

Using Analyzer Meta-Data for Automated Troubleshooting

Presenters

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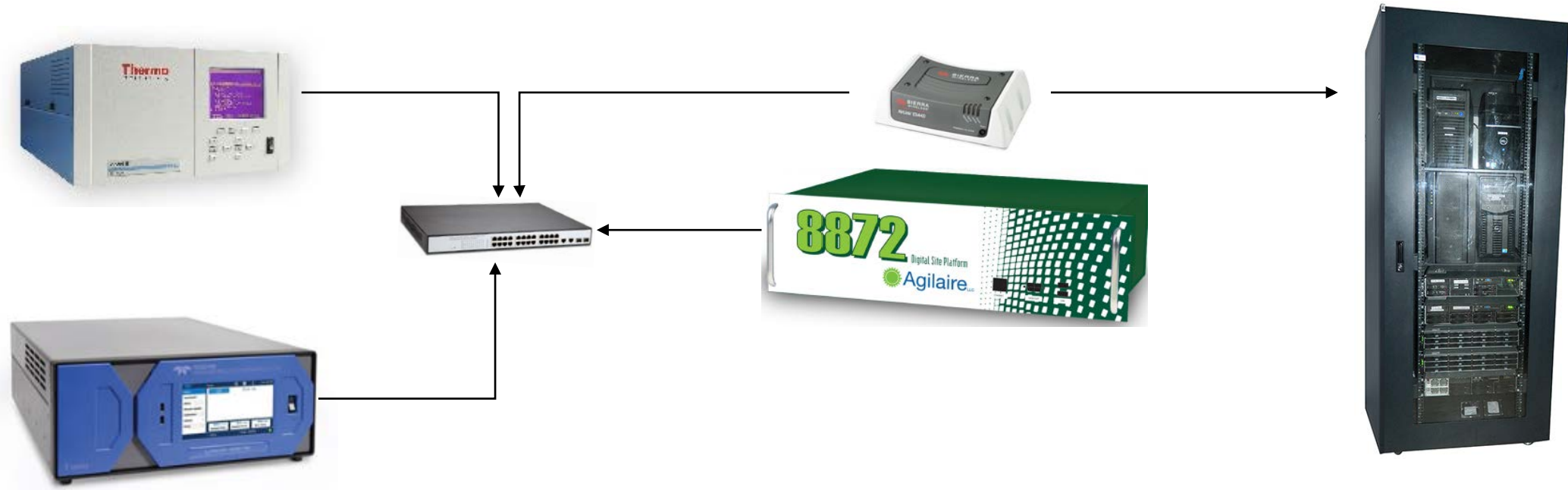
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Presentation Outline

- What is meta-data and how is it gathered?
- What does the Santa Barbara County network look like?
- The current state of technology and capabilities of equipment.
- Basic (inherent) benefits to gathering digital meta-data.
- How Santa Barbara uses meta-data for automated troubleshooting.
- Common problems, growing pains, and pitfalls.
- Joel Craig – Second half of presentation.

What is meta-data? How is it gathered?

- Definition (met·a·da·ta) – a set of data that describes and gives information about other data.
- Air Monitoring: Data that gives information regarding the functionality of the instrument, which dictates the quality of the measurement.
 - Flow rates, pressures, temperatures, voltages.
- Master (data logger) sends request to slave (gas analyzer) for a register response (flow rate). Repeats data request based on polling interval.



What does Santa Barbara's network look like?

- Santa Barbara district staff operate 8 monitoring stations.
- Of these 8 stations, 2 are collecting all gas concentration data and meta-data using Modbus RTU over TCP via Ethernet.
- All 8 stations have the majority of the gas analyzers, calibrator, and zero air generator reporting Modbus meta-data.
- Meta-data is collected on both 1 minute and hourly intervals.
- Currently collecting roughly 210 different meta-data parameters from the 8 stations we operate.
- We have experience using gas analyzers manufactured by Thermo and TAPI.
- We use a combination of data logger models 8832 and 8872.

