam boilers in the area were retrofitted with low NO_x burners. The Riviera Plant (PRV) had low NO_x burners installed in Spring 1994 and Fall 1994 on units 3 and 4 respectively. An interim NO_x emission limit of 0.62 pounds per million BTU on oil and 0.50 pounds per million BTU on natural gas was established in the air operating permits for PRV. These interim limits represent a 33% reduction in NO_x. A specific condition of the associated air operating permits required an 18 month test program be conducted to reach a targeted NO_x reduction of 40% (0.55 lb./mmbtu oil and 0.43 lb./mmbtu gas). The test program began during the fourth quarter of 1994 and continued through the second quarter of 1996. Quarterly reports outlining the progress of the test were filed with the FDEP each quarter.

This report will summarize the results of the test program, the lessons learned, and a recommendation regarding the final NO_x limits.

DISCUSSION

Low NO_x burner technology reduces NO_x by staging the fuel in the near-flame region, slowing down the rate of combustion and the consequential thermal NO_x production. An undesirable result of creating localized fuel to air ratio imbalances and flame perturbations is the potential for increasing opacity. The difficult task of lowering NO_x while maintaining acceptable opacity control is well documented throughout the industry[1,2], and Riviera Plant is no exception in this regard. Plant personnel, Palm Beach County Public Health Unit personnel, regional FDEP representatives, and the local community are very sensitive to the opacity from the units, and therefore, a great deal of effort has gone into operating the Riviera Plant with the least amount of opacity possible.

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[1] Electric Power Research Institute, *Factors Affecting NO_X Emissions in Heavy Oil Combustion,* June 1991.

[2] United States Environmental Protection Agency, *Evaluation and Costing of NO_X Controls for Existing Utility Boilers In The NESCAUM Region,* December 1992, pp. 7-17 -- 7-21.

In addition to the principle that NO_x and opacity are related, NO_x and unit load are related as well. As boiler load increases so, too, does NO_x (see fig. 1).

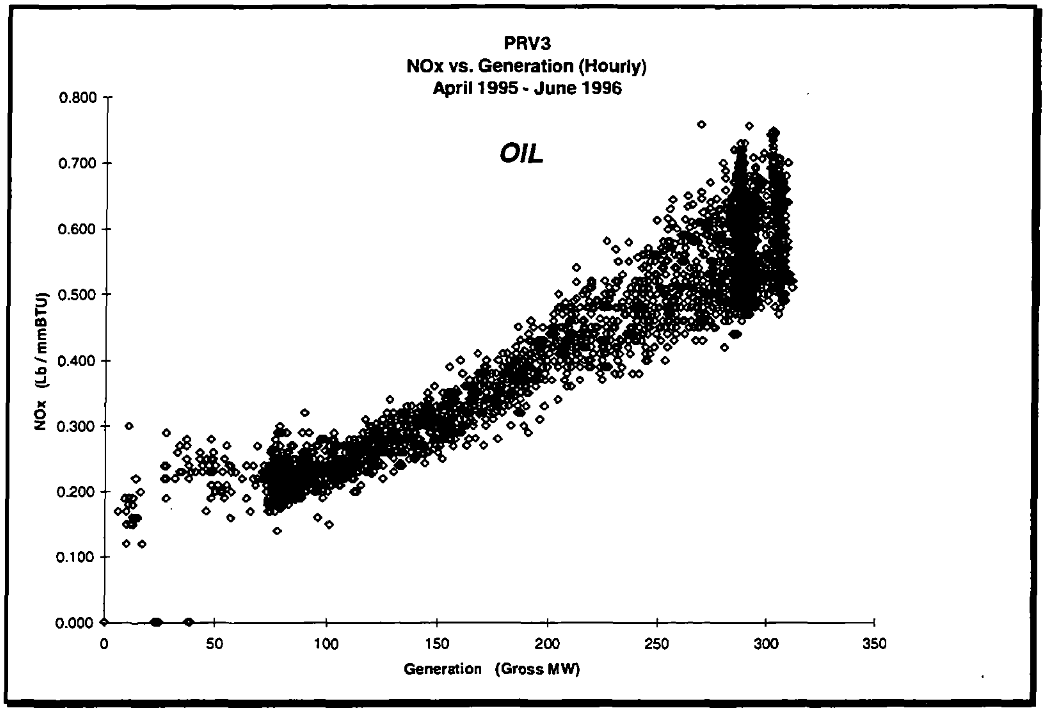


Figure 1

As can be seen, load rate and NO_x emission rate vary proportionally. This is particularly important during periods of high sustained loads, such as during the summer, or any time a unit is required to be dispatched with a high output factor. This, in effect, gives a somewhat "seasonal" component to the emission rate as well.

