

Spring 2015

The Use of a Advanced Process Controls in a Phosphoric Acid Reactor

Vaughn Astley

Follow this and additional works at: http://dc.engconfintl.org/phosphates_vii



Part of the [Materials Science and Engineering Commons](#)

Recommended Citation

Vaughn Astley, "The Use of a Advanced Process Controls in a Phosphoric Acid Reactor" in "Beneficiation of Phosphates VII", P. Zhang, FIPR; J. Miller, Univ. of Utah; L. Leal, Univ. of Sao Paolo; A. Kossir, OCP Group; E. Wingate, Worley-Parsons Services Pty Ltd. Eds, ECI Symposium Series, (2015). http://dc.engconfintl.org/phosphates_vii/23

This Conference Proceeding is brought to you for free and open access by the Proceedings at ECI Digital Archives. It has been accepted for inclusion in Beneficiation of Phosphates VII by an authorized administrator of ECI Digital Archives. For more information, please contact franco@bepress.com.

**The Use of
ADVANCED PROCESS
CONTROLS in a Phosphoric
Acid Reactor**

Vaughn Astley

**Beneficiation of Phosphates VII
Melbourne, Australia**

29th March to 3rd April, 2015

ADVANCED PROCESS CONTROLS (APC)

**Remember, Remember when
Automobiles/Cars has just a Steering
Wheel, Gearlever, and Three Pedals???**

**Maybe a Direction Indicator Stalk,
Maybe Windscreen Wipers Too!!!**

Independent Rear Suspension, WOW!!!

Now we have.....

APC

4EAT	ABS	ACE	ACC	ADAS
AGVS	ARC	ASR	ASTC	ATTS
AYC	CVRSS	DMCM	DSCC	EAS
EBCM	EBD	EBTCM	ECD	ECM
EDR	EGRCMDS		EHCUC	EHPAS
EMAS	ETS	EVTOP	FEDS	HICUS
ICC	ICWS	IEDIS	LDAS	NAICC
TCS	VSES	WVWWS		

Who Knows What These Do?

APC

4EAT	4 Speed Electronic Automatic Transmission	ECD	Electronically Controlled Deceleration
ABS	Antilock Brake System	ECM	Engine Control Module
ACE	Active Cornering Enhancement	EDR	Event Data Recorder
ACC	Adaptive Cruise Control	EHCUC	Electronic Hydraulic Control Unit
ADAS	Advanced Driver Assistance System	EHPAS	Electric Hydraulic Power Assisted Steering
AGVS	Automated Guided Vehicle System	EMAS	Engine Management and Analysis System
ARC	Active Roll Control	ETS	Enhanced Traction System
ASR	Acceleration Slip Regulation	EVTOP	Enhanced Tactical Vehicle Occupant Protection
ASTC	Automatic Stability and Traction Control	EGRCMDS	EGR Motor Commanded In Steps
ATTS	Advanced Torque Transfer System	FEDS	Flexible Engine Diagnostic System
AYC	Active Yaw Control	HICAS	High Capacity Actively Controlled Steering
CVRSS	Continuous Variable Road Sensing Suspension	ICC	Intelligent Cruise Control
DMCM	Driver Motor Control Module	ICWS	Intersection Collision Warning System
DSCC	Distance Sensing Cruise Control	IEDIS	Integrated Electronic Distributorless Ignition System
EAS	Electrically Assisted Steering	LDAS	Lane Departure Avoidance System
EBCM	Electronic Brake Control Module	NAICC	Navigation-Aided Intelligent Cruise Control
EBD	Electronic Brake force Distribution	TCS	Traction Control System
EBTCM	Electronic Brake Traction Control Module	VSES	Vehicle Stability Enhancement System
		WVWVS	Wireless Vehicle to Vehicle Warning System

APC

WOW!!!

All These Computer Controls from the Cars Sensors!!

Improved Fuel Economy!

More Power From Smaller Engines!

Less Emissions!!

FASTER ACCELERATION!!!

More Stability FASTER AROUND CORNERS!!!

Latest BMW has about 90 Computer Control Devices

Nearly All are Passive to Driver!!!!

APC

- **Continuously Controls Sulphate, P₂O₅ Strength and Operating Rate of PhosAcid Plants.....**
 - **PhosAcid Cruise Control!!!!!!**
 - **Development History**
 - **How it Works**
 - **How it Performs**
 - **Benefits**
 - **How it is Installed**

APC

- **History of Original Development and Implementation**
 - **1980's, IMC & Agrico Advisory Programs for Sulphate Control**
 - **Took ~2 Years to get the Sulphate Control to Perform,**
 - **Took ~4 years to get the P₂O₅ Gravity and Filter Feed Controls to an Acceptable Operational Status.**
 - **On-Line Control System for Sulphate, Rate and Strength Control**
- Implemented by IMC in 1991 at Three New Wales Plants**
 - **Installed at South Pierce, Faustina, and Uncle Sam after Merger with Agrico in 1993**
 - **Partial Installation at Riverview and Bartow After Merger with Cargill to Form Mosaic in 2004**

APC

- **Current Development and Implementation**
 - **Improved Program and Logic Codes Written From Scratch and Operator/Supervisor/DCS Interaction Improved in 2006**
 - **Wash Water Pulse Eliminated**
- **Many Inquiries, but Installed at Only One Other Plant.**

APC

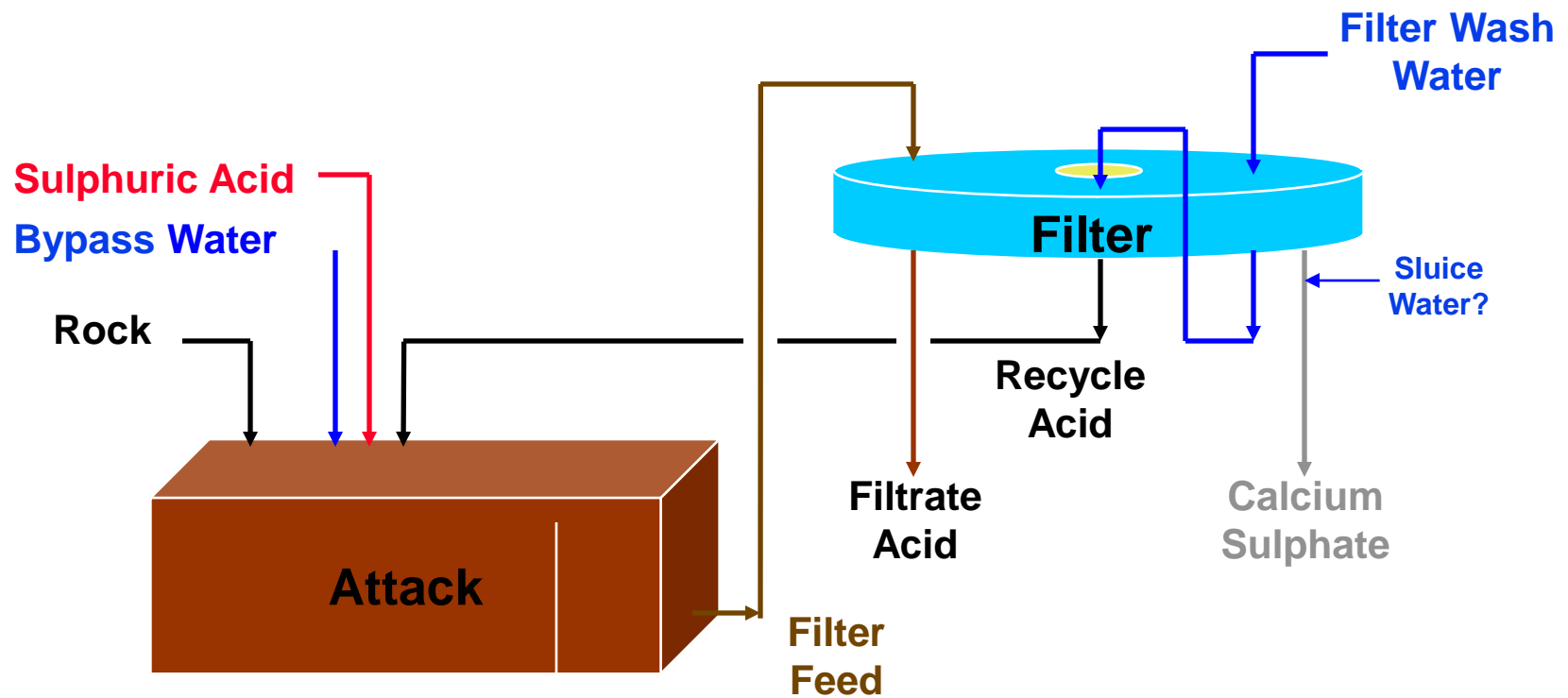
SO HOW DOES IT WORK!!!!

APC

- **Sulphate Control**
- **Phosphoric Acid Strength Control**
- **Filter Feed Control**
- **Filter Feed Level Control**
- **ByFinally Controlling Rock Rate**

