Corrosion Resistant Submerged Motor

with Pacific Design Technologies

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Statement of Disclaimer

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List of Nomenclature

AC Motor – Alternating Current motor

AMP – Aqua Mechanical Protections – the previous senior project team

CDL – Corrosion Defense League – the current senior project team

Conformability – there must be little to no bubbling, air gaps, or imperfections of the coating on the rotor

DC Motor – Direct Current motor

Dipped Coating – coating applied by dipping the rotor in a liquid coating

ID – inside diameter

OD – outside diameter

Parylene C – polymer coating

Parylene HT – high temperature polymer coating

PDT – Pacific Design Technologies – the company sponsoring the project

Vapor Deposition Coating – coating applied as a vapor, allowing for application to more intricate features and a thinner coating thickness

Working Fluid – PDT currently uses a water-glycol mixture for the fluid being pumped through the motor

Executive Summary

In order to create a more compact and reliable pump, the working fluid floods the motor/pump combination. However, this creates the need to have a rotor that is corrosion-resistant and completely sealed from the working fluid.

Currently, PDT employs a method where the rotor of the pump motor is "canned" with a stainless steel sleeve. Though this is an effective way to completely seal the rotor from the working fluid while also being corrosion resistant, it is extremely costly at about $1,500 per rotor and can have a lead time of 5 weeks.

To combat this, a multitude of vapor deposited and dipped coatings were tested to evaluate their effectiveness. All of the selected coatings were run through preliminary corrosion trials by a previous senior project group to determine their effectiveness in sealing the working fluid from the rotor. Further testing entailed in-pump tests that were executed to evaluate how the coatings performed compared to the stainless steel "canned" rotor. To do these more in depth tests, test assets needed to be procured, selected coatings applied, as well as the conduction of final testing and analysis. At the completion of testing, it was recommended that the Parylene C and Parylene HT coatings be reapplied thicker and more visibly and extended testing be performed on them, including but not limited to, longer duration testing.

Another goal that was being tackled was improving the insertion of the magnetized DC rotor into the stator housing. There were concerns of the coating being scratched when installed, so a few designs were chosen to assist in rotor installation in an effort to reduce damage to the applied coatings. At the conclusion of this project, a final tool design was selected, but not thoroughly tested. It is recommended to simply wrap the coated rotor in a sheet of high gloss paper to allow for easy and cost-effective insertion.

1.0 Introduction

The goal of this project is to identify and implement a cost-effective method of protecting the rotor of a submerged motor in a flooded pump design from corrosion. The Corrosion Defense League (CDL), composed of Deirdre Hyde, Loren MacDonald, and Cole Thompson, will be partnering with Pacific Design Technologies (PDT) to identify compatible protective coatings, develop and run tests of the coated rotors, and design tools necessary for execution. CDL will also be using previous research from Aqua Mechanical Protections (AMP), a senior project team that focused on researching and testing non-corrosive coatings.

2.0 Background

To protect the rotors from corrosion, PDT currently sends the rotor to a contracted machine shop to be covered or "canned" in stainless steel. This process requires intricate welds and machining, making it an extremely expensive and long-duration method. Although this process of canning the rotor protects it from corrosion, the $1,500 price tag and 5 week lead time make it a less-desirable option. Despite the extensive cost and time, the stainless steel can meets several engineering design requirements set by PDT:

- Protects the electrical components from corrosion and electrical conduction.
- Non-corrosive in the working fluid.
- Withstands a temperature range of -67° to 185°F.
- Made within the tolerance of 30 mils on each side between the OD of the rotor and the ID of the stator, while keeping the stator and rotor concentric with each other.
- Magnetically permeable enough to allow the pump to perform without major loss in efficiency.
- Thermally conductive enough to prevent the pump from overheating during operation.

Figure 1. A "canned stainless steel rotor (left) and a 3D-printed rotor model (right).

The new solution must meet and/or exceed all of the above standards for it to be considered.

To protect the rotors from corrosion, AMP investigated polymer coatings. The successful coatings they tested are:

- GVD Parylene C
- Jaro Corp Humiseal 1A33
- Specialty Coatings Parylene HT

During AMP's previous testing of the coated rotors, they found that the coatings became marred when the rotor was inserted into the stator. The magnetic force of the rotor is so great that the rotor is pulled off center and hits the sides of the stator upon insertion. A tool should be designed to maintain the centerline concentricity of the rotor and stator to prevent the marring of the protective coatings. Ideally, this tool should fit easily into the current assembly process that PDT has established for their submerged pump design; no drastic modifications should be made to the assembly process.

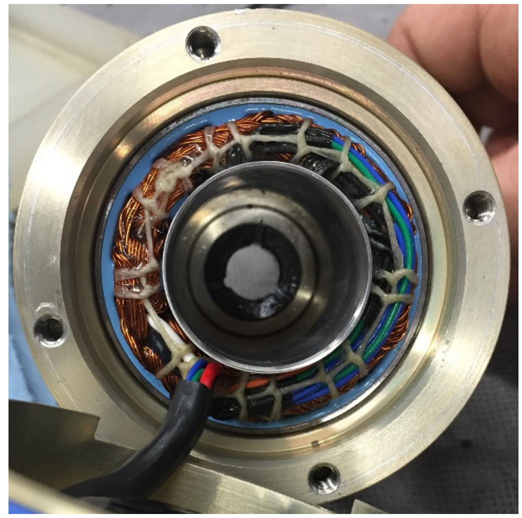

Figure 2. The interior of the DC motor without the rotor inserted.

3.0 Design Requirements and Objectives

The main objective for this project is to design a coated rotor that can be machined cheaper and faster than the current "canning" method. A tool should also be designed to assist in inserting the rotor into the stator to prevent the rotor coating from marring when pulled by the stator's magnetic force. PDT has derived the following design requirements for the coated rotor:

- Must be corrosion resistant to working fluid (water-glycol mixture).
- Must meet current motor performance and environmental requirements.
- Must have insulation resistance greater than 1 mega-ohm or more.
- Must be magnetically permeable.
- Must have a thickness less than 10 mils (0.010 inches).
- Must have high conformability.
- Must have a 10 year lifetime.
- Must be thermally conductive.
- Must have low thermal expansion coefficient.
- Must work in a temperature range of -67°F to 185°F.
- Must cost less than $100 per motor.
- Must have a throughput of 10 units per month.
- Must be compatible to PDT assembly and testing.
- Requires no additional assembly.

The rotor-inserting tool should:

- Require no drastic modifications to PDT's current assembly process
- Maintain concentricity and 0.010-inch clearance between rotor and stator
- Be unaffected by the magnetic force of the rotor.

4.0 Coating Selection

The previous senior project team, AMP, identified three compatible coatings that CDL also chose to test further. The selected coatings were:

1. Jaro Corp Humiseal 1A33 – This coating passed the testing performed by AMP and was recommended as a coating to pursue for more rigorous testing. A reliable contact has been identified that provided the information needed to pursue this coating. The coating was quoted at $300 per batch.
2. Specialty Coatings Systems Parylene HT – This coating passed the testing performed by AMP and was recommended as a coating to pursue for more rigorous testing. Specialty Coating Systems was the most helpful and easiest company to contact for information on their coatings. The coating was quoted at $1200 per batch.
3. Specialty Coating Systems Parylene C – This coating was completed and passed the testing performed by AMP, however was not recommended as a coating to pursue. Other companies also manufactured Parylene C, and GVD was recommended to provide this coating. GVD does not manufacture this coating anymore, so Parylene C was purchased through Specialty Coating Systems. The cost per batch is $750.
4. GVD Exsilis – This coating was not previously tested by AMP. More information was acquired on it after discovering that GVD does not manufacture Parylene C. Preliminary testing should be conducted similar to AMP's, before pursuing more rigorous testing. This coating costs $800 per batch.
5. DryWired 101x – This was a coating recommended by PDT's Engineering Director, Mike Brown, that had a possibility of providing the requirements need to coat a rotor. AMP did not provide any testing on this product. After initial contact with DryWired, we found it hard to continue communication to acquire more information about the coating. Due to the lack of communication from DryWired, it was decided not to pursue this coating for testing.

After researching the previous coatings, the coatings that were chosen to test were Jaro Corp's Humiseal 1A33, Specialty Coating System's Parylene HT, and Parylene C.

5.0 Design Development

This section focuses on the design of the tool that will be implemented into the assembly process to prevent marring of the rotor coating.

5.1 Preliminary Designs

Four initial design concepts were investigated to determine their effectiveness of protecting the rotor coating from marring due to the strong stator magnet.

5.1.1 Vertical Centered Rod Design

The vertical centered rod design involves centering the motor housing, with the stator inside, on a rod. This rod will be used to guide the rotor into the motor housing without touching the stator walls. The motor housing will be centered using a pattern machined into the base of the tool, along with two v-shaped grips to hold it steady.

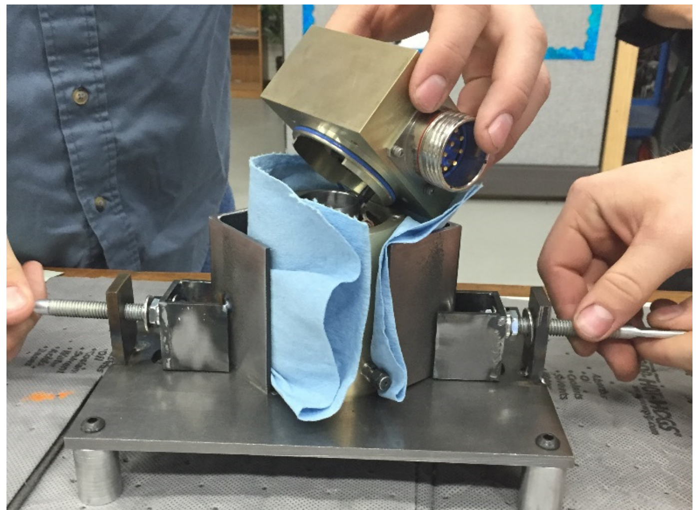

Figure 3. The motor housing positioned on the vertical centered rod prototype.

5.1.2 Two Clamp Slide Design

The two clamp slide design involves clamping the motor housing, with the stator inside, directly to the tool base. Another clamp, mounted to a slide will hold the rotor and insert it into the motor housing.

5.1.3 Molded Shell Design

The molded shell design uses a thin-shelled urethane cylinder that is concentric with the rotor. A handle is extruded from the shell and is held while inserting the rotor. The shell has to be thin enough to fit the small clearance between the rotor and stator.

5.1.4 Protective Film Design

The protective film design consists of having a very thin film, such as a balloon, enveloping the rotor as it is being inserted. Another possible option also includes Mylar films.

5.1.5 Shim Design

The shim design involves creating a tool with shims that are less than 5 thousandths of an inch thick. These shims will protect the coating while rubbing against the stator wall

5.2 Design Selection

Several design matrices were used to assist in the design selection.

Table 1. Morphological array of possible methods to be used for tool design.

Function	Means		
Centering motor housing	Adjustable clamps (vertical)	Fitted unmoving groove (horizontal)	Centered groove (vertical)
Inserting rotor	Moveable clamp (vertical & horizontal)	Centered rod (vertical)	Molded shell w/ handle
Holding rotor steady	Clamped shaft end (vertical & horizontal)	Tolerance of steady rod	Tolerance of mold
Centering rotor	Adjustable clamps	Centered rod & tolerance	Tolerance of mold

Table 2. Comparison of design features to identify the top priorities.

Objective	Safety	Cost	Compatibility	Operator	Simplicity	Total
Safety		1	1	1	1	4
Cost	0		0	1	1	2
Compatibility	0	1		1	1	3
Operator	0	0	0		0	0
Simplicity	0	0	0	1		1

Table 3. Decision matrix using weighted scores derived from Table 2.

Objective	Raw Score (1-10)				Weight factor	Weighted Scores			
	Vertical centered rod	Two clamp slide	Molded shell	Film		Vertical centered rod	Two clamp slide	Molded shell	Film
Safety	8	7	8	8	10	80	70	80	80
Cost	7	4	8	7	6	42	24	48	42
Compatibility	7	8	8	4	8	56	64	64	32
Operator	5	7	6	6	1	5	7	6	6
Simplicity	6	5	7	9	4	24	20	28	36
					Total Score	207	185	226	196

5.3 Final Design

Initially, the vertical centered rod and molded shell designs were chosen to be further developed and implemented in the future. The possibility of combining the two designs was also being considered. These designs were chosen with the help of the design matrices and seem to be the least complicated and most likely to succeed.

After some preliminary testing, the vertical centered rod was deemed to not be a viable option due to its inability to effectively position the rotor in the stator and keep the rotor from abruptly coming in to contact with the lower bearing. Due to this failed experience, it was decided to move forward with the molded shell design.


Figure 4. Shim insertion tool.

A few prototypes of the molded shell design were developed with the hopes to confirm that shells with the given wall thickness can be produced. However, it was discovered that this current process resulted in a wall thickness of about .030". Since this is larger than the target thickness of .010", the prototype pieces would need to be post machined to achieve the desired thickness. Post-machining the prototyped shell proved unsuccessful.

A shim tool was then developed to help guide the rotor into the stator. This design was unreliable, dangerous, and marred the coating when used during testing.

In the end, a combination of the shim and molded shell design was created which involved a durable and glossy sheet of paper that wrapped around the rotor. This method proved to work well when inserting the rotor, however it is not applicable for removal.

6.0 Testing Procedure

6.1 Tool Testing

Testing of the tool designs was completed at PDT's facility where all of the proper testing equipment was located. Although a detailed testing plan varied based on the tool design, the primary tool testing procedure entailed a preliminary visual check of the coated rotor, operation of the tool to insert the rotor into the stator, operation of the tool to remove the rotor, and a final visual check of the coated rotor. Success of the tool was determined by its ability to safely insert and remove the coated rotor without causing damage to the coating.

6.2 Rotor Coating Testing

A series of tests were performed in order to identify which coating best protects the rotor from corrosion. Because identifying and implementing a coating is the primary focus of this project, creation of the test procedure (see Appendix G) was the main goal of spring quarter. The highest performing coating was to be selected after preliminary verification tests and be tested over a period of 100 hours to determine its long-term durability for both an AC and DC motor/pump combo.

Before testing of the coated rotors began, data had to be collected on the current process. Baseline Canned DC motor testing was performed to establish performance curves that was used to determine which coatings are successful. The coated rotors had to perform at the same level or better than the baseline canned DC motor for them to be considered for further testing. PDT was not in possession of a canned AC rotor, so baseline AC motor testing could not be conducted.

Figure 5. PDT's current test setup for the high temperature testing.

Once the baseline data was collected, each coated rotor, both AC and DC, underwent Verification Testing. An initial visual inspection of the coated rotor was conducted to ensure the coating was undamaged. A performance check was then completed where, for both AC and DC motors, inlet and outlet pressure, differential pressure, flow rate, fluid temperature, input voltage, current, and total power were measured and recorded, in addition to power per phase and frequency for the AC motor. Performance maps were also developed by varying motor speeds. A final visual examination was conducted to identify any damage that may have occurred to the rotor coatings.

The top performing coating was selected to run Limited Life Tests for both AC and DC motors. This included running the pump with the best coated rotor for 100 hours with periodic cleanliness checks to gather data on the durability and longevity of the coating. Following the long duration test, a visual examination of the coating was conducted to account for any damage encountered. A low temperature start-up test was then run to check the coated rotor's performance at below-freezing temperatures. Finally, the coated rotor was exposed to high operating temperatures in a limited life temperature test.

7.0 Results

Extensive data was taken for each motor type and rotor coating. These tests include:

- Performance Testing for All Coating on AC and DC motors
- Room Temperature Limited Lifetime Testing
- High Temperature Limited Life Testing
- Cold Temperature Start-up

The data for the test listed above are located in Appendices H through P.

7.1 Deviations from the Test Procedure

During the testing some changes to the procedure were made due to competing testing time with PDT's consumer products. Instead of only testing one coating that passed all of the verification tests described in the Test Procedure (Appendix G), all the coatings underwent performance testing, limited life testing, and all DC motors underwent high temperature testing. Tests that were removed from the testing procedure for all AC and DC test assets were electrical bond strength, dielectric strength, insulation resistance and cleanliness testing for all the coatings. DC rotor test exclusions were Room Temperature Limited Life Testing for Parylene HT and Humiseal and Cold Start-up testing for all three DC coatings. AC rotor test exclusions were Cold Start-up testing for Parylene C and Humiseal and High Temperature Limited Lifetime Testing. As said before, some of the tests were forgone because of consumer product testing, however there were also some unforeseen problems that occurred during the testing. The first was the delamination of Humiseal during the AC High Temperature testing which limited the amount of data that was taken since there was only one AC and DC rotor per coating. Parylene HT also delaminated while testing which led to its limited data as well.

8.0 Analysis

Table 4. Summarizing coating performance based on initial design parameters. They are shown below on a pass/fail basis.

Design Parameter	Coating	Pass	Fail	Notes
Corrosion resistant	Parylene C	X		Significant corrosion on AC rotor underneath coating prior to testing
	Parylene HT	X		Minor corrosion on AC rotor underneath coating prior to testing
	Humiseal	X		
Meet current motor performance	Parylene C	X		
	Parylene HT		X	Close, but did not meet baseline performance.
	Humiseal		X	
Insulation resistance greater than 1 mega-ohm	Parylene C			Unable to test due to limited resources*
	Parylene HT			Unable to test due to limited resources*
	Humiseal			Unable to test due to limited resources*
Magnetically permeable	Parylene C	X		Checked the efficiency with respect to baseline and other coatings
	Parylene HT		X	Checked the efficiency with respect to baseline and other coatings
	Humiseal		X	Checked the efficiency with respect to baseline and other coatings
Thermally conductive	Parylene C	X		Pump does not overheat during any of the testing
	Parylene HT	X		Pump does not overheat during any of the testing
	Humiseal		X	Pump overheated during testing
Lifetime testing	Parylene C	X		
	Parylene HT		X	
	Humiseal		X	
Low thermal expansion coefficient	Parylene C	X		Tested indirectly
	Parylene HT	X		Tested indirectly
	Humiseal		X	Tested indirectly
Thickness less than 10 mils (0.010 inches)	Parylene C	X		
	Parylene HT	X		
	Humiseal	X		Just within limits, caused some rubbing on coating
High conformability	Parylene C	X		
	Parylene HT	X		
	Humiseal	X		Conditional. Additional testing may be needed
Temperature range of -67°F to 185°F	Parylene C	X		
	Parylene HT	X		
	Humiseal		X	
Cost less than $100 per motor	Parylene C	X		
	Parylene HT	X		
	Humiseal	X		
Throughput of 10 units per month	Parylene C	X		
	Parylene HT	X		
	Humiseal	X		
Compatible to PDT assembly and testing	Parylene C	X		
	Parylene HT	X		
	Humiseal	X		
Requires no additional assembly	Parylene C	X		
	Parylene HT	X		
	Humiseal	X		

8.1 Corrosion Resistance

Thorough testing of corrosion resistance was performed by the previous senior project group. The following results are based off of varied parameter tests conducted on the coated rotors.

8.1.1 Parylene C

AC Motor

The AC rotor was returned to PDT from SCS with major corrosion underneath the coating. This corrosion can cause issues with the bonding strength of the coating which can lead to delamination. At the conclusion of the Parylene C AC rotor testing, no additional corrosion could be visually identified.

DC Motor

The DC rotor was returned to PDT from SCS with no signs of corrosion. At the conclusion of the Parylene C DC rotor testing, no corrosion was visually identifiable, even though marring of the coating had occurred during insertion of the rotor into the stator.

8.1.2 Parylene HT

AC Motor

The AC rotor was returned to PDT from SCS with minor corrosion underneath the coating. This corrosion can cause issues with the bonding strength of the coating which can lead to delamination. At the conclusion of the Parylene HT AC rotor testing, no additional corrosion could be visually identified.

DC Motor

The DC rotor was returned to PDT from SCS with no signs of corrosion. At the conclusion of the Parylene HT DC rotor testing, some discoloration of the coating could be seen, but no signs of corrosion were present.

8.1.3 Humiseal

AC Motor

The AC rotor was returned to PDT from Jaro Corp with no signs of corrosion. At the conclusion of the Humiseal AC rotor testing, no corrosion could be visually identified.

DC Motor

The DC rotor was returned to PDT from Jaro Corp with no signs of corrosion. At the conclusion of the Humiseal DC rotor testing, no corrosion could be visually identified.

8.2 Insulation Resistance

Testing of insulation resistance was unable to be conducted due to client projects taking a higher priority of resources at PDT's testing facility.

8.3 Magnetic Permeability

Testing for magnetic permeability was part of the operating efficiency taken in the performance testing.

8.3.1 Parylene C

AC Motor

The AC rotor exceeded both of the other coatings in terms of operating efficiency.

DC Motor

The DC rotor exceeded both of the other coatings as well as the baseline rotor in terms of operating efficiency.

8.3.2 Parylene HT

AC Motor

The AC rotor was not as efficient as the Parylene C, but was more efficient than Humiseal.

DC Motor

The DC rotor was not as efficient as the Parylene C or the baseline rotor, but was more efficient than Humiseal

8.3.3 Humiseal

AC Motor

The AC rotor was the least efficient coating of the three.

DC Motor

The DC rotor was the least efficient coating of the three.

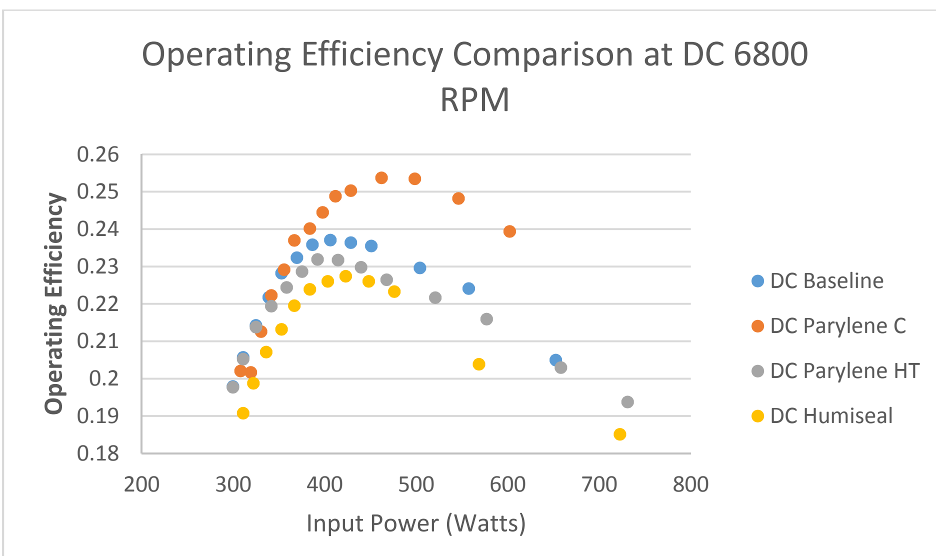

Figure 6. Operating efficiency with respect to the input power of a DC pump at 6800 RPM.

8.4 Coating Thickness

8.4.1 Parylene C

AC Motor

The coating was applied to the AC motor by SCS using vapor deposition. The coating thickness achieved was 0.000378 inches. This meets the requirement given by PDT of a coating thickness less than 0.005 inches.

DC Motor

The coating was applied to the DC motor by SCS using vapor deposition. The coating thickness achieved was 0.000378 inches. This meets the requirement given by PDT of a coating thickness less than 0.005 inches.

8.4.2 Parylene HT

AC Motor

The coating was applied to the AC motor by SCS using vapor deposition. The coating thickness achieved was 0.000386 inches. This meets the requirement given by PDT of a coating thickness less than 0.005 inches.

DC Motor

The coating was applied to the AC motor by SCS using vapor deposition. The coating thickness achieved was 0.000386 inches. This meets the requirement given by PDT of a coating thickness less than 0.005 inches.

8.4.3 Humiseal

AC Motor

The coating was applied to the AC motor by Jaro Corp using a dipping method. The coating thickness achieved was 0.0045 inches. This narrowly meets the requirement given by PDT of a coating thickness less than 0.005 inches. However, because of the tight tolerance, insertion of the rotor into the stator was difficult. This also led to rubbing of the coating.

DC Motor

The coating was applied to the DC motor by Jaro Corp using a dipping method. The coating thickness achieved was 0.0045 inches. This narrowly meets the requirement given by PDT of a coating thickness less than 0.005 inches. However, because of the tight tolerance, insertion of the rotor into the stator was difficult.

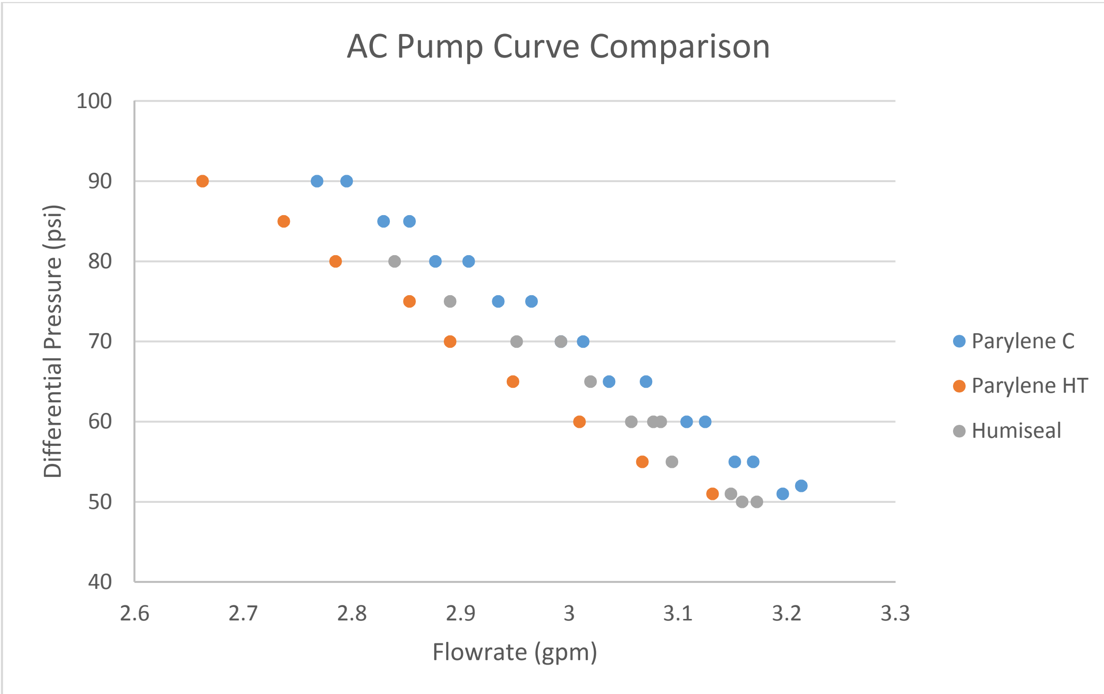

Figure 7. AC pump curves for all three coatings.

8.5 Conformability

8.5.1 Parylene C

AC Motor

The coating had high conformability. No air bubbles or other defects were visible upon inspection before testing occurred.

DC Motor

The coating had high conformability. No air bubbles or other defects were visible upon inspection before testing occurred.

8.5.2 Parylene HT

AC Motor

The coating had high conformability. No air bubbles or other defects were visible upon inspection before testing occurred.

DC Motor

The coating had high conformability. No air bubbles or other defects were visible upon inspection before testing occurred.

8.5.3 Humiseal

AC Motor

The coating had acceptable conformability. However, the dipping process produced some air bubbles and clumping of the coating that were visible upon inspection before testing occurred.

DC Motor

The coating had high conformability. No air bubbles or other defects were visible upon inspection before testing occurred.

8.6 Coating Life

8.6.1 Parylene C

AC Motor

The coating withstood limited life testing for 21.5 hours. Further testing will be done to ensure the desired 10-year lifetime is achievable.

DC Motor

The coating withstood limited life testing for 64.4 hours. Further testing will be done to ensure the desired 10-year lifetime is achievable.

8.6.2 Parylene HT

AC Motor

The coating withstood limited life testing for 20 hours. Further testing will be done to ensure the desired 10-year lifetime is achievable.

DC Motor

The coating withstood limited life testing for 105.8 hours. Further testing will be done to ensure the desired 10-year lifetime is achievable.

8.6.3 Humiseal

AC Motor

This coating only withstood 10 minutes of limited life testing before it heated up the motor to an unsafe temperature of 50°C.

DC Motor

Limited life testing was not conducted on this coating because it previously delaminated.

8.7 Thermal Conductivity/Expansion

Testing of thermal conductivity/expansion was done during the high temperature testing. The coating passed if the pump did not overheat during the test.

8.7.1 Parylene C

AC Motor

The AC motor did not overheat.

DC Motor
The DC motor did not overheat.

8.7.2 Parylene HT

AC Motor
The AC motor did not overheat.

DC Motor
The DC motor did not overheat.

8.7.3 Humiseal

AC Motor
The AC motor overheated.

DC Motor
The DC motor overheated. This lead to delamination of the coating.

8.8 Temperature Range

8.8.1 Parylene C

AC Motor
This test was not performed.

DC Motor
The Parylene C coating withstood a maximum temperature of 66.1°C during high temperature testing.

8.8.2 Parylene HT

AC Motor
This test was not performed.

DC Motor
The Parylene HT coating withstood a maximum temperature of 72.3°C during high temperature testing.

8.8.3 Humiseal

AC Motor
This test was not performed.

DC Motor
The Humiseal coating reached a temperature of 57.9°C, but delaminated shortly after.

8.9 Cost

8.9.1 Parylene C

The cost per batch is $750. A batch can hold 20 rotors. This puts the cost per rotor at $37.50, well below the $100 requirement.

8.9.2 Parylene HT

The coating was quoted at $1200 per batch. A batch can hold 20 rotors. This puts the cost per rotor at $60.00, well below the $100 requirement.

8.9.3 Humiseal

The coating was quoted at $300 per batch. A batch can hold 20 rotors. This puts the cost per rotor at $15.00, well below the $100 requirement.

9.0 Conclusions and Recommendations

It is recommended that any further testing should be conducted using the Parylene C and Parylene HT coatings, even though Parylene HT was one of the coatings that delaminated from the rotor during testing. Not only have these two coatings withstood the large temperature range and initial long duration testing, but they also produce a similar, if not better, pump efficiency for the DC motor than the current canning method. A current issue with the Parylene C and Parylene HT coatings is that they are very thin and soft, and the only process to confirm that the coatings are still intact is by using a microscope. Another downside is that the coatings can be damaged fairly easily. Specialty Coating Systems was contacted with these concerns and they responded saying that they have the ability to make the coating thicker and more visible. They also suggested submerging the rotor in a salt water bath and running a voltage across the coated rotor to determine if there are any defects in the coating. If bubbles form on a coated surface, then there is a defect at that location. To fully meet the design requirements set by PDT, the Parylene C and Parylene HT coatings should be applied thicker and also tested for insulation resistance, magnetic permeability, and thermal conductivity. Extended long duration testing should also be performed. Even though the Parylene HT coating delaminated, more extensive testing should be conducted. The reason for this coating delamination may be due to oxidization of the magnetic surface underneath prior to the coating application. SCS was contacted about this as well and will take measures in the future to ensure that the rotors do not oxidize prior to application of the coating.

A rotor insertion tool design and prototype was completed, but not fully developed. This was an additional project that PDT requested, but was not required to complete the coating testing. Multiple solutions were designed and attempted which included a rotor/stator positioning jig, a molded sleeve, and shims which all attempted to protect the coating from damage during the insertion process. In the end, the sleeve method looked the most promising. The rotor/stator positioning jig requires small tolerances, which increases manufacturing costs, and would require more assembly time than the current rotor insertion method. The shims follow a similar idea as the molded sleeve, however since the shims do not surround the entirety of the rotor, the coating runs a large risk of being damaged by the edges of the shims. These shims are also extremely sharp, since the thickness of the shims are less than five thousandths of an inch. This could cause the person using the tool to accidentally injure themselves. It is suggested that the molded sleeve design be modified to incorporate high gloss paper to protect the coating from the stator walls. This method would only work on the insertion of the rotor, but not removal. When inserting a tool to remove the rotor, there is a risk of damaging the coating. In the end, wrapping the rotor in a single layer of high gloss paper provides the most effective and least expensive method of inserting the rotor into the stator.

10.0 Appendices

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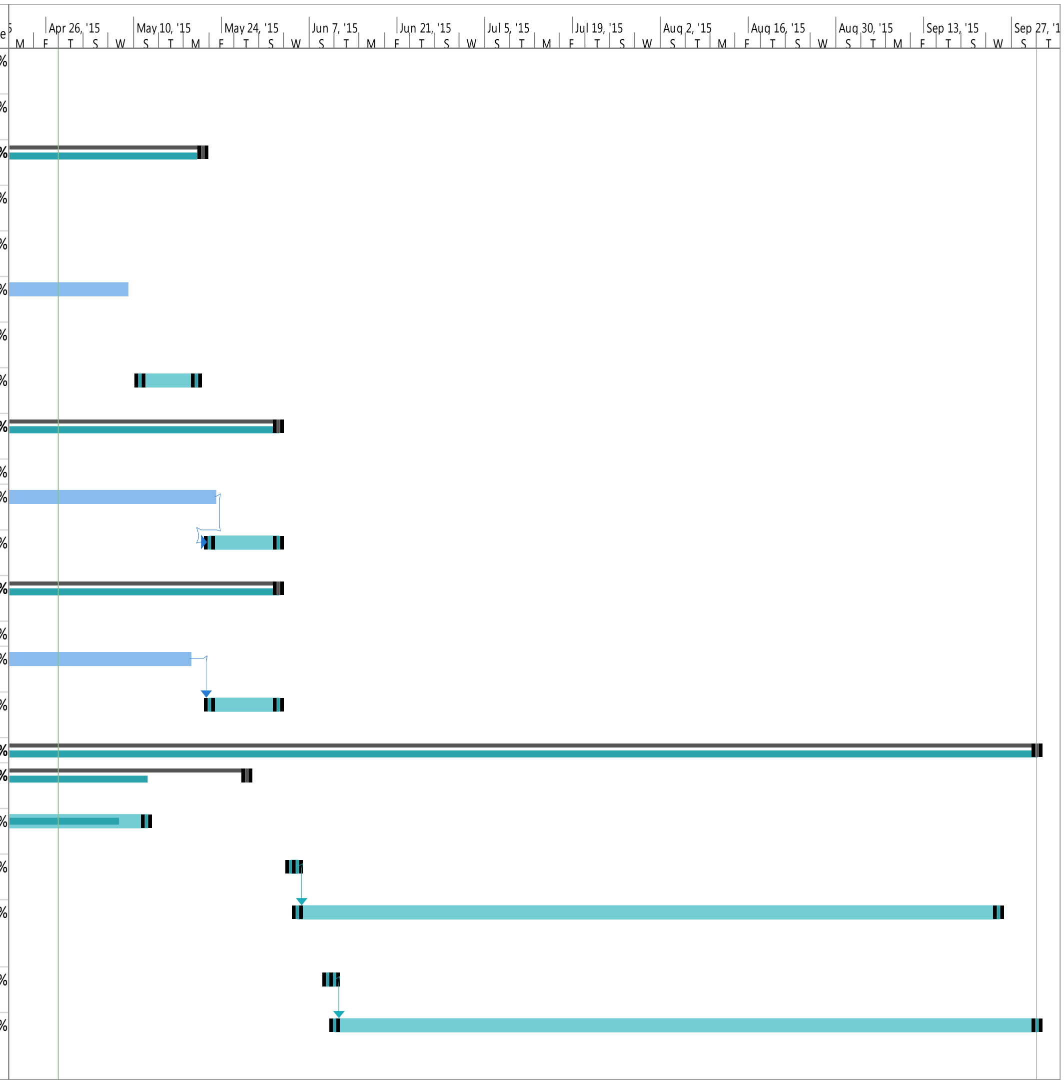
Appendix A- Gantt Chart

ID	Task Name	Duration	Start	Finish	% Complete
1	Research current & new coatings	15 days	Tue 1/27/15	Mon 2/16/15	100%
8	Conceptual Design Report	28 days	Tue 2/3/15	Thu 3/12/15	100%
2	**Tool Design**	**82 days**	**Tue 1/27/15**	**Wed 5/20/1**	**64%**
4	Start tool design	9 days	Thu 2/5/15	Tue 2/17/15	100%
5	Build/Test Tool	9 days	Thu 2/19/15	Tue 3/3/15	85%
6	Iteration	34 days	Tue 3/24/15	Fri 5/8/15	55%
3	Research tool design	6 days	Tue 1/27/15	Tue 2/3/15	100%
7	Finalize Tool	7 days	Mon 5/11/1	Tue 5/19/15	0%
9	**PDT AC motors**	**85 days**	**Tue 2/3/15**	**Mon 6/1/15**	**32%**
10	PDT AC drawings	18 days	Tue 2/3/15	Thu 2/26/15	100%
11	PDT AC procureme	59 days	Tue 3/3/15	Fri 5/22/15	15%
12	AC coatings	7 days	Fri 5/22/15	Mon 6/1/15	0%
13	**PDT DC motors**	**85 days**	**Tue 2/3/15**	**Mon 6/1/15**	**62%**
14	PDT DC drawings	14 days	Tue 2/3/15	Fri 2/20/15	100%
15	PDT DC procureme	59 days	Wed 2/25/1	Mon 5/18/1	60%
16	DC coatings	7 days	Fri 5/22/15	Mon 6/1/15	0%
17	**Assembly and Testin**	**160 day**	**Thu 2/19/15**	**Wed 9/30/1**	**12%**
18	**Design Test Procedure**	**70 days**	**Thu 2/19/15**	**Wed 5/27/15**	**90%**
19	Create data tabl	25 days	Tue 4/7/15	Mon 5/11/1	90%
20	DC pump assembly	1 day	Thu 6/4/15	Thu 6/4/15	0%
21	DC pump performance testing	80 days	Fri 6/5/15	Thu 9/24/15	0%
22	AC pump assembl	1 day	Wed 6/10/1	Wed 6/10/1	0%
23	AC pump performance testing	80 days	Thu 6/11/15	Wed 9/30/15	0%



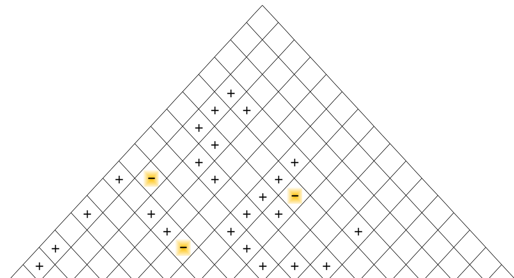
Appendix B- Quality Function Deployment (QFD)

QFD: House of Quality
Project: Corrosion Resistant Submerged Motor
Revision:
Date: 1/27/15

Correlations	
Positive	+
Negative	−
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

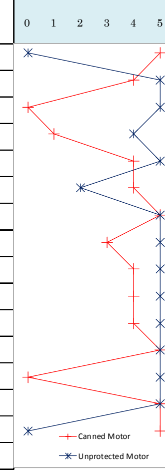
Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼



WHO: Pacific Design Technologies

Row #	Weight Chart	Relative Weight	Pratt and Whitney	Raytheon	General Dynamics		Maximum Relationship	WHAT: Customer Requirements (explicit & implicit) / HOW: Engineering Specifications	1 Cost Analysis ▼	2 Efficiency ◇	3 Visual check of rotor coating ▼	4 Visual Check of Corrosion ▼	5 Throughput of Rotor Coating ◇	6 Conpatibility ◇	7 Thisckness ◇	8 Thermal Expasion Coeffecent ▼	9 Temperature Resistance ◇	10 Long Duration Testing ▲	11 Resistance to Current ▲	12 Magnetic Permability ▲	13 Resistance to Vibrations ▲	14	15	16	Stainless Steel Rotor Shell	Motor with no anti-corrosion coating				Row #
1		12%	10	10	10		9	Non-corrosive	▽			●			○			○							5	0				1
2		11%	9	9	9		9	Diaelectric		○									●						4	5				2
3		8%	7	7	7		9	Less than $100	●				▽												0	5				3
4		5%	4	4	4		9	10 units manufactured per month	○				●												1	4				4
5		9%	8	8	8		9	Matched performance to current method	○	●				●	▽			○							4	5				5
6		8%	7	7	7		9	Conform to enviromental standards	○												●				4	2				6
7		9%	8	8	8		9	Durable	○		●	●			○			●							5	5				7
8		4%	3	3	3		9	Thickness Tolerance							●				▽						3	5				8
9		2%	2	2	2		9	Compatible with prefabricated rotors	▽	▽				●											4	5				9
10		8%	7	7	7		9	Magnetically permeable		●					○					●					4	5				10
11		4%	3	3	3		9	Low thermal expansion Coefficeient								●	○	▽							4	5				11
12		9%	8	8	8		9	Works from -10F- 185F									●	▽							5	5				12
13		1%	1	1	1		3	Easily Manufactured	○				○												0	5				13
14		1%	1	1	1		9	Conforms to set testing procedures	○					●											5	5				14
15		8%	7	7	7		9	10 year life	○		○	○					▽	●	▽						5	0				15
16		0%																												16

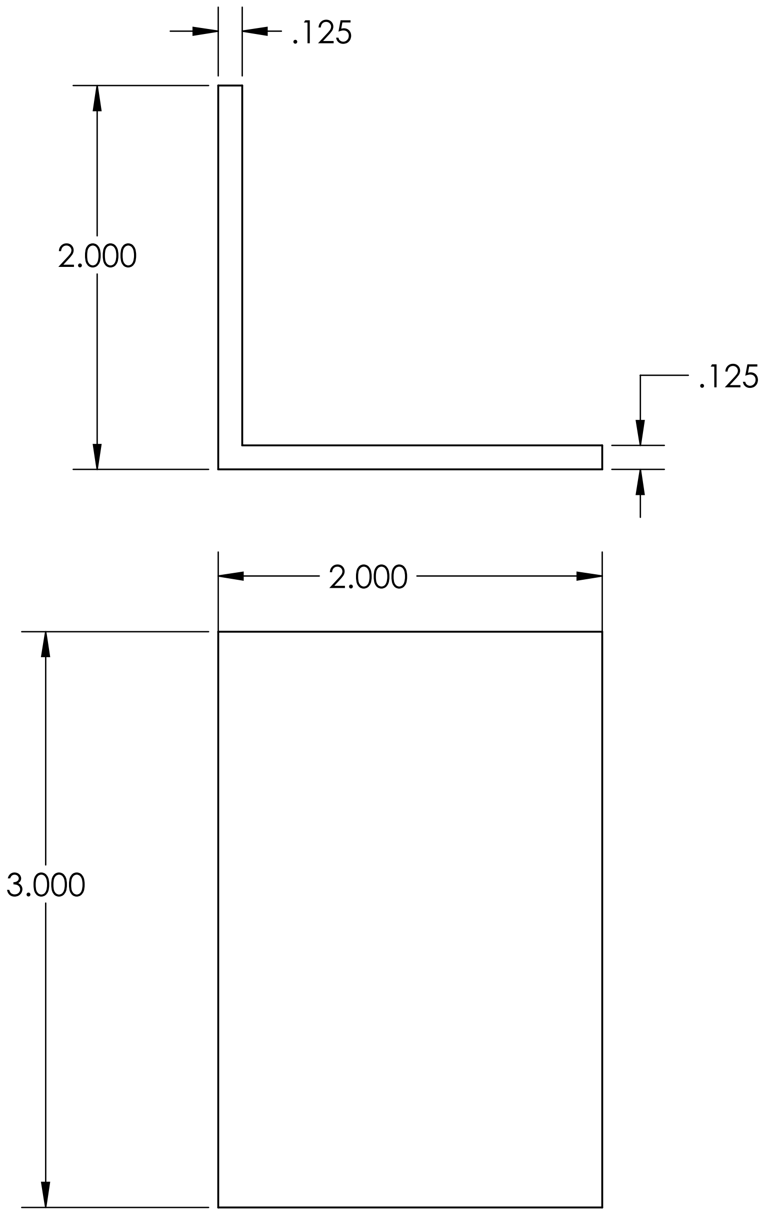
NOW: Current Product Assesment - Customer Requirements

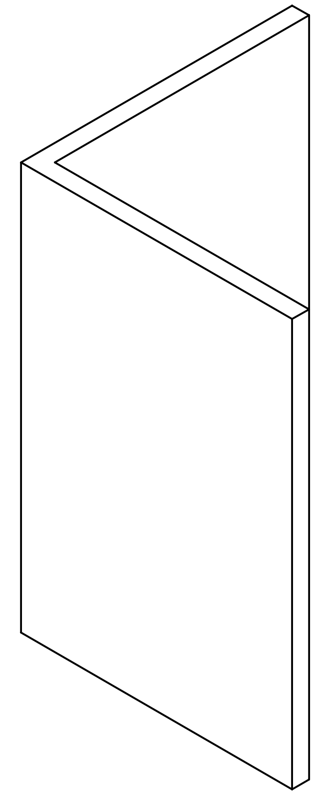


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
HOW MUCH: Target	$100 Maximum	Percent	Look for scratches/ marring	Look for any signs of rust	10 units/month	No modifications to existing equipment	10 microns	Minimize the Thermal Expansion Coefficient	(-10F) to 185F	100+ Hours	Diaelectric	Stainless Steel (H/m)	N/A			
Max Relationship	9	8	8	9	7	8	6	4	7	7	8	8	5			
Technical Importance Rating	215.29	192.94	109.41	215.29	54.118	116.47	129.41	31.765	103.53	235.29	107.06	74.118	74.118			
Relative Weight	13%	12%	7%	13%	3%	7%	8%	2%	6%	14%	6%	4%	4%			
Weight Chart																

Appendix C- Tool Drawing (Centered Rod Design)

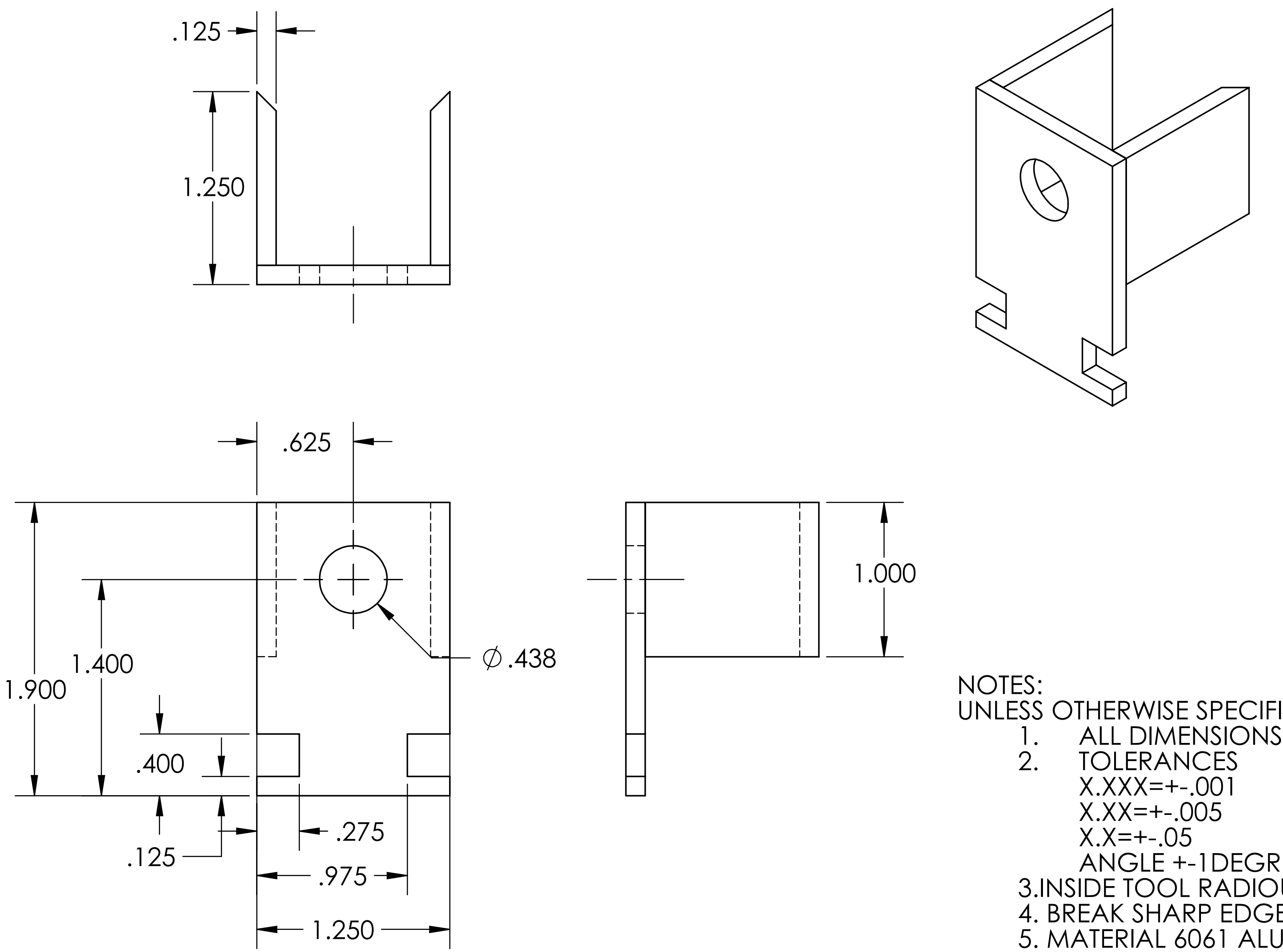
- Drawing 1-1 – 2”x2” Angle Iron
- Drawing 1-2- Angle Iron Mount
- Drawing 1-3- Clamp Mount
- Drawing 1-4- Base Plate
- Drawing 1-5- Tool Assembly





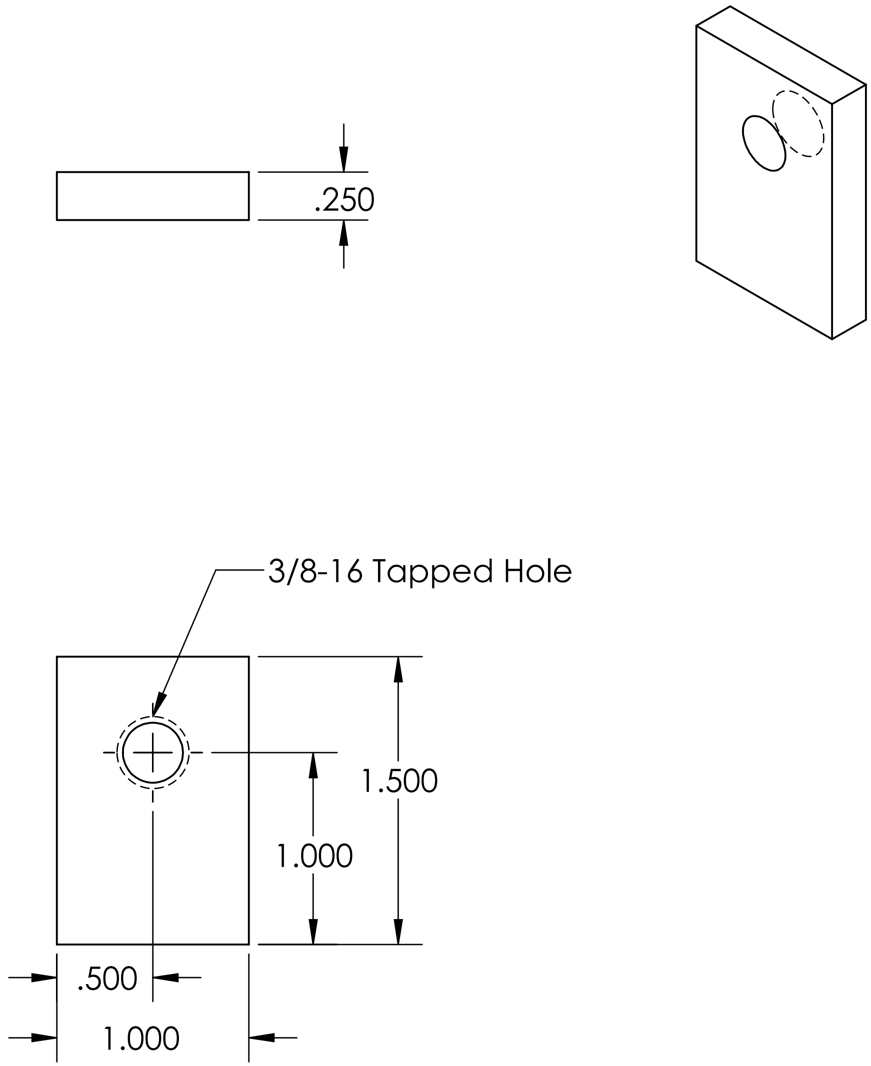
NOTES:
UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES
X.XXX=+-.001
X.XX=+-.005
X.X=+-.05
ANGLE +-1DEGREE
3.INSIDE TOOL RADIOUS .03 MAX
4. BREAK SHARP EDGES .03 MAX
5. MATERIAL 6061 ALUMINUM

Cal Poly Mechanical Engineering			Title: 2" x 2" Angle Iron		Drwn. By: Cole Thompson
CDL Senior Project	Dwg. #: 1-1		Date: 3/10/2015	Scale: 1:1	Chkd. By: Loren MacDonald



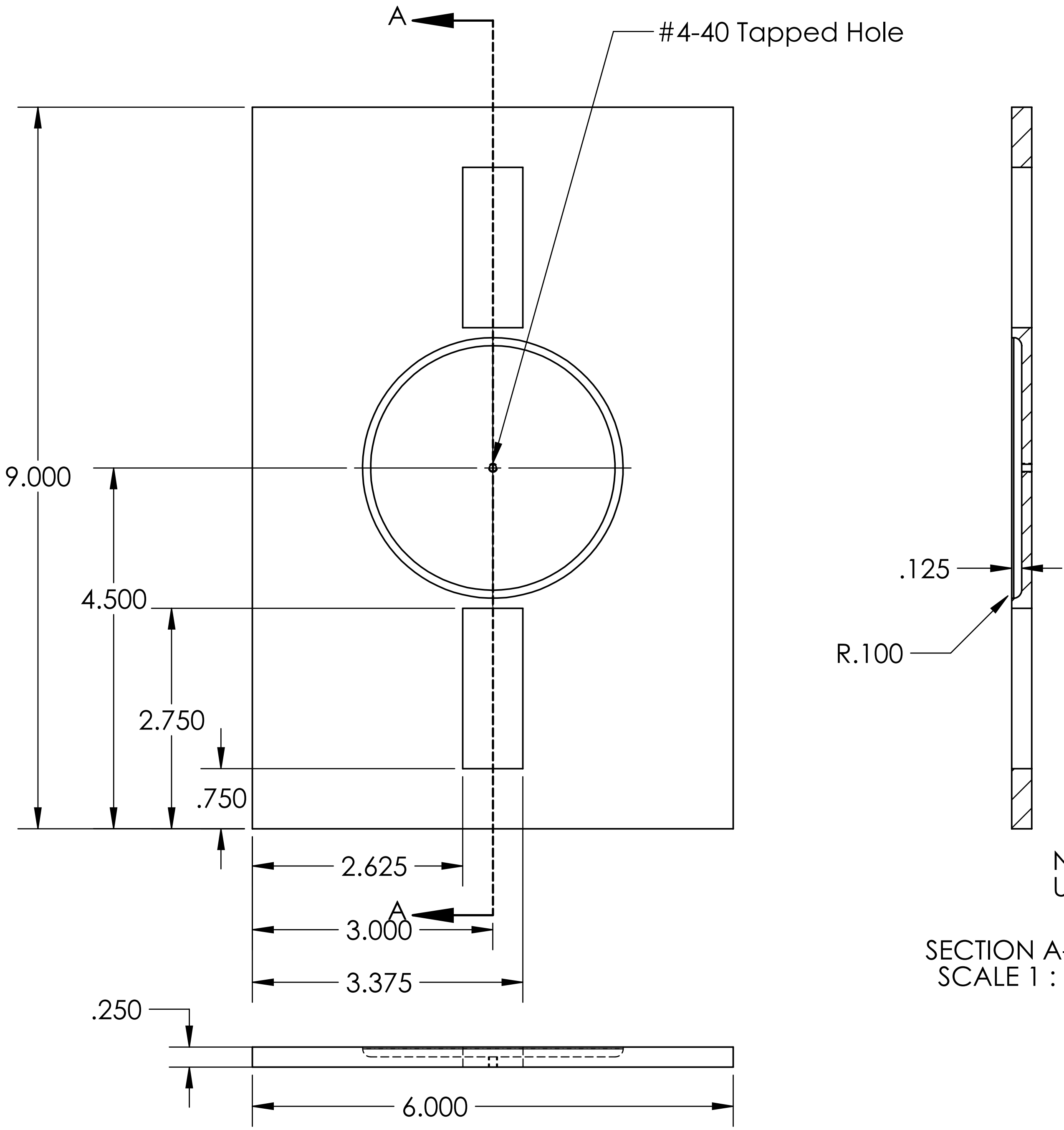
NOTES:
UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES
X.XXX=+-.001
X.XX=+-.005
X.X=+-.05
ANGLE +-1DEGREE
3.INSIDE TOOL RADIOUS .03 MAX
4. BREAK SHARP EDGES .03 MAX
5. MATERIAL 6061 ALUMINUM

Cal Poly Mechanical Engineering CDL Senior Project			Title: Angle Iron Mount		Drwn. By: Cole Thompson
	Dwg. #: 1-2		Date: 3/10/2015	Scale: 1:1	Chkd. By: Loren MacDonald



NOTES:
UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES
   X.XXX=+-.001
   X.XX=+-.005
   X.X=+-.05
   ANGLE +-1DEGREE
3.INSIDE TOOL RADIOUS .03 MAX
4. BREAK SHARP EDGES .03 MAX
5. MATERIAL 6061 ALUMINUM

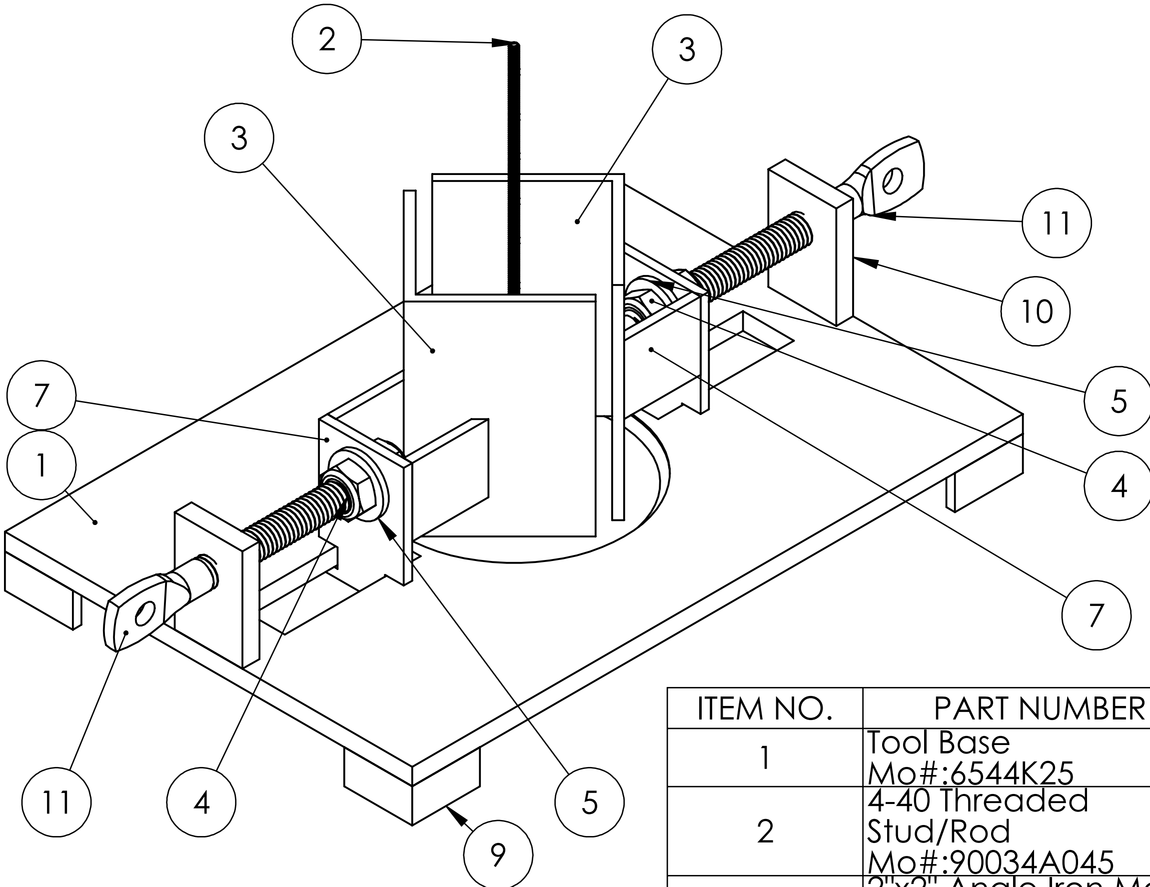
Cal Poly Mechanical Engineering			Title: CLAMP MOUNT		Drwn. By: Cole Thompson
CDL Senior Project	Dwg. #: 1-3		Date: 3/10/2015	Scale: 1:1	Chkd. By: Loren MacDonald



SECTION A-A
SCALE 1 : 2

NOTES:
UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES
X.XXX=+-.001
X.XX=+-.005
X.X=+-.05
ANGLE +-1DEGREE
3.INSIDE TOOL RADIOUS .03 MAX
4. BREAK SHARP EDGES .03 MAX
5. MATERIAL 6061 ALUMINUM

Cal Poly Mechanical Engineering			Title: BASE PLATE		Drwn. By: Cole Thompson
CDL Senior Project	Dwg. #: 1-4		Date: 3/10/2015	Scale: 1:2	Chkd. By: Loren MacDonald



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Tool Base Mo#:6544K25	Tool Base	1
2	4-40 Threaded Stud/Rod Mo#:90034A045	4-40 Threaded Stud/Rod	1
3	2"x2" Angle Iron Mo#: 9017K494	2"X2"X3" Steel Angle Iron	2
4	3/8" Thin Locknut Mo#: 90566A031	3/8" Thin Locknut	4
5	3/8" Steel Washer Mo#: 96659A108	3/8" Steel Washer	4
6	4-40 Thin Locknut Mo#: 90633A005	4-40 Thin Locknut	2
7	Clamp Mount	Clamp Mount	2
8	#4 Steel Washer Mo#: 90126A505	#4 Steel Washer	2
9	Tool Base Leg Mo#: 1388K471	Tool Base Leg	4
10	Clamp Screw Mount	Clamp Screw Mount	2
11	3/8"-16 Machine Screw Hanger Bolt	3/8"-16 Machine Screw Hanger Bolt	2

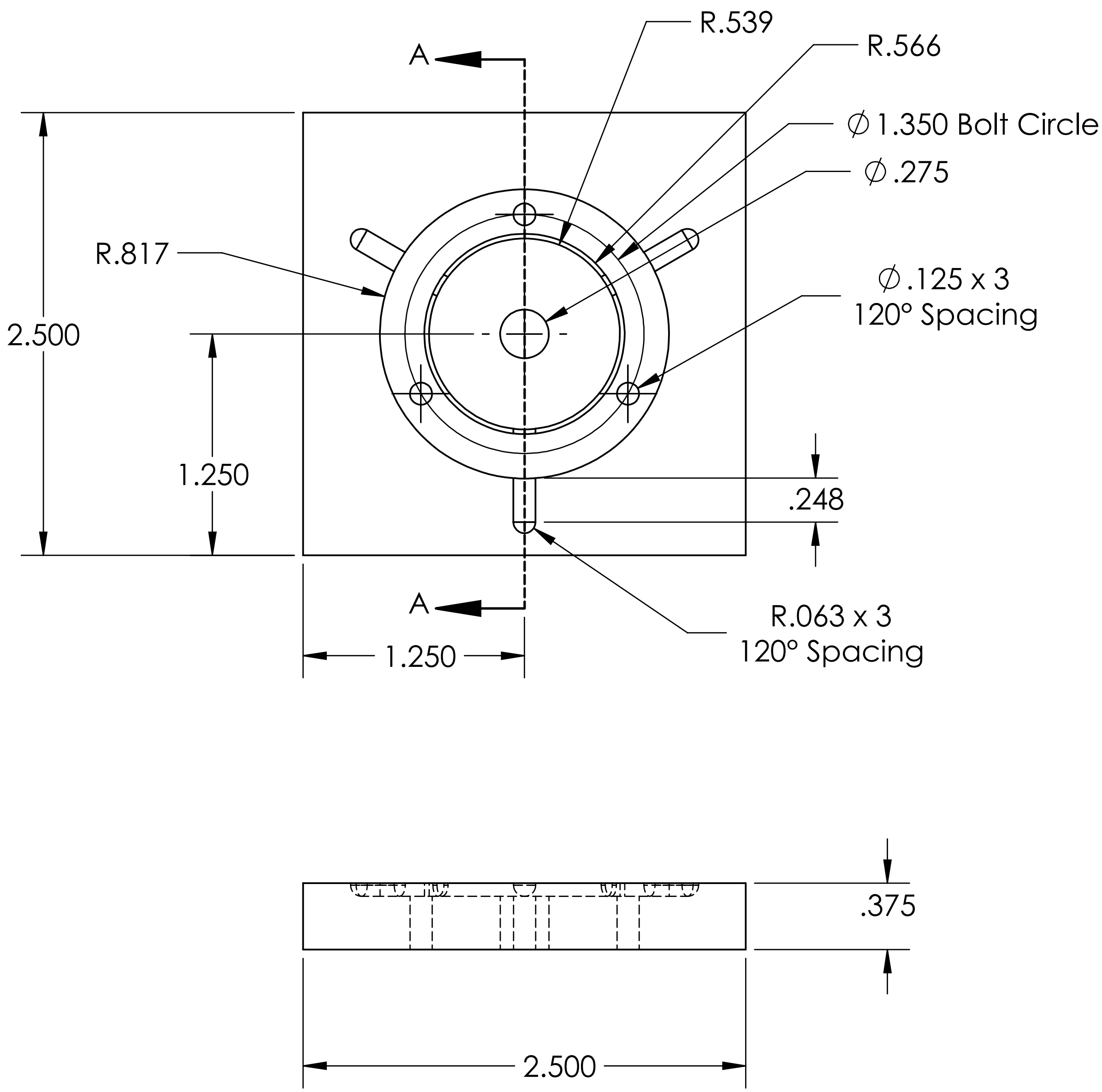
Cal Poly Mechanical Engineering CDL Senior Project			Title: TOOL ASSEMBLY	Drwn. By: Cole Thompson
	Dwg. #: 1-5		Date: 3/10/2015	Scale: 1:2	Chkd. By: Loren MacDonald

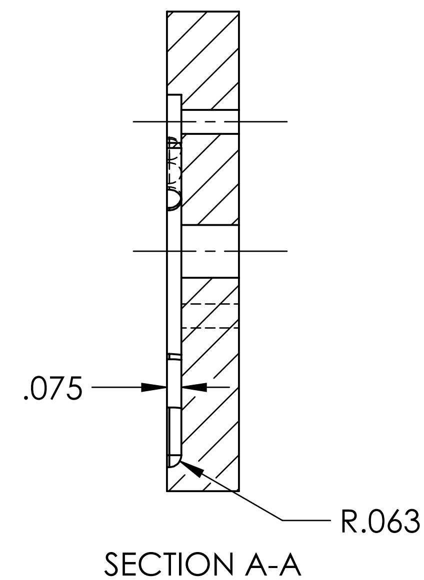
Appendix D- Centered Rod Tool Cost Analysis

Concentric Inserter						
Part	Part Number	Quantity in Part	Package Quantity	Purchase Quantity	Unit Cost ($)	Total Part Cost ($)
Tool Base	6544K25	1	1	1	52.1	52.10
4-40 Threaded Stud/Rod	90034A045	1	1	1	3.58	3.58
2"x2"x1/8" Angle Iron 1' length	9017K494	2	1	1	6.89	6.89
3/8" Thin Locknut	90566A031	4	100	1	5.32	5.32
3/8" Steel Washer	96659A108	4	50	1	7	7.00
4-40 Thin Locknut	90633A005	2	100	1	3.71	3.71
Clamp Mount	1388K471	2	1	1	45.96	45.96
#4 Steel Washer	90126A505	2	100	1	1.37	1.37
Tool Base Leg	1388K147	4	1	0	45.96	0.00
Clamp Screw Mount	6544K25	2	1	0	52.1	0.00
3/8"-16 Hanger Bolt	90172A639	2	5	1	9.66	9.66
All parts ordered through McMaster Carr					Total w/o Tax	135.59
					Total w/ tax	146.44

Appendix E- Tool Drawing (Mold Design)

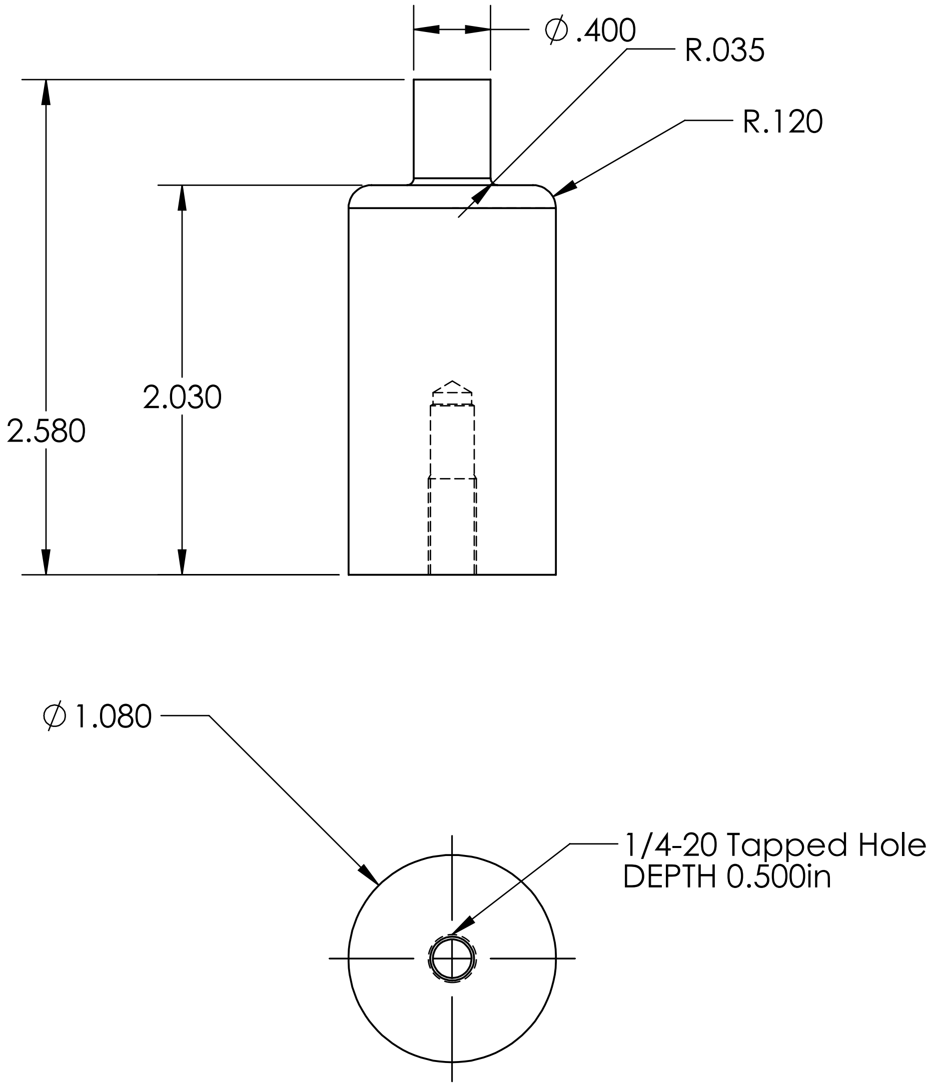
- Drawing 2-1- Total Mold Assembly
- Drawing 2-2- Mold Internal Core
- Drawing 2-3- Mold External Wall
- Drawing 2-4 Top Shaft and Washer





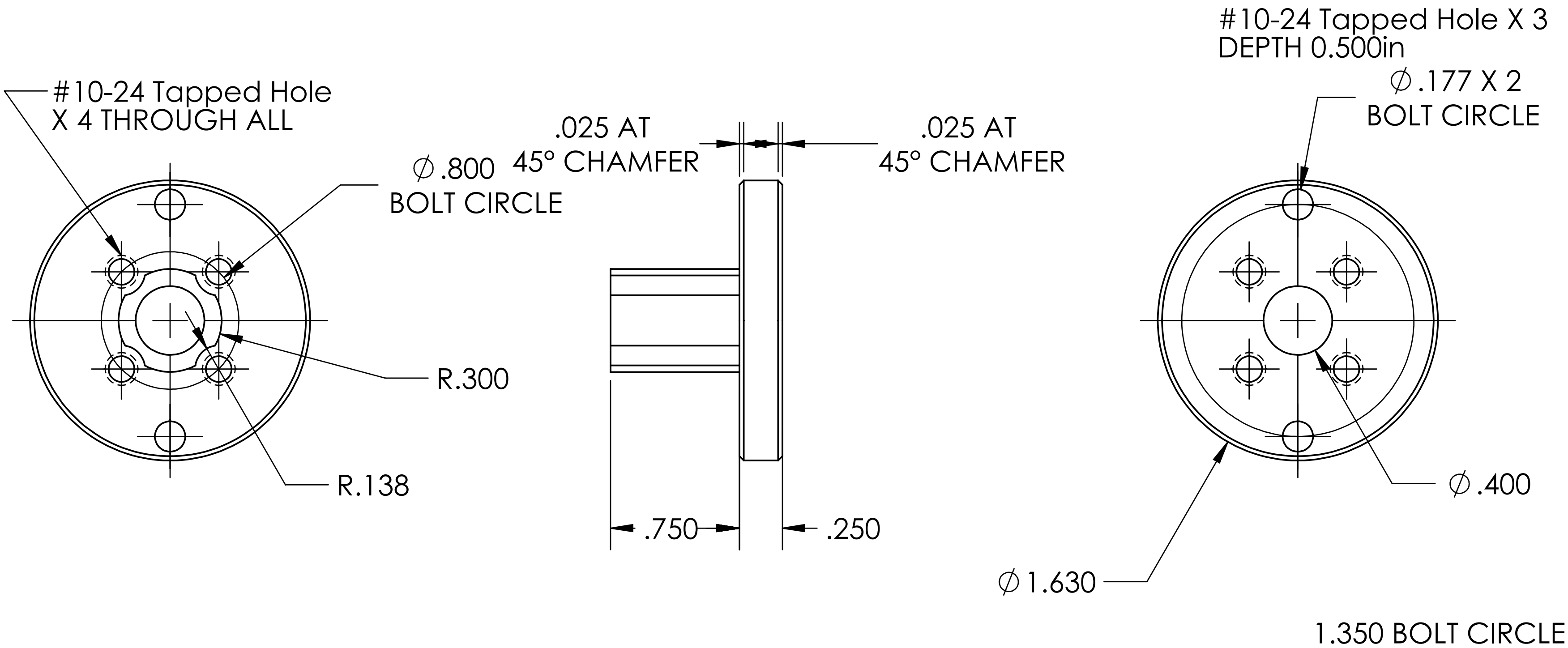
NOTES
UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES
   X.XX=±.05
   X.X=±.5
   ANGLES=±1°
3. INSIDE TOOL RADIUS .03 MAX
4. BREAK SHARP EDGES .03 MAX
5. MATERIAL 6061 ALUMINUM

Cal Poly Mechanical Engineering			Title: BASE		Drwn. By: LOREN MACDONALD
CDL Senior Project	Dwg. #: 2-1		Date:4/30/15	Scale: 1:1	Chkd. By: COLE THOMPSON



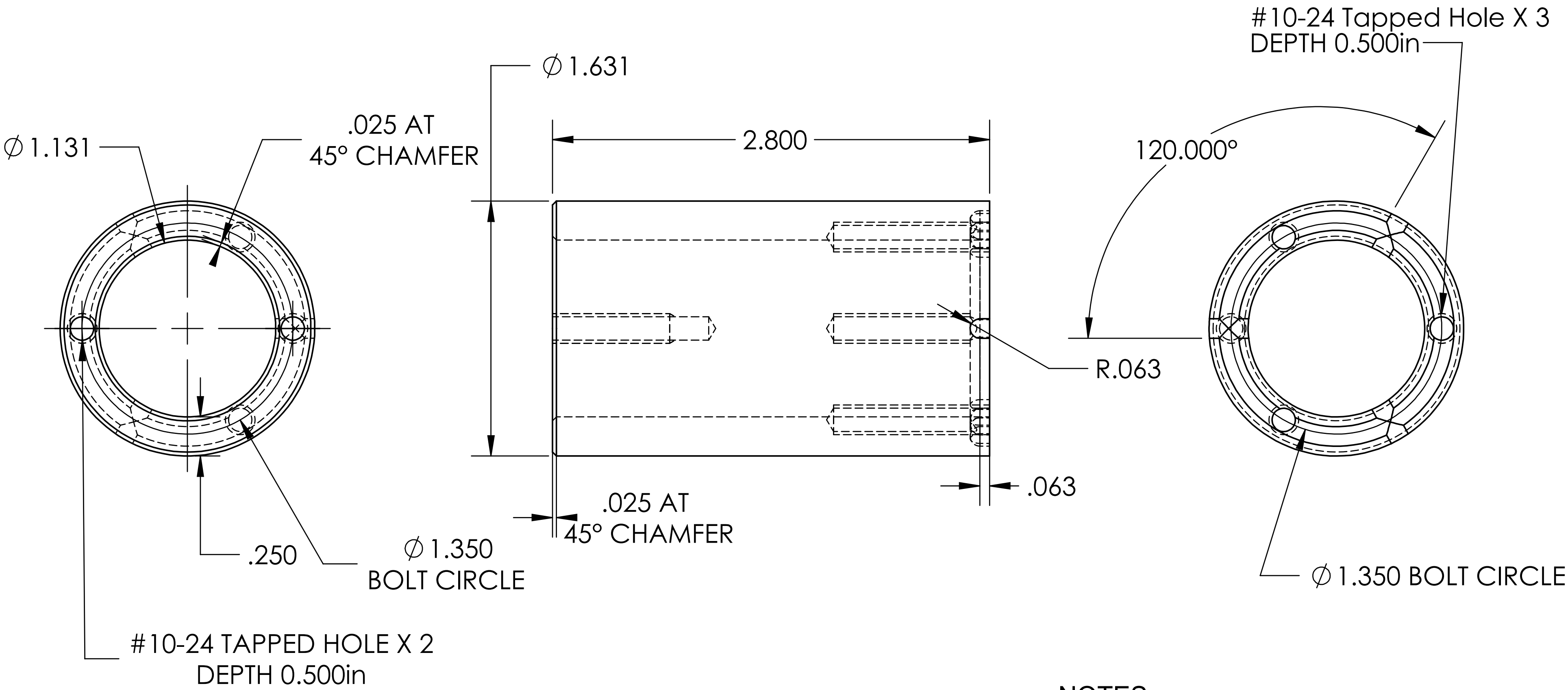
NOTES
UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES
   X.XX=±.05
   X.X=±.5
   ANGLES=±1°
3. INSIDE TOOL RADIUS .03 MAX
4. BREAK SHARP EDGES .03 MAX
5. MATERIAL 6061 ALUMINUM

