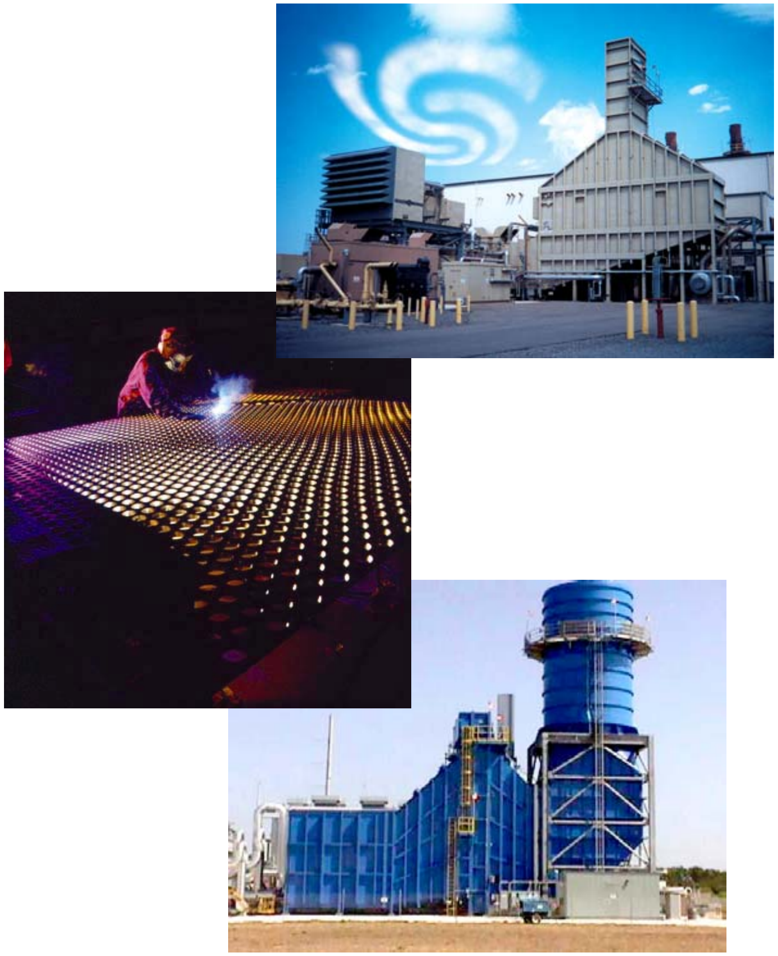


GAS TURBINE PERFORMANCE ENHANCEMENT WITH ONCE THROUGH HEAT RECOVERY STEAM GENERATORS

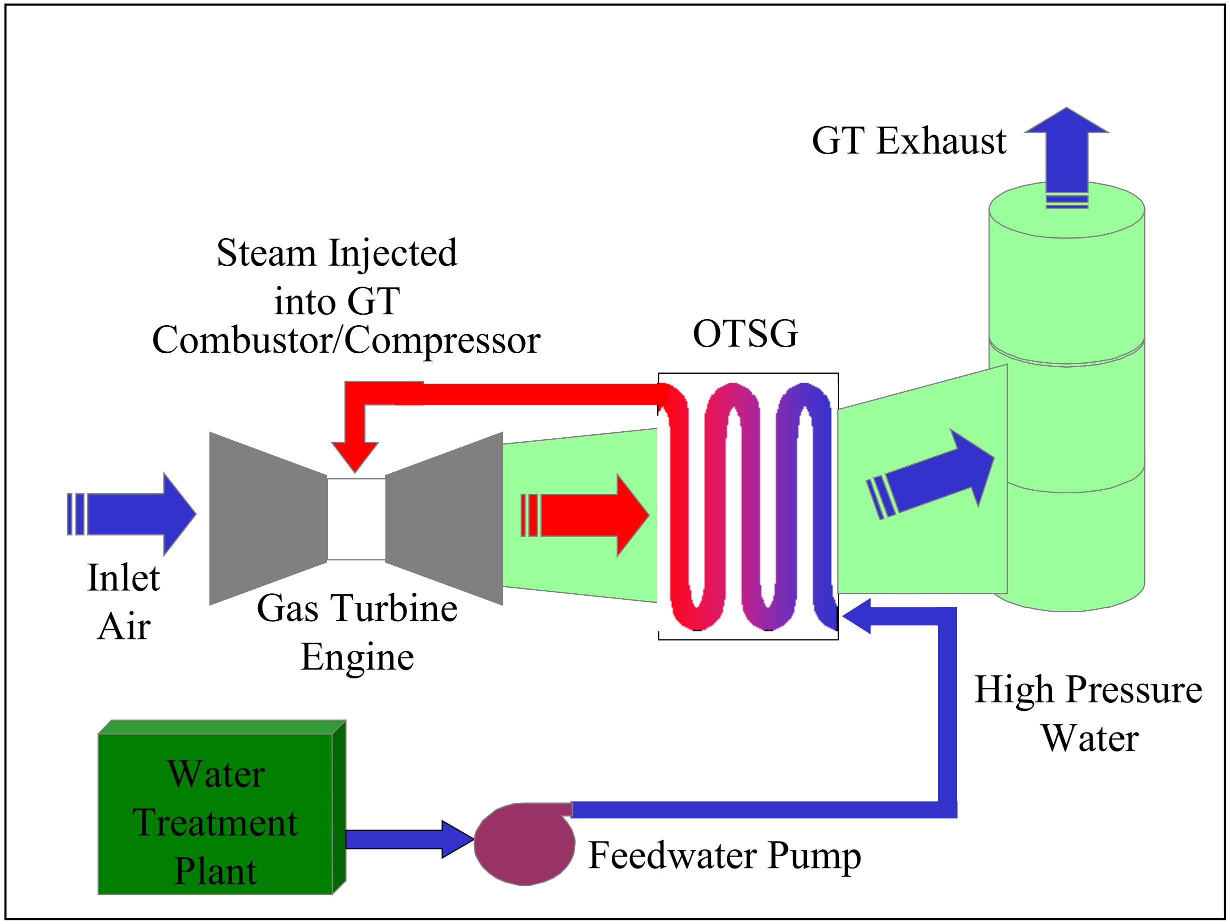
Presenter/Author: Jim McArthur, P.Eng.
Vice President, Technology
Innovative Steam Technologies

Presenter/Author: Michael Brady, P.Eng.
Manger, Sales and Marketing
Innovative Steam Technologies

December 2002

STEAM INJECTION PROCESS

Clean, dry steam injected into the gas turbine at approximately 300 psig and with approximately 50 F of superheat.



ADVANTAGES OF GAS TURBINE STEAM INJECTION OVER INLET AIR COOLING

- The power increase can be realized independent of ambient conditions (temperature or humidity). The power augmentation process will increase power in all climates and at all times of the year.

- Power augmentation results in greatly increased NO_x reductions. The injected steam reduces the flame temperature thereby reducing NO_x emissions.