APC

PHOSPHORIC ACID FLOWSHEET



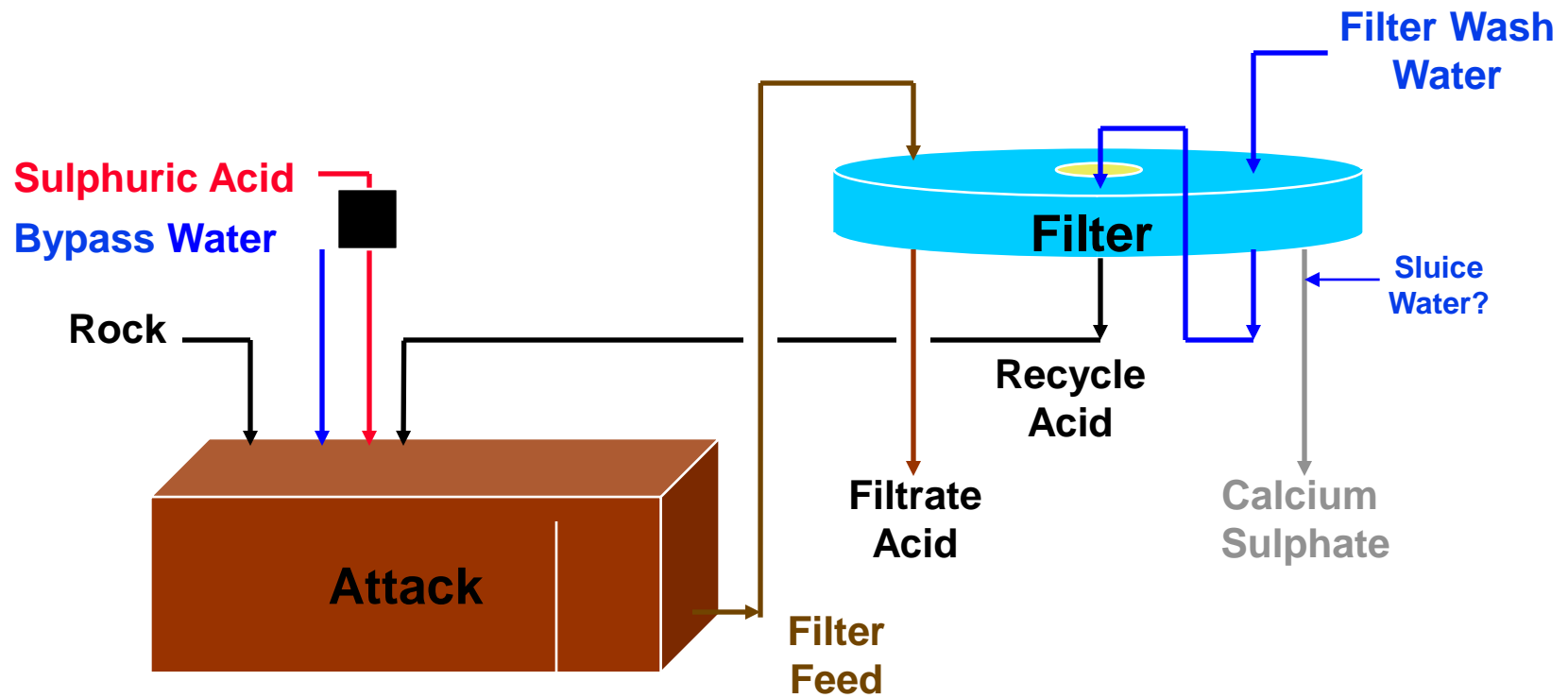
APC

● Sulphate Control

- Measure Sulphate in PhosAcid each Hour (Flexible)
- Targeted Sulphate Level is Set (performance)
- Acid to Rock Ratio Adjusted to Attain Target
- Ratio Adjusted After Sulphate Sample Result Entered
- Corrects Each Time Based Upon How Previous Adjustments **Performed!!!!**

