CONTROLS FOR APPLIANCE EFFICIENCY

How are data-enabled gas controls supporting and enabling higher efficiencies in gas appliances?

MAXITROL®

INTRODUCTION

Mark Masen – Director of Research and Development

- Controls design offers a unique perspective on industry developments and direction. Application can uncover efficiencies!
- Data is everywhere (touched on this last year) and can be used for realistic and beneficial functions to augment all segments of our industry.
- Tech and data will increase AF Control system sophistication and decrease complexity to support future designs.
- Efficiency is NOT in the eye of the beholder. It should consider all inputs.

VALVE DESIGN FOR EFFICIENCY

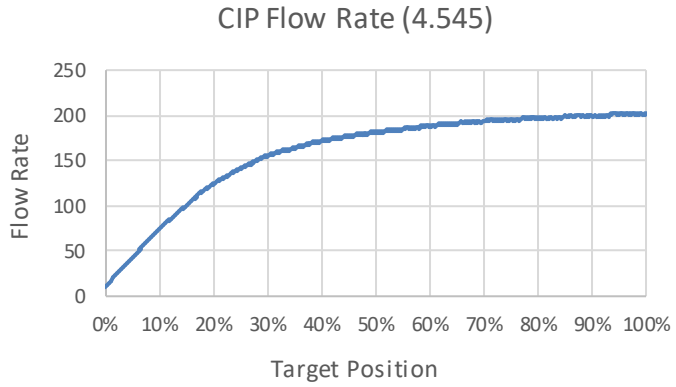
- Internal construction for improved operation
  - Passive AF ratio control (impulse line connected)
  - Sensitivity enables higher turndown
  - Adjustability enables excess air operation
- Improved movement
  - Precision and accuracy, low hysteresis
  - Adjustable characteristics for tuning and controller compatibility
  - Cp*dT…
- Data and connectivity
  - Stored design parameters expand possibilities
  - Digital communication for integration

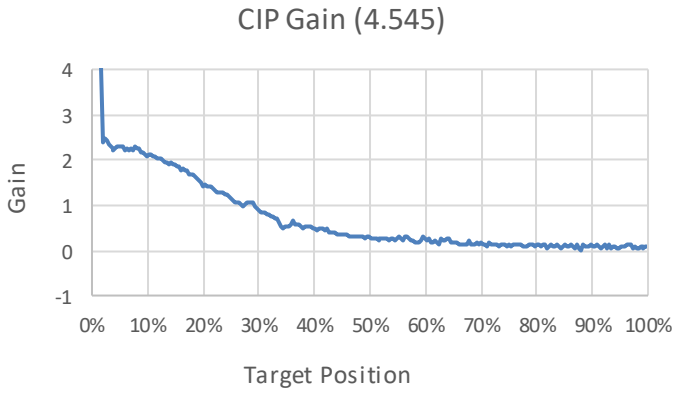
A WORD ON VARIABLE FIRING RATES

- Different load requirements
- Process stability over time
- Reduced ignition cycles
  - High turndown is not always most efficient!
- Multi-purpose appliances
- Marketing purposes

