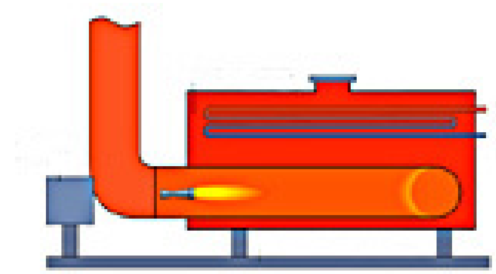
PETRO-CANADA OIL AND GAS

FIRE-TUBE IMMERSION HEATER OPTIMIZATION PROGRAM
&
Field Heater Audit Program

Energy Management Work Shop
"The Fuel Gas Challenge"

by **Phil Croteau** P. Eng.
Energy Efficiency Engineer

January 15-17, 2007



Outline (25 min session)

- Overview – Top 5 Priorities (PTAC – TEREE)
- PTAC – TEREE : the Origin of the “Fire-tube Heater Study”
- Combustion Efficiency. – Excess Air
- Heat Transfer – Fire-tube Design
- Combustion Efficiency – Fire-tube Selection
- Combustion Efficiency - Heat Flux Rate
- Burner Selection
- Burner Duty Cycle
- Combustion Efficiency – Reliability Guidelines
- Heater Tune-up – Inspection Procedure
- Insulation
- PCOG Fire-tube Immersion Heater Optimization Program
- Field Audit Program (NRCAN Energy Audit Incentive Program)
- Conclusion, Q&A

Overview: Top 5 Priorities, ER & EE

PTAC - TEREE Study 2004-2005: Top 5 Priorities for ER and EE

Petroleum Technology Alliance Canada

– Technology for Emission Reduction and Eco-Efficiency

1. Venting of Methane Emissions
2. Fuel Consumption in Reciprocating Engines
3. *Fuel Consumption in Fired Heaters*
4. Flaring and Incineration
5. Fugitive Emissions

Background

- Common concern for many upstream operating companies is the energy consumption associated with immersion heaters
- Energy often used to fire these heaters is high quality refined sales gas
- Common problem with the immersion heaters is that they may have low fuel efficiencies between 30% and 60%
- Compared to common boiler technology these heaters should be able to run at 70 to 80% efficiency
- Recent estimates suggest that heaters currently waste in excess of 2 to 3 billion BTU/hr of fuel (1360 to 2040 e3m3/d gas) that could be conserved to generate added sales
- At an average cost of $5/GJ this represents $100 to $150 million of lost revenues due to inefficient use of fuel gas
- Also represents an associated 1.5 million additional tonnes of carbon dioxide being discharged into the atmosphere per year

Project Sponsors

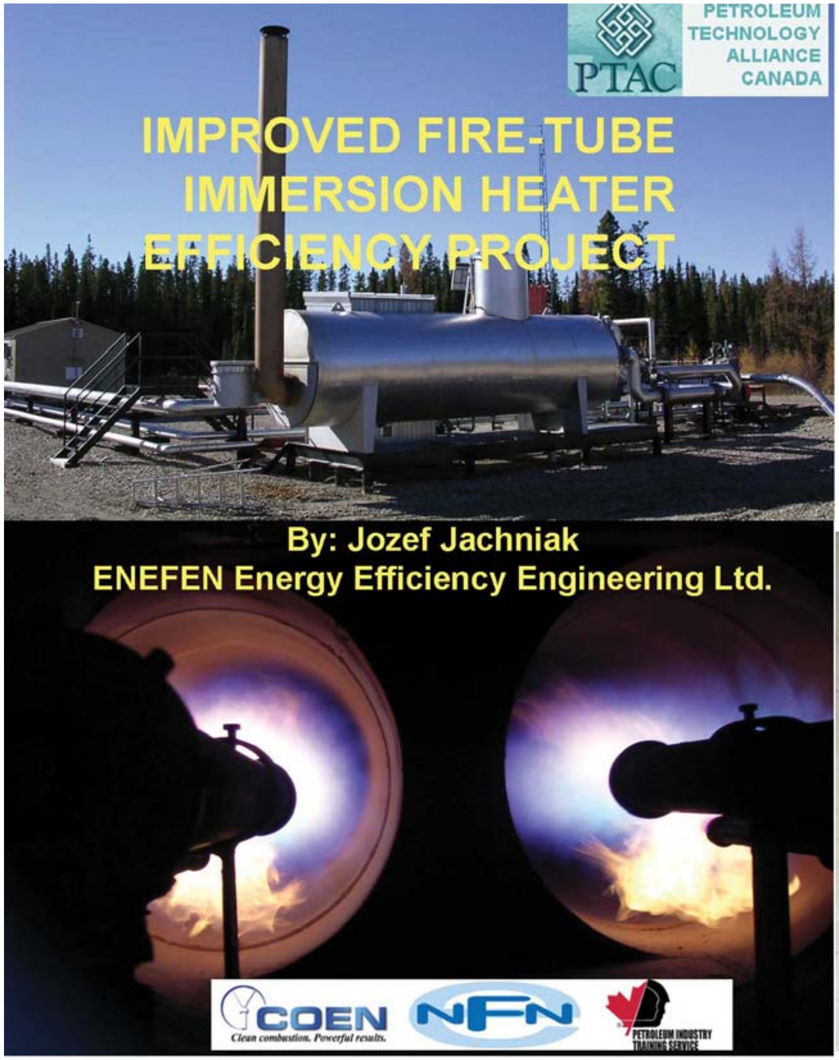
The following sponsors collaborated with PTAC to provide financial and technical support:

Petro-Canada	**Shell Canada**
EnCana Corporation	**CETAC-West**
Husky Energy	**CAPP**
Nexen	**BP Canada**

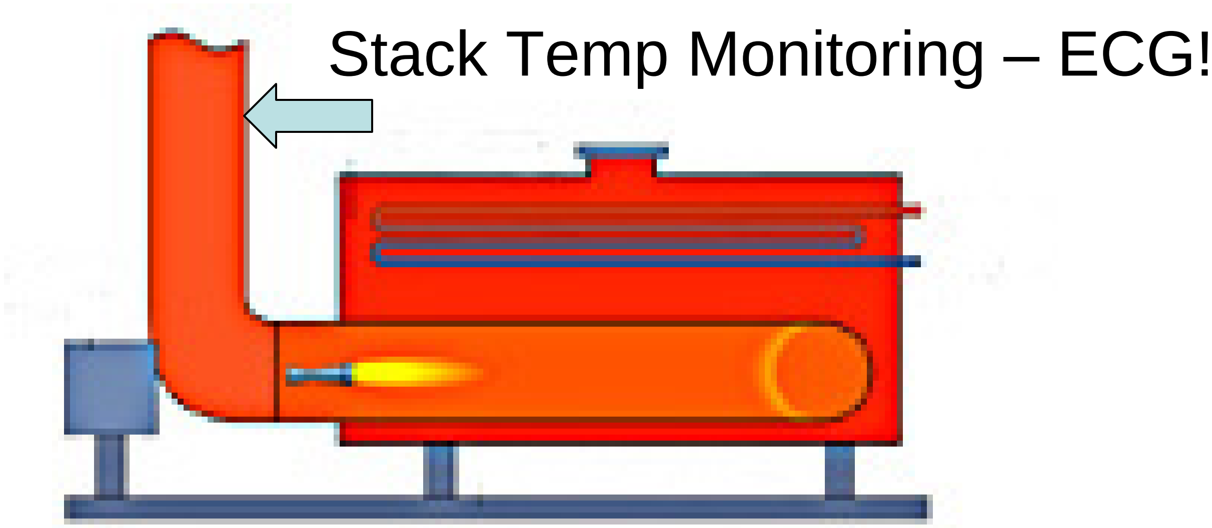
The report has now been publicly released, and is available to view on the PTAC website at

www.ptac.org/techeetteree.html

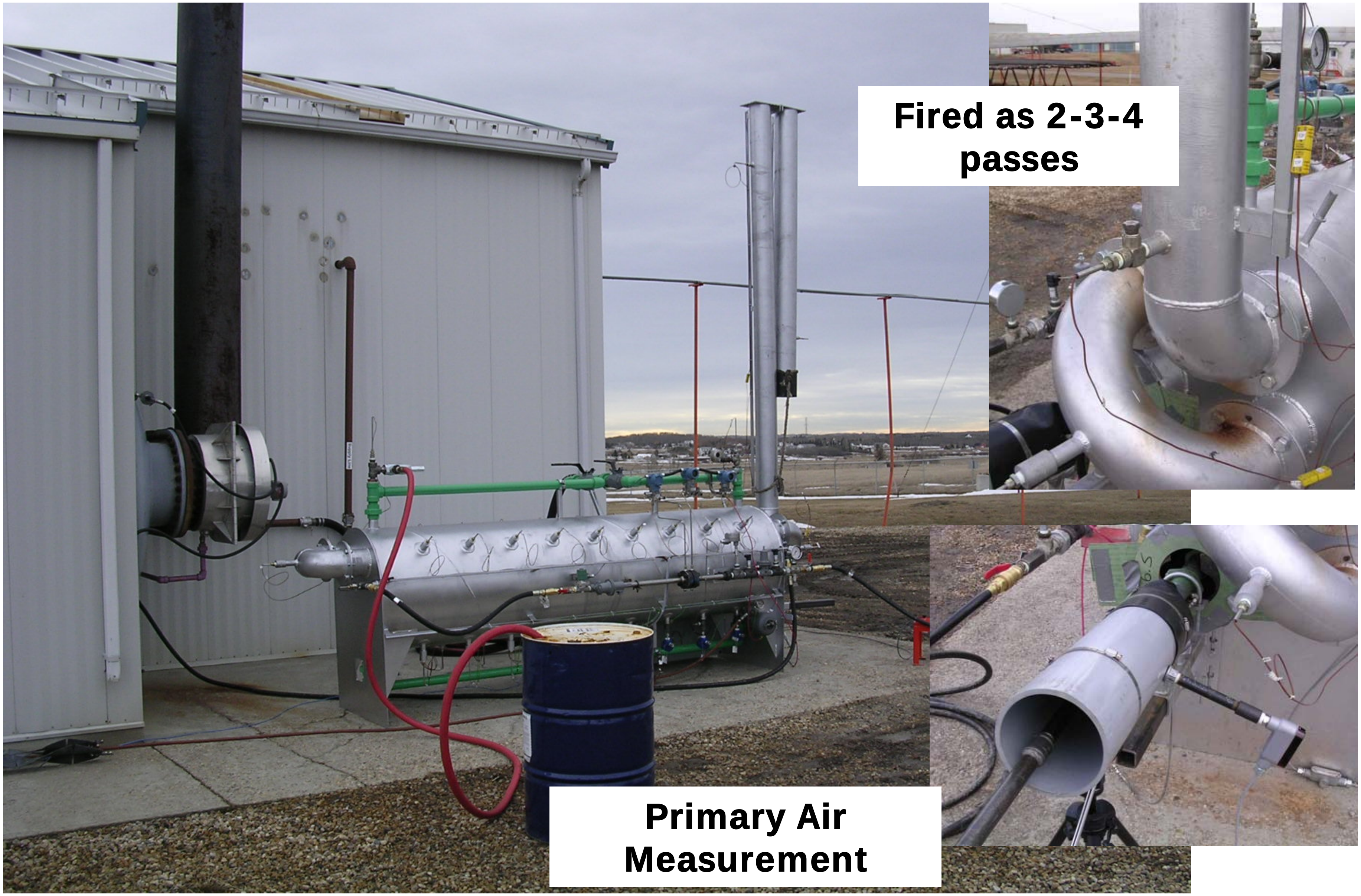
PTAC Fire-tube Heater Study



- We built a heater, fired it with several different burners!