Cal Poly Mechanical Engineering CDL Senior Project			Title: INTERNAL CORE	Drwn. By: LOREN MACDONALD
	Dwg. #: 2-2		Date:4/30/15 | Scale: 1:1	Chkd. By: COLE THOMPSON



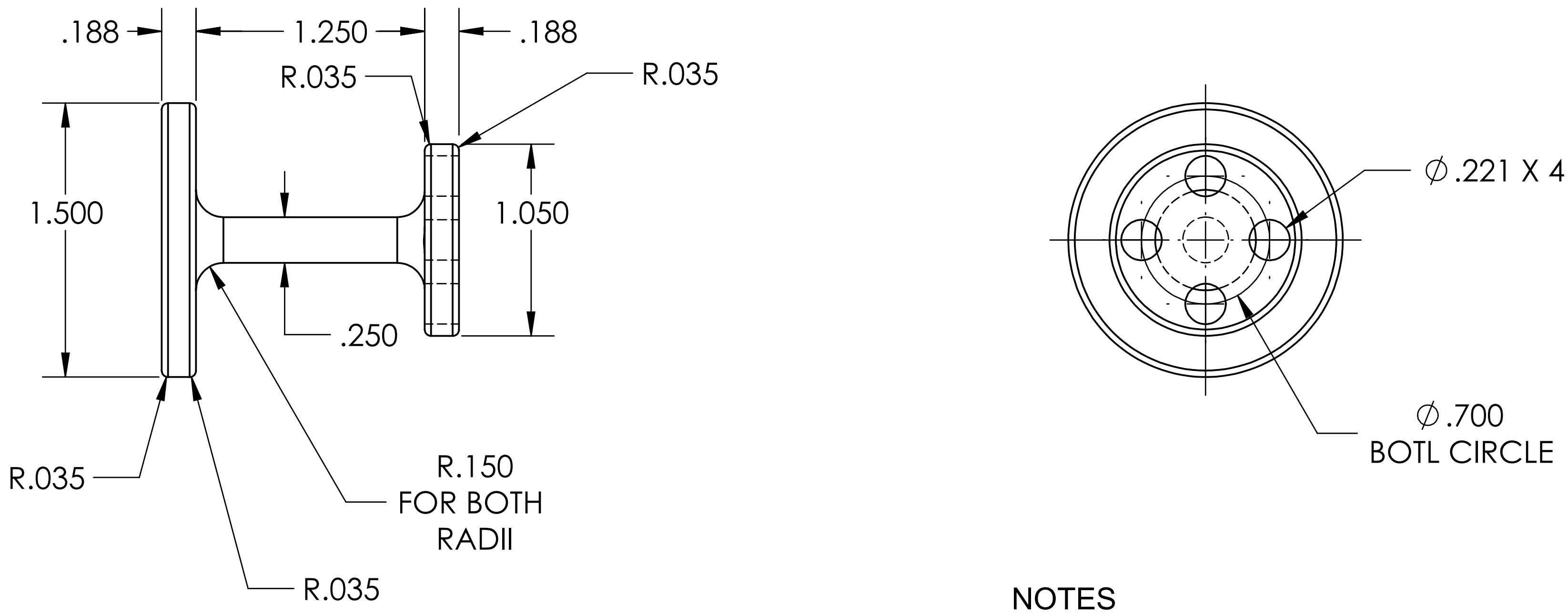
NOTES
UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES
   X.XX=±.05
   X.X=±.5
   ANGLES=±1°
3. INSIDE TOOL RADIUS .03 MAX
4. BREAK SHARP EDGES .03 MAX
5. MATERIAL 6061 ALUMINUM

Cal Poly Mechanical Engineering			Title: TOOL COVER		Drwn. By: LOREN MACDONALD
CDL Senior Project	Dwg. #: 2-3		Date:4/30/15	Scale: 1:1	Chkd. By: COLE THOMPSON



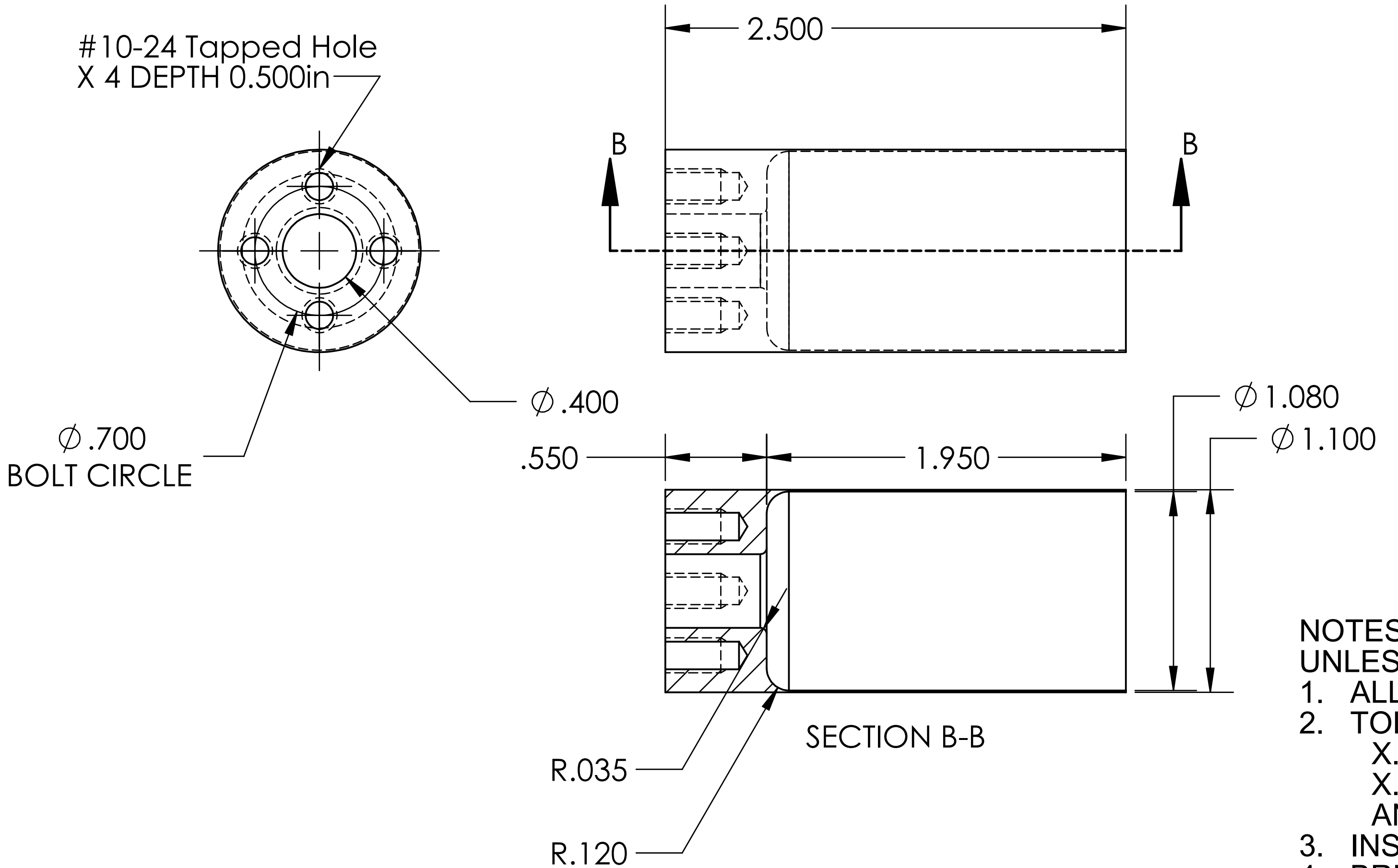
NOTES
UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES
   X.XX=±.05
   X.X=±.5
   ANGLES=±1°
3. INSIDE TOOL RADIUS .03 MAX
4. BREAK SHARP EDGES .03 MAX
5. MATERIAL 6061 ALUMINUM

Cal Poly Mechanical Engineering CDL Senior Project			Title: EXTERNAL TOOL		Drwn. By: LOREN MACDONALD
	Dwg. #: 2-4		Date:4/30/15	Scale: 1:1	Chkd. By: COLE THOMPSON



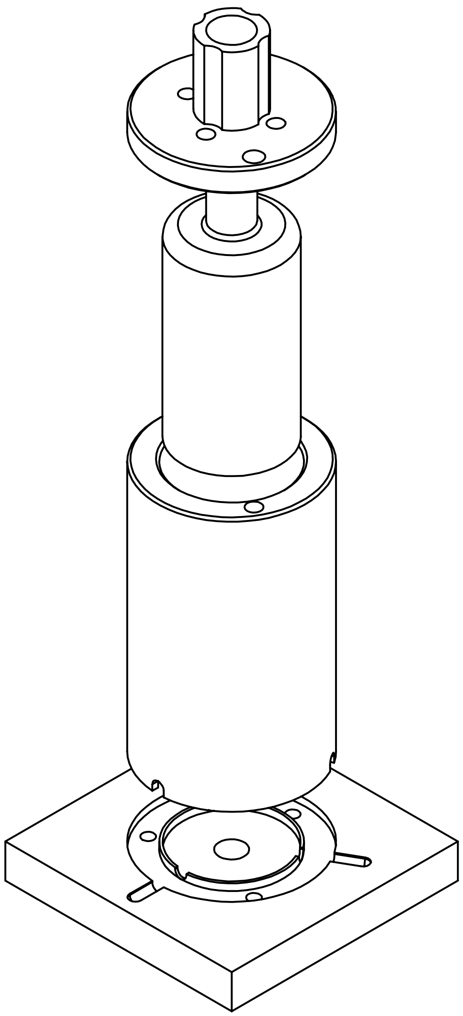
NOTES
UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES
   X.XX=±.05
   X.X=±.5
   ANGLES=±1°
3. INSIDE TOOL RADIUS .03 MAX
4. BREAK SHARP EDGES .03 MAX
5. MATERIAL 6061 ALUMINUM

Cal Poly Mechanical Engineering CDL Senior Project			Title: PULL HANDLE		Drwn. By: LOREN MACDONALD
	Dwg. #: 2-5		Date:4/30/15	Scale: 1:1	Chkd. By: COLE THOMPSON



NOTES
UNLESS OTHERWISE SPECIFIED
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES
   X.XX=±.05
   X.X=±.5
   ANGLES=±1°
3. INSIDE TOOL RADIUS .03 MAX
4. BREAK SHARP EDGES .03 MAX
5. MATERIAL POLY-URETHANE

Cal Poly Mechanical Engineering			Title: TOOL SHELL		Drwn. By: LOREN MACDONALD
CDL Senior Project	Dwg. #: 2-6		Date:4/30/15	Scale: 1:1	Chkd. By: COLE THOMPSON



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	BASE	ALUMINUM 6061	1
2	INTERNAL CORE	ALUMINUM 6061	1
3	TOOL COVER	ALUMINUM 6061	1
4	EXTERNAL TOOL	ALUMINUM 6061	1

Cal Poly Mechanical Engineering			Title: TOOL ASSEMBLY		Drwn. By: LOREN MACDONALD
CDL Senior Project	Dwg. #: 2-7		Date:4/30/15	Scale: 1:1	Chkd. By: COLE THOMPSON

Appendix F- Molded Tool Cost Analysis

Mold						
Part	Part Number	Quantity in Part	Package Quantity	Purchase Quantity	Unit Cost ($)	Total Part Cost ($)
Mold Base (3/8" AL 6061 Plate)	8975K617	1	1	1	7.69	7.69
1/4"-28 Screw - 2" Long	91255A568	2	10	1	10.83	5.89
10-24 Screw - 2" Long	90044A116	3	25	1	6.64	6.64
External Sleeve	8974K71	1	1	1	29.57	29.57
Mold Internal	8974K18	1	1	1	16.54	16.54
All parts ordered through McMaster Carr					Total w/o Tax	66.33
					Total w/ tax	71.64

Appendix G: Test Procedure

TEST PROCEDURE
TP-4021 & 4021-1

PDT Model No. 4021 & 4021-1
PUMPING UNIT

Prepared for:
PACIFIC DESIGN TECHNOLOGIES, INC.
6300 Lindmar Drive
Goleta, CA 93117

Submitted by:
CORROSION DEFENSE LEAGUE
California Polytechnic State University
1 Grand Avenue
San Luis Obispo, CA 93401

April 14, 2015

Revision: A   Date: 4/14/15

Written by: D. Hyde, L. MacDonald, C. Thompson   Date: 4/14/15

Approved:____________________   Date: ____________

The following restrictions apply when box is checked ☑

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REVISION SHEET

Revision	Description	Date
A	INITIAL RELEASE	4/14/15

Table of Contents

Table of Figures

1.0 General

NOTE: For any testing that may be conducted by a subcontractor off-site (not at a PDT facility), the subcontractor must submit any questions or requests for clarification about this procedure, to PDT in writing, whether by mail, fax or e- mail. PDT will respond in writing as well.

1.1 Purpose

The purpose of this Acceptance Test Procedure (ATP) is to set forth the engineering acceptance test requirements and procedure for the Pumping Unit PDT Models 4021 and 4021-1 as required by Pacific Design Technologies.

1.2 Testing

Testing described herein shall be conducted in the order listed to the extent practical.

1.3 Test Data Sheet

A test data sheet, as shown in Figure III – Test Data Sheet shall be maintained for each serialized unit tested. All data required on the data sheet shall be completed.

1.4 Test Fluid

The test fluid shall be an ethylene glycol water mixture per PDT standards.

1.5 Fluid Temperature

The fluid temperature for all testing described herein shall be as specified.

1.6 Environmental Conditions

1.6.1 Ambient Temperature

Normal room +60°F to +95°F (+15.5°C to + 35.0°C)

1.6.2 Altitude

Prevailing atmospheric

1.6.3 Humidity

Prevailing humidity

1.7 Test Tolerance

Allowable tolerance for test parameter values not specified as minimum or maximum, including instrument and calibration errors, shall be as follows:

Temperature:	±1°F
Time:	±5% or 15 minutes, whichever is less
Pressure:	± 2%
Electrical Power:	±2.5%
Voltage:	± 2%
Current:	± 2%
Electrical Frequency:	±1%
Flow:	± 2%

1.8 Test Equipment

Only the test equipment or its equivalent will be employed in the testing required herein. All test equipment will be calibrated per ANSI/NCSL Z540-1.

The following test equipment or its equivalent shall be used for testing:

Description	Manufacturer	Range
Pressure Gauge	Wika	0-30 psig
Pressure Gauge	Wika	0-200 psig
Temperature Sensor	Omega	-200°C to +400°C
Flow Meter	FloCat	0-2 gpm
Power Analyzer	Valhalla	0-100 amp
Micro Ohmmeter	AEMC	0μΩ -200Ω
Hand Pump	Simplex	0-6000 psig
IR/Dielectric Tester	Vitrek	Multi

1.9 Test Set-Up

The test set-up(s) shall be in accordance with Figure 1, 2, and 3.

1.10 Power

AC power shall be 115/200 VAC, 400 Hz, 3∅, 4-Wire, Wye.
DC power shall be 28V

1.11 Rated Parameters

Each pump's parameters shall be determined by baseline testing to be performed by PDT in late May of 2015.

2.0 Procedure

The following list provides an outline for the order in which the test will be performed:

2.0.1 Baseline Canned DC Motor with new plastic gerotor set

a. Initially examine motor set in accordance with Section 2.1 of this report.
b. The dielectric strength and insulation resistance of the stator will be measured in accordance with Sections 2.3 and 2.4 of this report
c. A bonding test will be performed to ensure safety of all parts, as detailed in Section 2.2 of this report
d. A break-in run will be performed to break-in the new gerotor in accordance with PDT's current methods.
e. A cleanliness check will be run in accordance with Section 2.9 of this report.
f. A performance mapping test will be run in accordance with Section 2.7 of this report.
g. A low temperature startup test will be run in accordance with Section 2.10 of this report.

2.0.2 Coated DC rotor verification tests (4x)

a. Initially examine motor set in accordance with Section 2.1 of this report.
b. A performance check will be run in accordance with Section 2.5 of this report on each coated rotor at the set speed determined from the baseline curves. If the performance check does not meet the baseline performance within a reasonable tolerance, end testing for that coating.
c. If the performance check does meet the baseline performance, conduct a performance spot test on the coated rotor in accordance with Section 2.8 of this report.
d. A visual examination of each coated rotor will then be conducted to ensure the coating is still intact and undamaged in accordance with Section 2.1 of this report.

2.0.3 AC Motor Safety Tests

a. The dielectric strength and insulation resistance of the stator will be measured in accordance with Sections 2.3 and 2.4 of this report

2.0.4 Coated AC rotor verification tests (4x)

a. Initially examine motor set in accordance with Section 2.1 of this report.
b. A bonding test will be performed to ensure safety of all parts, as detailed in Section 2.2 of this report.
c. A performance check will be run in accordance with Section 2.6 of this report on each coated rotor at the set speed determined from the baseline curves. If the performance check does not meet the baseline performance within a reasonable tolerance, end testing for that coating.
d. If the performance check does meet the baseline performance, conduct a performance spot test on the coated rotor in accordance with Section 2.8 of this report.

e. A visual examination of each coated rotor will then be conducted to ensure the coating is still intact and undamaged in accordance with Section 2.1 of this report.

2.0.5 Coated DC rotor limited life test

a. The data from the verification tests will be compared with the baseline data to select one coated rotor to continue testing.
b. The best performing coated rotor will endure limited life testing with periodic cleanliness checks as stated in detail in Section 2.11 of this report.
c. A visual examination will then be performed on the rotor in accordance with Section 2.1 of this report.
d. The rotor will then undergo a low temperature start-up test in accordance with Section 2.10 of this report.
e. The rotor will then be exposed to high temperatures in the limited life temperature testing as stated in Section 2.12 of this report.

2.0.5 Coated AC rotor limited life test

a. The data from the verification tests will be compared with the baseline data to select one coated rotor to continue testing.
b. The best performing coated rotor will endure limited life testing with periodic cleanliness checks as stated in detail in Section 2.11 of this report.
c. A visual examination will then be performed on the rotor in accordance with Section 2.1 of this report.
d. The rotor will then undergo a low temperature start-up test in accordance with Section 2.10 of this report.
e. The rotor will then be exposed to high temperatures in the limited life temperature testing as stated in Section 2.12 of this report.

2.1 Examination of Product

2.1.1 Each unit shall conform to the outline and interface mounting dimensions of PDT drawings 4021 & 4021-1. Record conformance and revision letter of drawing on test data sheet.

2.1.2 Before assembling and disassembling the pump, visually check the rotor coatings (if applicable), note any defects, and take photographs of all angles of the rotor, making sure they are in the same orientation before and after testing. Number photographs, note the number on the data sheet and attach photos to test data sheets.

2.2 Electrical Bonding Testing

2.2.1 Electrical bonding shall be performed on the DC canned motor and an AC motor with a coated rotor to ensure both motor types are safe.

2.2.2 Measure the bonding resistance between the pump's connector shell and the internal threads of the unit's inlet or outlet port. Record the resistance on Figure 4.

2.2.3 Criteria: The bonding resistance shall be a maximum of 2.5 milliohm

2.3 Dielectric Strength

2.3.1 Dielectric Strength test shall be conducted on the DC stator according to the following procedure. If available, vendor test data may be used to fulfill this requirement.

2.3.2 Test: 500 volts AC rms shall be applied between the grouped motor leads and the pump mounting surface or between grouped motor leads and the stator stack for 60 seconds minimum in accordance with MIL- STD-202, Method 301. Subsequent application following a passed test shall be at 80% voltage for 5 seconds.

2.3.3 Criteria: There shall be no flash-over, spark-over, or dielectric break down, and the leakage current shall not exceed 1milliampere. Record leakage current and conformance to sparks and flash-over on Figure 4.

2.3.4 For the AC stator, the Dielectric Strength test shall be conducted according to the following procedure. If available, vendor test data may be used to fulfill this requirement.

2.3.5 Test: 1250 volts AC rms shall be applied between the grouped motor leads and the pump mounting surface or between grouped motor leads and the stator stack for 60 seconds minimum in accordance with MIL- STD-202, Method 301. Subsequent application following a passed test shall be at 80% voltage for 5 seconds.

2.3.6 Criteria: There shall be no flash-over, spark-over, or dielectric break down, and the leakage current shall not exceed 1milliampere. Record leakage current and conformance to sparks and flash-over on Figure 4.

2.4 Insulation Resistance

2.4.1 Insulation Resistance Test shall be conducted on the DC canned motor-pump combo in accordance with the following procedure.

2.4.2 Test: 30 volts ±10% DC shall be applied between the grouped motor leads and the pump housing for 120 seconds minimum in accordance with MIL-STD- 202, Method 302, condition B.

2.4.3 Criteria: Insulation resistance shall not be less than 1 megohm. Record results on Figure 4.

2.4.4 Insulation Resistance Test shall be conducted on the AC canned motor-pump combo in accordance with the following procedure.

2.4.5 Test: 30 volts ±10% DC shall be applied between the grouped motor leads and the pump housing for 120 seconds minimum in accordance with MIL-STD- 202, Method 302, condition B.

2.4.6 Criteria: Insulation resistance shall not be less than 1 megohm. Record results on Figure 4.

2.5 Performance Check DC Coated Rotors

2.5.1 Test Set-Up: Install the UUT (3) in the test stand configured to Figure 1. Purge air from the test set-up and fill test stand using the GN_2 (1) and ethylene glycol water mixture reservoir (2).

2.5.2 Maintain an inlet pressure of 13 ± 2 psig as indicated on P1 and fluid temperature of +60°F to +95°F ± 3°F as indicated on T1.

2.5.3 Adjust V3 to the established rated parameters of flow rate and differential pressure based on baseline testing of the DC canned rotor.

2.5.4 Maintain rated conditions for five (5) minutes. For DC motor, record inlet pressure (P1), outlet pressure (P2), differential pressure, flow rate, fluid temperature, input voltage, current, and total power on Figure 5.

2.6 Performance Check AC Coated Rotors

2.6.1 Test Set-Up: Install the UUT (3) in the test stand configured to Figure 1. Purge air from the test set-up and fill test stand using the GN_2 (1) and ethylene glycol water mixture reservoir (2).

2.6.2 Maintain an inlet pressure of 13 ± 2 psig as indicated on P1 and fluid temperature of +65°F ± 3°F as indicated on T1.

2.6.3 Adjust V3 to the established rated parameters of flow rate and differential pressure based on baseline testing of the DC canned rotor.

2.6.4 Maintain rated conditions for five (5) minutes. For AC motor, record inlet pressure (P1), outlet pressure (P2), differential pressure, flow rate, fluid temperature, input voltage, current per phase, power per phase, total power, and frequency on Figure 4.

2.7 Performance Mapping

2.7.1 This test will only be run for the baseline DC canned motor.

2.7.2 Test Set-Up: Install the UUT (3) in the test stand configured to Figure 1. Purge air from the test set-up and fill test stand using the GN_2 (1) and ethylene glycol water mixture reservoir (2).

2.7.3 Maintain an inlet pressure of 13 ± 2 psig as indicated on P1 and fluid temperature of +65°F ± 3°F as indicated on T1.

2.7.4 Adjust V3 to provide the already establish rated parameters of flow rate and differential pressure based on baseline testing of the DC canned rotor.

2.7.5 Maintain rated conditions for five (5) minutes. Record inlet pressure (P1), outlet pressure (P2), differential pressure, flow rate, fluid temperature, input voltage, current, and total power on.

2.7.6 Adjust the motor speed to a new setting that will provide a variety of different efficiencies and flow rate. At this new setting, repeat step 2.7.5.

2.7.7 Continue repeating steps 2.7.5 and 2.7.6 until a sufficient number of performance points have been taken to create a performance curve of motor.

2.8 Performance Spot Test

2.8.1 Test Set-Up: Install the UUT (3) in the test stand configured to Figure 1. Purge air from the test set-up and fill test stand using the GN_2 (1) and ethylene glycol water mixture reservoir (2).

2.8.2 Maintain an inlet pressure of 13 ± 2 psig as indicated on P1 and fluid temperature of +65°F ± 3°F as indicated on T1.

2.8.3 Adjust V3 to the already establish rated parameters of flow rate and differential pressure based on baseline testing of the DC canned rotor.

2.8.4 Maintain rated conditions for five (5) minutes then for AC motor, record inlet pressure (P1), outlet pressure (P2), differential pressure, flow rate, fluid temperature, input voltage, current per phase, power per phase, total power, and frequency. For DC motor, record inlet pressure (P1), outlet pressure (P2), differential pressure, flow rate, fluid temperature, input voltage, current, and total power.

2.8.5 Adjust the flow rate, for AC, or motor speed, for DC, to a new setting that will provide a variety of different efficiencies, speeds, and flow rate. At this new setting repeat step 2.8.4.

2.8.6 Continue repeating steps 2.8.4 and 2.8.5 until a sufficient number of performance points have been taken to ensure that the performance of the motor is comparable to the baseline performance. If any data points appear to stray from the baseline performance curve, create a new performance curve with the current motor. The procedure is outlined in Section 2.7.

2.9 Cleanliness Testing

2.9.1 Install the UUT into the test stand configured to Figure 1.

2.9.2 Using the nitrogen source (1) and the UUT pump (3), completely fill the system with fluid and remove any entrained air.

2.9.3 Close valve (V5) and open valve (V2). Obtain the rated performance parameters of (TBD) gpm +10%/-0% and 70 psid. There is no specific fluid temperature required for this test. Hold the rated parameters for two minutes allowing any particulates to be trapped in the 4 micron filter (8).

2.9.4 Open valve (V5) and close valve (V2) for 5 seconds allowing any particulates that are in the bypass fluid loop to be drawn into the main fluid loop. Open valve (V2) and close valve (5) for 30 seconds.

2.9.5 Repeat step 2.8.4 three (3), times to ensure that all particulates in the entire system have been drawn into the 4 micron filter.

2.9.6 2 Minute Cleanliness Test: Run the pump for an additional two minutes with the fluid bypassing the 4 micron filter. At the end of two (2) minutes drain a volume of fluid from the sampling valve, V6 on Figure 1, equal to at least three times the volume of the sampling valve. Fill an empty clean sample bottle with 150 ml ± 5ml of fluid and perform a particle count in accordance with the particle counter manufacturer's instructions. Enter absolute particle counts on Figure 3. Attach print out from particle counter to Test Data Sheet.

2.9.7 1 Hour Cleanliness Test: Let the system run for 1 hour +5/-0 minutes. At the end of 1 hour drain a volume of fluid from the sampling valve equal to at least three times the volume of the sampling valve. Fill an empty clean sample bottle with 150 ml ± 5ml of fluid and perform a particle count in accordance with the particle counter manufacturer's instructions. Enter absolute particle counts on Figure 3. Attach print out from particle counter to Test Data Sheet.

2.10 Low Temperature Start-Up

2.10.1 Install the unit under test (UUT) in the test stand in accordance with Figure 1.

2.10.2 Purge air from the test set-up and fill test stand using the GN2 (1) and ethylene glycol-water mixture reservoir (2). Condition ethylene glycol-water mixture to 75°F±10°F.

2.10.3 Energize the pump and adjust V3 to produce a flow rate and differential pressure as determined from DC canned rotor baseline testing. Record flow rate, fluid temperature, inlet pressure, outlet pressure, and differential pressure on Figure 6.

DO NOT READJUST THE RESTRICTOR VALVE FOR THE REMAINDER OF THE TEST

2.10.4 Turn on the heat exchanger fan (6) and condition the chamber to -40°C. When fluid temperature as read on T1 reaches -40°C adjust inlet pressure to 0 psig±1psig and turn off pump and heat exchanger fan.

2.10.5 Let the UUT and test stand cold soak for a sufficient amount of time.

2.10.6 Ensure that the oscilloscope is adjusted to capture a current draw trace expected to last between 50 milliseconds and 5 seconds and have an amplitude of no more than (TBD) amps.

2.10.7 Energize the UUT. Monitor the oscilloscope, power analyzer, pressure gauges and flow meter to ensure a normal start-up.

2.10.8 Allow flow rate and differential pressure to stabilize.

2.10.9 Record required data on Figure 6.

2.10.10 Inspect UUT for signs of leakage and surface wetting.

2.10.11 Criteria: The current draw shall not exceed (TBD) amps within 150 milliseconds of start-up. There shall be no signs of leakage or surface wetting during or after the test. The start-up time shall not exceed 5 seconds in duration. Print out the oscilloscope trace and attach to test data sheets.

2.11 Limited Life Testing

2.11.1 Install the unit under test (UUT) in the test stand in accordance with Figure 1. Purge air from the test set-up and fill test stand using the GN2 (1) and ethylene glycol-water mixture reservoir (2). Adjust inlet pressure to 4 psig ±1 psig

2.11.2 Establish rated parameters of flow rate and differential pressure based on baseline testing of the DC canned rotor. Turn on heat exchanger fan (15).

2.11.3 Maintain rated conditions for five (5) minutes. For AC motor, record inlet pressure (P1), outlet pressure (P2), differential pressure, flow rate, fluid temperature, input voltage, current per phase, power per phase, total power, and frequency on Figure 6. For DC motor, record inlet pressure (P1), outlet pressure (P2), differential pressure, flow rate, fluid temperature, input voltage, current, and total power on Figure 6.

2.11.4 De-energize pump

2.11.5 Configure the pump timer/controller to energize the pump for 1 hour followed by a 5 second period in the de-energized state. This will constitute one cycle. The pump will be cycled 100 times for a total duration of 100 hours of energized time and 8.33 minutes of de-energized time. Connect a cycle counter (13) to the pump timer/controller.

2.11.6 Energize the pump and monitor test stand to ensure that the controllers (8) and (9) are operating correctly. It is allowed to make small adjustments to the system over the duration of this test in order to maintain rated parameters.

2.11.7 After 19 cycles of the pump being energized and every 20 cycles thereafter:

Open the filter bypass valve, V5 on Figure 1, and close the filter valve, V2 on Figure 1, to allow the fluid to collect particulates for 1 cycle (60 minutes).

At the end of that hour, collect a sample of the working fluid and run through the particle counter to measure the fluid cleanliness. Record on Figure 6.

For the AC motor: measure and record voltage, current per phase, power per phase, frequency, flow rate, inlet pressure, outlet pressure, and differential pressure on Figure 6.

For the DC motor: record, flow rate, fluid temperature, input voltage, current, total power, inlet pressure, outlet pressure, and differential pressure on Figure 6.

Close the filter bypass valve, V5 on Figure 3, and open the filter valve, V2 on Figure 1, and continue to run the limited lifetime test. Repeat this process every 20 cycles after the initial 19 cycles.

2.11.8 At the conclusion of 100 cycles, de-energize the pump.

2.12 Limited Life Temperature Testing

2.12.1 Install the unit under test (UUT) in the test stand in accordance with Figure 3. Purge air from the test set-up and fill test stand using the GN2 (1) and ethylene glycol-water mixture reservoir (2). Adjust inlet pressure to 4 psig ±1 psig

2.12.2 Establish rated flow rate and differential pressure as determined from DC canned rotor baseline testing. Turn on heat exchanger fan (15) to achieve a temperature of 100°F.

2.12.3 Maintain rated conditions for five (5) minutes then record inlet pressure (P1), outlet pressure (P2), differential pressure, flow rate, fluid temperature, input voltage, current per phase (AC motor only), power per phase (AC motor only), total power, and frequency (AC motor only) on Figure 6.

2.12.4 De-energize pump

2.12.5 Configure the pump timer/controller to energize the pump for 1 hour followed by a 5 second period in the de-energized state. This will constitute one cycle. The pump will be cycled 16 times for a total duration of 16 hours of energized time and 1.33 minutes of de-energized time. Connect a cycle counter (13) to the pump timer/controller.

2.12.6 Energize the pump and monitor test stand to ensure that the controllers (8) and (9) are operating correctly. It is allowed to make small adjustments to the system over the duration of this test in order to maintain rated parameters.

2.12.7 After 3 cycles of the pump being energized and every 4 cycles thereafter:

For the AC motor: measure and record voltage, current per phase, power per phase, frequency, flow rate, inlet pressure, outlet pressure, and differential pressure on Figure 6.

For the DC motor: record, flow rate, fluid temperature, input voltage, current, total power, inlet pressure, outlet pressure, and differential pressure on Figure 6.

2.12.8 After 16 cycles of the pump being energized. If test cycle needs to be stopped, only continue cycle count once working temperature has been achieved:

Open the filter bypass valve, V5 on Figure 3, and close the filter valve, V2 on Figure 3, to allow the fluid to collect particulates for 1 cycle (60 minutes)

At the end of that hour, collect a sample of the working fluid and run through the particle counter to measure fluid cleanliness. Record on Figure 6.

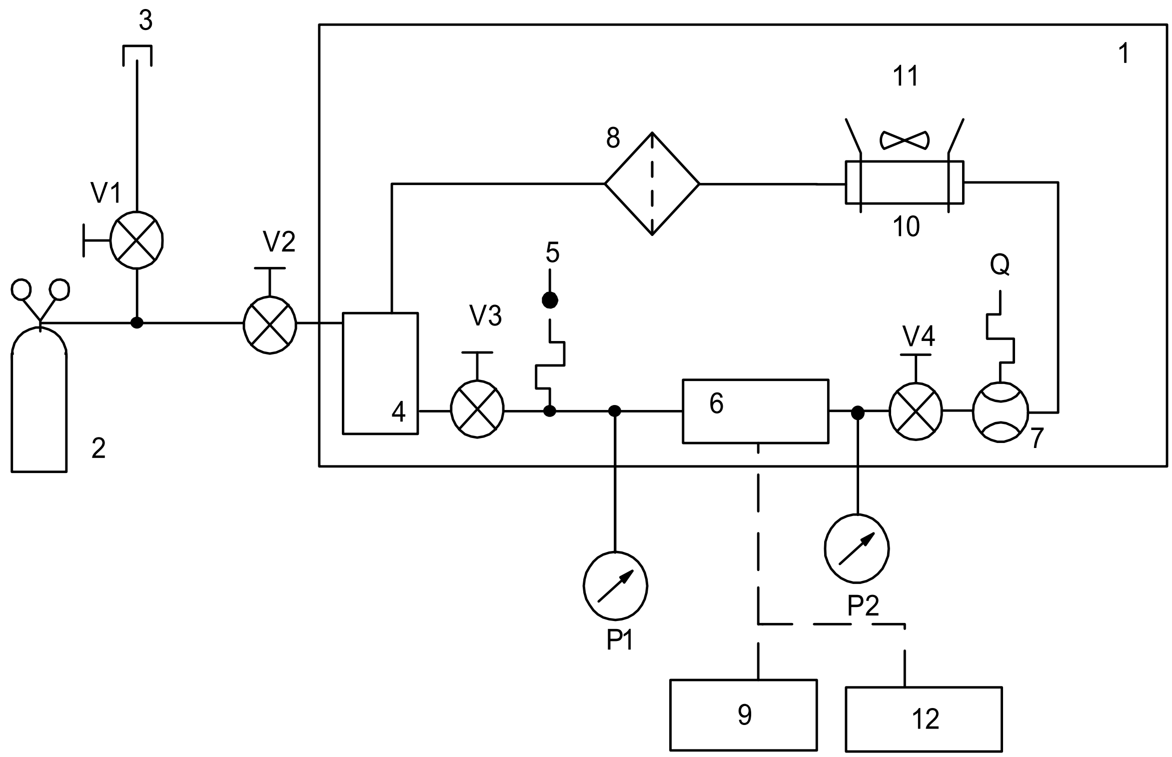
Close the filter bypass valve, V5 on Figure 3, and open the filter valve, V2 on Figure 3, and continue to run the limited lifetime test.

2.12.9 After 16 cycles at 100°F, turn on the heat exchanger to increase the chamber temperature to 130°F. Run the pump again for 16, 1 hour cycles following steps 2.12.5 through 2.12.8.

2.12.10 At the conclusion of 32 cycles, de-energize the pump.

2.12.11 Criteria: The pumping unit and accumulator shall continuously operate at rated parameters for the duration of the test.