APC

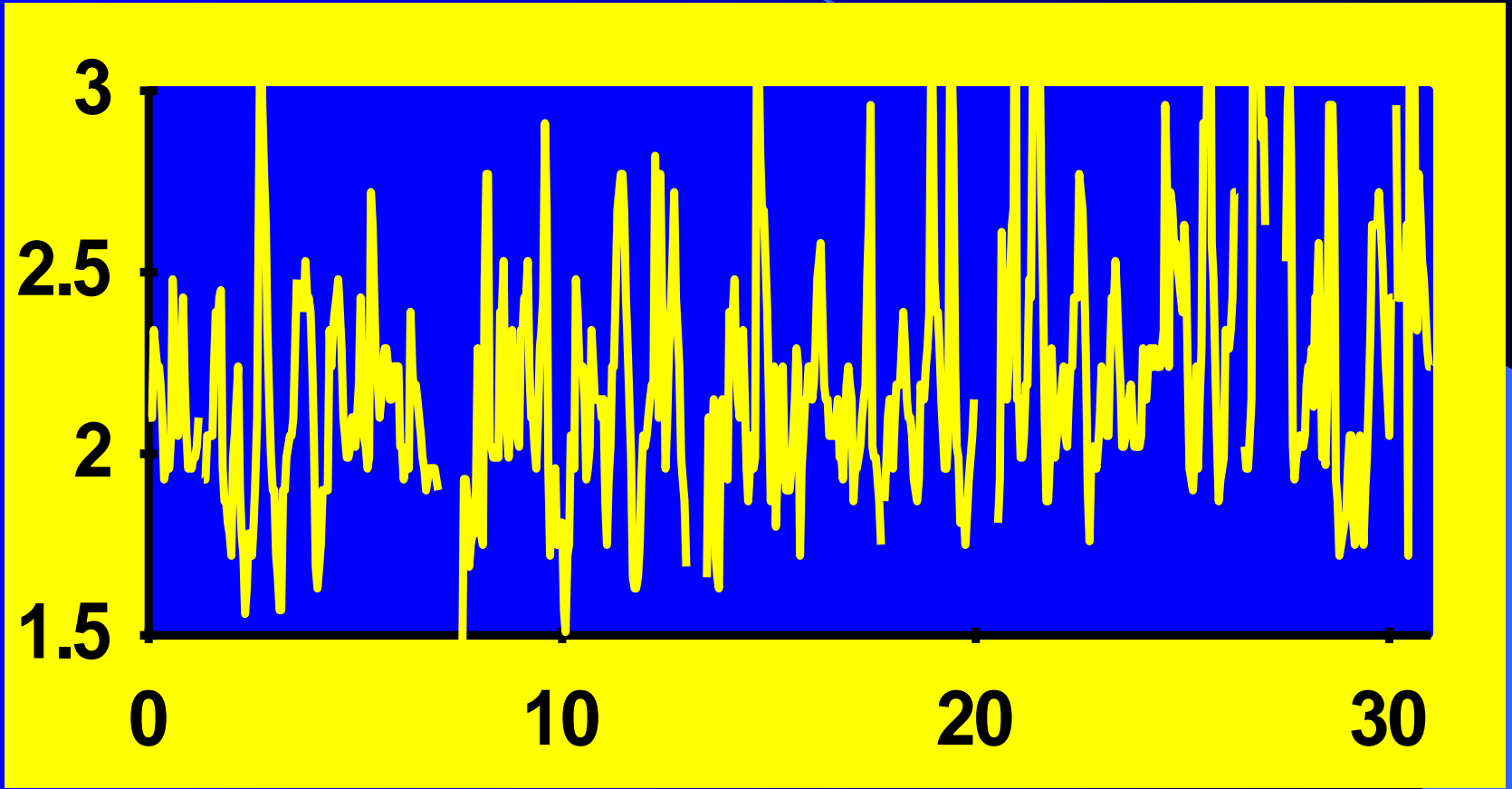
PHOSPHORIC ACID FLOWSHEET



Target ???
Act Avg 2.20
Std Dev 0.36

BC (Before Computers) SO₄ Control

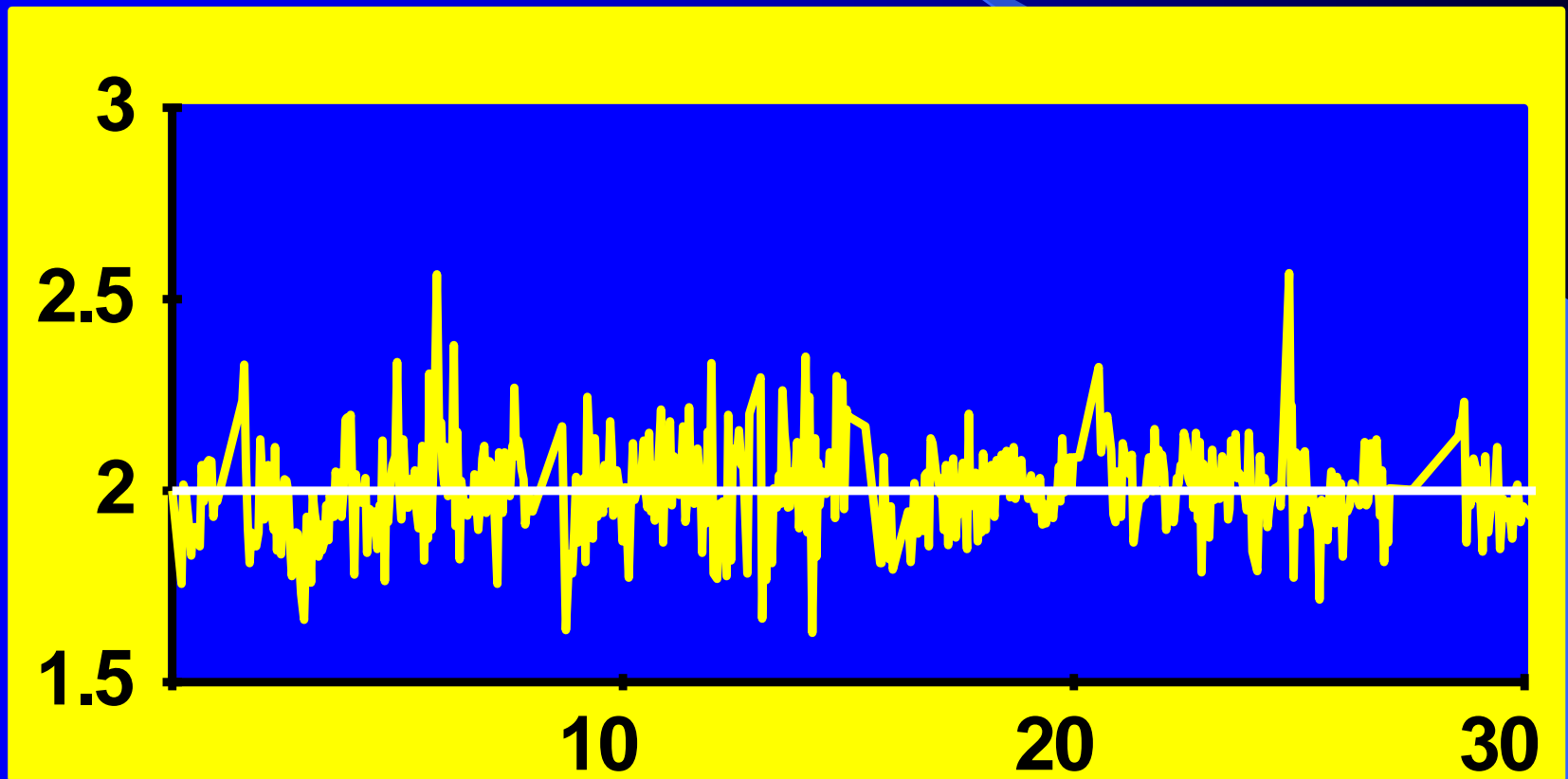
Wt %
SO₄



March, 1988

Target 2.00
Act Avg 2.00
Std Dev 0.12

On-Line SO₄ Control



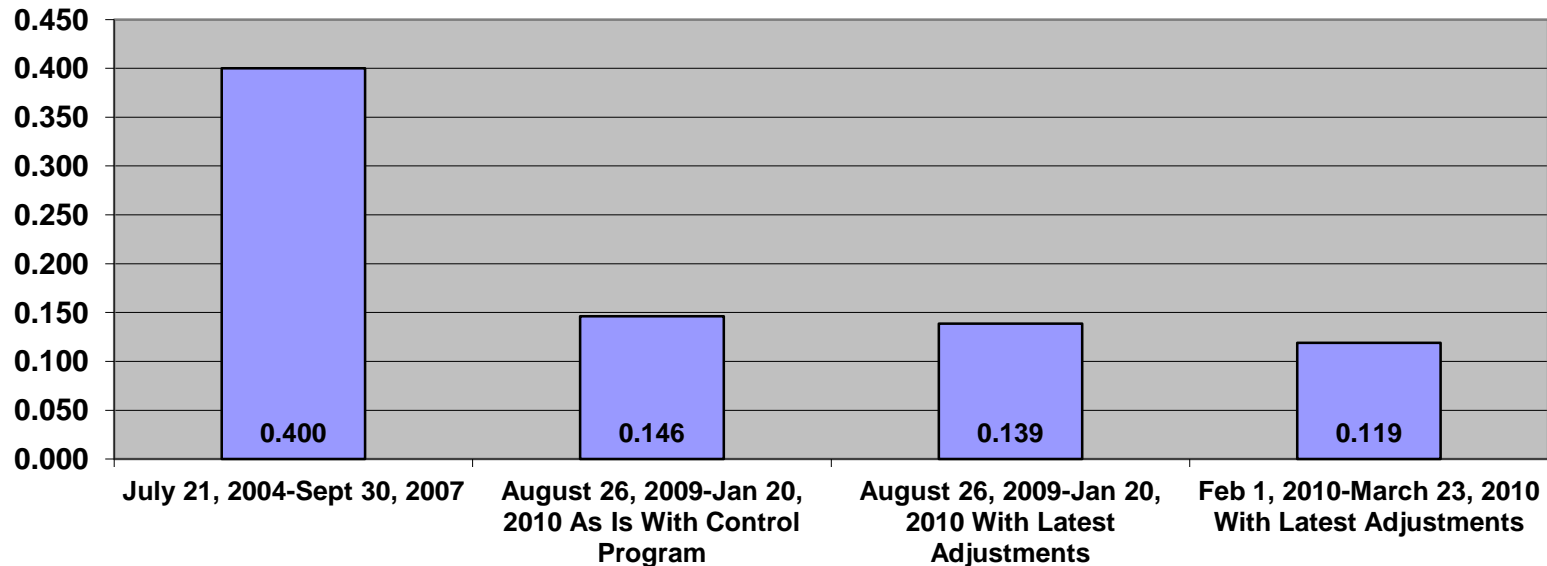
November, 1990

SO₄ Standard Deviation

More recent 2007 - 2010 Data

SO₄
Standard
Deviation

Average Free Sulfate Difference from Target



Before APC

Advisory

Partial
Cascade

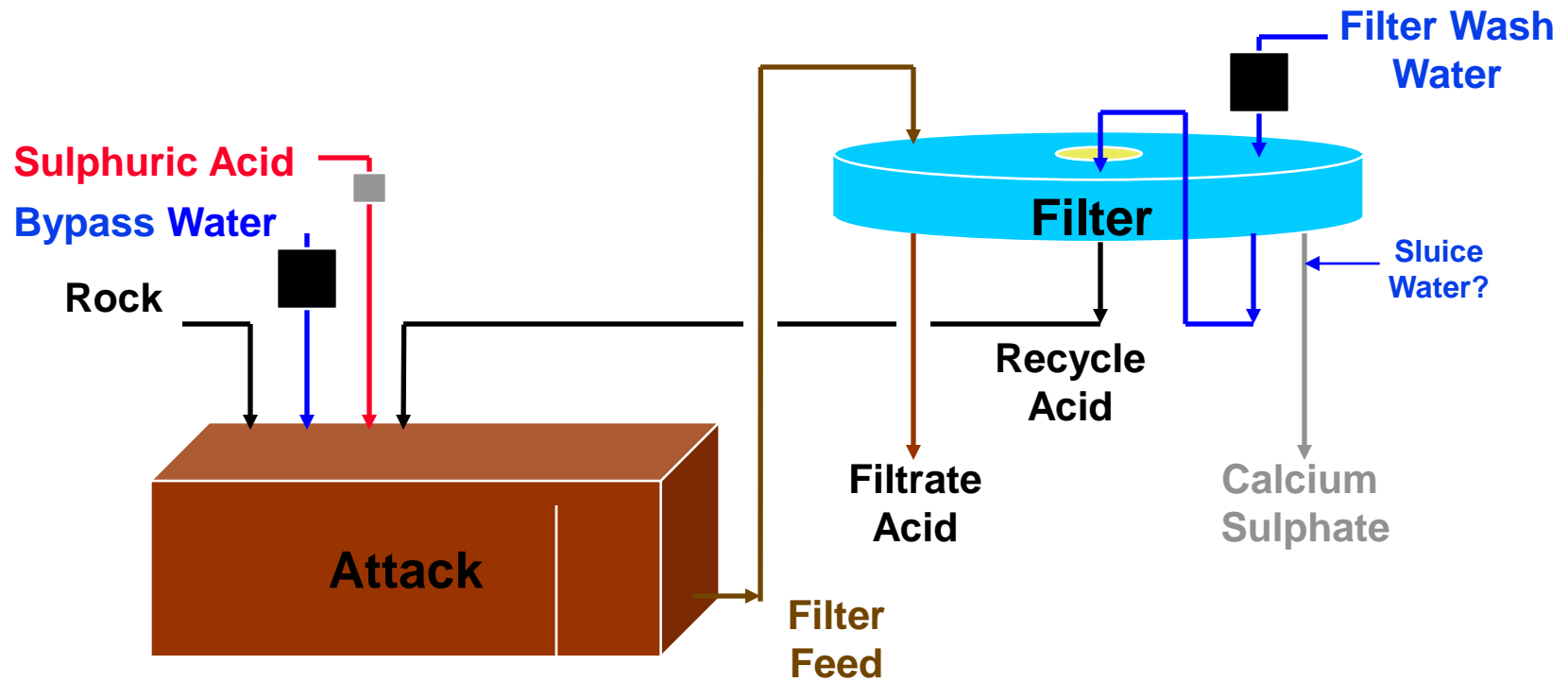
On-Line
Full
Cascade

APC

- **Sulphate Control.....Done**
- **Next We add:-**
- **Phosphoric Acid Strength Control**
 - **P2O5 target...Based on Downstream Needs**
 - **Continuously Monitors Water to Rock Ratio**
 - **Adjusts Filter Wash Water**
 - **Controls By-Pass Water**
 - **Adjust Ratio After Every Sample, (Hourly)**
 - **Corrects Each Time Based Upon How Last Adjustments Performed!!!!**

APC

PHOSPHORIC ACID FLOWSHEET

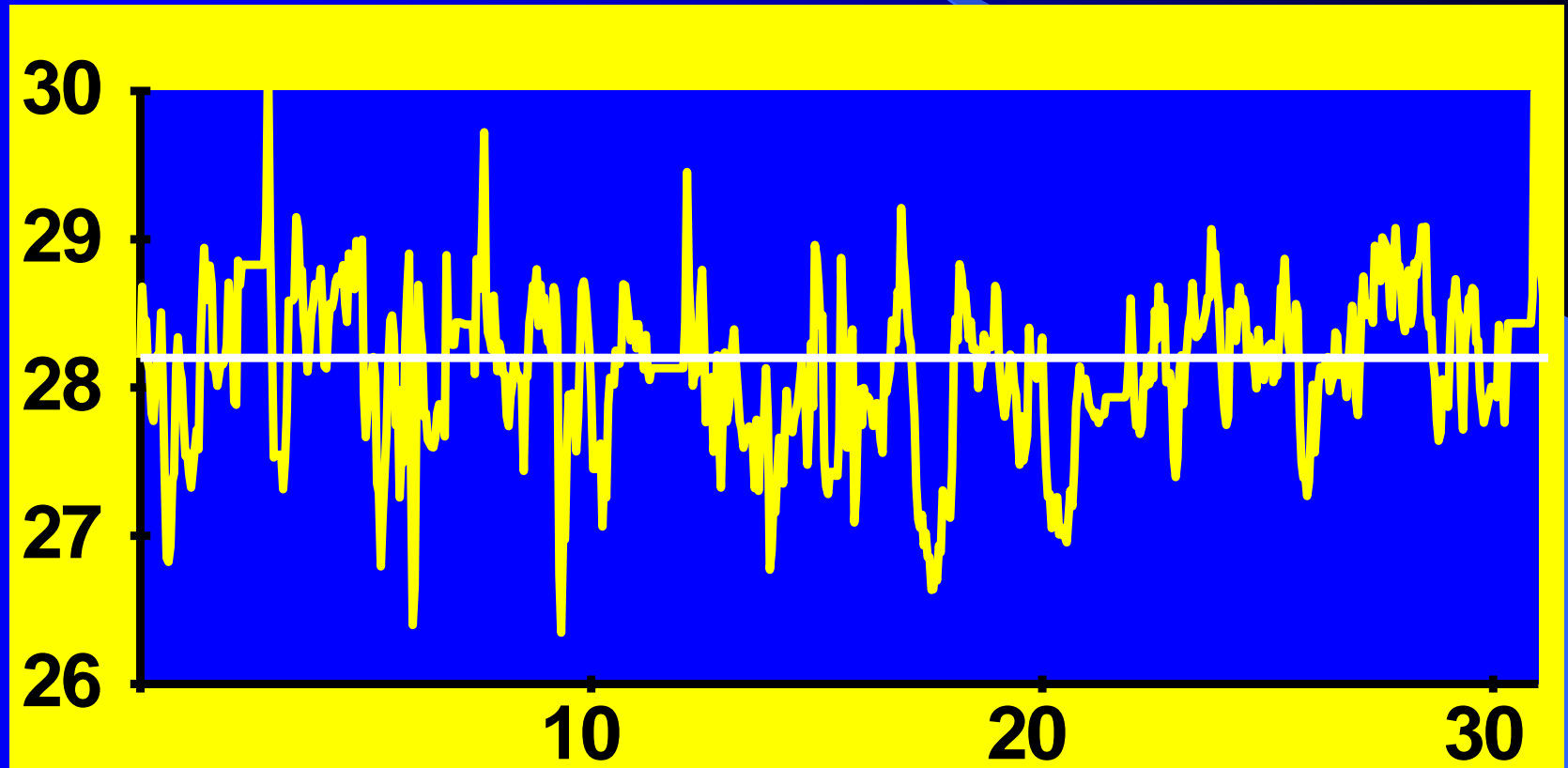


Target 28.20
Actual 28.13
Std Dev 0.53

BC (Before Computers)