PTAC Lineheater Study

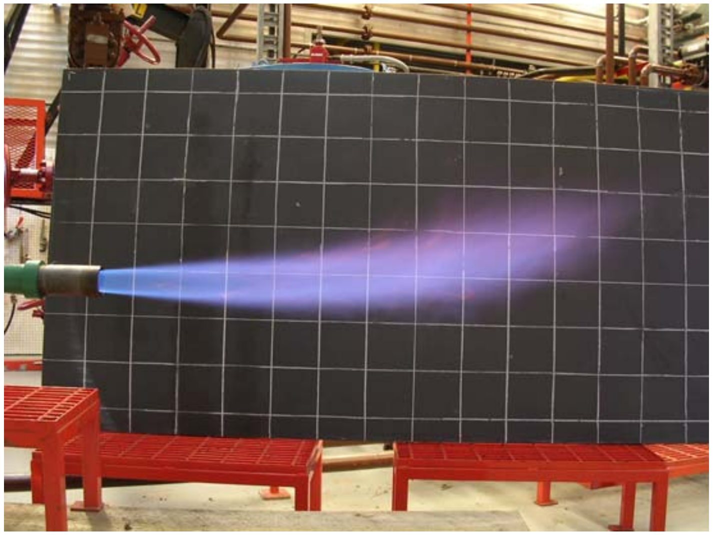


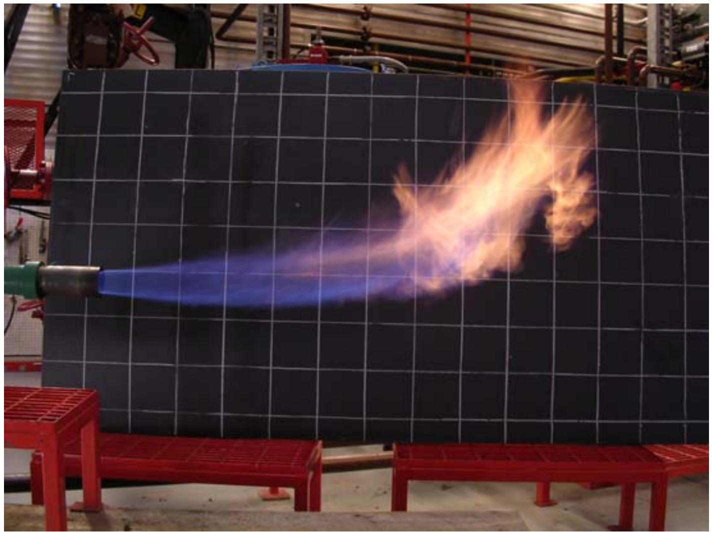
Burner Vendors Participating

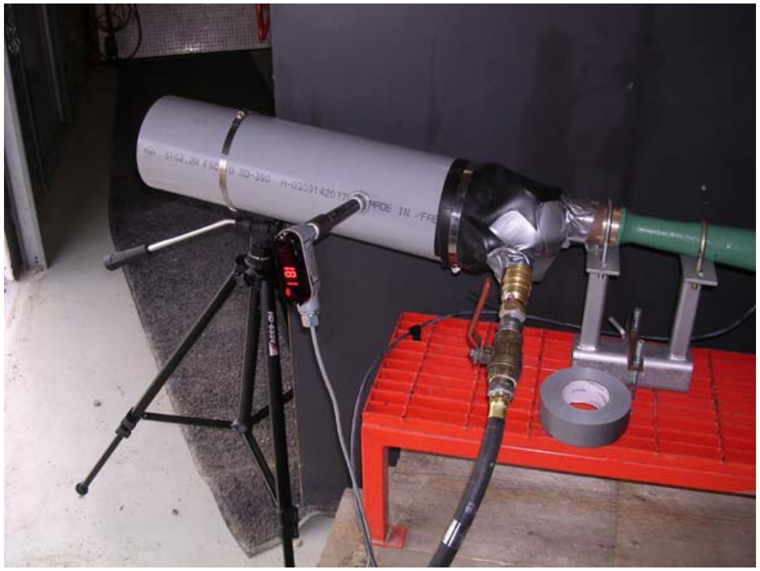
- A-Fire
- ACL
- Bekaert (MCI) (3)
  7 combinations
- Eclipse
- Hauck
- Kenilworth (4)
- Maxon (3)
- North American
- Pro-Fire (2)
- Pyronics (4)

