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An Investigation Into The Cmparability Of Common Jet Engine Materials With Next Generation Biofuels

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AN INVESTIGATION INTO THE COMPARABILITY OF COMMON JET
ENGINE MATERIALS WITH NEXT GENERATION BIOFUELS

by

Paul Yoon, B.Eng
Aerospace Engineering
Ryerson University, 2009

A thesis presented to Ryerson University

in fulfillment of the
requirements for the degree of
Masters of Applied Science
Aerospace Engineering

Toronto, Ontario, Canada

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Masters of Applied Science, 2012

Paul Yoon, Aerospace Engineering

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Abstract

Growing concerns regarding the environmental impact of burning fossil fuels and energy independence has spurred the transportation industry into developing a more eco-friendly and sustainable way to travel. The most promising frontier in this endeavor is the development of alternative fuels that will significantly reduce the carbon footprint of our current engines with little or no modifications required. The effect that one of these frontier fuels may have, camelina based biofuel, on various fuel system materials was evaluated in this report in accordance with ASTM D4054 in the form of a 50:50 mixture. The materials went through an immersion process at varying temperatures and tested under the numerous standards outlined by the American Society for Testing and Materials (ASTM). The results were compared to a benchmark Jet A1 fuel since the effects of this fuel on current fuel system materials is extensively known. The purpose of this research is to determine the viability of using a 50:50 biofuel mixture in current aircraft fuel systems by evaluating the physical properties after being fuel treated. The results showed that the biofuel mixture affected the non-metallic materials in varying degrees, while not affecting the metallic materials.

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CHAPTER 1

Introduction

1.1 Overview

As population grows and air traffic becomes increasingly dense, a method to curb our carbon footprint is becoming an increasingly pressing issue in the industry, government, and amongst public sentiment. Aviation presently represents about 2% of global emissions. This may be a relatively small slice of the emissions pie, but even a relatively small reduction in emissions can lead to great positive effects on the environment. It is also important to note that aircraft are contributing to emissions at a much higher altitude than surface level vehicles. Hence the effect on the atmosphere may or may not have a larger impact on our climate when compared to other modes of transport. Currently the most prevalent source of our energy is dug up from the ground, known as fossil fuel, and processed into aviation grade kerosene. We have been enjoying the benefits of this source of fuel as a relatively cheap way to provide energy for almost a century. However, times are changing. Fossil fuels are becoming i) increasingly more expensive to extract, ii) crude oil deposits which once were thought to be limitless are being depleted, and iii) the combustion of fossil fuels are causing environmental changes to the extent of which we can yet accurately predict. As such, there have been many investigations into the viability of fuels derived from a renewable source, in particular a renewable source which does not take away crop or land designated for human food consumption.

Any new introductions of fuels whether it is in the form of fuel additives or a completely new fuel mixture would require extensive compatibility investigation to determine whether or not the changes made to the base fuel are detrimental to existing aircraft fuel systems. This is the

question that this report attempts to address. By performing a comparison analysis between standard Jet A1 and a camelina based biodiesel blend we can observe changes in physical behaviour of various fuel system related materials. The biofuel blend being used for this experiment is a 50/50 mixture of camelina biodiesel and standard Jet A1 fuel.

In order to conduct a comparison analysis a series of standard tests are utilized as outlined in ASTM D4054, which is an operational handbook used as an overhead guide. ASTM D4054 outlines the fuel system materials to be included in the analysis, as well as their associated soaking temperatures and the particular testing to be undertaken. The scope of this report is as follows:

- i) Developing testing methodologies inclusive of: specimen preparation, soaking preparation, and test practices.
- ii) Determining the workability of laboratory equipment and achieving expected functionality.
- iii) Conducting material tests based upon ASTM test standards.
- iv) Evaluation of the resulting data collected for determination of the material compatibility of the Biofuel 50/50 to fuel system materials.

1.2 Chapter Synopsis

Chapter 2 - Literature reviews and discussion on the history of biofuels, physical properties of the various fuel system materials, and the effects of sustained contact of fuels on the various fuel system materials. It will present various supporting articles in relation to the compatibility research.