P₂O₅ Control

Wt %
P₂O₅



January, 1990

BC (Before Computers) P₂O₅ Control

31 Days of January, 1990

Target 28.20

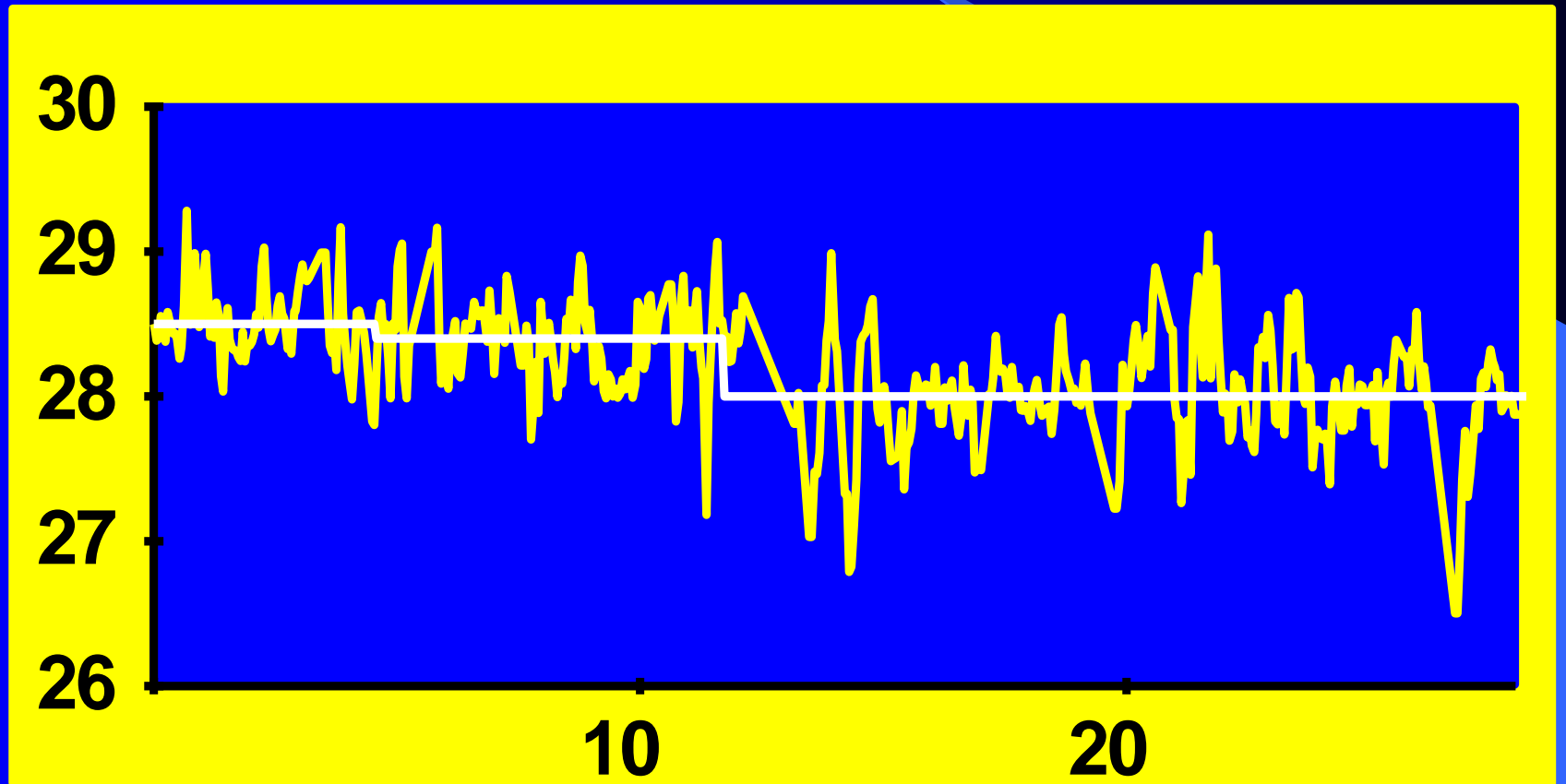
Actual 28.13

Std Dev 0.53

Target 28.38
Actual 28.38
Std Dev 0.32

On-Line
 P_2O_5 Control

Wt %
 P_2O_5



January, 1993

On-Line P205 Control

30 Days of November, 1993

Target 28.38

Actual 28.38

Std Dev 0.32

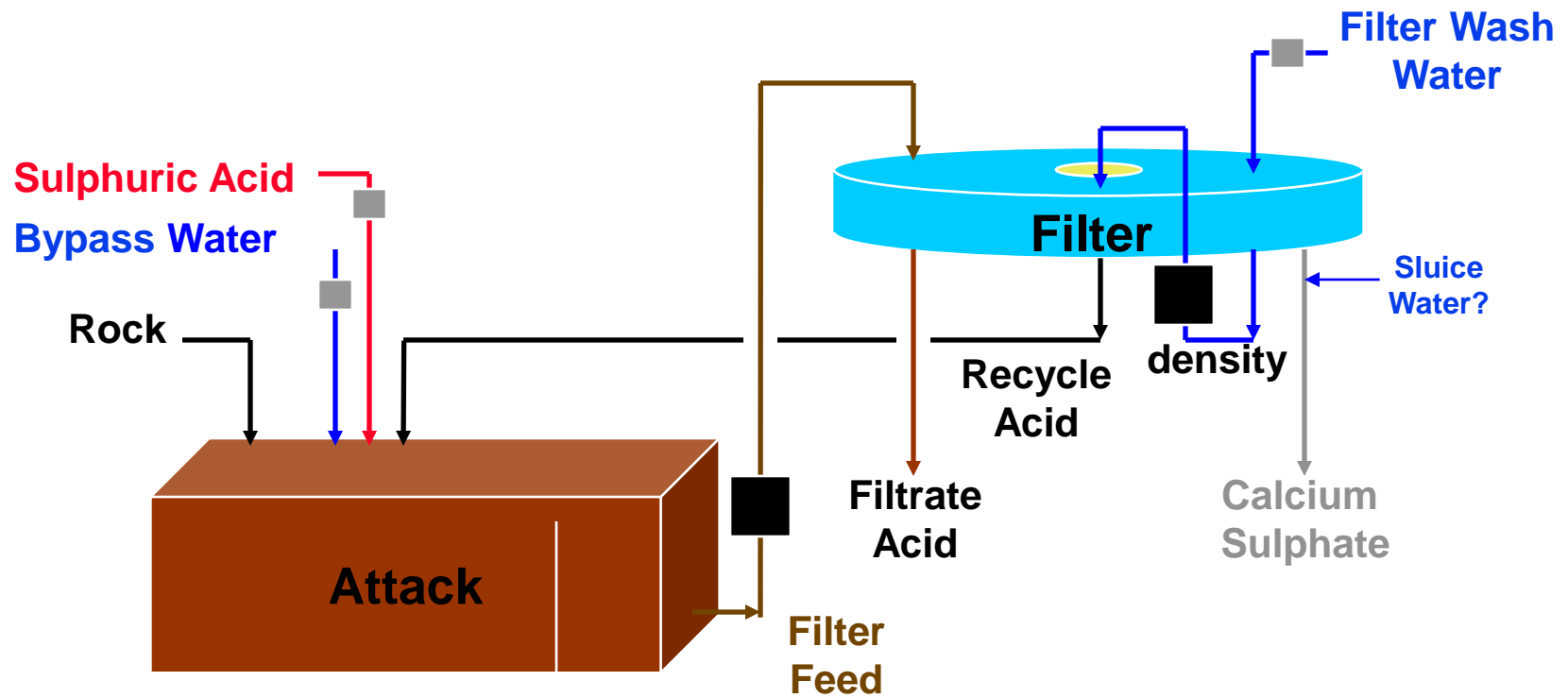
Was 0.53

APC

- **Sulphate ControlDone**
- **Phosphoric Acid Strength Control.....Done**
- **Next We Add:-**
- **Filter Feed Control**
 - **Tail Wash Filtrate Density Needed**

APC

PHOSPHORIC ACID FLOWSHEET



PHOSPHORIC ACID PLANT ON-LINE CONTROLS

- **Sulphate Control Done**
- **Phosphoric Acid Strength Control..... Done**
- **Filter Feed Control**
 - **No. 3 Filtrate Density Target**
 - **Density Target Sets Filtration Recovery**
 - **Filter Feed Rate Set is Based on Final Filtrate Density**

One Attack..... Three Filters!!!!

DeltaV Operate (Run) | Module: | Main: P_STRENGTH_CONTROL | Username: BKW | 5:28:23 PM

FILTER WASH WATER AND STRENGTH CONTROL

	1.00	1.05	1.00
Pond Water To #1 Cell 26FIC23102	24C Wash Water 06FIC602	#1 Belt Wash Water 26FIC008106	#2 Belt Wash Water 26FIC008107
SP 0.0	SP 375	SP 375.0	SP 400
PV 0.0	PV 375	PV 370.7	PV 400
CV 1.7	CV 19.3	CV 90.7	CV 60
AUTO	AUTO	AUTO	AUTO

HISTORY DISPLAY

Time	BC - P205 Strength Target	CG - TPH Water Req Reactor	CH - Limited TPH Water Change Reactor	CI - TPH Water Change Made Reactor	CJ - Expected P205 Target Last Change	CK - TPH Water Diff Required	CL - Total TPH Wash Required	CM - Total GPM Wash Required	CN - Bypass GPM Setpoint	CO - Total Filter Wash GPM	CP - 24C Wash GPM Setpoint	CQ - #1 Belt Wash GPM Setpoint	CR - #2 Belt Wash GPM Setpoint
12/07/2010 17:28:03	28.00	-2.07	-2.07	-2.07	0.00	14.06	273.7	1090.	-56.5	1090.	388.4	359.2	342.6
12/07/2010 17:27:03	28.00	-2.07	-2.07	-2.07	0.00	14.06	272.9	1087.	-59.0	1087.	382.6	361.1	343.4
12/07/2010 17:26:03	28.00	-2.07	-2.07	-2.07	0.00	14.06	273.0	1087.	-51.2	1087.	386.2	360.4	341.0
12/07/2010 17:25:03	28.00	-2.07	-2.07	-2.07	0.00	14.06	274.2	1092.	-50.8	1092.	394.8	348.0	349.4
12/07/2010 17:24:03	28.00	-2.07	-2.07	-2.07	0.00	14.06	272.7	1086.	-51.9	1086.	391.1	346.3	348.7

Rock Rate to Filtrate FlowRatio **1.62**

FILTER FEED AND ROCK RATE CONTROL

24C FILTER FEED	#1 FILTER FEED	#2 FILTER FEED	ENTER TONS/DAY	CU - H2O Factor
SP 900.0	SP 800.0	SP 800.0	1200	Gain
PV 903.8 GPM	PV 800.1 GPM	PV 800.3 GPM	ROCK SLURRY TO REACTOR	2.000
CV 36.7%	CV 51.6%	CV 44.6%	Reactor	2.000
AUTO	AUTO	AUTO	SP 5970 LB/MIN DRY ROCK	2.000
			PV 5963	2.000
			CV 82.9	
			AUTO	

Estimated Total Filtrate Flow to Clarifiers to maintain Digester Strength **585** gpm

Actual Total Flow **741** gpm

1.089 **1.109** **1.094** Filtrate SGU

1.100 **1.106** **1.100** Target SGU

S - 24C Dev Target Gravity	T - 1 Belt Dev Target Gravity	U - 2 Belt Dev Target Gravity	AD - New 24C Feed SetPoint	AE - New 1 Belt Feed SetPoint	AF - New 2 Belt Feed SetPoint	AO - New Rock Feed Rate Lb/Min
-0.012	0.0026	-0.005	900	800	800	5970
-0.014	0.0039	-0.008	900	800	800	5970
-0.014	0.0071	-0.009	900	800	800	5970
-0.015	0.0062	-0.010	900	800	800	5970
-0.016	0.0074	-0.009	900	800	800	5970

