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WCAP-16530-NP, Rev. 0 (Non-Proprietary)
Project No. 694

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OG-07-408

U.S. Nuclear Regulatory Commission
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Washington, DC 20555-0001

Subject: Pressurized Water Reactor Owners Group
Responses to NRC Requests for Clarification Regarding WCAP-16530,
"Evaluation of Chemical Effects in Containment Sump Fluids to Support GSI-
191" (PA-SEE-0275)

References:

1. PWR Owners Group letter, OG-07-129, "Pressurized Water Reactor Owners Group Responses to the NRC Second Set of Requests for Additional Information (RAI's) on WCAP-16530, 'Evaluation of Chemical Effects in Containment Sump Fluids to Support GSI-191'," April 3, 2007.
2. NRC letter from Sean E. Peters of NRR to Gordon Bischoff of PWROG dated March 23, 2007, "REQUEST FOR ADDITIONAL INFORMATION RE: PRESSURIZED WATER REACTOR OWNERS GROUP TOPICAL REPORT (TR) WCAP-16530-NP, 'EVALUATION OF POST-ACCIDENT CHEMICAL EFFECTS IN CONTAINMENT SUMP FLUIDS TO SUPPORT GSI-191' (TAC NO. MD1119)."
3. WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," February 2006.

Subsequent to the Pressurized Water Reactor Owners' Group (PWROG) submittal of responses (Ref. 1) to Nuclear Regulatory Commission (NRC) Request for Additional Information (Ref. 2), NRC in several instances requested additional clarifications via informal correspondence regarding WCAP-16530-NP (Ref. 3).

The attachment to this letter summarizes PWROG responses to these requests and represents final resolution of open items on the Ref. 3 topical report.

Enclosures 1 through 6 represent information referred to in Attachment 1 but which has not been previously transmitted formally to NRC.

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NRR

If you have any questions regarding the attached or the contents of this letter, please contact John Maruschak (412-374-3512) or any of the undersigned.

Regards,

A handwritten signature in black ink, appearing to read "Ted Schiffley, II", followed by the word "for" in a cursive script.

Frederick P. "Ted" Schiffley, II, Chairman
Pressurized Water Reactor Owners Group

FPS:RRD:mjl

Attachment: PWROG Responses to requests for clarification and supplemental information regarding WCAP-16530-NP

- Enclosure 1 Ken Johnson, Kenny Epperson, "Recent Shutdown Releases at McGuire," PWR Primary Shutdown Workshop, EPRI Offices, Charlotte, June 9-10, 2004.
- Enclosure 2 Excel spreadsheet entitled "ICET1 Al pred NRC vs WCAP Calculated pH no CO2.xls"
- Enclosure 3 Reid, R.E., "Evaluation of the Filterability of WCAP-16530-NP Aluminum Oxyhydroxide Precipitate Surrogate," Westinghouse Letter LTR-CDME-07-115, May 22, 2007.
- Enclosure 4 Westinghouse Document "Flow Rate and Differential Pressure Curves for the Constant Flow Rate Filtrations_Final-06192007.doc"
- Enclosure 5 Westinghouse Document "Autoclave Filterability Tests Draft 2.pdf"
- Enclosure 6 Westinghouse Document "Short summary -- Results of filterability testing 207 -- 2007-08-13.doc"

cc: Systems & Equipment Engineering Subcommittee
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Paul Klein, USNRC
John Lehning, USNRC
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PWROG Responses to Requests for Clarification and Supplemental Information Regarding WCAP-16530-NP

The following items, numbered 1 through 8, refer to NRC requests for clarification on the same-numbered responses submitted via Ref. A.

1. NRC COMMENT:

No further information requested.

2. NRC COMMENT:

The purpose of the response is to demonstrate a very low number for leachable chlorides in terms of the post-LOCA containment pool volume using conservative assumptions (e.g., 4 loop coating volume, 3 loop water volume). Two questions:

- (1) given the conservative nature of other assumptions, and leachable chloride data sheet values from a few ppm to over 600 ppm, why is 100 ppm selected for the calculation?
- (2) the data sheets provide leachable chloride as a mass concentration but the calculation appears to use the data as a volumetric concentration. Should these numbers be adjusted with consideration of the coating's specific gravity?

RESOLUTION:

The 100 ppm figure used was intended for use in an illustrative calculation. In retrospect, use of a higher value to bound the sump chloride concentration would have been a better approach.

Regarding the concept of mass versus volume concentration, it is recognized that various coatings manufacturers, as well as various formulations for coatings from the same manufacturer, have differing solids contents and consequently differing specific gravities. The volume concentration expression, however, is independent of solids content.

As the objective of the ICET test was to be inclusive of all plants, the volume concentration approach was chosen for the ICET test because it is independent of solids content, or specific gravity, of the coatings. Data reflecting the solids content of the coatings for which leaching data sheets were obtained was not available at the time the evaluation was being made to not test epoxy coatings for the ICET test.

Given the volume concentration, the mass concentration can be determined by multiplying the volume concentration by the specific gravity of the specific coating. An expected range of specific gravities for DBA-qualified epoxy extends from approximately 1.05 to 1.35

This being said, and for completeness, the following calculation – based on mass concentration - is offered as a bounding analysis to address the subject of chloride concentration:

Minimum reported sump volume at any plant: $20,400 \text{ ft}^3 = 577,320 \text{ L}$

Total submerged coating area: $150,748 \text{ ft}^2$

Conservative paint thickness: $10 \text{ mils} = 8.33\text{E-}04 \text{ ft}$

Conservative density of cured paint: $2 \text{ g/cm}^3 = 56,634 \text{ g/ft}^3$

Conservative leachable chloride content: 700 ppm (mg/kg)

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Resulting sump concentration (ppm by weight; i.e., mg/kg):

ppm Cl⁻ in Sump = mg Cl⁻ / Kg sump mass

mg Cl⁻ = (150,748 ft²) * (8.33E-04 ft) * (56,634 g/ft³) * (1Kg/1000g) * (700mg Cl/Kg Paint) = 4,978,194 mg Cl⁻

Sump Mass = 577,320 L * 1kg/L = 577,320 Kg

Sump Concentration: (4,978,194 mg Cl⁻) / (577,320 Kg sump mass) = 8.6mg Cl⁻/Kg sump solution = 8.6ppm.

To summarize, using an **extremely conservative** situation where the **conservatism**s are compounded, the upper-bound chloride concentration in the sump is calculated to be 8.6 ppm, which is negligible in light of the fact that this value is a **factor of eleven** smaller than the 100 ppm Cl added in ICET 1-4 and a **factor of five** lower than the 43 ppm added in ICET 5. Fluctuations in sump fluid density due to temperature are not significant enough to overcome a factor of 5 or 11.

3. NRC COMMENT:

Based on the French data, the RAI response assumes 20% of the oxide would be released and transport to the pool. Would the percentage of RCS oxide released during and subsequent to a LOCA be substantially higher than the value obtained from the study of 80 shutdowns? In addition, the RAI response indicates about 75% of the particles had sizes greater than 10um. Should the particle size distribution for a LOCA be similar to the data shown for 3 days prior to shutdown, i.e., about 75% in the 5 um to 10um range?

RESOLUTION:

The corrosion products released from the RCS in a PWR LOCA would be small. The theory and data supporting this conclusion are given as follows.

The two primary means for corrosion product release during an outage are chemical dissolution and physical shocks (Ref. B). The chemical dissolution is the result decreasing temperature, decreasing pH due to increased boron and decreasing temperature, and a change in the electrochemical potential of the system. The electrochemical potential will change from low values during operation to high values due to exposure to containment oxygen. The physical shocks will be generated by high fluid flows, and vibrations, and thermal expansion and contraction.

The LOCA release of corrosion products by chemical dissolution is expected to be similar to that experienced during a normal shutdown because the chemistry changes in the coolant during a LOCA will be similar to those experienced during a normal shutdown. The decrease in pH to approximately pH 5 (increased acidity) due to cooling and the addition of boric acid to 2500 ppm during a normal outage parallels the initial pH decrease during a LOCA. During a LOCA, the pH will return to higher values, typically between pH 7 and pH 8 due to the addition of buffer agents such as sodium hydroxide. This is similar to the return to pH 7 to 7.4 that PWR experiences during a normal start-up. During a normal shutdown extreme changes in electrochemical potential are induced to remove corrosion products. This is done by adding hydrogen peroxide to the RCS. During a LOCA, the chemical shock would be primarily caused by the admission of oxygen, a less potent oxidizing agent, from containment. Thus, normal shutdown releases by chemical dissolution can be used to bound LOCA releases.

Westinghouse knowledge of shutdown releases during normal refueling outages was reviewed to obtain a high estimate for a LOCA release due to chemical factors. Based on an informal compilation by Westinghouse of shutdown releases from 113 outages, the peak nickel concentration at a PWR due to peroxide addition at a normal shutdown was 13.93 ppm, which was associated with a rapid release of 5.4 kg of nickel. The total average nickel release for the industry is 2.9 kg per outage, and the maximum Ni release to date is 8.1 kg for an entire outage. With iron concentrations during outages typically below 1 ppm (and thus certainly less than

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1 kg total, even for the largest PWR RCS volumes), it is reasonable to use an estimated high value of 10 kg release due to chemistry changes during a LOCA.*

PWR corrosion product releases due to physical shocks are minimal. For instance, at the plant from this data compilation with the record shutdown nickel coolant concentration, shortly before the large chemically-induced release, one reactor coolant pump was turned off while another was started. There was no increase in coolant corrosion product concentrations. At another plant where coolant iron and nickel concentrations were recorded at record high levels during the cycle, the nickel concentration upon restart of the RCPs for the subsequent cycle increased by less than 1 ppm. Although flow changes due to a LOCA break may be greater than that at RCP start/stop, it has been shown that even for extreme agitation such as during fuel ultrasonic cleaning, there is not much material released beyond the initial chemically induced crud release. For instance, a study of ultrasonic cleaning of highly crudded fuel showed a release of 2.3 grams of corrosion product per assembly. This corresponds to bounding physical agitation release of 0.45 kg for the entire core. Typically, the crud released from the core is 37.4 percent of the total release during a normal end of cycle shutdown (Ref. C). Thus, a high estimate of 1.2 kg release from a PWR due to physical shocks is reasonable.

Thus, a bounding number for total release of RCS corrosion products during a LOCA is estimated to be 11.2 kg. Of this total, a maximum of 10 kg will be released as a result of chemical reactions and a maximum of 1.2 kg will be released from physical shocks.

RCS corrosion products released during a LOCA will be similar to those released during a normal outage, and as a result, will not present any unexpected problems. These corrosion products will be either dissolved, as in the case of nickel, or will be particulates that are relatively large compared to solid matter formed from chemical reactions in the sump. PWRs often measure the particulate fraction during a shutdown, and the particulate release always represents a small fraction of the total release. A study of corrosion product release at four different PWRs (Ref. 4) reveals that this dissolved fraction averaged 90% over 16 different outages. Applying a conservative ratio of 50% (which bounds the range of all 16 of these data points) to the bounding corrosion product release calculated herein results in a remainder of 5.6 kg in particulate form.

Finally, particle size analysis has shown that 75% of the particles are larger than 10 microns in diameter. (Ref. D). Applying this ratio results in 4.2 kg in particulates 10 microns or greater in diameter and the remaining 1.4 kg in particulate form less than 10 microns or less in diameter.

** Specific activity of 1.575 Curies per gram nickel assumed in calculations involving specific activity.*

4. NRC COMMENT:

No further information requested.

5. NRC COMMENT:

No further information requested.

6. NRC COMMENT:

Staff would like to get a copy of the calculations used to develop the figure.

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RESPONSE:

The spreadsheet (Ref. E) was transmitted to NRC staff via e-mail on May 16, 2007

7. NRC COMMENT:

What is the revised settling rate acceptance criteria?

RESOLUTION:

WCAP-16530-NP will be annotated (specifically, Figure 7.8-1 and the text in Sections 7.3.2, and 7.6) to make reference to the following statements:

- For future head loss tests in which the objective is to keep chemical precipitates suspended (e.g., via tank agitation):
 - For sodium aluminum silicate and aluminum oxyhydroxide, the settling rate should be measured within 24 hours of the time the surrogate will be used and the 1 hour settled volume shall be 6.0 ml or greater and within 1.5 ml of the freshly prepared material.
 - For calcium phosphate, settling rate should be measured within 24 hours of the time the surrogate will be used and the 1 hour settled volume shall be 5.0 ml or greater and within 1.5 ml of the freshly prepared material.
 - Testing should be conducted such that surrogate material is introduced in a way to ensure transportation of all material to the screen.
- For future head loss tests in which the objective is to settle chemical precipitates and other debris, surrogates that settle equal to or less than the 2.2 g/L concentration line shown in Figure 7.6-1 of WCAP-16530-NP (i.e., 1 or 2 hour settlement data on or above the line) are acceptable. Settling rate should be measured within 24 hours of the time the surrogate will be used.
- For those utilities that have performed testing using existing settling rate criteria, the following observations should be noted:
 - Testing performed by Pacific Gas and Electric Company (PG&E) showed that the settling rate and filtration properties of the sodium aluminum silicate surrogate were essentially constant over time.
 - The PG&E testing also showed that, although the settled volume of the aluminum oxyhydroxide surrogate slowly decreased over time, the head loss caused by the surrogate material increased over time, and thus head loss testing performed using the surrogate material was conservative.
- On the basis of these observations, previous testing performed using surrogate material evaluated under existing settling rate criteria are considered valid for head loss tests in which the objective was to keep chemical precipitates suspended and for which this objective was met.

8. NRC COMMENT:

No further information requested.

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Items designated “+1” and “+2” below refer to additional NRC requests for clarification subsequent to submittal of Ref. A.

“+1” NRC COMMENT:

Is there data that compares the filterability of sodium aluminum silicate to aluminum oxyhydroxide?

RESOLUTION:

Referring to Attachment 2 to Ref. F, the following information is available:

Precipitate Filter Coefficients

PPT Run	Precipitation Formation Method	Individual Filter Cake Coefficients (K_{fx})	PPT Type
2	PPT on cooling, Al pH 8	0.0033	AlOOH
24a	PPT on cooling, FibreFrax, pH 12	0.0066	NaAlSi ₃ O ₈
24b	PPT on cooling, FibreFrax, pH 12	0.0043	NaAlSi ₃ O ₈
24c	PPT on cooling, FibreFrax, pH 12	0.0027	NaAlSi ₃ O ₈
24d	PPT on cooling, FibreFrax, pH 12	0.0039	NaAlSi ₃ O ₈

Comparing the K_{fx} values above, there is not a significant difference between the precipitate forms in terms of filterability.

Furthermore, data collected from additional Westinghouse filtration tests (Ref. G) provide further evidence that there is no statistical difference between the sodium aluminum silicate and aluminum oxyhydroxide.

“+2” NRC COMMENT:

Does Westinghouse have any insights as to why the K_{fx} for aluminum oxyhydroxide in 4400 ppm boron is at least an order of magnitude lower than the value in tap water [see Ref. F, response to RAI #44]

RESOLUTION:

In addition to Westinghouse review of the original WCAP-16530-NP technical basis, further Westinghouse testing confirms the validity of the test methodology and supports the conclusion that the use of surrogate materials results in conservative pressure drops in screen testing, irrespective of whether the surrogates are prepared in tap water or boric acid solution. (Refs. G, H, J, K)

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In addition to the follow-on requests for clarification in regard to responses transmitted in Ref. A, following are supplemental clarification requests and resolutions since the Ref. A submittal:

NRC COMMENT:

Aluminum Release Rates

Prediction of aluminum release is very important since it accounted for approximately 3/4 of the total mass released during the WCAP testing. The RAI response and ICET data fit compares the results with the average Al corrosion rate over 30 days, even though the Al passivated around day 15 or so. The existing release rate equation underpredicts the dissolution in the early part of ICET and the staff questions using a 30 day average rate, for example, to compute dissolution during the spray phase. The rate should be computed during the active corrosion phase and then an argument made whether passivation should or should not occur at some point. Staff also questions whether the use of a target pH 10 to fit the ICET-1 data is appropriate for model fit. The best estimates of the pH in the test should be used. In ICET-1 we have measurements through the test.

RESPONSE:

In the WCAP-16530-NP text, after equation 6-2, the following statement will be referenced in annotation:

“At intermediate times (i.e., less than 30 days), Equation 6.2 will underpredict the release rate. Hence, the cumulative 30-day integrated aluminum corrosion product release value predicted by the WCAP-16530-NP model should be used for screen testing, even if an intermediate time period is being simulated. If a cumulative value at an intermediate time is desired, individual plants must justify the derivation of that value.”

NRC QUESTION:

What are the references for the theoretical filtration model?

RESOLUTION:

The model is a generalization of the model presented in Equation 28-13 on page 888 of Unit Operations of Chemical Engineering by McCabe and Smith (1967 edition). The terms of the model that involved individual particle parameters were lumped into the K value in the original equation since they would be largely indefinable with the type of gelatinous solids that would be formed in the current testing. The effect of multiple layers (including the filter itself) on the analysis of the data using this model is derived from Equation 28-21 on page 892 of the same reference. Again, the particle descriptive terms were lumped into the K value due to the indefinable nature of the solids in this type of testing. This multiple layered approach is the same as is used in the analysis of heat transfer through multiple layers of insulation, vessel walls and boundary layers.

NRC QUESTION:

For what types of filtering media (e.g., fiber, fiber/particulate, amorphous product) and filtrate conditions (e.g., flow, dP, debris bed loading) has the model been shown to be valid?

PWROG Responses to Requests for Clarification and Supplemental Information Regarding WCAP-16530-NP

RESOLUTION:

The model above is totally general and would apply to all of our conditions. The only possible exceptions would be if the solids and debris beds would be highly compressible or if the flow of liquid through the bed of particles or debris would be high enough to be in the turbulent region. For either case, the particulate bed would have the majority of the pressure drop. Because of the small size of the particles (~1 micron), the flow through the bed would be laminar. Also, because of the very thin (~1 mm thick) cakes that were formed which resulted in pressure drops of several psi, the bed would not be compressible. Since we used a filter that was not compressible, there is linear behavior in our lab tests. This is born out by the fact that the flow rate as a function of pressure drop curves were indeed linear. As far as the plant scale tests go, we do not know what the debris bed is. Again, since the tests are carried out under conditions of relatively low delta P (you indicated ~5 to 7 psi), I would doubt that there would be any significant effect of the debris bed on pressure drop even if it were somewhat compressible.

NRC QUESTION:

How does the WCAP test data (and subsequent data) compare with the model predictions?

RESOLUTION:

The model was used to generate the Kx values for various solids as a means to compare the different types of solids generated under different conditions on the same basis. Upon further clarification of the question as to the variability of the data, at the time, not enough testing was done to generate a good measure of test variability. The low variability of these tests has since been confirmed with additional test data.

NRC QUESTION:

Looking back at my notes, I also had one specific question on the text in the revised Section 5.4 in the WCAP RAI response. [Attachment 2 to Ref. F.] The model assumed (pg. 29 of 35) that the debris bed is relatively thin and incompressible based upon the applied pressure drops being very small (on the order of 1 to 6 psi). Yet isn't this model being used also for test data taken at higher pressure drops (e.g., in excess of 40 psi)?

RESOLUTION:

Even at the high pressure drops, the flow rate versus pressure drop curves were still reasonably linear. So again, because of the thin cake that was formed and the nature of the precipitate, the model assumption of an incompressible bed and therefore linearity still is valid.

NRC QUESTION:

Can the debris layer and amorphous layer truly be considered separate beds? Will the materials get into the filter media?

RESOLUTION:

In our filter tests, the pore size of the filter media was very small so that this effect is not likely to occur and the Kx of the filter and the solids would be separable. For actual debris beds, the effect of solids that are held up inside the bed is not modelable because of the variability of the beds and solids and the unknown interactions between the particles and debris bed materials. However, one could say that if the debris bed had

PWROG Responses to Requests for Clarification and Supplemental Information Regarding WCAP-16530-NP

very tight pores compared to the precipitates, it would act like the filter paper in the Westinghouse testing and the Westinghouse model would be directly applicable as far as the pressure drop that a given amount of like solids per area would cause. If the debris bed had pores that were significantly larger than the particles, then the Westinghouse model would significantly underestimate that amount of solids that could be put on the filter before the same pressure drop was obtained. However, the Westinghouse model could not calculate how much more solids could be added before the same pressure drop would be obtained.

NRC QUESTION:

Is anymore data available?

RESOLUTION:

Additional filterability data is available in References G, H, K, and L.

PWROG Responses to Requests for Clarification and Supplemental Information Regarding WCAP-16530-NP

NRC EDITORIAL COMMENTS ON WESTINGHOUSE RAI RESPONSES PROVIDED IN REF. F

Possible typos in the head loss discussion in the WCAP RAI response include:

- last sentence on page 33 of 35, should the description of K_{fs} refer to the screen coefficient?

Response: Acknowledged. This is a typographical error and should read:

The K_{fs} (filter coefficient) was obtained from the slope (z) of the dP versus flow measurement for the filter (Figure C-1) using the equation:

- page 30 of 35, should the units for K_{fs} have cP to the first power, as opposed to the negative first power?

Response: Acknowledged. This is a typographical error. The line

$K_{fs} = \text{the screen coefficient (gpm ft}^{-2} \text{psi}^{-1} \text{cP}^{-1})$

Should read:

$K_{fs} = \text{the screen coefficient (gpm ft}^{-2} \text{psi}^{-1} \text{cP)}$

- are the dimensions of K_{fs} in equation 5-7 the same as the dimensions of K_{fs} in equation 5-2?

Response: Acknowledged. This is a typographical error and should read:

$K_{fs} = n / A / z / [3785 \text{ ml/gal}]$

- similarly, are the dimension of K_f in equations 5-6 and 5-2 the same?

Response: Acknowledged. This is a typographical error and should read:

$K_f = n / A / z / [3785 \text{ ml/gal}]$

In addition to the above typographical errors identified by NRC, the following errors are noted:

- Page 29 of 35, the line:

$K_{fx} = \text{filter cake coefficient for a specific precipitate or solid } x \text{ (gpm lb}_m \text{ cP ft}^{-4} \text{psi}^{-1})$

Should read:

$K_{fx} = \text{filter cake coefficient for a specific precipitate or solid (gpm lb}_m \text{ cP ft}^{-4} \text{psi}^{-1})$

- Page 29 of 35, the line:

$m_x = \text{specific dry (1 hour @ 110}^\circ\text{C) solids } x \text{ loading (lb}_m \text{ ft}^{-2})$

Should read:

$m_x = \text{specific dry (1 hour @ 110}^\circ\text{C) solids loading (lb}_m \text{ ft}^{-2})$

- Page 29 of 35, the line:

4. The K_{fs} of the screen ($\text{gpm ft}^{-2} \text{psi}^{-1} \text{cP}^{-1}$) determined with the viscosity at the temperature of interest

Should read:

4. The K_{fs} of the screen ($\text{gpm ft}^{-2} \text{psi}^{-1} \text{cP}$) determined with the viscosity at the temperature of interest

PWROG Responses to Requests for Clarification and Supplemental Information Regarding WCAP-16530-NP

REFERENCES:

- A PWR Owners Group letter, OG-07-129, "Pressurized Water Reactor Owners Group Responses to the NRC Second Set of Requests for Additional Information (RAI's) on WCAP-16530, 'Evaluation of Chemical Effects in Containment Sump Fluids to Support GSI-191'," April 3, 2007.
- B PWR Primary Water Chemistry Guidelines: Volume 2, Revision 5, EPRI, Palo Alto, CA: 2003. TR-105714-V2R5, page 2-2.
- C F. Dacquait et.al. "Corrosion Product Transfer in French PWRs During Shutdown," SFEN-Chimie 2002 Conference on Water Chemistry in Nuclear Reactor Systems, Avignon, France (2002)
- D Ken Johnson, Kenny Epperson, "Recent Shutdown Releases at McGuire," PWR Primary Shutdown Workshop, EPRI Offices, Charlotte, June 9-10, 2004.
(See Enclosure 1.)
- E Excel spreadsheet entitled "ICET1 Al pred NRC vs WCAP Calculated pH no CO2.xls
(See Enclosure 2.)
- F PWR Owners Group letter, OG-06-387, "Pressurized Water Reactor Owners Group: Responses to the NRC Request for Additional Information (RAI) on WCAP-16530, 'Evaluation of Chemical Effects in Containment Sump Fluids to Support GSI-191'," November 21, 2006.
- G Reid, R.E., "Evaluation of the Filterability of WCAP-16530-NP Aluminum Oxyhydroxide Precipitate Surrogate," Westinghouse Letter LTR-CDME-07-115, May 22, 2007.
(See Enclosure 3.)
- H Westinghouse Document "Flow Rate and Differential Pressure Curves for the Constant Flow Rate Filtrations_Final-06192007.doc"
(See Enclosure 4.)
- K Westinghouse Document "Autoclave Filterability Tests Draft 2.pdf"
(See Enclosure 5.)
- L Westinghouse Document "Short summary – Results of filterability testing 207 – 2007-08-13.doc"
(See Enclosure 6.)

Enclosure 1

Recent Shutdown Releases at McGuire

PWR Primary Shutdown Workshop
June 9-10, 2004
EPRI Offices – Charlotte

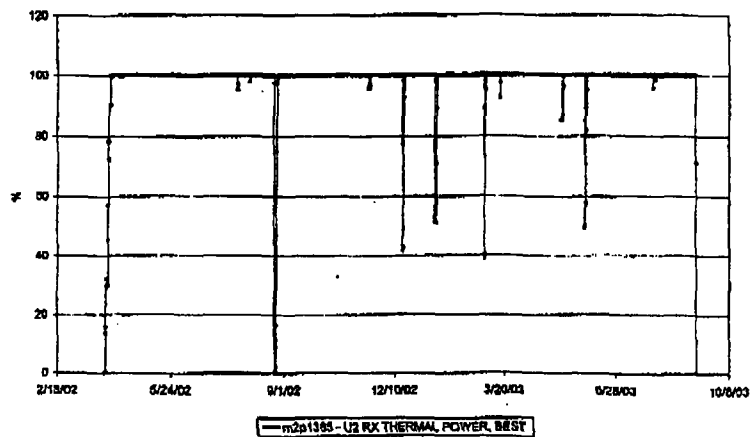
Ken Johnson
Kenny Epperson

Duke Power

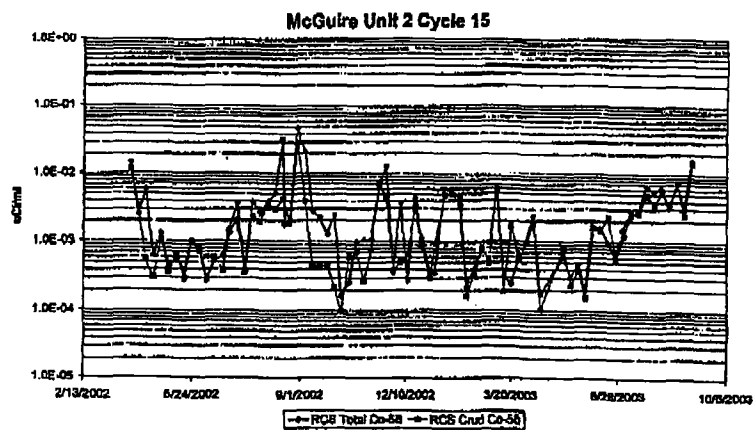
McGuire 2 Cycle 15 vs. McGuire 1 Cycle 16

- | | |
|---|---|
| • 4 th Cycle After S/G replacement | • 5 th Cycle after S/G replacement |
| • Constant 7.05 pH at 300°C | • Constant 7.05 pH at 300°C |
| • ~7.15 pH at Tave (307.3°C) | • ~7.15 pH at Tave (307.3°C) |
| • HDCI = 144 | • HDCI = 141 |
| • 11 power reductions | • 8 power reductions (lowest to 40%) |
| • 1 Manual Trip at 146 EFPD | • No trips |
| • 5 EFPD Tave Coastdown | • 7 EFPD Tave Coastdown |
| • 520.3 EFPD Total | • 509.1 EFPD Total |

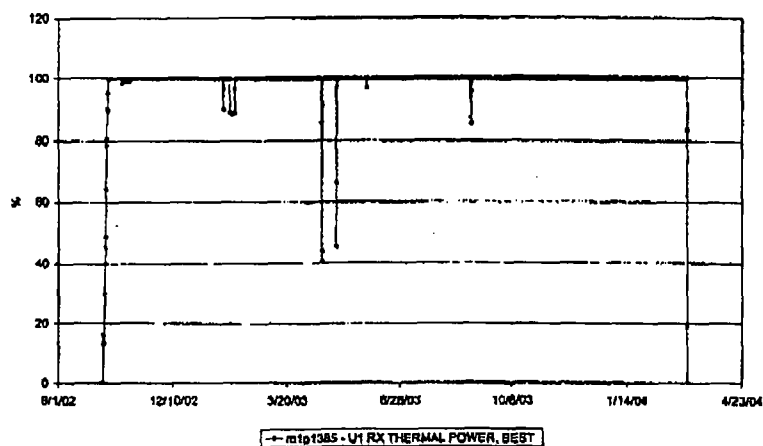
McGuire 2 Power



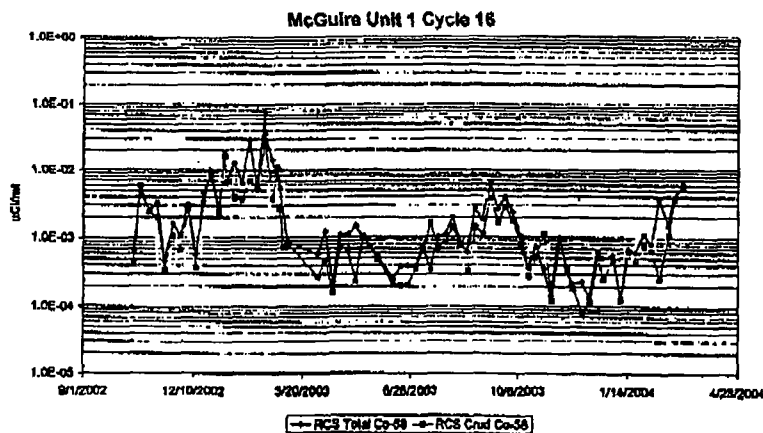
Cycle Co-58



McGuire 1 Power



Cycle Co-58



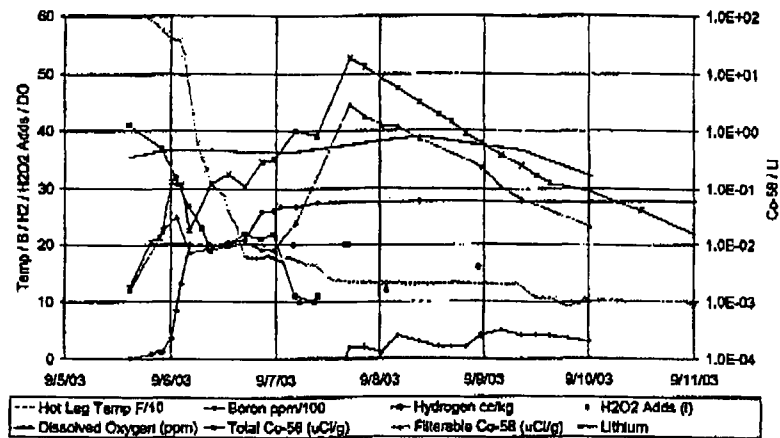
McGuire Shutdown Program

- No hydrogen reduction prior to shutdown
- At least 2 hours before $<500^{\circ}\text{F}$
- Delay RHR in service to $\sim 235^{\circ}\text{F}$
- At least 12 hours from $<400^{\circ}\text{F}$ to oxidation (with H_2 above the $\text{Ni}_{0.5}\text{Fe}_{2.5}\text{O}_4$ line)
- Parallel Mixed Beds
- 185 gpm cleanup flow rate