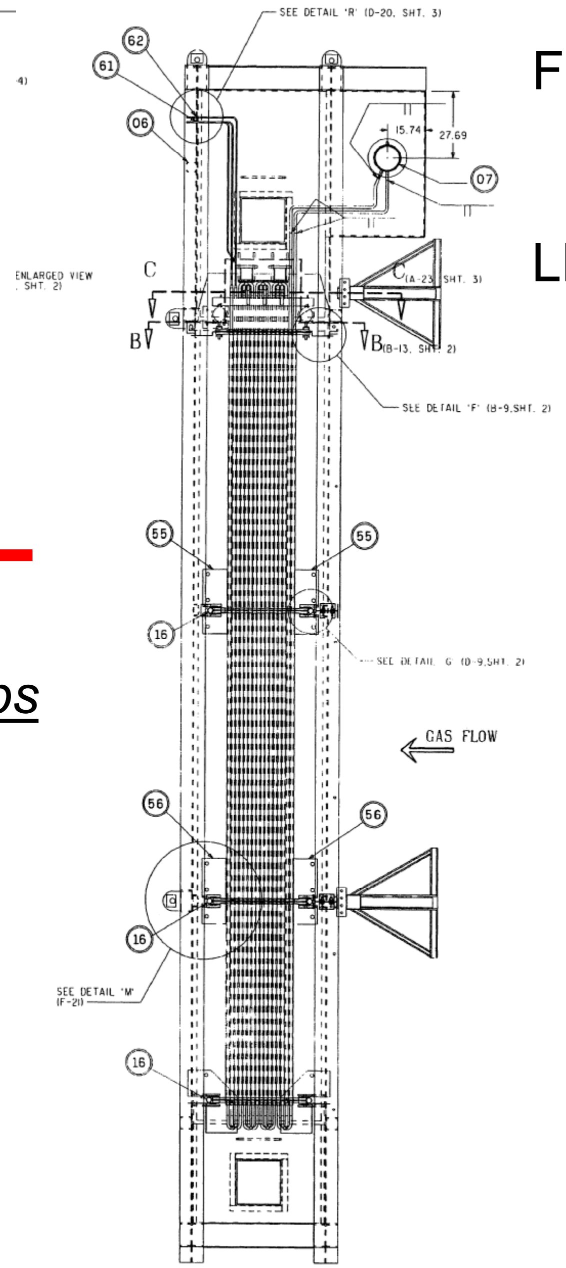
TYPICAL STEAM CONDITIONS

Frame 7FA - 125,000 lb/hr

- 700 F / 500 psia

LM6000 - 40,000 lb/hr

- 600 F / 650 psia



<u>Typical Gas Exit Temps</u>

Frame 7FA - 970 F

LM6000 - 640 F

<u>Typical Gas Inlet Temps</u>

Frame 7FA - 1120 F

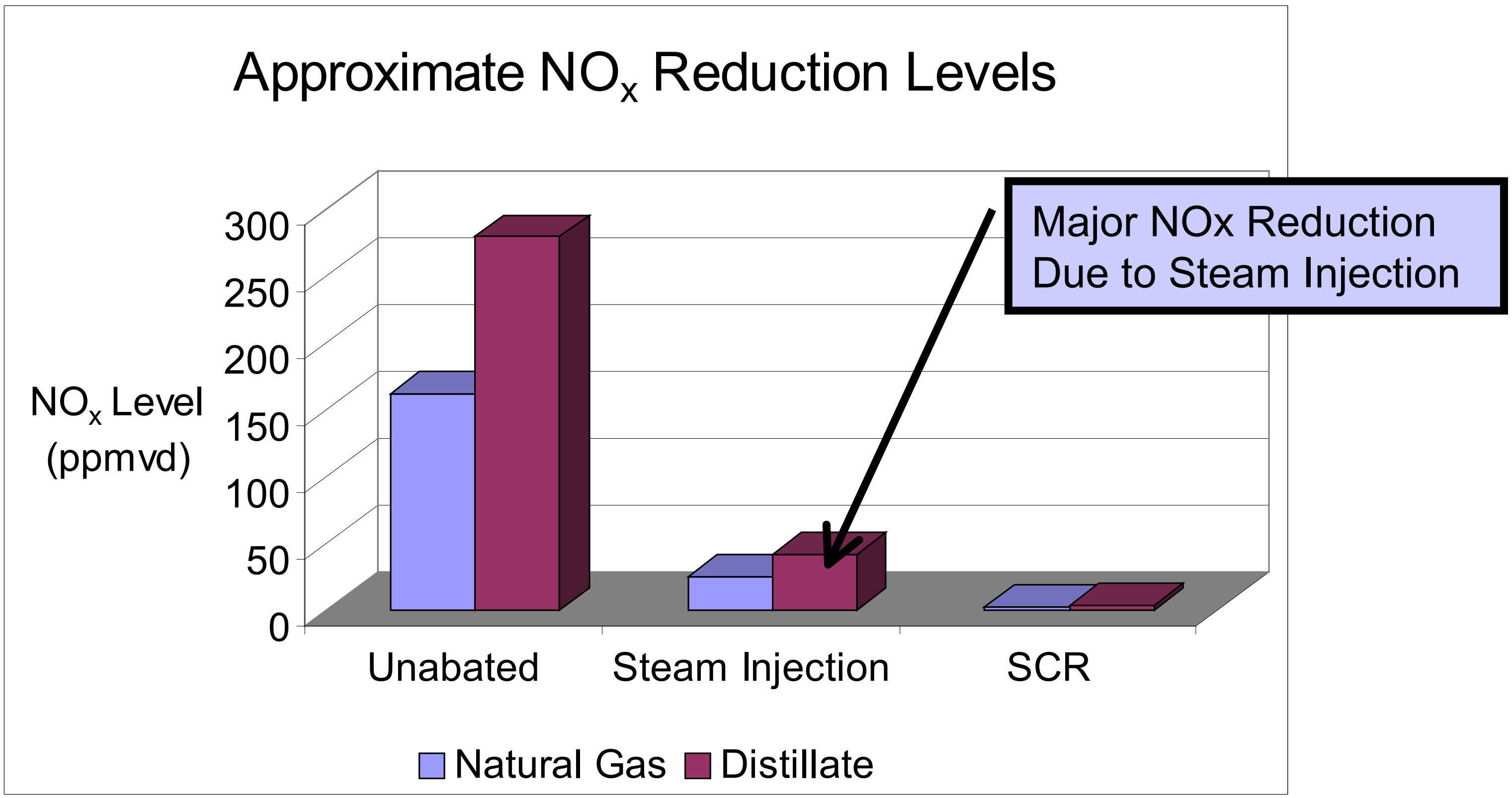
LM6000 - 800 F

GAS TURBINE STEAM INJECTION

- Three (3) purposes for steam injection
  - NOx Reduction
    - Steam injected upstream of compressor
  - Power Augmentation
    - Steam injected into compressor discharge
  - Gas turbine blade cooling