The relationship of opacity and unit output factor to the NO_x emission rate needs to be considered when determining the emission limits.

<u>TEST SUMMARY</u>

Tests were run throughout the load range on the units using a series of different atomizer designs to optimize NO_x, opacity, and boiler operating characteristics. Data gathered during the tests was used by the burner supplier to engineer and manufacture improved atomizer designs. See table #1 on the following page.

TABLE #1

RIVIERA PLANT ATOMIZER SUMMARY

ATOMIZER	***DATE***	***PERFORMANCE***	***COMMENTS***
INITIAL DESIGN	FOURTH QUARTER 1994	IMPROVEMENTS IN NO_X AND OPACITY DESIRED	
SECOND DESIGN	FIRST QUARTER 1995	LOWER NO_X ; HIGHER OPACITY	
THIRD DESIGN	FIRST QUARTER 1995	HIGHER NO_X ; LOWER OPACITY	
FOURTH DESIGN	THIRD QUARTER 1995	NO IMPROVEMENT IN OPACITY	
FIFTH DESIGN	THIRD QUARTER 1995	SLIGHT IMPROVEMENT IN OPACITY	FUEL OIL PRESSURE WAS TOO HIGH FOR FULL LOAD OPERATION
SIXTH DESIGN	FOURTH QUARTER 1995	POOR OPACITY CHARACTERISTICS	
SEVENTH DESIGN	FOURTH QUARTER 1995		*SELECTED AS THE FINAL DESIGN BASED ON BEST OVERALL PERFORMANCE*

The seventh atomizer design was found to have the best overall performance in all aspects: NO_x, and opacity emissions, boiler performance, fuel changes, and general unit operation.

Data was collected from the Continuous Emission Monitors (CEM) from April 1, 1995 through June 4, 1996 to provide the 30-day rolling average information and the associated pro-rated emission limits. The CEM data was also used in analyzing the longer range performance data. An analysis of the CEM data follows, beginning with Unit 3's performance relative to the current NO_x limit and the targeted limit as seen in Fig. 2 on the following page.

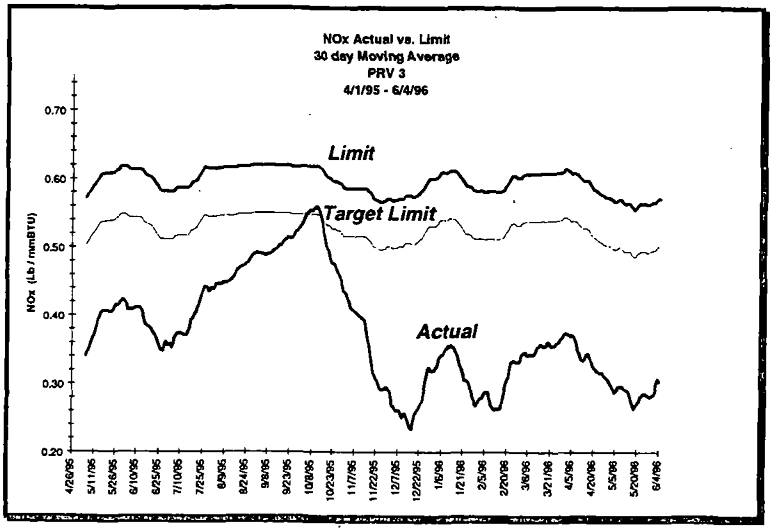


Figure 2

Although the actual 30-day rolling average values generally fall well below the current limit and targeted limit (an average reduction of 60% for the period), there is a period during September and October when the targeted limit would have been exceeded.

A review of the unit generating history as seen in Fig. 3 will help explain.

Generation was calculated on a 30-day rolling average basis to better understand the relationship between 30-day rolling average NO_x values and generation. Note that the maximum 30-day generation period (254.9 MW) occurred during the fall of 1995. This coincides with the peak NO_x value observed during the same period. Recalling the relationship of NO_x vs. load from Fig. 1, it can be seen that sustained periods of high load (> 250 MW) can cause the 30-day rolling average to rise above the targeted limit.