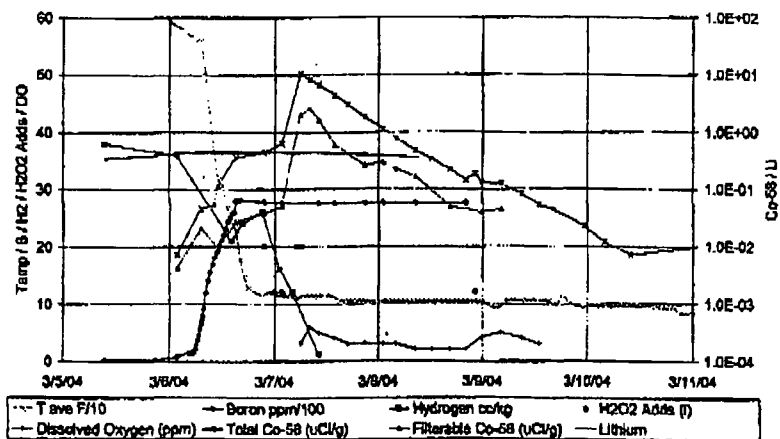
McGuire 2 RFO 15 vs. McGuire 1 RFO 16 Cooldown

- | | |
|---|---|
| • Trip from 20% Power | • Trip from 20% Power |
| • 4 hr 25 min to $<500^{\circ}\text{F}$ | • 2 hr 54 min to $<500^{\circ}\text{F}$ |
| • RHR in at 238°F | • RHR in at 235°F |
| • 16 hr 45 min to $<200^{\circ}\text{F}$ | • 10 hr 23 min to $<200^{\circ}\text{F}$ |
| • 28 hr 45 min to first peroxide addition | • 16 hr 20 min to first peroxide addition |
| • 41 hr 50 min to peak | • 20 hr 23 min to peak |

McGuire 2 Shutdown



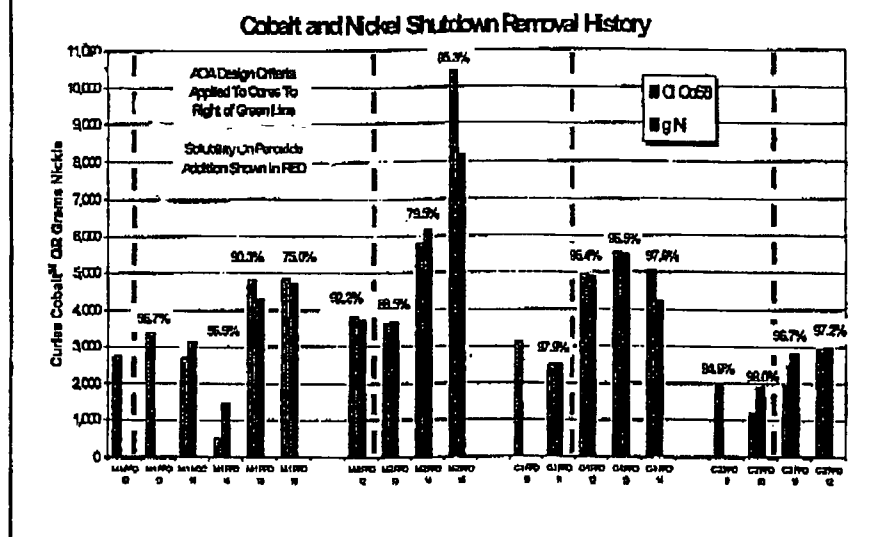
McGuire 1 Shutdown



McGuire 2 RFO 15 vs. McGuire 1 RFO 16 Activity

- | | |
|--|--|
| • 18.88 $\mu\text{Ci/ml Co}^{58}$ | • 10.43 $\mu\text{Ci/ml Co}^{58}$ |
| • 2.81 $\mu\text{Ci/ml filterable}$ | • 2.60 $\mu\text{Ci/ml filterable}$ |
| • 13.93 ppm Nickel | • 9.31 ppm Nickel |
| • 10,435 Ci Co^{58} removed | • 4,830 Ci Co^{58} removed |
| • 8,569 g Ni removed | • 4,701 g Ni removed |
| • 1.22 Ci $\text{Co}^{58}/\text{g Ni}$ | • 1.02 Ci $\text{Co}^{58}/\text{g Ni}$ |
| • Much more than previous outage | • Very similar to previous outage |

Comparing S/D Data Between Duke W Units



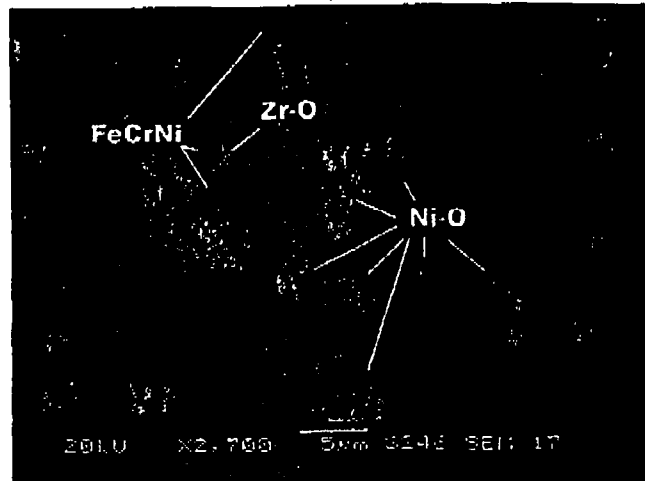
M1C16 Experience

- M1C16 crud burst characteristics looked similar to recent McGuire shutdowns. —
- However, as S/G eddy current work started, things were significantly different ...
 - S/G equipment heavily contaminated from EC probes
 - Dose on work platforms increased from this contamination
 - Presence of black powdery material noted
- Core offload also saw increase in dose rates (@ water surface) during progression
 - Cavity contamination present after fuel movement
- No other places in system noted abnormal conditions

M1C16 Problem Material

- Descriptions from workers identified source as fine black powder
- Gamma analysis of material showed >85% of activity was from Co⁵⁸
- Based on specific activity ratios, material had been incore recently
- Analysis of crud burst filtrate showed most of the particulate was some form of nickel metal
- No significant iron noted in any samples

Crud Burst Filtrate – Peak after H_2O_2 Addition



M1C16 – S/D Crud Burst

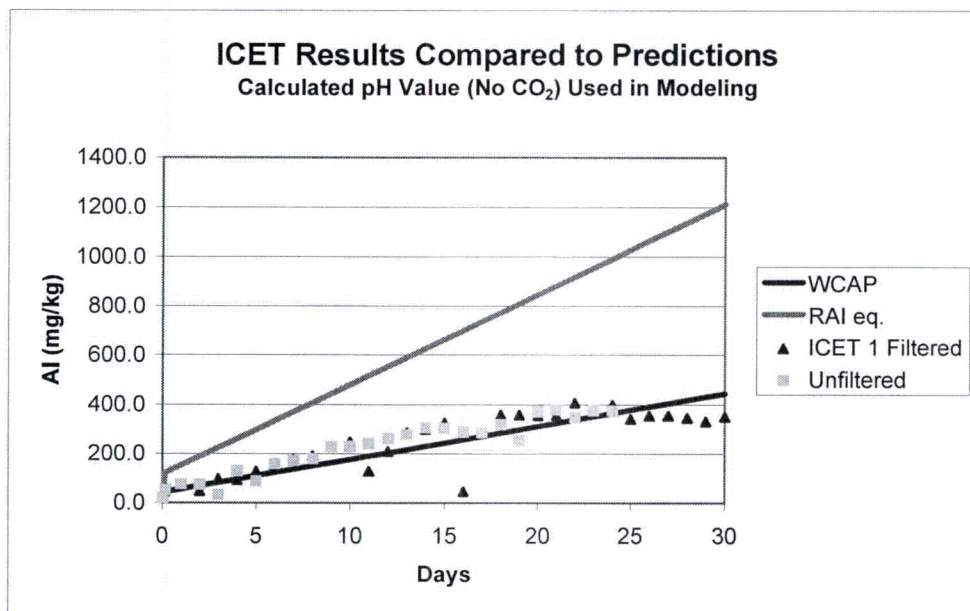
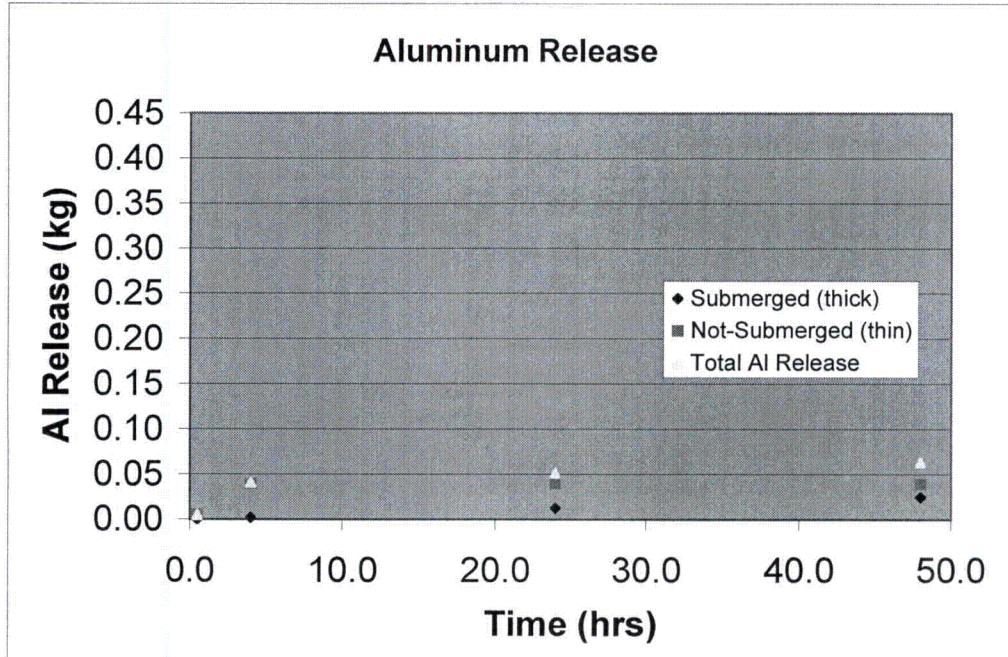
- Followed the Guidelines, no deviations
- A large particulate release occurred on peroxide addition
 - Solubility at peak Co^{58} activity was 75%
 - Total suspended solids increased unexpectedly, iron decreased
 - Large Cr^{61} release and plate out, all particulate
 - Saw similar behavior with Zr and Nb
- Cooldown rate and RCP swap at low temps did not affect release
 - B RCP started, D RCP secured at 158° F (~13 hrs prior to H_2O_2 addition)

Other M1C16 Observations

- Initial S/G dose indications were normal
- Appears nearly all the material was IN the S/G tubes
 - No significant issues until started EC work
 - Probes drag material out of tubes
 - Could not tell if predominately on Hot or Cold leg side
- Very strong relation to RCP runs during H₂O₂ addition and dose problems
 - B RCP run during crud burst, B S/G least problems
- OE showed sporadic observations of this type material
 - In some cases, associated with AOA
 - One tied to nickel based anti-seize compound (Fel-Pro N5000) left in the primary system after S/G tube work

Enclosure 2

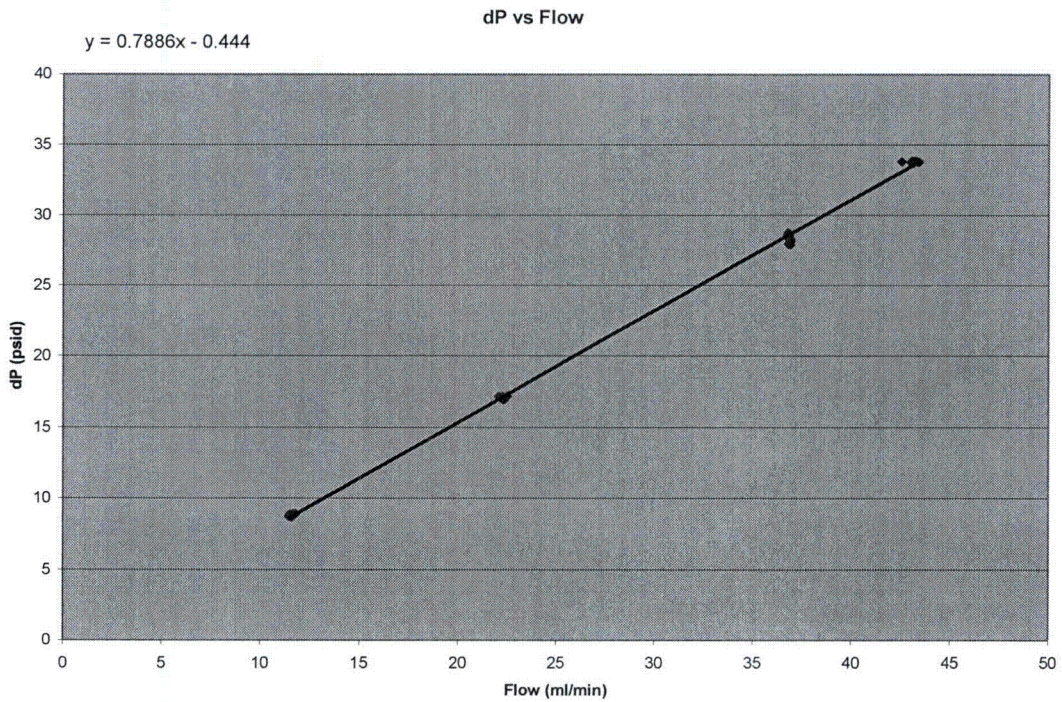
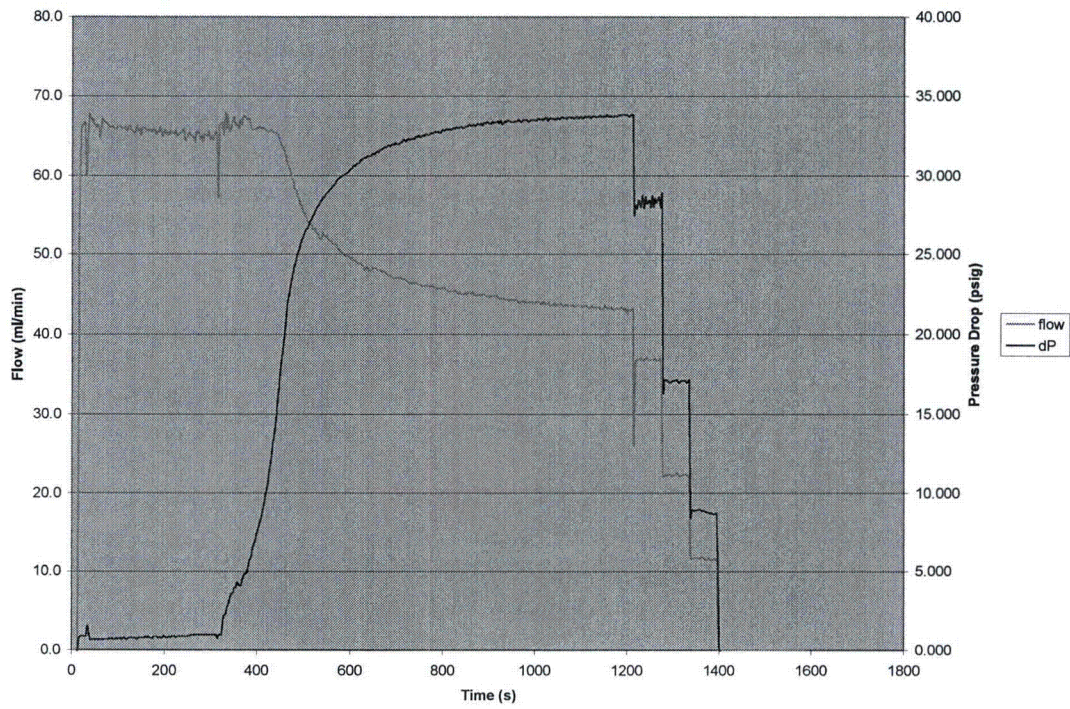
NRC	NRC		Conc from	Conc from RAI	Unfiltered AI	Filtered AI ICET	Unfiltered AI	Filtered AI ICET
Submerged	Unsubmerged	Days	WCAP	Equation	ICET 1 digitizer	1 digitizer	ICET 1 mg/kg	1 mg/kg
			(mg/kg)	(mg/kg)	reading	reading		
0.000492	0.013333908	0.020833	5.5	14.97107219			35	20
0.0054081		0.11	0.166667	44.6			48	52
0.0054319		0.11	0.167373	44.8			54	50
0.0335001		0.11	1	56.0			71	75
0.0672106		0.11	2	69.4	320	317	49	72
0.100921		0.11	3	82.9	339	319	98	31
0.1346315		0.11	4	96.3	297	354	94	129
0.168342		0.11	5	109.7	301	271	128	86
0.2020524		0.11	6	123.1	272	307	153	159
0.2357629		0.11	7	136.6	251	246	175	171
0.2694733		0.11	8	150.0	232	236	192	179
0.3031838		0.11	9	163.4	218	229	230	229
0.3368942		0.11	10	176.8	186	187	249	229
0.3706047		0.11	11	190.3	170	187	128	242
0.4043151		0.11	12	203.7	272	176	210	262
0.4380256		0.11	13	217.1	203	159	288	277
0.471736		0.11	14	230.5	137	146	301	306
0.5054465		0.11	15	244.0	126	122	326	303
0.5391569		0.11	16	257.4	105	124	46	289
0.5728674		0.11	17	270.8	341	136	284	285
0.6065778		0.11	18	284.2	140	139	359	317
0.6402883		0.11	19	297.7	77	112	359	255
0.6739988		0.11	20	311.1	77	165	355	371
0.7077092		0.11	21	324.5	80	67	356	378
0.7414197		0.11	22	338.0	79	61	409	347
0.7751301		0.11	23	351.4	35	87	368	375
0.8088406		0.11	24	364.8	69	63	401	373
0.842551		0.11	25	378.2	41	65	343	
0.8762615		0.11	26	391.7	90		355	
0.9099719		0.11	27	405.1	80		355	
0.9436824		0.11	28	418.5	80		347	
0.9773928		0.11	29	431.9	87		332	
1.0111033		0.11	30	445.4	100		352	
				1210.9	83			



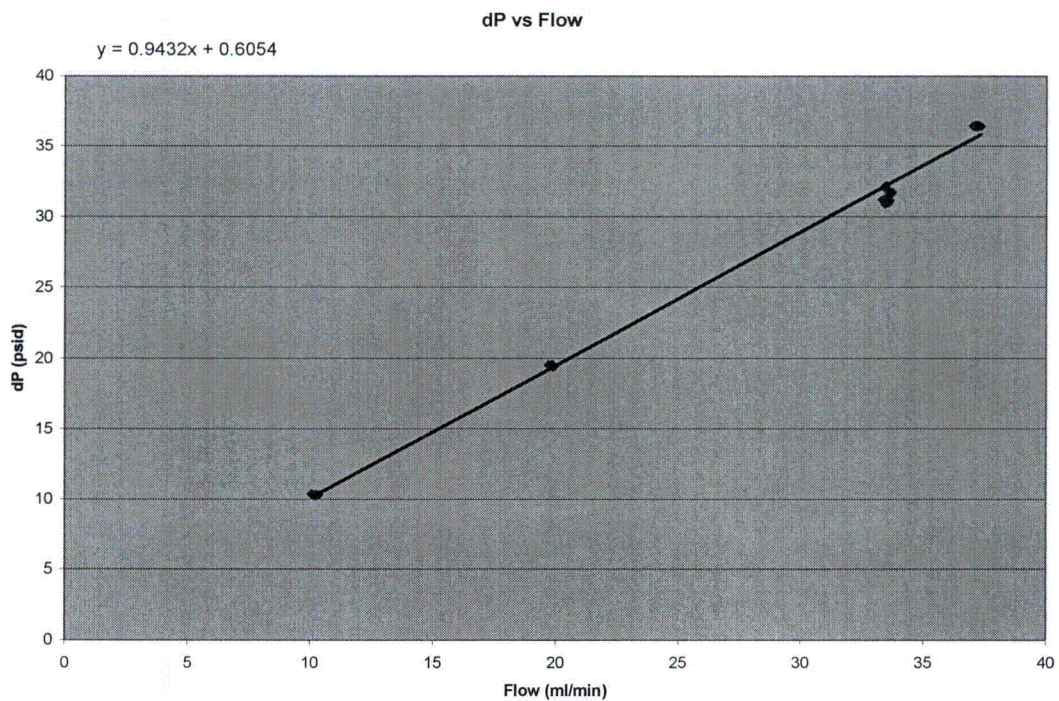
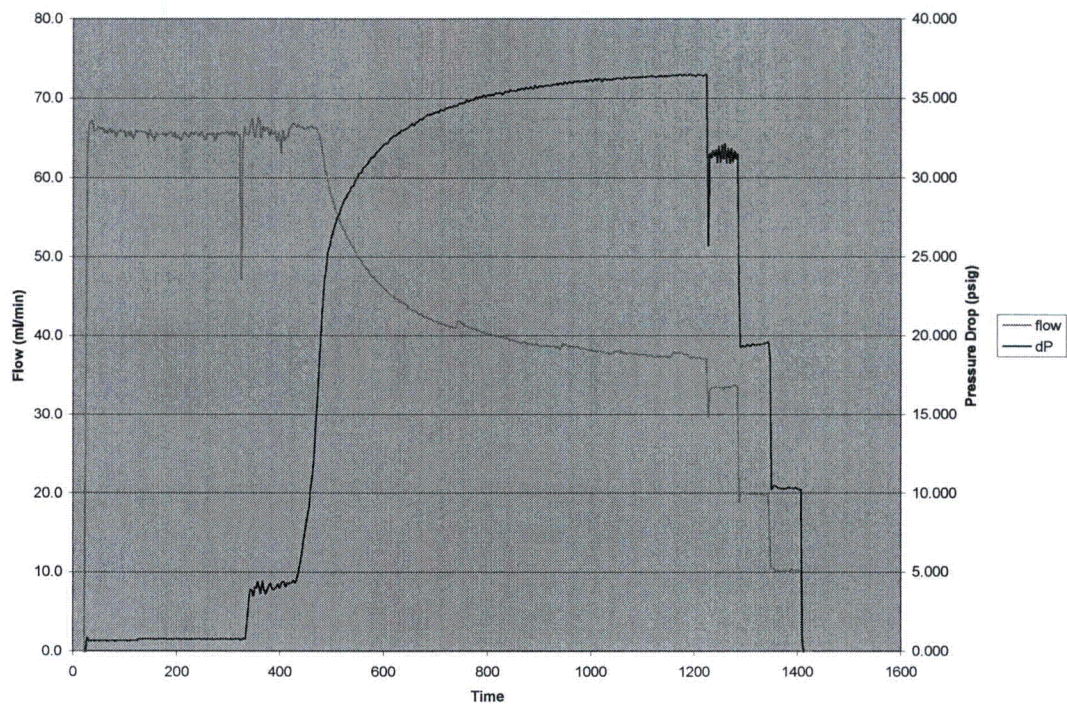
Enclosure 4

Flow Rate and Differential Pressure Curves for the Constant Flow Rate Filtrations
6/19/07

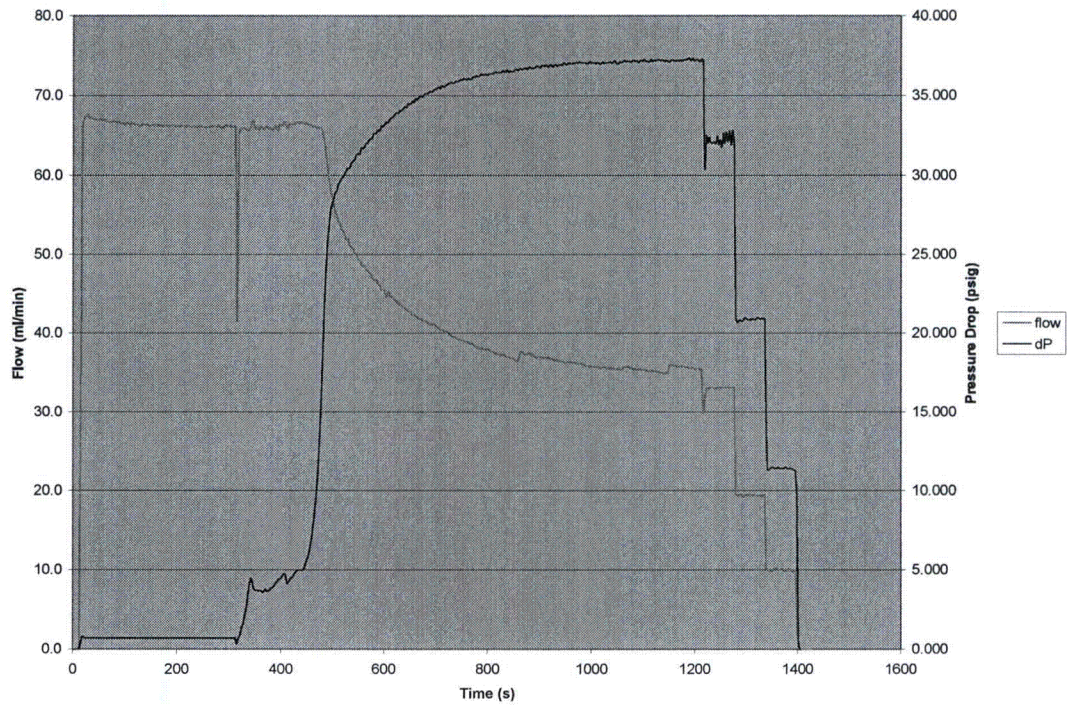
Sample: 212926-107-1-(1) **Test Solution:** ALOOH surrogate made in Tap Water
Simulated Coolant: Tap Water



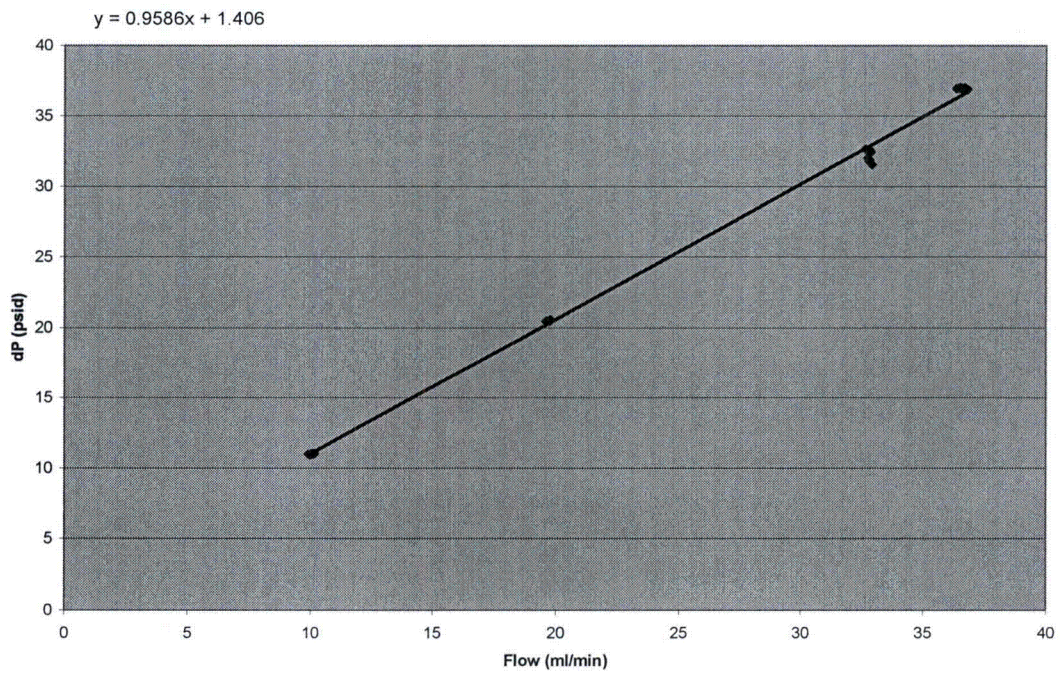
Sample: 212926-107-2-(2) **Test Solution:** ALOOH surrogate made in Tap Water
Simulated Coolant: Tap Water



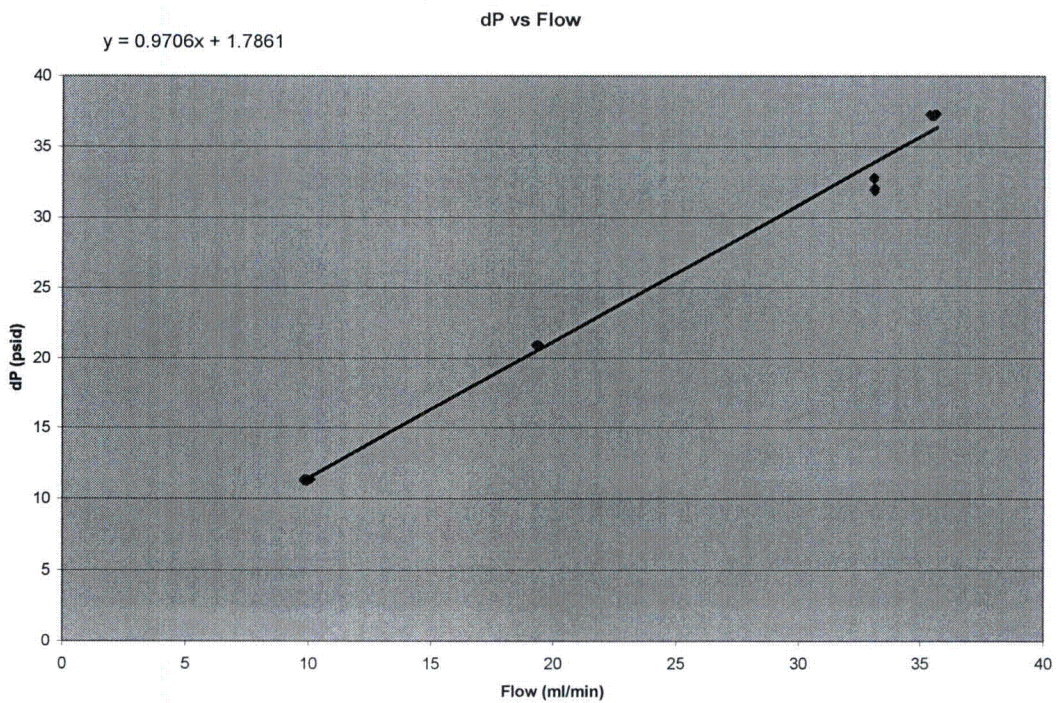
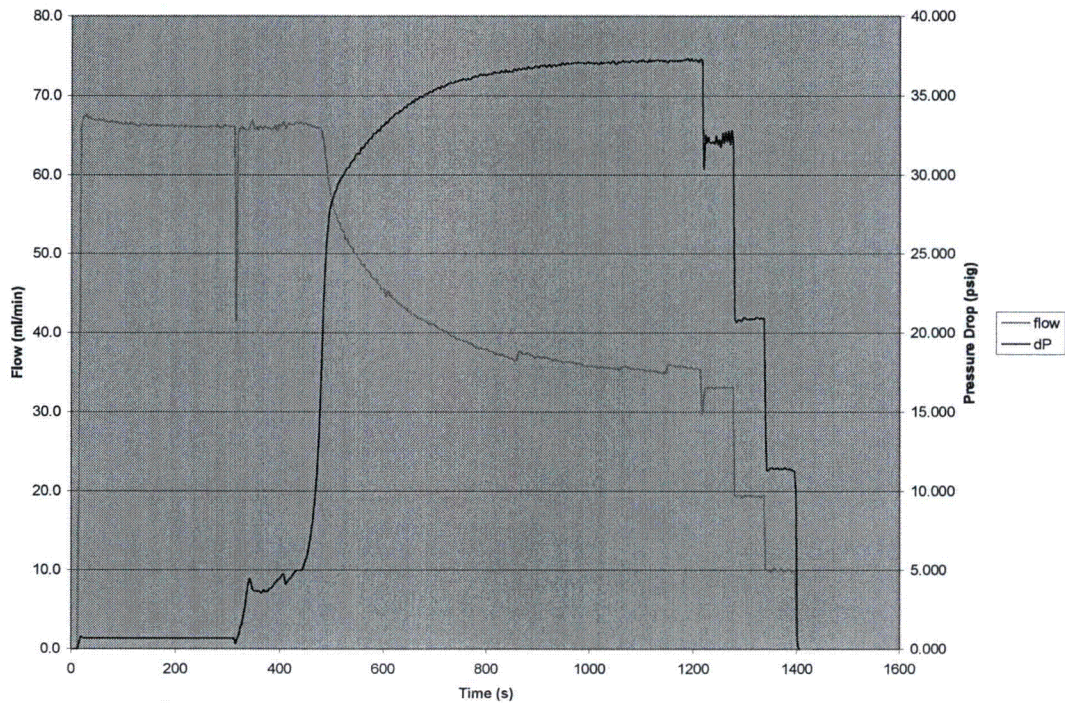
Sample: 212926-107-3-(3) **Test Solution:** AlOOH surrogate made in Tap Water
Simulated Coolant: Tap Water



