Exh. DCG-5
Dockets UE-190529/UG-190530 and
UE-190274/UG-190275 (*consolidated*)
Witness: David C. Gomez

BEFORE THE WASHINGTON
UTILITIES AND TRANSPORTATION COMMISSION

WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION, **Complainant,** **v.** **PUGET SOUND ENERGY,** **Respondent.**	**DOCKETS UE-190529 and UG-190530 *(consolidated)***
In the Matter of the Petition of **PUGET SOUND ENERGY** **For an Order Authorizing Deferral Accounting and Ratemaking Treatment for Short-life UT/Technology Investment**	**DOCKETS UE-190274 and UG-190275 (*consolidated*)**

EXHIBIT TO TESTIMONY OF

David C. Gomez

STAFF OF
WASHINGTON UTILITIES AND
TRANSPORTATION COMMISSION

Sologic RCA UE-190324 PSE Resp. to Staff Inf. DR Nos. 3 and 10

November 22, 2019

BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

Docket UE-190324
Puget Sound Energy
Power Cost Adjustment Mechanism Annual Report

WUTC STAFF INFORMAL DATA REQUEST NO. 010:

RE: Follow up on Staff Data Request No. 3 – Talen's in-depth analysis.

Staff Data Request No. 3, Subpart F asked about Talen's in-depth analysis of the potential factors that caused elevated particulate levels. PSE's response stated: "Talen MT has indicated the work product is anticipated to be complete in early June." Staff assumes that the due date is early June 2019. Please provide Talen's report as soon as it becomes available to PSE.

First Supplemental Response:

Attached as Attachment A to Puget Sound Energy's Response to WUTC Staff Informal Data Request No. 010, please find a copy of Talen MT's Root Cause Analysis Report prepared for Talen Mt. by Sologic.

BEFORE THE WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION

Dockets UE-190324
Puget Sound Energy
Power Cost Adjustment Mechanism Annual Report

WUTC STAFF INFORMAL DATA REQUEST NO. 003

SUBPART A: Provide all presentations, notes, minutes, correspondence (including emails) between Talen, Owners of Units 3 and 4, MDEQ and PSE relating to the 2018 Colstrip Outage and Derate to Units 3 and 4.

SUBPART B: According to Mr. Roberts, Colstrip Unit 3 was taken out of service by Talen on June 28, 2018 and Unit 4 on June 29, 2018. He also states that Talen detected its violation of its Air Permit (#0513-14) on June 21, 2018 for Unit 3 and Unit 4 on June 26, 2018.

- Describe the actions taken by PSE and/or Talen to immediately address the violation of the air permit (including replacement power) in the seven-days between when the violation was detected and when Talen informed MDEQ.
- Provide a copy of the letter, email, correspondence and/or notice (including date) where Talen informed PSE that it was in violation of its air permit.

SUBPART C: Explain to whom or what is Mr. Roberts referring to by “internal and external efforts” and “manufacturer specifications.” Please list the individuals and/or entities involved in the investigations described in the background section above. Describe the activities of each such individual and/or entity in the investigation into root cause and implementation of corrective action related to the 2018 outage and derate of Colstrip Units 3 and 4. Provide the current status of the investigation(s) given the results of the initial investigation were inconclusive as to root cause and the remedial actions described by Mr. Roberts above may or may not have resolved the air pollution issues with Unit 3 and 4.

SUBPART D: Provide all reports, analysis, drafts, documents, work product, correspondence (including, but not limited to, email communications) generated by the individuals and/or entities, identified in SUBPART C above.

SUBPART E: Does PSE plan to file in this docket any of the materials it identified in its response to SUBPART C and/or any other materials related to the 2018 outage and derate of Units 3 and 4? Does the Company plan to supplement the prefiled direct testimony and/or exhibits of any of its witnesses? Will PSE introduce any new witnesses and testimony to this docket (Docket UE-190324)?

SUBPART F: Mr. Roberts indicates that “Talen MT is conducting a more in-depth analysis of the potential factors that caused the elevated particulate levels.” What is the current status of Talen’s “in-depth” analysis and when will it be completed?

SUBPART G: Provide all of the correspondence (including emails), documents, data, reports and analysis relating to Talen’s investigation into increase particulate matter levels in Q1 of 2018 referred to above.

