Applied Process Control

Rick Meeker

Process Control Solutions, Inc.

P.O. Box 12544

Tallahassee, FL 32317-2544

(850) 385-5100

(850) 385-5200 fax

rmeeker@procontrolinc.com

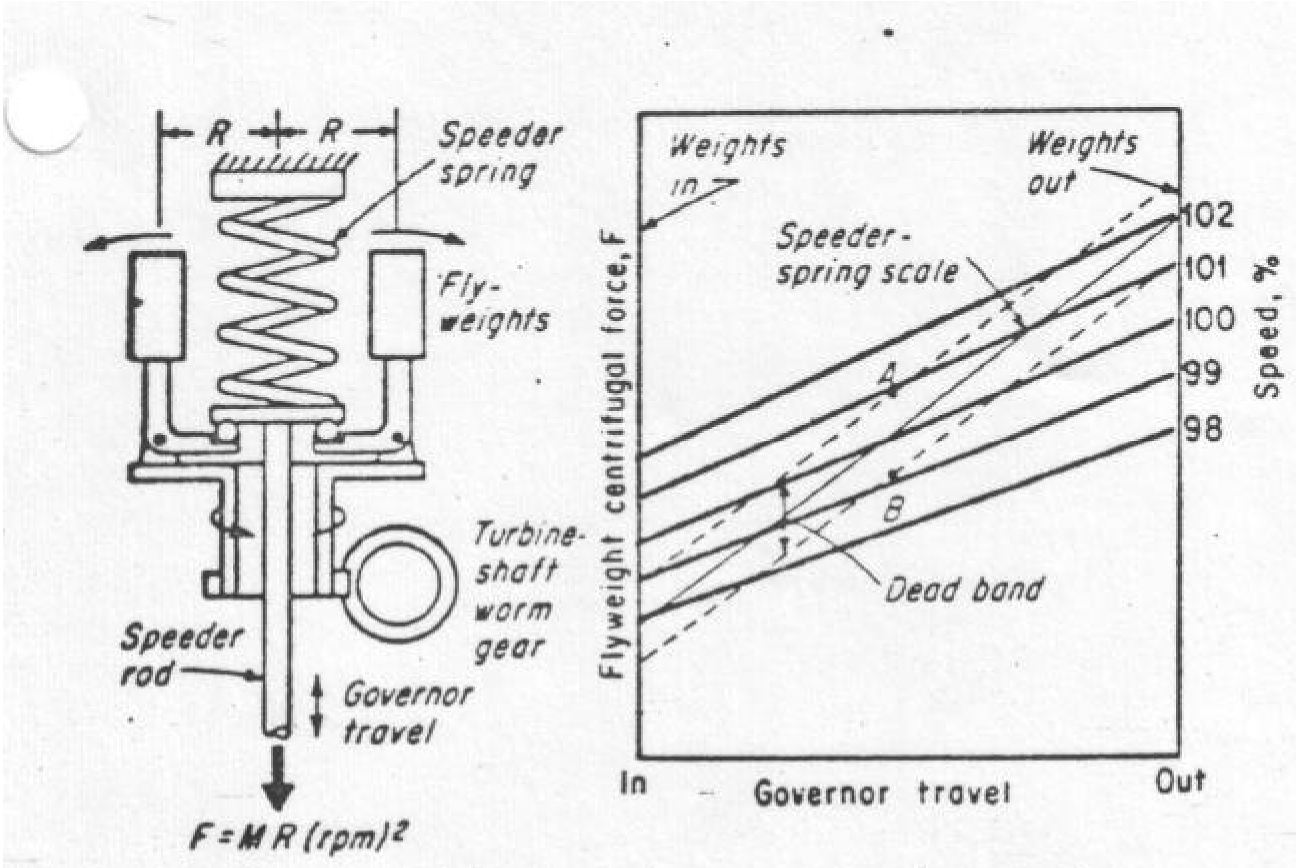
Outline

- Brief History of Automatic Control
- Control Hardware and Software
- Controller Tuning
- Features and Practical Implementation of Industrial PID