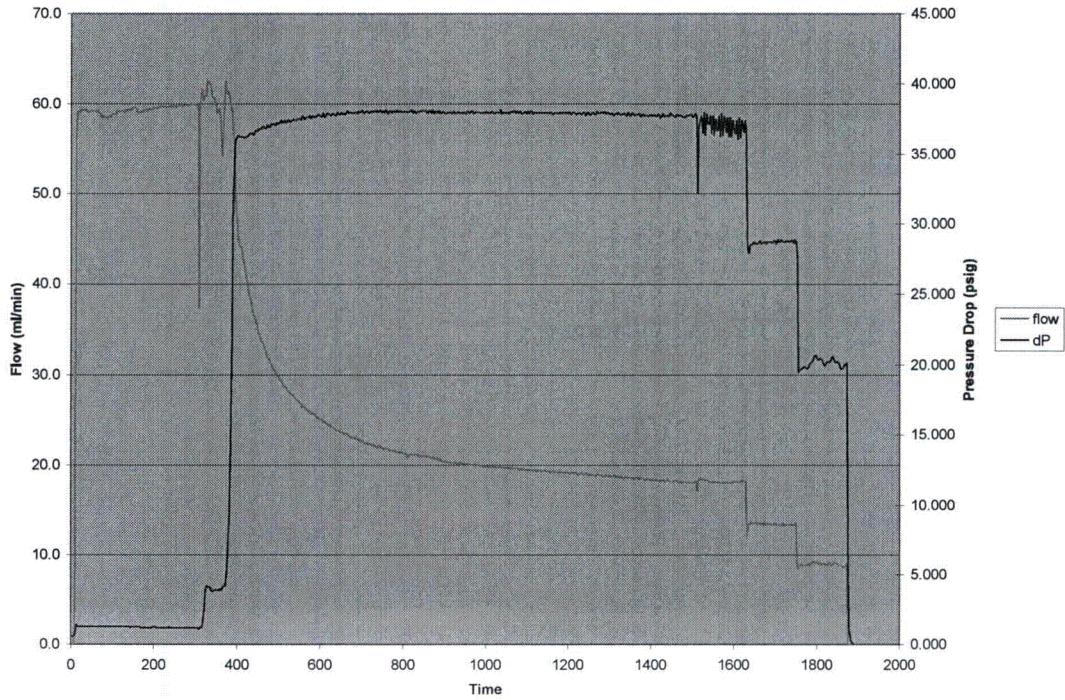
dP vs Flow



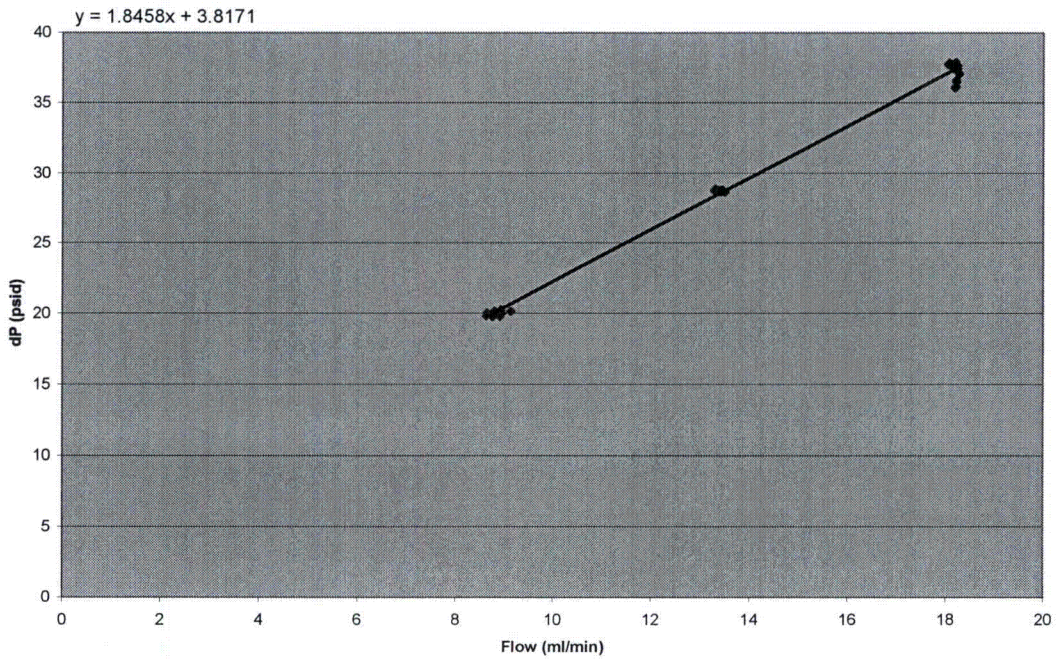
Sample: 212926-108-1-(4) Test Solution: AlOOH surrogate made in Tap Water
Simulated Coolant: Tap Water



Sample: 212926-119-4 Test Solution: AlOOH made in Tap Water
Simulated Coolant: 4400 ppm B Boric Acid



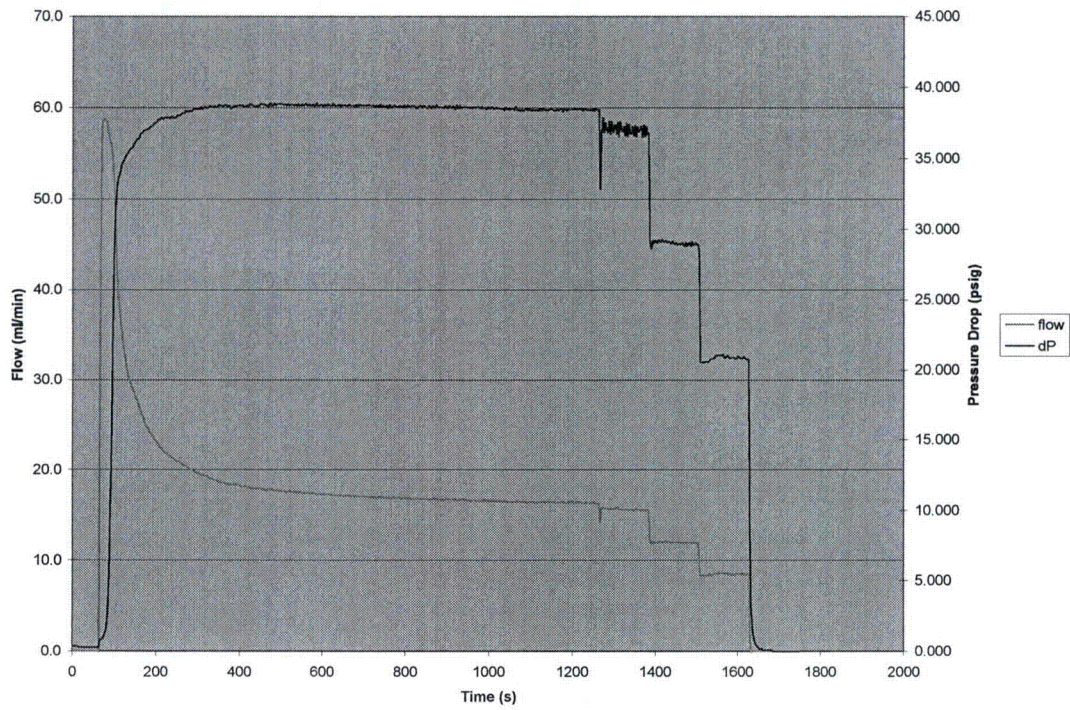
dP vs Flow



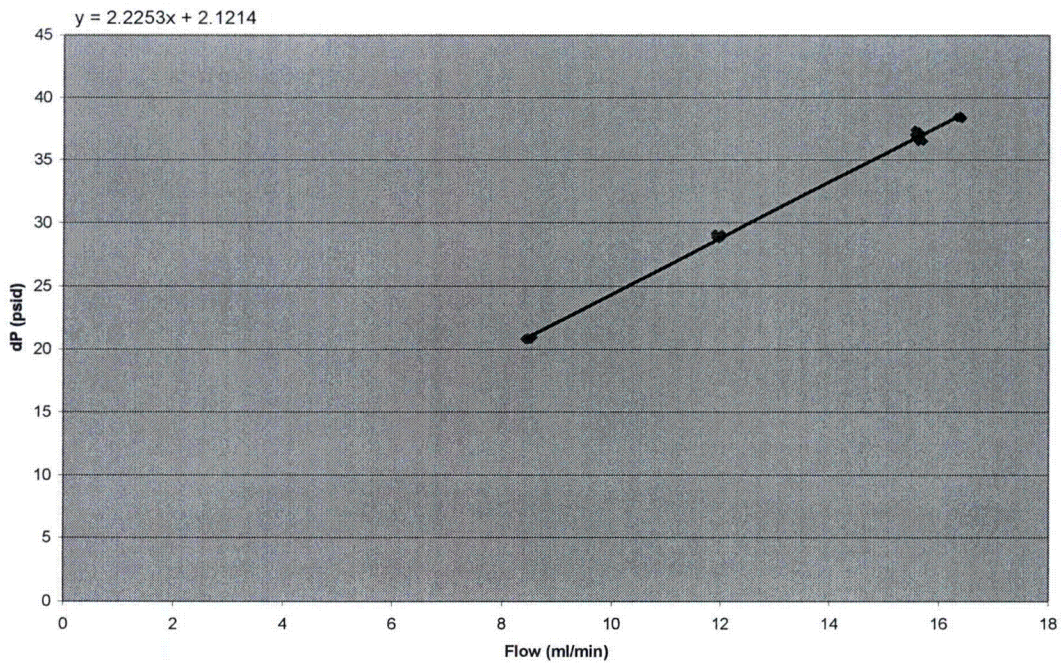
Sample: 212926-130-1 **Test Solution:** AlOOH surrogate made in Tap Water
Simulated Coolant: Tap Water **Note:** Bad Run-the filter holder leaked

File Not Available

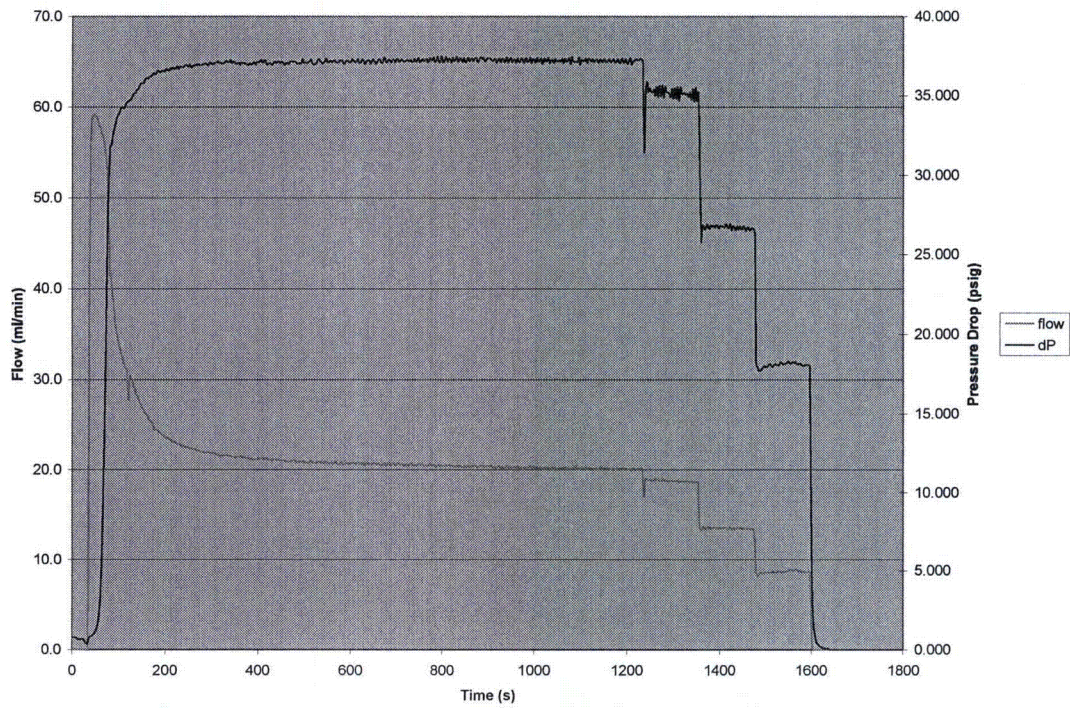
Sample: 212926-130-2 **Test Solution:** AlOOH surrogate made in Tap Water
Simulated Coolant: Tap Water



dP vs Flow

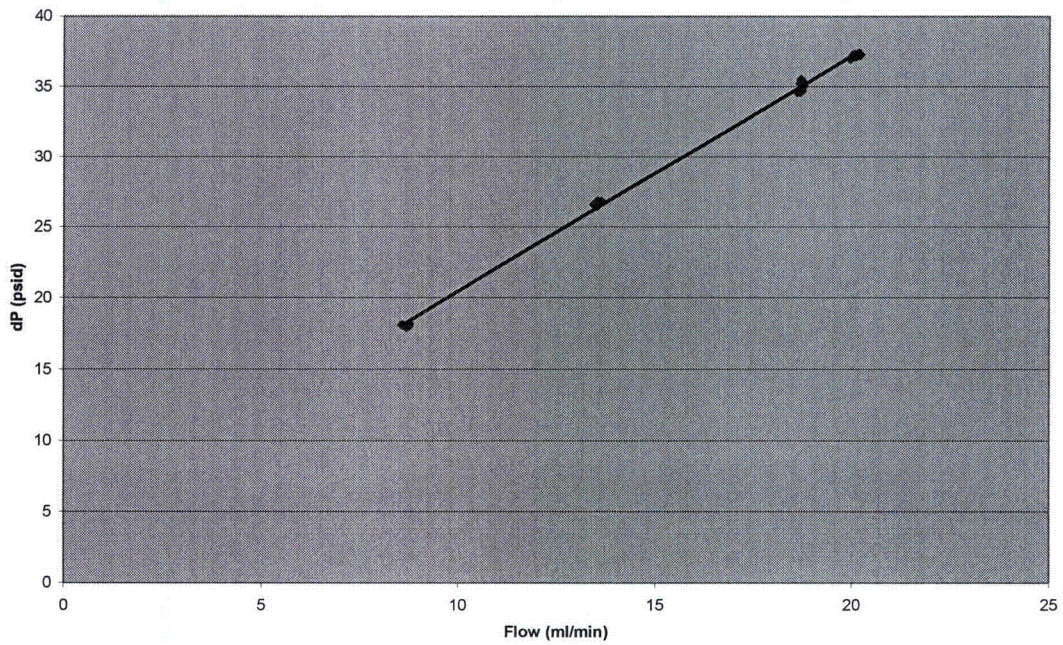


Sample: 212926-130-3 **Test Solution:** AlOOH surrogate made in Tap Water
Simulated Coolant: Tap Water

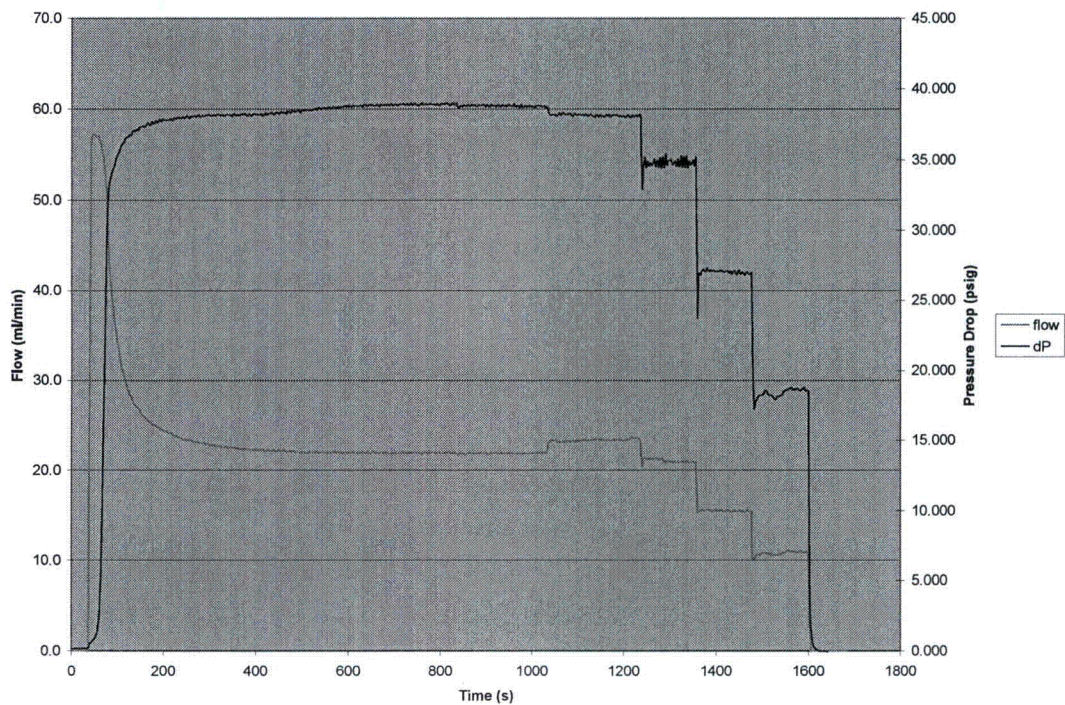


$$y = 1.6722x + 3.7463$$

dP vs Flow

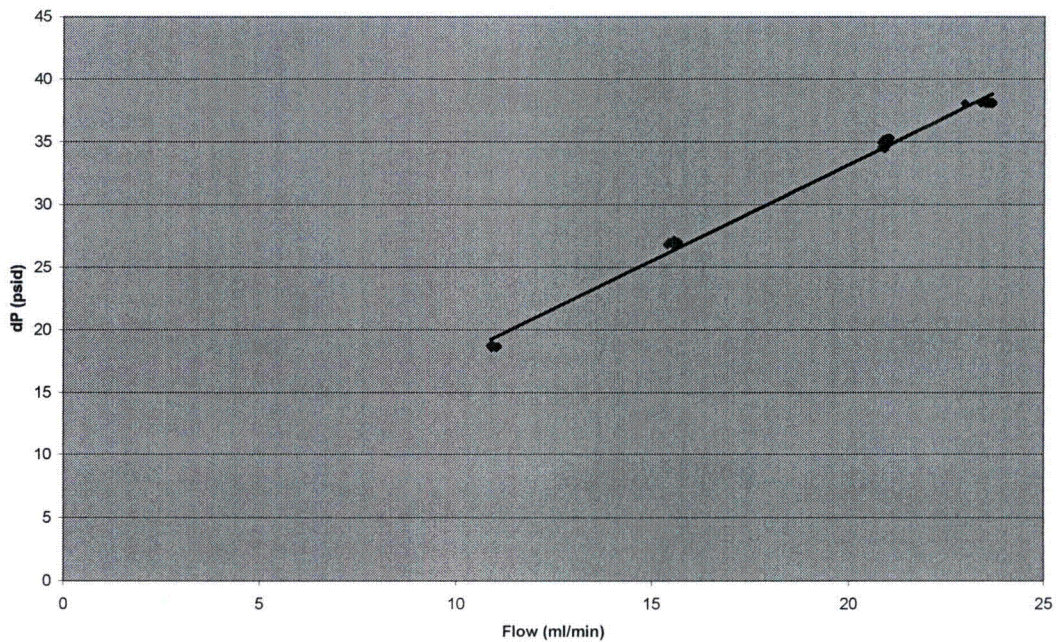


Sample: 212926-133-1 **Test Solution:** ALOOH surrogate made in Tap Water
Simulated Coolant: Tap Water

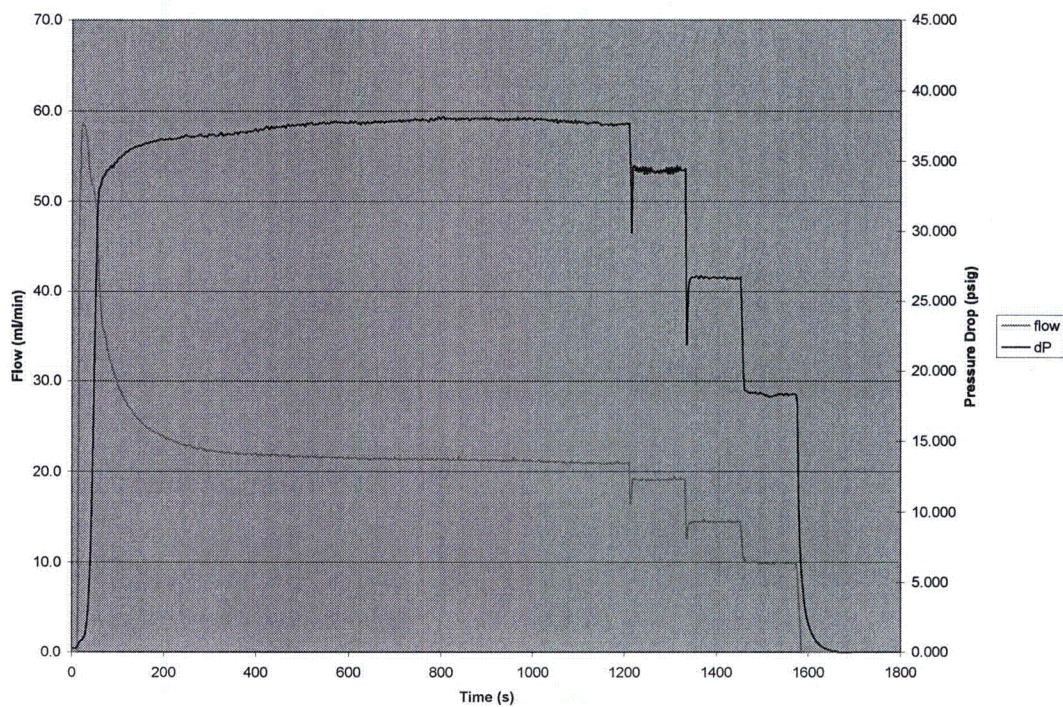


$$y = 1.5284x + 2.6019$$

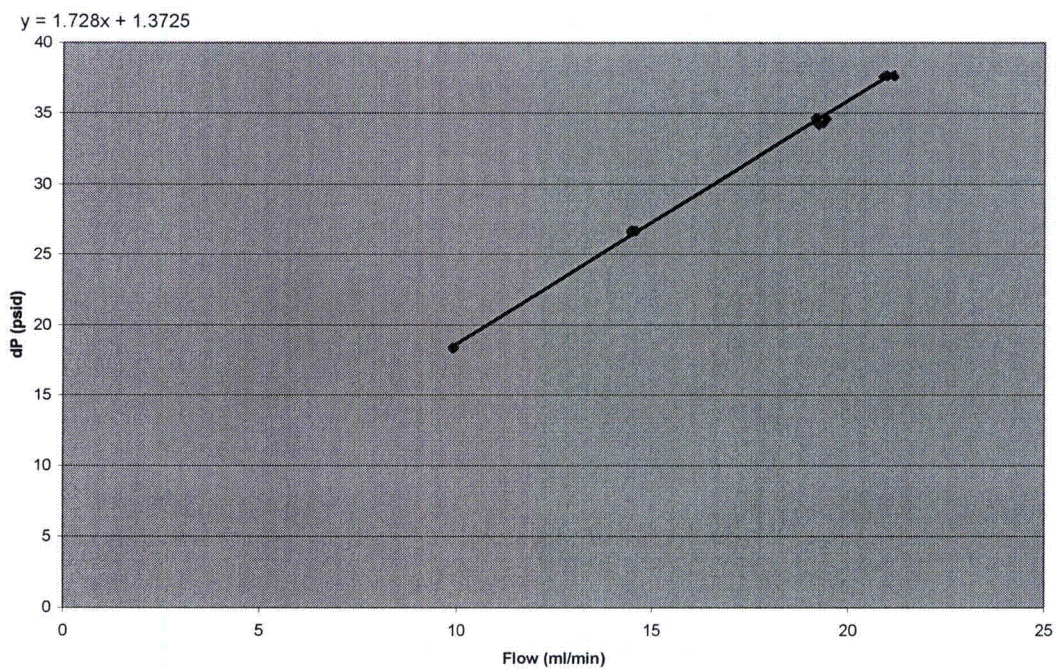
dP vs Flow



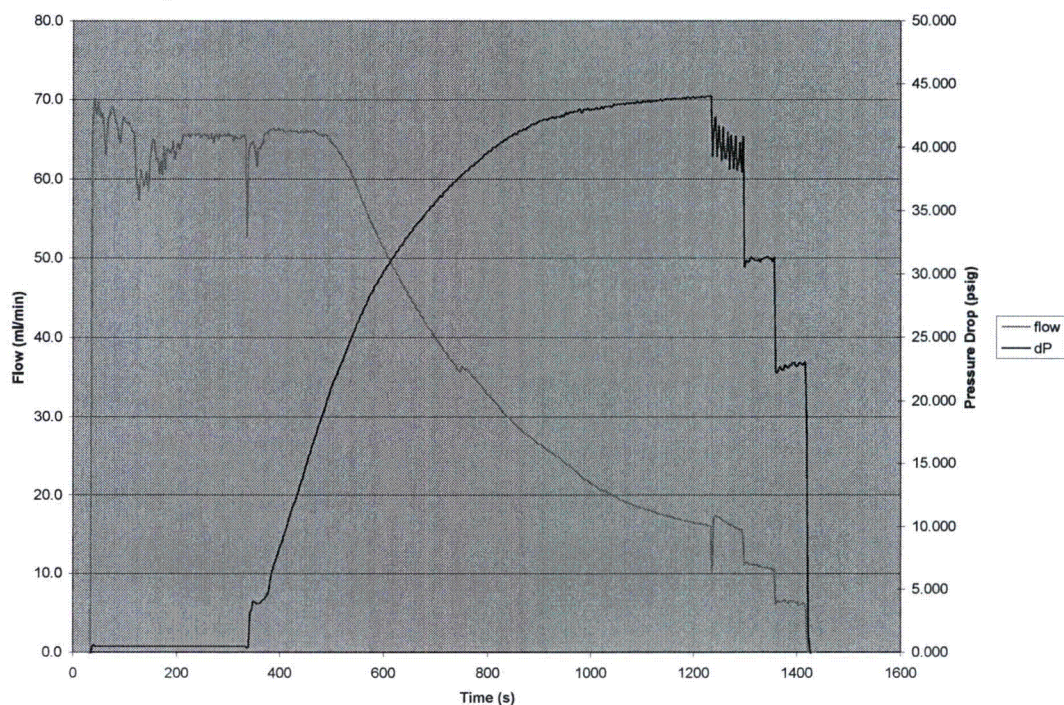
Sample: 212926-133-2 **Test Solution:** AlOOH surrogate made in Tap Water
Simulated Coolant: Tap Water



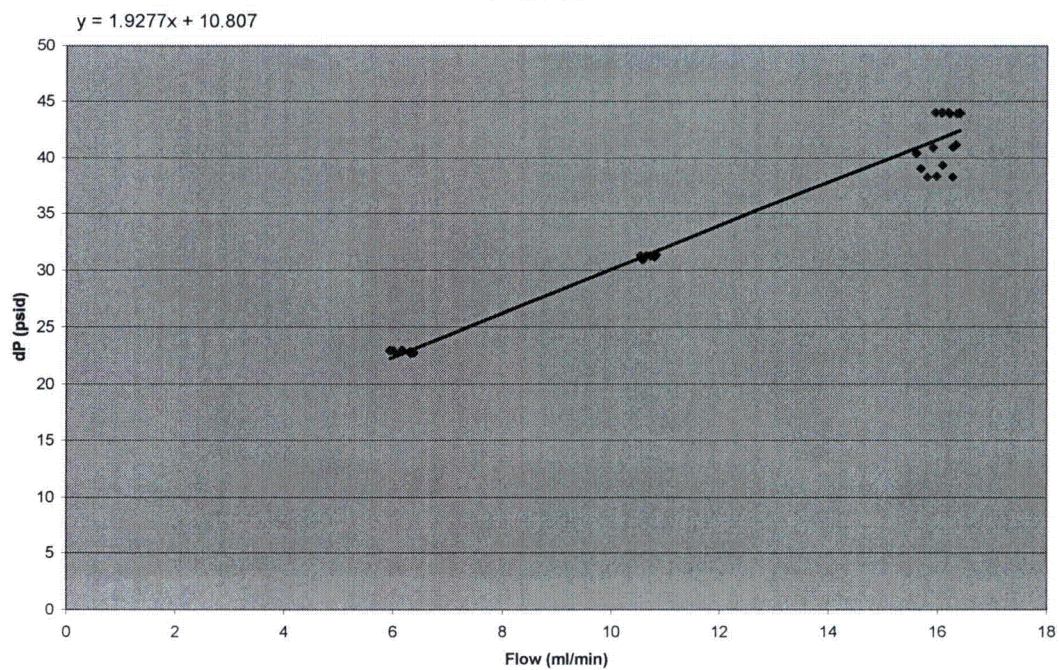
dP vs Flow



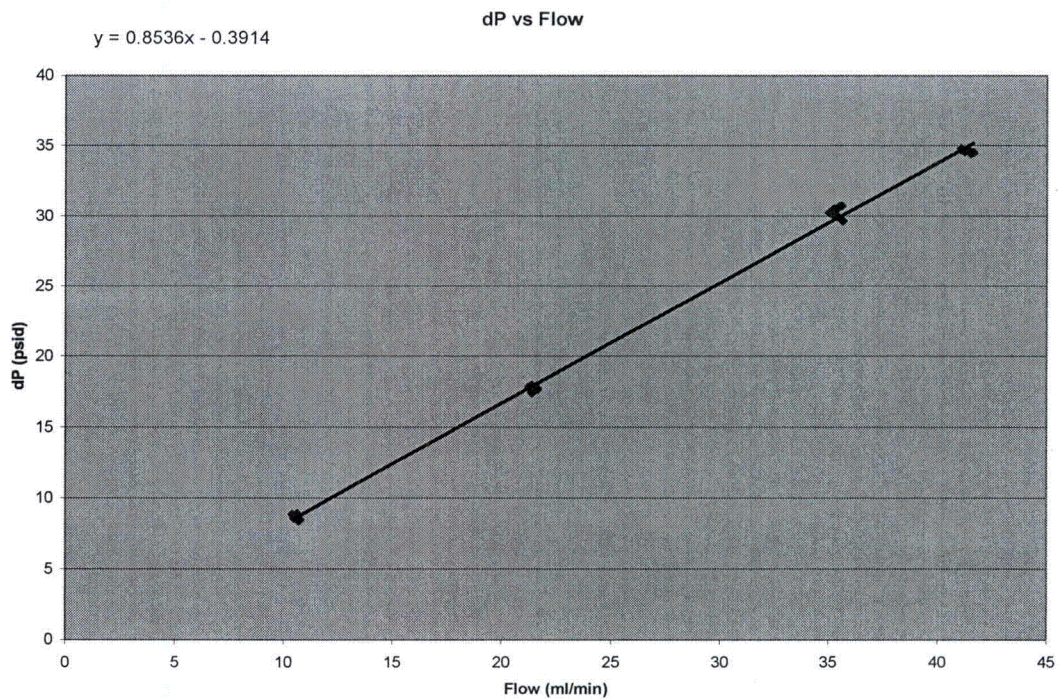
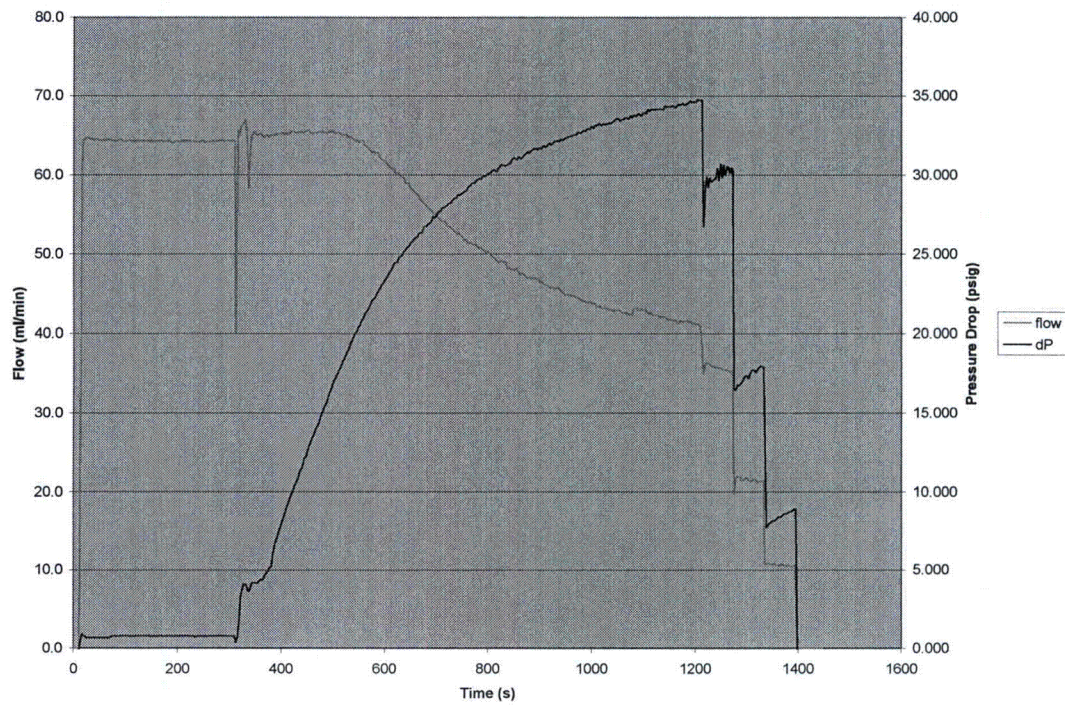
Sample: 212926-112-1-(b1) **Test Solution:** AlOOH surrogate made in 4400 ppm B Boric Acid **Simulated Coolant:** 4400 ppm B Boric Acid



