Spring 2015

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

Vaughn Astley

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		EHCU	EHPAS
EMAS	ETS	EVTOP	FEDS	HICUS
ICC	ICWS	IEDIS	LDAS	NAICC
TCS	VSES	WVVWS		

Who Knows What These Do?

APC

4EAT	4 Speed Electronic Automatic Transmission
ABS	Antilock Brake System
ACE	Active Cornering Enhancement
ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance System
AGVS	Automated Guided Vehicle System
ARC	Active Roll Control
ASR	Acceleration Slip Regulation
ASTC	Automatic Stability and Traction Control
ATTS	Advanced Torque Transfer System
AYC	Active Yaw Control
CVRSS	Continuous Variable Road Sensing Suspension
DMCM	Driver Motor Control Module
DSCC	Distance Sensing Cruise Control
EAS	Electrically Assisted Steering
EBCM	Electronic Brake Control Module
EBD	Electronic Brake force Distribution
EBTCM	Electronic Brake Traction Control Module
ECD	Electronically Controlled Deceleration
ECM	Engine Control Module
EDR	Event Data Recorder
EHCU	Electronic Hydraulic Control Unit
EHPAS	Electric Hydraulic Power Assisted Steering
EMAS	Engine Management and Analysis System
ETS	Enhanced Traction System
EVTOP	Enhanced Tactical Vehicle Occupant Protection
EGRCMDS	EGR Motor Commanded In Steps
FEDS	Flexible Engine Diagnostic System
HICAS	High Capacity Actively Controlled Steering
ICC	Intelligent Cruise Control
ICWS	Intersection Collision Warning System
IEDIS	Integrated Electronic Distributorless Ignition System
LDAS	Lane Departure Avoidance System
NAICC	Navigation-Aided Intelligent Cruise Control
TCS	Traction Control System
VSES	Vehicle Stability Enhancement System
WVVWS	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, P_2O_5 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 P_2O_5 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.

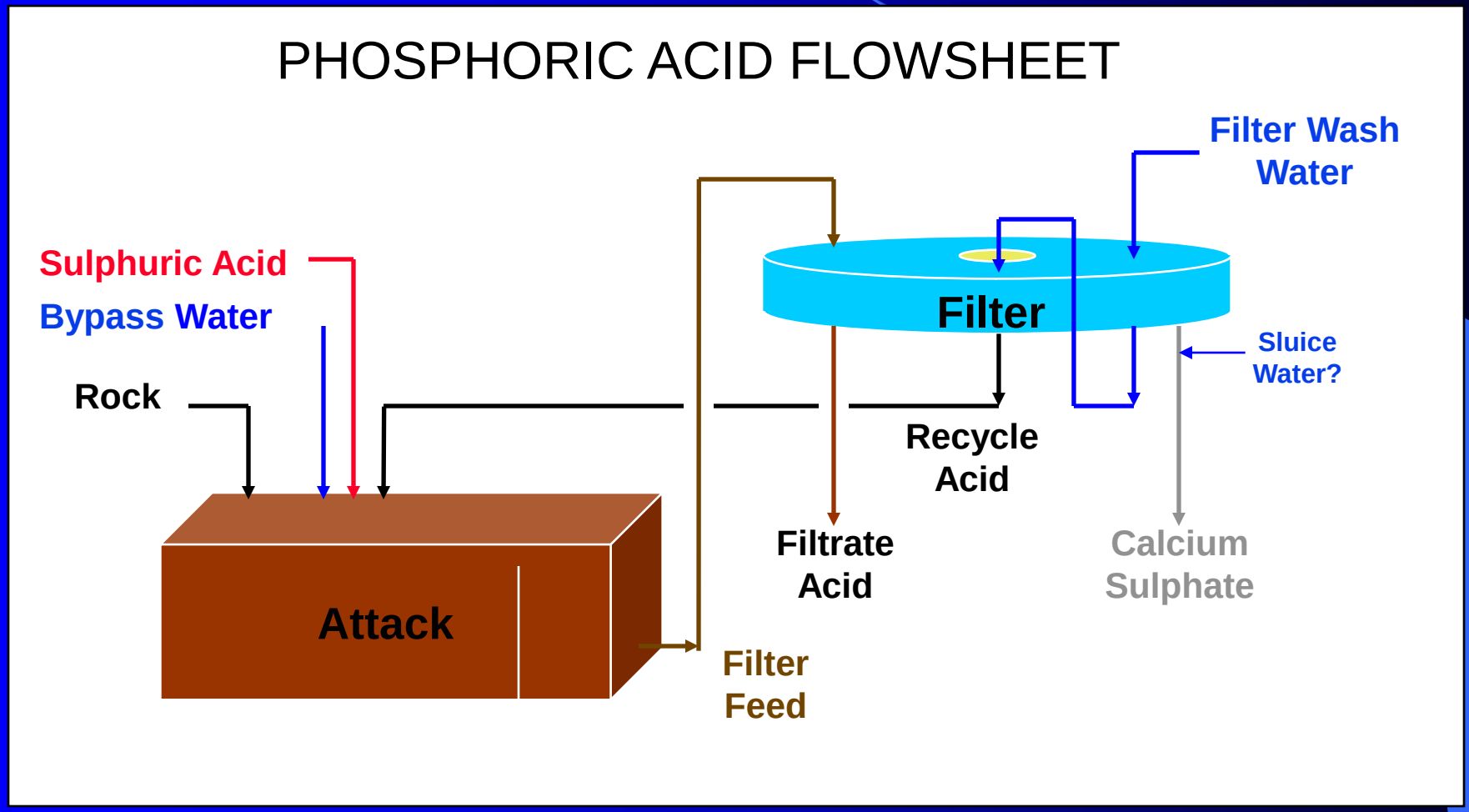
APC

SO HOW DOES IT WORK!!!!

APC

- Sulphate Control
- Phosphoric Acid Strength Control
- Filter Feed Control
- Filter Feed Level Control
- By ……Finally Controlling Rock Rate

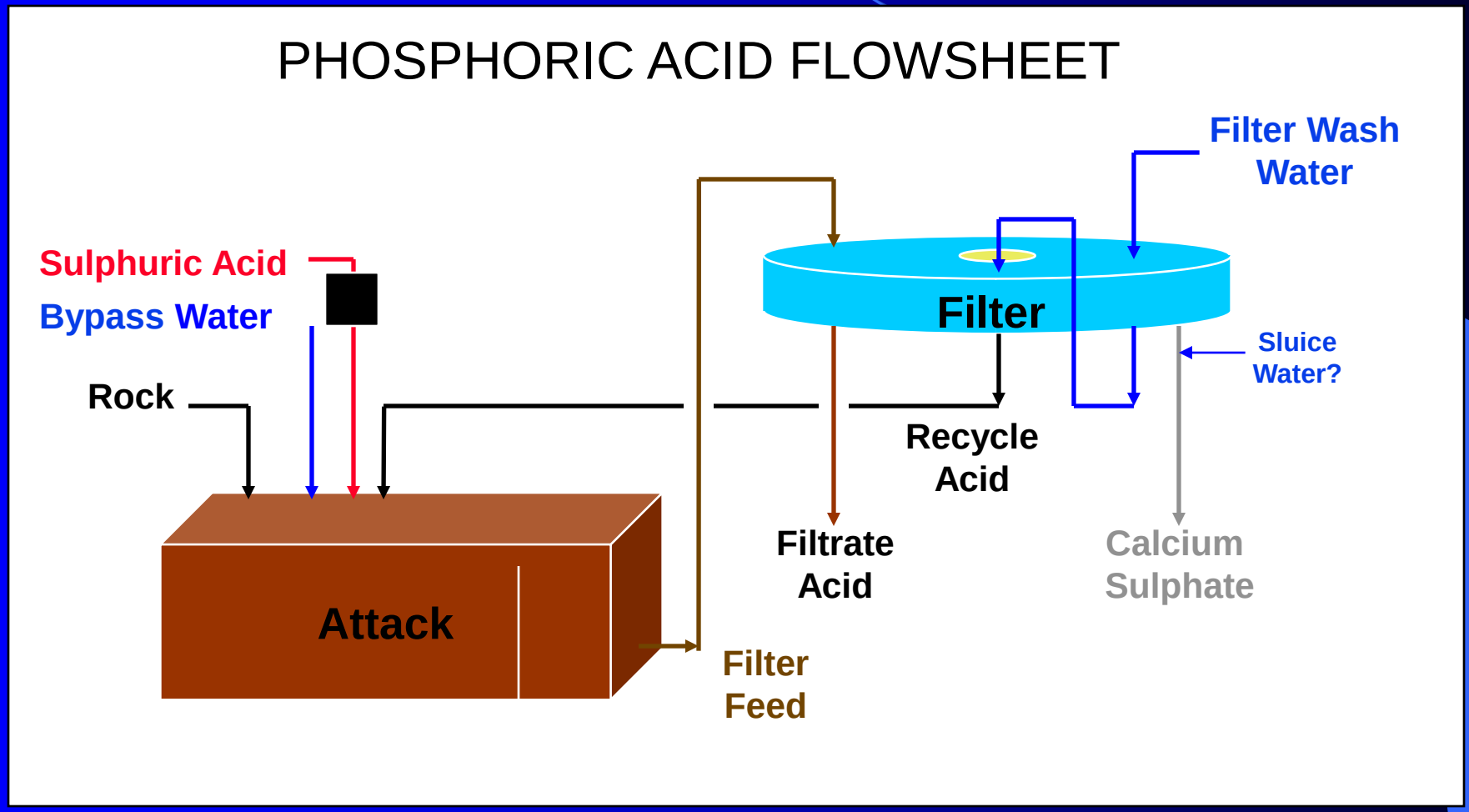
APC


PHOSPHORIC ACID FLOWSHEET
Filter Wash Water
Sulphuric Acid
Bypass Water
Rock
Filter
Sluice Water?
Recycle Acid
Filtrate Acid
Calcium Sulphate
Attack
Filter Feed