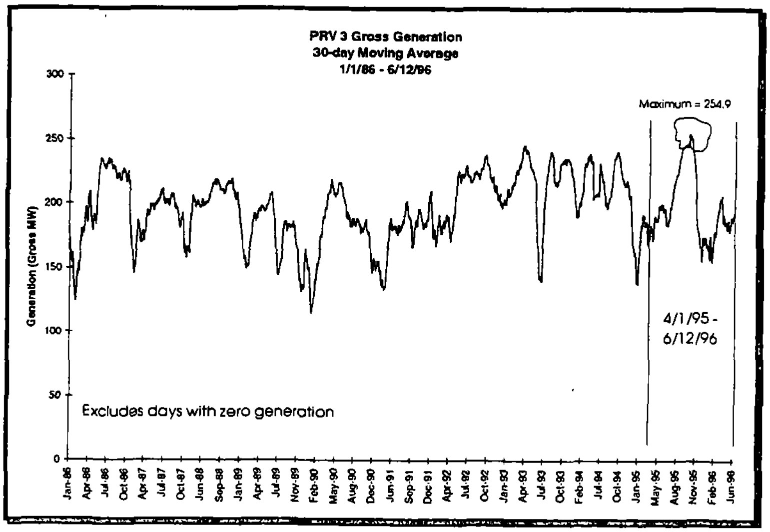


Figure 3

Data from Unit 4 show trends similar to Unit 3 (see Figs. 4 and 5).

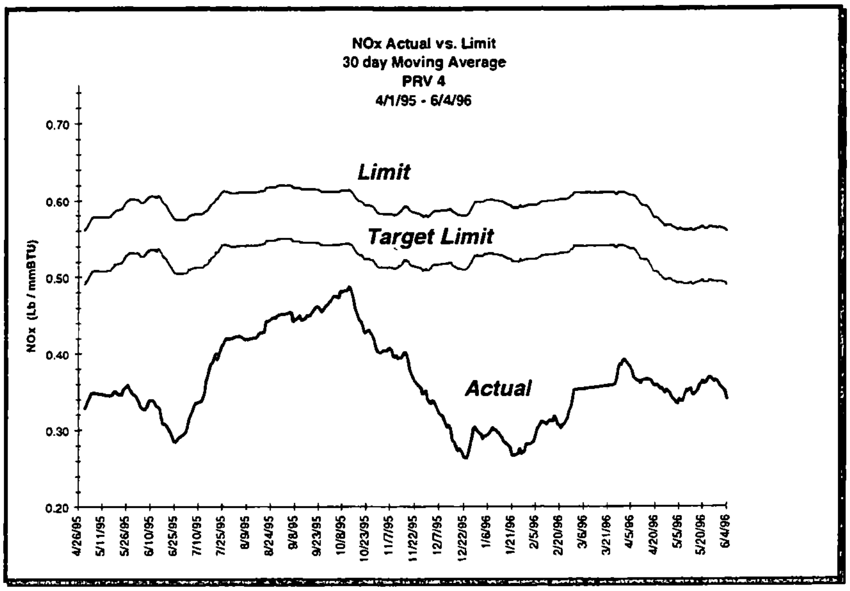


Figure 4

Note in Fig. 4 that the actual NO_x values approach, but do not exceed, the targeted limit. Also note from Fig. 5 that the maximum generation observed during the NO_x data collection period was only 240.4 MW. It is significant to note that the highest generation period for Unit 4 (252.7 MW) occurred during the Spring of 1994. Had 30-day rolling average NO_x data been available during that period the targeted limit would have, predictably, been exceeded.