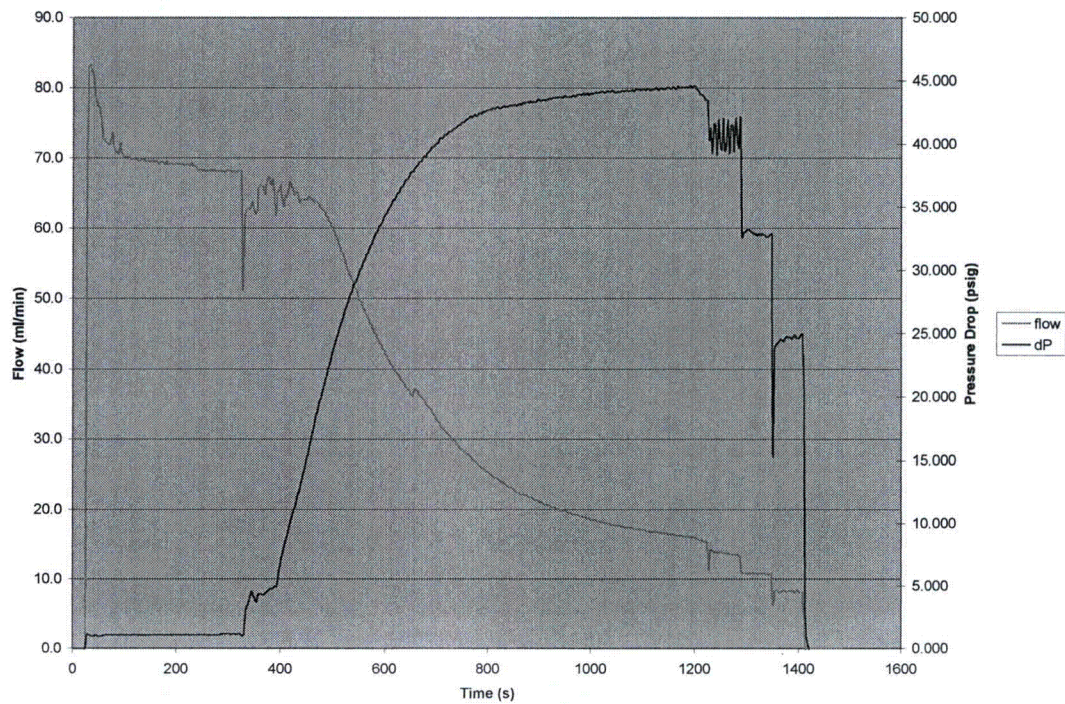
dP vs Flow



Sample: 212926-112-2-(b2) **Test Solution:** AlOOH surrogate made in 4400 ppm B Boric Acid **Simulated Coolant:** 4400 ppm B Boric Acid

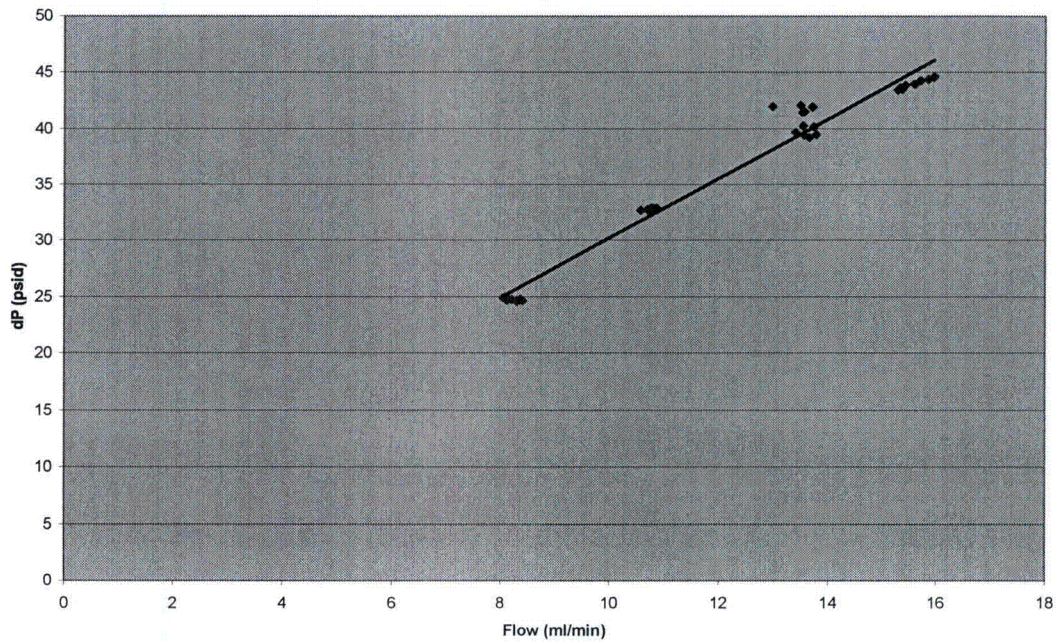


Sample: 212926-112-3-(b3) **Test Solution:** AlOOH surrogate made in 4400 ppm B Boric Acid **Simulated Coolant:** 4400 ppm B Boric Acid

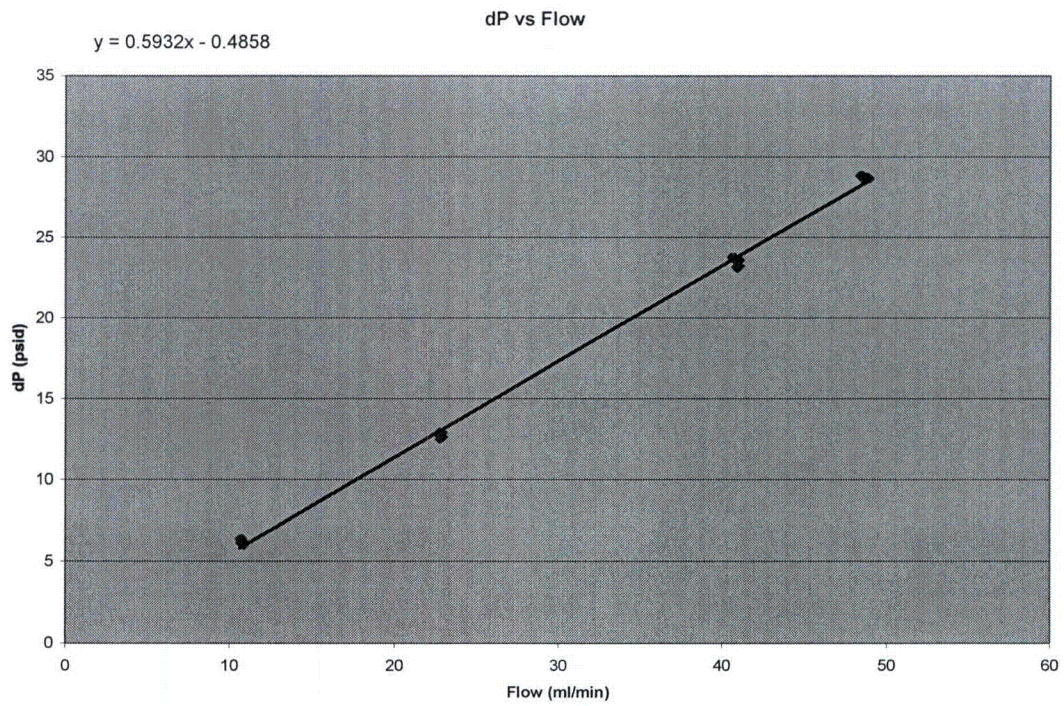
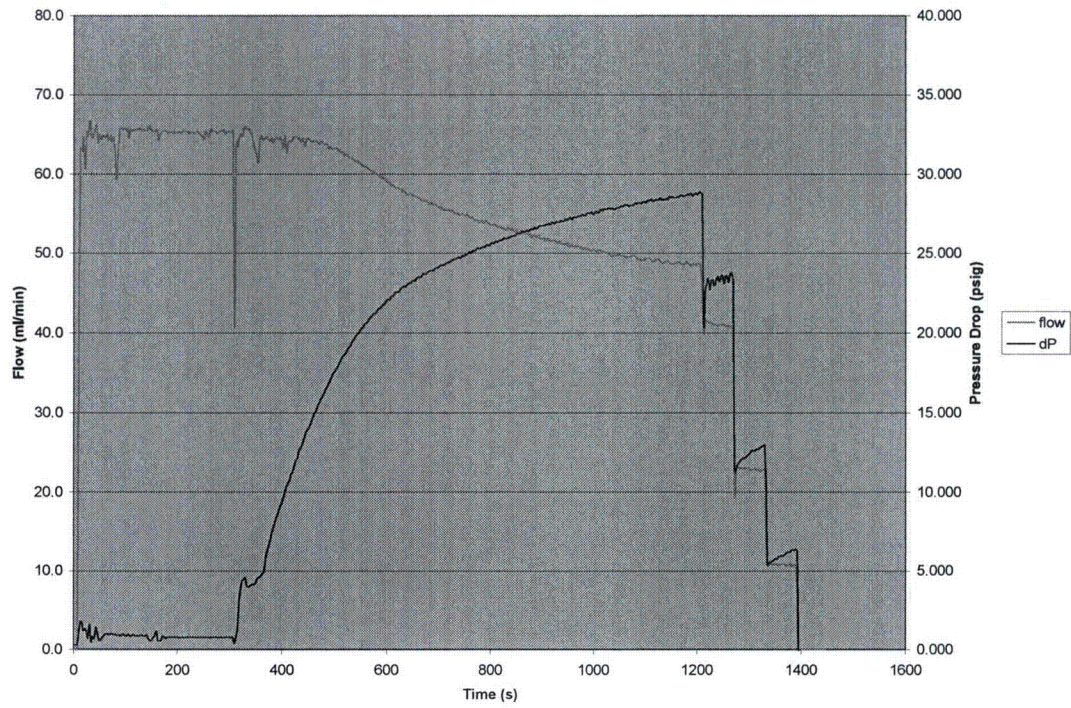


$$y = 2.6573x + 3.6536$$

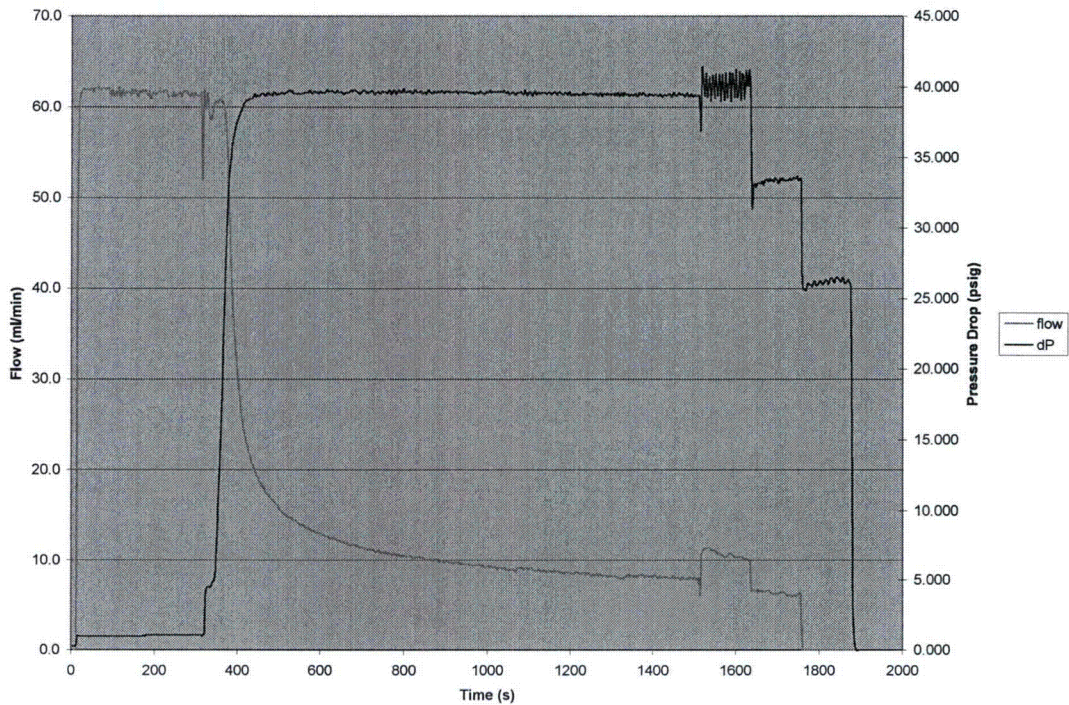
dP vs Flow



Sample: 212926-112-4-(b4) **Test Solution:** AlOOH surrogate made in 4400 ppm B Boric Acid **Simulated Coolant:** 4400 ppm B Boric Acid

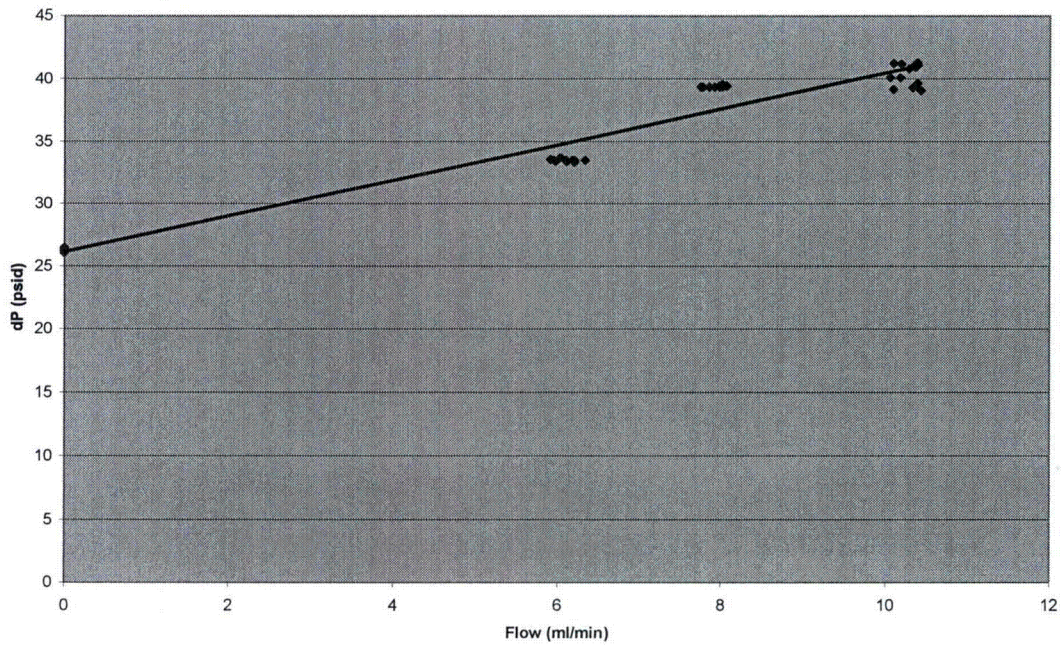


Sample: 212926-120-1 **Test Solution:** AlOOH surrogate made in 4400 ppm B Boric Acid **Simulated Coolant:** Tap Water **Note:** Bad Run-went to zero flow rate

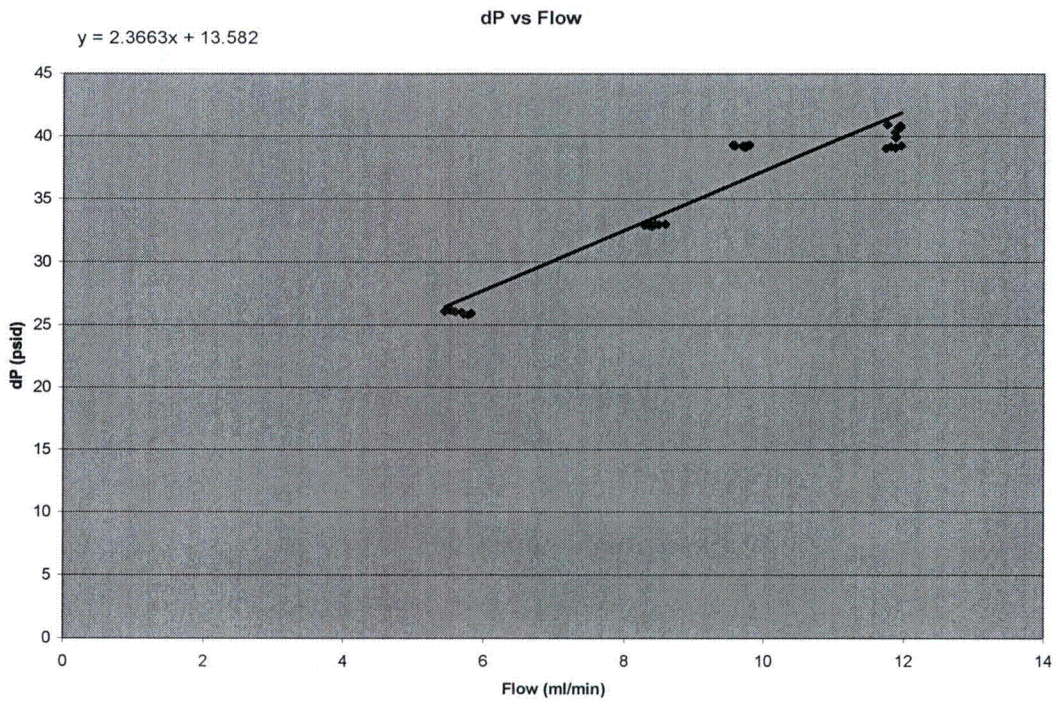
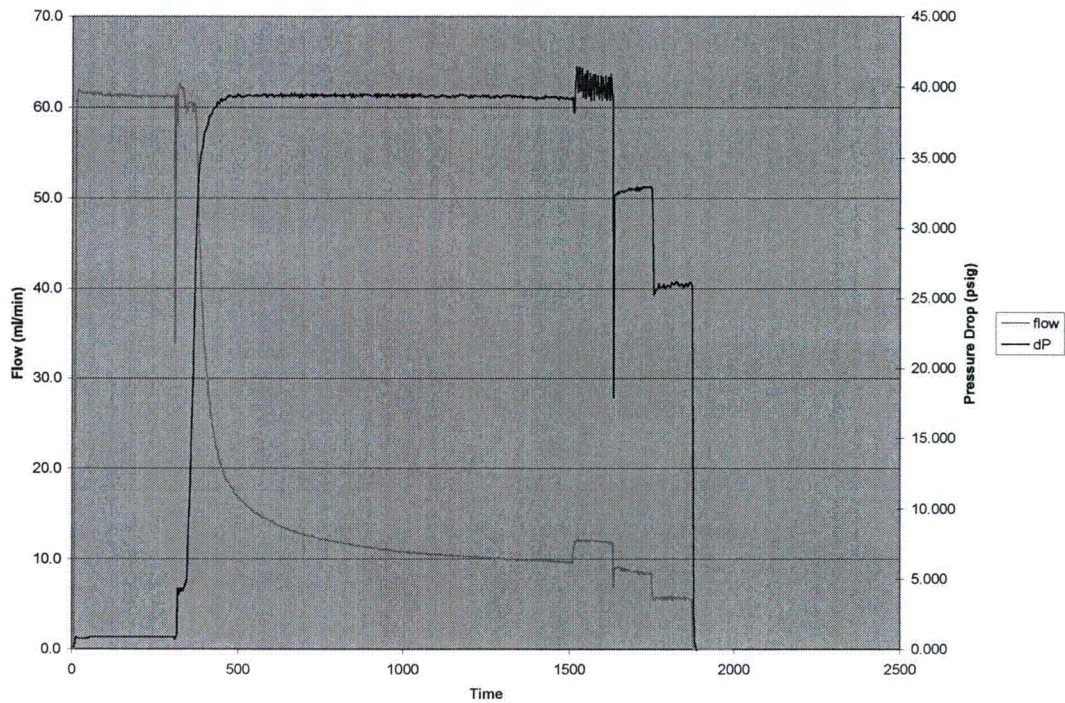


$$y = 1.4317x + 26.138$$

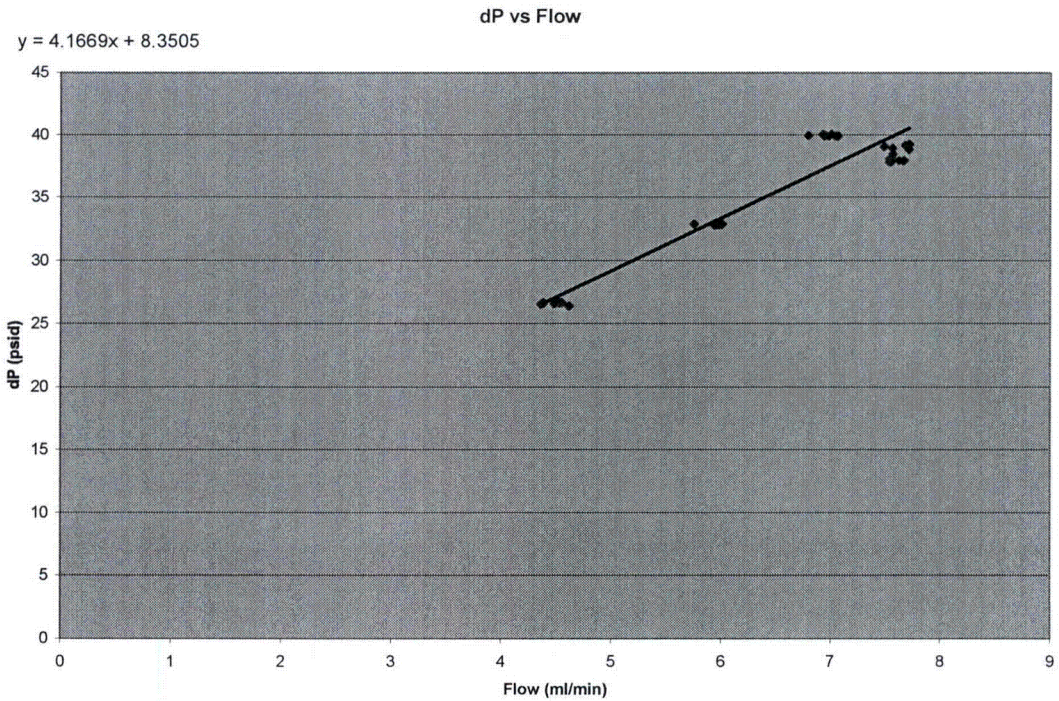
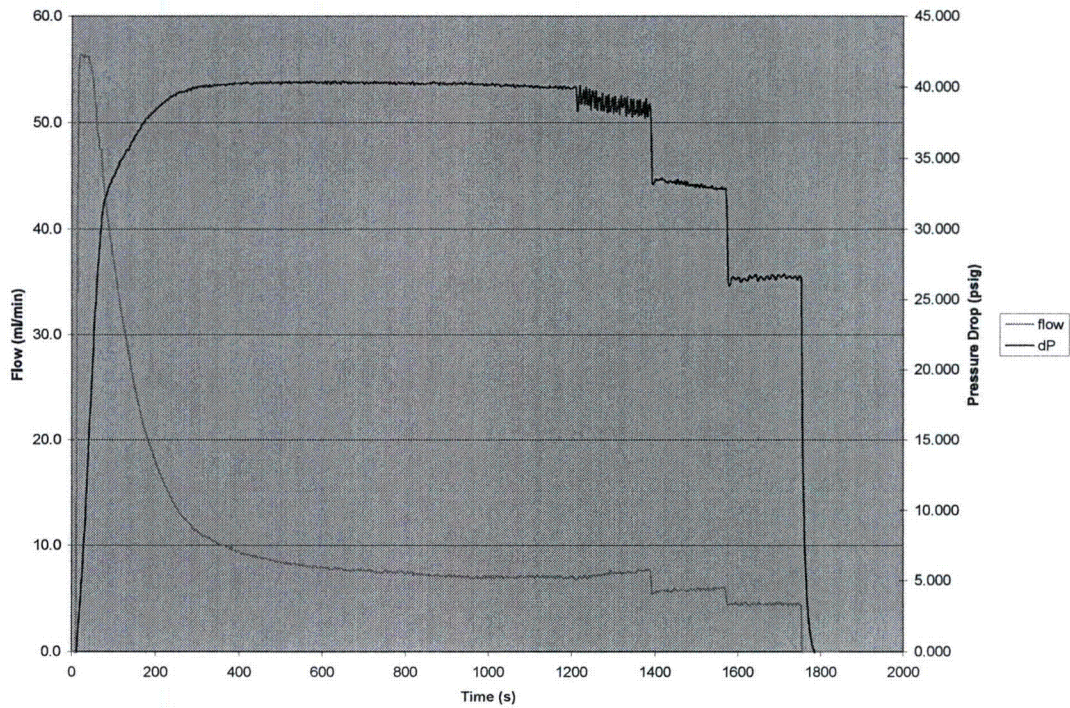
dP vs Flow



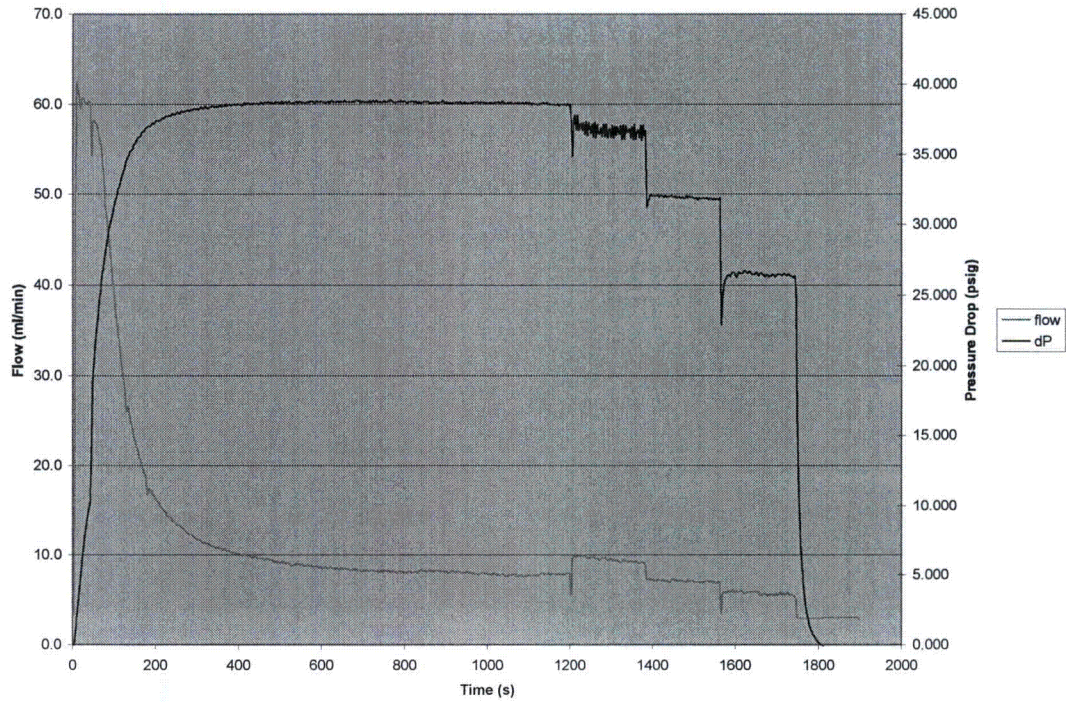
Sample: 212926-120-2 **Test Solution:** AlOOH surrogate made in 4400 ppm B Boric Acid **Simulated Coolant:** Tap Water- Bad – $R^2 < 0.9$



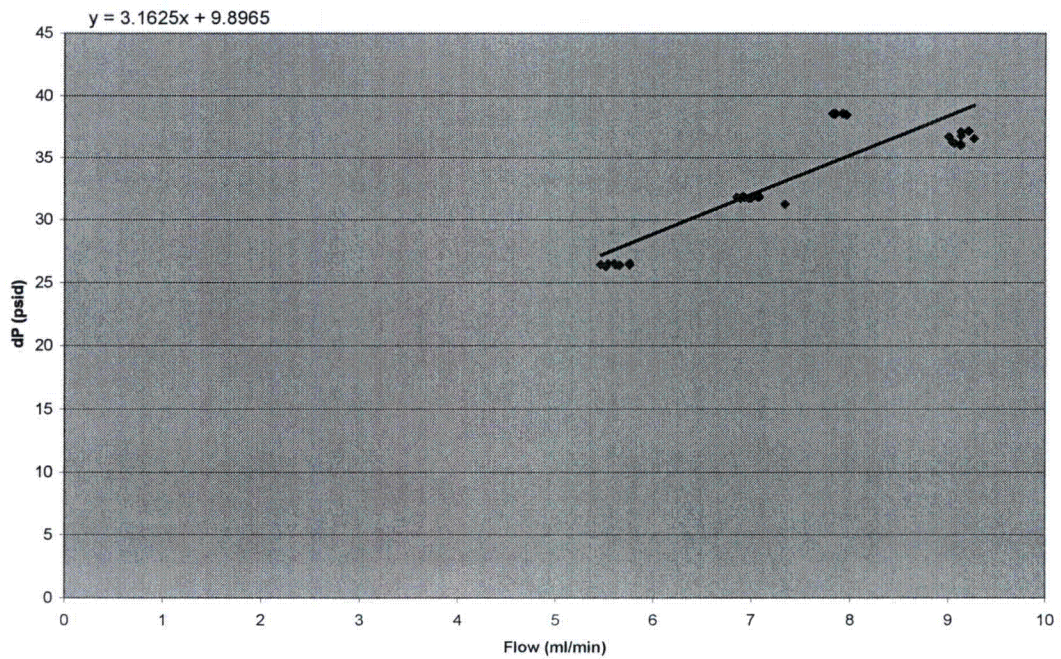
Sample: 212926-145-3 **Test Solution:** AlOOH surrogate made in 4400 ppm B Boric Acid **Simulated Coolant:** 4400 ppm B Boric Acid **Note:** Bad Run-contamination



