Achieving Uniform Combustion Using Burner Line Orifices To Balance Coal Flow Distribution

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WHY BALANCE THE COAL FLOW TO BURNERS?

- **Fuel Rich Burners are a Source of High CO and LOI**
- **Fuel Rich Burners Can also Cause Furnace Ash Deposits, Waterwall Corrosion, and Fouling in the Convective Section**
- **Furnace Wall Cleanliness is a Key Issue in Low-NO_x Firing with PRB Coals (Derates and Outages can Occur)**
- **Air Rich Burners Produce NO_x and Contribute to Boiler Efficiency Losses**
- **Low-NO_x Burner Vendors Typically Require the Coal Flow Variation Between Burners Not Exceed ±10% for Each Pulverizer**

TYPICAL COAL FLOW BALANCING QUESTIONS

1. **Do Fixed or Adjustable Coal Pipe Orifices Work?**

2. **Do Balanced "Clean Air" Velocities Ensure Good Combustion?**

3. **Are "Dirty Air" Measurements Necessary? If So, Why?**

4. **Does the ASME Pulverized Coal Sampling Method Produce Accurate Results?**

5. **Should Burner Coal Pipes be Balanced on Velocity or Coal Flow?**

TYPICAL COAL FLOW BALANCING QUESTIONS (cont'd)

6. **Has Burner Pipe Coal Flow Balancing Been Successful, and Once Balanced, How Long Does it Last?**
7. **What are the Benefits of Balancing Coal Flows?**
8. **How Does the Coal Flow Balance Vary Over the Load Range?**
9. **What Are the Choices for Measuring and Balancing Burner Pipe Coal Flow?**
10. **What is the Status of Burner Real-Time Coal and Air Flow Measurement and Control?**

“CLEAN” VS. “DIRTY” PRIMARY AIR FLOW MEASUREMENTS

- A Common Industry Practice is to Balance “Clean” Primary Air Flow Distribution Between Burner Pipes
- A Balanced “Clean” Air Distribution Does NOT Ensure Balanced “Dirty” Air or Coal Flow Distribution
- Two Phase Flow Effects Change the Flow Distribution When Coal is Present
- “Clean” Air Velocity Variations Between Pipes Often Are Greater Than “Dirty” Air Flow Variations
- “Dirty” Air and Coal Flow Variations Do Not Track in Exact Proportions but “Dirty” Air Flows Correlate Much Better Than “Clean” Air Flows

CLEAN AIR VS. DIRTY AIR COMPARISONS

Pulverizer Type	Final Dirty Air Deviations	Final Clean Air Deviations	Location
C-E	±4.8%	±13.4%	New Hampshire
C-E	±6.1%	±14.1%	New Hampshire
C-E	±3.3%	±25.0%	New Hampshire
B&W	±7.6%	±19.1%	Ohio
F-W	±3.4%	±17.7%	Iowa

ASME VS. ISO COAL SAMPLING METHODS

- ASME Coal Fineness Can Vary with Extraction Rate and the Coal Distribution in the Pipe (roping)

- Data Taken Along Only One or Two Coal Pipe Radii Can Produce Non-Representative Results

- Isokinetic Sampling in Areas of Low Coal Flow Can Produce Poor Sample Recovery Rates

- The Rotating Head on the ISO RotorProbe Sweeps the Entire Coal Pipe Cross Section

COAL FINENESS VARIATION WITH SAMPLE EXTRACTION RATE

	Isokinetic Sampling			
% Passing	Pipe 1F	Pipe 6F	Pipe 1R	Pipe 6R
50 Mesh	98.6	98.8	99.6	99.0
100 Mesh	90.7	92.4	94.0	93.1
200 Mesh	**70.5**	**74.7**	**77.5**	**73.2**
Recovery, %	40	63	51	60

	High Recovery Sampling			
% Passing	Pipe 1F	Pipe 6F	Pipe 1R	Pipe 6R
50 Mesh	98.0	97.1	99.0	99.6
100 Mesh	92.3	89.2	94.7	97.
200 Mesh	**71.0**	**66.5**	**71.9**	**82.0**
Recovery, %	105	118	81	92

COAL FINENESS DATA USING ASME PROBE

% Passing	Port I	Port J	Difference, %
50 mesh	99.38	98.16	1.22
100 mesh	94.90	88.90	6.00
200 mesh	71.96	62.64	9.32

COAL FLOW BALANCING EXPERIENCE WITH ISO ROTORPROBE™

Boiler Manufacturer	Firing Configuration	Unit Size
B & W (8) CE (11) Foster Wheeler (4) Riley Stoker (2)	T-Fired Single Furnace (1) T-Fired Divided Furnace (6) T-Fired Twin Furnace (2) Single Wall Fired (9) Opposed Wall Fired (4) Opposed Cell Burner (1) Turbo-Fired (2)	50 MW to 685 MW