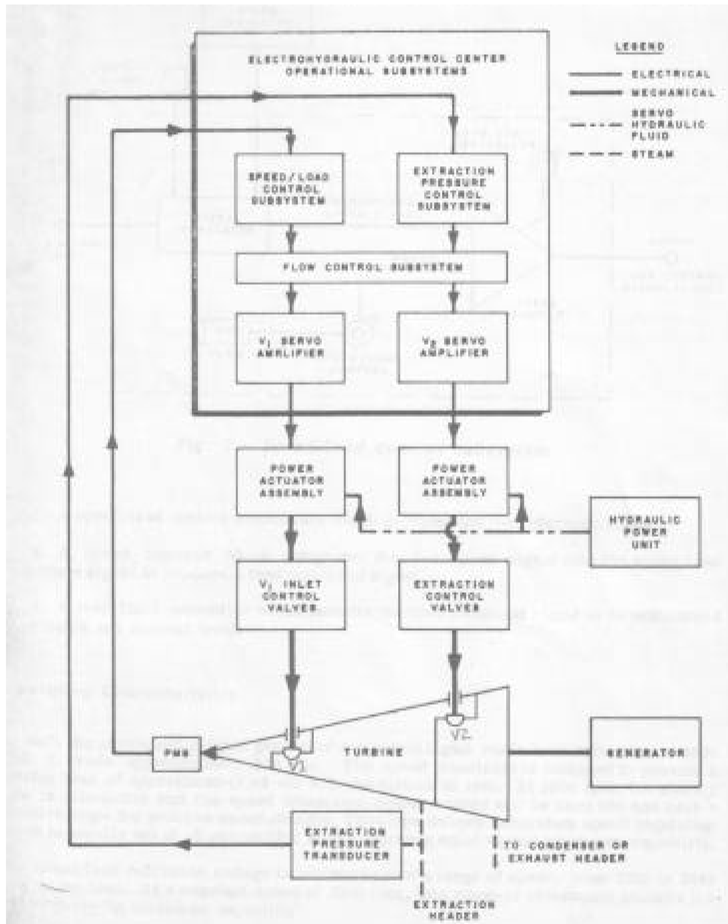
Automatic Control
A Brief (approximate) History

- 1782 - James Watt - the throttling fly-weight governor for the reciprocating steam engine
- 1880's - 1970's - pneumatic control
- 1960's - 1980's - electronic control
- 1980's - present - digital control
  - Distributed Control System (DCS)
  - Programmable Logic Controller (PLC)
  - Hybrid Control Systems