Current state of technology

- Fact or Fiction? The majority of the ambient air monitoring community has transitioned to the digital acquisition of data (Modbus)?
- Modbus has been around a long time.
 - Simple and robust serial protocol developed in 1979.
 - Found analyzer manual sections for Modbus back to 2007.
- Gas analyzer (slave) only half the equation.
- Seems to have stuck as the industry standard. Comes nearly pre-configured from several major vendors.
- Personal experience things are still improving today

Basic inherent benefits to modbus data

- Option to gather many parameters.
- Less wires on the back of the rack. Cleaner.
- No voltage calibration, noise immune, no approximation errors.
- Allows for better QC of data and minute resolution on point of failure identification.
- Historical trend of instrument performance.
- Allows for automated troubleshooting of instruments and pre-emptive instrument failure notification.

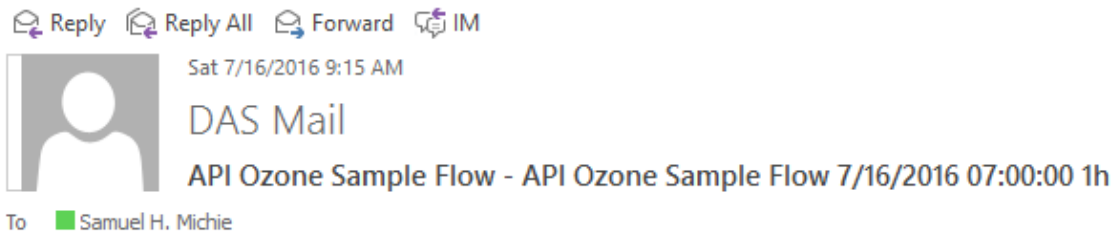
How we have automated troubleshooting

Air Vision ADVP Editor

The screenshot displays the 'Air Vision ADVP Editor' interface. It is divided into several sections:

- Rule Information:** Includes 'Rule Name' (API Ozone Photo Referenc), 'Description' (API ozone analyzers photometer reference alarm), 'Average Interval' (001h), and 'Max Lookback Intervals' (24).
- Actions:** Contains fields for 'Site', 'Parameter Template' (O3_REF), 'Assign Value', 'Assign Data Grade', 'Apply Null Code', 'Clear Null Code', 'Apply Qualifier Code', 'Clear Qualifier Code', 'Apply Flag', and 'Clear Flag'.
- Add Annotation Text:** Includes 'Subject' (API Ozone Photo Ref), 'Email Message' (API O3 Analyzer photo ref below 2600 mv), and 'Category' (QA Note).
- Conditions Triggering Rule:** Features 'Add Condition' and 'Delete Condition' buttons, a 'Condition List' (1 OR, 2 AND, 3), and 'Condition Details' for 'Condition Number' 1, 'Comparison Type' (Flag), 'Relationship' (Contains), and 'Compare' (Site, Parameter Template: O3_REF).
- To:** 'Flag Comparison Type' (h - High Alarm).