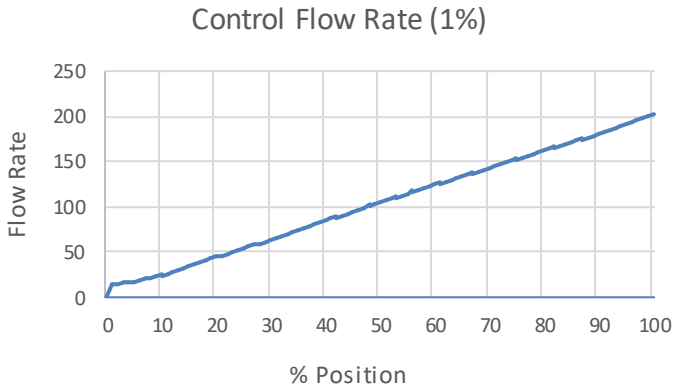
VALVE CHARACTERISTIC AND GAIN

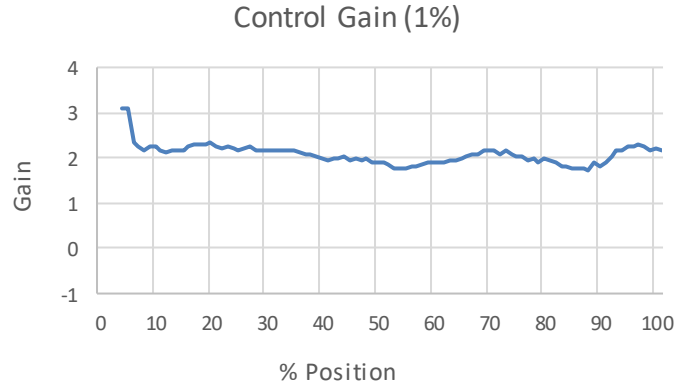
Typical





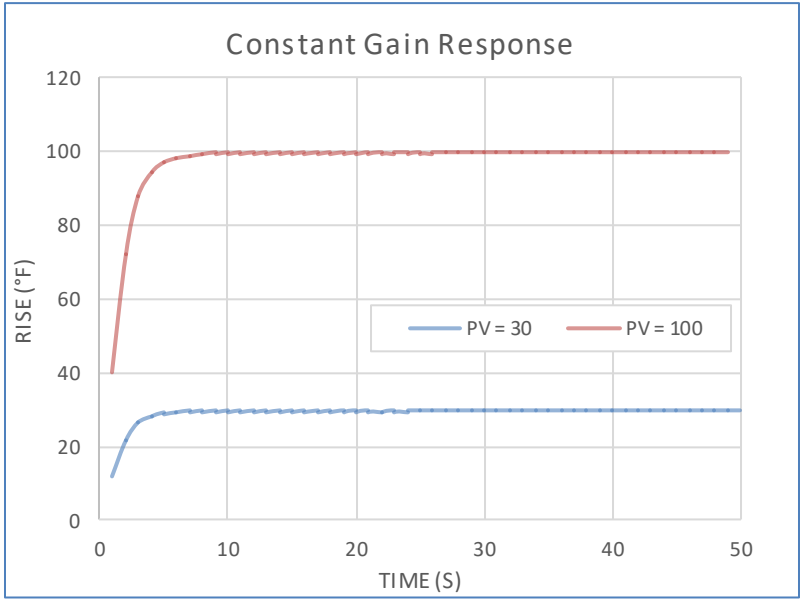
Improved



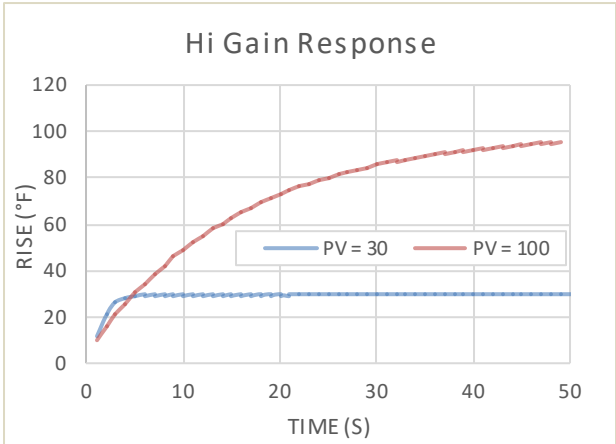


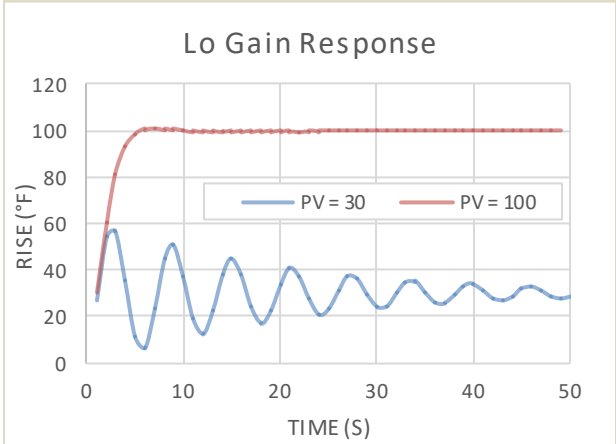
MAXITROL®

SYSTEM RESPONSE



Operating Point = 10% Operating Point = 90%

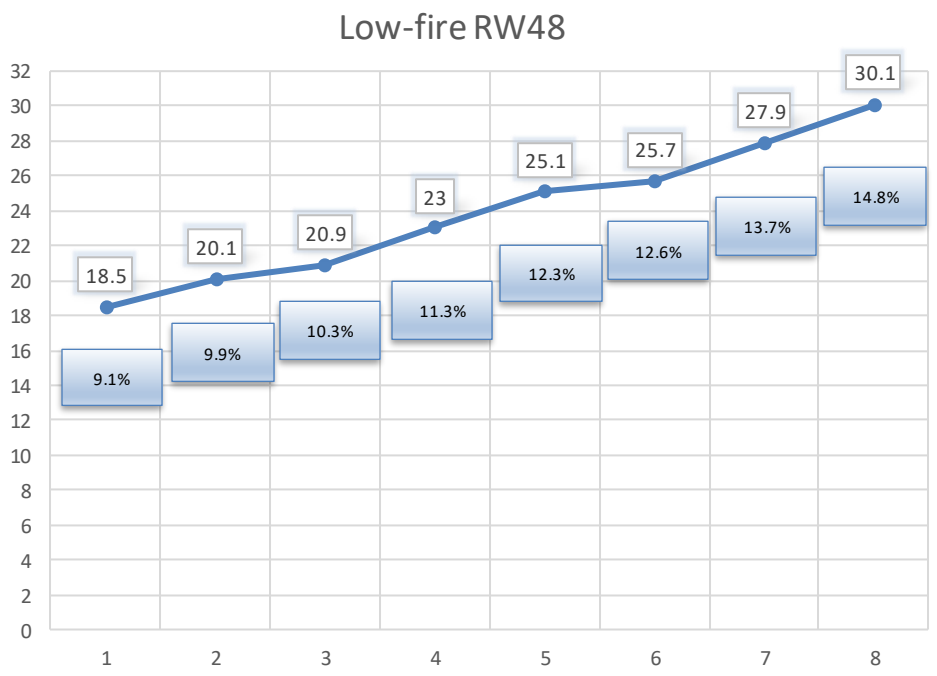




MAXITROL®

VALVE RESOLUTION

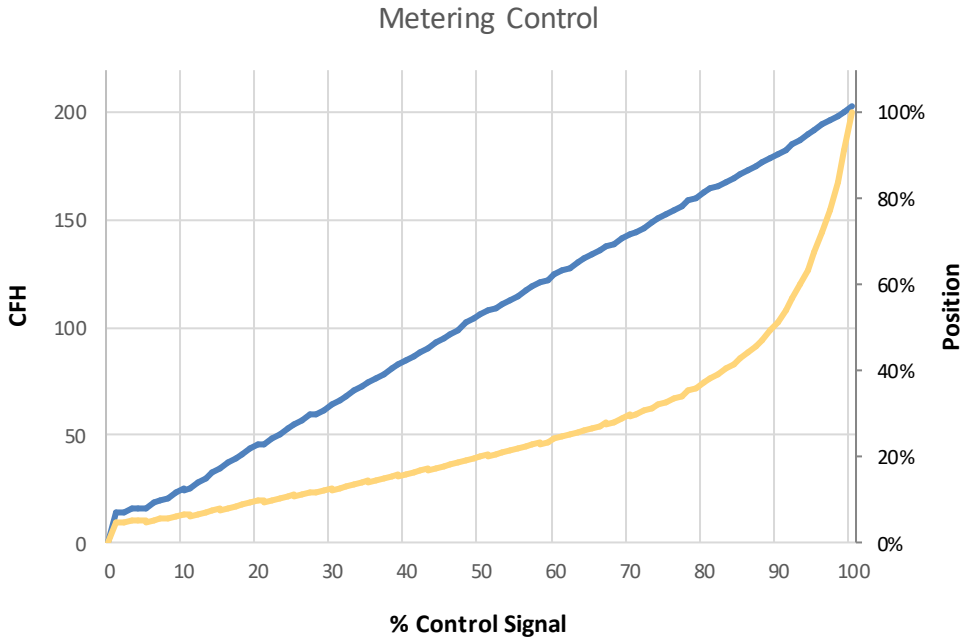
- Design Load = 203 CFH
- Design SG = 0.64
- Design dPtotal = 4.5” W.C.
- Design PLoad = 3.5” W.C.



MAXITROL®

IMPROVED VALVE SUMMARY

- Improve response