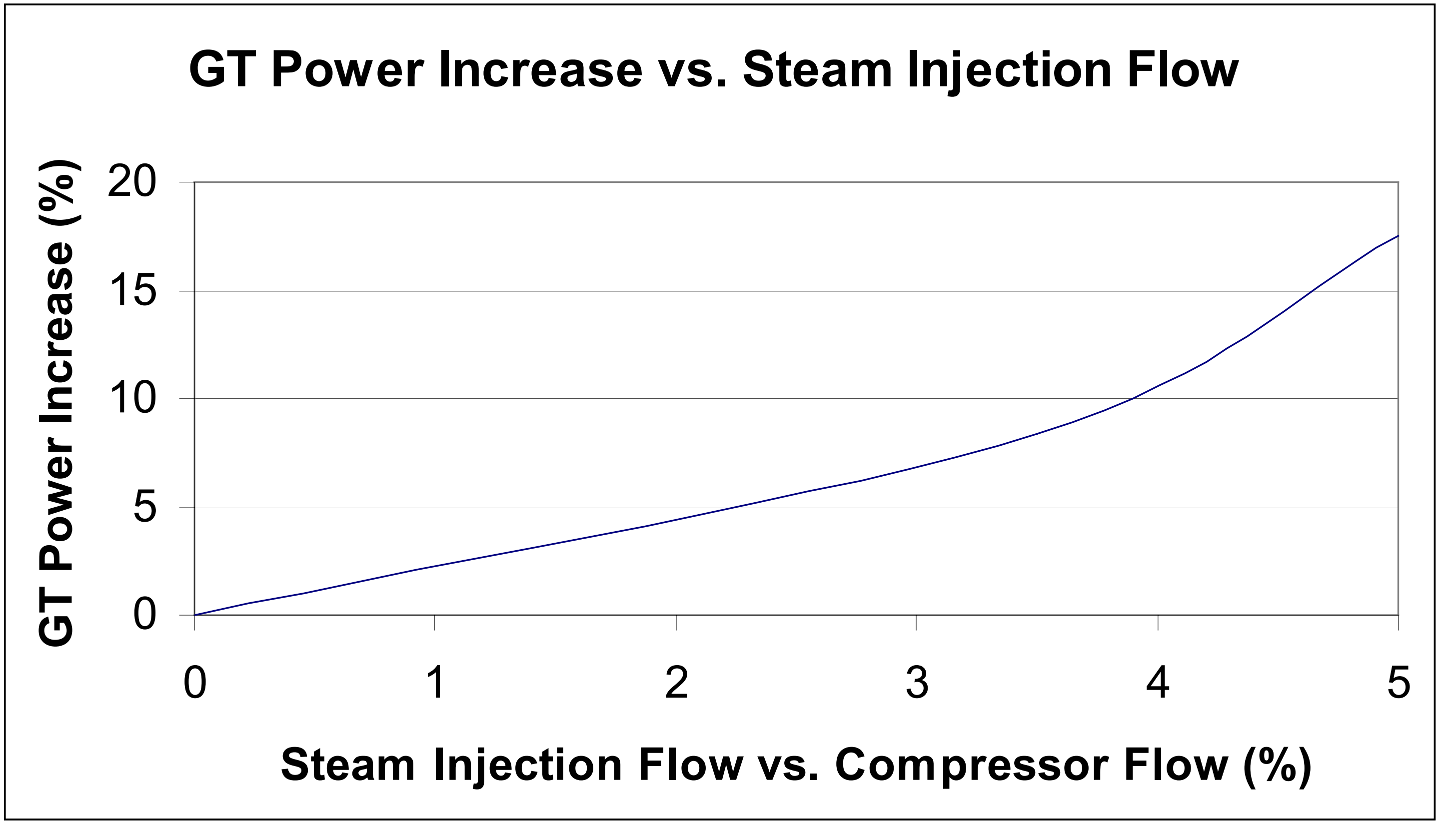
STEAM INJECTION FOR NO_x REDUCTION

- Steam Injection will substantially reduce gas turbine NO_x levels



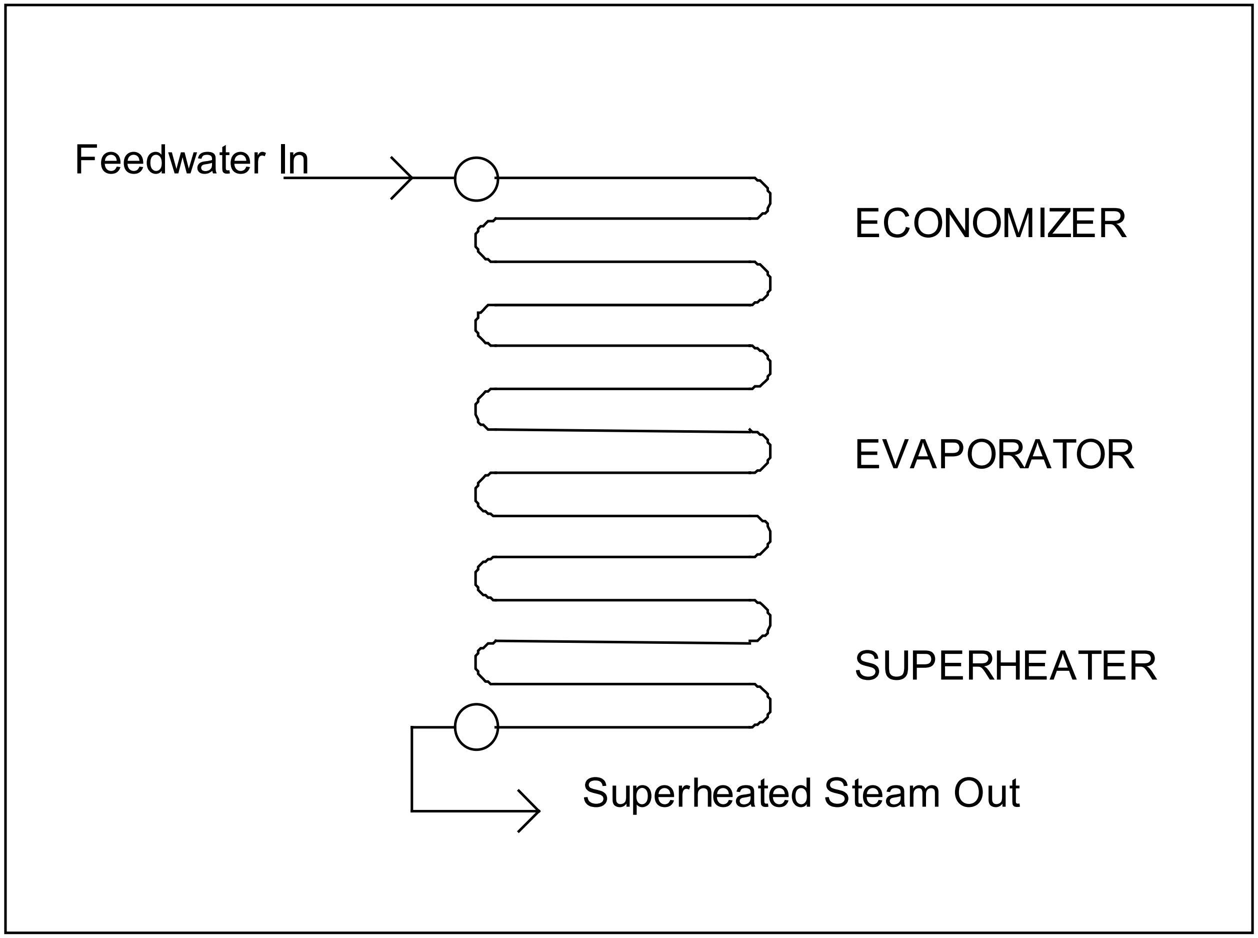
STEAM INJECTION FOR POWER AUGMENTATION

- Gas turbines generally are designed to allow steam injection levels of up to 5% of the compressor airflow with flows as high as 10% allowed on some gas turbines
- Steam injection will increase power output by approximately 17.5% for all ambient conditions (independent of temperature, humidity etc.)



APPLICATION OF OTSG TO STEAM INJECTION

OTSG - Once Through Steam Generator -in its simplest form, is a continuous tube in which preheating, evaporation and superheating of the working fluid takes place consecutively



APPLICATION OF OTSG TO STEAM INJECTION

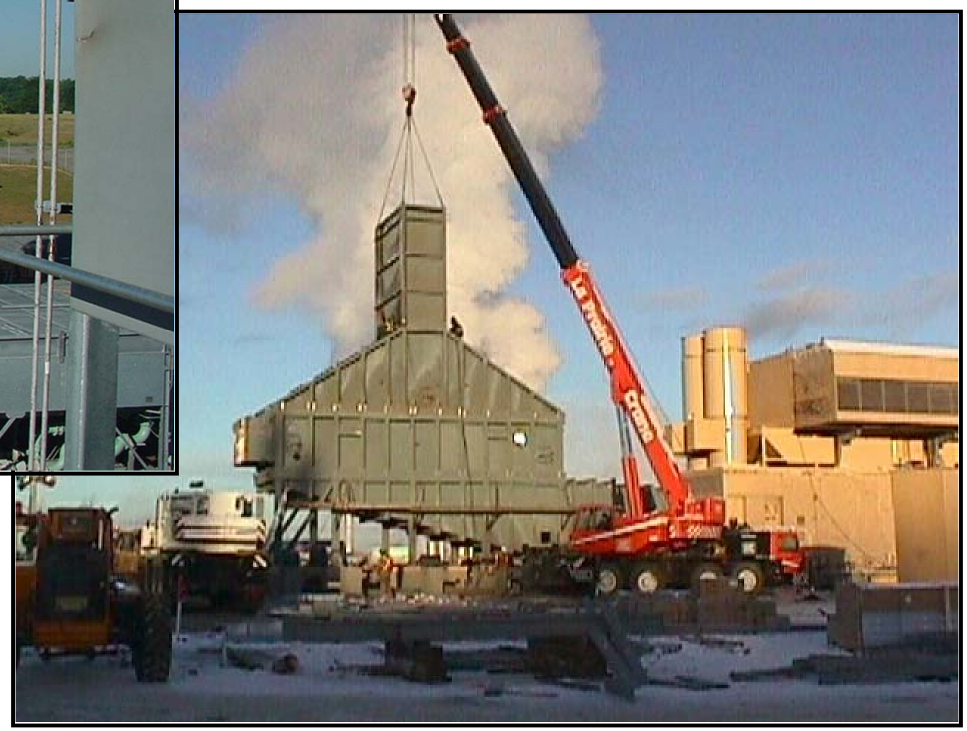
- Versatility (Horizontal or Vertical Gas Flow Arrangements)
- Minimum volume, weight, and complexity.
- Inherently safe as the water volume is minimized by using only small diameter tubing.
- Temperature or pressure control are easily achieved with only feedwater flow rate regulation.
- Complete elimination of all by-pass stack and diverter valve requirements while still allowing full dry run capability.
- Operational benefits such as improved off design (turn down) efficiency, cycling and transient response
- Complete modular design with inherently lower installation time and cost.