Sample: 212926-149-1 **Test Solution:** AlOOH surrogate made in 4400 ppm B Boric Acid **Simulated Coolant:** 4400 ppm B Boric Acid **Note:** Bad Run-contamination



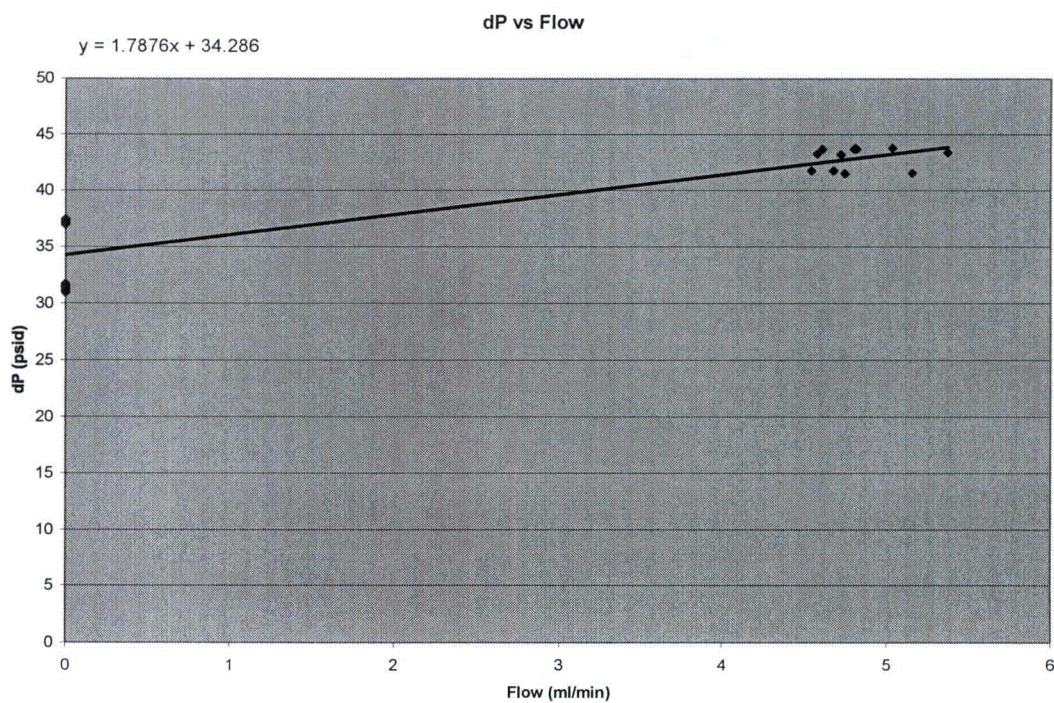
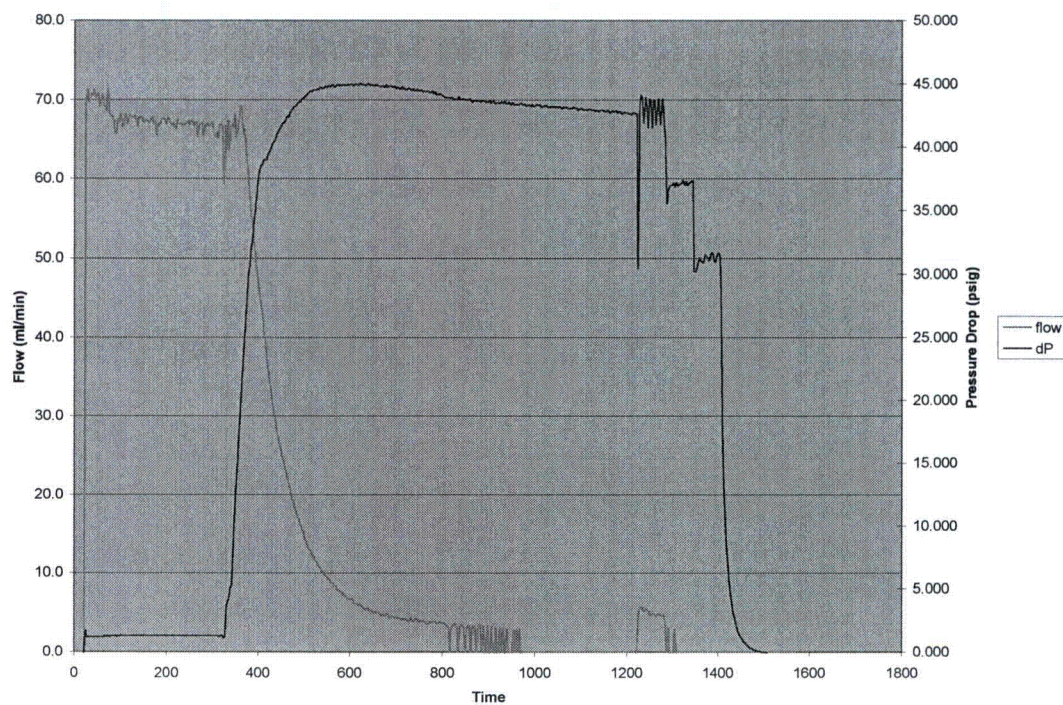
dP vs Flow



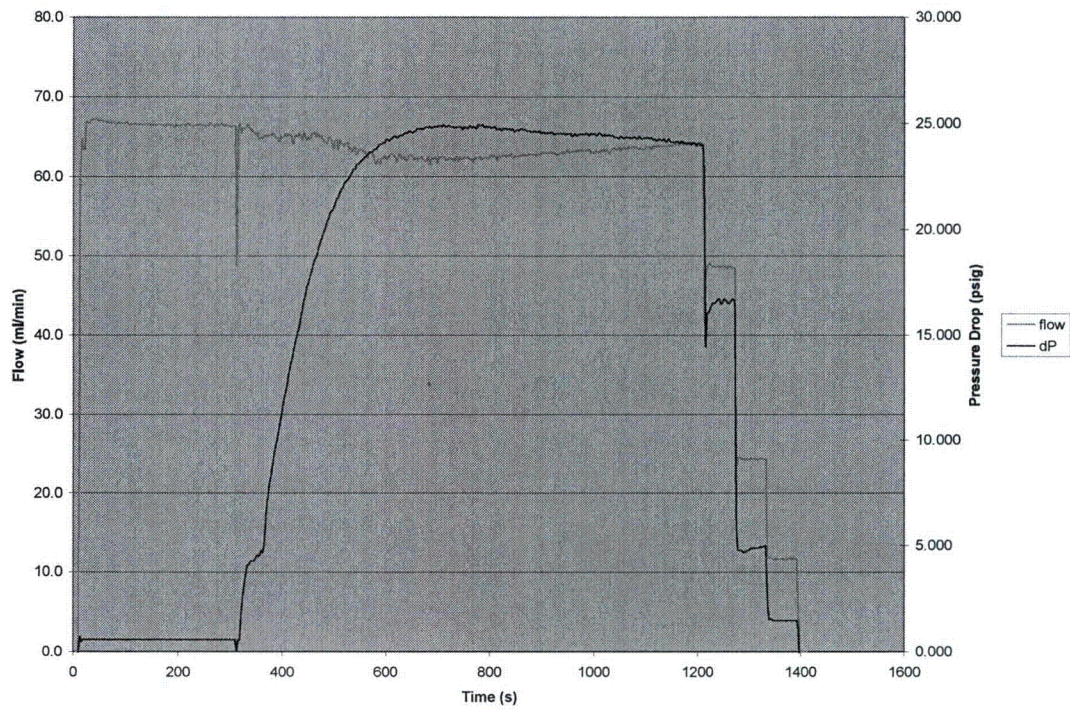
Sample: 212926-149-2 **Test Solution:** AlOOH surrogate made in 4400 ppm B Boric Acid **Simulated Coolant:** 4400 ppm B Boric Acid **Note:** Bad Run-contamination

File Not Available

Sample: 212926-113-1-(c1) **Test Solution:** Aluminum Corrosion product rapidly cooled made in 4400 ppm B Boric Acid **Simulated Coolant:** 4400 ppm B Boric Acid **Note:** Bad Run-Flow rate went to zero

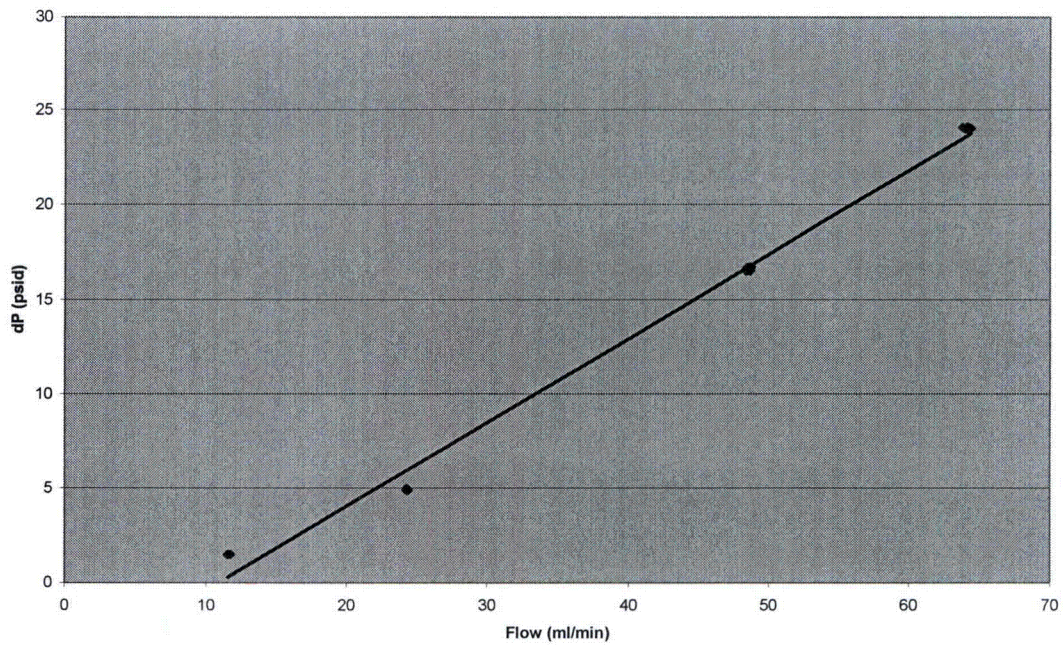


Sample: 212926-113-2-(c2) **Test Solution:** Aluminum Corrosion product rapidly cooled made in 4400 ppm B Boric Acid **Simulated Coolant:** 4400 ppm B Boric Acid

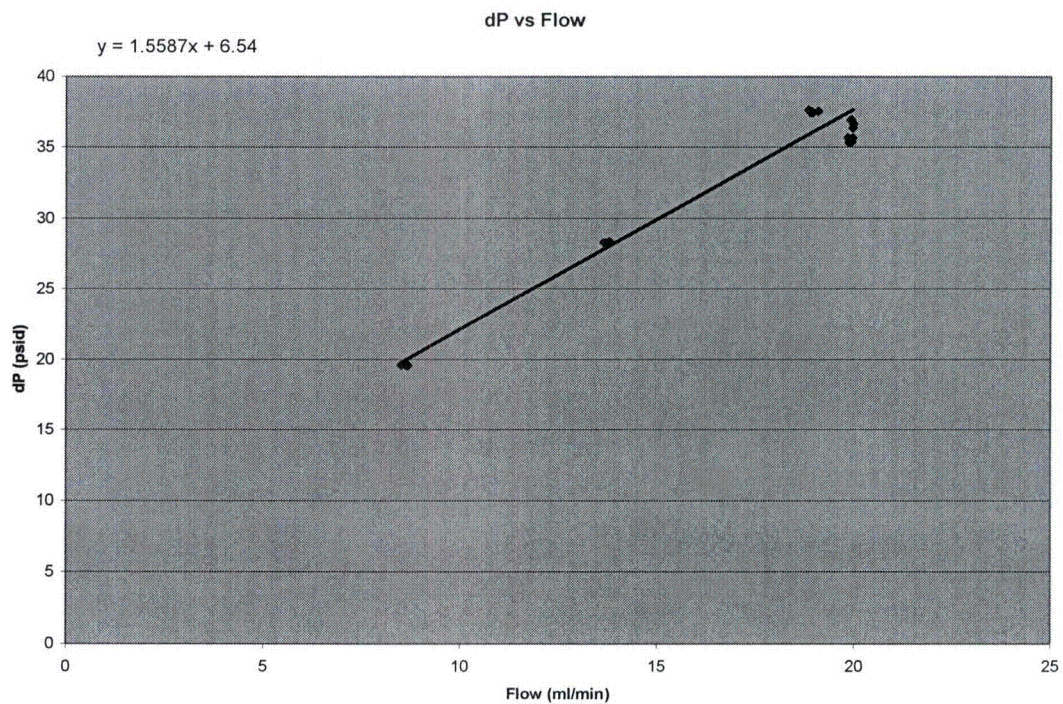
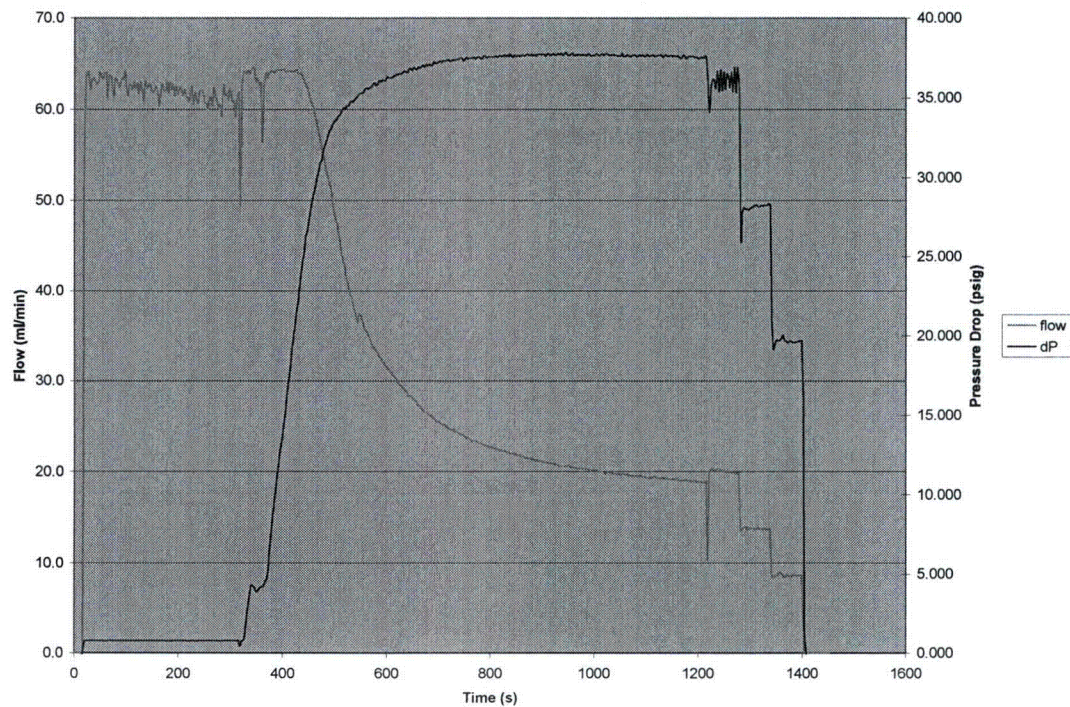


$$y = 0.444x - 4.8318$$

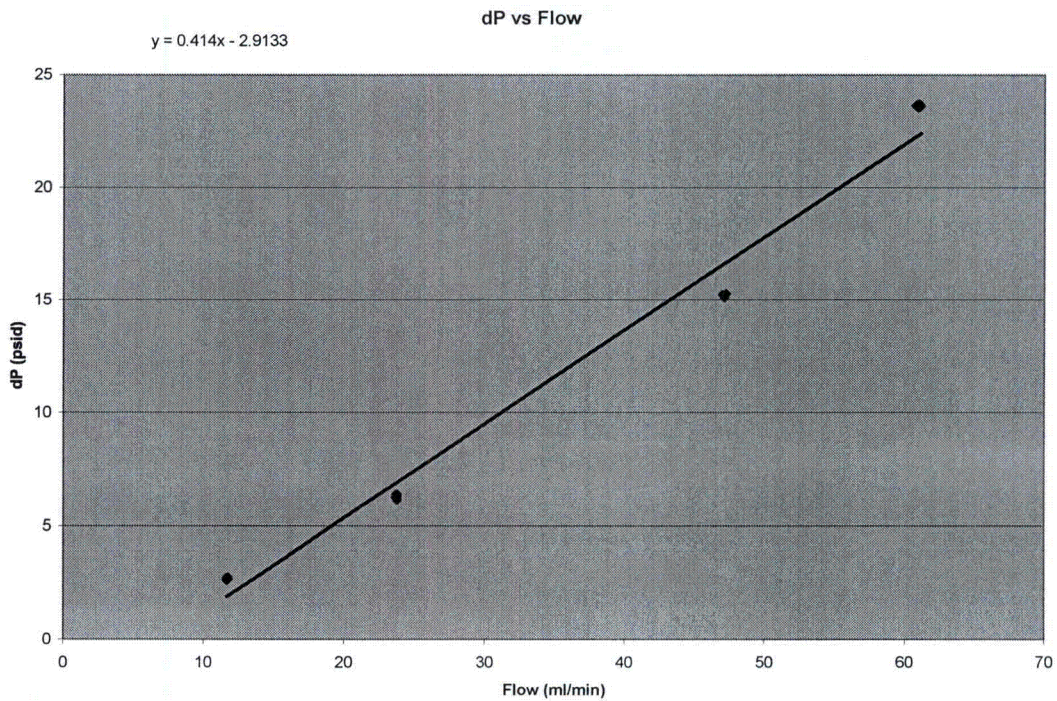
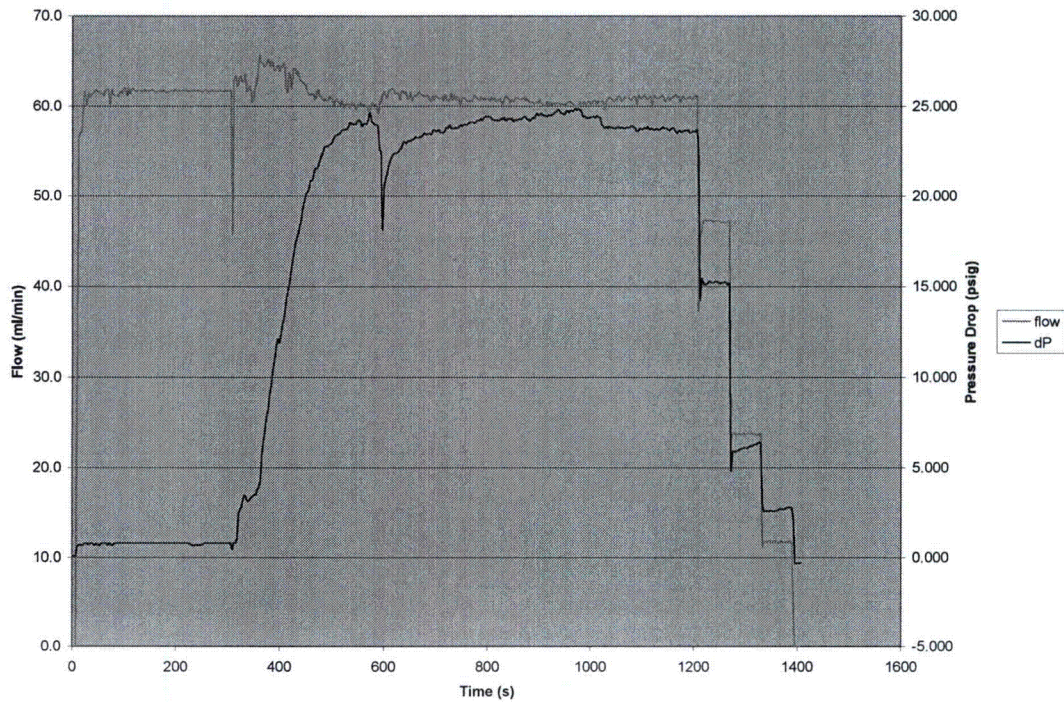
dP vs Flow



Sample: 212926-113-3-(c3) **Test Solution:** Aluminum Corrosion product rapidly cooled
made in 4400 ppm B Boric Acid **Simulated Coolant:** 4400 ppm B Boric Acid



Sample: 212926-113-4-(c4) **Test Solution:** Aluminum Corrosion product rapidly cooled
made in 4400 ppm B Boric Acid **Simulated Coolant:** 4400 ppm B Boric Acid
Note: Bad Run-Leak in the filter cartridge

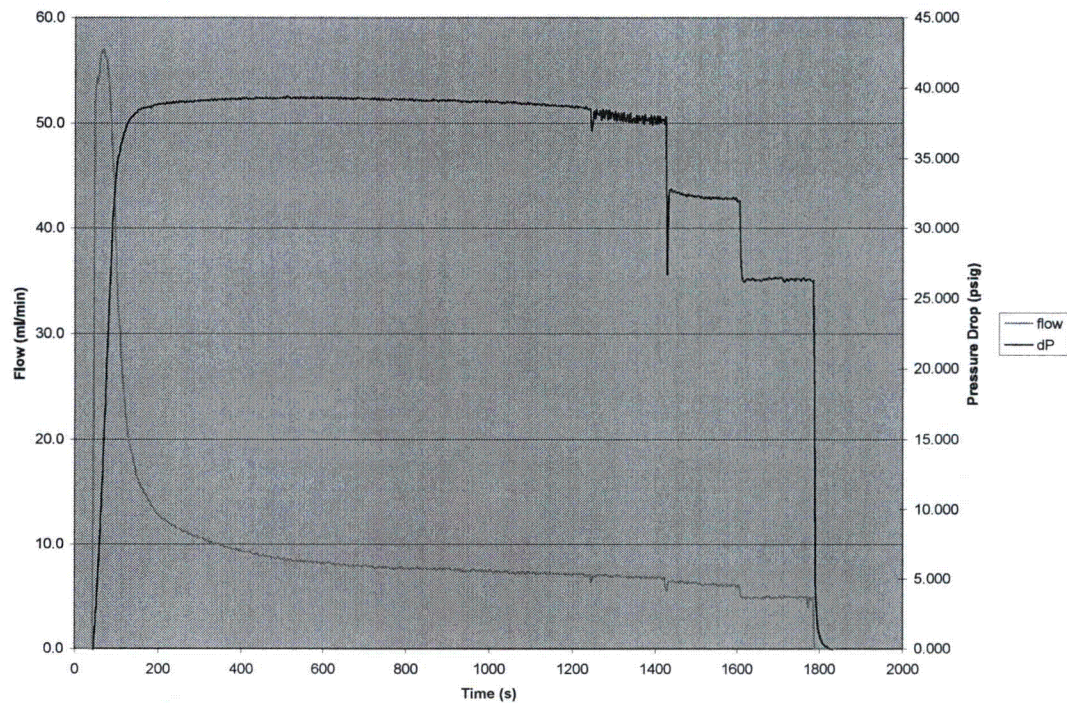


Sample: 212926-117-1-(c5) **Test Solution:** Aluminum Corrosion product rapidly cooled
made in 4400 ppm B Boric Acid **Simulated Coolant:** 4400 ppm B Boric Acid

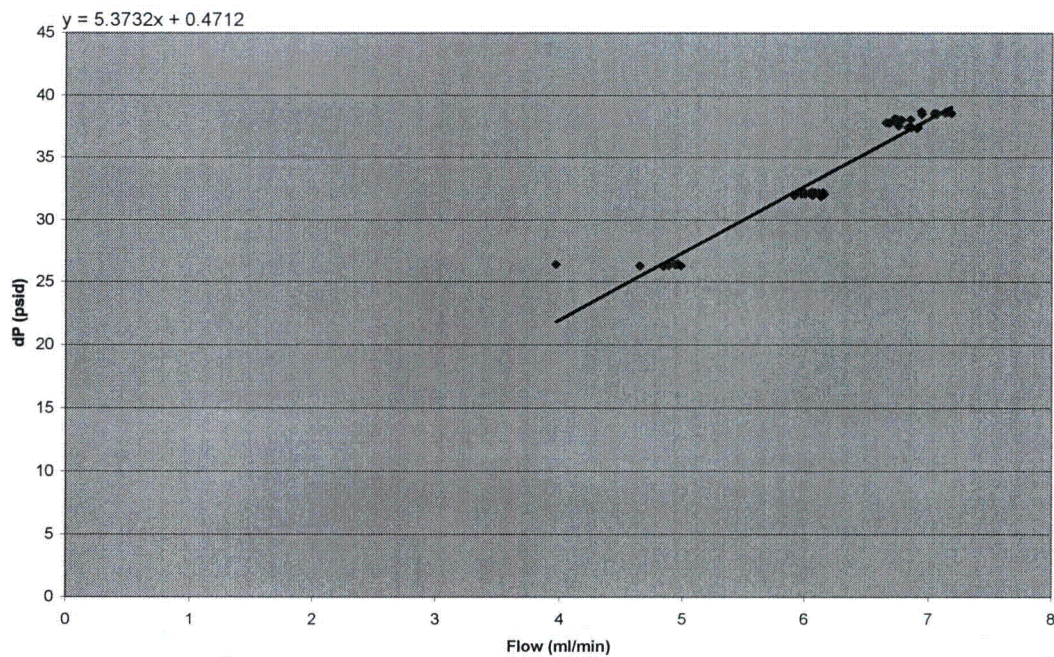
Note: Bad Run-Operator Error

File Not Available

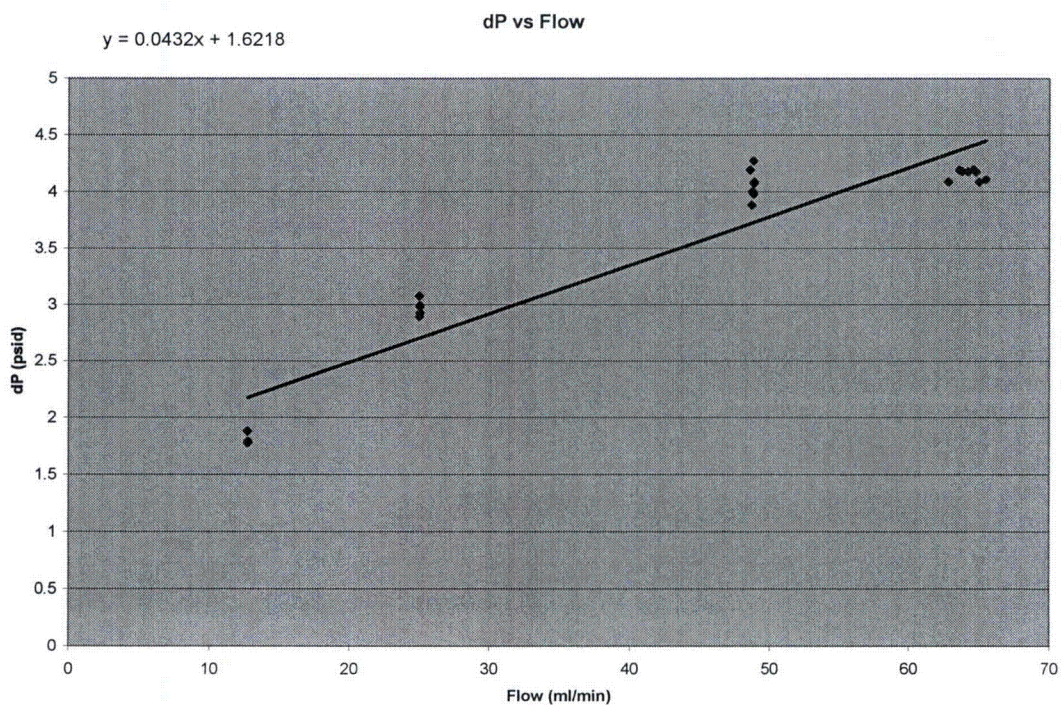
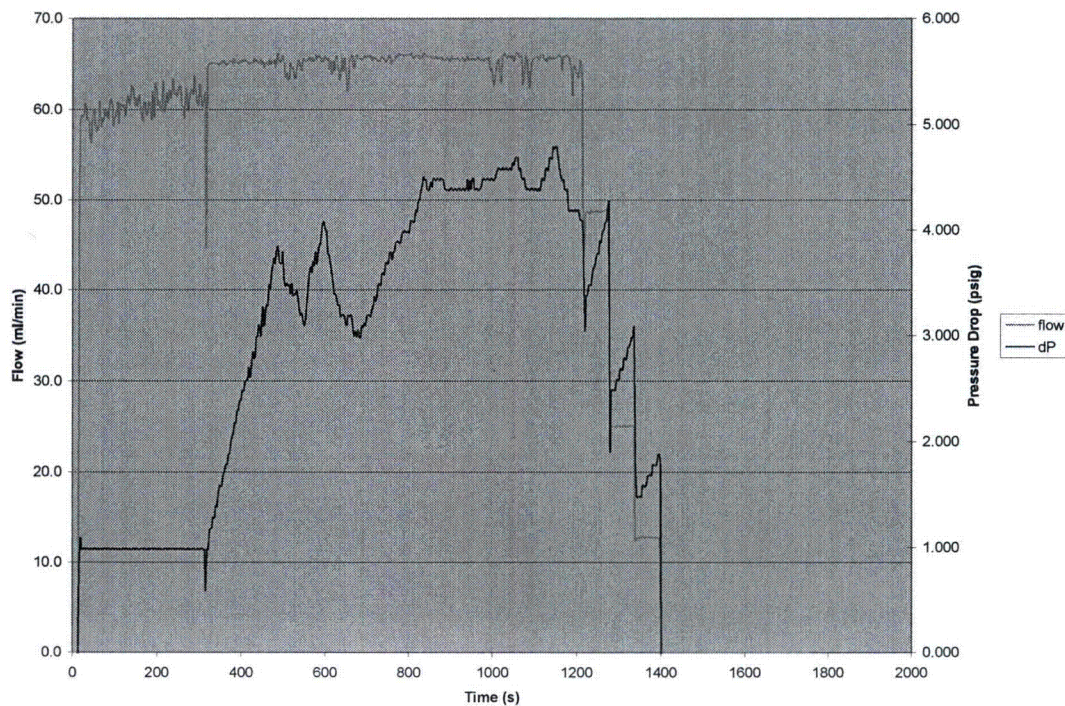
Sample: 212926-147-3 **Test Solution:** Aluminum Corrosion product rapidly cooled
made in 4400 ppm B Boric Acid **Simulated Coolant:** 4400 ppm B Boric Acid