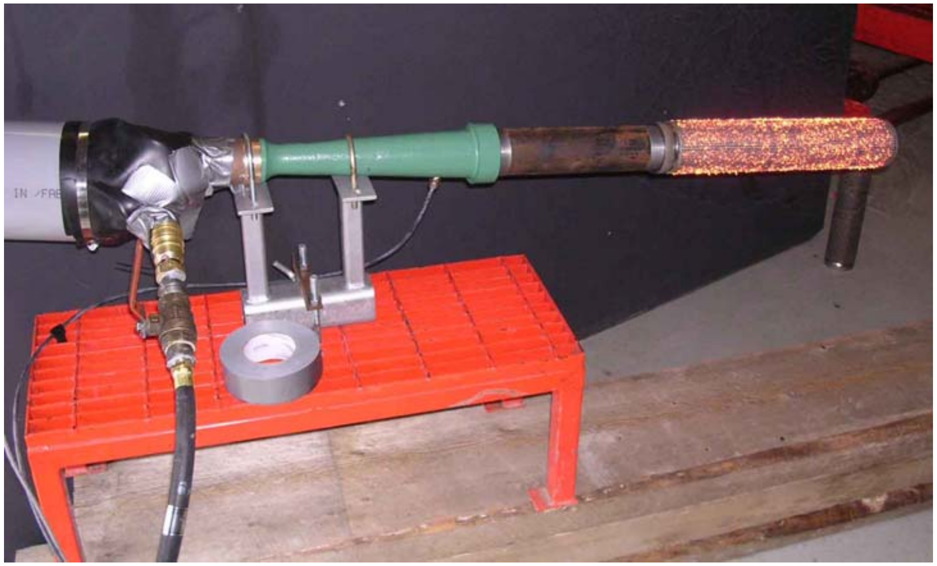
10 burner vendors = 25 burners tested

TESTS – OPEN FLAME TESTS

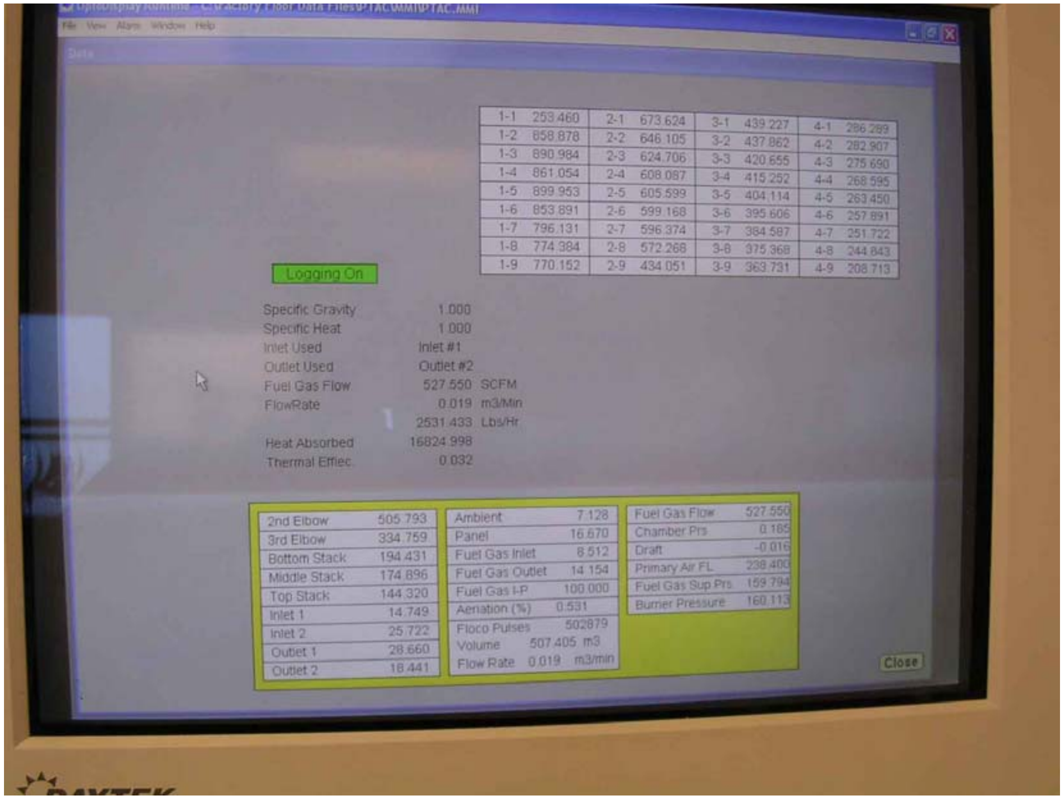


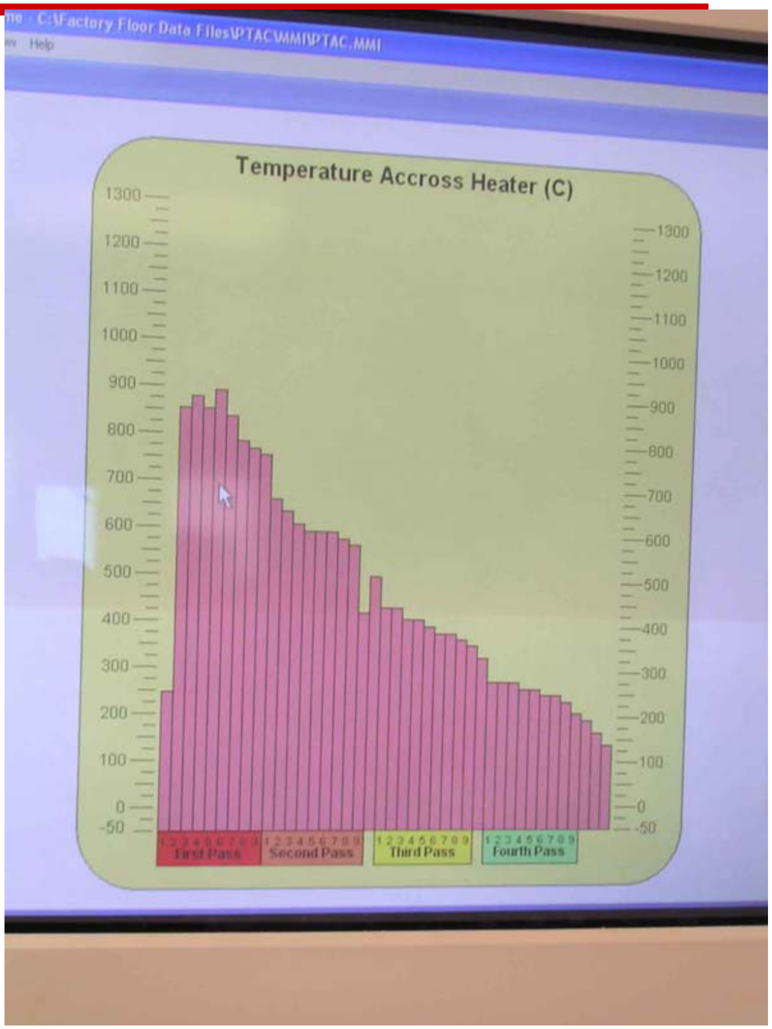






HEATER TEST STAND - INSTRUMENTATION



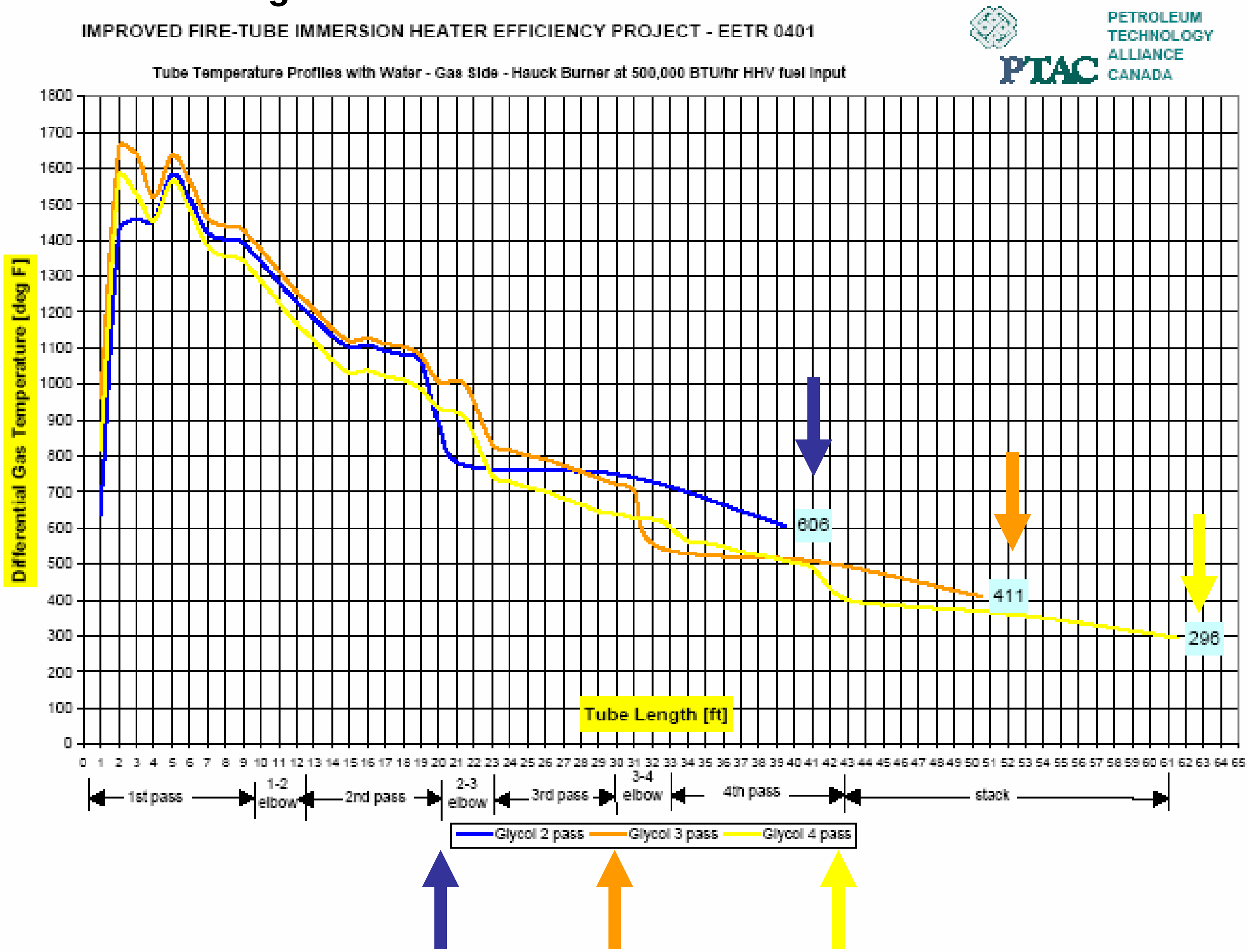


DCS control and data recording

Heat Transfer

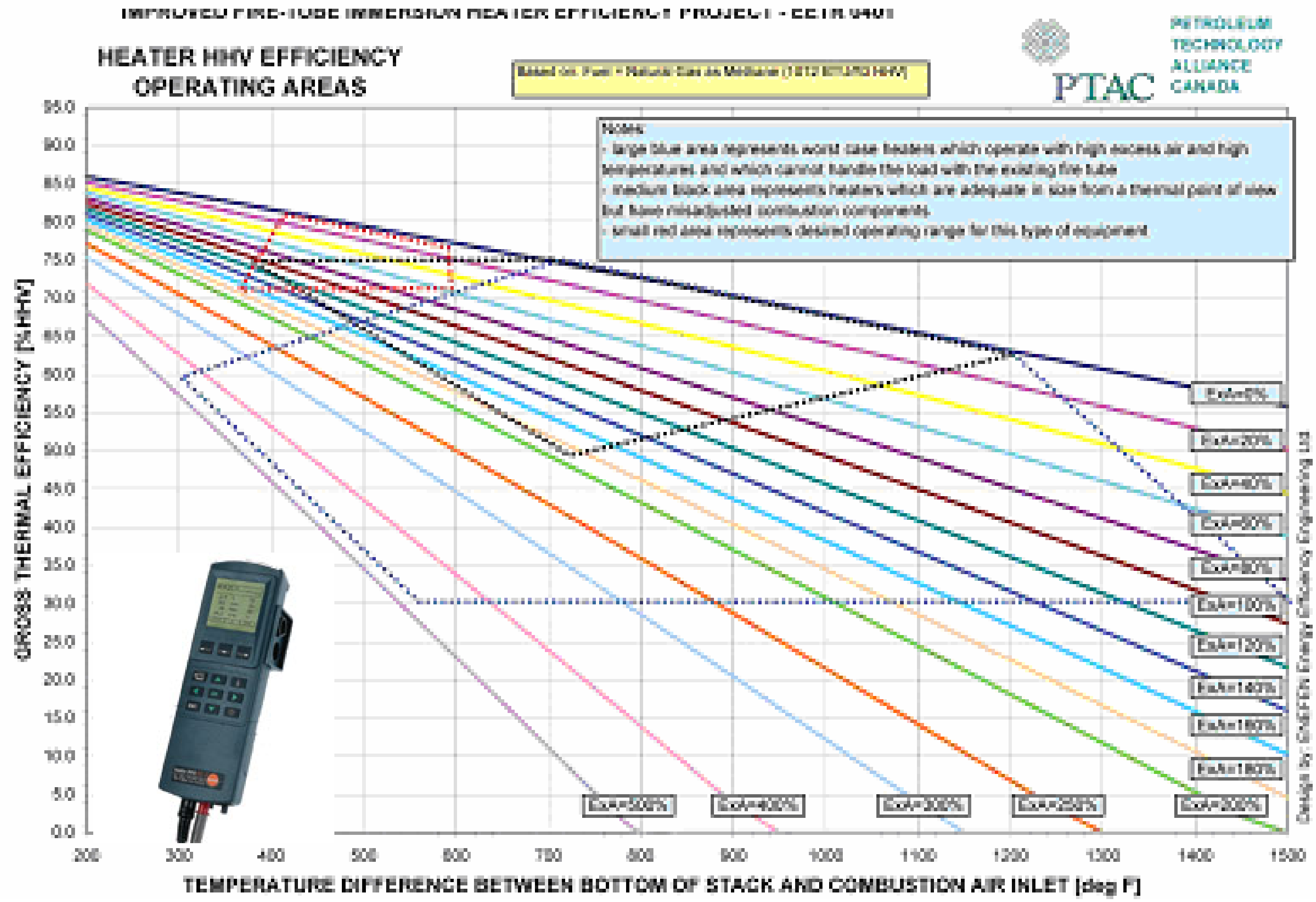
- Fire-tube Design

PTAC Test – Glycol, 2-3-4 passes

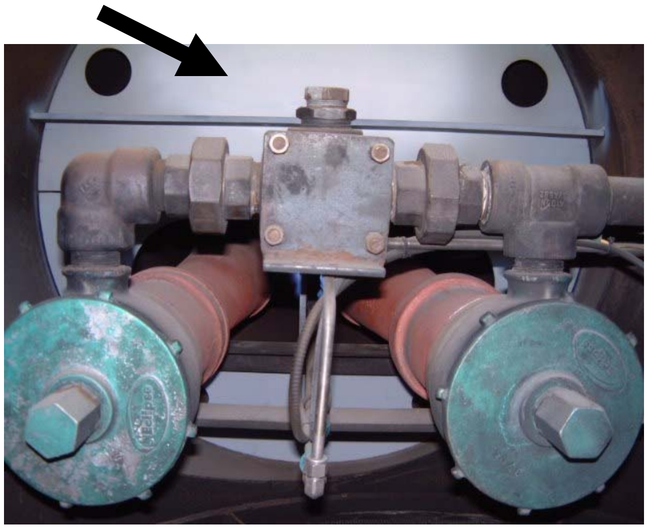


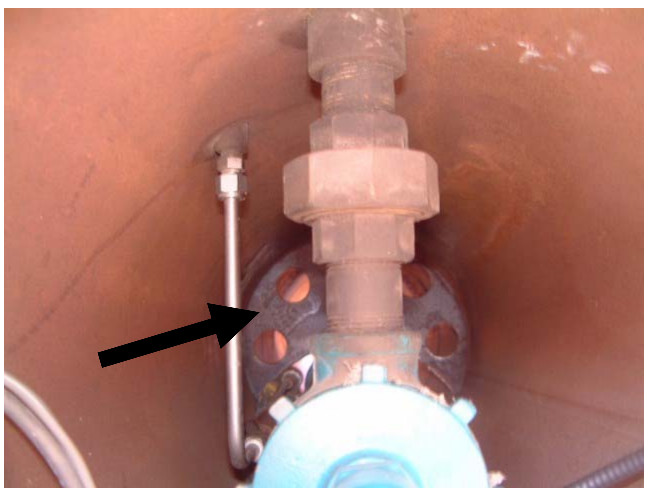
Combustion Efficiency – Excess Air

The GOOD, the BAD & the UGLY!



Combustion Air Control





Excess air baffles!

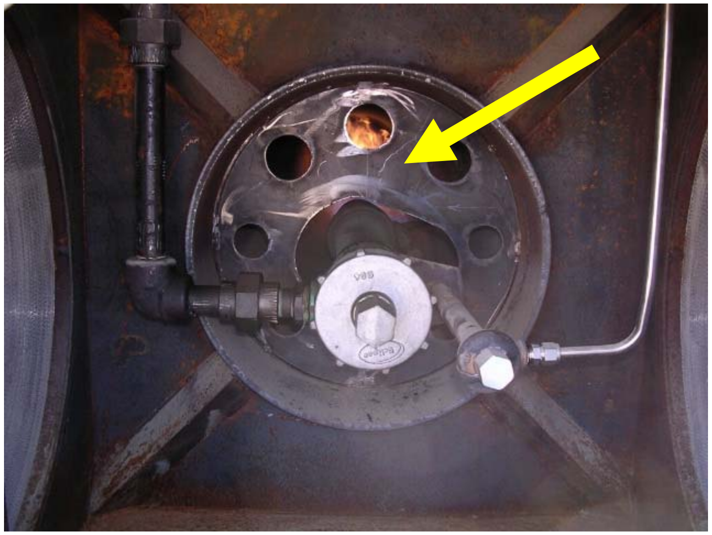
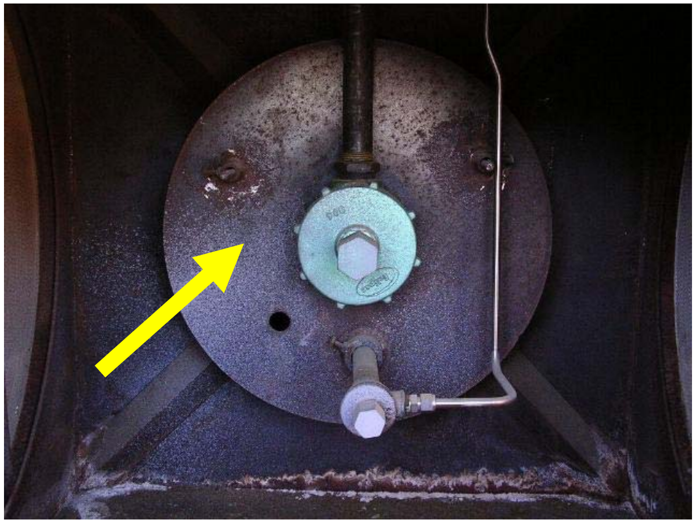
As found: fouled flame cell!

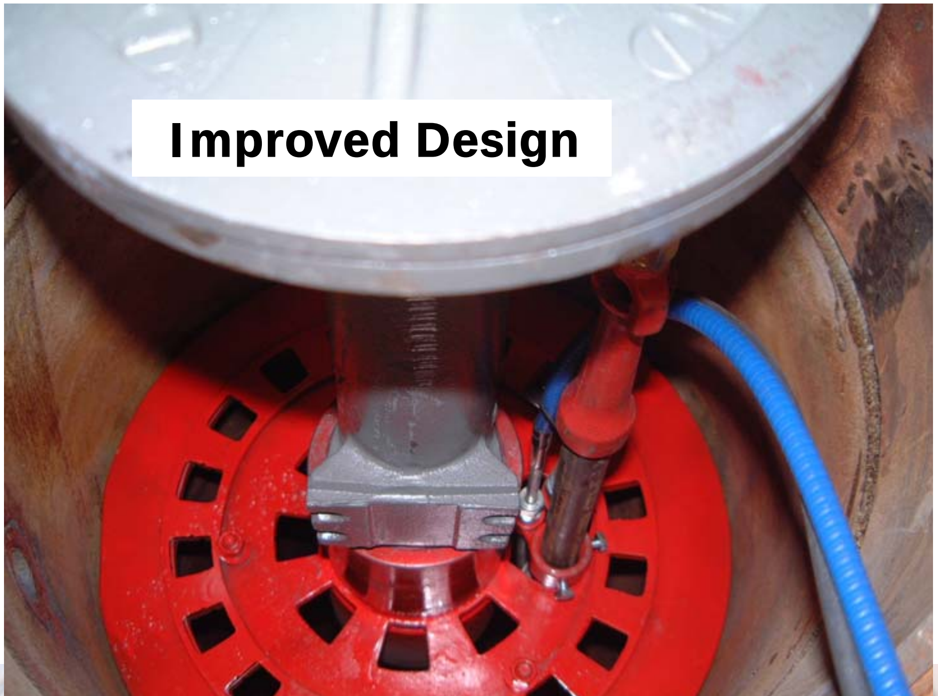
Excess air 0.0%

Stack CO >110,000 ppm !