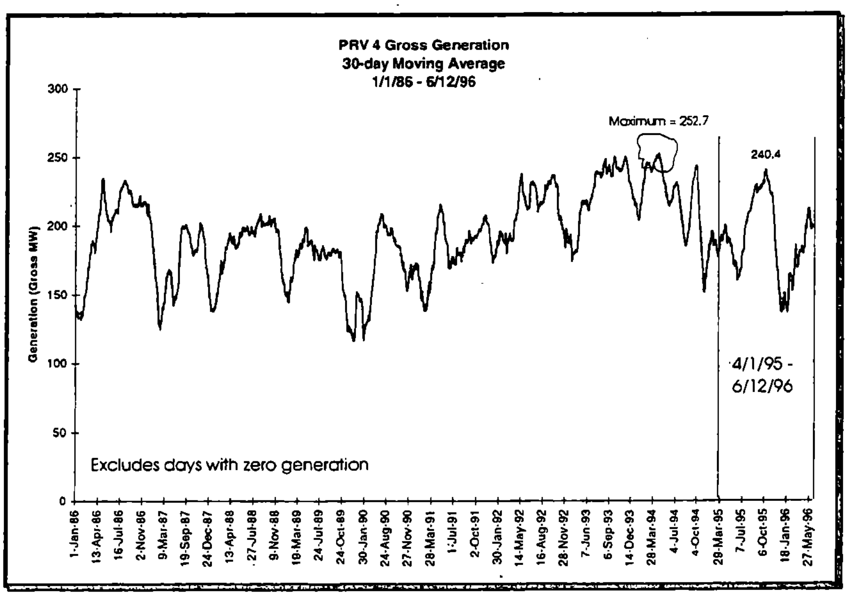


Figure 5

A condensation of the thousands of hourly data points from both units on each fuel is shown in Fig. 6.