STIG OTSG ARRANGEMENT VERSATILITY

- OTSGs can be designed for horizontal or vertical gas flow paths as required (gravitational forces not required for circulation of water/steam)

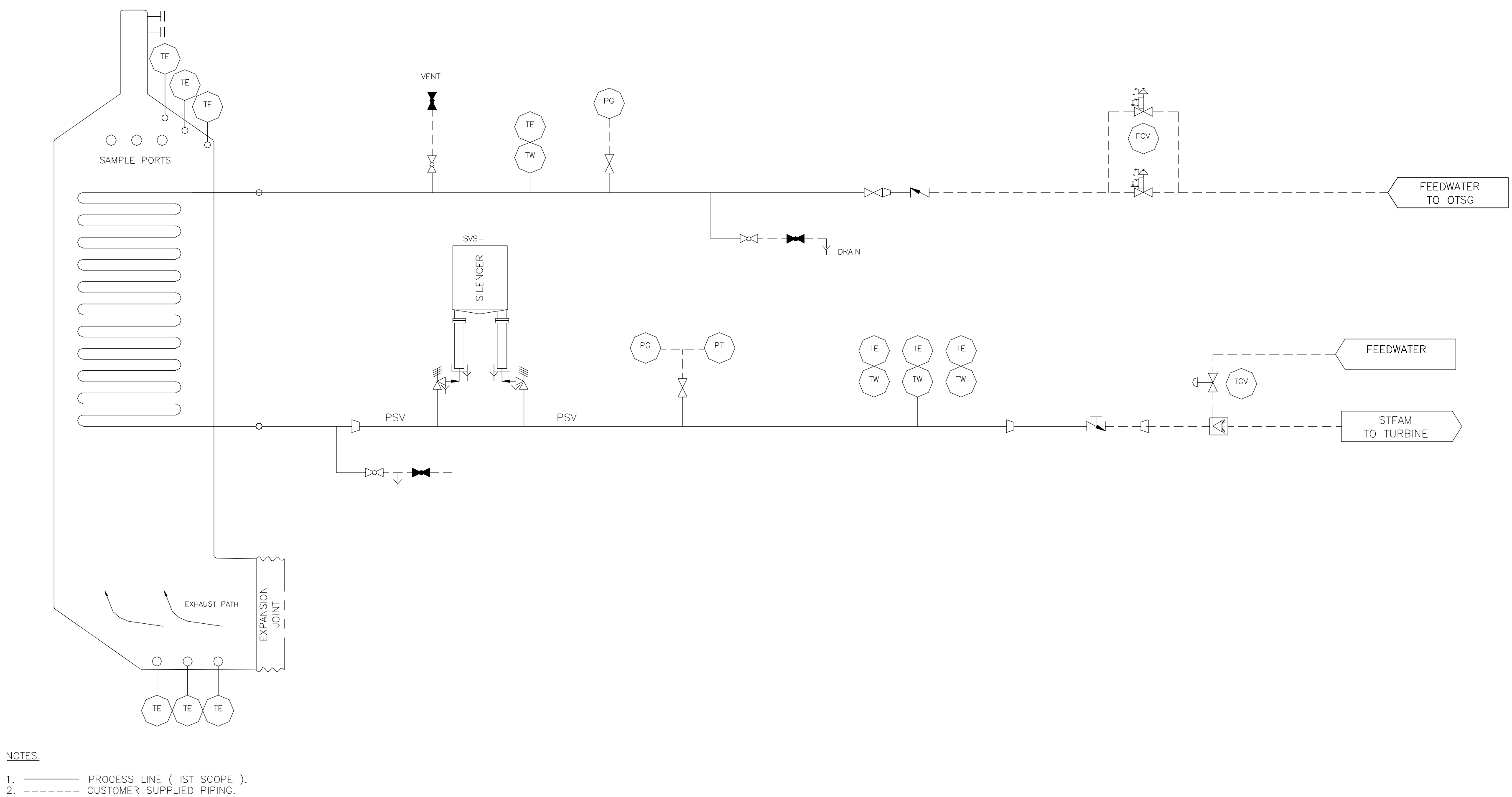
Horizontal gas flow - Frame 7FA

Vertical gas flow - LM6000



STIG OTSG MINIMUM COMPLEXITY

➢ Steam flow can be modulated to control steam temperature or pressure



DRY RUNNING CAPABILITY

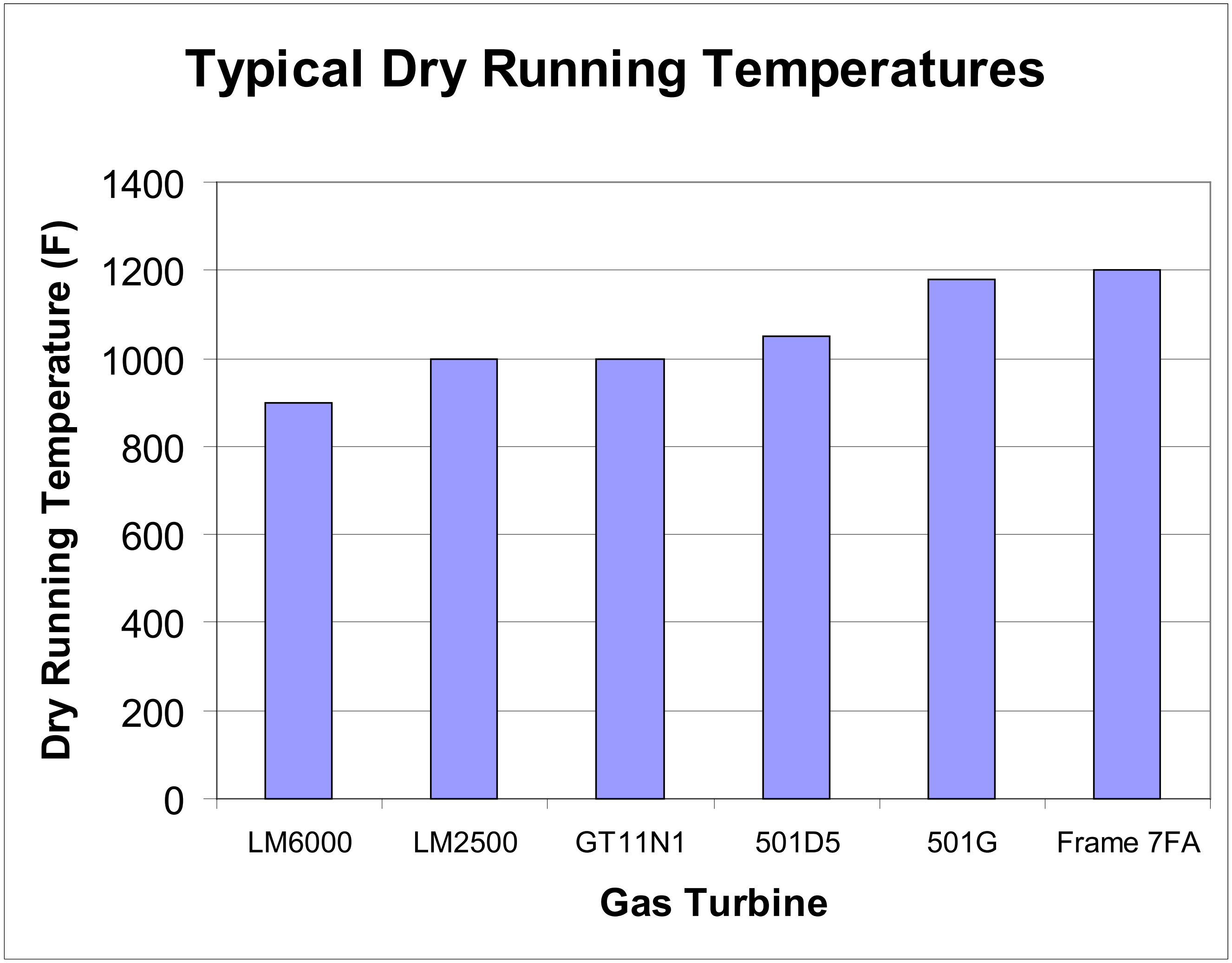
- Dry running refers to operation of the OTSG without any water/steam flow inside the tubing