Turbine Speed Governor



Turbine Speed Governor



Control

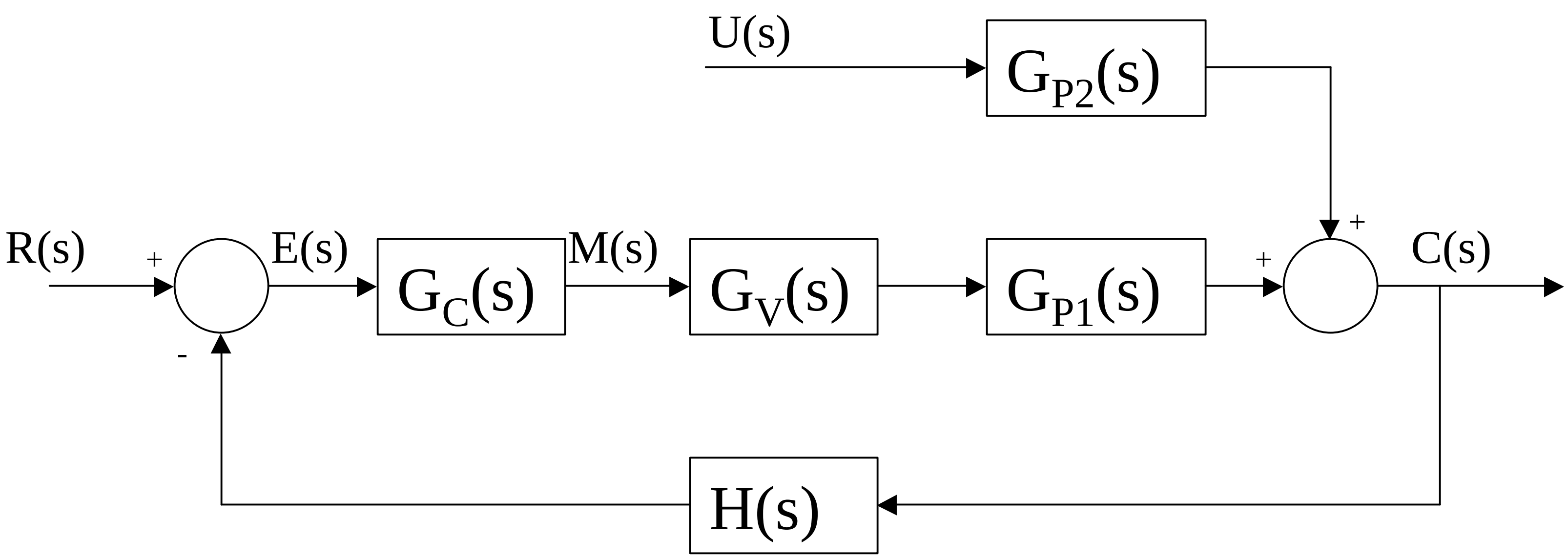
Control Applications

- Continuous
  - Analog
    - Pneumatic
    - Electronic
  - Digital
    - Computer
    - Distributed Control System (DCS)
- Discrete
    - Relay
    - Electronic - solid state logic
    - Programmable Logic Controller (PLC)

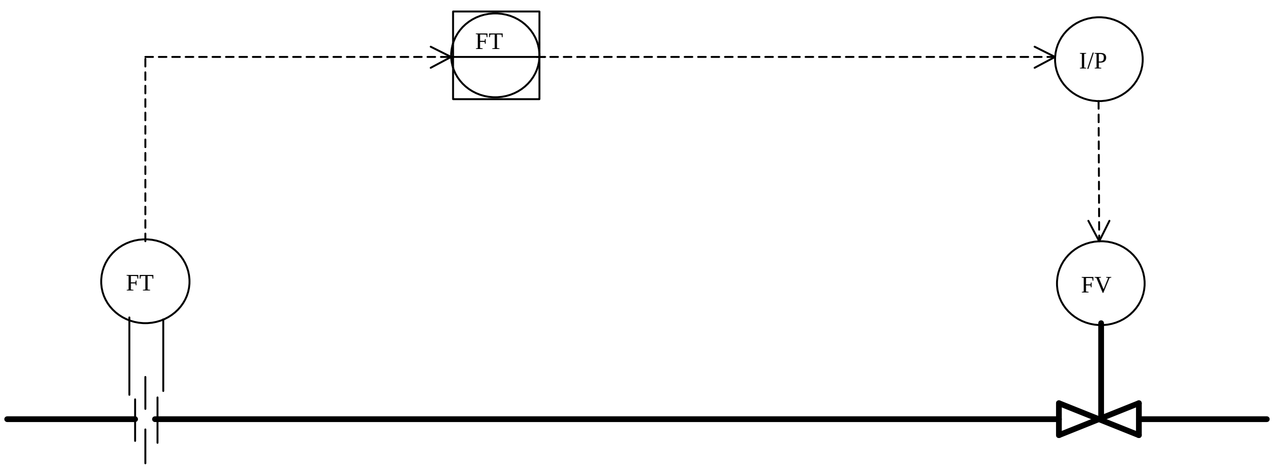
Feedback Control

- **On/Off** - Control within limits, not to a setpoint (e.g. sump level).
- **PID** - lag dominant processes
- **Model Predictive Control** - dead-time dominant processes

Feedback Control - The Control Loop



Feedback Control - The Control Loop



Control System Components

- The instrument / measurement
- I/O
- Control - DCS and PLC, hybrid
- Final Control Element
- HMI