SUBPART H: Provide all presentations, notes, minutes, emails and any other documentation provided to PSE’s management and/or Board of Directors concerning the Q1 2018 investigation into increased particulate matter (referred to in SUBPART F above) and the 2018 outage and derate of Colstrip Units 3 & 4. Include also all documentation, transcripts, notes, letters, correspondence memorializing decisions made by PSE’s management and/or Board of Directors concerning the Q1 2018 investigation into increased particulate matter (referred to in SUBPART F above) and the 2018 outage and derate of Units 3 & 4 (including decisions related to capital costs, expense, coal fuel supply and costs, and possible retirement of both units). If PSE’s management and/or Board of Directors made any decisions regarding the Q1 2018 investigation into increased particulate matter (referred to in SUBPART F above) and the 2018 Unit 3 & 4 outage and derate without memorializing them in a discoverable record, explain why.

SUBPART I: Mr. Roberts says that “Talen MT is working with MDEQ to determine appropriate penalties and compliance measures, which may include more frequent particulate matter testing or daily scrubber monitoring.”[1] Does PSE know the dollar amount and timing of when these penalties and enforcement actions will be imposed by MDEQ? Will PSE seek recovery of its share of the environmental penalties and/or added compliance costs imposed by MDEQ on Colstrip Units 3 and 4 in this case or will they be included in PSE’s 2019 rate case?

[1] UE-190234, Roberts Exhibit No. RJR-1T, Page 6:16-18.

<u>Response:</u>

PSE objects to WUTC Staff Informal Data Request No. 003 to the extent it purports to impose obligations upon PSE in excess of those required by the Washington Utilities and Transportation Commission's discovery rules (WAC 480-07-400 through 480-08-425). Without waiving such objection, and subject thereto, PSE responds as follows:

<u>SUBPART A</u>

Puget Sound Energy ("PSE") objects to WUTC Staff Informal Data Request No. 003, Subpart A, as neither relevant to this proceeding nor reasonably calculated to lead to the discovery of admissible evidence to the extent it requests information regarding penalties or below-the-line costs. Without waiving such objection, and subject thereto, PSE responds as follows:

Please see Attachment A to WUTC Staff Informal Data Request No. 003 for correspondence between Talen, Owners of Units 3 and 4, Montana Department of Environmental Quality ("MDEQ") and PSE relating to the 2018 Colstrip Outage and Derate to Units 3 and 4. Please also refer to the information provided in PSE's Responses to WUTC Staff Informal Data Request Nos. 001, 002, and 004.

<u>SUBPART B</u>

The compliance particulate matter (PM) tests occurred on 6/21/18 for Unit 3 and 6/26/18 for Unit 4, but final results from that testing was not received until June 28, 2018. The test utilizes a medium that must be dried after the physical collection to determine the results. Talen informed MDEQ of the test results on the same day it received the results (June 28, 2018). Attachment A to PSE's Response to WUTC Staff Informal Data Request No. 003 provides the document sent to MDEQ in response to their information request related to the Units 3&4 MATS PM issue.

The PM MATS violation was communicated by telephone to the co-owners on June 27, 2018.

<u>SUBPART C</u>

Attached as Attachment B to WUTC Staff Informal Data Request No. 003, please find a letter provided to the Montana Department of Environmental Quality titled "Response to MDEQ Colstrip MATS Information Request 9_17_18.pdf". Section 5 describes the investigation into root cause and implementation of corrective action related to the 2018 outage and derate of Colstrip Units 3 and 4. Please note that Attachment B references a MS Excel spreadsheet entitled, "Colstrip PM MATS DEQ Submittal 2018-09-17". PSE does not possess this spreadsheet, but PSE is contacting Talen MT to obtain a copy. PSE will supplement this informal data request and provide such copy to WUTC Staff when PSE receives it.

SUBPART D

Please see PSE's Response to WUTC Staff Informal Data Request No. 003, Subpart C, above.

SUBPART E

PSE has not contemplated filing additional testimony in this proceeding or whether it may be necessary to do so.

SUBPART F

The analysis of the potential factors that caused the elevated particulate levels is still in process and Talen MT has indicated the work product is anticipated to be complete in early June.

SUBPART G

PSE does not have any correspondence (including emails), documents, data, reports and analyses relating to Talen's investigation into increase particulate matter levels in Q1 of 2018 referred to above. As plant operator, Talen MT is tasked with maintaining the plant and, given that the facility was within compliance range, communication was not provided to PSE related to the 2018 Q1 elevated MATS PM tests.

