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October 23, 2008

Peter C. L. Roth, Esq.
Office of the Attorney General
Site Evaluation Committee Counsel
NH Department of Justice
33 Capitol Street
Concord, NH 03301

Re: Docket No. SEC 2008-02 - Application of Tennessee Gas Pipeline Company For a Certificate of Site and Facility Concord Lateral Expansion Project; Responses to Public Counsel's Informal Data Requests from Tech. Session of October 8, 2008

Dear Attorney Roth:

We are providing Tennessee Gas Pipeline Company's responses to your informal data requests from the Technical Session of October 8, 2008. We have phrased and responded to the requests as we understood them. The responses were prepared by a multi-disciplinary team of Tennessee Gas Pipeline Company personnel. We have used tabs only for those responses which required attaching documentation.

We very much look forward to having the Company answer any questions which you may have with respect to this material on Tuesday, October 28, when we will meet for our next Technical Session.

Sincerely yours,

Donald J. Pfundstein

DJP/skr
Enclosure

cc: Michael J. Iacopino, Esq.
Service List

Request 1: Is TGP willing to install a permeable parking surface at Pelham?

Response: Tennessee recommends against use of porous pavement at the Pelham compressor site. Tennessee's engineers investigated the technology of porous pavement through Web sites provided by Mr. Roth, other Web-based material, and contractors that have experience with the technology. Tennessee attempted to contact Roger Gaudette with Ford Motor Company by e-mail at rgaudette@ford.com , as recommended by Mr. Roth, in order to discuss the porous pavement installation at the Ford-Rouge Plant in Detroit, Michigan. The e-mail was sent back as non-deliverable. A follow-up phone call was placed to Ford but they could not find a Roger Gaudette. Tennessee spoke with Bob Givens with Omni Engineering (920-735-6900) in Appleton, Wisconsin, regarding porous pavement. Bob's company has researched porous pavement and was able to propose it for an impending project because it enabled the client to build on additional land that would have been required to be used as a water retention area. That project consists of pavement at the Experimental Aircraft Association near Wittman Airport in Oshkosh, Wisconsin. Porous pavement is only being used on about ten percent of the total project due to cost and because it should not be used in heavy traffic areas. The following is a list of points from verbal discussions with Bob, as well as e-mail correspondence with the installation contractor:

- Maintenance, in the form of vacuuming, is required to keep the surface porous and free of dirt;
- The installation will consist of porous asphalt on top, a layer of ¾" clear washed stone below the asphalt, a layer of fabric below the clear stone and then the soil. The fabric keeps the soil from clogging the clear stone;
- The installation contractor submitted a bid that consisted of three inch asphalt and did not include the material below the asphalt. The contractor quoted $13.15 per square yard for normal asphalt and $22.70 per square yard for porous asphalt. The contractor estimates that the area below the asphalt would be two to three times the cost of standard road/parking base; and
- A separate contractor indicated a forty percent cost increase over standard asphalt.

The general consensus is that the technology has improved over the years and can provide a benefit in certain areas of use, however it does not appear to be a good fit for the Pelham compressor station based upon the issues listed above and the following points:

- The compressor station total paved area for parking, as well as roads internal and external to the station fenceline, is estimated to be 42,500 square feet (0.97 acres) compared to a total land area of 11.6 acres. In other words, the paving is less than ten percent of the total acreage purchased by Tennessee.;
- Other non-paved areas of the compressor station will contain crushed rock or grass; and

- Tennessee has designed the compressor station and associated stormwater management system in accordance with the New Hampshire Department of Environmental Services site-specific alteration of terrain requirements to ensure that stormwater runoff generated within the developed site will be controlled, contained, and discharged in a manner that is consistent with the existing site conditions. As included in the certificate application submitted to the New Hampshire Energy Facility Site Evaluation Committee, the alteration of terrain permit application details the drainage plan that includes two containment basins to be constructed to control the site surface hydrology leading to Beaver Brook.

Request 2: Why is TGP planning to use an enviro-septic system vs. a pipe and stone system?

Response: Septic systems typically use three steps to treat raw sewage: (1) A septic tank to remove sixty-to-eighty percent of solids and grease from raw sewage, (2) a field for dispersing effluent from the septic tank (which contains the other twenty-to-forty percent of the solids and grease), and (3) a bacterial layer to digest compounds in the effluent. The solids deposited in the septic tank are removed and taken to an approved land filled or are subsequent treated in a tank where anaerobic bacteria breakdown the solids. Both Enviro-Septic and conventional systems have septic tanks, so there is no advantage between two systems in regard to the initial treatment.

In a conventional system the effluent from the septic tanks, as noted above, is dispersed through a system of perforated pipes and deposited on the soil surface for further treatment (digesting) by aerobic bacteria living on the soil surface.

In an Enviro-Septic system, similarly to the conventional system, the effluent from the septic tank is dispersed by a system of pipes. However, for the Enviro-Septic system, the effluent is treated inside of the pipes. This means that the effluent coming out of the pipes has already been digested by the bacteria. There are no solids or grease coming out of the pipe that clogs the soil, which otherwise would reduce the capacity of the leaching field. The treatment of effluent inside of the pipe is the major advantage of the Enviro-Septic system.

The following are differences between the systems:

1. As noted above, the Enviro-Septic system leaching field has a longer life because the bacterial breakdown of the effluent occurs inside of the pipe system and not in the soil.
2. The Enviro-Septic system has a smaller footprint than the conventional pipe and stone system.
3. The Enviro-Septic system costs less due the smaller size footprint.
4. The Enviro-Septic system is easier to install due to its smaller footprint.
5. Due to the treatment of effluent in the Enviro-Septic system inside of the pipe system, the aerobic bacterium is kept viable longer than if it is treated outside of the pipe (as in a conventional system).

Request 3: Please provide drawings of the buildings and equipment that will be installed as part of the project.

Response: Please see the attached documents behind Tab 3.

Request 4: Please provide a copy of the "safety matrix" you mentioned at the meeting.

Response: Please see the attached document behind Tab 4.

Request 5: Please provide job descriptions and qualifications for the various members of the construction inspection team.

Response: Please see the attached document behind Tab 5.

Request 6: Please provide the details of the cathodic protection system that will be used at Pelham.

Response: The excerpt from Tennessee's corrosion control manual related to compressor stations is attached behind Tab 6.

Request 7: Please provide the specifications and warranty information for the Pelham compressor.

Response: Please see the attached documents behind Tab 7.

Request 8: Has TGP ever made any warranty claims against Solar? If so, please provide the details.

Response: Tennessee is unaware of any warranty claims it may have made within the past five years.

Request 9: Please provide an estimate of the annual number of hours the emergency generator at the Pelham station is expected to run.

Response: The generator will be tested one weekday each week for one daytime hour. Historically, power outages in the Industrial Drive area have averaged three-to-four incidents per year, with an estimated duration of fewer than twenty-four hours per event.

Request 10: Please provide an estimate of the number of days the Pelham site is anticipated to exceed the limits in the air permit due to operating in extreme cold conditions (sub-0° F temps).

Response: Please refer to Table 2-2 from Tennessee's permit application. Historical weather data reflects the number of hours in sub-zero temperature ranges from eight to

181 hours on an annual basis. The combustion turbine is permitted for twenty-five parts per million ("ppm") (Table 3, Item #1, TP-BP-0544) under the New Source Performance Standard ("NSPS"), Subpart KKKK. NSPS Subpart KKKK specifies the twenty-five ppm limit in specific to above-zero temperature conditions and a higher emissions limit o 150 ppm for sub-zero conditions (40 CFR 60.4320, Table 1). Tennessee expects the combustion turbine to always comply with the NSPS limits as reflected in Table 1 of NSPS Subpart KKKK, during both above- and sub-zero conditions.

Request 11: What is the impact of station start-up and shutdown on air emissions?

Response: Please refer to Tables 2-4 and 2-6 of the permit application. During start-up and shutdown, the combustion turbine is operating between zero and fifty percent load. Because the optimal performance of the turbine is between fifty and one hundred percent, exhaust concentrations during start-up and shutdown can exceed the concentrations that are guaranteed for normal operational loads. Even assuming a conservatively over-estimated number of start-ups and shutdowns per year, Tennessee expects the impact to be negligible. In recognition of such negligible impact, start-up and shutdown emissions are exempt from the permit limits.

Request 12: What would be the impact of a 55' stack vs. a 92' stack on air emissions at the neighboring properties?

Response: Tennessee conducted air dispersion modeling at both the 55' and 92' stack heights. The results are summarized below.

Table A Maximum Predicted Concentrations for Compressor Station 270B1 with a 55 foot and 92.5 foot Stack Height at the Closest Residential Receptors Compared to the Significant Impact Levels (SIL) and National Ambient Air Quality Standards (NAAQS)

				55 Foot Stack		**92.5 Foot Stack (GEP)**	
Pollutant	**Ave. Period**	**SIL ($\mu g/m^3$)**	**NAAQS ($\mu g/m^3$)**	**Maximum Concentration ($\mu g/m^3$)**	**Percent of NAAQS ($\mu g/m^3$)**	**Maximum Concentration ($\mu g/m^3$)**	**Percent of NAAQS ($\mu g/m^3$)**
NO_2	Annual	1	100	0.34	0.34	0.08	0.080
PM_{10}	24-Hour	5	150	0.26	0.17	0.06	0.040
	Annual	1	50	0.024	0.05	0.006	0.012
SO_2	3-Hour	25	1300	0.31	0.02	0.10	0.007
	24-Hour	5	365	0.16	0.04	0.03	0.008
	Annual	1	80	0.014	0.02	0.004	0.005
CO	1-Hour	2000	40,000	9.23	0.02	4.76	0.012
	8-Hour	500	10,000	8.26	0.08	1.808	0.018

The maximum predicted concentrations for both stack heights are all considerably less than half of one percent of the National Ambient Air Quality Standards ("NAAQS"), which are set to protect public health and welfare with a margin of safety (including consideration of the most sensitive populations). All maximum concentrations for both stack heights are considered insignificant according to Environmental Protection Agency and NH Department of Environmental Services criteria because they are well below defined Significant Impact Levels ("SIL") as shown in the table. Thus, under either measure, the choice of a 55' vs. 92' stack height has no appreciable air quality impact.

To minimize any potential visual or safety impact of the stack, stack heights are typically designed and built at less than "good engineering practice" height if maximum air pollutant concentrations are predicted to be less than SIL.

Request 13: Has Tennessee ever violated any air emissions permit limits for other stations on its system?

Response: Tennessee paid fines of $2050 and $11, 500 on March 27, 2008, and November 11, 2006, respectively, for minor emissions violations. Both incidents occurred at stations that are not as technologically advanced as the Pelham station will be.

Request 14: Does the project impact the hydrology of Beaver Brook?

Response: The project is designed to eliminate any potential impact to the hydrology of Beaver Brook ("Brook"). There is no work proposed within the Brook that would alter the flow regime nor is there any work proposed within fifty feet of the wetland area associated with the Brook. The earthwork associated with the compressor station is engineered to control surface runoff and will not affect the groundwater table. During construction at the site, Tennessee will require its contractors to install and maintain appropriate silt fence, hay bale, and temporary slope breakers as erosion control to minimize the potential for sediment transport from the construction site. The implementation of erosion control procedures will follow the Federal Energy Regulatory Commission's Upland Erosion Control, Revegetation, and Maintenance Plan. The project will also comply with the site's New Hampshire Department of Environmental Services alteration of terrain permit.

Request 15: What measures will Tennessee use to avoid impacting the Brook's hydrology?

Response: Tennessee has designed the compressor station and associated stormwater management system in accordance with the New Hampshire Department of Environmental Services Site-Specific Alteration of Terrain requirements to ensure that stormwater runoff generated within the developed site will be controlled, contained, and discharged in a manner that is consistent with the existing site conditions. As included in the certificate application submitted to the New Hampshire Energy Facility Site Evaluation Committee, the alteration of terrain permit application details the drainage plan that includes two containment basins to be constructed to control the site surface hydrology leading to the Brook. The alteration of terrain permit takes into account the addition of approximately one acre of new impervious cover on the approximately eleven acre site for use as building facilities, a paved access road, and a paved parking area. The remaining site acreage continues its function as pervious surface. The calculated loss of stormwater infiltration to the grounds due to the project is mitigated by the measures detailed in the alteration of terrain permit. No planned work is to take place within fifty feet of the wetland area associated with the Brook.

Request 16: What would be the impact to the Brook if such measures were not used?

Response: If standard erosion control measures were not implemented during construction, there could be temporary impacts to the Brook associated with erosion and uncontrolled stormwater runoff that could result in siltation of the water. Without a post-construction stormwater management system in place, such impacts could continue on a long term basis, which could result in sediment deposits in the stream and adverse impacts to fisheries and habitats. The lack of a post-construction stormwater management system could also result in increases in stormwater runoff volume and velocity, which could negatively affect certain characteristics of the Brook.

Request 17: Does Tennessee need to claim any exceptions or reservations to the FERC erosion control plan?

Response: Tennessee has not requested and does not require any variances from the FERC Upland Erosion Control and Revegetation Plan. Tennessee will comply with the erosion control provisions therein.

Request 18: Who permits the hydrostatic test water discharge?

Response: The hydrostatic test water discharge plan is reviewed and approved by the United States Environmental Protection Agency. This approval has not yet been applied for because the permit has a short life. Applications for such permits are typically submitted thirty to sixty days prior to discharge.

Request 19: What, if any, contaminants are in the hydrostatic test water immediately prior to discharge?

Response: The hydrostatic test water is not anticipated to contain regulated contaminants. The source water will be from local municipal supply. The pipeline undergoing testing is constructed with new, never before used, steel pipe. Cleaning devices will be used to remove debris and any foreign material from the pipeline prior to the hydrostatic test. The removed waste material will be properly disposed of at an appropriate off-site regulated waste facility. The hydrostatic test water will not be discharged directly to surface waters or storm water inlets. The discharge water will be released to the ground in a well vegetated area. The discharge will be controlled by use of valve flow control or an energy dissipating splash plate contained within a hay bale and filter fabric erosion-siltation corral and/or discharged through a filter fabric sock. To further ensure that the discharge will not contain pollutants, Tennessee will not add any chemicals to the hydrostatic test water.

Request 20: Does the hydro test water discharge impact the designated wellhead area at or around the Pelham station?

Response: Tennessee anticipates the use and discharge of approximately 40,000 gallons of water during the pressure test. The volume of test water discharged is relatively minor and will be allowed to infiltrate back to the ground, where it will eventually recharge the groundwater. The hydrostatic test water discharge will not impact the wellhead area because it will be sourced from local municipal supply, the water will only be in contact with new steel pipe (thus the discharge will be free of regulated contaminants), and the water will be discharged outside the designated wellhead area.

Request 21: From where will TGP get its hydro test water?

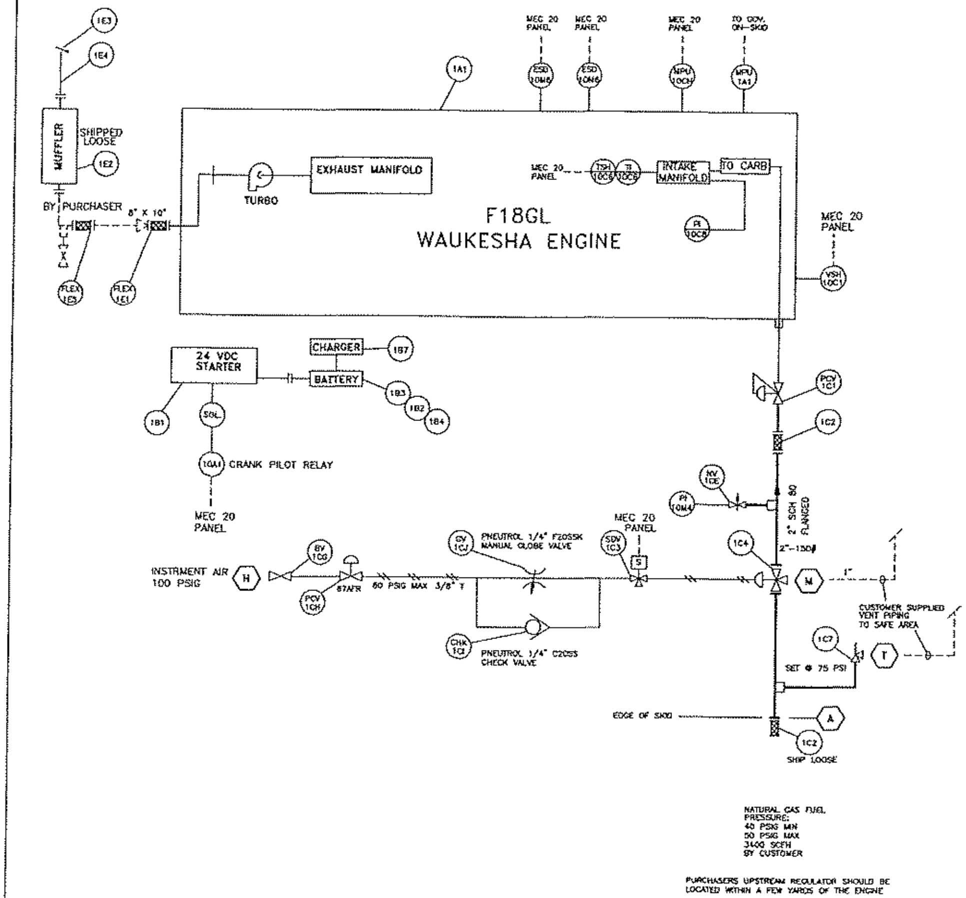
Response: Tennessee will obtain the appropriate approval from the Town of Pelham to utilize the municipal water supply to source the hydrostatic test water from a nearby hydrant. Alternatively, municipal water will be trucked to the site. Under no circumstance will Beaver Brook be used as a source of hydrostatic test water.

Request 22: Please provide a copy of the landscaping plan that was filed with FERC.

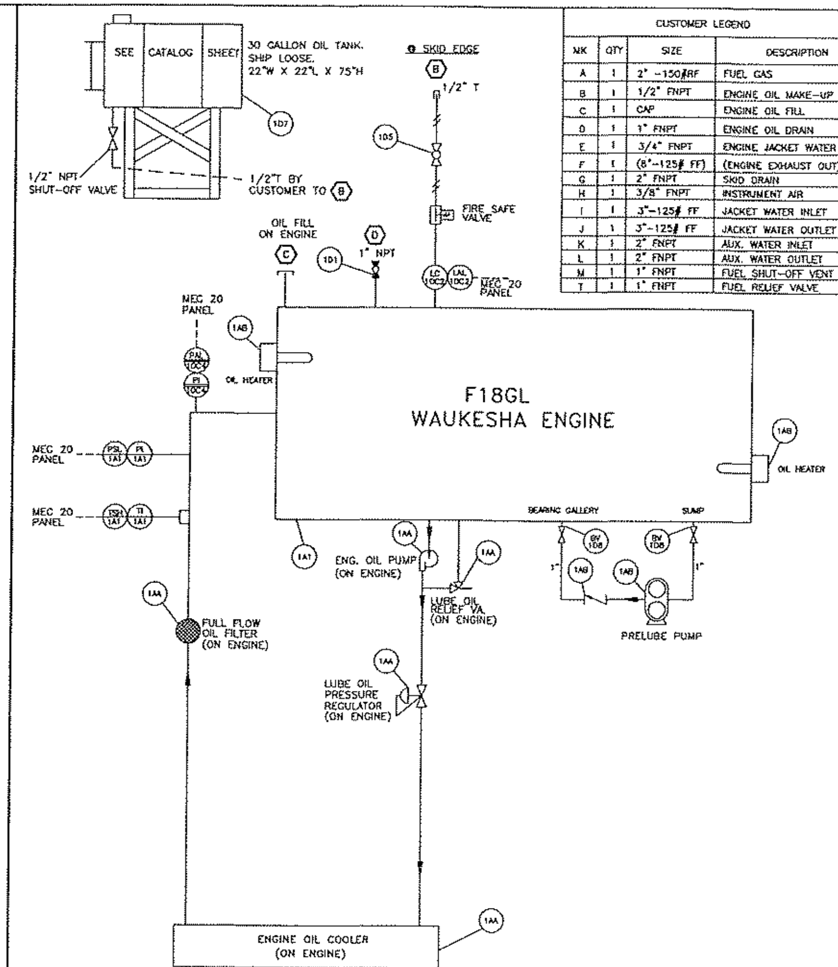
Response: Please see the attached document behind Tab 22.

Request 23: Please provide documents related to Keyspan's projected need for gas transportation service from the project facilities.

Response: Please see the attached documents behind Tab 23.



FUEL AND START SCHEMATIC



OIL FLOW SCHEMATIC

CUSTOMER LEGEND

MK	QTY	SIZE	DESCRIPTION
A	1	2" -150#RF	FUEL GAS
B	1	1/2" FNPT	ENGINE OIL MAKE-UP
C	1	CAP	ENGINE OIL FILL
D	1	1" FNPT	ENGINE OIL DRAIN
E	1	3/4" FNPT	ENGINE JACKET WATER DRAIN
F	1	(8"-125# FF)	(ENGINE EXHAUST OUT)
G	1	2" FNPT	SKID DRAIN
H	1	3/8" FNPT	INSTRUMENT AIR
I	1	3"-125# FF	JACKET WATER INLET
J	1	3"-125# FF	JACKET WATER OUTLET
K	1	2" FNPT	AUX. WATER INLET
L	1	2" FNPT	AUX. WATER OUTLET
M	1	1" FNPT	FUEL SHUT-OFF VENT
T	1	1" FNPT	FUEL RELIEF VALVE

NOTES:

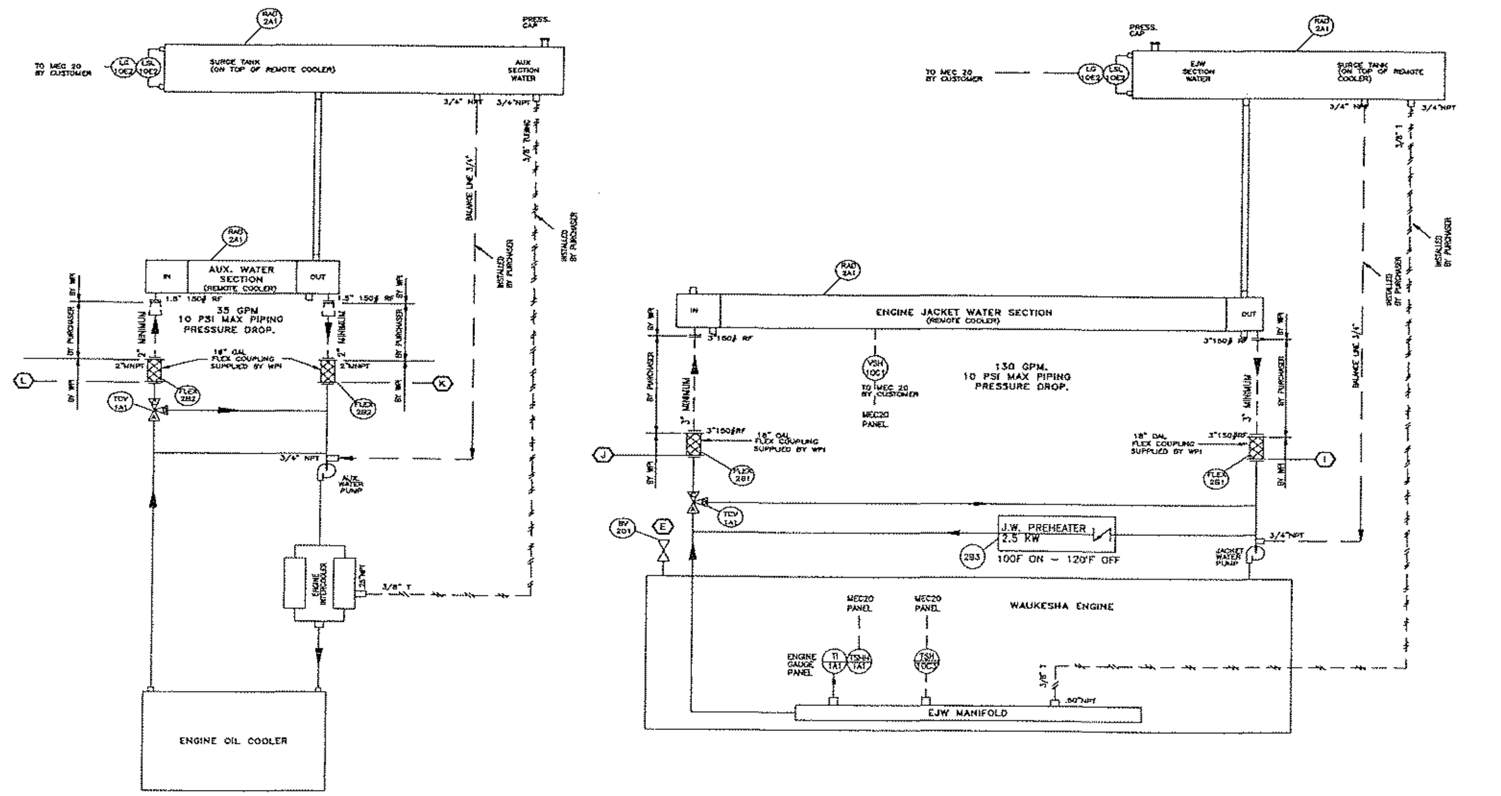
1. LOCAL GAUGE PANEL MOUNTED ON ENGINE.
2. MEC 20 PANEL MOUNTED AT GENERATOR.

No	BY	DATE	ISSUE / REVISION
0	FC	12 AUG 08	FOR APPROVAL
1	FC	29 AUG 08	CERTIFIED

WAUKESHA-PEARCE IND., INC.
12320 S Main
Houston, Texas, 77035
Tel.(713) 723-1050
Fax.(713) 551-0572

SCALE	ENG./DESIGN	DRAWN	CHECKED	ENG. APPR
NONE	28 JUL 08	12 AUG 08	7 AUG 08	11 AUG 08
	FC	VN	DM	FC

TGP
STATION 270B1
F18GL/GENERATOR/RADIATOR TGP-118861
OIL / EXHAUST / FUEL & START SCHEMATIC
F03-0470-050 1



CUSTOMER LEGEND			
MK	QTY	SIZE	DESCRIPTION
A	1	2" ~150#RF	FUEL GAS
B	1	1/2" FNPT	ENGINE OIL MAKE-UP
C	1	CAP	ENGINE OIL FILL
D	1	1" FNPT	ENGINE OIL DRAIN
E	1	3/4" FNPT	ENGINE JACKET WATER DRAIN
F	1	(8"~125# FF)	(ENGINE EXHAUST OUT)
G	1	2" FNPT	SKID DRAIN
H	1	3/8" FNPT	INSTRUMENT AIR
I	1	3"~125# FF	JACKET WATER INLET
J	1	3"~125# FF	JACKET WATER OUTLET
K	1	2" FNPT	AUX. WATER INLET
L	1	2" FNPT	AUX. WATER OUTLET
M	1	1" FNPT	FUEL SHUT-OFF VENT
T	1	1" FNPT	FUEL RELIEF VALVE

NOTES:

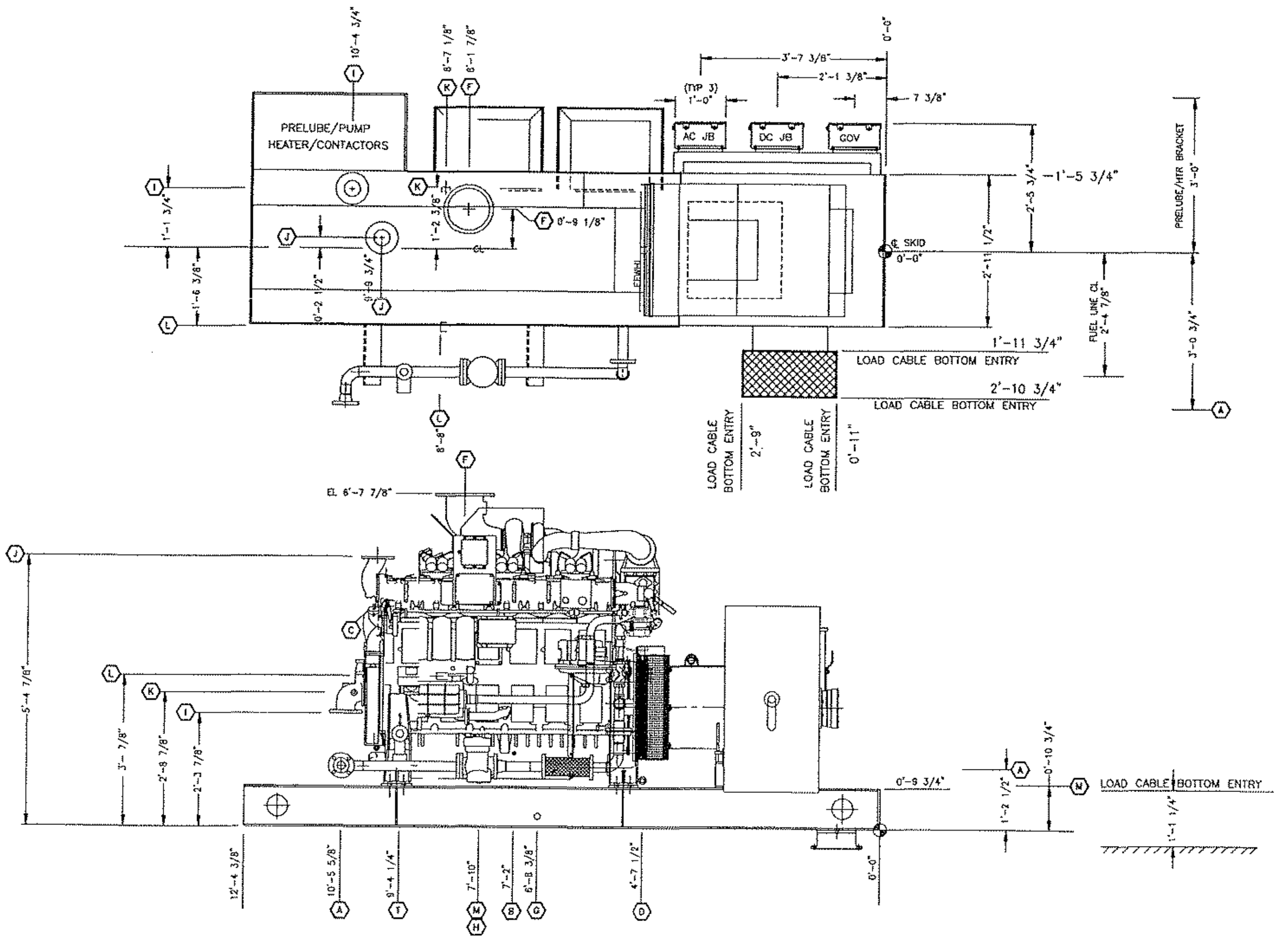
1. PURCHASER TO INSTALL LOW POINT DRAINS W/PLUGS IN INTERCONNECTING JW AND AUX WATER PIPING.
2. BLANK
3. HIGH POINT VENTS FROM AUX. INTERCOOLER & EJW MANIFOLD HEADER MUST BE TUBED BACK TO SURGE TANK WITH NO POCKETS.
4. ⊖ LOCAL GAUGE PANEL MOUNTED ON ENGINE.
4. VENT PIPING TO BE ROUTED WITH NO POCKETS.
5. EXPANSION TANK TO BE HIGHEST POINT IN COMPLETE SYSTEM.
6. BALANCE LINES ARE REQUIRED AS SHOWN.

No	BY	DATE	ISSUE / REVISION
0	FC	12 AUG 08	FOR APPROVAL
1	FC	29 AUG 08	CERTIFIED

WAUKESHA-PEARCE IND., INC.
12320 South Main, Houston, Texas 77035
Tel.(713) 723-1050 Fax.(713) 551-0799

SCALE		ENG/DESIGN	DRAWN	CHECKED	ENG. APPR
N.T.S.	DATE	28 JUL 08	31 JUL 08	7 AUG 08	11 AUG 08
	BY	FC	YN	DM	FC

TGP
STATION 270B1
F18GL/ GENERATOR/RADIATOR TGP-118861
WATER FLOW DIAGRAM
F03-0470-051 1



CUSTOMER LEGEND			
MK	QTY	SIZE	DESCRIPTION
A	1	2" -150#RF	FUEL GAS
B	1	1/2" FNPT	ENGINE OIL MAKE-UP
C	1	CAP	ENGINE OIL FILL
D	1	1" FNPT	ENGINE OIL DRAIN
E	1	3/4" FNPT	ENGINE JACKET WATER DRAIN
F	1	(8"-125# FF)	(ENGINE EXHAUST OUT)
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H	1	3/8" FNPT	INSTRUMENT AIR
I	1	3"-125# FF	JACKET WATER INLET
J	1	3"-125# FF	JACKET WATER OUTLET
K	1	2" FNPT	AUX. WATER INLET
L	1	2" FNPT	AUX. WATER OUTLET
M	1	1" FNPT	FUEL SHUT-OFF VENT
T	1	1" FNPT	FUEL RELIEF VALVE

NOTES:

1. ALL CUSTOMER CONNECTIONS ARE ± 1/4" TOLERANCE.
2. ESTIMATED UNIT WEIGHT (DRY) = 10,600LB
3. SHOP TO SHIM UNDER ENGINE/GENERATOR AS REQUIRED.
4. NOT USED.
5. ALL CONNECTIONS TO UNIT MUST BE FLEXIBLE.
6. GROUND UNIT. SIZE FOR NEC CODE.

No	BY	DATE	ISSUE / REVISION
0	FC	11 AUG 08	FOR APPROVAL
			CIRCUIT BREAKER MOVED TO LEFT SIDE.
1	FC	18 AUG 08	CERTIFIED

WAUKESHA-PEARCE IND., INC.
12320 South Main, Houston, Texas, 77035
Tel(713) 723-1050
Fax(713) 551-0799

SCALE	DATE	ENG/DESIGN	DRAWN	CHECKED	ENG. APPR
NONE		28 JUL 08	12 AUG 08	7 AUG 08	11 AUG 08
	BY	FC	VN	DM	FC

TGP
STATION 270B1
F18GL/GENERATOR/RADIATOR P.O. TGP-118861
GENERAL ARRANGEMENT
F03-0470-200 1

CUSTOMER LEGEND			
MK	QTY	SIZE	DESCRIPTION
A	1	2" -150#RF	FUEL GAS
B	1	1/2" FNPT	ENGINE OIL MAKE-UP
C	1	CAP	ENGINE OIL FILL
D	1	1" FNPT	ENGINE OIL DRAIN
E	1	3/4" FNPT	ENGINE JACKET WATER DRAIN
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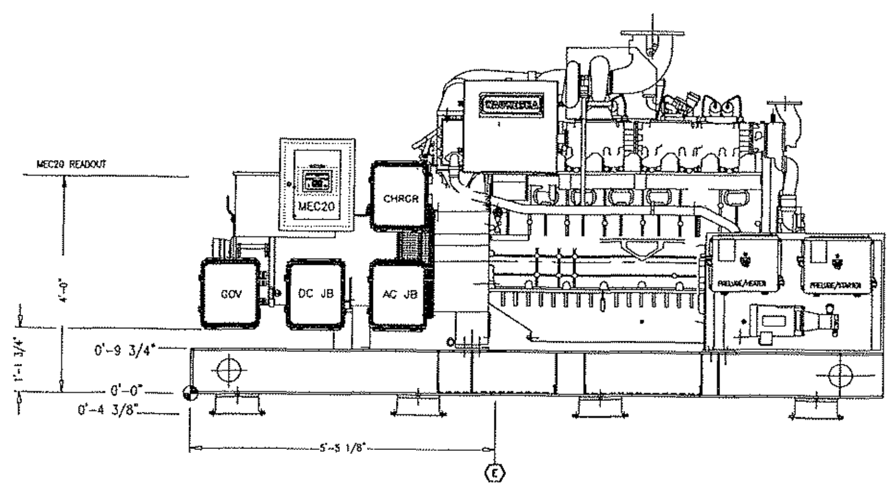
I	1	3"-125# FF	JACKET WATER INLET
J	1	3"-125# FF	JACKET WATER OUTLET
K	1	2" FNPT	AUX. WATER INLET
L	1	2" FNPT	AUX. WATER OUTLET
M	1	1" FNPT	FUEL SHUT-OFF VENT
Z	1	1" FNPT	FUEL RELIEF VALVE



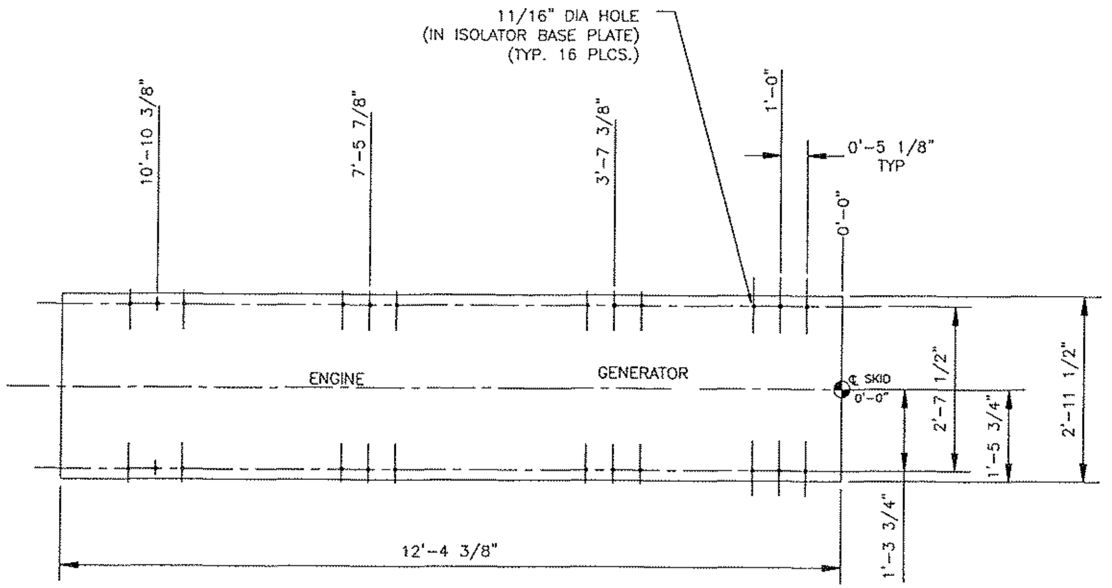
NOTES:
1. ALL CUSTOMER CONNECTIONS ARE ± 1/4" TOLERANCE.
2. ESTIMATED UNIT WEIGHT (DRY) = 10,600LB
3. SHOP TO SHIM UNDER ENGINE/GENERATOR AS REQUIRED.
4. NOT USED.
5. ALL CONNECTIONS TO UNIT MUST BE FLEXIBLE.
6. GROUND UNIT. SIZE FOR NEC CODE.

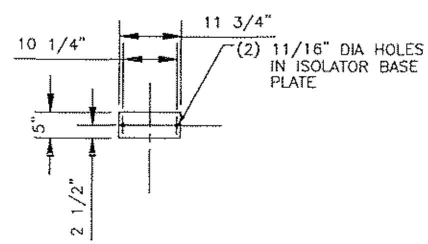
No	BY	DATE	ISSUE / REVISION
0	FC	12 AUG 08	FOR APPROVAL
			CIRCUIT BREAKER MOVED TO LEFT SIDE
1	FC	26 AUG 08	CERTIFIED

WAUKESHA-PEARCE IND., INC.
12320 South Main
Houston, Texas 77054
Tel.(713) 723-1050
Fax(713) 551-0799

SCALE		ENG/DESIGN	DRAWN	CHECKED	ENG. APPR
NONE	DATE	28 JUL 08	31 JUL 08	7 AUG 08	11 AUG 08
	BY	FC	VN	DM	FC

TGP
STATION 270B1
F18GL/GENERATOR/RADIATOR P.O. TGP-115861
GENERAL ARRANGEMENT
F03-0470-201 1





ISOLATOR FOOT PRINT
TYP. 8 PLACES

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No	BY	DATE	ISSUE / REVISION
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1	FC	29 AUG 08	CERTIFIED

WAUKESHA-PEARCE IND., INC.
12320 S Main, Houston, Texas, 77035
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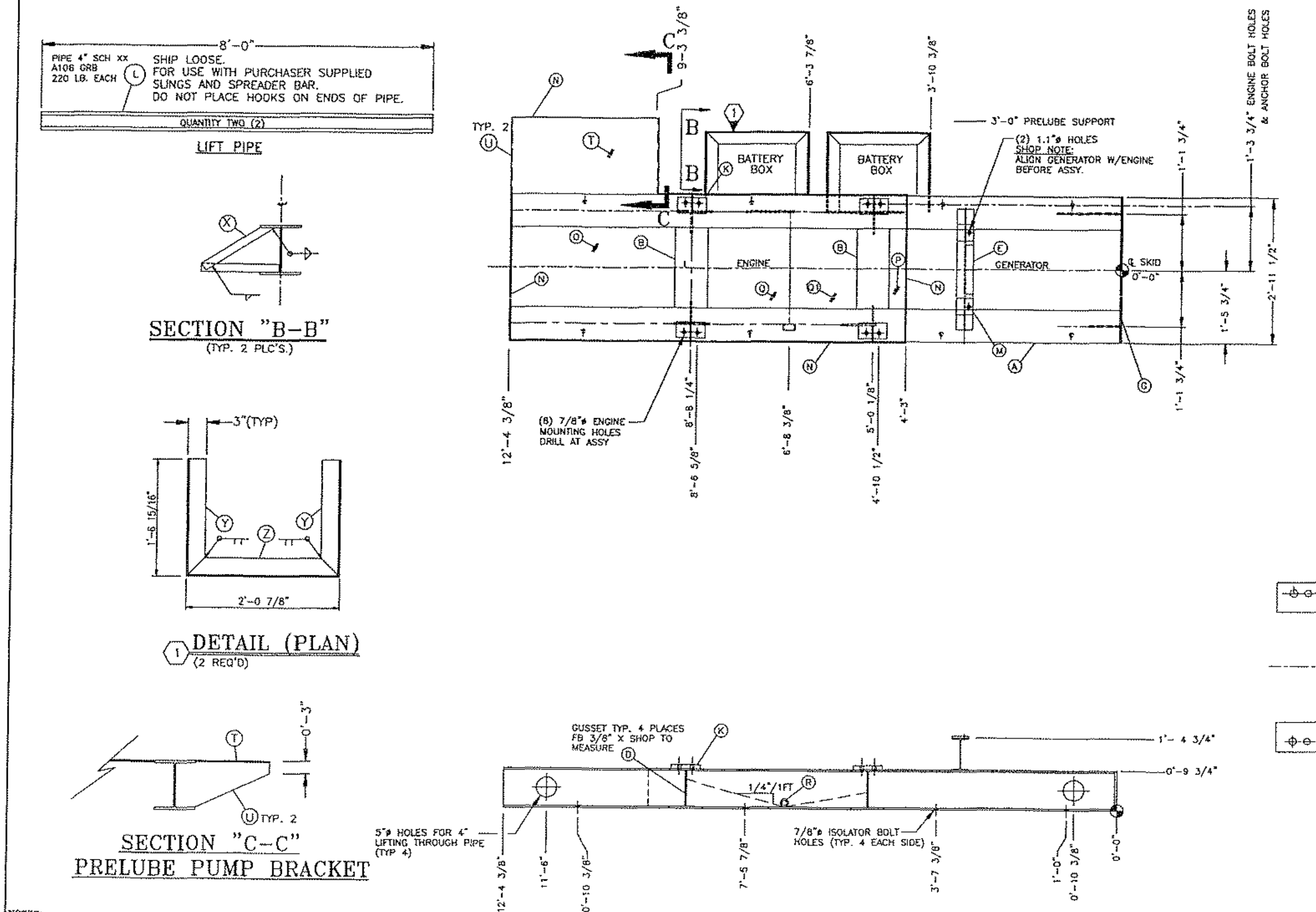
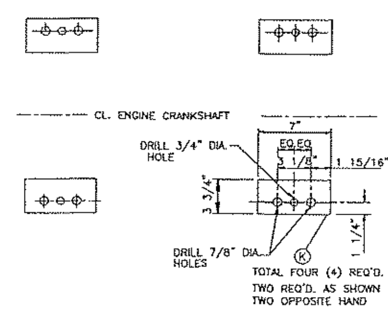
SCALE		ENG/DESIGN	DRAWN	CHECKED	ENG. APPR
NONE	DATE	28 JUL 08	31 JUL 08	11 AUG 08	11 AUG 08
	BY	FC	VH	DM	FC

TGP
STATION 270B1
F18GL/GENERATOR/RADIATOR P.O. TGP-118861
ANCHOR BOLT LAYOUT
DWG F03-0470-210 REV 1



BILL OF MATERIALS				
MK	QTY	DESCRIPTION	LENGTH	WT.
A	2	W 10 x 33	12'-4"	815
B	2	W 10 x 33	2'-3 1/2"	152
C	–	NOT USED	–	–
D	4	FB 3/8" THK	SHOP	8
E	1	SHOP	2'-5 1/2"	40
F	–	NOT USED	–	–
G	1	PL: 3/8" THK. x 9 3/4"	2'-11 1/2"	37
H	–	NOT USED	–	–
J	–	NOT USED	–	–
K	4	F.B. 1" x 3 3/4" C.R.S.	0'-7"	15
L	2	PIPE: 4" SCH XX	8'-0"	440
M	–	F.B. 1.10" x 6" C.R.S.	6"	–
N	–	STRIP 1/4" x 1"	25'-1" TTL	18
O	1	PL: 1/4" THK x 19 1/2"	3'-4 1/2"	65
P	1	PL: 1/4" THK x 19 1/2"	0'-4 1/4"	11
Q	1	PL: 1/4" THK x 19 1/2"	SHOP	65
R	1	HALF CPLG. 2" 3000# W/PLUG		6
S	–	NOT USED	–	–
T	1	PL 1/4" X 18"	3'-0"	12
U	2	PL 1/4" X 11 1/4"	1'-11"	32
Q1	1	PL: 1/4" THK x 19 1/2"	SHOP	65
X	4	FB. 1/4" x 2"	1'-8"	12
Y	4	ANGLE: 1/4" x 3" x 2"	1'-6 15/16"	32
Z	2	ANGLE: 1/4" x 3" x 2"	2'-0 7/8"	18

APPROXIMATE TOTAL WEIGHT – 1843 LBS.



ENGINE BEARING PLATE DETAIL

N.T.S.

NOTES:

1. ALL FLANGE TO FLANGE CONNECTIONS TO BE GROOVE WELD DESIGN.
2. ALL WEB TO FLANGES OR WEB TO WEB CONNECTIONS TO BE DOUBLE FILLET.
3. ALL FILLET WELDS TO BE 1/2 THE THK. OF THE SMALLEST JOINING MEMBER, 3/16" MIN. UNLESS NOTED OTHERWISE.
4. WPI TO MOUNT ENGINE AND GENERATOR ON SOLEPLATES AND 1/8" SHIMPACK.

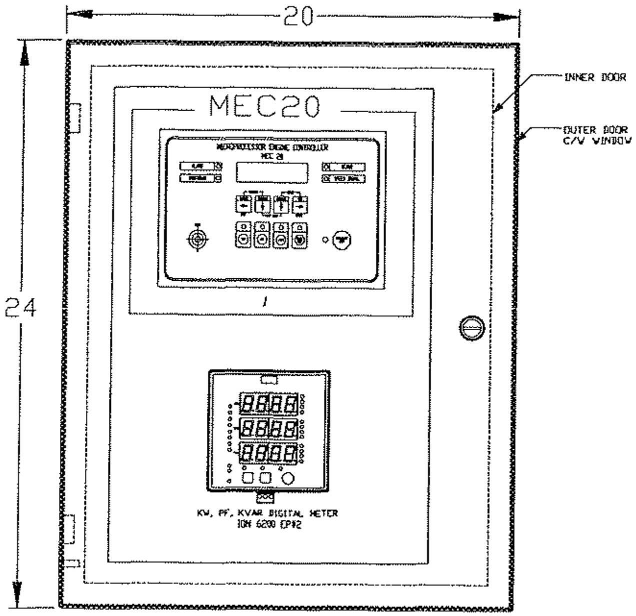
SEALWELD ITEMS N, O, P, Q, Q1, S, AND R.
DECKPLATE ITEMS O AND P FLUSH W/TOP OF STEEL.
ITEM R AS CLOSE TO BOTTOM FLANGE AS FEASIBLE.

No	BY	DATE	ISSUE / REVISION
0	FC	12 AUG 08	FOR APPROVAL
1	FC	29 AUG 08	CERTIFIED

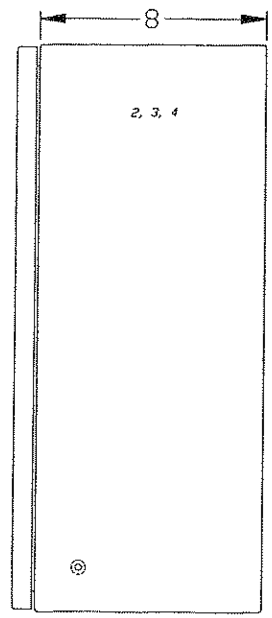
WAUKESHA-PEARCE IND., INC.
12320 South Main
Houston, Texas 77054
Tel.(713) 723-1050
Fax(713) 551-0799

SCALE	ENG/DESIGN	DRAWN	CHECKED	ENG. APPR
NONE	28 JUL 08	31 JUL 08	7 AUG 08	11 AUG 08
	FC	VN	DN	FC

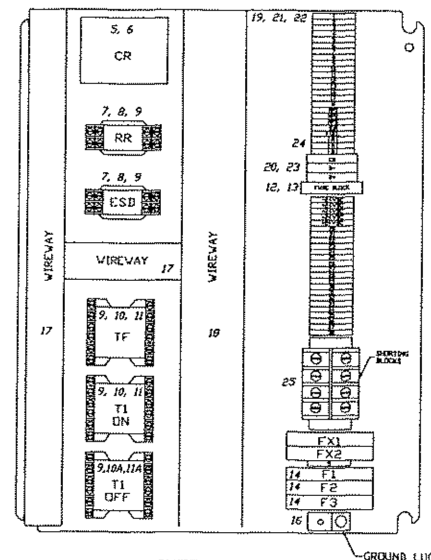
TGP
STATION 270B1
F18GL/GENERATOR/RADIATOR P.O. TGP-118861
SKID STRUCTURE
F03-0470-300 1



PANEL LAYOUT
COLOR: ASA #61 GRAY
TYPE: NEMA 4



RHS VIEW



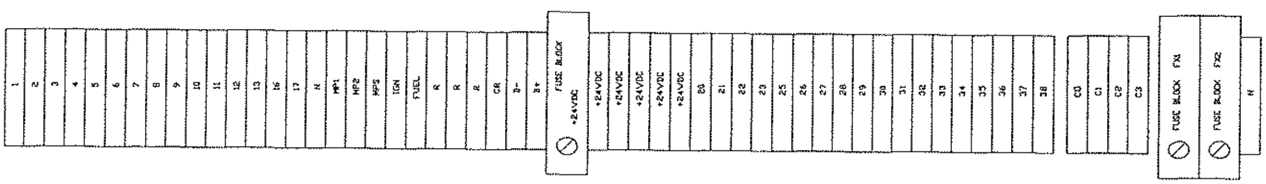
INTERIOR LAYOUT

STANDARD CONSTRUCTION

1	TERMINAL DATA: DC POSITIVE & NEGATIVE TERMINALS. WK4/U: 1C - #20-#10 AWG. 2C - #14 AWG MAX. WK6/U: 1C - #20-#8 AWG. 2C - #14 AWG MAX. 10% SPARE TERMINALS PROVIDED.
2	WIRING DATA: COLOR CODE - PER DWG. WIRE MARKERS - NONE CRIMP CONNECTORS - NONE WIRE TYPE #18-#14 AWG TEW, 105°C. COPPER CONTROL WIRE.
3	GROUND LUG: 1C - STUD 1/4x20 1/0 LUG
4	EXTERNAL LABELING: WHITE LETTERS ON BLACK BACKGROUND LAMICOIDS, AFFIXED BY MEANS OF SELF-ADHESIVE BACKING.
5	INTERNAL LABELING: VINYL LABELS WITH INDELIBLE INK PRINTING, MATCHING DEVICE DESIGNATIONS ON DRAWINGS.

SYMBOL LEGEND

- DC+ COMMON POSITIVE CONDUCTOR [+]
- DC- COMMON NEGATIVE CONDUCTOR [-]
- COMMON CHASSIS GROUND
- N COMMON NEUTRAL CONDUCTOR
- GRD EQUIPMENT SAFETY GROUNDING CONDUCTOR
- - DASHED CONNECTIONS BY INSTALLER
- - CONTROL WIRE - TEW



TERMINAL BLOCK LAYOUT

SHORTING BLOCK LAYOUT

NOTES:

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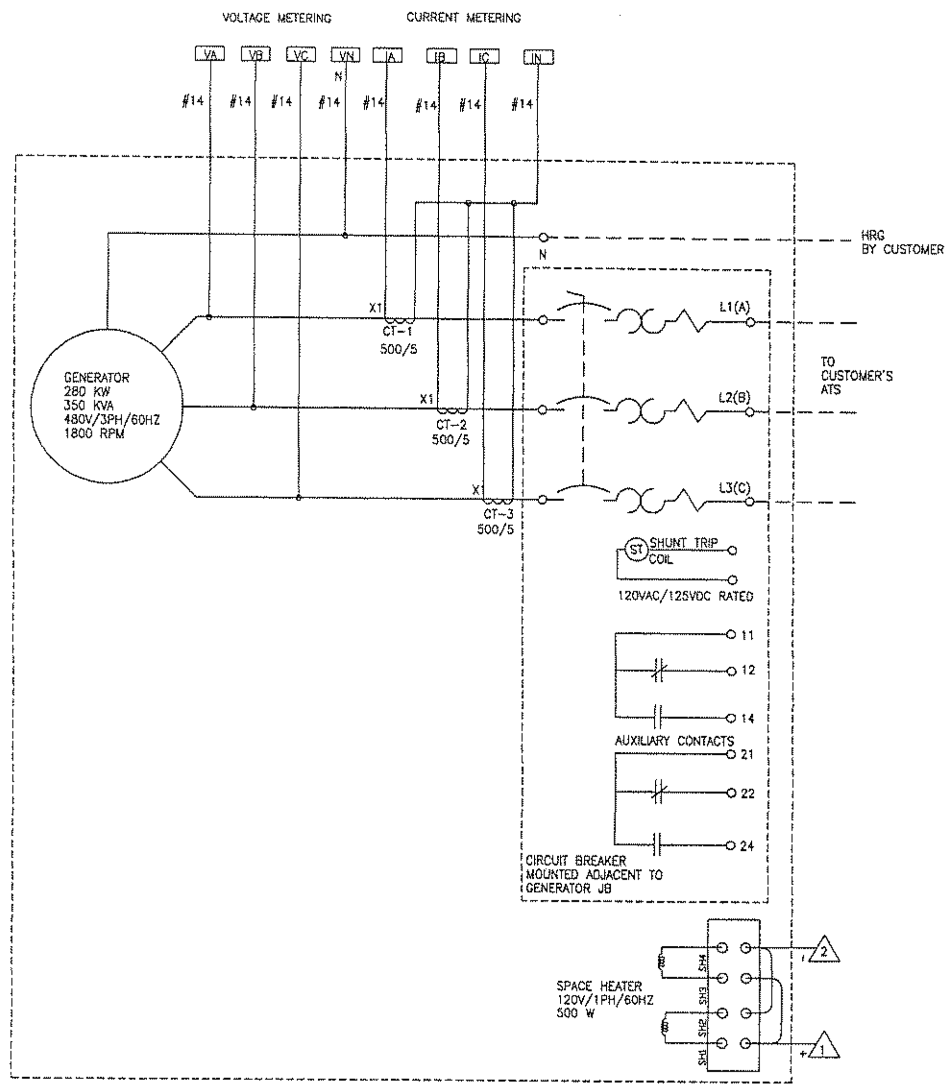
SCALE	ENG/DESIGN	DRAWN	CHECKED	ENG. APPR
NONE	25 JUL 08	12 AUG 08	7 AUG 08	11 AUG 08
	FC	VN	DW	FC

TGP
STATION 270B1
F18GL/GENERATOR/RADIATOR SHEET 1 OF 7
SKID ELECTRICAL CONNECTIONS
F03-0470-400 1

GENERATOR JUNCTION BOX



NOTES:

CUSTOMER WIRING NOTES:

1. SIZE PER NEC CODE.
2. CONTROL WIRING TO BE STRANDED COPPER.
3. SHIELDED TWISTED PAIR CABLE WHERE INDICATED, BELDEN 8762 OR EQUAL. SHIELD TO BE GROUNDED AT ENGINE END ONLY.
4. RUN AC WIRING IN SEPARATE CONDUIT.
5. BATTERY CHARGER TO BE WIRED DIRECT TO BATTERY POSTS BY CUSTOMER.
6. RUN DC POWER WIRING, DC CONTROL WIRING, AND SHIELDED MAG PICK-UP WIRING TOGETHER IN SEPARATE CONDUIT.
7. ALL SWITCHES ARE SHOWN IN NORMAL OPERATING STATE.
8. DISCONNECT ALL ELECTRICAL POWER SUPPLIES BEFORE MAKING ANY CONNECTIONS OR SERVICING ANY PART OF THE ELECTRICAL SYSTEM.