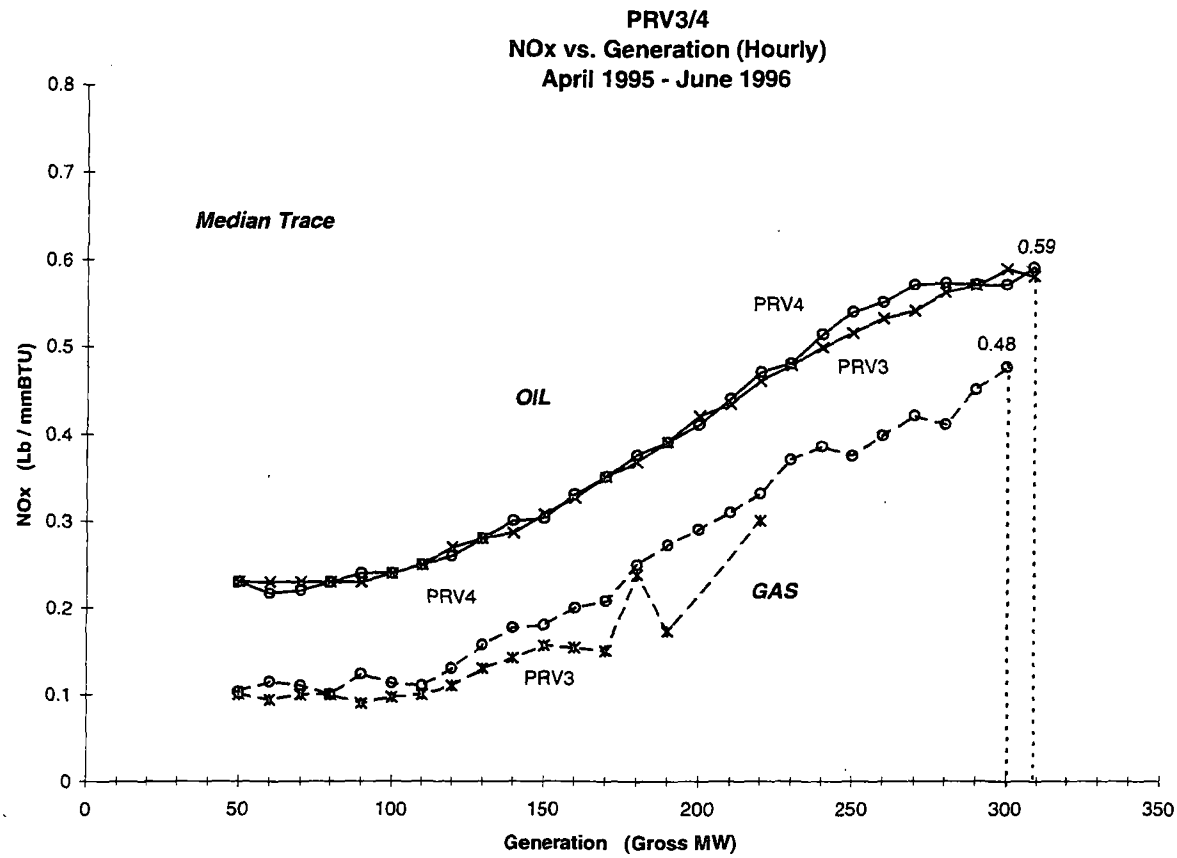


Figure 6

The Median Trace is the middle value (not the average) of all the hourly data points for each 10 MW segment of load. This helps to desensitize the data from the effect of any outlying points. Both units are essentially identical on oil with an emission rate of 0.59 lb./mmbtu at approximately 310 MW. Gas fuel data for both units compare very well until about half load. Unit 3 cannot operate well on gas above about 170 MW due to steam temperature limits, so very few data points for it are available. The emission rate for Unit 4 at full load on gas is 0.48 lb./mmbtu.

In order to operate the units for sustained periods within the targeted limits, load would be restricted to approximately 255 MW on oil, and approximately 285 MW on gas. The current limits of 0.62 lb./mmbtu on oil and 0.50 lb./mmbtu on gas would not be exceeded during extended periods of high load operation and would require no load restrictions.

CONCLUSION

The Riviera units can be fitted with an atomizer design (such as design #2) that would assure that the targeted NO_x values are never exceeded during those occasions when high loads must be sustained for extended periods. However, it is FPL's opinion the resulting increase in opacity during all hours of operation does not justify the incremental NO_x benefit at high load in order to reach the targeted limits. Units 3 and 4 have achieved a 60% and 61% reduction in NO_x respectively during the test period with good opacity performance. Considering that the tri-county area has been reclassified as being in attainment, further reductions in NO_x at the expense of opacity does not seem warranted. We do not believe it would be in the best overall interest of the local air quality to jeopardize the gains achieved.

We, therefore, recommend that the current NO_x limits of 0.62 lb./mmbtu on oil and 0.50 lb./mmbtu on gas should be continued.

GENERAL BURNER OPERATION

The overall design of the burner is shown in Drawing PRV3-M9000-53 and Figure 2-1 the reference number's refer to Figure 2-1. The P & ID drawing PRV3-M9000-51 is provided for reference. Primary and secondary air enter the burner from the windbox through the annular air gap [1] as shown. To provide even distribution of the air through the air gap, the windbox is typically provided with baffles [not shown], which are designed and located in accordance with established design principles. An "Aerosim" model of the air supply system was made to establish the baffle arrangement (refer to the model report).

The air gap is designed to accelerate the primary and secondary air without flow disturbance from the lower velocity in the windbox; this acceleration aids in providing a more uniform distribution of the air at the periphery of the annulus. The air then turns 90 degrees, and is further accelerated through the converging section of the venturi [2], which provides the final means of establishing uniform air flow. From this section, the air stream begins expanding through the diverging section of the venturi. Near the exit end of the venturi, the air splits into two distinct concentric streams. The air stream passing through the swirler [3] is referred to as primary air. The swirler imparts a centrifugal spin to the air, and directs it angularity outward from the burner centerline. When a center-fired gas gun [22] is supplied, or when a center oil gun [4,16,19] is employed, a portion of this primary air reacts with the fuel under sub-stoichiometric conditions. For the replacement burners at Florida Power and Light Riviera Plant Units 3 & 4, a center fired gas gun and an oil gun are supplied.

The air passing around the outside periphery of the swirler is defined as secondary air. It continues a controlled expansion in the quarl section of the burner [20], where it reacts with the unburned (or partially burned) fuel from the center reaction to complete the combustion process. For applications which are provided with gas pokers [5] located in the secondary air zone, the secondary air provides the oxygen for this combustion reaction as well.

The outward spin provided to the primary air, and to any combustion products formed in the vortex region, results in a low pressure region immediately in front of the swirler. Consequently, a portion of the combustion gases spinning outward from the swirler, along with a portion of the gases in the secondary air region, are drawn from a region several feet in front of the swirler and recirculated back into this low pressure region. This "recirculation" of flue gases back into the area in front of the swirler provides flame stabilization and helps to reduce NOx emissions in the primary combustion zone by reducing the flame temperature and lowering the "effective" oxygen concentration.