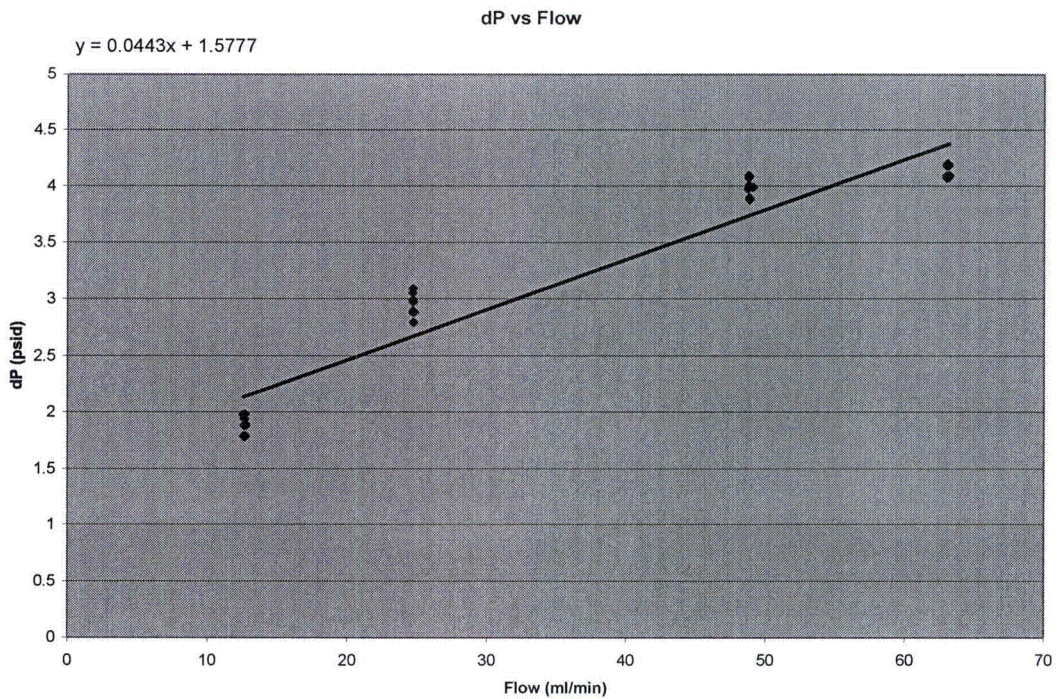
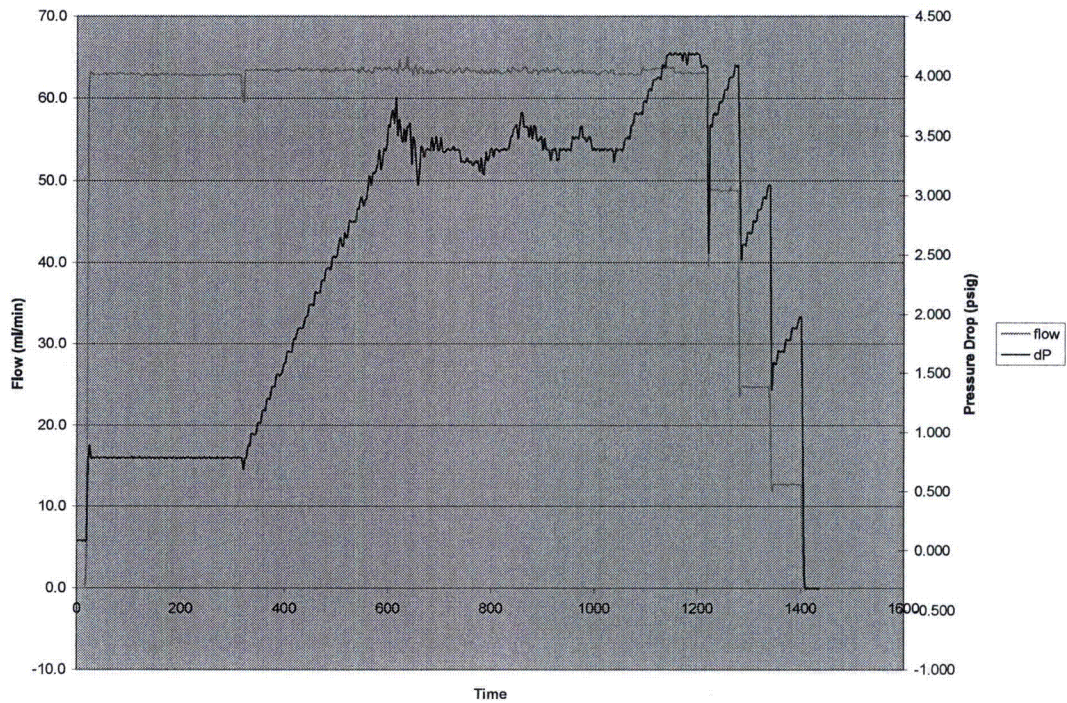
dP vs Flow



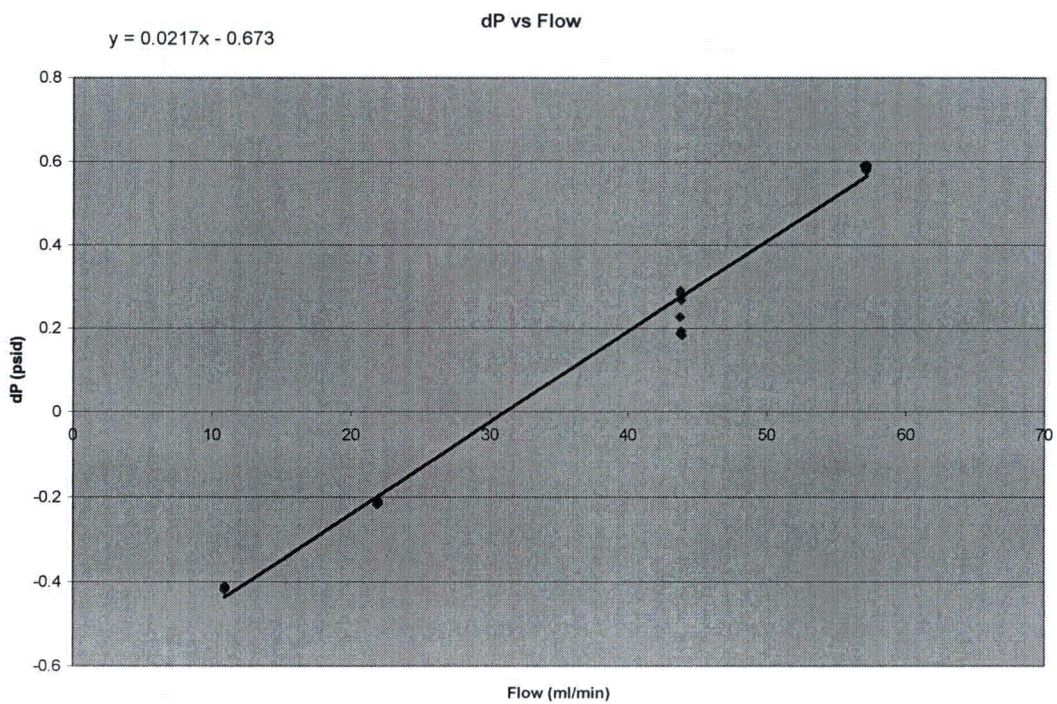
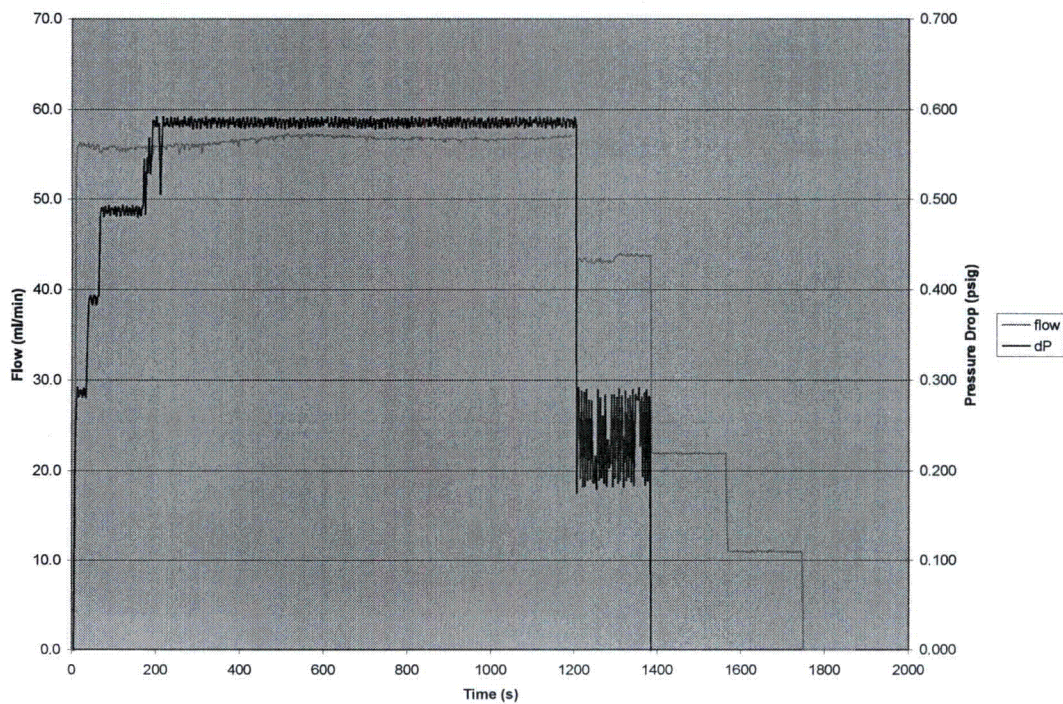
Sample: 212926-114-1-(d1) **Test Solution:** Aluminum Corrosion product slowly cooled
made in 4400 ppm B Boric Acid **Simulated Coolant:** 4400 ppm B Boric Acid – Bad R²
< 0.9



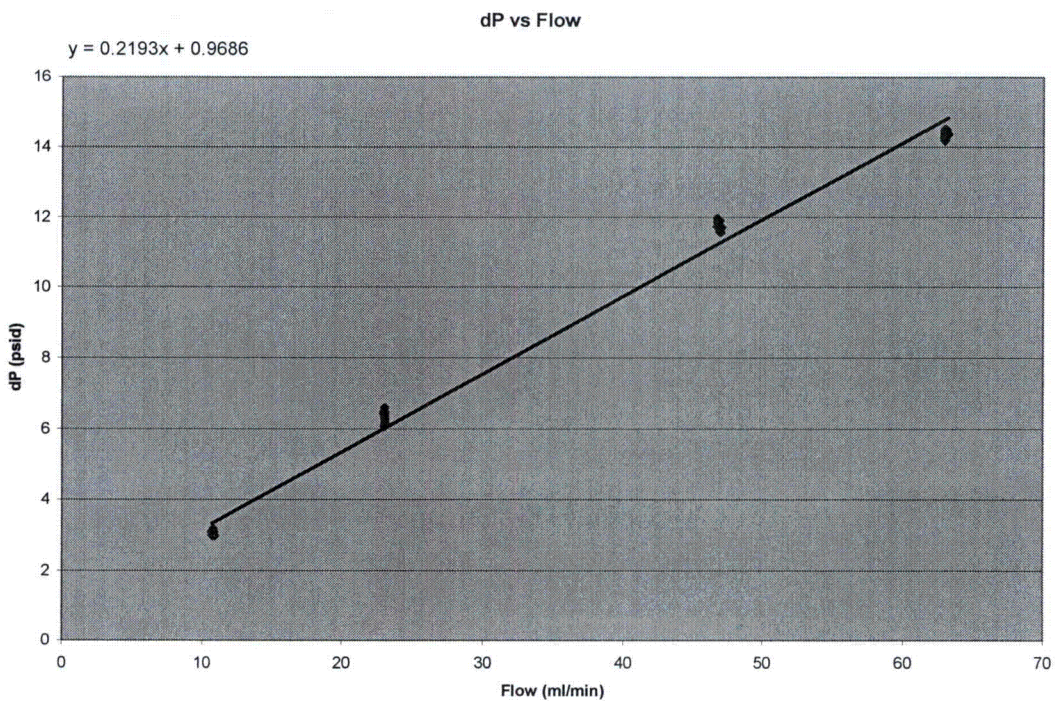
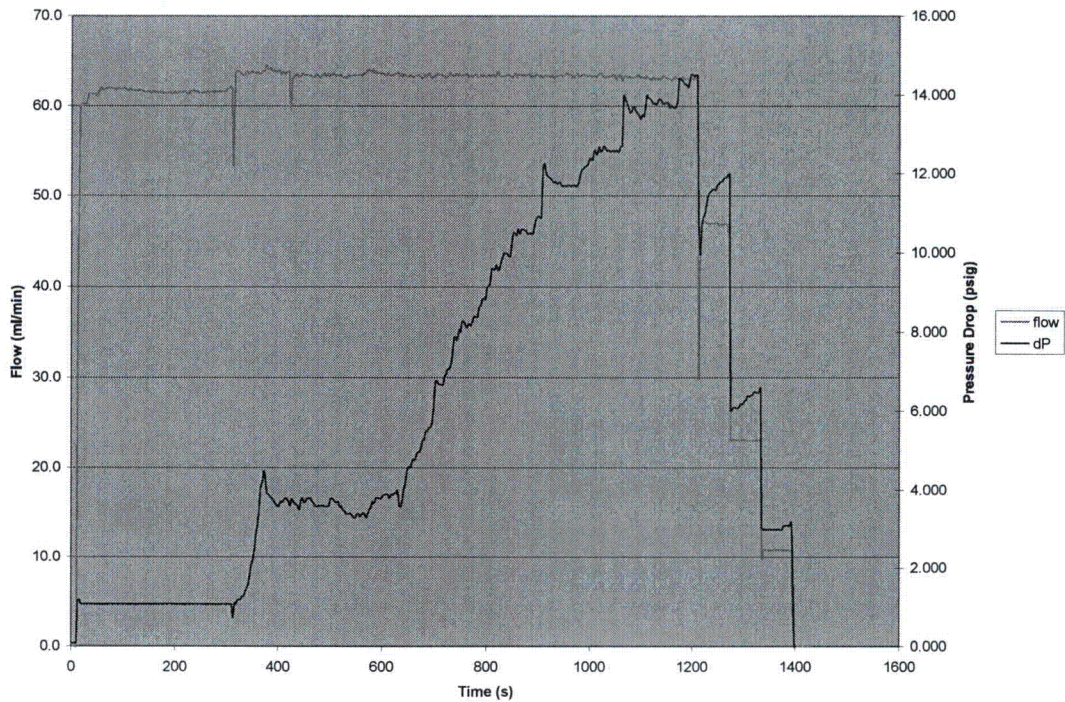
Sample: 212926-114-1-(d2) **Test Solution:** Aluminum Corrosion product slowly cooled
made in 4400 ppm B Boric Acid **Simulated Coolant:** 4400 ppm B Boric Acid



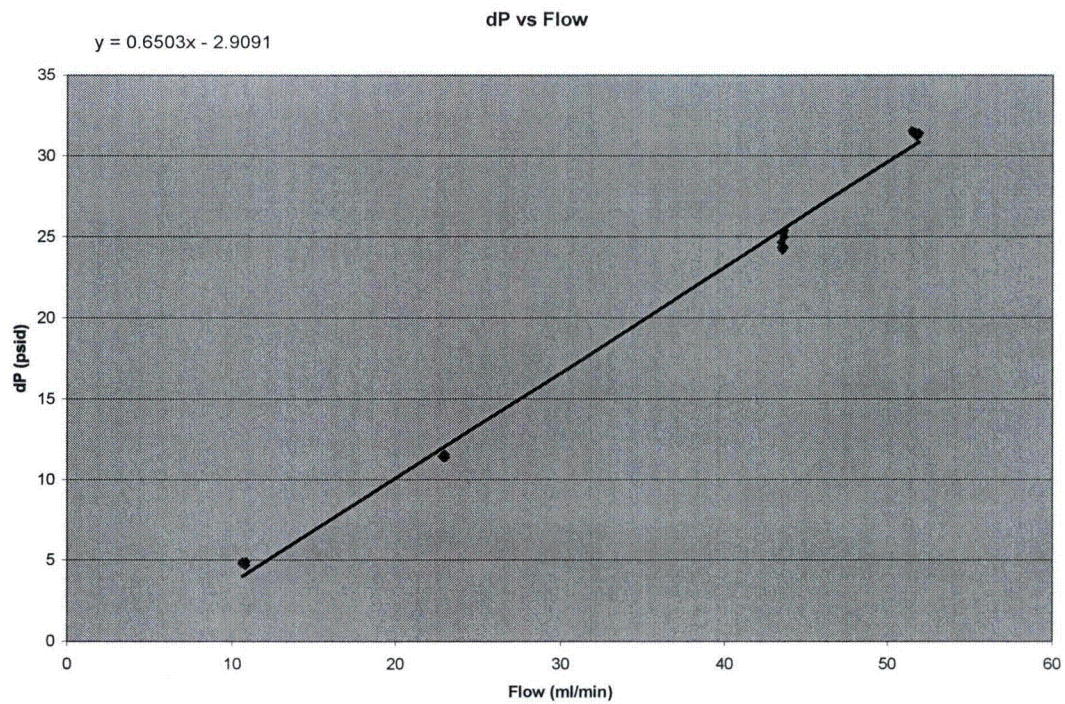
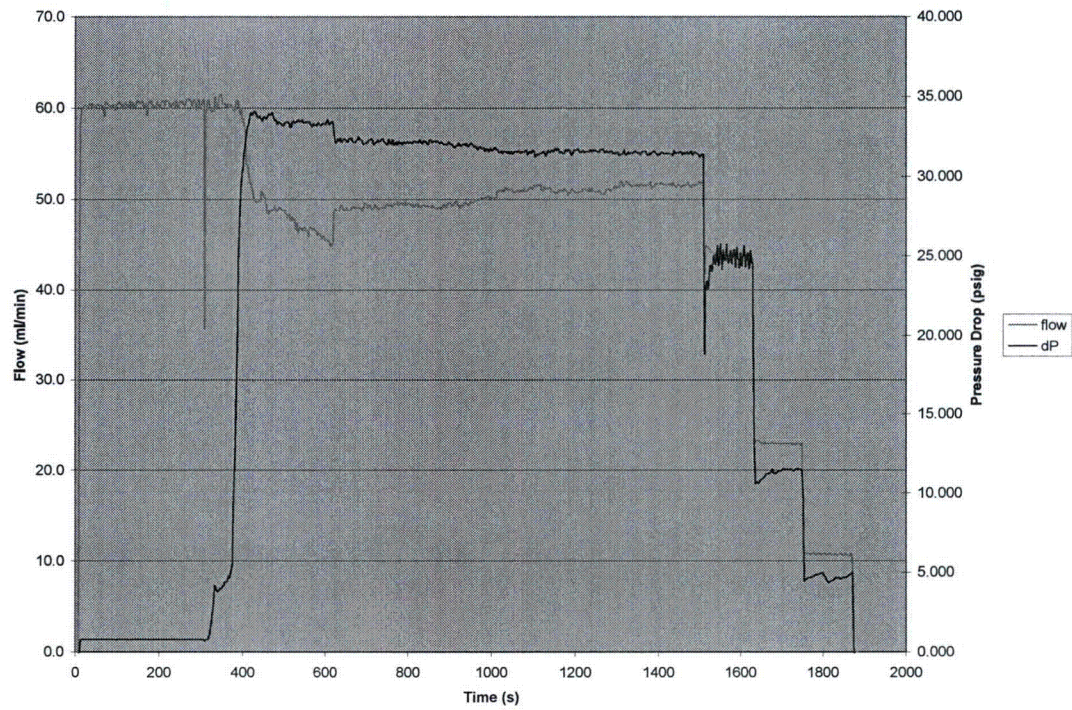
Sample: 212926-147-4 **Test Solution:** Aluminum Corrosion product slowly cooled
 made in 4400 ppm B Boric Acid **Simulated Coolant:** 4400 ppm B Boric Acid
Note: Bad Run-there was contamination in the system



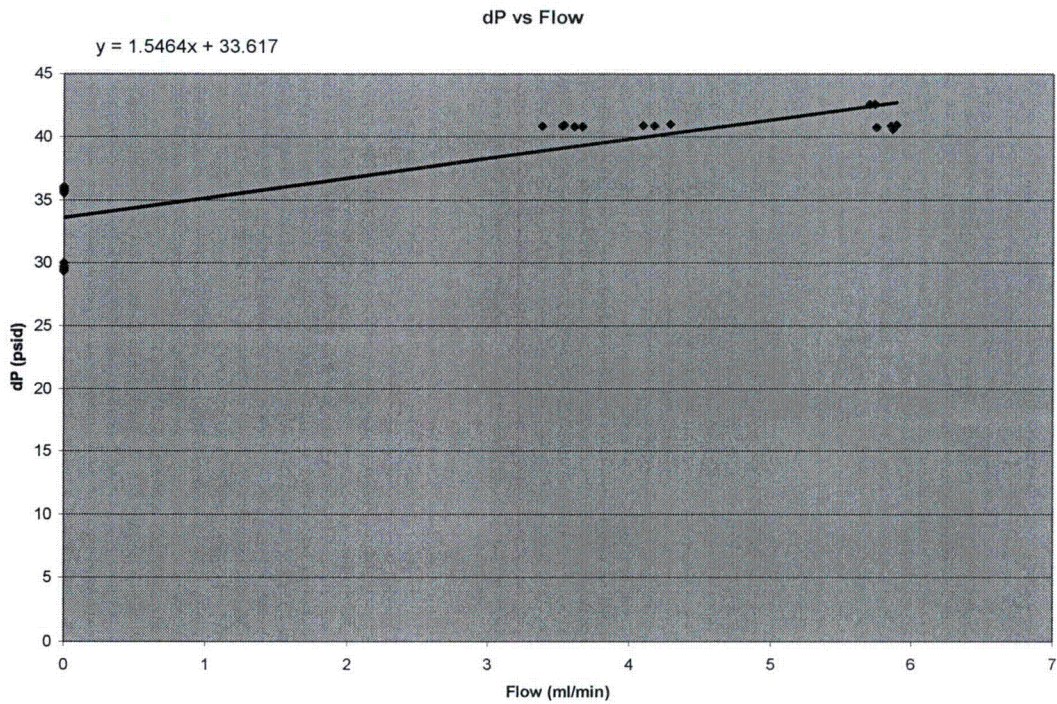
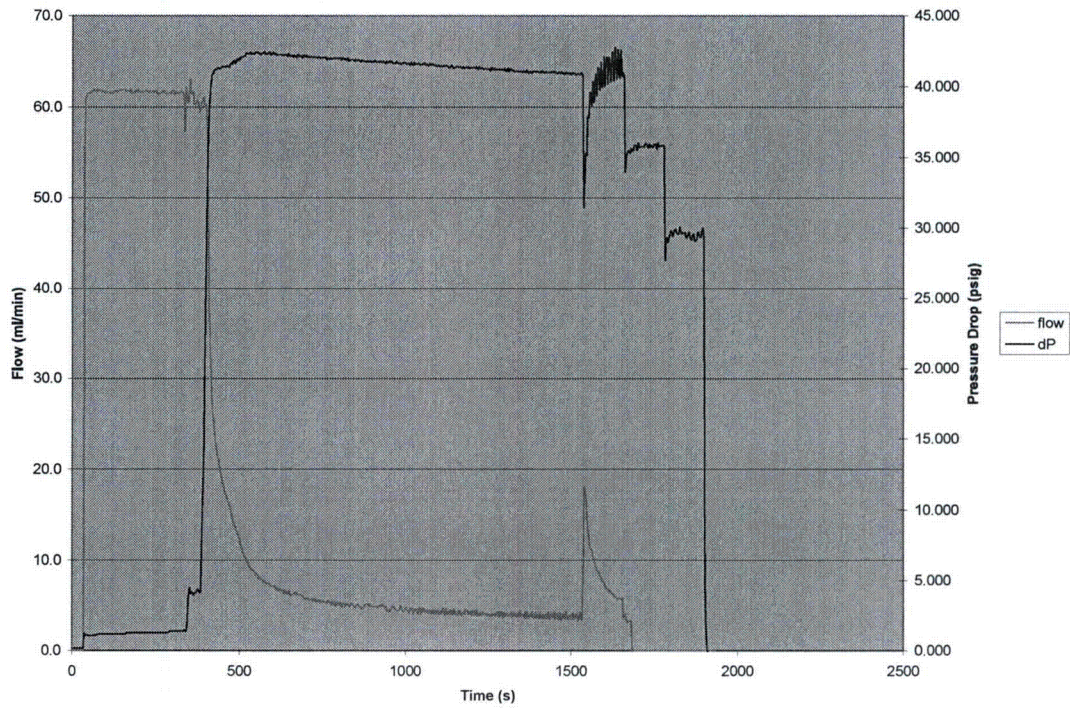
Sample: 212926-117-3-(N3) **Test Solution:** Sodium Aluminum Silicate Surrogate made in Tap Water **Simulated Coolant:** Tap Water **Note:** Bad Run-Pressure Stability Requirement not Met



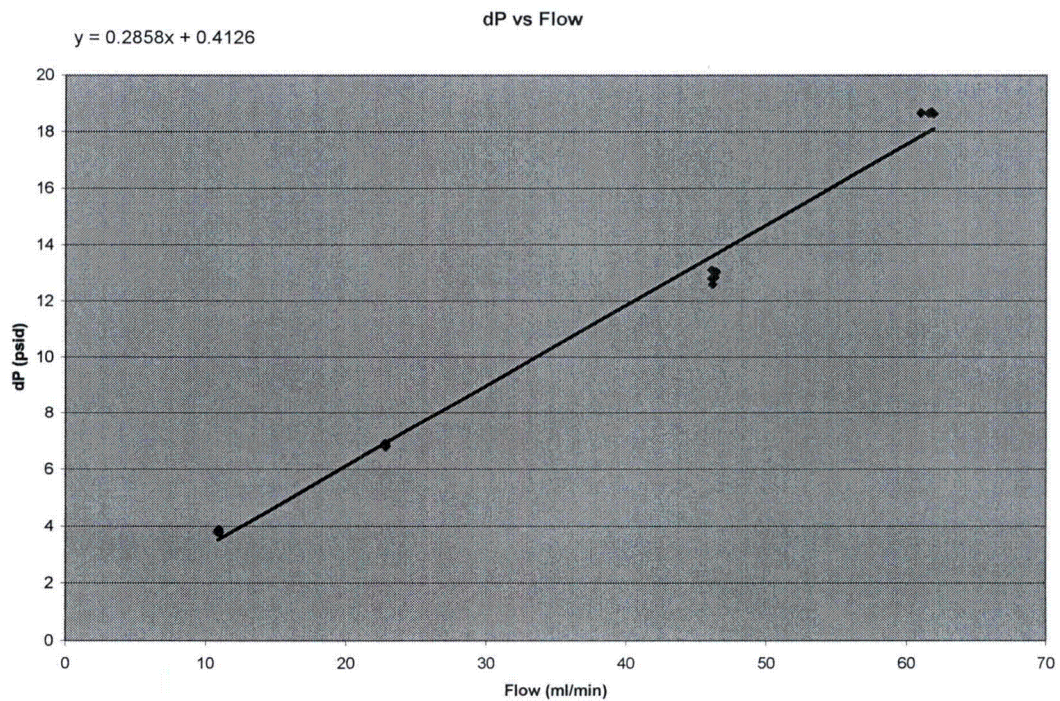
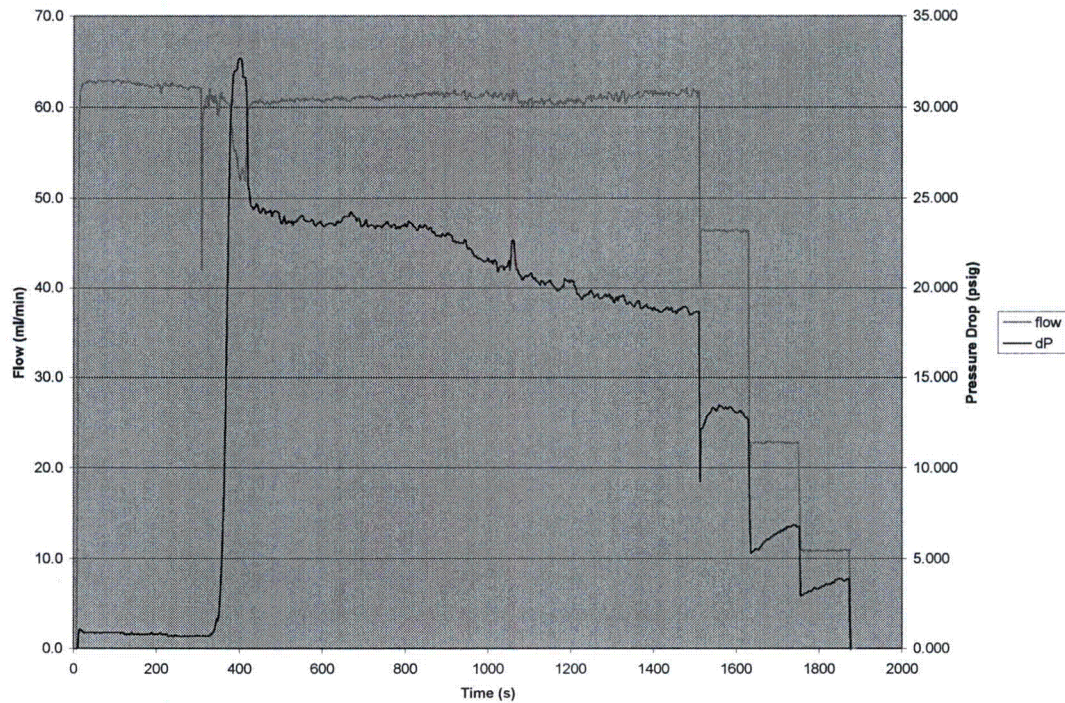
Sample: 212926-117-4-(N4) **Test Solution:** Sodium Aluminum Silicate Surrogate made in Tap Water **Simulated Coolant:** Tap Water **Note:** Bad Run – dP loss exceeded limit



Sample: 212926-119-1 **Test Solution:** Sodium Aluminum Silicate Surrogate made in Tap Water **Simulated Coolant:** Tap Water **Note:** Bad Run-went to zero flow