SUBPART H

As stated in PSE's Response to WUTC Staff Information Data Request No. 003, Subpart G, PSE does not have any presentations, notes, minutes, emails and any other documentation provided to PSE's management and/or Board of Directors concerning the Q1 2018 investigation into increased particulate matter. PSE's management and/or Board of Directors did not make any decisions related to the Q1 2018 investigation into increased particulate matter so no documentation, transcripts, notes, letters, correspondence memorializing decisions are available.

Please see Attachment B to PSE's Response to WUTC Staff Informal Data Request No. 003 for documentation provided to PSE via Talen MT concerning the 2018 outage and derate of Colstrip Units 3 & 4.

SUBPART I

PSE does not know for certain the dollar amount and timing of when penalties and enforcement actions will be imposed by the MDEQ. In communication with Talen MT, who is working with MDEQ on behalf of the Colstrip facility, PSE understands the penalty is likely to be between $400,000 - $450,000 in total, with PSE responsible for approximately 25%. PSE does not know when MDEQ will file the penalty and enforcement provisions. Any penalties or costs associated with compliance will not be incorporated into this docket or included in PSE’s 2019 general rate case.

SOLOGIC®

Root Cause Analysis Report

Talen Energy - Colstrip MT 2018 Emissions Issue

Revision: Final

July 2, 2019

Prepared For:

Talen Montana

Presented By:

Brian Hughes
Sr. Vice President
Sologic, LLC

Table of Contents:

Role of Sologic, LLC:

Sologic provides root cause analysis [RCA] facilitation and reporting services only. Results are based entirely upon the information provided by Talen Energy and/or other third-party personnel present at the RCA group facilitation and included in subsequent meetings and revisions. Sologic's services are limited to facilitating the RCA process and producing the RCA report.

Sologic is not qualified to assess any technical aspects of the issue for which the RCA is being performed. Sologic has not contributed any information, theories or recommendations relating to the technical aspects of the RCA and cannot guarantee the implementation of or effectiveness of any solutions developed by the RCA team.

Executive Summary:

On 6/21/2018 and 6/26/2018, the 2018 2nd quarter compliance MATS stack particulate matter [PM] emissions tests on Units 3 & 4 of the Colstrip Power Plant (Colstrip, MT, USA) resulted in levels causing the site-wide MATS PM average to exceed the compliance limit. This investigation finds that the elevated PM levels were likely due to a combination of the following causes:

- <u>Fuel Chemistry Variation:</u> The Colstrip Power Plant obtains fuel from a single source. The chemical composition of the fuel varies as it is extracted from different sections of the mine. These variations, in combination with boiler combustion conditions, can contribute to a larger volume of sub-micrometer particulate which is able to bypass the scrubber.
- <u>Boiler Combustion Conditions:</u> Operators make adjustments to the boiler combustion conditions to balance slagging, NO_X, production demand, and other conditions. Depending on fuel chemistry, boiler combustion conditions can also contribute to higher PM emissions. Opacity detectors should alert operators to the increase in PM, but in this case they did not. This was likely due to the formation of larger agglomerates, which are not detectable by the existing opacity detectors.
- <u>Scrubber Solids Carry-Over:</u> There was an increase in scrubber solids carry-over after make-up water was brought in from the 3 & 4 EHP F-Cell. This was done to reduce the water level to make repairs to the pond liner. F-Cell contains higher dissolved solids, and these solids subsequently were introduced to the scrubber. The original design of the scrubbers results in the potential for unbalanced gas flow through the mist eliminator [ME] area. When scrubber dissolved solids are high, this can result in scrubber carryover contributing to PM emissions.
- <u>Reactive Fiberglass PM Filters:</u> A batch of fiberglass PM test filters were found to be more reactive with SO_2 than previous batches of filters of the same type and from the same supplier. This higher reactivity caused the formation of sulfate on the filter, resulting in increased weight on the filter and a higher PM emission calculation.

No single cause on its own can account for the elevated PM levels. However, after changing boiler combustion parameters, switching to quartz PM filters, and maintaining better control over the make-up water, the PM tests have remained in compliance. While fuel chemistry variations are a possible contributing cause, the available data was not conclusive. No changes have been made to the fuel source as a result of the 2018 elevated PM levels. The fuel chemistry variations are difficult to control because the coal comes from a single source and it is quickly consumed after arriving on site.