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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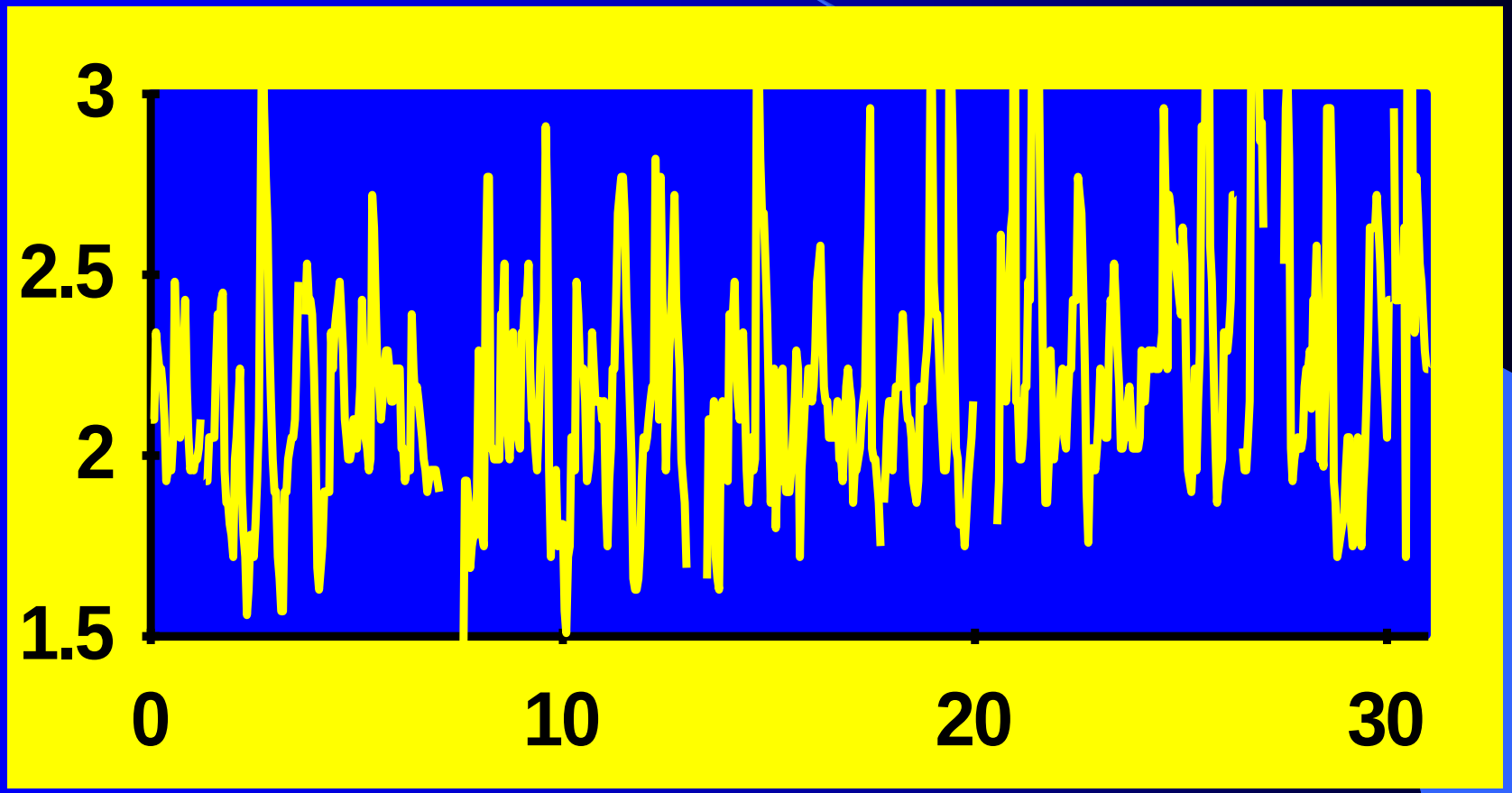
Filter Feed

Target ???
Act Avg 2.20
Std Dev 0.36

BC (Before Computers)