Pulverizer Type	Test Dates
CE Exhauster (29) B&W Roller Mill (27) Foster Wheeler Ball Tube Mill (16) Riley Stoker Ball Tube Mill (6)	1993 - 2002

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IMPROVEMENTS IN COAL FLOW BALANCE

ulverizer Type	Initial Coal Flow Deviation	Final Coal Flow Deviation	Orifice Type	Location
F-W	±11.7%	±1.5%	Fixed	IL
B&W	±29.2%	±4.3%	Fixed	OH
C-E	±25.4%	±3.2%	Adjustable	CT
C-E	±28.3%	±9.6%	Adjustable	CT
B&W	±16.1%	±4.1%	Fixed	CT
C-E	±32.4%	±4.4%	Adjustable	CT
C-E	±38.0%	±7.7%	Fixed	OH
C-E	±38.2%	±8.3%	Fixed	MI
B&W	±22.8%	±4.9%	Fixed	OH
C-E	±39.3%	±11.3%	Fixed	OH
F-W	±31.5%	±4.8%	Fixed	CT
F-W	±12.3%	±3.6%	Fixed	CT

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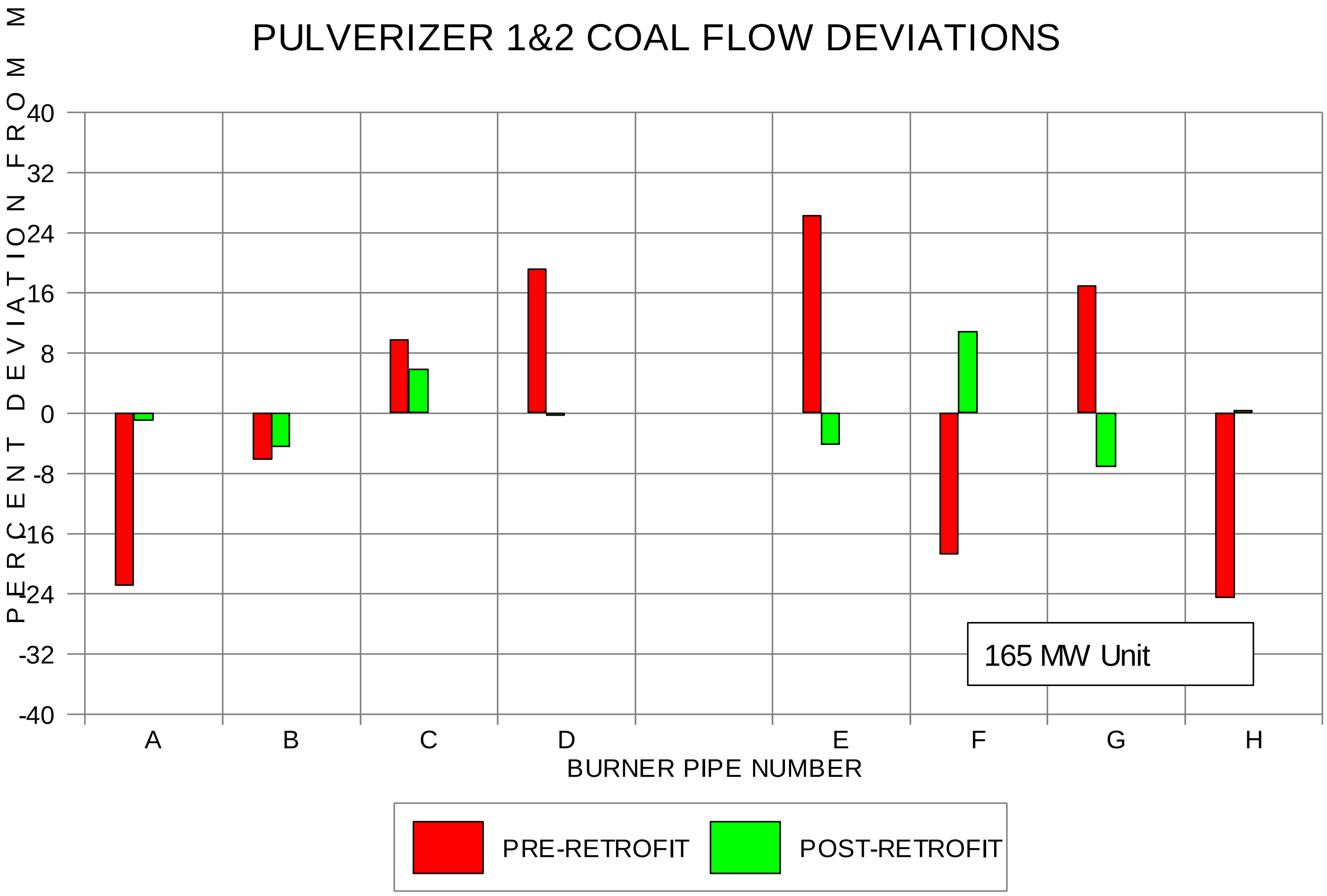
IMPROVEMENTS IN COAL FLOW BALANCE (continued)