The swirler is carefully sized with respect to the outlet divergent section of the venturi register to optimize this recirculation and minimize burner pressure drop. The shroud [7] around the swirler prevents radial flow of the primary air, and also reduces turbulence between the primary and secondary air streams. Where a center-fired gas gun or oil atomizer is provided, the premix can [8] admits some primary air to the root of the flame produced in this region; this assists with flame stability and keeps the swirler and atomizer free of deposits when firing oil.

For gas-fired applications, proprietary gas injection schemes are employed to assist in further lowering NOx emissions. The objective of the schemes is to create regions of fuel-rich combustion, surrounded by regions of fuel-lean combustion.

A third stream of combustion air is added around the outside of the venturi. This air stream is defined as "tertiary air" [21]. It provides further "staging" of the combustion process for NOx reduction, and can also be used to assist in shaping the flame.

The control of the split between the primary/secondary and tertiary air quantities will be established in the design phase by proper selection of the sizes of the primary/secondary air gap, venturi, and the swirler, along with proper sizing of the tertiary air annulus.

As shown in the drawing, a piezometer ring [11] is installed in the throat of the venturi (referred to as the "vena contracta") to measure the absolute pressure of the primary/secondary air at this location. The piezometer ring consists of a pressure equalizing chamber which is connected to multiple holes provided around the circumference of the venturi throat. A tap on the piezometer ring is then connected via tubing [12] to the outside of the burner assembly. An additional pressure tap [13] is located on the radiation flange [14] of the burner, which provides windbox static pressure. By connecting these two pressure taps to a differential pressure transmitter (or manometer), the draft loss from the windbox to the most constricted part of the venturi can be established. This is the highest differential pressure in the burner system, and is important as an air flow control parameter. As discussed later in this section, the ability to accurately establish the primary/secondary flow is a critical operational factor. This is particularly true if a tertiary air section is provided, since it can provide an accurate indication of the percentage of each air stream. If multiple burners are provided, this air flow measurement is also critical, since it allows a comparison of the air flow to each burner, and thereby assures a proper balance between the burners.

Generally, one additional pressure tap is provided (by the boiler manufacturer) for measurement of furnace pressure. By connecting this tap, along with the windbox tap, to a differential pressure transmitter or manometer, the total burner draft loss can be established. This pressure differential is known as the "Register Draft Loss" (RDL). It is also a measure of the total air flow, which may be essential to the control of the burner system.