Flame cells are not filters!

Excess Air/O2 Control



Improved Design


Preliminary Design

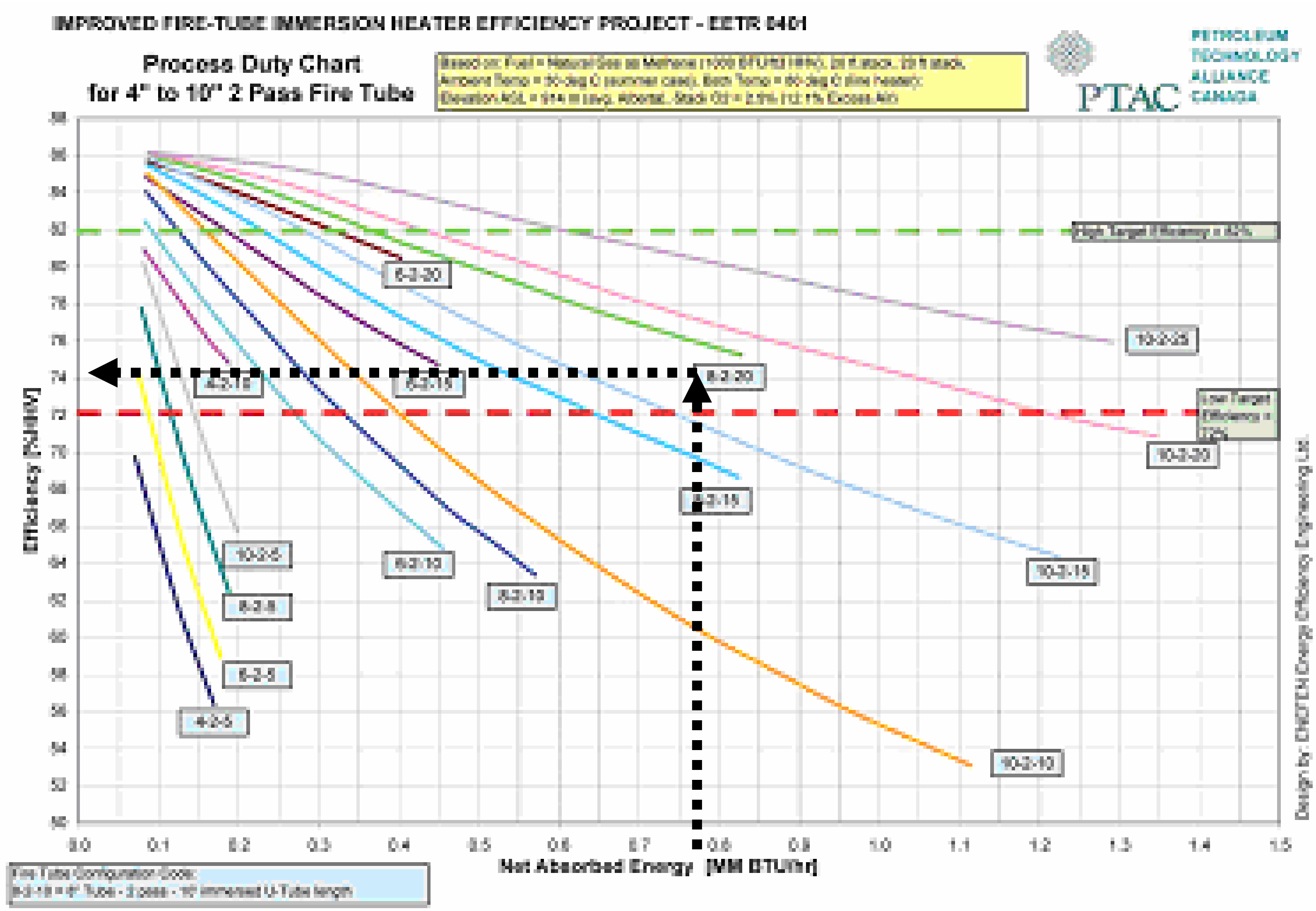

Boundary Lake Salt Bath


WCH 5-13 “Long and Skinny”

COMBUSTION EFFICIENCY

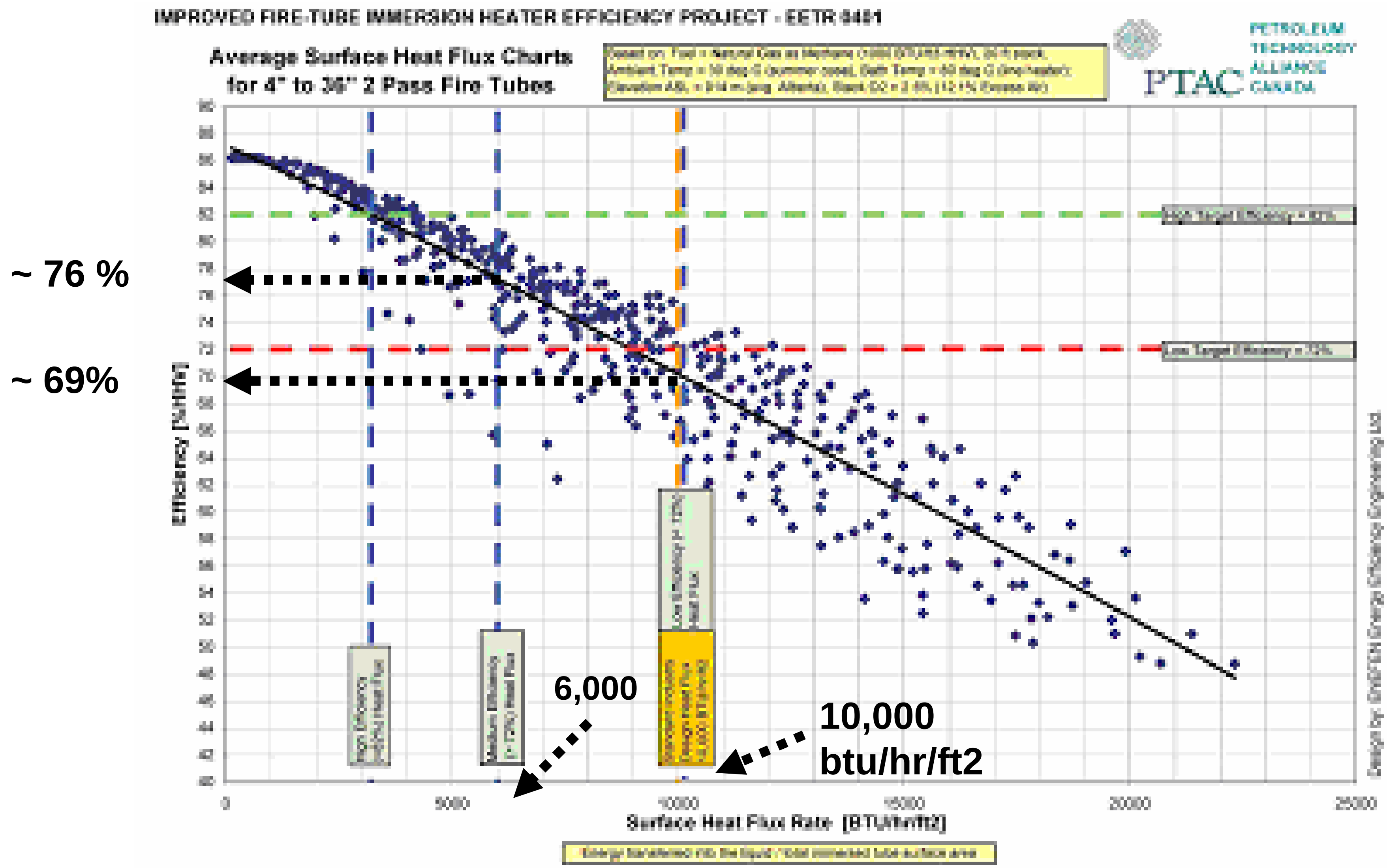
- IMPACTED BY FIRE-TUBE SELECTION

(SENSIBLE HEAT RECOVERY!)



COMBUSTION EFFICIENCY

- IMPACTED BY FIRE-TUBE HEAT FLUX RATE



Burner Selection

- HIGH PRIMARY AIR INSPIRATION, TURNDOWN, FUNCTIONALITY
- MAXON VENTITE

PETROLEUM TECHNOLOGY ALLIANCE CANADA
PTAC

IMPROVED FIRE-TUBE IMMERSION HEATER EFFICIENCY PROJECT
Project EETR 0401
Burner Characteristics
Design by: ENEFEN Energy Efficiency Engineering Ltd.

Manufacturer:	Maxon Large	Address:	6375 Dixie Road, Unit 3
Description:	3" Ventite		
		City, Province, Code:	Mississauga, ON L5T 2E1
Orifice:	1/8"	Telephone / Fax:	(905) 795-0717/(905) 795-1819
Overall Length:	21"	Web Site:	http://www.maxoncorp.com

General Arrangement

Compact burner assembly features gas nozzle venturi, mixer, and primary air shutter combination. Heavy duty cast iron components

Gas Nozzle

Heavy duty cast iron nozzle includes internal flame retention device with large main gas orifice and 8 smaller holes located around its perimeter. Available with integral pilot and flame rod mount (PilotPak).

Gas Mixer & Primary Air Adjustment

Gas mixer features a low entrance loss bell shaped inlet. Heavy duty cast iron "register" type shutter includes a locking screw. Gas Connection through the back of the mixer. Simple rear access to the orifice by unbolting the back plate of the register.

Secondary Air Adjustment

No secondary air adjustment incorporated

PETROLEUM TECHNOLOGY ALLIANCE CANADA
PTAC

IMPROVED FIRE-TUBE IMMERSION HEATER EFFICIENCY PROJECT
Project EETR 0401
Burner Open Flame Tests
Design by: ENEFEN Energy Efficiency Engineering Ltd.

Manufacturer:	Maxon Large
Description:	3" Ventite
Orifice:	1/8"
Date:	16-Mar-05

524,000 BTU/hr ; 100%

304,000 BTU/hr ; 100%

148,000 BTU/hr ; 100%

531,000 BTU/hr ; 50%

295,000 BTU/hr ; 50%

118,000 BTU/hr ; 50%

530,000 BTU/hr ; 28%

289,000 BTU/hr ; 28%

117,000 BTU/hr ; 28%

531,000 BTU/hr ; 10%

290,000 BTU/hr ; 10%

BURNER SELECTION

- ECLIPSE

PTAC PETROLEUM TECHNOLOGY ALLIANCE CANADA	IMPROVED FIRE-TUBE IMMERSION HEATER EFFICIENCY PROJECT		
	Project EETR 0401		
	Burner Characteristics		
	Design by: ENEFEN Energy Efficiency Engineering Ltd.		
Manufacturer:	Eclipse	Address:	#5,3530-11A Street N.E.
Description:	1-1/2" Eclipse Mixer, With 1-1/2" Compound Barrel, 1-1/2" x 2-1/2" Venturi, 2-1/2" Nozzle	City, Province, Code:	Calgary, AB T2E 6M7
Orifice:	1/8"	Telephone / Fax:	(403) 291-9211/(403) 291-9214
Overall Length:	30"	Web Site:	www.eclipsenet.com

General Arrangement

Typical complete assembly of Eclipse burner common in the industry. Assembly consists of a mixer, compound barrel, Venturi, and gas nozzle.

Gas Nozzle

Eclipse Ferrofix Nozzle with built-in flame retention feature. Nozzle produces long and narrow flame pattern as compared to a wider flame available with Sticktite nozzles.

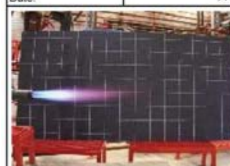
Gas Mixer & Primary Air Adjustment

Eclipse mixer commonly used in the industry also by some of the other burner manufacturers. Basic mixer features cast iron body with gas orifice and primary air shutter. Also supplied with the burner is a needle valve which allows fine adjustment to the orifice opening. The optional compound barrel is used to enhance fuel/air mixing, and is recommended for heavier fuel gases.