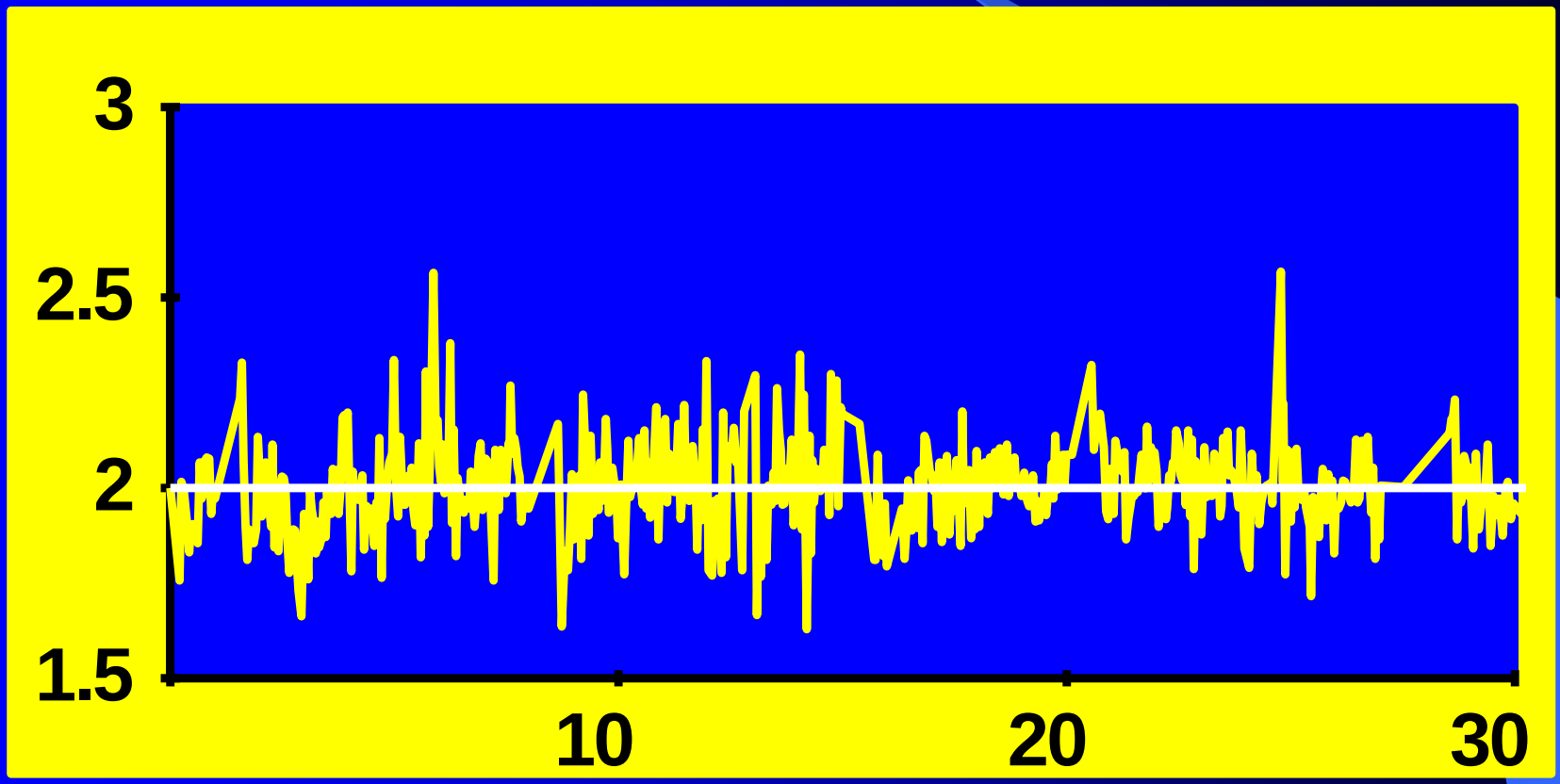
SO_4 Control



March, 1988

Target 2.00
Act Avg 2.00
Std Dev 0.12

On-Line
SO_4 Control

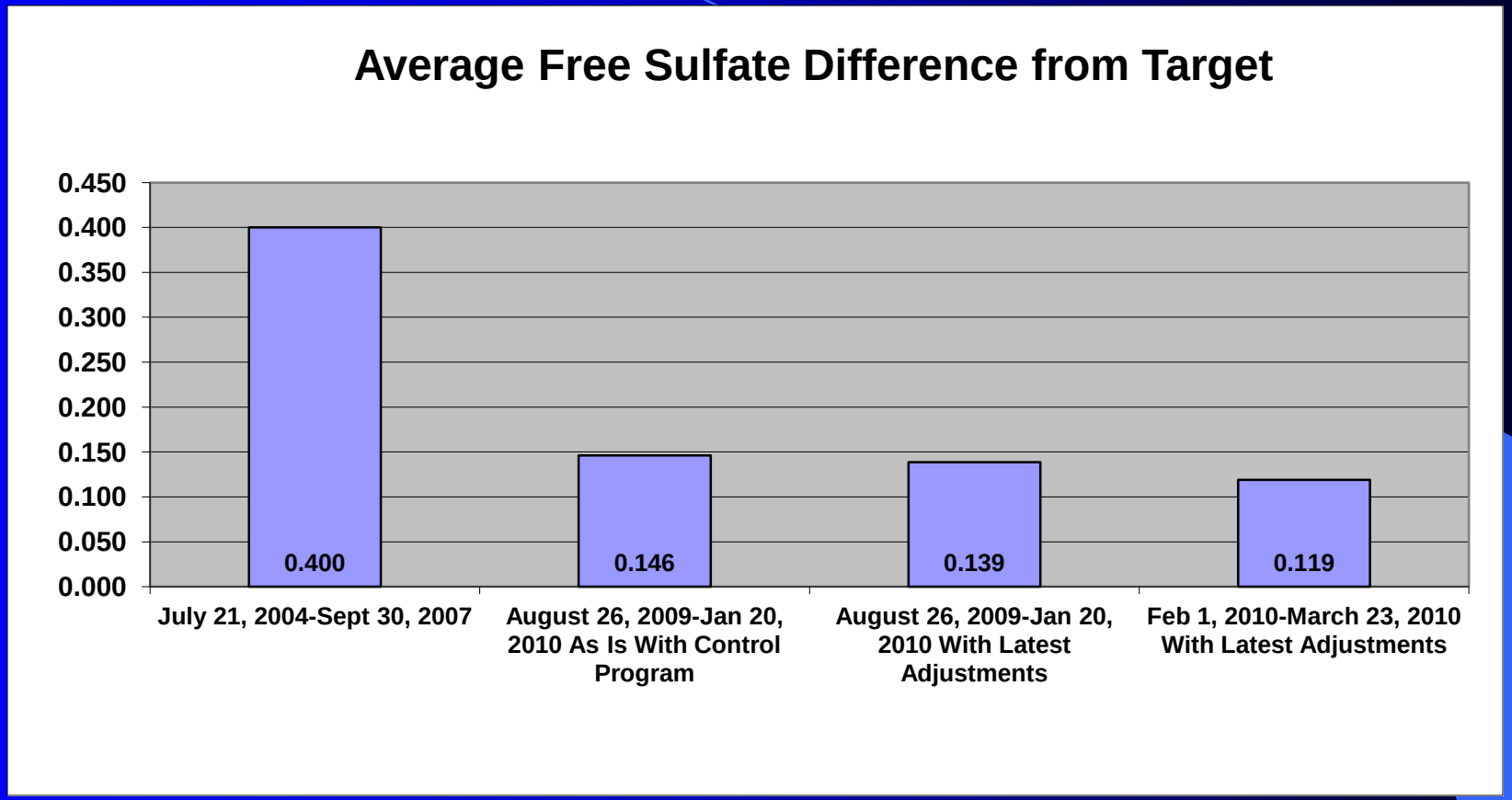


November, 1990

SO_4 Standard Deviation

More recent 2007 - 2010 Data

SO_4 Standard Deviation

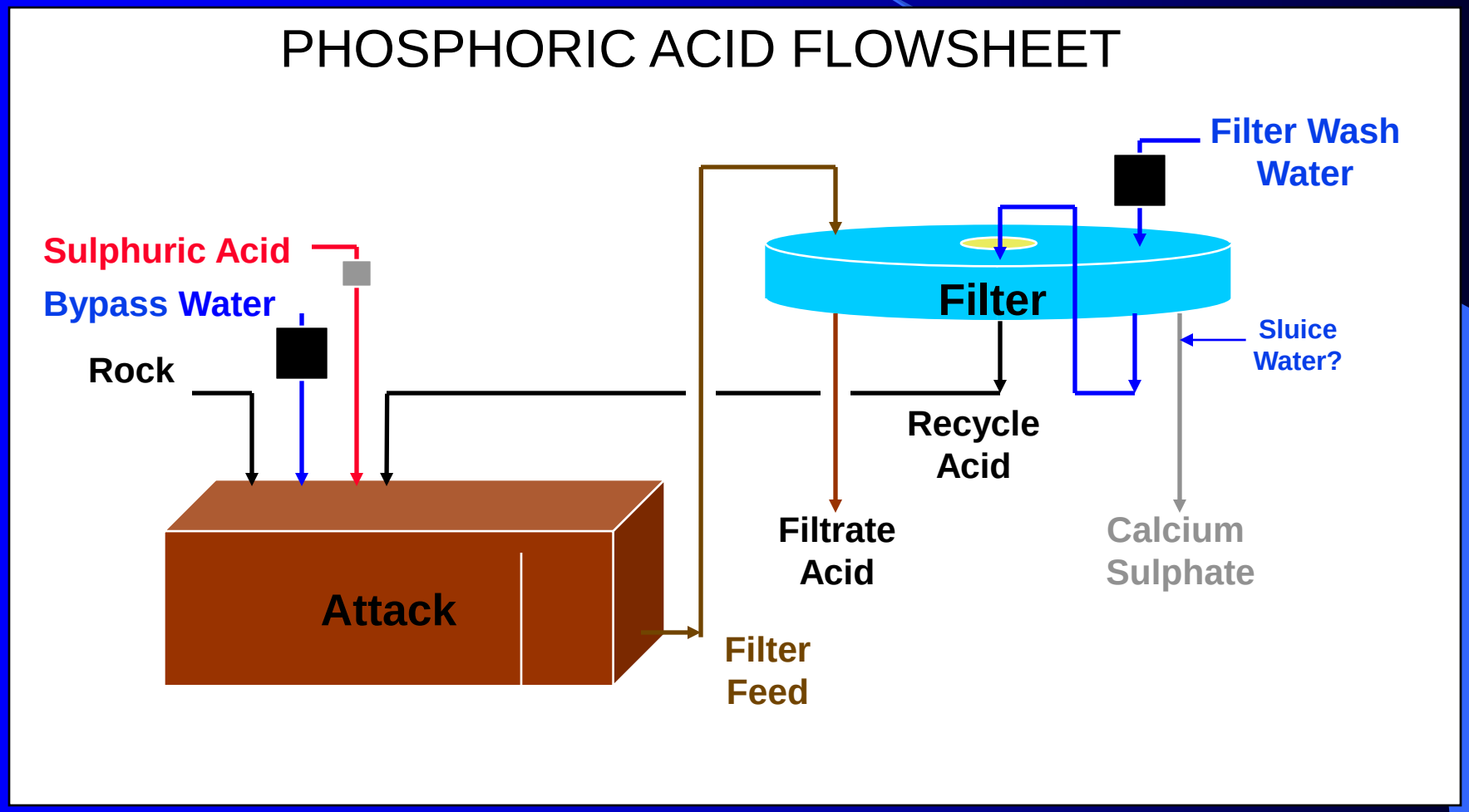


Before APC | Advisory | Partial Cascade | On-Line Full Cascade

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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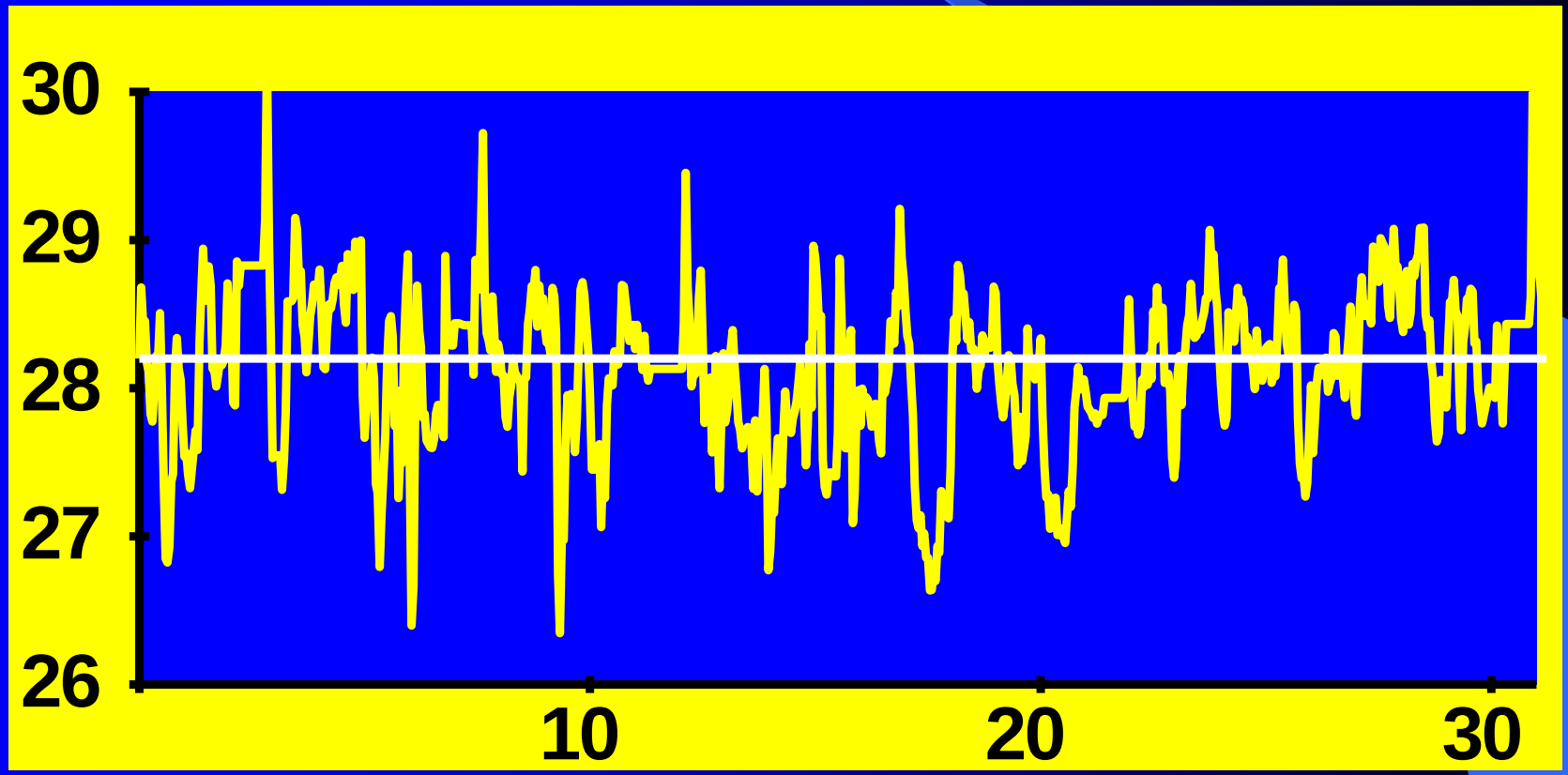
Sulphuric Acid
Bypass Water
Rock
Filter
Sluice Water?
Recycle Acid
Filtrate Acid
Calcium Sulphate
Attack
Filter Feed