LEGEND

- — — — CUSTOMER WIRING - SIZE PER NEC CODE
- ——— WPI WIRING
- ○ DC JUNCTION BOX ON-SKID
- △ AC JUNCTION BOX ON-SKID
- □ NEC 20 CONTROL PANEL ON-SKID

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0	FC	12 AUG 08	FOR APPROVAL
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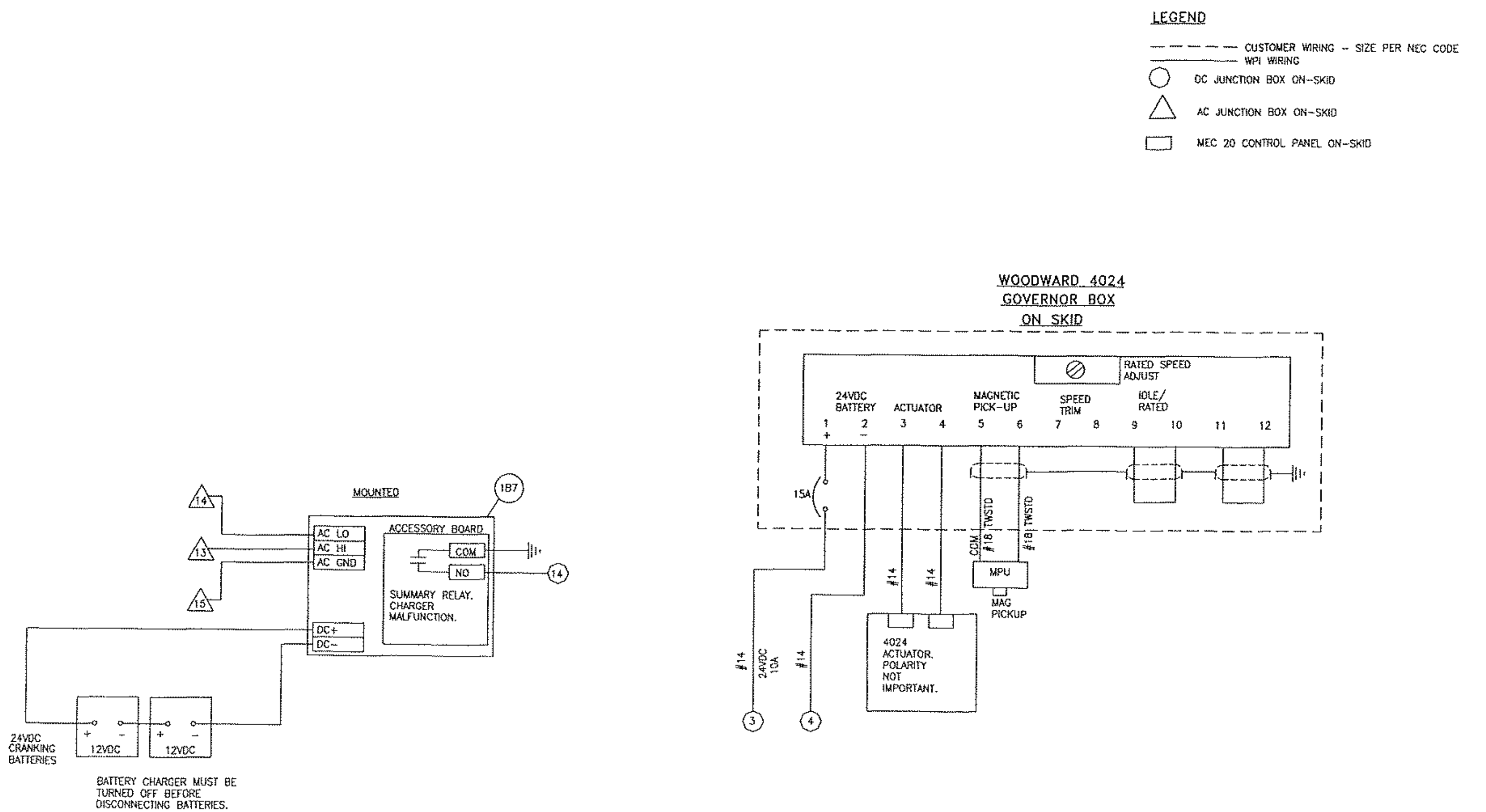
Fax (713) 551-0798

SCALE	ENG/DESIGN	DRAWN	CHECKED	ENG. APPR
NONE	28 JUL 08	31 JUL 08	7 AUG 08	11 AUG 08
	FC	VH	DW	FC

TGP
STATION 87031
F18GL/GENERATOR/RADIATOR SHEET 2 OF 7
SKID ELECTRICAL CONNECTIONS
F03-0470-400 1



NOTES:

No	BY	DATE	ISSUE / REVISION
0	FC	12 AUG 08	FOR APPROVAL
1	FC	29 AUG 08	CERTIFIED

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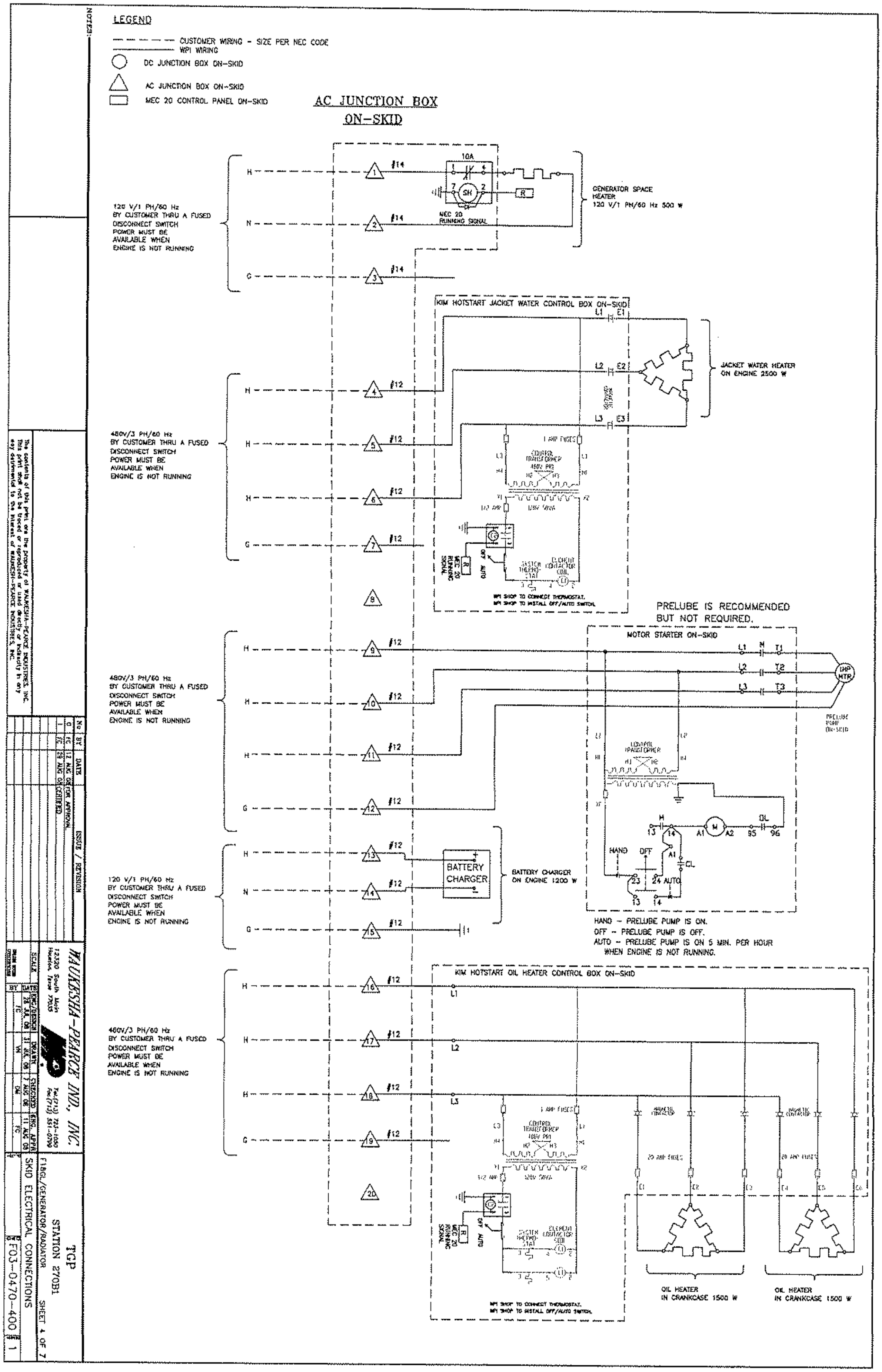
Fax.(713) 551-0799

SCALE	ENG/DESIGN	DRAWN	CHECKED	ENG. APPR
NONE	28 JUL 08	31 JUL 08	7 AUG 08	11 AUG 08
	FC	VH	DN	FC

TGP
STATION 270B1
F18GL/GENERATOR/RADIATOR — SHEET 3 OF 7
SKID ELECTRICAL CONNECTIONS
F03-0470-400 — 1



NOTES:
LEGEND
CUSTOMER WIRING - SIZE PER NEC CODE
WPI WIRING
DC JUNCTION BOX ON-SKID
AC JUNCTION BOX ON-SKID
MEC 20 CONTROL PANEL ON-SKID
AC JUNCTION BOX ON-SKID
120 V/1 PH/60 Hz BY CUSTOMER THRU A FUSED DISCONNECT SWITCH POWER MUST BE AVAILABLE WHEN ENGINE IS NOT RUNNING
10A
MEC 20 RUNNING SIGNAL
GENERATOR SPACE HEATER 120 V/1 PH/60 Hz 500 W
KIM HOTSTART JACKET WATER CONTROL BOX ON-SKID
JACKET WATER HEATER ON ENGINE 2500 W
480V/3 PH/60 Hz BY CUSTOMER THRU A FUSED DISCONNECT SWITCH POWER MUST BE AVAILABLE WHEN ENGINE IS NOT RUNNING
CONTROL TRANSFORMER 480V PRI
120V 50VA
SYSTEM THERMO-STAT
ELEMENT CONTACTOR COIL
OFF AUTO
WPI SHOP TO CONNECT THERMOSTAT.
WPI SHOP TO INSTALL OFF/AUTO SWITCH.
PRELUBE IS RECOMMENDED BUT NOT REQUIRED.
MOTOR STARTER ON-SKID
PRELUBE PUMP ON-SKID
HAND OFF AUTO
HAND - PRELUBE PUMP IS ON.
OFF - PRELUBE PUMP IS OFF.
AUTO - PRELUBE PUMP IS ON 5 MIN. PER HOUR WHEN ENGINE IS NOT RUNNING.
BATTERY CHARGER
BATTERY CHARGER ON ENGINE 1200 W
KIM HOTSTART OIL HEATER CONTROL BOX ON-SKID
20 AMP FUSES
OIL HEATER IN CRANKCASE 1500 W
OIL HEATER IN CRANKCASE 1500 W
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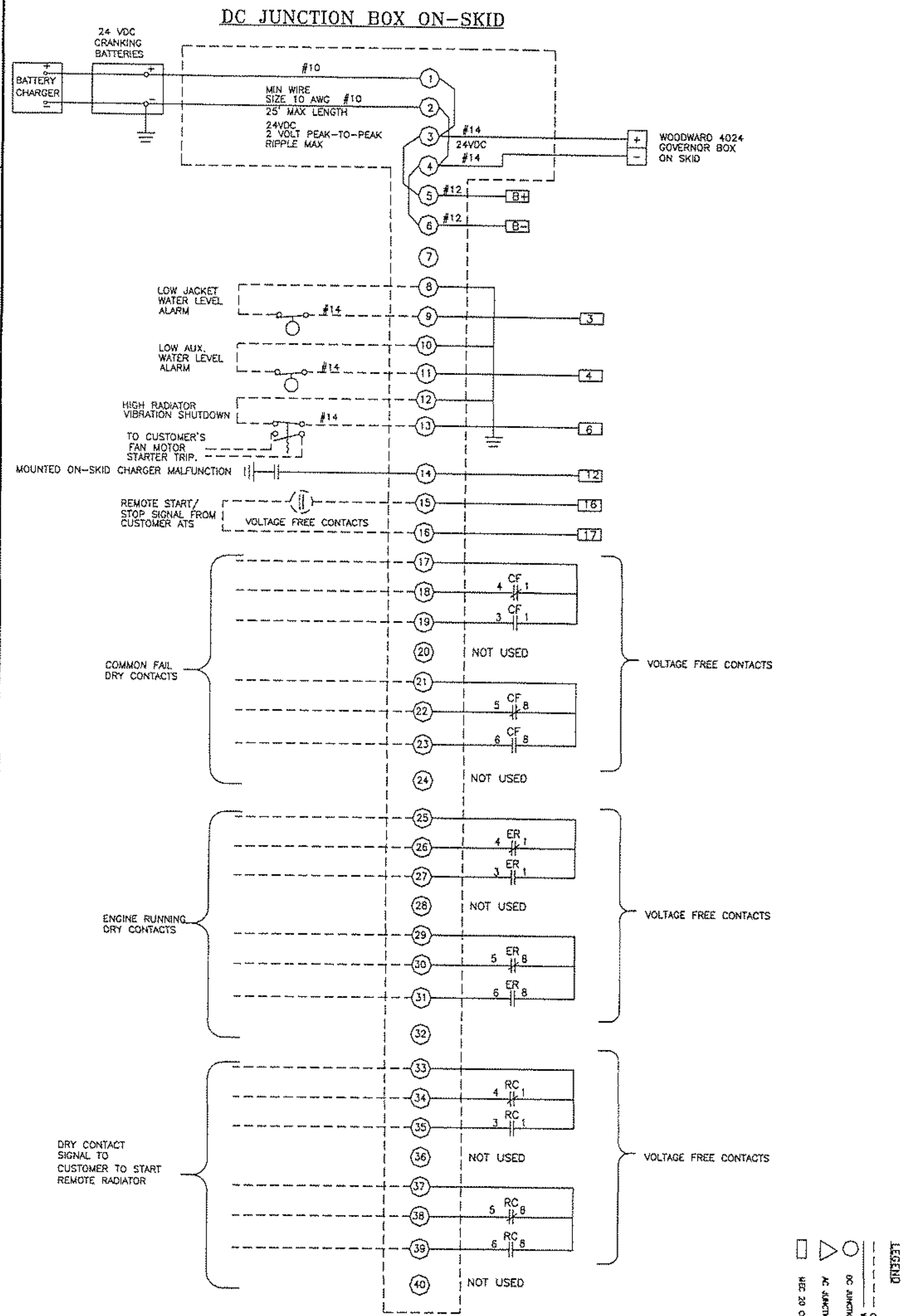
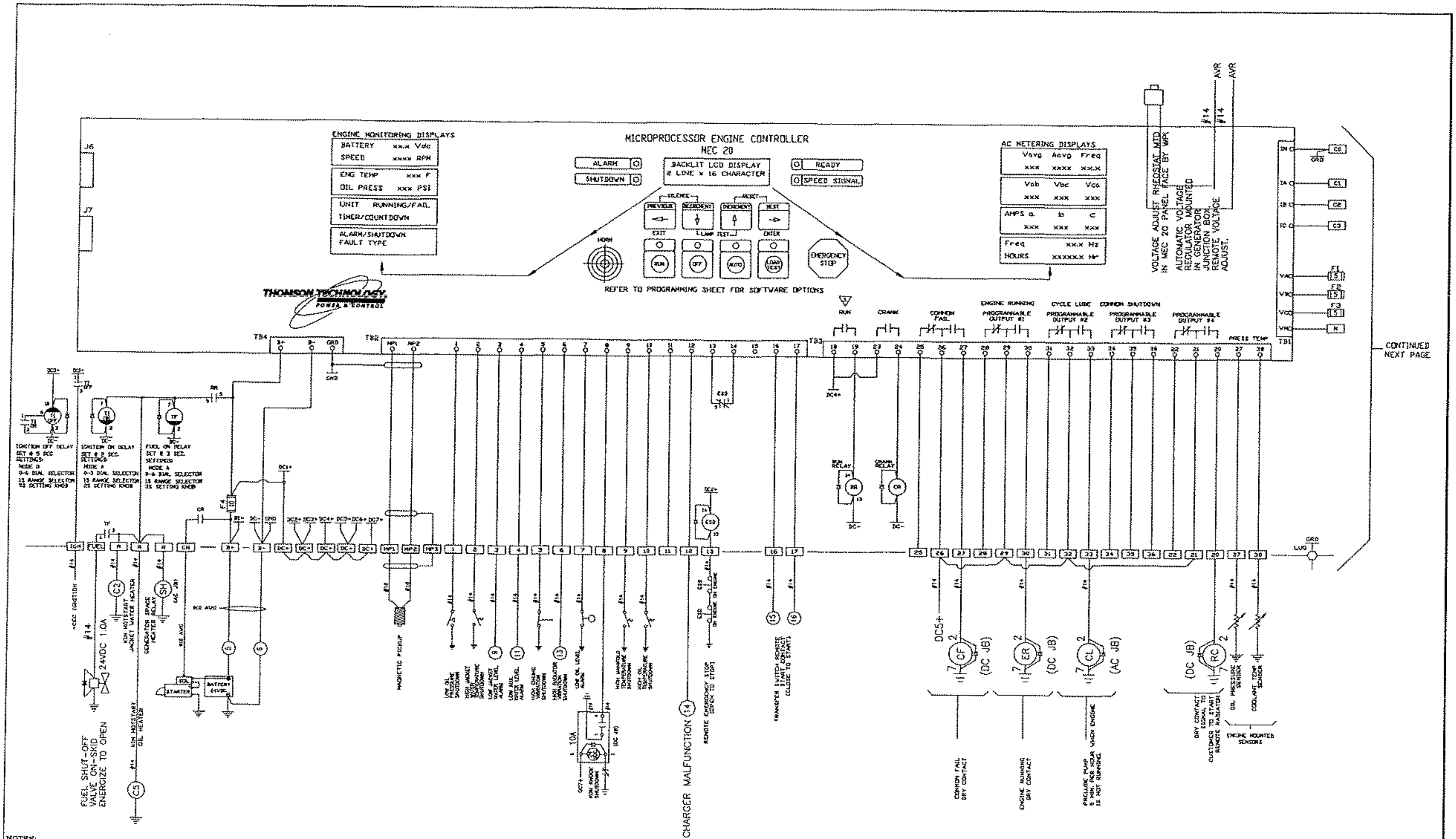
WAUKESHA-PEARCE IND., INC.
12320 South Main Houston, Texas 77035
TGP
STATION 270B1
F18GL/GENERATOR/RADIATOR SHEET 4 OF 7
SKID ELECTRICAL CONNECTIONS
F03-0470-400
1



NOTES:

WAUKESHA-PEARCE IND., INC.

TGP
STATION 270B1
F18GL/GENERATOR/RADIATOR SHEET 5 OF 7
SKID ELECTRICAL CONNECTIONS
F03-0470-400



NOTES:

LEGEND

- — — CUSTOMER WIRING-SIZE PER NEC CODE
- ——— WPI WIRING
- ○ DC JUNCTION BOX ON-SKID
- △ AC JUNCTION BOX ON-SKID
- ○ MEC 20 CONTROL PANEL ON-SKID

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0	FC	12 AUG 08	FOR APPROVAL
0	FC	29 AUG 08	CERTIFIED

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Fax.(713) 551-0799

SCALE	ENG/DESIGN	DRAWN	CHECKED	ENG. APPR
NONE	28 JUL 08	31 JUL 08	7 AUG 08	11 AUG 08
	FC	VH	DM	FC

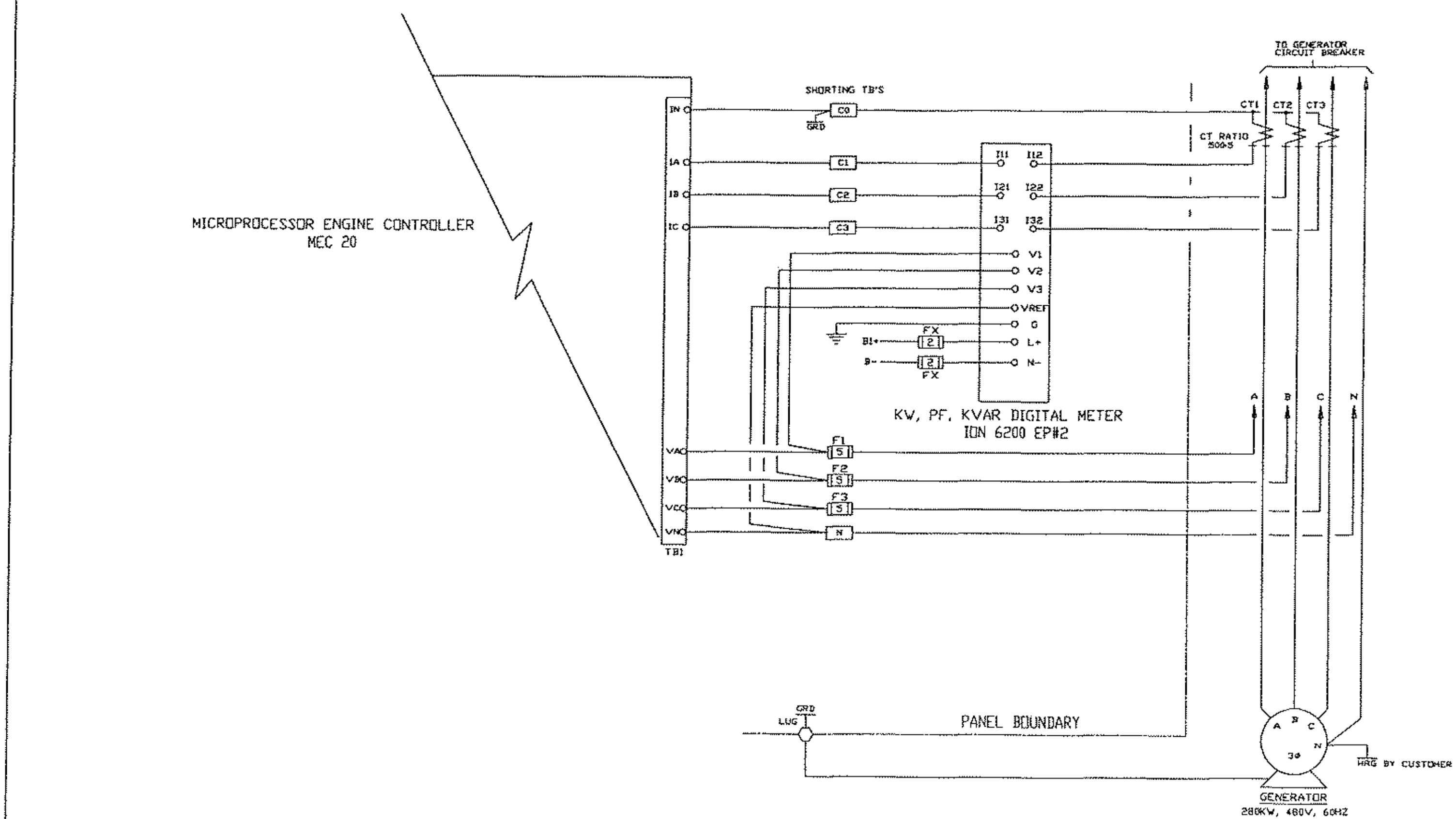
TGP

STATION 270B1

F18GL/GENERATOR/RADIATOR SHEET 6 OF 7

SKID ELECTRICAL CONNECTIONS

F03-0470-400 1



NOTES:

LEGEND

- CUSTOMER WIRING-SIZE PER NEC CODE
- WPI WIRING
- ○ DC JUNCTION BOX ON-SKID
- △ AC JUNCTION BOX ON-SKID
- ○ MEC 20 CONTROL PANEL ON-SKID

No	BY	DATE	ISSUE / REVISION
0	FC	12 AUG 08	FOR APPROVAL
1	FC	29 AUG 08	CERTIFIED

WAUKESHA-PEARCE IND., INC.

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SCALE	ENG/DESIGN	DRAWN	CHECKED	ENG. APPR
NONE	28 JUL 08 FC	31 JUL 08 VN	7 AUG 08 OM	11 AUG 08 FC

TGP

STATION 270B1

F18GL/GENERATOR/RADIATOR — SHEET 7 OF 7

SKID ELECTRICAL CONNECTIONS

F03-0470-400 1

1. WAUKESHA INSTALLATION MANUAL FORM 1091 APPLIES. PLEASE ASK YOUR WPI SALESMAN PH 713-723-1050 FOR THIS FREE MANUAL.
2. WAUKESHA-PEARCE INDUSTRIES, INC. START-UP SERVICEMEN ARE REQUIRED, BUT NOT INCLUDED. WPI RATE SCHEDULE APPLIES. A WPI WAUKESHA ENGINE MECHANIC AND WPI ELECTRICAL TECHNICIAN ARE NEEDED FOR ON-SITE GENSET COMMISSIONING. PURCHASERS MAINTENANCE CREW ARE NEEDED TO PROVIDE LABOR, TOOLS, MATERIALS, AND ASSISTANCE TO THE WPI PERSONNEL. WPI SHOULD BE HIRED TO VISIT THE SITE DURING OFFLOADING/INITIAL GENSET ALIGNMENT, AND FOR START-UP/COMMISSIONING. TASKS PERFORMED BY WPI INCLUDE, CHECK MOUNTING, CHECK SKID LEVEL, CHECK ENGINE LEVEL, CHECK GENERATOR COUPLING ALIGNMENT, CHECK FUEL, COOLANT, OIL, EXHAUST, AND ELECTRICAL CONNECTIONS, CHECK WIRING, CHECK FLUIDS, CHECK SAFETIES, CHECK ENGINE, START ENGINE, ADJUST CRANKCASE BREATHER, AND ADJUST FUEL SYSTEM. PLEASE CALL THE WPI ENGINE DIVISION SERVICE MANAGER PH 713-723-1050 TO SCHEDULE WPI SERVICEMEN.
3. CALCULATE ENGINE EXHAUST BACKPRESSURE PER FORM 1091-7. ALL EXHAUST PIPING, SUPPORTS, ROLLERS, HANGARS, ETC. FOR ZERO FORCES AND MOMENTS AT TURBO, INCLUDING ACCOMODATION OF HEAT EXPANSION, BY PURCHASER.
4. THOROUGH CLEANING OF OFF-SKID FUEL PIPING CONSISTING OF MECHANICAL CLEANING TO REMOVE DIRT, SCALE, RUST, AND WELD SLAG, BY PURCHASER, IS REQUIRED.
5. COOLING SYSTEM IS DESIGNED FOR 50/50 INHIBITED NON-AUTOMOTIVE ETHYLENE GLYCOL/DEMINERALIZED WATER SOLUTION.
6. LOCATE AND READ THE WPI OPERATING AND MAINTENANCE MANUAL WHICH INCLUDES JOB SPECIFIC DRAWINGS, DATA, OPERATING/MAINTENANCE MANUALS, AND PARTS LISTS.
7. CALL YOUR LOCAL LUBRICANTS SUPPLIER AND THE WPI SERVICE MANAGER FOR HELP SELECTING THE PROPER GAS ENGINE OIL FOR THIS APPLICATION.
8. ALL CUSTOMER PIPING AND ELECTRICAL CONDUIT CONNECTIONS AT ENGINE, AT ENGINE PIPING, AND AT GENERATOR, MUST BE FLEXIBLE.
9. DISCONNECT BATTERY CHARGER FIRST, THEN DISCONNECT ALL ELECTRICAL POWER SUPPLIES, SUCH AS BATTERIES, BEFORE MAKING ANY CONNECTIONS OR SERVICING ANY PART OF THE ELECTRICAL SYSTEM.
10. THE GENERATOR NEUTRAL CONDUCTOR, PART OF THE CURRENT CARRYING WINDINGS, MUST BE SEPARATELY AND SOLIDLY GROUNDED (OR HRG). A SEPARATE GROUNDING CONDUCTOR, TO PROVIDE A PATH TO GROUND FROM THE GENERATOR FRAME/SKID, IS REQUIRED. SIZED PER NEC CODE.

NOTES:

No	BY	DATE	ISSUE / REVISION
1	FC	12 AUG 08	CERTIFIED

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Fax (713) 551-0799

SCALE	ENG/DESIGN	DRAWN	CHECKED	ENG. APPR
NONE	28 JUL 08	31 JUL 08	7 AUG 08	11 AUG 08
	FC	VN	DH	FC

TGP
STATION 270B1
F18GL/GENERATOR/RADIATOR TGP-118881
GENERAL NOTES
F03-0470-701 1

EXHAUST SYSTEM INSTALLATION GUIDELINES

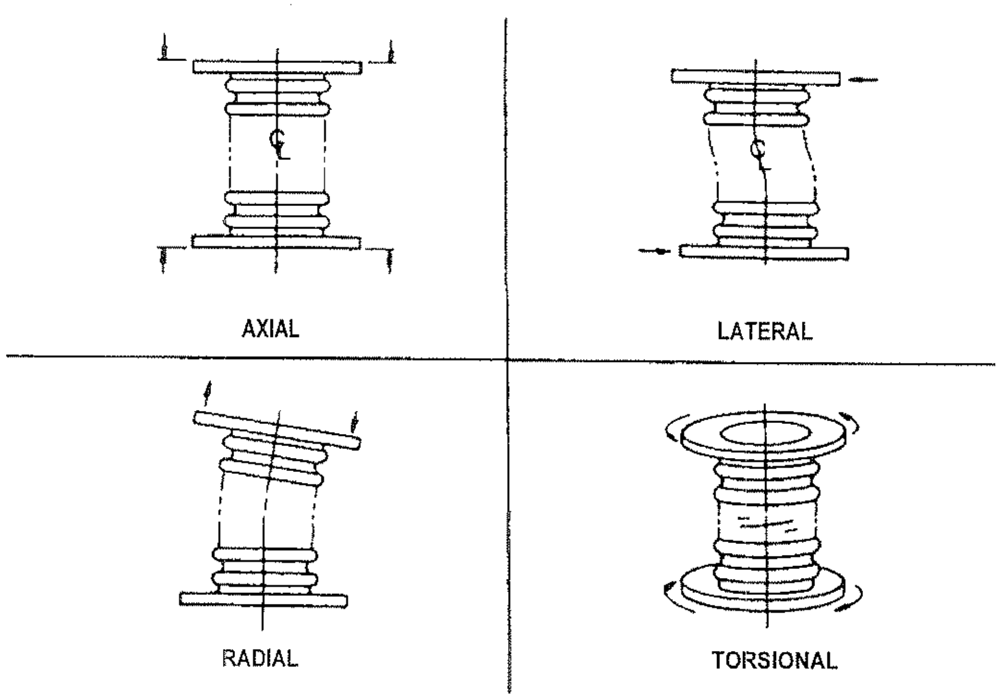
1. Allow for thermal expansion of the exhaust pipe beyond the Waukesha flex. The Waukesha exhaust flex (when supplied) will accommodate engine thermal expansion but cannot tolerate movement imposed by external thermal growth. Insulated pipes will run hotter and consequently expand more.

COEFFICIENT OF EXPANSION

Steel	0.00065 in/in/100° F
Stainless steel	0.00099 in/in/100° F

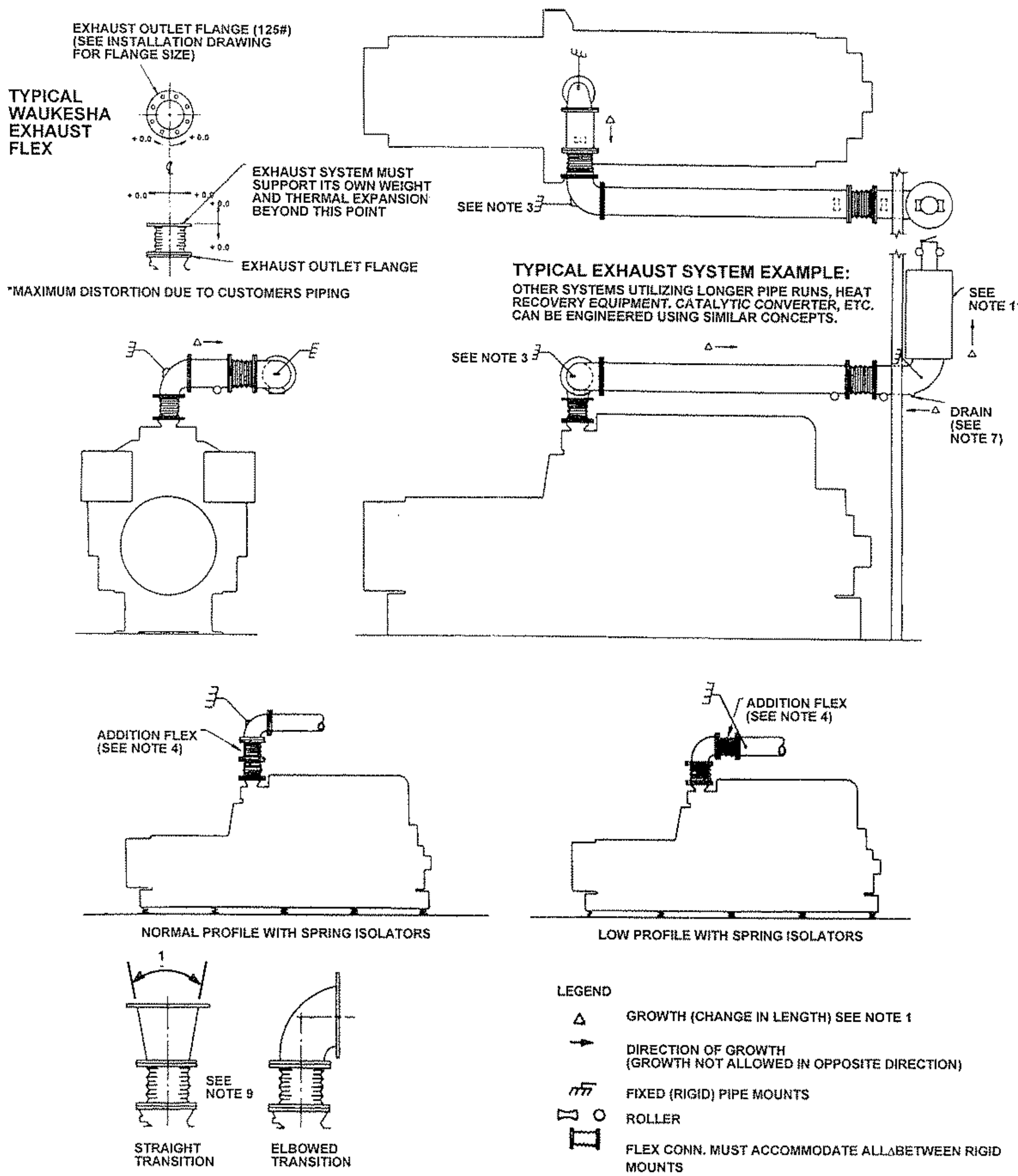
EXAMPLE: 10 ft. of steel pipe on a L7042G with an exhaust temperature of 1060° F will expand based on 60° F ambient. (0.00065 in/in/100° F) (10 ft) (12 in/ft) (1060° -60° /100) = .78 in.

2. Remember that a flex connection has "spring constants" (lateral, axial, radial, torsional) that should be considered when engineering the exhaust system. Transmission of forces to the engine exhaust system (engine exhaust flange) must be nil. (Any specific load or bending moment limits shown on an engine's installation drawing must not be exceeded.)
3. Design the exhaust system so it will not impose torsional forces on the exhaust flex connection.
4. The exhaust flex connection should be designed to allow for flexing caused by engine operation, acceleration, deceleration, starting and stopping. The Waukesha exhaust flex (when supplied) will accommodate engine vibrations with a solidly mounted unit, but cannot tolerate the additional forces/displacement imposed by mounting on spring isolators. Additional flex capabilities will be required when the unit is mounted on isolators.
5. Consider expected life. Cyclic flexing can lead to premature failure by causing fatigue breakage.
6. Utilize a combination of fixed supports, rollers and flex connections to provide a well designed exhaust system. See sketches for additional concepts.
7. Provide water traps/drains to prevent exhaust condensation and/or rain from reaching the engine. This is especially true on long pipe runs. Use rain caps where applicable. Slope piping away from engine.

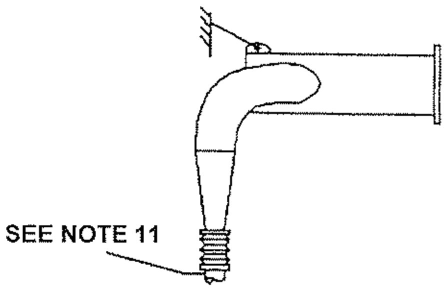


DRESSER Waukesha	EXHAUST SYSTEM INSTALLATION GUIDELINES	EN: 112676 DATE: 11/96	Ref. S 8242

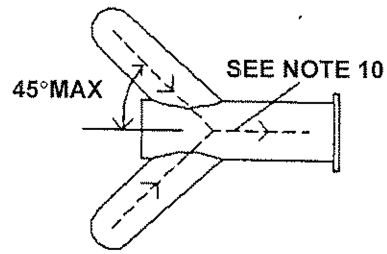
8. The minimum requirements for the design of the exhaust system should be to contain explosions that could be encountered during the operation of the engine. Waukesha recommends the use of carbon steel schedule 20 pipe as a minimum. Stainless steel schedule 10 pipe is preferred because of its greater strength properties at elevated temperatures. Waukesha does not recommend using double walled piping or slip joints on engine exhausts.
9. Utilize smooth transition to final pipe size when a transition in size is required. Waukesha recommends a diverging angle of 15 degrees for low pressure drop (see sketches for straight and elbowed transitions).
10. Engines with two exhaust outlets combined into one (such as 12VAT25GL engine) must have a symmetrical design up to and including the point of convergence of the two exhaust streams to produce proper flow and restriction balance. Convergence angle from the center of symmetry must not exceed 45 degrees. The outlet area of the y-connection must be equal to or greater than the sum of the two inlet areas.
11. Size piping and silencer so that exhaust system back pressure, as measured at the engine outlet flange, is less than that indicated in the specifications page in the tech data book.
12. Provide clearance to permit use of a chain hoist for removal of heavy components.
13. For other exhaust system parameters see chapter seven, (Exhaust System) of the "Waukesha Installation Manual" (Form 1091).


EXHAUST OUTLET FLANGE (125#)
(SEE INSTALLATION DRAWING FOR FLANGE SIZE)
TYPICAL WAUKESHA EXHAUST FLEX
EXHAUST SYSTEM MUST SUPPORT ITS OWN WEIGHT AND THERMAL EXPANSION BEYOND THIS POINT
EXHAUST OUTLET FLANGE
*MAXIMUM DISTORTION DUE TO CUSTOMERS PIPING
SEE NOTE 3
TYPICAL EXHAUST SYSTEM EXAMPLE:
OTHER SYSTEMS UTILIZING LONGER PIPE RUNS, HEAT RECOVERY EQUIPMENT, CATALYTIC CONVERTER, ETC. CAN BE ENGINEERED USING SIMILAR CONCEPTS.
SEE NOTE 3
SEE NOTE 11
DRAIN (SEE NOTE 7)
ADDITION FLEX (SEE NOTE 4)
ADDITION FLEX (SEE NOTE 4)
NORMAL PROFILE WITH SPRING ISOLATORS
LOW PROFILE WITH SPRING ISOLATORS
SEE NOTE 9
STRAIGHT TRANSITION
ELBOWED TRANSITION
LEGEND
GROWTH (CHANGE IN LENGTH) SEE NOTE 1
DIRECTION OF GROWTH (GROWTH NOT ALLOWED IN OPPOSITE DIRECTION)
FIXED (RIGID) PIPE MOUNTS
ROLLER
FLEX CONN. MUST ACCOMMODATE ALL Δ BETWEEN RIGID MOUNTS

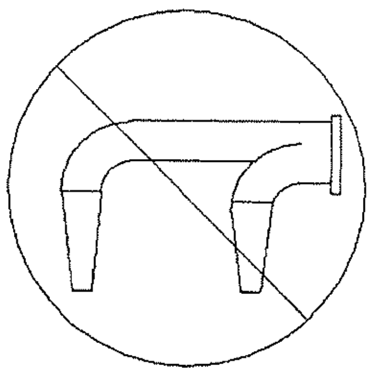
DUAL OUTLET (SIDE VIEW)



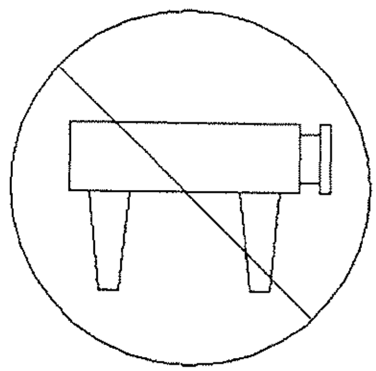
DUAL OUTLET (TOP VIEW)



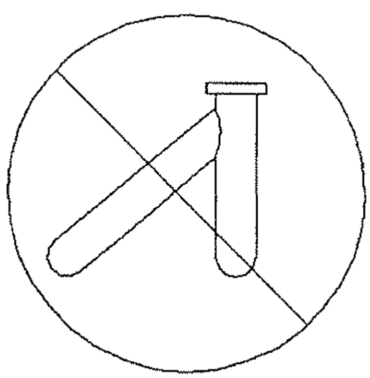
The dual outlets shown below violate the symmetry requirement or have a converging angle which exceeds 45° potentially causing high or unbalanced restriction.



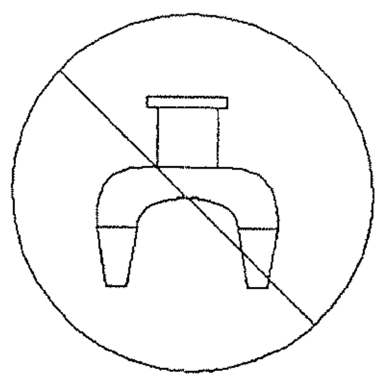
DUAL OUTLET WITH UNEQUAL LENGTH LEGS



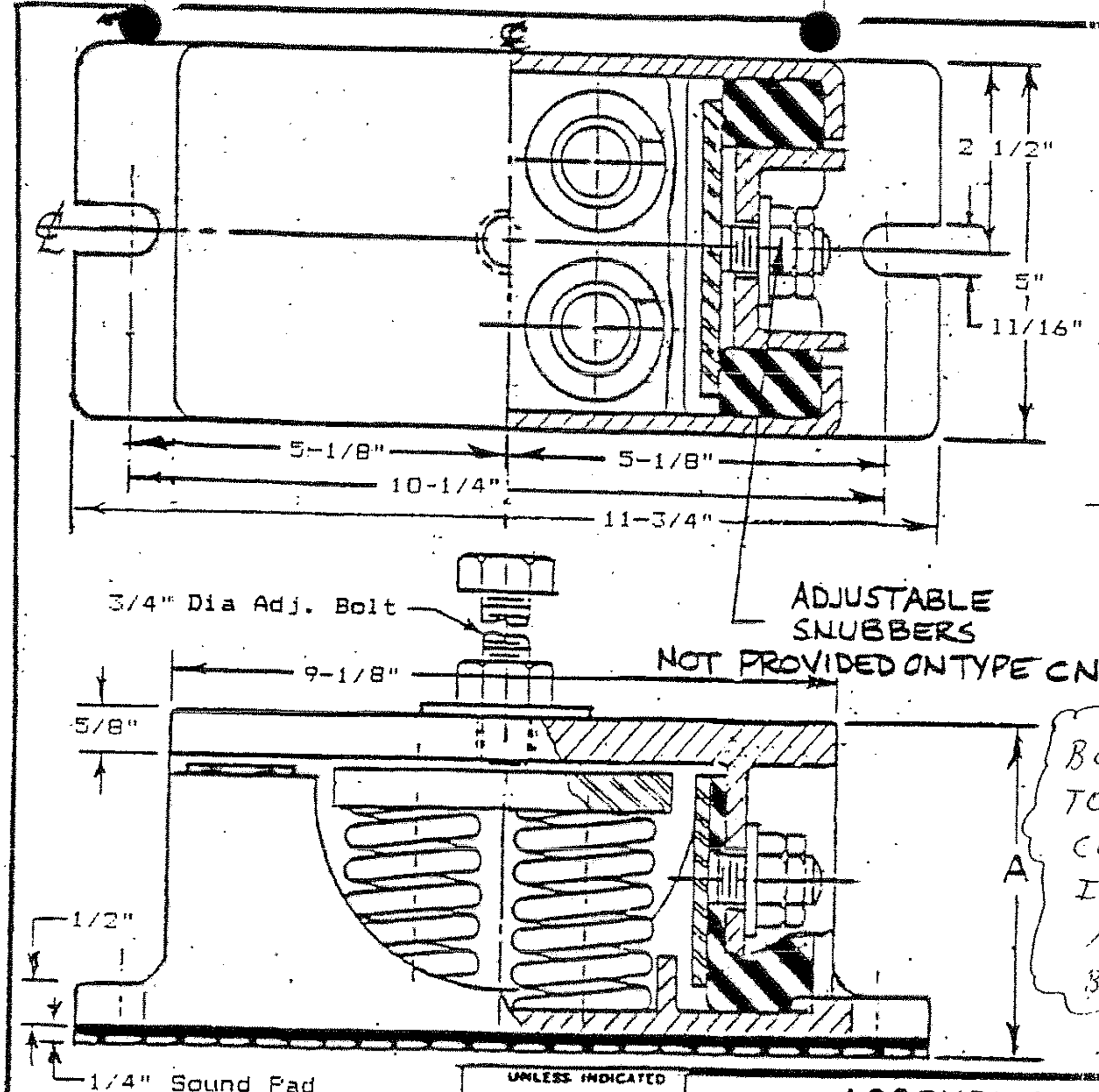
DUAL OUTLET INTO HEADER WITH SIDE DISCHARGE



BRANCH INTO MAIN LINE



DUAL OUTLET INTO A TEE



ISOL. NO.	RATED LOAD STEADY	IMPACT	"A" MIN. FREE HT.
CK 4-1	500	—	5-3/4"
CK 4-2	800	—	
CK 4-3	1200	—	
CK 4-4	2000	—	
CK4-5	2800	—	
CK4-6	4800	—	
CK4-S5	1300	1040	4-3/8"
CK4-S6	1800	1440	
CK4-S7	2400	1900	
CK4-S8	4400	3300	4-1/2"
CK4-S9	5200	4900	4-7/8"

BOLT (TYP. 2) ISOLATOR BASE TO FLAT (NOT ROUGHENED) CONCRETE PAD. SHIM BETWEEN ISOLATOR AND CONCRETE AS NEEDED FOR ALL ISOLATOR BASES SAME ELEVATION ±1/8".
WPI

4A2

UNLESS INDICATED	
DECIMALS	
FRACTION	
ANGLES	
RMS FINISH	
ORD NO.	
SCALE	

NO.	REVISION	DATE

ASSEMBLY ISOLATION TECHNOLGY TYPE CK-4 W/ EXTERNAL ADJUSTMENT

ISOLATION TECHNOLOGY INC.
P.O. BOX 460
MASSAPEQUA, N.Y. 11758

032290-2

4A 2

ISOLATION TECHNOLOGY, INC.

P.O. BOX 460
MASSAPEQUA, N.Y. 11758

TEL 516-253-3314
FAX 516-253-3316

Please Note Our New Area Code is [illegible]

INSTALLATION AND ADJUSTMENT INSTRUCTIONS
ISOLATION TECHNOLOGY TYPES CK, CN, AND WK VIBRATION ISOLATORS

1. Isolators are shipped fully assembled and are spaced and arranged in accordance with installation drawings or as recommended by ISOLATION TECHNOLOGY.

2. Set isolators on sub-base, shimming or grouting where required to level all isolator base plates "A" at same elevation (1/4" maximum difference in elevation can be tolerated).Isolator top plates "B" and base plates "A" must be properly aligned. Do not force into line. Isolator base plates must rest on a flat surface. Bolt thru holes "L" or cement to sub-base when required type WK must be securely bolted.

3. Release bolts and / or nuts "J" and "K" until snubber compression plate "F" is not binding snubbers "H". (Not required for type CN).

4. Place machine or foundation on isolators. The isolator top plates will descend. *

5. For type WK isolator (and on some special applications for other types) mounting bolt holes "G" are provided in the isolator top plate to furnish additional means of fastening the machine on the isolators.

ADJUSTMENT PROCEDURE

6. Insert isolator leveling bolt "D" with nut "C" thru bolt holes in the machine base or foundation and screw into isolator top plate "B" until contact is made with compression plate "E".

7. If clearance at "X" is less than 1/4" on any isolator, screw the leveling bolt "D" down two complete turns on each isolator, making a complete circuit of all isolators. Repeat this procedure until there is more than 1/4" clearance or more at all isolators. DO NOT TURN THE BOLTS MORE THAN TWO TURNS ON EACH CIRCUIT AS IT WILL MAKE ADJUSTMENT MORE DIFFICULT AND MAY OVERLOAD ISOLATORS. If initial clearance "X" exceeds 1/4" on all isolators omit this step.

8. If machine is not level after procedure #7 is completed, screw down an equal amount on leveling bolt "D" of all isolators toward the LOW END until it is level. (Operating height of all isolators can be increased, if desired, by repeating step #7 on ALL isolators , after machine is level, until required height is reached. NOTE: "X" should not exceed 3/4".

9. Tighten nut "C" to complete spring adjustment.

4A2

HORIZONTAL CHOCK ADJUSTMENT
(Not required for type CN)

NOTE: Best isolating efficiency will be obtained if plates "F" are just barely touching snubbers "H". Snubber tightening should be used only where necessary to prevent excessive movement of the machine at start-up or shutdown. For impact machines such as punch presses, damping provided by slight snubber adjustment will be useful in controlling movement, since the vibration transmission will not be increased by small amounts of damping. Overtighteinig of snubbers will cause vibration transmission.

10. Operate the machine. Tighten nuts or bolts "J" at each end of all isolators until bolts of WK are finger tight, or until there is no horizontal play in the studs of type CK.

11. If movement is excessive, tighten the nuts or bolts "J" on each end 1/4 turn at a time on ALL isolators until movement is reduced to an allowable maximum.

12. Tighten lock nuts "K", to complete the installation.

* When the load is applied (step #4) , the top plate moves down and compresses the spring until: (A) the springs support the load, or (B) the top plate rests on the bottom housing. In case (A), screwing on the leveling bolt will immediately start to raise the equipment; in case (B), screwing down on the leveling bolt compresses the springs until they support the equipment weight, at which point further turning will raise the equipment.

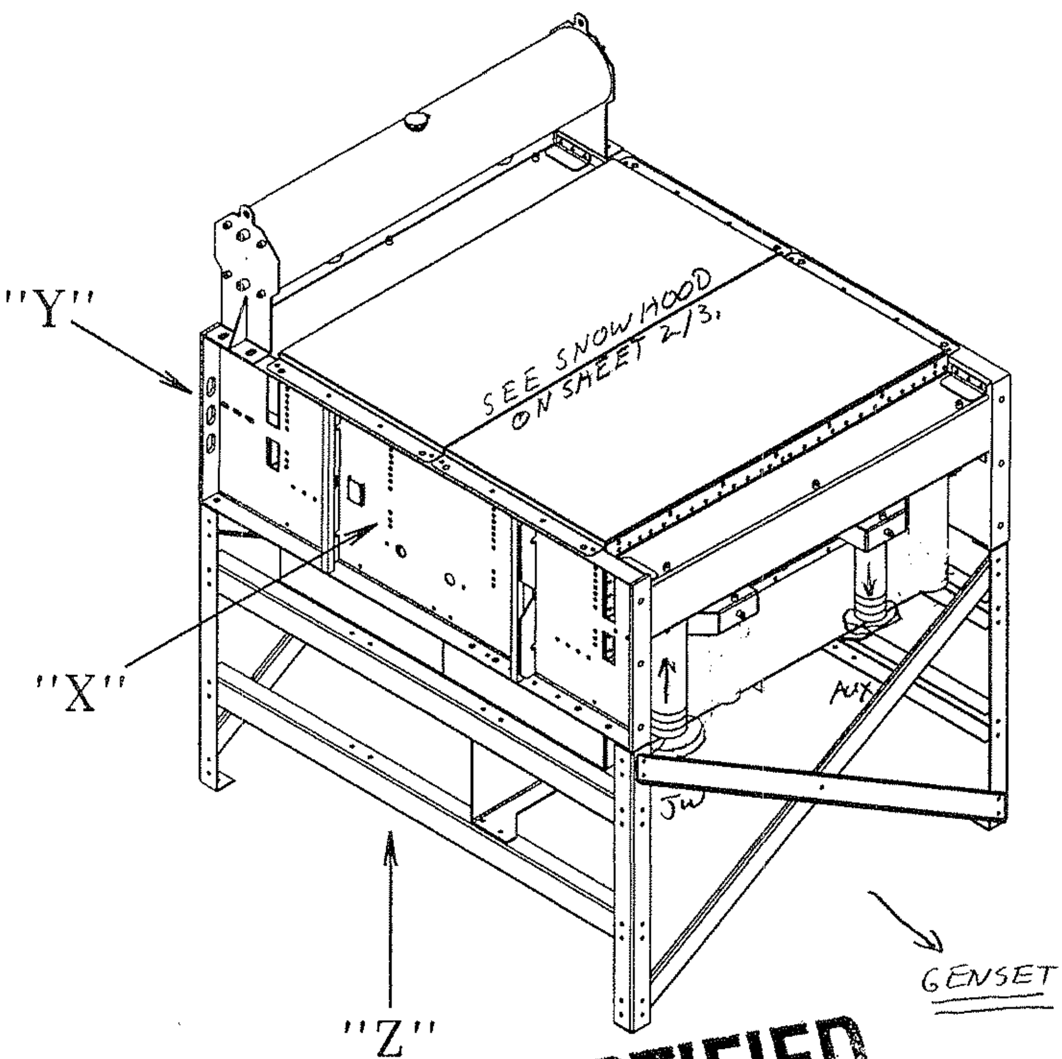
HM19F

Young Touchstone
A Wabtec company

WPI
F03-0470
1/3

DS

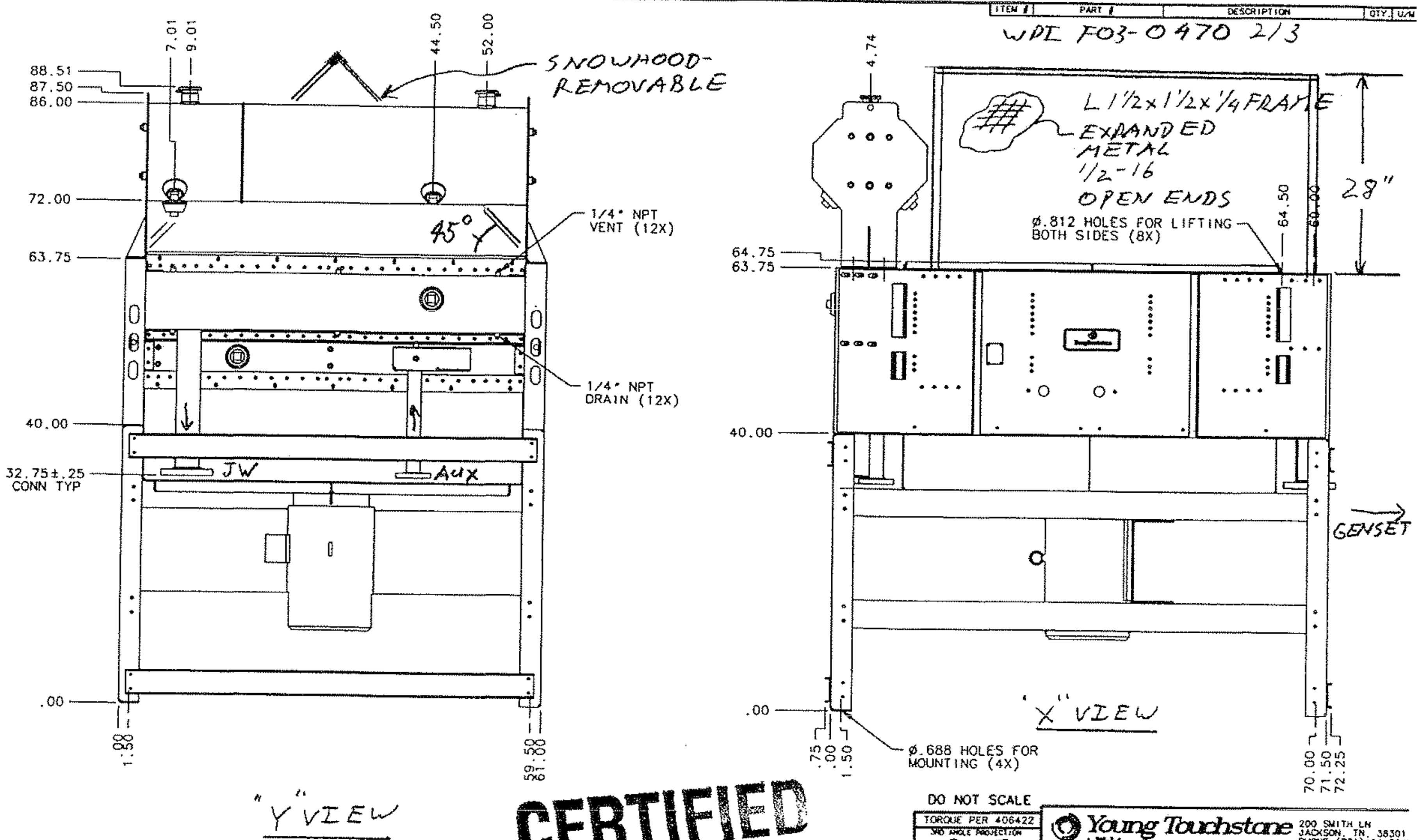
MODEL HM
HORIZONTAL CORE/REMOTE MOUNT/DIRECT MOTOR DRIVEN FAN
SUBMITTAL/APPROVAL DRAWING - PAGE 1 OF 4



CERTIFIED

ISOMETRIC VIEW

ALL DIMENSIONS ARE SUBJECT TO CHANGE
8/8/03



CERTIFIED

DO NOT SCALE

REV	ECN	DESCRIPTION	BY	DATE
		SUBMITTAL PRINT ONLY	JNB	8/15/08

TORQUE PER 406422

3RD ANGLE PROJECTION

FINISH PART PER DRAWING #07798

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES

DECIMALS .X ± .120 .XX ± .030 .XXX ± .015 ANGLES ±1°

Young Touchstone A Wabtec Company 200 SMITH LN JACKSON, TN. 38301 PHONE (731)424-504

THIS PRINT, PROPERTY OF YOUNG TOUCHSTONE, CONTAINS PROPRIETARY INFORMATION AND MUST NOT BE COPIED, REPRODUCED, OR USED DETRIMENTALLY TO OUR INTEREST.