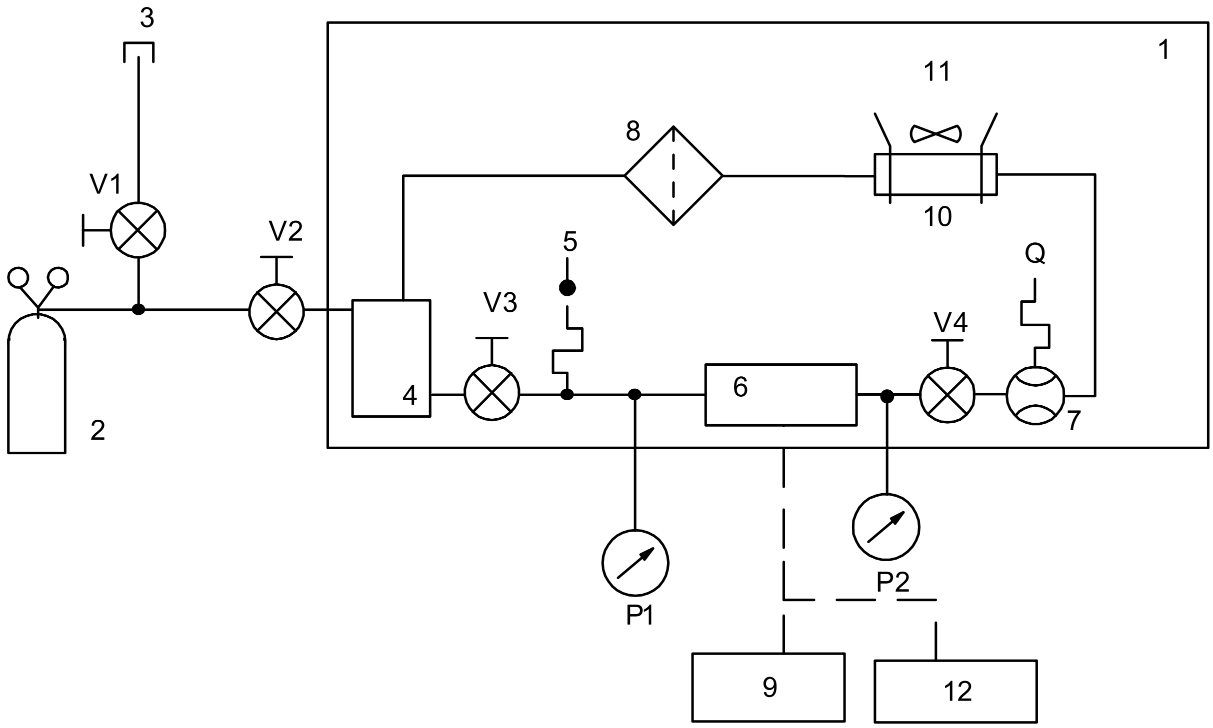
Figure 1: General Test Schematic



1. Thermal Chamber
2. Gas Source, GN2
3. Vent
4. Reservoir, EGW
5. Sensor, Temperature
6. UUT
7. Flow Meter
8. Filter, 4 Micron
9. Power Supply/Analyzer
10. Heat Exchanger, Air to Liquid
11. Fan
12. Oscilloscope

P1 Pressure Gauge, 0-30
P2 Pressure Gauge, 0-200
V1 Valve, Vent, Ball Type
V2 Valve, Isolation, Ball Type
V3 Valve, Isolation, Ball Type
V4 Valve, Restrictor, Ball Type

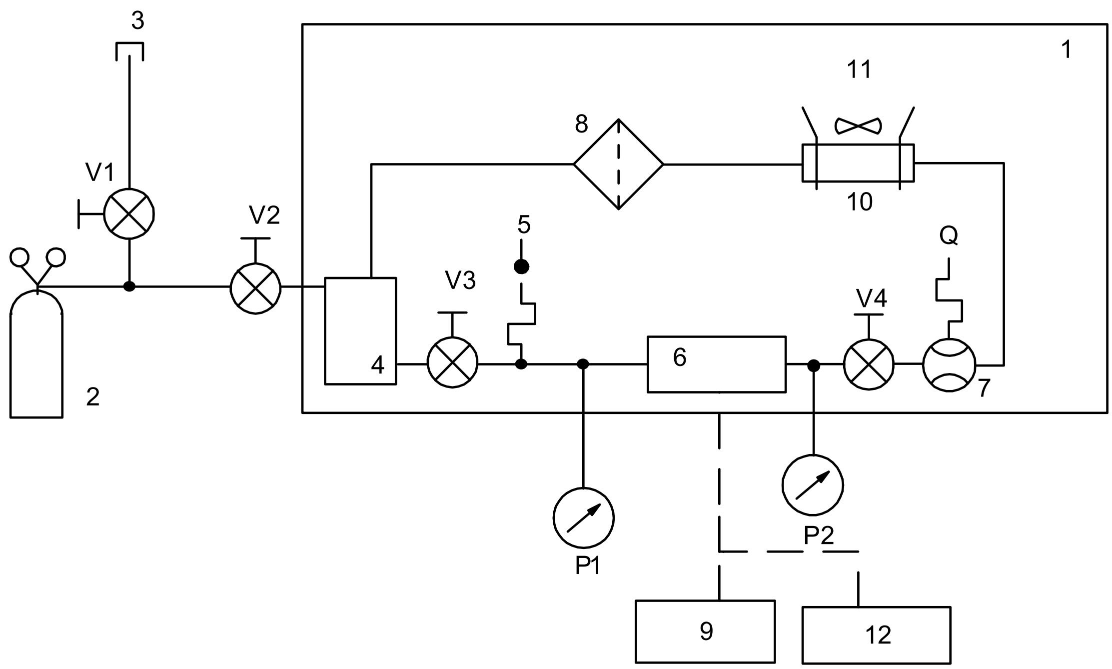
Figure 2: Low Temperature Start-up Test Schematic



1. Thermal Chamber
2. Gas Source, GN2
3. Vent
4. Reservoir, EGW
5. Sensor, Temperature
6. UUT
7. Flow Meter
8. Filter, 4 Micron
9. Power Supply/Analyzer
10. Heat Exchanger, Air to Liquid
11. Fan
12. Oscilloscope

P1 Pressure Gauge, 0-30
P2 Pressure Gauge, 0-200
V1 Valve, Vent, Ball Type
V2 Valve, Isolation, Ball Type
V3 Valve, Isolation, Ball Type
V4 Valve, Restrictor, Ball Type

Figure 3: Limited Life Test Schematic



1. Thermal Chamber
2. Gas Source, GN2
3. Vent
4. Reservoir, EGW
5. Sensor, Temperature
6. UUT
7. Flow Meter
8. Filter, 4 Micron
9. Power Supply/Analyzer
10. Heat Exchanger, Air to Liquid
11. Fan
12. Oscilloscope

P1 Pressure Gauge, 0-30
P2 Pressure Gauge, 0-200
V1 Valve, Vent, Ball Type
V2 Valve, Isolation, Ball Type
V3 Valve, Isolation, Ball Type
V4 Valve, Restrictor, Ball Type

Figure 4: Baseline Testing

Sheet 1 of 3

DC Rotor Coating Pre-Test Inspection				
NOMENCLATURE	SCS Parylene C	SCS Parylene HT	GVD Excilis	Jaro Corp. Humiseal
Conforms to drawing ____ and coating conforms to the specifications on the purchase order sent to the coating manufacturer	_______✓	_______✓	_______✓	_______✓
Damage to Coating (Take a photograph, number the photograph, and attach to the back of the data sheet for comparison)	_____ Number _____ Number _____ Number	_____ Number _____ Number _____ Number	_____ Number _____ Number _____ Number	_____ Number _____ Number _____ Number

AC Rotor Coating Pre-Test Inspection				
NOMENCLATURE	SCS Parylene C	SCS Paryleyne HT	GVD Excilis	Jaro Corp. Humiseal
Conforms to drawing ____ and coating conforms to the specifications on the purchase order sent to the coating manufacturer	_______✓	_______✓	_______✓	_______✓
Damage to Coating (Take a photograph, number the photograph, and attach to the back of the data sheet for comparison)	_____ Number _____ Number _____ Number	_____ Number _____ Number _____ Number	_____ Number _____ Number _____ Number	_____ Number _____ Number _____ Number

DC Canned Motor		
NOMENCLATURE	VALUES	Canned Rotor
Dielectric Strength	Leakage Current <= 1 milliamp	____ (mA)
	No Flashover/sparks	_______✓
Insulation Resistance	Insulation Resistance >= 1MΩ	_____ (MΩ)
Electrical Bonding	Bonding Resistance <= 2.5mΩ	_____(mΩ)
Low Temperature Start-Up	Maximum amps drawn in first 150 milliseconds of start-up < 3.5amps	_____ (A)
	Oscilliscope trace attached	_______✓
	Start-up Duration < 5sec	____ (sec)
	No evidence of leakage of surface wetting	_______✓
Cleanliness- First Sample: 2 minutes of operation	5 to 15 micron	_______Particles
	15 to 25 micron	_______Particles
	25 to 50 micron	_______Particles
	50 to 100 micron	_______Particles
	over 100 micron	_______Particles
Attached Particle counter Print-out	Print-out Attached	_______✓
Cleanliness- Second Sample: 1 hour of operation	5 to 15 micron	_______Particles
	15 to 25 micron	_______Particles
	25 to 50 micron	_______Particles
	50 to 100 micron	_______Particles
	over 100 micron	_______Particles
Attached Particle counter Print-out	Print-out Attached	_______✓

Sheet 3 of 3

NOMENCLATURE	VALUES	Canned Rotor
Rated Performance Test	Flow Rate: (TBD) +.15/-0 gpm	______ gpm
	Temperature T1: 80°F ±3 °F	______°F
	Inlet Pressure P1: 13 ±2 psig	______psig
	Outlet Pressure P2: Record	______psig
	P2 – P1:70 psid minimum	______psid
	Input Voltage	______VDC
Current	Current Draw	______amps
Power	Total Power: TBD watts max	______Watts
AC Motor		
Dielectric Strength	Leakage Current <= 1 milliamp	____ (mA)
	No Flashover/sparks	________✓
Insulation Resistance	Insulation Resistance >= 1MΩ	_____ (MΩ)

Figure 5: Coated Rotor Verification Testing

Sheet 1 of 3

DC Motor

NOMENCLATURE	VALUES	Canned Rotor	SCS Parylene C	SCS Parylene HT	GVD Excilis	Jaro Corp. Humiseal
Rated Performance Test	Flow Rate: (TBD) +.15/-0 gpm	_______ gpm	_______ gpm	_______ gpm	_______ gpm	_______ gpm
	Temperature T1: 65°F ±3 °F	_______°F	_______°F	_______°F	_______°F	_______°F
	Inlet Pressure P1: 13 ±2 psig	_______psig	_______psig	_______psig	_______psig	_______psig
	Outlet Pressure P2: Record	_______psig	_______psig	_______psig	_______psig	_______psig
	P2 – P1: 70 psid minimum	_______psid	_______psid	_______psid	_______psid	_______psid
	Input Voltage	_______VDC	_______VDC	_______VDC	_______VDC	_______VDC
Current	Current Draw	_______amps	_______amps	_______amps	_______amps	_______amps
Power	Total Power: TBD watts max	_______Watts	_______Watts	_______Watts	_______Watts	_______Watts

AC Motor

NOMENCLATURE	VALUES	SCS Parylene C	SCS Parylene HT	GVD Excilis	Jaro Corp. Humiseal
Rated Performance Test	Flow Rate: (TBD) +.15/-0 gpm	_______ gpm	_______ gpm	_______ gpm	_______ gpm
	Temperature T1: 65°F ±3 °F	_______°F	_______°F	_______°F	_______°F
	Inlet Pressure P1: 13 ±2 psig	_______psig	_______psig	_______psig	_______psig
	Outlet Pressure P2: Record	_______psig	_______psig	_______psig	_______psig
	P2 – P1: 70 psid minimum	_______psid	_______psid	_______psid	_______psid
	Input Voltage: 115/200 VAC, 3Æ	_______VAC	_______VAC	_______VAC	_______VAC
	Frequency: 400 Hz	_______Hz	_______Hz	_______Hz	_______Hz
Current Per Phase	Phase A: Record	_______amps	_______amps	_______amps	_______amps
	Phase B: Record	_______amps	_______amps	_______amps	_______amps
	Phase C: Record	_______amps	_______amps	_______amps	_______amps
Power Per Phase	Ø A: Record	_______Watts	_______Watts	_______Watts	_______Watts
	Ø B: Record	_______Watts	_______Watts	_______Watts	_______Watts
	Ø C: Record	_______Watts	_______Watts	_______Watts	_______Watts
	Total Power: TBD watts max	_______Watts	_______Watts	_______Watts	_______Watts

DC Rotor Coating Post Performance Test Inspection				
NOMENCLATURE	SCS Parylene C	SCS Parylene HT	GVD Excilis	Jaro Corp. Humiseal
Conforms to drawing ____ and coating conforms to the specifications on the purchase order sent to the coating manufacturer	_______✓	_______✓	_______✓	_______✓
Damage to Coating (Take a photograph, number the photograph, and attach to the back of the data sheet for comparison)	_____ Number _____ Number _____ Number	_____ Number _____ Number _____ Number	_____ Number _____ Number _____ Number	_____ Number _____ Number _____ Number

AC Rotor Coating Post Performance Test Inspection				
NOMENCLATURE	SCS Parylene C	SCS Paryleyne HT	GVD Excilis	Jaro Corp. Humiseal
Conforms to drawing ____ and coating conforms to the specifications on the purchase order sent to the coating manufacturer	_______✓	_______✓	_______✓	_______✓
Damage to Coating (Take a photograph, number the photograph, and attach to the back of the data sheet for comparison)	_____ Number _____ Number _____ Number	_____ Number _____ Number _____ Number	_____ Number _____ Number _____ Number	_____ Number _____ Number _____ Number

Figure 6: Coated Rotor Limited Life Testing

Sheet 1 of 6

Coating ________________________________

NOMENCLATURE	VALUES	20 Cycles	40 Cycles	60 Cycles	80 Cycles	100 Cycles
Limited Lifetime Testing DC Motor	Flow Rate: (TBD) +.15/-0 gpm	______ gpm	______ gpm	______ gpm	______ gpm	______ gpm
	Temperature T1: 65°F ±3 °F	______°F	______°F	______°F	______°F	______°F
	Inlet Pressure P1: 13 ±2 psig	______psig	______psig	______psig	______psig	______psig
	Outlet Pressure P2: Record	______psig	______psig	______psig	______psig	______psig
	P2 – P1: 70 psid minimum	______psid	______psid	______psid	______psid	______psid
	Input Voltage	______VDC	______VDC	______VDC	______VDC	______VDC
Current	Current Draw	______amps	______amps	______amps	______amps	______amps
Power	Total Power: TBD watts max	______Watts	______Watts	______Watts	______Watts	______Watts
Cleanliness	5 to 15 micron	_______Particles	_______Particles	_______Particles	_______Particles	_______Particles
	15 to 25 micron	_______Particles	_______Particles	_______Particles	_______Particles	_______Particles
	25 to 50 micron	_______Particles	_______Particles	_______Particles	_______Particles	_______Particles
	50 to 100 micron	_______Particles	_______Particles	_______Particles	_______Particles	_______Particles
	over 100 micron	_______Particles	_______Particles	_______Particles	_______Particles	_______Particles
Attached Particle counter Print-out	Print-out Attached	_______✓	_______✓	_______✓	_______✓	_______✓

Coating ________________________________

NOMENCLATURE	VALUES	20 Cycles	40 Cycles	60 Cycles	80 Cycles	100 Cycles
Limited Lifetime Testing AC Motor	Flow Rate: (TBD) +.15/-0 gpm	______ gpm	______ gpm	______ gpm	______ gpm	______ gpm
	Temperature T1: 65°F ±3 °F	______°F	______°F	______°F	______°F	______°F
	Inlet Pressure P1: 13 ±2 psig	______psig	______psig	______psig	______psig	______psig
	Outlet Pressure P2: Record	______psig	______psig	______psig	______psig	______psig
	P2 – P1: 70 psid minimum	______psid	______psid	______psid	______psid	______psid
	Input Voltage: 115/200 VAC, 3Æ	______VAC	______VAC	______VAC	______VAC	______VAC
	Frequency: 400 Hz	______Hz	______Hz	______Hz	______Hz	______Hz
Current Per Phase	Phase A: Record	______amps	______amps	______amps	______amps	______amps
	Phase B: Record	______amps	______amps	______amps	______amps	______amps
	Phase C: Record	______amps	______amps	______amps	______amps	______amps
Power Per Phase	Ø A: Record	______Watts	______Watts	______Watts	______Watts	______Watts
	Ø B: Record	______Watts	______Watts	______Watts	______Watts	______Watts
	Ø C: Record	______Watts	______Watts	______Watts	______Watts	______Watts
	Total Power: TBD watts max	______Watts	______Watts	______Watts	______Watts	______Watts
Cleanliness	5 to 15 micron	_______Particles	_______Particles	_______Particles	_______Particles	_______Particles
	15 to 25 micron	_______Particles	_______Particles	_______Particles	_______Particles	_______Particles
	25 to 50 micron	_______Particles	_______Particles	_______Particles	_______Particles	_______Particles
	50 to 100 micron	_______Particles	_______Particles	_______Particles	_______Particles	_______Particles
	over 100 micron	_______Particles	_______Particles	_______Particles	_______Particles	_______Particles
Attached Particle counter Print-out	Print-out Attached	_______✓	_______✓	_______✓	_______✓	_______✓

Coated DC Rotor		
NOMENCLATURE	VALUES	Coating _______________
Low Temperature Start-Up	Maximum amps drawn in first 150 milliseconds of start-up < 3.5amps Oscilliscope trace attached Start-up Duration < 5sec No evidence of leakage	_____ (A) _______✓ ____ (sec) _______✓
Coated AC Rotor		
NOMENCLATURE	VALUES	Coating _______________
Low Temperature Start-Up	Maximum amps drawn in first 150 milliseconds of start-up < 3.5amps Oscilliscope trace attached Start-up Duration < 5sec No evidence of leakage	_____ (A) _______✓ ____ (sec) _______✓

		Coating ______________________________			
NOMENCLATURE	VALUES	4 Cycles	8 Cycles	12 Cycles	16 Cycles
High Temperature Test, DC Motor	Flow Rate: (TBD) +.15/-0 gpm	_______ gpm	_______ gpm	_______ gpm	_______ gpm
	Temperature T1: 100°F ±3 °F	_______°F	_______°F	_______°F	_______°F
	Inlet Pressure P1: 13 ±2 psig	_______psig	_______psig	_______psig	_______psig
	Outlet Pressure P2: Record	_______psig	_______psig	_______psig	_______psig
	P2 – P1: 70 psid minimum	_______psid	_______psid	_______psid	_______psid
	Input Voltage	_______VDC	_______VDC	_______VDC	_______VDC
Current	Current Draw	_______amps	_______amps	_______amps	_______amps
Power	Total Power: TBD watts max	_______Watts	_______Watts	_______Watts	_______Watts
NOMENCLATURE	VALUES	20 Cycles	24 Cycles	28 Cycles	32 Cycles
High Temperature Test, DC Motor	Flow Rate: (TBD) +.15/-0 gpm	_______ gpm	_______ gpm	_______ gpm	_______ gpm
	Temperature T1 130°F ±3 °F	_______°F	_______°F	_______°F	_______°F
	Inlet Pressure P1: 13 ±2 psig	_______psig	_______psig	_______psig	_______psig
	Outlet Pressure P2: Record	_______psig	_______psig	_______psig	_______psig
	P2 – P1: 70 psid minimum	_______psid	_______psid	_______psid	_______psid
	Input Voltage	_______VDC	_______VDC	_______VDC	_______VDC
Current	Current Draw	_______amps	_______amps	_______amps	_______amps
Power	Total Power: TBD watts max	_______Watts	_______Watts	_______Watts	_______Watts

		Coating ______________________			
NOMENCLATURE	VALUES	4 Cycles	8 Cycles	12 Cycles	16 Cycles
High Temperature Test, AC Motor	Flow Rate: (TBD) +.15/-0 gpm	______ gpm	______ gpm	______ gpm	______ gpm
	Temperature T1: 100°F ±3 °F	______°F	______°F	______°F	______°F
	Inlet Pressure P1: 13 ±2 psig	______psig	______psig	______psig	______psig
	Outlet Pressure P2: Record	______psig	______psig	______psig	______psig
	P2 – P1: 70 psid minimum	______psid	______psid	______psid	______psid
	Input Voltage: 115/200 VAC, 3Æ	______VAC	______VAC	______VAC	______VAC
	Frequency: 400 Hz	______Hz	______Hz	______Hz	______Hz
Current Per Phase	Phase A: Record	______amps	______amps	______amps	______amps
	Phase B: Record	______amps	______amps	______amps	______amps
	Phase C: Record	______amps	______amps	______amps	______amps
Power Per Phase	Ø A: Record	______Watts	______Watts	______Watts	______Watts
	Ø B: Record	______Watts	______Watts	______Watts	______Watts
	Ø C: Record	______Watts	______Watts	______Watts	______Watts
	Total Power: TBD watts max	______Watts	______Watts	______Watts	______Watts
NOMENCLATURE	VALUES	20 Cycles	24 Cycles	28 Cycles	32 Cycles
High Temperature Test, AC Motor	Flow Rate: (TBD) +.15/-0 gpm	______ gpm	______ gpm	______ gpm	______ gpm
	Temperature T1 130°F ±3 °F	______°F	______°F	______°F	______°F
	Inlet Pressure P1: 13 ±2 psig	______psig	______psig	______psig	______psig
	Outlet Pressure P2: Record	______psig	______psig	______psig	______psig
	P2 – P1: 70 psid minimum	______psid	______psid	______psid	______psid
	Input Voltage: 115/200 VAC, 3Æ	______VAC	______VAC	______VAC	______VAC
	Frequency: 400 Hz	______Hz	______Hz	______Hz	______Hz
Current Per Phase	Phase A: Record	______amps	______amps	______amps	______amps
	Phase B: Record	______amps	______amps	______amps	______amps
	Phase C: Record	______amps	______amps	______amps	______amps
Power Per Phase	Ø A: Record	______Watts	______Watts	______Watts	______Watts
	Ø B: Record	______Watts	______Watts	______Watts	______Watts
	Ø C: Record	______Watts	______Watts	______Watts	______Watts
	Total Power: TBD watts max	______Watts	______Watts	______Watts	______Watts

Rotor Coating Inspection ______		
NOMENCLATURE	AC Rotor Coating	DC Rotor Coating
Damage to Coating (Take a photograph, number the photograph, and attach to the back of the data sheet for comparison)	______ Number ______ Number ______ Number	______ Number ______ Number ______ Number
Rotor Coating Inspection ______		
NOMENCLATURE	AC Rotor Coating	DC Rotor Coating
Damage to Coating (Take a photograph, number the photograph, and attach to the back of the data sheet for comparison)	______ Number ______ Number ______ Number	______ Number ______ Number ______ Number

Appendix H: DC Baseline Performance Test Data

I4021 Test Data Sheet
Model 4016: 28 VDC motor, plastic gerotor pump
Fluid: 60% (by Vol.) EGW 6200 RPM
Date: 8/5/2015
Tech: M. Hardisty ~60 minutes of cumulative run time
Baseline Rotor

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	51	41	788	2.6965	31.4	6200	8.7	28	243.6	32.8	34.1	40.6	0.1975
10	60	50	770	2.6353	31.4	6200	9.6	28	268.8	32.8	34	40.3	0.2134
10	65	55	761	2.6047	31.3	6200	10.1	28	282.8	32.7	34	40.1	0.2205
10	70	60	753	2.5775	31.4	6200	10.5	28	294	32.7	34	40	0.2289
10	75	65	745	2.5503	31.3	6200	10.9	28	305.2	32.7	33.9	40	0.2364
10	80	70	736	2.5197	31.3	6200	11.5	28	322	32.8	33.9	39.9	0.2384
10	85	75	728	2.4925	31.3	6200	12	28	336	32.7	33.9	39.8	0.2422
10	90	80	720	2.4653	31.4	6200	12.6	28	352.8	32.8	33.9	39.8	0.2433
10	95	85	712	2.4381	31.4	6200	13.2	28	369.6	32.8	33.9	39.7	0.244
10	100	90	704	2.4109	31.4	6200	13.8	28	386.4	32.8	34	39.8	0.2444
10	110	100	690	2.3633	31.4	6200	15.2	28	425.6	32.9	34.1	39.9	0.2417
10	120	110	675	2.3123	31.3	6200	16.7	28	467.6	33	34.3	40.1	0.2368
10	130	120	660	2.2613	31.4	6200	18.4	28	515.2	33.1	34.5	40.4	0.2292
10	140	130	646	2.2137	31.4	6200	20.2	28	565.6	33.2	34.7	40.8	0.2215
10	150	140	632	2.1661	31.5	6200	22.3	28	624.4	33.5	35	41.4	0.2114

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	52	42	803	2.7475	31.3	6300	9.1	28	254.8	32.7	33.9	40	0.1971
10	60	50	786	2.6897	31.3	6300	9.8	28	274.4	32.7	33.9	39.8	0.2133
10	65	55	777	2.6591	31.3	6300	10.3	28	288.4	32.7	33.9	39.7	0.2207
10	70	60	768	2.6285	31.3	6300	10.8	28	302.4	32.7	33.9	39.8	0.227
10	75	65	760	2.6013	31.3	6300	11.3	28	316.4	32.7	33.9	39.9	0.2326
10	80	70	753	2.5775	31.3	6300	11.8	28	330.4	32.7	33.9	39.8	0.2377
10	85	75	745	2.5503	31.3	6300	12.3	28	344.4	32.7	33.9	39.8	0.2417
10	90	80	736	2.5197	31.3	6300	13	28	364	32.7	33.9	39.7	0.241
10	95	85	727	2.4891	31.3	6300	13.7	28	383.6	32.8	34	39.8	0.2401
10	100	90	719	2.4619	31.3	6300	14.5	28	406	32.8	34	39.9	0.2375
10	110	100	705	2.4143	31.4	6300	15.8	28	442.4	32.9	34.2	40.1	0.2375
10	120	110	689	2.3599	31.3	6300	17.5	28	490	33	34.3	40.3	0.2306
10	130	120	675	2.3123	31.4	6300	19.2	28	537.6	33.1	34.6	40.7	0.2246
10	140	130	662	2.2681	31.4	6300	21	28	588	33.3	34.8	41.1	0.2183
10	150	140	646	2.2137	31.4	6300	23.2	28	649.6	33.4	35.2	41.7	0.2076

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	53	43	815	2.7883	31.4	6400	9.4	28	263.2	32.9	34.3	41.4	0.1983
10	60	50	802	2.7441	31.3	6400	10	28	280	32.9	34.2	41.1	0.2133
10	65	55	792	2.7101	31.3	6400	10.5	28	294	32.8	34.1	40.7	0.2207
10	70	60	783	2.6795	31.3	6400	11	28	308	32.8	34.1	40.7	0.2272
10	75	65	774	2.6489	31.3	6400	11.6	28	324.8	32.8	34	40.6	0.2307
10	80	70	766	2.6217	31.3	6400	12.1	28	338.8	32.8	34.1	40.5	0.2358
10	85	75	758	2.5945	31.3	6400	12.6	28	352.8	32.8	34.1	40.5	0.2401
10	90	80	750	2.5673	31.3	6400	13.3	28	372.4	32.9	34.1	40.4	0.24
10	95	85	741	2.5367	31.4	6400	14	28	392	32.8	34.2	40.3	0.2394
10	100	90	732	2.5061	31.4	6400	14.8	28	414.4	32.9	34.2	40.4	0.2369
10	110	100	718	2.4585	31.4	6400	16.2	28	453.6	32.9	34.3	40.4	0.2359
10	120	110	703	2.4075	31.4	6400	17.9	28	501.2	33.1	34.5	40.7	0.23
10	130	120	690	2.3633	31.4	6400	19.5	28	546	33.2	34.7	41	0.2261
10	140	130	675	2.3123	31.5	6400	21.7	28	607.6	33.4	35	41.4	0.2153
10	150	140	660	2.2613	31.6	6400	25.4	28	711.2	33.5	35.4	41.9	0.1937

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	54	44	827	2.8291	31.1	6500	9.7	28	271.6	32.7	34.1	41.1	0.1995
10	60	50	815	2.7883	31.2	6500	10.3	28	288.4	32.7	34.1	40.9	0.2104
10	65	55	806	2.7577	31.2	6500	10.8	28	302.4	32.7	34	40.6	0.2183
10	70	60	797	2.7271	31.2	6500	11.3	28	316.4	32.7	34	40.5	0.2251
10	75	65	787	2.6931	31.2	6500	11.8	28	330.4	32.7	34	40.7	0.2306
10	80	70	780	2.6693	31.2	6500	12.3	28	344.4	32.7	34	40.6	0.2361
10	85	75	772	2.6421	31.2	6500	13	28	364	32.7	34	40.5	0.2369
10	90	80	763	2.6115	31.2	6500	13.7	28	383.6	32.8	34.1	40.4	0.237
10	95	85	755	2.5843	31.2	6500	14.4	28	403.2	32.8	34.2	40.4	0.2371
10	100	90	748	2.5605	31.3	6500	15.3	28	428.4	32.9	34.3	40.6	0.2341
10	110	100	733	2.5095	31.3	6500	16.8	28	470.4	32.9	34.5	40.8	0.2322
10	120	110	719	2.4619	31.3	6500	18.6	28	520.8	33.1	34.7	41.1	0.2263
10	130	120	705	2.4143	31.3	6500	20.8	28	582.4	33.2	35	41.4	0.2165
10	140	130	690	2.3633	31.3	6500	23.1	28	646.8	33.4	35.3	41.8	0.2067

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	55	45	840	2.8733	30.8	6600	10	28	280	32.3	33.7	40.9	0.201
10	60	50	830	2.8393	30.8	6600	10.5	28	294	32.3	33.7	40.7	0.2102
10	65	55	822	2.8121	30.8	6600	11	28	308	32.3	33.6	40.4	0.2186
10	70	60	811	2.7747	30.8	6600	11.5	28	322	32.3	33.6	40.5	0.225
10	75	65	804	2.7509	30.8	6600	12	28	336	32.3	33.6	40.4	0.2316
10	80	70	795	2.7203	30.8	6600	12.6	28	352.8	32.3	33.6	40.3	0.2349
10	85	75	787	2.6931	30.8	6600	13.1	28	366.8	32.3	33.6	40.2	0.2397
10	90	80	780	2.6693	30.8	6600	13.8	28	386.4	32.3	33.6	40.2	0.2405
10	95	85	770	2.6353	30.8	6600	14.4	28	403.2	32.4	33.6	40.2	0.2418
10	100	90	762	2.6081	30.9	6600	15.1	28	422.8	32.4	33.7	40.2	0.2416
10	110	100	748	2.5605	30.9	6600	16.6	28	464.8	32.5	33.8	40.3	0.2398
10	120	110	733	2.5095	30.9	6600	18.3	28	512.4	32.7	34	40.5	0.2345
10	130	120	720	2.4653	30.9	6600	20	28	560	32.7	34.3	40.9	0.2299
10	140	130	705	2.4143	31	6600	22.1	28	618.8	33	34.7	41.6	0.2208

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	56	46	854	2.9209	30.4	6700	10.4	28	291.2	32	33.4	40.6	0.2008
10	60	50	845	2.8903	30.4	6700	10.8	28	302.4	32	33.3	40.4	0.208
10	65	55	837	2.8631	30.4	6700	11.3	28	316.4	31.9	33.3	40.1	0.2166
10	70	60	827	2.8291	30.5	6700	11.8	28	330.4	32	33.3	40.1	0.2236
10	75	65	820	2.8053	30.5	6700	12.4	28	347.2	32	33.3	40.1	0.2286
10	80	70	812	2.7781	30.5	6700	12.9	28	361.2	32	33.3	40	0.2343
10	85	75	804	2.7509	30.5	6700	13.5	28	378	32	33.3	40	0.2376
10	90	80	795	2.7203	30.5	6700	14.3	28	400.4	32.1	33.4	40	0.2366
10	95	85	788	2.6965	30.5	6700	14.8	28	414.4	32.1	33.4	39.9	0.2407
10	100	90	781	2.6727	30.5	6700	15.7	28	439.6	32.1	33.5	40	0.2382
10	110	100	767	2.6251	30.6	6700	17.1	28	478.8	32.3	33.7	40.2	0.2386
10	120	110	751	2.5707	30.6	6700	18.8	28	526.4	32.4	33.9	40.5	0.2338
10	130	120	736	2.5197	30.6	6700	20.6	28	576.8	32.6	34.2	40.9	0.2282
10	140	130	722	2.4721	30.7	6700	22.7	28	635.6	32.7	34.5	41.4	0.2201

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	56	46	866	2.9617	31	6800	10.7	28	299.6	32.5	34	41	0.1979
10	60	50	859	2.9379	31.1	6800	11.1	28	310.8	32.6	33.9	40.9	0.2057
10	65	55	850	2.9073	31.1	6800	11.6	28	324.8	32.5	33.9	40.9	0.2143
10	70	60	841	2.8767	31	6800	12.1	28	338.8	32.6	33.9	40.9	0.2217
10	75	65	832	2.8461	31.1	6800	12.6	28	352.8	32.6	33.9	40.8	0.2282
10	80	70	824	2.8189	31	6800	13.2	28	369.6	32.6	33.9	40.7	0.2324
10	85	75	816	2.7917	31.1	6800	13.8	28	386.4	32.6	33.9	40.6	0.2358
10	90	80	808	2.7645	31.1	6800	14.5	28	406	32.7	34	40.6	0.2371
10	95	85	800	2.7373	31.1	6800	15.3	28	428.4	32.7	34.1	40.7	0.2364
10	100	90	792	2.7101	31.1	6800	16.1	28	450.8	32.7	34.2	40.8	0.2355
10	110	100	777	2.6591	31.1	6800	18	28	504	32.8	34.4	41	0.2296
10	120	110	762	2.6081	31.1	6800	19.9	28	557.2	32.9	34.7	41.3	0.2241
10	130	120	748	2.5605	31.2	6800	23.3	28	652.4	33.2	35	41.6	0.205

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	58	48	880	3.0093	29.9	6900	11.2	28	313.6	31.5	33	40.4	0.2005
10	65	55	867	2.9651	29.9	6900	11.9	28	333.2	31.5	33	40.2	0.213
10	70	60	856	2.9277	30	6900	12.5	28	350	31.6	33	40	0.2184
10	75	65	848	2.9005	30	6900	13	28	364	31.6	33	39.9	0.2254
10	80	70	840	2.8733	30	6900	13.6	28	380.8	31.6	33	39.8	0.2299
10	85	75	833	2.8495	30	6900	14.2	28	397.6	31.6	33.1	40	0.2339
10	90	80	825	2.8223	30.1	6900	14.9	28	417.2	31.7	33	40	0.2355
10	95	85	817	2.7951	30.1	6900	15.6	28	436.8	31.8	33.1	40	0.2367
10	100	90	808	2.7645	30.2	6900	16.4	28	459.2	31.9	33.2	40.1	0.2358
10	110	100	795	2.7203	30.1	6900	18	28	504	31.9	33.4	40.3	0.2349
10	120	110	780	2.6693	30.2	6900	19.9	28	557.2	32	33.6	40.7	0.2294
10	130	120	764	2.6149	30.3	6900	22.1	28	618.8	32.1	33.9	40.9	0.2207
10	140	130	750	2.5673	30.3	6900	24.1	28	674.8	32.4	34.4	41.5	0.2153

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	60	50	900	3.0773	27	7000	11.9	28	333.2	28.6	29.9	36.2	0.201
10	65	55	888	3.0365	27.2	7000	12.8	28	358.4	28.9	30.2	36.7	0.2028
10	70	60	878	3.0025	27.3	7000	13.6	28	380.8	28.9	30.4	36.8	0.2059
10	75	65	872	2.9821	27.4	7000	14.1	28	394.8	29.1	30.6	37.1	0.2137
10	80	70	863	2.9515	27.5	7000	14.9	28	417.2	29.2	30.9	37.3	0.2155
10	85	75	855	2.9243	27.5	7000	15.8	28	442.4	29.3	31	37.6	0.2158
10	90	80	846	2.8937	27.7	7000	16	28	448	29.5	31.4	38	0.2249
10	95	85	838	2.8665	27.8	7000	16.9	28	473.2	29.7	31.5	38.6	0.2241
10	100	90	830	2.8393	28.3	7000	17.9	28	501.2	30.2	32.1	39.6	0.2219
10	110	100	815	2.7883	28.4	7000	20.2	28	565.6	30.4	32.6	40	0.2146
10	120	110	800	2.7373	28.4	7000	22.9	28	641.2	30.6	33	40.3	0.2044
10	130	120	785	2.6863	28.6	7000	23.6	28	660.8	30.9	33.5	41.2	0.2123

Appendix I: Parylene C DC Test Data

- Parylene C DC Performance Test Data
- Parylene C DC Room Temperature Limited Life Test Data
- Parylene C DC High Temperature Limited Life Test Data

Parylene C DC Performance Test Data

I4021 Test Data Sheet
Model 4016: 28 VDC motor, plastic gerotor pump
Fluid: 60% (by Vol.) EGW
Date: 7/30/2015
Tech: M. Hardisty
Rotor Coating: Parylene C

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	60	50	902	3.0841	27.6	7000	12.1	28	338.8	29.1	30.5	40.6	0.1981
10	65	55	891	3.0467	27.6	7000	12.6	28	352.8	29.3	30.6	40.6	0.2067
10	70	60	882	3.0161	27.7	7000	13.4	28	375.2	29.4	30.6	40.6	0.2099
10	75	65	875	2.9923	27.7	7000	13.8	28	386.4	29.4	30.6	40.6	0.2191
10	80	70	868	2.9685	27.7	7000	14.4	28	403.2	29.4	30.6	40.6	0.2243
10	85	75	860	2.9413	27.8	7000	15	28	420	29.5	30.6	41.2	0.2286
10	90	80	853	2.9175	27.8	7000	15.9	28	445.2	29.7	30.7	41.2	0.2282
10	95	85	844	2.8869	27.8	7000	16.3	28	456.4	29.9	30.7	41.1	0.234
10	100	90	836	2.8597	27.8	7000	16.8	28	470.4	29.9	30.8	41.3	0.2381
10	110	100	820	2.8053	27.9	7000	18.3	28	512.4	30	31	41.5	0.2383
10	120	110	808	2.7645	28	7000	19.5	28	546	30.1	31	41.7	0.2424
10	130	120	793	2.7135	28.1	7000	21	28	588	30.3	31.3	42	0.241
10	140	130	776	2.6557	28.2	7000	27.2	28	761.6	30.2	33.8	42.3	0.1973

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	54	44	806	2.7577	28.8	6300	9.4	28	263.2	30.1	32.2	36	0.2007
10	60	50	796	2.7237	28.8	6300	9.9	28	277.2	30.1	32.2	36	0.2138
10	65	55	787	2.6931	28.7	6300	10.4	28	291.2	30.1	32.2	36	0.2214
10	70	60	779	2.6659	28.8	6300	10.8	28	302.4	30.1	32.1	36	0.2302
10	75	65	769	2.6319	28.8	6300	11.3	28	316.4	30.1	32.1	36	0.2353
10	80	70	760	2.6013	28.8	6300	11.7	28	327.6	30.1	32.1	36.1	0.2419
10	85	75	753	2.5775	28.8	6300	12.2	28	341.6	30.1	32	36.7	0.2463
10	90	80	745	2.5503	28.8	6300	12.6	28	352.8	30.2	32	36.9	0.2517
10	95	85	737	2.5231	28.8	6300	13.2	28	369.6	30.2	31.9	37	0.2526
10	100	90	728	2.4925	28.9	6300	13.7	28	383.6	30.2	31.9	37.1	0.2545
10	110	100	715	2.4483	28.9	6300	14.7	28	411.6	30.2	32	37.1	0.2589
10	120	110	700	2.3973	28.9	6300	15.9	28	445.2	30.4	32.1	37.2	0.2578
10	130	120	686	2.3497	28.9	6300	17.2	28	481.6	3.5	32.2	37.5	0.2548
10	140	130	672	2.3021	28.9	6300	18.9	28	529.2	30.6	32.3	37.9	0.2461
10	150	140	656	2.2477	28.9	6300	22.3	28	624.4	30.8	32.9	38.6	0.2193