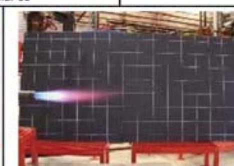
Secondary Air Adjustment

No secondary air adjustment incorporated

PTAC PETROLEUM TECHNOLOGY ALLIANCE CANADA	IMPROVED FIRE-TUBE IMMERSION HEATER EFFICIENCY PROJECT
	Project EETR 0401
	Burner Open Flame Tests
	Design by: ENEFEN Energy Efficiency Engineering Ltd.
Manufacturer:	Eclipse
Description:	1-1/2" Eclipse Mixer, With 1-1/2" Compound Barel, 1-1/2" x 2-1/2" Venturi, 2-1/2" Nozzle
Orifice:	1/8"
Date:	14-Mar-05



496,000 BTU/hr ; 100% open



353,000 BTU/hr ; 100% open

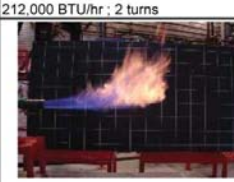
224,000 BTU/hr ; 100% open

497,000 BTU/hr ; 2 turns

212,000 BTU/hr ; 2 turns

119,000 BTU/hr ; 2 turns

497,000 BTU/hr ; 0.5 turns



320,000 BTU/hr ; 0.5 turns

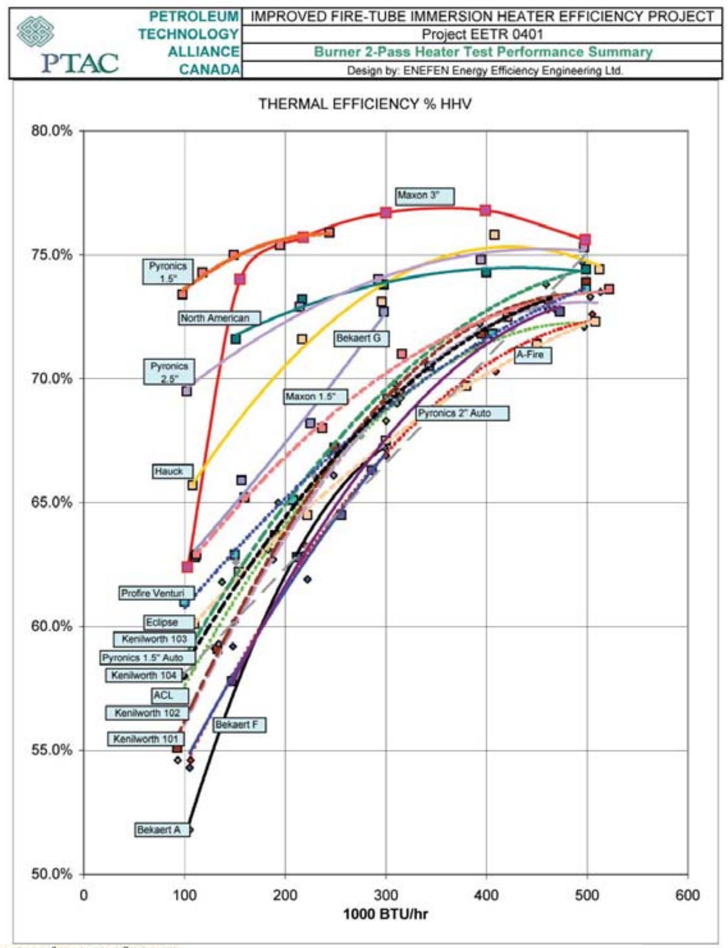
198,000 BTU/hr ; 0.5 turns

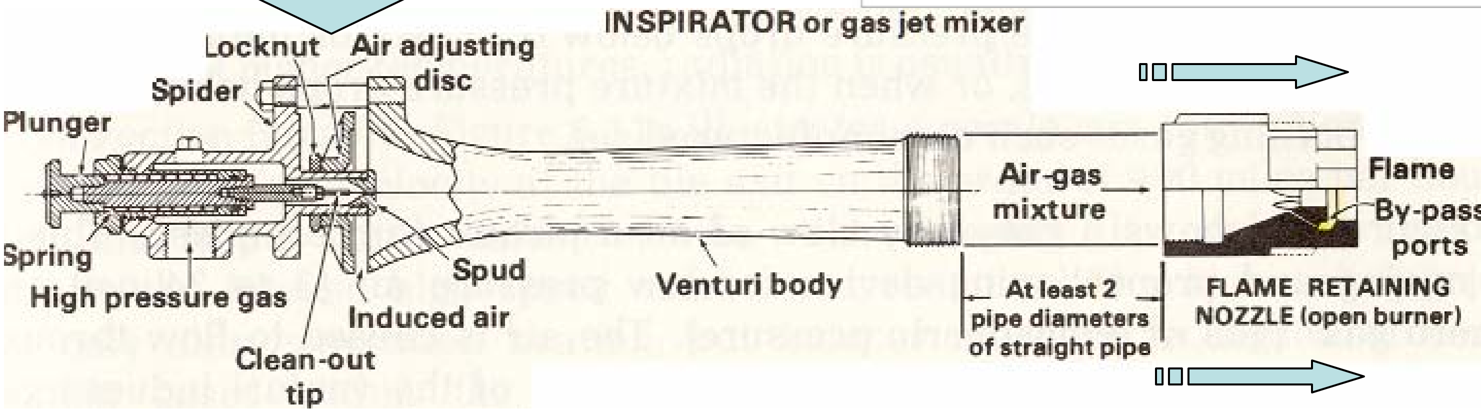
BURNER SELECTION

- HIGH PRIMARY AIR INSPIRATION,

TURNDOWN,

FUNCTIONALITY

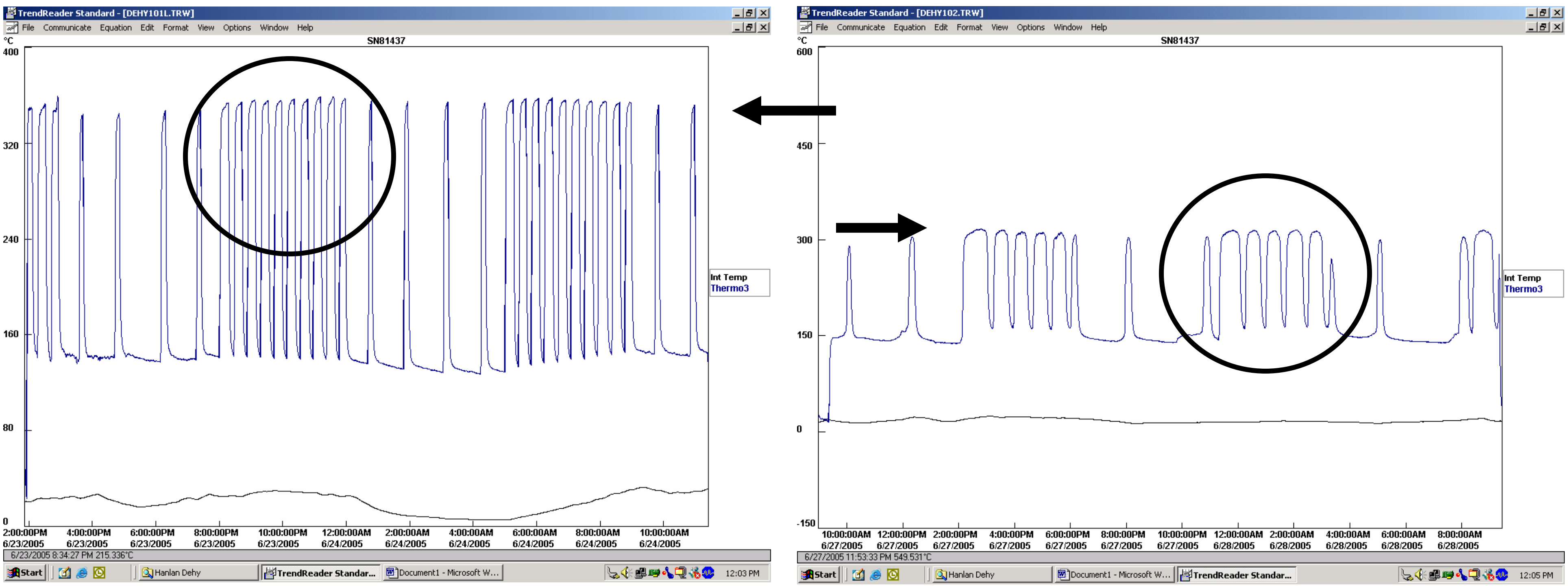




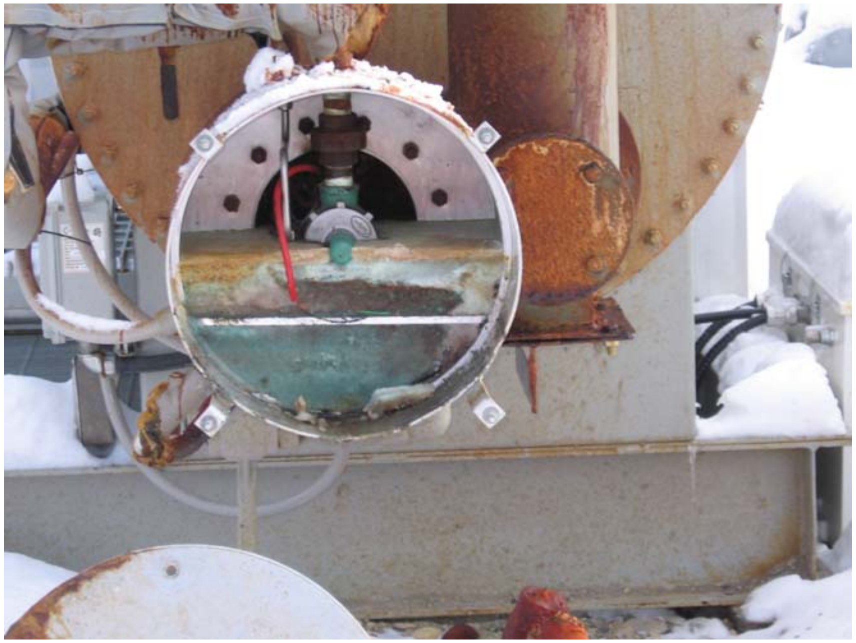
Burner Duty Cycle Management

- short duty cycle at high firing rate vs.

the longer duty cycle firing at a lower rate



Duty Cycle to the Extreme - This is the consequence of an extremely low main burner duty cycle, only the pilot ran, condensing moisture in “Products of Combustion”. Water accumulates and freezes at the flame cell as it tries to drain out. Level rises until even the pilot is extinguished! This is a concern for oversized heaters, more common a problem than we accept.



Combustion Efficiency, Emission and Reliability Guidelines 4 Pages

IMMERSION HEATER FIELD INSPECTION AND EFFICIENCY EVALUATION REPORT	PTAC PETROLEUM TECHNOLOGY ALLIANCE CANADA
COMBUSTION EFFICIENCY, EMISSIONS AND RELIABILITY GUIDELINES	Design by: ENEFEN Energy Efficiency Engineering Ltd.