  - Constant valve gain
  - Effective at all firing rates
  - Enable control sophistication
- Increase firing rate resolution
  - Better load matching
  - Improved process stability



MAXITROL®

CONTROLS FOR EFFICIENCY

- Control methods
  - Realtime analysis of system data
    - Trends and transients
    - Predictive maintenance
  - Open-loop or alternate sensing strategies
    - dT in solid fuel
    - Metering and modeling (Cp*dT)
- Distributed architecture
    - Sharing common components and features across multiple lines
    - More data, where it is needed (T, RH…)
    - Improved EMC performance

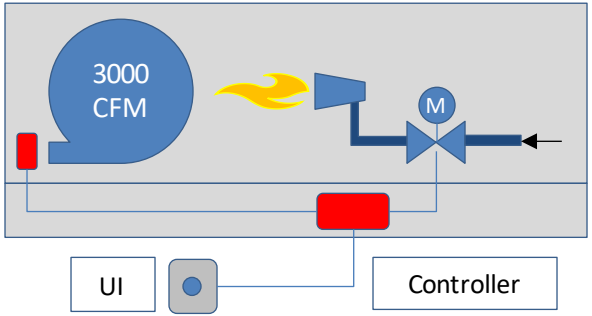
SYSTEM EXAMPLE

- Practical Application
  - Direct-fired line burner (10-100%)
  - Fixed fan speed
  - Control discharge temp
  - Simplify system installation
- Solution
  - Valve in metering configuration
  - Temperature rise modeling
  - Eliminate discharge sensor
- Design data
  - Load = 275 CFH
  - SG = 0.64
  - Ptotal = 7” W.C.
  - PLoad = 5” W.C.
  - SCFM = 3000
  - SP = 0.5”W.C.

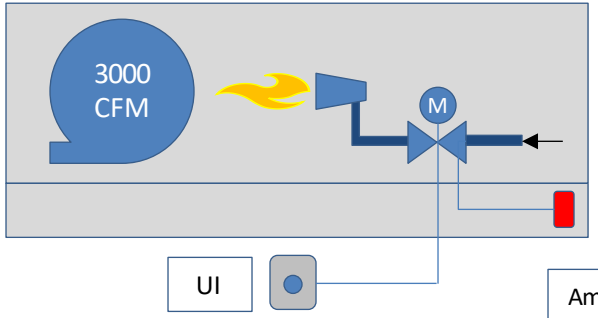
SYSTEM ILLUSTRATION

Current Setup

Discharge Sensor
- Unsteady reading
- Field installed
- Wiring and conduit
- EMC susceptible