E-Mail Notification



Message: API O3 Analyzer sample flow outside +/- 10% 800 cc/m

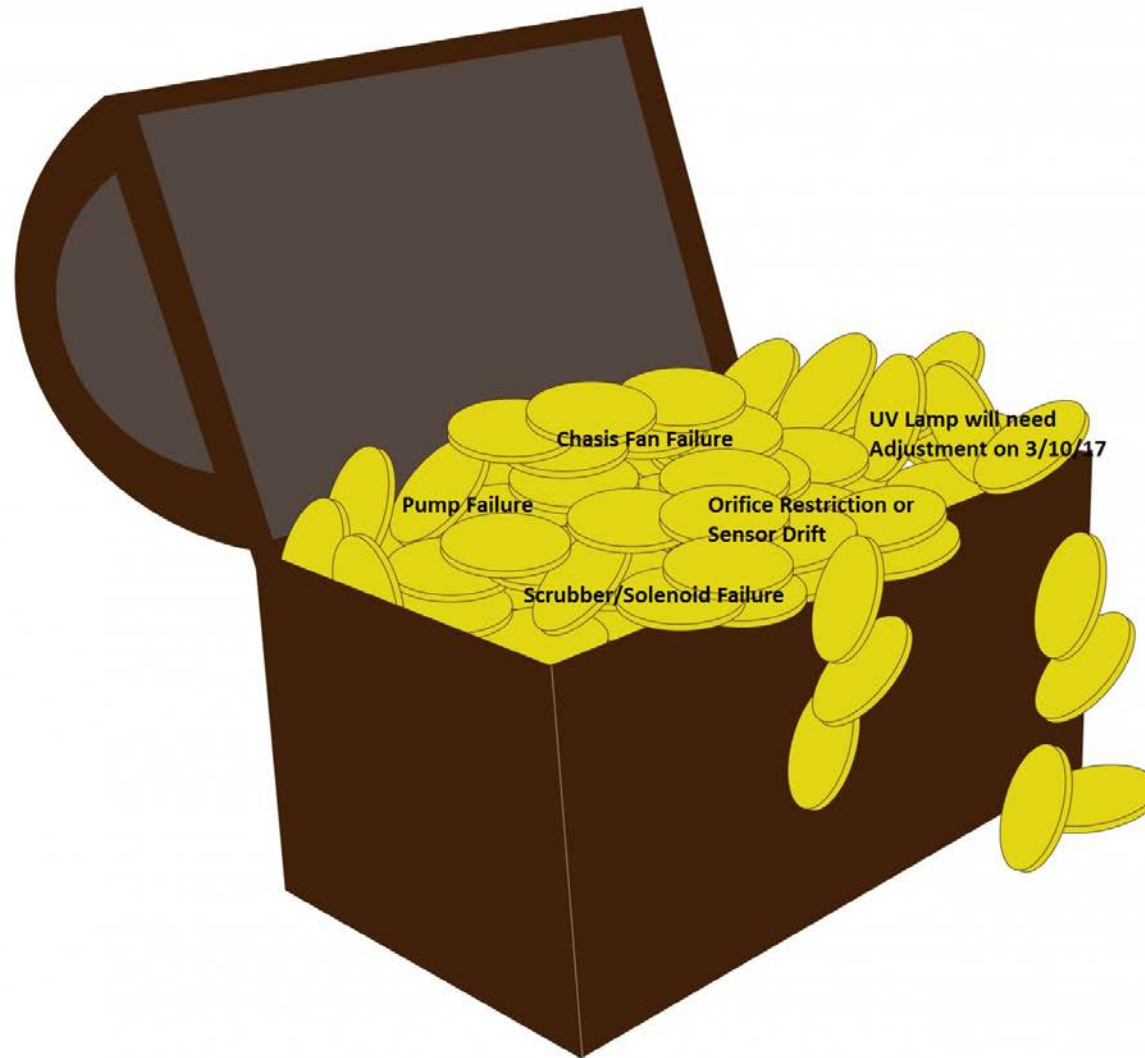
Applying Actions on reading: Goleta:O3_SampF:001h at 7/16/2016 07:00:00 with value 628.710559
-> Annotation Added "API O3 Analyzer sample flow outside +/- 10% 800 cc/m "

- Parameter outside manufacturer specifications.
- Use high/low flags in data logger and ADVP to identify flag presence.
- ADVP looks at past 24 hours once a day in the morning (lamp, Rcell).
- ADVP looks at every hour (flow).
- Rate of Change (ROC) signifies upcoming failure.

Common problems, growing pains, pitfalls

- 8832 known issues with negative registers, certain parameters report incorrectly from common analyzers.
- Data transmission errors and troubleshooting. One bad apple spoils the bunch.
- Considerable time in configuration of DAS and loggers.
- Start slow, one instrument at a time. Take the time to decide on parameters. Setup templates first. Start with meta data and slowly move towards transitioning AQS parameters.

There's Gold in that Meta-Data



But you have to dig for it...

How I Dig for Gold in Meta-Data

- Develop history of normal meta-data from each analyzer.
- Automated screening using tightened tolerance to identify any data that is not within “normal” based on data history.
- Set up patterns of out-of-tolerance that are associated with specific failures so when that pattern is detected, the likely failure is automatically identified.
- When analyzer failures occurs, use the meta-data from the period of failure to “teach” the workbook how to identify that particular failure mode.