PID Control

- Proportional-Integral-Derivative (PID) Controller

$$m(t) = \overline{m} + K_c e(t) + \frac{K_c}{\tau_I}\int e(t)\,dt + K_c \tau_D \frac{de(t)}{dt}$$

Tuning Methods

- Ziegler Nichols (1/4 decay)
- Cohen-Coon (reaction curve)
- Minimum Error Integral (ISE, IAE, ITAE)
- Controller Synthesis (lambda)

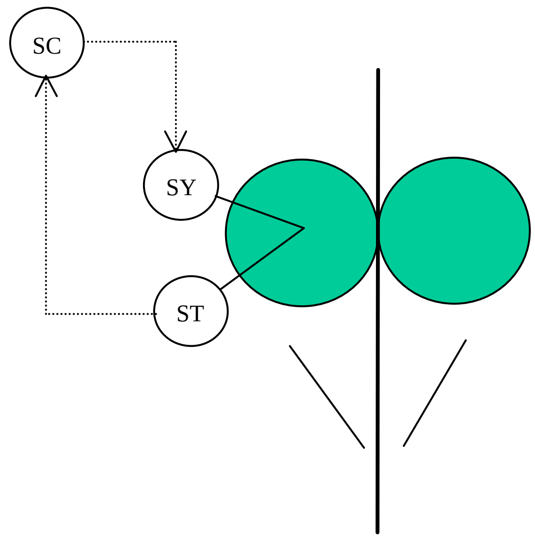
Controller Synthesis

- PI Controller Tuning Formulas:

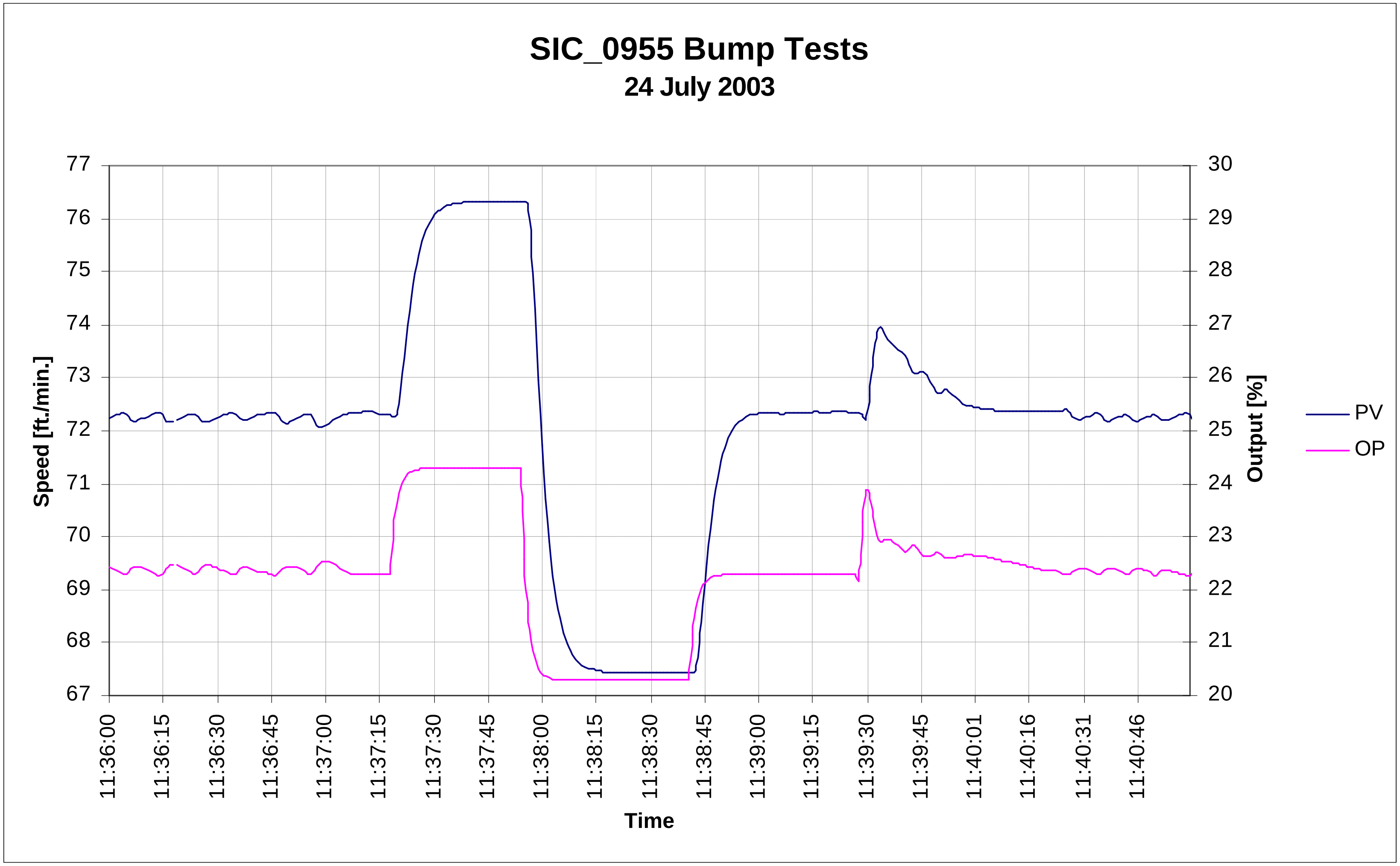
Kc = tau / [Kp*(lambda+t0)

