Recovery and Power Boiler Optimization

by

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Value Delivery

- In the last 7 years, we have tested 42 of the 55 operating recovery boilers in Canada, 8 more RBs in the U.S. and 21 power boilers at Cdn mills
- Operations in 31^{+} of the Cdn. recovery boilers, 16 of the power boilers and 6 of the U. S. recovery boilers have been optimized
- Recovery boiler throughput was increased by 3 – 20%, while reducing the water wash frequency
- Hog steam generation in the optimized power boilers was increased by 6.7 – 31%, producing savings of $1.1 – 7.6 million U. S./yr in purchased fossil fuel for each boiler

Boiler Optimization Technology

- Developed over a 9 year period, patented and used commercially for the last 7 years
- Deep fundamental understanding came from work on recovery boiler CFD model development and validation
- Unique tools and guidelines employed
- Measurements (not subjective assessments) guide optimization

Recovery Boiler Combustion Air Distribution

- Air is injected at multiple vertical levels and from all 4 boiler walls at one or more air level

- The interactions of these air jets create a high velocity chimney which promotes carryover

- The location and strength of the chimney (peak velocities) is determined by the air flow and the distribution between boiler walls

Recovery Boiler Combustion Air Distribution

- Unbalanced air distribution between the walls at a given level pushes the chimney closer to the boiler walls and associated liquor guns, increasing carryover and PM emissions
- Interlacing the secondary and tertiary air can reduce the size of the chimney and peak gas velocities and enhance mixing
- Optimization of the vertical air splits increases bed temperatures and reduction efficiency while decreasing TRS emissions

Poor Recovery Boiler Air Distribution

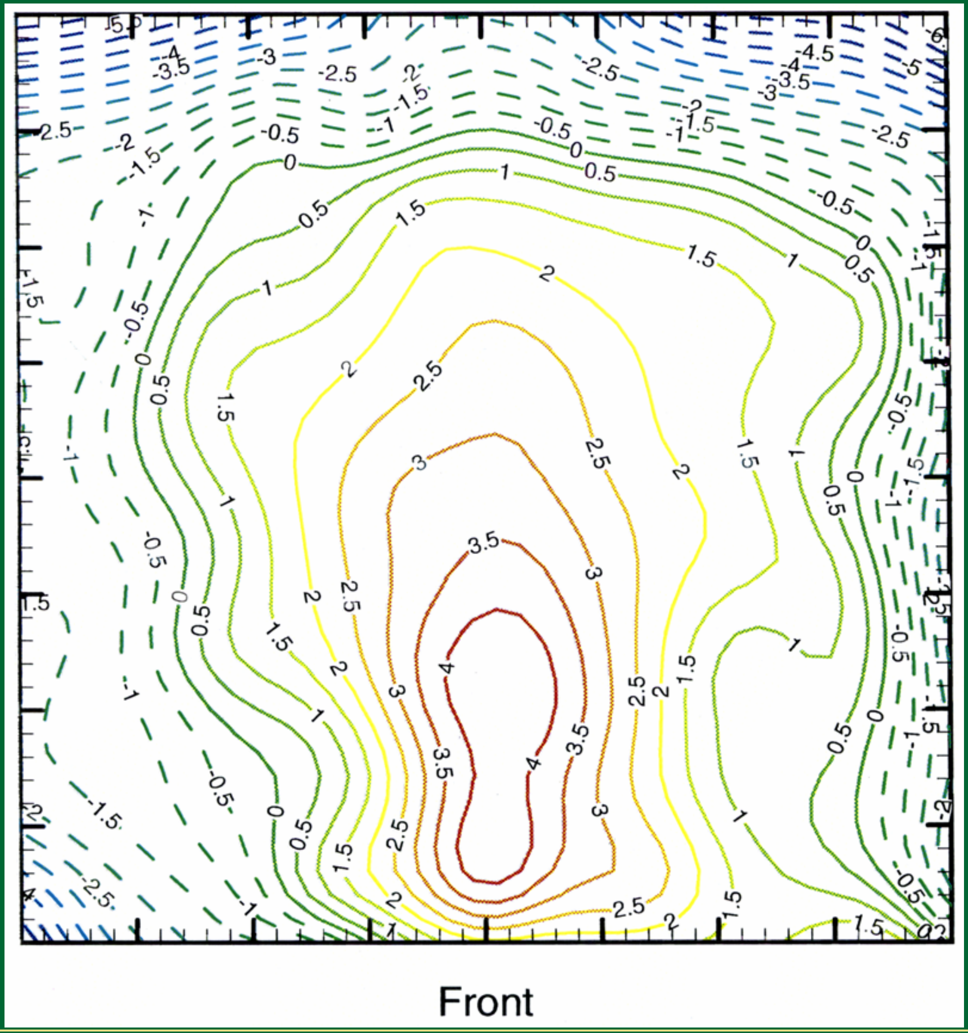
- High carryover
- Rapid boiler plugging
- Low reduction efficiencies
- Smelt spout plugging problems
- High TRS and particulate emissions
- Reduced boiler throughput

- Setting up your recovery boiler air system without the proper tools is akin to timing your car's engine by ear.