PHOS OVERVIEW | #1 BELT FILTER | 24C FILTER | #2 BELT FILTER | D E F G H P S T V O R W | SULFATE CONTROL

23XS046 | 22TT201B_104 | 06PT_405 | 06PDT_404

Sat 14:57:38 | EAST SULFURIC UPS ALARM | 23XS046/DISCRETE ALARM | LOW | CRITICAL | ESP_CTRL1

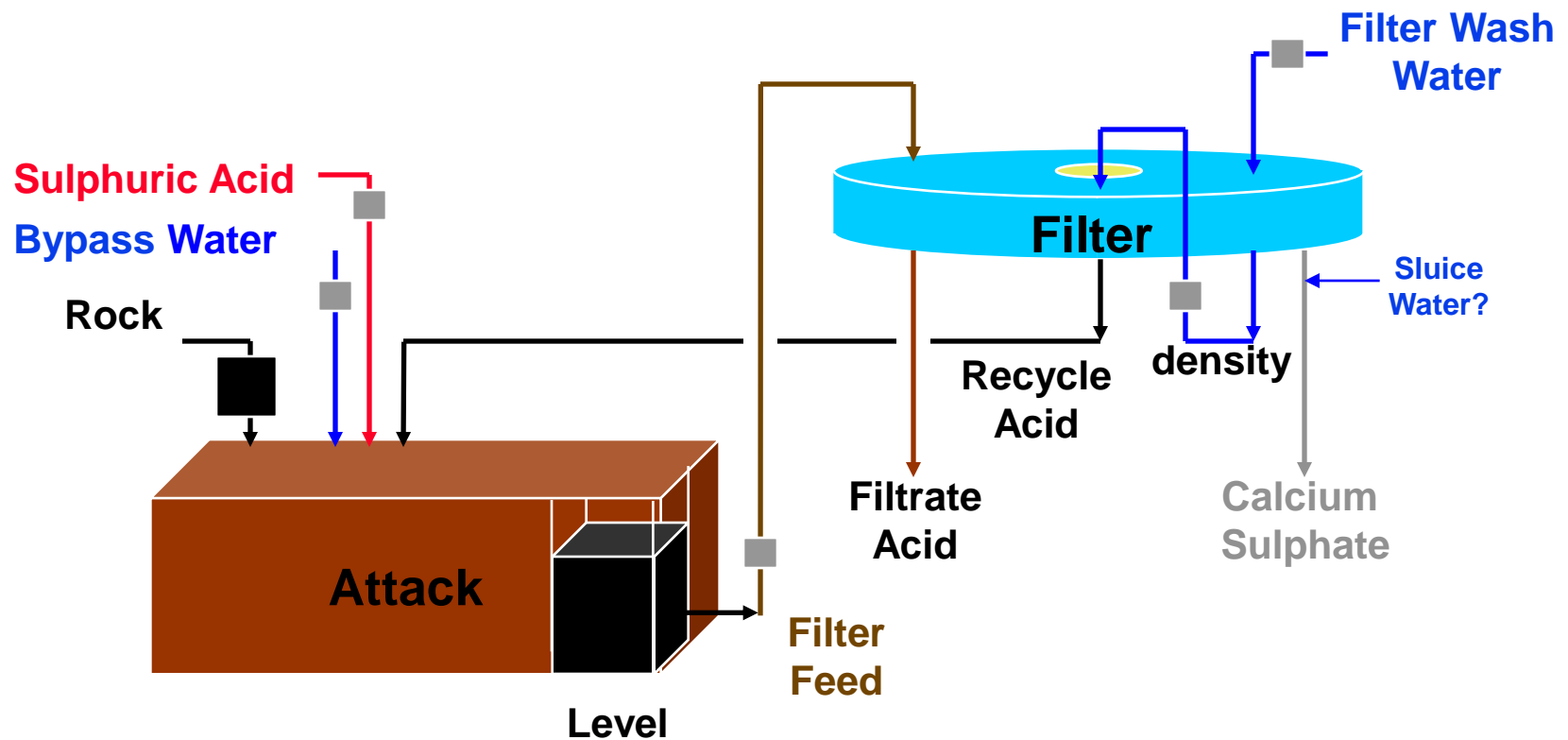
Start | FlexLock | Exploring DeltaV | DeltaV Operate (Run) | 5:28 PM

APC

- **Sulphate ControlDone**
- **Phosphoric Acid Strength Control.....Done**
- **Filter Feed Control**
- **Finally We Add:-**
- **Rock Rate**
 - **Rock Rate Set is Simply Based on the Filter Feed Level**

APC

PHOSPHORIC ACID FLOWSHEET



APC

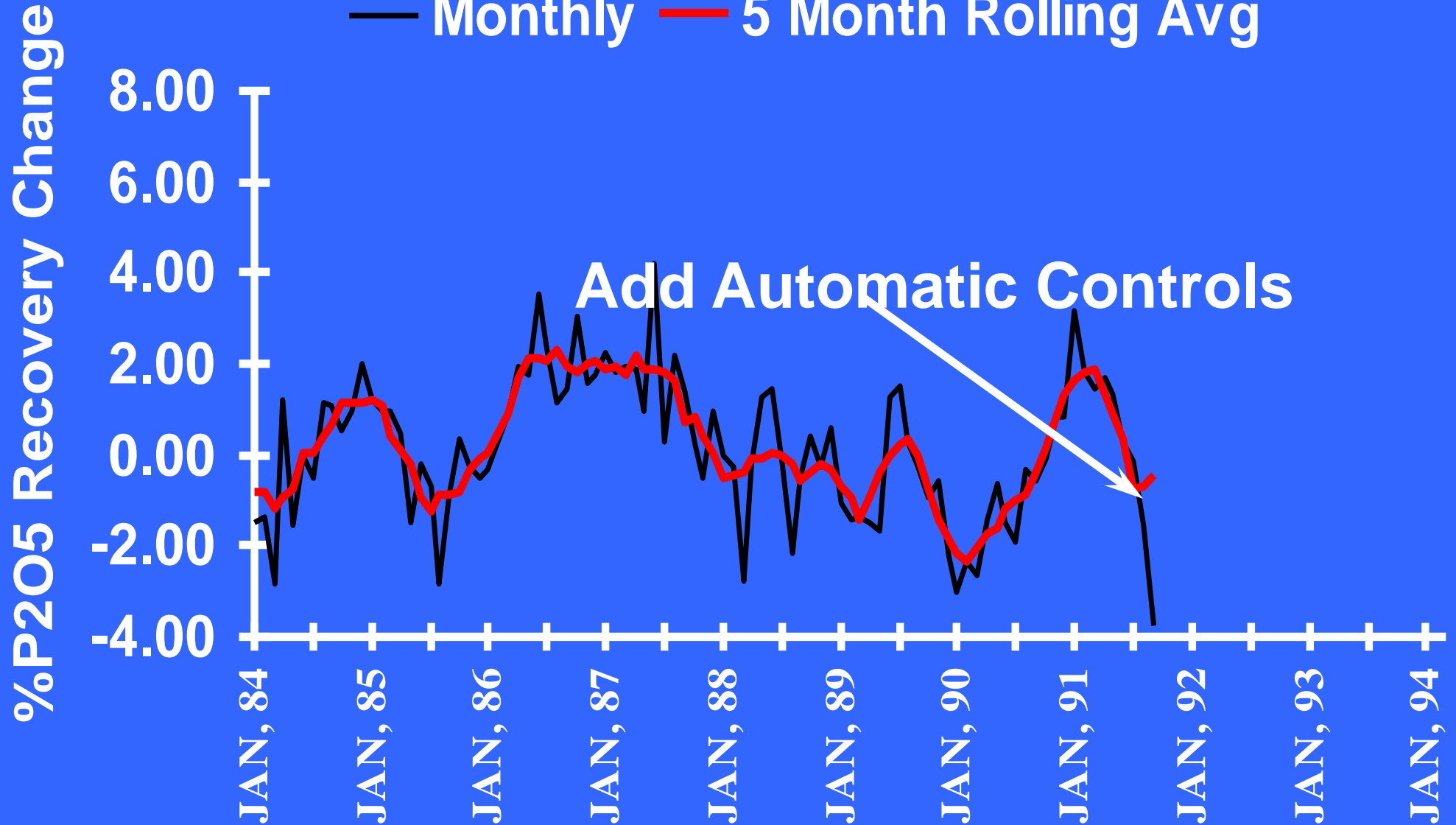
- **Initially Sulphate Control was the Focus for First Two or Three Years.**
- **The Next Several years were Needed to Optimize the Programs Used to Control the More Complex P_2O_5 Attack Gravity.**
- **Finally, Again Three or so Years Needed for the Slurry Filter Feed and Filter Operation to be Perfected.**
- **So What Happened??**