Ways to Find the Gold Nugget-Using the Workbook

- As part of normal monthly data validation process, evaluate monthly meta-dataset.
 - Workbook provides graphs and conditionally formatted cells to quickly ID undetected problems that may require invalidation of data.
 - Workbook provides easy way to ID beginning/end of a problem requiring invalidation.
- When Other Indications Suggest a Failure (auto-cal, etc.), load partial month of meta-dataset and let workbook evaluate for failures.
 - Provides a tool to quickly troubleshoot problems prior to visiting the site.
 - Does not require extensive experience with analyzer operation to troubleshoot.

Example Monthly Data Statistics and Graphs – No Failures

Raw Hourly and Minute Statistics

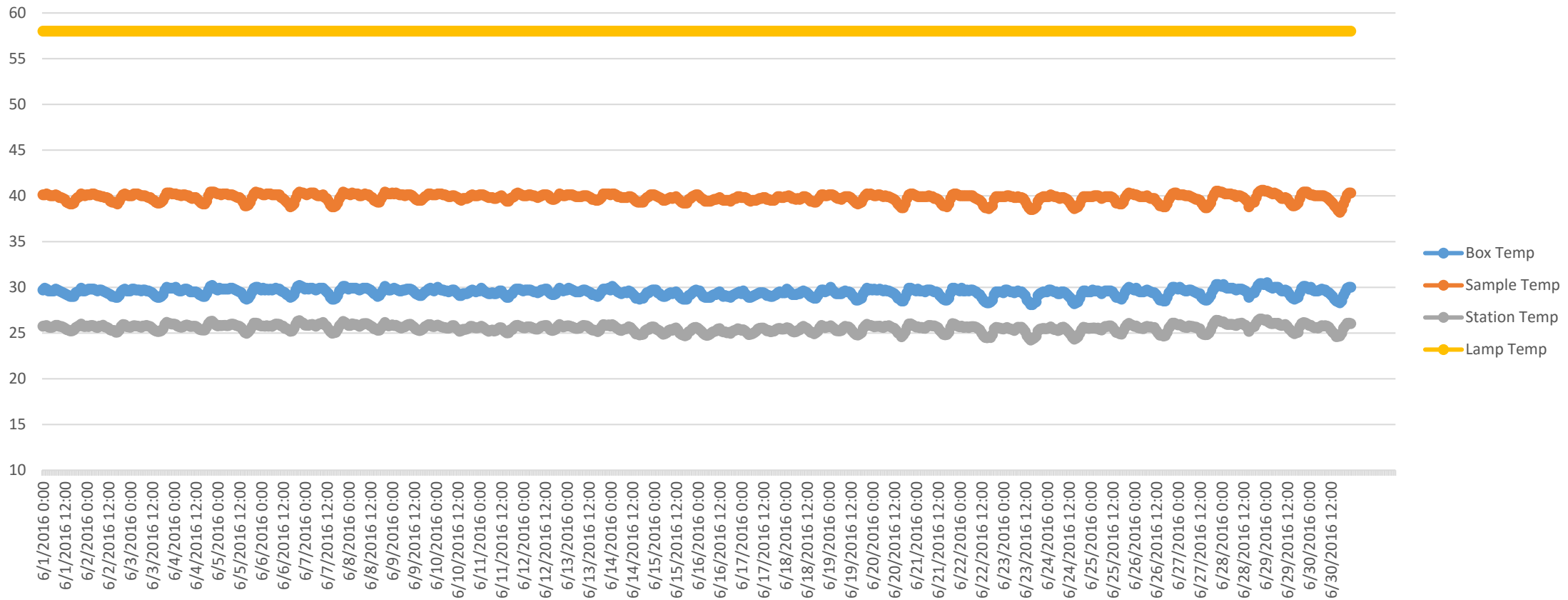
Parameter	Box Temp	Lamp Temp	O3_Ref	Flow	Samp. Temp	Samp Press	STM	Flow adj for Samp. Press	box-stm Temp	samp-box Temp	O3ref 24 hour delta	O3_Ref Minute Data	O3_Ref ZERO-SPAN
Maximum	30.50	58.00	3339.30	752.83	40.60	27.50	26.53	748.99	4.26	10.60	6.40	3340.10	0.38
Minimum	28.10	58.00	3243.50	740.42	38.20	27.10	24.23	742.91	3.52	9.90	-0.80	3243.00	-0.22
Average	29.46	58.00	3290.99	745.81	39.78	27.29	25.54	745.81	3.92	10.33	3.04	3290.89	0.1322
Standard Deviation	0.40	0.00	26.33	2.51	0.41	0.09	0.38	1.20	0.11	0.13	1.11	26.33	0.146561