1	**EFFICIENCY DEFINITION**: Efficiency is defined as the percentage of gross BTU input that is realized as useful BTU output of a heater. There are two ways of calculating this efficiency: the HHV efficiency uses the higher heating value of fuel input, and the LHV efficiency uses lower heating value of fuel input.
2	**LHV AND HHV BASED EFFICIENCY CALCULATIONS**: For example pure methane HHV = 1012 BTU/cuft and LHV = 911 BTU/cuft, and the difference is the amount of energy used to evaporate water produced during the combustion process from the hydrogen contained in the fuel. Hence for the same combustion process using methane as a fuel the LHV efficiency value is about 10% higher than the HHV efficiency value. Where the LHV efficiency is easier to use for evaluation of traditional style heaters which do not condense water out of the products of combustion, it cannot be meaningfully used for newer condensing type heaters. In addition, since fuel is measured and sold based on its HHV value, only the HHV based efficiency should be used for the economic evaluation of the heater performance. LHV based efficiency is typically used in the US and the HHV efficiency is more commonly used in Canada. All regulatory requirements in Canada related to burner and fuel controls rating are based on HHV of fuel. Since many heater specifications and many combustion analyzers do not clearly state the basis for efficiency calculations, caution should be exercised when using these efficiency values.
3	**COMBUSTION EFFICIENCY - OVERALL COMBUSTION EFFICIENCY - FUEL EFFCIENCY - HEATER THERMAL EFFICIENCY**: These terms are used in the industry interchangeably, although with a fair amount of confusion. To clarify: any of these efficiency terms is based on the calculation of 100% of energy input into the heater (expressed in either LHV or HHV terms) minus the summation of all the losses from that heater, which equals to the useful heat output to the process load. The losses can be either combustion related or heater design specific.
4	**COMBUSTION LOSSES FROM THE HEATER**: These losses include: - latent heat of evaporation to moisture in the stack formed from oxidation of hydrogen in the fuel - unburned fuel (VOC's in the stack) including hydrocarbons, CO, soot (free carbon), H2S or any other combustible compound which did not get oxidized to form CO2 or H2O - sensible heat lost to heat the product of combustion above the ambient air temperature. Products of combustion include also nitrogen, excess oxygen and H2O vapour from ambient air humidity and possibly the unburned fuel which do not take part in the combustion process but are also heated to the stack temperature. Note that besides combustion air, ambient tramp air can also infiltrate the heater through cracks and openings, however that tramp air would be then included in the products of combustion.
5	**HEATER DESIGN SPECIFIC LOSSES**: These losses include: - wall / piping / insulation losses - the energy which radiates out of the heater into the surroundings and is carried away by air (wind), foundations, or connecting equipment. Note that only the heat loss from the portion of the stack surface below the location of the thermocouple used for the efficiency measurement would be considered as a loss for this calculation. - opening losses include any products of combustion leaks from the heater other than stack gas. - conveyor losses include heat carried away by any form of process "conveyor" which does not stay in the process "product". This would also include heat loss through the piping connecting process to the heater. - heat storage losses - the energy which is stored in the heater steel, insulation, heat transfer medium, connected equipment, foundation, etc. For heaters, which operate continuously the amount of stored energy remains constant after the initial heatup. For heaters which operate in batch mode or which cycle on/off, the amount of stored heat changes and must be replenished every time the heater is refilled and restarted.
6	**STACK OXYGEN**: Stack oxygen level should be maintained between 2% and 4%, which corresponds to between 9.5% and 21.1% excess air. Below 2% oxygen, sharp increase in CO emissions is expected; above 4% oxygen additional excess air "taking a free ride" through the heater decreases the combustion efficiency
7	**STACK CO:** Stack CO levels should be maintained below 400 ppm safety ceiling. Ideally, in a properly tuned system CO levels below 100 are desirable. Typically, depending on the burner design, CO readings increase at low (below 2%) or high (above 11%) oxygen levels. High CO readings indicate incomplete combustion due to insufficient air flow or due to flame quenching with too much air.
8	**STACK NOx:** Stack NOx levels are a function of burner design and specifically flame shape and temperature. Smaller and hotter flames tend to produce higher NOx levels. Also burners with a single fuel injection port tend to produce higher NOx levels than those with multiple smaller and spread out ports (fuel staging effect). Typically, properly designed natural draft burners produce between 60 ppm and 80 ppm corrected to 3% oxygen (V/V dry basis) in the stack. Within a given burner design NOx formation is pretty well fixed and cannot be changed by regular tune up techniques.

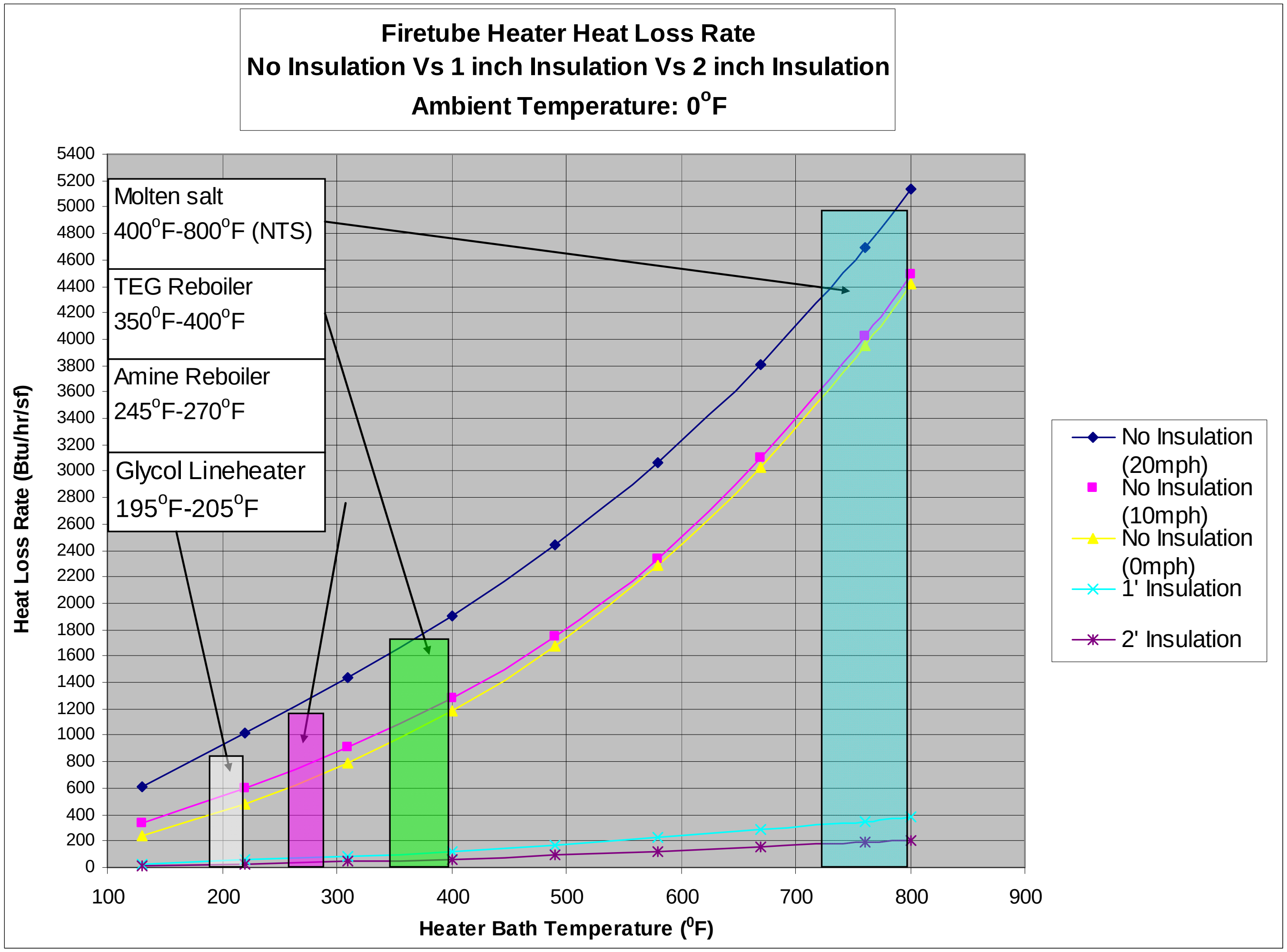
Heater Tune-up / Inspection Procedure
2 Pages

IMMERSION HEATER FIELD INSPECTION AND EFFICIENCY EVALUATION REPORT	PTAC PETROLEUM TECHNOLOGY ALLIANCE CANADA
HEATER TUNE UP / INSPECTION PROCEDURE	Design by: ENEFEN Energy Efficiency Engineering Ltd.

1	**Gas Leak Test:** Check area around the heater and inside the fuel train or control enclosure (if present) for safe H2S, O2 and LEL levels
2	**Visual Inspection:** Inspect heater for obvious signs of deterioration, corrosion, damage to instrumentation or fuel train components
3	**Pilot observation:** Check if heater main burner is firing. If not, check if the pilot is on. If pilot is not on check if the fuel to the pilot is turned on and if so turn the pilot fuel off and wait a few minutes for the fire tube to ventilate. Check with the control room if there is any reason why the heater is turned off. Once safe to do so, turn the main burner manual fuel valve off, relight the pilot and observe. The pilot should be at least 4" to 8" in length, if smaller, try to increase fuel flow to pilot until "solid" pilot is established.
4	**Record Heater Data:** Record heater data such as make, model, year built, serial number, design process duty, burner type and size, burner orifice size, fire tube OD and length, stack OD and height, etc. as per enclosed inspection and evaluation report sheet.
5	**Main flame observation:** Check all heater permissives such as liquid level LO, temperature HI shutdown, bath temperature setpoint. If everything is OK, open the main burner manual valve. Observe main flame shape, colour, stability, anchoring, noise, impingement on the tube surface.
6	**Fuel Pressure Measurement:** Measure and record fuel gas supply pressure, and main burner pressure (after regulation) while it is firing.
7	**Fuel Flow Measurement:** If available measure fuel gas flow to the main burner by timing the gas meter or measuring pressure drop across the fuel metering orifice. Another simple method is the measurement of the burner gas orifice size and calculation of the gas flow using orifice pressure drop charts. Since the mixture pressure inside the burner Venturi is typically negligible compared to the burner inlet pressure, the burner inlet pressure can be used as an approximation of the pressure drop in the charts. Note, that this method cannot be utilized if the fuel gas orifice is used in conjunction with an adjusting needle valve as it is often the case with Eclipse mixers.
8	**Heater bath temperature check:** Locate bath temperature gauge and record bath temperature. Record also the temperature control setpoint of the temperature controller.
9	**Stack Measurements:** Locate sampling port in the straight length of stack above the fire tube exit from the heater. If no port is available, drill and tap 3/8"UNC hole in the stack. Using combustion analyzer take reading of: Flue Temperature, O2, CO, NOx and efficiency. Record also the ambient air temperature. After taking the sample install a 3/8" bolt using high temperature anti-seize compound or a brass bolt.
10	**HI CO / LOW O2 with air passages closed:** If CO reading is high (in thousands of ppm) and O2 reading very low (close to zero), the heater is being fired substoichiometrically without sufficient oxygen. Remove sample probe from the stack immediately to prevent damaging the CO analyzer cell. Let analyzer purge the cell until CO reading drops to zero. Open access port in the flame arrestor to allow more air flow. Insert analyzer probe back into the stack and observe CO readings. If readings have improved, with the access port open, there is a good possibility that the flame cell is plugged up and needs cleaning. Check also position of any secondary air control devices to make sure that they are not blocking the air flow into the burner.
11	**HI CO / LOW O2 with air passages open.** Burner primary air is misadjusted and must be opened. Open slowly watching the analyzer CO readings until CO levels are low. If there is no or slow reaction, reduce fuel gas pressure to main burner gradually also watching for changes in CO. On some burner models (Eclipse) there could be also a fuel needle valve present which could be adjusted. Note that overfiring of the heater without sufficient combustion air does not increase the heat transfer and it may even decrease it through tube sooting or decrease in the flame temperature. It is also unsafe and may lead to a premature heater failure.
12	**HI CO / HIGH O2** The indication is that there is too much combustion air. Reduce the primary and secondary air down to 3 to 4% oxygen in the stack.

Insulation Heat Loss from Vessel Shell

- reduction in lost heat (demand) is a 100% saving, adjustments to appliance efficiency, etc. is only partial



PCOG Fire-tube Immersion Heater Optimization Program

PETRO-CANADA

PETRO-CANADA OIL AND GAS

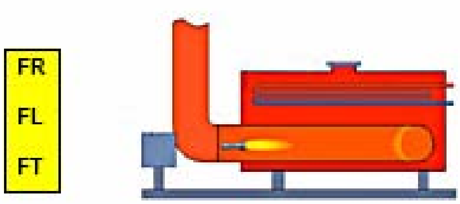
PETRO-CANADA

FIRE-TUBE IMMERSION HEATER
OPTIMIZATION PROGRAM

"When you can measure what you are speaking about, and express it in numbers; you know something about it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind."
Lord Kelvin (1891)

"If you cannot measure it, you cannot improve it."
Lord Kelvin (1895)

"You cannot manage what you do not measure."
Commonly used today!



"You cannot manage what you do not measure."

Philip J. Croteau - P.Eng.
Gerald Hewitt – Operations
Harley Siebold - Operations

Rev. Mar 27, 2006
DRAFT

Essential Elements of a Heater Optimization Program

Executive Summary

- quantify your number of heaters
- identify/understand their service
- quantify how much fuel they are thought to consume
- make assumptions of their current efficiency
- identify the potential efficiency target and savings
- identify how to get there

Statement of Commitment

- **Body of the Program Document**

Conclusions

TRAINING, AUDITING, MAINTENANCE

& TAKING ACTION TO IMPROVE!

Overview: Fire-tube Heater Survey

Just how many fire-tube heaters do we/you fire!

- Following is an ~ count of both PCOG and third party. If we don't steward the third party heaters, who will.

- Do we/you have heaters operated by third party?

195	**FR – Reboilers: Amine, Glycol …**
510	**FL – Lineheaters: Glycol, Salt Bath …**
11	**FT - Treaters**
716	

Target is to audit 1/3 of heaters per year on 3 yr rotation.