Chapter 3 - Overview of the materials and preparations will be provided in this chapter. A synopsis of the various materials that are investigated in this research is outlined. Specimen preparation methods are detailed in this chapter.

Chapter 4 - Overview of the test program will be provided in this chapter. The various materials to be tested will be defined, along with the associated soaking temperatures and test requirements outlined by ASTM D4054 and the sub-documents. A detailed procedural outline will be provided, along with identification of equipment used. Test methodology is thoroughly explained in this section.

Chapter 5 - The results are summarized in this chapter and the experimental data is presented in graphical, table or pictorial form.

Chapter 6 - Noted observations and further discussions are made in this chapter. The pass or fail status of the material is defined in this chapter for all applicable tests of the materials. Trending patterns are also discussed as well as other significant observations.

Chapter 7 - Final comments and closing statements are presented in this chapter.

CHAPTER 2

Literature review

2.1 Introduction

The purpose of this research was to determine the efficacy of a bio-based Biodiesel/Jet A1 mixture in the fuel systems components of aircrafts. The search for a renewable source of jet fuel that leaves little to no carbon footprint has intensified in the last decade due to a host of accumulating factors. Primarily of which is the ever increasing cost of crude oil which is the base source of the bulk majority contemporary fuels used in today's aircraft. Factoring in our environment and the growing movement to mitigate climate change and we now have significant pressure to discover better ways to fuel our way from place to place. Altering the fuel is the first step in improving carbon footprint as it requires the least amount of modifications to present-day aircrafts, thereby decreasing any initial cost burdens placed on aircraft operators and simplifies implementation into the current system. Biofuels should therefore be sourced from articles that are either a renewable source or a waste product that can be converted to be useful as a propellant.

The numbers of source candidates that meet this requirement are slim. Some examples include using algae, camelina, tallows, jatropha, and other waste oils. Of these fuel candidates, the most promising fuel source by far is currently biodiesel derived from camelina and jatropha oil. Fuels which are synthesized from these sources have very common chemical properties with each other, and therefore their effects on fuel system components will reveal similar characteristics. Jatropha oil is derived from the jatropha plant which produces a very oily seed that can be crushed to extract the oils and processed to develop biodiesels suitable to be used in aircraft

engines. *Jatropha* is a plant that is highly toxic, and has the ability to grow in relatively nutritionally poor and dry areas. However, plants grown in such nutrient deficient conditions demonstrate smaller yields than if it were in nutritionally richer soils. Therefore, a heavy emphasis is currently placed on the search for an acceptable source for bio-based fuels (Tomes D. 2011).

2.2 History of Biofuels and Alternative Energy

The leading technology for converting a variety of carbon-based materials into liquid fuels is the Fischer-Tropsch (F-T) process (Marsh G. 2008). Invented in Germany in the 1920s, this versatile system first converts feedstock to a synthetic gaseous mix of mainly carbon, hydrogen and oxygen called syngas. This is then catalysed into liquid hydrocarbon, which is subsequently refined into a range of synfuels including jet fuel. Significant drawbacks of the F-T system are its cost and carbon dioxide emissions. Gasifying the initial feedstock is energy intensive and therefore expensive. Converting coal or gas to liquid (CTL and GTL) hydrocarbons produces more CO₂ even than emitted in refining crude oil (assuming that the CO₂ is not sequestered and stored). While a military organisation might be prepared to accept the cost and ‘own goal’ in environmental terms for the sake of an assured fuel supply, this course is clearly not ideal. Far better, it would seem, to use plant-derived biofuels along with wastes and other biomass, both as the feedstock and as the energy source for the process, thereby reducing CO₂ emissions by 70 to 90% (Marsh G. 2008).