- Should steam injection not be required during certain times of the year, the OTSG can be run dry without a gas bypass stack and damper.

- Dry running can also be used for removing soot resulting from liquid fired gas turbine or SCR applications

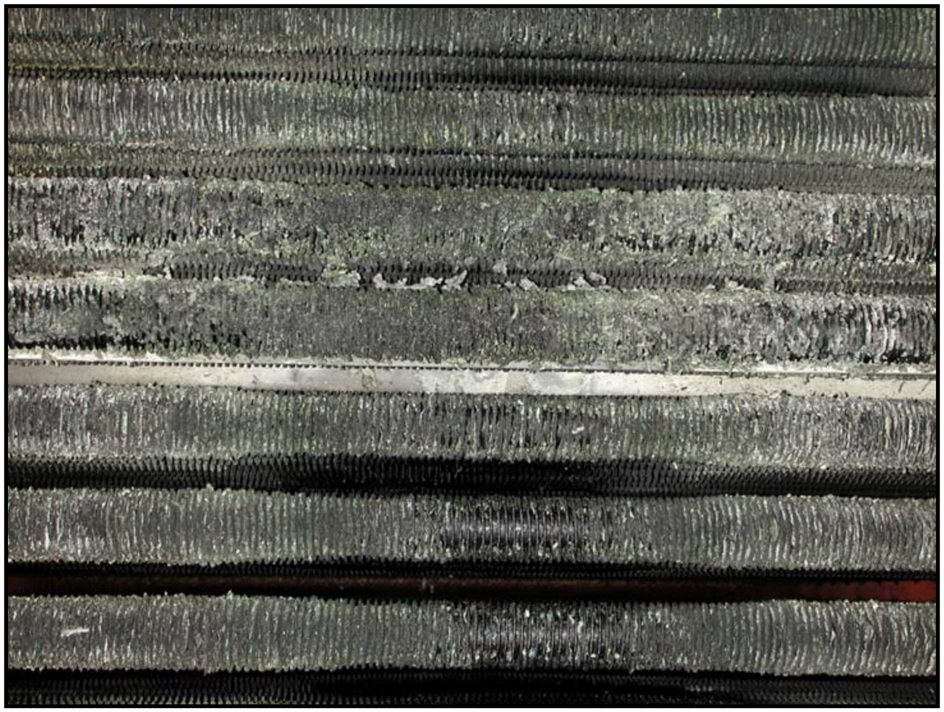
DRY RUNNING TEMPERATURES

- Tube material selection and operational guidelines will depend on the maximum gas temperature expected during dry running



FIELD PICTURES OF DRY RUNNING RESULTS

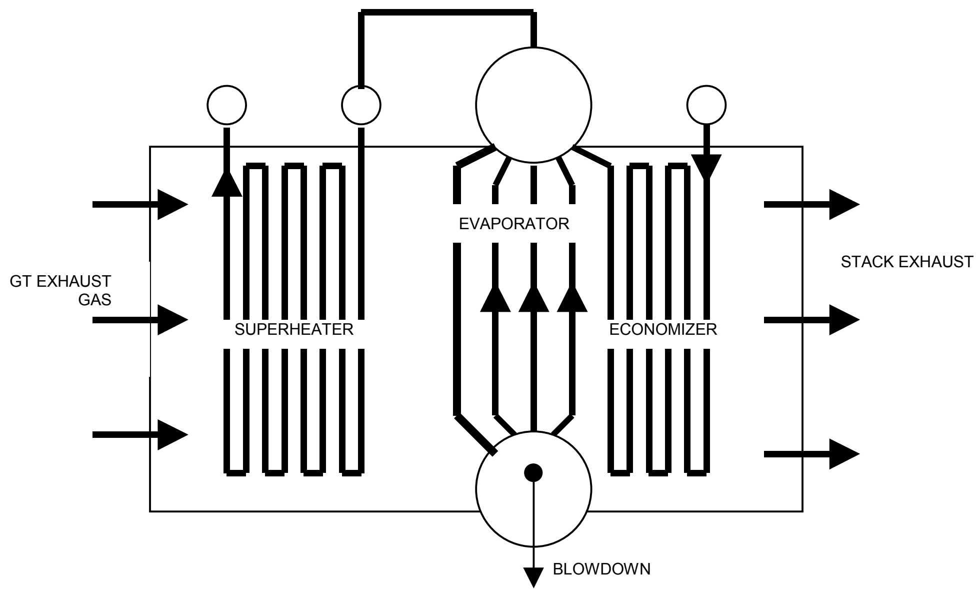
Soot deposits on inlet tubing
of liquid fired LM2500 with SCR