PCOG Statement of Commitment

- excerpt from "Fire-tube Immersion Heater Optimization Program"

Statement of Commitment:

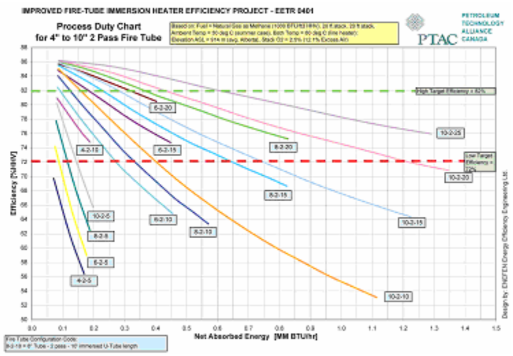
Through our TLM program, Petro-Canada focuses on improvements in the elements of safety, environment, reliability, economics and the general management of our facilities.

As one of the areas of focus, Petro-Canada had recently committed resources and funding to participate in a study to review and improve our understanding in the design and operation of fire-tube immersion heaters and follow-up with implementation to optimize that equipment. Management is committed to improving the performance of these heaters through expectations of support from Operations, Maintenance and Engineering (OME).

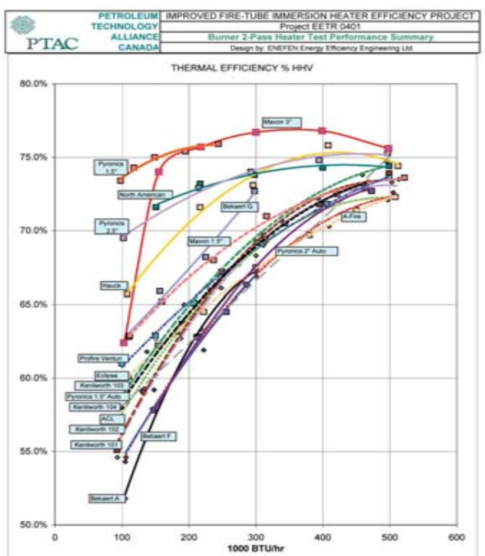
FIRE-TUBE IMMERSION HEATER DESIGN & OPERATION

Heat Transfer

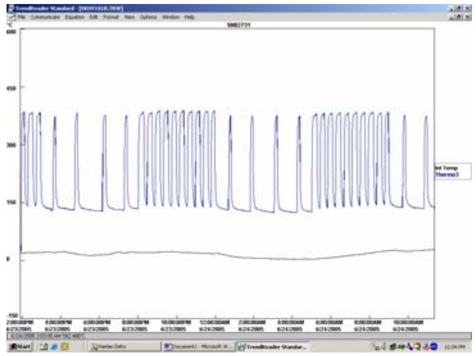
- Fire-tube Design

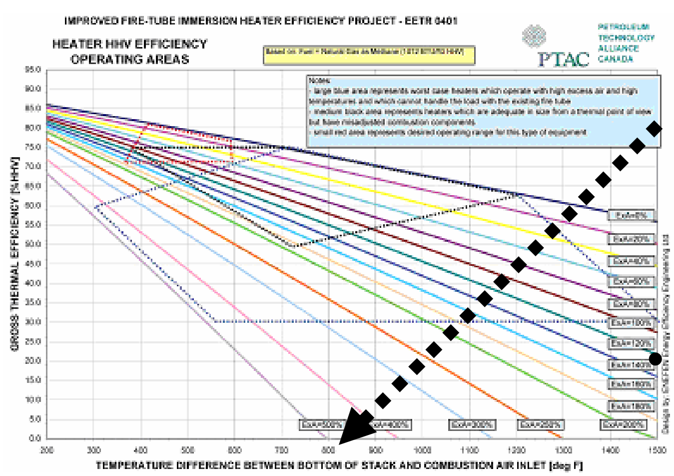


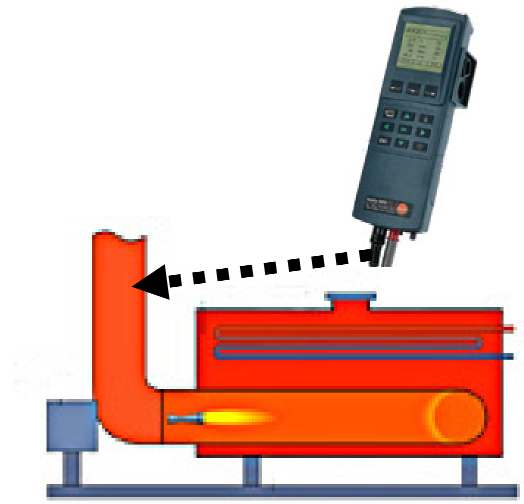
Burner Selection



Duty Cycle







Combustion Analysis

– 3 T's plus Excess O2

Time – Temperature - Turbulence

+ Excess O2: approx. 3%

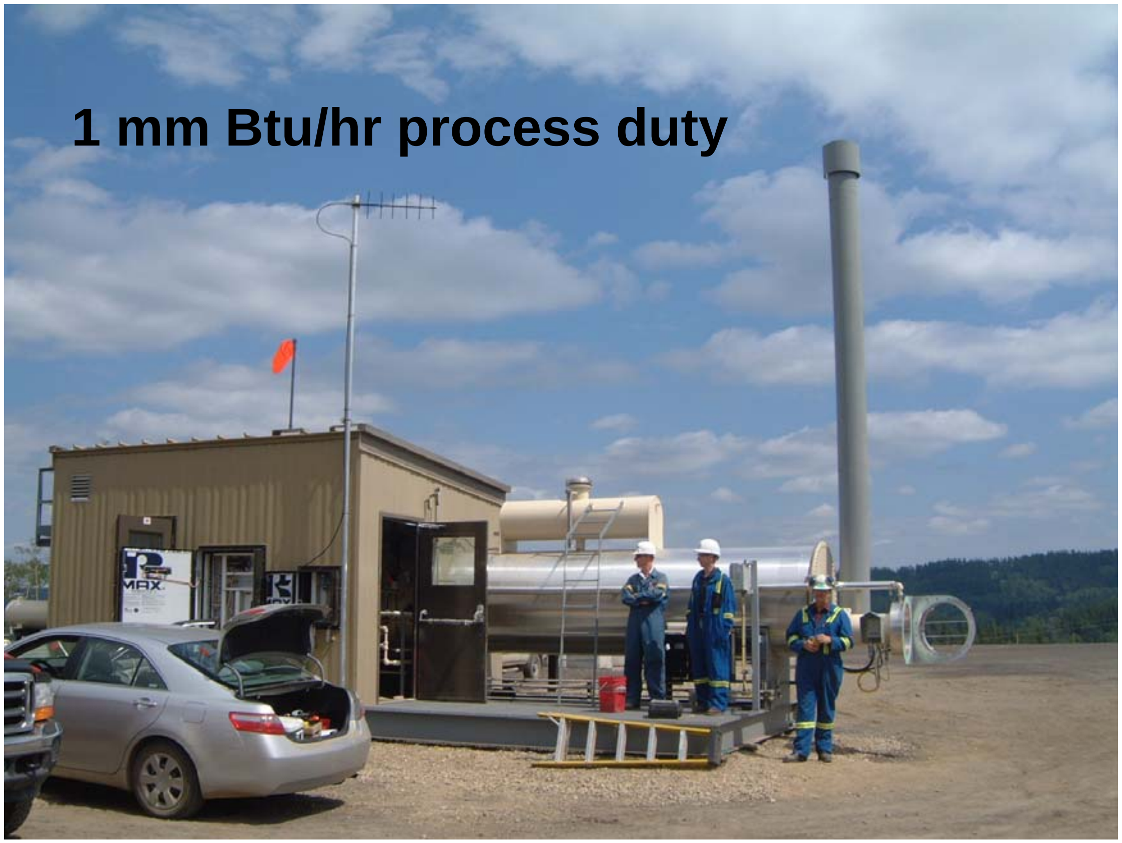
Time at Temperature

"NEW" addition of the 4th T – Training!

Long and Skinny Fire-tube to Improve Heat Transfer

Sept 2006 test heater built, **Wildcat Hills Choke Heater**

6' was added to standard fire-tube Flux = 7,000 Btu/hrft2



- Longer, more slender fire-tube is not new, many older heaters were built this way and exhibited better efficiency!

Vendor made the fire-tube, shell and process coils longer (with fewer return bends, lowering coil press drop!), shell dia. finished smaller.

Fabricated cost of steel ended up similar to standard design.

PCOG Fire-tube Heater Field Audits

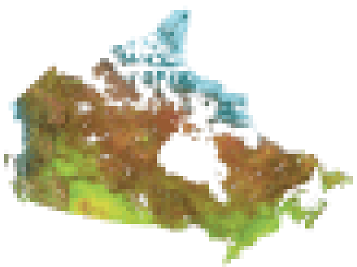
- **Petro-Canada is actively participating in 10 applications pursuing fire-tube heater efficiency improvements.**

- **Assisted by the NRCAN audit process we are attempting to assess 1/3 of our heater fleet/yr. on an ongoing cycle.**

NRCAN Industrial Energy Audit Incentive Program

Office of Energy Efficiency

This incentive is designed to help defray the cost of hiring a professional energy auditor to conduct an on-site audit at an industrial facility.



Natural Resources Canada | Ressources naturelles Canada

Fire-tube Heater "Field Audit" Program

NFN	ENEFEN Energy Efficiency Engineering Ltd.	
	#307 - 4806 47th Avenue, Leduc, AB, T9E 5X3, Canada	
	Alberta TEL: (780) 940-3464	Contact: Jozef Jachniak, P.Eng.
	BC TEL: (604) 808-1974	jjachniak@enefen.com
	FAX: 1-866-583-0520	www.enefen.com

EFFICIENCYGRAM™ IMMERSION FIRE-TUBE HEATER PERFORMANCE EVALUATION REPORT

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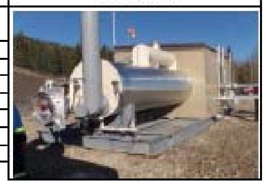
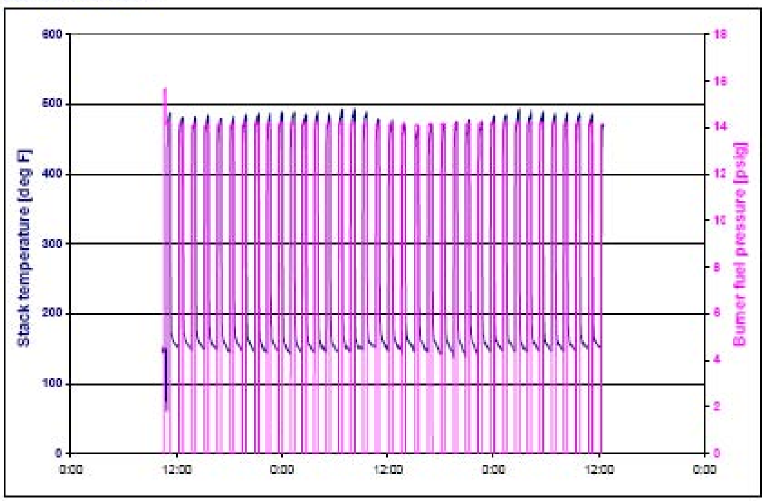
Report by:	Report Date:	Report No.:
Jozef Jachniak, P.Eng.	4-Oct-06	EG-0610002