BC (Before Computers)
P_2O_5 Control

Target 28.20
Actual 28.13
Std Dev 0.53



BC (Before Computers)
P_2O_5 Control

31 Days of January, 1990

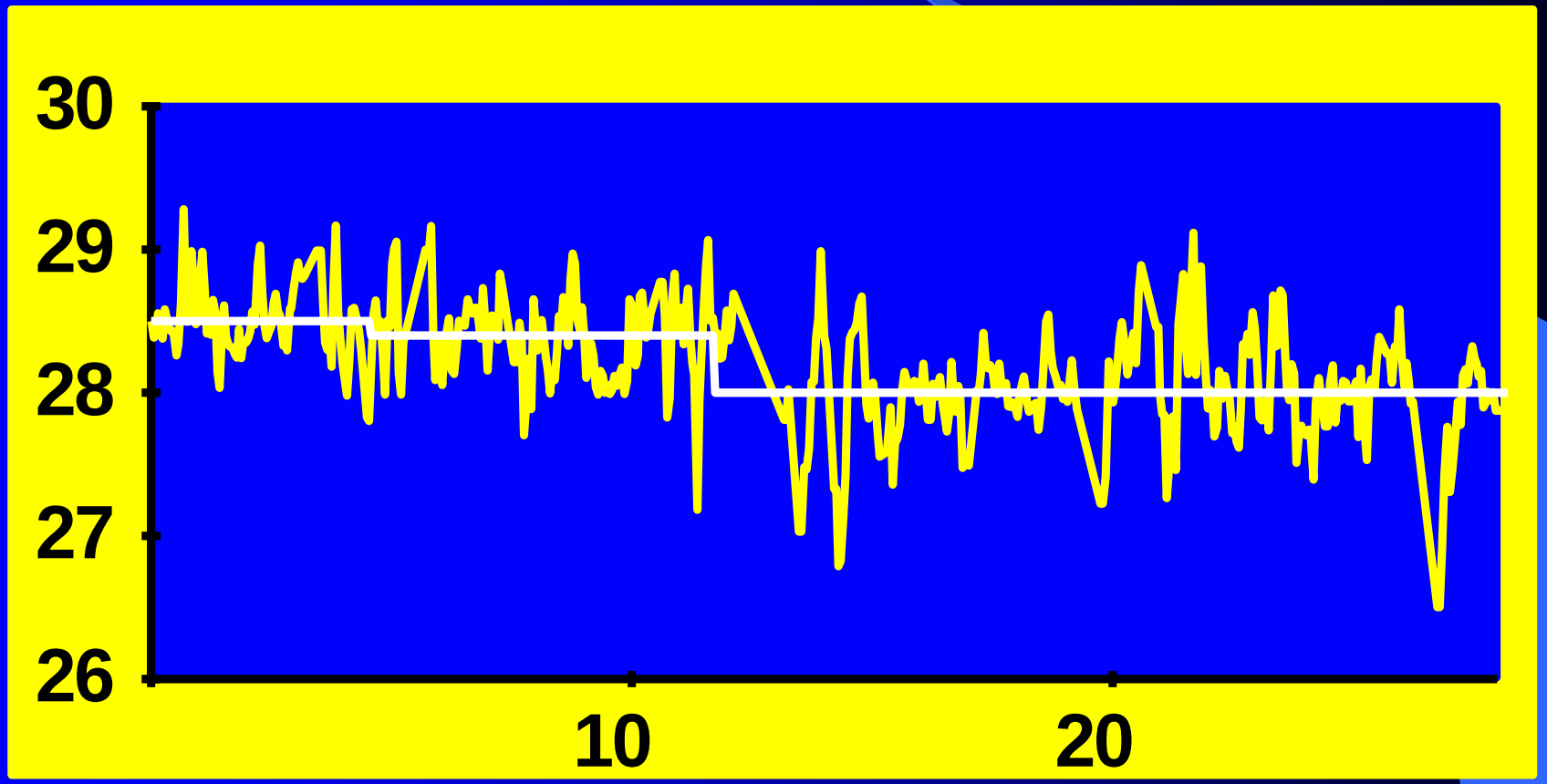
Target 28.20

Actual 28.13

Std Dev 0.53

Target 28.38
Actual 28.38
Std Dev 0.32

On-Line
P_2O_5 Control



January, 1993

On-Line
P_2O_5 Control

30 Days of November, 1993

Target 28.38

Actual 28.38

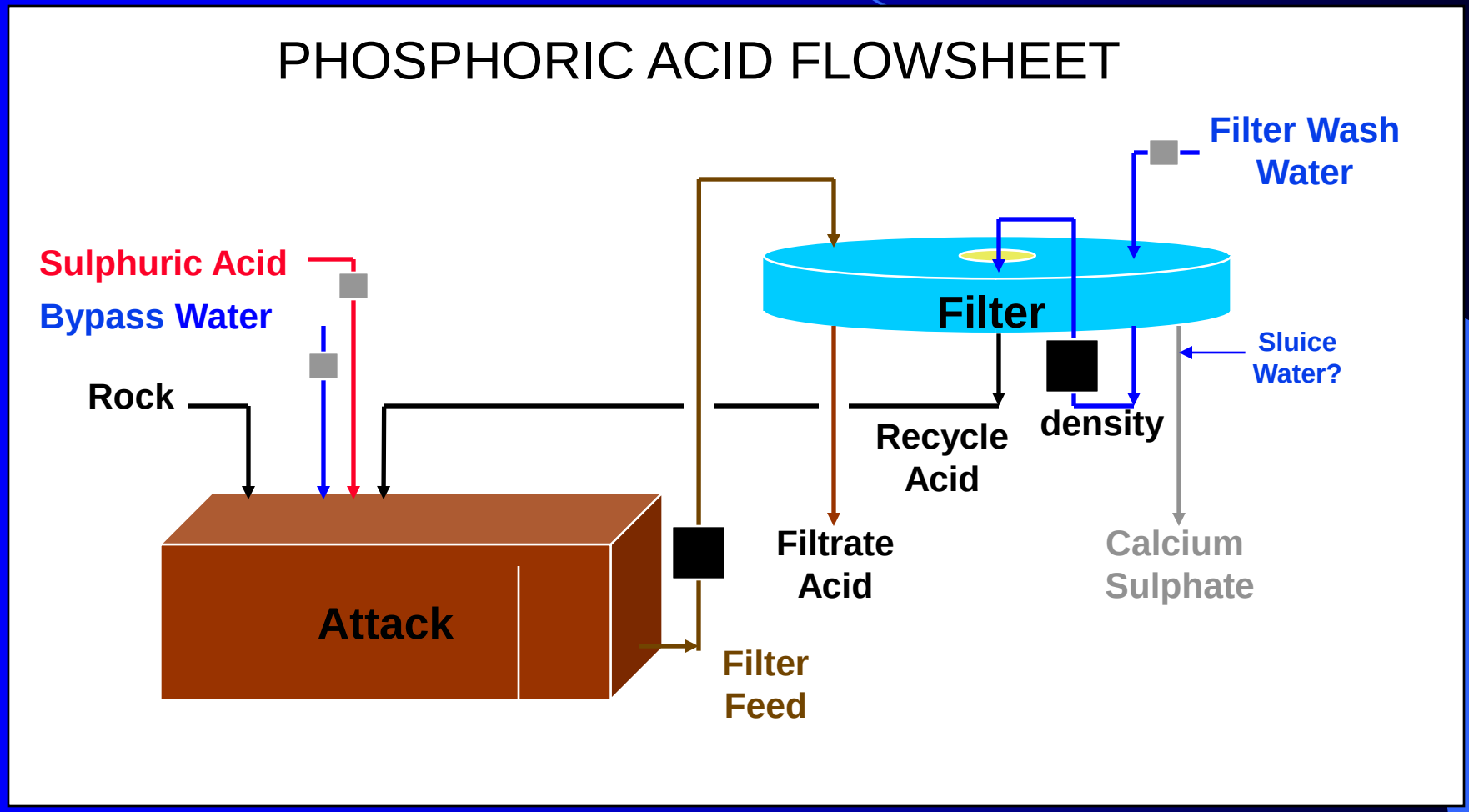
Std Dev 0.32

Was 0.53

APC

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

APC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Filter Wash Water
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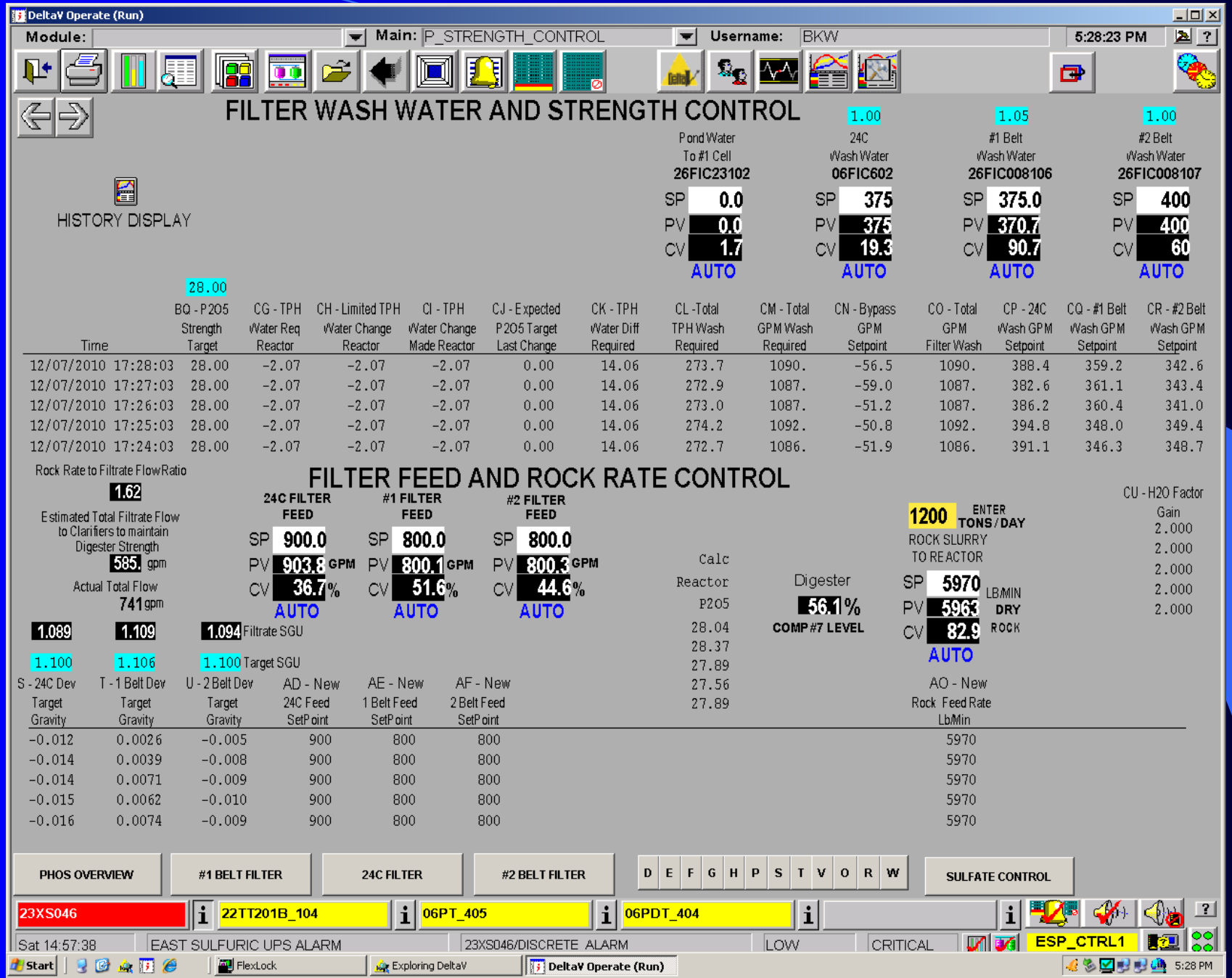
density
Filtrate Acid
Calcium Sulphate
Attack
Filter Feed