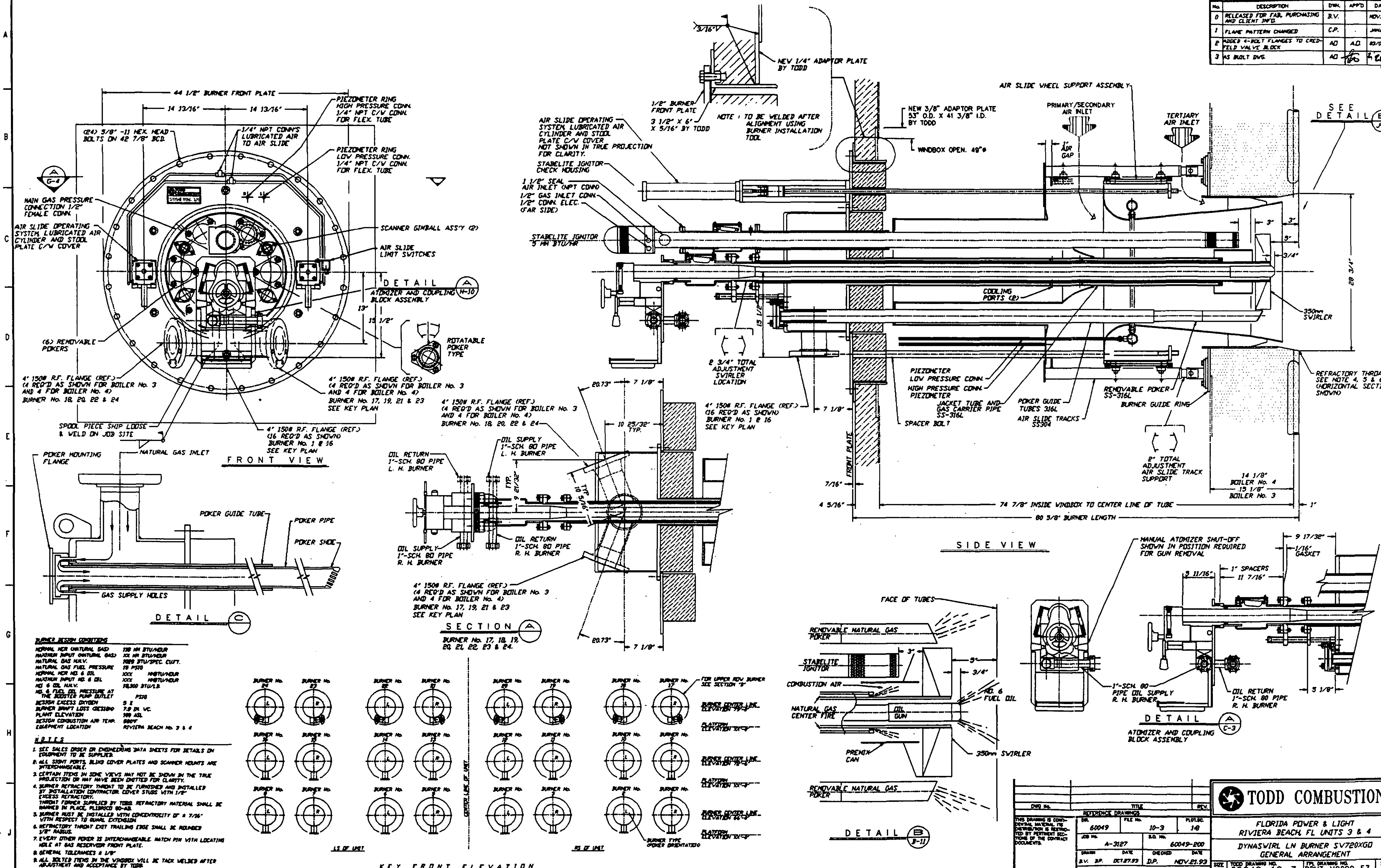
For gas firing, the gas is introduced at two locations, (1) through the gas poker shoes [5] located in the secondary air annulus, and (2) through the center-fired gas gun [22]. Gas for the poker shoes is introduced to the burner system through the gas reservoir [15] on the fuel carriage assembly, where it flows into each of the several poker pipes [6]. The gas passes down the poker pipes, and exits into the furnace through the poker shoes [5]. The poker shoes are drilled with several injection orifices, properly sized to provide the correct velocity to the exiting gas. In addition, the poker shoes are angled such that the gas is directed in predetermined directions in the furnace relative to the venturi. This angling of the poker shoes is a key element in providing the proper flame shape and minimum emissions.

When a center-fired gas gun is supplied, gas for the gun enters the burner through the same inlet as the pokers. The gas gun is designed as a "tube within a tube". The gas passes down the gun through the annulus between the inner and outer tube. The gas mixture exits the gas gun through a specially designed gas gun nozzle located at the rear of the swirler. Air for the combustion of this fuel is provided through a premix "can" located around the outside of the assembly near the furnace end; the position of the premix can relative to the swirler controls the air/gas mixture entering the swirler. The air for this center-fired gas gun combustion is simply a portion of the total primary air stream.

For oil fired applications, the oil is introduced through a centrally located oil atomizer assembly [16]. Oil supply and return are maintained as separate streams inside the jacket tube [19] of the assembly until atomization occurs at the sprayer plate [4]. At this point, oil is "atomized" into small droplets, and injected into the furnace. The oil atomizer assembly is designed in such a way that the entire assembly can be removed from the burner for inspection and maintenance without disconnecting the oil supply and return piping. When a center-fired gas gun is provided in addition to the oil gun, the oil atomizer assembly slides down the inside of the gas gun assembly. Slots are included in the gas gun assembly to provide cooling air to the oil atomizer assembly. When the oil gun is not being used the oil gun must be cleared of oil and cooling steam must be flowing through the oil gun otherwise the oil sprayer plate will be overheated and damaged. The oil gun can also be removed when oil firing is not selected.

The fuel is initially ignited by the ignitor assembly [18]. This ignitor may be any of a variety of different types. The ignitor is located near the outside edge of the swirler, and behind it at a prescribed distance. During the ignition phase of startup, the ignitor provides a small but intense flame directed inward toward the center of the burner. This intense flame ignites the main fuel.