INTERPRET DIMENSIONS AND TOLERANCES PER ANSI Y14.5M-1982

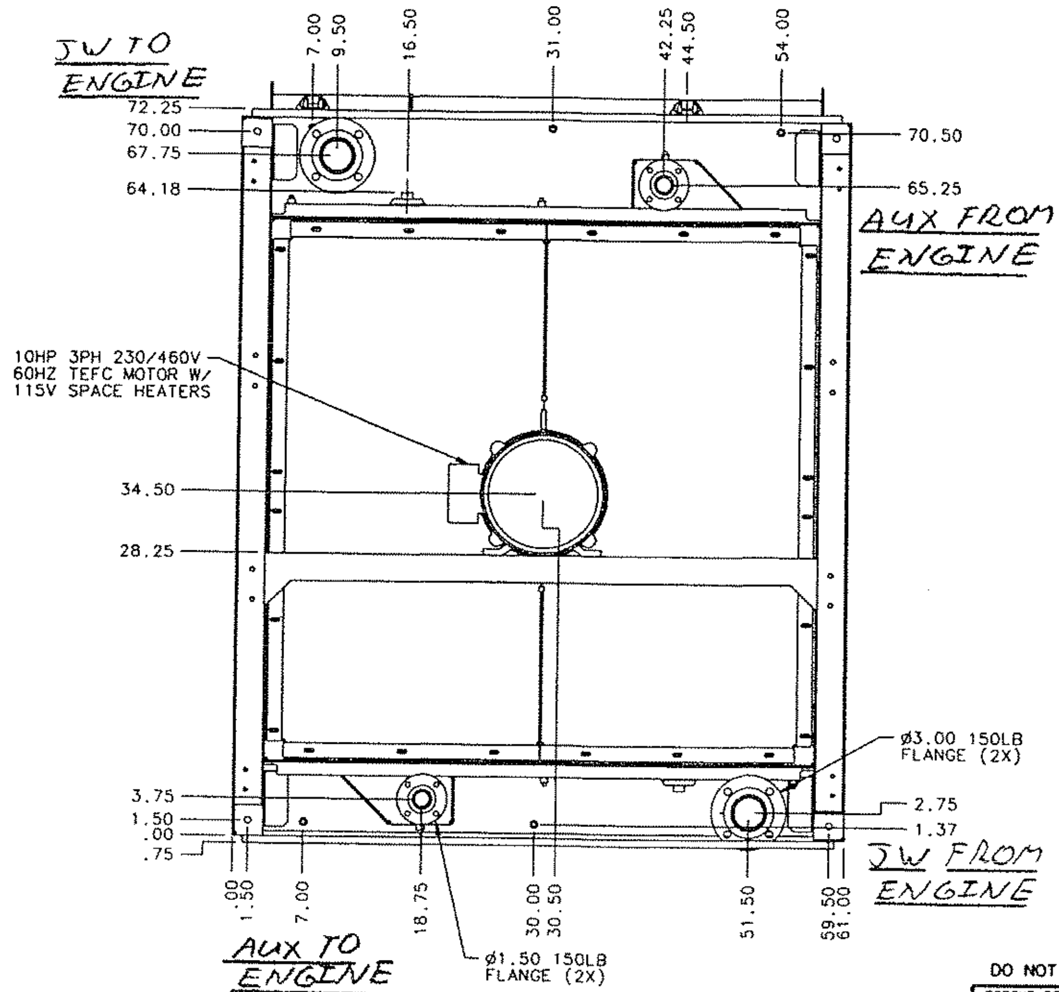
DRAWN BY	DATE
JNB	8/15/08
SIM TO:	NO. OF SHTS
*	2

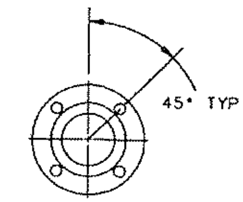
FINAL ASSEMBLY
HM19F6125310M035

PART NUMBER 425132

ITEM #	PART #	DESCRIPTION	QTY	U/M

WPI F03-0470 3/3





FLANGE DETAIL

CERTIFIED

NOTE:
1) YT MODEL #: HM19 F61 253 10M 035 XGGX XXXX.

REV	ECN	DESCRIPTION	BY	DATE
		SUBMITTAL PRINT ONLY	JNB	8/15/08

DO NOT SCALE

TORQUE PER 406422

3RD ANGLE PROJECTION

FINISH PART PER DRAWING #07798

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES

DECIMALS .X ± .120 .XX ± .030 .XXX ± .015 ANGLES ±1°

Young Touchstone A Wabtec Company 200 SMITH LN JACKSON, TN. 38301 PHONE (731)424-504

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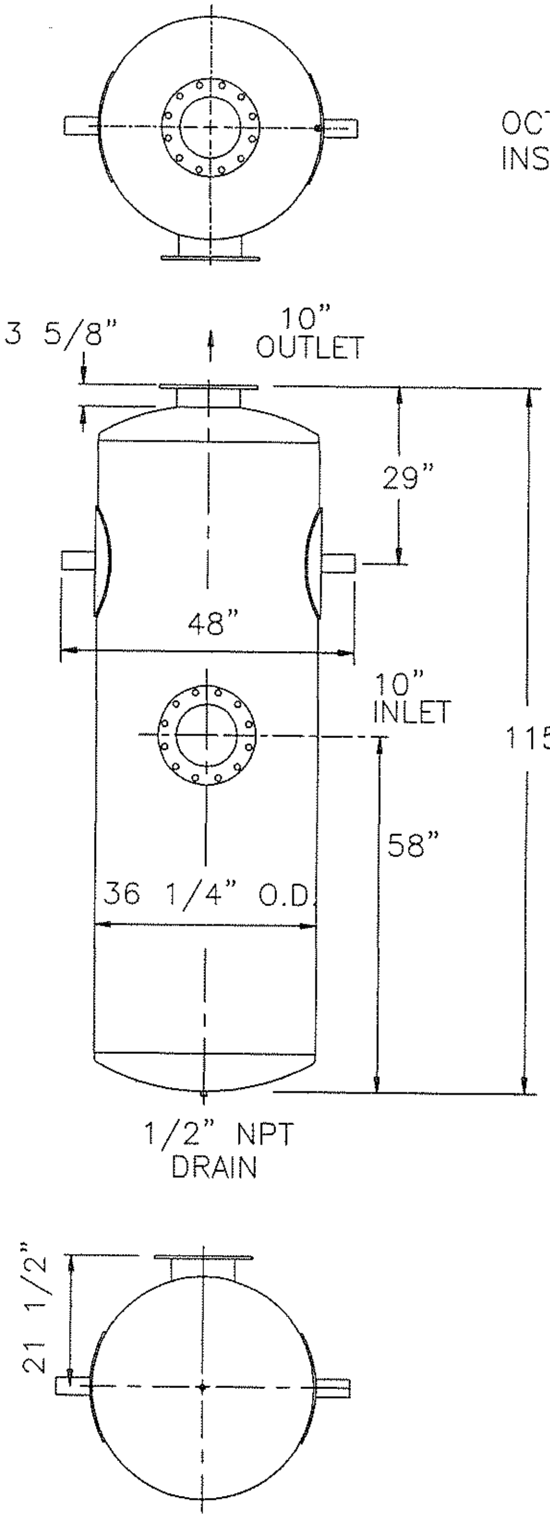
INTERPRET DIMENSIONS AND TOLERANCES PER ANSI Y14.5M-1982

DRAWN BY	DATE
JNB	8/15/08
S/N TO:	NO. OF SHT
•	2

FINAL ASSEMBLY
HM19F6125310M035

PART NUMBER 425132



SERVICE : EXHAUST SILENCER FOR ENGINE
PRESSURE DROP: (4.0)*(Velocity Head In 10")

OCTAVE BAND	63	125	250	500	1K	2K	4K	8K
INSERTION LOSS	22	30	35	33	29	28	28	29

MATERIALS OF CONSTRUCTION :
SHELL : DOUBLE WRAP 16 GA CARBON STEEL
HEADS : 3/16" CARBON STEEL

EXTERNAL PAINT : HIGH TEMP BLACK

WEIGHT: 920 LBS.

TRUNNION SUPPORT
2 1/2" PIPE (SIZE) WITH
3/8" PLATE, 18" O.D.

10" INLET AND OUTLET FLANGES
1/2" PLATE, 16" O.D.
(12) 1" DIA. HOLES
ON 14 1/4" B.C. STRADDLE C.L.

CERTIFICATION

CUSTOMER: WAUKESHA-PEARCE
CUSTOMER P.O. NO.: 3151294S

DATE: 6/13/07 BY: J. JOHNSON

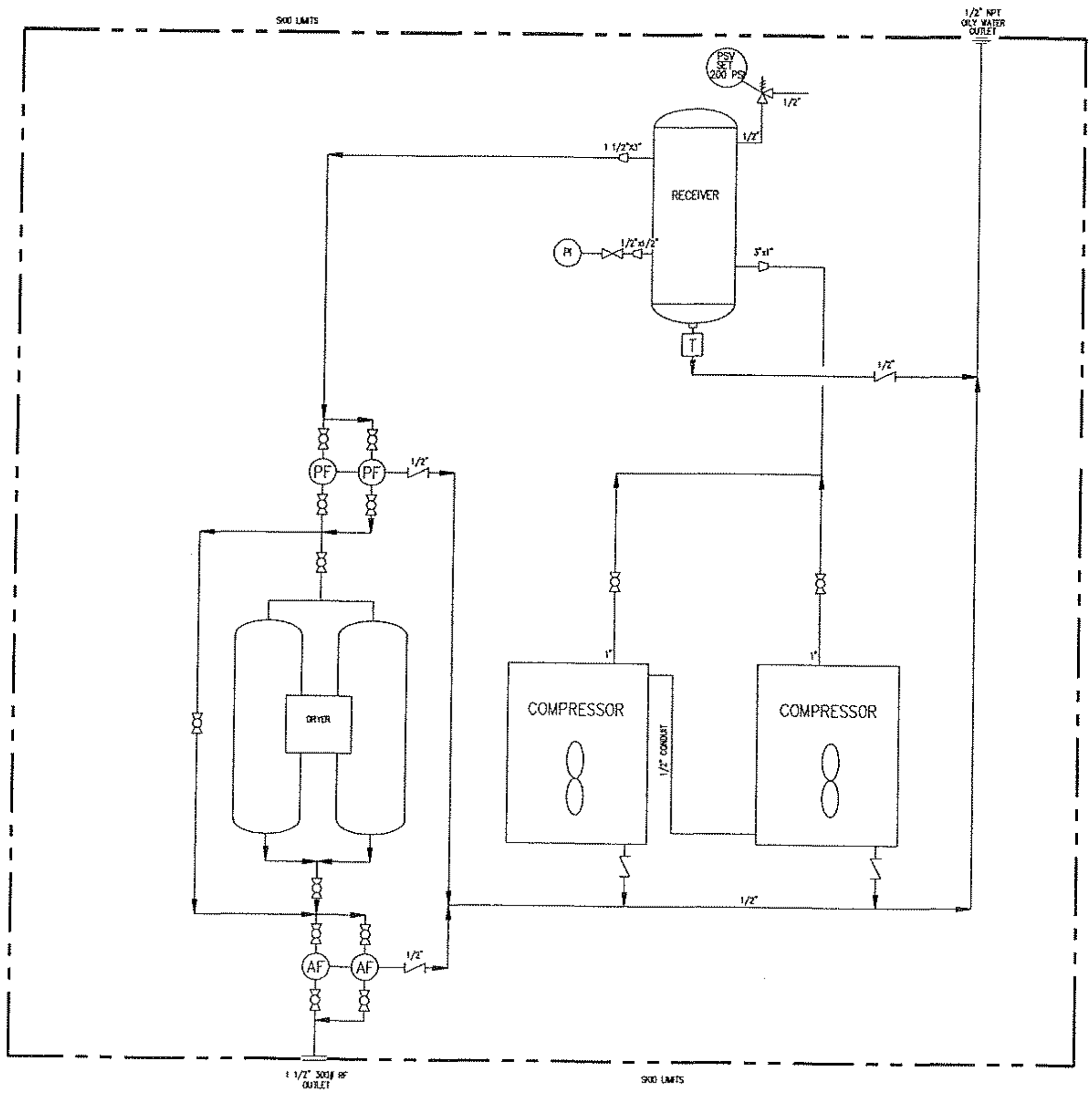
No.	REVISIONS	APPR.	
.	.	.	.

MAXIM
SILENCERS

10635 BRIGHTON LANE
STAFFORD, TEXAS 77477
PHONE (832) 554-0980
FAX (832) 554-0990

10"M51 EXHAUST SILENCER
(WITH SIDE INLET AND TRUNNION)

			ORDER NO.	DRAWING NO.	REV
DRAWN	TJW	6/6/01			
CHECKED	JJ	8/4/02	40285-01	142-8A11329	.
APPROVED				10M51-SI-TRUN	



LEGEND

PSV	PRESSURE SAFETY VALVE SET @ 200 PSI	KUNKLE 6010DCM01
PI	PRESSURE GAUGE 2 1/2"LF, 0-300 PSI 1/2" BTM. CONNECTION	GRAINGER 2C664
T	DRAIN TRAP	PINNACLE PI-CAD-250
PF	PREFILTER SEPARATOR (COALESCER)	CC-350-SA
AF	AFTER-FILTER (PARTICULATE)	CP-600

NO.	REVISIONS	MADE BY	CHK'D BY	DATE
A	ISSUED FOR CUSTOMER APPROVAL	MS	MY	09/08

Pinnacle Industries, LTD.

407 EAGLE ST. PASADENA, TX 77506 PHONE: (713) 472-2222 FAX: (713) 472-1359

CUSTOMER: TENNESSEE GAS PIPELINE

PURCHASE ORDER NO.: TGP-120736

PROJECT: ID 128248

LOCATION: STATION 27081 PELHAM, NH PROJECT

DESCRIPTION :

PIPING & INSTRUMENT DIAGRAM (P&ID)

AIR COMPRESSOR PACKAGE

DRAWING NO.: 35-0711-61-PID

ITEM NO.:

SCALE: N.T.S. | QUANTITY: ONE | SHEET 1 OF 1 | REV. A

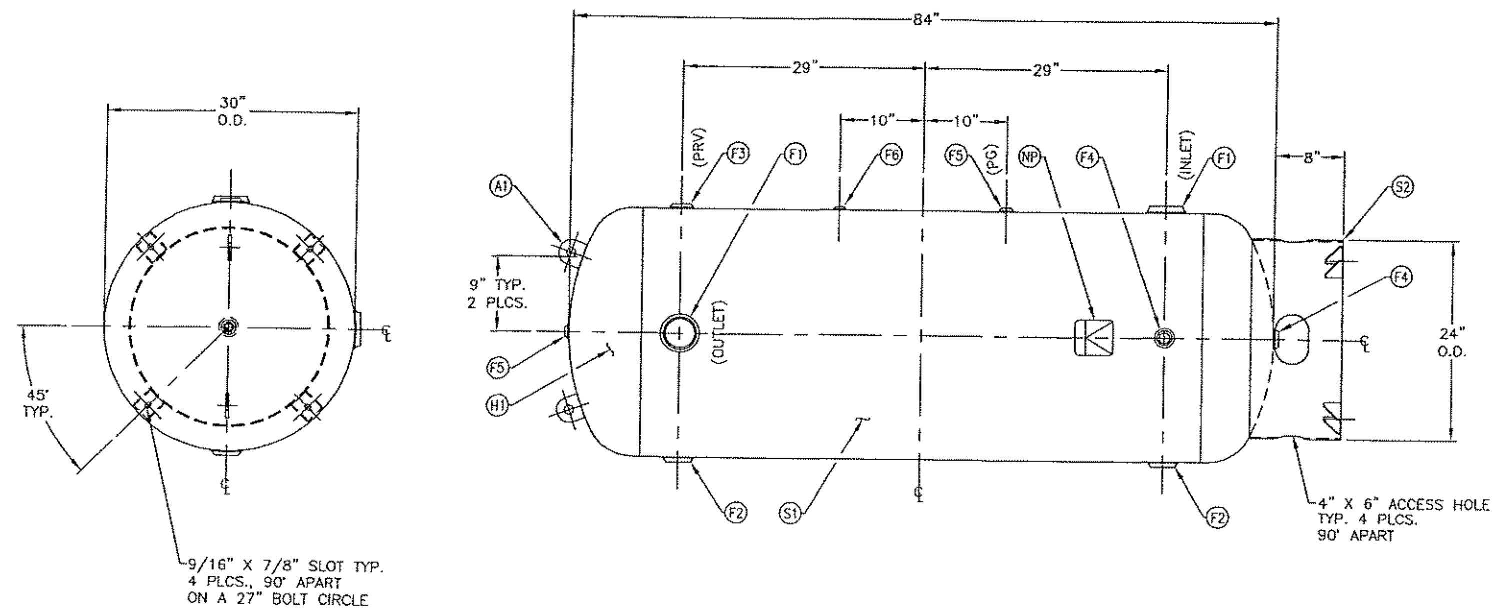
DRAWN BY: MS | CHK'D BY: MY | DATE: 9/30/08

NO.	REVISIONS	MADE BY	CHK'D BY	DATE
0	RELEASED FOR FABRICATION	MS	MY	09/08
A	ISSUED FOR CUSTOMER APPROVAL	MS	MY	09/02/08

Pinnacle Industries, LTD.
407 EAGLE ST. PASADENA, TX 77506 PHONE: (713) 472-2222 FAX: (713) 472-1359

CUSTOMER: TENNESSEE GAS PIPELINE
PURCHASE ORDER NO.: TGP-120736
PROJECT: ID 128248
LOCATION: STATION 27081 PELHAM, NH COMPRESSOR STATION
DESCRIPTION :
GENERAL ARRANGEMENT
RECEIVER
DRAWING NO.: 35-0711-61-REC
ITEM NO.:
SCALE: N.T.S. QUANTITY: ONE
DRAWN BY: MS CHK'D BY: MY DATE: 9/2/08
SHEET 1 OF 1 REV. 0

NO.	QTY.	DESCRIPTION	SPEC	SUB-DWG.
S1	1			
H1	2			
F1	2	3"-NPT 1500# RADIAL FLANGE	SA-181-70	
F2	2	2"-NPT 1500# RADIAL FLANGE	SA-181-70	
F3	1	1 1/2"-NPT 1500# RADIAL FLANGE	SA-181-70	
F4	2	1"-NPT 1500# FLAT FLANGE	SA-181-70	
F5	2	1/2"-NPT 1500# FLAT FLANGE	SA-181-70	
F6	1	1/4"-NPT 1500# FLAT FLANGE	SA-181-70	
A1	2	3/8" X 3" X 3" LIFT LUG		A84509
S2	1	24" O.D. BASERING ASSY. FOR 30" O.D. TANK		A85002
NP	1	ASME DATA PLATE	C1010	



SYM	DATE	BY	REVISION	APP	XREF REV.

NOTES

1. EXTERIOR OF TANK TO BE COATED W/ STD. GRAY PRIMER.

SPECIFICATIONS

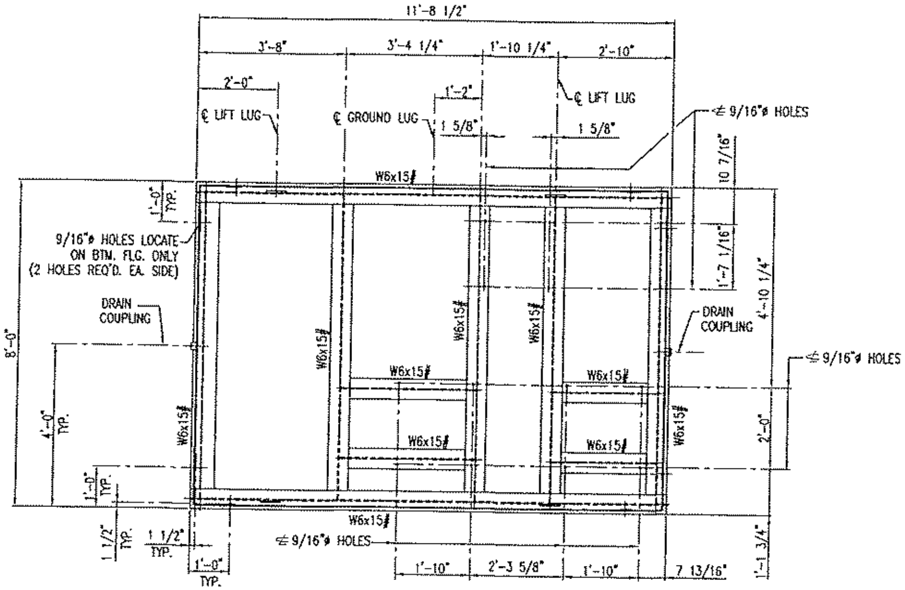
O.D. 30 LGTH. 84	SH. MAT'L.
MAWP 200 PSI @ 400°F	HD. MAT'L.
RT-4 MDMT -20 °F @ 200 PSI	GAL 240 S.A. 58.8
EXMT UG20(f) TEST 260 PSI	WT. 806 CU.FT. 31.1
XRAY SPOT/NONE	CORR ALW .125 SH .125 HD
CRN ---	CODE ASME SECT. VIII DIV. 1
	PER DATE OF DWG/LAST REV

WELD DETAILS: M-1932
STD. TOLERANCES (UNLESS OTHERWISE NOTED): M-2461

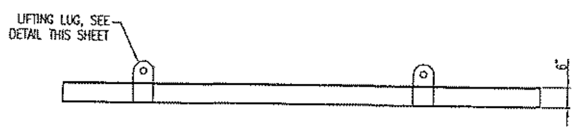
MANCHESTER TANK Q:\3000

30" X 84"
VERTICAL AIR RECEIVER

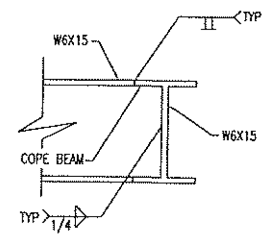
DRAWN BY DATE SCALE: NONE
APP. BY DATE DRAWING NO. 307816



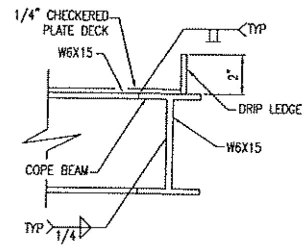
PLAN VIEW



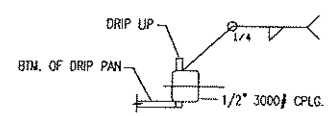
ELEVATION



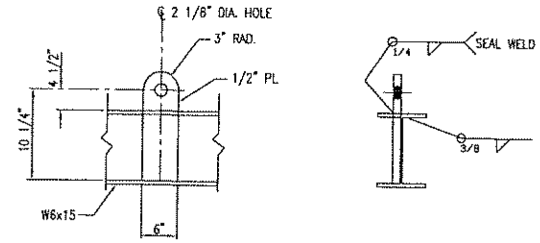
TYPICAL BEAM TO BEAM CONNECTION DETAIL



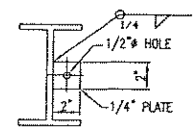
TYPICAL BEAM TO BEAM CONNECTION DETAIL



DRAIN CPLG. DETAIL
(1 REQ'D. @ EA. END)
(2 REQ'D. TOTAL)



LIFTING LUG DETAIL
N.T.S.

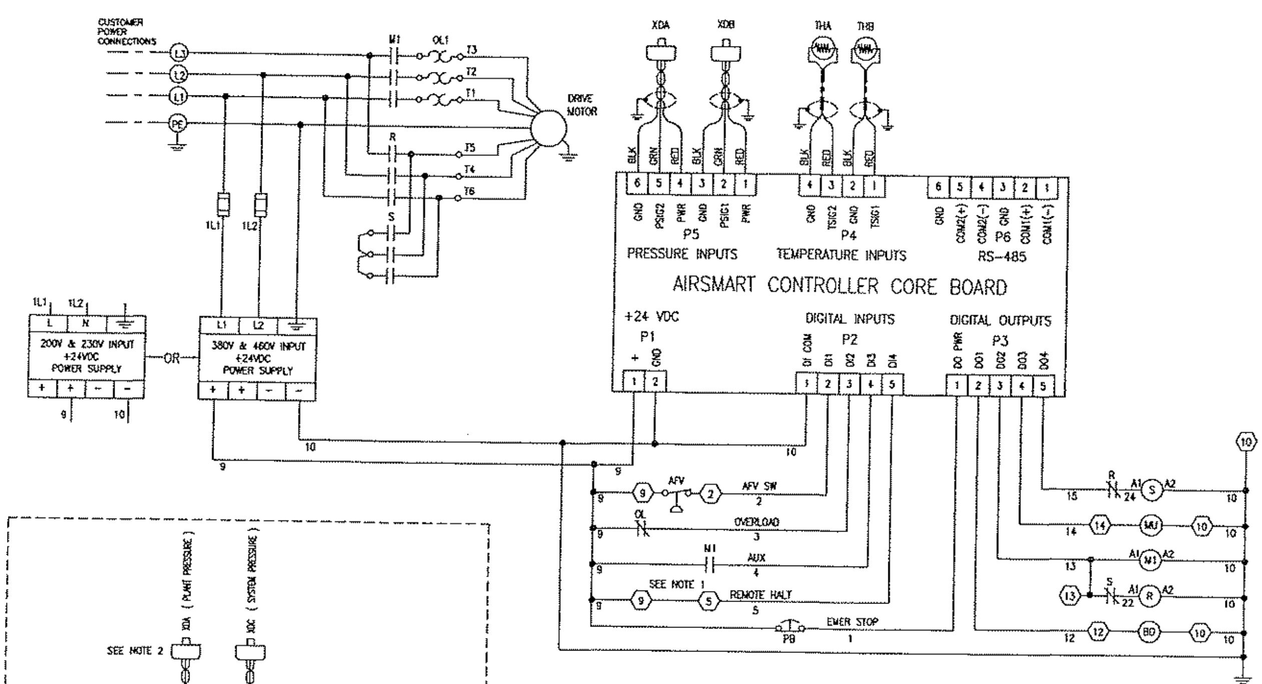


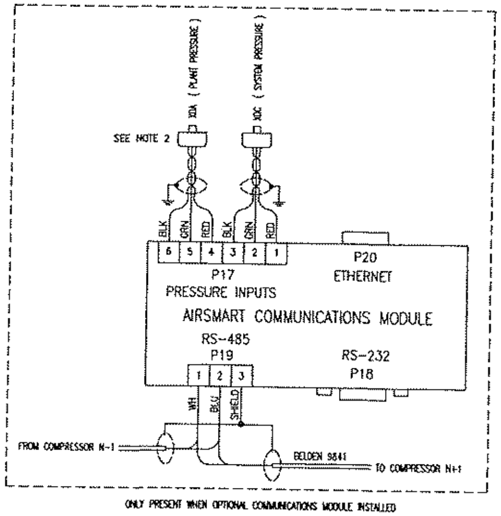
GROUNDING LUG DETAIL
N.T.S.

NO.	REVISIONS	MADE BY	CHK'D BY	DATE
A	ISSUED FOR CUSTOMER APPROVAL	MS	MY	10/08

Pinnacle Industries, LTD.
407 EAGLE ST. PASADENA, TX 77506 PHONE: (713) 472-2222 FAX: (713) 472-1359

CUSTOMER: TENNESSEE GAS PIPELINE
PURCHASE ORDER NO.: TGP-120736
PROJECT: ID 128248
LOCATION: STATION 270B1 PELHAM, NH PROJECT
DESCRIPTION :
SKID DETAILS
AIR COMPRESSOR PACKAGE
DRAWING NO.: 35-0711-61-SK
ITEM NO.:
SCALE: N.T.S. | QUANTITY: ONE
DRAWN BY: MS | CHK'D BY: MY | DATE: 10/03/08
SHEET 1 OF 1 | REV. A





NOTE 1: FOR CONTROL BY REMOTE CONTACT, REMOVE JUMPER BETWEEN TERMINALS 5 & 9, CONNECT CONTACT TO TERMINALS 5 & 9.

NOTE 2: WHEN COMMUNICATIONS MODULE IS INSTALLED AND "XDC" IS INSTALLED, CONNECT "XDA" TO P17, PINS 4-6.

NOTE 3: ACTUAL POWER SUPPLY CONNECTION POINTS MAY VERY FROM WHAT IS SHOWN, BUT ARE IDENTIFIED AS SHOWN.

LEGEND:

- AFV – AIR FILTER VACUUM SWITCH
- BD – BLOWDOWN VALVE
- THA – COMPRESSOR DISCHARGE THERMISTOR
- THB – SEPARATOR THERMISTOR
- XDA – PLANT PRESSURE TRANSDUCER
- XDB – RESERVOIR PRESSURE TRANSDUCER
- XDC – SYSTEM PRESSURE TRANSDUCER
- MU – MAGNETIC UNLOADER
- N+1 – NEXT SEQUENCED COMPRESSOR
- N-1 – PREVIOUS SEQUENCED COMPRESSOR
- ☐ – CONNECTION TO CONTROL BOARD
- ⬡ – PANEL TERMINAL BLOCK

MAIN MOTOR	YD STARTER
FAN MOTOR	NONE
CONTROLLER	AIRSMART
ACCESSORY	NONE

NO.	REVISIONS	MADE BY	CHK'D BY	DATE
A	ISSUED FOR CUSTOMER APPROVAL	MS	MY	10/06

Pinnacle Industries, LTD.

CUSTOMER: TENNESSEE GAS PIPELINE

DESCRIPTION: AIR COMPRESSOR

SCALE: X.XX QUANTITY: ONE SHEET 1 OF 1

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOL. ON DECIMALS: .X = ±.05
TOL. ON DECIMALS: .XX = ±.02
TOL. ON DECIMALS: .XXX AS SPECIFIED
TOL. ON ANGLES: ± 0°-30'

DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994
THREADS PER ASME B1.1

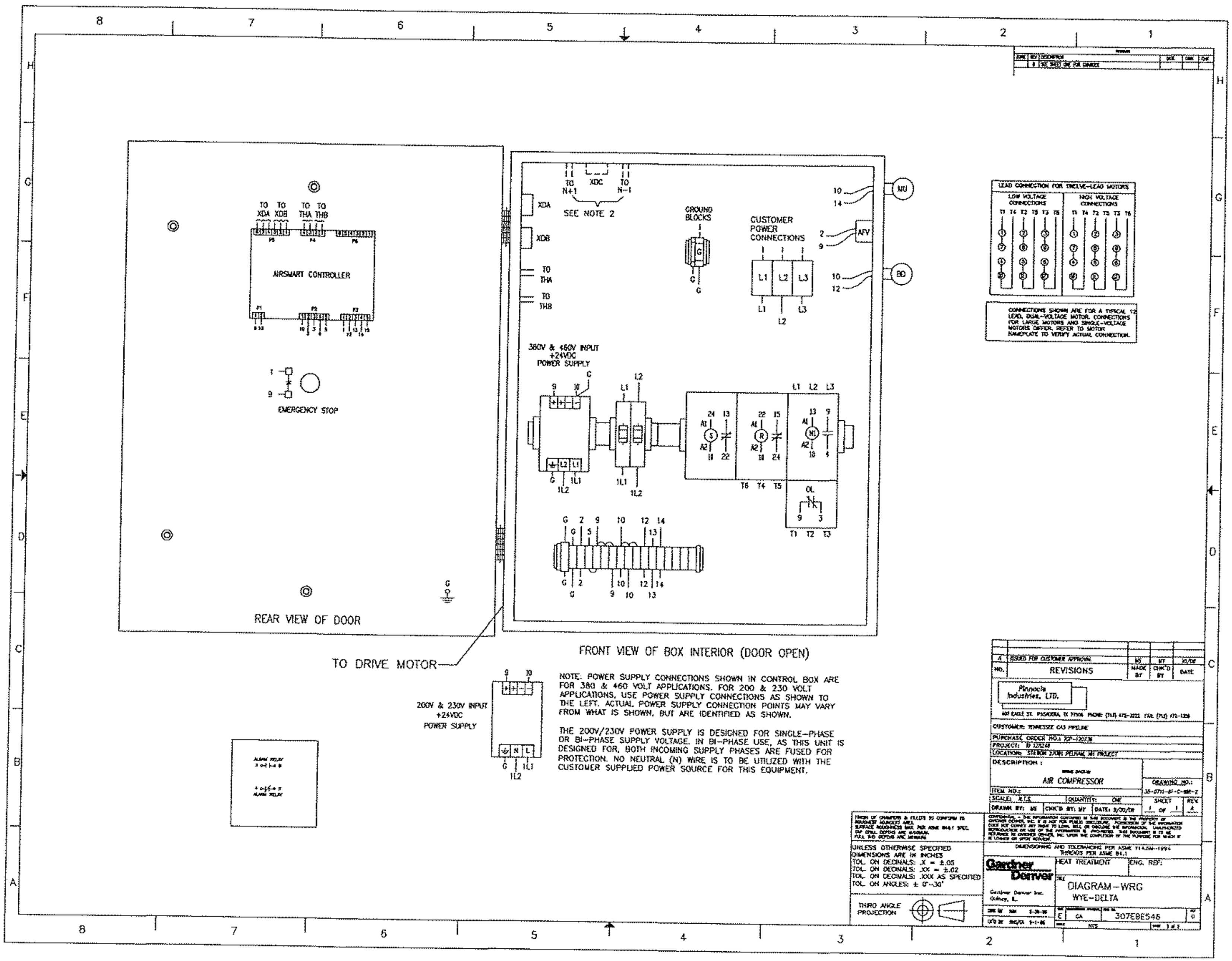
THIRD ANGLE PROJECTION

Gardner Denver
Gardner Denver Inc.
Quincy, IL

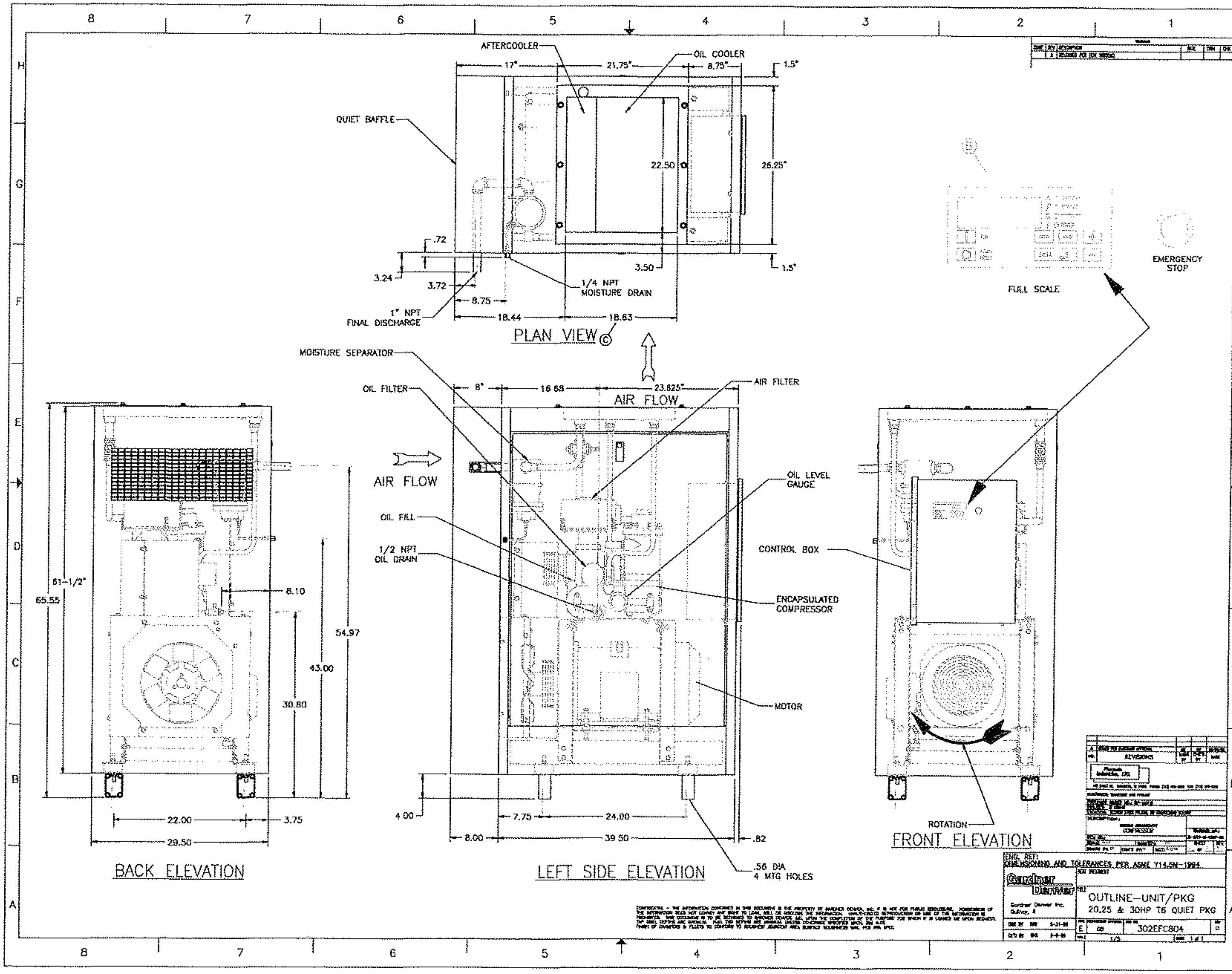
HEAT TREATMENT | ENG. REF:

DIAGRAM–WRG
WYE–DELTA

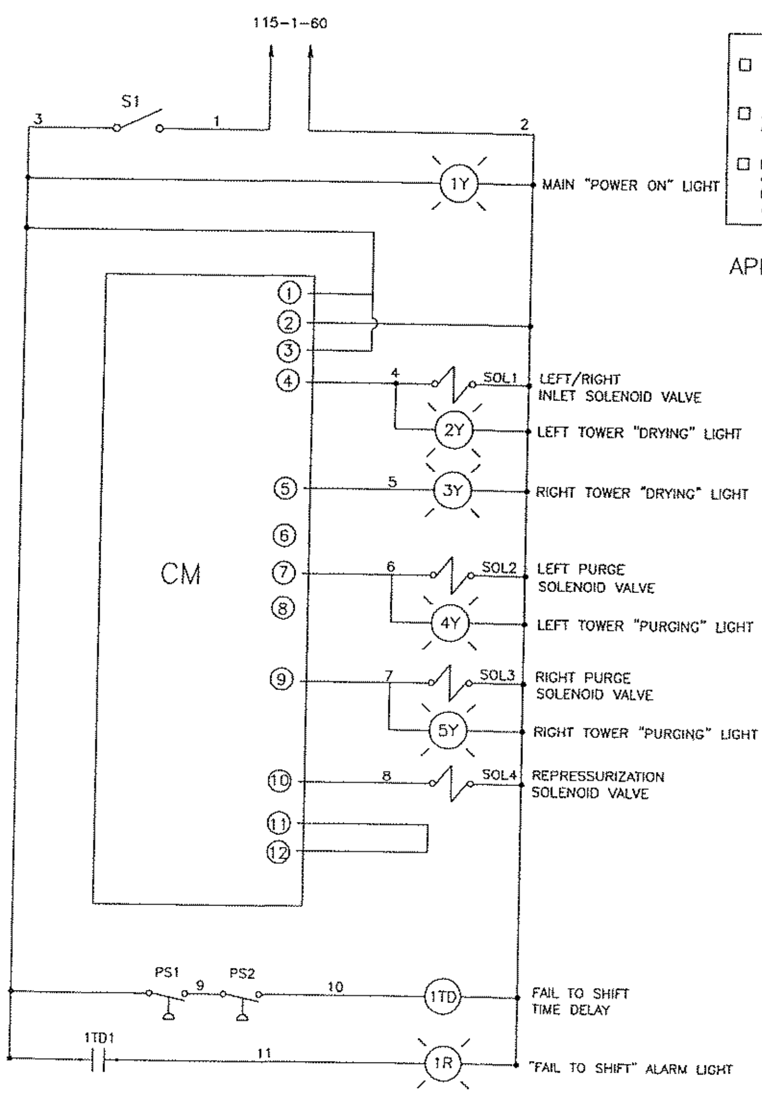
307EBE546



REAR VIEW OF DOOR
AIRSMART CONTROLLER
TO XDA TO XDB TO THA TO THB
EMERGENCY STOP
TO DRIVE MOTOR
FRONT VIEW OF BOX INTERIOR (DOOR OPEN)
XDA
XDB
TO THA
TO THB
TO N+1 XDC TO N-1
SEE NOTE 2
GROUND BLOCKS
CUSTOMER POWER CONNECTIONS
L1 L2 L3
AFV
MU
BO
380V & 460V INPUT +24VDC POWER SUPPLY
200V & 230V INPUT +24VDC POWER SUPPLY
OL
LEAD CONNECTION FOR TWELVE-LEAD MOTORS
LOW VOLTAGE CONNECTIONS
HIGH VOLTAGE CONNECTIONS
CONNECTIONS SHOWN ARE FOR A TYPICAL 12 LEAD, DUAL-VOLTAGE MOTOR. CONNECTIONS FOR LARGE MOTORS AND SINGLE-VOLTAGE MOTORS DIFFER. REFER TO MOTOR NAMEPLATE TO VERIFY ACTUAL CONNECTION.
NOTE: POWER SUPPLY CONNECTIONS SHOWN IN CONTROL BOX ARE FOR 380 & 460 VOLT APPLICATIONS. FOR 200 & 230 VOLT APPLICATIONS, USE POWER SUPPLY CONNECTIONS AS SHOWN TO THE LEFT. ACTUAL POWER SUPPLY CONNECTION POINTS MAY VARY FROM WHAT IS SHOWN, BUT ARE IDENTIFIED AS SHOWN.
THE 200V/230V POWER SUPPLY IS DESIGNED FOR SINGLE-PHASE OR BI-PHASE SUPPLY VOLTAGE. IN BI-PHASE USE, AS THIS UNIT IS DESIGNED FOR, BOTH INCOMING SUPPLY PHASES ARE FUSED FOR PROTECTION. NO NEUTRAL (N) WIRE IS TO BE UTILIZED WITH THE CUSTOMER SUPPLIED POWER SOURCE FOR THIS EQUIPMENT.
A ISSUED FOR CUSTOMER APPROVAL
NO. REVISIONS MADE BY CHK'D BY DATE
Pinnacle Industries, LTD.
DESCRIPTION :
AIR COMPRESSOR
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOL. ON DECIMALS: .X = ±.05
TOL. ON DECIMALS: .XX = ±.02
TOL. ON DECIMALS: .XXX AS SPECIFIED
TOL. ON ANGLES: ± 0°-30'
THIRD ANGLE PROJECTION
Gardner Denver
HEAT TREATMENT
ENG. REF:
DIAGRAM-WRG
WYE-DELTA
307EBE548



AFTERCOOLER
OIL COOLER
QUIET BAFFLE
17"
21.75"
8.75"
1.5"
22.50
26.25"
.72
3.24
3.72
8.75
3.50
1.5"
1/4 NPT MOISTURE DRAIN
1" NPT FINAL DISCHARGE
18.44
18.63
PLAN VIEW
EMERGENCY STOP
FULL SCALE
MOISTURE SEPARATOR
OIL FILTER
8"
16.68
23.825"
AIR FILTER
AIR FLOW
AIR FLOW
OIL LEVEL GAUGE
OIL FILL
1/2 NPT OIL DRAIN
CONTROL BOX
ENCAPSULATED COMPRESSOR
MOTOR
61-1/2"
65.55
8.10
54.97
43.00
30.80
22.00
3.75
29.50
4.00
7.75
24.00
8.00
39.50
.82
.56 DIA 4 MTG HOLES
ROTATION
BACK ELEVATION
LEFT SIDE ELEVATION
FRONT ELEVATION
ENG. REF: DIMENSIONING AND TOLERANCES PER ASME Y14.5M-1994
Gardner Denver
Gardner Denver Inc. Quincy, Il
OUTLINE-UNIT/PKG
20,25 & 30HP T6 QUIET PKG
302EFC804
1/3
1 of 1



☐ Authorized to manufacture product as shown on submitted drawings.

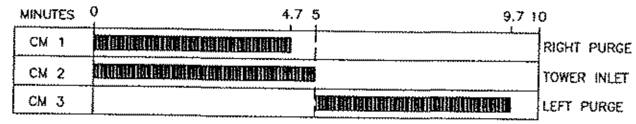
☐ Authorized to manufacture product with as noted changes.

☐ Not authorized to manufacture product. Please make noted or discussed revisions and resubmit drawings for approval. (Please note that checking this box will hold or stop all production of this order).

APPROVED BY: ____________

DATE: ____________

ITEM	DESCRIPTION
S1,1Y	OFF/ON SELECTOR SWITCH & MAIN "POWER ON" LIGHT
2Y	LEFT TOWER "DRYING" LIGHT
3Y	RIGHT TOWER "DRYING" LIGHT
4Y	LEFT TOWER "PURGING" LIGHT
5Y	RIGHT TOWER "PURGING" LIGHT
1R	"FAIL TO SHIFT" ALARM LIGHT
SOL1	CONTROL SOLENOID VALVE(INLET)
SOL2	CONTROL SOLENOID VALVES(PURGE)
SOL3	CONTROL SOLENOID VALVES(PURGE)
SOL4	REPRESSURIZATION SOLENOID VALVE
CM	ELECTRONIC CONTROL MODULE



NO.	REVISIONS	MADE BY	CHK'D BY	DATE
A	ISSUED FOR CUSTOMER APPROVAL	MS	MY	10/08

Pinnacle Industries, LTD.

407 EAGLE ST. PASADENA, TX 77506 PHONE: (713) 472-2222 FAX: (713) 472-1359

CUSTOMER: TENNESSEE GAS PIPELINE

PURCHASE ORDER NO.: TGP-120736

PROJECT: ID 128248

LOCATION: STATION 270B1 PELHAM, NH PROJECT

DESCRIPTION : ELECTRICAL SCHEMATIC DRYER

DRAWING NO.: 35-0711-61-D-ELEC

ITEM NO.:

SCALE: N.T.S. QUANTITY: ONE

DRAWN BY: MS CHK'D BY: MY DATE: 10/03/08

SHEET 1 OF 1 REV. A

REV.	DATE	DRN.	CHK'D	REVISION DESCRIPTION

GREAT LAKES AIR PROD.

APPROVED FOR CONST BY | DATE | REV. | DATE | PROJ. LOCATION

TITLE: GPS175N4XP2-116 ELECTRICAL SCHEMATIC

DRN. KEVIN — DATE 9/19/2008

CHK'D MARK — DATE 9/19/2008

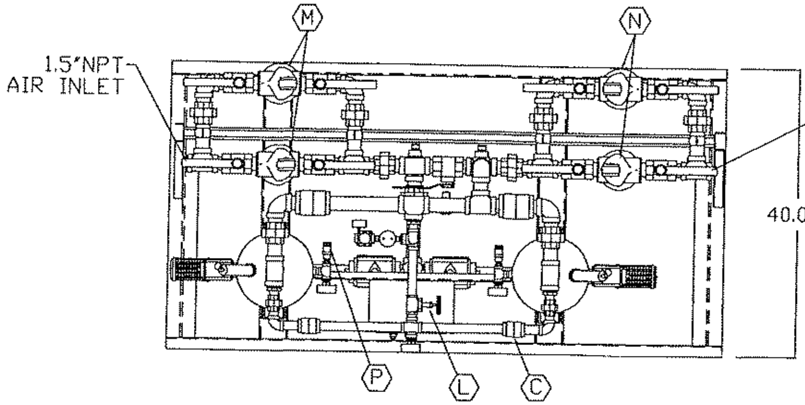
SCALE NONE

PLOT 1"= 1"

DRAWING NO. 94460 REV.

CAD FILE NO. E:\ACADWIN\GPSEL\GPS175N4XP2-116 Pinnacle Electrical

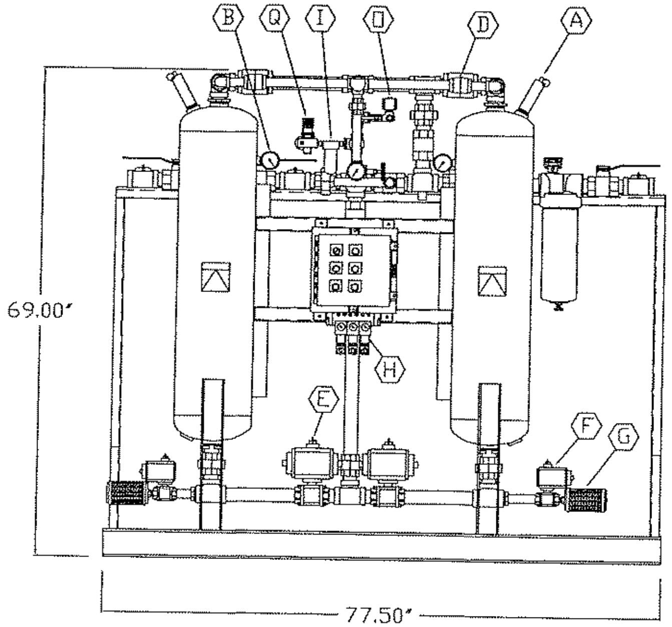
PROJECT: PINNACLE INDUSTRIES, INC.

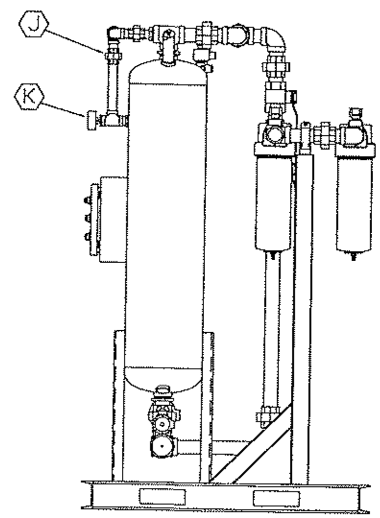


- ☐ Authorized to manufacture product as shown on submitted drawings.
- ☐ Authorized to manufacture product with as noted changes.
- ☐ Not authorized to manufacture product. Please make noted or discussed revisions and resubmit drawings for approval. (Please note that checking this box will hold or stop all production of this order).

APPROVED BY; ____________

DATE; ____________





ITEM	QTY.	DESCRIPTION
A	2	PRESSURE RELIEF VALVE
B	2	TOWER PRESSURE GAUGE
C	2	PURGE CHECK VALVE
D	2	OUTLET CHECK VALVE
E	2	INLET DIVERSION VALVE
F	2	PURGE EXHAUST VALVE
G	2	PURGE EXHAUST MUFFLER
H	1	CONTROL SOLENOID MANIFOLD
I	1	VISUAL MOISTURE INDICATOR
J	1	PURGE FLOW ORIFICE
K	1	PURGE FLOW INDICATOR
L	1	PURGE FLOW REGULATOR
M	2	GC350-SA COALESCING PREFILTER
N	2	GP-600 PARTICULATE AFTERFILTER
O	1	REPRESSURIZATION VALVE
P	2	PRESSURE SWITCH
Q	1	PRESSURE REGULATOR

NOTES:

1. ALL DIMENSIONS ARE IN INCHES.
2. MAWP: 250 PSIG, MAX. TEMP. 225°F.

NO.	REVISIONS	MADE BY	CHK'D BY	DATE
A	ISSUED FOR CUSTOMER APPROVAL	MS	MY	10/08

Pinnacle Industries, LTD.

407 EAGLE ST. PASADENA, TX 77506 PHONE: (713) 472-2222 FAX: (713) 472-1359

CUSTOMER: TENNESSEE GAS PIPELINE

PURCHASE ORDER NO.: TGP-120736

PROJECT: ID 128248

LOCATION: STATION 27081 PELHAM, NH PROJECT

DESCRIPTION: GENERAL ARRANGEMENT DRYER

DRAWING NO.: 35-0711-61-D-GA

ITEM NO.:

SCALE: N.T.S. QUANTITY: ONE

DRAWN BY: MS CHK'D BY: MY DATE: 10/03/08

SHEET 1 OF 1 REV. A

REV.	DATE	DRN.	REVISION DESCRIPTION	APRV.

Great Lakes Air Products Inc.

SCALE	1"=1"	DRN.	K. Kerridge
PLOT	1"= 1"	DATE	9/16/08
		CHK'D	M. Rynicki
		DATE	9/16/08

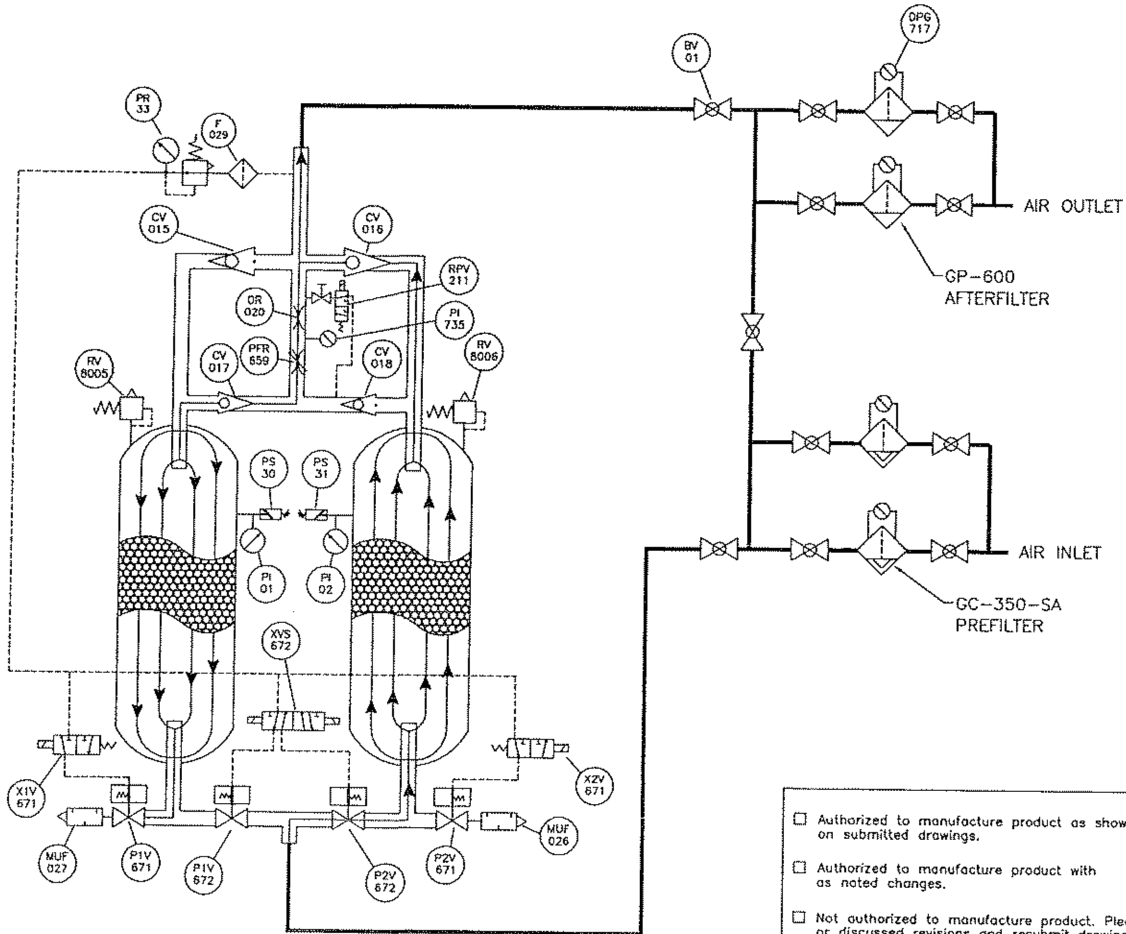
TITLE: GPS175N4XP2-116 REGENERATIVE DRYER

This drawing is the property of: GREAT LAKES AIR PRODUCTS INC. 5861 COMMERCE DRIVE WESTLAND, MICHIGAN 734-326-7080 Written authorization required for duplication.