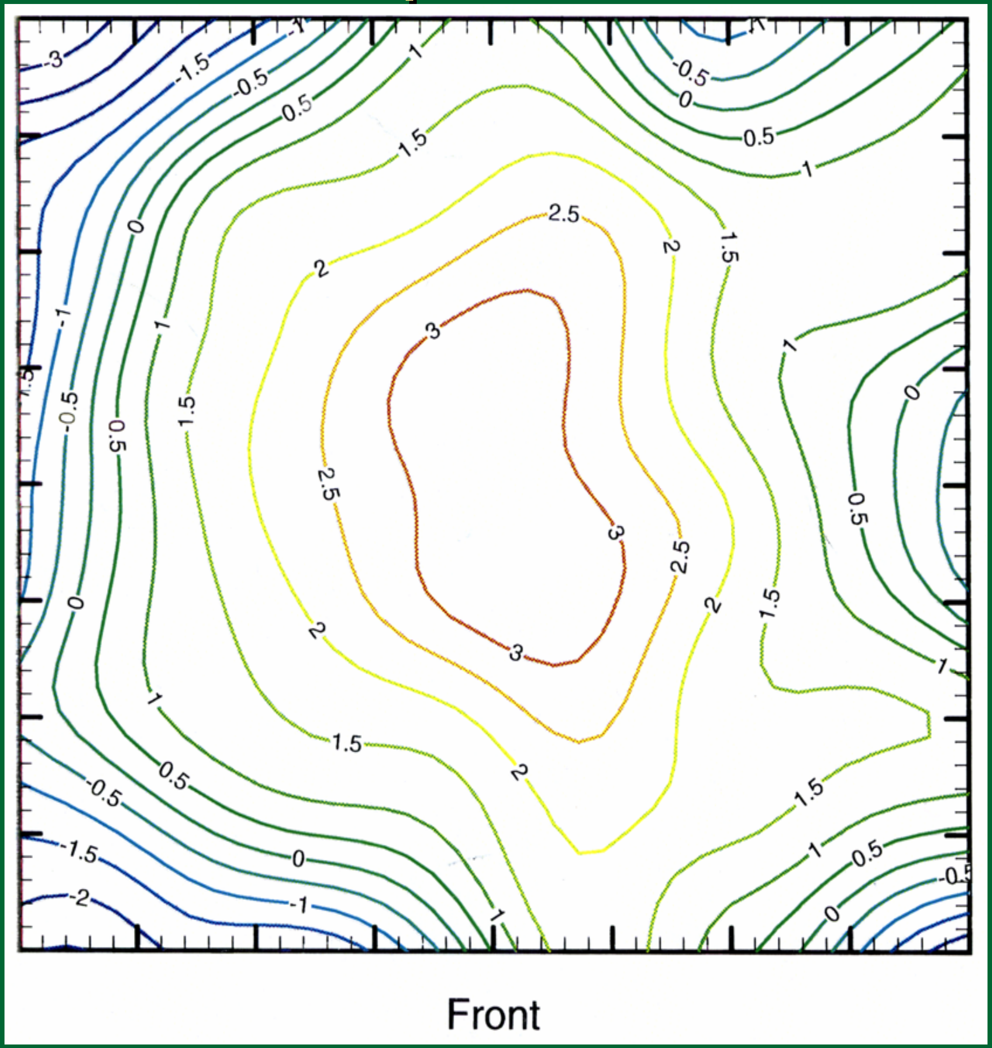
Key Measurements

- Combustion air flow and distribution
- Cold flow gas velocity profiles (now optional)
- Gas velocities with fossil fuel and black liquor firing (not often required any more)
- Char bed and furnace temperature profiles
- Carryover measurements at the bullnoze level