Summary of Corrective/Preventive Actions:

Boiler Combustion:

- *Implemented:* Change the objectives of furnace optimization to control PM while also balancing slagging and NO_X emissions.
- *In Progress:* Reinstall wall soot blowers. Wall soot blowers were removed in years past because they did not appear to be needed for combustion control. They are being reinstalled with the primary purpose of gaining better control over slag and overall combustion conditions. This action should also have a positive impact on PM because it provides operators with better control over exit gas temperatures and improved combustion optimization.
- *Under Evaluation:* Provide a more accurate diagnostic aid to measure PM. This would provide plant operations with real-time PM data so adjustments could be made immediately.

Scrubber Solids Carry Over:

- *Implemented:* A separate project was implemented to install flow-balancing plates. Flow testing verifies a significant improvement in flow distributions. This will also help minimize contributions to PM from scrubber solids carry-over.
- *Implemented:* Operators to measure solids in the ME water twice per shift and control to less than 25% to help ensure fewer solids are available for carry-over. This action has had a positive impact on solids carry-over.
- *In Progress:* Treat pond return water through the pond return brine concentrator to help control dissolved solids.

Reactive Fiberglass PM Filters:

- *Implemented:* Switch from fiberglass to quartz filters: Although both fiberglass and quartz filters are used successfully in emission testing, quartz filters are less reactive in $S0_2$ environments. The data indicate that one lot of fiberglass filters may have contributed to the elevated PM levels in 2018.

Additional Recommendations:

Fuel Chemistry Variation

- *Recommended:* Perform an ultimate and mineral ash analysis of monthly fuel samples in order to build a fuel chemistry profile. This will allow for a more accurate diagnosis in the event of future elevated PM levels.

Overview:

On 6/21/2018 and 6/26/2018, the 2018 2nd quarter compliance MATS stack particulate matter [PM] emissions tests on Units 3 and 4 of the Colstrip Power Plant resulted in levels that caused the site-wide MATS PM average to exceed the facility's compliance limit of 0.03 lbs./MMBtu. Units 3 & 4 are substantially similar to one another. From 6/21/18 – 9/5/18, investigation and corrective actions were implemented which successfully brought PM emissions back into compliance. During the period of non-compliance, Units 3 & 4 PM test results ranged from 0.023 lbs./MMBtu to 0.050 lbs./MMBtu. The 2017 4th quarter site-wide MATS PM test results had been in compliance (0.026), while the 2018 1st quarter site-wide MATS PM tests were right at the compliance limit (0.030). Review of the PM Compliance Assurance Monitoring [CAM] Plan for the 2018 1st quarter revealed no obvious indication or cause of higher than normal or increasing PM levels. Thus, the magnitude of the 2018 2nd quarter exceedance was unexpected.

It should be noted that Units 1 & 2 did not experience the same elevated levels of PM, although there was one high PM emission test on Unit 1 in September, 2018, conducted when the unit was experiencing slagging conditions. It should also be noted that Units 1 & 2 were offline during Q2 2018. PM levels on Units 1 & 2 were confirmed by a test conducted in September of 2018. While the operation and maintenance procedures for Units 1 & 2 are similar to those for Units 3 & 4, there are differences in the boiler flame characteristics, furnace geometries, and heat release rates per cubic foot of furnace volume that affect gas stream and boiler wall temperature distributions. The fuel for Units 1 and 2 is also sourced from a different area of the mine.

Emissions Testing Method:

Talen measures PM emissions using EPAs Reference Methods 2 - 5. A sample of flue gas is obtained under isokinetic sampling conditions and passed through a filter under specific temperature conditions for one hour. The filter is then retrieved, desiccated, and the PM mass measured. The measured filterable PM mass is then divided by the heat input rate to the boiler during the time of the emission test to determine PM emissions in units of pounds of PM per million BTU (lbs./MMBtu) boiler heat input.

Potential PM Emission Contributors:

This RCA investigation identified both anomalous and baseline contributors to PM emissions. Also identified were other potential contributing conditions that were initially considered and then subsequently disproved. All potential PM contributors were identified, then the unit operating data and diagnostic test data were reviewed to determine if each potential contributor was reasonably consistent with the observed facts. Therefore, both baseline and anomalous contributors to PM were examined, rather than only the anomalies. In some cases, the evaluation program data and information showed that the hypothesized PM emission modes were contributors to baseline PM emissions, yet disproved them as anomalies that could explain the elevated PM levels occurring simultaneously in both Units 3 & 4 during the summer of 2018.