DRAWING NO. 92568 REV.

CAD FILE NO. E:\ACADWIN\GPSMEC\GPS175N4XP2-116 Pinnacle

PROJECT: PINNACLE INDUSTRIES



MATERIALS		
ITEM	DES.	DESCRIPTION
672	XVS	INLET CONTROL SOLENOID VALVE
671	X1V,X2V	PURGE CONTROL SOLENOID VALVE
015,016	CV	OUTLET CHECK VALVE
017,018	CV	PURGE CHECK VALVE
671	P1V,P2V	PURGE EXHAUST VALVE
672	P1V,P2V	INLET DIVERSION VALVE
659	PFR	PURGE FLOW REGULATOR
735	PI	0-300 PRESSURE GAUGE(PURGE FLOW INDICATOR)
01,02	PI	0-300 TOWER PRESSURE GAUGE
020	OR	PURGE FLOW ORIFICE
8005/6	RV	PRESSURE RELIEF VALVE
029	F	VISUAL MOISTURE INDICATOR
026,027	MUF	PURGE EXHAUST MUFFLER
01	BV	BALL VALVE
30,31	PS	PRESSURE SWITCH
33	PR	PRESSURE REGULATOR VALVE
211	RPV	REPRESSURIZATION VALVE
717	DPG	DIFFERENTIAL PRESSURE GAUGE

---------- CONTROL TUBING

☐ Authorized to manufacture product as shown on submitted drawings.

☐ Authorized to manufacture product with as noted changes.

☐ Not authorized to manufacture product. Please make noted or discussed revisions and resubmit drawings for approval. (Please note that checking this box will hold or stop all production of this order).

APPROVED BY: ______________

DATE: ______________

NO.	REVISIONS	MADE BY	CHK'D BY	DATE
A	ISSUED FOR CUSTOMER APPROVAL	MS	MY	10/08

Pinnacle Industries, LTD.
407 EAGLE ST. PASADENA, TX 77506 PHONE: (713) 472-2222 FAX: (713) 472-1359

CUSTOMER: TENNESSEE GAS PIPELINE
PURCHASE ORDER NO.: TGP-120736
PROJECT: ID T28248
LOCATION: STATION 270B1 PELHMAN, NH PROJECT
DESCRIPTION :
FLOW DIAGRAM
DRYER

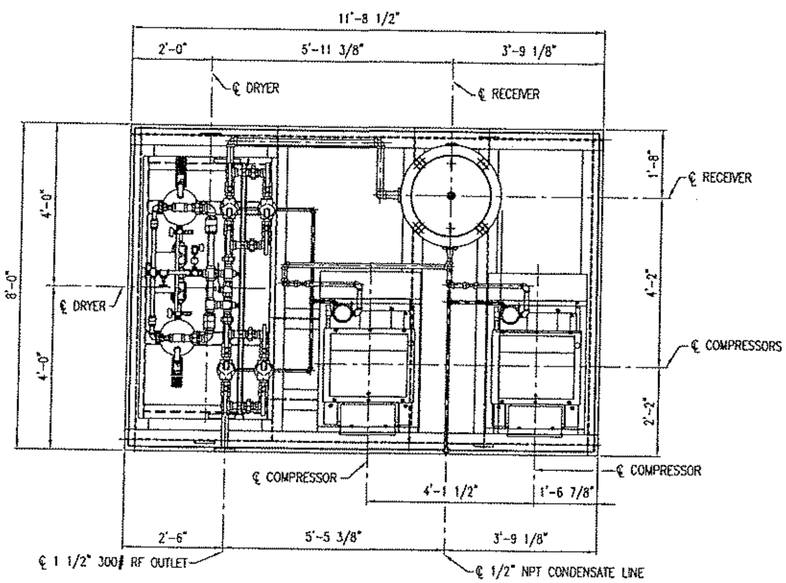
DRAWING NO.: 35-0711-61-D-PID

ITEM NO.:			
SCALE: N.T.S.		QUANTITY: ONE	SHEET 1 OF 1
DRAWN BY: MS	CHK'D BY: MY	DATE: 10/03/08	REV. A

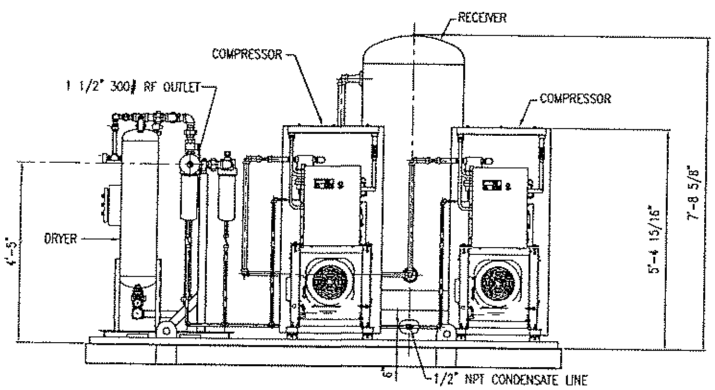
REV.	DATE	DRN.	CHK'D	REVISIONS DESCRIPTION

GREAT LAKES AIR PROD.

APPROVED FOR CONST BY	REV. DATE		TITLE
		DRN. K. Kerridge	GPS175N4XP2-116 P&ID
		DATE 9/19/08	
		CHK'D B. Larson	
		DATE 9/19/08	DRAWING NO. 97174 REV.
		SCALE N/A	
		PLOT 1"= 1"	
CAD FILE NO. G:\ACADWIN\FLOW\GPS\GPS175N4XP2-116 Pinnacle Flo			PROJECT. Pinnacle Industries



PLAN VIEW



ELEVATION

NOTES:

1. UNIT TO BE PAINTED PER SPEC. AC-135A
2. ALL WELDING TO BE SEAL WELDED.

NO.	REVISIONS	MADE BY	CHK'D BY	DATE
A	ISSUED FOR CUSTOMER APPROVAL	MS	MY	09/08

Pinnacle Industries, LTD.

407 EAGLE ST. PASADENA, TX 77506 PHONE: (713) 472-2222 FAX: (713) 472-1359

CUSTOMER: TENNESSEE GAS PIPELINE

PURCHASE ORDER NO.: TGP-120736

PROJECT: ID 128248

LOCATION: STATION 270B1 PELHAM, NH PROJECT

DESCRIPTION :

GENERAL ARRANGEMENT

AIR COMPRESSOR PACKAGE

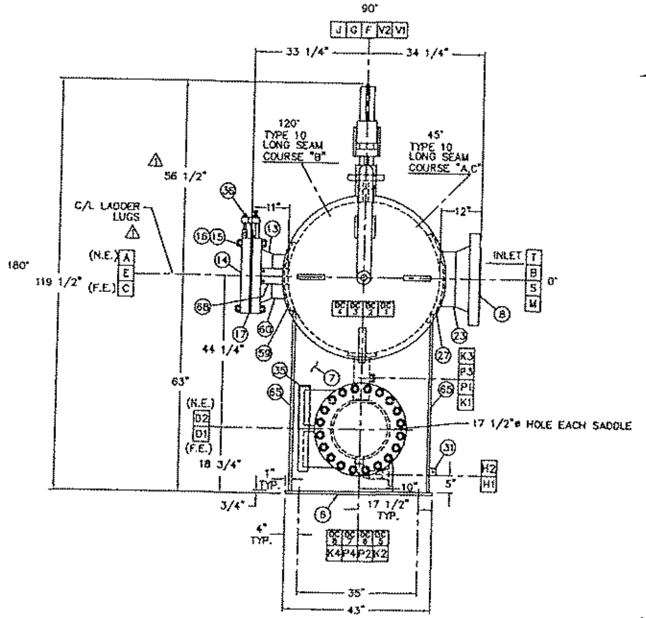
DRAWING NO.: 35-0711-61-GA

ITEM NO.:

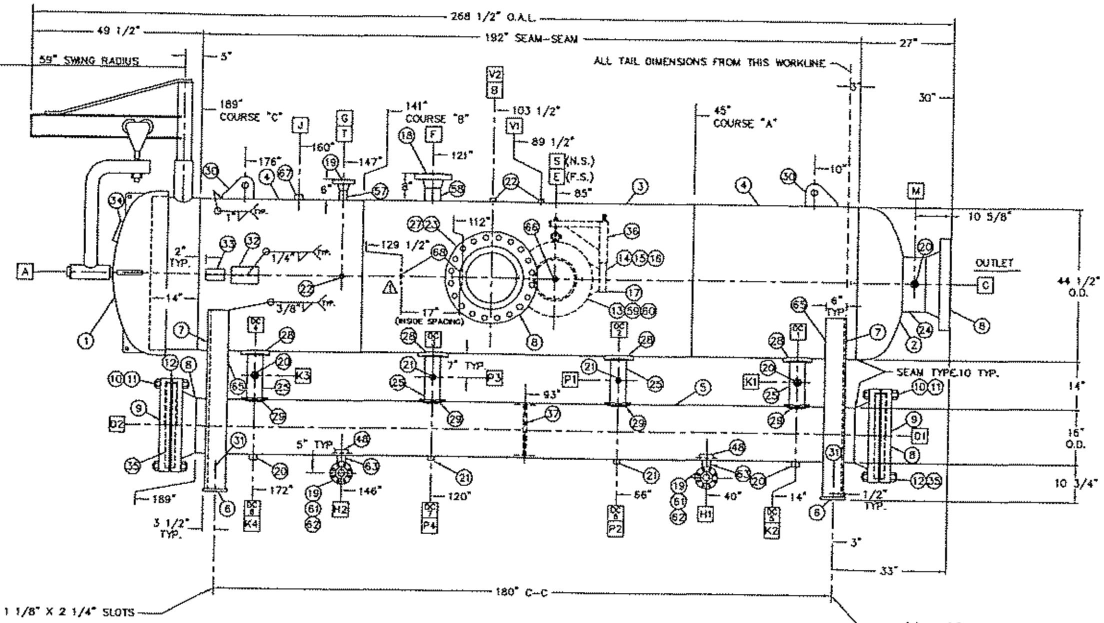
SCALE: N.T.S. QUANTITY: ONE

DRAWN BY: MS CHK'D BY: MY DATE: 9/30/08

SHEET 1 OF 1 REV. A



END ELEVATION



SIDE ELEVATION

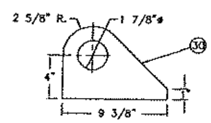
GENERAL NOTES

CONSTRUCTION: SECTION VIII A.S.M.E. CODE DIVISION 1-2007 & STAMPED NATIONAL BOARD
THIS VESSEL IS MANUFACTURED FOR A HYDROSTATIC TEST PRESSURE OF 1.3x DESIGN PRESSURE

CUSTOMER: TENNESSEE GAS PIPELINE	
SERIAL NO.: 08-029	TEST PRESSURE: 1200 P.S.I.G. FOR 4 HR(S)
P.O. NO.: TGP-0000118854	CORROSION ALLOWANCE: 1/8"
DESIGN PRESSURE: 800 P.S.I.G.	RADIOGRAPHED: 100% ALL BUTT WELDS
DESIGN TEMPERATURE: 200 °F.	PRODUCTION IMPACTS: NO
M.D.M.T.: -20 °F. @ 800 P.S.I.G.	APPROX. UNIT WEIGHT: 32000 LBS.
POSTWELD HEAT TREATMENT: NO @ °F.	TAG OR MARK: PELHAM COMP.STA. 27081
JOINT EFFICIENCY: 100%	LOCATION: PELHAM NH

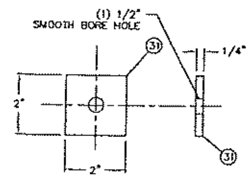
ALL BOLT HOLES TO STRADDLE TRUE CENTERLINES !

NEAR WHITE BLAST & PAINT PER AC-135:
2 1/2-4 MILS D.F.T. WILKOPON HS 347-67 PRIMER
2-3 MILS D.F.T. WILKOTHANE HS 722-72 (FEDERAL STANDARD 595 COLOR FS-36134 GRAY) △2
2-3 MILS D.F.T. WILKOTHANE HS 720-18 (CLEAR)

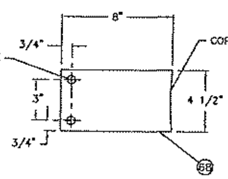


LIFTING LUG DETAIL
SCALE: N.T.S. REQ'D: 2

NOTE:
1. FOR A MORE DEFINITIVE TEST, KING TOOL COMPANY PERFORMS ULTRASONIC EXAMINATION OF BUTT WELDS 8" NOMINAL PIPE SIZE AND SMALLER IN LIEU OF RADIOGRAPHY.



GROUNDING LUG DETAIL
SCALE: N.T.S. REQ'D: 2



△ LADDER LUG DETAIL
SCALE: N.T.S. REQ'D: 2
(LADDER BY OTHERS)

CERTIFIED
10/3/2008
JERRY COMBEST

MARK	RATING	NO. REQ'D	SERVICE	REV NO.	STYLE	TYPE	O.D.	I.D.	D	T	L	E	H	W	X	Y	Z
DC5-8	4" SCH.120	4	DOWNCOMER		C	N6	4 1/2"	3.624"	7 1/2"	1/2"				1/2"	3/8"		
DC1-4	4" SCH.120	4	DOWNCOMER		C	N8	4 1/2"	3.624"	8 1/2"	1"				3/4"	5/8"		
V1,2	1/2"-6000# NPT	2	PDI		C	C4	1 1/2"							3/8"			
T	1/2"-6000# NPT	1	PI		C	C4	1 1/2"							3/8"			
S	3/4"-6000# NPT	1	TI		C	C4	1 3/4"							3/8"			
P1-4	3/4"-6000# NPT	4	LG		C	C2	1 3/4"							3/8"			
M	1"-6000# NPT	1	SUPPLY GAS		C	C4	2 1/4"							3/8"			
K1-4	1"-6000# NPT	4	HLLA		C	C4	2 1/4"							3/8"			
J	1"-6000# NPT	1	PSV		C	C4	2 1/4"							3/8"			
H1,2	2"-600# RF	2	DRAIN		B	N4	2 3/8"	1.689"						3/8"			
G	2"-600# RF	1	BLOWDOWN		B	N4	2 3/8"	1.689"						3/8"			
F	4"-600# RF	1	VENT		B	N4	4 1/2"	3.626"						3/8"			
E	12"-600# RF	1	INSPECTION		B	N14	12 3/4"	11.626"	21"	1 1/8"	11"	14 1/8"		1"	3/4"	1"	
D1,2	16"-600# RF	2	SUMP ACCESS			10	16"	14.688"									
C	16"-600# RF	1	OUTLET		B	N13	16"	14.688"	25"	1"		18 1/4"		3/4"	3/4"	3/4"	
B	16"-600# RF	1	INLET		B	N8	16"	14.688"	28"	1 1/8"	12"			1"	7/8"		
A	42" I.D. X 1183#	1	FILTER ACCESS			10	44 1/2"	42 1/4"									

(D, T, L, E, H: DIMENSION; W, X, Y, Z: WELD LEG DIMENSION)

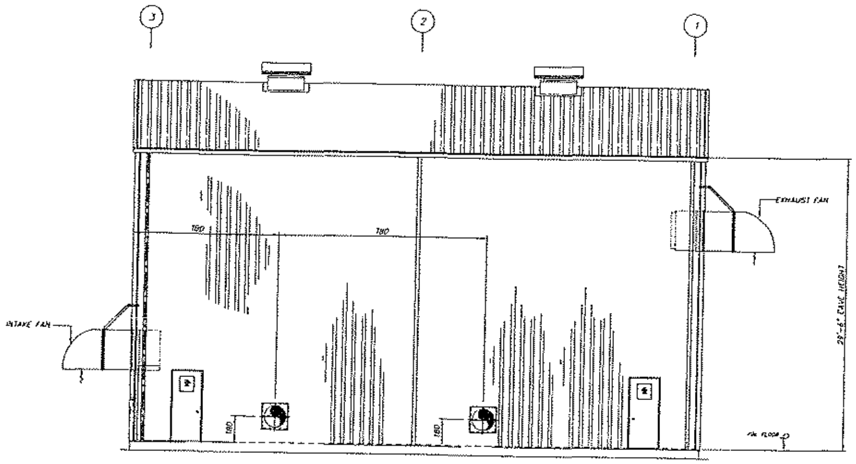
CERTIFIED BY Kingtool LONGVIEW, TEXAS — MANUFACTURED BY
W — M.A.W.P. 800 PSI @ 200 °F
RT1 — M.D.M.T. -20 °F @ 800 PSI
SER. NO. 08-029 DIAMETER 42 I.D. INCHES
DATE BUILT: MODEL KNSW-42-50
PELHAM COMP.STA. 270 81

SERIAL NO: 08-029
NO. REQ'D: 1

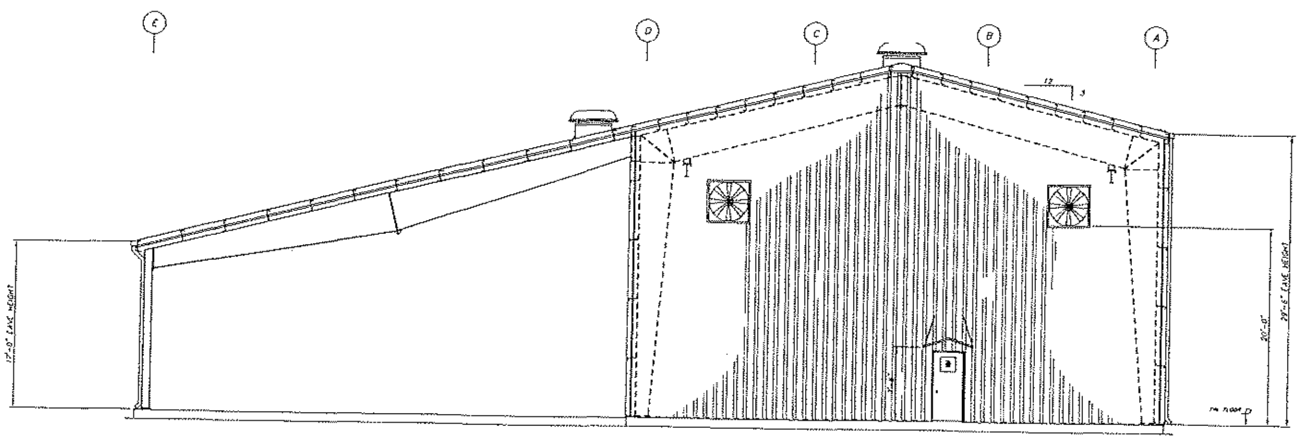
NO.	BY	DATE	REVISIONS
2	RL	10/3	ADD COLOR NUMBER
1	JLC	09-10	ADD LADDER LUGS, CLOSURE DIMS

CUSTOMER FIELD CONNECTION LAYOUT
KingTool COMPANY LONGVIEW, TEXAS
42" I.D. X 800 PSIG HORIZONTAL NON-SELF-CLEANING FILTER SEPARATOR

CUSTOMER: TENNESSEE GAS PIPELINE	
MODEL: KNSW-42-50	CHK'D:
DRAWN BY: CT	SCALE: 3/4" = 1'-0" / DATE: 8/08/08
DRAWING NUMBER: KTC-08029-T	



NORTH ELEVATION



WEST ELEVATION

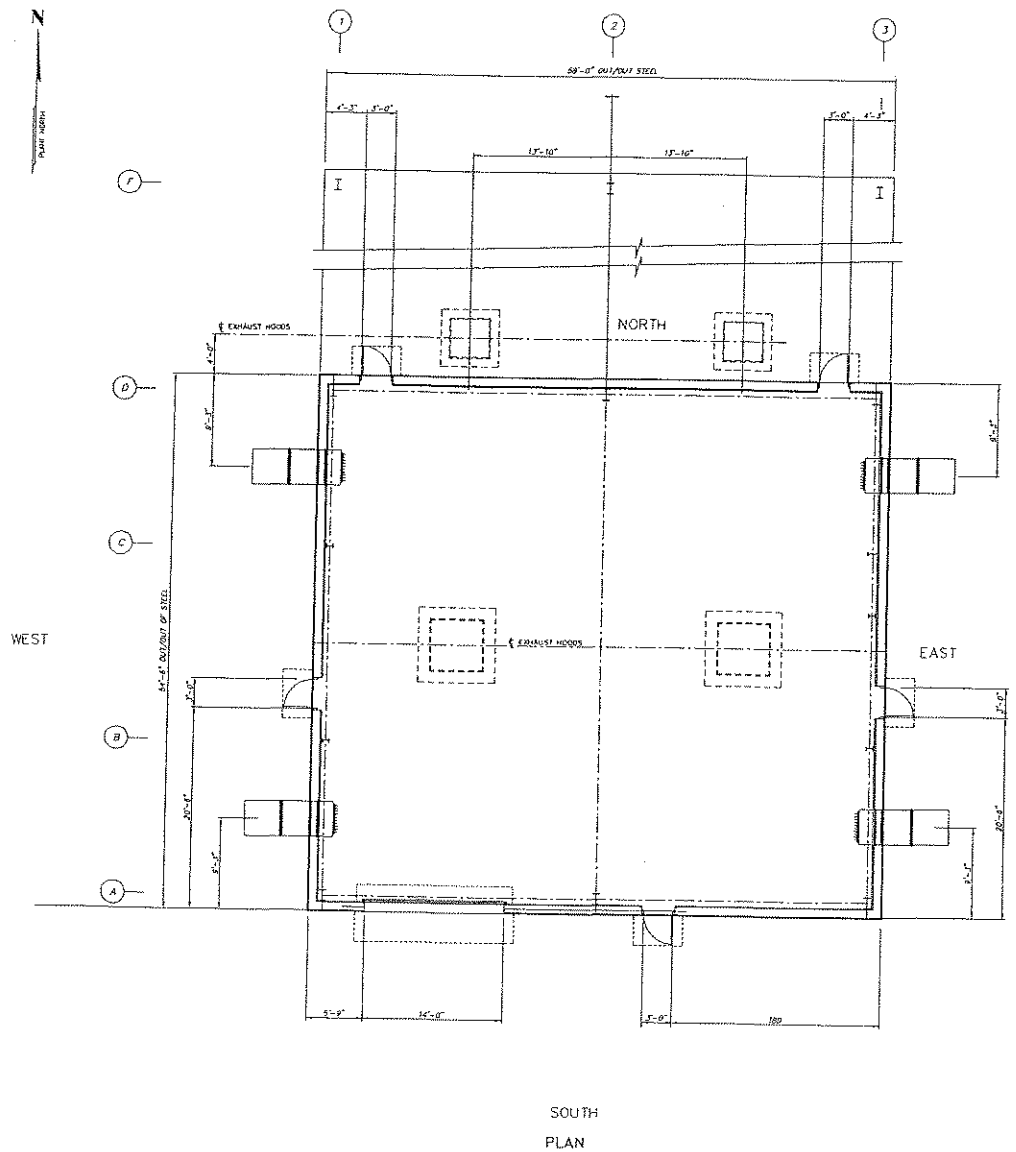
TO-C270B1-C1-AC1-1			PLAN - COMPRESSOR BUILDING "A"		
DRAWING NUMBER			DRAWING TITLE		
REFERENCE DRAWINGS					
A	07/05	DC	ISSUED FOR COMMENTS	128248	
NO.	DATE	BY	DESCRIPTION	PROJ. ID	APPR.
REVISIONS					

Tennessee Gas Pipeline
an El Paso company

NORTH AND WEST ELEVATIONS
COMPRESSOR BUILDING "A"

COMPRESSOR STATION 270B1

Division: NORTHERN		Op. Area: HOPKINTON	
State: NEW HAMPSHIRE		Cty/Parish: HILLSBOROUGH	
Section:	Township:	Range:	
Drafter: DC	Date: 7/08	Project ID: 128248	
Check:	Date:	Scale: 3/16" = 1'-0"	
Approved:	Date:	Filename: TO-C270B1-C1-AC1-3.dwg	
TO-C270B1-C1-AC1-3		Sheet:	A



TD-C270B1-C1-AC1-1	L2A/VORS - COMPRESSOR BUILDING "A"
DRAWING NUMBER	DRAWING TITLE

REFERENCE DRAWINGS

NO.	DATE	BY	DESCRIPTION	PROJ. ID	APPR.
A	07/08	GG	ISSUED COMMENTS	128248	

REVISIONS

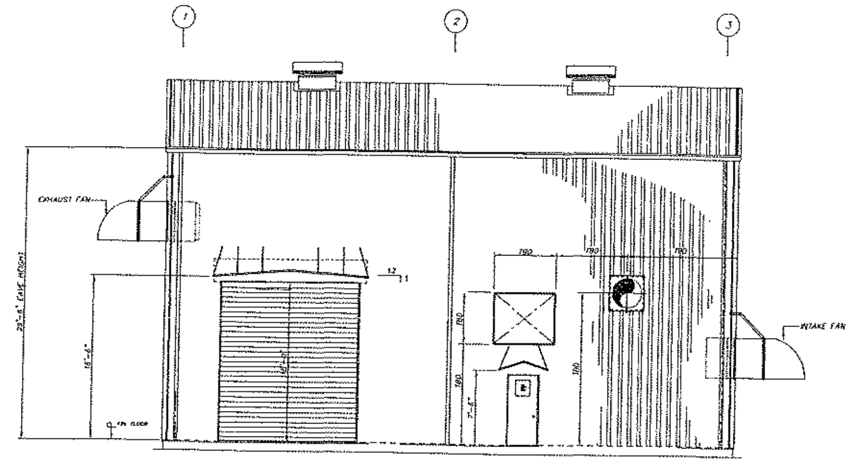
Tennessee Gas Pipeline
an El Paso company

PLAN
COMPRESSOR BUILDING "A"

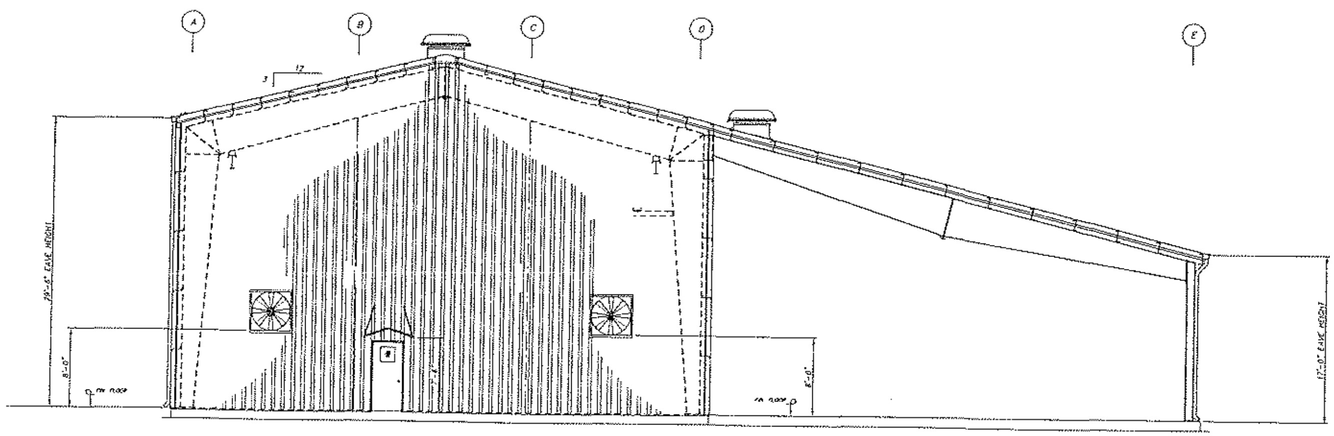
COMPRESSOR STATION 270B1

Division: NORTHERN		Op. Area: HOPKINTON	
State: NEW YORK		Co./Par.: HILLSBOROUGH	
Section:	Township:	Range:	
Drawn: GG	Date: 07/08	Project ID: 128248	
Chk'd:	Date:	Scale: AS SHOWN	
Approved:	Date:	Filename: TD-C270B1-C1-AC1-1.dwg	

TD-C270B1-C1-AC1-1 | Sheet: 1 of 1 | Type: ACAD | A



SOUTH ELEVATION



EAST ELEVATION

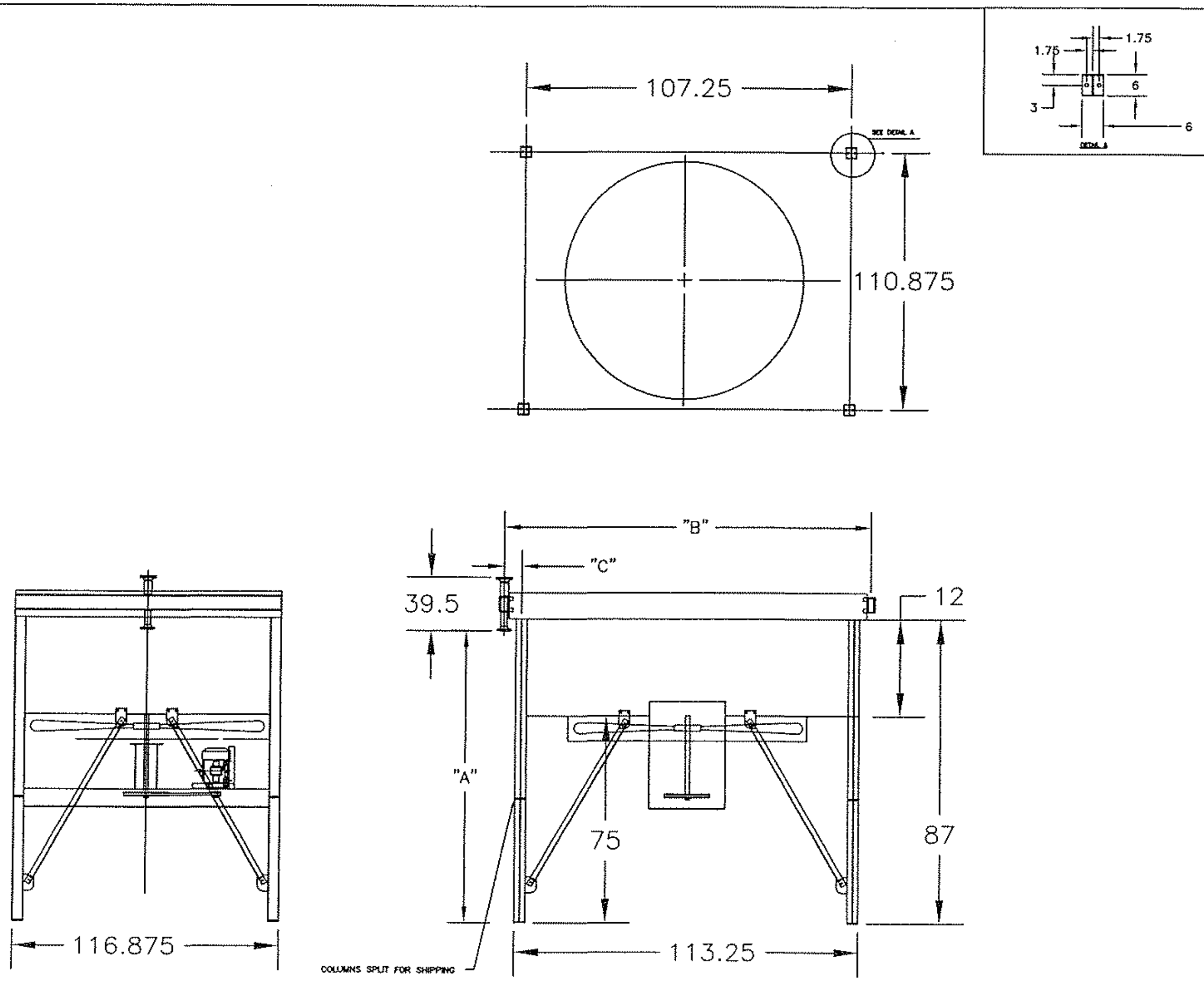
TO-C27081-C1-AC1-1		PLAN - COMPRESSOR BUILDING "A"			
DRAWING NUMBER		DRAWING TITLE			
REFERENCE DRAWINGS					
A	07/08	DG	ISSUED FOR COMMENTS	128248	
NO.	DATE	BY	DESCRIPTION	PROJ. ID	APPR.
REVISIONS					

Tennessee Gas Pipeline
an El Paso company

SOUTH AND EASTELEVATIONS
COMPRESSOR BUILDING "A"

COMPRESSOR STATION 27081

Division: NORTHERN		Op. Area: HOPKINTON	
State: NEW HAMPSHIRE		Cou/Par: HILLSBOROUGH	
Section:	Township:	Range:	
Drafter: DG	Date: 7/08	Project ID: 128248	
Chk'd:	Date:	Scale: 3/16" = 1'-0"	
Approved:	Date:	Filename: TO-C27081-C1-AC1-2.dwg	
TO-C27081-C1-AC1-2		Sheet: of / Type: ACAD	A



FAN DATA

FAN Class 10000 Series 30 EC 96 IN. DIAMETER 3 Blades
59311 ACFM 7.34 DEG.

DRIVE REDUCER
BELTS . BEARINGS 1.6875

MOTOR DATA

MOTOR HP 10 RPM 1750 215T TEFC 460/3/60

COIL DATA

COIL 1: Atmospheric Gas Cooler AC-100 Job No. TGP 27081
NOZZLE (IN) 2 - 12" 600# RF-WN
(OUT) 2 - 12" 600# RF-WN
LOUVER OPERATOR: N/A DESIGN PRESSURE: 800
CODE: ASME DESIGN TEMP: 250

NOTES:

1. COOLER TO BE HOT DIPPED GALVANIZED W ZINC METALIZED HEADERS
2. MURPHY VS2-EX VIBRATION SWITCH (1 PER FAN)
3. NUMBER OF BAYS: 1

REFERENCE DIMS	A	B	C
Job No. TGP 27081	76.75	131.5	12.125

REV	DATE	DESCRIPTION	BY
+	+	+	+
+	+	+	+
+	+	+	+
+	+	+	+

Chart Cooler Service Company, Inc
Tulsa, OK

DRAWN BY: SYS	APPROVED BY:
SCALE: NONE	10/3/2008

El Paso Pipeline Group
EQUIPMENT OUTLINE

Model: H96	13602

Tennessee Gas Pipeline
Concord Compressor Expansion Project
Hillsboro County, NH

Compressor Building Protection System Standard Matrix

RSH Engineering
Rev A 090508

	Compressor Bldg Heat Detection	Compressor Bldg Flame Detection		Compressor Bldg Hazardous Atmosphere			Smoke Detectors [1]	Manual ESD (Pull Handle or PB)		Test Buttons		Manual FGS (Bldg Shutdown Button)	
System Output	**High Heat / Rate of Raise**	**Fault**	**Fire or UV/IR**	**Fault**	**20% LEL**	**40% LEL**	**MCC**	**Pressure Sw**	**Push Button[2]**	**ESD**	**FGS**	**Push Button[4]**	**Pressure Sw**
Unit Stop Action	Estop*	No	Estop*	No	No	Vented Fast*	Normal then fast after 120 secs	Estop*	Estop*	No	No	Estop*	Estop*
ESD (De-Engerize Solenoid - Plant)[A]	Yes	No	Yes	No	No	See Note [A]	No	no	Yes	Yes	No	No	No
FGS (Bldg Shutdown)[A]	Yes	No	Yes	No	No	See Note [A]	No	Yes	Yes	No	Yes	Yes	No
Shunt Trip Lube Oil System	Yes	No	Yes	No	No	No	No	Yes	Yes	No	No	Yes	Yes
Shunt Trip Lights & Receptacles	Yes	No	Yes	No	No	Yes	No	Yes	Yes	No	No	Yes	Yes
Visual Indication (Strobe Lights)	Red	Amber or Blue	Red	Amber or Blue	Red	Red	Amber	Red	Red	Amber & Blue	Amber & Blue	Red	Red
Horn Indication (Unattended)	Fire** (Time-out after 5 minutes)	no	Fire** (Time-out after 5 minutes)	No	No	No	No	Fire** (Time-out after 5 min.)	Fire** (Time-out after 5 min.)	No	No	No	No
Horn Indication (Attended)	Fire**	Fault	Rapid**	Fault	Low Level	High Level	Rapid	Fire	Fire	No	No	Rapid	Rapid
Compressor Bldg Purge & Exhaust Fans ***	Off***	No Action	Off***	No Action	On	Remain On	No Action	Off***	Off***	No Action	No Action	No Action	No Action
Mainline Valve Control [3]	Enabled	No Action	Enabled	No Action	No Action	No Action	No Action	Enabled	Enabled	No	No	No Action	No Action
Gas Control Signal	Alarm	Warn	Alarm	Warn	Warn	Alarm	Warn then Alarm after 120 secs	Alarm	Alarm	No	No	Alarm	Alarm

See Page 2 for Notes

Compressor Building Protection System Standard Matrix

Note [A]: FGS vs. ESD: If a FGS does not result in the isolation and venting of all sources of gas within the compressor building, then a Plant ESD must be initiated.
Note [B]: All "SYSTEM OUTPUT" control output functions associated with "Alarm" or UV Only are not performed if the installed system includes the confirmed "Fire" or UV/IR flame detection method.

Note *: EMERGENCY stop involves issuing an Emergency Stop to the unit control system that will immediately cycle the unit valves to a "safe" condition, and lockout the controls to prevent a re-start. Two additional stops can supplement the emergency stop action depending on the control mechanism required to turn off lube pumps and shunt trip incoming power feeds.

A "FIRE or ESD STOP" may be issued to turbine controls to inhibit the normally initiated emergency DC Post Lube. The Stop shall require the venting of the compressor case if associated with a FGS.

FAST stop involves issuing a Fast Stop to unit control system that will shutdown the unit without a coast down and cycle the unit valves in sequence, and not lockout the controls. The Stop shall require the venting of the compressor case if associated with a FGS

NORMAL stop is not a protection function but involves issuing a Normal Stop to the unit control system to shutdown after a coast down, cycle the unit valves in sequence, and not lockout the controls.

Note **: FIRE code consists of an alarm horn of a long continuous blast that does not cease until a timer has expired (5, 10, 15 minutes or maybe never) or until acknowledged.

RAPID code consists of a brief alarm horn blast (about 3 sec.) followed by a rapid series of horn pulses (3/4 sec. ON, 1/2 sec. OFF) until acknowledged or timed out (about 90 sec.)

FAST code consists of a series of horn pulses (3/4 sec. ON, 3/4 sec. OFF) until acknowledged or timed out (about 90 sec.)

SLOW code consists of a series of horn pulses (1-1/2 sec. ON, 1-1/2 sec. OFF) until acknowledged or timed out (about 90 sec.)

FAULT code consists of a repeating series of brief alarm horn blasts (2 sec. ON, 20 sec. OFF) repeated until acknowledged.

LOW LEVEL code consists of series of 2 alarm horn blasts (2 sec. ON, 2 sec. OFF) followed by a pause (20 sec.) and repeated until acknowledged.

HIGH LEVEL code consists of series of 3 alarm horn blasts (2 sec. ON, 2 sec. OFF) followed by a pause (20 sec.) and repeated until acknowledged.

AUXILIARY input is the lowest priority horn code that is disabled until a more serious condition has ceased.

Note ***:
The purge and exhaust fan electrical loads in the compressor building are to be shunt tripped along with the "Shunt Trip Lube Oil Systeml" control output function.

General
Note: Not all Control Inputs (like smoke detectors in the compressor building or hazardous atmosphere detectors in the control room) are required at all locations.
Note [1]: Many Smoke Detectors that meet NFPA Requirements have a latched output that must be re-set by cycling the power. Delayed actions associated for devices of this type are not required.
Note [2]: Electrically Operated ESD Control Stations may be installed in place of multiple Pneumatic Control Stations. Stations include the Building Protection Control Panel, and may also include Compressor Building Exits, and convient locations about the building and yard.
Note [3]: Because the inputs that drive this output are transient in nature, the output must be latched and then reset when the ESD system is Reset.
Note [4]: Electrically Operated FGS (Building Shutdown) Control Stations may be installed in many locations, but usually include the Building Protection Control Panel, and Compressor Building Exits.
Note [5]: Blue beacons may be provided as an option to indicate a "Fault" condition. This is to provide an additional indication to supplement the Amber Strobes

Chief Inspector

The Chief Inspector is the Company's authorized representative and is to inspect and coordinate the construction project and ensure conformance with the Company specifications. The Chief Inspector ensures that the project proceeds in accordance with the contract requirements and that all necessary construction documentation is compiled and transmitted to the Project Sponsor. Depending on organizational structure, the Chief Inspector role may be filled by a Contract employee or Company employee (Construction Specialist classification). The Chief Inspector reports directly to the designated Project Manager and possesses project stop work authority.

Chief Inspector responsibilities shall include:

- Continuously inspect the Contractor's workmanship and ensure conformance to Company specifications.
- Ensure compliance with all project specific environmental requirements as outlined within the project Environmental Construction Plan and/or as directed by the project Environmental Inspector.
- Ensure compliance with all project specific right-of-way requirements as outlined within the Right-of-Way Line List and/or as directed by the project Right-of-Way Agent.
- Ensure personal and Contractor compliance with the minimum safety standards as outlined within the Company's Safety and Health Handbook.
- Thorough review and familiarity with project scope of work, drawings, and specific specification including environmental and right-of-way requirements.
- Technical liaison between the Project Manager and Contractor. Identify and communicate resource requirements such as survey, radiographic, inspection, materials, test equipment, etc.
- Disseminate and explain Company specifications and project specific documentation to craft inspectors.
- Maintain line of communication with Area Operating Office regarding project progress (scheduling of personnel to support gas-handling operations; job plan development; scheduling of "tailgate" meetings for tie-ins; and scheduling facility commissioning and in-service).
- Advance planning and organization of all construction activities including, inspection, survey and radiographic duties; materials availability; tie-ins and service disruptions; and commissioning and start-up.

- Maintain, coordinate and communicate weekly progress and schedule. Weekly progress report shall include identification of potential cost and schedule issues as well as safety, environmental, progress and quality control issues.
- Verify, approve and forward, to the Project Manager, Contractor progress billing invoices.
- Obtain approval from the Project Manager prior to commencing any extra work activities. Obtain agreement for extra work compensation and complete extra work change order form prior to undertaking any extra work.

- Steward, document and actively participate in weekly Contractor safety meetings and safety audits.

- Plan, schedule and administer "tail gate" meetings prior to commencing safety sensitive work (tie-ins, excavations requiring shoring, line evacuation, hot cuts, etc.).

- Ensure sign-up sheets are completed daily.

- Report all (Company & Contractor) incidents to the Project Manager in accordance to the reporting procedures outlined within the Safety and Health Handbook.

- Perform material "take-off" and ascertain status of all materials. Communicate material issues to the Project Manager in a timely manner.

- Verify welder's qualifications are current and are correct for the work.

- Ensure conformance to Company and/or otherwise approved welding procedures.

- Ensure each welder is making sound welds at each joint in accordance to the Company specifications including utilization of the correct welding procedure.

- Ensure repairs made to correct defects are sufficient and in accordance the Company specifications.

- Ensure all welding material is stored in accordance to the Company and manufacturers' specifications.

- Review certifications of hydrostatic test and welder testing instruments and equipment. Consult the Project Manager and/or Metallurgical Services for technical guidance or interpretation of Company specification.

- Ensure all test equipment (dead weights and recorders) meets the minimum acceptance criteria identified in the Company specifications. Including inspection of contractor supplied hoses, valves, fittings, caps, and manifolds prior to testing.

- Ensure that the radiographer's certification is complete and correct, that acceptable radiographic procedures are established, that the technician(s) has a copy of the Company specifications and that the technician is familiar with Company procedures including documentation and form completion. Consult the Project Manager and/or Metallurgical Services for technical guidance or interpretation of Company specifications.

- Ensure radiographic procedure compliance (including developing and handling of film) and that the appropriate procedure is used and this procedure is producing acceptable radiographs. Consult the Project Manager and/or Metallurgical Services for technical guidance or interpretation of Company specifications.
- Coordinate the radiographic crew with project schedule to effectively manage cost and anticipate production weld problems.
- Ensure that all proposed design changes or material substitutions are discussed and approved by the Project Manager prior to proceeding with the work.
- Verify that the survey party chief(s) is familiar with pipeline construction, has a copy of the survey requirements, and has the proper materials and equipment to perform the work.
- Ensure the timely completion of all required documentation (including "Red-line" drawings) and forward to the Project Manager and others, in accordance with instructions in the Construction Inspector's Guidebook.
- Communicate "lessons learned" and foster an environment of continuous improvement. Participate in post-job review meeting.

Certified Welding Inspector (WIS, AWS)

The Certified Welding Inspector is the Company's authorized representative and is to inspect and ensure that proper welding and radiographic procedures are qualified and utilized, the radiographers used are certified, the welders are qualified, sound welds are produced, and proper documentation is maintained. These activities must be performed in accordance with the appropriate Company specifications approved by Metallurgical Services. The Certified Welding Inspector works under the direction of the Chief Inspector.

Certified Welding Inspector responsibilities shall include:

- Continuously inspect the Contractor's workmanship and ensure conformance to Company specifications.
- Ensure compliance with all project specific environmental requirements as outlined within the project Environmental Construction Plan and/or as directed by the project Environmental Inspector.
- Ensure compliance with all project specific right-of-way requirements as outlined within the Right-of Way Line List and/or as directed by the project Right-or-Way Agent.
- Ensure personal and Contractor compliance with the minimum safety standards as outlined within the Company's Safety and Health Handbook.
- Review and become familiar with the construction drawings and Company welding specifications.
- Ensure that all proposed design changes or material substitutions are discussed and approved by the Chief Inspector and that proper Company approval is obtained prior to proceeding with the work.
- Plan and organize inspection duties in advance with the Chief Inspector and assist them in coordinating the radiographic crew's activities with the Contractor's project schedule to effectively manage cost and anticipate production weld problems.
- Verify the qualification of all contract welders, by either witnessing their qualification test or verifying that the welder is currently qualified by the company and properly recorded in Metallurgical Services' records. All initial and/or retest contract welder qualification reports must be filed with and deemed current by Metallurgical Services, prior to allowing the welder to weld on any company project. Make sure that all contract welders weld only within their qualifications. (A contract welding inspector is not required to qualify or verify the qualification of company welders.)
- Monitor the quality of welds being made and the quality of the radiographic inspection to ensure that sound welds are being made.

- Verify that each welder is making sound welds and is following the Company and/or otherwise approved welding procedure and specification on the job site. Monitor all of the welding procedure requirements periodically during welding, such as preheating, proper voltage and amperage ranges, welding direction, travel speed, etc.

- Verify all weld repairs made to correct defects in welds does sufficiently correct the defect and the finished weld satisfies the requirements as outlined by the appropriate codes and Company specifications.

- Ensure that the radiographer's certification is complete and correct; acceptable radiographic procedures are established; and the technician(s) has a copy of the Company specifications and is familiar with Company procedures, documentation and form completion.

- Ensure that proper documentation is maintained by the radiographic crew, including the disposition of each reject.

- Ensure the appropriate radiographic procedure is used (including developing and handling of film) and such procedure is producing acceptable radiographs with the image of the essential hole or wire of the penetrameter being clearly visible on each film. Also verify that the correct size, type and kind of penetrameter used for the diameter and wall thickness of the pipe weld being radiographed. Consult the Project Manager and/or Metallurgical Services for technical guidance or interpretation of company radiographic specifications.

- Verify that all welding materials (welding rods, pipe w.t., transitions pieces, etc.) used in the installation are in compliance with Company requirements and specifications, stored in accordance to the Company and manufacturer's specifications; and damaged materials are not used for any weld.

- Keep the Chief Inspector aware immediately of any daily problems or anticipated problems with the welding phase of the construction project. Make immediate notification of any unsafe issue or a specification or applicable code violation. Only the Chief Inspector has stop work authority.

- Ensure that radiographic film, NDT reports, radiographer's qualification reports, nondestructive testing weld examination reports, list of qualified welders' reports, and welding coupon test reports are labeled properly and/or filled out correctly and given to the Chief Inspector for proper distribution and review.

Electrical Inspector

The Electrical Inspector is the Company's authorized representative and is to inspect all electrical, communication, and instrumentation installations on construction projects and ensure such installations are performed in accordance with Company drawings, plans, specifications and the terms of the construction contract or agreement.

The Electrical Inspector must have a thorough working knowledge of electrical, communication and instrumentation systems for natural gas pipeline or industrial facilities. This includes having a basic knowledge of data acquisition systems and knowledge of the current accepted edition of the National Electric Code (ANSI/NFPA 70).

The Electrical Inspector works under the direction of the Chief Inspector.

Electrical Inspector responsibilities shall include:

- Continuously inspect the Contractor's workmanship and ensure conformance to Company specifications.
- Ensure compliance with all project specific environmental requirements as outlined within the project Environmental Construction Plan and/or as directed by the project Environmental Inspector.
- Ensure compliance with all project specific right-of way requirements as outlined within the Right-of-Way Line List and/or as directed by the project Right-of-Way Agent.
- Ensure personal and Contractor compliance with the minimum safety standards as outlined within the Company's Safety and Health Handbook.
- Review and become familiar with the project scope of work, drawings, specific specifications, and the electrical and/or instrumentation section of the construction contract or agreement.
- Verify all materials used in the electrical and/or instrumentation installation are in compliance with Company requirements and specifications.
- Ensure any design changes or material substitutions are discussed with the Chief Inspector/Senior Inspector and that proper Company approval from the Project Manager is obtained prior to proceeding with the work.
- Keep the Chief Inspector aware of any daily problems or anticipated problems with the electrical and/or instrumentation phase of the construction project.
- Read and interpret piping, conduit, wiring, and instrumentation drawings pertaining to the electrical and/or instrumentation phase of the construction project.

- Evaluate and ensure that the control logic in project electrical drawings will adequately interface with existing systems.
- Become familiar with the interpretation of hazardous class area locations as defined by the N.E.C. and Company specifications and ensure approved wiring methods and enclosures for these areas are installed properly.
- Perform and/or supervise the loop checks of electrical construction and document information.
- Ensure flame and gas detection systems and their operation are in accordance with Company specifications for the environment to be controlled.
- Ensure all A/C power systems including single phase and three phase systems and proper wiring methods are installed in accordance with Company specifications.
- Ensure the interfacing of pneumatic and electrical control systems (i.e., actuators, pressure, and I to P transmitters) are installed in accordance with Company specifications.
- Perform Material "take-off" and ascertain status of all electrical materials or components. Communicate material issues to the Chief Inspector in a timely manner.
- To ensure proper completion of company reports, documentation and as-built "Red-lined" drawings, provide the Chief Inspector or his designee, with all necessary information, including as-built changes in the Material "take-offs" and drawings prior to leaving the job site.

Utility Inspector

The Utility Inspector is the Company's authorized representative and is to observe the Contractor's progress and inspect all activities in his/her assigned areas in accordance with Company drawings, plans, specifications and the terms of the construction contract or agreement. The Utility Inspector works under the direction of the Chief Inspector and will also be asked to assist other certified craft inspectors, as directed. The following areas of responsibility are normally assigned to Utility Inspectors:

- Fencing
- Rights-of-Way Clearing and Grading
- Stringing and Joint Tally of Pipe Received
- Ditching and Bending
- Coating, and Holiday Detection by Jeeping
- Road and Railroad Boring
- Directional Drilling Assistance (inspector relief)
- Lowering In (recording final joint tally, incl. w.t., grade, type coating & pipe mill)
- Tie-ins (pipe surveillance - incl. magnetic particle testing, plus coating application and repairs)
- Padding and Backfilling
- Concrete Foundations (forms, rebar, anchor bolt placement, test on concrete)
- Building Erection plus Above Ground Pipe Support Construction
- Tubing and Screwed Pipe Connections
- Cathodic Protection (installation assistance)
- Property Damage, Private or Public (assist in repair)
- Vendor Equipment (installation assistance)
- Clean Up and Painting
- Other Inspection Areas (as assigned)

Utility Inspector responsibilities shall include:

- Continuously inspect the Contractor's workmanship and ensure conformance to Company specifications.

- Ensure compliance with all project specific environmental requirements as outlined within the project Environmental Construction Plan and/or as directed by the project Environmental Inspector.

- Ensure compliance with all project specific right-of-way requirements as outlined within the Right-of-Way Line List and/or as directed by the project Right-of-Way Agent.
- Ensure personal and Contractor compliance with the minimum safety standards as outlined within the Company's Safety and Health Handbook.

- Review and become familiar with the drawings, specifications, and the construction contract or contractor agreement plus rights-of-way requirements.

- Inspect the work performed by the Contractor on assigned areas of responsibility to ensure Company standards and specifications are completed satisfactorily.
- Ensure that any design changes or material substitutions are discussed with the Chief Inspector or his designee (if Chief Inspector is absent) and that proper Company approval is obtained.
- Keep the Chief Inspector and aware of any daily problems and/or anticipated problems. Make immediate notification of any unsafe issue or a specification or applicable code violation.
- May assist with inspection, under the direction of other certified craft inspectors assigned to the project.
- May assist with hydrostatic test setup and/or perform such tests in the field.
- To ensure proper completion of company reports, documentation and as-built "Red-lined" drawings, provide the Chief Inspector or his designee, with all necessary information, including as-built changes, joint tally information (w.t., grade, type coating and pipe mill designation), pipe surveillance data, and cathodic protection facility locations prior to leaving the job site.

Environmental Inspector

The Environmental Inspector is the Company's authorized representative and is to inspect and ensure that all field project construction is being conducted in compliance with the applicable environmental plans/procedures and the requirements of federal, regional, state, and local environmental permits or approvals, as prepared and approved by the Company Environmental Department. In particular, these construction projects may involve activities which are regulated by the Federal Energy Regulatory Commission (FERC) under 18CFR157.206(b). Prior to construction, project-specific environmental materials will be provided to the environmental inspector, which include detailed plans, procedures and environmental conditions to be complied with before, during, and after construction. Environmental Inspector training (tailored for a specific project) may be conducted just prior to the commencement of construction, dependent upon the environmental issues associated with said project. At least one qualified Environmental Inspector, either with sole or with cross-functional duties, will be assigned to each construction project. The Environmental Inspector works under the direction of the Chief Inspector but has dual reporting responsibilities to both the Chief Inspector and the Company Environmental Department. During construction, the other inspectors are also responsible for monitoring environmental issues and reporting any concerns, problems or irregularities to the assigned Environmental Inspector for proper handling.

With full assistance, cooperation and support from the Chief Inspector, the Environmental Inspector responsibilities shall include:

- Continuously inspect the Contractor's workmanship in regard to environmental issues and ensure conformance to Company specifications.
- Ensure compliance with all project specific environmental requirements and/or as directed by the assigned representative of the Company Environmental Department.
- Ensure compliance with all project specific right-of-way requirements as outlined within the Right-of-Way Line List and/or as directed by the project Right-of-Way Agent.
- Ensure personal and Contractor compliance with the minimum safety standards as outlined within the Company's Safety and Health Handbook.
- Coordinate and/or perform updated environmental training as new construction Contractor employees and/or Company assigned inspectors begins working on the construction site.
- Photograph and document specific areas and workspaces before, during and after construction.
- Identify areas that require stabilization.
- Ensure erosion and sedimentation control devices (hay bales, silt fence, etc.) are installed and maintained properly.

- Monitor temporary restoration and re-vegetation of upland areas, water bodies and wetlands.
- Ensure construction activities occur within authorized work areas.
- Ensure streets near the authorized work areas are sufficiently cleaned at the end of each workday.
- Monitor waste collection and disposal.
- Inspect activities daily to verify and document that the Construction Contractors are complying with requirements of environmental plans, procedures, permits or clearances, and (if applicable) the FERC Certificate environmental conditions and mitigation measures.
- Corrects and reports environmental compliance problems. The Environmental Inspector has "Stop Task" authority and makes "Stop Work" recommendations to the Chief Inspector or Senior Inspector, who have overall project "Stop Work" authority for a project spread or crew.
- Document environmental activities with daily logs, weekly reports, and other required documentation.
- Identify potential environmental compliance problems and initiate appropriate action prior to occurrence.
- Monitor and make recommendations to the contractor when returning the soil profile to pre-construction conditions. Photograph such areas before and after construction.
- Educate other inspectors on project specific environmental concerns and invite them to bring their environmental concerns to his/her attention as they occur.
- Maintain the environmental plans and documents during construction (e.g., updating project alignment drawings to illustrate the locations of additional temporary and permanent erosion controls).
- Ensure the repair of ineffective erosion control measures within 24 hours of identification.
- Ensure appropriate marking of identified surface and subsurface drainage and irrigation system locations.
- Ensure double ditching procedures are adequate in agricultural and residential areas and when necessary, perform or oversee the compaction tests of subsoil and topsoil.
- Verify imported soils used as fill and/or additional cover in sensitive areas (i.e., agricultural, residential and wetland areas) are from an approved source to meet permit conditions and/or meets the landowner's requirements.