Mill C Cold Flow Velocity Profile Before Optimization



Mill C Cold Flow Velocity Profile After Optimization



Recovery Boiler Optimization

- Both the air system and the liquor firing system have to be optimized
- Balance and optimize air first
- Optimize liquor firing parameters (gun pressures & firing temperatures) according to proprietary guidelines
- Then adjust gun angles and air splits to maximize lower furnace temperatures & minimize carryover

Heat Loading in Some Optimized Recovery Boilers

Recovery Boiler	Heat loading Million BTU/h/ft^2	Aspect ratio
J	1.2	2.5
E	1.16	2.3
F	1.14	2.6
G	1.22	2.8
H	1.23	3.1

Benefits of Recovery Boiler Optimization Technology

- 3 - 20% increases in recovery boiler throughput ($5.1 to $34 million US per year in incremental pulp production in a 1000 tpd kraft mill)
- Reduction of water washes to 1 or 2/year ($500,000 - $2.5 million US per year)
- Dramatic reductions in TRS emissions; 30-50% typical when they are initially high

Power Boiler Optimization

- Modified the tools to extend application to hog fuel power boilers. Power boiler optimization can:
  - Minimize fossil fuel consumption
    - Great savings due to the increasingly high energy prices
    - Additional benefits from biomass CO_2 credits (under Kyoto)
  - Reduce PM, NO_x, SO_2, dioxins and other emissions

- Dioxin emission research on 10 coastal hog fuel boilers

- Optimization tests on 11 interior hog fuel boilers

Power Boiler Evaluation Tests

- Baseline hog combustion efficiency
  - Assess and balance the air delivery systems
  - Assess the hog delivery and feeding systems
  - Check the boiler control logic and instrumentation
  - Observe fuel-air mixing behavior and measure combustion temperatures
  - Sample and analyze fuel, flue gas and ash
  - Monitor boiler emissions
- Short term trials at higher than normal firing rates to identify the boiler limitations
- Measurements, modeling, and troubleshooting experience combined to give the lowest cost solution

Typical Problems Identified

- Non optimal air splits
  - Poorly designed OFA systems (layout /location)
  - Unnecessary gas firing or too much burner air
  - Inoperable dampers
  - Inadequate fan capacity
  - Non-uniform / mis-matched UGA and fuel distribution
  - Errors in control logic and inappropriate combustion control strategies
- Inadequate hog delivery
  - Variable fuel quality
  - Loading interruptions and surge bin/auger problems
  - Poorly designed or operated hog feeders
  - Distribution air pressure too low or too high
- Poor calibration of gas analyzers
- Special restrictions
  - Boiler either too short or too narrow
  - Boiler exit temperature requirements when burning sludges in some jurisdictions

Examples of Trial Results

- Hog steam increased from 200 to 350 klb/h by
  - solving air flow control and damper movement problems
- Hog steam increased from 99 to 110 t/h by
  - increasing the undergrate air flow
  - re-balancing and enhancing the HMZ over fire air system, and
  - installing a new NCG/methanol burner closer to the grate.
- Hog steam increased from 202 to 234 klb/h by
  - increasing the overfire air flow from 110 to 140 klb/h (OFA/UGA ratio from 0.7 to 0.95), and
  - balancing the rear and front OFA (Rear/Front OFA to 1.15 from 1.6)
- Hog steam increased from 25 to 32.5 t/h by
  - shifting from auto to manual control
  - reducing gas firing to the minimum (4%), and
  - increasing the FD Fan outlet air pressure from 1.4 to 1.7 kPa

Estimated Savings in Short Term Trials

Mill ID	Boiler ID	Trial Results				
		Date	Hog Steam Increase, t/h	Hog Steam Increase, %	CO_2 Savings, t/yr	Fuel Cost Savings, M$/yr
Mill A	Boiler A1	2003	22.7	25.0	37,316	**3.09**
	Boiler A2	2003	37.2	36.1	61,199	**5.06**
Mill B	Boiler B1	2004	9.7	35.8	15,960	**1.32**
	Boiler B2	2004	11.5	55.0	18,921	**1.57**
Mill C	Boiler C	2005	11	11.1	18,099	**2.16**
Mill D	Boiler D	2004	21.5	20.5	35,375	**2.93**
Mill E	Boiler E	2004	14.5	15.8	23,882	**1.98**
Mill F	Boiler F	2004	21.7	31.2	35,749	**2.96**
Mill G	Boiler G	2004	11.7	30.7	19,250	**1.59**
Mill H	Boiler H	2005	13.7	16.7	22,614	**2.09**

Evaluation of Benefit Actually Generated

- Requested operating data from mills participating in the power boiler optimization project
- Received data on six boilers:
  - Boiler A1, A2, B1, B2, C: data for a full year before and after optimization
  - Boiler E: pre- and post optimization data for 6 months
- Mill D did not send data; the project for boiler upgrading to implement Paprican’s recommendations, though budgeted, was postponed to 2006.
- Mill F indicated that manpower was not available to extract the requested data.
- The power boiler at Mill G is not on the DCS and operating data cannot be readily retrieved.