Pulverizer Type	Initial Coal Flow Deviation	Final Coal Flow Deviation	Orifice Type	Location
F-W	±21.1%	±7.6%	Adjustable	KY
F-W	±19.7%	±7.6%	Adjustable	WV
F-W	±16.3%	±4.7%	Fixed	IN
C-E	±22.5%	±3.2%	Fixed	Canada
B&W	±48.5%	±8.8%	Fixed	OH
B&W	±15.8%	±6.7%	Fixed	PA
B&W	±13.2%	±3.1%	Fixed	MI
B&W	±20.4%	±7.2%	Fixed	MI
B&W	±31.9%	±1.4%	Fixed	MI
C-E	±22.4%	±12.3%	Fixed	MI
C-E	±15.1%	±3.4%	Fixed	OH
C-E	±16.1%	±7.7%	Fixed	OH
C-E	±18.8%	±4.6%	Fixed	OH

TYPICAL IMPROVEMENT WITH ORIFICE MODIFICATIONS



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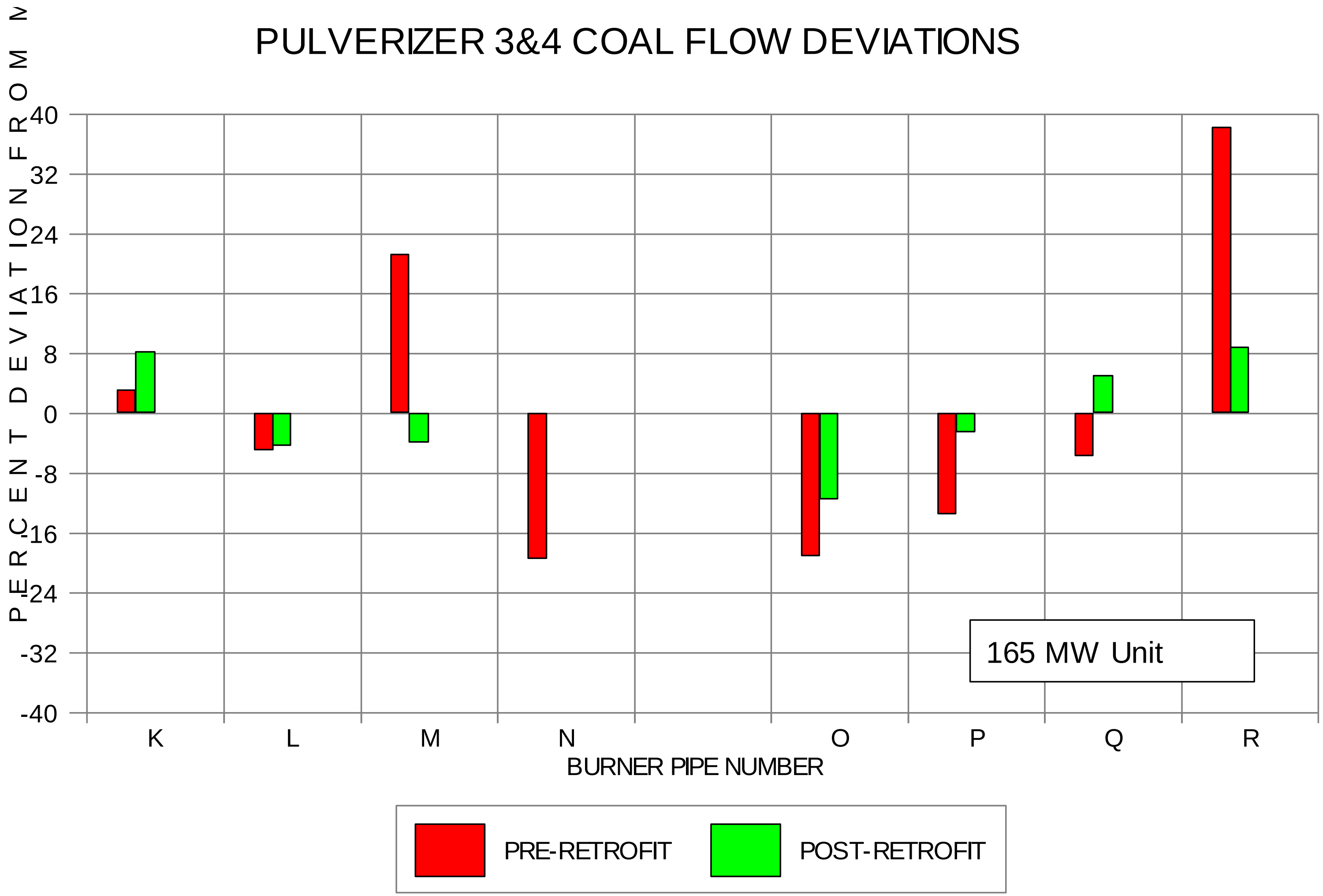
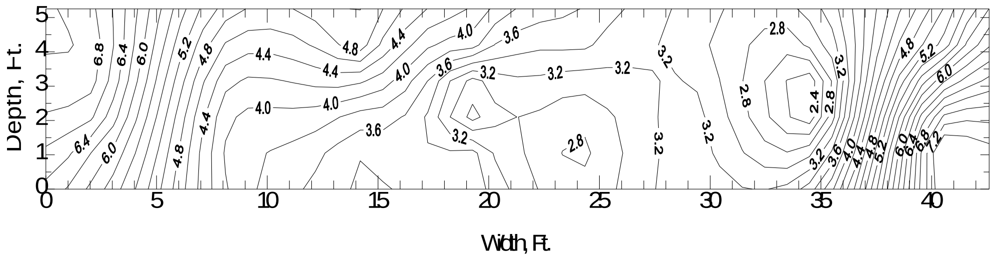
TYPICAL IMPROVEMENT WITH ORIFICE MODIFICATIONS (cont'd)