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	54	44	823	2.8155	28.2	6400	9.8	28	274.4	29.3	30.9	33.4	0.1965
10	60	50	813	2.7815	28.2	6400	10.3	28	288.4	29.3	31	33.7	0.2099
10	65	55	805	2.7543	28.2	6400	10.8	28	302.4	29.4	31.2	34.2	0.218
10	70	60	796	2.7237	28.2	6400	11.2	28	313.6	29.4	31.3	34.6	0.2268
10	75	65	787	2.6931	28.2	6400	11.7	28	327.6	29.5	31.4	34.9	0.2326
10	80	70	780	2.6693	28.3	6400	12.1	28	338.8	29.6	31.5	35.2	0.24
10	85	75	772	2.6421	28.3	6400	12.5	28	350	29.7	31.5	35.4	0.2464
10	90	80	763	2.6115	28.3	6400	13	28	364	29.7	31.6	35.7	0.2498
10	95	85	756	2.5877	28.3	6400	13.6	28	380.8	29.8	31.6	36.1	0.2514
10	100	90	747	2.5571	28.4	6400	14.1	28	394.8	29.8	31.6	36.5	0.2537
10	110	100	734	2.5129	28.4	6400	15.1	28	422.8	29.9	31.7	36.7	0.2587
10	120	110	720	2.4653	28.4	6400	16.3	28	456.4	29.9	31.8	37	0.2586
10	130	120	704	2.4109	28.5	6400	17.7	28	495.6	30.1	31.8	37.4	0.2541
10	140	130	692	2.3701	28.6	6400	19.2	28	537.6	30.3	32	38	0.2494
10	150	140	677	2.3191	28.6	6400	21.9	28	613.2	30.4	32.7	38.6	0.2304

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	55	45	831	2.8427	29	6500	10	28	280	30.4	32.8	37.6	0.1988
10	60	50	821	2.8087	29	6500	10.4	28	291.2	30.4	32.7	37.4	0.2099
10	65	55	812	2.7781	29	6500	10.9	28	305.2	30.4	32.7	37.2	0.2179
10	70	60	804	2.7509	28.9	6500	11.3	28	316.4	30.4	32.6	37.1	0.227
10	75	65	796	2.7237	28.9	6500	11.8	28	330.4	30.3	32.6	37.1	0.2332
10	80	70	788	2.6965	28.9	6500	12.3	28	344.4	30.3	32.5	37.1	0.2385
10	85	75	778	2.6625	28.9	6500	12.8	28	358.4	30.4	32.4	37.3	0.2425
10	90	80	771	2.6387	28.9	6500	13.2	28	369.6	30.4	32.3	37.7	0.2486
10	95	85	765	2.6183	28.9	6500	13.7	28	383.6	30.4	32.3	37.9	0.2525
10	100	90	757	2.5911	28.9	6500	14.3	28	400.4	30.5	32.3	37.9	0.2535
10	110	100	742	2.5401	28.9	6500	15.4	28	431.2	30.5	32.4	38.1	0.2564
10	120	110	728	2.4925	29	6500	16.6	28	464.8	30.6	32.4	38.5	0.2567
10	130	120	715	2.4483	29.1	6500	17.9	28	501.2	30.7	32.5	38.7	0.2551
10	140	130	700	2.3973	29.1	6500	20	28	560	30.8	32.8	39	0.2422
10	150	140	686	2.3497	29.1	6500	24.6	28	688.8	31	34	39.5	0.2079

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	56	46	845	2.8903	28.9	6600	10.4	28	291.2	30.3	33	38	0.1987
10	60	50	837	2.8631	29	6600	10.7	28	299.6	30.3	32.9	37.7	0.208
10	65	55	828	2.8325	29	6600	11.1	28	310.8	30.3	32.8	37.5	0.2182
10	70	60	820	2.8053	29	6600	11.6	28	324.8	30.4	32.7	37.3	0.2255
10	75	65	811	2.7747	28.9	6600	12.1	28	338.8	30.3	32.6	37.3	0.2317
10	80	70	803	2.7475	28.9	6600	12.6	28	352.8	30.3	32.6	37.3	0.2373
10	85	75	795	2.7203	28.9	6600	13	28	364	30.4	32.5	37.3	0.244
10	90	80	788	2.6965	28.9	6600	13.5	28	378	30.4	32.4	37.6	0.2484
10	95	85	780	2.6693	28.9	6600	14.1	28	394.8	30.4	32.3	37.9	0.2501
10	100	90	772	2.6421	28.8	6600	14.7	28	411.6	30.4	32.3	38.1	0.2514
10	110	100	757	2.5911	28.9	6600	15.8	28	442.4	30.5	32.3	38.2	0.2549
10	120	110	745	2.5503	28.9	6600	17.1	28	478.8	30.5	32.4	38.4	0.255
10	130	120	729	2.4959	29	6600	18.6	28	520.8	30.6	32.5	38.7	0.2503
10	140	130	717	2.4551	29	6600	20.6	28	576.8	30.9	33	39.4	0.2408

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	57	47	857	2.9311	28.9	6700	10.7	28	299.6	30.2	32.8	37.2	0.2001
10	60	50	850	2.9073	28.8	6700	11	28	308	30.2	32.7	37	0.2054
10	65	55	843	2.8835	28.8	6700	11.5	28	322	30.2	32.6	36.9	0.2144
10	70	60	836	2.8597	28.8	6700	11.9	28	333.2	30.2	32.6	36.7	0.2241
10	75	65	827	2.8291	28.8	6700	12.4	28	347.2	30.2	32.6	36.8	0.2305
10	80	70	817	2.7951	28.8	6700	12.9	28	361.2	30.3	32.4	36.9	0.2358
10	85	75	810	2.7713	28.8	6700	13.4	28	375.2	30.2	32.4	37	0.2411
10	90	80	802	2.7441	28.8	6700	13.9	28	389.2	30.3	32.3	37.2	0.2455
10	95	85	795	2.7203	28.8	6700	14.4	28	403.2	30.3	32.3	37.8	0.2496
10	100	90	789	2.6999	28.8	6700	14.9	28	417.2	30.4	32.3	37.9	0.2535
10	110	100	773	2.6455	28.8	6700	16	28	448	30.4	32.3	38.2	0.257
10	120	110	758	2.5945	28.8	6700	17.4	28	487.2	30.5	32.4	38.5	0.255
10	130	120	747	2.5571	28.9	6700	18.8	28	526.4	30.6	32.5	38.6	0.2537
10	140	130	732	2.5061	28.9	6700	20.8	28	582.4	30.8	32.8	39.5	0.2435

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	58	48	871	2.9787	28.7	6800	11	28	308	30.3	33	37.7	0.202
10	60	50	865	2.9583	28.7	6800	11.4	28	319.2	30.2	32.9	37.5	0.2017
10	65	55	858	2.9345	28.8	6800	11.8	28	330.4	30.3	32.8	37.2	0.2126
10	70	60	850	2.9073	28.7	6800	12.2	28	341.6	30.2	32.8	37.1	0.2223
10	75	65	842	2.8801	28.7	6800	12.7	28	355.6	30.2	32.7	37	0.2291
10	80	70	834	2.8529	28.7	6800	13.1	28	366.8	30.2	32.6	37.1	0.237
10	85	75	825	2.8223	28.7	6800	13.7	28	383.6	30.3	32.5	37.4	0.2402
10	90	80	816	2.7917	28.8	6800	14.2	28	397.6	30.3	32.3	38	0.2445
10	95	85	809	2.7679	28.8	6800	14.7	28	411.6	30.4	32.3	38.1	0.2488
10	100	90	800	2.7373	28.9	6800	15.3	28	428.4	30.3	32.4	38.4	0.2503
10	110	100	787	2.6931	28.9	6800	16.5	28	462	30.5	32.5	38.6	0.2537
10	120	110	771	2.6387	28.9	6800	17.8	28	498.4	30.6	32.5	38.9	0.2535
10	130	120	758	2.5945	28.9	6800	19.5	28	546	30.7	32.6	39.1	0.2482
10	140	130	744	2.5469	28.9	6800	21.5	28	602	30.8	33	39.5	0.2394

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	59	49	884	3.0229	28.3	6900	11.5	28	322	29.9	32.6	37	0.2002
10	65	55	872	2.9821	28.3	6900	12.2	28	341.6	29.8	32.5	36.8	0.209
10	70	60	863	2.9515	28.3	6900	12.7	28	355.6	29.8	32.5	36.7	0.2168
10	75	65	854	2.9209	28.3	6900	13.3	28	372.4	29.9	32.4	36.7	0.2219
10	80	70	847	2.8971	28.3	6900	13.7	28	383.6	29.9	32.4	36.8	0.2301
10	85	75	841	2.8767	28.4	6900	14	28	392	30	32.3	37	0.2396
10	90	80	833	2.8495	28.4	6900	14.6	28	408.8	30	32.3	37.4	0.2427
10	95	85	825	2.8223	28.5	6900	15.2	28	425.6	30	32.2	37.9	0.2453
10	100	90	817	2.7951	28.5	6900	15.8	28	442.4	30.1	32.1	38.4	0.2475
10	110	100	802	2.7441	28.5	6900	17	28	476	30.1	32.2	38.5	0.2509
10	120	110	790	2.7033	28.6	6900	18.5	28	518	30.3	32.4	38.7	0.2499
10	130	120	774	2.6489	28.6	6900	20.3	28	568.4	30.4	32.6	39	0.2434
10	140	130	759	2.5979	28.6	6900	22.5	28	630	30.6	33.5	39.6	0.2333

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	60	50	902	3.0841	27.6	7000	12.1	28	338.8	29.1	30.5	40.6	0.1981
10	65	55	891	3.0467	27.6	7000	12.6	28	352.8	29.3	30.6	40.6	0.2067
10	70	60	882	3.0161	27.7	7000	13.4	28	375.2	29.4	30.6	40.6	0.2099
10	75	65	875	2.9923	27.7	7000	13.8	28	386.4	29.4	30.6	40.6	0.2191
10	80	70	868	2.9685	27.7	7000	14.4	28	403.2	29.4	30.6	40.6	0.2243
10	85	75	860	2.9413	27.8	7000	15	28	420	29.5	30.6	41.2	0.2286
10	90	80	853	2.9175	27.8	7000	15.9	28	445.2	29.7	30.7	41.2	0.2282
10	95	85	844	2.8869	27.8	7000	16.3	28	456.4	29.9	30.7	41.1	0.234
10	100	90	836	2.8597	27.8	7000	16.8	28	470.4	29.9	30.8	41.3	0.2381
10	110	100	820	2.8053	27.9	7000	18.3	28	512.4	30	31	41.5	0.2383
10	120	110	808	2.7645	28	7000	19.5	28	546	30.1	31	41.7	0.2424
10	130	120	793	2.7135	28.1	7000	21	28	588	30.3	31.3	42	0.241
10	140	130	776	2.6557	28.2	7000	27.2	28	761.6	30.2	33.8	42.3	0.1973

Parylene C DC Limited Life Test Data

I4021 Test Data Sheet

Model 4021: 28VDC motor, plastic gerotor pump — Coating Parylene — Total Runtime for this test: 64.4 hours

Fluid: 60% (by Vol.) EGW

Date: 9/8/2015

Tech: A. Matthews

running time:

3-Sep	######	4:50 PM	0.38	9.1
4-Sep	######	3:15 PM	0.32	7.8
8-Sep	######	4:30 PM	0.35	8.5
9-Sep	######	5:00 PM	0.38	9.0
15-Sep	2:20 PM	4:30 PM	0.09	2.2
16-Sep	######	5:00 PM	0.39	9.3
17-Sep	######	4:37 PM	0.40	9.6
22-Sep	######	5:00 PM	0.38	9.0

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow GPM	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Input Power (Watts)	Pump Cover Temp (°C)	Motor Housing Temp (°C)	Chamber Air Temp (°C)	OE
10	65	55	855	2.9243	27	6800	12	28	336	28.2	32.1	25.5	21%
10	65	55	853	2.9175	28.9	6800	12	28	171.3	29.4	30.5	25.6	41%
10	65	55	835	2.8563	36.7	6800	11.7	28	172.1	37.6	42.4	27	40%
10	65	55	831	2.8427	40.8	6800	11.5	28	173.9	41.7	46.1	28.1	39%
10	65	55	840	2.8733	33.9	6800	11.6	28	173.8	34.9	39.5	27.5	40%
10	67	57	841	2.8767	33	6800	11.7	28	173.9	34.1	38.8	28	41%
10	67	57	841	2.8767	33.1	6800	11.7	28	173.8	34.1	38.7	27.8	41%
10	67	57	842	2.8801	33.2	6800	11.7	28	173.9	34.2	38.8	28	41%
10	67	57	839	2.8699	33.2	6800	11.7	28	173.6	34.2	38.8	27.9	41%
10	65	55	837	2.8631	33.4	6800	11.6	28	177.5	34.5	39.2	28	39%
10	65	55	855	2.9243	26.5	6800	12.2	28	176	27.4	30.7	24.8	40%
10	66	56	843	2.8835	31.1	6800	11.9	28	175.6	32.2	37	26.7	40%
10	67	57	839	2.8699	34.4	6800	11.7	28	176.2	35.4	39.9	29.4	40%
10	66	56	835	2.8563	35.2	6800	11.6	28	175.5	36.1	40.7	29.8	40%
10	67	57	836	2.8597	34.4	6800	11.6	28	182.2	35.4	40	29.2	39%
10	67	57	836	2.8597	34.6	6800	10	28	175.5	35.5	40.1	29.5	40%
10	67	57	836	2.8597	34.6	6800	11.7	28	175.5	35.6	39.6	29.2	40%
10	65	55	857	2.9311	25.3	6800	11.9	28	333.2	26.5	30.8	23.9	21%
10	65	55	843	2.8835	32.4	6800	11.5	28	322	33.4	38.1	28.3	21%
10	65	55	850	2.9073	27.2	6800	11.9	28	333.2	28.2	32.4	19.8	21%
10	65	55	855	2.9243	24.7	6800	12.2	28	341.6	25.9	30.3	19.7	20%
10	65	55	854	2.9209	24.7	6800	121	28	3388	25.7	30.2	19.6	2%
10	65	55	853	2.9175	24.7	6800	12.1	28	338.8	25.8	30.2	19.7	21%
10	65	55	853	2.9175	24.7	6800	12	28	336	25.7	30.1	19.7	21%
10	65	55			24.7	6800	11.9	28	333.2	25.7	30.2	19.7	
10	65	55			25.5	6800	11.7	28	327.6	26.7	30.8	24.7	
10	65	55			37.6	6800	11.1	28	310.8	38.5	43.2	32.5	
10	58	48			45	6000	8	28	224	45.7			
10	58	48			45	6000	8	28	224	45.7			
10	90	80	835	2.8563	29.3	7000	15.6	28	436.8			38.8	23%
10	90	80	825	2.8223	33.9	7000	15.4	28	431.2			43.3	23%
10	90	80	825	2.8223	34	7000	15.1	28	422.8			43.3	23%
10	90	80	842	2.8801	26.2	7000	15.2	28	425.6			28.9	24%
10	90	80	829	2.8359	32.7	7000	15.1	28	422.8			39.9	23%
10	90	80	830	2.8393	33.7	7000	15.1	28	422.8			42.9	23%
10	90	80	829	2.8359	34	7000	15.2	28	425.6		40.1	43.1	23%
10	90	80	829	2.8359	34.2	7000	15.2	28	425.6		40.5	43.4	23%
10	90	80	827	2.8291	35.3	7000	15.2	28	425.6		41.4	44.6	23%
10	90	80	828	2.8325	34	7000	15.2	28	425.6				23%
10	90	80	830	2.8393	34	7000	15.2	28	425.6		40.1	43.1	23%
10	90	80	840	2.8733	27	7000	15.1	28	422.8		28.4	29.3	24%
10	90	80	828	2.8325	32.4	7000	14.8	28	414.4		38.7	41.4	24%
10	90	80	827	2.8291	33	7000	14.7	28	411.6		39.1	41.9	24%
10	90	80	827	2.8291	33.2	7000	14.8	28	414.4		39.5	42.2	24%
10	90	80	826	2.8257	33.5	7000	14.8	28	414.4		39.7	42.4	24%
10	90	80	826	2.8257	33.6	7000	14.8	28	414.4		39.9	42.6	24%
10	90	80	827	2.8291	33.8	7000	14.8	28	414.4		40	42.9	24%
10	90	80	**842**	2.8801	27.2	7000	14.8	28	414.4		30.4	31.7	24%
10	90	80	823	2.8155	34.4	7000	14.7	28	411.6		40.7	43.8	24%
10	90	80	821	2.8087	34.1	7000	14.5	28	406		40	43.3	24%
10	90	80	823	2.8155	33.8	7000	14.6	28	408.8		39.9	43	24%
10	90	80	822	2.8121	34.1	7000	14.6	28	408.8		40.1	43.3	24%
10	90	80	822	2.8121	34.3	7000	14.6	28	408.8		40.2	43.5	24%

Parylene C DC High Temperature Limited Life Test Data

I4021 Test Data Sheet

Model 4021: 28VDC motor, plastic gerotor pump

Coating Parylene **Total Runtime for this test: 26.5 hours**

Fluid: 60% (by Vol.) EGW

running time:					
	28-Sep	######	5:00 PM	0.35	8.5
	29-Sep	######	5:00 PM	0.42	10.0
	30-Sep	######	4:00 PM	0.33	8.0

Date: 10/8/2015

Tech: K. Hashimoto

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure PSID	Flow (Hz)	Flow GPM	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Input Power (Watts)	Pump Cover Temp (°C)	Motor Housing Temp (°C)	Chamber Air Temp (°C)	OE
10	90	80	845	2.8903	25.9	7000	15	28	420		29.2	30.6	24%
10	89	79	836	2.8597	30.7	7000	14.8	28	414.4		36.4	39.3	24%
10	88	78	828	2.8325	35	7000	14.6	28	408.8		40.6	43.5	24%
10	86	76	821	2.8087	40.3	7000	14.5	28	406		46	49.3	23%
10	85	75	816	2.7917	44.7	7000	14.3	28	400.4		49.7	53.2	23%
10	85	75	812	2.7781	49.7	7000	14.3	28	400.4		55.1	58.4	23%
10	85	75	808	2.7645	55.3	7000	13.9	28	389.2		60	63.3	23%
10	85	75	807	2.7611	57.4	7000	13.9	28	389.2		62.1	65.4	23%
10	85	75	806	2.7577	57.5	7000	13.8	28	386.4		62.1	65.5	23%
10	85	75	807	2.7611	57.5	7000	13.7	28	383.6		62.2	65.5	23%
10	87	77	822	2.8121	37.3	7000	14.2	28	397.6		42	44.1	24%
10	86	76	800	2.7373	57.5	7000	13.6	28	380.8		62	65.3	24%
10	86	76	799	2.7339	57.5	7000	13.6	28	380.8		61.9	65.3	24%
10	86	76	799	2.7339	57.5	7000	13.5	28	378		62	65.3	24%
10	86	76	800	2.7373	57.5	7000	13.6	28	380.8		62.1	65.5	24%
10	86	76	801	2.7407	57.6	7000	13.7	28	383.6		62	65.6	24%
10	86	76	801	2.7407	57.6	7000	13.6	28	380.8		62.1	65.6	24%
10	86	76	801	2.7407	57.5	7000	13.6	28	380.8		62.2	65.5	24%
10	86	76	799	2.7339	55.9	7000	13.6	28	380.8		60.6	63.9	24%
10	86	76	799	2.7339	58.3	7000	13.3	28	372.4		62.5	66.1	24%
10	86	76	800	2.7373	56.5	7000	13.3	28	372.4		60.9	64.3	24%

Appendix J: Parylene C AC Test Data

- Parylene C AC Performance Test Data
- Parylene C AC Limited Life Test

Parylene C AC Performance Test Data

I4021 Test Data Sheet
Model 4021: 115 VAC motor, plastic gerotor pump
Fluid: 60% (by Vol.) EGW
Date: 8/10/2015
Tech: M. Hardisty

Parylene C
2:09PM - 3:20PM
3:20PM - 3:41PM

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure PSID	Flow (Hz)	Flow GPM	Fluid Temp (°C)	Speed (RPM)	Current A (Amps)	Current B (Amps)	Current C (Amps)	Current AVG (Amps)	Input Power A (Watts)	Input Power B (Watts)	Input Power C (Watts)	Input Power AVG (Watts)	Motor Housing Temp (°C)	Pump Cover Temp (°C)	OE
10	62	52	940	3.2133	25	~6800	2.95	2.87	2.8	2.8733	169.4	171.2	176.2	516.8	35.1	28.5	0.1407
10	65	55	927	3.1691	25.3	~6800	2.95	2.87	2.8	2.8733	172.5	173.5	178.6	524.6	39.9	29.4	0.1446
10	70	60	914	3.1249	25.5	~6800	2.95	2.88	2.82	2.8833	175.9	176.6	180.9	533.4	41.5	30	0.153
10	75	65	898	3.0705	25.9	~6800	2.97	2.89	2.83	2.8967	180.6	181.4	186.3	548.3	42.5	30.4	0.1584
10	80	70	881	3.0127	26.2	~6800	2.99	2.91	2.86	2.92	185.5	186	181	552.5	43.4	30.9	0.1661
10	85	75	867	2.9651	26.5	~6800	3	2.93	2.87	2.9333	189.6	190.3	195.2	575.1	43.9	31.2	0.1683
10	90	80	850	2.9073	26.8	~6800	3.02	2.95	2.89	2.9533	194.9	195	199.5	589.4	44.7	31.6	0.1718
10	95	85	834	2.8529	27.5	~6800	3.04	2.96	2.92	2.9733	199.1	198.7	204.4	602.2	45	32.4	0.1753
10	100	90	817	2.7951	27.8	~6800	3.06	2.98	2.94	2.9933	204.3	203.6	209.2	617.1	45.7	32.7	0.1774
10	61	51	935	3.1963	30.8	~6800	2.961	2.877	2.81	2.8827	167.5	169.3	174.1	510.9	33.8	33.2	0.1389
10	65	55	922	3.1521	30.7	~6800	2.942	2.86	2.797	2.8663	170	171.6	176	517.6	38	34	0.1458
10	70	60	909	3.1079	30.7	~6800	2.947	2.87	2.804	2.8737	173.1	174.9	179.6	527.6	41	34.5	0.1538
10	75	65	888	3.0365	30.7	~6800	2.964	2.885	2.826	2.8917	179	180.1	185	544.1	42	34.7	0.1579
10	80	70	875	2.9923	30.8	~6800	2.98	2.9	2.842	2.9073	183.8	184.2	189.5	557.5	42.8	35	0.1635
10	85	75	858	2.9345	30.8	~6800	2.998	2.921	2.886	2.935	189.3	189.6	194.5	573.4	43.8	35.2	0.1671
10	90	80	841	2.8767	30.9	~6800	3.015	2.94	2.889	2.948	194.3	194	199.5	587.8	44.3	35.3	0.1704
10	95	85	827	2.8291	31	~6800	3.034	2.96	2.91	2.968	199.3	198.3	204.1	601.7	45	35.5	0.1739
10	100	90	809	2.7679	31.1	~6800	3.057	2.98	2.933	2.99	204.5	203.4	208.6	616.5	45.7	35.8	0.1759

Parylene C AC Room Temperature Limited Life Test Data

I4021 Test Data Sheet
Model 4021: 115 VAC motor, plastic gerotor pump
Fluid: 60% (by Vol.) EGW
Date: 8/21/2015
Tech: M. Hardisty

Parylene C
ran for ~20 hours (1 hr on, 5 sec off)
Chamber On to 10°

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure PSID	Flow (Hz)	Flow GPM	Fluid Temp (°C)	Speed (RPM)	Current A (Amps)	Current B (Amps)	Current C (Amps)	Current AVG (Amps)	Input Power A (Watts)	Input Power B (Watts)	Input Power C (Watts)	Input Power AVG (Watts)	Motor Housing Temp (°C)	Pump Cover Temp (°C)	OE
10	63	53	936	3.1997	25.2	~6800	2.944	2.871	2.819	2.878	171.9	173.6	179.3	524.8	40.1	28.1	0.1406
10	65	55	934	3.1929	19.6	~6800	2.945	2.873	2.818	2.8787	174.3	175.6	181	530.9	41.4	23.4	0.144
10	65	55	933	3.1895	19	~6800	2.948	2.873	2.82	2.8803	174	175.8	181.2	531	40.9	22.8	0.1438
10	65	55	936	3.1997	19.1	~6800	2.949	2.875	2.819	2.881	174.6	175.3	181	530.9	41	22.9	0.1443
10	64	54	940	3.2133	20.2	~6800	2.978	2.895	2.835	2.9027	176.8	177.9	182.7	537.4	32.5	23.1	0.1405
10	65	55	935	3.1963	18.9	~6800	2.955	2.87	2.82	2.8817	175.4	175.9	180.5	531.8	40.7	22.8	0.1439
10	65	55	933	3.1895	18.9	~6800	2.954	2.871	2.82	2.8817	175.3	175.5	181	531.8	40.8	22.8	0.1436
10	65	55	936	3.1997	19.1	~6800	2.954	2.87	2.822	2.882	175.2	175.5	181	531.7	40.8	22.9	0.1441
10	65	55	936	3.1997	19.1	~6800	2.952	2.87	2.82	2.8807	175.3	175.9	180.7	531.9	40.8	23	0.144
10	65	55	936	3.1997	19.1	~6800	2.955	2.87	2.82	2.8817	175.4	176.1	181.3	532.8	40.8	22.9	0.1438
10	64	54	936	3.1997	19	~6800	2.953	2.87	2.819	2.8807	175.3	175.9	181.1	532.3	40.9	22.9	0.1413
10	64	54	935	3.1963	18.9	~6800	2.953	2.869	2.818	2.88	175.1	176.2	180.7	532	40.7	22.8	0.1412
10	65	55	936	3.1997	19.1	~6800	2.953	2.872	2.817	2.8807	175.5	175.2	181.1	531.8	40.9	23	0.144
10	65	55	936	3.1997	19.1	~6800	2.952	2.87	2.819	2.8803	175	175.9	181.5	532.4	40.9	22.9	0.1439
10	63	53	937	3.2031	24.8	~6800	2.978	2.876	2.888	2.914	188.2	166	173.1	527.3	31.7	26.9	0.1401
10	65	55	935	3.1963	19.1	~6800	2.946	2.808	2.883	2.879	188.7	167.7	174.9	531.3	40.3	23	0.144
10	65	55	936	3.1997	19	~6800	2.944	2.809	2.882	2.8783	188.6	167.4	174.1	530.1	40.2	22.9	0.1445
10	65	55	935	3.1963	19	~6800	2.941	20801	2.88	6935.6	188.7	167.7	175.2	531.6	40.2	23.9	0.1439
10	65	55	934	3.1929	19	~6800	2.947	2.806	2.883	2.8787	188.9	167.8	175.1	531.8	40.3	22.8	0.1437
10	65	55	935	3.1963	19	~6800	2.945	2.805	2.88	2.8767	188.7	167.5	175.1	531.3	40.5	22.8	0.144
	65	65	934	3.1929	19	~6800	2.944	2.808	2.881	2.8777	189	168.1	174.7	531.8	40.4	22.9	0.1699

Appendix K: Parylene HT DC Test Data

- Parylene HT DC Performance Test Data
- Parylene HT DC Room Temperature Limited Life Test Data
- Parylene HT DC High Temperature Limited Life Test Data

Parylene HT DC Performance Test Data

I4021 Test Data Sheet
Model 4016: 28 VDC motor, plastic gerotor pump
Fluid: 60% (by Vol.) EGW 7000 RPM
Date: 8/3/2015
Tech: M. Hardisty
Rotor Coating: Parylene HT

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	59	49	900	3.0773	26.1	7000	12.2	28	341.6	26.9	28.7	32.7	0.1921
10	65	55	890	3.0433	26.3	7000	13.5	28	378	26.9	29.3	33.5	0.1927
10	70	60	881	3.0127	26.4	7000	15	28	420	27.2	29.7	34	0.1873
10	75	65	873	2.9855	26.5	7000	16.1	28	450.8	27.3	30.2	34.5	0.1874
10	80	70	864	2.9549	26.6	7000	17.3	28	484.4	27.4	30.5	34.9	0.1859
10	85	75	855	2.9243	26.7	7000	17.8	28	498.4	27.5	30.8	35.2	0.1915
10	90	80	848	2.9005	26.8	7000	16.3	28	456.4	27.7	31.3	37.8	0.2213
10	95	85	838	2.8665	27.6	7000	18.9	28	529.2	28.7	32.3	38.1	0.2004
10	100	90	830	2.8393	27.8	7000	19.8	28	554.4	28.8	32.5	38.4	0.2006
10	110	100	815	2.7883	27.9	7000	23.3	28	652.4	28.9	33.2	38.8	0.186
10	120	110	801	2.7407	28.1	7000	25.4	28	711.2	29.1	33.6	39.2	0.1845

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	52	42	800	2.7373	32.4	6300	9	28	252	32.9	35.6	42.7	0.1986
10	60	50	785	2.6863	32.4	6300	9.8	28	274.4	32.8	35.5	42.4	0.213
10	65	55	775	2.6523	32.3	6300	10.3	28	288.4	32.8	35.4	42.1	0.2201
10	70	60	767	2.6251	32.3	6300	10.8	28	302.4	32.8	35.4	42	0.2267
10	75	65	758	2.5945	32.3	6300	11.3	28	316.4	32.8	35.4	41.9	0.232
10	80	70	750	2.5673	32.3	6300	11.8	28	330.4	32.8	35.4	41.7	0.2367
10	85	75	740	2.5333	32.3	6300	12.6	28	352.8	32.8	35.4	41.5	0.2344
10	90	80	733	2.5095	32.3	6300	13.2	28	369.6	32.8	35.5	41.4	0.2364
10	95	85	725	2.4823	32.3	6300	13.9	28	389.2	32.8	35.5	41.4	0.236
10	100	90	717	2.4551	32.3	6300	14.7	28	411.6	32.8	35.6	41.3	0.2336
10	110	100	703	2.4075	32.4	6300	16	28	448	32.8	35.7	41.3	0.2339
10	120	110	688	2.3565	32.4	6300	17.8	28	498.4	32.9	35.8	41.3	0.2264
10	130	120	675	2.3123	32.4	6300	19.8	28	554.4	33	36.2	41.5	0.2178
10	140	130	660	2.2613	32.5	6300	22.2	28	621.6	33.1	36.4	41.6	0.2058
10	150	140	648	2.2205	32.5	6300	24.7	28	691.6	33.2	36.9	42	0.1956

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	53	43	815	2.7883	32.1	6400	9.4	28	263.2	32.7	35.2	42	0.1983
10	60	50	801	2.7407	32.2	6400	10	28	280	32.6	35.2	41.6	0.213
10	65	55	791	2.7067	32.2	6400	10.6	28	296.8	32.6	35.2	41.4	0.2183
10	70	60	782	2.6761	32.2	6400	11.2	28	313.6	32.6	35.2	41.3	0.2228
10	75	65	774	2.6489	32.2	6400	11.7	28	327.6	32.6	35.2	41.3	0.2288
10	80	70	767	2.6251	32.1	6400	12.2	28	341.6	32.6	35.2	41.3	0.2341
10	85	75	756	2.5877	32.2	6400	13	28	364	32.7	35.3	41.3	0.2321
10	90	80	750	2.5673	32.2	6400	13.7	28	383.6	32.7	35.4	41.2	0.233
10	95	85	740	2.5333	32.2	6400	14.5	28	406	32.7	35.4	41.3	0.2308
10	100	90	735	2.5163	32.2	6400	14.9	28	417.2	32.8	35.5	41.3	0.2363
10	110	100	719	2.4619	32.3	6400	16.6	28	464.8	32.8	35.7	41.3	0.2305
10	120	110	706	2.4177	32.3	6400	18.2	28	509.6	32.9	35.9	41.5	0.2271
10	130	120	691	2.3667	32.3	6400	20.5	28	574	33	36.1	41.7	0.2153
10	140	130	677	2.3191	32.3	6400	22.6	28	632.8	33.2	36.7	41.9	0.2074

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	54	44	827	2.8291	31.9	6500	9.7	28	271.6	32.3	34.8	40.6	0.1995
10	60	50	815	2.7883	32	6500	10.3	28	288.4	32.3	34.8	40.6	0.2104
10	65	55	805	2.7543	31.9	6500	10.8	28	302.4	32.3	34.9	40.5	0.218
10	70	60	796	2.7237	31.9	6500	11.4	28	319.2	32.3	34.9	40.6	0.2228
10	75	65	788	2.6965	31.9	6500	11.9	28	333.2	32.4	349	40.7	0.2289
10	80	70	780	2.6693	31.9	6500	12.4	28	347.2	32.4	34.9	40.7	0.2342
10	85	75	772	2.6421	32	6500	13	28	364	32.4	34.9	40.7	0.2369
10	90	80	764	2.6149	32	6500	14.1	28	394.8	32.4	35	40.8	0.2306
10	95	85	755	2.5843	32	6500	14.8	28	414.4	32.5	35.3	40.9	0.2307
10	100	90	748	2.5605	32	6500	15.4	28	431.2	32.5	35.4	41	0.2326
10	110	100	735	2.5163	32	6500	17.4	28	487.2	32.6	35.6	41.1	0.2248
10	120	110	717	2.4551	32.1	6500	19.5	28	546	32.6	35.9	41.2	0.2153
10	130	120	704	2.4109	32.1	6500	21.8	28	610.4	32.8	36.4	41.6	0.2063
10	140	130	690	2.3633	32.2	6500	23.8	28	666.4	32.9	36.7	41.9	0.2007

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	55	45	838	2.8665	32.3	6600	10	28	280	32.7	35.3	41.8	0.2005
10	60	50	828	2.8325	32.3	6600	10.5	28	294	32.7	35.3	41.5	0.2097
10	65	55	818	2.7985	32.2	6600	11	28	308	32.7	35.3	41.3	0.2175
10	70	60	809	2.7679	32.2	6600	11.6	28	324.8	32.7	35.3	41.3	0.2225
10	75	65	800	2.7373	32.3	6600	12.2	28	341.6	32.7	35.3	41.3	0.2267
10	80	70	793	2.7135	32.3	6600	12.7	28	355.6	32.8	35.3	41.2	0.2325
10	85	75	785	2.6863	32.3	6600	13.4	28	375.2	32.7	35.4	41.1	0.2337
10	90	80	777	2.6591	32.3	6600	14.2	28	397.6	32.8	35.5	41.1	0.2329
10	95	85	768	2.6285	32.3	6600	15	28	420	32.8	35.6	41.2	0.2315
10	100	90	760	2.6013	32.4	6600	15.8	28	442.4	32.8	35.6	41.3	0.2303
10	110	100	745	2.5503	32.3	6600	17.3	28	484.4	32.9	35.9	41.5	0.2291
10	120	110	732	2.5061	32.4	6600	18.9	28	529.2	32.9	36	41.5	0.2267
10	130	120	718	2.4585	32.4	6600	21.3	28	596.4	33	36.4	41.8	0.2153
10	140	130	703	2.4075	32.5	6600	23.7	28	663.6	33.1	36.6	42	0.2053

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	55	45	850	2.9073	32.2	6700	10.4	28	291.2	32.8	35.5	42.8	0.1955
10	60	50	842	2.8801	32.1	6700	10.8	28	302.4	32.7	35.5	42.5	0.2073
10	65	55	832	2.8461	32.2	6700	11.4	28	319.2	32.7	35.4	42	0.2134
10	70	60	823	2.8155	32.2	6700	11.9	28	333.2	32.7	35.4	41.8	0.2207
10	75	65	815	2.7883	32.2	6700	12.4	28	347.2	32.7	35.4	41.8	0.2272
10	80	70	807	2.7611	32.2	6700	13	28	364	32.7	35.4	41.7	0.2311
10	85	75	799	2.7339	32.2	6700	13.7	28	383.6	32.7	35.4	41.7	0.2326
10	90	80	790	2.7033	32.2	6700	14.5	28	406	32.8	35.5	41.6	0.2318
10	95	85	783	2.6795	32.2	6700	15.3	28	428.4	32.8	35.6	41.6	0.2314
10	100	90	776	2.6557	32.3	6700	16	28	448	32.8	35.7	41.6	0.2322
10	110	100	760	2.6013	32.3	6700	17.7	28	495.6	32.9	36	41.8	0.2284
10	120	110	745	2.5503	32.3	6700	19.9	28	557.2	33	36.3	42	0.2191
10	130	120	731	2.5027	32.4	6700	21.9	28	613.2	33.1	36.6	42.3	0.2132
10	140	130	718	2.4585	32.5	6700	25.1	28	702.8	33.2	37.2	43	0.1979

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	56	46	865	2.9583	31.7	6800	10.7	28	299.6	32.2	35	41.8	0.1977
10	60	50	857	2.9311	31.7	6800	11.1	28	310.8	32.3	35	41.7	0.2052
10	65	55	848	2.9005	31.7	6800	11.6	28	324.8	32.1	35	41.5	0.2138
10	70	60	839	2.8699	31.7	6800	12.2	28	341.6	32.2	35	41.5	0.2194
10	75	65	831	2.8427	31.7	6800	12.8	28	358.4	32.2	35	41.5	0.2244
10	80	70	823	2.8155	31.7	6800	13.4	28	375.2	32.2	35	41.4	0.2286
10	85	75	814	2.7849	31.7	6800	14	28	392	3.3	35	41.3	0.2319
10	90	80	806	2.7577	31.7	6800	14.8	28	414.4	32.3	35.1	41.3	0.2317
10	95	85	798	2.7305	31.8	6800	15.7	28	439.6	32.4	35.3	41.3	0.2298
10	100	90	790	2.7033	31.9	6800	16.7	28	467.6	32.4	35.4	41.3	0.2265
10	110	100	775	2.6523	31.9	6800	18.6	28	520.8	32.4	35.7	41.4	0.2217
10	120	110	760	2.6013	31.9	6800	20.6	28	576.8	32.5	36	41.7	0.2159
10	130	120	747	2.5571	31.9	6800	23.5	28	658	32.6	36.3	42	0.203
10	140	130	731	2.5027	32.1	6800	26.1	28	730.8	33.1	37.6	43.3	0.1938

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	58	48	884	3.0229	31.1	6900	11.2	28	313.6	31.7	34.6	42.6	0.2014
10	60	50	873	2.9855	31.1	6900	11.4	28	319.2	31.8	34.5	42	0.2035
10	65	55	863	2.9515	31.2	6900	12	28	336	31.7	34.5	41.8	0.2103
10	70	60	855	2.9243	31.2	6900	12.6	28	352.8	31.7	34.5	41.5	0.2165
10	75	65	846	2.8937	31.2	6900	13.2	28	369.6	31.8	34.5	41.4	0.2215
10	80	70	838	2.8665	31.2	6900	13.8	28	386.4	31.8	34.5	41.3	0.226
10	85	75	830	2.8393	31.2	6900	14.7	28	411.6	31.8	34.6	41.2	0.2252
10	90	80	822	2.8121	31.3	6900	15.5	28	434	31.9	34.8	41.1	0.2256
10	95	85	814	2.7849	31.3	6900	16.3	28	456.4	31.9	34.9	41.1	0.2257
10	100	90	806	2.7577	31.4	6900	17.4	28	487.2	32	35.2	41.4	0.2217
10	110	100	792	2.7101	31.4	6900	19.1	28	534.8	32.1	35.4	41.5	0.2206
10	120	110	779	2.6659	31.5	6900	21.3	28	596.4	32.2	35.7	41.7	0.214
10	130	120	760	2.6013	31.5	6900	24.8	28	694.4	32.2	36.1	42	0.1957