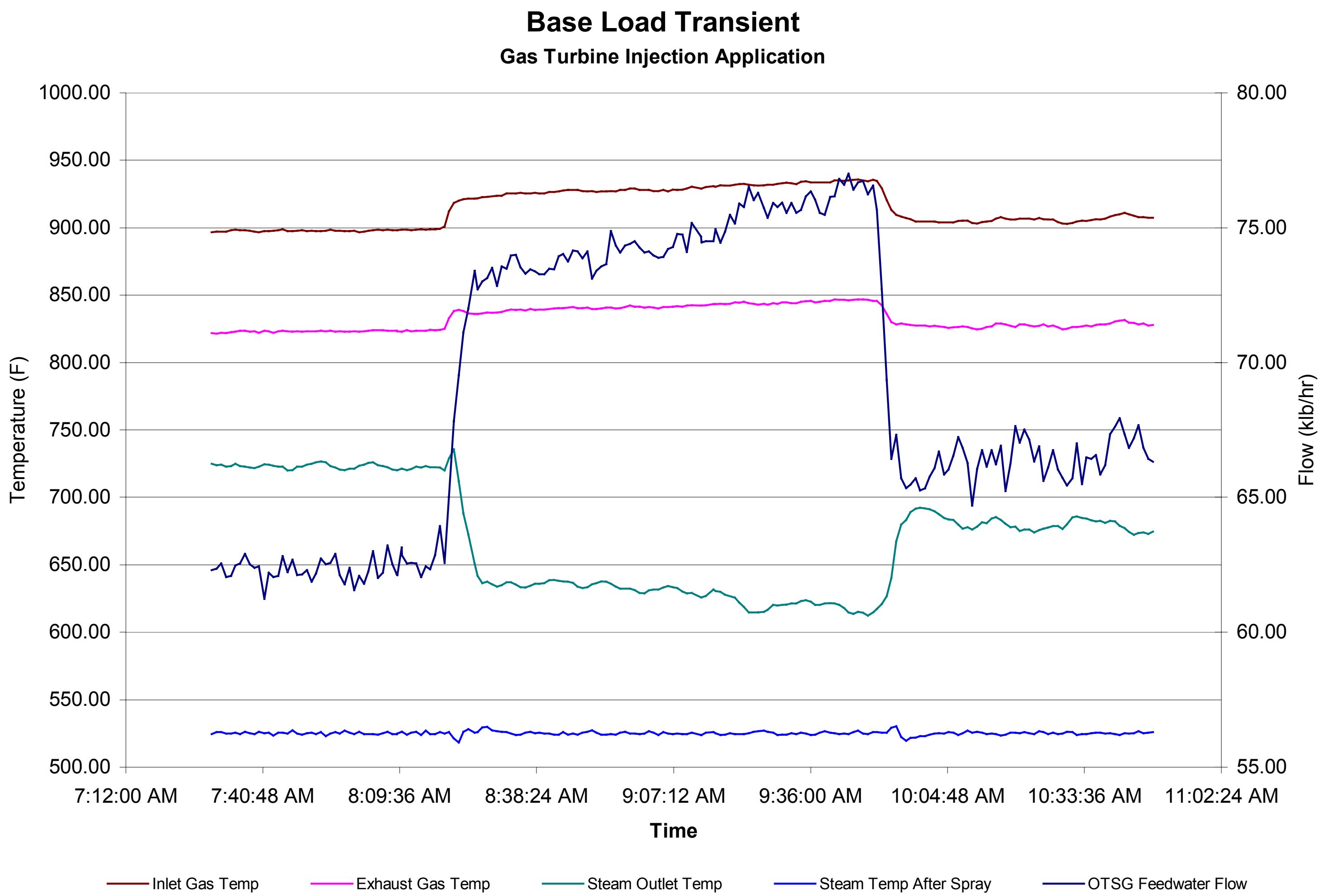
Results of dry running

CYCLING AND TRANSIENT RESPONSE

- Traditional drum type HRSGís are limited in their fast response and transient capability by the steam drums and associated water inventory and mass of metal which require heating. Using an OTSG and eliminating the drums and interconnecting piping, the fast start and cycling capabilities are vastly improved.



TRANSIENT RESPONSE - FIELD DATA



COMPLETE MODULAR DESIGN

- Erection span for the OTSG installation with all of the additional balance of plant equipment is usually limited to 800 to 1000 labour hours per system.
- The main steps are as follows:
  - Prep OTSG Module
  - Connect crane with spreader beam top and bottom of pressure part module
  - Hoist module, lowering bottom end and raising top end
  - Lift module vertically and swing into position within existing exhaust duct
  - Slide OTSG module into ducting

STIG - Erection

- Modules are shipped to site by road
- Typical Dimensions:
  - ñ 40í long
  - ñ 12í wide
  - ñ 6í high
  - ñ 100,000 lbs

STIG - Erection

- Shipping Restraints are Removed
- 2 Crane Lift

STIG - Erection

- OTSG in vertical position
- 2nd Crane Removed

STIG - Erection

- Top supported finned tube bundle
- Modules are Shop Assembled
  - ñ Side by Side module arrangement
- Dry Running to 1500F with all Alloy 800 tubing
- Fast Start Up

STIG - Erection

- OTSG placed into ducting
- Other Tasks Required:
  - Seal Welds
  - Connect to external steam and feedwater piping
  - Connection of OTSG inter-module headers

- Most PPAís have the ability to create additional revenue for the plant operators.
- Revenue increase opportunities based on structure of PPA:

ï **I)** PPA structured to create plant revenue for base load or peak load power production (kW).

Flexible Production Payment structure.

$$PPA_{REVENUE}\ f(kW) = (kW_{BASE} + kW_{PEAK}) + \underbrace{(kW_{BASE} + kW_{PEAK})_{EXCESS}}_{\text{Steam Augmentation}}$$

ï **II)** PPA structured to create revenue based on continuous installed capacity (plant on or off), power production payment is based on availability of power (kW).

Capacity and Energy Production Payment structure.

$$PPA_{REVENUE}\ f(kW) = (kW_{CAPACITY} + kW_{ENERGY\ PRODUCTION}) + \underbrace{(kW_{CAPACITY} + kW_{ENERGY\ PRODUCTION})_{EXCESS}}_{\text{Steam Augmentation}}$$

ï **III)** PPA structure is fixed and no payment for excess power production only on fixed power production (kW_{MAX}).

Fixed and Capped Production Payment structure.

ñ $$PPA_{REVENUE}\ f(kW) = (kW_{EFIXED\ ENRGY\ PRODUCTION}) + \underbrace{\text{Fuel Savings}}_{\text{Steam Augmentation}}$$

Performance Enhancement Example

The OTSGô steam injection gas turbine application can increase the GTís power output by 8-12% and in some cases, depending on the design of the gas turbine, up to 17.5% and reduce the NOx emissions by 80%.

Based on the following Plant Arrangement:

- 2 x 155MW Gas Turbines, Total Plant Output 310,000kW regular
- Steam Injection Flow of approximately 118,400lb/hr 34495psia @ 700°F per OTSGô /GT
- Equivalent to 3.5% of the compressor air flow. Resulting Power Increase of 8.4%.
- A significant increase in revenue can be achieved with this example for PPAs that are either a ***Flexible Production Payment*** structure or a ***Capacity and Energy Production Payment*** structure defined above (I & II).

Performance Enhancement Example Contíd

Generated Power	plant kW	GT kW	**Gas consumption**	LHV
Power generated before OTSG (KW)/regular	310000	2 x 155000	BTU/kWhr current	9630
Power generated before OTSG (KW)/peak	310000	2 x 155000	BTU/kWhr enhanced	9270
Power generated after OTSG (KW)/regular	336000	2 x 168000	BTU/kWhr	4978
Power generated after OTSG (KW)/peak	336000	2 x 168000	Gas price ($/MMBTU)	$3.08
Revenue generation starting year	2003			
Number of months of opex in 1st year	12			
Power Augmentation (% increase)	8.4			
Steam Injection Flow of approximately 118,400lb/hr 34495psia @ 700degF per OTSGô /GT				

$$\text{\# of Btu saved/kWhr for the Excess Power Produced} = \frac{\text{(BTU/kWhr enhanced x Power generated after OTSG (KW)/regular) - (BTU/kWhr current x Power generated before OTSG (KW)/regular)}}{\text{Excess Power Generated (kW)}}$$

$$= \frac{\text{(9270Btu/kWhr x 336000kW) - (9630Btu/kWhr x 310000)}}{336000 - 310000}$$

$$= \frac{129420000}{26000}$$

$$= 4978 \text{ Btu/kWhr}$$

Performance Enhancement Example Contíd

There is an alternative saving for clients who have a PPA that is a ***Fixed and Capped Production Payment*** as structure in III above. This saving would be in the form of fuel economy on the gas turbines.