Yellow box = Max/Min Warning

Red box = Max/Min Fail

Lamp Adj? NO

Station Temperature and Internal Analyzer Temperatures

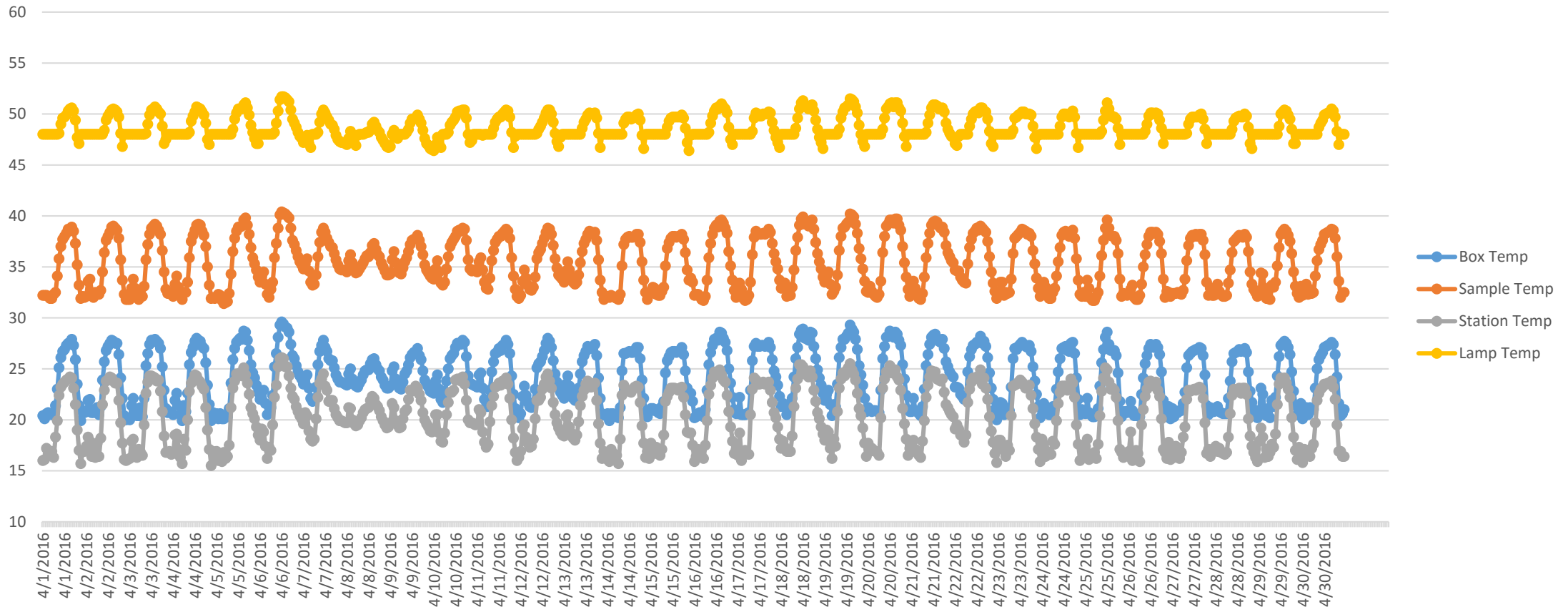


Example Monthly Data Statistics and Graphs – With Failures

Raw Hourly and Minute Statistics

Parameter	Box Temp	Lamp Temp	O3_Ref	Flow	Samp. Temp	Samp Press	STM	Flow adj for Samp. Press	box-stm Temp	samp-box Temp	O3ref 24 hour delta	O3_Ref Minute Data	O3_Ref ZERO-SPAN	
Maximum	29.60	51.70	3520.00	868.00	40.40	27.85	26.10	853.80	4.90	12.30	64.00	3520.00	6.20	=Max/Min Warning