Summary of Actual Benefits

Mill ID	Boiler ID	Actual Results					
		Comparing Periods	**Hog Steam Increase, t/yr**	**Hog Steam Increase, %**	**Fossil Energy Savings, GJ/yr**	**CO2 Savings, t/yr**	**Money Savings, $/yr**
Mill A	Boiler A1	Mar02 - Feb03 & Year 2004	191,922	31.4	770,004	39,871	8,892,413
	Boiler A2	Mar02 - Feb03 & Year 2004	176,425	28.0	707,829	36,651	8,174,392
Mill C	Boiler C	Sept03 - Aug04 & Sept04 - Aug05	50,013	7.5	200,657	10,390	1,264,659
		Comparing Periods	**Hog Steam Increase, t/0.5yr**	**Hog Steam Increase, %**	**Fossil Energy Savings, GJ/0.5yr**	**CO2 Savings, t/0.5yr**	**Money Savings, $/0.5yr**
Mill E	Boiler E	1 April-14 Sept 04 & 15 Sept 04-31 Mar 05	26,496	6.7	106,305	5,504	638,340
Mill B	Boiler B1	Potential hog steam increase was not realized. Major reasons are: Aging boiler system; Planned boiler upgrading incomplete; Deteriorating hog quality, Hog loading and feeding issues					
	Boiler B2						
Mill D	Boiler D	Expected improvement has not been achieved as the project of boiler upgrading, thought budgeted, has been postponed to 2006.					
Mill F	Boiler F	Responded to our request but no data has been provided.					
Mill G	Boiler G	DCS not available and extracting the operating data not possible					
Mill H	Boiler H	Response to our request for data has not yet been received.					

Stack Emissions

- Mill A: PM emissions for both #3 and #4 power boilers and two recovery boiler
  - 159 mg/m3 for 2002 pre-optimization
  - 143 mg/m3 for 2004 post-optimization
  - Apparently, the higher hog firing rate in 2004 did not hike the overall PM emissions (scrubber type changed in the 2nd quarter of 2004)
- Mill C: PM Emissions have been always low (< 15 mg/m3). The higher hog firing rate after optimization did not increase emissions
  - Pre-optimization gas emissions not available
  - Paprican measured post-opt gas emissions using a portable CEM

NO (ppm)	CO (ppm)	SO_2 (ppm)	CO_2 (%)	O_2 (%)
103.8	62.8	5.3	9.8	10.0

- Mill E: Though hog firing rate was higher, PM emissions were lower after optimization

Particulate Emissions from Boiler E

Parameter	Unit	Pre Opt	Post Opt	
Period Covered		April 1 to Sept 14 - 04	Sept 15 to Nov 14 - 04	Nov 15 04 to Mar 31 - 05
Gas Flow	GJ/h	17.7	25.4	32.1
Total Steam	klb/h	208.4	218.4	232.8
Calculated Gas Steam	klb/h	9.7	14.0	17.6
Hog Steam	klb/h	198.6	204.4	215.2
PM Emissions	mg/m3	36.2	35.1	28.7
Flue Gas Flow	m3/min	1792	2135	2180
PM Emissions	kg/t of o.d. hog	0.22	0.24	0.19

Summary

- 42 of the 55 operating recovery boilers in Canada, 8 more RBs in the U.S. and 21 power boilers at Cdn mills tested in the last 7 years
- Operations in 75- 80% of these boilers have been optimized with little or no capital investment
- Recovery boiler throughput was increased by 3 – 20%, while reducing the water wash frequency
- Hog steam generation in the optimized power boilers was increased by 6.7 – 31%, producing savings of $1.3 – 8.9 million Cdn./yr in purchased fossil fuel for each boiler

Boiler Optimization Services

- Paprican's boiler optimization services were offered exclusively to member company mills until 2006
- These services are now being offered to North American mills through our Boiler Optimization and Emissions Control Business Unit
- We are also investigating licensing options that will increase our ability to meet the demand for both power and recovery boiler optimization services

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