Fuel Savings Clculation			HEAT RATE = BTU/kWhr
Btu/kWhr current	9630	= FUEL / 310MW	
Btu/kWhr enhanced	9270	= FUEL / 310MW	
FUEL=	2985300000	Btu	@ 9630Btu/kWh
	2985.3	MMBtu	
FUEL=	2873700000	Btu	@ 9270Btu/kWh
	2873.7	MMBtu	
The Difference	111.6	MMBtu	
Fuel price	3.08	$/MMBtU	
Saving per:	Hr	1	$ 344
	Day	1	$ 8,249
	Days	30	$ 247,484
	1 Year	365	$ 3,011,057

Revenue and Payback Calculation

➢ ***Capacity and Energy Production Payment PPA***

A Case Study Example:

Generated Power	plant kW	GT kW	**Gas consumption**	LHV
Power generated before OTSG (KW)/regular	310000	2 x 155000	BTU/kWhr current	9630
Power generated before OTSG (KW)/peak	310000	2 x 155000	BTU/kWhr enhanced	9270
Power generated after OTSG (KW)/regular	336000	2 x 168000	BTU/kWhr	4978
Power generated after OTSG (KW)/peak	336000	2 x 168000	Gas price ($/MMBTU)	$3.08
Revenue generation starting year	2003			
Number of months of opex in 1st year	12			
Power Augmentation (% increase)	8.4			
Steam Injection Flow of approximately 118,400lb/hr 34495psia @ 700degF per OTSGô /GT				
Operating hours per year	**hr/year**		**PPA contractual revenue**	**$**
Operating hours (regular opex) / portion of year	6000		Capacity PMT (US$/KW installed)	47.02
OTSG requirement % of hours	70%		Energy PMT (US$/KWhr)	0.0018

Revenue and Payback Calculation Contíd

Capex (Capital Expenses)

	Ref	2002
Construction		
2 x OTSG	i	2700
Deminiralized water plant	i	300
Steam injection control valve	i	50
GT upgrade and accessories	i	50
Commissioning	i	50
Civil works (all inclusive)	i	3230
Freight (within North America)	i	120
Contingency (5% of the sum)	i	480
Subcontractor fee (10% of civil)	f	0
Sub total - Construction (A)	f	6980
Advisory		
Gas turbine engineering	i	25
Legal	(*)	80
Tax	(*)	50
Financial	I/ex s	75
Other technical	i	50
Dev and structuring fee	I/ex s	1500
Sub total - Advisory (B)	f	1780
Insurance and bonding		
Insurance		32
Performance bond		10
Other bonding		
Sub total Insurance/Bonding (D)	f	42
Financial		
Interest During Construction (IDC)	Fin/ex s	460
Upfront fee	Fin/ ex s	44
Sub total Financial (E)	f	504.72
Total Capex (A + B + D + E)	f	9306.72

Note: Values in $1000USD
(*) these costs can be spread on several projects

Source	Prices as of 28/06/2002 US$ per MW (sell side only) High	Low	Average
Cinergy	56.00	42.00	49.63
Comed	60.00	45.00	53.73
Entergy	42.50	37.25	40.42
Mid C	8.50	3.00	6.11
NP-15	40.50	36.25	38.41
Nepool	90.00	77.00	82.61
PJM West	75.00	63.00	67.56
Palo Verde	49.50	43.00	46.09
SP-15	44.50	37.00	41.84
TVA	45.50	42.25	43.75
Average	51.20	42.58	47.02
Price / kW	0.05120	0.04258	0.04702

1 KWH	3412 Btus	
1MW	1000000	watt
1KW	1000	watt

Revenue and Payback Calculation Contíd

Example Revenue Calculation 10 Year Period for *Capacity and Energy Production Payment* PPA

	Ref	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
		0	1	2	3	4	5	6	7	8	9	10	11
Capacity/Energy PMT revenue													
Host plant energy generation beforeOTSG (KW/hr) / regular	CNTRL	0	310,000	310,000	310,000	310,000	310,000	310,000	310,000	310,000	310,000	310,000	310,000
Host plant energy generation before OTSG (KW/hr) / peak	CNTRL	0	310,000	310,000	310,000	310,000	310,000	310,000	310,000	310,000	310,000	310,000	310,000
Host plant energy generation after OTSG (KW/hr) / regular	CNTRL	0	336,000	336,000	336,000	336,000	336,000	336,000	336,000	336,000	336,000	336,000	336,000
Host plant energy generation after OTSG (KW/hr) / peak	CNTRL	0	336,000	336,000	336,000	336,000	336,000	336,000	336,000	336,000	336,000	336,000	336,000
Net energy generated by IST-RF installation / regular	f	0	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000
Host plant operating hours (regular opex) / portion of year	CNTRL	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200	4,200
Total operating hours per year	f	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760
Capacity factor	f	47.95%	47.95%	47.95%	47.95%	47.95%	47.95%	47.95%	47.95%	47.95%	47.95%	47.95%	47.95%
Escalation on Capacity PMT	CNTRL	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Escalation on Energy PMT	CNTRL	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Capacity PMT	CNTRL	0	1,223	1,223	1,223	1,223	1,223	1,223	1,223	1,223	1,223	1,223	1,223
Energy PMT	CNTRL	0	197	197	197	197	197	197	197	197	197	197	197
Total PPA revenue (A)	f	0	1,419	1,419	1,419	1,419	1,419	1,419	1,419	1,419	1,419	1,419	1,419
% of Capacity PMT revenue over total revenue	f	0	86.1%	86.1%	86.1%	86.1%	86.1%	86.1%	86.1%	86.1%	86.1%	86.1%	86.1%
% of Energy PMT revenue over total revenue	f	0	13.9%	13.9%	13.9%	13.9%	13.9%	13.9%	13.9%	13.9%	13.9%	13.9%	13.9%
Gas saving revenue													
BTU/Kwhr before OTSG	CNTRL	9,630	9,630	9,630	9,630	9,630	9,630	9,630	9,630	9,630	9,630	9,630	9,630
BTU/Kwhr after OTSG	CNTRL	9,270	9,270	9,270	9,270	9,270	9,270	9,270	9,270	9,270	9,270	9,270	9,270
Escalation of gas price	f/CNTRL	1.000	1.015	1.030	1.046	1.061	1.077	1.093	1.110	1.126	1.143	1.161	1.178
Gas price (escalated)	CNTRL	3.080	3.126	3.221	3.368	3.574	3.851	4.211	4.673	5.264	6.019	6.985	8.228
Gas saving / MW/hr/ per incremental capacity	f/CNTRL	14.33	14.54	14.76	14.98	15.21	15.44	15.67	15.90	16.14	16.38	16.63	16.88
Gas saving revenue (B)	f	0	1,588	1,612	1,636	1,661	1,686	1,711	1,737	1,763	1,789	1,816	1,843
Gas saving passed thru to Utility (OPEX)	f	0	159	161	164	166	169	171	174	176	179	182	737
Total revenue (A+B)	f	0	3,007	3,031	3,055	3,080	3,105	3,130	3,156	3,182	3,208	3,235	3,262
Cummulative Total Revenue		0	3,007	6,038	9,094	12,174	15,278	18,408	21,564	24,746	27,954	31,189	34,451

Notes: Revenue is in $1000USD.

Revenue and Payback Calculation Based on Debt Service Structure

- Todayís energy market leaves less room for allowable risk
- Many large US based power production companies are retrenching and freezing new capital investment, or investing in offshore power projects in EU, ME, and Asia
- IST has developed solution, involving a debt service structure that requires zero capital investment on the part of the owners, operators and/or developers.
  - ª The debt service is a financing structure, which pays down the debt, and creates revenue for the participating groups. The group can involve such parties as the plant Owner and Operator, the GT Manufacture, the OTSGô supplier (IST), the Utility and the Gas Company.