Minimum	19.90	46.40	3277.00	827.00	31.40	27.17	15.50	829.86	2.40	10.30	-51.00	3248.00	-16.00	=Max/Min Fail
Average	24.12	48.68	3402.04	842.63	35.41	27.39	20.34	842.61	3.78	11.29	3.79	3402.27	-1.39333	
Standard Deviation	2.77	1.13	48.37	7.08	2.57	0.10	2.92	4.54	0.45	0.34	16.34	48.89	4.993992	
Lamp Adj? NO														

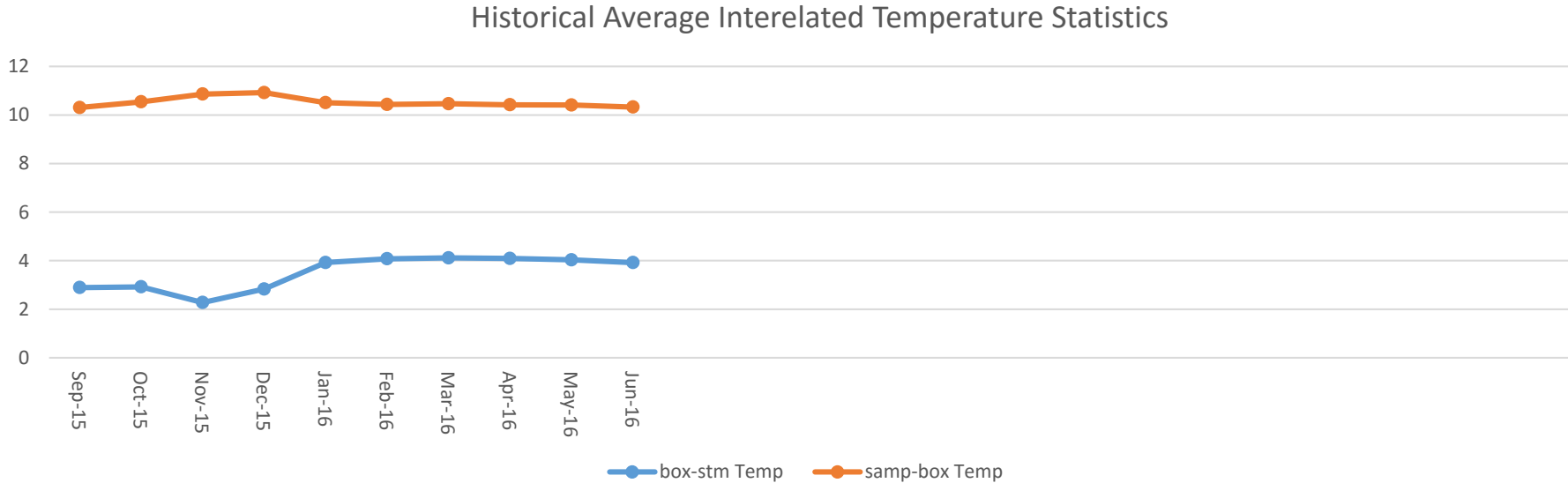
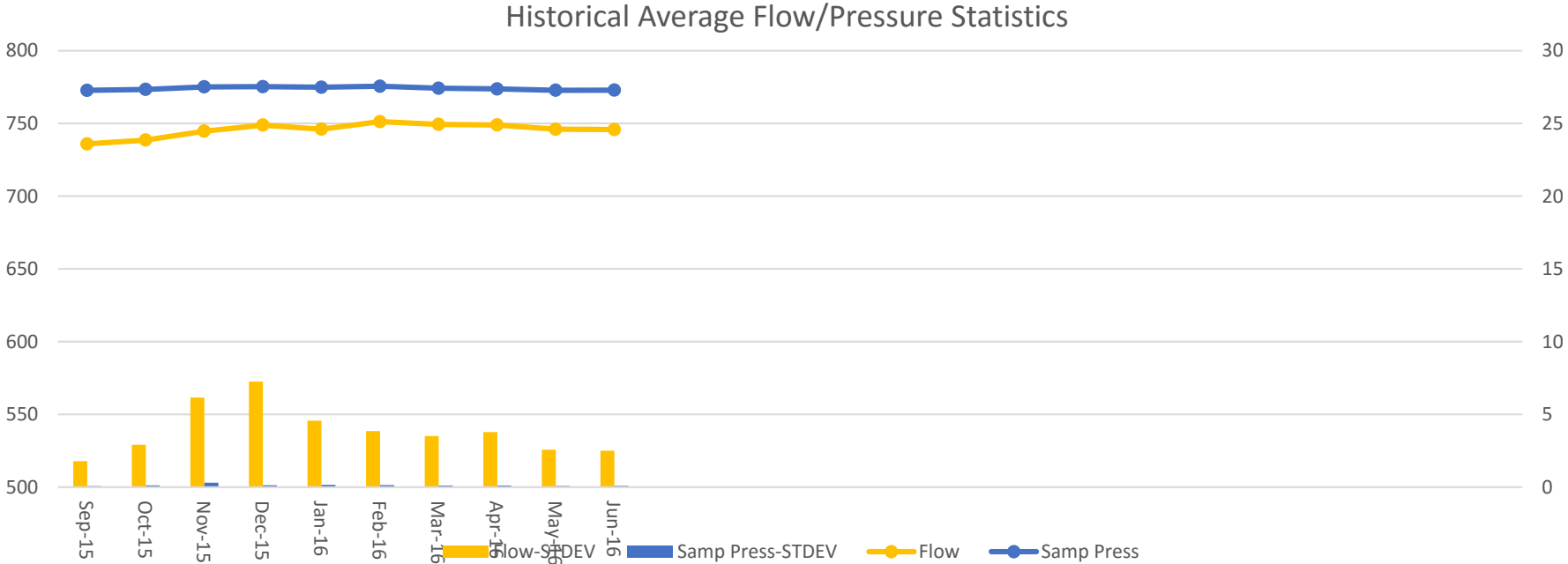
Station Temperature and Internal Analyzer Temperatures