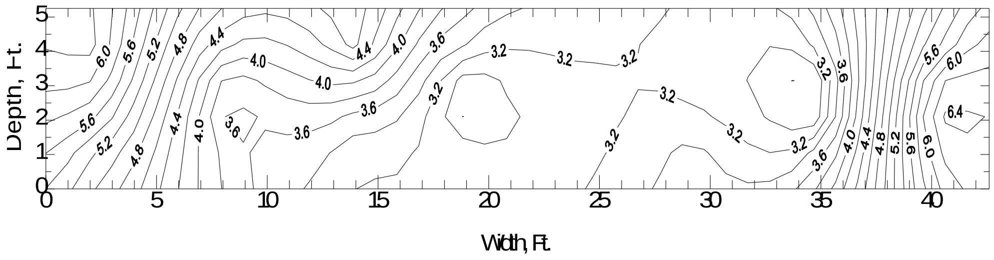


TYPICAL IMPROVEMENT IN COMBUSTION UNIFORMITY

BASELINE ECONOMIZER EXIT O_2 (%) PROFILE



POST ORIFICE REPLACEMENT O_2 (%) PROFILE



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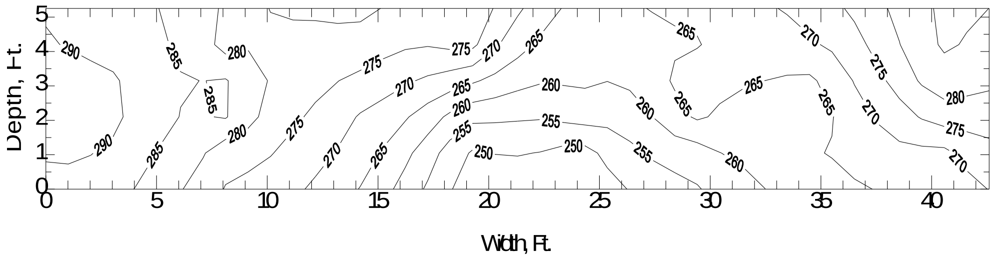
TYPICAL IMPROVEMENT IN COMBUSTION UNIFORMITY (continued)