APC

How it Performed

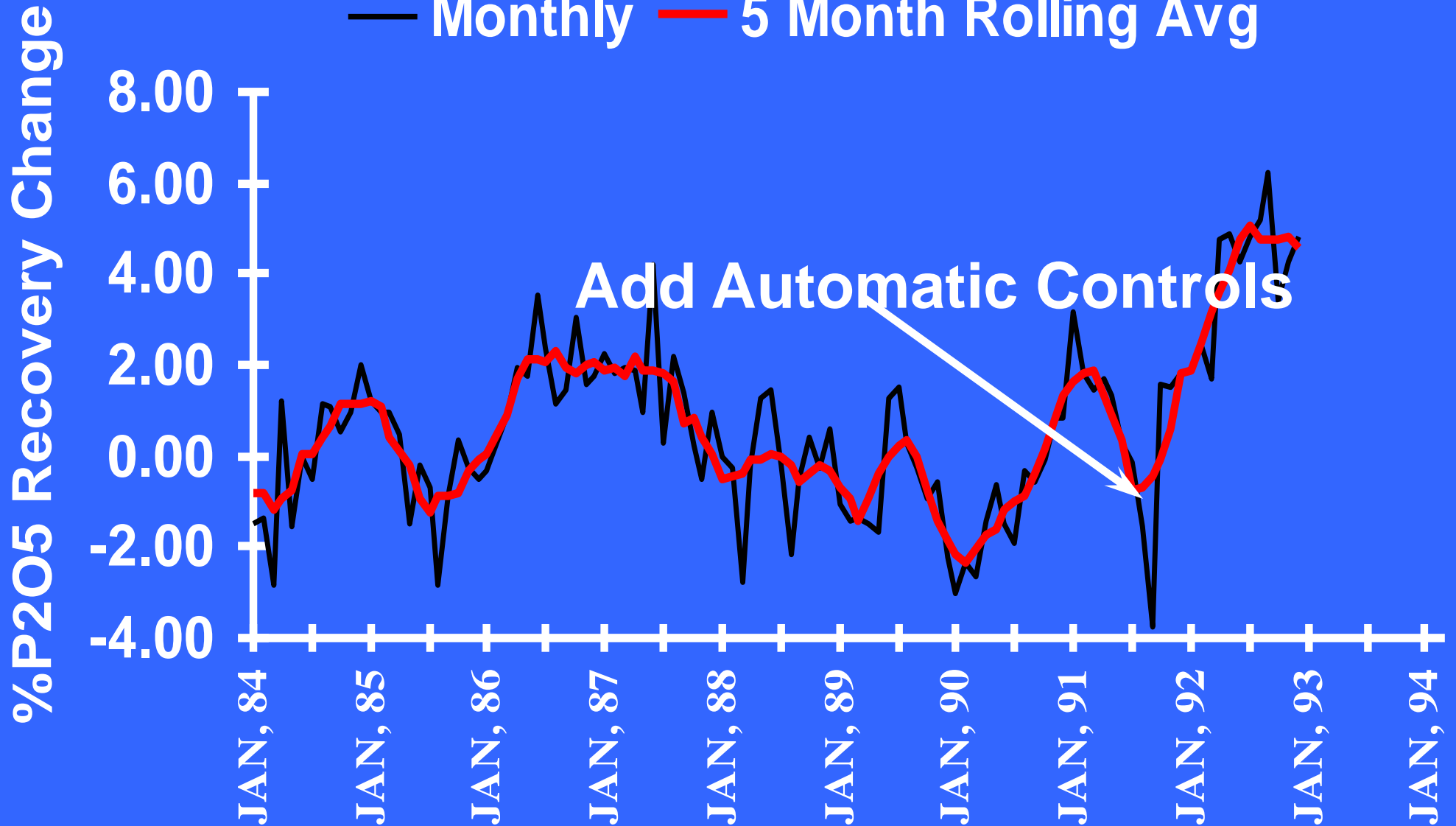
P2O5 Recovery vs Time

— Monthly — 5 Month Rolling Avg



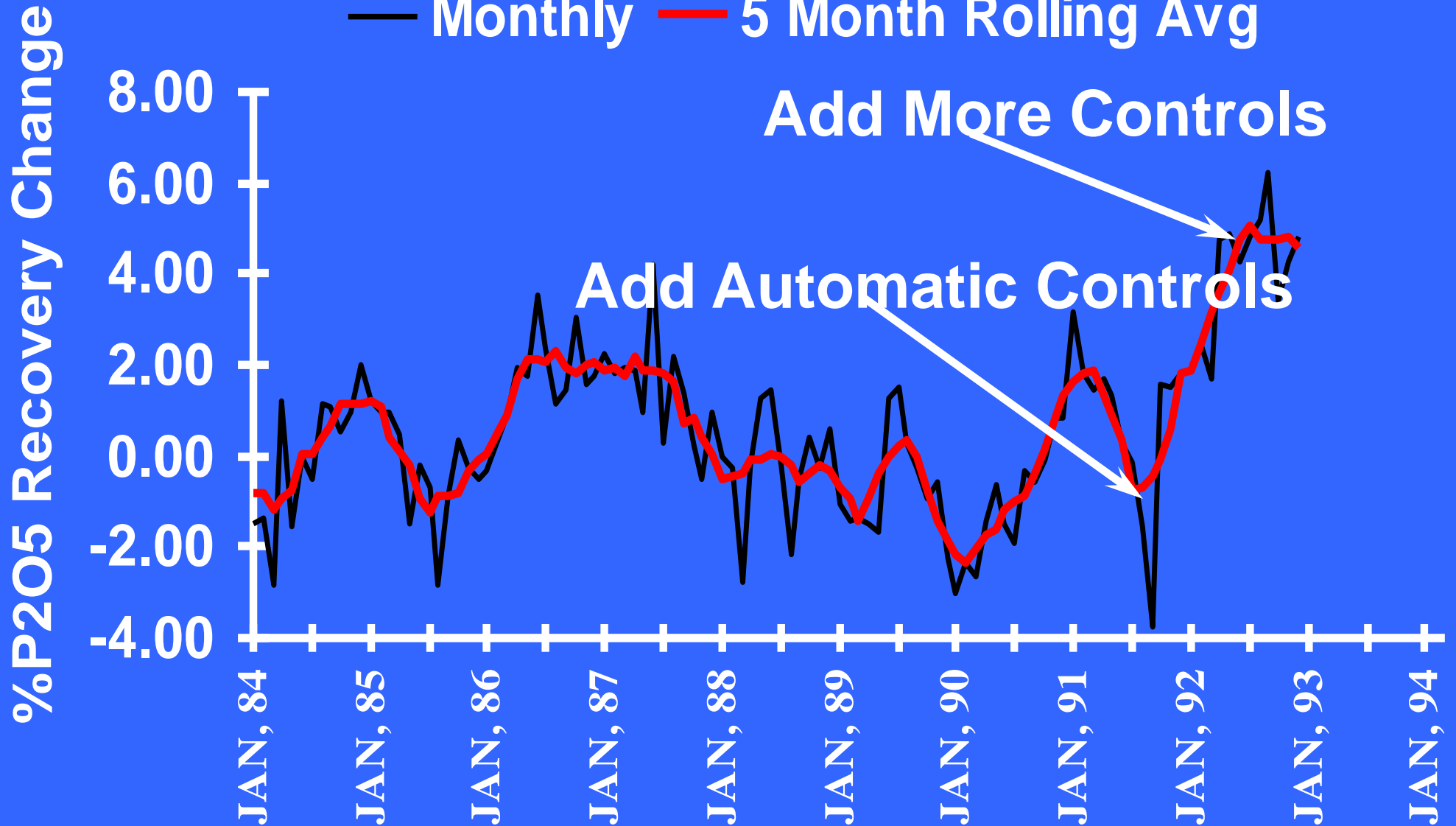
P2O5 Recovery vs Time

— Monthly — 5 Month Rolling Avg



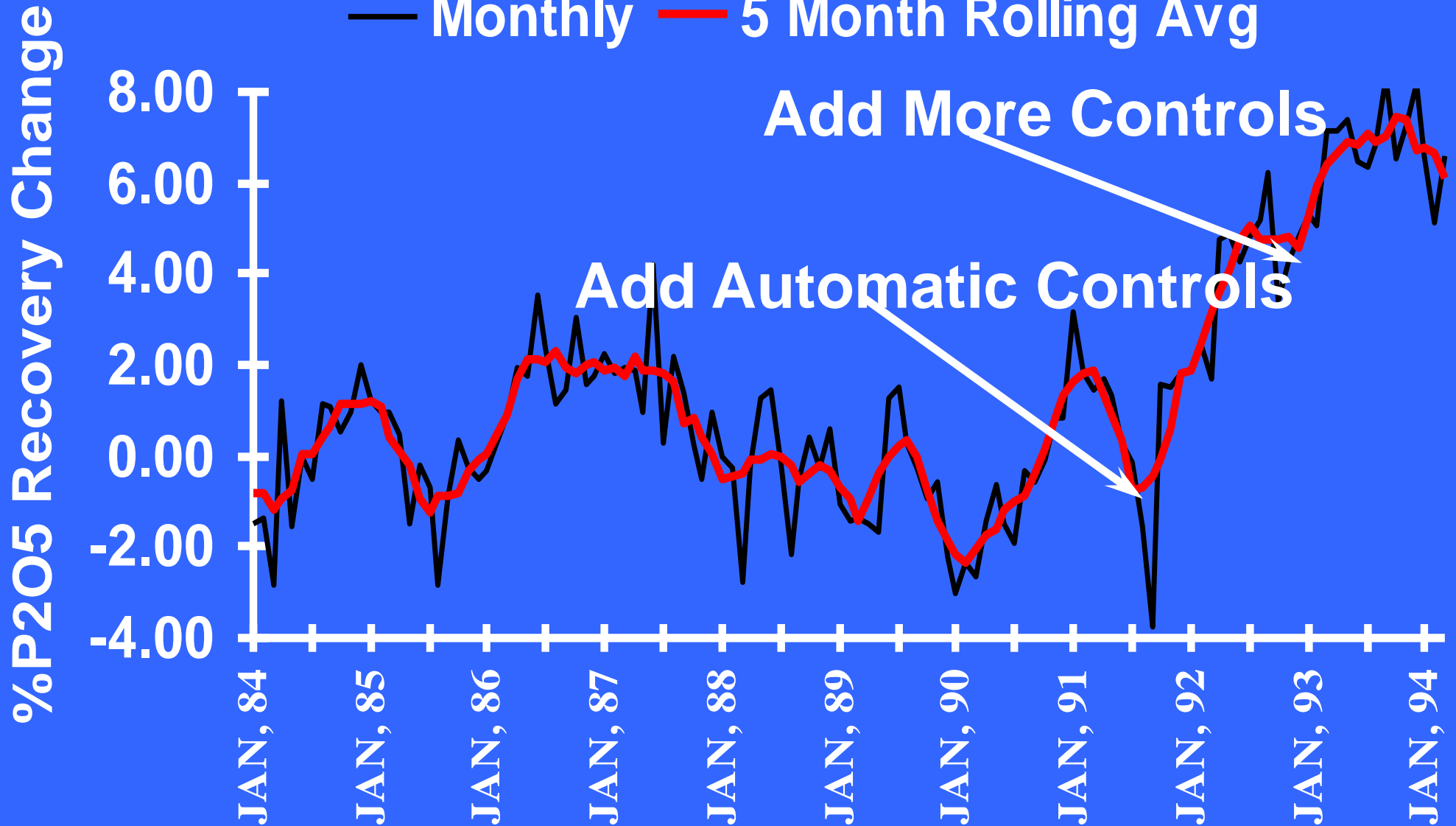
P2O5 Recovery vs Time

— Monthly — 5 Month Rolling Avg

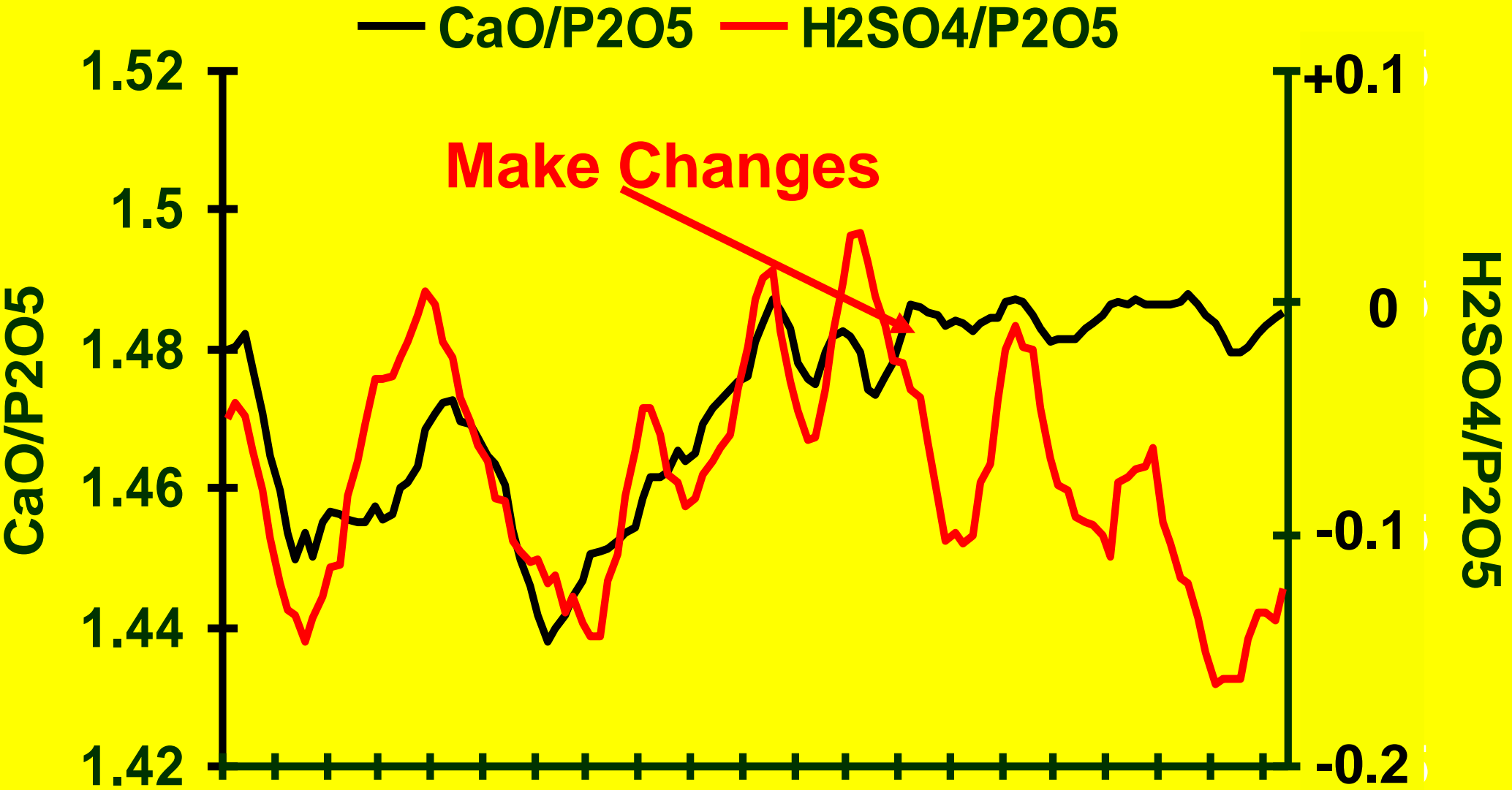


P2O5 Recovery vs Time

— Monthly — 5 Month Rolling Avg



H2SO4/P2O5 vs CaO/P2O5



Average Daily Production

— Monthly — 5 Month Rolling Average



Average Daily Production

— Monthly — 5 Month Rolling Average



APC

- **Did the On Line Controls Give an Improvement of about 0.5% or 7%?**
- **It Did Both**
- **The Reduction in Water Soluble/Citrate Soluble Losses in the Gypsum was About 0.75%**