Negotiated Variables	Fixed Commercial Variables (at time of retrofit)
Price Sweep Options (Shared Group ROI)	Operating Hours per year
Construction and Payment schedule	Generated Power
Financing Costs/Term	PPA Contractual Revenue
Insurance Cost	Working Capital
Insurance and Bonding	Depreciation & Taxes
Advisory (Legal, Financial, Engineering Consultant)	Escalation on Capacity PMT
New Equipment Capital Cost	Escalation on Energy PMT
Number of Invoved Parties	US Inflation (CPI)
	Gas Price Escalation
	Gas Consumption
	Water Consumption
	Opex (Operating Expenses)
	General & Admin Expenses of OTSG
	Energy Price Escalation

Revenue and Payback Calculation Based on Debt Service Structure contíd

IST

Group Companies' Cash Flow

Year	Ref	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
number of years		0	1	2	3	4	5	6	7	8	9	10	11
Capacity revenue	PL+BS	0	1,223	1,223	1,223	1,223	1,223	1,223	1,223	1,223	1,223	1,223	1,223
Energy revenue	PL+BS	0	197	197	197	197	197	197	197	197	197	197	197
Gas saving revenue	PL+BS	0	1,588	1,612	1,636	1,661	1,686	1,711	1,737	1,763	1,789	1,816	1,843
Cash opex	PL+BS	0	445	452	459	467	474	482	490	498	507	515	1,077
Operating CF	f	0	2,562	2,579	2,596	2,613	2,631	2,648	2,666	2,684	2,702	2,720	2,185
PF loan	Fin	7,447	0	0	0	0	0	0	0	0	0	0	0
Equity	Fin	1,862	0	0	0	0	0	0	0	0	0	0	0
m Excess RA balance													
Total sources	f	9,309	2,562	2,579	2,596	2,613	2,631	2,648	2,666	2,684	2,702	2,720	2,185
Capex	Capex	8,802	0	0	0	0	0	0	0	0	0	0	0
increase/(decrease) in WC	PL+BS	0	334	2	2	2	2	2	3	3	3	3	-43
UpFront + Commitment Fees	Fin	47	0	0	0	0	0	0	0	0	0	0	0
Interest payment	Fin	0	670	626	578	526	469	406	338	264	184	96	0
interest capitalized (IDC)	Fin	461	0	0	0	0	0	0	0	0	0	0	0
income tax paid	Tax	0	0	0	149	468	680	894	932	973	1,017	1,168	973
Senior p'l repmt	Fin	0	490	534	582	635	692	754	822	896	977	1,065	0
Interest (earned)													
Total uses	f	9,309	1,495	1,163	1,312	1,631	1,843	2,057	2,095	2,136	2,180	2,331	930
Net net CF	f	0	1,068	1,416	1,284	983	788	591	570	547	521	389	1,255
IST	f	0	427	567	514	393	315	236	228	219	209	155	502
Host	f	0	641	850	771	590	473	354	342	328	313	233	753
ACF for senior debt service	f	0	2,228	2,577	2,445	2,143	1,948	1,751	1,731	1,708	1,682	1,549	1,255
ACF for senior p'l service	f	0	1,558	1,951	1,867	1,617	1,480	1,345	1,392	1,443	1,498	1,453	1,255
ACF for sub debt service	f	0	1,281	1,700	1,541	1,179	945	709	684	657	626	466	1,506
Ratios													
ICR	f	0.00	3.32	4.12	4.23	4.08	4.16	4.31	5.12	6.46	9.15	16.17	0.00
DSCR to senior debt < tax	f	0.00	4.55	4.82	4.45	4.11	3.80	3.51	3.24	2.99	2.76	2.55	0.00
DSCR to senior debt > tax	f	0.00	1.92	2.22	2.11	1.85	1.68	1.51	1.49	1.47	1.45	1.33	0.00
Debt to Equity ratio	PL+BS	31.97	-20.37	166.96	6.71	3.58	1.96	1.10	0.64	0.35	0.15	0.00	0.00

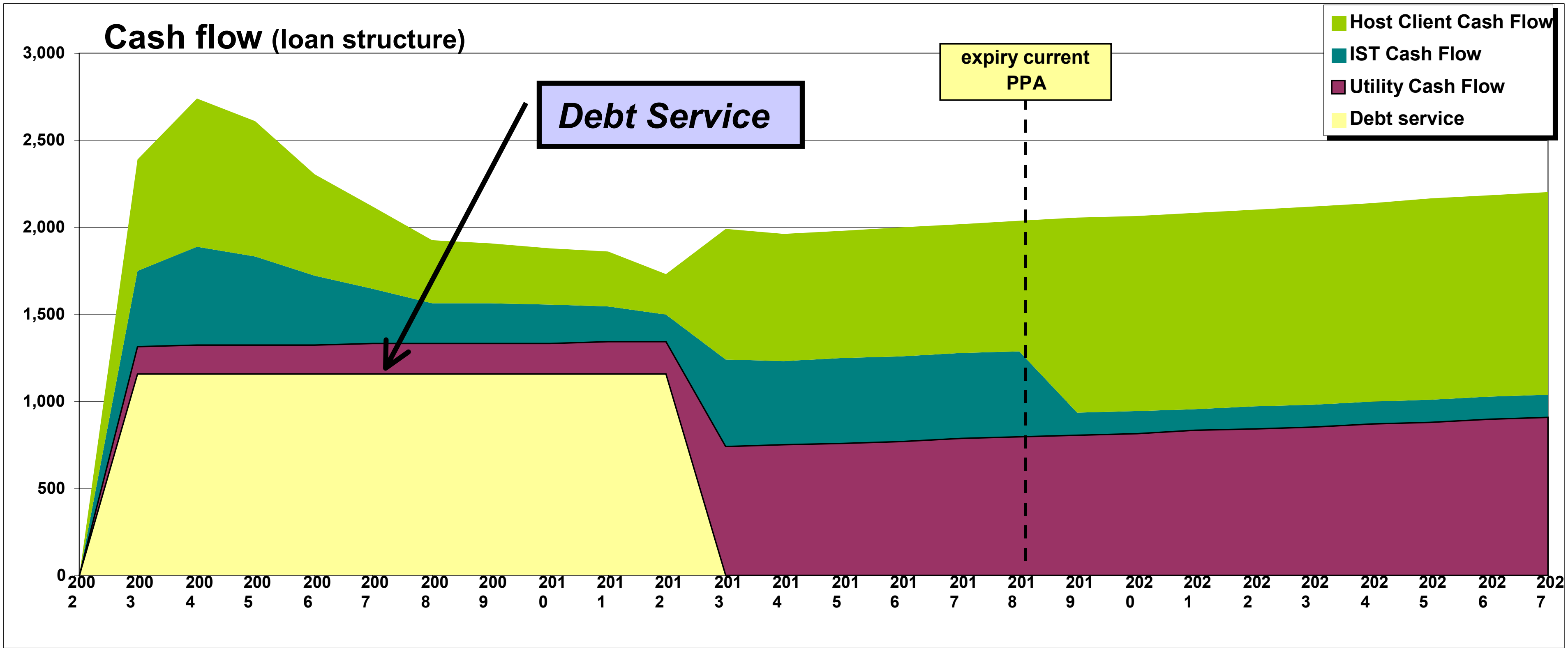
Revenue and Payback Calculation Based on Debt Service Structure contíd

- A financial model can be produced to quantify the shared cash flow
  - ñ Assuming the companies involved in the debt service financing structure:
    - ª Host Client, the Utility, and IST ñ OTSGô Supplier.
    - ª IST contributes $1.862MMUSD as equity to the Capex,
    - ª Then the total loan/finance amount will be $7.447MMUSD based on the initial Capex of $9.306MMUSD defined in Table 3 above.

- The group is paying down the debt, similar to a mortgagee for the fixed term and retaining profits above the loan repayment
- There is a financial factor, Debit Coverage Service Ratio (DCSR), which defines the excess above the principal and interest loan amounts.
  - ñ A DCSR of 1.3 means there is excess 30% of the loan repayment amount, which would indicate a good investment.
  - ñ The OTSGô steam injection case study below indicates a DCSR after tax of 1.33 ñ 2.22, again a good investment.
  - ñ The analysis in this table also indicates a debt repayment after 10 years.

- During this 10-year period the Utility, Host Client and IST are producing a positive return on investment.
- The companies involved in the debt service financing structure would negotiate a Cash Flow ***(Profit Split)*** based on their involvement and ownership to the retrofit project. As illustrated.

Hypothetical Loan/Cash Flow split



Revenue split (x 000)	ref#	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Debt service	CF	0	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	1,160	0	0	0	0	0	0	0	0	0	0	0
IST Cash Flow	CF	0	427	567	514	393	315	236	228	219	209	155	502	486	489	491	493	496	125	125	126	126	127
Utility Cash Flow	Rev	0	159	161	164	166	169	171	174	176	179	182	737	748	760	771	783	794	806	818	831	843	856
Host Client Cash Flow	CF	0	641	850	771	590	473	354	342	328	313	233	753	730	733	737	740	744	1,121	1,126	1,131	1,136	1,142