Proposed Setup



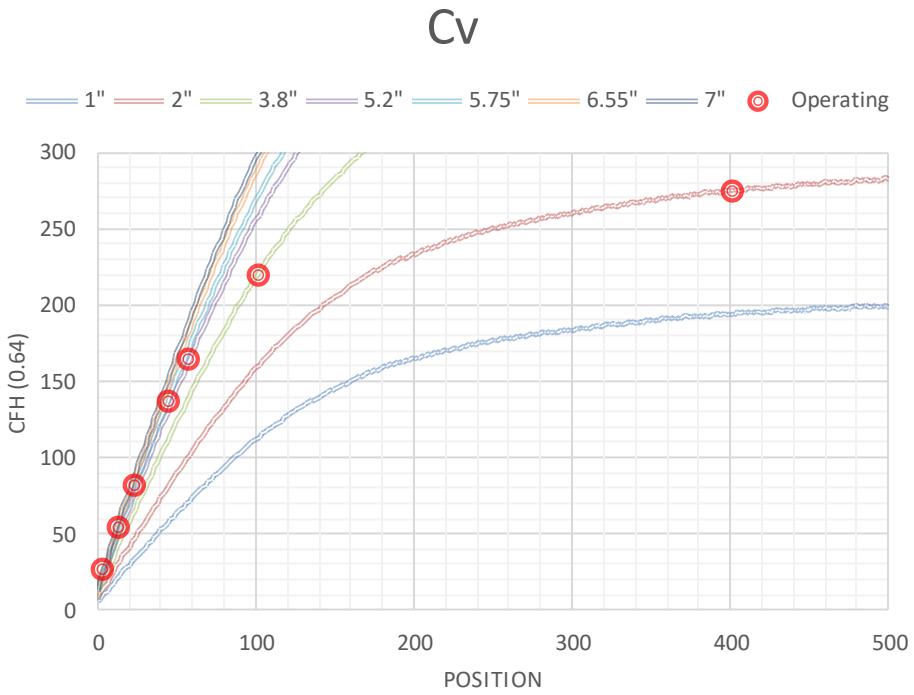
Control Valve
- Onboard controller
- Metering configuration
- External data (MODBUS)

Ambient Sensor
- Steady readings
- Prewired (or not at all!)
- Reduced static Px

MAXITROL®

VALVE IN METERING CONFIGURATION

- Programmable design data
  - Q_{design} = 275 CFH
  - P_{design} = 5” W.C.
  - P_{total} = 7”W.C.
  - SG = 0.64
- Control input is firing rate
  - 2-10VDC, 4-20mA etc.
  - Between Q_{design} and Minimum setting
- Auditing by Inlet Px
  - Steady and consistent



MAXITROL®

TEMPERATURE RISE MODELING

- Calls for a firing rate
  - Valve responds directly
- Model flexibility
  - Industry
  - Dh (Cp*dT)

Temperature (°F)	Rise (°F)	Dh (cp*Dt)	Volume (ACFM)	Mass (lbm/min)	Total Heat (btu/hr)	dBTU	% change
-40	110	26.42	2428.2	182.72	289662	9872	3.6%
-35	105	25.22	2457.2	184.89	279790	10186	3.7%
-30	100	24.02	2486.1	187.07	269604	10500	3.8%
-25	95	22.82	2515.0	189.25	259104	10813	3.9%
-20	90	21.62	2543.9	191.42	248291	11127	4.0%
-15	85	20.42	2572.9	193.60	237163	11441	4.2%
-10	80	19.22	2601.8	195.78	225722	11755	4.3%
-5	75	18.02	2630.7	197.95	213968	12068	4.4%
0	70	16.81	2659.7	200.13	201899	12382	4.5%
5	65	15.61	2688.6	202.31	189517	12696	4.6%
10	60	14.41	2717.5	204.48	176821	13010	4.7%
15	55	13.21	2746.5	206.66	163812	13323	4.8%
20	50	12.01	2775.4	208.84	150489	13637	5.0%
25	45	10.81	2804.3	211.01	136851	13951	5.1%
30	40	9.61	2833.2	213.19	122901	14265	5.2%
35	35	8.41	2862.2	215.37	108636	14578	5.3%
40	30	7.21	2891.1	217.55	94058	14892	5.4%
45	25	6.01	2920.0	219.72	79166	15206	5.5%
50	20	4.80	2949.0	221.90	63960	15519	5.6%
55	15	3.60	2977.9	224.08	48441	15833	5.8%
60	10	2.40	3006.8	226.25	32608	16147	5.9%
65	5	1.20	3035.8	228.43	16461	10928	4.0%
68.33	1.67	0.40	3055.0	229.88	5533	5533	2.0%
70	0	0.00	3064.7	230.61	0		