- **However, Other Losses Also Decreased**
 - **Flash Cooler Losses**
 - **Less Upsets on Filter and Filterability**
 - **Line Scrub Losses (Less Build Up, Steadier Super-Saturation levels)**
 - **Less Filter Scaling (Ditto)**
 - **Tank Clean Out Losses**
 - **Less Frequent Down Days**
- **A Smoother Operation Leads to Many Improvements Downstream**

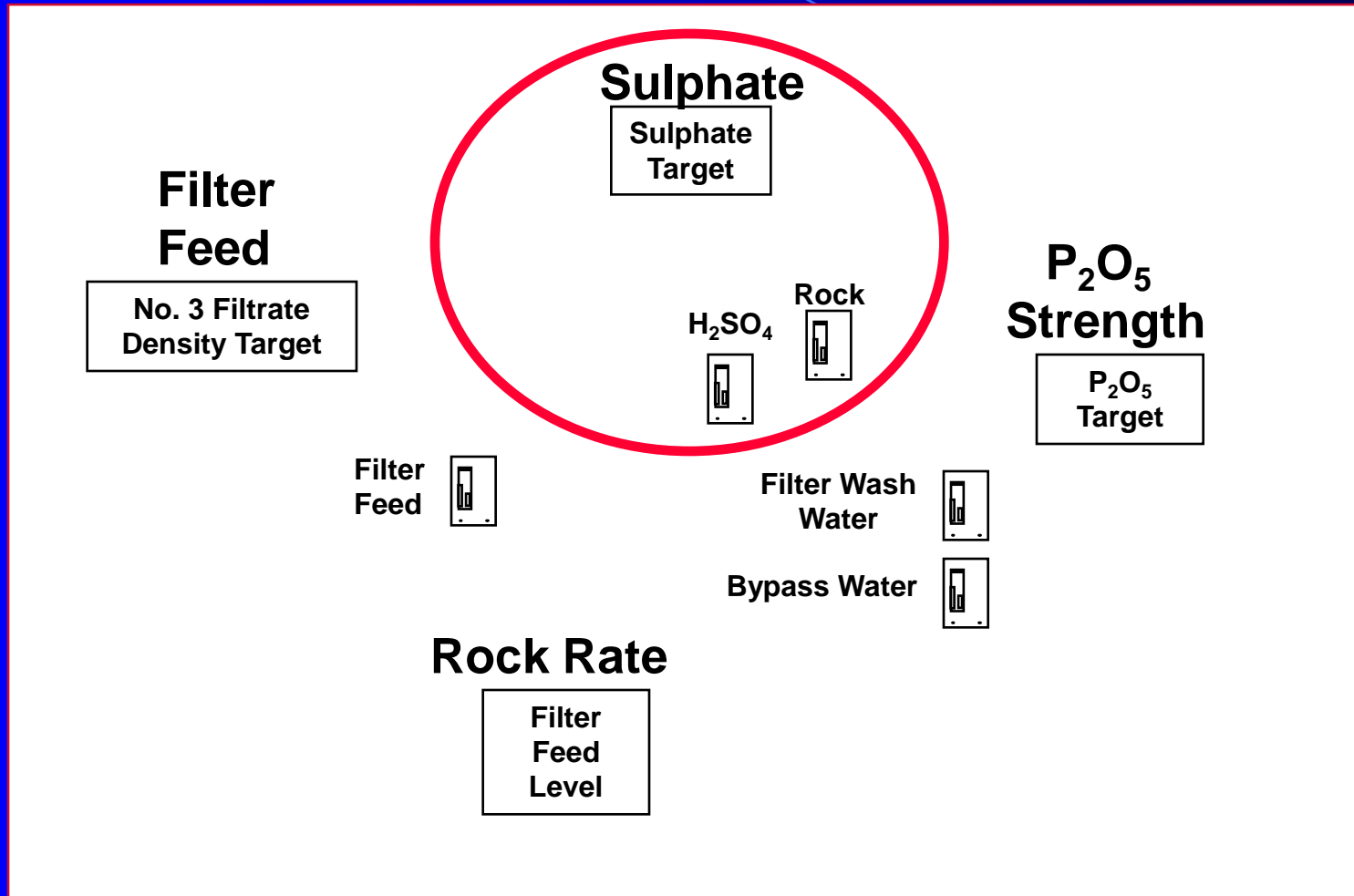
APC

- **In Early On Line Control System Implementations**
 - **The Reduction in Filter Losses After the Implementation of On-Line Controls was About 0.5 - 1%**
 - **(But at a Higher Rate and With an Inferior Rock Quality)**
 - **But the Improvement in the Overall Recovery for the PhosAcid Facility was Over 7%**
- **Results Will Depend on How Well Current Facility is Operated!!!**