- Provide notification of construction activities to agencies as required in permits.

- Monitor hydrostatic test fill and spill activities and conduct sampling of the test water, as necessary.

- Make recommendations to the contractor for the proper placement of dewatering structures and slope breakers to ensure they will not cause soil erosion or direct water into known cultural resources sites or locations of sensitive species.

- Work with water and wetland resource agencies to assure the applicable environmental plans, procedures and permit requirements are properly implemented.

- Monitor trench-dewatering activities and make recommendations to the contractor to help avoid the deposition of sand, silt, and/or sediment near the point of discharge into a wetland or waterbody. If such deposition is occurring, the dewatering activity shall be stopped and the design of the discharge shall be changed to prevent a repeat occurrence. Advise the Chief Inspector when conditions (such as wet weather) make it advisable to restrict construction activities.

- Review the Contractor's pre-job inventory and location of lubricants, fuel, and other materials that could be discharged on to the workspace area grounds. Prior to commencing construction, consult with the construction project's assigned Company Environmental Coordinator to determine reportable spill quantities for materials on the inventory. Ensure MSDS information is available for all materials, including the natural gas and/or products in existing adjacent piping or pipelines.

- Classify each material on the previous pre-job inventory as hazardous or non-hazardous. Contact the assigned Company Compliance Specialist to obtain the approved waste transporters and disposal sites for both hazardous and non-hazardous material waste and advise the Chief Inspector accordingly.

- Ensure all Contractor's equipment is supplied with adequate absorbent diapers to prevent unavoidable small leaks or emergency line break leaks (such as, engine oil, hydraulic oil, lubricants, antifreeze, etc.) from contaminating the ground. Any excessive leaks needing repair should be reported to the Chief Inspector for immediate Contractor attention.

- Ensure the Construction Contractor has an action plan that will be implemented, should a spill occur, including emergency notification procedures. Review the Spill Prevention and Control Plan to ensure all items listed are adequately covered by the Construction Contractor and/or others prior to commencing construction.

- If not covered herein, the Environmental Inspector shall ensure that all of the listed responsibilities for Lead Environmental Inspector (LEI) under the preceding tab are also satisfactorily completed.

NOTE: THE INFORMATION IN THIS DOCUMENT IS AN EXCERPT FROM SECTION 300 OF THE EL PASO CORROSION CONTROL MANUAL.

ANNUAL SURVEYS

Table of Contents

Introduction

The Natural Gas Pipeline Safety Act resulted in the establishment of Federal minimum standards for corrosion control. Cathodic protection (CP) must be applied to pipelines and be tested each calendar year (at intervals not to exceed 15 months) to determine if CP is adequate per Title 49-CFR-Part 192-Section 465-External Corrosion Control: Monitoring.

These procedures define Company requirements to meet these and other regulations, as well as best practice and sound engineering judgment.

Complete documentation and proper record keeping is an integral part of Company operating procedures and compliance with regulations.

Survey Requirements

Annual pipe-to-electrolyte pipe-to-soil potential surveys will be conducted over all pipeline, compressor station, meter station, platform and other applicable facilities in compliance with O&M procedures using Company approved instrumentation.

Annual surveys should be completed within **thirty (30) days** of their start date in order to survey under as consistent as possible weather and soil conditions.

Data entry and all applicable paperwork are to be completed and transmitted to Corrosion Control Services within **thirty (30) days** after completion date in order to provide timely analysis and remediation scheduling. Any deficiencies requiring remedial action found in conducting the survey must be reported in a timely manner as per the Company O&M procedures.

If applicable, to completely evaluate CP effectiveness, onshore Annual Surveys may be *rotated*, or surveyed during different times of the year. This will enable CP data to be evaluated as to seasonal variations.

If the applicable survey grouping is started later than 12 months from the previous completion date or the survey grouping is to be "rotated", O&M Procedures **must** be considered to ensure the Annual Survey does not exceed the 15 month time frame between surveys for **each individual reading**.

Survey Grouping

A single pipe-to-soil reading at a test point only validates a single point (normally 3 feet or less) on the pipeline system. Test points are normally put into a logical grouping to facilitate CP evaluations, allow trend analysis over a large area, and aid in the filing and documentation of the survey as required by Federal Regulations.

The Tennessee Gas Pipeline system and the corrosion database program (Paradigm) are divided into "charts." They can be from one to several valve sections depending on the needs of the area.

El Paso Natural Gas and El Paso Field Services pipeline systems and the corrosion database program (Paradigm) are divided into segments.

The area covered by a test point grouping (chart or segment) may not be altered without the approval of Corrosion Control Services.

Current Sources

Before conducting a survey, CP current sources that have an influence on the surveyed pipe section must be checked for proper operation.

Read and record voltage and current output for all impressed current sources. Read and record current output of bond stations, and sacrificial anodes where practical.

All existing annual survey test points and data must be maintained for the life of the system unless prior approval is obtained from Corrosion Control Services to deactivate the test point.

Test Point

This is the point over the centerline of the pipe where the reference electrode (half-cell) must be placed to take the potential reading. A pipeline locator may be required to locate the center of the pipe. The reference electrode must be placed over the centerline of the buried piping.

Since the test point may vary from the "pipe contact" location, the test point location designated by milepost/station number/GPS coordinates is the recorded data location.

P/S potentials taken over blacktop, concrete, frozen ground, or other extremely high resistance surfaces are considered invalid due to the high IR drop that may be present and the possibility the reading indicated may be remote to the relative position of the half-cell. Half-cell contact must be made with the representative environment that surrounds the pipeline.

It may be necessary to wet the point of contact (with potable water) in areas of dry or high resistivity soils to lower the contact resistance of the half-cell to an acceptable level. In areas paved with asphalt or frozen, the high resistance cover should be removed. Where possible, a permanent access point should be installed.

Because there is an abundance of gravel at stations, it may be necessary to use a shovel and dig down to soil at some test points in order to get an accurate measurement.

Reference Electrode Check

Before conducting the survey, check the reference electrode per procedure *CORR-005: Maintaining Reference Electrodes.*

Survey Cycle

When an interrupted survey is performed, corresponding 'on/off' potentials must be logged at each half-cell position to allow for IR determinations.

The normal survey interruption cycle of the current sources is 800 ms 'on' and 200 ms 'off' for a total duty cycle of 1 second. In some cases, an interruption cycle of 500 ms on and 100 ms off for a total duty cycle of 600 ms may be used. Other survey cycles may be used with approval of Corrosion Control Services.

Meters used to record survey data must be approved for use with these cycles by Corrosion Control Services.

Survey Meters

All annual surveys (where practical) will be recorded electronically using a company-approved meter. The calibration of the meter must be checked before the beginning of any annual survey with a power source of a known voltage. Use

of special meters requires Corrosion Control Services approval prior to use for annual survey readings.

Minimum Pipeline Survey Data Requirements

DC voltage and amperage outputs at all impressed current sources.

A structure-to-environment potential at each designated test point as defined by the computerized survey. These potentials normally consist of an "ON" potential and if applicable may include an "instant off", polarized, or native potential.

Any test point found below criteria must have a survey performed (2.5-10 foot

Test points for new facilities are to be added to the survey.

Normally during the annual surveys, an atmospheric survey will be performed on all exposed pipe and all aboveground facilities, within the specified times frames.

Missed Readings

Any test lead that is broken and cannot be read shall be listed as a deficiency and corrected promptly, usually within one year of discovery.

Any test point that is inaccessible and cannot be read for whatever reason at the time of the survey shall be listed as a deficiency. If it is possible that the condition preventing access has changed, make follow-up attempts monthly (or periodically) and document in Paradigm the attempts and reasons for not making the reading prior to the 15th month (or end of year), if the reading cannot be made. If the access problem is due to permissions, gates, locks, permits, etc., make the proper notifications and document your actions in Paradigm. Do not wait until the 12th month or later to perform the survey if there is a known potential access problem. Surveys should be scheduled to avoid typical seasonal problems like flooding, snow, etc. or other anticipatable obstacles.

All existing annual survey test points and data must be maintained for the life of the system unless prior approval is obtained from Corrosion Control Services to deactivate the test point.

Process for deactivating test points:

1. Review close-interval surveys, annual survey data or other historical records to ensure that sufficient test leads remain to evaluate the effectiveness of the cathodic protection system.

2. Obtain approval from Corrosion Control Services to deactivate the test point.

3. Enter an Inactive Date and Inactive Reason in the Paradigm database. Ensure that this point is automatically removed from survey routes.

4. If the test point is no longer readable, follow appropriate company processes to remove the test point from the alignment sheets, drawings, GIS and any other database, with approval of Corrosion Control Services.

If readings cannot be made practically, Corrosion Control Services may deactivate the test point temporarily according to the process listed above.

Analyzing the Survey

All P/S potentials will be evaluated with regard to criteria and limits.

All survey test points not read on the survey will be listed as deficiencies.

A trend analysis will be performed on all data for a minimum of three (3) years to evaluate any change in the level of protection. Any substantial change in the trend will be evaluated as to cause and its projected effect.

Any reading showing a substantial change will be investigated to determine its cause and evaluated to determine its projected effect.

Rectifier(s) and/or any other cathodic protection current sources will be evaluated for required output.

AC potentials will be evaluated to determine magnitude and cause. AC potentials above 15 VAC are a potential safety concern, will be listed as deficiencies, and will have prompt remediation, if necessary.

Stress Corrosion Cracking (SCC)

Two forms of SCC are found on pipelines, high pH (also known as classical) SCC and near-neutral pH (or low pH) SCC. Many factors interact in a complex manner to produce SCC, including metallurgy, residual stresses, cyclical stresses, temperature, and chemical composition of the electrolyte to name a few. The environmental risk factors of high pH SCC include:

- High pH SCC is typically found within 20 miles downstream of a compressor station.
- High pH SCC occurs in a relatively narrow cathodic potential range of -600 to -750 mV $Cu/CuSO_4$ IR free
- Temperatures greater than 100°F are necessary for high pH SCC susceptibility under normal conditions.
- Operating stress greater than 60% SMYS.
- Cracks are commonly associated with coal tar and asphalt coatings.

For segments that fall under these risk factors, or with a known history of high pH SCC, IR free potentials in the range of -600 to -750 mV versus Cu-CuSO4 should be avoided.

Near-neutral pH SCC primarily occurs due to disbonded coatings that shield the cathodic protection current from reaching the structure. There is a corrosion condition below the disbonded coating that results in an environment with a pH of between 6 and 8. This type of SCC is commonly associated with tape coatings. Because of the electrical shielding, this form of SCC is not associated with a particular range of potentials.

Documenting the Survey

When the Annual Survey of a pipeline, chart, and/or segment has been completed, and the data entered into the appropriate database and analyzed, that survey should be promptly submitted to Corrosion Control Services with a completed ANNUAL PIPELINE CORROSION SURVEY summary letter and appropriate attachments. Any deficiencies must be reported and documented per company O&M procedures.

A copy of the survey should be put into the DOT files.

Any close-interval survey, done with the Annual Survey, shall be included on the resurvey form and a printout of the close-interval survey and readings is to be submitted with the Annual Survey.

Maintaining the Paradigm Annual Survey Database

Database

All pipeline facilities should be set up in *Paradigm*. Facilities should be located in the proper hierarchy. Each reading location should be entered under the proper segment and tab. Reading locations include test stations, rectifiers, bonds and critical bonds, groundbeds, towers, offshore pipelines, and piles.

All test points should use the actual milepost/station number for half-cell placement. Mile post/station numbers can be corrected. During the Annual Survey when a feature such as a test point or rectifier is found to be incorrectly designated, change it to the correct value. If the milepost/station number change is at a rectifier, correct it on the appropriate monitoring form and notify Corrosion Control Services. Remember, mileposts are calculated from station numbers, not the other way around! Anytime a milepost or station number is changed, a reason must be entered in to the *Description* field of the database for the test point.

The required readings for each reading location should be made active.

The appropriate criteria should be established for each p/s reading. This is normally 850 mV ON, IR considered.

The appropriate limits should be established for each reading. These are listed in Exhibit 1 at the end of this section.

Corrections, deletions, or additions can be made to the *Description* section. The *Description* section is intended to give information to the person making the survey, not to the person(s) reading the resulting printout. The standard corrosion abbreviations found in Exhibit 2 should be used in this section.

For many test points, special instructions are necessary for the person conducting the survey to know how to find the test points. Include these special instructions in the appropriate Paradigm database field. The *Description* field is currently displayed on all reports and on the DVM.

For TGP, the *AnSurvey Route* field is used to give directions, instructions, irregularity information, etc. to the person conducting the survey. This information is not currently displayed on Paradigm reports and on the DVM, but will be included in the next upgrade.

The *Comment* field is useful to denote events or conditions for that year's Annual Survey. This section should not supplement the Route File. Comments should be associated with a particular reading or year's survey. General comments should be put in the *Description* field.

Atmospheric locations, and compressor stations must be entered and maintained using Paradigm for EPNG. TGP atmospheric and station surveys may be entered into the Paradigm database or recorded on the appropriate company form.

Data from retired or abandoned facilities MUST NOT be deleted. Approved methods for making data inactive or archiving data must be used. There are numerous circumstances that may require deleting an individual data set from a database. The data containing the information is not to be deleted but must be converted to an inactive test point. This will maintain the test point's history and assist in documentation. A large group of points can be moved to another section of the hierarchy and made inactive. The data for a reference point or group of points cannot be deleted from the database or deactivated from the database without Corrosion Control Services approval. Test points can then be deactivated with approval from Corrosion Control Services.

For individual databases, the technician will maintain all the facilities for which he is responsible. Duplication of facilities in multiple databases shall not occur. If the responsibilities for a facility are shared, and more than one technician will enter data, the database should be shared on a network.

For individual databases, the technician is responsible for backing up the

Exhibit 1: Limits for Testpoints

DESCRIPTION	UPPER	LOWER	REMARKS

DESCRIPTION	UPPER	LOWER	REMARKS
On P/S	2500	850	
Off P/S – Interrupted	1260	850	
Polarized *P/S* Potential	1260	850	
Rectifier DC volts			Upper = Unit Maximum Rated Output
Rectifier DC amps			Upper = Unit Maximum Rated Output, Lower = Minimum Required Current Output
AC *P/S* Volts	15		

Note: Limits can only be changed with Corrosion Control Services Approval

Exhibit 2: Typical Corrosion Abbreviations

PREFIXES	DEFINITION
PS or P/S	Pipe-to-Soil
SL	Same Point Local
UL	Up Station Local
DL	Down Station Local
US-XXX	Up Station-XXX Ft.
DS-XXX	Down Station-XXX Ft.
SUFFIXES (Used with Rectifiers or Galvanic Ground Beds)	
V	Volts
A	Amperes
MA	Milliamperes
SUFFIXES (Used with Bond Currents)	
MA	Milliamperes
AMP	Amperes
POS	Positive Polarity
NEG	Negative Polarity

Annual Compressor Station Survey

The annual Compressor Station survey may be conducted using one of two survey procedures at the discretion of Corrosion Control Services. Procedure #1 is conceptually a P/S potential survey taken at 3-foot intervals over all the underground piping with all current sources ON. Procedure #2 are P/S potential surveys taken with readings only at designated test point locations with all current sources ON.

Procedure 1 (Close-Interval Survey)

Current Sources

Before conducting an ON survey, all CP current sources that have an influence on the surveyed piping section must be checked for proper operation.

Read and record voltage and current output for all impressed current sources.

All existing annual survey test points and data must be maintained for the life of the system unless prior approval is obtained from Corrosion Control Services to deactivate the test point.

Always connect to the individual structure being surveyed. If surveying multiple lines in a common trench, multiple survey runs may be necessary to achieve a valid survey, due to metallic IR drop, shielding effects, coating effectiveness and the station grounding system.

Test Point

This is the point over the centerline of the piping where the reference electrode must be placed to take the potential reading. A pipeline locator may be required to locate the center of the pipeline.

Since the test point may vary from the pipeline contact location, the test point location designated by milepost/station number is the recorded data location.

P/S potentials taken over blacktop, concrete, frozen ground, or other extremely high resistance surfaces are considered invalid due to the high IR drop that may be present and the possibility the reading indicated may be remote to the relative position of the half-cell. Half-cell contact must be made with the representative environment that surrounds the pipeline.

It may be necessary to water the point of contact with the half-cell in areas of dry or high resistivity soils to lower the contact resistance of the half-cell to an acceptable level.

The reference electrode must be placed over the centerline of the buried piping.

Because there is an abundance of gravel at stations, it may be necessary to use a shovel and dig down to soil at some test points in order to get an accurate measurement.

Pullout (Shunted) Readings

A *pullout* (also known as a *shunted* reading) is a reading or group of readings taken remote from the contact point, over the pipe.

The most common survey pullout method involves the person carrying the survey instrument, disposable wire and electrode(s).

Another method keeps the person, survey instrument, and rewind spool of reusable wire at the "pipe contact" while the electrode(s) is pulled out along the piping by an assistant.

Each pullout should be in the preferred survey direction, given a unique run number and indicated on the CP survey print.

A local reading must be designated for every pipe contact.

Survey Interval

The maximum interval along the piping at which P/S potentials may be made is **three (3) feet**. The distance may be shorter and non-uniform, but must not exceed three feet in distance.

Reference Electrode Check

Check reference electrode per procedure *CORR-005: Maintaining Reference Electrodes*.

Survey Cycle

When an interrupted survey is performed, corresponding 'on/off' potentials must be logged at each half-cell position to allow for IR determinations.

The normal survey interruption cycle of the current sources is 800 ms 'on' and 200 ms 'off' for a total duty cycle of 1 second. In some cases, an interruption cycle of 500 ms on and 100 ms off for a total duty cycle of 600 ms may be used. Other survey cycles may be used with approval of Corrosion Control Services.

The meter recording the data must be capable of reading these cycles.

Survey Meters

All Annual Surveys (where practical) will be recorded electronically using a company-approved meter. The calibration of the meter must be checked before the beginning of any Annual Survey with a power source of a known voltage. Use of special meters requires Corrosion Control Services approval prior to use for annual survey readings.

Survey Types

Normal annual surveys are performed in ON mode. With Corrosion Control Services approval, 'IR-free' or 'polarized potential' survey methods may be performed.

In some instances, a Native (depolarized) potential survey may be required to establish a base line for use in determining if 100 mV of polarization is present on the structure.

In rare occasions, a Side Drain survey may be conducted in areas of bare piping or severe coating defects.

If the area of the pipe is covered by the road surface is of sufficient length, the area must be evaluated to determine if test holes or flush test stations are required to fully evaluate the section.

Distance Flagging

A distance flag should be entered into the data stream every 100 feet as the survey proceeds. The most common method is to pre-mark the pipeline at 100-foot intervals by using either a survey chain or by pacing off the length.

Minimum Survey Data Requirements

As a minimum, the following information is required for the survey:

- Minimum of 30 P/S potentials per 100 foot flags.
- ON near and far ground readings at pipe contact.
- **P/S** potential readings are required at all pipe contacts.
- Polarized surveys require both ON and polarized potentials.

- NATIVE surveys require a native potential only.
- Influencing rectifier current and voltage outputs.
- A description entered for all features or reference points.
- ON potentials over all crossover lines connected to the line being surveyed, from the line being surveyed to the next mainline.
- ON potentials are to be taken at the building walls where the piping enters the wall underground and at all piping risers.
- ON potentials are to be taken on all buried tanks.

Procedure 2 (Testpoint)

Current Sources

Before conducting an ON Survey, all CP current sources that have an influence on the surveyed piping section must be checked for proper operation. Ensure all distributed anodes are operating as needed. Anodes can be read directly or with a potential profile to ensure normal operation.

Read and record voltage and current output for all impressed current sources.

All existing annual survey test points and data must be maintained for the life of the system unless prior approval is obtained from Corrosion Control Services to deactivate the test point.

Always connect to the individual structure being read.

Test Point

The test point location is designated by map number, station coordinates, or read order number in conjunction with an annual survey station map.

P/S potentials taken over blacktop, concrete, frozen ground, or other extremely high resistance surfaces are considered invalid due to the high IR drop that may be present and the possibility the reading indicated may be remote to the relative position of the half-cell. Half-cell contact must be made with the representative environment that surrounds the pipeline. In areas paved with asphalt or frozen, the high resistance cover should be removed. Where possible, a permanent access point should be installed.

It may be necessary to water the point of contact with the half-cell in areas of dry or high resistivity soils to lower the contact resistance of the half-cell to an acceptable level.

The reference electrode must be placed over the centerline of the buried piping, and within 6 inches of the riser.

Reference Electrode Check

Check reference electrode per procedure *CORR-005: Maintaining Reference Electrodes.*

Survey Cycle

If an interrupted survey is performed, corresponding 'on/off' potentials must be logged at each testpoint to allow for IR determinations.

The normal survey interruption cycle of the current sources is 800 ms 'on' and 200 ms 'off' for a total duty cycle of 1 second. In some cases, an interruption cycle of 500 ms on and 100 ms off for a total duty cycle of 600 ms may be used. Other survey cycles may be used with approval of Corrosion Control Services.

The meter recording the data must be capable of reading these cycles.

Survey Meters

All Annual Surveys (where practical) will be recorded electronically using a company-approved meter. The calibration of the meter must be checked before the beginning of any Annual Survey with a power source of a known voltage. Use of special meters requires Corrosion Control Services approval.

Minimum Survey Data Requirements

As a minimum, the following information is required for the survey:

- **P/S** ON potential readings are required at all testpoints.
- Influencing rectifier current and voltage outputs.
- ON potentials are to be taken on all buried tanks.
- Add test stations for new facilities to survey (as necessary). The test lead must be read on the next Annual Survey.

Analyzing the Survey

Procedure 1 (Close-Interval Survey)

Download survey information from the survey instrument to the PC. Then analyze the data for any area(s) in need of remedial correction or future monitoring.

Edit the data to correct information that was omitted or improperly entered during the survey. Examples are incorrect or omitted station numbers, missing reference points, etc.

If an interrupted survey was conducted, print out all wave prints for analysis. Determine if there were any transients on the piping and if they affected the potentials being collected. Ensure that all interrupters were synchronized and operating properly.

Graph the survey data for analysis.

Evaluate the near and far ground readings for differences in potential. Differences can be caused by the location the readings were taken, pipe OD and wall thickness, pipe weight, distance between pipeline connection points, and amount of current flowing in the pipe. Large potential differences should be evaluated to identify isolation problems, unknown current sources, etc.

AC potential readings will be evaluated as to magnitude, cause, and effect.

Side drains or lateral potentials will be evaluated as to direction of current flow. Current flow should be toward the pipeline. There should be no current flow towards the pipe during the off cycle when conducting interrupted survey.

Rectifier and other impressed current source settings will be evaluated and new minimum current requirements will be set as required for each unit.

All unexplained indications of current pickup or discharge will be evaluated as to cause.

All P/S potential readings will be evaluated for profile irregularities, which may or may not be below criteria. These will be tabulated as part of the survey and monitoring assigned to them.

If a 100 mV polarization survey has been performed, the difference between the polarized (instant off) potential and the depolarized (native) potential must be at least equal to 100 mV.

On areas of the pipeline where SCC has been detected, polarized potentials in the range of -600 to -750 mV should be avoided. Potentials in this range along with certain conditions can contribute to stress corrosion cracking. See the section on SCC in Analyzing the Survey under Annual Pipeline Survey.

Analyze all skip areas.

List all skips where the potentials cannot be observed, The areas (description, beginning station, ending station, reason skipped) are to be listed on the summary letter attached to the appropriate company form.

- If the potential profile does not meet any of these criteria, then the area is to be entered on the deficiency list and efforts must be made to drill through the pavement to take P/S potentials to verify the level of CP.

P/S Potential Limits - High tensile strength steels (Grade X-60 and higher) may require an upper P/S potential in order to prevent hydrogen embrittlement and hydrogen blistering of coatings. An ON potential more negative than 2500 mV should raise a flag as an area for further investigation. The **true polarized potential** at which hydrogen is generated may be **extremely difficult** to determine in the field. Therefore, ON potentials over 2500 mV will be justified by the field corrosion control personnel in conjunction with Corrosion Control Services. The company limit is a polarized potential of 1260 mV at the drain point. Polarized potentials exceeding 1260 mV should be reported as deficiencies. If the close-interval survey disclosed remote area(s) where the potential is running close to this limit, then an Allowable Maximum (AM) can be setup to monitor such areas in the future.

Anode potentials are to be evaluated to determine their working potentials. The amount of normal background potential in the station yard is to be considered.

Procedure 2 (Testpoint Survey)

Analyze the data for any area(s) in need of remedial correction or future monitoring.

Edit the data to correct information that was omitted or improperly entered during the survey. Examples are incorrect or omitted station numbers, missing reference points, etc.

AC potential readings will be evaluated as to magnitude and cause.

All unexplained indications of current pickup or discharge will be evaluated as to cause.

All P/S potential readings will be evaluated for profile irregularities, which may or may not be below criteria.

On areas of the pipeline where SCC has been detected, polarized potentials in the range of -600 to -750 mV should be avoided. Potentials in this range along with certain conditions can contribute to stress corrosion cracking. See the section on SCC in Analyzing the Survey under Annual Pipeline Survey.

P/S Potential Limits - High tensile strength steels (Grade X-60 and higher) may require an upper P/S potential limit in order to prevent hydrogen embrittlement. Thin film coatings such as fusion bond epoxy (FBE) are susceptible to hydrogen blistering. An ON potential more negative than 2500 mV should raise a flag as an area for further investigation. The true polarized potential at which hydrogen is generated may be extremely difficult to determine in the field. Therefore, ON potentials more negative than 2500 mV will be justified by the field corrosion control personnel in conjunction with Corrosion Control Services. Polarized potentials exceeding limits should be reported as deficiencies.

Initiate the appropriate remedial action form for all deficiencies noted during the survey that cannot be corrected by routine adjustments to the rectifier(s) or immediate repairs.

Complete documentation and computer data entry of:

- Rectifier readings and annual inspections,
- Remedial actions taken,
- Potentials before and after remedial actions,
- Discrepancies that could not be corrected, and
- Update drawings with any changes.

Place a copy of the survey in the DOT file and send a copy to Corrosion Control Services.

Submitting the Survey

Complete the appropriate documentation for all surveys, either by entering the data into the database and/or completing required hard copies.

NOTE: THE INFORMATION IN THIS DOCUMENT IS AN EXCERPT FROM SECTION 300 OF THE EL PASO CORROSION CONTROL MANUAL.

6.6 Warranty

6.6.1 Solar warrants the Products to be free from defects in workmanship and materials rendered or used by Solar in the performance of the Order. Solar warrants that the Field Services provided by Solar under the Order will be performed in a workmanlike manner. These warranties are subject to the Terms of Warranty and shall apply only to claims made during the applicable warranty period as determined in accordance with the Period of Warranty.

6.6.2 The applicable warranty periods are as follows, for:

(i) New and Refurbished Equipment: The warranty period shall be the first to expire of that period (a) which begins upon such equipment first being placed in service or upon demonstrated capability to support such service and ends twelve (12) months thereafter, or (b) which begins on Solar's notification to El Paso Energy of the readiness of the New or Refurbished Equipment for delivery Ex Works Solar's facility and ends eighteen (18) months thereafter.

(ii) Engineered Products: The warranty period shall be for twelve (12) months from the date of shipment from Solar's facility.

(iii) Parts: The warranty period is twelve (12) months from date of shipment from Solar's facility.

(iv) Repair: Parts replaced and works performed are warranted for a warranty period of twelve (12) months from the date of shipment from Solar's facility.

(v) Overhaul and/or Exchange: The warranty period is twelve (12) months from the date of shipment from Solar's facility.

(vi) Field Services: The warranty period is ninety days (90) and such warranty period will commence on the earlier of the resumed operation of the unit or ninety days (90) from the service date.

6.6.3 For Products, Solar's obligation under this warranty is expressly limited to repair or replacement, as Solar elects, of any warranted and defective portion of the Products free of charge (excluding freight and labor costs to remove and replace) at Solar's repair center, provided:

(i) All Products are installed and used in accordance with Solar's recommended practices;

(ii) Any failed Products are returned to Solar's repair center in accordance with Solar's standard claim instructions, transportation charges prepaid;

(iii) Solar's examination of any failed Products confirms the existence of a warranted defect; and

(iv) Any claim under this warranty is made within thirty (30) days of discovery of the defect and, in any event, before the expiration of the applicable warranty period. This warranty shall not apply to: (a) normal maintenance, service, adjustments; or consumables (b) the removal or reinstallation of any warranted Products: (c) any

Products or parts of Products which have been repaired or altered unless such repair or alteration is done by Solar; or, (d) any damage caused by the effects of corrosion, erosion, or wear and tear or failure occasioned by operation or any condition of service that more severe than specified by Solar.

6.6.4 All claims for defective Field Services under this warranty must be made in writing immediately upon discovery but in any event within thirty (30) days from the furnishing thereof. Upon submission and substantiation of a claim, Solar shall, at its option, either: (a) correct the defective services; or (b) refund an equitable portion of the price of the Field Service.

6.6.5 Training and Documentation are provided without warranty or recourse and on an "as is" basis.

6.6.6 **EXCEPTING ONLY WARRANTY OF TITLE, THE FOREGOING IS EXPRESSLY IN LIEU OF ALL OTHER WARRANTIES, REPRESENTATIONS AND LIABILITIES WHATSOEVER, EXPRESSED, IMPLIED AND STATUTORY, INCLUDING WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.**

APPENDIX C

Equipment Specifications and Vendor Data

Emissions Data from Solar Turbines for Centaur 50-6200LS

Solar Turbines
A Caterpillar Company

PREDICTED EMISSION PERFORMANCE

Customer	
Job ID	
Inquiry Number	
Run By: Brian K Maul	Date Run: 13-Nov-07

Engine Model: CENTAUR 50-6200LS CS/MD 59F MATCH	
Fuel Type: SD NATURAL GAS	Water Injection: NO
Engine Emissions Data: REV. 0.1	

1 — 6703 Hp, 100.0% Load | Elev. 200 ft | Rel. Humidity 60.0% | Temperature 0 Deg. F

	NOx EMISSIONS	CO EMISSIONS	UHC EMISSIONS
PPMvd at 15% O2	25.00	50.00	25.00
ton/yr	23.95	29.16	8.35
lbm/MMBtu (Fuel LHV)	0.100	0.122	0.035
lbm/(MW-hr) (gas turbine shaft pwr)	1.09	1.33	0.38
lbm/hr	5.47	6.66	1.91

2 — 6346 Hp, 100.0% Load | Elev. 200 ft | Rel. Humidity 60.0% | Temperature 40.0 Deg. F

	NOx EMISSIONS	CO EMISSIONS	UHC EMISSIONS
PPMvd at 15% O2	25.00	50.00	25.00
ton/yr	22.87	27.85	7.98
lbm/MMBtu (Fuel LHV)	0.100	0.122	0.035
lbm/(MW-hr) (gas turbine shaft pwr)	1.10	1.34	0.38
lbm/hr	5.22	6.36	1.82

3 — 5027 Hp, 75.0% Load | Elev. 200 ft | Rel. Humidity 60.0% | Temperature 0 Deg. F

	NOx EMISSIONS	CO EMISSIONS	UHC EMISSIONS
PPMvd at 15% O2	25.00	50.00	25.00
ton/yr	20.70	25.20	7.22
lbm/MMBtu (Fuel LHV)	0.100	0.122	0.035
lbm/(MW-hr) (gas turbine shaft pwr)	1.26	1.53	0.44
lbm/hr	4.73	5.75	1.65

Notes

1. For short-term emission limits such as lbs/hr., Solar recommends using "worst case" anticipated operating conditions specific to the application and the site conditions. Worst case for one pollutant is not necessarily the same for another.
2. Solar's typical SoLoNOx warranty, for ppm values, is available for greater than 0 deg F, and between 50% and 100% load for gas fuel, and between 65% and 100% load for liquid fuel (except for the Centaur 40). An emission warranty for non-SoLoNOx equipment is available for greater than 0 deg F and between 80% and 100% load.
3. Fuel must meet Solar standard fuel specification ES 9-98. Emissions are based on the attached fuel composition, or, San Diego natural gas or equivalent.
4. If needed, Solar can provide Product Information Letters to address turbine operation outside typical warranty ranges, as well as non-warranted emissions of SO2, PM10/2.5, VOC, and formaldehyde.
5. Solar can provide factory testing in San Diego to ensure the actual unit(s) meet the above values within the tolerances quoted. Pricing and schedule impact will be provided upon request.
6. Any emissions warranty is applicable only for steady-state conditions and does not apply during start-up, shut-down, malfunction, or transient event.

Solar Turbines
A Caterpillar Company

PREDICTED EMISSION PERFORMANCE

Customer	
Job ID	
Inquiry Number	
Run By: Brian K Maul	Date Run: 13-Nov-07

Engine Model: CENTAUR 50-6200LS CS/MD 59F MATCH	
Fuel Type: SD NATURAL GAS	Water Injection: NO
Engine Emissions Data: REV. 0.1	

4 — 4760 Hp, 75.0% Load, Elev. 200 ft, Rel. Humidity 60.0%, Temperature 40.0 Deg. F

	NOx EMISSIONS	CO EMISSIONS	UHC EMISSIONS
PPMvd at 15% O2	25.00	50.00	25.00
ton/yr	19.19	23.37	6.69
lbm/MMBtu (Fuel LHV)	0.100	0.122	0.035
lbm/(MW-hr) (gas turbine shaft pwr)	1.23	1.50	0.43
lbm/hr	4.38	5.33	1.53

5 — 3351 Hp, 50.0% Load, Elev. 200 ft, Rel. Humidity 60.0%, Temperature 0 Deg. F

	NOx EMISSIONS	CO EMISSIONS	UHC EMISSIONS
PPMvd at 15% O2	25.00	50.00	25.00
ton/yr	17.19	20.93	5.99
lbm/MMBtu (Fuel LHV)	0.100	0.122	0.035
lbm/(MW-hr) (gas turbine shaft pwr)	1.57	1.91	0.55
lbm/hr	3.92	4.78	1.37

6 — 3173 Hp, 50.0% Load, Elev. 200 ft, Rel. Humidity 60.0%, Temperature 40.0 Deg. F

	NOx EMISSIONS	CO EMISSIONS	UHC EMISSIONS
PPMvd at 15% O2	25.00	50.00	25.00
ton/yr	16.01	19.50	5.58
lbm/MMBtu (Fuel LHV)	0.100	0.122	0.035
lbm/(MW-hr) (gas turbine shaft pwr)	1.55	1.88	0.54
lbm/hr	3.66	4.45	1.27

Notes

1. For short-term emission limits such as lbs/hr., Solar recommends using "worst case" anticipated operating conditions specific to the application and the site conditions. Worst case for one pollutant is not necessarily the same for another.
2. Solar's typical SoLoNOx warranty, for ppm values, is available for greater than 0 deg F, and between 50% and 100% load for gas fuel, and between 65% and 100% load for liquid fuel (except for the Centaur 40). An emission warranty for non-SoLoNOx equipment is available for greater than 0 deg F and between 80% and 100% load.
3. Fuel must meet Solar standard fuel specification ES 9-98. Emissions are based on the attached fuel composition, or, San Diego natural gas or equivalent.
4. If needed, Solar can provide Product Information Letters to address turbine operation outside typical warranty ranges, as well as non-warranted emissions of SO2, PM10/2.5, VOC, and formaldehyde.
5. Solar can provide factory testing in San Diego to ensure the actual unit(s) meet the above values within the tolerances quoted. Pricing and schedule impact will be provided upon request.
6. Any emissions warranty is applicable only for steady-state conditions and does not apply during start-up, shut-down, malfunction, or transient event.

Solar Product Information Letter 164
Description of SoLoNOx II

THIS PIL SUITABLE FOR DISTRIBUTION OUTSIDE SOLAR

Solar® Turbines **Product Information Letter**

A Caterpillar Company

DATE: 11 December 2001

NUMBER: PIL 164

SUBJECT: **SoLoNOx II Low Emissions Systems**

AUTHOR: L.H. Cowell / K.O. Smith

INTRODUCTION

In 1992, Solar introduced the first industrial gas turbines employing a lean-premixed combustion system for emissions control. Since then, Solar has placed more than 750 SoLoNOx gas turbines into service. These turbines are routinely meeting emissions limits as strict as 25 ppmv NOx and 50 ppmv CO (15% O_2) on natural gas. Other gas turbine manufacturers have eventually followed suit and, at this time, nearly every manufacturer has introduced a low emissions gas turbine product line based on lean-premixed combustion.

Despite the significant improvements in gas turbine emissions since 1992, regulatory agencies continue to consider and implement more stringent emissions regulations. To meet the need for lower NOx, Solar has completed development work on the Centaur 50 and Taurus 60 engines and is now prepared to offer these models fired on natural gas as SoLoNOx II with 15 ppm NOx emission warranties.

PURPOSE

The purpose of this Product Information Letter (PIL) is to describe the unique features of SoLoNOx II. Also included are discussions of the changes to engine controls and operation, the design qualification completed, and the product experience gained to date.

SOLONOX II CAPABILITIES

SoLoNOx II is currently offered for gas Centaur 50 and Taurus 60 engines. In the future, reduced emissions capabilities will be offered on both gas and dual fuel Taurus 70, Mars and Titan engines. For Centaur 50 and Taurus 60 engines and packages, SoLoNOx II warranty and performance capabilities are:

- Emissions (NOx / CO / UHC ppm @15% O2) – Natural Gas: 15 / 25 / 15
- Low Emissions Operating Range – Continuous compliance over the 50-to-100% load range of the engine with ambient temperatures above -20°C (0°F).
- Performance – Unchanged power and heat rate compared to SoLoNOx.
- RAMD – Reliability, availability, maintainability and durability levels expected to meet or exceed SoLoNOx.
- Exchangeability – SoLoNOx II engines are compatible with SoLoNOx packages with limited modifications.

Lean-Premixed Combustion

SoLoNOx and SoLoNOx II employ lean-premixed combustion to reduce NOx emissions. Lean-premixed combustion reduces the conversion of atmospheric nitrogen to NOx by reducing the combustor flame temperature. Since NOx formation rates are strongly dependent on flame temperature, lowering flame temperature (by lean operation) is an extremely effective strategy for reducing NOx emissions (Figure 1). Lean combustion is enhanced by premixing the fuel and combustor airflow upstream of the combustor primary zone. This premixing prevents stoichiometric burning locally within the flame, thus ensuring the entire flame is at a fuel lean condition.

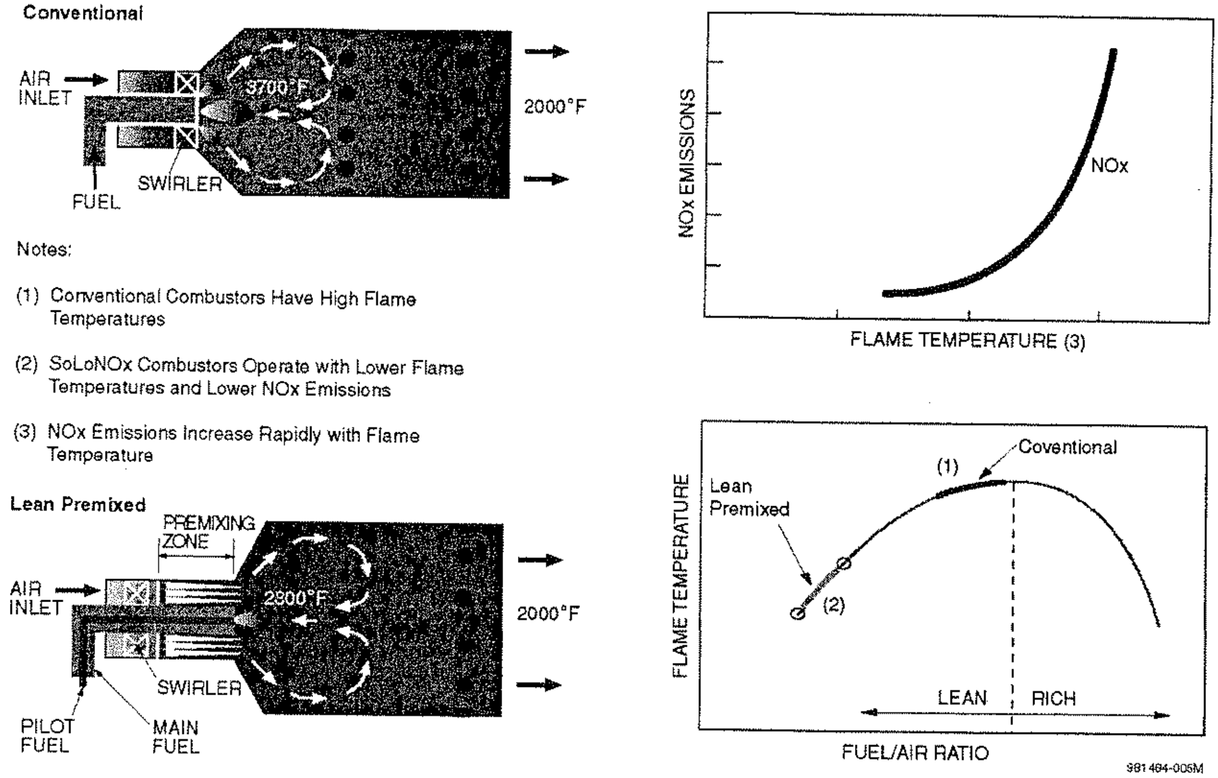


Figure 1. How Lean-Premixed Combustion Reduces NOx Emissions

There are two aspects of lean-premixed combustion that warrant attention:

- CO / NOx trade-off
- Combustor operating range

CO / NOx Trade-off

Since the flame temperature of a lean-premixed combustor is designed to be near the lean flammability limit, lean-premixed combustor performance is characterized by a CO / NOx trade-off (Figure 2). At the combustor design point, both CO and NOx are below target levels; however, deviations from the design point flame temperature cause emissions to increase. A reduction in temperature tends to increase CO emissions due to incomplete combustion; an increase in temperature will increase NOx. This trade-off must be addressed during part-load turbine operation when the combustor is required to run at an even leaner condition. The trade-off also comes into play in development efforts to reduce lean-premixed combustor NOx emissions by further reducing the primary zone design point temperature.

Combustor Operating Range

In a gas turbine, the lean-premixed CO / NOx trade-off is manifested as a limited load range over which emissions limits can be satisfied. As a gas turbine moves away from full-load operation, a lean-premixed combustor will eventually produce excessive CO emissions. To broaden the operating range, low emissions gas turbines can use combustor airflow control within the gas turbine to maintain a nearly constant flame temperature.

Combustor airflow control is achieved with compressor air bleed at part load to broaden the operating range of the lean-premixed combustion system for two-shaft engines. Single-shaft gas turbines use the inlet guide vanes (IGV) to perform the variable geometry function.

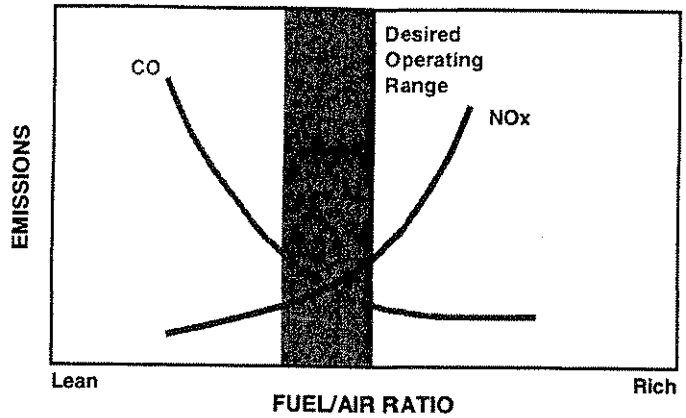


Figure 2. Typical Lean-Premixed Combustor Emissions

SOLONOX II DESIGN

The primary change from SoLoNOx to SoLoNOx II is to incorporate an **A**ugmented **B**ackside **C**ooled (ABC) combustor liner. SoLoNOx II also employs the latest fuel injector design and improvements to the fuel and controls systems. The following sections describe the ABC combustor and other changes made for SoLoNOx II.

Augmented Backside Cooled (ABC) Liners

The present generation of lean-premixed combustors primarily uses film cooling to maintain acceptably low combustor wall temperatures. Film cooling involves the passage of cooling air through holes in the liner and the formation of a cooling film on the hot side of the liner, using internally positioned louvers or effusion cooling as depicted in Figures 3 and 4.

Research has shown that the method used to cool a lean-premixed combustor liner can have a significant effect on emissions. Specifically, conventional film cooling can lead to reaction quenching at the combustor primary zone wall. This quenching process leads to high CO emissions because the CO, a combustion intermediate, is prevented from oxidizing to CO_2. The quenching is traceable to the injection of a relatively large flow of cooling air into the primary zone.

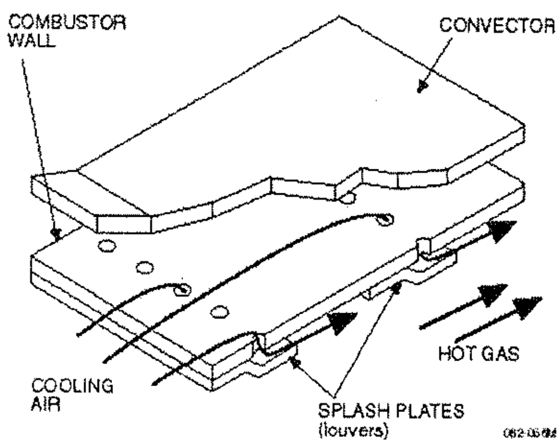


Figure 3. Louver Cooling Design

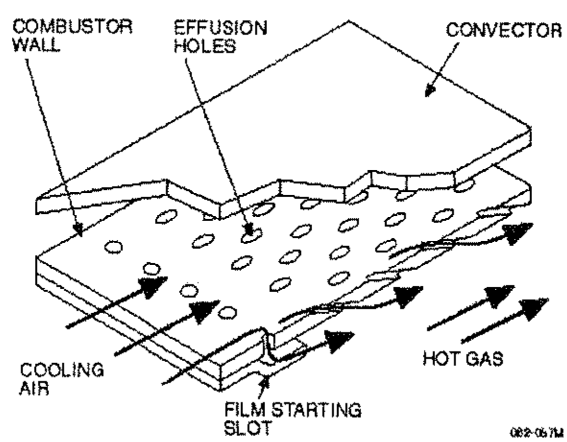


Figure 4. Effusion-Cooling Design

The development of an advanced liner that does not promote reaction quenching provides a two-fold benefit in terms of emissions. First, of course, CO emissions are reduced. Additionally, the lower CO levels allow combustor reoptimization to a lower flame temperature. This produces lower NOx levels along with the lower CO concentrations. Figure 5 shows graphically how the ABC liner reduces CO emissions and the corresponding optimum fuel/air ratio reduces NOx emissions.

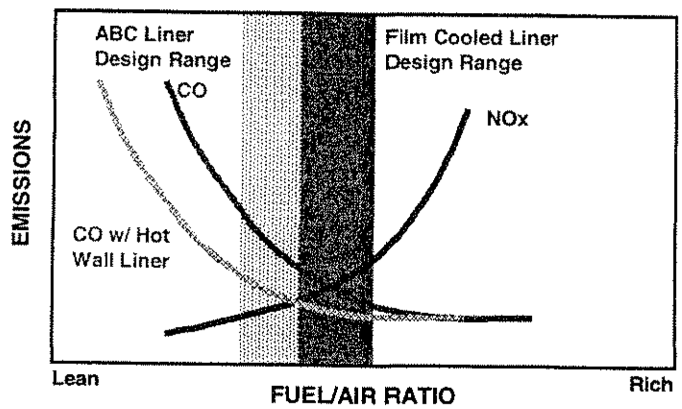


Figure 5. Extension of Design Range with ABC Combustor Liner for Low Emissions

ABC liners forego cooling air injection completely. Instead, combustor wall temperatures are controlled solely through convective cooling by a high velocity airstream on the cold side of the liner (Figure 6). In most instances, the high heat flux from the flame requires augmenting of the backside convective process to keep liner wall temperatures from becoming excessive. Turbulators in the form of trip strips, fins, and pins act to increase the cooling flow turbulence at the liner wall and augment the heat removal process.

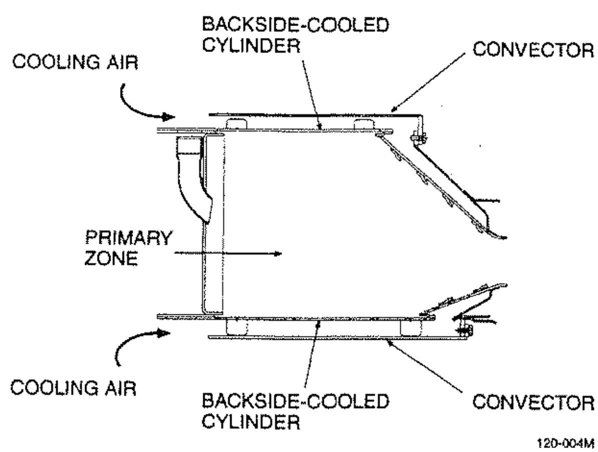


Figure 6. Augmented Backside-Cooled (ABC) Combustor Cross Section

Although effective in reducing CO formation through quenching, backside cooling is a challenge to implement because of the high flame temperatures and heat fluxes associated with gas turbine combustors. An additional degree of liner protection can be achieved through the application of a thermal barrier coating (TBC) on the hot sides of the liner walls. These TBCs are frequently composed of zirconia-based materials that are plasma-sprayed on the liner. A typical TBC coating of approximately 0.25 mm (0.01 in.) can reduce wall temperatures by approximately 40℃ (72℉).

The durability of the ABC liner is expected to meet or exceed durability demonstrated with film-cooled liners. Liner durability is determined by two factors: temperature and temperature gradient. Wall temperatures must be kept sufficiently low to prevent long-term oxidation or thermal creep. Solar's experience indicates that in most circumstances a wall temperature limit of 1600°F provides excellent life. This criterion is applied to the design of all gas turbine liners, including film-cooled diffusion flame and DLE film-cooled liners, as well as backside cooled liners.

Excessive thermal gradients along the liner wall can lead to high stress concentration gradients that cause buckling or cracking. Assessing liner thermal gradient limits requires a combination of thermal paint temperature analysis, stress analysis and operating experience. The thermal gradients in Solar's film-cooled liners have been determined to be acceptable for long liner life. Generally, the thermal gradients in ABC liners are lower than most film-cooled liners. Therefore, the corresponding life of ABC liners is expected to meet or exceed film-cooled liners.

Fuel Injectors

SoLoNOx II uses the latest version of fuel injectors from SoLoNOx. As can be seen in Figure 7, these injectors are significantly larger than the conventional combustion counterparts due to the higher airflow through the injector air swirlers and the required volume of the premixing chamber used to mix the fuel and air. The injector module includes a premixing main fuel injector and a pilot fuel injector.

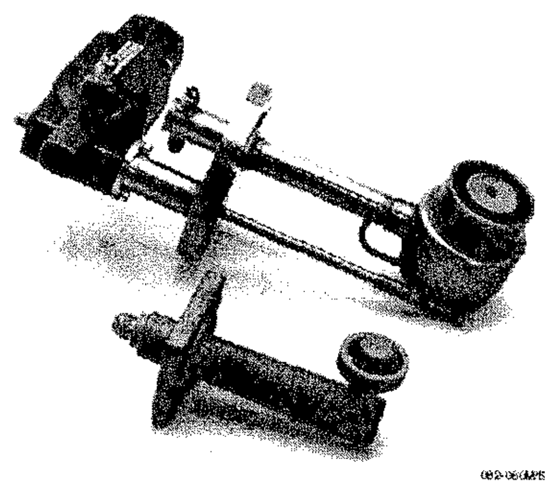


Figure 7. Comparison of SoLoNOx and Conventional Fuel Injectors

Main Fuel Circuit. The premixing main fuel injector uses an axial swirler to impart a high degree of swirl to the primary zone air. A series of multi-orificed, radial fuel tubes injects natural gas fuel into air just downstream of the air swirler. Uniform mixing of the fuel and air occurs within the annular premixing chamber prior to reaching the combustor primary zone. The strong swirl stabilizes the combustion process in the primary zone by establishing a recirculation zone that draws reacted hot gases back upstream, thus providing a continuous ignition source. Above 50% engine load, greater than 95% of the fuel is introduced through the main fuel tubes.

Pilot Fuel Circuit. The pilot fuel injector circuit is used mainly for lightoff and low-load operation. The pilot fuel injector consists of an air swirler and tangential fuel inlet ports to provide partial premixing of air and fuel prior to combustion. During lightoff and low-load operation, approximately 30 to 50% of the fuel passes through the pilot injector, providing a rich fuel / air mixture. Combustor stability is enhanced in this mode compared to lean-premixed operation, although NOx and CO emissions are higher. Above 50% engine load, the pilot fuel is reduced to less than 5% of the total fuel flow to optimize emissions performance. The pilot fuel is also momentarily increased during off-load transients to help stabilize the flame during the transient.

Combustor Air Management

The airflow to the SoLoNOx II combustor is controlled to avoid lean extinction and broaden the low emissions operating range in the same way as for SoLoNOx. Two techniques are used to control the primary zone airflow to maintain the primary zone fuel/air ratio near its optimum low emissions level during part-load engine operation. Two-shaft gas turbines used for gas compression and mechanical drives, bleed air from the combustor casing at part load. Single-shaft gas turbines used for power generation maintain optimum primary zone fuel/air ratios by modulating the compressor inlet guide vanes (IGV). Closing the IGVs reduces the airflow through the engine compressor and combustor.

Swirler Inlet Valve

Centaur 50S and Taurus 60S gas turbine fuel injectors have had a two-position swirler inlet valve (SIV) located upstream of the main air swirler, which was used to control the airflow into the combustor primary zone. The design intent was to offer additional low emissions combustor operating range without increasing the engine heat rate. However, in practice, the part-load heat rate reduction has been lower than anticipated. Therefore, with SoLoNOx II gas-only Centaur 50S and *Taurus* 60S gas turbines, the injector SIV has now been removed to reduce system complexity and cost and improve injector durability.

Engine Casings

SoLoNOx II gas turbines use the same engine casing as SoLoNOx.

Control System

SoLoNOx II and SoLoNOx engines utilize identical control philosophies, incorporating methods to improve control precision, accuracy and reliability. During start-up and low-load operation, the pilot flow rate has been optimized to achieve maximum flame stability for the most rapid and flexible transient capability. Below 50% load for gas fuel (80% for liquid fuel), the combustor airflow is managed in the same way as in a conventional engine. SoLoNOx and SoLoNOx II differ from conventional above 50% for gas (80% for liquid) of the rated load – the low emissions mode. The control system for SoLoNOx II engines modulates either the bleed valve or IGVs to keep the combustion primary zone temperature within a specified range. Accurate control of the primary zone temperature is critical to controlling NOx and CO emissions. SoLoNOx II requires highly accurate electric actuators on the system being modulated to control the primary zone temperature to ensure repeatable and accurate emissions control. The benefits of using electric actuators extends beyond emissions to other elements of engine performance and transient response. The SoLoNOx II gas turbine controls use the power turbine inlet temperature (T_5) as an indirect measurement of the primary zone temperature to control the bleed valve or IGV position as a function of engine load.

Fuel Systems

As with SoLoNOx, the natural gas fuel system for SoLoNOx II gas turbines includes two separate fuel circuits: one for the pilot system and one for the main system. Separate fuel manifolds are used to supply pilot and main gas to the respective fuel circuits of each fuel injector. The fuel flow split between main and pilot is controlled with a precision electronic valve on the pilot line. During start-up and low-load operation, high flow rates of pilot gas are used. When the engine is in the low emissions mode, the pilot fuel valve throttles the pilot valve to low levels. The low pilot flow is used to stabilize the flame.

QUALIFICATION AND EXPERIENCE

The primary improvement associated with SoLoNOx II is the incorporation of the ABC liner. Extensive qualification work was completed on the combustor liner in both rig and engine tests. The initial SoLoNOx II package was qualified in the factory and the field.

ABC Liner Development

Initial development work on the ABC combustor was directed at the Centaur 50 gas turbine in a joint Solar / U.S. Department of Energy program. A short in-house gas turbine test documented excellent emissions performance and acceptable wall temperatures at full-load conditions. A 50-hour cyclic test was completed to demonstrate thermal barrier coating (TBC) spalling resistance.

A field test of a prototype Centaur 50 ABC combustor is ongoing. Testing of this liner was initiated in 1998 in a two-shaft Centaur 50S at a compressor station in Arizona. More than 18,000 hours of operation were achieved at that site. Site emissions were consistently less than 15 ppm NOx and 25 ppm CO from 50 to 100% of rated engine load and ambient temperatures from the 40 to 110°F. In December 2000, the prototype liner was pulled from the engine and examined thoroughly. The liner was in excellent condition with no signs of TBC spalling or cracking and no indications of any premature wear. In early 2001, this same liner was installed in a single-shaft Centaur 50S used in a cogeneration application in Massachusetts. To date, the liner has accumulated an additional 4750 hours, bringing the total liner firing time to 22,750 hours. Emissions continue to be below 15 ppm NOx at this cold weather plant (Figure 8) in both winter and summer. Although not indicated, the corresponding CO emissions are below 10 ppm at all engine loads.