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

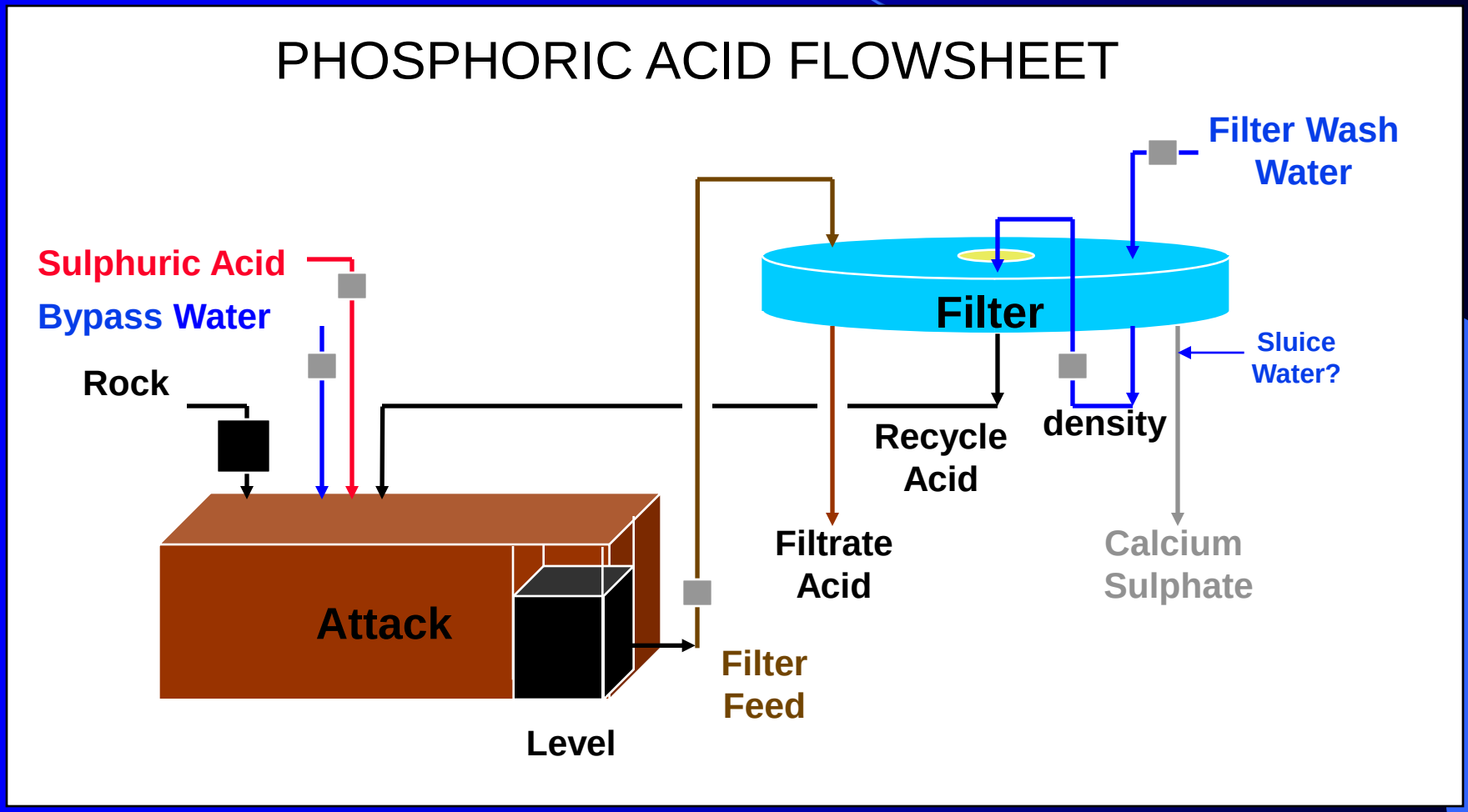
One Attack….. Three Filters!!!!!



APC

- Sulphate Control ……..……..Done
- 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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Filter Wash Water
Sulphuric Acid
Bypass Water
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Filter
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density
Filtrate Acid
Calcium Sulphate
Attack
Filter Feed
Level