BASELINE NO_c (ppm @ 3% O_2) PROFILE



POST ORIFICE REPLACEMENT NO_c (ppm @ 3% O_2) PROFILE

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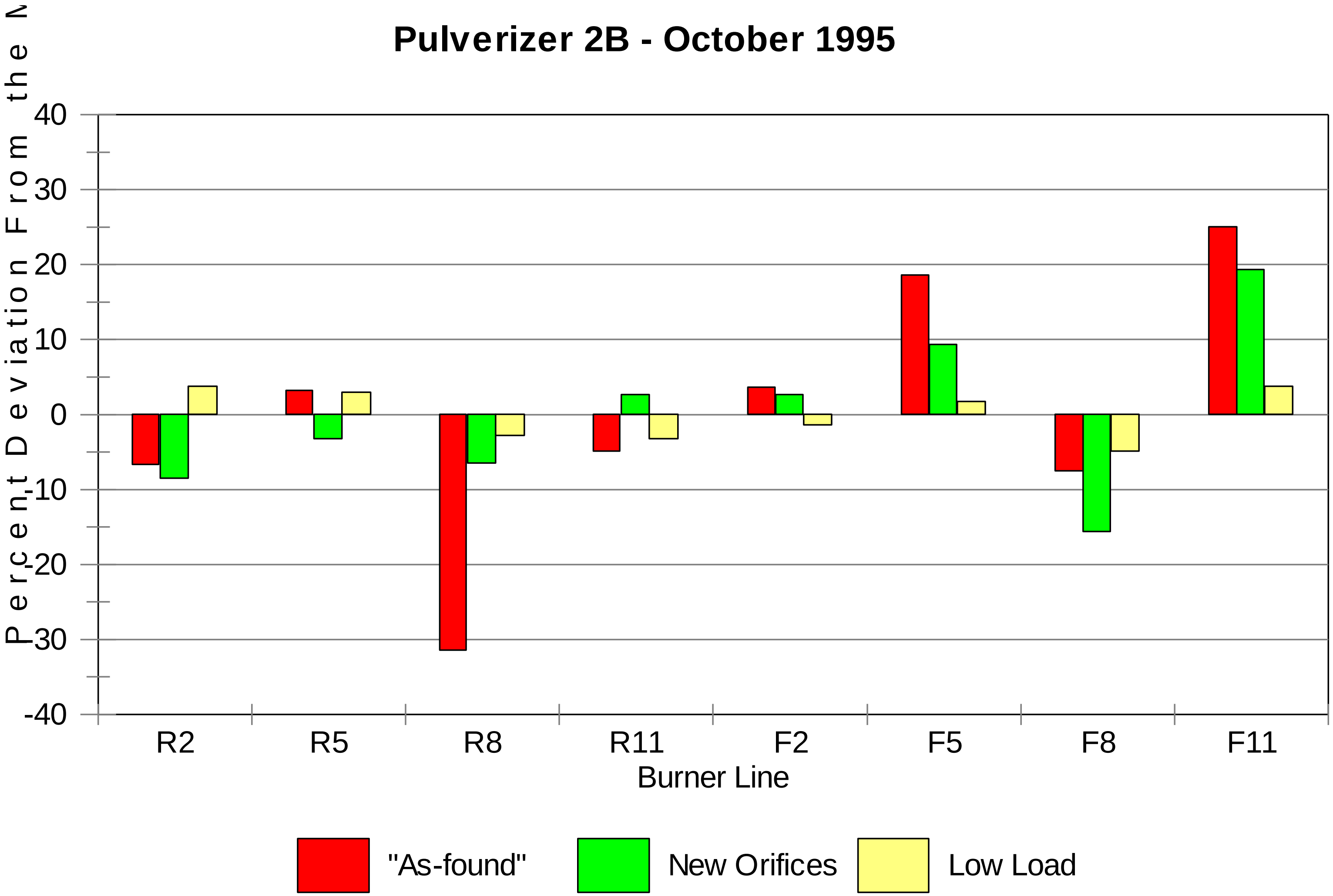
OPERATIONAL ISSUES

- The Difference in Coal Flow Distribution (Pipe-to-Pipe) Tends to Decrease as Pulverizer Loading (i.e., throughput) Decreases
- “High” Pipes Tend to Stay High and “Low” Pipes Tend to Stay Low as Load Varies
- Coal Flow Distribution Remained Unchanged Using a Real-Time Coal Flow Measurement System Over a 3-Month Demonstration Period
- RotorProbe Coal Flow Data Taken 4 Years Later Duplicated the Initial Flow Distribution Profile