Note: cp = 0.2402 (btu/lbm*°F)

ELIMINATE DISCHARGE SENSOR

- Nuisance transients
  - Fan turbulence
  - Temperature stratification
  - IR reflections
- Less wiring
  - Decreased labor cost
  - No field install trouble
  - Improved EMC
- Additional value
  - Decreased static px

THANK YOU

Questions or Comments?

Maxitrol Company
23555 Telegraph Road
Southfield, MI 48033
USA

Phone: 248-356-1400
Fax: 248-356-0829
mmasen@maxitrol.com

ERRATA

ASGE 2023

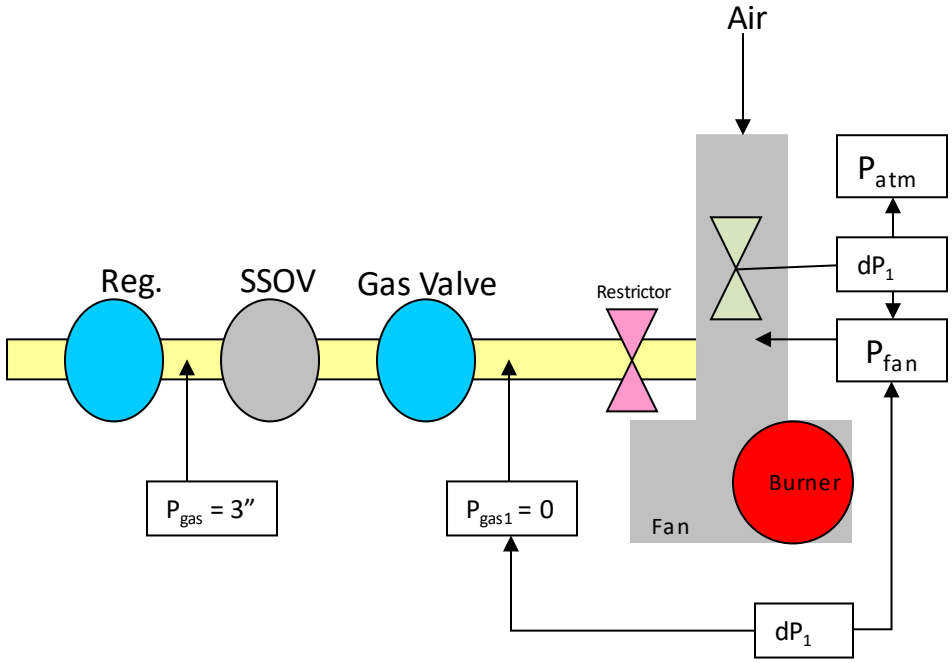
MAXITROL®

PASSIVE RATIO CONTROL EXAMPLE

- 500kbtu/hr
- Passive Controls
- Premix burner (Nat. gas)
- 3:1 current control
- 10:1 desired control

PASSIVE RATIO SETUP AND STRATEGY

- High-sensitivity gas valve
  - V/S interface
  - Impulse connected
- Air control
  - Fan speed
  - Static Px
- 0.25”WC min. burner Px
  - H2 could be higher?



FLAME SPEED (scielo et.al.)