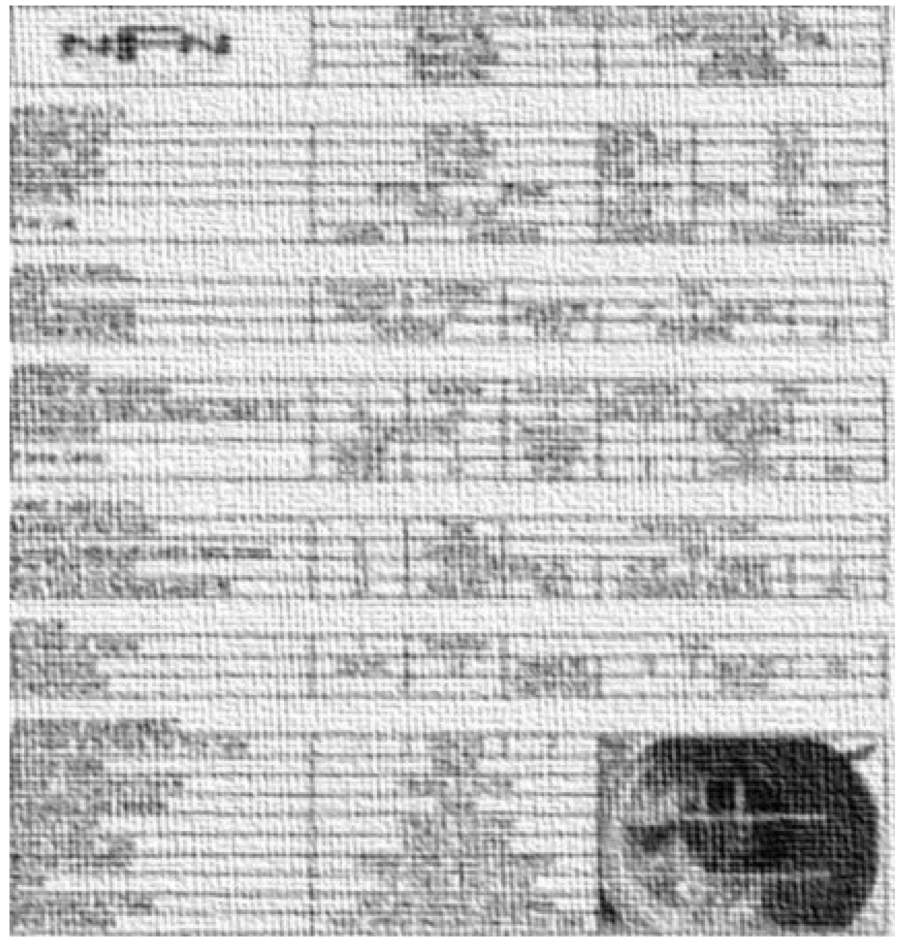
CUSTOMER DATA

Client:	Petro Canada Oil and Gas
Plant:	Wildcat Hills Gas Plant
Area:	Viking Field
LSD:	05-13-28-07-W5
Contact:	Phil Croteau
Phone Number:	403-296-5977
Date:	4-Oct-06



HEATER TREND DATA





- Stack temp and fuel gas pressure to burner orifice are key variables!

Combustion Analysis – O2, Excess Air, CO, NOx, comb. efficiency, ambient, bath and stack temp,

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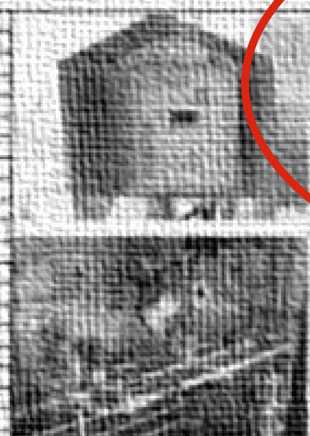
FUEL TRAIN & CONTROLS

[illegible]



FUEL FLOW MEASUREMENT

[illegible]

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STACK MEASUREMENT

Bath Temperature	deg F	95.00	
	deg C	35.00	
Ambient Temperature	deg F	46.40	
	deg C	8.00	
Stack Temperature	deg F	500.00	Stack temperature too high
	deg C	260.00	
Oxygen (O2)	%	9.40	Stack oxygen high
Excess Air (ExA)	%	81.0	Excess air high
Carbon Monoxide (CO)	ppm	9	CO within ideal range
Nitrogen Oxide (NOx)	ppm	40	
Analyzer Measured Efficiency	%	77.80	Efficiency within acceptable range
Calculated Efficiency	%	74.58	Based on stack O2, CO, and temperature
Effective Efficiency	%	82.16	Based on integration of data kit results
Achievable Efficiency	%	85.46	Based on optimized burner size & setup

DATA KIT HEATER PERFORMANCE TRENDING

Data Quality Check			
# of Samples Collected		[illegible]	
Invalid Temperature Readings	-	0	
Invalid Pressure Readings	-	0	
First Valid Sample Row #	-	3	
Last Valid Sample Row #	-	12337	
# of Valid Contiguous Samples	-	12035	
Cycles			
Fuel PT drift threshold	psig	0.1	Pressure transmitter drift below which flow=0
Burner Stability Threshold (BST)	psig	1.0	Fuel pressure below which burner is unstable
# of times heater switched ON	-	36	in excess of 30 seconds
# of times heater switched OFF	-	36	in excess of 30 seconds
Total number of ON/OFF switches	-	71	
Temperature Control Stability	-	100%	Percent of cycles > 30 seconds long
Measured Times			
Total Sampling Time	hours	50.138	
Shortest ON Time	hours	0.417	
Longest ON Time	hours	0.692	
Average ON Time	hours	0.433	
Total ON Time	hours	15.575	
Shortest OFF or below BST Time	hours	0.136	
Longest OFF or below BST Time	hours	1.100	
Average OFF or below BST Time	hours	0.987	
Total Time below BST	hours	0.008	BST = Burner Stability Threshold
Total OFF Time	hours	34.554	
DUTY CYCLE = ON / Total Time	%	31.065	@ fuel pressure above BST pressure
Measured Temperatures			
Maximum Stack Temperature	deg F	494.32	
Minimum Stack Temp during OFF time	deg F	135.6	
Average Cooling Time	minutes	46.2	To within 10% of the minimum stack temperature

Heater Utilization – New Equip Performance Validation, in this case heater was only firing 31% duty at < 1/3 design firing rate. Only 10% design utilization, not ideal for a new heater!

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DATA KIT HEATER PERFORMANCE TRENDING Cont'd

Measured Fuel Flows			
Total Fuel Consumed During Test	SCF	21154.6	
Fuel wasted below BST pressure	SCF	0.9	BST= Burner Stability Threshold
Fuel used effectively for heating	SCF	6833.3	Based on effective efficiency computation
% Wasted Fuel	%	0.0%	
Maximum Fuel Flow	SCFH	482.8	
Average Fuel Flow During ON TIME	SCFH	438.7	
Average Fuel Flow below BST	SCFH	112.7	
Constant Equivalent Fuel Flow	**SCFH**	**136.3**	
Constant Pilot Fuel Flow (nominal)	SCFH	30.0	
Constant Total Fuel Flow	**SCFH**	**166.3**	

THERMAL PERFORMANCE

Current Peak Condition			
Fuel Peak Input incl. pilot	MM BTU/hr	0.49	
Process Peak Heat Input	MM BTU/hr	0.40	
Fire-Tube Surface Heat Flux Rate	BTU/hr/ft2	2,131	
Crossectional Heat Flux	BTU/hr/in2	2,829	
Equivalent Continuous Flow			
Constant Equivalent Fuel Input	MM BTU/hr	0.17	
Process Heat Requirement	MM BTU/hr	0.13	
Fire-Tube Surface Heat Flux Rate	BTU/hr/ft2	681	
Crossectional Heat Flux	BTU/hr/in2	904	
Fire-Tube Rating			
Heater name plate rating (per tube)	MM BTU/hr	1.50	
Original rating based on 10K heat flux	MM BTU/hr	[illegible]	Heater designed for 7000 BTU/hr/ft2 heat flux
Utilization of Original Rating	**%**	**6.8%**	9.7% based on 7000 BTU/hr/ft2 heat flux

BURNER SIZING ANALYSIS

Burner Capacity Requirement			
Extra Burner Capacity	[illegible]	[illegible]	
Total Required Fuel Input	MM BTU/hr	0.21	
Less pilot capacity	MM BTU/hr	0.03	
Main Burner Fuel Input	MM BTU/hr	0.18	
Existing Burner(s)			
Number of burners per fire-tube	-	1	
Existing Burner Size	in	4	
Revised Burner Sizing - Single burner selection			
Fire-Tube Size	in	14	
Maximum allowable burner size	in	4	Limited by fire-tube diameter
Burner size to meet capacity	**in**	**1.5**	Burner size less than maximum
Maximum nominal burner capacity	BTU/hr	212,000	
Minimum nominal burner capacity	BTU/hr	53,000	
% Maximum Burner Fire	%	83.90	
Nominal maximum burner pressure	psig	20.00	
Orifice size required	in	0.0746	
Closest Drill #	#	**#48**	
Drill Diameter	in	0.0760	

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UPGRADE RECOMMENDATIONS — Urgency of upgrades: 3 = high, 2 = medium, 1 = low

Process Improvements		
1.1 Target Efficiency (%HHV)	85.5	Based on optimized burner size & setup
1.2 Review Process Requirements	3	Gross mismatch between firing rate & process demand
1.3 Lower Bath Temperature		
1.4 Shut heater off when not needed		
1.5 Review temp. sensor location		
1.6 Review external heat losses		
1.7 Repeat data logging		
1.8 Repeat stack analysis		
1.9 Other process improvement		
Maintenance Improvements		
2.1 Clean flame cell		
2.2 Clean fire-tube		
2.3 Fix fire-tube		
2.4 Adjust combustion air		
2.5 Adjust fuel gas pressure		
2.6 Clean burner		
2.7 Clean pilot		
2.8 Set up control logic		
2.9 Test flame arrester		
2.10 Other maintenance improvement		
Minor Modifications		
3.1 Add / modify secondary air plate	3	Necessary to control excess air
3.2 Replace burner	3	Improper burner size, arrangement or condition
3.3 Replace pilot		
3.4 Align burner		
3.5 Align pilot		
3.6 Change burner orifice		
3.7 Remove burner adjusting needle		
3.8 Add view port		
3.9 Replace flame cell		
3.10 Install burner union		
3.11 Install housing coupling(s)		
3.12 Install wiring seal on windbox		
3.13 Change regulator spring		
3.14 Change regulator orifice		
3.15 Replace pressure gauges		
3.16 Change TSH/TSHH to snap acting		
3.17 Other minor modification		
Major Modifications		
4.1 Install / replace BMS, ignition flame detection		
4.2 Install power source		
4.3 Modify to interruptible pilot		
4.4 Add / replace safety shutoff valve(s)		
4.5 Add / replace manual valve(s)		
4.6 Add / replace LSLL		
4.7 Add / replace TSH / TSHH		
4.8 Add fuel gas PSHH / PSLL		
4.9 Address other safety issue		

Opportunity to save capital building heaters smarter, smaller!

Summary Sheet of Expected Savings

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UPGRADE RECOMMENDATIONS — Urgency of upgrades: 3 = high 2 = medium 1 = low

Major Modifications (cont'd)		
4.10 Add HI/LO/OFF control		
4.11 Add modulating control		
4.12 Upgrade venting system		
4.13 Change pressure regulator(s)		
4.14 Modify instrument gas system		
4.15 Replace burner housing		
4.16 Insulate heater		
4.17 Insulate stack		
4.18 Add stack height		
4.19 Add stack thermometer		
4.20 Replace fire-tube		
4.21 Add lighting / view port to fire tube		
4.22 Other major modification		

ESTIMATE OF SAVINGS

Measured Constant Total Fuel Flow	SCFH	155.3	
Seasonal Fuel Flow Correction	%	25.00	To compensate for winter demand
Annual Fuel Consumption (based on nominal 1000 BTU / SCF HHV)	SCF	1,820,898	Based on 8760 hrs/A operation
	m3	51,563	constant total fuel flow
	MM BTU	1821	
	GJ	1921	
Effective Efficiency	%	82.16	
Achievable efficiency	%	85.46	
Improvement in efficiency	%	3.30	
Annual Fuel Savings Due to Efficiency Improvement	%	3.86	
	SCF	70,276	
	m3	1,990	
	MM BTU	70	
	GJ	74	
Annual Fuel Savings Due to Elimination of Fuel Pressures below BST	SCF	164	
	m3	5	
	MM BTU	0	
	GJ	0	
Total Annual Fuel Savings	SCF	70,440	
	m3	1,995	
	MM BTU	70	
	GJ	74	
Annual CO_2 Emission Reduction	tons/year	3.7	

Conclusion

The means to achieve improved efficiency is as simple as:

- **training – theory, operations, combustion testing with analyzer, CMMS (EMPAC)**
- **manage excess air in combustion**
- **manage the burner duty cycle**
- **strive for 82% combustion efficiency (depends on service, i.e. bath approach temp)**
- **provide adequate insulation to reduce energy demand (reduction is a 100% improvement)**
- **steward regular combustion analysis and inspection of heaters spring and fall, focusing on duty cycles, CO in combustion, excess air and stack temperature (fire-tube exit temp)**
- **integrate burner duty with process demand where possible**
- **design new equipment to address the items above (burners and fire-tubes)**
- **maintain CMMS records of fired equipment**
- **DESIGN YOUR HEATER TO MEET THE SERVICE – DUTY, FIRING MODE, ENGAGE (OME), PRODUCTION AND PROJECT GROUPS!**