COAL FLOW DEVIATION WITH NEW ORIFICES AND WITH LOAD



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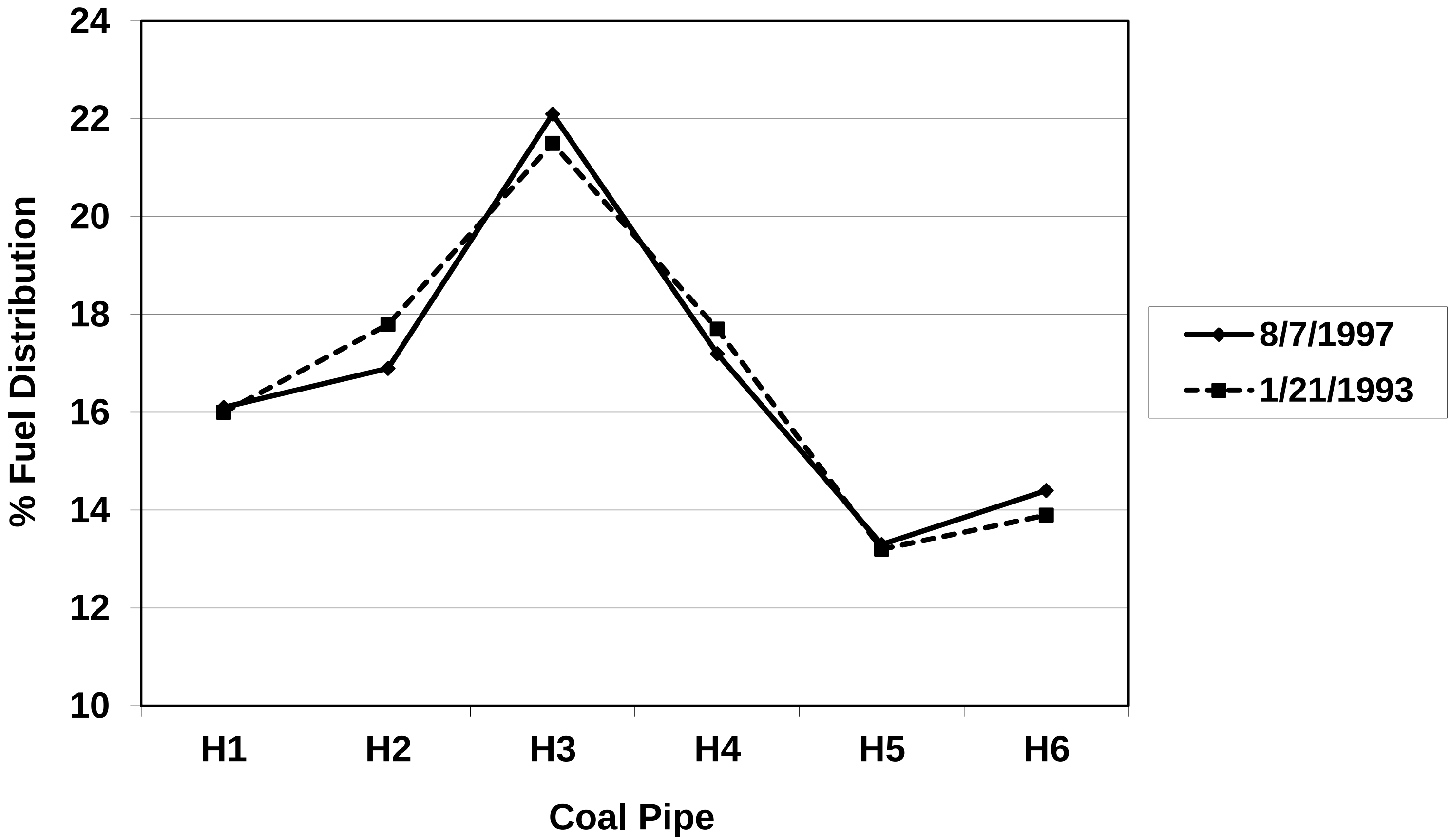
H MILL FUEL DISTRIBUTION – 1993 VS. 1997



Coal Pipe	H1	H2	H3	H4	H5	H6
8/7/1997	16.1	16.9	22.1	17.2	13.3	14.4
1/21/1993	16.0	17.8	21.5	17.7	13.2	13.9