Scope of RCA

1. Elevated levels of fine fly ash
    a. Combustion conditions and variations in coal characteristics
    b. Differences in the extent of agglomerate formation
2. Scrubber Solids Carryover
    a. Scrubber overload
    b. Scrubber performance issues
3. Method 5 filter SO_2 adsorption
4. Large particle emission from the reheaters
5. PM emission testing accuracy
6. Increased sulfuric acid formation and nucleation to form fine particles
7. Improper Equipment Operation/Performance:
8. Carbonaceous Particulate Matter:

Elevated Levels of Fine Fly Ash:

Analysis indicated elevated levels of fine (particle size of less than 1 micrometer) fly ash during the summer of 2018. Particle size is relevant because the scrubber PM removal efficiency decreases as particle size decreases below 2 micrometers. A higher concentration of sub-micrometer particles would result in a larger quantity of PM passing through the scrubber, ultimately increasing measured PM emissions.

The fine fly ash from the summer of 2018 was found to contain a higher concentration of calcium than the bulk fly ash. This calcium can react with SO_2 at various stages in transit through the exhaust system. This increases the mass of the particulate, thereby increasing measured PM. There is also evidence that the fine fly ash from the summer of 2018 contained a higher concentration of calcium than the fine fly ash from the summer of 2017, and may have also had a finer particle size distribution. This would allow the 2018 fine fly ash to adsorb more SO_2 per unit mass of fly ash than the 2017 fine fly ash. This characteristic would further aggravate the increase in measured PM.

In general, the formation of fine fly ash is the result of vaporization and subsequent homogeneous nucleation to form spherical particles and/or chemical reduction of metal oxide to form metal suboxides, which then melt and form glass-like semi-spherical sub-micrometer particles. Numerous SEM photomicrographs demonstrated that these sub-micrometer particles comprise the large majority of particles on the PM filters. The extent of formation of these fine particles is related to the furnace temperature and the coal ash fusion temperature – the temperature at which the ash begins to deform or fuse together. Furnace temperature is controllable by the plant to a point, although it is also a function of the design of the units. Coal ash fusion temperature is a property of the coal itself and varies depending on the chemical makeup of the coal.

Combustion Conditions and Variations in Coal Characteristics:

Evidence suggests, but does not conclusively prove, that variations in fuel composition during the summer of 2018, in conjunction with combustion conditions, may have contributed to elevated PM levels. Fuel composition dictates the coal ash fusion temperature. Colstrip relies on a single coal source, which is mined nearby and transported via conveyor to the plant. Specific coal chemistry fluctuates throughout the mine and there are multiple variables that contribute to the specific chemical transformations that occur when coal is burned.

The increased PM emissions in the summer of 2018 may have been caused in part by increased coal sodium content, which was identified in analysis of fuel samples from the summer of 2018. Increased sodium content, in conjunction with boiler combustion conditions, can cause formation of fine particulate. The increased sodium reduces the ash fusion temperature and accelerates burner flame CO and char-related chemical reduction of silicon and aluminum oxides in the coal ash particles to form metal suboxides. Compounds such as SiO_2 that do not melt at normal furnace temperatures are converted to a suboxide (such as SiO) that can easily melt and vaporize at normal furnace temperatures. The vaporized SiO and other suboxides then oxidize, homogeneously nucleate, and cluster to form the sub-micrometer spherical particles and clusters of spherical particles observed in the Talen 3 & 4 PM emission samples.

Sub-micrometer-sized particles in the range of 0.1 to 2.0 micrometers are difficult to collect in a venturi scrubber. Sub-micrometer-sized particles penetrating the scrubbers can form large agglomerates due to the high static charges created in the venturi throats.

Differences in the Extent of Agglomerate Formation:

A significant number of agglomerates were discovered in the filter samples. Agglomerates are the result of sub-micrometer particles combining to form larger particles. They form for a variety of reasons at various stages in transit. Those agglomerates that form prior to the scrubber are large enough to be effectively removed by the scrubber. Therefore, any agglomerates found on the stack sample filters must have formed after passing through the scrubber. The most likely scenario causing post-scrubber agglomeration is via static generated by the plumb bob/venturi. The particles become charged in the venturi and then agglomerate in flight.