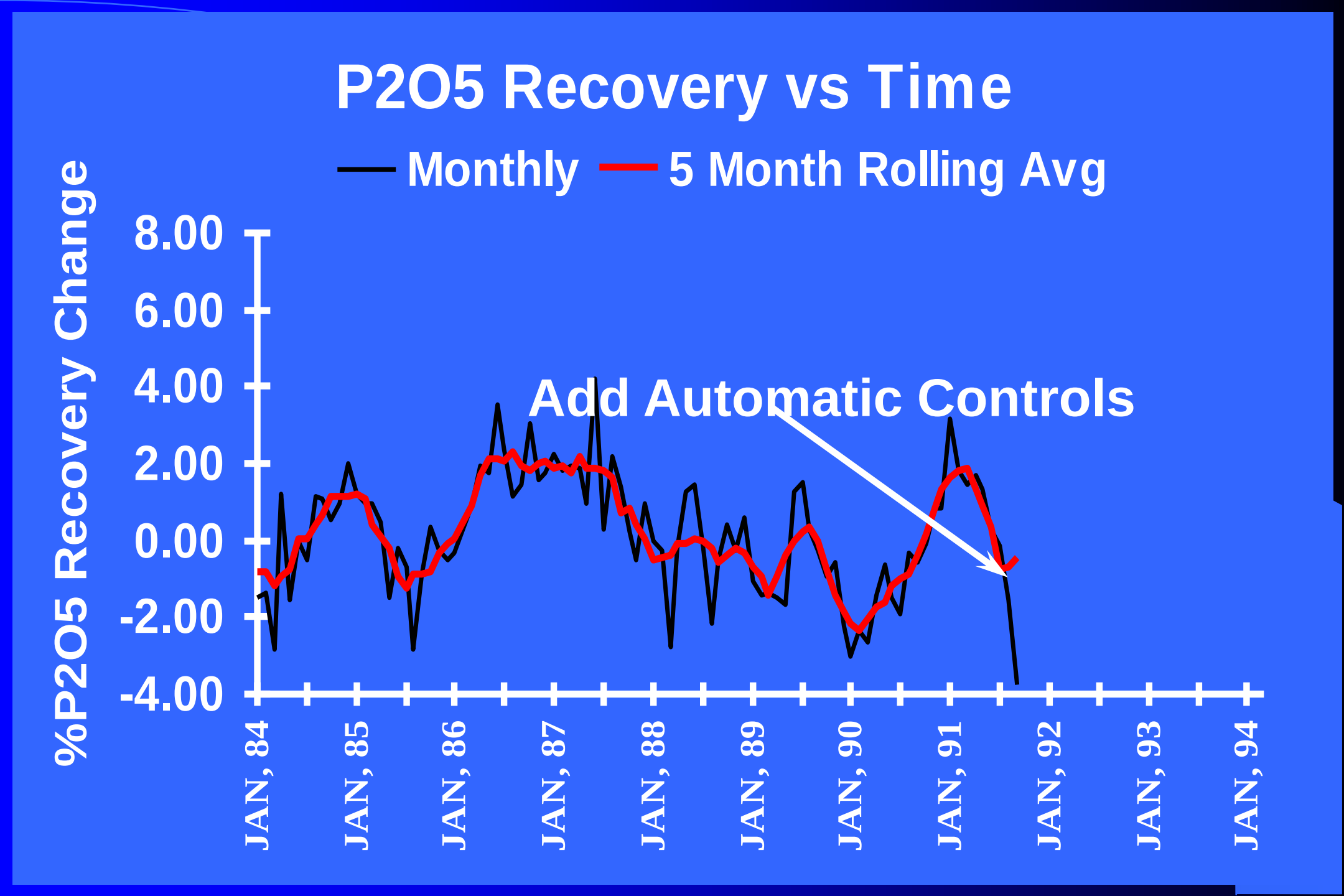
APC

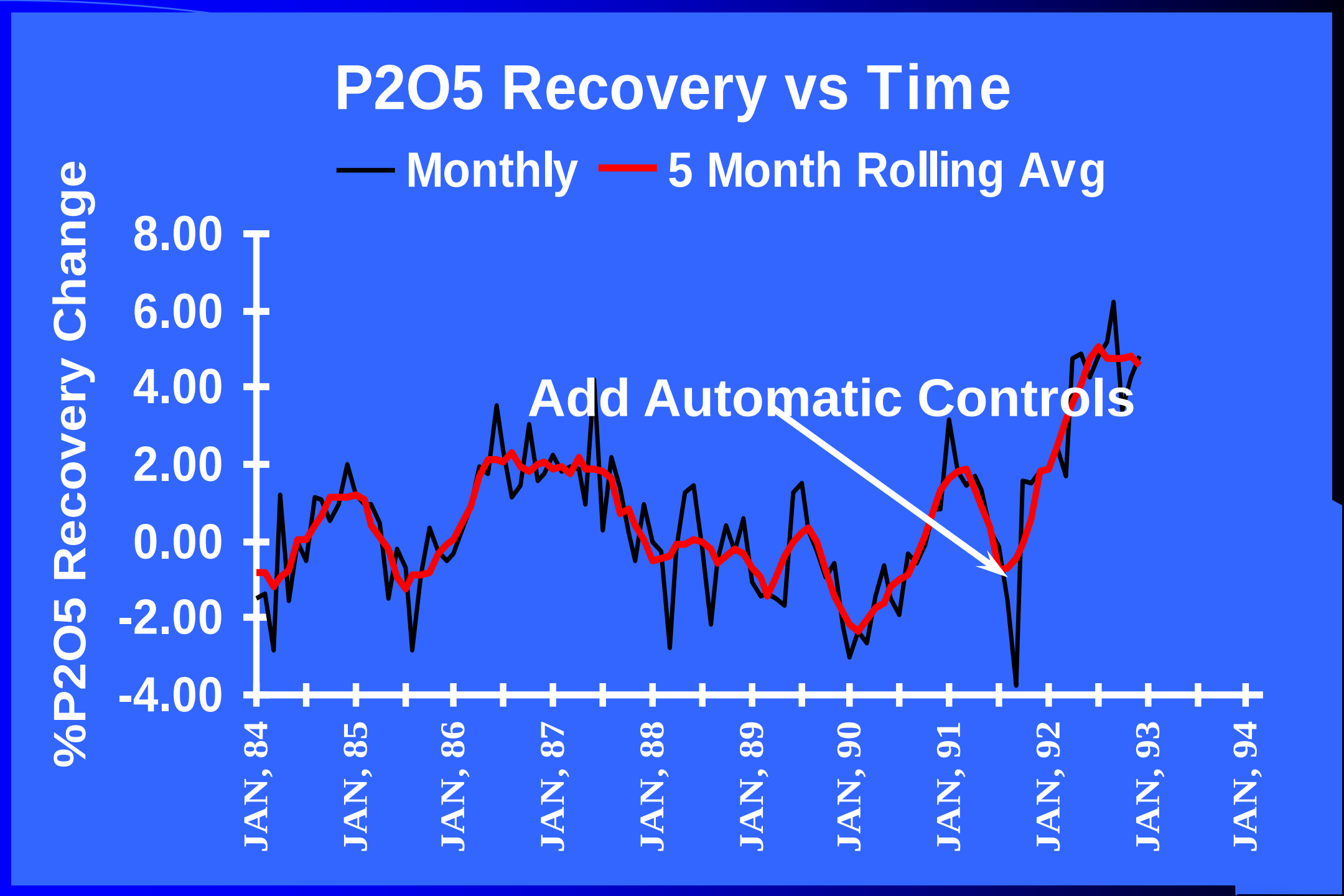
- Initially Sulphate Control was the Focus for First Two or Three Years.
- The Next Several years were Needed to Optimize the Programs Used to Control the More Complex P_2O_5 Attack Gravity.
- Finally, Again Three or so Years Needed for the Slurry Filter Feed and Filter Operation to be Perfected.

- So What Happened??

APC

How it Performed


P2O5 Recovery vs Time
Monthly
5 Month Rolling Avg
%P2O5 Recovery Change
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
Add Automatic Controls
JAN, 84
JAN, 85
JAN, 86
JAN, 87
JAN, 88
JAN, 89
JAN, 90
JAN, 91
JAN, 92
JAN, 93
JAN, 94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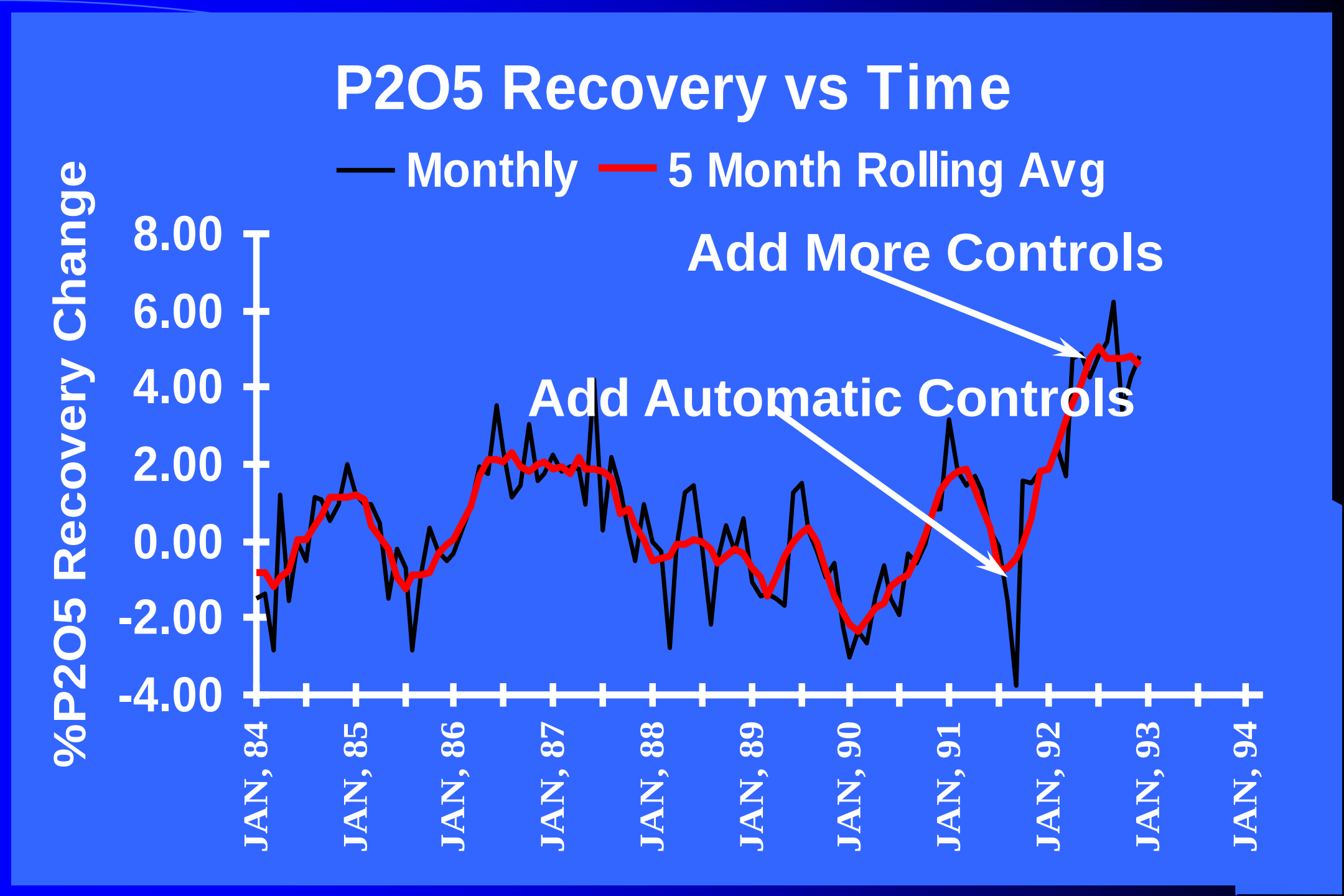
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Monthly
5 Month Rolling Avg
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8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
Add More Controls
Add Automatic Controls
JAN, 84
JAN, 85
JAN, 86
JAN, 87
JAN, 88
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JAN, 93
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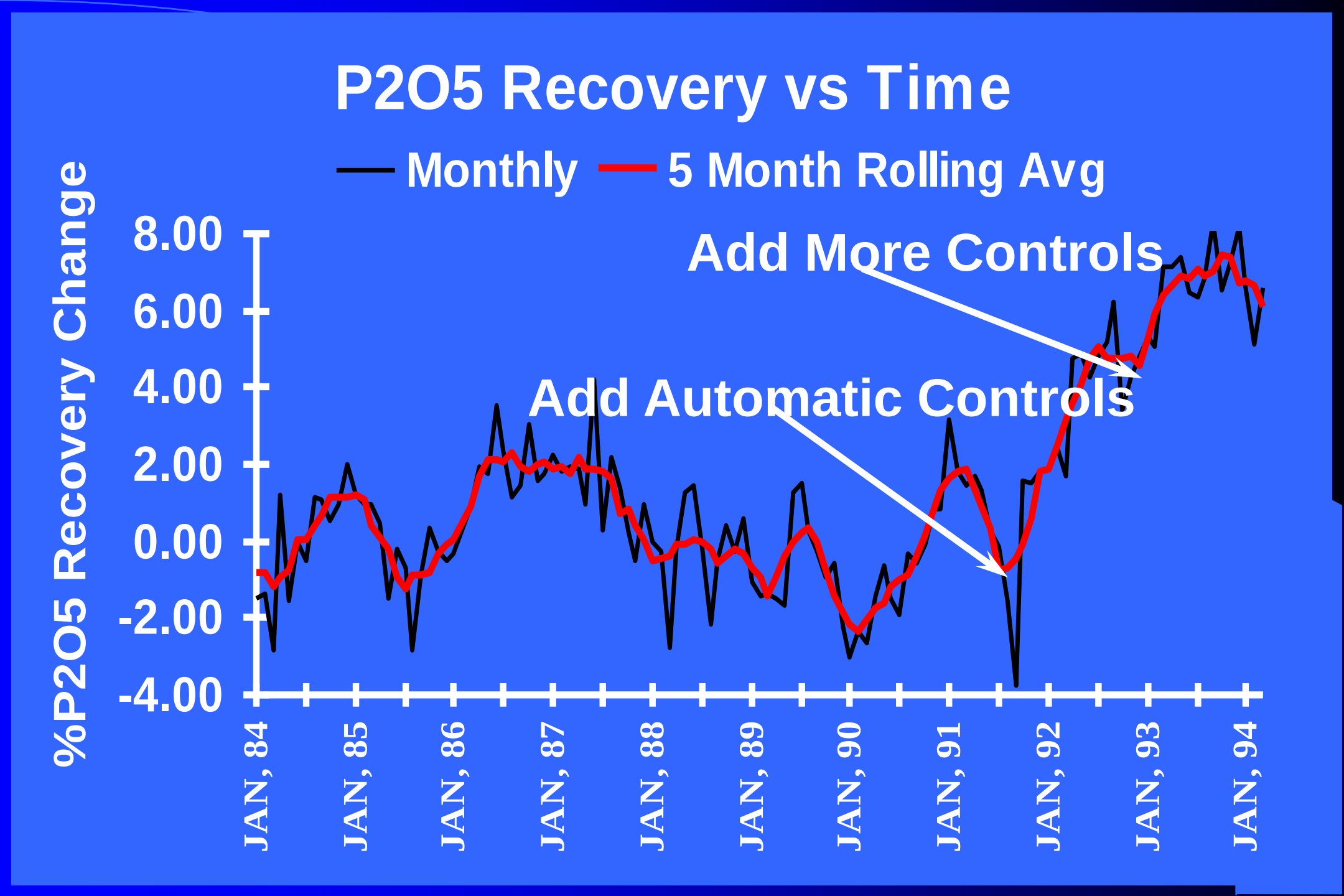
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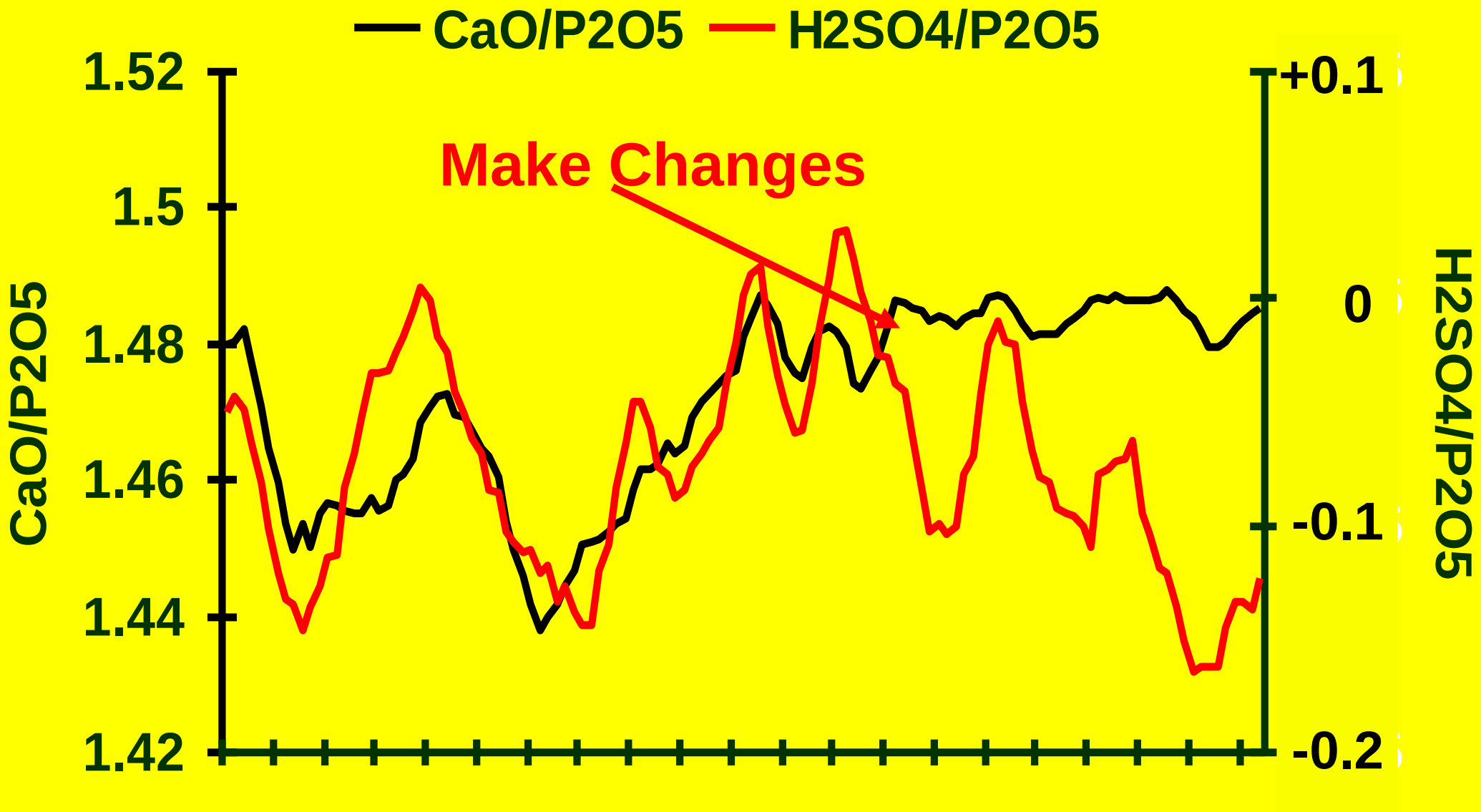
H2SO4/P2O5 vs CaO/P2O5