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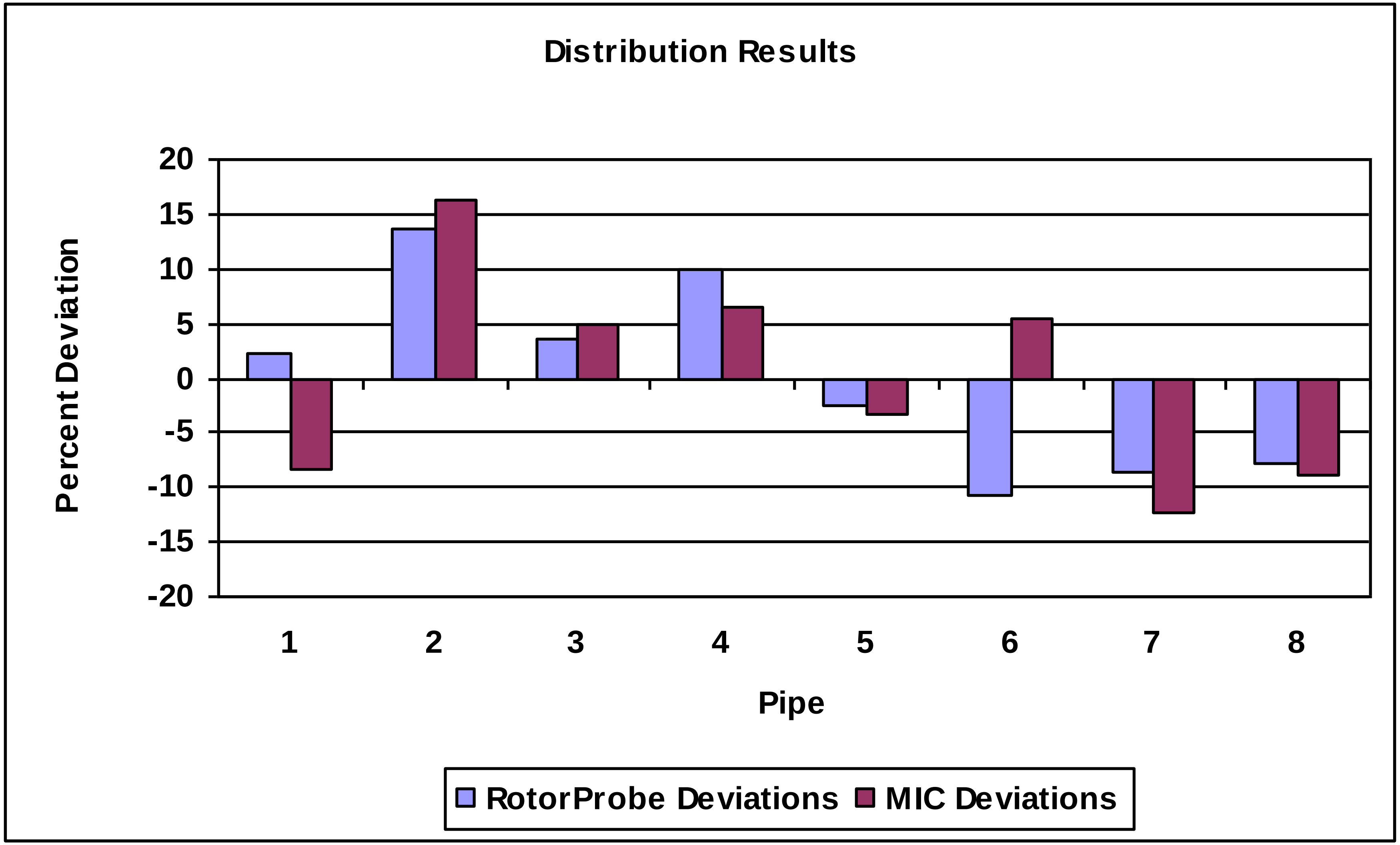
REAL-TIME COAL FLOW MEASUREMENT

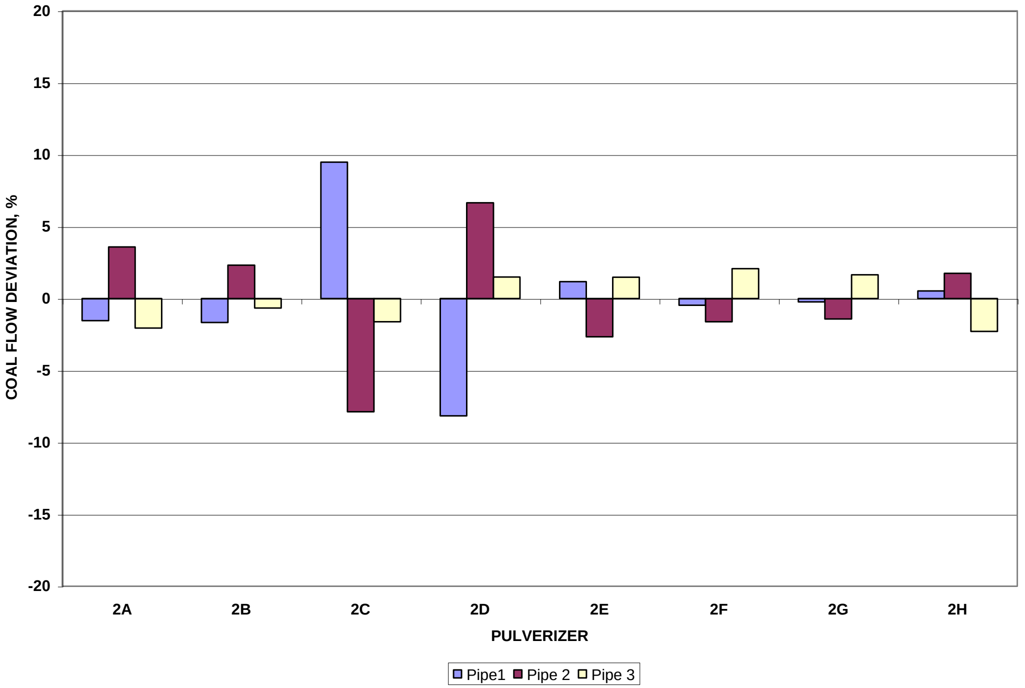
- **EPRI Survey of Real-Time Coal and Air Flow Measurement Systems – Most Are in Preliminary Evaluation Phase**
- **Data Comparing Performance of Real-Time Systems to Industry Standard Measurement Methods is Limited**
- **Paper Contains Case Histories Comparing Two Microwave Systems to ISO 9931 RotorProbe Data**
- **Performance of Microwave Systems Varied Significantly with the Design and Installation**