T1 = tau

Impregnation Roll Speed



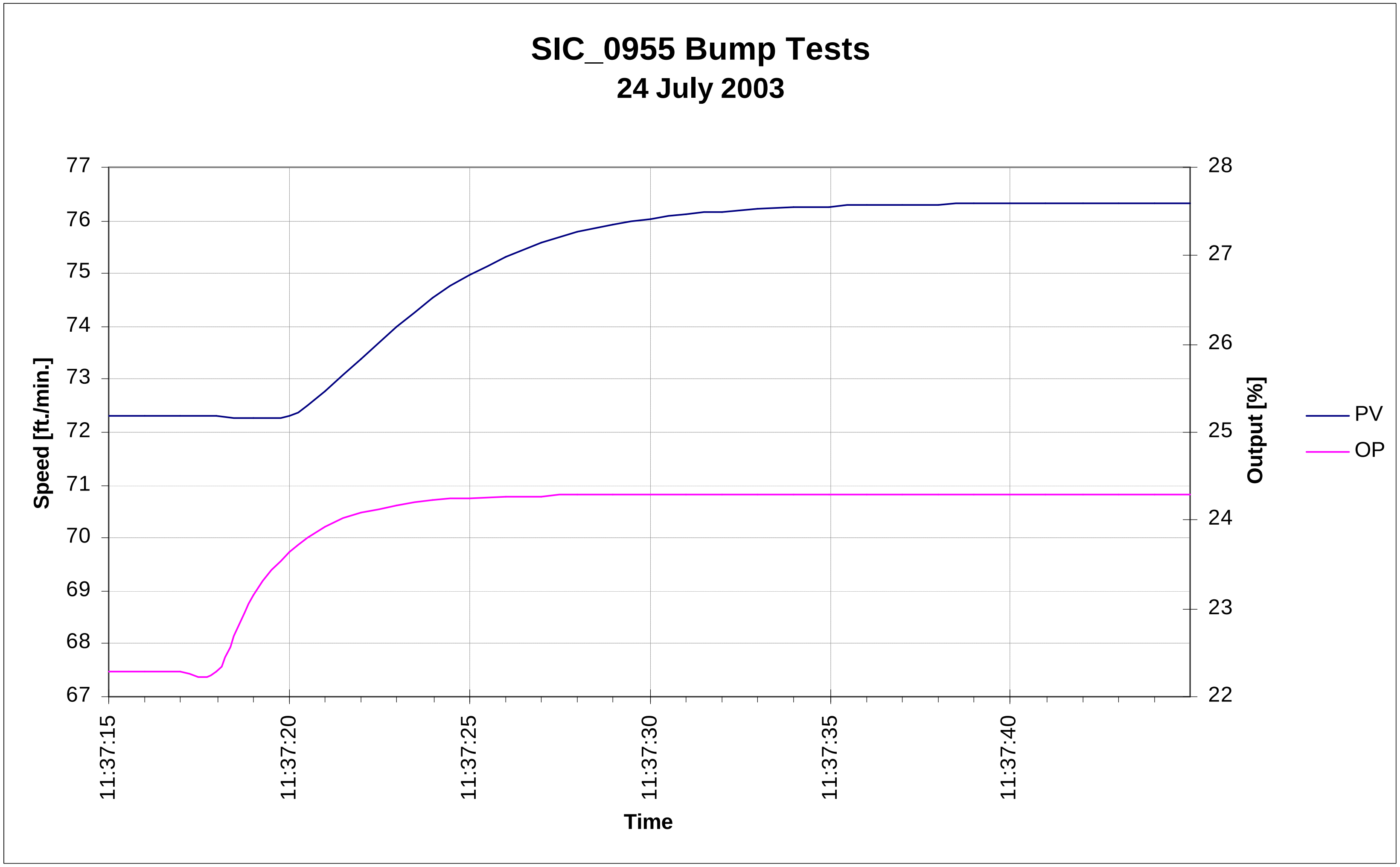
Impregnation Roll Speed Control



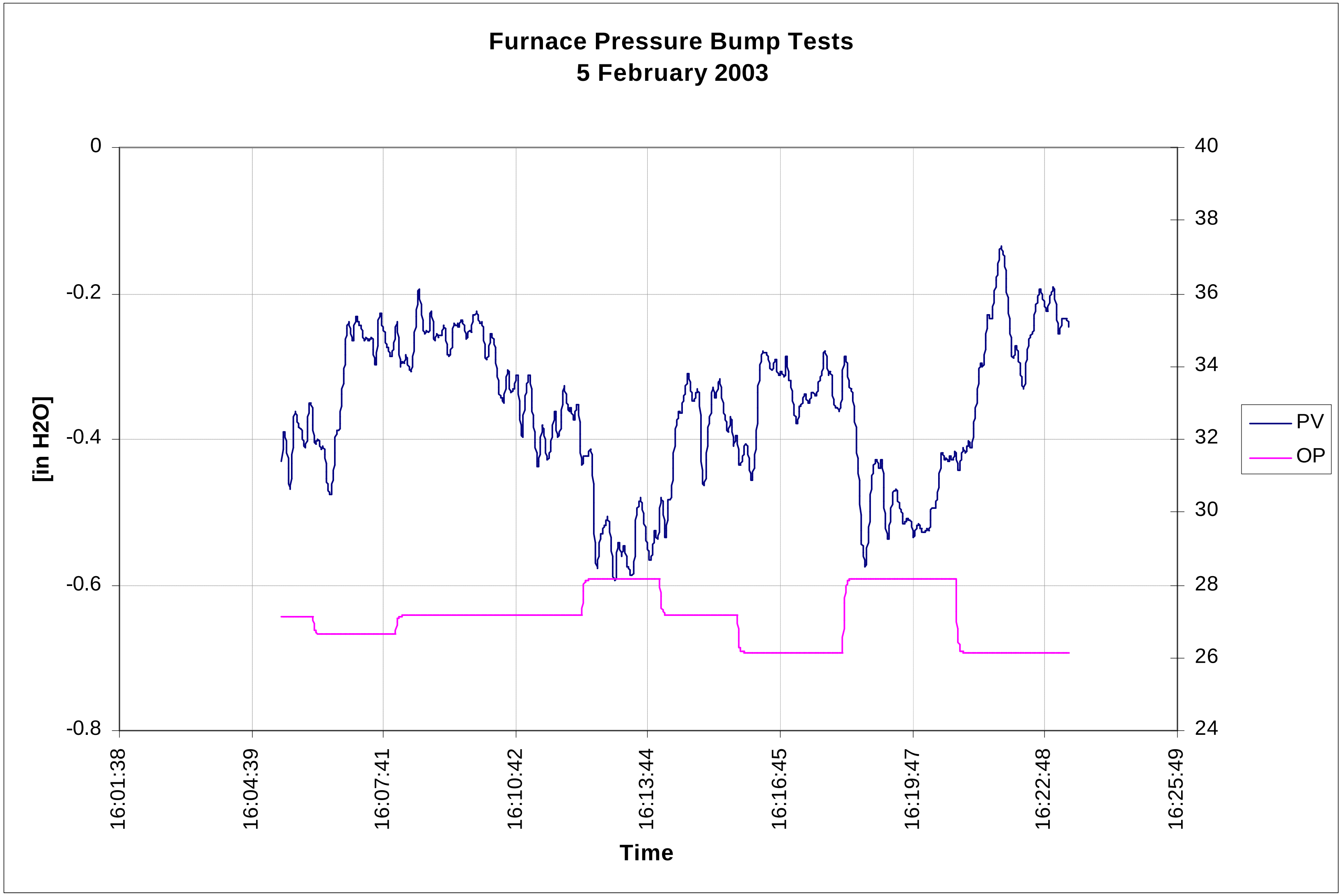
Impregnation Roll Speed Control

SIC-0995 range:		0	252	ft/min	
Bump:	*1*	*2*	*3*	avg	
Kp	0.794	0.873	0.972	0.880	[%/%]
Minimum Variance Tuning:					
Kc (EnT)	0.420	0.382	0.343	0.379	[%/%]
4tau	0.333	0.367	0.300	0.333	[min.]
T1 (EnT)	0.083	0.092	0.075	0.083	[min.]
Fit 1 Model:					
Kp	0.794				
t0	0.033				
tau	0.108				
Ziegler Nichols Tuning:					
Kc (ZN)	3.6855				
T1 (ZN)	0.111				