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	59	49	894	3.0569	29.9	7000	11.7	28	327.6	30.5	33.1	39.4	0.199
10	65	55	880	3.0093	29.9	7000	12.5	28	350	30.6	33.3	39.4	0.2058
10	70	60	872	2.9821	30	7000	13.1	28	366.8	30.7	33.4	39.4	0.2123
10	75	65	863	2.9515	30.1	7000	13.8	28	386.4	30.7	33.5	39.4	0.2161
10	80	70	854	2.9209	30.1	7000	14.5	28	406	30.7	33.6	39.6	0.2192
10	85	75	847	2.8971	30.1	7000	15.3	28	428.4	30.8	33.8	39.8	0.2208
10	90	80	839	2.8699	30.2	7000	16.4	28	459.2	30.9	34	40	0.2176
10	95	85	830	2.8393	30.2	7000	17.5	28	490	31	34.2	0.2	0.2144
10	100	90	824	2.8189	30.3	7000	18.6	28	520.8	31.1	34.5	40.3	0.212
10	110	100	806	2.7577	30.4	7000	20.9	28	585.2	31.2	35.1	40.7	0.2051
10	120	110	791	2.7067	30.5	7000	22.8	28	638.4	31.4	35.6	41.1	0.203
10	130	120	778	2.6625	30.7	7000	25.4	28	711.2	31.7	36.4	42.7	0.1955

Parylene HT DC Room Temperature Limited Life Test Data

I4021 Test Data Sheet
Model 4021: 28VDC motor, plastic gerotor pump
Fluid: 60% (by Vol.) EGW
Date:
Tech:

Coating: Parylene HT — Total Runtime for this test: 105.8 hours

running time: [date]	[start]	[finish]	days	hours
10/7/2015	9:45 AM	4:30 PM	0.28	6.8
10/8/2015	7:45 AM	2:00 PM	0.26	6.3
10/12/2015			0.00	7.5
10/13/2015			0.00	9.5
10/14/2015			0.00	9.5
10/15/2015			0.00	9.5
10/16/2015				8.5
10/19/2015				9.5
10/20/2015				8.8
10/21/2015				10.3
10/22/2015				9.8
10/26/2015				10.0

Date	Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure PSID	Flow (Hz)	Flow GPM	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Input Power (Watts)	Pump Cover Temp (°C)	Motor Housing Temp (°C)	Motor Cover Temp (°C)	OE
10/7/2015	10	90	80	844	2.8869	33	7000	14.1	28	394.8		43.3	51.5	25%
10/8/2015	10	89	79	840	2.8733	34	7000	13.8	28	386.4		44	52.6	26%
10/12/2015	10	89	79	840	2.8733	34.7	7000	13.8	28	386.4		44.5	52.6	26%
10/13/2015	10	89	79	839	2.8699	35.4	7000	13.7	28	383.6		45.1	53.7	26%
10/14/2015	10	89	79	841	2.8767	33.8	7000	13.8	28	386.4		45.5	52.3	26%
10/15/2015	10	89	79	845	2.8903	33.4	7000	14	28	392		43	51	25%
10/16/2015	10	89	79	842	2.8801	33.1	7000	13.8	28	386.4		42.2	50.5	26%
10/19/2015	10	89	79	845	2.8903	33	7000	13.9	28	389.2		42.5	49.3	26%
10/20/2015	10	89	79	842	2.8801	32.7	7000	14.1	28	394.8		43.6	52.2	25%
10/21/2015	10	89	79	844	2.8869	34.1	7000	14	28	392		42.3	49.3	25%
10/22/2015	10	89	79	845	2.8903	32.5	7000	14	28	392		42.4	50.7	25%
10/26/2015	10	89	79	846	2.8937	33	7000	14	28	392		42.5	51	25%

Parylene HT DC High Temperature Limited Life Test Data

I4021 Test Data Sheet

Model 4021: 28VDC motor, plastic gerotor pump

Fluid: 60% (by Vol.) EGW

Date: 10/8/2015

Tech: K. Hashimoto

Coating DPX-HT

Total Runtime for this test: 22.7 hours

running time:				
2-Oct	######	4:00 PM	0.26	6.3
5-Oct	######	4:30 PM	0.37	8.8
6-Oct	######	3:00 PM	0.32	7.6

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow GPM	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Input Power (Watts)	Pump Cover Temp (°C)	Motor Housing Temp (°C)	Chamber Air Temp (°C)	OE
10	90	80	847	2.8971	28.1	7000	15.7	28	439.6		34.4	39	23%
10	90	80	842	2.8801	29.5	7000	15.3	28	428.4		36.6	44.3	23%
10	89	79	830	2.8393	37.8	7000	15	28	420		46	53	23%
10	88	78	825	2.8223	40	7000	15.1	28	422.8		48.6	55.3	23%
10	87	77	820	2.8053	46.7	7000	14.7	28	411.6		54.7	61.4	23%
10	86	76	813	2.7815	54	7000	14.3	28	400.4		61.5	68.5	23%
10	86	76	815	2.7883	57.3	7000	14	28	392		64.7	72	24%
10	86	76	815	2.7883	57.6	7000	13.8	28	386.4		64.8	72.2	24%
10	86	76	815	2.7883	57.6	7000	13.7	28	383.6		64.8	72.3	24%
10	90	80	849	2.9039	28	7000	14.6	28	408.8		37.5	43.6	25%
10	84	74	817	2.7951	55.7	7000	13.3	28	372.4		62.7	69.6	24%
10	84	74	817	2.7951	57.3	7000	13.3	28	372.4		64.2	71.2	24%
10	84	74	817	2.7951	57.4	7000	13.2	28	369.6		64.2	71.5	24%
10	84	74	818	2.7985	57.4	7000	13.2	28	369.6		64.3	71.6	24%
10	84	74	818	2.7985	57.4	7000	13.2	28	369.6		64.4	71.7	24%
10	84	74	818	2.7985	57.4	7000	13.1	28	366.8		64.4	71.9	25%
10	84	74	818	2.7985	57.4	7000	13.1	28	366.8		64.4	71.9	25%
10	84	74	818	2.7985	57.3	7000	13.1	28	366.8		64.3	71.8	25%
10	90	80	850	2.9073	26.9	7000	14.8	28	414.4		28	30.5	24%
10	84	74	818	2.7985	55.2	7000	13.2	28	369.6		62.3	69.4	24%
10	84	74	818	2.7985	57.3	7000	13.1	28	366.8		64.1	71.5	25%
10	85	75	819	2.8019	57.4	7000	13.1	28	366.8		64.3	71.7	25%
10	85	75	819	2.8019	57.4	7000	13.1	28	366.8		64.3	71.6	25%
10	85	75	820	2.8053	57.4	7000	13.2	28	369.6		64.4	71.9	25%

Appendix L: Parylene HT AC Test Data

- Parylene HT AC Performance Test Data
- Parylene HT AC Room Temperature Limited Life Test Data
- Parylene HT AC Cold Start-Up Test Data

Parylene HT AC Performance Test Data

I4021 Test Data Sheet

Model 4021: 115 VAC motor, plastic gerotor pump

Fluid: 60% (by Vol.) EGW

Date: 8/11/2015

Tech: M. Hardisty

Parylene HT

3:15PM - 3:20PM

3:25PM - 3:28PM

3:30PM - 3:32PM

3:35PM - 3:36PM

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure PSID	Flow (Hz)	Flow GPM	Fluid Temp (°C)	Speed (RPM)	Current A (Amps)	Current B (Amps)	Current C (Amps)	Current AVG (Amps)	Input Power A (Watts)	Input Power B (Watts)	Input Power C (Watts)	Input Power AVG (Watts)	Motor Housin g Temp (°C)	Pump Cover Temp (°C)	OE
10	61	51	916	3.1317	25	~6800	2.938	2.868	2.793	2.8663	170.6	173.4	178.2	522.2	37.7	27.5	0.1331
10	65	55	897	3.0671	25.3	~6800	2.943	2.874	2.8	2.8723	174.2	173.8	180.9	528.9	41.8	28.3	0.1388
10	70	60	880	3.0093	25.7	~6800	2.951	2.885	2.811	2.8823	178.4	180.1	184.4	542.9	44.3	28.9	0.1448
10	75	65	862	2.9481	25.9	~6800	2.96	2.894	2.83	2.8947	182.4	183.5	188.5	554.4	45.7	29.3	0.1504
10	80	70	845	2.8903	26.2	~6800	2.979	2.913	2.847	2.913	186.9	187.5	192.5	566.9	46.6	29.7	0.1553
10	85	75	834	2.8529	27.4	~6800	3.004	2.942	2.876	2.9407	189.2	190.6	195.8	575.6	42.6	30.6	0.1618
10	90	80	814	2.7849	27.8	~6800	3.009	2.948	2.896	2.951	194.8	195.5	201.2	591.5	45.9	31.2	0.1639
10	95	85	800	2.7373	28	~6800	3.046	2.979	2.93	2.985	199.3	199.6	205.3	604.2	43.6	31.3	0.1676
10	100	90	778	2.6625	28.2	~6800	3.055	2.989	2.945	2.9963	205.1	204.9	210.5	620.5	46.3	31.7	0.1681

Parylene HT AC Room Temperature Limited Life Test Data

I4021 st Data Sheet
Model 4021: 115 VAC motor, plastic gerotor pump
Fluid: 60% (by Vol.) EGW
Date: 8/21/2015
Tech: M. Hardisty

Parylene HT
ran for ~30 mins with chamber OFF
an for ~20 hours (1 hr on, 5 sec off) with chamber ON

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure PSID	Flow (Hz)	Flow GPM	Fluid Temp (°C)	Speed (RPM)	Current A (Amps)	Current B (Amps)	Current C (Amps)	Current AVG (Amps)	Input Power A (Watts)	Input Power B (Watts)	Input Power C (Watts)	Input Power AVG (Watts)	Motor Housing Temp (°C)	Pump Cover Temp (°C)	OE
10	61	51	924	3.1589		~6800	2.88	2.88	2.88	2.88				0			
10	90	80	835	2.8563	32.2	~6800	3.001	2.94	2.896	2.9457	196.9	196.7	202.7	596.3	52.2	35.4	0.1668
10	63	53	937	3.2031	23	~6800	2.958	2.869	2.824	2.8837	173.9	174.6	180.6	529.1	34.5	14.8	0.1396
10	62	52	930	3.1793	23.5	~6800	2.922	2.825	2.792	2.8463	171.3	173.7	177.6	522.6	44.2	14.8	0.1377
10	63	53	935	3.1963	22.8	~6800	2.919	2.845	2.791	2.8517	172.1	173.2	179.2	524.5	46.6	10.2	0.1406
10	64	54	941	3.2167	19.3	~6800	2.921	2.853	2.802	2.8587	173.9	175.1	180.5	529.5	45.8	9.9	0.1428
10	64	54	941	3.2167	19	~6800	2.916	2.855	2.804	2.8583	173.8	175.3	180.9	530	46	9.8	0.1426
10	64	54	942	3.2201	19	~6800	2.925	2.85	2.798	2.8577	173.9	174.8	180.9	529.6	46.6	9.8	0.1429
10	64	54	939	3.2099	19	~6800	2.919	2.85	2.802	2.857	173.8	175	181.1	529.9	46.7	9.8	0.1424
10	64	54	941	3.2167	19.1	~6800	2.916	2.851	2.8	2.8557	173.9	174.9	181.1	529.9	46.5	9.7	0.1427
10	65	55	942	3.2201	19.1	~6800	2.921	2.85	2.798	2.8563	173.6	175	180	528.6	46.9	9.8	0.1458
10	63	53	942	3.2201	22.4	~6800	2.987	2.918	2.848	2.9177	177.5	180.1	185.5	543.1	25.5	10	0.1368
10	64	54	934	3.1929	19.2	~6800	2.941	2.866	2.809	2.872	176	177.6	182.7	536.3	44	9.8	0.1399
10	64	54	938	3.2065	19.2	~6800	2.933	2.858	2.806	2.8657	175.6	177.5	182.3	535.4	45.5	9.8	0.1408
10	64	54	934	3.1929	19.1	~6800	2.925	2.865	2.806	2.8653	176.2	177.7	183	536.9	45.4	9.8	0.1398
10	63	53	937	3.2031	19.2	~6800	2.928	2.853	2.801	2.8607	175.5	176.3	181.4	533.2	47.7	9.8	0.1386
10	65	55	944	3.2269	15.2	~6800	2.999	2.93	2.807	2.912	182.2	184.6	189.9	556.7	22.9	9.8	0.1388
10	64	54	934	3.1929	19	~6800	2.914	2.863	2.807	2.8613	175.5	176.8	182.2	534.5	46.1	9.8	0.1404
10	64	54	934	3.1929	19.3	~6800	2.925	2.857	2.802	2.8613	175.5	176.6	181.9	534	46.5	9.8	0.1405
10	64	54	936	3.1997	19.2	~6800	2.93	2.852	2.798	2.86	175.5	176.9	181.9	534.3	47.3	9.8	0.1407
10	64	54	935	3.1963	19.2	~6800	2.928	2.852	2.799	2.8597	175.9	176.5	181.4	533.8	47.5	9.8	0.1407
10	64	54	945	3.2303	19.5	~6800	2.96	2.88	2.82	2.8867	176.8	177.8	183.1	537.7	34.2	10.1	0.1412
10	64	54	937	3.2031	19	~6800	2.93	2.85	2.79	2.8567	176.1	176.5	181.4	534	46	9.7	0.141
10	64	54	936	3.1997	18.8	~6800	2.94	2.86	2.81	2.87	176.2	177	182.4	535.6	44.7	9.6	0.1404
10	64	54	934	3.1929	18.9	~6800	2.92	2.86	2.8	2.86	175.9	175.9	182	533.8	46.7	9.6	0.1406

Parylene HT AC Cold Start-Up Test Data

I4021 Test Data Sheet
Model 4021: 115 VAC motor, plastic gerotor pump — Parylene HT
Fluid: 60% (by Vol.) EGW
Date: 8/21/2015
Tech: M. Hardisty
Cold soak start @ 1:00PM at -45°C. End @ 3:00PM

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure PSID	Flow (Hz)	Flow GPM	Fluid Temp (°C)	Speed (RPM)	Current A (Amps)	Current B (Amps)	Current C (Amps)	Current AVG (Amps)	Input Power A (Watts)	Input Power B (Watts)	Input Power C (Watts)	Input Power AVG (Watts)	Motor Housing Temp (°C)	Pump Cover Temp (°C)	OE
Warmed up					-44.7	~6800									-44.8	-44.4	
really fast					-24	~6800									-13	-13.4	
4	170	166	555	1.9043	-31.6	~6800	4.21	4.11	4.13	4.17	365	353	362		-3.6	-20.3	
8.2	78		932	3.1861	-3.3	~6800	3.06	2.98	2.95	3	203.5	202.8	209		27.9	3.3	
10	71		944	3.2269	7.6	~6800	3.01	2.92	2.88	2.93	188.8	188.6	194.2		31.4	12.1	

Appendix M: Humiseal DC Test Data

- Humiseal DC Performance Test Data
- Humiseal DC Room Temperature Limited Life Test Data
- Humiseal DC High Temperature Limited Life Test Data

Humiseal DC Performance Test Data

I4021 Test Data Sheet
Model 4016: 28 VDC motor, plastic gerotor pump
Fluid: 60% (by Vol.) EGW 7000 RPM burn-in
Date: 8/4/2015
Tech: M. Hardisty ~54 minutes cumulative runtime
Rotor Coating: Humiseal 1A33

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	60	50	900	3.0773	27	7000	12.5	28	350	28.7	30.8	39.5	0.1913
10	65	55	890	3.0433	27.1	7000	13.2	28	369.6	28.9	31.1	39.9	0.1971
10	70	60	880	3.0093	27.2	7000	14.2	28	397.6	29	31.6	40.2	0.1977
10	75	65	872	2.9821	27.3	7000	14.7	28	411.6	29.2	31.7	40.5	0.205
10	80	70	863	2.9515	27.4	7000	17.9	28	501.2	29.3	32.4	41	0.1794
10	85	75	856	2.9277	27.5	7000	16.2	28	453.6	29.5	32.5	41.4	0.2107
10	90	80	847	2.8971	27.6	7000	20	28	560	29.6	32.3	42.2	0.1801
10	95	85	840	2.8733	27.7	7000	20.5	28	574	29.8	33.2	43.1	0.1852
10	100	90	830	2.8393	27.8	7000	20.5	28	574	29.9	33.7	43.7	0.1938
10	110	100	816	2.7917	27.9	7000	22.8	28	638.4	30.2	34	44.5	0.1903

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	52	42	800	2.7373	31.6	6300	9.4	28	263.2	32.9	34.5	41	0.1901
10	60	50	787	2.6931	31.7	6300	10	28	280	33	34.5	40.9	0.2093
10	65	55	777	2.6591	31.7	6300	10.6	28	296.8	32.9	34.5	40.8	0.2145
10	70	60	768	2.6285	31.7	6300	11.1	28	310.8	33	34.5	40.7	0.2209
10	75	65	760	2.6013	31.7	6300	11.6	28	324.8	33.1	34.5	40.7	0.2266
10	80	70	750	2.5673	31.7	6300	12.1	28	338.8	33	34.5	40.6	0.2309
10	85	75	742	2.5401	31.7	6300	12.7	28	355.6	33.1	34.6	40.7	0.2332
10	90	80	733	2.5095	31.7	6300	13.4	28	375.2	33.1	34.6	41	0.2329
10	95	85	725	2.4823	31.7	6300	14.2	28	397.6	33.3	34.7	41.4	0.231
10	100	90	717	2.4551	31.7	6300	15.4	28	431.2	33.2	34.8	41.6	0.223
10	110	100	702	2.4041	31.7	6300	17.8	28	498.4	33.4	35.3	41.9	0.2099
10	120	110	689	2.3599	31.8	6300	19.9	28	557.2	33.5	35.8	42.4	0.2028
10	130	120	674	2.3089	31.8	6300	22.8	28	638.4	33.7	36.3	42.9	0.1889

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	53	43	814	2.7849	31.4	6400	9.7	28	271.6	32.7	34.3	40.7	0.1919
10	60	50	802	2.7441	31.4	6400	10.3	28	288.4	32.8	34.3	40.6	0.2071
10	65	55	792	2.7101	31.4	6400	10.8	28	302.4	32.8	34.3	40.5	0.2145
10	70	60	783	2.6795	31.4	6400	11.3	28	316.4	32.8	34.3	40.5	0.2212
10	75	65	774	2.6489	31.4	6400	11.9	28	333.2	32.8	34.3	40.5	0.2249
10	80	70	765	2.6183	31.5	6400	12.5	28	350	32.9	34.3	40.6	0.2279
10	85	75	757	2.5911	31.5	6400	12.9	28	361.2	32.9	34.3	40.9	0.2342
10	90	80	750	2.5673	31.5	6400	13.5	28	378	32.9	34.3	41.1	0.2365
10	95	85	741	2.5367	31.5	6400	14.5	28	406	33	34.4	41.2	0.2311
10	100	90	734	2.5129	31.5	6400	15.2	28	425.6	33.1	34.5	41.4	0.2313
10	110	100	719	2.4619	31.5	6400	17.3	28	484.4	33.2	34.7	41.5	0.2212
10	120	110	702	2.4041	31.5	6400	19.6	28	548.8	33.3	35.3	42.2	0.2097
10	130	120	688	2.3565	31.6	6400	22.4	28	627.2	33.5	35.8	42.9	0.1962

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	53	43	831	2.8427	30.9	6500	10	28	280	31.9	32.5	34.8	0.19
10	60	50	818	2.7985	30.9	6500	10.6	28	296.8	31.9	32.8	35.5	0.2052
10	65	55	810	2.7713	30.9	6500	11.1	28	310.8	32	33	36.2	0.2134
10	70	60	800	2.7373	31	6500	11.6	28	324.8	32.1	33.1	34.7	0.2201
10	75	65	791	2.7067	31	6500	12.2	28	341.6	32.2	33.2	37.2	0.2242
10	80	70	783	2.6795	31	6500	12.7	28	355.6	32.2	33.3	37.5	0.2296
10	85	75	775	2.6523	31	6500	13.3	28	372.4	32.3	33.4	37.9	0.2325
10	90	80	767	2.6251	31	6500	14	28	392	32.3	33.5	38.5	0.2332
10	95	85	758	2.5945	31	6500	14.9	28	417.2	32.5	33.7	39.3	0.2301
10	100	90	750	2.5673	31	6500	15.9	28	445.2	32.5	33.9	39.7	0.2259
10	110	100	736	2.5197	31.1	6500	18.2	28	509.6	32.7	34.5	40.5	0.2152
10	120	110	721	2.4687	31.2	6500	20.5	28	574	32.9	35.1	41.5	0.2059
10	130	120	705	2.4143	31.2	6500	24.8	28	694.4	33.1	35.8	42.5	0.1816

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	54	44	840	2.8733	31.2	6600	10.3	28	288.4	32.5	34.1	40.6	0.1908
10	60	50	830	2.8393	31.1	6600	10.8	28	302.4	32.6	34.1	40.6	0.2043
10	65	55	820	2.8053	31.1	6600	11.4	28	319.2	32.5	34.1	40.6	0.2104
10	70	60	811	2.7747	31.2	6600	11.9	28	333.2	32.6	34.1	40.8	0.2175
10	75	65	802	2.7441	31.2	6600	12.5	28	350	32.7	34.1	41	0.2218
10	80	70	794	2.7169	31.2	6600	13	28	364	32.7	34.1	41.1	0.2274
10	85	75	786	2.6897	31.2	6600	13.6	28	380.8	32.7	34.2	41.2	0.2306
10	90	80	777	2.6591	31.3	6600	14.3	28	400.4	32.7	34.2	41.4	0.2312
10	95	85	769	2.6319	31.3	6600	15.1	28	422.8	32.8	34.3	41.6	0.2303
10	100	90	761	2.6047	31.3	6600	16.1	28	450.8	32.8	34.4	41.8	0.2263
10	110	100	747	2.5571	31.4	6600	19	28	532	33	34.8	42.2	0.2092
10	120	110	732	2.5061	31.4	6600	21.5	28	602	33.2	35.4	42.7	0.1993
10	130	120	717	2.4551	31.4	6600	24.7	28	691.6	33.3	35.9	43.1	0.1854

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	55	45	853	2.9175	30.7	6700	10.7	28	299.6	32	33.2	37.9	0.1907
10	60	50	845	2.8903	30.7	6700	11.2	28	313.6	32	33.3	38.3	0.2006
10	65	55	836	2.8597	30.7	6700	11.7	28	327.6	32	33.3	38.5	0.209
10	70	60	827	2.8291	30.7	6700	12.2	28	341.6	32.1	33.4	38.7	0.2163
10	75	65	819	2.8019	30.8	6700	12.8	28	358.4	32.1	33.5	39	0.2212
10	80	70	810	2.7713	30.8	6700	13.4	28	375.2	32.2	33.6	39.1	0.225
10	85	75	802	2.7441	30.8	6700	13.9	28	389.2	32.2	33.6	39.7	0.2302
10	90	80	793	2.7135	30.8	6700	14.6	28	408.8	32.3	33.6	40.3	0.2311
10	95	85	785	2.6863	30.9	6700	15.6	28	436.8	32.4	33.8	40.8	0.2275
10	100	90	778	2.6625	30.8	6700	17.3	28	484.4	32.4	34	41.1	0.2153
10	110	100	762	2.6081	30.9	6700	20.1	28	562.8	32.6	34.7	41.5	0.2017
10	120	110	750	2.5673	31	6700	21.5	28	602	32.7	35.1	42	0.2042
10	130	120	733	2.5095	31	6700	26.7	28	747.6	33	35.6	42.8	0.1753

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	56	46	866	2.9617	30.3	6800	11.1	28	310.8	31.7	33.2	39.9	0.1908
10	60	50	860	2.9413	30.3	6800	11.5	28	322	31.7	33.3	40	0.1988
10	65	55	850	2.9073	30.3	6800	12	28	336	31.7	33.3	40.1	0.2071
10	70	60	842	2.8801	30.4	6800	12.6	28	352.8	31.8	33.3	40.2	0.2132
10	75	65	832	2.8461	30.3	6800	13.1	28	366.8	31.9	33.3	40.3	0.2195
10	80	70	824	2.8189	30.4	6800	13.7	28	383.6	32	33.4	40.8	0.2239
10	85	75	816	2.7917	30.4	6800	14.4	28	403.2	32	33.4	41	0.226
10	90	80	807	2.7611	30.4	6800	15.1	28	422.8	31.9	33.5	41.4	0.2274
10	95	85	800	2.7373	30.5	6800	16	28	448	32.1	33.6	41.6	0.226
10	100	90	793	2.7135	30.5	6800	17	28	476	32.3	34	42.1	0.2233
10	110	100	778	2.6625	30.6	6800	20.3	28	568.4	32.4	32.2	42.4	0.2039
10	120	110	764	2.6149	30.7	6800	31.7	28	887.6	32.6	35.2	43.3	0.141
10	130	120	748	2.5605	30.7	6800	25.8	28	722.4	32.8	35.8	44.1	0.1851

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	58	48	881	3.0127	29.2	6900	11.6	28	324.8	30.7	32.5	39.5	0.1938
10	65	55	868	2.9685	29.3	6900	12.4	28	347.2	30.8	32.4	39.6	0.2047
10	70	60	858	2.9345	29.3	6900	12.9	28	361.2	30.8	32.5	39.7	0.2122
10	75	65	850	2.9073	29.3	6900	13.5	28	378	30.9	32.6	39.8	0.2176
10	80	70	840	2.8733	29.4	6900	14.2	28	397.6	31.1	32.7	40.1	0.2202
10	85	75	833	2.8495	29.5	6900	14.8	28	414.4	31.1	32.7	40.5	0.2245
10	90	80	824	2.8189	29.5	6900	15.5	28	434	31.2	32.8	41.3	0.2262
10	95	85	816	2.7917	29.5	6900	16.7	28	467.6	31.3	32.9	41.6	0.2209
10	100	90	808	2.7645	29.6	6900	19	28	532	31.4	33.4	41.9	0.2036
10	110	100	793	2.7135	29.7	6900	21.4	28	599.2	31.6	34	42.3	0.1971
10	120	110	780	2.6693	29.8	6900	23.3	28	652.4	31.8	34.5	42.9	0.1959

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow (GPM)	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Power (Watts)	Temp Pump Cover (°C)	Temp Motor Housing (°C)	Temp Motor Cover (°C)	OE
10	60	50	898	3.0705	27.7	7000	12	28	336	28.9	30	33.4	0.1989
10	65	55	887	3.0331	27.9	7000	12.7	28	355.6	29.1	30.4	34.3	0.2042
10	70	60	878	3.0025	27.9	7000	13.3	28	372.4	29.3	30.6	35.1	0.2105
10	75	65	868	2.9685	27.9	7000	13.9	28	389.2	29.3	30.8	35.7	0.2158
10	80	70	860	2.9413	27.9	7000	14.5	28	406	29.5	30.9	36.7	0.2207
10	85	75	853	2.9175	28.1	7000	15.1	28	422.8	29.6	31	37.3	0.2253
10	90	80	844	2.8869	28.1	7000	15.9	28	445.2	29.7	31.2	37.9	0.2258
10	95	85	837	2.8631	28.3	7000	16.9	28	473.2	29.9	31.4	38.6	0.2238
10	100	90	827	2.8291	28.3	7000	19.4	28	543.2	30.1	32.2	39.5	0.204
10	110	100	813	2.7815	28.4	7000	22.4	28	627.2	30.4	33	40.5	0.193
10	120	110	798	2.7305	28.6	7000	25.5	28	714	30.7	34.1	41.9	0.1831

Humiseal DC High Temperature Limited Life Test Data

I4021 Test Data Sheet
Model 4021: 28VDC motor, plastic gerotor pump — Coating Humiseal — Total Runtime for this test: 1.1 hours
Fluid: 60% (by Vol.) EGW — running time: 1-Oct ###### ###### 0.05 1.1
Date: 10/8/2015
Tech: K. Hashimoto

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure (PSID)	Flow (Hz)	Flow GPM	Fluid Temp (°C)	Speed (RPM)	Current (Amps)	Voltage (VDC)	Input Power (Watts)	Pump Cover Temp (°C)	Motor Housing Temp (°C)	Chamber Air Temp (°C)	OE
10	90	80	830	2.8393	32.5	7000	15.5	28	434		36.7	36.9	23%
10	90	80	828	2.8325	35.5	7000	15.2	28	425.6		42.5	44.1	23%
10	89	79	821	2.8087	40	7000	15.1	28	422.8		46.6	48.5	23%
10	88	78	813	2.7815	45	7000	14.8	28	414.4		51.3	53.2	23%
10	87	77	810	2.7713	50	7000	14.8	28	414.4		56.1	57.9	22%

Appendix N: Humiseal AC Test Data

- Humiseal AC Performance Test Data
- Humiseal AC Room Temperature Limited Life Test Data

Humiseal AC Performance Test Data

I4021 Test Data Sheet
Model 4021: 115 VAC motor, plastic gerotor pump
Fluid: 60% (by Vol.) EGW Humiseal
Date: 8/13/2015
Tech: M. Hardisty

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure PSID	Flow (Hz)	Flow GPM	Fluid Temp (°C)	Speed (RPM)	Current A (Amps)	Current B (Amps)	Current C (Amps)	Current AVG (Amps)	Input Power A (Watts)	Input Power B (Watts)	Input Power C (Watts)	Input Power AVG (Watts)	Motor Housing Temp (°C)	Pump Cover Temp (°C)	OE
10	60	50	928	3.1725	29.1	~6800	2.974	2.901	2.84	2.905	176	177.9	183.4	537.3	36.8	31.8	0.1285
10	70	60	900	3.0773	29.2	~6800	2.991	2.917	2.86	2.9227	183.9	185	190.3	559.2	41.6	32.6	0.1437
10	61	51	921	3.1487	28	~6800	2.967	2.895	2.822	2.8947	176.1	178.2	181.8	536.1	41.8	31.5	0.1304
10	65	55	905	3.0943	28.2	~6800	2.961	2.891	2.827	2.893	178.7	180.5	185.4	544.6	46.2	32.2	0.136
10	70	60	902	3.0841	29	~6800	2.983	2.92	2.859	2.9207	183.4	185.3	190.5	559.2	40	32.1	0.144
10	75	65	883	3.0195	29.1	~6800	2.994	2.932	2.872	2.9327	188.9	189.7	194.9	573.5	46.9	33	0.149
10	80	70	875	2.9923	30.2	~6800	3.029	2.963	2.903	2.965	193.1	194	199.4	586.5	42.6	33.5	0.1554
10	85	75	845	2.8903	30.7	~6800	3.05	2.985	2.925	2.9867	198	198.6	203.8	600.4	42.9	34.1	0.1571
10	90	80	830	2.8393		~6800				0				0			
10	60	50	924	3.1589	28.4	~6800	2.985	2.92	2.851	2.9187	175.6	178.4	183.8	537.8	30.7	29.9	0.1278
10	70	60	894	3.0569	28.5	~6800	2.993	2.929	2.861	2.9277	183.8	185.5	191	560.3	36.6	31.2	0.1425
10	80	70	863	2.9515	28.6	~6800	3.017	2.96	2.903	2.96	193.3	194.5	200	587.8	40.9	32.2	0.153

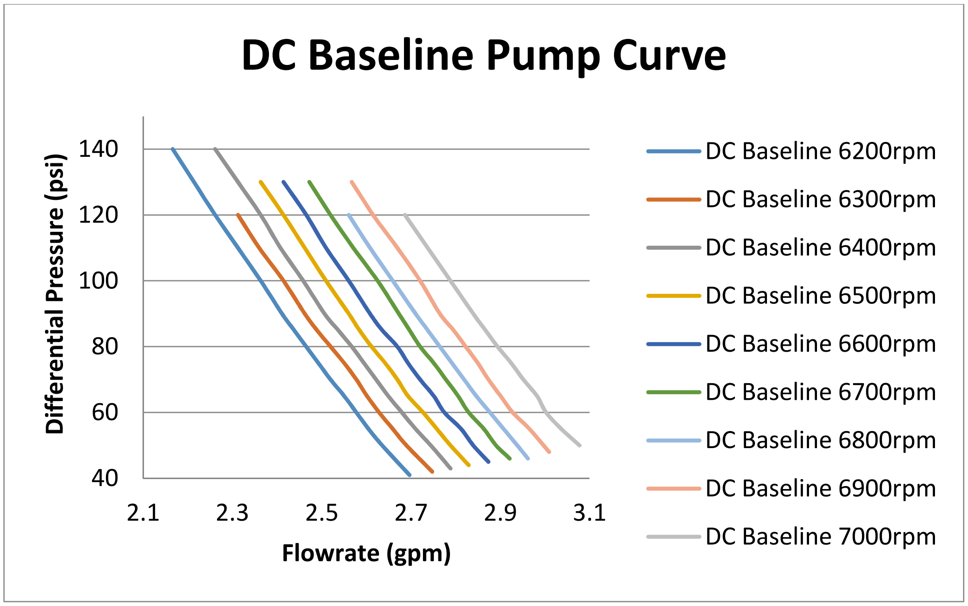
I4021 Test Data Sheet
Model 4021: 115 VAC motor, plastic gerotor pump — Humiseal 1A33
Fluid: 60% (by Vol.) EGW — 10 mins running
Date: 8/21/2015
Tech: M. Hardisty — FAILED

Inlet Pressure (psig)	Outlet Pressure (psig)	Diff Pressure PSID	Flow (Hz)	Flow GPM	Fluid Temp (°C)	Speed (RPM)	Current A (Amps)	Current B (Amps)	Current C (Amps)	Current AVG (Amps)	Input Power A (Watts)	Input Power B (Watts)	Input Power C (Watts)	Input Power AVG (Watts)	Motor Housing Temp (°C)	Pump Cover Temp (°C)	OE
10	63	53	636	2.1797	28.6	~6800	2.981	2.914	2.854	2.9163	178.8	180.8	185.8	545.4	36.1	31.3	0.0922
10	65	55	560	1.9213	32.1	~6800	2.977	2.912	2.85	2.913	178.7	180.2	185.5	544.4	39.2	34.6	0.0845

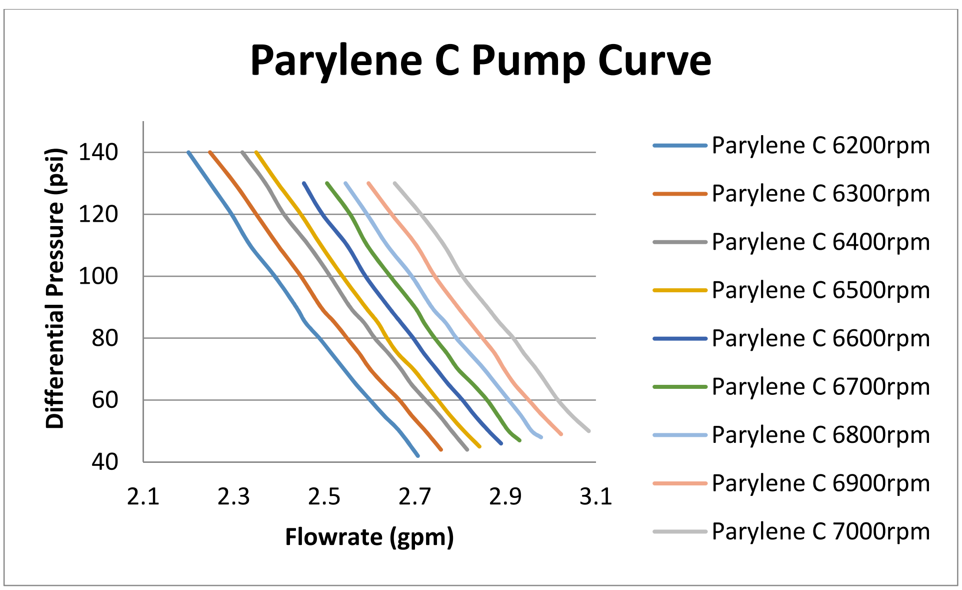
Appendix O: DC Graphs

- DC Baseline Pump Curve
- DC Parylene C Pump Curve
- DC Parylene HT Pump Curve
- DC Humiseal Pump Curve
- DC Operating Efficiency Comparison Curves