This discussion regarding agglomerates is relevant for two reasons: 1) SEM photomicrographs of samples collected downstream of the scrubber confirm the presence of a large number of agglomerated sub-micrometer particles in the gas stream exiting the mist eliminators, and 2) The agglomerated particles generate a lower response than the sub-micrometer particles from which they are formed when viewed by the opacity/PM CEMS monitors. These monitors determine opacity by measuring the scattering of light. Small, sub-micrometer particulate results in greater light scattering than the same mass concentration of larger particulate, and therefore generates a larger response from the analyzer. Ideally, an increase in PM emissions would be detected by the opacity/PM CEMS, which would then alert operators to the fact that PM levels were trending out of compliance, allowing them to then take action. Yet, these monitors did not detect the higher levels of particulate emissions that occurred in the summer of 2018. It is possible that the fine fly ash present in the summer of 2018 had a smaller particle size distribution, relative to the 2017 fine fly ash, which may have allowed more of the fine fly ash particles to form agglomerates. This increased formation of agglomerates may explain why the opacity/PM CEMS did not detect the increase in PM emissions.

Boiler Combustion Contributions

Combustion optimization also likely played a role in the formation of sub-micrometer particles. Operators make adjustments to the burners to control multiple factors, such as slagging and NOx production, while also maintaining desired production levels. In general, higher temperatures in the burner flame reducing zones will, depending on fuel composition, result in formation of a greater number of sub-micrometer particles. However, operators would not have been aware if these adjustments resulted in higher PM emissions because the opacity/PM CEMS did not detect these higher levels for the reasons described above.

Scrubber Solids Carry Over:

Under certain conditions, droplets of scrubber slurry containing solids can “carry over” from the scrubber to the stack, thereby contributing to an increase in PM. Multiple types of scrubber carry-over were examined, including those attributed to normal scrubber performance and carry-over that would occur during a scrubber overload event.

Scrubber Overload:

Scrubber overload occurs when too much flue gas passes through each scrubber, causing a higher level of PM than the scrubber can remove. There are eight scrubbers available for each boiler/unit. However, the system is designed so that seven scrubbers will effectively handle a full boiler load. This allows one scrubber to be offline as needed for maintenance. Units 3 & 4 were each operating with seven scrubbers at the time of the high PM tests. Scrubber pressure drop data and stack gas flow rates each demonstrated normal operation in accordance with system design specifications and good operational practices. Therefore, there was no previous indication that scrubber overload was a cause of the high PM tests. In order to confirm, the eighth scrubber was brought online to provide additional scrubber capacity. Diagnostic PM tests using all eight scrubbers indicated no improvement in the elevated PM level.

Scrubber Performance Issues:

Scrubber performance issues were considered, including: re-entrainment of droplets containing solids from the mist eliminators [ME] or absorption sprays; plumb bob/venturi liquid flow problems; and problems with scrubber chemistry.

Mist Eliminator:

Four possible ME problems were considered, including: problems with replacement MEs that were installed as part of routine maintenance to address normal wear and tear over time; ME fouling; overloading due to ME design; and unbalanced ME flow.

The mist eliminators were replaced as part of routine maintenance to address normal wear and tear. Unit 3 ME's were replaced between 2010 – 2017, with the last ME replaced in September 2017. Unit 4 ME's were replaced between 2016 – 2018. This represented a change to the system, therefore it was considered as a possible cause of elevated PM. However, the replacement MEs were ruled out when quarterly PM tests conducted after the replacement MEs were installed showed no subsequent increase in PM.

ME fouling was also considered, and then ruled out after PM levels remained out of compliance after the MEs were thoroughly cleaned.

ME overloading was ruled out after testing by the supplier (Munters) demonstrated that they met carryover specifications.

The original design of the scrubbers resulted in the potential for unbalanced gas flow through the ME area, with areas of high and low velocity. This is the result of the scrubber outlet duct being located on one side of the scrubber vessel. After flow distribution plates were installed to balance the flow, PM rates improved. Therefore, ME design was confirmed as a contributor to baseline PM level.

Absorption Sprayer Capacity:

There are two levels of absorption spray nozzles in the scrubber, however only a single set of nozzles operates during normal operation. In order to identify whether the absorption sprayer capacity was exceeded, both spray headers were run at the same time. However, subsequent PM levels remained high. Therefore, the scrubber absorption sprayers were ruled out as a source of PM.

Plumb Bob/Venturi:

Unbalanced scrubbing liquor flow in the plumb bob/venturi section of the scrubber was considered as a potential cause. Orifices were installed in the venturi spray lines to balance the flow. However, no significant improvement in PM emissions was observed.