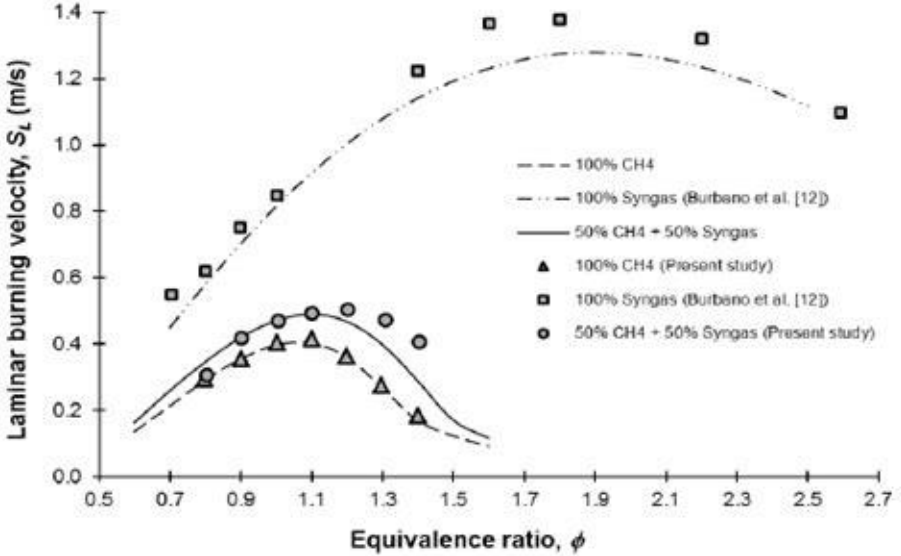


Figure 5. Laminar burning velocity of natural gas (100% CH_4), *syngas* (40% H_2 + 40% CO + 20% CO_2) and the mixture 50% CH_4 + 50% *syngas* to 0.828 atm and 295 K. Lines: numerical results; Symbols: experimental data

PASSIVE RATIO CONTROL DATA

	% Air	% Fire	Diff	Air		Fuel		Fan		TD-AIR	TD-GAS	% Rich	Lambda	Voltage %
				In W.C.	CFH	Delta P	CFH	Voltage	AF					
1	102.5%	99.9%		9.50	5123	1.65	499	9.00	10.3					
2	100.0%	96.9%		9.05	5000	1.60	484	8.20	10.3					
3	93.4%	90.9%		7.90	4672	1.50	454	6.65	10.3					
4	86.0%	84.9%		6.70	4302	1.40	424	5.15	10.1					
5	79.7%	78.9%		5.75	3985	1.30	394	4.25	10.1					
6	73.6%	72.9%		4.90	3679	1.20	364	3.50	10.1					
7	66.9%	66.8%		4.05	3345	1.10	334	2.95	10.0					
8	61.3%	60.8%		3.40	3065	1.00	304	2.55	10.1					
9	54.6%	54.8%		2.70	2731	0.90	274	2.10	10.0					
10	52.6%	52.3%		2.50	2628	0.86	262	1.95	10.0					
11	48.2%	48.7%		2.10	2409	0.80	243	1.75	9.9					
12	41.4%	42.6%		1.55	2069	0.70	213	1.50	9.7					
13	36.4%	39.0%		1.20	1821	0.64	195	1.35	9.3					
14	34.1%	36.6%		1.05	1703	0.60	183	1.25	9.3					
15	31.5%	34.1%		0.90	1577	0.56	171	1.15	9.2					
16	26.6%	30.5%		0.64	1330	0.50	152	1.00	8.7					
17	22.8%	28.1%		0.47	1139	0.46	140	0.90	8.1					
18	20.5%	26.8%		0.38	1025	0.44	134	0.85	7.6					
19	18.5%	25.6%		0.31	925	0.42	128	0.80	7.2					
20	16.9%	24.4%		0.26	847	0.40	122	0.75	6.9					
21	11.0%	22.0%		0.11	551	0.36	110	0.60	5.0					
22	8.1%	20.8%		0.06	407	0.34	104	0.55	3.9					