Average Daily Production

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

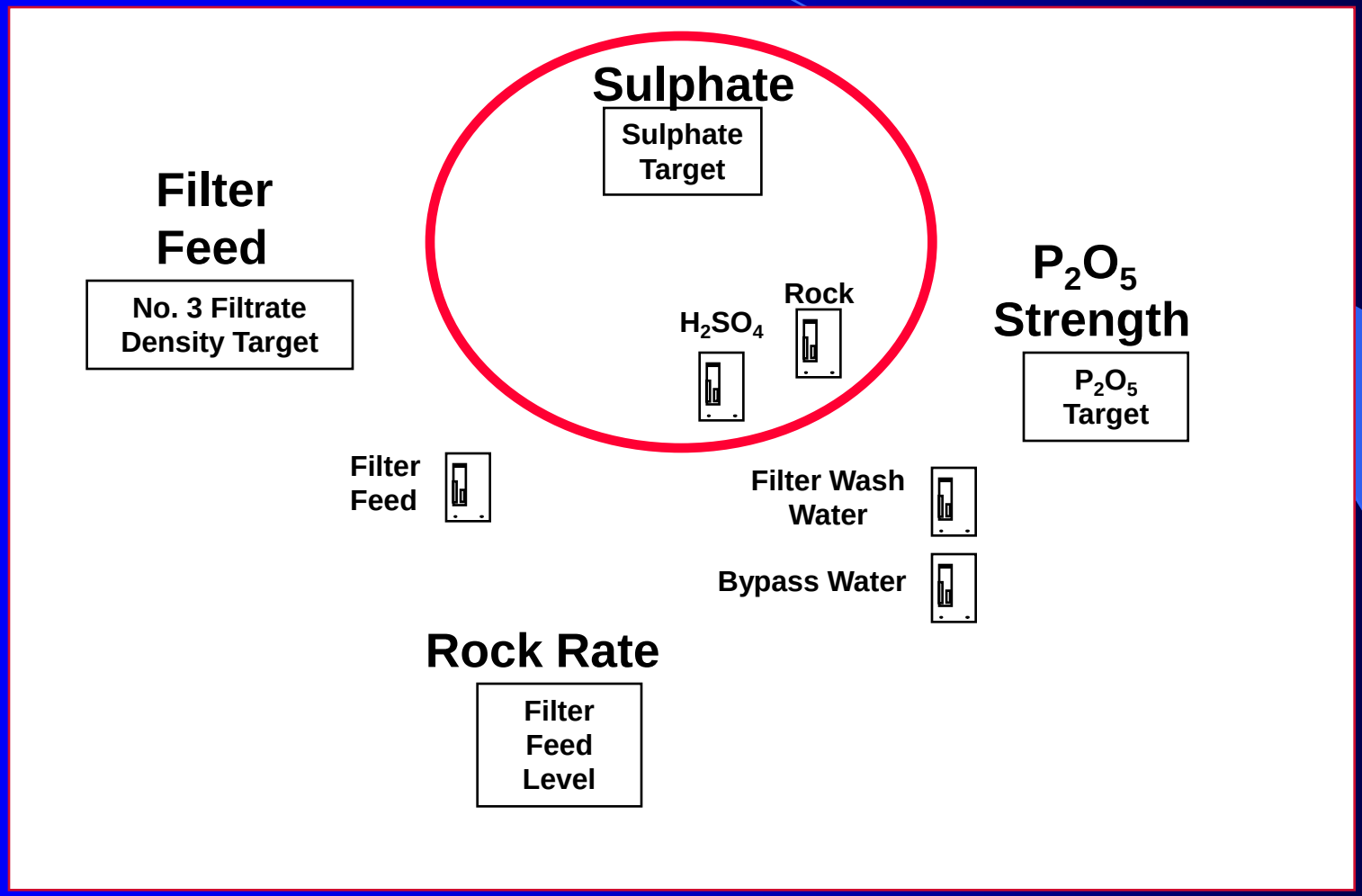
APC

- 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!!!