Scrubber Chemistry Issues:

Chemistry issues with scrubber liquids, solids, and gypsum crystals were considered. Scrubber liquids, including a change in antifoam additive and anti-scalant, which could potentially affect the scrubber recirculation liquid surface tension and thereby affect droplet size distributions in the venturi throats, were ruled out. Tests performed using different antifoam chemicals, as well as the removal of antifoam chemicals altogether, showed no change in PM emissions. Taking the anti-scalant completely out of service resulted in no impact to PM emissions. The formation of small gypsum crystals was ruled out after the addition of chemicals to modify crystal structure had no impact on PM emissions.

Scrubber solids from the wash tray tank, the recycle tank, and the ME wash water were considered. Wash tank solids were ruled out as contributors after draining the wash tank and refilling it with water containing low solids had minimal impact on PM emissions. The MEs are supplied by water from the cooling tower blow down. This water contains a higher level of dissolved solids, which could potential contribute to high PM levels. To test, raw water (which contains significantly lower solids) was used for ME wash. This reduced PM emissions, indicating that the cooling tower blow down water is a source of baseline PM emissions. However, use of raw water is not sustainable given the permit requirement of zero water discharge.

There was an increase in recycle tank solids after scrubber make-up water was brought in from the 3 & 4 EHP F-Cell. This occurred during the time of higher-than-normal PM results. The action was taken to reduce the water level of F-Cell to make repairs to the pond liner. F-Cell contains higher dissolved solids due to forced evaporation, which is done to maintain zero water discharge status. These solids subsequently were introduced to the scrubber and may have contributed to the anomalous increase in PM emissions.

Filter Adsorption of SO_2:

Fiberglass filters have historically been used to perform PM testing at the Colstrip Power Plant. However, the filter lot used during summer 2018 was discovered to have a higher soluble sodium content, which may have caused the filters to be more reactive with SO_2. Therefore, this lot of filters may have captured additional SO_2, which would then cause an increase in the measured PM level. Confirmation of this would require analysis of the filter content to determine:

- Whether the sodium existed on the filters as sodium hydroxide, sodium silicate, sodium chloride, or some other soluble sodium salt,
- The extent to which these compounds would adsorb SO_2, and
- The impacts of post-test filter desiccation on SO_2 desorption.

This analysis has not been completed because it was determined that the expense of such a test would exceed any benefits, given that that PM levels dropped after making the switch from fiberglass to quartz filters. Quartz filters will be used for PM tests going forward.
Note that PM levels dropped after switching from fiberglass to quartz filters, which strongly implicates the fiberglass filters as contributors to elevated PM. However, filter adsorption cannot account for all the elevated PM.

Large Particles:

Larger particles (> 20 micrometers) were discovered, but only accounted for approximately 7% - 10% of the baseline stack PM, and an even lower fraction of the stack PM during the summer of 2018. The presence of large particles was not considered an emission problem but rather a symptom of emission problems – such as (1) gas-liquid maldistribution in the venturi throats, and/or (2) large calcium sulfate scale or rust particles breaking off of the reheater surfaces. The reheater re-entrainment particles are also a secondary factor caused by ME droplet re-entrainment. Therefore, the large particles issue was not investigated further.

Testing Accuracy:

Testing inaccuracies were considered, but then disproved after conducting side-by-side testing with an independent third party and Talen personnel, and then having another independent third party emission testing firm review the Talen test data and results.

Improper Equipment Operation/Performance:

Improper equipment operation and/or performance was considered, but then disproved. After Q1 2018 tests, Talen reviewed the indicators in the Compliance Assurance Monitoring [CAM] plan and discovered no cause for the higher PM emissions and no indication that the Q2 2018 PM tests would suddenly deviate to an extent never seen before at Colstrip Units 3 & 4. Talen also reviewed operation of Units 3 & 4 with engineers, operations, and maintenance, including the boiler and scrubber crews, and found no indications of abnormal operations. A review of scrubber plumb bob static pressure drop, opacity, and PM CEMS indicated normal operations, suggesting PM emissions rates similar to what had been previously seen on Units 3 & 4. Between June 29 and July 7, 2018, Talen verified compliance with operational procedures, conducted a thorough inspection of the boilers and the associated controls, and completed minor maintenance on components that were identified needing repair. The inspections revealed no deviations from operational procedures and no significant maintenance needs.