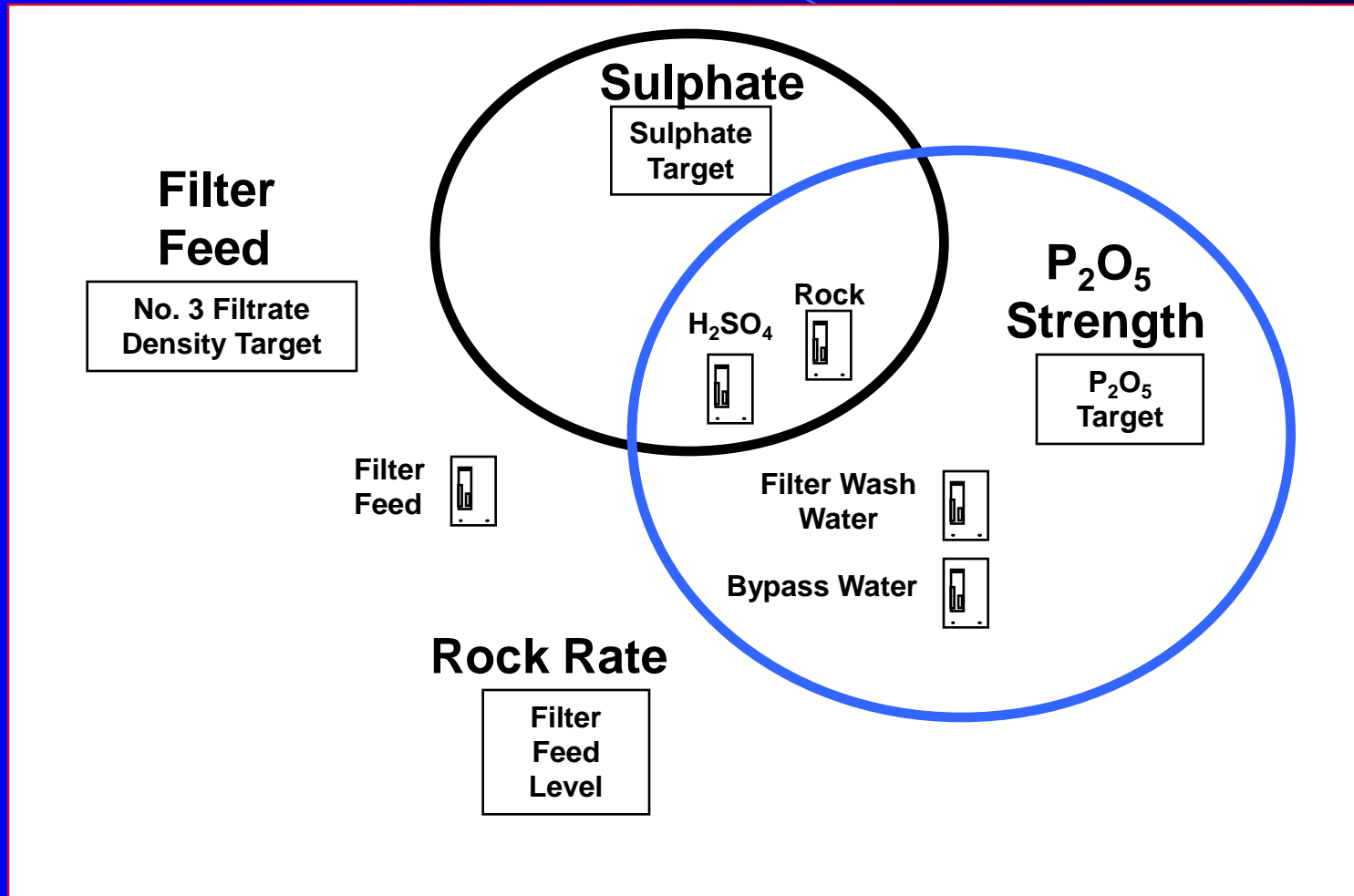
APC

- **How It All Links Together.....**

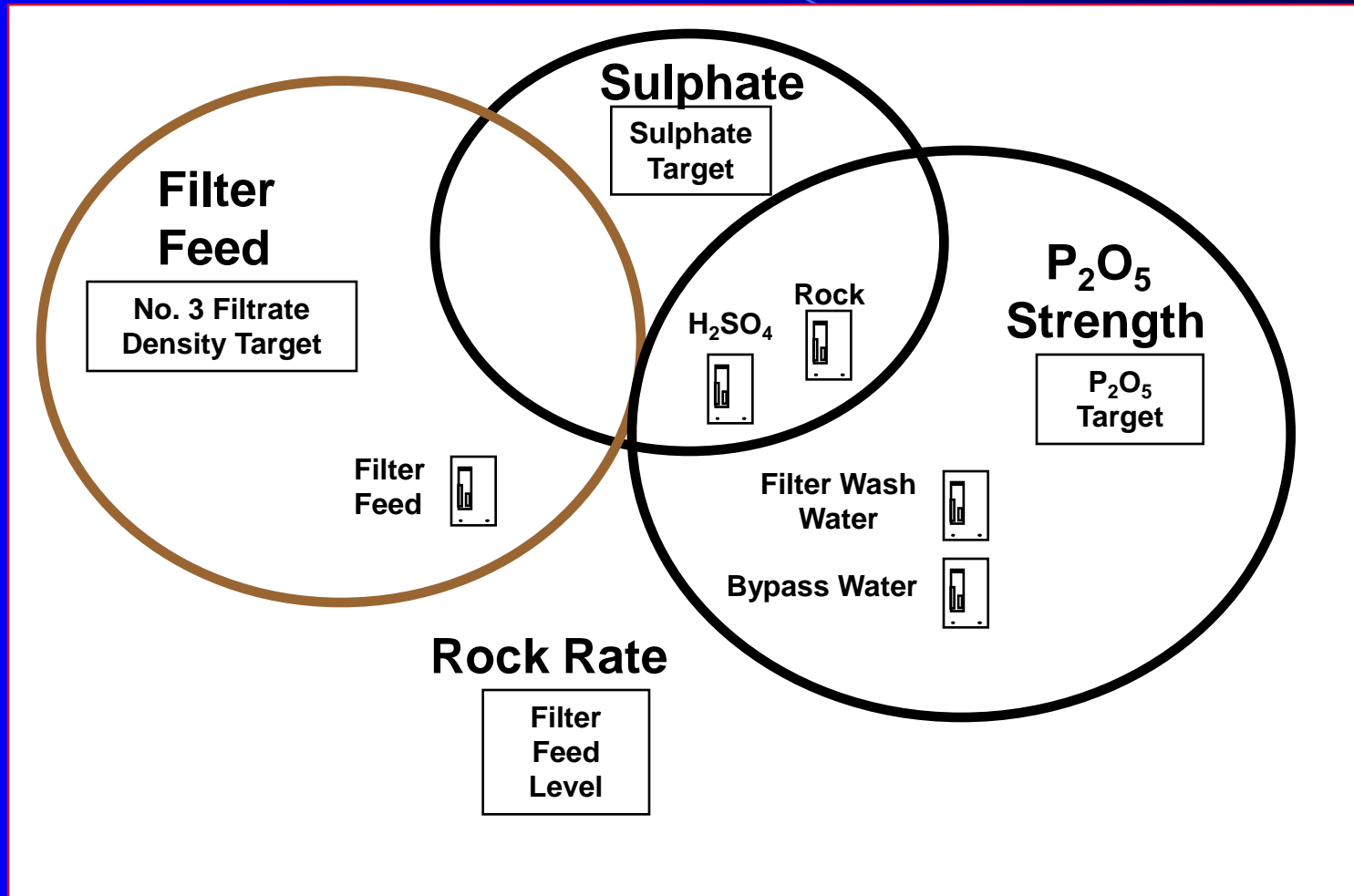
The PhosAcid Control Strategies



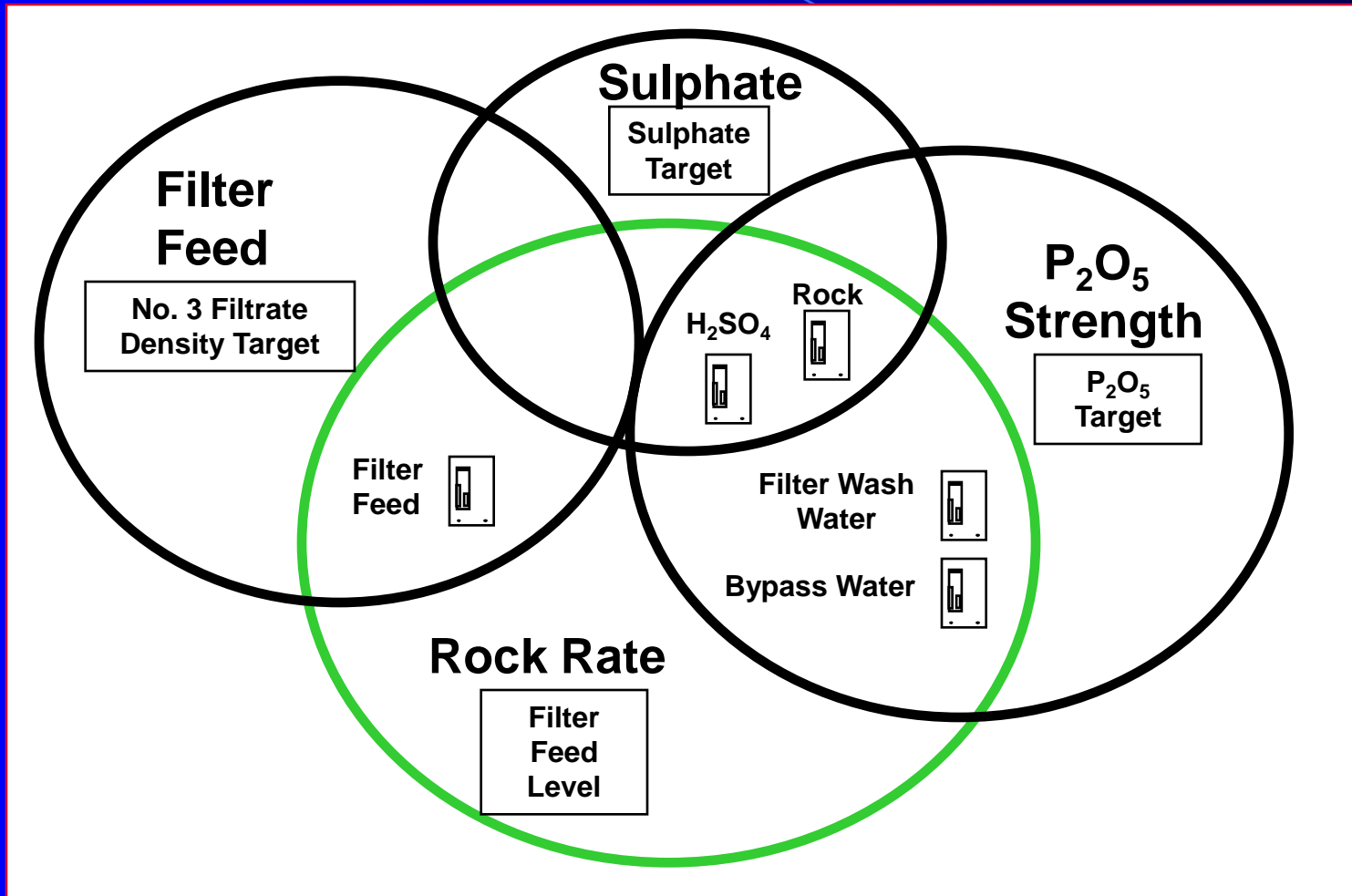
The PhosAcid Control Strategies



The PhosAcid Control Strategies



The PhosAcid Control Strategies



PHOSPHORIC ACID PLANT ON-LINE CONTROLS

- **Control Limits and Logic (Some Fuzzy) for**
 - **Multiple Filters and Flow Partitioning**
 - **Upset Conditions**
 - **Data Entry Errors**
 - **Rate and Flow Limits**
 - **Adaptive In That Drift In Instrumentation Has Little Effect**
 - **Use of Data to Enhance Operations**

Large Rate Improvements

- **Increased Reactor/Filter Rates**
 - Higher Average Operating Rates
- **Increased Operating Time Due to:**
 - Less Frequent Filter Scrubs
 - Longer Times Between Turn-Rounds
 - Less Line Scaling

How Are Other Attacks Controlled Now?

- **Characteristics of Currently Operating Control Systems**
 - Use Look-Up Charts...
 - Bump and Step Charts,
 - Tables of Adjustments
 - Simple Programs.. Enter SO_4 Deviation and Rock Rate, Tells Operator How to Change Sulphuric Acid.
 - What-If diagrams.
 - Need Constant Attention of Operator
 - **Wouldn't Cruise Control be Better?**
 - **i.e. Even Stability Control!!**

APC

How it is Installed

SO HOW TO CATCH UP!!!

What we do.....

- **Two Week Site Visit, Evaluation of Plant Performance, Lab Data, and Analysis of Electronic DCS Data,**
- **Need 3 to 6 months of 1 Minute DCS and All Laboratory Loss Data, (250,000 rows!!!)**
- **We Estimate Benefit to Recovery and Production,**
- **We Determine Cost of Full APC Installation, Including Training,**
- **About \$34K (Intn'l) to Accomplish This First Step**
 - **THEN, if Acceptable, Implement Full APC**

APC

- **Is Control too Complicated and Costly to Install and Maintain?**
 - **(Turn-Key... ~\$400,000 to Install for Domestic, ~\$500,000 for International Facilities and <\$5,000/Yr to Maintain)**
 - **Similar Trains are ~\$100K Each**
- **Do We Need On-Line Analysis**
 - **You Don't need Continuous Analysis, Just The Routine Hourly Sulphate and Gravities is All that is Needed!!!**

Implementation Of Full APC

- **Site Visits to Observe Operations and Collect Data.**
- **A Year or Two of Electronic (1 Min DCS Data), & Lab Data to Develop Computer Control Programs**
- **DCS Programming with Operational Code**
- **Operator Training and Debugging**
- **Several Site Visits for Installation and Training**
- **Stepwise Commissioning, and Operator Training in:-**
 - **Free SO₄ Operation & Control,**
 - **Target P₂O₅ Strength Control,**
 - **Filter Feed and Multi-Filter Operation,**
 - **Finally Level Control & Rock Feed.**

Implementation Of Full APC

Total Installation Cost Say About \$450K

A 1% Recovery Improvement at 4000 tpd P_2O_5 is 40 tpd

A 2% Production Improvement at 4000 tpd P_2O_5 is 80 tpd

At Roughly \$350/ ton P_2O_5 @ 120tpd is thus \$40,000 per day!!

● About a 12 Day payback!!

If you are @ 1200 tpd P_2O_5 then about a Month!!!

SMOOOOOOOTH Running!!

Poor Operation, \$980,000 pa.

Higher Losses \$750,000 pa.

Upsets, Plant Crashes, \$850,000 pa.

Higher Scaling Costs, \$350,000 pa

Operator Mistakes \$699,997.7 pa.

Good Control....Priceless (MasterCard Ad)

Thank You

VaughnAstley@DrPhosphate.com

A Set of Notes in French are shown in “notes’ view

Des commentaires en langue Française de la présente présentation y sont incluses