This completes the discussion of the general design of the burner. However, this overview does not discuss the more intimate concepts involved in the design of the burner, those concepts which differentiate the Todd burner from other designs and which are critical to its proper functioning. The next section of this manual is devoted to these concepts.



REVISIONS				
No.	DESCRIPTION	DWN.	APP'D	DATE
0	RELEASED FOR FAB, PURCHASING AND CLIENT INFO.	B.V.		NOV.21.93
1	FLAME PATTERN CHANGED	C.P.	.	JAN.07.94
2	ADDED 4-BOLT FLANGES TO CRED-FELD VALVE BLOCK	AO	A.O.	03/02/94
3	AS BUILT DWG.	AO	[signature]	2/20/98

BURNER DESIGN CONDITIONS

NORMAL MCR (NATURAL GAS)	110 MM BTU/HOUR
MAXIMUM INPUT (NATURAL GAS)	XX MM BTU/HOUR
NATURAL GAS H.H.V.	1020 BTU/SPEC. CUFT.
NATURAL GAS FUEL PRESSURE	15 PSIG
NORMAL MCR NO. 6 OIL	XXX MMBTU/HOUR
MAXIMUM INPUT NO. 6 OIL	XXX MMBTU/HOUR
NO. 6 OIL H.H.V.	18,300 BTU/LB
NO. 6 FUEL OIL PRESSURE AT THE BOOSTER PUMP OUTLET	PSIG
DESIGN EXCESS OXYGEN	5 %
BURNER DRAFT LOSS (DESIGN)	7.9 IN. W.C.
PLANT ELEVATION	100 ASL
DESIGN COMBUSTION AIR TEMP.	600°F
EQUIPMENT LOCATION	RIVIERA BEACH No. 3 & 4

NOTES

1. SEE SALES ORDER OR ENGINEERING DATA SHEETS FOR DETAILS ON EQUIPMENT TO BE SUPPLIED.
2. ALL SIGHT PORTS, BLIND COVER PLATES AND SCANNER MOUNTS ARE INTERCHANGEABLE.
3. CERTAIN ITEMS IN SOME VIEWS MAY NOT BE SHOWN IN THE TRUE PROJECTION OR MAY HAVE BEEN OMITTED FOR CLARITY.
4. BURNER REFRACTORY THROAT TO BE FURNISHED AND INSTALLED BY INSTALLATION CONTRACTOR. COVER STUDS WITH 1/2" EXCESS REFRACTORY.
   THROAT FORMER SUPPLIED BY TODD. REFRACTORY MATERIAL SHALL BE RAMMED IN PLACE, PLIBRICO 80-AB.
5. BURNER MUST BE INSTALLED WITH CONCENTRICITY OF ± 7/16" WITH RESPECT TO QUARL EXTENSION.
6. REFRACTORY THROAT EXIT TRAILING EDGE SHALL BE ROUNDED 1/2" RADIUS.
7. EVERY OTHER POKER IS INTERCHANGEABLE. MATCH PIN WITH LOCATING HOLE AT GAS RESERVOIR FRONT PLATE.
8. GENERAL TOLERANCES ± 1/8"
9. ALL BOLTED ITEMS IN THE WINDBOX WILL BE TACK WELDED AFTER ADJUSTMENT AND ACCEPTANCE BY TODD.
10. FOR BALOONED ITEMS REFER TO INSTRUCTION MANUAL.

DWG No.	TITLE	REV.

REFERENCE DRAWINGS

DIR. 60049	FILE No. 10-3	PLOT.SC. 1:8
JOB No. A-3127	S.O. No. 60049-200	
DRAWN B.V. D.P. DATE OCT.27.93	CHECKED D.P. DATE NOV.21.93	
APP. BY THOMAS DePLONTY	DATE 03/02/94	

TODD COMBUSTION

FLORIDA POWER & LIGHT
RIVIERA BEACH, FL UNITS 3 & 4

DYNASWIRL LN BURNER SV720XGD
GENERAL ARRANGEMENT

SIZE	TODD DRAWING NO.	FPL DRAWING NO.	REV.
D	60049-10-3	PRV3-M9000-53	3
SCALE : 1 1/2" = 12"		SHEET 1 of 1	