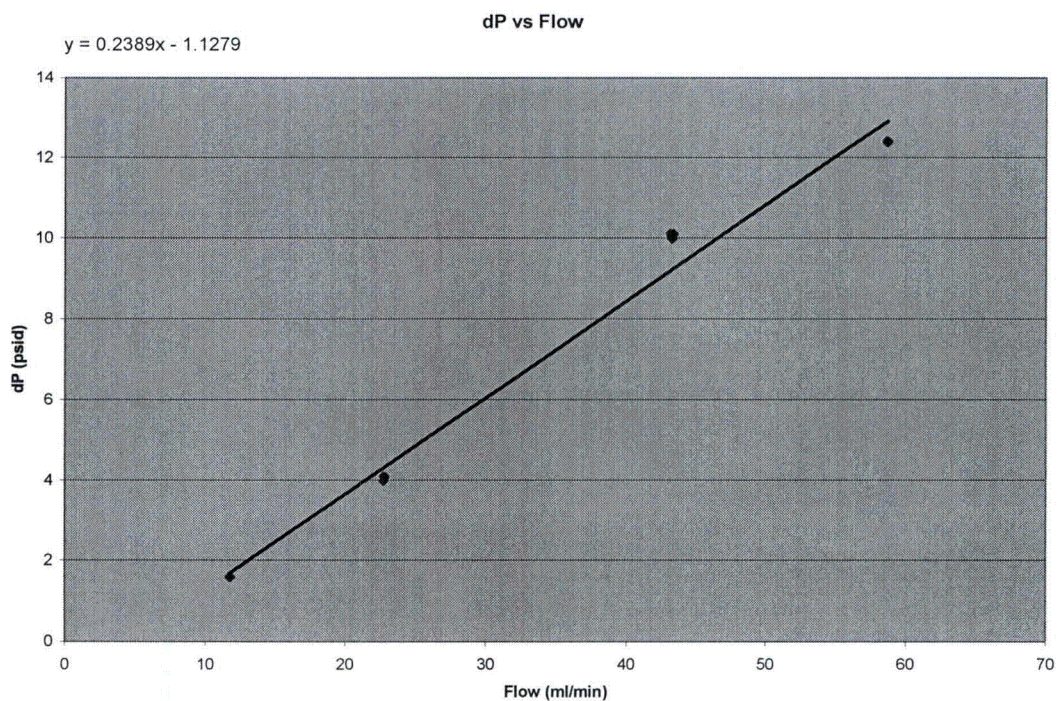
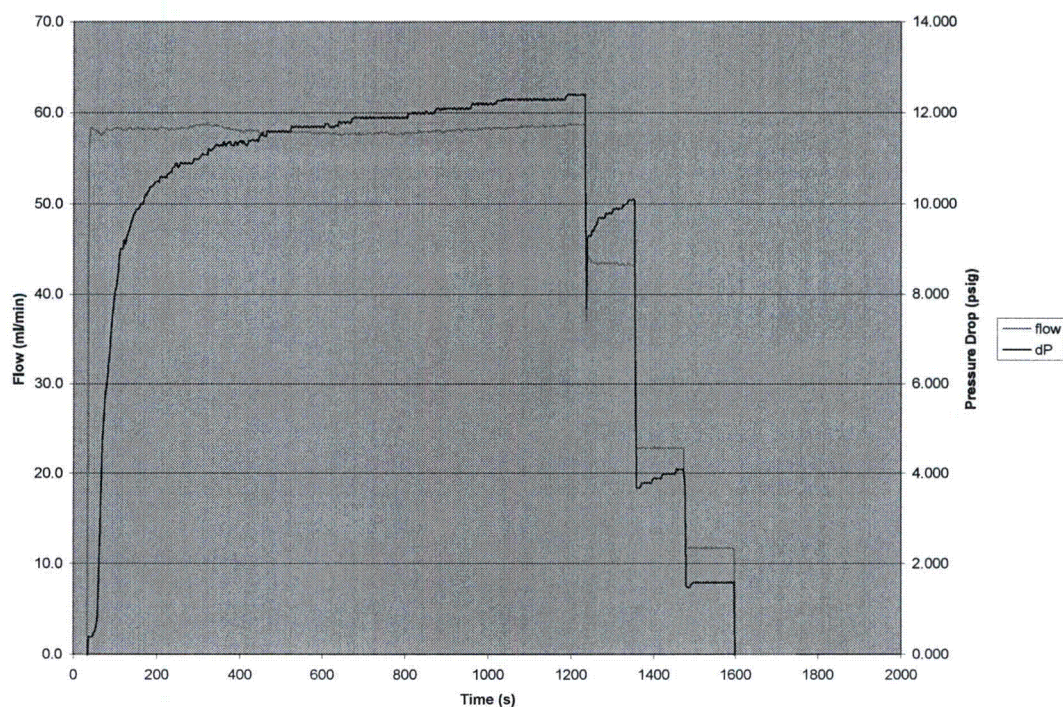
Sample: 212926-119-2 **Test Solution:** Sodium Aluminum Silicate Surrogate made in Tap Water **Simulated Coolant:** Tap Water **Note:** Bad Run-operator error



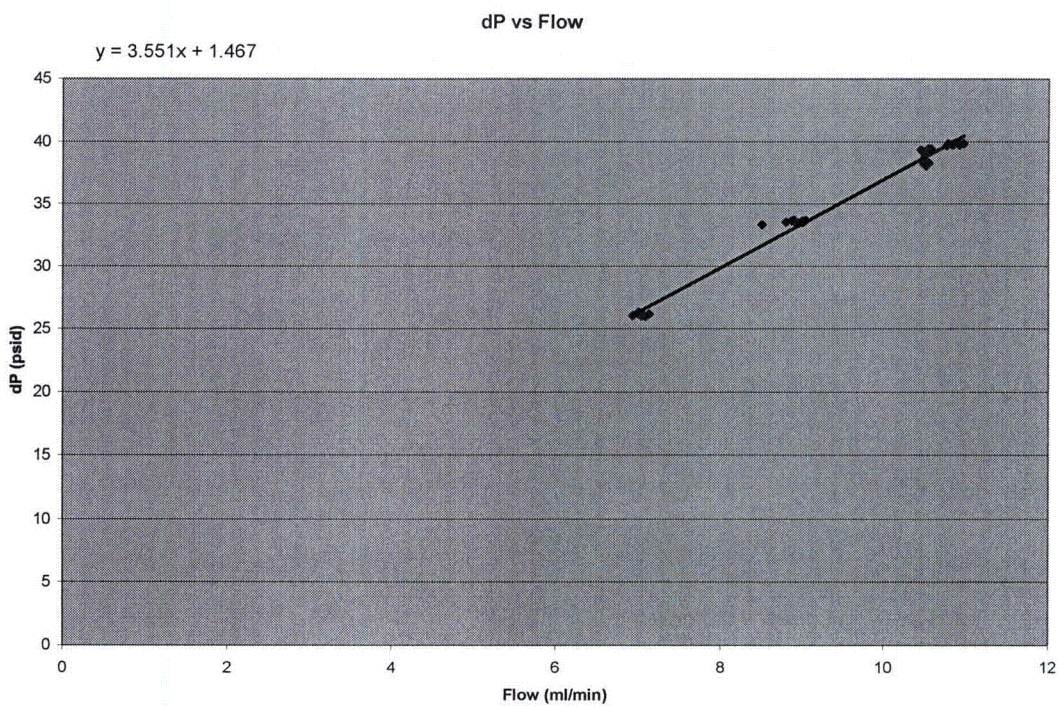
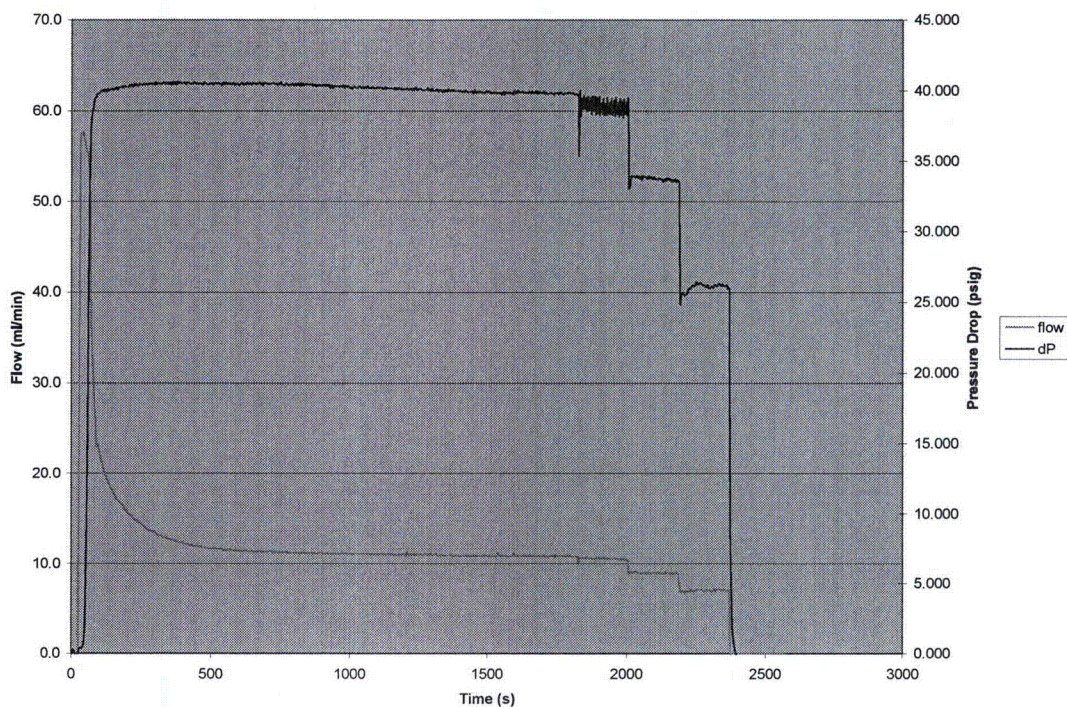
Sample: 212926-119-3 **Test Solution:** Sodium Aluminum Silicate Surrogate made in
Tap Water **Simulated Coolant:** Tap Water **Note:** Bad Run-Pressure Stability
Requirement not Met

File Not Available

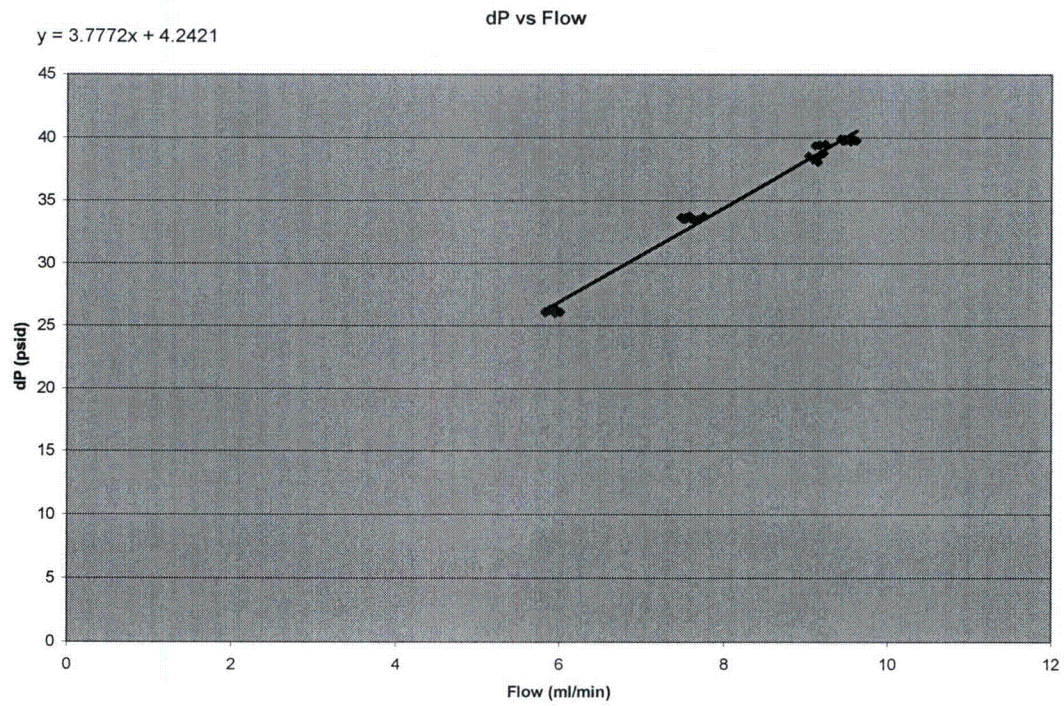
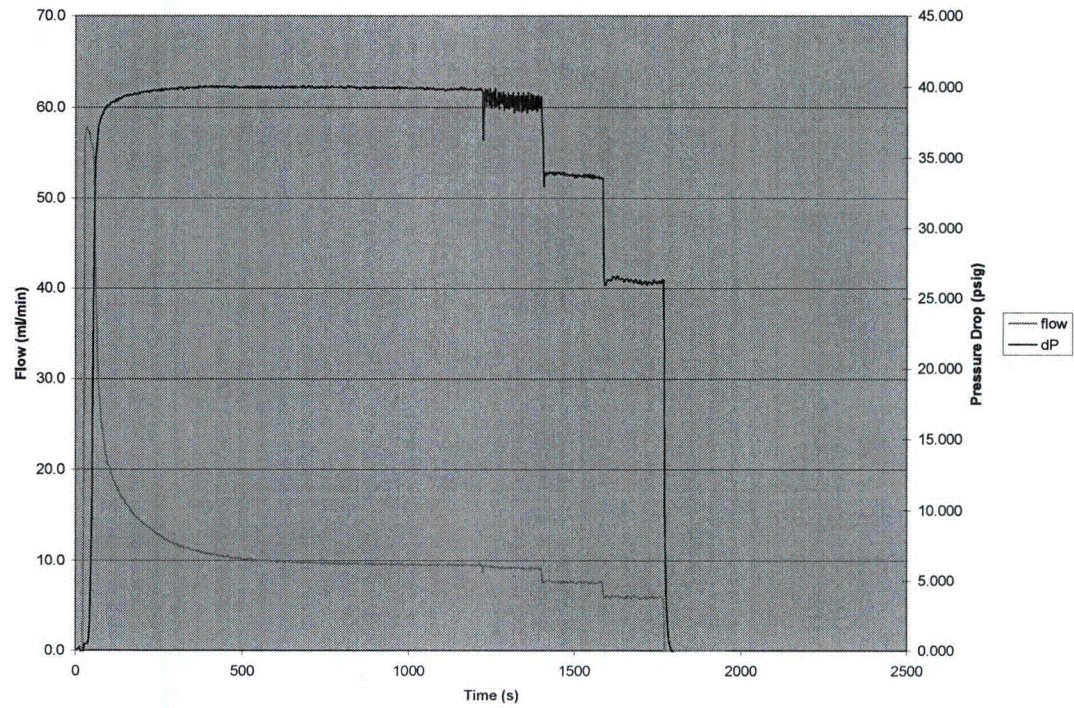
Sample: 212926-137-1 **Test Solution:** Sodium Aluminum Silicate Surrogate made in Tap Water **Simulated Coolant:** Tap Water



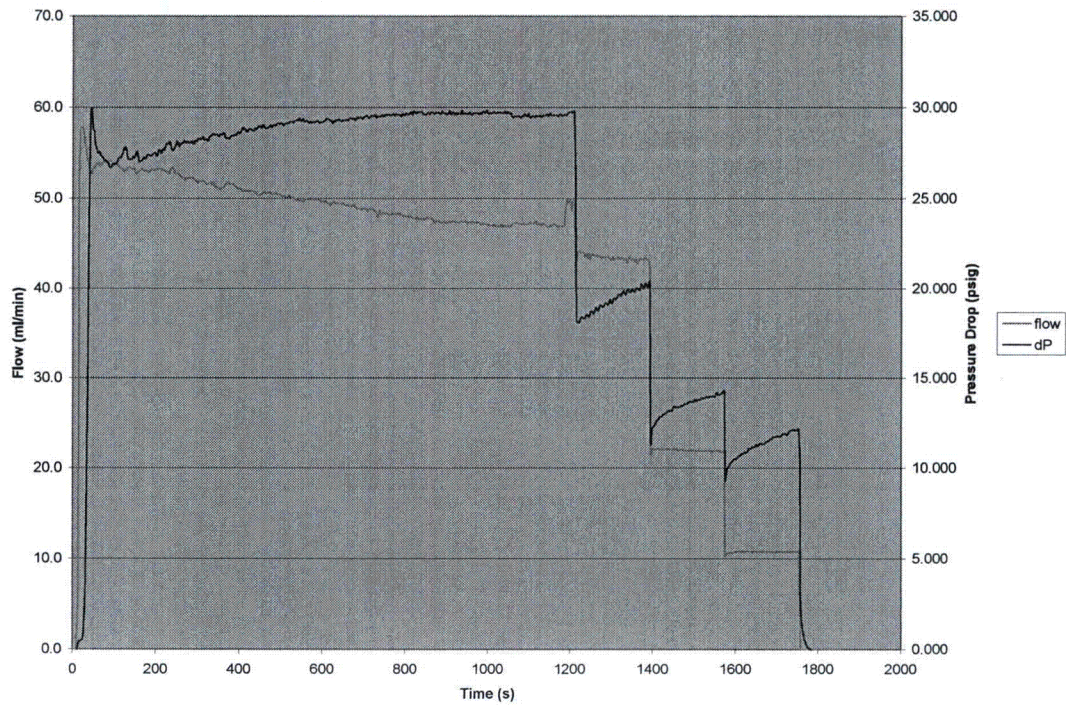
Sample: 212926-137-2 **Test Solution:** Sodium Aluminum Silicate Surrogate made in Tap Water **Simulated Coolant:** Tap Water



Sample: 212926-137-3 **Test Solution:** Sodium Aluminum Silicate Surrogate made in Tap Water **Simulated Coolant:** Tap Water

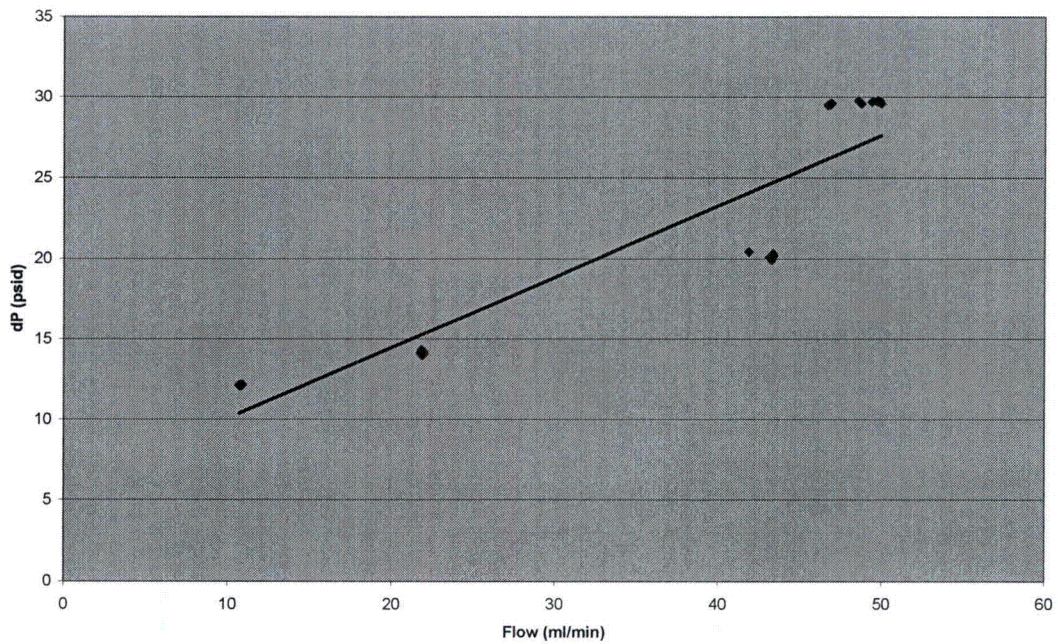


Sample: 212926-138-1 **Test Solution:** Sodium Aluminum Silicate Surrogate made in Tap Water **Simulated Coolant:** Tap Water **Note:** Bad Run- $R^2 < 0.9$

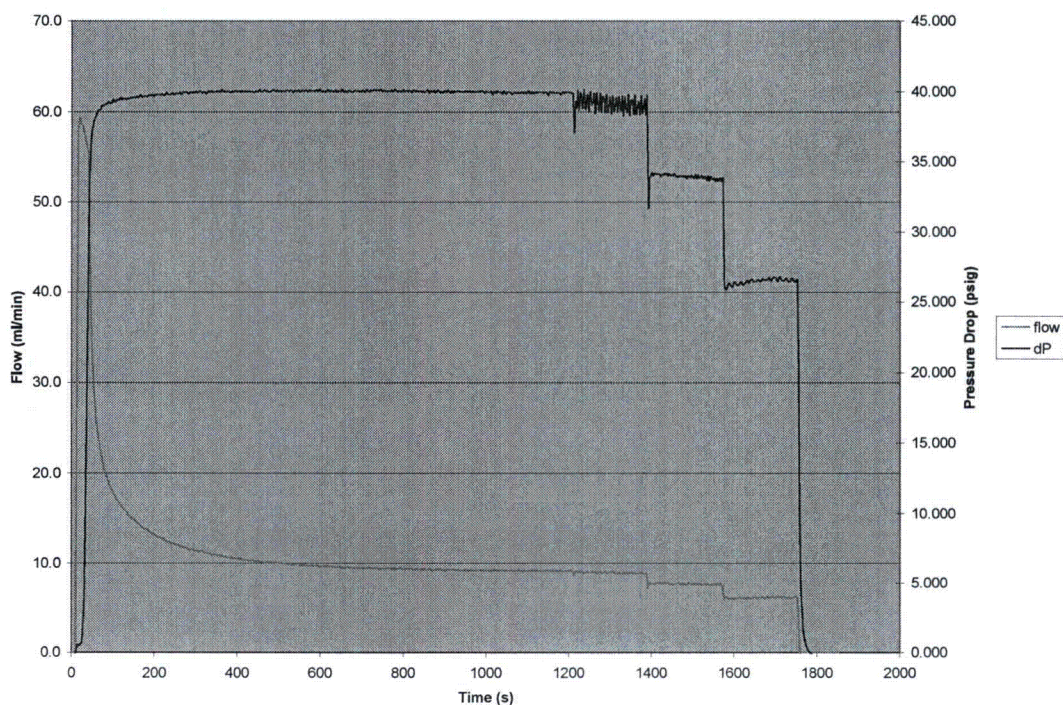


$$y = 0.4388x + 5.6873$$

dP vs Flow

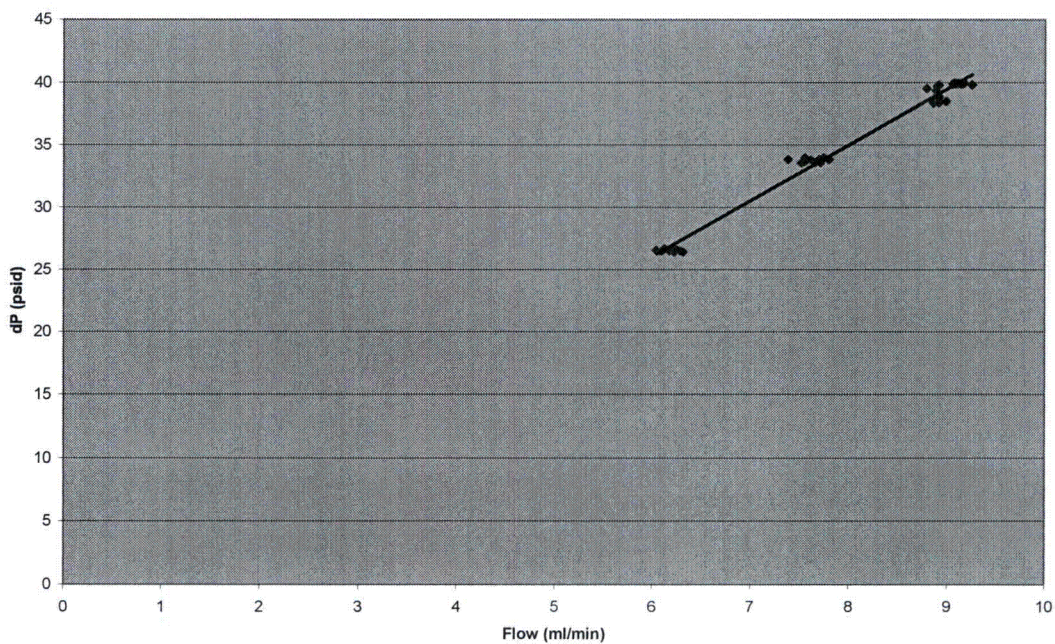


Sample: 212926-138-2 **Test Solution:** Sodium Aluminum Silicate Surrogate made in Tap Water **Simulated Coolant:** Tap Water

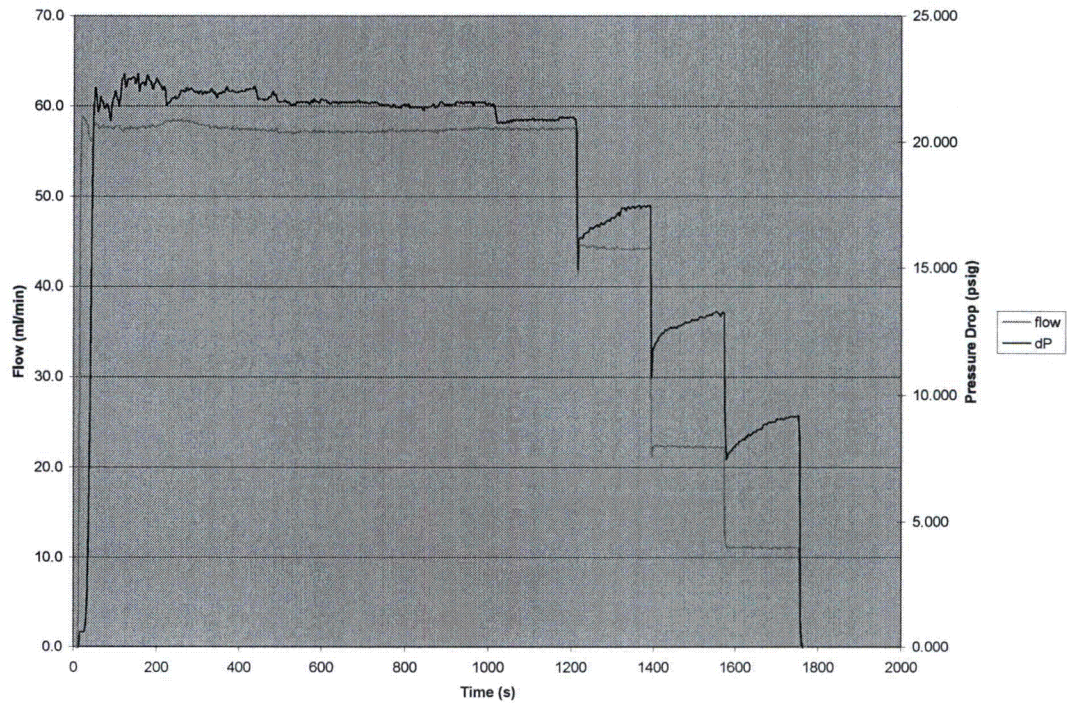


$$y = 4.4806x - 0.8483$$

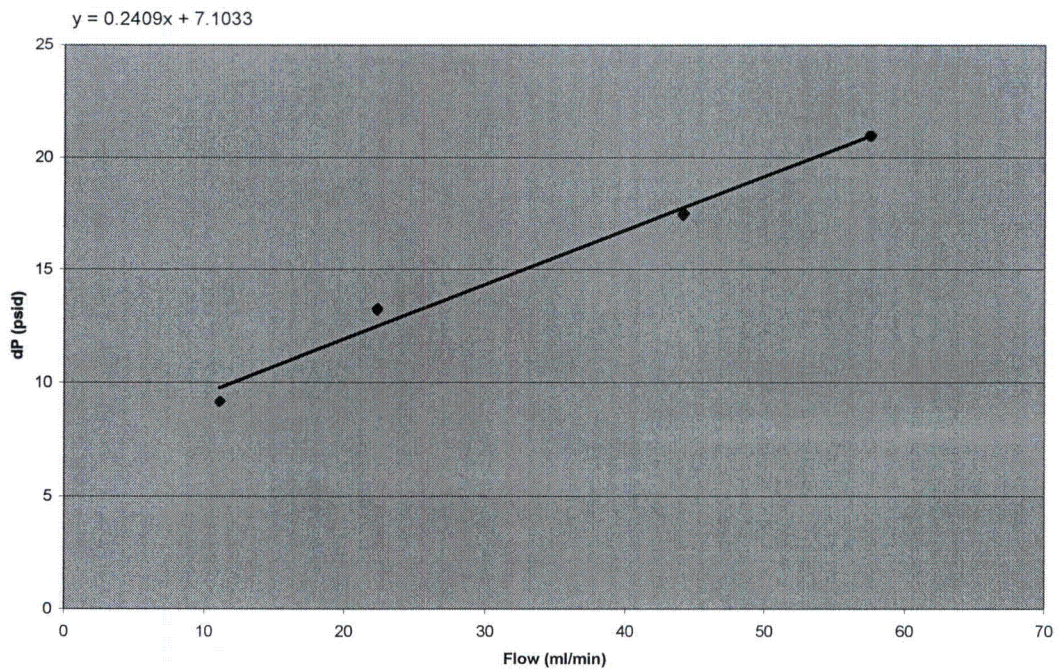
dP vs Flow



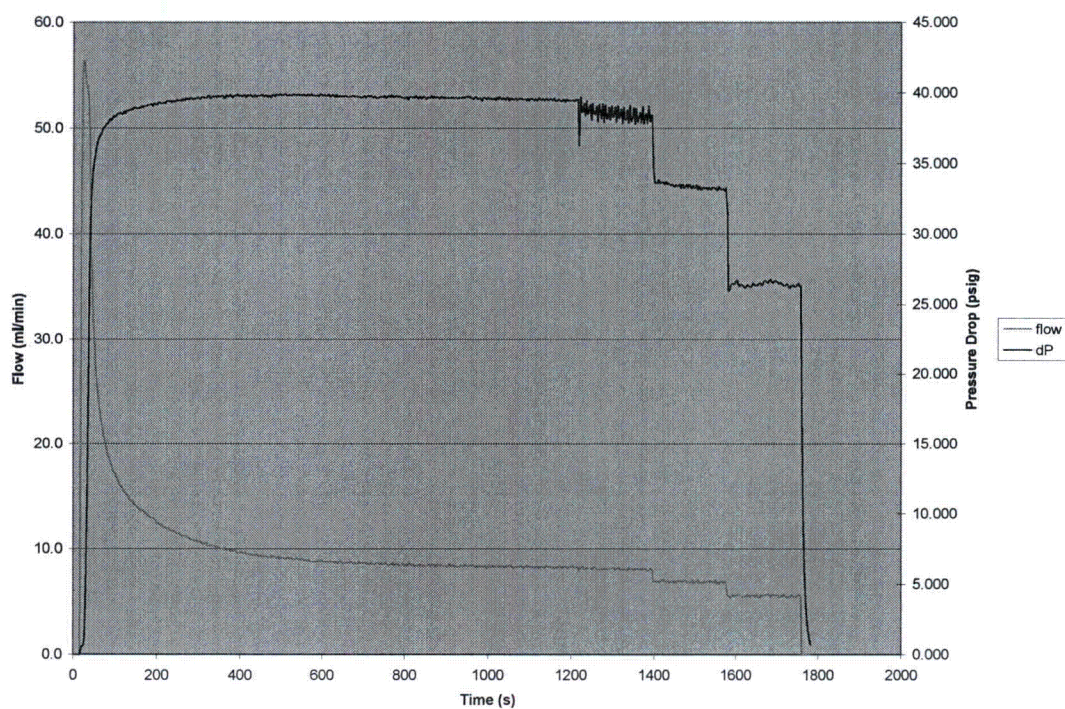
Sample: 212926-138-3 **Test Solution:** Sodium Aluminum Silicate Surrogate made in Tap Water **Simulated Coolant:** Tap Water