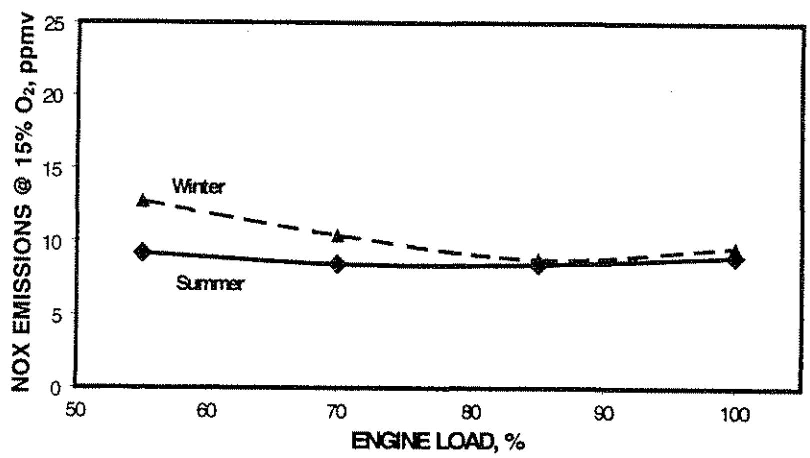


Figure 8. ABC Liner Emissions Performance in a Cogeneration Application in Massachusetts

Following the very successful demonstration of the prototype, the ABC liner design was made production ready. Additional rig and engine testing were completed to verify that the minor changes required for the production design did not impact durability or performance. The liner was tested to verify that the outlet temperature profile is suitable for turbine hot end life. An engine thermal paint test (Figure 9) was completed to assess maximum wall temperatures and thermal gradients. The paint colors and uniformity of thermal paint shading on the combustor liner in Figure 9 indicate acceptable temperatures and gradients. A detailed mechanical analysis was completed, indicating low stress levels and concentrations. The ABC liner is now in full production and successfully qualified for SoLoNOx II.

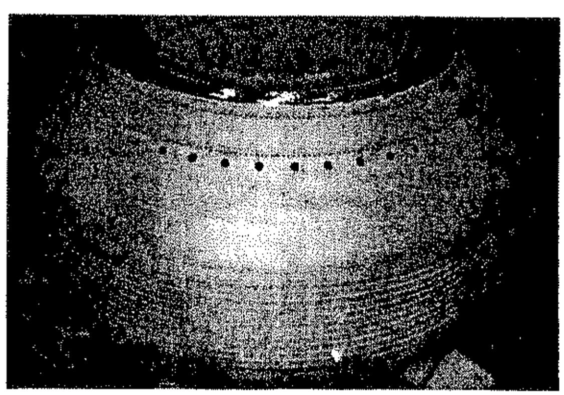


Figure 9. Thermal Paint Applied to an ABC Combustor Liner Indicating Acceptable Temperatures and Low Thermal Gradients

SoLoNOx II Experience

SoLoNOx II has been offered on a "demonstration" basis since mid-2000. Five gas Taurus 60S and one Centaur 50S turbine have been built, factory tested and shipped to site. Four of the Taurus 60S CED packages are in operation at one site in a cogeneration application in Texas. The other Taurus 60S and the Centaur 50S are two-shaft machines and will run in pipeline compressor applications.

Engine build and factory test for all six SoLoNOx II units were completed with no differences from SoLoNOx units except reduced NOx. Engine operation was not affected nor was power or heat rate. The transient ability to handle full off-loads and on-loads was consistent with similar SoLoNOx engines.

Figure 10 summarizes the factory emissions for these units, indicating the capability to meet 15-ppm emissions warranties with margin from 50 to 100% load. CO and unburned hydrocarbon emissions were below 10 ppm for all operating points indicated.

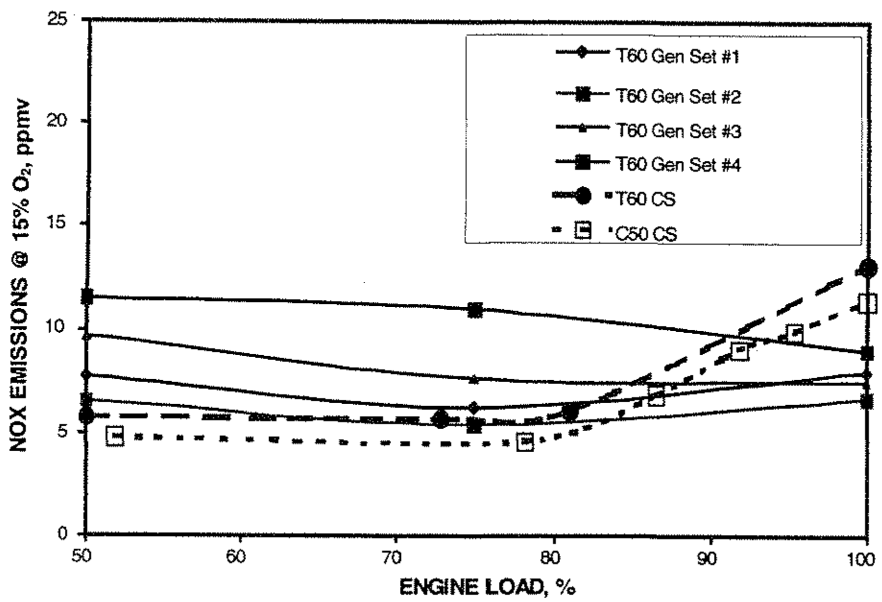


Figure 10. Factory Emissions Performance SoLoNOx II Demonstrator Units

Operation of SoLoNOx II in the field was initiated in June 2001 with the four Taurus 60S packages in Texas. These units were commissioned without difficulties and have been operating without issues, meeting 15 ppm NOx. The customer reports satisfaction with the units. The early hour operation of these units plus the 22,750 hours of engine time demonstrating ABC liner indicates that SoLoNOx II will be a product with excellent reliability, availability, maintainability, and durability (RAMD).

SUMMARY

SoLoNOx II is now being offered for gas-only Centaur 50S and Taurus 60S HED and CED engines and packages. SoLoNOx II emissions warranties can be offered as low as 15 ppm NOx and 25 ppm CO over an operating range of 50 to 100% load and ambient temperatures above 0°F. Development and qualification work continues to offer lower emissions for the Taurus 70, Mars and Titan engines and for all dual fuel SoLoNOx products.

At the heart of SoLoNOx II is a change in the combustor to an ABC liner configuration. Also included are improvements to the IGV and bleed valve actuators and fuel valves to improve precision, speed, and reliability. The improved actuators and fuel valves are now standard for all new shipments, but upgrades are necessary for existing package retrofits. There are no operational impacts or restrictions associated with SoLoNOx II.

The ABC liner has been extensively qualified, including more than 22,750 hours of engine operating time in the field. SoLoNOx II emission levels and performance have now been demonstrated on six production units. Four of these units are operating successfully in the field.

ACKNOWLEDGEMENTS

Design, development and production implementation of the Centaur 50 and Taurus 60 ABC combustor liner were completed by A. Batakis, A. Fahme, K. Maden, E. Metzdorf, D. Pessin, J. Powell, and P. Schneider.

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Solar Product Information Letter 167
Emissions in Sub-Zero Ambient Conditions

SoLoNOx Products – Emissions in Non-SoLoNOx Modes

Leslie Witherspoon
Solar Turbines Incorporated

PURPOSE

Solar's dry-low NOx emissions systems (SoLoNOx) have been developed to provide the lowest emissions possible during normal operating conditions. In order to optimize the performance of the turbine, the combustion and fuel systems are designed to reduce NOx, CO and unburned hydrocarbons (UHC) without penalizing stability or transient capabilities. At very low load and cold temperature extremes, the SoLoNOx system must be controlled differently in order to assure stable operation. These required adjustments to the engine controls at extreme conditions cause emissions to increase. Emission warranty limitations are, therefore, imposed for load (50 to 100%) and for cold ambient temperatures (>0°F).

The purpose of this PIL is to provide emissions estimates for NOx, CO and UHC at these off-design conditions.

COLD AMBIENT EMISSIONS ESTIMATES

Solar's standard temperature range warranty for *SoLoNOx* engines is >0°F. At ambient temperatures below 0°F, the unit is no longer in *SoLoNOx* mode and emissions are expected to be higher than when operating in *SoLoNOx* mode. At ambient temperatures below 0°F, many of Solar's turbine engine models are controlled to increase pilot fuel from approximately 3 to 10% of the total fuel flow to improve flame stability. Without this increase in pilot fuel at temperatures below 0°F, the engines may exhibit combustor rumble since operation may be near the lean stability limit.

For permitting purposes, customers have used the New Source Performance Standard (NSPS) levels, 40 CFR 60, subpart GG for a conservative NO_x emission estimate at ambient temperatures below 0 °F. Table 4 herein summarizes NSPS NOx emission levels for Solar's equipment.

In some cases, either the customer or regulatory agency desires a "less conservative" estimate of actual emissions for when the turbine is not operating in *SoLoNOx* mode. For such instances, the following actual emission estimates are provided. "Expected" emissions are extrapolated from San Diego factory tests and may vary at these extreme temperatures and as a result of variations in other parameters such as fuel composition, fuel quality, etc. Emission warranties cannot be offered for ambient temperatures below 0°F.

For ***SoLoNOx* engine models**, except for *Centaur* 40 and *Mars* 90, expected emissions (ppm corrected to 15% O_2) as a function of ambient temperature are given in Table 1.

Table 1. Expected Emissions below 0°F (except for Centaur 40 and Mars 90)

Ambient	Fuel System	Fuel	NOx, ppm	CO, ppm	UHC, ppm
0°F to -20°F	Gas only (50 to 100% load)	Gas	42	100	50
	Dual fuel (80 to 100% load)	Gas	72	100	50
		Liquid	120	150	75
Below -20°F	Gas only (50 to 100% load)	Gas	120	150	75
	Dual fuel (80 to 100% load)	Gas	120	150	75
		Liquid	120	150	75

Table 4. NSPS Limits (NOx, ppmv @ 15% O_2)

Product		Gas Fuel	Gas Fuel >1/3 Power to Grid	Liquid Fuel[a,b]	Liquid Fuel[a,b] >1/3 Power to Grid
Titan 130-19500	GSC	209[a]	105[a]	205	102
	CS/MD	214[a]		210	
Mars 100-15000	GSC	209[c]	105[a]	207	104
	CS/MD	203[c]		201	
Mars 90-13000	GSC	205[c]		197	
	CS/MD	199[c]		193	
Taurus 70-10300	GSC	212[a]		210	
	CS/MD	207[a]		201	
Taurus 60-7300, -7800	GSC	190[c]/193[c]		188/191	
	CS/MD	190[c]/193[c]		188/191	
Mercury 50	**EXEMPT**				
Centaur 50-6200, -6100	GSC	184[c]		183	
	CS/MD	180[c]		177	
Centaur 40-4700	GSC	182[c]		179	
	CS/MD	167[c]		165	
Saturn 20-1600	GSC	156[c]		155	
	CS/MD	150[c]		150	

[a] *SoLoNOx*, water Injection, or add-on control is required to meet NSPS
[b] Fuel bound nitrogen content assumed to be <0.015% by volume
[c] Conventional turbine meets NSPS

mates of NO_x, CO, and UHC emissions when operating below 50% load and above -20°F. The estimated emissions can be assumed to vary linearly as load is decreased from just below 50% load to idle.

The above values apply for any product for gas only or dual fuel systems using pipeline quality natural gas. At ambient temperatures below -20°F, the NO_x emission estimate is 120 ppmv for loads <50%. For liquid fuel operation below 80% load, emissions documentation is in progress.

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For ***Centaur* 40 and *Mars* 90** engine models, expected emissions (ppm corrected to 15% O_2) as a function of ambient temperature are given in Table 2.

Some regulatory agencies in states with colder winter climates (primarily Alaska and Wyoming) have started to ask about cold ambient temperature restrictions and corresponding emissions below 0°F. In all cases to date, the regulatory agency did not require a certain emission level to be met, but merely asked what emissions are expected so that emissions could be appropriately estimated for annual emissions inventory purposes and NSR applicability issues.

Some customers have used the permitting strategy of installing digital thermometers to record ambient temperature. The amount of time is recorded that the ambient temperature falls below 0°F. The amount of time below 0°F is then used with the emission estimates shown above to estimate "actual" emissions.

For customers who wish to permit at a single emission rate over all temperatures, inlet air heating can be used to raise the engine inlet air temperature (T1) above 0°F. With inlet air heating to keep T1 above 0 °F, standard emission warranty levels may be offered.

EMISSIONS ESTIMATES AT LESS THAN 50% LOAD

At operating loads <50%, *SoLoNOx* engines are controlled to increase stability and transient response capability. The control steps that are required affect emissions in two ways: 1) pilot fuel flow is increased, increasing NO_x emissions, and 2) airflow through the combustor is increased, increasing CO emissions. Note that 50% load is an approximation and that engine controls are triggered either by power output for single-shaft engines or gas producer speed for two-shaft engines.

For permitting purposes, Solar has historically recommended the use of New Source Performance Standard (NSPS) levels, 40 CFR 60, subpart GG for conservative NO_x emission estimates outside the typical load range warranty. (Table 4 herein summarizes NSPS NOx emission levels for Solar's equipment.)

In some cases, either the customer or regulatory agency desires a "less conservative" estimate of actual emissions for when the turbine is not operating in *SoLoNOx* mode. For such instances, the actual emission, ±20%, are estimated based on a combination of empirical calculations and the limited test data available. Table 3 provides esti-

Table 2. Expected Emissions below 0°F for Centaur 40 and Mars 90 Engines

Ambient	Fuel System	Fuel	NOx, ppm	CO, ppm	UHC, ppm
Below 0°F	Gas only (50 to 100% load) *Centaur* 40 and *Mars* 90	Gas	120	150	75
	Dual fuel (80 to 100% load) *Centaur* 40 (Dual fuel not applicable for *Mars* 90)	Gas or Liquid	120	150	75

Table 3. Estimated Emissions

Engine Load	NOx, ppm	CO, ppm	UHC, PPM
Less than 50%	70	2200	300
Idle	50	3500	500

Solar Product Information Letter 168
VOC, SO2, and HCHO Emission Estimates

Volatile Organic Compound, Sulfur Dioxide, and Formaldehyde Emission Estimates

Leslie Witherspoon
Solar Turbines Incorporated

PURPOSE

The purpose of this PIL is to summarize methods available to estimate emissions of volatile organic compounds (VOC), sulfur dioxide (SO_2), and formaldehyde from gas turbines. Most customers are required to estimate emissions of these pollutants during the air permitting process.

INTRODUCTION

In absence of site specific or representative source test data, Solar refers customers to a United States Environmental Protection Agency (EPA) document titled "AP-42," or other appropriate EPA reference documents. AP-42 is a collection of emission factors for different emission sources. The emission factors found in AP-42 are a generally accepted way of estimating emissions when more representative data are not available. The most recent version of AP-42 (dated April 2000) can be found at http://www.epa.gov/ttn/chief/ap42/index.html.

Solar does not typically warranty the emission rates for VOC, SO_2, or formaldehyde.

Volatile Organic Compounds

Most permitting agencies require gas turbine users to estimate emissions of VOC, a subpart of the unburned hydrocarbon (UHC) emissions, during the air permitting process. Volatile organic compounds, non-methane hydrocarbons (NMHC), and reactive organic gases (ROG) are some of the many ways of referring to the non-methane (and non-ethane) portion of an "unburned hydrocarbon" emission estimate.

For natural gas fuel, most Solar customers use 10-20% of the UHC emission rate to represent VOC emissions. The estimate of 10-20% is based on a ratio of total non-methane hydrocarbons to total organic compounds. The use of 10-20% provides a conservative estimate and has been accepted by permitting authorities over the years. The 10% level assumption is most commonly used by customers in the air permitting process.

For liquid fuel, it is appropriate to estimate that 100% of the UHC emission estimate is VOC.

Sulfur Dioxide

Sulfur dioxide emissions are produced by conversion of sulfur in the fuel to SO_2. Since Solar does not control the amount of sulfur in the fuel, we are unable to generically predict SO_2 emissions. Customers generally estimate SO_2 emissions with a mass balance calculation by assuming that any sulfur in the fuel will convert to SO_2.

As an alternative to a mass balance calculation, EPA's AP-42 document can be used. AP-42 (Table 3.1-2a., April 2000) suggests emission factors of 0.0034 lb/MMBtu for gas fuel (HHV) and 0.033 lb/MMBtu for liquid fuel (HHV).

Formaldehyde

In gas turbines, formaldehyde emissions are a result of incomplete combustion. Formaldehyde in the exhaust stream is unstable and very difficult to measure. In addition to turbine characteristics including combustor design, size, maintenance history, and load profile, the formaldehyde emission level is also affected by:

- Ambient Temperature
- Humidity
- Atmospheric Pressure
- Fuel Quality
- Formaldehyde Concentration in the Ambient Air

- Test Method Measurement Variability
- Operational factors

Table 1 summarizes total hazardous air pollutants (HAP) and formaldehyde emission factors for gas turbines < 50MW in size. The emission factor data is taken from an EPA memo: "Revised HAP Emission Factors for Stationary Combustion Turbines, 8/22/03". The emission factors in the memo are a compilation of the HAP data EPA collected during the Maximum Achievable Control Technology (MACT) standard development process. The emission factor documentation shows there is a high degree of variability in formaldehyde emissions from gas turbines, depending on the manufacturer, rating size of equipment, combustor design, and testing events. To estimate formaldehyde emissions from gas turbines, users should use the emission factor(s) that best represent the gas turbines actual/planned operating profile.

The 95% Upper Confidence of Mean and 95% Upper Confidence of Data emission factors from the August 22, 2003, memo are shown in Table 1. The EPA memo also presents HAP emission factors in the following categories: mean, median, maximum, and minimum.

Table 1. EPA's Total HAP and Formaldehyde Emission Factors for <50 MW Lean Premix Gas Turbines burning Natural Gas.
(Source: Revised HAP Emission Factors for Stationary Combustion Turbines, OAR-2002-0060, IV-B-09, 8/22/03)

Pollutant	Engine Load	95% Upper Confidence of Mean (lb/MMBtu HHV)	95% Upper Confidence of Data (lb/MMBtu HHV)	Memo Reference
Total HAP	> 90%	0.00144	0.00258	Table 19
Total HAP	All	0.00160	0.00305	Table 16
Formaldehyde	> 90%	0.00127	0.00241	Table 19
Formaldehyde	All	0.00143	0.00288	Table 16

Table 2 summarizes approximate ton per year formaldehyde emissions from Solar's current production models based on the 95% Upper Confidence of Data emission factors as shown in Table 1 and ISO condition fuel flow data.

Table 2. Formaldehyde Emissions Estimates for Solar's Products (59°F, 60% RH, sea level, no losses)

Solar Turbine Model	Fuel Input, MMBtu/hr LHV (HHV)	Formaldehyde Emission Estimate, tpy	
		Using the 95% Upper Confidence of Data Emission Factor - All Loads	Using the 95% Upper Confidence of Data Emission Factor – > 90% Load
Saturn 20	16.8 (18.5)	0.23	0.20
Centaur 40	42.7 (47.0)	0.59	0.50
Centaur 50	50.3 (55.3)	0.70	0.58
Taurus 60	58.1 (63.9)	0.81	0.67
Taurus 70	71.9 (79.1)	1.00	0.83
Mars 90	99.2 (109.1)	1.38	1.15
Mars 100	111.5 (122.7)	1.55	1.29
Titan 130	132.0 (154.2)	1.83	1.53

In August, 2003, EPA finalized the combustion turbine Maximum Achievable Control Technology (MACT) standard. A gas turbine will be considered "new" if it is part of a project that commenced construction (enter into a contractual agreement) after January 14, 2003. "New" turbines at major sources of hazardous air pollutants (HAP), >10 tpy of a single HAP, >25 tpy of all HAPs, will need to comply with the MACT standard of 91 ppb.

As you can see from Table 2 it is unlikely that any multiple unit Solar turbine project will be a major source of HAPs. However, if a gas turbine is placed at a site that is a major source of HAPs due to other emission sources at the site (most vulnerable customers include compressor stations with reciprocating engine base, chemical plants, and refineries), then the gas turbine MACT standard will be applicable.

If the MACT is applicable, new gas turbines will be required to meet 91 ppb formaldehyde. Source test data to date do not indicate that mid-range industrial gas turbines can meet the formaldehyde standard without the use of an oxidation catalyst. In fact, the preamble to the final MACT standard noted that the 91 ppb value is "post control", e.g. a measured level after a CO oxidation catalyst. With this in mind, Solar will not warranty formaldehyde at the 91 ppb level.

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Solar Product Information Letter 170
Startup and Shutdown Emissions

Emission Estimates at Start-up, Shutdown, and Commissioning for SoLoNOx Products

Leslie Witherspoon
Solar Turbines Incorporated

PURPOSE

Emissions during start-up, shutdown, and commissioning of Solar's size class of gas turbine are negligible and are not warranted by Solar. Without appropriate forewarning, however, many customers and regulators will treat Solar's turbines as though they were large utility turbines. The purpose of this PIL is to provide insight into the different situation with Solar's class of turbine and provide emission estimates for start-up, shutdown, and commissioning.

INTRODUCTION

Due to the surge of energy projects in the utility sector and the start-up and shutdown emission characteristics of large utility turbines, some regulatory agencies have been asking Solar's customers to account for emissions during start-up and shutdown conditions in their air permitting. The operating characteristics and emissions profile of Solar's size class of turbine is different than those of a utility-size combined-cycle power plant. This basic fact is often overlooked by regulatory agencies and can cause Solar's customers to expend significant effort in estimating start-up and shutdown emissions that are essentially insignificant. In most cases, once our estimated start-up emissions are relayed to the permitting engineers, the issue is dropped.

Start-up occurs in one of three modes: cold, warm, or hot. In general, the start-up duration for a hot, warm, or cold *Solar* turbine is less than 10 minutes in simple-cycle and most combined heat and power designs. Heat recovery steam generator (HRSG) steam pressure is usually 250 psig or less. At 250 psig or less, thermal stress within the HRSG is minimized and, therefore, firing ramp up is not limited.

A utility-size combined-cycle power plant typically operates at 1800 to 2400 psig. At 1800 to 2400 psig, a 2 to 3 hour start-up sequence is required for a **cold** start (steam turbine shutdown for greater than 72 hours), 1 to 2 hours for a **warm** start (steam turbine shutdown for 8 to 72 hours); and 30 minutes for a **hot** start (steam turbine shutdown for less than 8 hours). Large simple-cycle gas turbines generally start-up in 10 to 30 minutes.

Start-up, shutdown, and commissioning emissions will **not** be guaranteed by Solar Turbines. The information presented in this document is representative for both single and two-shaft engines only. Operation of duct burners and/or any add-on control equipment is not considered in the estimates.

START-UP EMISSION ESTIMATES

The start-up duration is the same for cold, warm, and hot starts. Expected start-up emissions are summarized in Table 1, in parts per million by volume (ppmv, and in Table 2, in pounds per year for each product. The emission estimates are calculated from empirical exhaust characteristics. Getting to the *SoLoNOx* mode takes three steps:

1. Purge-crank
2. Ignition and acceleration to idle
3. Loading / thermal stabilization

During the "purge-crank" step, rotation of the turbine shaft is accomplished with an electric starter motor to remove any residual fuel gas in the engine flow path and exhaust. During "ignition and acceleration to idle," fuel is introduced into the combustor and ignited in a diffusion flame mode

Table 1. Estimated Emissions during Start-Up (ppmv)

Start-up Step	Combustion Mode	Approx. Time, minutes	NOx, ppmv	CO, ppmv	UHC, ppmv
1. Purge-Crank	None	4	---	---	---
2. Ignition-Idle-Generator Synchronization	Diffusion	3	50	3500	500
3. Loading / Thermal Stabilization	Transitional	6	70	2200	300
4. 50% to Full Load	*SoLoNOx*	Variable	<25	<50	<25

and the engine rotor is accelerated to idle speed. The third step consists of applying up to 50% load while allowing the combustion flame to transition and stabilize. Once 50% load is achieved, the turbine transitions to *SoLoNOx* mode (Step 4) and the engine control system begins to hold the combustion primary zone temperature and limit pilot fuel to achieve the carbon monoxide (CO) and nitrogen oxides (NOx) emission levels.

The specific load at which a unit enters *SoLoNOx* mode (Step 4) varies by engine model and ambient temperature. For two-shaft engine, the *SoLoNOx* "trigger" load also varies by gas producer speed (NGP).

It is important to note that Steps 2 and 3 are short-term transient conditions making up less than 10 minutes. No emission guarantee is provided by Solar for <50% load. NOx, CO, and unburned hydrocarbons (UHC) are guaranteed at 25 ppmv, 50 ppmv, and 25 ppmv respectively, when operating greater than 50% load.

SHUTDOWN EMISSIONS

Normal, planned cooldown / shutdown duration varies by engine model. The *Centaur* 40, *Centaur* 50, and *Taurus* 60 take about five minutes. The *Taurus* 70, *Mars* 90 and 100, and *Titan* 130 take about 10 minutes. Typically, the emissions will be similar to Start-up Step 4 for 90 seconds and Step 3 for the balance of the estimated duration (assumes unit was operating at full-load).

COMMISSIONING EMISSIONS

Commissioning generally takes place over a two-week period. Static testing, where no combustion occurs, usually requires one week and no emissions are expected. Dynamic testing, where combustion will occur, will see the engine start and shutdown a number of times and a variety of loads will be placed on the system. It is impossible to predict how long the turbine will run and in what combustion / emissions mode it will be running. The dynamic testing period is generally followed by one to two days of "tune-up" during which the turbine is running at various loads, most likely within low emissions mode (warranted emissions range).

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Table 2. Estimation of Start-up and Shutdown Emissions (lb/yr) for SoLoNOx Gas Fuel

Data will NOT be warranted under any circumstances

		Centaur 40 4700S						Centaur 50 6200SII						Taurus 60 7800SII						Taurus 70 10300S					
		Exhaust Flowrate (lb/hr)	O2 %	H2O%	NOx (lbs)	CO (lbs)	UHC (lbs)	Exhaust Flowrate (lb/hr)	O2 %	H2O%	NOx (lbs)	CO (lbs)	UHC (lbs)	Exhaust Flowrate (lb/hr)	O2 %	H2O%	NOx (lbs)	CO (lbs)	UHC (lbs)	Exhaust Flowrate (lb/hr)	O2 %	H2O%	NOx (lbs)	CO (lbs)	UHC (lbs)
Start-up	Step 2 (3 min)	146,415	19.13	2.44	0.13	5.33	0.43	150,409	18.52	2.99	0.18	7.63	0.62	171,774	19.3	2.29	0.13	5.56	0.45	211,378	18.56	2.95	0.25	10.53	0.86
	Step 3 (6 min)	146,415	19.13	2.44	0.35	6.70	0.52	150,409	18.52	2.99	0.50	9.59	0.75	171,744	19.3	2.29	0.37	6.99	0.54	211,378	18.56	2.95	0.69	13.24	1.03
Total Start-up Emissions					0.5	12.0	1.0				0.7	17.2	1.4				0.5	12.5	1.0				0.9	23.8	1.9
Shut-down	Step 4 (90 sec)	147,718	15.46	5.70	0.11	0.13	0.04	151,411	14.35	6.68	0.13	0.16	0.05	173,937	14.33	6.70	0.15	0.19	0.05	213,837	14.32	6.70	0.19	0.23	0.07
	Step 3 (3.5 min)	146,415	19.13	2.44	0.20	3.91	0.30	150,409	18.52	2.99	0.29	5.60	0.44	171,744	19.3	2.29	0.21	4.08	0.32	211,378	18.56	2.95	0.98	18.76	1.46
Total Shut-down Emissions					0.3	4.0	0.3				0.4	5.8	0.5				0.4	4.3	0.4				1.2	19.0	1.5

		Mars 90 13000S						Mars 100 15000S						Titan 130 19500S					
		Exhaust Flowrate (lb/hr)	O2 %	H2O%	NOx (lbs)	CO (lbs)	UHC (lbs)	Exhaust Flowrate (lb/hr)	O2 %	H2O%	NOx (lbs)	CO (lbs)	UHC (lbs)	Exhaust Flowrate (lb/hr)	O2 %	H2O%	NOx (lbs)	CO (lbs)	UHC (lbs)
Start-up	Step 2 (3 min)	179,125	17.2	4.15	0.35	14.71	1.20	179,761	17.18	4.17	0.35	14.84	1.21	390,263	18.88	2.66	0.39	16.52	1.35
	Step 3 (6 min)	179,125	17.2	4.15	0.97	18.49	1.44	179,761	17.18	4.17	0.98	18.65	1.45	390,263	18.88	2.66	1.09	20.76	1.62
Total Start-up Emissions (lbs)					1.3	33.2	2.6				1.3	33.5	2.7				1.5	37.3	3.0
Shut-down	Step 4 (90 sec)	318,755	15.0	6.11	0.25	0.31	0.09	331,545	14.62	6.44	0.29	0.36	0.10	394,751	14.39	6.64	0.35	0.42	0.12
	Step 3 (8.5 min)	179,125	17.2	4.15	1.37	26.20	2.04	179,761	17.18	4.17	1.38	26.43	2.06	390,263	18.88	2.66	1.54	29.42	2.29
Total Shut-down Emissions (lbs)					1.6	26.5	2.1				1.7	26.8	2.2				1.9	29.8	2.4

Assumes ISO conditions: 59F, 60% RH, sea level, no losses
Exhaust flowrates for Step 2 and 3 from FASTE @ 1% load using diffusion flame equivalent model; Mars 90 and 100 use 10% load diffusion flame data.
Exhaust flowrates for Step 4 from FASTE @ 100% load using SoLoNOx models.
Assumes unit is operating at full load prior to shut-down.
Assumes gas fuel.

Solar White Paper on:
Developments in Low Emissions Combustion Systems

Concord Expansion Project
Compressor Station 270B1
Application for Temporary Permit

Developments in Low Emissions Combustion Systems for Industrial Gas Turbines

Solar® Turbines

A Caterpillar Company

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TPSOLONOX/901

Developments in Low Emissions Combustion Systems for Industrial Gas Turbines

R.A. Eimers, Director, Engineering
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L. Cowell, Product Manager, SoLoNOx Products

INTRODUCTION

In 1992, Solar introduced the first industrial gas turbines employing a lean-premixed combustion system for emissions control. Since then, Solar has placed more than 825 *SoLoNOx*™ gas turbines into service. These turbines routinely are meeting emissions limits as strict as 25 ppmv NOx and 50 ppmv CO (15% O_2) on natural gas. Other gas turbine manufacturers have followed suit and, at this time, nearly every manufacturer has introduced a low emissions gas turbine product line based on lean-premixed combustion technology.

Despite the significant improvements in gas turbine emissions over the last eight years, regulatory agencies continue to consider and implement more stringent emissions regulations. For example, NOx control levels for gas turbines have been set as low as 1 ppmv in Massachusetts. Levels this low require the use of expensive exhaust gas cleanup systems in addition to advanced low NOx combustion technology. CO levels as low as 10 ppmv may be required by future emissions regulations.

The primary purpose of this paper is to provide a broad overview of low emissions combustor development and how it is being shaped by emissions regulations that are continually changing. Discussed in this paper is a description of the development and present status of *SoLoNOx*; a discussion of how increasingly restrictive emissions regulations impact industrial gas turbine production; and a review of new combustion technologies with the potential to achieve lower emissions levels. Solar continues to explore combustion technologies in the belief that clean combustion is a more cost-effective path to low emissions than exhaust gas cleanup.

LEAN-PREMIXED COMBUSTION

SoLoNOx employs lean-premixed combustion to reduce NOx emissions. Lean-premixed combustion reduces the conversion of atmospheric nitrogen to NOx by reducing the combustor flame temperature. Since NOx formation rates are strongly dependent on flame temperature, lowering flame temperature (by lean operation) is an extremely effective strategy for reducing NOx emissions (Figure 1). Lean combustion is enhanced by premixing the fuel and combustor airflow upstream of the combustor primary zone. This premixing prevents stoichiometric burning locally within the flame, thus ensuring the entire flame is at a fuel lean condition.

There are three aspects of lean-premixed combustion that warrant attention:

- CO/NOx tradeoff
- Combustor operating range
- Combustor pressure oscillations

CO/NOx Tradeoff

Since the flame temperature of a lean-premixed combustor is designed to be near the lean flammability limit, lean-premixed combustor performance is characterized by a CO/NOx tradeoff (Figure 2). At the combustor design point, both CO and NOx are below target levels; however, deviations from the design point flame temperature cause emissions to increase. A reduction in temperature tends to increase CO emissions due to incomplete combustion; an increase in temperature will increase NOx. This tradeoff must be addressed during part-load turbine operation when the combustor is required to run at an even leaner condition. The tradeoff also comes

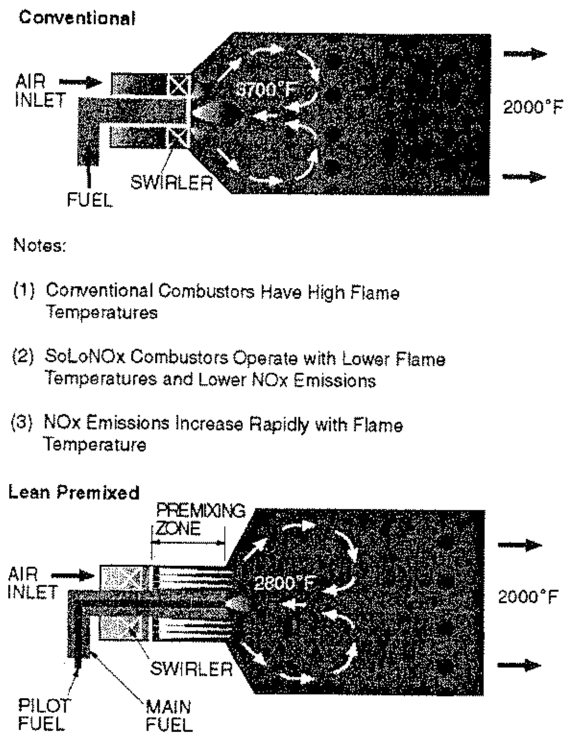


Figure 1. How Lean-Premixed Combustion Reduces NOx Emissions

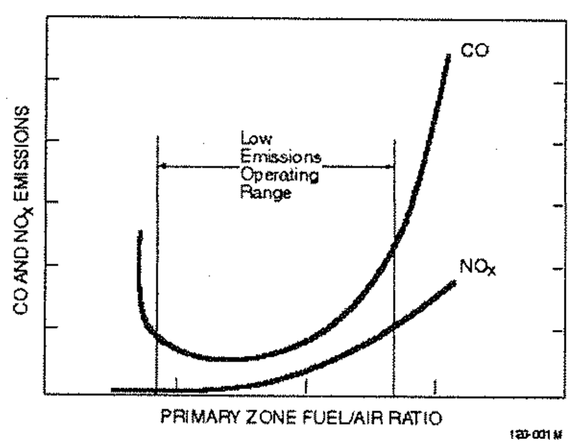


Figure 2. Typical Lean-Premixed Combustor Emissions

into play in development efforts to reduce lean-premixed combustor NOx emissions by further reducing the primary zone design point temperature.

Combustor Operating Range

In a gas turbine, the lean-premixed CO/NOx tradeoff is manifested as a limited load range over which emissions limits can be satisfied. As a gas turbine moves away from full-load operation, a lean-premixed combustor will eventually produce excessive CO emissions.

To broaden the operating range, low emissions gas turbines can use variable geometry to maintain the combustor primary zone at its optimum low emissions point despite load changes. Variable geometry involves combustor airflow control within the gas turbine to maintain a nearly constant flame temperature.

The current generation of low emissions gas turbines uses either compressor air bleed or variable geometry at part-load to broaden the operating range of the lean-premixed combustion system. Although effective, compressor bleed results in a reduction in part-load efficiency because high-pressure air is vented to the atmosphere upstream of the gas generator.

Some applications such as single-shaft gas turbines can use the inlet guide vanes (IGV) to perform the variable geometry function without an efficiency impact; however, the IGV technique is not applicable to two-shaft gas turbines.

Combustor Pressure Oscillations

The introduction of lean-premixed combustion systems for gas turbines has raised manufacturer awareness of the consequences of large combustor pressure oscillations. Simply put, lean flames have a greater tendency to cause pressure oscillations that can lead to engine damage. It is recognized that the reduced stability of a lean-premixed flame contributes to combustor oscillations. Despite increased awareness, however, manufacturers are still working to develop design methodologies and combustion system features that prevent excessive combustor pressure oscillations.

The three lean-premixed combustion system characteristics previously identified represent significant constraints in efforts to develop advanced combustion systems that will further reduce gas turbine NOx and CO emissions.

SOLONOX DEVELOPMENT

In 1987, Solar began a major development effort to integrate dry, low NOx combustion technology into its product line. Several potential low NOx combustion techniques were evaluated and lean-premixed combustion was selected as the most promising approach for near-term application. Advantages of lean-premixed combustion include the concept's proven potential for low NOx emissions, general similarity of combustion system hardware to that used in conventional gas turbines, and Solar's extensive lean-premixed technology base developed through earlier research work.

Combustion System Description

Development of the *SoLoNOx* combustion system required modifications to the following engine components:

- Combustor Liner
- Fuel Injectors
- Variable Geometry Systems
- Engine Casings
- Control System
- Fuel System

Combustor Liner

The lean-premixed combustor liner is generally similar to a conventional liner in terms of geometry, materials and construction (Figure 3). The most significant difference in the lean-premixed liner is an increase in combustor volume. The larger volume is required to ensure complete combustion and low CO and UHC emissions at the lower overall flame temperature of the lean-premixed combustor (Figure 4). Since combustor length was constrained by the engine exchangeability objective, the increased combustor volume was achieved by increasing the outer liner diameter. The larger liner required an increase in the diameter of the combustor housing (Figure 5).

A second difference in the lean-premixed liner is the absence of large air injection ports in the combustor primary zone. All air used in the combustion process is introduced through the air swirlers of the fuel injectors. Remaining compressor delivery air is used for cooling the walls or for dilution to achieve the specified radial temperature profile and pattern factor at the combustor exit.

Early *SoLoNOx* combustor liners incorporate conventional air film louver wall cooling techniques. More recently, an improved effusion-cooled liner design has been developed

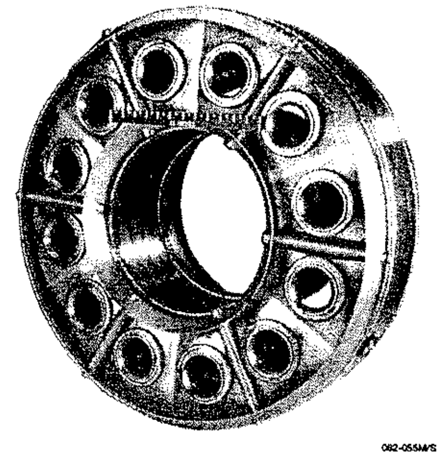


Figure 3. Lean-Premixed Annular Combustor Inlet Section

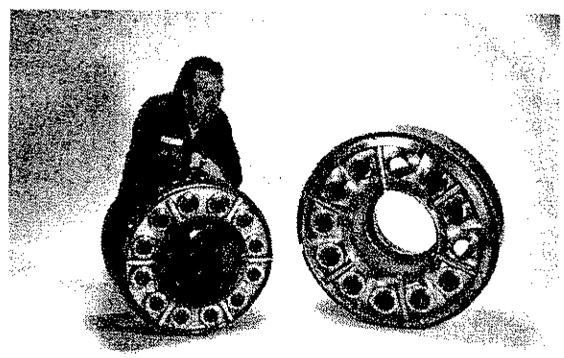


Figure 4. Comparison of Conventional and SoLoNOx Combustor Liners

to give improved CO compliance at ambient temperatures below -20°C (0°F).

The first production *SoLoNOx* combustors used louvers on the inside of the liner to direct air axially along the walls to produce a protective film of cooling air between the wall and the hot combustion gases (Figure 6). This method of liner cooling is commonly used in industrial and aircraft gas turbine combustors. The cooling air film gradually mixes with the hot gas stream; thus, a succession of louvers must be placed along the liner to maintain the required temperatures. This method of wall cooling uses relatively high levels of cooling air, because the wall just downstream of the louver must be overcooled in order to keep the wall adjacent to the next louver below the maximum temperature limit.

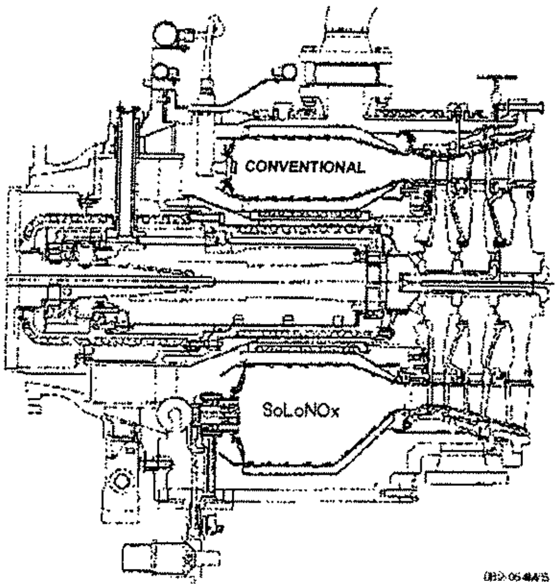


Figure 5. Comparison of Conventional and SoLoNOx Combustion Systems

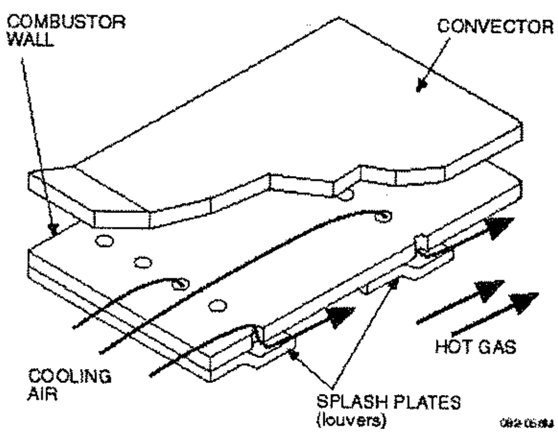


Figure 6. Louver Cooling Design

Effusion cooling of the combustor walls has been developed for *SoLoNOx* combustor liners in order to reduce the cooling air required and, in turn, reduce CO emissions.

The injection of cooling air along the combustor wall can quench the combustion reactions in the wall region, thus contributing to CO and UHC emissions.

The basic geometry of the effusion-cooled liner is the same as the louvered version. Effusion cooling is obtained by starting a film of air with a cooling louver at the front of the combustor and then continuously feeding this film with additional air through a multitude of small diameter holes laser drilled at an angle of 20 degrees to the wall surface (Figure 7).

An effusion liner has the total cooling air reduced by about 20% relative to the louvered liner. Thermal gradients in an effusion liner are significantly less than in the louvered liner while still maintaining acceptable wall temperatures. Additional cooling effectiveness is achieved by adding an impingement shield to the *SoLoNOx* combustor liner and combining air impingement on the back side of the combustor wall with effusion through the wall (Figure 8).

As Solar continues to develop lower emissions combustion products, combustors using only back-side convective cooling are being introduced. The total avoidance of cooling air

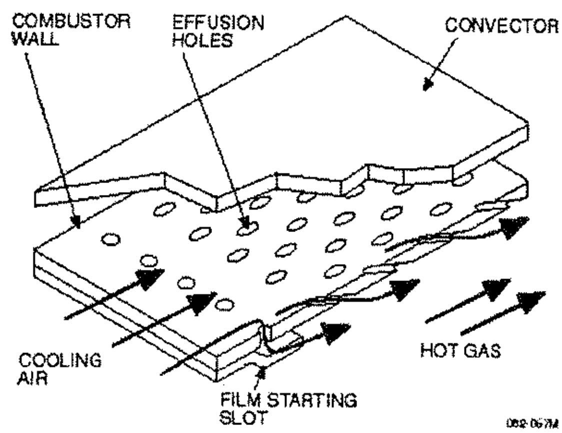


Figure 7. Effusion-Cooling Design

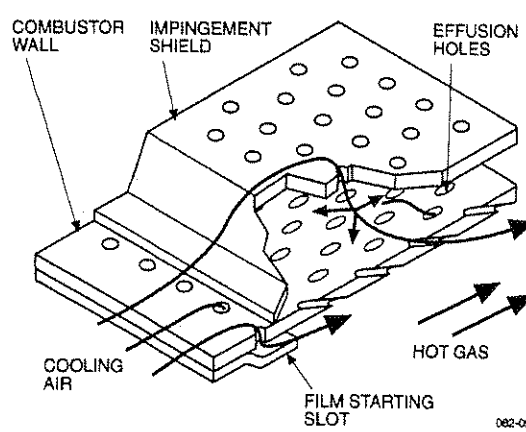


Figure 8. Impingement/Effusion-Cooling Design

injection into the combustor primary zone allows greater latitude for combustor optimization for minimum NOx and CO.

Fuel Injectors

SoLoNOx fuel injectors (Figure 9) are significantly larger than their conventional counterparts due to the higher airflow through the injector air swirlers and the required volume of the premixing chamber used to mix the fuel and air. The injector module includes a premixing main fuel injector, a pilot fuel injector, and in some cases a variable geometry system for part-load control purposes.

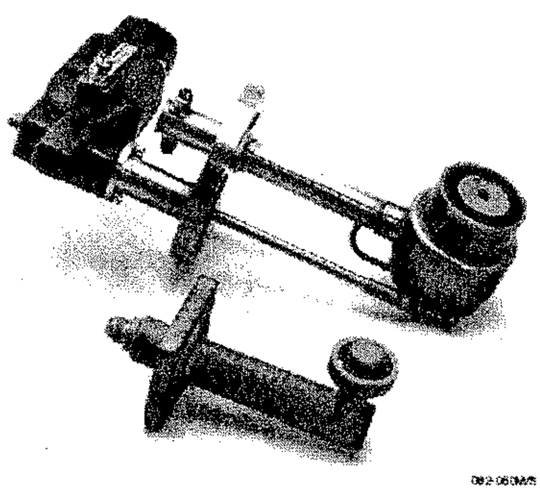


Figure 9. Comparison of SoLoNOx and Conventional Fuel Injectors

Main Fuel Circuit. The premixing main fuel injector uses an axial swirler to impart a high degree of swirl to the primary zone air. A series of multi-orificed, radial-fuel tubes injects natural gas fuel into air just downstream of the air swirler. Uniform mixing of the fuel and air occurs within the annular premixing chamber prior to reaching the combustor primary zone. The strong swirl stabilizes the combustion process in the primary zone by establishing a recirculation zone that draws reacted hot gases back upstream, thus providing a continuous ignition source. Above 50% engine load, the majority of the fuel (approximately 90 to 100%) is introduced through the main fuel tubes.

Pilot Fuel Circuit. The pilot fuel injector circuit is used mainly for lightoff and low-load operation. The pilot fuel injector consists of an air swirler and tangential fuel inlet ports to provide partial premixing of air and fuel prior to combustion. During lightoff and low-load operation, approximately 30 to 50% of the fuel passes through the pilot injector, providing a rich fuel/air mixture. Combustor stability is enhanced in this mode compared to lean-premixed operation, although NOx and CO emissions are higher. Above 50% engine load, the pilot fuel is reduced to less than 10% of the total fuel flow to optimize emissions performance. The pilot fuel is also momentarily increased during off-load transients to help stabilize the flame during the transient.

Variable Geometry Systems

Several variable geometry systems have been employed to avoid lean extinction and broaden the low emissions operating range of the lean-premixed *SoLoNOx* combustion system. Each technique provides control of the primary zone airflow to maintain the primary zone fuel/air ratio near its optimum low emissions level during part-load engine operation.

Casing Bleed. Two-shaft gas turbines used for gas compression and mechanical drives, bleed air from the combustor casing at part load. This method of variable geometry has proved effective in controlling the CO emissions while using the production bleed valve of conventional engines. A consequence of air bleed, however, is a deterioration in engine part-load thermal efficiency, since the compressed bleed air no longer enters the turbine section of the engine to produce power.

Inlet Guide Vanes. Single-shaft gas turbines used for power generation, maintain optimum primary zone fuel/air ratios by modulating the compressor IGVs. Closing the IGVs reduces the airflow through the engine compressor and combustor. No bleeding of high-pressure air is required.

Swirler Inlet Valve. In addition to casing bleed, *Centaur* 40S, *Centaur* 50S, and *Taurus* 60S gas turbine fuel injectors have a two-position swirler inlet valve (SIV) located upstream of the main air swirler, which is used to control the airflow into the combustor primary zone. This valve is pneumatically actuated from outside the combustor casing. In the open position, full airflow passes through the swirler. In the closed position, the slotted SIV reduces the primary zone airflow. By closing the SIV, the primary zone fuel/air ratio is changed in a step-wise fashion. Additional low emissions combustor operating range is obtained without any heat rate penalty.

Engine Casings

Larger combustor casings are required for the *SoLoNOx* system due to the increased diameter of the combustor liner and larger fuel injectors. This larger combustor case also requires modification to the mating compressor diffuser and gas producer turbine cases. The overall length of the engine remains unchanged.

Control System

The *SoLoNOx* gas turbine control system is identical to the conventional gas turbine system at start-up and low-load operation, but differs when the gas turbine operates in the low emissions mode (above approximately 30 to 50% of the rated load). The control system for *SoLoNOx* engines modulates the variable geometry systems to keep the combustion primary zone temperature within a specified range. Accurate control of the primary zone temperature is critical to controlling NOx and CO emissions. Direct measurement of this temperature, which is greater than 1540°C (2800°F), over an extended period of time is impractical, however. Conventional gas turbines use the power turbine inlet temperature (T5) as an indirect measurement of the combustor exit or turbine inlet temperature. The *SoLoNOx* gas turbines also use this same T5 for control.

Fuel System

The natural gas fuel system for *SoLoNOx* gas turbines includes two separate fuel circuits: one for the pilot system and one for the main. Separate fuel manifolds are used to supply pilot and main gas to the respective fuel circuits of each fuel injector. The fuel flow split between main and pilot is controlled with a precision electronic valve on the pilot line. During start-up and low-load operation, high-flow rates of pilot are used. When the engine is in the low-emissions mode, the pilot fuel valve throttles the pilot valve to low levels. The low-pilot flow is used to stabilize the flame.

Initial Field Test Engines

The first prototype production *SoLoNOx* gas turbines used in gas transmission service were installed at customer field evaluation sites in 1992. A *Centaur* 50S gas turbine, rated at 4100 kW (5500 hp), was installed at the El Paso Natural Gas Company (EPNG) Window Rock Station near Window Rock, Arizona (Figure 10). In mid-1992, a *Mars* 100S gas turbine, rated at 10 500 kW (14,000 hp), was installed at the Pacific Gas Transmission (PGT) station near Rosalia, Washington.

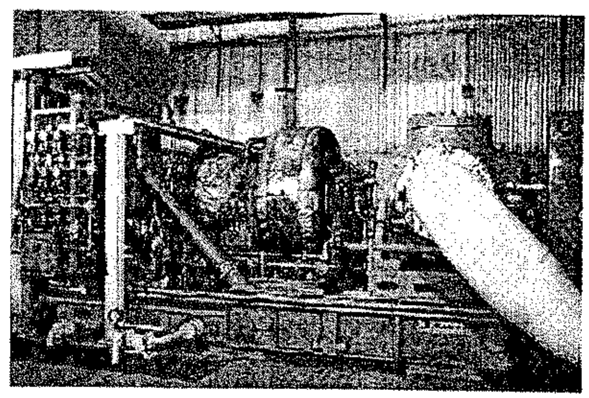


Figure 10. Centaur 50S Engine Installed at EPNG, Window Rock Station, Arizona

Production Engines

Production *Centaur, Taurus, Mars* and *Titan SoLoNOx* gas turbines are now in service as prime movers for gas transmission, mechanical-drive applications, and power generation throughout the U.S., Canada, Europe, and Japan. These engines have demonstrated the capability of meeting the emissions guarantees at ambient temperatures between -20°C (0°F) in Canada and 50°C (120°F) in the Arizona/California desert. Operation has also been successful on lower Btu fuels such as the

Dutch Groningen gas, but with slightly higher CO emissions than natural gas. The experience to date has shown excellent durability of the *SoLoNOx* combustion hardware. Inspections of the high time engines indicate that these engines will have life expectancies equivalent to Solar's conventional engines. Table 1 presents a compilation of *SoLoNOx* engine operating experience.

Table 1. SoLoNOx Experience through June 2001

Type	Units Sold	Estimated Hours
Centaur 40	88	2,910,000
Centaur 50	102	1,130,000
Taurus 60	335	6,080,000
Taurus 70	127	1,180,000
Mars 90/100	180	2,475,000
Titan 130	38	63,000
Total	**870**	**13,838,000**

Dual Fuel Capability

The need to provide low emissions dual fuel capability for power generation applications presents its own set of complexities and technical challenges. The injector designs (Figure 11) become physically complex and the operability issues relative to long-term injector durability and maintenance are challenging.

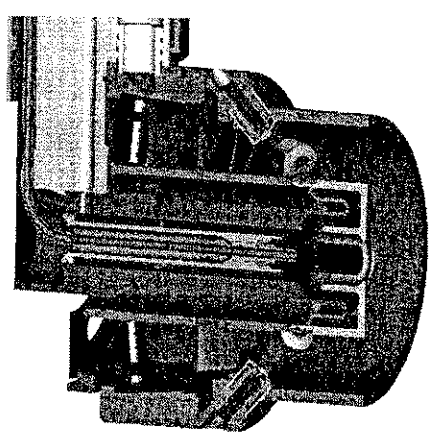


Figure 11. Typical Dual Fuel Injector Design

Solar has been building field experience with dual fuel *SoLoNOx* capability since 1995. There are now more than 100 dual fuel, low-emissions engines successfully operating in the field.

The major technical challenge is injector coking, in steady-state operation as well as during fuel transfers. Over the last two years, significant improvements have been made in the capability of the associated purge systems and a number of enhancements required in fuel handling have been defined. The current injector design and development efforts are focused on long-term coking issues with the high temperature and pressure environment in which the injector operates, while continuing to focus on lower emissions capability on liquid fuel.

MAINTAINING PRODUCT STABILITY

It is understandable that one might assume that *SoLoNOx* is a mature *Solar* gas turbine technology, since nine years have passed and hundreds of turbines have been installed since 1992. Yet, numerous forces have been at work over this period that have required *SoLoNOx* to evolve technically. A look to the future suggests that these same forces will continue to act. To continue to meet market requirements, *SoLoNOx*, as well as other dry low emissions (DLE) systems, will have to evolve. The forces that are driving the evolution of *SoLoNOx* include:

- Continuing need to reduce NOx emissions to meet increasingly strict air quality regulations.
- Promulgation of increasingly strict CO emissions limits.
- Market desire for dual fuel capability (natural gas and No. 2 distillate) at many power generation sites and the growing desire to use a broad range of alternate fuels that need to have no visible smoke when operating on liquid fuels, even during transient operation.
- Product cost reductions.
- Need to uprate engine performance over time to meet customer requirements.
- Desire to introduce new turbine products to provide a more diversified product line.

- Ability to address technical "surprises" that arise during product introduction or extended operation in the field. A prime example is the occurrence of unacceptably high combustor pressure oscillations, which have forced combustion system design changes throughout the entire gas turbine manufacturing community.

In this environment of ever-changing driving forces, it is unlikely that low-emissions combustion systems will be able to maintain complete design stability.

Combustor Performance Functions

A well-designed gas turbine combustor must satisfy a wide range of performance criteria. The primary goal of achieving essentially 100% combustion efficiency is only one of many requirements. Other requirements include:

- Producing a specific radial exit temperature profile in the gas flow delivered to the turbine section of the engine.
- Having a generally uniform circumferential exit temperature (as reflected in the pattern factor) to ensure turbine nozzle durability.
- Having sufficient operating stability to permit engine light-off and acceleration to full-load conditions.
- Providing combustion stability during large on-load and off-load transients operating without excessive combustor pressure oscillations.
- Maintaining sufficiently low material temperatures to meet durability requirements (30,000 hours for Solar) even under highly cyclic operating conditions.
- Burning widely different fuels (gases and liquids) in gas only and dual fuel systems.
- Avoiding coking of combustor components during liquid fuel operation.
- Functioning acceptably with engine inlet temperatures that may range from 0°F to over 120°F.
- Functioning acceptably in different configurations of the same turbine product. For example, gas turbines for power generation have different operating characteristics than engines for mechanical drive applications. In addition, operating characteristics may vary in engines that are specifically designated to operate at extremely hot or extremely cold customer sites.
- Meeting all of the above requirements while maintaining trace emissions concentrations (NOx, CO and UHC) at low, parts per million levels.