COMPARISON OF ROTORPROBE™ AND MIC MICROWAVE DATA

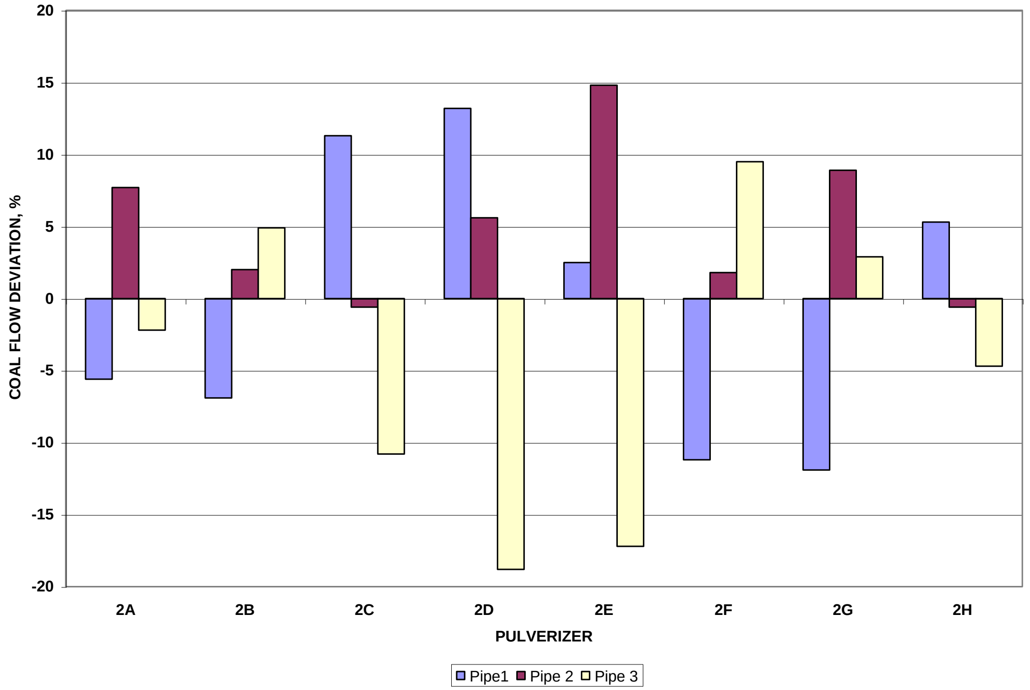


OTHER MICROWAVE VS. ROTORPROBE™ COMPARISONS

MICROWAVE DATA



ROTORPROBE™ DATA



MICROWAVE SYSTEM TEST RESULTS

- **MIC Microwave System Data Compared Favorably with ISO 9931 RotorProbe™ Data (Typically within ±5%)**

- **Microwave System "A" Data Were Not Consistent with RotorProbe™ Data**
  - Coal flow distribution changes not consistent with orifice adjustments
  - Coal flow distribution data fluctuated over time; RotorProbe™ relatively repeatable

- **Performance Confirmation Testing of Real-Time Coal Flow Measurement Systems with ISO 9931 RotorProbe™ is Recommended**

SUMMARY OF COAL FLOW BALANCING EXPERIENCE

- **Coal Pipe Orifices Do Work (More Than 25 Units of all Types Balanced Over the Last 7 Years)**
- **Dirty Air and Coal Flow Balance Measurements Are Critical; Clean Air Data Has Little Meaning**
- **ISO RotorProbe Method Essential for Coal Fineness Measurements Because of Coal Roping; Data from ASME Method Can be Biased**
- **Balance Burners on Coal Flow Distribution, Not Primary Air Flow**
- **Coal Flow Measurements with a RotorProbe Have Been Duplicated Over a Four Year Interval; Common Occurrence, not an Exception**

SUMMARY OF COAL FLOW BALANCING EXPERIENCE (cont'd)

- NO_x Reductions with Coal Flow Balancing - Typical of Other Boiler Tuning (10-15%) but CO and LOI Reductions in Excess of 30% Possible

- Coal Flow Balance with Fixed or Adjustable Orifices is Usually Maintained Over the Load Range for Well Maintained Equipment

- RotorProbe Coal Flow Testing and Balancing With Orifices More Cost-Effective than Capital Intensive Real-Time Flow Measurement Systems

- Performance of Microwave Real-Time Systems Vary Significantly with Design and Installation