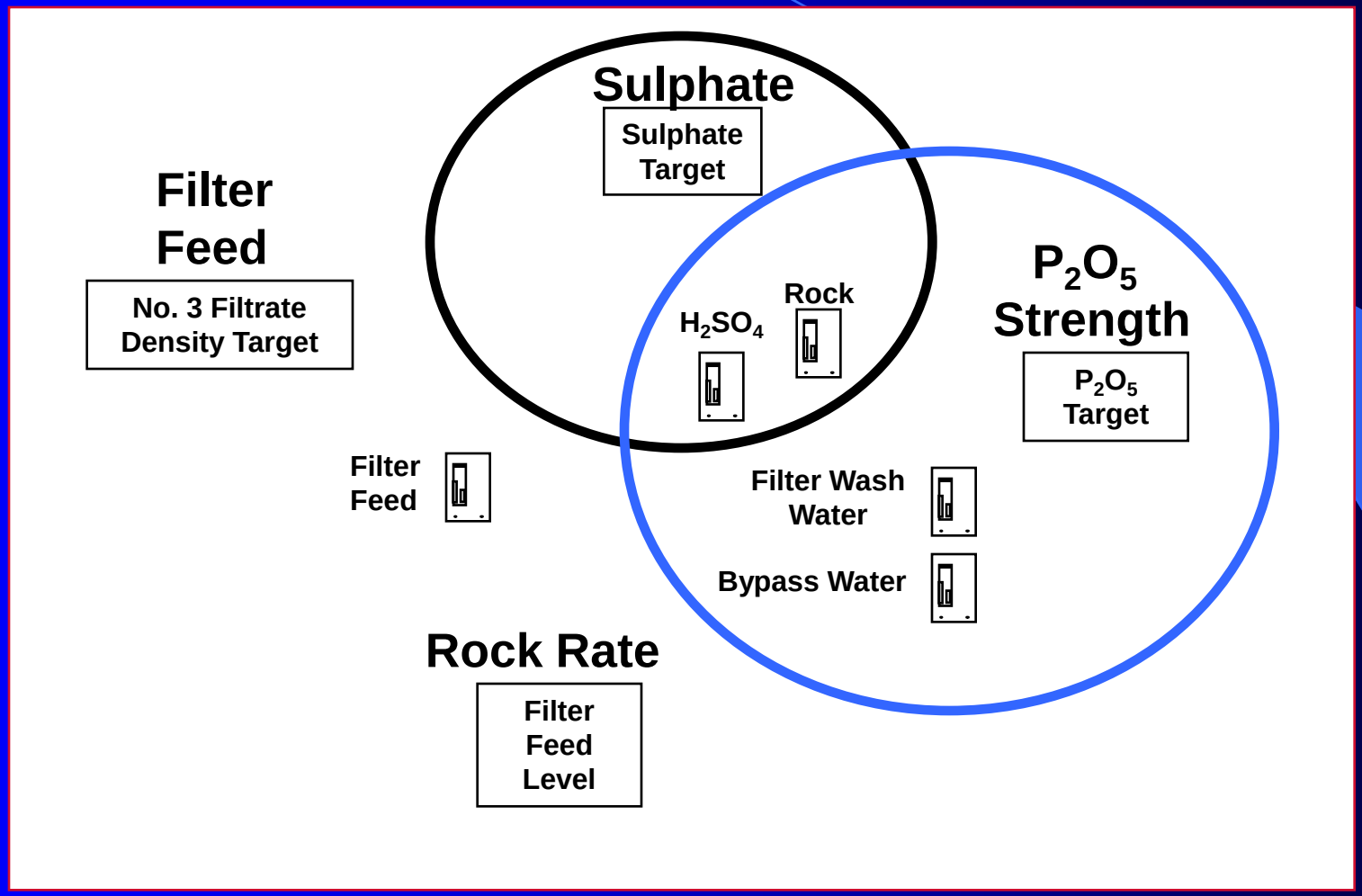
APC

- **How It All Links Together…..**

The PhosAcid Control Strategies



The PhosAcid Control Strategies



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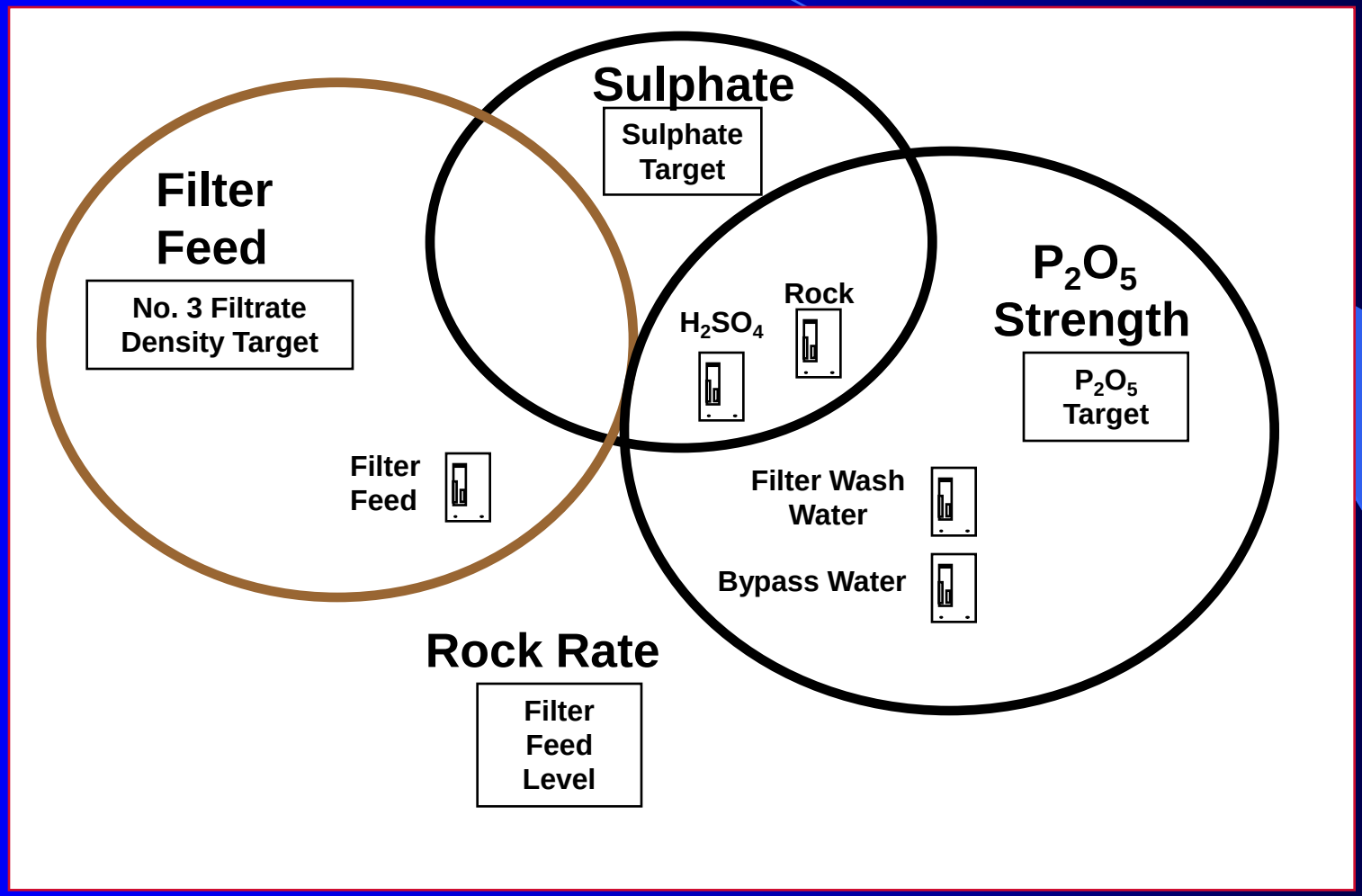
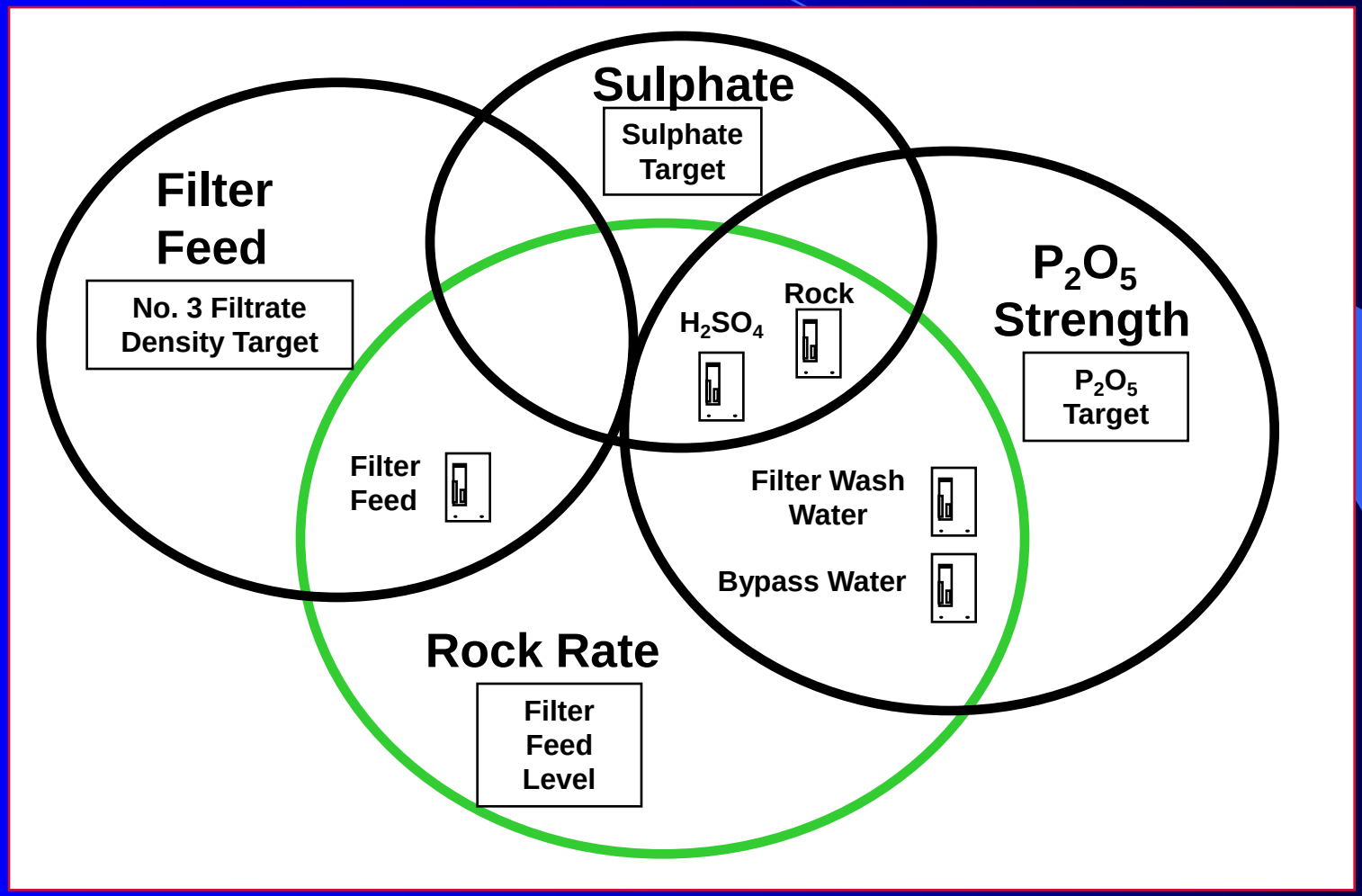


The PhosAcid Control Strategies



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 SO_4 Operation & Control,
  - Target P_2O_5 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