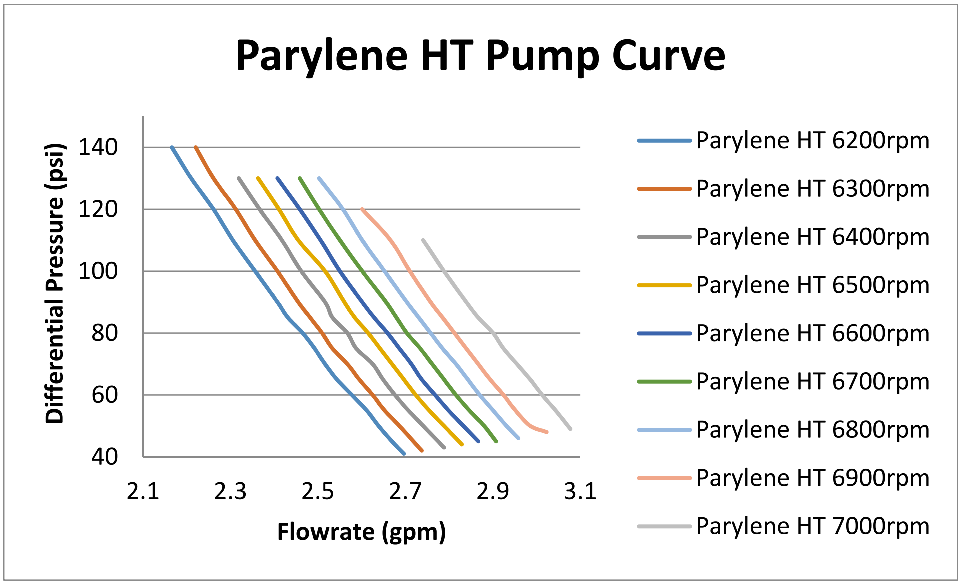
DC Baseline Pump Curve



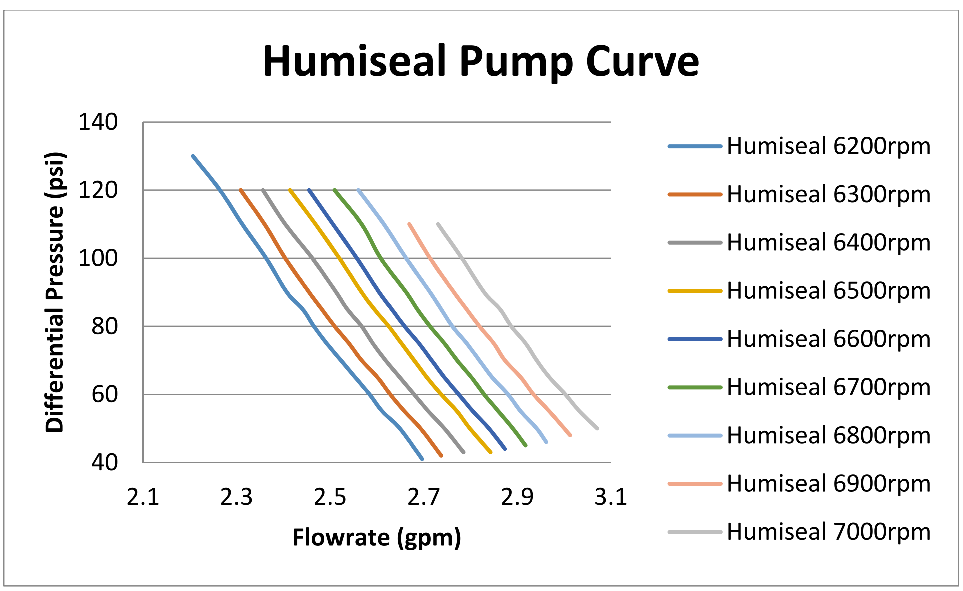
DC Parylene C Pump Curve



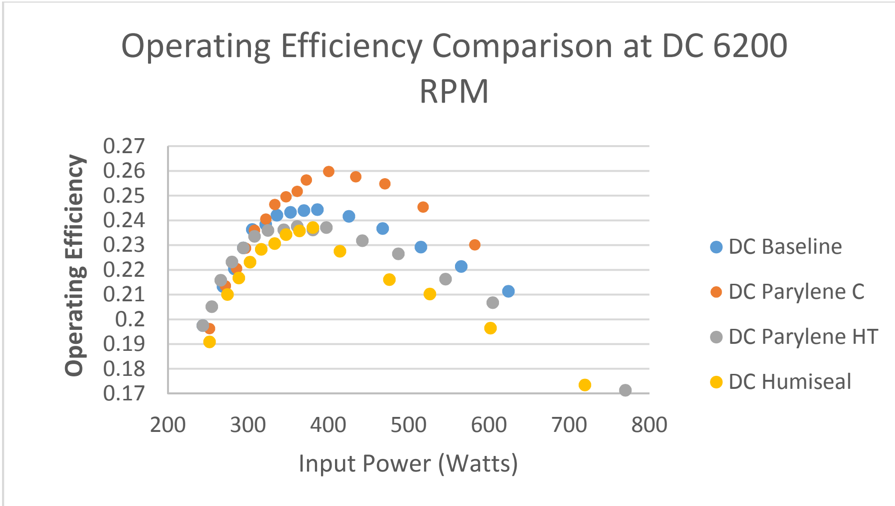
DC Parylene HT Pump Curve

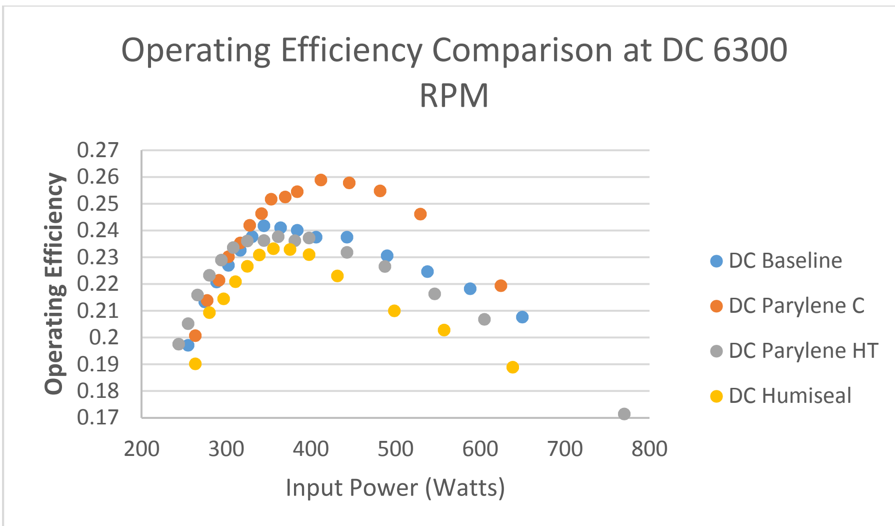


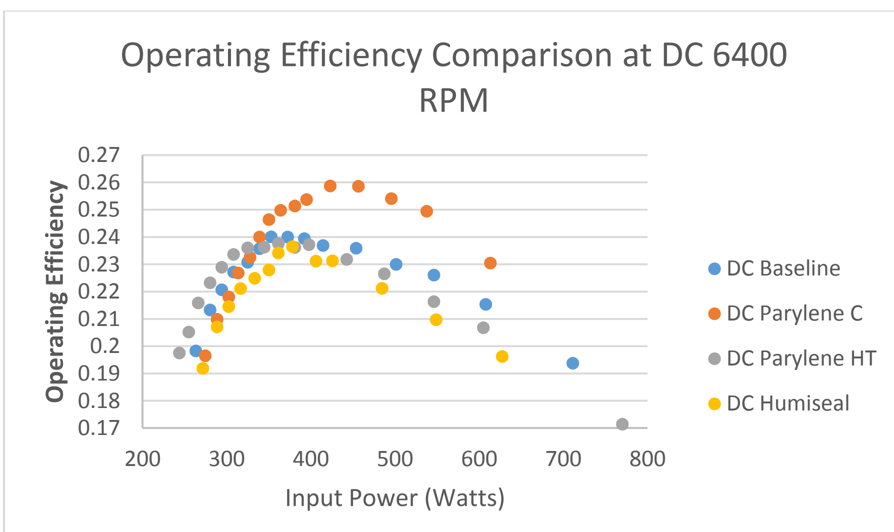
DC Humiseal Pump Curve

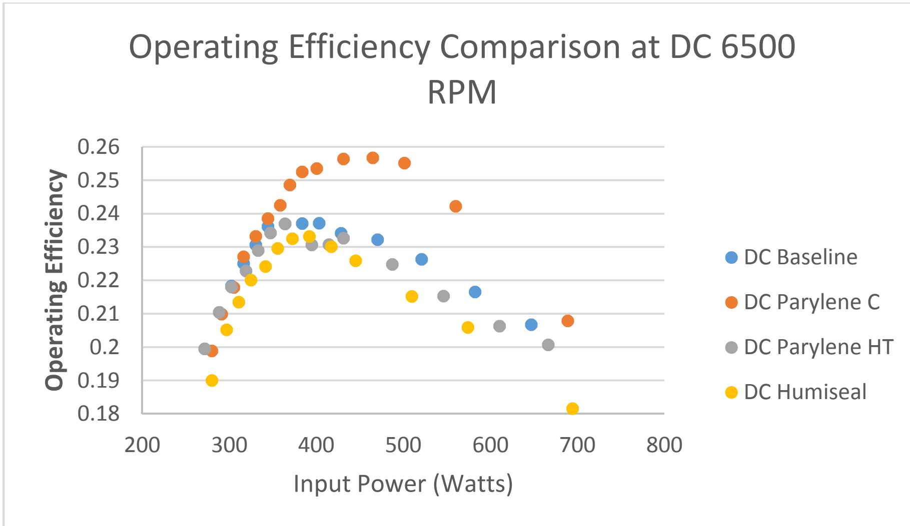


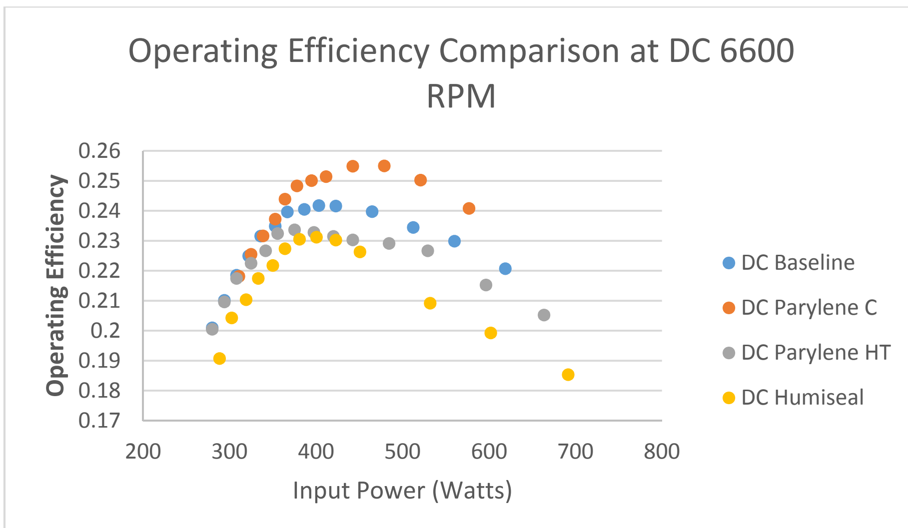
DC Operating Efficiency Comparison Curves

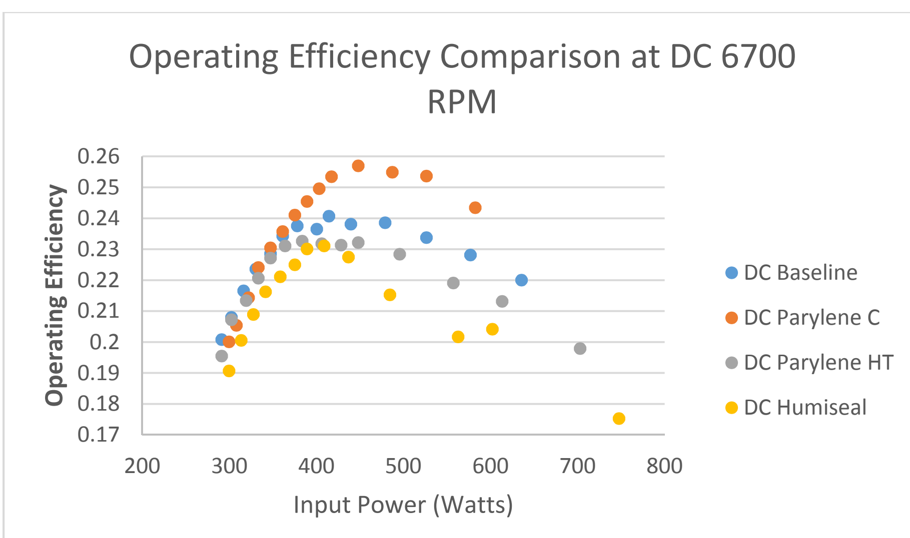


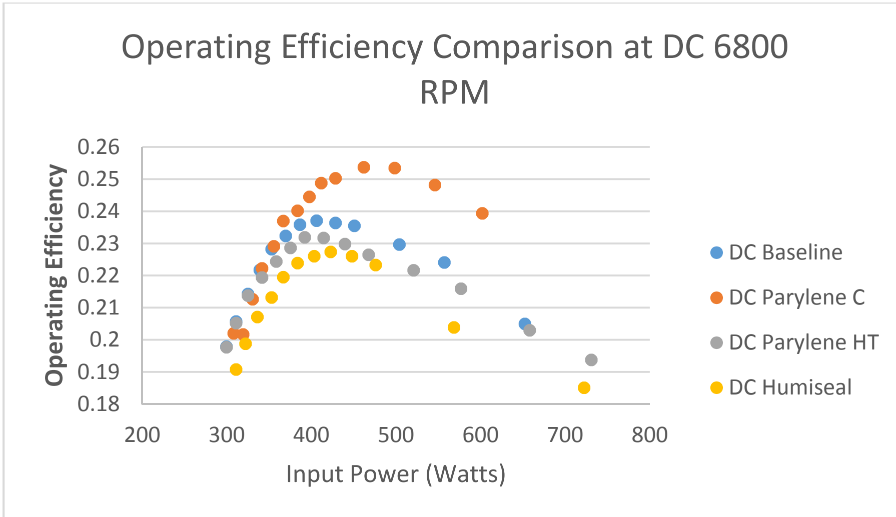


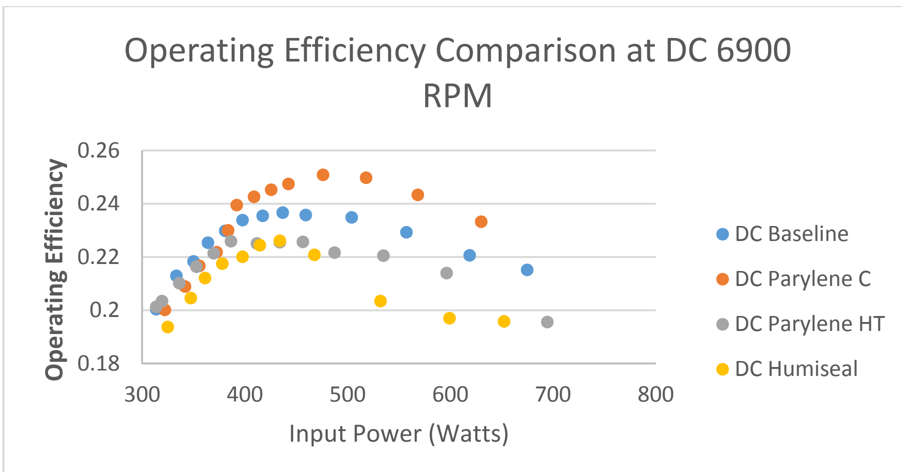


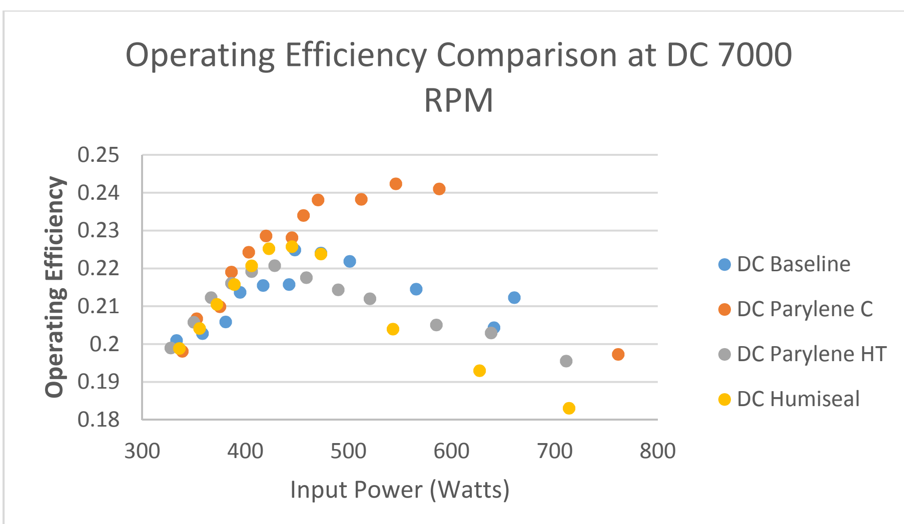

Operating Efficiency Comparison at DC 6500 RPM
Operating Efficiency
0.26
0.25
0.24
0.23
0.22
0.21
0.2
0.19
0.18
200
300
400
500
600
700
800
Input Power (Watts)
DC Baseline
DC Parylene C
DC Parylene HT
DC Humiseal


Operating Efficiency Comparison at DC 6600 RPM
Operating Efficiency
0.26
0.25
0.24
0.23
0.22
0.21
0.2
0.19
0.18
0.17
200
300
400
500
600
700
800
Input Power (Watts)
DC Baseline
DC Parylene C
DC Parylene HT
DC Humiseal


Operating Efficiency Comparison at DC 6700 RPM
Operating Efficiency
0.26
0.25
0.24
0.23
0.22
0.21
0.2
0.19
0.18
0.17
200
300
400
500
600
700
800
Input Power (Watts)
DC Baseline
DC Parylene C
DC Parylene HT
DC Humiseal


Operating Efficiency Comparison at DC 6800 RPM
Operating Efficiency
0.26
0.25
0.24
0.23
0.22
0.21
0.2
0.19
0.18
200
300
400
500
600
700
800
Input Power (Watts)
DC Baseline
DC Parylene C
DC Parylene HT
DC Humiseal

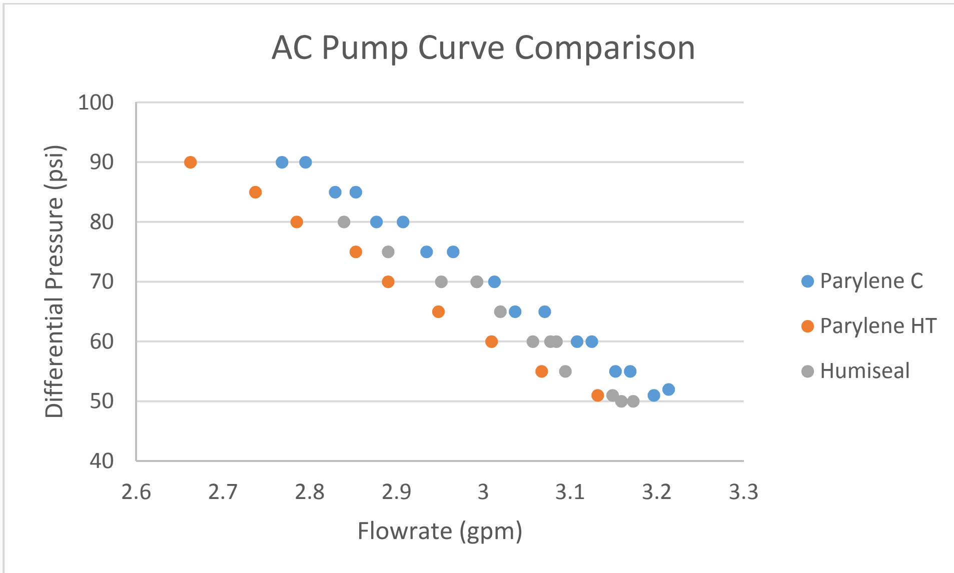

Operating Efficiency Comparison at DC 6900 RPM
Operating Efficiency
0.26
0.24
0.22
0.2
0.18
300
400
500
600
700
800
Input Power (Watts)
DC Baseline
DC Parylene C
DC Parylene HT
DC Humiseal


Operating Efficiency Comparison at DC 7000 RPM
Operating Efficiency
0.25
0.24
0.23
0.22
0.21
0.2
0.19
0.18
300
400
500
600
700
800
Input Power (Watts)
DC Baseline
DC Parylene C
DC Parylene HT
DC Humiseal

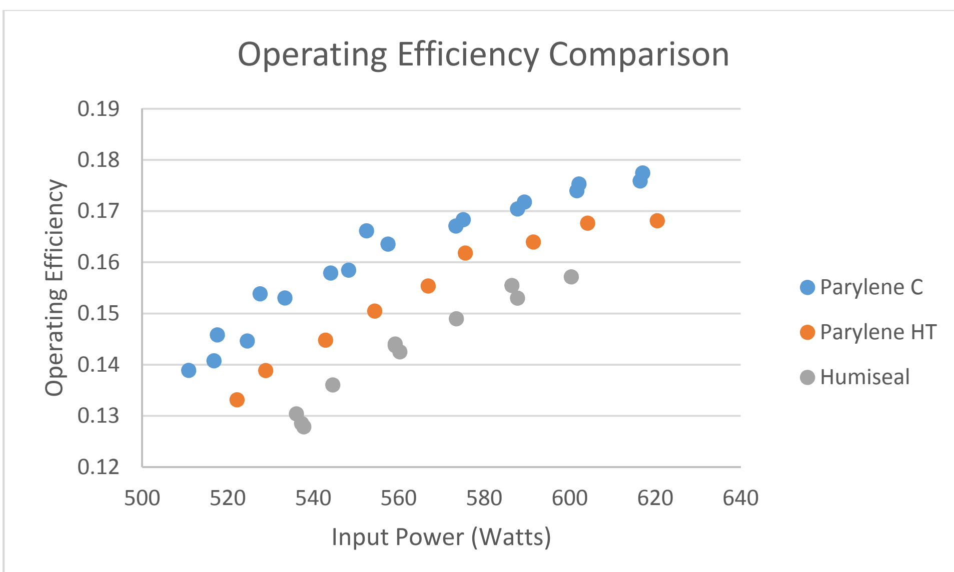
Appendix P: AC Graphs

- AC Pump Curve Comparison
- AC Operating Efficiency Comparison Curve

AC Pump Curve Comparison



AC Operating Efficiency Comparison Curve



Appendix Q- Technical Data Sheets

- Jaro Corp- Humiseal A133
- Specialty Coating Systems- Paralyene HT/Paralyene C
- GVD- Excilis
- Drywired- 101X

JARO CORP

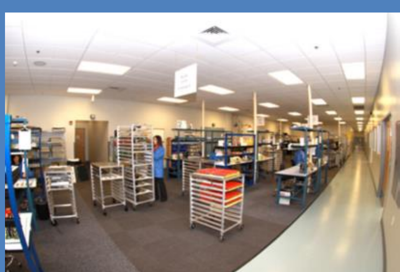
Conformal Conductive Dielectric Coatings Applications

Professionally applied Environmentally responsive since 1984

JARO 30th ANNIVERSARY 1984 - 2014

Jaro Corp. specializes in the application of functional coatings for the electronics industry. The use of conformal, conductive and dielectric coatings provides an economical solution for all of your environmental protection, EMI / RFI shielding and dielectric isolation requirements. By focusing solely on our core technology since 1984, we have gained the experience necessary to solve even the most challenging coating issues.

In 2007, Jaro Corp. moved into a new facility specifically designed with the needs of the coatings industry in mind. With 34,000 square feet of available production space, our new location helps us meet the increasing demands and requirements of our customers, while providing us with the space needed to support our continued growth.



Quality Control Standards

All work is performed and inspected to the following industry standards:

J-STD-001 **IPC-A-610**
IPC-CC-830 **MIL-I-46058**

JARO CORP

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Ipswich, MA 01938
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sales@jarocorp.com
www.jarocorp.com

ANAB ACCREDITED

ITAR Compliant International Traffic in Arms Regulations

Ask us about our fast track west coast processing

Our Facility

We designed our 34,000 square foot building to be used specifically for the application of functional coatings. Our extensive experience was instrumental in determining the features that would help us improve workflow, provide the handling / processing precautions important to our customers, reduce our impact on the environment and allow us to advance along with the latest technology.

ESD

Protecting our customers' circuit board assemblies from electrostatic discharge was a top priority in the design and outfitting of our facility. Conductive flooring and multiple paths to earth ground were incorporated throughout the building to guarantee the effectiveness of our extensive ESD system. The system is based on ANSI/ESD S20.20 – 1999 and includes ESD awareness training and the use of ESD wrist straps, heel straps and lab coats. In addition, all work surfaces, handling trays and carts are constructed of static dissipative material and are tested regularly.

Equipment

Jaro Corp. utilizes the latest manual and automated spray equipment technology to provide the best product possible. Coatings are manually applied in six production spray booths, each of which is dedicated to a specific coating type. To accommodate larger quantities, coatings are also applied using our computer-controlled selective coating lines. A separate laboratory is reserved for prototype runs and for research and development projects. Conventional, infrared and UV curing systems are employed to meet the requirements of any coating type.

Environment

Temperature and humidity are monitored and controlled through the use of multiple air make-up units. Each spray booth uses its own dedicated unit to guarantee the optimal conditions for the application of each specific coating type.

ISO 9001:2008* & *AS9100:2009 Certified

For more information regarding services provided by Jaro Corp.,

Please contact : John Rufo, Regional Sales Manager

FREE "Coat and Quote" Ask for details

johnrufo@jarocorp.com Phone: 760-889-9331

JARO CORP

Conformal Conductive Dielectric Coatings Applications

Professionally applied Environmentally responsive since 1984

JARO 30th ANNIVERSARY 1984 - 2014

Jaro Corp. has over 50 different coatings in stock at all times. Information on many of these products can be found on our website at: http://jarocorp.com/datasheets.html.

Conformal Coatings with *fast track processing*

Conformal coatings are dielectric materials applied to printed circuit boards or other electronic substrates to protect their circuitry from environmental stresses such as moisture, fungus, dust and corrosion. They also minimize dendritic growth and the electro migration of metal between conductors. These coatings work to significantly extend the life of electronic devices used in extreme environments.
Conformal coatings generally fall into four categories: acrylics, polyurethanes, silicones and epoxies. Each coating type has specific traits that ensure optimal performance under various conditions.

We work closely with all of our customers to help determine which type of coating best suits your needs.
Conformal coatings are applied by a variety of methods, including spraying, dipping and computer-controlled selective coating systems.

EMI / RFI Coatings

EMI/RFI coatings (electro-magnetic interference and radio-frequency interference) (EMI / RFI) shielding, are mainly inside plastic enclosures. These coatings can be used to either shield EMI / RFI emissions generated by the electronics within your device, or to protect the device from surrounding EMI / RFI interference. They are also used to add conductive surfaces to dielectric materials or to prepare substrates for plating applications.

Dielectric Coatings

A dielectric coating is a nonconductive, i.e., an insulating, coating. At Jaro Corp., we manufacture and apply our own dielectric coating: JARO 650 Series Polyimide. This coating is a proprietary polyimide thermoset material which features remarkable resistance to extreme temperatures, oxidative degradation, weathering and radiation. JARO 650 Series Polyimide also offers exceptional protection against abrasive and frictional wear, solvents and electricity— providing insulation of up to 3100 volts per mil.

Secondary Processes

Cleanliness testing: Jaro Corp. can test for the presence of ionic residues on circuit board assemblies using an Omegameter Ionograph 500 M SMD II ionic contamination tester.
Cleaning: We offer a variety of cleaning processes, including a terpene solvent wash, an IPA wash and a solvent wipe.
Underfilling / Staking / Potting: These common secondary operations can be performed to the most stringent specifications using any customer specified material.
Coating removal: Various chemical methods are used for either a partial or complete removal of conformal coating from PCBs. More resilient coatings may also be removed mechanically, using an ESD safe CCR2000 conformal coating removal station.

For more information regarding services provided by Jaro Corp.,

Please contact: John Rufo, Regional Sales Manager

FREE "Coat and Quote" Ask for details

johnrufo@jarocorp.com Phone: 760-889-9331

SPECIALTY COATING SYSTEMS™

Structural integrity.

SCS PARYLENE PROPERTIES

No other company understands Parylene coatings better than we do. SCS is the direct descendant of the companies that developed Parylene and began using it in commercial applications. We have been providing Parylene coating services, equipment and materials for over 40 years, as well as aggressively researching and developing new Parylene variants and application processes to find innovative coating solutions for customers' advanced technologies.

Introduction

Parylene is the name for members of a unique polymer series. The basic member of the series, Parylene N, is poly(para-xylylene), a completely linear, highly crystalline material. Parylene N is a primary dielectric, exhibiting a very low dissipation factor, high dielectric strength, and a low dielectric constant invariant with frequency. The crevice-penetrating ability of Parylene N is second only to that of Parylene HT®. The Parylene structures are shown in Figure 1.

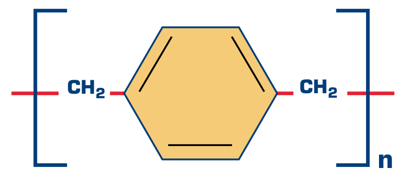
Parylene C, the second commercially available member of the series, is produced from the same raw material (dimer) as Parylene N, modified only by the substitution of a chlorine atom for one of the aromatic hydrogens. Parylene C has a useful combination of electrical and physical properties plus a very low permeability to moisture and corrosive gases.

Parylene D, the third available member of the series, is produced from the same raw material as the Parylene N dimer, modified by the substitution of chlorine atoms for two of the aromatic hydrogens. Parylene D is similar in properties to Parylene C with the added ability to withstand slightly higher use temperatures.

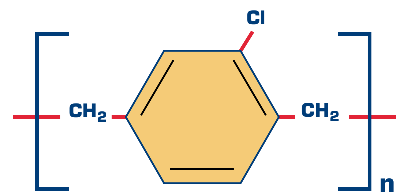
Parylene HT, the newest commercially available Parylene, replaces the alpha hydrogen atoms of the N dimer with fluorine. This variant of Parylene is useful in high temperature applications (short-term up to 450°C) and those in which long-term UV stability is required. Parylene HT also has the lowest coefficient of friction and dielectric constant, and the highest penetrating ability of the four variants.

Due to the uniqueness of vapor phase deposition, the Parylene polymers can be formed as structurally continuous films from as thin as several hundred angstroms to 75 microns.

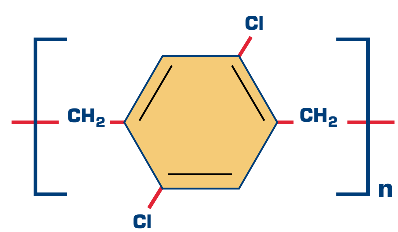
Figure 1. Parylenes N, C, D and Parylene HT Chemical Structures



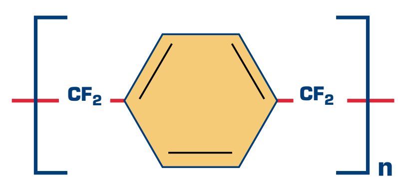
Parylene N



Parylene C

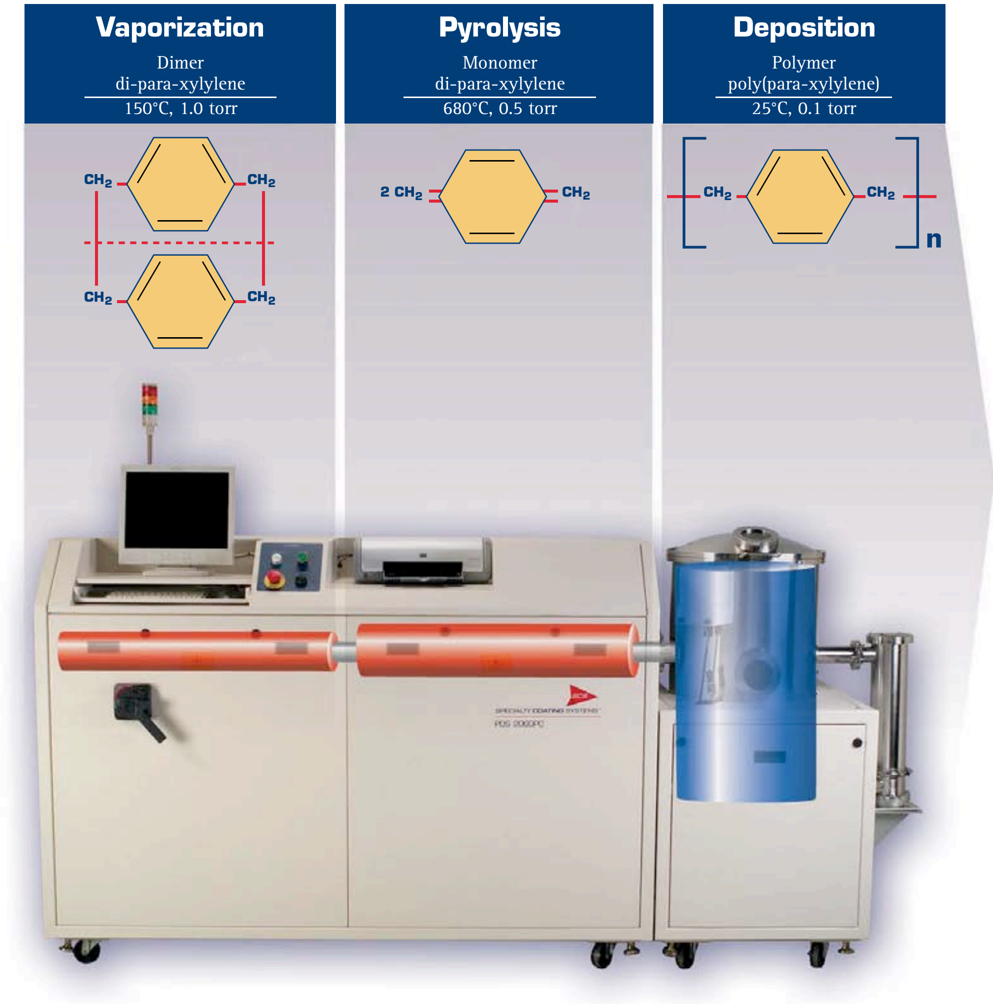


Parylene D



Parylene HT®

Figure 2. Parylene Vapor Deposition Polymerization (VDP)
(Parylene N illustrated)



The Deposition Process

The Parylene polymers are deposited by a process which resembles vacuum metallization, however, while vacuum metallization is conducted at pressures of 10^{-5} torr or below, the Parylenes are formed at around 0.1 torr. Under these conditions, the mean free path of the gas molecules in the deposition chamber is on the order of 0.1 cm. The deposition is not line-of-sight, all sides of an object to be coated are uniformly impinged by the gaseous monomer, resulting in a truly conformal, pinhole-free coating. Substrates to be coated are required to have only a reasonable vacuum tolerance.

The Parylene deposition process consists of three distinct steps as outlined in Figure 2.

The first step is the vaporization of solid dimer at approximately 150°C. The second step is the quantitative cleavage (pyrolysis) of the dimer vapor at the two methylene-methylene bonds at about 680°C, which yields the stable monomeric diradical, para-xylylene. Finally, the monomeric vapor enters the room temperature deposition chamber where it spontaneously polymerizes on the substrate. The substrate temperature never rises more than a few degrees above ambient.

No liquid phase has ever been isolated, therefore Parylene suffers none of the fluid effects that can cause pooling, flowing, bridging, meniscus or edge-effect flaws. Parylene also contains no solvents, catalysts or plasticizers that can leach or outgas from the coating.

Properties

The electrical, barrier, mechanical, thermal, optical, biocompatibility and other properties of Parylenes N, C, D and Parylene HT are discussed below. These properties are compared to those reported for other conformal coating materials such as acrylics, epoxies, polyurethanes and silicones.

A. Electrical Properties

The electrical properties of Parylene are shown in Table 1.

1. *Thin Film Dielectric Properties*
   One of the features of Parylene coatings is that they can be formed in extremely thin layers. The data in Table 1 show that Parylenes, even in very thin layers, have excellent dielectric withstanding voltages. It has also been demonstrated that the voltage breakdown per unit thickness increases with decreasing film thickness.

2. *Circuit Board Insulation Resistance*
   A critical test of the protection afforded by a Parylene coating is to coat circuit board test patterns (as described in MIL-I-46058C) and subject them to insulation resistance measurements during a temperature-humidity cycle (MIL-STD-202, methods 106 and 302). In brief, this test consists of 10 cycles (one cycle per day), with each cycle consisting of seven steps. The seven steps range from low temperature, low humidity (25°C, 50% RH) to more severe conditions (65°C, 90% RH). Resistance readings are taken initially and at the 65°C, 90% RH step for each cycle of the 10-day test.

   Results are shown in Table 2 for Parylene C coating thicknesses from 50.8 µm to 2.5 µm. It is interesting to note that even for the very thin coatings (2.5 µm), the insulation resistance values are about one order of magnitude above the prescribed specification.

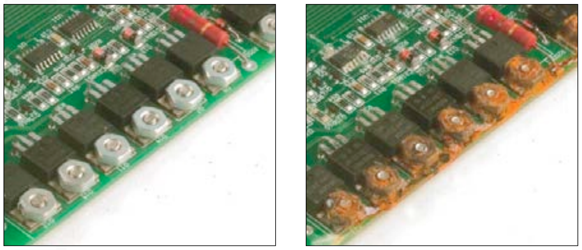
B. Barrier Properties and Chemical Resistance

1. *Barrier*
   The barrier properties of the Parylenes are given in Table 3. The water vapor transmission rates (WVTR) are compared with those of other conformal coating materials. The WVTR for Parylene C is superior to the most common polymeric materials.

   Circuit boards coated with SCS Parylene HT were salt-fog tested by an independent testing facility. The coated boards showed no corrosion or salt deposits after 144 hours of exposure in accordance with ASTM B117-(03) (see Figure 3). Boards coated with Parylene C exhibited similar results.

2. *Chemical Resistance*
   The Parylenes resist room temperature chemical attack and are insoluble in all organic solvents up to 150°C. Parylene C can be dissolved in chloro-napthalene at 175°C, and Parylene N softens at the solvent's boiling point (265°C). Both polymers are resistant to permeation by most solvents. Parylene HT films do not swell significantly with exposure to automotive chemicals and fluids, and there are no perceivable changes in the film's optical or mechanical properties.

Figure 3. Circuit boards after 144 hours of salt-fog exposure



Coated with SCS Parylene HT — *Uncoated*

Table 1. Parylene Electrical Properties

Properties	Method	Parylene N	Parylene C	Parylene D	Parylene HT	Acrylic (AR)[a,b]	Epoxy (ER)[a,b]	Polyurethane (UR)[a,b]	Silicone (SR)[a,b]
Dielectric Strength V/mil	1	7,000	5,600	5,500	5,400	3,500	2,200	3,500	2,000
Volume Resistivity ohm·cm, 23°C, 50% RH	2	1.4×10^{17}	8.8×10^{16}	1.2×10^{17}	2.0×10^{17}	1.0×10^{15}	1.0×10^{16}	1.0×10^{13}	1.0×10^{15}
Surface Resistivity ohms, 23°C, 50% RH	2	1.0×10^{13}	1.0×10^{14}	1.0×10^{16}	5.0×10^{15}	1.0×10^{14}	1.0×10^{13}	1.0×10^{14}	1.0×10^{13}
Dielectric Constant									
60 Hz	3	2.65	3.15	2.84	2.21	–	3.3 – 4.6	4.1	3.1 – 4.2
1 KHz		2.65	3.10	2.82	2.20	–	–	–	–
1 MHz		2.65	2.95	2.80	2.17	2.7 – 3.2	3.1 – 4.2	3.8 – 4.4	3.1 – 4.0
Dissipation Factor									
60 Hz	3	0.0002	0.020	0.004	<0.0002	0.04 – 0.06	0.008 – 0.011	0.038 – 0.039	0.011 – 0.02
1 KHz		0.0002	0.019	0.003	0.0020	–	–	–	–
1 MHz		0.0006	0.013	0.002	0.0010	0.02 – 0.03	0.004 – 0.006	0.068 – 0.074	0.003 – 0.006

a. *Handbook of Plastics, Elastomers, and Composites*, Chapter 6, "Plastics in Coatings and Finishes," 4th Edition, McGraw Hill, Inc., New York, 2002.

b. *Conformal Coating Handbook, Humiseal Division, Chase Corporation, Pennsylvania, 2004.*

Test Methods:
1. ASTM D 149
2. ASTM D 257
3. ASTM D 150

(International conversion chart on back cover.)

Table 2. Parylene C Circuit Board Screening

Insulation Resistance (ohms), MIL-STD-202, method 302

Parylene Thickness (µm)	Initial Measurement	Precycle	Step 5 Cycle 3	Step 5 Cycle 7	Step 5 Cycle 10	Step 7 Cycle 10
	25°C, 50% RH	25°C, 90% RH	65°C, 90% RH	65°C, 90% RH	65°C, 90% RH	25°C, 90% RH
50.8	2.0×10^{14}	1.8×10^{13}	2.3×10^{12}	2.5×10^{11}	1.4×10^{11}	7.5×10^{12}
38.1	5.0×10^{14}	2.4×10^{13}	8.6×10^{11}	1.9×10^{11}	1.1×10^{11}	5.2×10^{12}
25.4	2.0×10^{14}	9.2×10^{12}	8.1×10^{11}	3.4×10^{11}	1.3×10^{11}	6.3×10^{12}
12.7	5.0×10^{14}	2.3×10^{13}	4.1×10^{12}	2.4×10^{11}	1.1×10^{11}	4.7×10^{12}
7.6	5.0×10^{14}	2.7×10^{13}	4.4×10^{12}	9.0×10^{10}	4.7×10^{10}	2.9×10^{12}
2.5	5.0×10^{14}	3.2×10^{10}	1.3×10^{11}	1.1×10^{11}	6.4×10^{10}	2.3×10^{12}

(International conversion chart on back cover.)