Clearly, combustor development can be a challenging activity, particularly when stringent emissions requirements exist. Compounding this challenge is the complexity of the gas turbine combustion process. The combustion process involves highly turbulent, reacting, high temperature, two-phase (for liquid fuels) flows that defy accurate quantitative modeling. Consequently, commercial combustor development always involves an iterative process of analysis, design, and performance testing.

Meeting Emissions Guarantees

Although gas turbine output, efficiency and cost are the most important considerations for the majority of turbine operators, emissions have become a "gate" through which turbines must pass to compete in emissions-sensitive markets.

Simplistically, the turbine manufacturer has two emissions-related milestones that must be met to ensure a viable low emissions product. First, the turbine manufacturing process must be sufficiently repeatable to ensure that new engines consistently meet their emissions guarantees during both pre-shipment testing and engine start-up at the customer's site. In addition, the manufacturer must establish a design that is sufficiently robust to meet emissions guarantees over an extended period of operation at the customer's site.

Meeting Emissions Guarantees at the Factory

By and large, the major challenge in routinely meeting emissions guarantees with new engines relates to airflow management within the turbine. Production processes and tooling must be maintained so that the precise airflow distribution required within the engine is achieved. This includes the percentage of air flowing to the fuel injectors, the liner and through other passages used to cool turbine components downstream of the combustor. Manufacturing variations in any of the injector flow areas (there are 12 to 14 nominally identical injectors in Solar's low emissions engines), in the open area of the combustor liner, or in the orifices used to control turbine cooling will have a direct impact on the flame temperature in the primary zone of the combustor. Since NOx emissions are exponentially sensitive to flame temperature, airflow distribution is critical in meeting emissions guarantees. If too much air passes through the one or more of injectors, CO emissions may be excessive. If too little air enters the combustor through the injectors, NOx emissions may be higher than guaranteed.

Other factors that influence the emissions achieved with new turbines include:

- Uniformity with which fuel is delivered to each of the 12 to 14 injectors. Non-uniform fuel flows will lead to non-uniform flame temperatures in the combustor. High local flame temperatures will contribute to high NOx while low temperature zones may cause excessive CO emissions.
- Variable rates of air leakage through seals between the combustor and other engine components can lead to air maldistributions. Seals must provide for differential thermal expansion between engine components without allowing excessive air leakage through the seal.

One final phenomenon that impacts engine test success relates to the occurrence of unacceptably high combustor pressure oscillations. Combustor oscillations tend to be of the "rumble" type (below 100 Hz) or of the "buzz" type (200 to 500 Hz). Excessive oscillations can lead to higher levels of emissions and, ultimately, liner component failure due to high-cycle fatigue. At the present time, the elements of combustor design that lead to high amplitude oscillations are receiving significant attention in the industry and are becoming better understood.

The primary means of combating oscillations is through the use of pilot flames to enhance the stability of the main flames downstream of each fuel injector. In cases where oscillations occur, the amount of fuel needed for the pilot injectors varies from engine to engine. This is largely a reflection of manufacturing variability. In extreme cases, the pilot fuel required to dampen oscillations may be so large as to push NOx emissions above guaranteed levels. Combustor pressure oscillations are undoubtedly the most frustrating characteristic of lean-premixed combustion systems. Two engines, nominally identical, may have very different levels of oscillations. Attempts to correlate oscillations with engine hardware characteristics (manufacturing variances) have not been completely successful.

Meeting Emissions Guarantees in the Field

The sensitivity of emissions to combustor and engine component design features was discussed above. From that discussion, it is clear that degradation in the combustion system components through extended operation in the field may also impact emissions. The potential mechanisms for emissions degradation are many, including:

- Poor fuel quality that contaminates fuel valves and injector passages, compromising performance of these components.
- Poor air quality and/or maintenance practices that lead to excessive compressor blade fouling.
- Mechanical failures of bleed valve actuators and fuel system valving.
- Fretting of component interfaces that leads to increased air leakage with time.
- Blockage of liquid fuel ports or the degradation of liquid fuel injection patterns due to coking.
- Fuel leakage within the injectors due to thermal or mechanical stresses. The need for dual fuel injectors to have gas and liquid fuel main passages, gas and liquid fuel pilot passages, and a pilot air passage makes these injectors very complex.

Since component life is affected by turbine duty cycle, so too are emissions. Engines experiencing frequent cyclic loading and engines operated at peak conditions can be expected to show degradation in hardware more rapidly and have a higher potential for undesirably high emissions.

Additionally, regarding turbine component degradation with time, two other factors may be significant in causing turbine emissions to be different in the field from emissions measured at the factory. First, a wider variation in ambient temperatures at the operator's site will almost always occur relative to Solar's test venue in San Diego. Extremely hot or cold ambient conditions will impact NOx and CO emissions. In addition, since natural gas and No. 2 diesel are not pure fuels, fuel composition variations can cause variations in emissions levels. This may not only occur between two different test sites, but also at an operator's site where significant fuel composition variations occur over the life of the engine.

Product Stability Status

Based on the rapidly growing experience base with lean-premixed combustion systems, gas turbine manufacturers are now well aware that emissions are extremely sensitive to a number of factors, some of which are beyond the control of the manufacturer. These factors include:

- Combustor and engine design parameters
- Manufacturing variability
- Ambient conditions
- Fuel composition variations
- Component degradation over time
- Fuel quality (contaminants)
- Engine duty cycle
- Combustor pressure oscillations

The development of robust low emissions gas turbines across a product line is now fully appreciated as the formidable task that it is. Low emissions turbine development in a regulatory environment in which the emissions targets are changing with time and are established on a regional basis adds additional complexity to an already complex task. Manufacturers have to stretch their development resources to address issues at two levels. At the first level, the challenge is to maintain a growing fleet of engines and assure that current emissions regulations can be met. At another level, resources are needed to continue technology development for the stricter emissions requirements that are anticipated for the future, but not quantified definitively (either control level or implementation date). Virtually every aspect of gas turbine manufacturing is in a cascade effect (Figure 12). The engineering and manufacturing challenges are considerable. The costs to the manufacturer are much greater than the cost increments reflected on the engine price tag.

In light of the now recognized technical challenges, the progress made in the last nine years in reducing gas turbine NOx emissions from hundreds of parts per million to under 25 ppm should be recognized as a major technical achievement and a significant factor in improved air quality. However, the regulatory trend towards ever-lower emissions levels is driving the development of further advancements in combustion system technologies.

ADVANCED COMBUSTION TECHNOLOGIES

In response to the trend toward more stringent emissions regulations, gas turbine manufacturers are assessing their current lean-premixed systems to establish viable combustion system technology enhancements. The areas that exhibit the greatest potential for lower emissions include advanced combustor liners, more effective variable geometry systems, integration of control systems, and alternative combustion processes.

Advanced Combustor Liners

The present generation of lean-premixed combustors primarily uses film cooling to maintain acceptably low combustor wall temperatures. Film cooling involves the passage of cooling air through holes in the liner and the formation of a cooling film on the hot side of the liner using internally positioned louvers.

Research has shown that the method used to cool a lean-premixed combustor liner can have a significant effect on emissions. Specifically, conventional film cooling can lead to reaction quenching at the combustor primary zone wall. This quenching process leads to high CO emissions because the CO, a combustion intermediate, is prevented from oxidizing to CO_2. The quenching is traceable to the injection of a relatively large flow of cooling air into the primary zone.

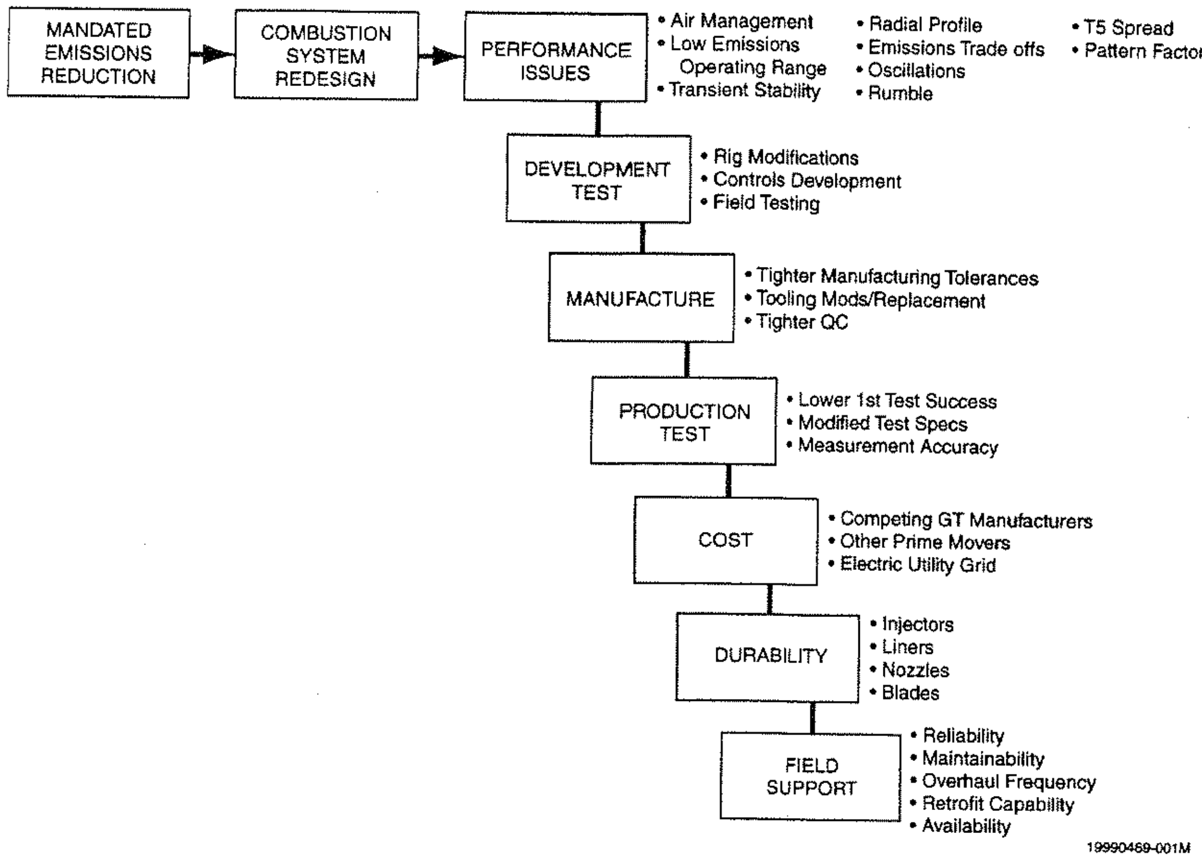


Figure 12. Cascading Effects of Reduced Emissions Limits

The development of an advanced liner with a "hot wall" that does not promote reaction quenching will provide a two-fold benefit in terms of emissions. First, of course, CO emissions will be reduced. Additionally, the lower CO levels will allow combustor reoptimization to a lower flame temperature. This will produce lower NOx levels along with the lower CO concentrations, as illustrated in Figure 13.

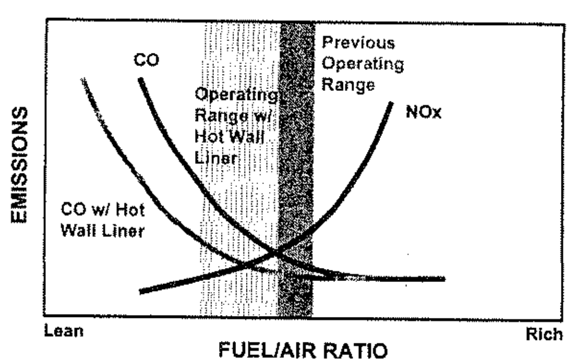


Figure 13. ABC Combustor Cross Section

Development work is ongoing in an effort to mitigate the reaction-quenching characteristic of film cooling. Technologies being studied include both augmented backside cooled (ABC) and ceramic combustor liners.

Augmented Backside Cooled Liners

ABC liners forego cooling air injection completely. Instead, combustor wall temperatures are controlled solely through convective cooling by a high velocity airstream on the cold side of the liner (Figure 14). In most instances, the high heat flux from the flame requires augmenting of the backside convective process to keep liner wall temperatures from becoming excessive. Turbulators in the form of trip strips, fins, and pins act to increase the cooling flow turbulence at the liner wall and augment the heat removal process. An alternative approach is to use impingement cooling with cooling flows through the outer convector.

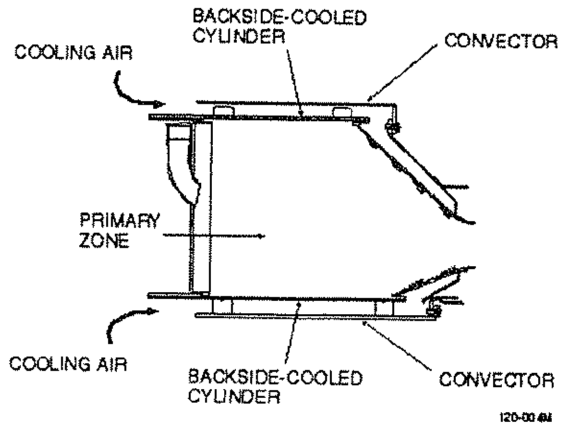


Figure 14. ABC Combustor Cross Section

Although effective in reducing CO formation through quenching, backside cooling is a challenge to implement because of the high flame temperatures and heat fluxes associated with gas turbine combustors. An additional degree of liner protection can be achieved through the application of a thermal barrier coating (TBC) on the hot sides of the liner walls. These TBCs are frequently composed of zirconia-based materials that are plasma-sprayed on the liner. A typical TBC coating of approximately 0.25 mm (0.01 in.) can reduce wall temperatures by approximately 40C° (72F°).

Ceramic Combustor Liners

The ceramic combustor addresses the CO quenching issue in the same manner as the ABC liner. Cooling air injection through the liner is avoided, thus providing potential emissions benefits. These emissions benefits have been found to be very similar to those of the ABC combustor.

In the ceramic combustor configuration employing a continuous fiber ceramic composites (CFCC) design, the inner and outer combustor cylinders, which form the combustor primary zone, have been redesigned to incorporate CFCC cylinders. The ceramic cylinders are housed within metallic cylinders that bear the structural and pressure loads on the assembly.

The advantage of the ceramic combustor versus an ABC combustor is that ceramic materials can tolerate higher temperatures. Typical CFCC materials are expected to give good service at liner temperatures near 1100°C (2011°F) as opposed to the 850°C (1560°F) limit for typical metallic combustor liners. Monolithic ceramics can tolerate even higher temperatures, but are characteristically brittle. Currently, the high risk of turbine damage from these brittle materials effectively precludes their use in an industrial gas turbine.

Although CFCCs can tolerate higher temperatures, when used as a combustor material they still require cooling. Back-side cooling of the primary zone CFCC cylinders is needed to moderate wall temperatures for good durability. Use of a metallic housing for the CFCC liners makes it more difficult to achieve adequate CFCC cooling.

Development Status

Initial development work on both the ABC combustor and ceramic combustor has been directed at the *Centaur* 50 gas turbine in a joint Solar/U.S. Department of Energy (DOE) program. One of the primary program goals is to explore the potential for lower emissions using these advanced combustor technologies.

The ABC combustor utilizes a backside-cooled primary zone with the dome and dilution sections maintaining the current production metal configuration (Figure 15). A yttria-stabilized zirconia TBC is applied to the hot sides of the two primary zone cylinders.

Testing to date has been very successful. A short in-house gas turbine test documented performance and acceptable wall temperatures was completed to evaluate the TBC spalling

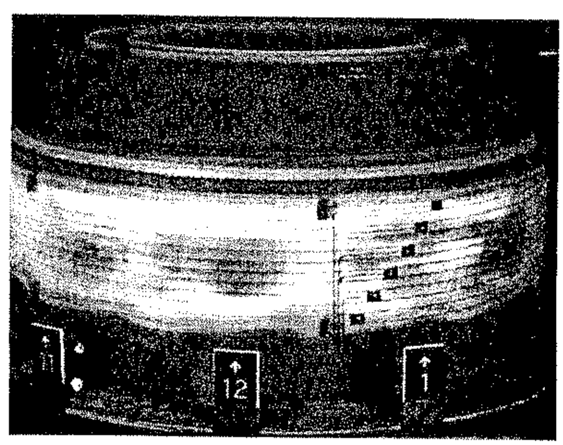


Figure 15. ABC Combustor for Centaur 50S Gas Turbine

at full-load conditions. A 50-hour cyclic test resistance. Results from both tests were encouraging and significant emissions reductions with this liner design observed. Figure 16 presents typical ABC liner emissions data.

At the present time, a field test of a production prototype *Centaur* 50 ABC combustor is ongoing. The field test will demonstrate performance over an extended time period and over a wider range of turbine operation. More than 22,000 hours of successful operation have been logged.

The prototype ceramic combustor design parallels the ABC design (Figure 17). The primary zone combustor cylinders of the production *Centaur* 50 gas turbine liner were replaced with SiC CFCC cylinders manufactured by DuPont Lanxide and B.F. Goodrich. The combustor has undergone extensive testing.at Solar in both combustor rigs and an in-

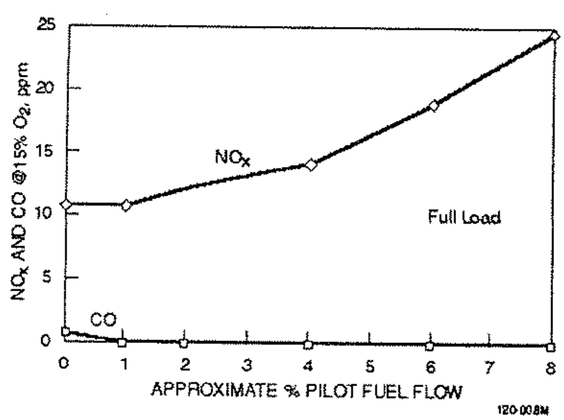
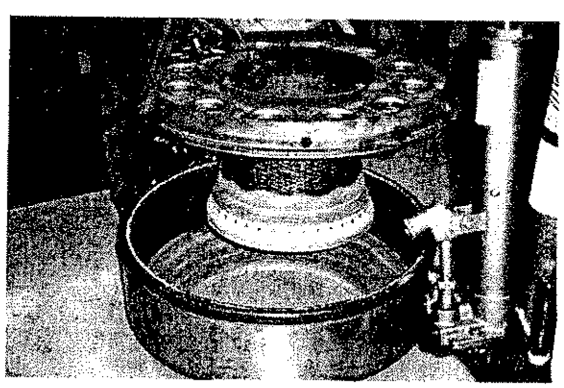


Figure 16. Typical ABC Liner Emissions (Full Load)



120-009M/S

Figure 17. CFCC Liner for Centaur 50S Gas Turbine

house gas turbine. The testing has documented that the CFCC combustor meets all performance goals established for the liner and has emissions essentially identical to the ABC combustor.

At this point, the development focus is on CFCC material durability. In a 4000-hour field evaluation, the CFCC cylinders showed a moderate degree of oxidation. It has been determined that the 1200°C (2190°F) temperature limit specified early in the program for these materials is too high for a gas turbine environment. Design modifications have been completed to augment the cooling of the CFCC cylinders and drop the temperatures to the 1100°C (2011°F) level. Durability is expected to increase at the lower temperature. Field testing of this combustor design is underway.

In general, Solar's development results have demonstrated a significant emissions advantage with the ABC combustor. This technology is now being implemented in *SoLoNOx* engines with the *Centaur* 50 and *Taurus* 60 gas turbines being the first engines to use the ABC liner.

Variable Geometry Systems

Variable geometry systems provide control over the airflow entering the gas turbine combustor primary and dilution zones. In a non-variable geometry combustion system, the flow split between the primary and dilution zones remains constant as turbine load varies. As a result, the operating range over which low emissions can be maintained is quite narrow. Varying the combustor airflow split allows the primary zone stoichiometry to be maintained at an optimum condition across a larger portion of the turbine load range. The ultimate benefit is a wider range of low emissions operation due to a finer degree of control over the combustion process.

Current lean-premixed gas turbines use compressor air bleed or IGV modulation to perform the variable geometry function. Although effective, both approaches have a negative impact. Air bleed results in a loss in turbine efficiency at part load. IGV modulation is suitable only for single-shaft gas turbines, where the compressor and gas generator are mechanically linked. In cogeneration applications, it can result in excessive boiler inlet temperatures at part-load conditions.

Variable power turbine nozzles also can be used to perform the variable geometry function. However, the use of modulating components in the high temperature turbine section raises gas turbine durability issues.

Development work is focused on a system that will enhance the performance of low emissions gas turbines at part load.

Controls Integration

A key element in achieving lower emissions in gas turbines is the further integration of the control system to more accurately control the combustion primary zone temperature (Tpz). Since the primary zone temperature is too high to measure directly, it has to be derived from a thermodynamic heat balance across the combustion system. The parameters used in this calculation are the compressor discharge temperature, the power turbine inlet temperature, the flow split between the combustor primary zone air and the total combustor airflow, and the ratio of the power turbine inlet temperature to the first-stage turbine inlet temperature (T3).

Development work to date has led to the use of electronic actuators and variable pilot circuit controls. The long-term vision is to incorporate closed-loop controls with on-line, real-time sensing of NOx and CO levels. The shorter-term activity is focused on developing and improving the accuracy of the control algorithms necessary to control Tpz over the required load and ambient ranges.

Catalytic Combustion

The success of the first-generation lean-premixed combustion system has established that the technology is well-suited to meet NOx emissions levels as low as 25 ppmv. Development test data and production system performance suggest that lean-premixed combustion has the potential for even lower NOx levels. Lean-premixed combustion should be capable of meeting 15 ppmv NOx limits and perhaps limits as low as 9 ppmv. However, for a 9-ppmv NOx lean-premixed system, there may be significant load-range restrictions on the gas turbine, particularly if CO emissions limits are reduced from today's requirements. To achieve NOx emissions levels in the low, single-digit range and not compromise turbine performance, it may be necessary to find an alternative to lean-premixed combustion. Catalytic combustion, or some yet to be recognized technology, will be necessary at the 3-ppmv NOx level, a level that is beyond the capabilities of lean-premixed combustion.

Concept Description

Catalytic combustion produces extremely low NOx levels by operating at very low flame temperatures of 1250 to 1350°C (2280 to 2460°F). Catalytic combustor flame temperatures are below levels that can be sustained in a lean-premixed combustor. The major element of this ultra-low NOx technology is a catalytic reactor that initiates and stabilizes the combustion process at conditions not normally sustainable through homogeneous (lean-premixed) combustion. Catalytic combustor components for gas turbine applications are illustrated in Figure 18.

The catalytic system has a number of features that are reminiscent of lean-premixed combustion and, in fact, a catalytic combustor can correctly be considered a catalytically stabilized, lean-premixed system. A typical catalytic combustor includes the following components: preburner, fuel injection/premixing section, catalytic reactor, homogeneous burn-out zone, part-load injector, and variable geometry system. All but the preburner and catalytic reactor are found in some form in the lean-premixed combustor.

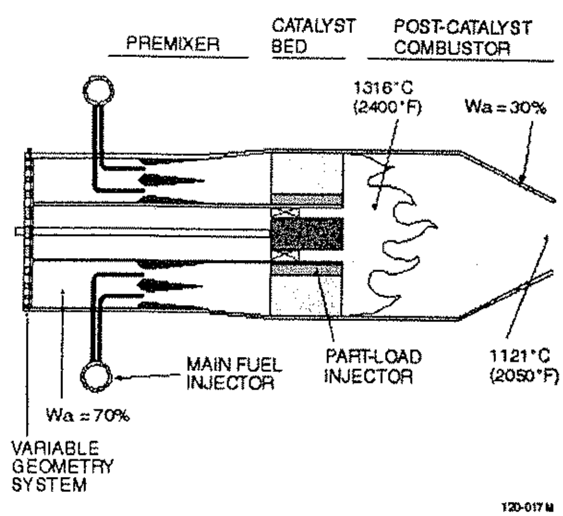


Figure 18. Catalytic Combustor Schematic

Although under development for nearly 20 years, catalytic combustion has yet to prove itself totally in a gas turbine environment. This is attributable to both unresolved technical issues and the lack of a significant market need. The state of catalytic combustion today is comparable to the status of lean-premixed combustion 10 years ago. Significant rig testing is ongoing, but the technology has not yet progressed to the long-term field-test stage. Significant technology milestones in the areas of catalyst and substrate durability, system integration, and controls remain to be achieved. Additionally, the economics of the technology need to be established as acceptable for the catalytic combustor to succeed in the marketplace.

SUMMARY

Despite the great success of the first-generation low emissions gas turbines in lowering NOx emissions, manufacturers are dealing with the reality of even more stringent emissions regulations. Gas turbine manufacturers are working to improve the lean-premixed combustion systems used in current low emissions gas turbines and develop new and cleaner combustion technologies.

Improvements being advanced for lean-premixed combustion systems include advanced liner cooling technologies and more effective variable geometry systems. These technologies are well along in their development and are nearing or are already in the field-test stage. Full commercialization will depend upon a combination of technical success, market need, and economics.

Experience with lean-premixed systems over the last few years indicates that there is a practical lower NOx limit associated with lean-premixed combustion. This limit appears to be in the 5-to-15 ppmv range. To achieve NOx levels below this through low emissions combustion, gas turbine manufacturers are looking to catalytic combustion as the most likely candidate.

One issue affecting the development of advanced gas turbine combustion technology is the uncertainty in emissions levels that will be required in the future and a timeline for their implementation. Manufacturers are unable to focus development resources cost effectively on well-established emissions targets, but must broaden development efforts to meet a range of emissions constraints. With limited resources available, this results in a slower pace of technology development.

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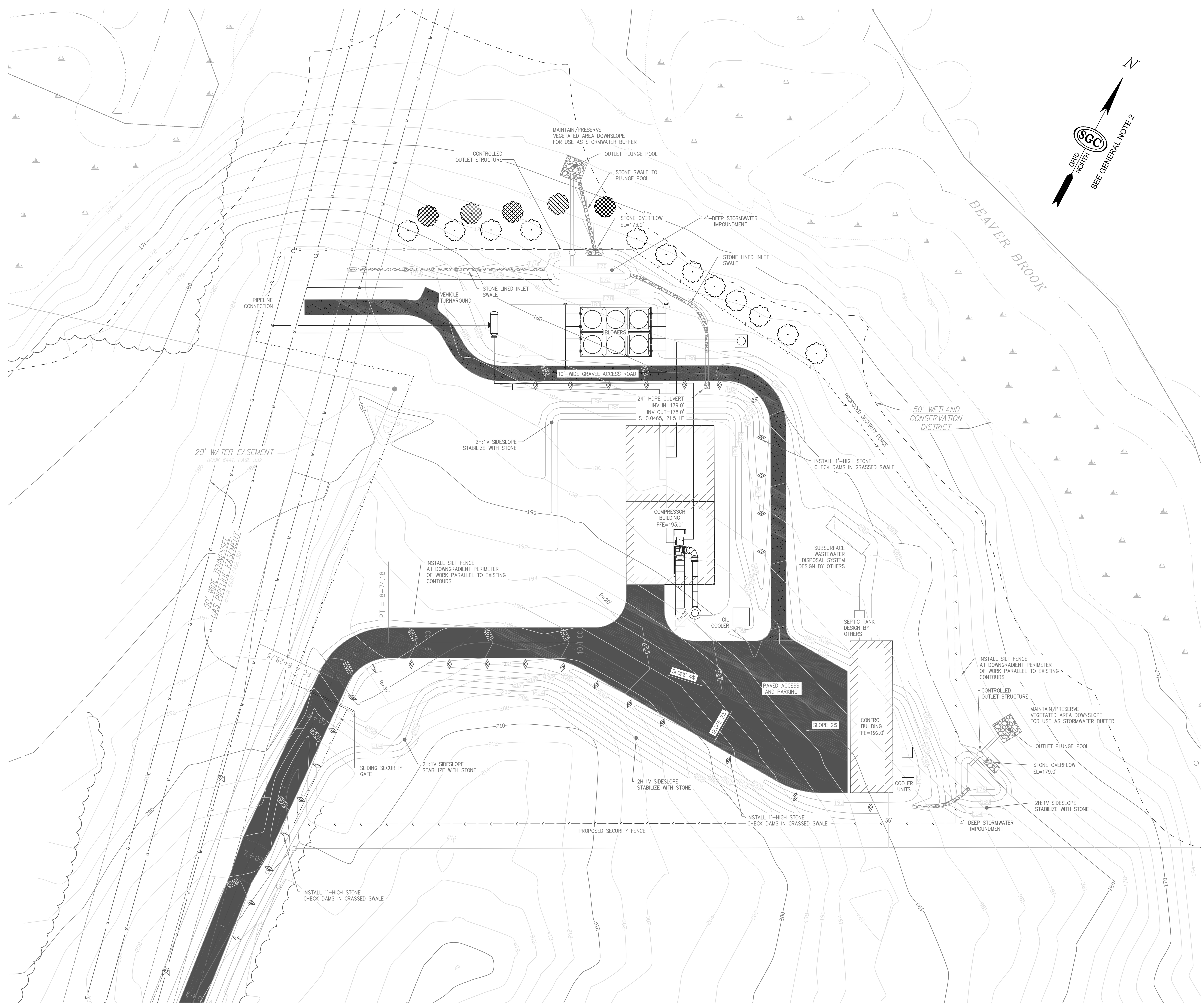

GENERAL NOTES:

1. THIS DRAINAGE AND GRADING PLAN WAS PREPARED BY SGC ENGINEERING, LLC PURSUANT TO A PROFESSIONAL SERVICES CONTRACT BETWEEN EL PASO CORPORATION AND SGC ENGINEERING LLC, DATED MARCH 19, 2008
2. NORTH SHOWN HEREON IS GRID NORTH BASED ON UTM ZONE 19, NAD83, US SURVEY FEET.
3. ELEVATIONS SHOWN HEREON ARE REFERENCED TO NAVD88, US SURVEY FEET.
4. EXISTING FEATURES SHOWN ON THIS PLAN ARE THE RESULT OF A FIELD SURVEY CONDUCTED BY SGC ENGINEERING, LLC ON JULY 12–20, 2007.
5. WETLANDS SHOWN HEREON WERE FIELD LOCATED BY SGC ENGINEERING, LLC. THE AREA WITHIN FIFTY FEET OF THE DELINEATED WETLANDS SHOWN HEREON ARE PART OF THE WETLAND CONSERVATION DISTRICT, NO CUTTINIG IS ALLOWED WITHIN THIS DISTRICT.

PLAN REFERENCES:

1. BOUNDARY, TOPOGRAPHIC AND PLANNIMETERIC MAPPING AS SHOWN ON THIS PLAN IS REFERENCED TO A PLAN ENTITLED "BOUNDARY AND TOPOGRAPHIC SURVEY OF PROPERTY LOCATED ON INDUSTRIAL PARK ROAD, PELHAM, HILLSBOROUGH COUNTY, NH, PREPARED FOR EL PASO CORPORATION, BY SGC ENGINEERING, LLC, DATED 07/07/2007.
2. SITE LAYOUT OF GAS UTILITY BUILDINGS AND INFRASTRUCTURE BY EL PASO CORPORATION.
3. PRELIMINARY CIVIL DESIGN AND LAYOUT BY EL PASO CORPORATION.

LANDSCAPE PLAN NOTES:

1. REMOVAL OF EXISTING INDIVIDUAL LARGE TREES IN TEMPORARY WORKSPACE WILL BE EVALUATED BY ENVIRONMENTAL INSPECTOR AND PIPELINE CONTRACTOR ON A CASE-BY-CASE BASIS, AND REMOVAL WILL BE MINIMZED TO THE EXTENT PRACTICABLE. TREES THAT CAN BE RETAINED WILL BE MARKED AND PROTECTED. PLANTING AND RESTORATION WILL ACCOMMODATE THE PRESENCE OF THE TREES OR VEGETATION THAT ARE NOT REMOVED.
2. ASSUME PLANTING DENSITY OF 15 FEET ON CENTER IN TEMPORARY WORKSPACE OUTSIDE OF PERIMETER FENCE OR PLANT PLACEMENT TO ACHIEVE DESIRED VISUAL SCREENING.

RECOMMENDED PLANTING LIST:

COMMON NAME	SCIENTIFIC NAME	SIZE
EASTERN WHITE PINE	PINUS STROBUS	8–9'
AMERICAN ARBORVITAE	THUJA OCCIDENTAILIS VAR. NIGRA	9–10'
RHODODENDRON	ROHODODENDRON CATAWBIENSE VAR. BOURSAULT	4–5'

ENSR | AECOM

LEGEND

EXISTING

- LOCUS PROPERTY LINE
- ADJACENT PROPERTY LINE
- EASEMENT
- WETLAND CONSERVATION DISTRICT LIMITS
- GRADE CONTOUR
- STREAM CENTERLINE
- GAS PIPELINE
- WATER MAIN
- EDGE OF WATER
- WETLANDS
- PROPERTY MONUMENTS
- TEST PIT
- WATER VALVE
- GAS MARKER

PROPOSED

- BUILDING
- FENCE
- PAVEMENT
- GRAVEL
- SILT FENCE
- ROAD CENTERLINE
- GRADE CONTOUR
- CULVERT
- STONE CHECK DAM
- RIP RAP
- SPOT GRADE
- TEMPORARY CONSTRUCTION ENTRANCE
- AMERICAN ARBORVITAE
- WHITE PINE

REVISIONS:

NO.	DATE	
0	---	CLIENT REVIEW
1	06-20-2008	NH DES RESPONSE

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HOUSTON, TEXAS 77002

DATE: 04/11/2008	DRAWN: NRP	PROJECT.: 628001
DESIGN: NRP	CHECK: JMR	FILE.: SITE_628001

TITLE:
LANDSCAPING AND SITE SCREENING PLAN
COMPRESSOR STATION 270B1
CONCORD EXPANSION PROJECT
PELHAM, NEW HAMPSHIRE

SCALE: 1" = 30'

SHEET: 1.0

May 2, 2006

Ms. Elizabeth Danehy Arangio
KeySpan Energy Delivery
52 Second Avenue
Waltham, MA 02451

Dear Liz

Pursuant to your request for additional capacity on Tennessee Gas Pipeline Company's ("Tennessee") Concord Lateral. Tennessee has prepared cost estimates for compression to expand the lateral capacity. From these cost estimates, Tennessee has performed preliminary analyses for two scenarios under which Tennessee would be willing to fully subsidize the construction of the facilities required to provide the requested service. To keep KeySpan Energy Delivery ("KeySpan") informed and begin the discussions concerning the Concord Lateral expansion, Tennessee is pleased to provide the following information:

<u>Scenario 1 – 20,000 Dth/d</u>

Highlights

1. KeySpan contracts for 20,000 Dth/d from Dracut receipt meter to Concord delivery meter.
2. Tennessee will construct a 3550 horsepower, mid-point compressor station.
3. Tennessee will expand the existing meter station to accommodate the additional volumes.

Contract Quantity (Dth/d)	20,000
Term	Twenty Years
Primary Receipt Point	Dracut
Primary Delivery Point	Concord
Demand Rate (Dth/d)	$0.47 ($14.30 Dth/month)
Commodity Rate	Maximum per Tariff
Fuel	Tariff for Zone 6 to 6
Estimated Capital (in millions)	$12.71

<u>Scenario 2 – 40,000 Dth/d Stair-Stepped</u>

Highlights

1. KeySpan contracts for a total 40,000 Dth/d from Dracut receipt meter to Concord delivery meter.
2. 20,000 Dth/d beginning in November 2008, with 5,000 Dth/d increases every 2 years
3. Tennessee will construct a 6130 horsepower, mid-point compressor station.
4. Tennessee will expand the existing meter station to accommodate the additional volumes.

Contract Quantity (Dth/d)	Year 1 – 2 20,000 Year 3 – 4: 25,000 Year 5 – 6: 30,000 Year 7 – 8: 35,000 Year 9 – 20: 40,000
Term	Twenty Years
Primary Receipt Point	Dracut
Primary Delivery Point	Concord
Demand Rate (Dth/d)	$0.43 ($13.08 Dth/month)
Commodity Rate	Maximum per Tariff
Fuel	Tariff for Zone 6 to 6
Estimated Capital (in millions)	$16.60

The above information is valid through May 31, 2006. Please note that this project will require an open season per Tennessee's Federal Energy Regulatory Commission ("FERC") Gas Tariff, execution of a precedent agreement, and filing of a 7(c) application with the FERC. As such, the earliest Tennessee can envision such a project being placed in-service is November 1, 2008, and that would depend upon the results of field surveys to determine the federal, state and local permits required to complete the project.

Any agreement resulting from our discussions is subject to El Paso Corporation management's approval and formal written agreements covering transportation service and facility construction on acceptable terms and conditions between KeySpan and Tennessee, as well as compliance with Tennessee's FERC Gas Tariff, including the General Terms and Conditions referenced therein and to all applicable laws, orders, rules, and regulations of duly constituted authorities having jurisdiction.

Tennessee is excited about working with KeySpan to meet its growth on the Concord Lateral. If you have any questions or would like to discuss the information, please do not hesitate to contact Andy Levine at (713) 420-2699 or Dodson Skipworth at (713) 420-2727. We look forward to your response.

Sincerely,

Andrew E. Levine
Manager, Business Development
Tennessee Gas Pipeline Company

Sincerely,

Dodson Skipworth
Marketing Manager
Tennessee Gas Pipeline Company

Tennessee Gas Pipeline
an El Paso company

January 16, 2007

Ms. Elizabeth Danehy Arangio
KeySpan Energy Delivery
52 Second Avenue
Waltham, MA 02451

Dear Liz:

On May 2, 2006, Tennessee Gas Pipeline Company ("Tennessee") provided KeySpan Energy Delivery ("KeySpan") a letter containing indicative costs and rates for Tennessee to create additional capacity on the Concord Lateral. Following the issuance of that letter, Tennessee and KeySpan have had several discussions about this project, culminating in KeySpan requesting that Tennessee provide up-to-date information. Pursuant to that request, Tennessee has completed further analysis to define the specifics of a project to expand the Concord Lateral and to provide refined and refreshed cost estimates. To keep KeySpan informed and continue the discussions concerning the Concord Lateral expansion, Tennessee is pleased to provide the following information:

Concord Lateral Expansion Scenario

Highlights

1. KeySpan contracts for 20,000 Dth/d from Dracut receipt meter to Laconia delivery meter.
2. Tennessee will construct a 4770 horsepower, Solar Centaur compressor station near Nausha.
3. Tennessee will expand the existing meter station to accommodate the additional volumes.

Contract Quantity (Dth/d)	20,000
Term	Twenty Years
Primary Receipt Point	Dracut
Primary Delivery Point	Laconia
Demand Rate (Dth/d)	$0.61 ($18.55 Dth/month)
Commodity Rate	Maximum per Tariff
Fuel	Tariff for Zone 6 to 6
Estimated Capital (in millions)	$17.83

Explanation of Changes from May 2, 2006

1. Cost – Tennessee has experienced an approximately twenty-five to thirty percent increase in both material and installation costs in the past eighteen months.
2. Compression – In consultation with its Environmental, Health & Safety Department, Tennessee has modified the compression design to include the installation of a 4770 horsepower, Solar Centaur unit. Because NH has RACT regulations, a Centaur is required to meet emission standards.
3. Land – Tennessee has determined that its existing land in the area is not sufficient nor in the proper location to site the proposed compression and will need to purchase an approximately fifteen acre track for placement of the station.

The above information is valid through March 12, 2007. Please note that this project will require an open season per Tennessee's Federal Energy Regulatory Commission ("FERC") Gas Tariff, execution of a precedent agreement, and filing of a 7(c) application with the FERC. As such, the earliest Tennessee can envision such a project being placed in-service is November 1, 2009 and that would depend upon the results of field surveys to determine the federal, state and local permits required to complete the project.

Any agreement resulting from our discussions is subject to El Paso Corporation management's approval and formal written agreements covering transportation service and facility construction on acceptable terms and conditions between KeySpan and Tennessee, as well as compliance with Tennessee's FERC Gas Tariff, including the General Terms and Conditions referenced therein and to all applicable laws, orders, rules, and regulations of duly constituted authorities having jurisdiction.

Tennessee Gas Pipeline
[illegible]
[illegible]
[illegible]

Tennessee is excited about working with KeySpan to meet its growth on the Concord Lateral. If you have any questions or would like to discuss the information, please contact Andy Levine at (713) 420-2699 or Dodson Skipworth at (713) 420-2727. We look forward to your response.

Sincerely,

Andrew E. Levine
Manager, Business Development
Tennessee Gas Pipeline Company

Sincerely,

Dodson Skipworth
Marketing Manager
Tennessee Gas Pipeline Company

Levine, Andrew E (Andy)

From: Levine, Andrew E (Andy)
Sent: Thursday, January 18, 2007 7:36 AM
To: Elizabeth Danehy Arangio
Cc: nculliford@keyspanenergy.com; tpoe@keyspanenergy.com; Skipworth, Norman D (Dodson)
Subject: RE: Revised Concord Lateral Information

Liz –
I apologize for any damage I caused from the shock. I'll attempt to explain the major drivers behind the cost increase, but will also be happy to discuss it with you as well.

Increase in material and labor costs - As you may already be aware, there has been a significant increase in the cost of materials and labor over the past two years. Not only have the costs increased, but the lead times to receive materials have expanded. We were able to mitigate some of this on CXN – NE by ordering compression earlier than originally estimated (with cancellation charges), but we are experiencing overruns on installation. We have included our latest information on material and installation costs in this revision to the information offering.

Compression utilized – The 5/2/06 memo contemplated the installation of reciprocating compressors, which are cheaper and can be more easily customized to the exact required horsepower. Upon being asked to revise the estimate, we brought in our Environmental, Health and Safety Department (Air Permit Specialist), who perform research on the requirements in NH to receive an air permit. Based upon the recommendation of EH & S, we have modified the design to include a single Solar Centaur (turbine), because this is the smallest unit that will meet NH's RACT regulations. This is a more expensive unit than the design utilized in the 5/2/06 letter.

Land to site the station – In the original letter, we anticipated using an existing small tract of land that TGP owns. Upon consultation with EH&S and a site visit, it was determined that this site was not acceptable. With the larger horsepower and change to turbine compression, the site is not large enough. Additionally, the parcel of land has an apartment complex adjacent to it, creating Noise Sensitive Areas (NSA's) in very close proximity. It would be difficult if not impossible to meet noise requirements with residents this close.

Meter change - It is my understanding that the Concord meter has not been utilized recently, is in disrepair, and is scheduled to be abandoned. With Laconia in the same yard, it was the logical replacement.

I hope this helps explain the causes of the increase. I attempted to include this information in the letter as I anticipated you would have questions. TGP is committed to pursuing all available options to serve KeySpan's requirements in NH. We're happy to discuss a negotiated rate proposal indexed to actual expenditures if you feel (as many people do) that the construction "bubble" in the energy business will burst before 2009. I've also ask my facility planner to determine if there is additional capacity that can be (or is) create from this compression with little on no additional cost. If there is, it will not reduce the overall cost but may average the rate down, if KeySpan is willing to subscribe for additional capacity.

If you have other ideas or would like to meet and brainstorm, Dodson and I would welcome the opportunity. Please call me so that I can answer additional questions or provide a more detailed explanation.

Sincerely,

Andrew E. Levine
Manager, Business Development
Tennessee Gas Pipeline Company
713.420.2699
cell 713.824.7522
fax 713.420.4343

From: Elizabeth Danehy Arangio [mailto:earangio@keyspanenergy.com]

Sent: Thursday, January 18, 2007 6:43 AM
To: Levine, Andrew E (Andy)
Cc: nculliford@keyspanenergy.com; tpoe@keyspanenergy.com; Skipworth, Norman D (Dodson); Elizabeth Danehy Arangio
Subject: Re: Revised Concord Lateral Information

Hi Andy,
How are you? Hope all is well.

I looked over the new information and after picking myself up from the floor, just wanted to touch base with you on a few things. First, I see you changed the delivery point from Concord to Laconia - why the change? Also, what are the drivers that contributed to the $5M increase?

I'm in the office all day today so if it's easier to give me a call - I'll be here - 781-466-5057.

Thanks,
Liz

Levine, Andrew E (Andy) wrote:

Liz/Nancy/Ted,
Happy New Year! Hope things are going well and you're enjoying these 3 days of winter we will receive this year. Attached please find refreshed information on the cost of a Concord Lateral Expansion. Please review the information and let Dodson or me know if you have questions. Call me when winter is over, or Friday, whichever comes first. Thanks.

Sincerely,

Andrew E. Levine
Manager, Business Development
Tennessee Gas Pipeline Company
713.420.2699
cell 713.824.7522
fax 713.420.4343

From: Pena, Marissa D
Sent: Tuesday, January 16, 2007 3:24 PM
To: Levine, Andrew E (Andy)
Subject:

Tennessee Gas Pipeline
an El Paso company

February 5, 2007

Ms. Elizabeth Danehy Arangio
KeySpan Energy Delivery
52 Second Avenue
Waltham, MA 02451

Dear Liz:

On May 2, 2006, and then updated on January 16, 2007, Tennessee Gas Pipeline Company ("Tennessee") provided KeySpan Energy Delivery ("KeySpan") with a letter containing indicative costs and rates for Tennessee to create additional capacity on the Concord Lateral. Following the issuance of the January 16, 2007 letter, Tennessee and KeySpan met to review the project specifics and determine the optimum expansion scenarios, culminating in KeySpan requesting that Tennessee provide a revised letter with the results. Additionally, it was decided at that meeting Tennessee should seek a more detailed estimate in the next two months with site specifics and contractor quotes to be in a position to make a formal offer to KeySpan.

Pursuant to KeySpan's request for documenting the latest expansion scenarios, to keep KeySpan informed and continue the discussions concerning the Concord Lateral expansion, Tennessee is pleased to provide the following information:

Concord Lateral Expansion Scenarios

20,000/d Case
Highlights:

1. KeySpan contracts for 20,000 Dth/d from Dracut receipt meter to Laconia delivery meter.
2. Tennessee will construct a 4770 horsepower, Solar Centaur compressor station near Nashua.
3. Tennessee will expand the existing meter station to accommodate the additional volumes.

Contract Quantity (Dth/d)	20,000
Term	Twenty Years
Primary Receipt Point	Dracut
Primary Delivery Point	Laconia
Demand Rate (Dth/d)	$0.60 ($18.25 Dth/month)
Commodity Rate	Maximum per Tariff
Fuel	Tariff for Zone 6 to 6
Estimated Capital (in millions)	$16.8

30,000/d Case
Highlights:

1. KeySpan contracts for 30,000 Dth/d from Dracut receipt meter to Laconia delivery meter.
2. Tennessee will construct a 4770 horsepower, Solar Centaur compressor station near Nashua.
3. Tennessee will expand the existing meter station to accommodate the additional volumes.

Contract Quantity (Dth/d)	30,000
Term	Twenty Years
Primary Receipt Point	Dracut
Primary Delivery Point	Laconia
Demand Rate (Dth/d)	$0.40 ($12.17 Dth/month)
Commodity Rate	Maximum per Tariff
Fuel	Tariff for Zone 6 to 6
Estimated Capital (in millions)	$16.8

Tennessee Gas Pipeline
1001 Louisiana Street Houston, Texas 77002
PO Box 2511 Houston, Texas 77252-2511
tel 713.420.2131

The above information should be considered valid through April 5, 2007 due to market changes in capital (material and construction) costs. Please note that this project will require an open season per Tennessee's Federal Energy Regulatory Commission ("FERC") Gas Tariff, execution of a precedent agreement, and filing of a 7(c) application with the FERC. As such, the earliest Tennessee can envision such a project being placed in-service is November 1, 2009, and that would depend upon the results of field surveys to determine the federal, state and local permits required to complete the project.

Any agreement resulting from our discussions is subject to El Paso Corporation management's approval and formal written agreements covering transportation service and facility construction on acceptable terms and conditions between KeySpan and Tennessee, as well as compliance with Tennessee's FERC Gas Tariff, including the General Terms and Conditions referenced therein and to all applicable laws, orders, rules, and regulations of duly constituted authorities having jurisdiction.

Tennessee is excited about working with KeySpan to meet its growth on the Concord Lateral. If you have any questions or would like to discuss the information, please contact Mike Stokdyk at (713) 420-2415 or Dodson Skipworth at (713) 420-2727. We look forward to your response.

Sincerely,

Mike Stokdyk

Mike Stokdyk
Manager, Business Development
Tennessee Gas Pipeline Company

cc: A. Levine
D. Skipworth

KEYSPAN ENERGY

52 Second Avenue, Waltham, MA 02451

FAX

Date: 3/19/07

Number of pages including cover sheet: 3

To: Mike Stokdyk

Company: TGP

Fax: 713/420-4343

From: Elizabeth Danehy Arangio

Phone: (781) 466-5057

Fax: (781) 290-0186

REMARKS: [ ] Urgent [ ] For your review [ ] Reply ASAP [ ] Please comment

Concord Lateral Expansion Project
NON-BINDING OPEN SEASON REQUEST FORM

This Request Form must be faxed or mailed to one of the following contacts and received by 11:00am CCT on Monday March 19, 2007:

Tennessee Gas Pipeline Company 1001 Louisiana Street Houston, TX 77002 Attn: Mike Stokdyk	Tennessee Gas Pipeline Company 1001 Louisiana Street Houston, TX 77002 Attn: Dodson Skipworth
Fax: (713) 420-4343	Fax: (713) 420-4343

SHIPPER INFORMATION

Shipper Name: EnergyNorth Natural Gas, Inc. d/b/a KeySpan Energy Delivery New Engl

Shipper Address: 52 Second Ave 4th floor
Waltham, MA 02451

Shipper Contact: Elizabeth Arangio

Title: Director

Telephone: 781-466-5057
Fax: 781-290-0186
Email: earangio@keyspanenergy.com

Shipper Type: (Circle one)
LDC / Producer / Marketer / Aggregator / Broker / End User
Other (describe) __________

TRANSPORTATION INFORMATION

Requested Term of firm contract: 20 years

A minimum term of twenty years is required. Tennessee will consider requests for terms shorter than twenty years. However, shippers contracting for such shorter terms may be asked to pay a rate adjusted to reflect such shorter terms. Term must be for a consecutive period. Tennessee currently intends to place this project in-service on or about November 1, 2009.

Firm Contract Commencement date: November 1, 2009

Receipt Point: Dracut, MA

Delivery Point: Laconia, NH

Delivery point is (circle one) Existing Proposed

Tennessee reserves the right to reject bids that would require the construction of facilities beyond those described herein.

A separate Request Form must be submitted for each bid (i.e., for each separate receipt/delivery point combination requested). Only physical points may be specified.

Maximum Daily Quantity: 30,000 Dth/d, exclusive of fuel.

Additional information / comments in support of bid

Submitted by: Elizabeth Arangio

Title: Director

Telephone: 781-466-5067 / 617-20-1790

Fax: 781-290-0186

Signature: [signature] Date: 3-19-07

PRECEDENT AGREEMENT

This Precedent Agreement ("Agreement") is made and entered into effective as of the 29 day of August, 2007 by and between TENNESSEE GAS PIPELINE COMPANY, a Delaware corporation, herein called "Transporter," and Energy North Natural Gas, Inc. d/b/a KeySpan Energy Delivery New England, a New Hampshire corporation, herein called "Shipper."

WHEREAS, Transporter owns and operates an interstate natural gas transmission pipeline system that extends in a northeasterly direction from the gas supply area in Texas, Louisiana, and the offshore Gulf of Mexico; through the States of Texas, Louisiana, Arkansas, Mississippi, Alabama, Tennessee, Kentucky, West Virginia, Ohio, Pennsylvania, New York, New Jersey, Massachusetts, New Hampshire, Rhode Island, and Connecticut ("Transporter's System"); and

WHEREAS, on February 15, 2007, Transporter initiated an open season for additional firm transportation service from the interconnection of Tennessee's system with the Maritimes and Northeast Pipeline system at Dracut, Massachusetts ("Dracut Interconnect") to delivery points on Transporter's Concord Lateral ("Concord Open Season") in connection with the proposed Concord Lateral Expansion Project (the "Project"); and

WHEREAS, Shipper participated in Transporter's Concord Open Season for additional firm capacity and requested Transporter to provide it long-term firm natural gas transportation service; and

WHEREAS, Shipper acknowledges that the rendition by Transporter of the firm natural gas transportation service requested by Shipper may require Transporter to construct certain facilities (the "Project Facilities") on Transporter's System.

NOW, THEREFORE, in consideration of the mutual covenants and agreements contained herein, Transporter and Shipper agree as follows:

1. Transporter agrees, subject to the satisfaction of the conditions set forth herein, to construct the necessary Project Facilities to render firm transportation service for Shipper at the applicable rate selected by Shipper below and pursuant to a firm transportation agreement ("Firm Agreement") between Transporter and Shipper, which Firm Agreement shall be in a form substantially similar to Exhibit A hereto.

2. Subject to the terms and conditions of this Agreement, Transporter and Shipper agree to execute and deliver the Firm Agreement, in accordance with the provisions of Section 11 of this Agreement, pursuant to which Transporter shall transport and deliver for Shipper on a firm basis up to 30,000 dekatherms ("Dth") of natural gas per day. Service thereunder shall commence on the latter of November 1, 2009, or the date on which Transporter is able to render service to Shipper under the Project (the "Commencement Date"), for a primary term ending twenty years from the Commencement Date, from the receipt point as specified in Section 3 below ("Receipt Point") to the delivery point as specified in Section 3 below ("Delivery Point").

3. The Receipt Point shall be Dracut, Massachusetts; meter #12538. The Delivery Point shall be Laconia, New Hampshire ; meter #20426.

4. Transporter shall have the right to reduce the transportation quantity specified in Section 2 above if that reduction is necessary, in Transporter's sole discretion, to render the overall Project or any applicable portion of the Project economic. Transporter shall have the right to either terminate this Agreement or reduce the transportation quantity specified in Section 2 if, in Transporter's sole discretion, such termination or reduction is necessary to comply with any Federal Energy Regulatory Commission ("FERC") regulation, requirement, directive, or order, or with Transporter's FERC Gas Tariff.

5. Upon execution of this Agreement, Shipper must select one of the following rate options:

X Shipper selects for the primary term of the Firm Agreement the negotiated rate for its service as reflected in Exhibit B hereto.

_____ Shipper selects the recourse rate for its service, which shall be the applicable rate, surcharges, and fuel and loss percentage under Transporter's Rate Schedule FT-A, as may be revised from time-to-time.

6. Shipper shall use reasonable efforts to obtain before October 1, 2007, the approval of its executive management and board of directors to execute the Firm Agreement pursuant to the terms of this Agreement. Shipper shall have the right, upon thirty days prior written notice provided to Transporter no later than October 1, 2007, to terminate this Agreement if Shipper's executive management or board of directors does not approve the execution of the Firm Agreement pursuant to the terms of this Agreement.

7. Transporter shall use reasonable efforts to obtain before October 26, 2007, the approval of its executive management and board of directors for the construction of the Project Facilities and the execution of the Firm Agreement pursuant to the terms of this Agreement. Transporter shall have the right, upon thirty days prior written notice provided to Shipper no later than October 26, 2007, to terminate this Agreement if Transporter's executive management or board of directors does not approve the construction of the Project Facilities and the execution of the Firm Agreement pursuant to the terms of this Agreement.

8. If Shipper or Transporter exercises the right to terminate this Agreement pursuant to Section 6 or 7, respectively, the parties shall attempt in good faith to negotiate within the thirty day period an amendment to this Agreement to accomplish the business objectives of this Agreement in light of such executive management's or board of

directors' disapproval. This Agreement shall terminate upon the expiration of the foregoing thirty day period unless within such period (a) both parties' respective executive management and board of directors provide the necessary approvals, (b) the parties mutually agree to an amendment of this Agreement, or (c) the parties agree in writing to extend the thirty day period.

9. Transporter shall use commercially reasonable efforts to obtain all necessary authorizations, including any necessary authorizations from the FERC (collectively, "Transporter's Authorizations"), to construct the Project Facilities, sign the Firm Agreement, and to render the proposed firm transportation service for Shipper pursuant to the terms and conditions specified herein, in the Firm Agreement, and in Transporter's FERC Gas Tariff. Shipper agrees to support Transporter's filing(s) to implement the Project Facilities, service, and rates, as proposed by Transporter.

10. If the Transporter's Authorizations referenced in Section 9 are not satisfactory to Transporter, in Transporter's sole discretion, then Transporter shall have the right to terminate this Agreement upon ninety days prior written notice to Shipper. The authorizations that must be satisfactory to Transporter include, but are not limited to, rates, facilities, terms and conditions of service, and environmental conditions. If notice is given by Transporter that the Transporter's Authorizations are not satisfactory, the parties shall attempt in good faith to negotiate within the ninety day period an amendment to this Agreement to accomplish the business objectives of this Agreement in light of the lack of satisfactory Transporter's Authorizations. This Agreement shall terminate upon the expiration of the foregoing ninety day period unless within such period (a) a change to the Transporter's Authorizations renders them satisfactory to Transporter, (b) the parties otherwise mutually agree to an amendment of this Agreement, or (c) the parties agree in writing to extend the ninety day period.

11. If the Transporter's Authorizations are satisfactory to Transporter, in Transporter's sole discretion, Transporter shall so notify Shipper. Within ten days after such notice, Transporter and Shipper shall execute and deliver the Firm Agreement.