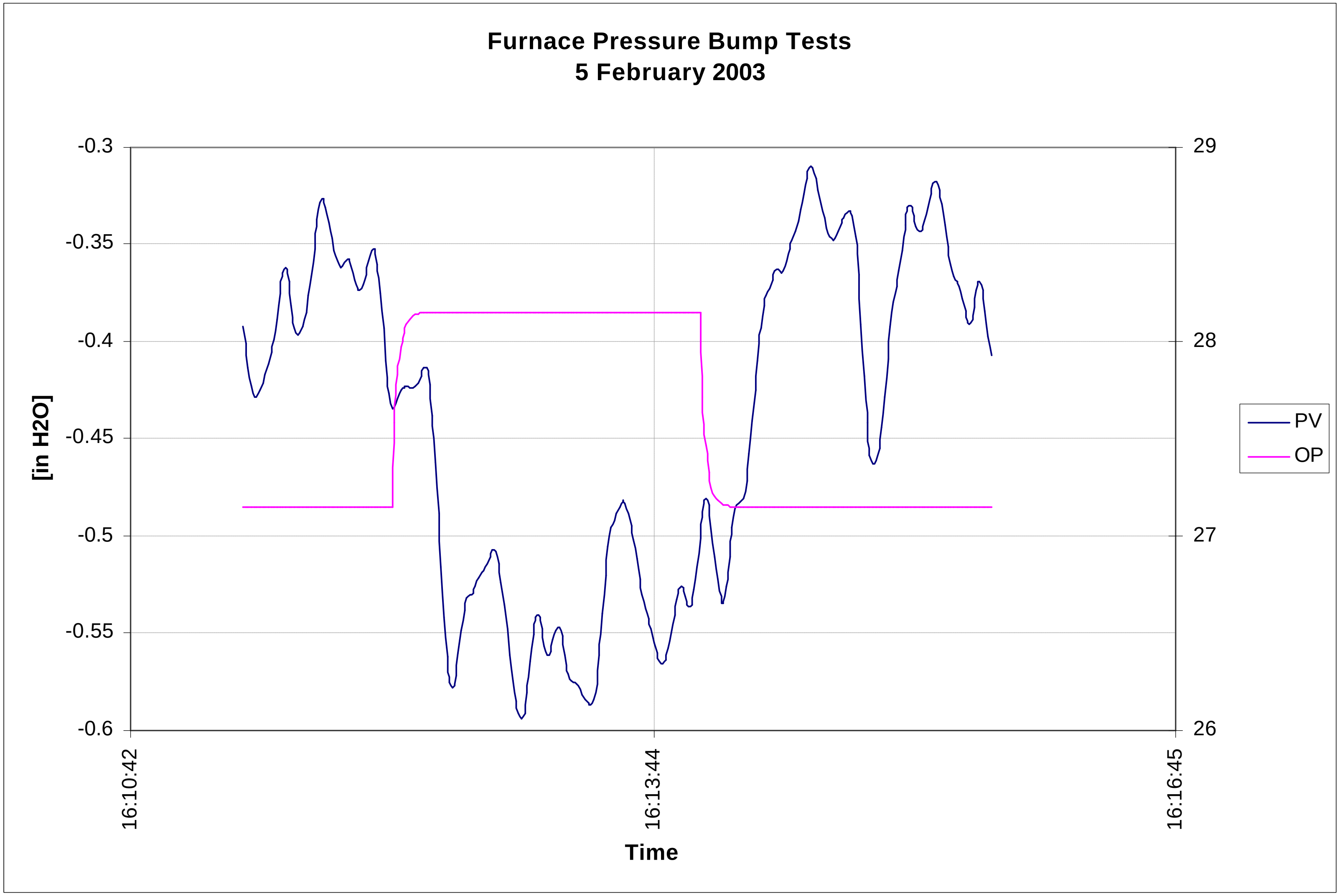
Impregnation Roll Speed Control



Furnace Draft Control



Furnace Draft Control



Furnace Draft Control

Tuning based on selected bumps from 2/5/2003 data					
t1 and t2 for FOPDT fit 3 tuning selected from data on data worksheet,					
see rows formatted light orange					
bump#:	**1**	**2**	**3**	**4**	average
FOPDT model fit ("fit 3")					
CsStart	-0.4	-0.516	-0.326	-0.425	
deltaCs	-0.15	0.15	-0.18	0.199	
0.283*dCs	-0.042	0.042	-0.051	0.056	
Cs1	-0.442	-0.474	-0.377	-0.369	
t1 [min.]	0.203	0.267	0.258	0.417	
0.632*dCs	-0.095	0.095	-0.114	0.126	
Cs2	-0.495	-0.421	-0.440	-0.299	
t2 [min.]	0.240	0.317	0.333	0.533	
tau [min.]	0.055	0.075	0.113	0.175	0.1044
t0 [min.]	0.185	0.242	0.221	0.358	0.2515
t0/tau	3.364	3.222	1.963	2.048	2.6491
Dahlin synthesis tuning	tc multiple =		0.5		
tc [min.]	0.0925	0.1208	0.1104	0.1792	0.1257
Kp [%/%]	1.8750	1.8750	2.2500	2.4900	2.1225
Kc	0.1057	0.1103	0.1509	0.1308	0.1244
Ti [min.]	0.0550	0.0750	0.1125	0.1750	0.1044
Td [min.]	0.0925	0.1208	0.1104	0.1792	0.1257

PID Tuning Notes

- Setpoint vs. disturbance tuning
- Presence of deadtime
  - t0>0.25tau?
  - t0>tau?
- Process requirements - what is most important:
  - fast return to setpoint?
  - minimum variance?

Digital PID Control

- Position form:

$$m_n = K_c\left[e_n + \frac{T}{t_I}\sum_{k=0}^{n} e_k + \frac{T_d}{T}\left(e_n - e_{n-1}\right)\right] + M_R$$

- Velocity form:

$$m_n - m_{n-1} = K_c\left[\left(e_n - e_{n-1}\right) + \frac{T}{t_I} e_n + \frac{T_d}{T}\left(e_n - 2e_{n-1} + e_{n-2}\right)\right]$$