Table 3. Parylene Barrier Properties

Polymer	Gas Permeability at 25°C, (cc·mm)/(m²·day·atm)[a] N_2	O_2	CO_2	H_2	Water Vapor Transmission Rate (g·mm)/(m²·day)
Parylene N	3.0	15.4	84.3	212.6	0.59[b]
Parylene C	0.4	2.8	3.0	43.3	0.08[c]
Parylene D	1.8	12.6	5.1	94.5	0.09[b]
Parylene HT	4.8	23.5	95.4	–	0.22[d]
Acrylic (AR)	–	–	–	–	13.9[e]
Epoxy (ER)	1.6	2.0 – 3.9	3.1	43.3	0.94[e]
Polyurethane (UR)	31.5	78.7	1,181	–	0.93 – 3.4[e]
Silicone (SR)	–	19,685	118,110	17,717	1.7 – 47.5[e]

a. ASTM D 1434
b. ASTM E 96 (90% RH, 37°C)
c. ASTM F 1249 (90% RH, 37°C)
d. ASTM F 1249 (100% RH, 38°C)
e. *Coating Materials for Electronic Applications*, Licari, J.J., Noyes Publications, New Jersey, 2003.

(International conversion chart on back cover.)

C. Thermal, Cryogenic, Vacuum and Sterilization Properties

1. *Thermal*

   Based on an Arrhenius extrapolation of test data, Parylene C is expected to survive continuous exposure to air at 80°C for 10 years (100,000 hours). In oxygen-free atmospheres, or in the vacuum of space, the Parylenes are expected to perform similarly on continuous exposure to 220°C. Parylene HT has been demonstrated to survive continuous exposure to air at 350°C.

   In all cases, higher temperature shortens useful life. If the requirements for your application are near or exceed this time-temperature-atmospheric conditions envelope, it is recommended that you test the complete structure under conditions more closely resembling the actual conditions of intended use.

   General thermal properties are summarized in Table 4.

2. *Cryogenic*

   Unsupported 50.8 µm films of Parylene C can be flexed 180° six times at -200°C before failure occurs. Comparable films of polyethylene, polyethylene terephthalate and polytetrafluoroethylene fail at three, two and one flexes, respectively.

   Steel panels coated with Parylene C and chilled in liquid nitrogen at -196°C withstood impacts of more than 11.3 N•m in a modified Gardner falling ball impact test. This compares with values of about 28.2 N•m at room temperature.

   Supported films of Parylene N withstand thermal cycling from room temperature to -269°C without crackling, peeling from substrate, or degrading of electrical properties.

3. *Vacuum Stability*

   Vacuum tests conducted at the Jet Propulsion Laboratory show that total weight loss at 49.4°C and 10^{-6} torr was 0.12% for Parylene C and 0.30% for Parylene N. Volatile collectible, condensable material values were less than 0.01% (the limit of sensitivity of the test) for both polymers.

4. *Parylene Sterilization*

   Parylenes N, C, and Parylene HT were exposed to a variety of sterilization methods, including steam autoclave, gamma and e-beam irradiation, hydrogen peroxide plasma and ethylene oxide. Post-sterilization analysis compared the impact of these agents on sterilized samples versus unsterilized control samples. Further details on the sterilization tests can be reviewed in the SCS Biomedical Coating Technologies brochure.

D. Physical and Mechanical Properties

Physical and mechanical properties of the Parylenes are summarized in Table 5. Because of their high molecular weight (~500,000) and because the melting temperatures and crystallinity are high, the Parylenes cannot be formed by conventional methods such as extrusion or molding. Solubility in organic or other media, except at temperatures above 175°C, is so low that they cannot be formed by casting.

Impact resistance is high when the Parylene polymers are supported on test panels. Gardner falling ball impact tests on 25.4 µm thick Parylene C coated steel "Q" panels are in the 28.2 N•m range.

Wear index values (measured on a Taber® Abraser machine using CS-17 "Calibrase" wheel with 1,000 gram weight) were 22.5 for Parylene C and 8.8 for Parylene N. By comparison, polytetrafluoroethylene is 8.4, high impact polyvinylchloride is 24.4, epoxy is 41.9 and polyurethane is 59.5.

Parylene may be annealed to increase cut-through resistance, increase hardness and improve abrasion resistance. This is the result of polymer density and an increase in crystallinity.

Table 4. Parylene Thermal Properties

Properties	Method	Parylene N	Parylene C	Parylene D	Parylene HT	Acrylic (AR)	Epoxy (ER)	Polyurethane (UR)	Silicone (SR)
Melting Point (°C)[a]	1	420	290	380	>500	85 – 105[b]	NA	~170[b]	NA
T5 Point (°C) (modulus = 690 MPa)	2, 3	160	125	125	377	–	110	~30	~125
T4 Point (°C) (modulus = 70 MPa)	2, 3	>300	240	240	>450	–	120	–	~80
Continuous Service Temperature (°C)	–	60	80	100	350	82[b]	177[b]	121[b]	260[b]
Short-Term Service Temperature (°C)	–	80	100	120	450	–	–	–	–
Linear Coefficient of Thermal Expansion at 25°C (ppm)	4	69	35	38	36	55 – 205[b,c]	45 – 65[b,c]	100 – 200[b,c]	250 – 300[b,c]
Thermal Conductivity at 25°C (W/(m•K))	5, 6	0.126	0.084	–	0.096	0.167 – 0.21[c,d]	0.125 – 0.25[c,d]	0.11[c,d]	0.15 – 0.31[c,d]
Specific Heat at 20°C (J/(g•K))	–	0.837	0.712	–	1.04	1.04[b]	1.05[b]	1.76[b]	1.46[b]

a. The temperature at which heat flow properties show signs of change.

b. *Handbook of Plastics, Elastomers, and Composites,* Chapter 6, "Plastics in Coatings and Finishes," 4th Edition, McGraw Hill, Inc., New York, 2002.

c. *Coating Materials for Electronic Applications, Licari, J.J.,* Noyes Publications, New Jersey, 2003.

d. *Lange's Handbook of Chemistry,* 5th Edition, McGraw Hill, Inc., New York, 1999.

Test Methods:
1. DSC
2. Taken from Secant modulus-temperature curve (except Parylene HT)
3. ASTM 5026 (Parylene HT only)
4. TMA
5. ASTM C 177 (except Parylene HT)
6. ASTM 1461 (Parylene HT only)

(International conversion chart on back cover.)

Table 5. Parylene Physical and Mechanical Properties

Properties	Method	Parylene N	Parylene C	Parylene D	Parylene HT	Acrylic (AR)[a,b]	Epoxy (ER)[a,b]	Polyurethane (UR)[a,b]	Silicone (SR)[a,b]
Secant (Young's) Modulus (psi)	1, 2	350,000	400,000	380,000	370,000	2,000 – 10,000	350,000	1,000 – 100,000	900
Tensile Strength (psi)	3	7,000	10,000	11,000	7,500	7,000 – 11,000	4,000 – 13,000	175 – 10,000	350 – 1,000
Yield Strength (psi)	3	6,100	8,000	9,000	5,000	–	–	–	–
Elongation to Break (%)	3	Up to 250	Up to 200	Up to 200	Up to 200	2 – 5.5	3 – 6	>14	100 – 210
Yield Elongation (%)	3	2.5	2.9	3.0	2.0	–	–	–	–
Density (g/cm³)	4	1.10 – 1.12	1.289	1.418	1.32	1.19	1.11 – 1.40	1.10 – 2.50	1.05 – 1.23
Index of Refraction (n_D^{23})	5, 6	1.661	1.639	1.669	1.559	1.48	1.55 – 1.61	1.50 – 1.60	1.43
Water Absorption (% after 24 hrs)	7	Less than 0.1	Less than 0.1	Less than 0.1	Less than 0.01	0.3	0.05 – 0.10	0.6 – 0.8	0.1
Rockwell Hardness	8	R85	R80	R80	R122	M68 – M105	M80 – M110	68A – 80D (Shore)	40A – 45A (Shore)
Coefficient of Friction									
Static	9	0.25	0.29	0.33	0.15	–	–	–	–
Dynamic		0.25	0.29	0.31	0.13	–	–	–	–

a. *Coating Materials for Electronic Applications,* Licari, J.J., Noyes Publications, New Jersey, 2003.

b. *Handbook of Plastics, Elastomers, and Composites,* Chapter 6, "Plastics in Coatings and Finishes," 4th Edition, McGraw Hill, Inc., New York, 2002.

Test Methods:
1. ASTM D 882 (except Parylene HT)
2. ASTM D 5026 (Parylene HT only)
3. ASTM D 882
4. ASTM D 1505
5. Abbe Refractometer (except Parylene HT)
6. ASTM D 542 (Parylene HT only)
7. ASTM D 570
8. ASTM D 785
9. ASTM D 1894

(International conversion chart on back cover.)

E. Optical Properties and Radiation Resistance

1. *Optical Properties*

Parylene exhibits very little absorption in the visible region and is, therefore, transparent and colorless. Below wavelengths of about 280 nm, all the Parylenes absorb strongly, as shown in Figure 4.

The Fourier Transform infrared spectra for 12.7 μm Parylene films are shown in Figures 5, 6, 7 and 8.

2. *Radiation Resistance*

Parylenes N, C, D and Parylene HT films show a high degree of resistance to degradation by gamma rays in vacuum. Tensile and electrical properties were unchanged after 1,000 kGy dosage at a dose rate of 16 kGy/hr. Exposure in air leads to rapid embrittlement.

Although stable indoors, Parylenes N, C and D are not recommended for long-term use when exposed to direct sunlight (UV light). Parylene HT exhibits significant resistance to UV light, with no property degradation from accelerated exposures of up to 2,000 hours in air.

Figure 4. Ultraviolet Spectra of Parylenes N, C, D and Parylene HT

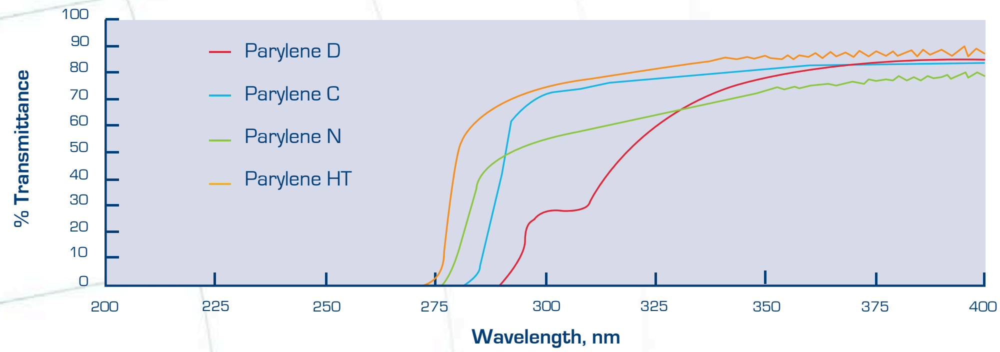


Figure 5. FTIR Absorbance Spectrum of Parylene N

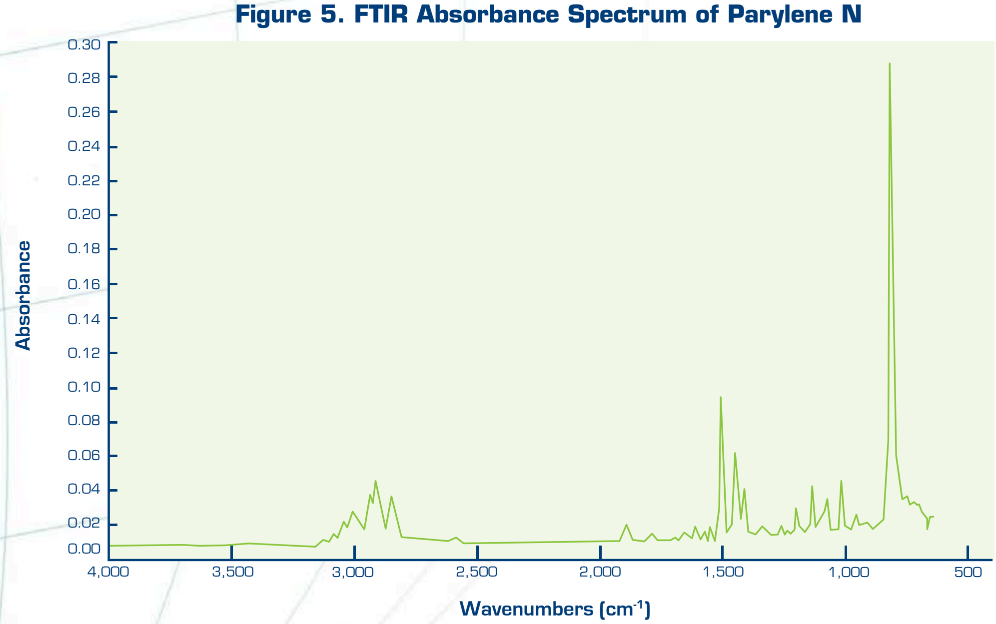


Figure 6. FTIR Absorbance Spectrum of Parylene C

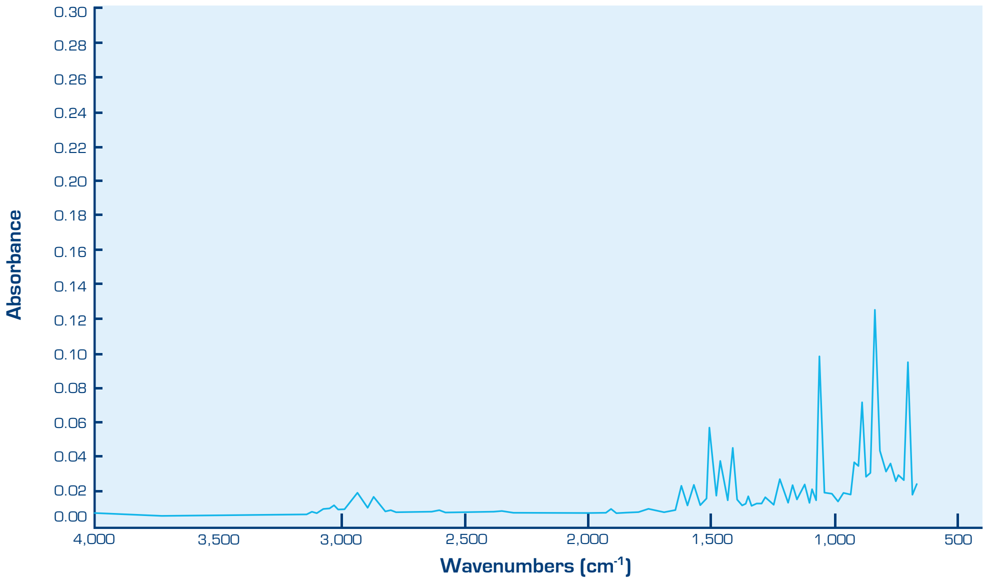


Figure 7. FTIR Absorbance Spectrum of Parylene D

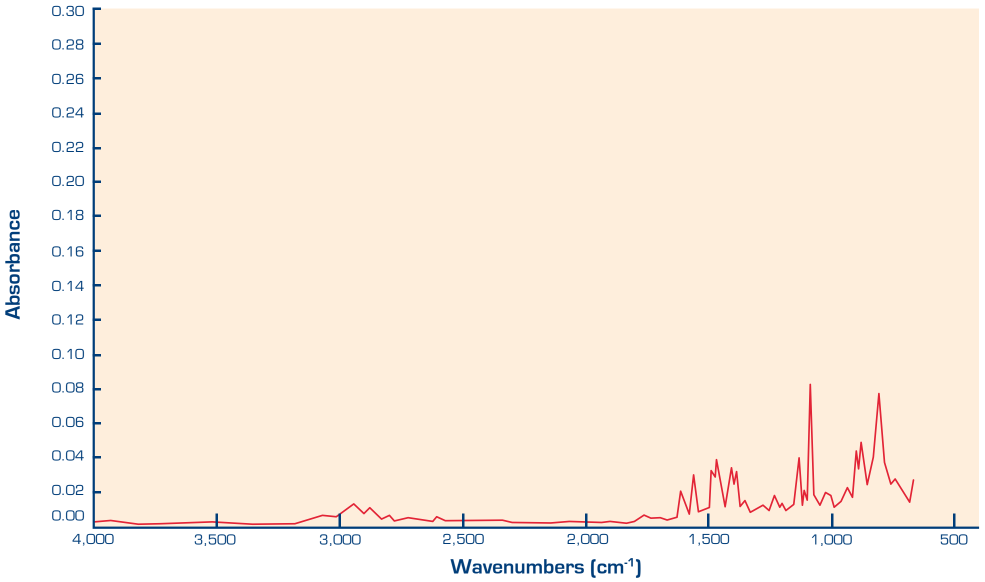
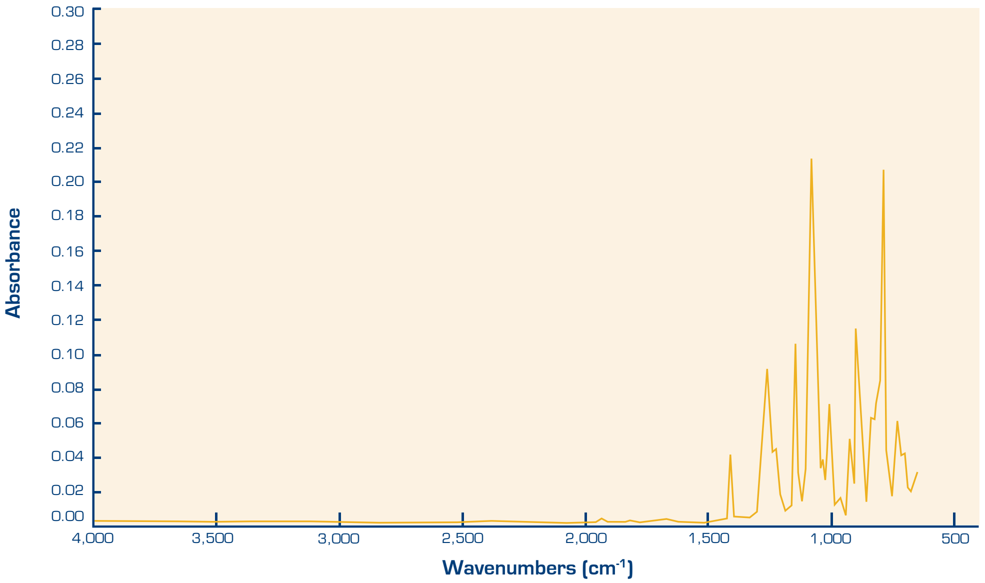


Figure 8. FTIR Absorbance Spectrum of Parylene HT



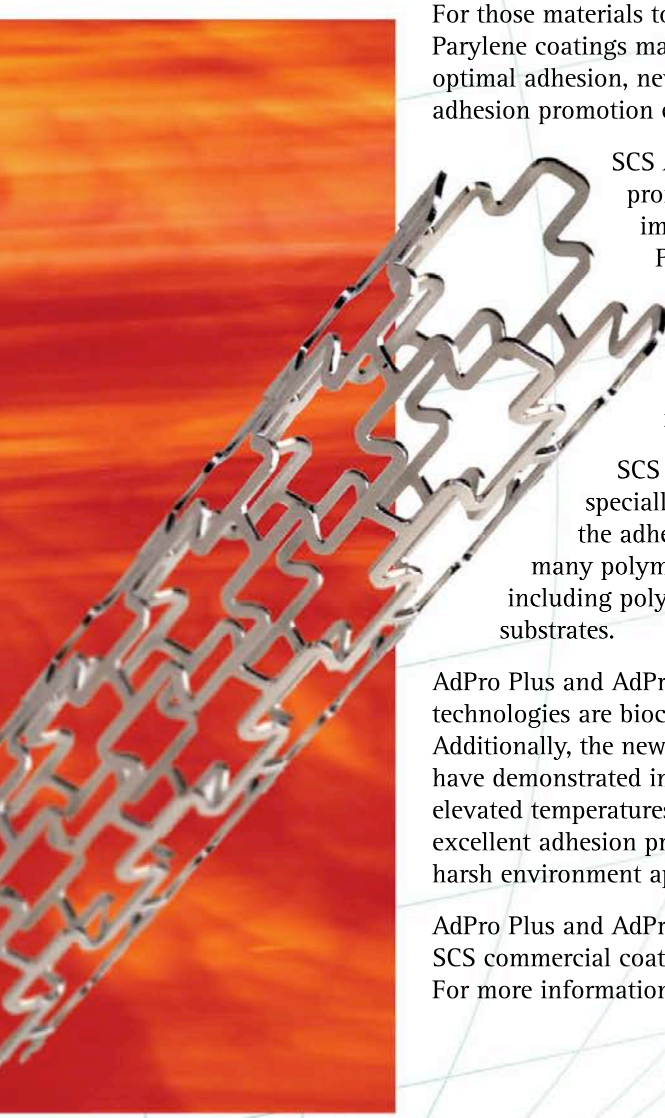
F. Biocompatibility and Biostability

SCS Parylenes N, C and Parylene HT have been tested according to the Biological Evaluation requirements of ISO 10993. Further, the biocompatibility and biostability of SCS Parylenes have been demonstrated in a wide range of medical coating applications over the past four decades.

Adhesion

In the medical device, electronics, automotive and military/aerospace industries, various thin-film coatings are utilized for surface modification, protection and biostability to enhance the overall reliability of the device and end product. Factors such as surface contamination, presence of oxide layers and low surface energy substrates can lead to poor adhesion and the reduction in the effectiveness of coatings used in these devices.

Optimal adhesion of Parylene to a wide variety of substrates, including metal, plastic, elastomer, glass, paper, etc., is commonly achieved by a treatment with A-174 silane prior to Parylene coating. For those materials to which Parylene coatings may not achieve optimal adhesion, newer methods of adhesion promotion exist.



Stent courtesy of MeKo, Germany

SCS AdPro Plus® adhesion promotion technology improves adhesion of Parylene coatings to metallic substrates, including titanium, stainless steel, gold, chromium and solder mask, to name a few.

SCS AdPro Poly® was specially engineered to solve the adhesion challenges of many polymeric materials, including polyimide (Kapton®) substrates.

AdPro Plus and AdPro Poly adhesion technologies are biocompatible. Additionally, the new adhesion technologies have demonstrated improved stability at elevated temperatures, making them excellent adhesion promotion tools for harsh environment applications.

AdPro Plus and AdPro Poly are available to SCS commercial coating service customers. For more information, contact SCS.

Applications

Automotive

Ultra-thin SCS Parylene coatings protect critical sensors, circuit boards and other electronic components from harsh chemicals, fluids and gases. They also protect components at high temperatures encountered during prolonged use in automotive and heavy-duty engines and systems.

Electronics

SCS Parylene coatings are conformal and uniform, ensuring complete coverage of circuit boards, ferrite cores and other electronics packages, such as MEMS, labs on chips and sensors. SCS Parylene C coatings have been shown to mitigate the formation of metallic whiskers, OSEs (odd shape eruptions) and dendrites.

Medical

SCS Parylenes, listed in the FDA's Biomaterials Compendium, provide an ideal surface modification for implantable and non-implantable devices such as catheters, seals, stents, cochlear implants, surgical tools, pacemakers and components. The coatings protect devices and components from moisture, biofluids and biogases and serves as a biocompatible surface for tissue contact.

Military/Aerospace

SCS Parylenes offer extreme tolerance of severe environments and are used in many military and aerospace applications, including equipment for international space programs. Parylene coatings are also excellent for electronics used in aerospace applications and military vehicles and equipment, to protect against elements such as dust, sand, moisture, and chemical and biological agents.

Standards and Certifications

Each SCS customer has very unique and exact product and performance specifications that must be met. SCS experience and expertise is leveraged on every project – from the initial planning phases, to advanced engineering, to the development of customer-specific application processes – in order to meet the most challenging customer specifications and quality requirements.

The following is a brief overview of the standards and certifications to which SCS and/or SCS Parylene coatings comply:

- SCS maintains AS9100 Rev. C certified coating centers.
- SCS maintains ISO 9001:2008 certified coating centers.
- SCS maintains ISO 14644 cleanrooms.
- SCS coating centers are experienced in the Production Parts Approval Process (PPAP).
- SCS Parylenes N, C and Parylene HT are ISO 10993 and USP Class VI certified.
- SCS maintains comprehensive U.S. FDA Device and Drug Master Files that may be referenced in FDA submissions by SCS commercial coating service customers.
- SCS Parylenes meet the requirements of IPC-CC-830.
- SCS Parylenes are listed on the QPL for MIL-I-46058C.
- SCS Parylene C is UL (QMJU2) recognized.
- SCS Parylene coating services, raw materials and equipment comply with the European Union's RoHS Directive.

If you have any questions or would like more detail on the information presented here, please contact SCS.

Product Safety

Specialty Coating Systems has compiled the information contained herein from what it believes are authoritative sources and believes that it is accurate and factual as of the date printed. It is offered solely as a convenience to its customers and is intended only as a guide concerning the products mentioned. Because the user's product formulation, specific use application, and conditions of use are beyond SCS control, SCS makes no warranty or representation regarding the results that may be obtained by the user. It shall be the responsibility of the user to determine the suitability of any products mentioned for the user's specific application. SCS urges you to review, prior to use, the Material Safety Data Sheets (MSDS) for SCS products mentioned herein. These documents are available by contacting SCS.

This information is not to be taken as a warranty or representation for which Specialty Coating Systems assumes legal responsibility nor as permission to practice any patented invention without a license.

Table 6. International Conversions

To convert g/cm^3 to kg/m^3, multiply by 1,000.
To convert psi to MPa, divide by 145.
To convert J/(g•K) to Cal/(g•K), divide by 4.184.
To convert W/(m•K) to Cal/(s•cm•K), divide by 418.4.
To convert (g•mm)/(m^2•day) to (g•mil)/(100in^2•day), multiply by 2.54.
To convert (cc•mm)/(m^2•day•atm) to (cc•mil)/(100in^2•day•atm), multiply by 2.54.

Innovative solutions for advanced technologies.

Specialty Coating Systems leads the industry in providing Parylene solutions for its global customers' advanced technologies. SCS is a direct descendant of the companies that originally developed Parylene, and we have more than 40 years of experience and expertise that we leverage on every project for our customers—from the initial planning phases, to advanced engineering, to the development of application processes.

Our worldwide resources include highly experienced sales engineers, some of the world's foremost Parylene specialists, and expert manufacturing personnel, working in eleven state-of-the-art coating facilities around the globe. In addition to Parylene coating services, we design and manufacture industry-leading Parylene deposition systems; liquid spray, dip and spin coating systems; ionic contamination test systems; and UV and thermal cure units. Our equipment is used in environments that range from university and research labs to high-volume production applications.

Our extensive and proactive approach to production and quality requirements—testing, validating, documenting and processing—provides our customers peace of mind and minimizes their resources needed to meet the most challenging industry specifications and quality requirements.

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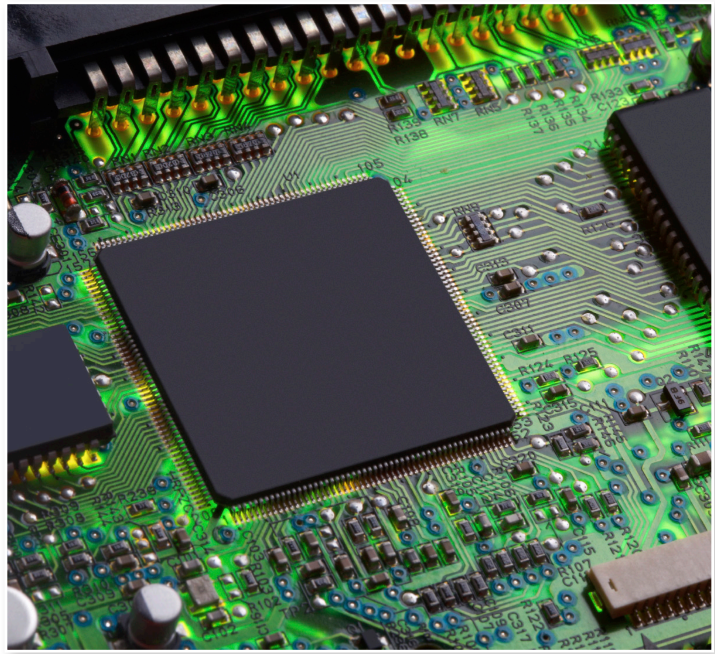
Ultrathin Coatings

Environmental Protection for Electronics



Reliable Protection

Whether operating advanced radar systems or a touch-screen phone, today's customers call for electronics that perform in all environments reliably, without failure.

GVD has developed a simple one-step coating process for advanced electronics protection. Our conformal Exilis coatings streamline manufacturing and extend the life of coated electronics, preventing damage from harsh environments.

In partnership with our customers, GVD creates solutions to complex coating problems in the defense, aerospace, medical and automotive industries. Our room-temperature vapor-deposition process produces high-quality thin films that protect a variety of products, including:

- Printed circuit boards and assemblies
- RF and microwave electronics
- Sensors
- LEDs
- MEMS

GVD Features and Benefits

- **High Conformality**—Coats complex surface features
- **Excellent Adhesion**—Simplifies demasking, enhances protection from water ingress
- **Low-Temperature Process**—Coats delicate structures and temperature-sensitive materials
- **No Drying or Curing**—Products are ready for immediate use
- **Low Dielectric Constant**—Negligible impact on RF performance
- **Hydrophobic**—Protects electronics from moisture
- **Solvent Free**—Eliminates pooling, buildup or thinning of coating in critical areas

GVD Coating Properties

Property	Standard	Value
Salt-Fog Test	MIL-STD-810G	Pass
Insulation Resistance	MIL-I-46058C	Pass
Flammability	UL94-HB	Pass
Water Absorption (%)	ASTM D570-98	<0.1
Adhesion (on silicon)	ASTM D3359 B	5.0B
Dielectric Constant (1 MHz)	NA*	2.62
Dissipation Factor (1 MHz)	NA*	0.001

*NA—Testing performed using MDC Model 802B-150 mercury probe

Table 1

Proven Performance

GVD's electronics-encapsulation coatings meet all MIL-I-46058C testing standards and pass a majority of the IPC-CC-830 testing standards.

Contact us at:

inquiries@gvdcorp.com
Telephone: (617) 661.0060
Fax: (617) 812.0553
Visit us at www.gvdcorp.com

Coated Product Performance Data

Properties	Method	GVD Exilis	Parylene C (XY)	Acrylic (AR)	Epoxy (ER)	Urethane (UR)	Silicone (SR)
Dielectric Constant	1						
100 Hz		2.66	3.15	—	3.3–4.6	4.1	3.1–4.2
1 kHz		2.64	3.10	—	—	—	—
1 MHz		2.62	2.95	2.7–3.2	3.1–4.2	3.8–4.4	3.1–4.0
Dissipation Factor	2						
100 Hz		0.0027	0.020	0.04–0.06	0.008–0.011	0.038–0.039	0.011–0.02
1 kHz		0.0014	0.019	—	—	—	—
1 MHz		0.0012	0.013	0.02–0.03	0.004–0.006	0.068–0.074	0.003–0.006
Dielectric Strength V/mil	3	7,200	5,600	3,500	2,200	3,500	2,000
Volume Resistivity Ohm-cm, 23°C, 50% RH	2	4.0×10^{15}	1.4×10^{16}	1.0×10^{14}	1.0×10^{16}	1.0×10^{13}	1.0×10^{15}
Use Temperature							
Continuous (°C)		200	80	100	150	100	180
Short-Term (°C)		250	115	125	200	125	260

Test Methods (XY, AR, ER, UR, SR):
1. ASTM D 149
2. ASTM D 257
3. ASTM D 150

Test Methods (Exilis):
1–3. MDC 802B-150 mercury probe

Table 2

Insulation Resistance (megaohms) MIL–STD–202, Method 106

GVD Coating	Initial Measurement	1st Cycle	4th Cycle	7th Cycle	10th Cycle	After 24 Hours 25°C/50% RH
2.3 µm Bilayer	2.1×10^7	9.5×10^5	1.3×10^6	1.8×10^6	1.8×10^6	8.1×10^7

Table 3

Dielectric Properties
GVD's ultrathin conformal coatings are deposited in submicron-to-micron-thick layers, fractions of the thickness of conventional coatings such as Parylene C. Thinness combined with a low dielectric constant results in a minimal impact on high frequency RF signals.

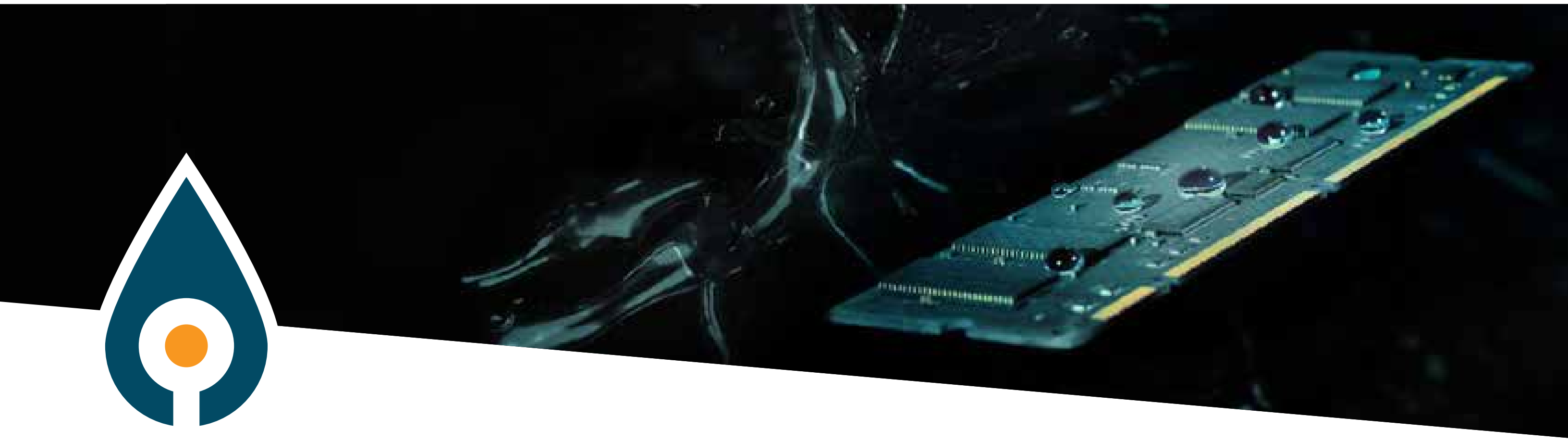
Insulation Resistance
Results in Table 3 indicate that even with the very thin 2.3 micron bilayer coating, the insulation resistance values are well above the 1.0×10^4 megaohm requirement per MIL-STD-202, Method 106.

Adhesion
Both GVD's Exilis and PTFE coatings have unsurpassed adhesion to coated surfaces, with no risk of coating peel-back or delamination, as demonstrated by ASTM D3359 Method B and Nanoscratch testing.

Environmental Protection
Exilis coatings have demonstrated stability in salt water under continuous bias for 8+ years. Effective protection in salt-fog environments have been seen with GVD Exilis coatings as thin as 750 nanometers. Coated boards showed no corrosion or salt deposits after 48 hours of salt-fog exposure per MIL-STD-810G, Method 509.5.

Chemical Resistance
GVD's Exilis demonstrates solvent resistance to acetone and isopropyl alcohol. GVD's optional PTFE top coat has excellent chemical and solvent resistance.

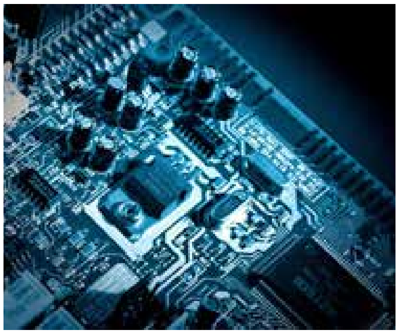
Thermal Stability
GVD's Exilis coating is stable for continuous use up to 200°C and can be treated to operate continuously up to 250°C. GVD's PTFE top coat is stable for continuous use up to 260°C.



DRYWIRED® 101X is our patented hydrophobic and oleophobic, PFOS & PFOA-free fluoropolymer liquid chemical solution refined by material scientists and chemists over the past 30 years. 101X is the ideal solution for nanocoating electronic components at the manufacturing (OEM) level. 101X dries in minutes to a thin, transparent film with excellent anti-wetting properties against a variety of liquids including consumer beverages and chemicals such as heptane, toluene and acetone. 101X film provides corrosion resistance to copper, aluminum, ceramic, steel and tin. It can be implemented into the manufacturing line during component production as a dip, spray or aerosol without the need of costly machinery. 101X is made in the USA and can be customized for adhesion to a variety of substrates including plastics, vinyl, polycarbonate, metals, glass, ceramics and oxide surfaces among others.

Uses:

- Fluidic & Biomedical Devices
- Drones
- PC Boards
- MR Heads
- Micro Motors
- Ball Bearing Tracks
- MEMS
- Inkjet Print Heads
- Hard Disk Drive Components
- Atomic Force Microscopes
- TFT-LCD
- Films
- Membranes



Solution Properties:

All values determined at 25°C unless otherwise specified)
Appearance: Visually clear and colorless Color: 1
Solids: 1 to 20 %
Boiling Point: 61°C
Freeze Point: -135°C
Critical Density: 555 kg kg/m3
Liquid Density: 1475 kg/m3
Viscosity: 0.375 centistokes
Heat of Vaporization: 111.6 B.P., kJ/kg
Flash point: None
Surface Tension: 13.6 dynes/cm
Specific Heat: 1200 J/kg-K
Dielectric Strength: 28 kV (RMS) @ 0.1 inch gap
Dielectric Constant: 7.39 @ 100 Hz- 10MHz
Dissipation Factor: 0.035 @ 500 MHz
Thermal Conductivity: 0.0675 W/m-K
Volume Resistivity: 3.29 x 109 ohm-cm
Solubility of Water in Fluid: 95 ppm by weight
Solubility of Air in Fluid: 53% volume air @ 1 atm per volume fluid ml
Toxicity: low toxicity, inhalation non-toxic
Application: Dip/Spray/Roll

Film Properties:

Appearance: Clear, colorless, non-fluorescing film
Contact Angle to Oil: 60 Degrees
Contact Angle to Water: 120 Degrees
Surface Tension: 8-10 dynes/cm (air-dried); 5-7 dynes/cm (heated)
Specific Gravity: 1.72
Hardness: #2 pencil
Melting Point: 75°C (with a second transition at 115°C) Flammability: non-burning
Heat Stability: 150°C (continuous); 250°C (one hour)
Refractive Index: 1.35
Dielectric strength: 2500 volts/25 micrometers
Dielectric Constant: 2.25 @ 100 KHz
Dissipation Factor: 0.016 @ 100 KHz
Volume Resistivity: 4.5 (10)15 ohm-cm
Toxicity: non-toxic

Variations:

DryWired®'s 101X solutions can be customized and optimized for adhesion to a variety of different substrates including plastics, vinyl, polycarbonate, metals, glass, ceramics, and oxide surfaces among others. The different formulations can be provided upon request at concentration levels ranging from .5% - 20%.