Sulfuric Acid Mist in Flue Gas:

Sulfuric acid formation and nucleation to form sub-micrometer-sized droplets that penetrate the venturi scrubbers was considered, but then disproved after testing over a two-week period failed to identify the presence of significant sulfuric acid concentrations during controlled condensation tests (NCASI Method 8A) conducted in the stack and by EPA Method 202 tests conducted at the scrubber inlets.

Carbonaceous Particulate Matter:

Carbonaceous particulate matter is possible due to incomplete combustion and poor fuel firing practices (poor coal fineness, inadequate oxygen levels, or severe load swings). Loss on Ignition [LOI] tests on both units indicated that carbonaceous particulate levels were low and that combustion conditions were therefore considered complete.

Summary Table of Causes Considered During RCA:

The following table lists the various causes from the RCA considered as potential sources of elevated PM. Also included in the table is whether the cause was disproved or confirmed as well as whether it would have contributed to baseline PM or an anomalous increase in PM.

Potential Cause Considered			Result	PM Contribution
Elevated Levels of Reactive Fine Fly Ash				
	Fuel source variations in conjunction with combustion conditions		**Confirmed**	**Anomaly**
Scrubber Slurry Carry Over				
	Scrubber Overload		Disproved	Anomaly
	Scrubber Performance Issues			
		Scrubber Solids – Recycle Tank	**Confirmed**	**Anomaly**
		Maldistributed Flue Gas Velocities	**Confirmed**	**Baseline**
		Replacement MEs	Disproved	Anomaly
		ME Fouling	Disproved	Anomaly
		ME Overload	Disproved	Anomaly
		Absorption Sprays	Disproved	Baseline
		Plumb Bob / Venturi	Disproved	Baseline
		Scrubber Liquids – Anti-foam	Disproved	Anomaly
		Scrubber Liquids – Anti-scalant	Disproved	Anomaly
		Gypsum Crystal Size	Disproved	Anomaly
		Scrubber Solids – Wash Tray Tank	Disproved	Baseline
		Scrubber Solids – ME Wash Water	Disproved	Baseline
Filter Adsorption of SO_2			**Confirmed**	**Anomaly**
Large Particles			Disproved	Baseline
Testing Inaccuracies			Disproved	Anomaly
Improper Equipment Operation / Performance			Disproved	Anomaly
Sulfuric Acid Mist			Disproved	Baseline
Carbonaceous Particulate Matter			Disproved	Baseline

Potential Solutions:

This list of potential solutions was generated during the root cause analysis for consideration by Talen for the purpose of developing a path forward.

Recommended Solutions:

Burner Combustion:

- Change the objectives of furnace optimization: The burners are currently tuned to minimize slagging and NO_X emissions, while also maintaining output. Recommend including control of PM as an objective of boiler operation.
  Status: In process

- Reinstall wall soot blowers: Wall soot blowers were originally installed, but were removed in years past. Now they are being reinstalled to help control slag. This should also have a positive impact on PM. This provides operators with better control over exit gas temperatures and combustion conditions.
  Status: In process

- Provide a diagnostic aid to measure PM: This would provide plant operations with real-time PM data. The plant is investigating other sensing options that are more sensitive to PM than the existing opacity monitors.
  Status: Under evaluation

Scrubber Solids Carry Over:

- Install flow balancing plates: This has been implemented and flow testing verifies a significant improvement in flow distributions. This should help eliminate contributions to PM from solids carry-over.
  Status: Implemented

- Control scrubber water solids to less than 25%: Operators to measure solids in scrubber water twice per shift and control solids to less than 25%: Resulted in positive impact on solid contribution to carry-over.
  Status: Implemented

- Treat a portion of the pond return scrubber makeup water: The plant is planning to treat a slip stream of the pond return scrubber makeup water to reduce dissolved solids.
  Status: In process

PM Filter:

- Switch to quartz filters: Although both fiberglass and quartz filters are used successfully in emission testing, quartz filters are less reactive in SO_2 environments.
  Status: Implemented

Additional Recommendation(s)

Fuel Variation Monitoring

- Analyze monthly fuel samples: It is probable that the plant will experience variations in coal chemistry at some point in the future. Recommend performing monthly ultimate fuel composition and mineral ash analyses, ash mineral analyses, and ash fusion temperature analyses and storing the results in a database to develop a comprehensive fuel chemistry profile. The plant was previously conducting proximate analyses for moisture, BTU, sulfur and ash.
  Status: In process

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