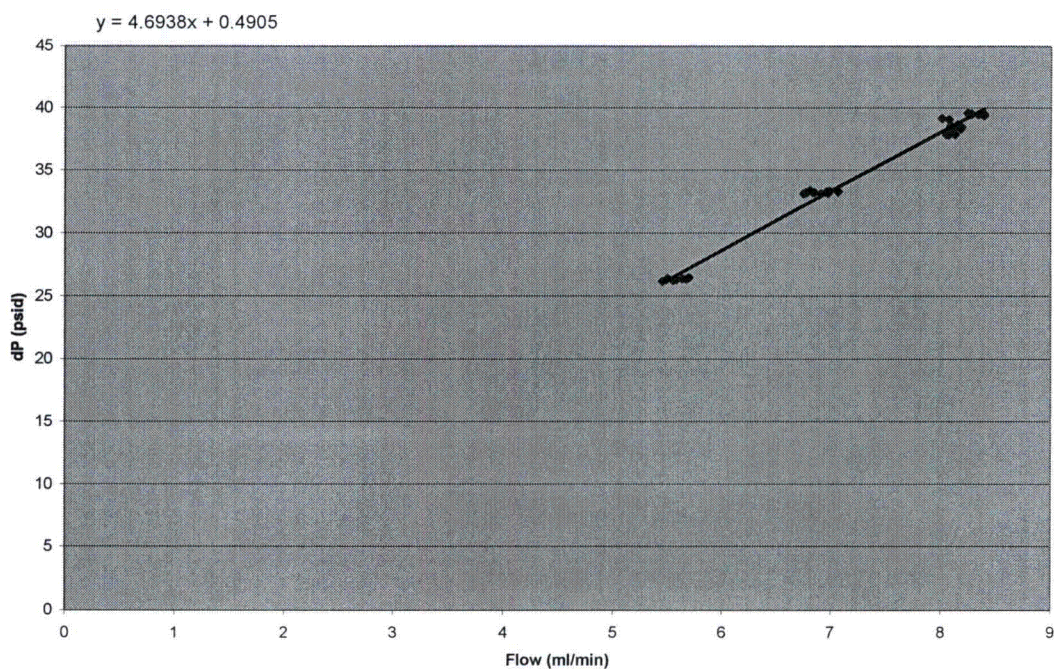
dP vs Flow



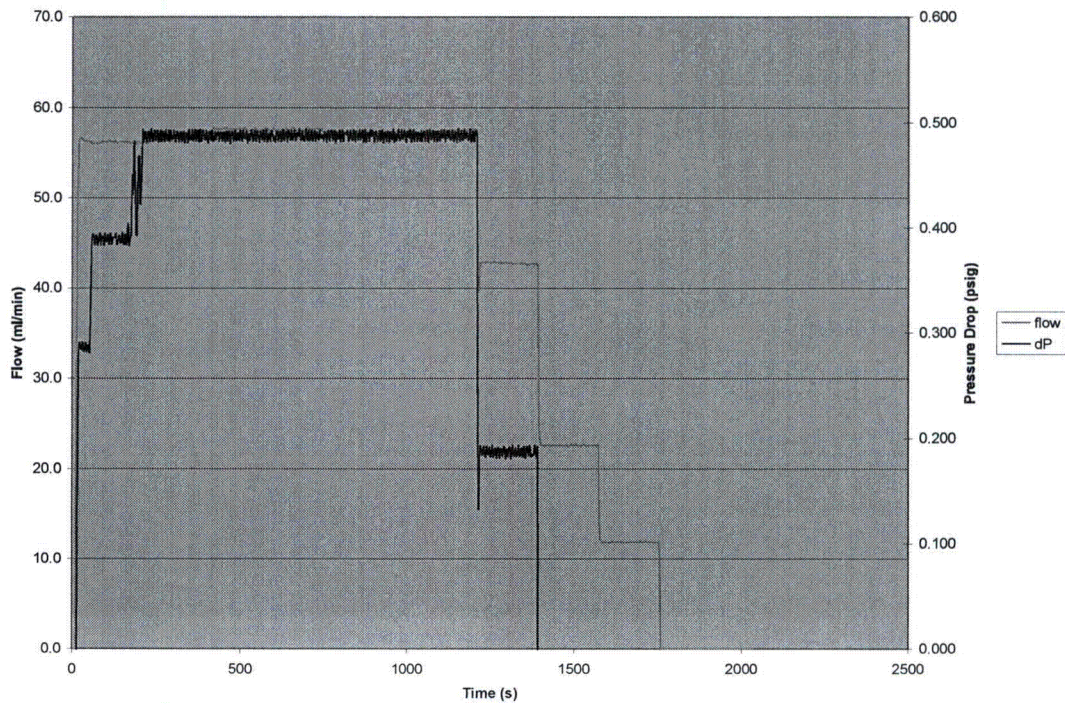
Sample: 212926-139-1 **Test Solution:** Sodium Aluminum Silicate Surrogate made in Tap Water **Simulated Coolant:** Tap Water



dP vs Flow

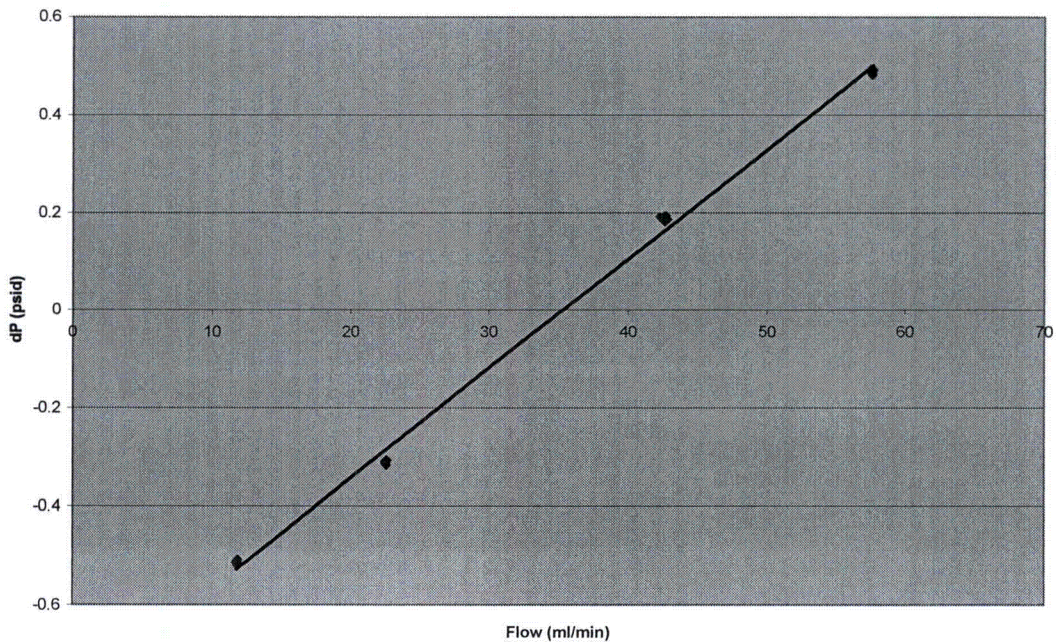


Sample: 212926-145-1 **Test Solution:** Sodium Sizewell B Sludge made in 4400 ppm B Boric Acid **Simulated Coolant:** 4400 ppm B Boric Acid **Note:** Bad Run-the dP was too low (<0.1 psi)

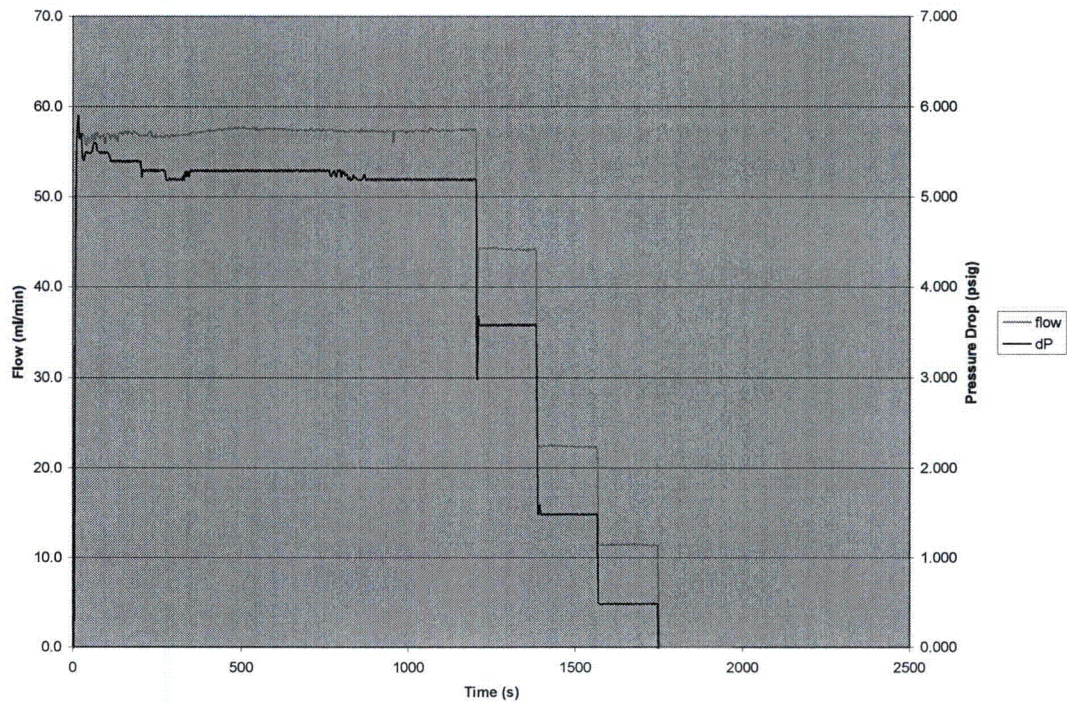


$$y = 0.0224x - 0.7914$$

dP vs Flow

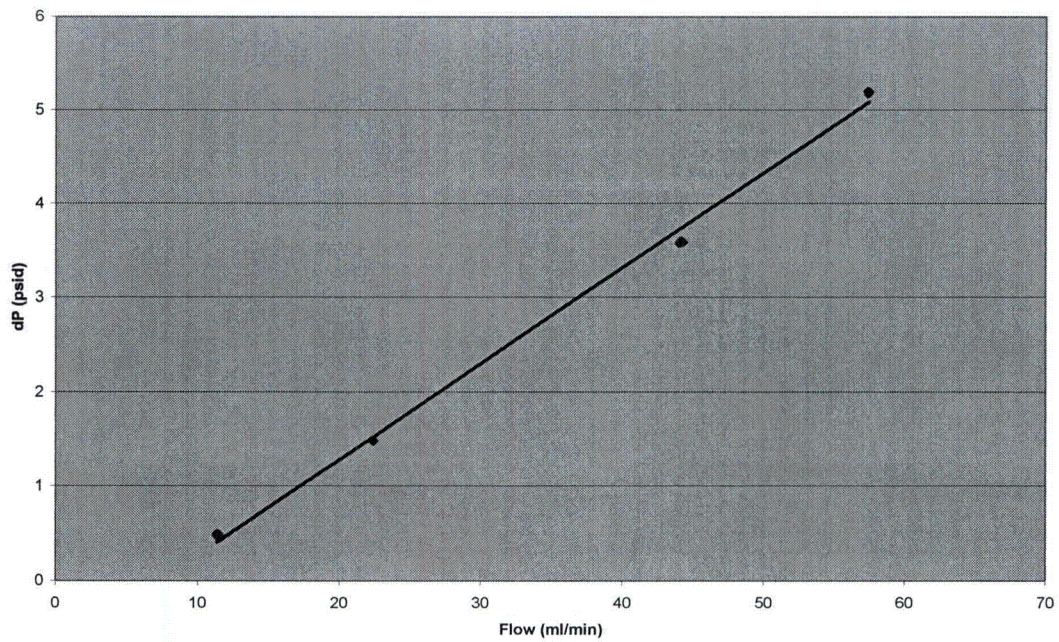


Sample: 212926-148-1 **Test Solution:** Sodium Sizewell B Sludge made in 4400 ppm B
Boric Acid Simulated Coolant: 4400 ppm B Boric Acid

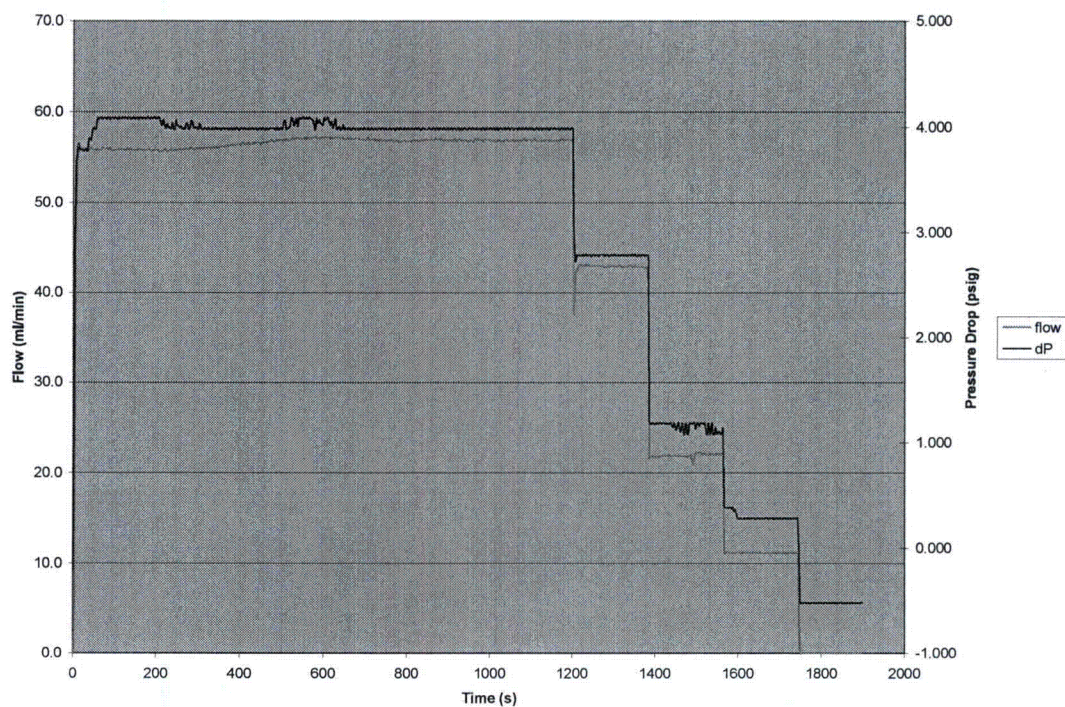


$$y = 0.1015x - 0.7456$$

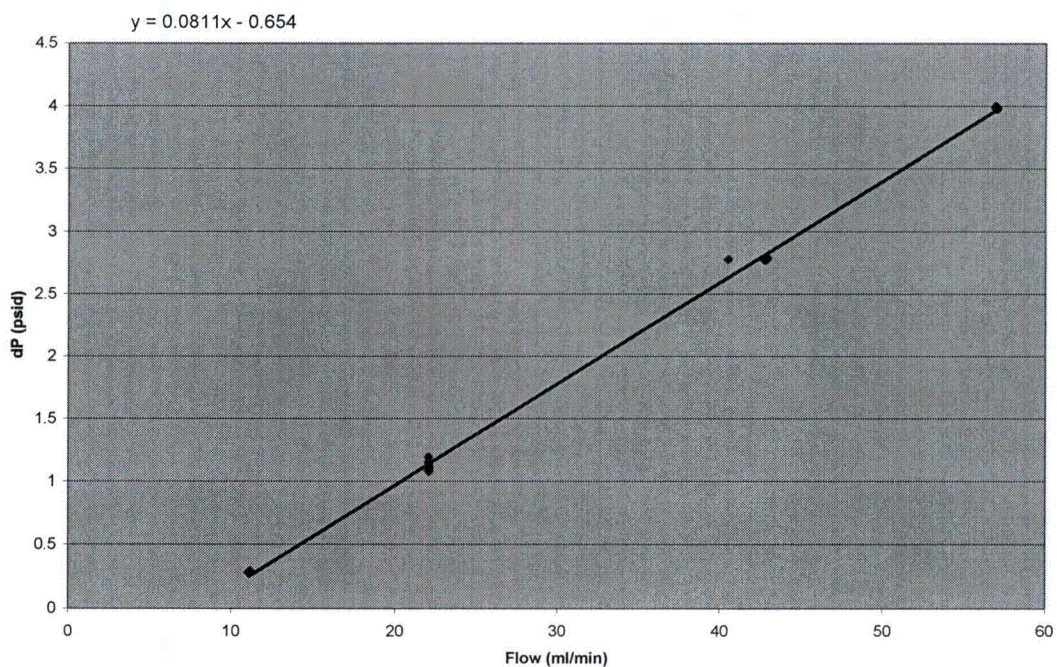
dP vs Flow



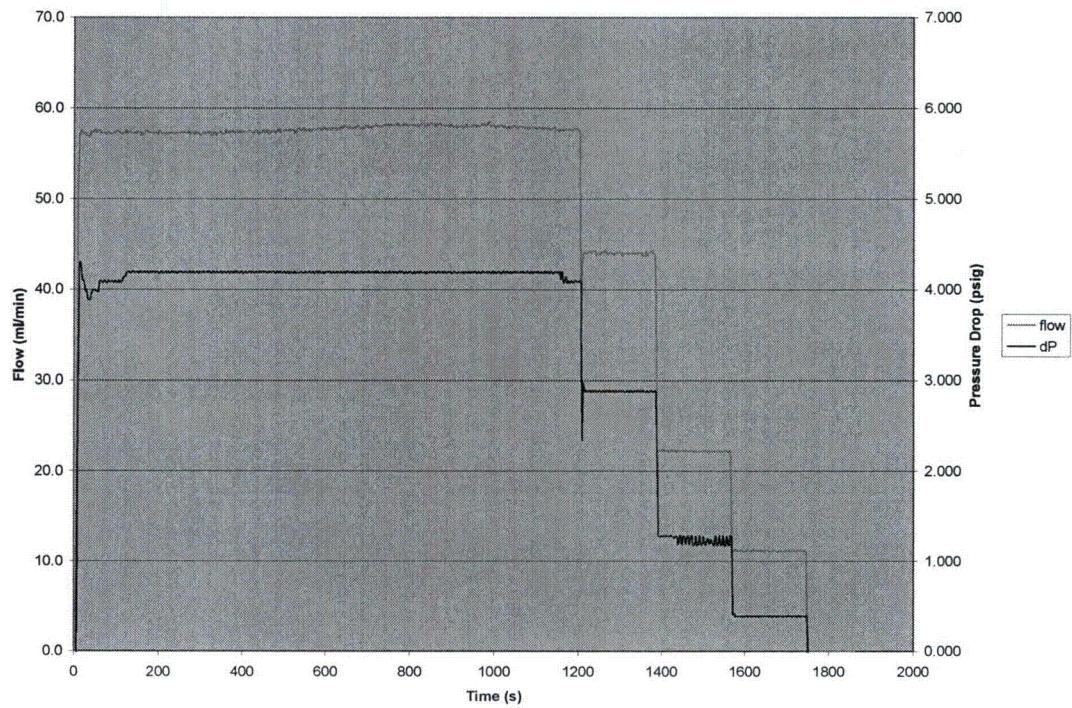
Sample: 212926-148-2 **Test Solution:** Sodium Sizewell B Sludge made in 4400 ppm B
Boric Acid Simulated Coolant: 4400 ppm B Boric Acid



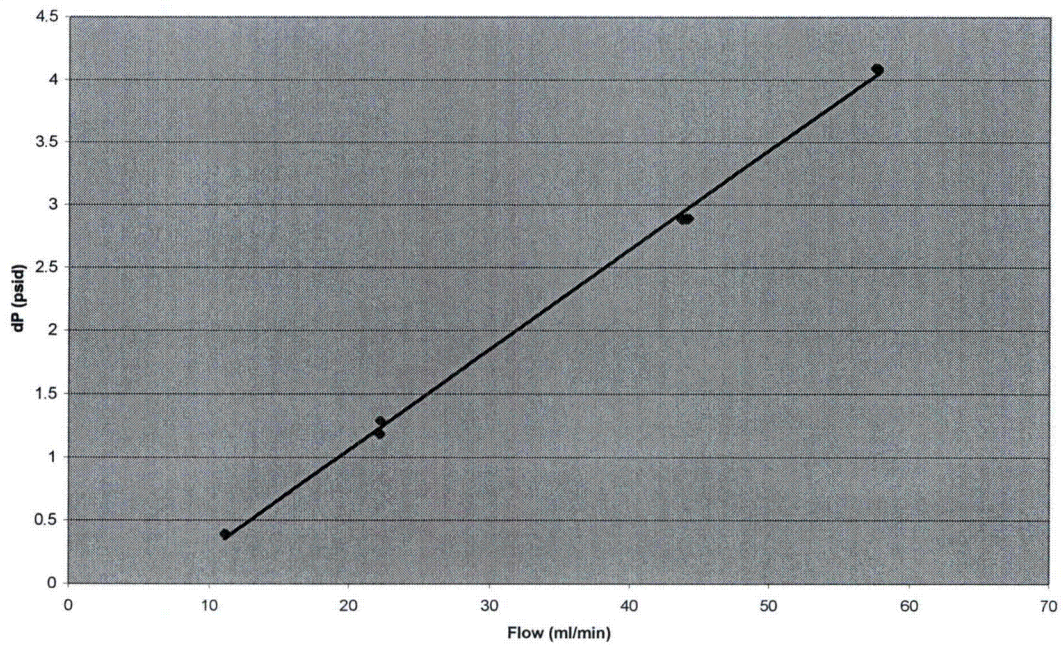
dP vs Flow



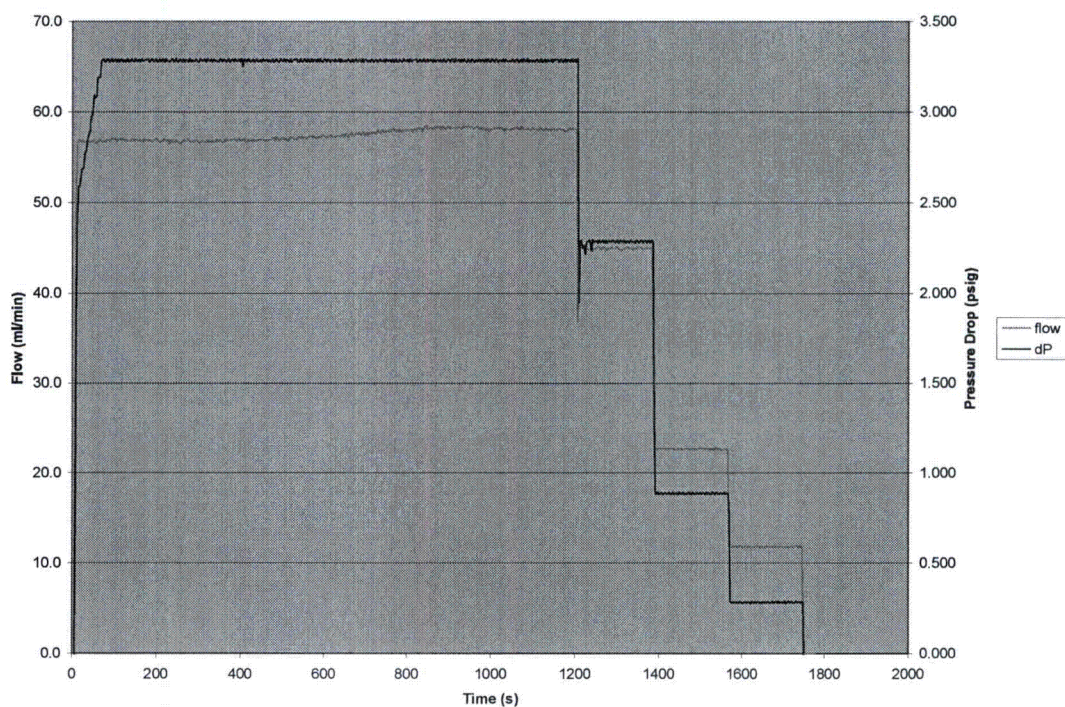
Sample: 212926-148-3 **Test Solution:** Sodium Sizewell B Sludge made in 4400 ppm B Boric Acid **Simulated Coolant:** 4400 ppm B Boric Acid



dP vs Flow
 $y = 0.0792x - 0.5272$



Sample: 212926-148-4 **Test Solution:** Sodium Sizewell B Sludge made in 4400 ppm B Boric Acid **Simulated Coolant:** 4400 ppm B Boric Acid



$$y = 0.0646x - 0.5342$$

dP vs Flow

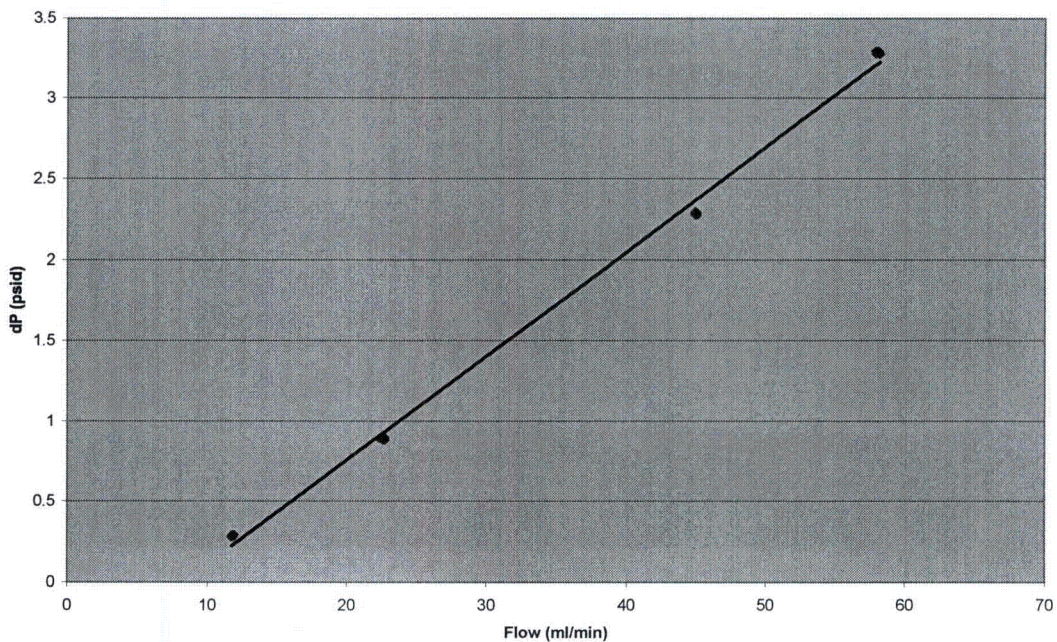


Table 1 summarizes the results of the white paper testing and the Palisades ICET runs that have been obtained Westinghouse this year.

Table 1 Results of White Paper Filtration Testing and Palisades ICET Runs

Sample Name	Temp	Kfx
AIOOH Surrogate at 2.2 g/L in tap water made 5/24/07	78	5.50E-05
AIOOH Surrogate at 2.2 g/L in tap water made 5/24/07	78	8.20E-05
AIOOH Surrogate at 2.2 g/L in tap water made 5/24/07	78	6.77E-05
AIOOH Surrogate at 2.2 g/L in tap water made 5/24/07	78	5.73E-05
AIOOH Surrogate at 2.2 g/L in tap water made 5/24/07	78	4.00E-05
AIOOH Surrogate at 2.2 g/L in tap water made 5/24/07	78	5.07E-05
AIOOH Surrogate at 2.2 g/L in tap water made 5/24/07	78	5.95E-05
AIOOH Surrogate at 2.2 g/L in tap water made 5/24/07	78	5.63E-05
AIOOH Surrogate at 2.2 g/L in tap water made 5/24/07	78	3.92E-05
AIOOH Surrogate at 2.2 g/L in 4400 ppm B made 5/24/07	78	1.34E-04
AIOOH Surrogate at 2.2 g/L in 4400 ppm B made 5/24/07	78	1.70E-04
AIOOH Surrogate at 2.2 g/L in 4400 ppm B made 5/24/07	78	4.74E-05
AIOOH Surrogate at 2.2 g/L in 4400 ppm B made 5/24/07	78	2.62E-04
Al corrosion product in 4400 ppm B + pH 12 NaOH fast cooled	78	2.11E-05
Al corrosion product in 4400 ppm B + pH 12 NaOH fast cooled	78	1.78E-05
Al corrosion product in 4400 ppm B + pH 12 NaOH fast cooled	78	2.57E-05
Al corrosion product in 4400 ppm B + pH 12 NaOH slow cooled	78	5.43E-03
Sodium Aluminum Silicate made in Tap Water 9.7 g/L 5/26/13	78	3.55E-05
Sodium Aluminum Silicate made in Tap Water 9.7 g/L 5/26/14	78	3.81E-05
Sodium Aluminum Silicate made in Tap Water 9.7 g/L 5/26/16	78	2.81E-05
Sodium Aluminum Silicate made in Tap Water 9.7 g/L 5/26/17	78	5.39E-04
Sodium Aluminum Silicate made in Tap Water 9.7 g/L 5/26/18	78	2.58E-05
Sizewell B sludge	78	3.95E-01
Sizewell B sludge	78	3.36E-01
Sizewell B sludge	78	3.47E-01
Sizewell B sludge	78	3.60E-01
NaOH pH 10 A23 32 days bottom fraction	76	1.10E-03
NaOH pH 10 A21 33 days bottom fraction run 7	78	1.77E-02
NaOH pH 10 A21 33 days bottom fraction run 6	60	6.30E-03
NaOH pH 10 A21 33 days bottom fraction run 5	63	3.40E-03
NaOH pH 10 A21 33 days bottom fraction run 2	69	2.98E-03
NaOH pH 10 A23 32 days middle fraction	77	6.72E-04
NaOH pH 10 A21 33 days middle fraction run 4	77	4.20E-03
NaOH pH 10 A21 33 days middle fraction run 3	61	5.31E-03
NaOH pH 10 A21 33 days middle fraction run 2	62	9.48E-04
NaOH pH 10 A21 33 days middle fraction run 1	59	2.26E-03
NaOH pH 10 A23 32 days top fraction	77	3.96E-04
NaOH pH 10 A21 33 days top fraction	78	3.91E-04
NaOH pH 10 A21 33 days top fraction	78	4.31E-04
NaOH pH 10 A21 33 days middle fraction run 5	77	4.28E-03
NaOH pH 10 7 days bottom fraction run 7	79	4.24E-03

Sample Name	Temp	Kfx
NaOH pH 10 7 days bottom fraction run 8	77	2.39E-03
NaOH pH 10 7 days bottom fraction run 9	76	2.01E-03
NaOH pH 10 7 days bottom fraction run 6-2	78	2.71E-03
NaOH pH 10 7 days middle fraction run 1	79	2.42E-03
NaOH pH 10 7 days middle fraction run 2	76	1.51E-03
NaOH pH 10 7 days middle fraction run 4	76	1.53E-03
NaOH pH 10 7 days middle fraction run 5	77	1.34E-03
NaOH pH 10 one day autoclave 21	182.8	3.52E-04
NaOH pH 10 after 7 days in Autoclave 21	140.7	1.65E-04
NaOH pH 10 after 7 days in Autoclave 23	145.7	1.28E-04
NaOH 33 days Autoclave 21 Palisades Simulation Hot	157.2	5.84E-04
NaOH 33 days Autoclave 23 Palisades Simulation Hot	154.1	9.23E-04
NaTB pH 7, 7 days bottom fraction run 1	78	6.80E-03
NaTB pH 7, 7 days bottom fraction run 2	78	5.56E-03
NaTB pH 7, 7 days bottom fraction run 3	78	7.76E-03
NaTB pH 7, 7 days bottom fraction run 4	78	5.28E-03
NaTB pH 7.8 after one day autoclave 14	173	3.06E-04
NaTB pH 7.0 after one day	165.5	2.24E-04
NaTB pH 7.8 after 7 days in Autoclave 14	135.5	1.35E-04
NaTB pH 7.0 after 7 days in Autoclave 25	149.1	2.67E-04
NaTB pH 7pt8 33 days Autoclave 23 Palisades Simulation Hot	135.6	1.13E-04
NaTB pH 7, 7 days middle fraction run 2	78	2.47E-02
NaTB pH 7, 7 days middle fraction run 3	78	5.41E-03
NaTB pH 7, 7 days middle fraction run 4	78	3.77E-03
NaTB pH 7, 7 days middle fraction run 5	79	5.09E-03
NaTB pH 7, 7 days middle fraction run 6	79	4.49E-03
NaTB pH 7.8 33 days bottom fraction run 5	68	4.08E-03
NaTB pH 7.8 33 days bottom fraction run 2	55	1.64E-02
NaTB pH 7.8 33 days bottom fraction run 3	53	1.47E-02
NaTB pH 7.8 33 days bottom fraction run 1	55	1.61E-02
NaTB pH 7.8 33 days top fraction run 5	69	3.24E-03
NaTB pH 7.8 33 days top fraction run 4	69	2.13E-03
NaTB pH 7.8 33 days top fraction run 3	60	6.90E-03
NaTB pH 7.8 33 days top fraction run 2	59	7.61E-03

Figure 1 indicate that the surrogates (the first three bars) have lower K_{fx} values than the more realistic precipitates formed at higher temperature (the remaining bars), and thus are conservative.