	% Air	% Fire	Diff	Air		Fuel		Fan						
				In W.C.	CFH	Delta P	CFH	Voltage	AF	TD-AIR	TD-GAS	% Rich	Lambda	Voltage %
1	102.6%	99.9%	-0.02	10.00	5130	1.65	499	9.00	10.3	1	1	3	1.03	100.0
2	100.0%	96.9%	-0.02	9.50	5000	1.60	484	8.20	10.3	1	1	3	1.03	91.1
3	91.8%	90.9%	-0.03	8.00	4588	1.50	454	6.65	10.1	1	1	1	1.01	73.9
4	85.8%	84.9%	-0.03	7.00	4292	1.40	424	5.15	10.1	1	1	1	1.01	57.2
5	79.5%	78.9%	-0.04	6.00	3974	1.30	394	4.25	10.1	1	1	1	1.01	47.2
6	72.5%	72.9%	-0.03	5.00	3627	1.20	364	3.50	10.0	1	1	0	1.00	38.9
7	68.8%	66.8%	-0.1	4.50	3441	1.10	334	2.95	10.3	1	1	3	1.03	32.8
8	62.8%	60.8%	-0.1	3.75	3141	1.00	304	2.55	10.3	2	2	0	1.03	28.3
9	56.2%	54.8%	-0.1	3.00	2810	0.90	274	2.10	10.3	2	2	3	1.03	23.3
10	53.8%	51.7%	-0.1	2.75	2690	0.85	259	1.95	10.4	2	2	4	1.04	21.7
11	48.7%	45.7%	-0.1	2.25	2433	0.75	228	1.75	10.7	2	2	6	1.07	19.4
12	43.5%	40.2%	-0.1	1.80	2176	0.66	201	1.50	10.8	2	2	8	1.08	16.7
13	39.7%	36.6%	-0.1	1.50	1987	0.60	183	1.35	10.9	3	3	8	1.09	15.0
14	35.5%	32.9%	-0.09	1.20	1777	0.54	165	1.25	10.8	3	3	7	1.08	13.9
15	32.4%	30.5%	-0.09	1.00	1622	0.50	152	1.15	10.6	3	3	6	1.06	12.8
16	27.1%	25.6%	-0.02	0.70	1357	0.42	128	1.00	10.6	4	4	6	1.06	11.1
17	24.3%	23.2%	-0.03	0.56	1214	0.38	116	0.90	10.5	4	4	4	1.05	10.0
18	21.8%	20.2%	-0.09	0.45	1088	0.33	101	0.85	10.8	5	5	7	1.08	9.4
19	20.3%	18.3%	-0.09	0.39	1013	0.30	92	0.80	11.1	5	5	10	1.11	8.9
20	17.2%	15.9%	0	0.28	858	0.26	79	0.75	10.8	6	6	7	1.08	8.3
21	13.8%	13.4%	0	0.18	688	0.22	67	0.60	10.2	7	7	2	1.02	6.7
22	11.2%	11.0%	0.02	0.12	562	0.18	55	0.55	10.2	9	9	2	1.02	6.1
23	7.9%	9.8%	0.02	0.06	397	0.16	49	0.50	8.1	13	10	-23	0.81	5.6
24	6.5%	9.8%	0.04	0.04	324	0.16	49	0.48	6.6	15	10	-51	0.66	5.3
25	4.6%	9.8%	0.06	0.02	229	0.16	49	0.48	4.7	22	10	-113	0.47	5.3
26	4.6%	9.8%	0.06	0.02	229	0.16	49	0.48	4.7	22	10	-113	0.47	5.3
27	4.6%	9.8%	0.06	0.02	229	0.16	49	0.48	4.7	22	10	-113	0.47	5.3

PASSIVE RATIO CONTROL RESULT