Tabular Summary of Most Recent Monthly Statistics and their Deviation From Historical Averages – No Failures

Most Recent Month Averages												
Parameter	Box Temp	Lamp Temp	O3_Ref	Flow	Samp. Temp	Samp Press	STM	Flow adj for Samp. Press	box-stm Temp	samp-box Temp	min. O3_ref	O3_Ref Zero-Span Diff
Maximum	30.50	58.00	3339.30	752.83	40.60	27.50	26.53	748.99	4.26	10.60	3340.1	0.38
Minimum	28.10	58.00	3243.50	740.42	38.20	27.10	24.23	742.91	3.52	9.90	3243	-0.22
Average	29.46	58.00	3290.99	745.81	39.78	27.29	25.54	745.81	3.92	10.33	3290.892	0.13
Standard Deviation	0.40	0.00	26.33	2.51	0.41	0.09	0.38	1.20	0.11	0.13	26.33272	0.15
Current Averages Deviation from Historical Averages (current-historical)												
Parameter	Box Temp	Lamp Temp	O3_Ref	Flow	Samp. Temp	Samp Press	STM	Flow adj for Samp. Press	box-stm Temp	samp-box Temp	min. O3_ref	O3_Ref Zero-Span Diff
Maximum	-0.70	0.00	N/A	12.37	-0.80	0.10	-1.82	8.05	1.04	-0.10	N/A	-0.16
Minimum	1.76	0.00	N/A	3.42	1.16	-0.02	1.35	3.94	0.59	0.08	N/A	0.03
Average	0.80	0.00	N/A	0.30	0.58	-0.13	0.32	0.30	0.46	-0.22	N/A	0.03
Standard Deviation	-0.42	0.00	-7.74	-1.54	-0.34	-0.05	-0.40	-1.30	-0.05	-0.04	-9.23	-0.04
Allowable Deviation from Historical Averages (Set by Operator-HIDDEN SET HERE)												
Allowable Min Max for Valid Analyzer Operation (set on Current Monthly Raw Data Tab, HIDDEN DO NOT MODIFY HERE)												
Projection for O3 Reference Adjustment Date-												
Does not appear lamp adjustment was made in current month												
Regression correlation coefficient >0.96 so projecting using regression												
Regression Correl= 0.996119												
Projected Date when O3Ref will be below 2500 and analyzer will go into fault= 03/02/17												
Suggest adjustment at least 30 days prior to date O3Ref is projected to go into fault.												