12. If Transporter determines at any time that all or any applicable portion of the Project would not be economic, in Transporter's sole discretion, Transporter shall have the right to terminate this Agreement upon thirty days prior written notice to Shipper ("Notice of Termination"). This Agreement shall terminate upon the expiration of the thirty day period unless within such period (a) Transporter, in writing, withdraws such Notice of Termination or (b) the parties, in writing, enter into a mutually acceptable amendment to this Agreement.

13. Shipper shall use commercially reasonable efforts to obtain before March 1, 2008, all necessary authorizations from the New Hampshire Public Utility Commission ("NHPUC") to sign the Firm Agreement pursuant to this Agreement. If such authorizations are not satisfactory to Shipper, in Shipper's sole discretion, then Shipper shall have the right to terminate this Agreement upon thirty days prior written notice to Transporter given before March 1, 2008. If such notice is given by Shipper, the parties shall attempt in good faith to negotiate within the thirty day period an amendment to this Agreement to accomplish the business objectives of this Agreement in light of the lack of satisfactory authorizations. This Agreement shall terminate upon the expiration of the foregoing thirty day period unless within such period (a) a change to the NHPUC authorizations render them satisfactory to Shipper, (b) the parties otherwise mutually agree to an amendment of this Agreement, or (c) the parties agree in writing to extend the thirty day period.

14. Notwithstanding anything contained in this Agreement to the contrary, Transporter shall be under no obligation to commence or continue at any time the acquisition of pipe and materials, the acquisition of rights-of-way, the construction of the Project Facilities, or any other activity involving either the commitment or actual

expenditure of funds by Transporter that may be required to construct the Project Facilities or to provide the proposed transportation service for Shipper unless (a) Transporter has received all Transporter's Authorizations on terms satisfactory to Transporter, in Transporter's sole discretion; (b) Transporter has determined, in its sole discretion, that construction of the Project Facilities and the rendition of firm transportation service to Shipper is economic; and (c) Shipper and Transporter have executed the Firm Agreement.

15. Shipper shall satisfy the credit assurance provisions outlined in Transporter's FERC Gas Tariff by October 1, 2007, and shall have a continuing obligation to maintain such credit assurance. In the event Shipper fails to establish itself as creditworthy by October 1, 2007, and/or maintain such creditworthiness thereafter, Transporter shall have the right to terminate this Agreement upon thirty days written notice.

16(a). If Transporter exercises its termination right under Section 15, then Shipper shall reimburse Transporter for Shipper's pro rata share, based upon Shipper's contracted volume divided by the total Project contracted volume, of all of Transporter's costs incurred, accrued, allocated to, or for which Transporter is contractually obligated to pay in conjunction with its efforts to satisfy its obligations under this Agreement ("Pre-Service Costs"). Shipper's reimbursement for such Pre-Service Costs shall constitute Transporter's sole and exclusive remedy for the actions described this Section 16(a).

(b) If Shipper (i) fails to perform, in whole or in part, its material duties and obligations hereunder; (ii) during the term of this Agreement, interferes with or obstructs the receipt by Transporter of any Transporter's Authorizations and, as a result of such actions by Shipper, Transporter does not receive any of Transporter's Authorizations in form and substance as requested by Transporter or does not receive such Transporter's Authorizations at all; or (iii) otherwise breaches this Agreement, Transporter shall, without limiting its ability to collect any and all other damages related to such breach by

Shipper, be entitled to collect from Shipper all of the Pre-Service Costs incurred or accrued as of the date of such breach.

(c) Pre-Service Costs shall include, but not be limited to, costs and/or out-of-pocket expenditures incurred, accrued, allocated to, or for which Transporter is contractually obligated to pay to third parties, as well as all internal overhead and administration and any other internal costs incurred or accrued, from the effective date of this Agreement through and including the effective date of any termination, associated with engineering, construction, materials and equipment, environmental, regulatory, and/or legal activities incurred in furtherance of Transporter's efforts to satisfy its obligations under this Agreement.

17. Any notice and/or request provided for in this Agreement or any notice either party may desire to give to the other shall be in writing transmitted by facsimile before 5 p.m. Central time and then by overnight courier to the post office address of the party intended to receive the same, as the case may be, as follows:

Transporter: Tennessee Gas Pipeline Company
1001 Louisiana Street
Houston, TX 77002
Attn: Director, Marketing and Business Development
FAX: (713) 420-4343

Shipper:
EnergyNorth Natural Gas, Inc.
d/b/a KeySpan Energy Delivery New England
52 Second Avenue, 4th Floor
Waltham, MA 02451
Attn: Elizabeth Arangio
FAX: (781-290-0186)

Notice is effective as of the date of the facsimile.

18. Any entity that shall succeed by purchase, merger, consolidation, or other transfer to the properties of either Transporter or Shipper, either substantially or as an entirety, shall be entitled to the rights and shall be subject to the obligations of its

predecessor in interest under this Agreement. Either party may, without relieving itself of its obligations under this Agreement, assign any of its rights hereunder to a company with which it is affiliated, but otherwise no assignment of this Agreement or of any of the rights or obligations hereunder shall be made, unless there first shall have been obtained the written consent thereto of the other party to this Agreement, which consent shall not be unreasonably withheld. It is agreed, however, that the restrictions on assignment contained in this section shall not in any way prevent either party to this Agreement from pledging or mortgaging its rights hereunder as security for its indebtedness. Once the Firm Agreement is executed, any assignment of such Firm Agreement is subject to the terms and conditions of Transporter's FERC Gas Tariff and the terms of this Agreement shall no longer control.

19.Shipper agrees to cooperate in the preparation and filing of all necessary applications for authorizations and, subject to the terms and conditions herein, agrees to proceed with due diligence to prosecute such application(s), if necessary.

20. No modification of the terms and provisions of this Agreement shall be made except by the execution by both parties of a written agreement.

21. THE INTERPRETATION AND PERFORMANCE OF THIS AGREEMENT SHALL BE IN ACCORDANCE WITH AND CONTROLLED BY THE LAWS OF THE STATE OF TEXAS, EXCEPT THAT ANY CONFLICT OF LAWS RULE OF THE STATE OF TEXAS THAT WOULD REQUIRE REFERENCE TO THE LAWS OF SOME OTHER STATE OR JURISDICTION SHALL BE DISREGARDED.

22. Unless terminated sooner pursuant to the terms herein, this Agreement shall terminate upon the execution of the Firm Agreement. Upon termination of this

Agreement for any reason provided for herein, neither party shall have any further rights or obligations under this Agreement.

23. No waiver by a party of any default(s) by the other party in the performance of any provision, condition, or requirement of this Agreement shall operate or be construed as a waiver of any future default(s), whether of a like or of a different character, nor in any manner release the defaulting party from performance of any other provision, condition, or requirement herein.

24. This Agreement, and all of the terms and provisions contained herein, and the respective obligations of the parties hereunder, are subject to Transporter's FERC Gas Tariff and to all valid laws, orders, rules, and regulations of duly constituted governmental authorities having jurisdiction.

25. If any provision of this Agreement is declared null and void or voidable by a court of competent jurisdiction, such declaration shall in no way affect the validity or effectiveness of the other provisions of this Agreement, which shall remain in full force and effect, and the parties shall thereafter undertake commercially reasonable efforts to agree upon an equitable adjustment of the provisions of this Agreement with a view to effecting its purpose.

26. No presumption shall operate in favor of or against any party as a result of any responsibility or role that any party may have had in the drafting of this Agreement.

27. This Agreement sets forth all understandings and agreements between the parties respecting the subject matter hereof, and all prior agreements, understandings, and representations, whether written or oral, respecting the subject matter hereof are merged into and superseded by this Agreement.

IN WITNESS WHEREOF, the parties have caused this Agreement to be executed by their duly authorized representatives as of the date first hereinabove written.

TENNESSEE GAS PIPELINE COMPANY

By:
Name: James Bulinckx
Title: Agent & Attorney-in-Fact

ENERGY NORTH NATURAL GAS, INC.
d/b/a KeySpan Energy Delivery New England

By:
Name: Richard A. Rapp, Jr.
Title: Vice President

EXHIBIT A

Service Package No: ________
Amendment No: ________

GAS TRANSPORTATION AGREEMENT
(For Use under FT-A Rate Schedule)

THIS AGREEMENT is made and entered into as of the ________ day of ________, ________, by and between TENNESSEE GAS PIPELINE COMPANY, a Delaware Corporation, hereinafter referred to as "Transporter" and EnergyNorth Natural Gas, Inc., d/b/a KeySpan Energy Delivery New England, a New Hampshire Corporation, hereinafter referred to as "Shipper." Transporter and Shipper shall collectively be referred to herein as the "Parties."

WHEREAS, Shipper and Transporter have entered into a Precedent Agreement dated [DATE] (the "Precedent Agreement"), pursuant to which Transporter agreed to file an application with the Federal Energy Regulatory Commission ("FERC") for the necessary authorizations to (i) provide certain natural gas transportation service and (ii) construct and operate the facilities necessary to provide such service; and

WHEREAS, Transporter has now been authorized by the FERC order issued on [DATE] in [DOCKET] to render the firm transportation service described herein and to construct and operate the necessary facilities;

THEREFORE, the Parties agree to the following:

ARTICLE I - DEFINITIONS

1.1 TRANSPORTATION QUANTITY - shall mean the maximum daily quantity of gas which Transporter agrees to receive and transport on a firm basis, subject to Article II herein, for the account of Shipper hereunder on each day during each year during the term hereof, which shall be 30,000 dekatherms. Any limitations on the quantities to be received from each Point of Receipt and/or delivered to each Point of Delivery shall be as specified on Exhibit "A" attached hereto.

1.2 EQUIVALENT QUANTITY - shall be as defined in Article I of the General Terms and Conditions of Transporter's FERC Gas Tariff.

ARTICLE II – TRANSPORTATION

2.1 TRANSPORTATION SERVICE – After receipt and acceptance by Transporter, in its sole determination, of all FERC and other authorizations necessary to provide service hereunder and the satisfactory completion by Transporter, in Transporter's sole determination, of the facilities required to provide such service, beginning on the Commencement Date (as defined in Section 2.2 below), Transporter agrees to accept and receive daily on a firm basis, at the Point(s) of Receipt from Shipper or for Shipper's account such quantity of gas as Shipper makes available up to the Transportation Quantity, and to deliver to or for the account of Shipper to the Point(s) of Delivery an Equivalent Quantity of gas.

2.2 COMMENCEMENT OF SERVICE – Upon completion of construction of the pipeline facilities required to enable Transporter to render the transportation service described herein and after receipt and acceptance by Transporter of all FERC and other necessary authorizations, as further described in Section 2.1 above, Transporter will notify Shipper, in writing, of the date on which transporter will be ready to commence transportation service under this Agreement (the "Commencement Date").

ARTICLE III - POINT(S) OF RECEIPT AND DELIVERY

The Primary Point(s) of Receipt and Delivery shall be those points specified on Exhibit "A" attached hereto.

ARTICLE IV

Transporter shall construct, install, own, and operate the facilities necessary for Transporter to receive and deliver the gas as contemplated herein for Shipper's account at the Point(s) of Receipt and the Point(s) of Delivery.

ARTICLE V - QUALITY SPECIFICATIONS AND STANDARDS FOR MEASUREMENT

For all gas received, transported and delivered hereunder the Parties agree to the Quality Specifications and Standards for Measurement as specified in the General Terms and Conditions of Transporter's FERC Gas Tariff Volume No. 1. To the extent that no new measurement facilities are installed to provide service hereunder, measurement operations will continue in the manner in which they have previously been handled. In the event that such facilities are not operated by Transporter or a downstream pipeline, then responsibility for operations shall be deemed to be Shipper's.

ARTICLE VI - RATES AND CHARGES FOR GAS TRANSPORTATION

6.1 TRANSPORTATION RATES - Commencing upon the Commencement Date, the rates, charges, and surcharges to be paid by Shipper to Transporter for the transportation service provided herein shall be in accordance with Transporter's Rate Schedule FT-A and the General Terms and Conditions of Transporter's FERC Gas Tariff. Except as provided to the contrary in any written or electronic agreement(s) between Transporter and Shipper in effect during the term of this Agreement, Shipper shall pay Transporter the applicable maximum rate(s) and all other applicable charges and surcharges specified in the Summary of Rates in Transporter's FERC Gas Tariff and in this Rate Schedule. Transporter and Shipper may agree that a specific discounted rate will apply only to certain volumes under the agreement. Transporter and Shipper may agree that a specified discounted rate will apply only to specified volumes (MDQ, TQ, commodity volumes, Extended Receipt and Delivery Service Volumes or Authorized Overrun volumes) under the Agreement; that a specified discounted rate will apply only if specified volumes are achieved (with the maximum rates applicable to volumes above the specified volumes or to all volumes if the specified volumes are never achieved); that a specified discounted rate will apply only during specified periods of the year or over a specifically defined period of time; that a specified discounted rate will apply only to specified points, zones, markets or other defined geographical area; and/or that a specified discounted rate will apply only to production or reserves committed or dedicated to Transporter. Transporter and Shipper may agree to a specified discounted rate pursuant to the provisions of this Section 6.1 provided that the discounted rate is between the applicable maximum and minimum rates for this service.

In addition, a discount agreement may include a provision that if one rate component which was at or below the applicable Maximum Rate at the time the discount agreement was executed subsequently exceeds the applicable Maximum Rate due to a change in Transporter's Maximum Rates so that such rate component must be adjusted downward to equal the new applicable Maximum Rate, then other rate components may be adjusted upward to achieve the agreed overall rate, as long as none of the resulting rate components exceed the Maximum Rate applicable to that rate component. Such changes to rate components shall be applied prospectively, commencing with the date a Commission Order accepts revised tariff sheet rates. However, nothing contained herein shall be construed to alter a refund obligation under applicable law for any period during which rates that had been charged under a discount agreement exceeded rates which ultimately are found to be just and reasonable.

6.2 INCIDENTAL CHARGES - Shipper agrees to reimburse Transporter for any filing or similar fees, which have not been previously paid for by Shipper, which Transporter incurs in rendering service hereunder.

6.3 CHANGES IN RATES AND CHARGES - Shipper agrees that Transporter shall have the unilateral right to file with the appropriate regulatory authority and make effective changes in (a) the rates and charges applicable to service pursuant to Transporter's Rate Schedule FT-A, (b) the rate schedule(s) pursuant to which service hereunder is rendered, or (c) any provision of the General Terms and Conditions applicable to those rate schedules. Transporter agrees that Shipper may protest or contest the aforementioned filings, or may seek authorization from duly constituted regulatory authorities for such adjustment of Transporter's existing FERC Gas Tariff as may be found necessary to assure Transporter just and reasonable rates.

ARTICLE VII - BILLINGS AND PAYMENTS

Transporter shall bill and Shipper shall pay all rates and charges in accordance with Articles V and VI, respectively, of the General Terms and Conditions of the FERC Gas Tariff.

ARTICLE VIII - GENERAL TERMS AND CONDITIONS

This Agreement shall be subject to the effective provisions of Transporter's Rate Schedule FT-A and to the General Terms and Conditions incorporated therein, as the same may be changed or superseded from time to time in accordance with the rules and regulations of the FERC.

ARTICLE IX - REGULATION

9.1 This Agreement shall be subject to all applicable and lawful governmental statutes, orders, rules and regulations and is contingent upon the receipt and continuation of all necessary regulatory approvals or authorizations upon terms acceptable to Transporter. This Agreement shall be void and of no force and effect if any necessary regulatory approval is not so obtained or continued. All Parties hereto shall cooperate to obtain or continue all necessary approvals or authorizations, but no Party shall be liable to any other Party for failure to obtain or continue such approvals or authorizations.

9.2 The transportation service described herein shall be provided subject to Subpart G, Part 284 of the FERC Regulations.

ARTICLE X - RESPONSIBILITY DURING TRANSPORTATION

Except as herein specified, the responsibility for gas during transportation shall be as stated in the General Terms and Conditions of Transporter's FERC Gas Tariff Volume No. 1.

ARTICLE XI - WARRANTIES

11.1 In addition to the warranties set forth in Article IX of the General Terms and Conditions of Transporter's FERC Gas Tariff, Shipper warrants the following:

(a) Shipper warrants that all upstream and downstream transportation arrangements are in place, or will be in place as of the requested effective date of service, and that it has advised the upstream and downstream transporters of the receipt and delivery points under this Agreement and any quantity limitations for each point as specified on Exhibit "A" attached hereto. Shipper agrees to indemnify and hold Transporter harmless for refusal to transport gas hereunder in the event any upstream or downstream transporter fails to receive or deliver gas as contemplated by this Agreement.

(b) Shipper agrees to indemnify and hold Transporter harmless from all suits, actions, debts, accounts, damages, costs, losses and expenses (including reasonable attorneys fees) arising from or out of breach of any warranty by Shipper herein.

11.2 Transporter shall not be obligated to provide or continue service hereunder in the event of any breach of warranty.

ARTICLE XII - TERM

12.1 This contract shall be effective as of the date hereof; provided, however, that Transporter shall be under no obligation to receive or to deliver any quantities of natural gas hereunder prior to the Commencement Date. This Agreement shall remain in force and effect, unless modified as per Exhibit B, until the expiration of twenty years following the Commencement Date ("Primary Term") and on a month to month basis thereafter unless terminated by either Party upon at least thirty (30) days prior written notice to the other Party; provided, however, that if the Primary Term is less than one year, then notice of termination may be provided via PASSKEY; provided further, that if the Primary Term is one year or more, then any rights to Shipper's extension of this Agreement after the Primary Term shall be governed by Article III, Section 10.4 of the General Terms and Conditions of Transporter's FERC Gas Tariff; and provided further, that if the FERC or other governmental body having jurisdiction over the service rendered pursuant to this Agreement authorizes abandonment of such service, this Agreement shall terminate on the abandonment date permitted by the FERC or such other governmental body.

12.2 Any portions of this Agreement necessary to resolve or cash out imbalances under this Agreement as required by the General Terms and Conditions of Transporter's Tariff shall survive the other parts of this Agreement until such time as such balancing has been accomplished; provided, however, that Transporter notifies Shipper of such imbalance not later than twelve months after the termination of this Agreement.

12.3 This Agreement will terminate automatically upon written notice from Transporter in the event Shipper fails to pay all of the amount of any bill for service rendered by Transporter hereunder in accord with the terms and conditions of Article VI of the General Terms and Conditions of Transporter's FERC Gas Tariff.

ARTICLE XIII - NOTICE

Except as otherwise provided in the General Terms and Conditions applicable to this Agreement, any notice under this Agreement shall be in writing and mailed to the post office address of the Party intended to receive the same, as follows:

TRANSPORTER: Tennessee Gas Pipeline Company
P. O. Box 2511
Houston, Texas 77252-2511

Attention: Director, Transportation Control

SHIPPER:
NOTICES: EnergyNorth Natural Gas, Inc.
d/b/a KeySpan Energy Delivery New England
52 Second Avenue, 4th Floor
Waltham, MA 02451

Attention: Elizabeth Arangio

BILLING: EnergyNorth Natural Gas, Inc.
d/b/a KeySpan Energy Delivery New England
52 Second Avenue, 4th Floor
Waltham, MA 02451

Attention: Elizabeth Arangio

or to such other address as either Party shall designate by formal written notice to the other.

ARTICLE XIV - ASSIGNMENTS

14.1 Either Party may assign or pledge this Agreement and all rights and obligations hereunder under the provisions of any mortgage, deed of trust, indenture, or other instrument which it has executed or may execute hereafter as security for indebtedness. Either Party may, without relieving itself of its obligation under this Agreement, assign any of its rights hereunder to a company with which it is affiliated. Otherwise, Shipper shall not assign this Agreement or any of its rights hereunder, except in accord with Article III, Section 11 of the General Terms and Conditions of Transporter's FERC Gas Tariff.

14.2 Any person which shall succeed by purchase, merger, or consolidation to the properties, substantially as an entirety, of either Party hereto shall be entitled to the rights and shall be subject to the obligations of its predecessor in interest under this Agreement.

ARTICLE XV - MISCELLANEOUS

15.1 THE INTERPRETATION AND PERFORMANCE OF THIS CONTRACT SHALL BE IN ACCORDANCE WITH AND CONTROLLED BY THE LAWS OF THE STATE OF TEXAS, WITHOUT REGARD TO THE DOCTRINES GOVERNING CHOICE OF LAW.

15.2 If any provision of this Agreement is declared null and void, or voidable, by a court of competent jurisdiction, then that provision will be considered severable at either Party's option; and if the severability option is exercised, the remaining provisions of the Agreement shall remain in full force and effect.

15.3 Unless otherwise expressly provided in this Agreement or Transporter's Gas Tariff, no modification of or supplement to the terms and provisions stated in this Agreement shall be or become effective until Shipper has submitted a request for change through PASSKEY and Shipper has been notified through PASSKEY of Transporter's agreement to such change.

15.4 Exhibit "A" attached hereto is incorporated herein by reference and made a part hereof for all purposes.

IN WITNESS WHEREOF, the Parties hereto have caused this Agreement to be duly executed as of the date first hereinabove written.

TENNESSEE GAS PIPELINE COMPANY

BY: ______________________________
Agent and Attorney-in-Fact

SHIPPER: ENERGYNORTH NATURAL GAS, INC.
d/b/a KEYSPAN ENERGY DELIVERY NEW ENGLAND

BY: ______________________________

TITLE: ____________________________

DATE: ____________________________

EFFECTIVE DATE OF AMENDMENT: Commencement Date
RATE SCHEDULE: FTA
SERVICE PACKAGE: _______
SERVICE PACKAGE TQ: 30,000 Dth

METER	METER NAME	INTERCONNECT PARTY NAME	COUNTY	ST	ZONE	R/D	LEG	TOTAL-TQ	BILLABLE-TQ
012538	Dracut Receipt				06	R	200	30,000	30,000
020426	Laconia, New Hampshire				06	D	200	30,000	30,000
						Total TQ		30,000	30,000

NUMBER OF RECEIPT POINTS: 1________________
NUMBER OF DELIVERY POINTS: 1________________

Note: Exhibit "A" is a reflection of the contract and all amendments as of the amendment effective date.

GAS TRANSPORTATION AGREEMENT
(For Use under FT-A Rate Schedule)

EXHIBIT B

TO GAS TRANSPORTATION AGREEMENT
DATED____________________
BETWEEN
TENNESSEE GAS PIPELINE COMPANY
AND

____

BUYOUT/EARLY TERMINATION PROVISIONS*

SERVICE PACKAGE: ______________________________

BUYOUT PERIOD(S) ____

____

____

AMOUNT OF TQ REDUCED
FOR PERIOD(S) ____

____

____

AMOUNT OF
BUYOUT PAYMENT
FOR PERIOD(S) ____

____

____

ANY LIMITATIONS ON
THE EXERCISE OF THE
BUYOUT/TERMINATION
OPTION AS BID BY
THE SHIPPER:

* NOTICE MUST BE GIVEN AS PROVIDED FOR IN THE NET PRESENT VALUE STANDARD OF THE GENERAL TERMS AND CONDITIONS.

EXHIBIT B

DATE

EnergyNorth Natural Gas, Inc.
d/b/a KeySpan Energy Delivery New England
52 Second Avenue, 4th Floor
Waltham, MA 02451
Attention: Ms. Elizabeth Arangio

RE: Firm Transportation Negotiated Rate Letter Agreement
Tennessee FT-A Service Package No. _______

Dear Ms. Arangio:

Tennessee Gas Pipeline Company ("Transporter") held an open season in accordance with applicable provisions of its FERC Gas Tariff entitled "Concord Open Season" ("Open Season"). EnergyNorth Natural Gas, Inc. d/b/a KeySpan Energy Delivery New England ("Shipper") was a successful bidder in the Open Season and elected the negotiated rate option as offered by Transporter.

In response to the request of Shipper, and pursuant to Section 5.6 of Transporter's FT-A Rate Schedule, and upon the completion of the construction and placing in-service of the necessary facilities, Transporter hereby agrees to adjust its then applicable FT-A transportation rate for FT-A service provided under the above referenced Service Package as follows:

1. a) If Shipper, its assignee(s) or its agent(s) (hereinafter collectively referred to as "Shipper") violates the terms of this Negotiated Rate Agreement or the terms of the above-referenced Service Package, Transporter shall have the right, in its sole discretion, to immediately terminate this Negotiated Rate Agreement and/or assess, from the date of the violation, the applicable maximum monthly reservation rate for the entire contract quantity and the maximum applicable daily commodity rates on all transactions occurring under this Negotiated Rate Agreement.

   b) For the period commencing on the Commencement Date and extending through the Primary Term (as defined in Sections 2.2 and 12.1 of the above referenced Service Package) for gas delivered by Transporter on behalf of Shipper under the above referenced service package, the applicable FT-A rates shall be a monthly reservation rate of $12.17 per Dth and the maximum applicable commodity rates under Rate Schedule FT-A. These rates are not inclusive of surcharges.

   In addition, Shipper shall pay applicable fuel and lost and unaccounted for charges.

2. This Negotiated Rate Agreement shall be filed with the Federal Energy Regulatory Commission ("FERC") and is subject to approval by the FERC. In addition, the effectiveness of this Negotiated Rate Agreement is contingent upon a) the Parties executing the above-referenced Service Package and b) service commencing thereunder.

3. If any terms of this Negotiated Rate Agreement are disallowed by any order, rulemaking, regulation or policy of the FERC, Transporter may immediately terminate this Negotiated Rate Agreement. If any terms of this Negotiated Rate Agreement are in any way modified by order, rulemaking, regulation or policy of the FERC, Transporter and Shipper may mutually agree in good faith to amend this Negotiated Rate Agreement in order to ensure that the original commercial intent of the

parties is preserved. In the event that the parties cannot achieve mutual agreement, Transporter reserves the right to immediately terminate this Negotiated Rate Agreement.

Please acknowledge your acceptance of this proposal by signing and returning via mail or facsimile to the undersigned at (713) 420-4343. One fully executed copy will be returned for your records.

Sincerely,

Dodson Skipworth
Manager, Marketing
Tennessee Gas Pipeline Company

TENNESSEE GAS PIPELINE COMPANY

By:____________________________

Date:____________________________

J. Heath Deneke
Agent and Attorney-In-Fact

ENERGYNORTH NATURAL GAS INC.
d/b/a KeySpan Energy Delivery New England

By:____________________________

Date: ____________________________

STATE OF NEW HAMPSHIRE
PUBLIC UTILITIES COMMISSION

DG 07-101

ENERGYNORTH NATURAL GAS, INC. d/b/a
KEYSPAN ENERGY DELIVERY

Petition for Approval of a Firm Transportation Agreement
with Tennessee Gas Pipeline Company

Order Approving Settlement Agreement

O R D E R N O. 24,825

February 29, 2008

APPEARANCES: Sarah B. Knowlton, Esq., of McLane, Graf, Raulerson, and Middleton, and Thomas P. O'Neill, Esq., on behalf of EnergyNorth Natural Gas, Inc. d/b/a KeySpan Energy Delivery New England; Kenneth E. Traum, of the Office of the Consumer Advocate, on behalf of residential utility ratepayers; and Edward N. Damon, Esq. for the Staff of the New Hampshire Public Utilities Commission.

I. PROCEDURAL HISTORY

On September 14, 2007, EnergyNorth Natural Gas, Inc. d/b/a KeySpan Energy Delivery New England (EnergyNorth or the Company) filed with the Commission a petition for approval of a firm transportation agreement with Tennessee Gas Pipeline Company (TGP) to provide EnergyNorth additional capacity of 30,000 MMBtus[1] per day on the Concord Lateral. The Concord Lateral is TGP's northernmost branch pipeline off its main pipeline, originating in Dracut, Massachusetts and terminating in Concord. In connection with the agreement, TGP would construct and operate the facilities necessary to render firm transportation service and EnergyNorth would incur an annual demand cost of $4,380,000. Service would commence on the latter of November 1, 2009 or the date on which TGP is able to render service to EnergyNorth for a primary term of twenty years. The filing was accompanied by supporting

[1] An MMBtu is one million British thermal units of heat energy.

testimony of Elizabeth D. Arangio, Director of Gas Supply Planning, Theodore Poe, Jr., Manager of Energy Planning, John S. Stavrakas, P.E., Director of Engineering, and Paul M. DeRosa, Lead Pricing Analyst.

On October 4, 2007, the Office of Consumer Advocate (OCA) filed its notice of intent to participate in this docket on behalf of residential utility consumers consistent with RSA 363:28. On October 9, 2007, the Commission issued an order of notice establishing a pre-hearing conference, which was held at the Commission on November 8, 2007. The order of notice specified that the following issues, among others, would be investigated: (1) whether EnergyNorth's investigation and analysis of the alternatives for satisfying the resource need is reasonable; and (2) whether EnergyNorth's entry into the long term arrangement with TGP for additional pipeline capacity is prudent and in the public interest. Following the pre-hearing conference, the Company, OCA and Staff met in a technical session and agreed upon a proposed procedural schedule that was submitted by Staff on November 13, 2007, and approved by secretarial letter the following day. Revisions to the procedural schedule proposed by the parties and Staff were granted by secretarial letters on January 3, 15 and 29, 2008. On November 16, 2007, EnergyNorth filed a motion for protective order and confidential treatment regarding its response to Staff's data request Tech1-3.

Staff filed the testimony of John B. Adger, Jr. and Yavuz Arik of Liberty Consulting Group (Liberty) on January 10, 2008. Their testimony evaluated EnergyNorth's proposal to enter into the agreement with TGP and certain alternative options. On February 1, 2008, EnergyNorth filed the surrebuttal testimony of Elizabeth D. Arangio. A settlement agreement between EnergyNorth and Staff was filed on February 8, 2008. On February 13, 2008, EnergyNorth filed a motion for protective order and confidential treatment regarding certain responses to Staff's data requests and attachments to the Company's surrebuttal testimony. A hearing on the settlement agreement was held on February 14, 2008. On February 29, 2008, Staff filed its recommendation supporting the Company's requests for confidential treatment.

II. SETTLEMENT AGREEMENT

Under the settlement agreement, EnergyNorth and Staff agreed that the Company's decision to enter into the TGP agreement is prudent and consistent with the public interest. Accordingly, the Company and Staff agreed that the TGP agreement should be approved. In addition, the settlement agreement provided that the Company, Staff and OCA will participate in a planning conference in or around July 2009 in which the Company will present to the OCA and the Staff its plans to meet its incremental gas supply need associated with the Concord Lateral upgrade for the 2009/2010 heating season. Particular questions to be addressed include the following:

- What the Company has done, and what it intends to do, to ensure the broadest possible array of alternatives for firm, peaking gas supplies delivered to Dracut for the ensuing winter season;
- How the Company expects to use all of the capacity available to it on the Concord Lateral for the ensuing winter season to minimize costs to its customers in New Hampshire.

The Company will also describe its plans to issue a request for proposal to potential suppliers to meet its overall portfolio needs for the 2009-2010 heating season. Review by the Staff and OCA of the Company's plans does not relieve the Company of its obligation to prudently operate its business and obtain gas supplies on a least cost basis nor does it bind Staff or OCA to a particular position regarding the adequacy and/or effectiveness of the Company's plans.

III. POSITIONS OF THE PARTIES AND STAFF

A. EnergyNorth

EnergyNorth supported its petition with testimony describing the proposed agreement with TGP and the analysis undertaken by the Company resulting in its conclusion that the proposed agreement is needed and is the least cost alternative under a range of pricing and demand scenarios, and compares favorably to the range of reasonably available alternatives based on price and non-price factors. The Company's analysis focused on a comparison of the proposed agreement with TGP with certain on-system peaking options available to the Company involving the addition or expansion of supplemental storage and vaporization facilities.

The Company also considered the possibility of using demand-side management options to satisfy the forecasted need but concluded that such options could not provide the level of resources required to meet forecasted customer demand over the Company's planning horizon. The Company stated that the customer participation rates and money needed to achieve the necessary incremental savings over and above the savings already achieved by existing energy efficiency programs and included in the demand forecast would be extraordinary and not realistically achievable. The Company also expressed concern about the reliability of demand-side management options to meet peak day demands.

According to EnergyNorth, its base case design day forecast submitted in Docket No. DG 06-105 shows a minimum need for incremental peak day delivery capability of 5,310 MMBtus per day on the peak day beginning in 2009/2010, increasing to 19,660 MMBtus per day by 2010/2011. In addition, the forecast shows a minimum need for incremental peak season supply totaling 53,300 MMBtus per day beginning in 2008/2009, increasing to 128,000 MMBtus per day by 2010/2011.

According to EnergyNorth, capacity on the Concord Lateral is currently fully subscribed. TGP's upgrade of the Concord Lateral would create incremental capacity that EnergyNorth could use to transport gas supplies from Dracut, where the Tennessee Gas Pipeline interconnects with both the Maritimes & Northeast Pipeline and Portland Natural Gas Transmission System, to the Company's citygates in New Hampshire. The Company stated that the upgrade would allow the Company to purchase gas supply at Dracut from a number of sources, thus increasing the reliability and diversity of supply within the Company's overall portfolio.

To facilitate the proposed agreement, TGP would need to construct a new mid-point compressor station and expand its existing meter station to accommodate the incremental volumes eligible for transport on the Concord Lateral. EnergyNorth stated that TGP's costs of completing the Concord Lateral upgrade are reflected in the rate negotiated by the Company and TGP. For the twenty-year period covered by the proposed agreement, EnergyNorth would pay TGP a fixed monthly reservation (demand) rate of $12.17 per dekatherm[2] and the maximum applicable commodity rates under TGP's Federal Energy Regulatory Commission (FERC) schedule FT-A, exclusive of surcharges and applicable fuel and lost and unaccounted for charges, in exchange for which the Company would be provided with a maximum daily transportation quantity of 30,000 MMBtus on a peak day and peak season basis.[3]

The proposed arrangement with TGP is documented by a Precedent Agreement dated August 29, 2007 between the Company and TGP to which is attached a Gas Transportation Agreement (For Use Under FT-A Rate Schedule) and a Firm Transportation Negotiated Rate

[2] A dekatherm (Dth) is equivalent to one MMBtu or ten therms.

[3] Since the total contract cost is the same regardless of the number of units purchased by the Company from TGP between the minimum needed quantity of 19,660 MMBtus per day and the contract quantity of 30,000 MMBtus per day, the Company chose to enter an agreement for the maximum capacity available from TGP given its investment to complete the Concord Lateral upgrade. According to EnergyNorth, if the Company had contracted for additional capacity above the specified maximum daily transportation quantity, TGP would have increased the total cost of the contract.

Letter Agreement. The Precedent Agreement memorializes the whole arrangement until such time as the Gas Transportation Agreement is executed before the in-service date of November 1, 2009. The Firm Transportation Negotiated Rate Letter Agreement is filed with FERC and is subject to FERC approval.

In order to compare the relative price and non-price attributes of a pipeline project expanding the capacity available to serve EnergyNorth's service territory versus a distribution project that would add on-system storage and vaporization capabilities, the Company first assessed the type and size of on-system facilities that would be needed. The Company determined that two potential on-system alternatives would provide an additional 25,000 MMBtus per day[4] of incremental vaporization output capability: the construction of new liquefied natural gas (LNG) facilities in Concord to add 0.3 Bcf[5] storage capability, with and without liquefaction, and the construction of new and expanded propane facilities in Concord and Nashua to add 0.15 Bcf of storage capability at each of the locations. In the Company's view, no other alternative would provide the necessary level of resources required to meet forecasted customer demand over the Company's long term planning horizon or that would interconnect directly with the Company's distribution system on a safe and reliable basis.[6]

Next, the Company prepared capital and operating cost projections for the alternatives to the Concord Lateral upgrade and calculated the levelized, annual costs of the alternatives, exclusive of supply costs, for comparison to the annual demand charges for the Concord Lateral upgrade. Finally, the Company developed a linear-programming (LP) model designed to

[4] According to the Company, this was the largest on-system capability that could be added without a costly distribution system upgrade.
[5] A Bcf is one billion cubic feet gas and is approximately equivalent to 1,000,000 dekatherms of heat energy.
[6] The Company stated it also met with both Portland Natural Gas Transmission System and Maritimes and Northeast Pipelines LLC to discuss the possibility of a direct connect to the Company's distribution system but it quickly concluded that a direct connection was not a viable option.

identify the most cost-effective resource addition, inclusive of projected supply costs. The output of the LP model indicated that the Concord Lateral upgrade is a more cost effective alternative for meeting the identified need for incremental capacity than any of the on-system alternatives. Specifically, EnergyNorth's annual total contract cost for the proposed agreement with TGP would be $4,380,000, compared to approximately $8.1 million for an LNG facility without liquefaction, approximately $11 million for a new LNG facility with liquefaction, and $6.5 million for a propane facility.

The Company also concluded that non-price factors weighed in favor of the Concord Lateral upgrade and against the alternatives. For example, the use of on-system alternatives would require trucking necessary to transport LNG or propane to the Company's facilities, which the Company believed presented safety and reliability concerns not implicated by the Concord Lateral upgrade. The Company also stated that there is a greater likelihood of operational contingencies with the use of on-system alternatives than with a pipeline facility, including the need to carefully mix supplies of propane-air with pipeline supplies of natural gas in order to prevent harm to customer appliances.

Based on its review of EnergyNorth's analysis, Liberty concluded that if peak period supplies are available on a firm basis at Dracut for an average premium of $12 per MMBtu or less over the Henry Hub price, which is a realistic assumption in Liberty's view, then those supplies are the most cost effective solution to EnergyNorth's peaking problem at this time. Liberty recommended that EnergyNorth be required to demonstrate that supplies will be available on a firm basis at the inlet to the Concord Lateral on terms that are competitive with its on-system alternatives for peaking supplies.

The Company responded that the recommended showing can be made. The Company contacted four suppliers which are active at Dracut and with which the Company has done business to obtain non-binding indicative pricing information for the 2009-2010 heating season. Although the pricing which the Company received varied, depending on the load factor of the need, the Company stated that the pricing information was consistent with its experience buying firm supplies delivered at Dracut. In the Company's view, the pricing is indicative of what the market expects gas supplies to cost in 2009-2010 based on today's market and, as evidenced by the wide range of indicative pricing received, there are likely costs built into the pricing to allow for the unknowns of what may or may not materialize in the 2009-2010 market at Dracut.

The Company stated that one of the three suppliers responding to the Company's request provided a price quotation very near the pricing assumptions made by the Company. However, the Company did not recommend locking into a contract now. First, the Company noted that the most recent studies and reports corroborate the market expectation that due to incremental gas supplies entering the Northeast, the basis price for gas supply is expected to decrease over time. Second, the volumes the Company quoted to the suppliers reflect minimum usage of the proposed contract. The Company has not taken into account the effects of adding the TGP contract into its overall portfolio and the changes it would have on existing resources. For example, the addition of the Concord Lateral capacity to the Company's portfolio could enable the Company to purchase supply at Dracut in lieu of its current citygate service, and the addition of the Concord Lateral capacity could allow the Company the opportunity to optimize the use of its existing underground storage and to supplement LNG and propane supplies, including its dedicated LNG liquid contract with Distrigas. In the Company's view, it would be prudent to issue the request for proposals for the necessary supply in the spring or summer of 2009. The

Company explained that notwithstanding the proposed settlement agreement, it remained under an obligation to prudently purchase its gas supplies, including the purchase of supplies in 2009.

EnergyNorth explained that TGP had recently filed its application for FERC approval and it expects to receive FERC approval in early 2009. This would allow construction of the necessary facilities in the spring and summer of 2009, in time for increased firm transportation service commencing November 1, 2009.

In closing, the Company stated that it had identified an incremental need for citygate deliverability of gas to reliably serve its customers. The Company conducted an in depth analysis of various options to meet that demand and has determined that the Concord Lateral upgrade and the proposed arrangement with TGP is the most prudent and cost effective means of meeting that need. The Company requested that the Commission find the settlement agreement to be in the public interest and to approve it in its entirety. Since the Company needs to notify TGP by the end of February if it is not going to proceed with the proposed arrangement, the Company requested an order approving the settlement agreement by that time.

B. OCA

The OCA stated that although it did not sign the settlement agreement between the Company and Staff, that fact should not be interpreted as opposition by the OCA to the settlement. According to the OCA, resource constraints prevented the OCA from devoting sufficient time to the docket and gaining sufficient comfort with the settlement. OCA stated it would like to see more emphasis placed on demand side management and energy efficiency options as part of any solution to increased gas demand in the future.

C. Staff

Staff stated it supports the settlement agreement for the reasons discussed by Liberty Consulting Group. Liberty Consulting Group was engaged by the Commission to evaluate the proposed agreement with TGP and review EnergyNorth's analysis in support of its proposal. Of particular relevance to this docket, Liberty had recently advised the Staff of the Connecticut Department of Utility Control (DPUC) in connection with a proposal for an LNG-based peaking facility that was approved by the DPUC and recently commenced operation.

Liberty restricted its evaluation of the alternatives to the LNG with liquefaction option because of service quality issues associated with the use of propane air in some locations and because the LNG without liquefaction option presents issues of access to and terms for the provision of LNG supply that could compromise its viability as an option. Liberty stated, for example, that the Company's contracts for LNG supply limit the quantities available during peak winter months and the availability of sufficient trucks for transporting LNG from the source to the Company's peaking facilities can be a binding constraint. In addition, according to Liberty, it is widely understood that providers of LNG give better prices to customers which have their own liquefaction capability, thus making it a more attractive option in this respect.

Liberty did not analyze a demand-side management alternative for meeting the incremental capacity need because it did not have any data that would have allowed that alternative to be put into the mix of choices. Accordingly, it took no position on the Company's rationale for excluding demand-side management as an option at this time. Liberty agreed with the OCA that, besides demand-side management programs, the use of interruptible rates is an alternative that could be examined in connection with meeting a peaking demand.

Liberty identified several concerns and shortcomings regarding EnergyNorth's analysis. For example, it found that the Company had double counted some of the component costs of the on-system alternatives and had used several inappropriate parameters for its revenue requirements analysis, further increasing the apparent costs of the on-system alternatives. Liberty also had some methodological questions about the Company's optimization analysis which it addressed with the Company.

Liberty, with Staff's assistance, adjusted the Company's analysis at each stage. Based on information provided by EnergyNorth and information from its Connecticut experience, Liberty estimated that approximately $56 million would be required for a 0.3 Bcf tank with 25,0000 MMBtu sendout capacity and liquefaction capability. Liberty observed that smaller facilities would be even more costly per unit of capacity because of costs that do not vary in size. Comparing the levelized annual capacity costs derived from its analysis, Liberty stated that the estimated capacity cost of the Concord Lateral upgrade, adjusted in order to make a fair comparison, was $3.7 million while the on-system LNG with liquefaction alternative was estimated to be approximately $6.5 million, a difference of approximately $2.8 million.

One of the important adjustments regarding the supply costs of the alternatives being analyzed was to the estimated basis differential[7] for gas delivered to the inlet of the Concord Lateral. Prices at that location are necessary to run the Company's LP optimization model since the Company's proposed arrangement with TGP and one of its current gas supply resources require it.

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[7] Basis differential is the observed difference in price between gas available at a receipt point and gas delivered to a delivery point, in this case from Henry Hub to the inlet of the Concord Lateral at Dracut. According to Liberty, a large differential reflects the value of pipeline transportation between a gas source and New England during periods of transportation constraints, such as when the weather is very cold.

Liberty explained that the Company added $2.30 per MMBtu to the Henry Hub price during the winter months as the estimated basis differential. Liberty expressed concern that while a $2.30 per MMBtu basis differential may be appropriate for baseload supplies, it is not representative of the market differentials that would be likely during periods of peak demand.

According to Liberty, the data suggest that the daily basis between Henry Hub and either Dracut or TGP Zone 6 is approximately $0.50 except on cold winter days when the differential goes much higher. Liberty concluded that the $2.30 per MMBtu number is much too low to be applied to the peaking supplies that are an important part of the analysis. Liberty stated that the basis differentials observed during the very cold month of January 2004 should be considered indicative of what they would be when the incremental capacity would be called on. Liberty noted that although the basis differential went as high as $57 during January 2004, the weighted average basis differential for EnergyNorth's spot purchases in that month was approximately $12 per MMBtu. Liberty observed that even though basic gas prices are higher, and oil prices are much higher, than they were in 2004, it relied on the $12 per MMBtu value for its analysis because that number has actually been observed.

According to Liberty, the on-system LNG with liquefaction alternative would allow EnergyNorth to buy gas during the summer when the basis differential is only about $0.50 to $0.60 per MMBtu. Although hard to predict, the basis differential associated with the proposed arrangement with TGP may be higher if supply has to be purchased in the winter. Liberty stated that the difference between the estimated capacity costs of the two alternatives, approximately $2.8 million, is in effect available to offset this higher basis differential.

After making its suggested changes to the inputs and parameters involved in the Company's analysis, Liberty recomputed the levelized revenue requirements associated with each alternative and repeated the Company's optimization analysis to see how the results would change when Liberty's values were substituted for the Company's.

In retesting the higher basis as a surcharge on the incremental Concord Lateral capacity, Liberty found that for 2009-2010 the optimization model still picked the Concord Lateral option over the LNG with liquefaction alternative. When Liberty reran the model with 2011-2012 gas prices and the 2004 basis differential, the model still picked the Concord Lateral option. Testing even higher differentials, Liberty found that with a basis differential of $16.93 per MMBtu (which is 40% higher than that experienced in January 2004) the model split the requirements between the Concord Lateral and Liberty's LNG with liquefaction alternative. Liberty also found that the model was still splitting the requirement at $21.93 per MMBtu, though more of it would be supplied by the LNG alternative.

Liberty concluded that the proposed agreement with TGP provides cost effective access to sources of peak period supplies that the Company requires. Liberty agreed with the Company that, besides the question of cost, there are some attractive aspects of the Concord Lateral upgrade option, including the fact that the availability of that capacity would allow the Company to make certain adjustments within the portfolio that might lower other costs and have the effect of offsetting some of the cost of the proposed agreement with TGP. Liberty stressed that the Concord Lateral upgrade is not a resource that the Company can use to meet its requirements for peaking capacity but rather is a means of providing access to potential sources of peaking capacity that are in addition to the Company's existing on-system peaking plants.

Liberty recommended that the Company be required to show that those supplies will be available on a firm basis at Dracut on terms that are competitive with its on-system alternatives for peaking supplies. In Liberty's view, for the period of interest in Liberty's analysis, if peak period supplies are available on a firm basis at Dracut for an average premium of $12 per MMBtu or less over the Henry Hub price, then those supplies are the most cost effective solution to EnergyNorth's peaking problem at the present time. Accordingly, Liberty recommended that the Company be required to show that firm peaking supplies can be made available over the next five years at Dracut at a price that would not upset the comparisons made in its analysis. Liberty expressed confidence that on the basis of its experience with the New England gas markets, such a showing could be made and thus concluded that the Company's proposal to enter into the TGP contract should be approved once the requisite showing was made.

At hearing, Liberty confirmed that EnergyNorth had made the showing Liberty had recommended. Liberty first noted that one of the suppliers approached by the Company had provided a quote that was in the acceptable range and two others expressed a willingness to offer firm supply at Dracut but at a daily price. Liberty also noted that two motivated sellers were not asked for indicative pricing due to on-going negotiations regarding other supply arrangements. Finally, Liberty confirmed that longer term studies suggest that winter period basis differentials will decline because of increases of LNG supply to New England from projects such as Canaport and Neptune and because of increased capacity available to the Northeast from multiple pipeline projects.

Liberty discussed the planning conference provided for in the settlement agreement. At the planning conference to be held in July 2009, the Company will review its approach to obtaining supply before issuing requests for proposals. The objective will be to look at the widest possible array of supply alternatives, which will likely include call options priced at monthly or daily indexes and delivered peaking services. The Company will also discuss the anticipated use of all Concord Lateral capacity and on-system peaking facilities.

Liberty also noted that questions regarding the Company's longer term options for meeting its growing requirement for peak period capacity remain to be addressed. Liberty stated that continued load growth in the future will pose a problem similar to that addressed by the Company's proposed agreement with TGP. Liberty stated that capacity choices involve long lead times[8] and if the Company can foresee a requirement for additional capacity as soon as three years from now as indicated by one forecasting model used for some of the discovery responses submitted by the Company in this docket, the time to start planning for the next increment of capacity is now. Liberty urged that given the lengthy nature of the facility siting and approvals process, consultations to support the possible development of on-system options should begin soon. Liberty opined that those issues could be addressed as part of the Company's integrated resource planning process.

IV. MOTIONS FOR PROTECTIVE ORDER AND CONFIDENTIAL TREATMENT

A. Motion for Protective Order and Confidential Treatment Regarding Response to Staff Data Request Tech 1-3, filed on November 16, 2007

EnergyNorth requested that the Commission issue a protective order giving confidential treatment to certain computer source code and ancillary computer files in response to Staff's Data Request Tech 1-3, which requested discovery of the text files for the linear programming (LP) computer model used by the Company to evaluate the proposed Concord Lateral and potential alternative projects. EnergyNorth asserted that the text files requested were developed internally by EnergyNorth and have commercial value, and if publicly disclosed, the model, or services based on the model, could be sold to gain a commercial advantage. EnergyNorth claimed that such disclosure would be giving away EnergyNorth's own work product, resulting

[8] As an example, Liberty related that even with a site in hand and a willing community, it took a Connecticut gas utility six and a half years to go from the initial proposal to the DPUC for an LNG-based peaking facility to the facility being placed in service.

in a commercial disadvantage to the Company. EnergyNorth maintained that the LP model it developed constitutes confidential commercial information and stated it does not disclose the information to anyone outside of its corporate affiliates and their representatives. EnergyNorth requested that the protective order also be extended to any discovery, testimony, argument, or briefing relative to the confidential information.

B. Motion for Protective Order and Confidential Treatment Regarding Information Provided in Certain Responses to Staff's Data Requests and Attachments to Surrebuttal Testimony, Filed on February 13, 2008

EnergyNorth requested that the Commission issue a protective order giving confidential treatment to Staff data requests 1-20 (an attachment that includes a summary of bid responses for the fall 2007 RFPs for supplies), 2-23 (daily effective degree day data for Manchester), 2-24 (Attachment E contains bidder and price quotes for the Dracut 20,000 dth RFP dated July 31, 2007), 2-27 (Attachments A-E include daily and monthly Henry Hub pricing and Attachments F-J include daily Dracut pricing between September 2003 and September 2007), 2-28 (Attachments A-F include monthly pricing for propane for the past 5 years), 2-29 (Attachments A-F contain purchases by supplier and price in January 2004), 2-34 (correspondence with AES/Granite Ridge re potential purchase of incremental services), Tech 2-1 (Attachment A contains time-series Platt's/Inside FERC monthly settlement prices), and 3-22 (Amendment No. 2 to the natural gas firm peaking agreement with Granite Ridge), as well as attachments 2-8 to the surrebuttal testimony of Elizabeth D. Arangio (attachments contain listing by name of gas suppliers solicited as part of the RFP process, price quotes for the 2009/2010 peak season at Dracut, and market intelligence on projected costs of natural gas from third-party consultants).

The Company asserted that with the exception of its response to Staff 2-23 and Tech 2-1, all of the listed data responses, as well as attachments EDA-2 through 8, contain pricing information and responses to requests for proposals that constitute confidential information that is exempt from public disclosure under RSA 91-A. In addition, EnergyNorth claimed it has a contractual obligation to keep the information provided by potential gas suppliers in the RFP responses confidential and that the release of that information would likely have a negative impact on the responses and information in future RFPs. EnergyNorth stated that this information is similar to that which the Commission has routinely provided protective treatment in a number of cost of gas and other proceedings. EnergyNorth maintained that the information provided in response to Staff 2-23 and Tech 2-1 is proprietary to third-party vendors and that it had an obligation to maintain the information in confidence under its arrangements with those vendors. EnergyNorth stated that it maintains the pricing information and the information provided by third party vendors confidentially and does not generally make it available to third parties. The Company asserted that release of the information for which confidential treatment is sought is likely to result in a competitive disadvantage for the Company in the form of less advantageous or more expensive gas supply contracts since suppliers possessing the confidential information would be aware of EnergyNorth's expectations regarding gas supply contracts and other contract terms, and would be unlikely to propose to supply such goods and services on terms significantly more advantageous to the Company.

Finally, EnergyNorth requested that Staff's outside consultant be prohibited from using the confidential information for any purpose other than for services provided to the Commission and, specifically, that the consultant return to the Commission or EnergyNorth at the conclusion of the consultant's services all materials containing any of the confidential material and be prohibited from using the confidential information for any other client it may have or for its own purposes.

At hearing, Staff requested that the Company provide additional support for granting confidential treatment for certain of the items identified by the Company in its motion, relating to Henry Hub pricing and Dracut pricing (2-27), propane pricing (2-28), and certain monthly settlement prices (Tech 2-1). The Company responded that this information is obtained from various third parties with which the Company has a contractual obligation to maintain the information in confidence.

V. COMMISSION ANALYSIS

A. Merits

N.H. Code Admin. Rules Puc 203.20(b) provides that the Commission will approve a disposition of any contested case by settlement if the Commission determines that "the result is just and reasonable and serves the public interest." For the reasons set forth below, we find that the settlement agreement satisfies these standards and we therefore approve it.

We note that the decision of whether to approve the proposed arrangement between EnergyNorth and TGP is an important one involving a long term commitment of substantial ratepayer dollars, $4,380,000 for 20 years, not including the supply costs. Moreover, as reflected in its direct testimony in Docket No. DG 06-105, Staff had initially expressed skepticism about using a new pipeline project, which is often associated with high fixed capacity costs and low variable commodity costs, to meet a low load factor, i.e., peaking demand increment, which is normally satisfied at least cost with peaking capacity and associated supplies.[9] Under such rather unusual circumstances, we believe it is reasonable to review the prudence of the Company's proposal in advance of the final decision to enter the proposed arrangement rather than after the fact as is customary.

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[9] Liberty also maintained that EnergyNorth's requirement is for peak period supplies which is normally met by peaking capacity.

The Company has performed a detailed analysis of the alternative supply oriented solutions with input from its pricing analyst, engineers, and gas planners, and documented the analysis at some length in testimony. In cooperation with Staff, Liberty, an outside expert with recent relevant experience with the costs of constructing and operating LNG-based peaking plants, has reviewed the Company's analysis and carefully evaluated the proposed agreement between EnergyNorth and TGP in light of a likely on-system, LNG-based peaking alternative. Liberty changed the Company's inputs and parameters about which it had doubts, addressed methodological questions about the Company's LP optimization model with the Company, and reran the model before finally satisfying itself that the Company's fundamental conclusion, namely that the proposed agreement with TGP represents the preferred solution for meeting the Company's need for incremental capacity, is sound. The Company and Liberty have conducted thorough evaluations and reached the same conclusions. We are persuaded that, as agreed to in the settlement, the Company's decision to enter into the TGP agreement is prudent and consistent with the public interest.

Of course, decisions must still be made about the supplies that will be acquired to take advantage of the incremental capacity on the Concord Lateral. That will be the focus of the planning conference between the Company, Staff and OCA to be held in July 2009. The Company recognizes, and we agree, that notwithstanding the settlement, it remains under an obligation to prudently purchase its gas supplies, including the purchase of supplies in 2009. Beyond the issues to be discussed at the planning conference, Liberty noted that capacity choices of the kind faced by the Company in this case require long lead times and advance planning.

B. Motions for Protective Order and Confidential Treatment

The Right-to-Know Law provides each citizen with the right to inspect all public records in the possession of the Commission. *See* NH RSA 91-A:4, I. The statute contains an exemption, invoked here, for "confidential, commercial, or financial information." RSA 91-A:5, IV. Our applicable rule, N.H. Code Admin. Rules Puc 203.08, is designed to facilitate the implementation of the statute as it has been interpreted by the courts. In most cases, a balancing test is used to determine whether confidential treatment should be granted. *See e.g., Union Leader Corp. v. New Hampshire Housing Fin. Auth.*, 142 N.H. 540 (1997).

We note that Staff has concluded that grounds exist for granting the two motions for confidential treatment and that much of the information for which such treatment is sought is similar to information for which the Commission has granted confidential treatment in the past. In addition, the information in these responses are not publicly available elsewhere. As to such information, in balancing the interests for and against public disclosure of the information for which confidential treatment is sought, we are persuaded on the basis of the record in this docket that the interests of EnergyNorth, and ultimately its ratepayers, as well as the legitimate interests of third parties in non-disclosure outweigh the public's interest in obtaining access to the information.

We will therefore grant confidential treatment to the extent set forth above. Consistent with past practice, the confidential treatment provisions of this order are subject to the on-going rights of the Commission, on its own motion or on the motion of Staff, any party or any other member of the public, to reconsider in light of RSA 91-A, should circumstances so warrant.

Based upon the foregoing, it is hereby

ORDERED, the settlement agreement is approved; and it is

FURTHER ORDERED, that the motions for protective order and confidential treatment are granted to the extent set forth above.

By order of the Public Utilities Commission of New Hampshire this twenty-ninth day of February, 2008.

Thomas B. Getz Chairman	Graham J. Morrison Commissioner	Clifton C. Below Commissioner

Attested by:

ChristiAne G. Mason
Assistant Executive Director & Secretary