Example Graphs of Historical Data Statistics



Example Automated Troubleshooting Screen – With Failures

MIN/MAX EXCEED-FAULT CONDITION ON CURRENT MONTHS DATA	MIN/MAX EXCEED-WARNING CONDITION ON CURRENT MONTHLY DATA	PATTERN RECOGNITION SHOWS POTENTIAL FAILURE/PROBLEM
Lamp Temp exceed Min-FAULT CONDITION	Lamp Temp exceed Min-WARNING	STM STDEV higher than normal-POOR STM CONTROL, INVESTIGATE SITE TEMP CONTROL
		O3_Ref Z/S Difference-POSSIBLE SCRUBBER FAILURE OR SOLENOID LEAK

Example Failure Mode Tests for Meta Data Patterns

Gradual drop in sample flow-POSSIBLE ORIFICE OBSTRUCTION/FLOW SENSOR DRIFT	Drop in current months flow>50 AND drop in last months flow>15
Rapid drop in sample flow-INDICATES GENERAL PNEUMATIC PROBLEM	Any 24 hour drop in flow in current data>50
Apparent pump failure-COMplete FAILURE	Any current hour flow reading<50
Apparent pump failure-DIAPHRAM RIP	Current Data 24 hour drop in flow >50 AND corresponding Spress increase >0.2
Apparent restriction to flow-POSSIBLE PLUG IN INLET LINES	Current Data 24 hour increase in (flow*(average spress/actual spress)>50 ---this effectively looks for a drop in flow with a corresponding decrease in spressure
Box-STM higher than normal-POSSIBLE CHASSIS FAN (OR FAN FILTER) PROBLEM	Current Data Max 24 hour Box-STM>6
Box-STM near zero-POSSIBLE LID OFF CHASSIS	Current Data Min 24 hour Box-STM<1
O3_Ref STDEV higher than normal-LAMP STABILITY PROBLEM, LAMP REPLACEMENT NEEDED	Current Data hourly O3_REF STD DEV>(1.5*max historical monthly O3_REF STD DEV) AND no lamp adjustment detected
STM STDEV higher than normal-POOR STM CONTROL, INVESTIGATE SITE TEMP CONTROL	Current Data STM STDDEV>(1.5*max historical STM STD DEV)
O3_Ref Z/S Difference-POSSIBLE SCRUBBER FAILURE OR SOLENOID LEAK	Any daily autocal where [(O3_REF durring zero)-(O3_REF durring span)]>3mv OR >(2*max historical)

Pros and Cons of Different Approaches

ADVP Type Approach

- Provides on the fly real-time evaluation
- Less effort once set up
- May not provide all the tests
- Software needs to be purchased
- Needs to be utilized with specific data system

Workbook Approach

- Free if you have Excel
- Can be used with any data system
- Able to suggest type of failure
- More Flexible for more tests
- May be able to detect more subtle problems
- More work to maintain
- Only manual, no real-time evaluation

Conclusion and Requests

- Analyzer meta-data currently underutilized.
- Many options for increased use of meta-data, all will improve data quality.
- Seek balance between efforts to evaluate meta-data and benefits.
- To request free ozone meta-data workbook and/or provide failure mode meta-data, contact Joel Craig.

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