Alternatives to food plant-derived fuels are the focus of research taking place around the world. Some are produced from waste and other organic feed stocks. Others are based on oils generated by micro-organisms, in particular algae – the organisms responsible for the blooms that grow on ocean surfaces and the scum that floats on ponds. The National Renewable Energy Laboratory

(NREL) in the United States estimates that high lipid algae could produce up to three times more oil than soybeans on an equivalent area and resource basis (Marsh G. 2008). *Jatropha* is also discovered to be a very attractive candidate for the development of a plant-derived fuel for the aforementioned reasons in the previous paragraphs. Its' seeds are known to have 25% to 35% of extractable oil by weight and are used as a significant fuel source in India and Southeast Asia (Tomes D. 2011).

2.3 Earlier Development of Material-Fuel Compatibility Studies

In aircraft fuel systems, fuel comes into contact with a wide variety of materials. Biodiesel is chemically different from that of diesel derived from petroleum. Petro-diesel is a mixture of hydrocarbons, while biodiesel is a mixture of fatty acid esters. The material compatibility using conventional petroleum based fuels have long been established. However, there is much less information available on the compatibility of fuel system elastomers with biodiesel. It has been reported in *Biodiesel Compatibility with Carbon Steel and HDPE Parts: Fuel Processing Technology* (Maru MM, et al. 2009) that degradation of certain elastomers is one of the main issues related to material incompatibility in biodiesel. Combustion characteristics of biofuels are different from those of regular fuels due to: differences in fuel flow, physical phase change, fuel atomization to chemical reaction, and heat exchange. In addition to combustion issues, replacing fossil-based fuels with biofuels can lead to other concerns about engine performance, durability and fuel storage (W.E.C. 2010).

An article by Bessee and Fey (Bessee GB, Fey JP. 1997) investigated how the introduction of methyl soyester and diesel blends affected the tensile strength, elongation, hardness and swelling of several common elastomers. They showed that nitrile rubber, nylon 6/6, and high-density polypropylene showed changes in physical properties. Telfon, Viton 401-C and Viton GFLT

were unaffected. An article titled *Biodiesel Research* (Shafer A. 1994) found that methylesters can cause swelling of triloburtyl-dilene and nitrile rubbers. The reason for the effect on nitrile elastomers when subjected to biodiesel fuels may be due to the fuel containing more carboxylic groups as compared to those in petrodiesel. Elastomers tend to degrade more by these carboxylic polar groups of biodiesel (Haseeb A. 2010).

An experimental study was performed by the University of Malaya (Haseeb A. 2010) regarding the compatibility of three different elastomer materials: nitrile rubber (NBR), polychloroprene (PR), and Fluoro-Viton A with a palm derived biofuel. Three different concentrations were investigated in this research: B0 (zero percent biofuel), B10 (10% biofuel), and B100 (100% biofuel) for 500 hours. The study then performed experimental tests at the end of the immersion period by measuring changes in mass, volume, hardness, tensile strength and elongation as shown below:

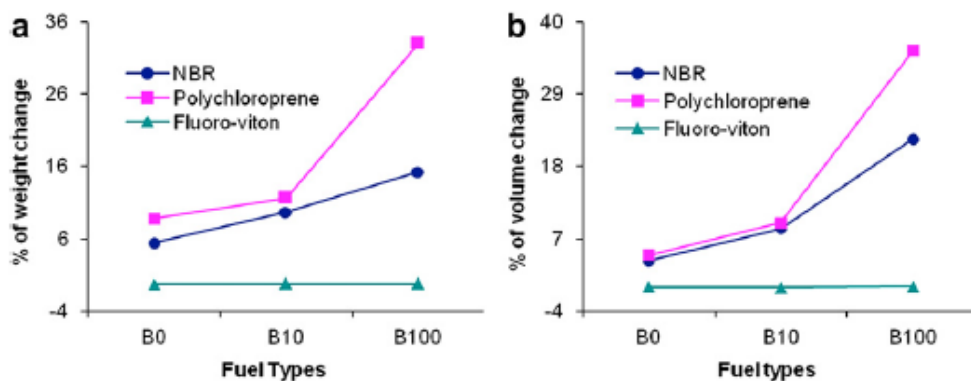


Figure 2.1 - (a) weight and (b) volume of different elastomers after immersion at room temperature for 500h (Haseeb A. 2010)

Figure 2.1 clearly shows how the increase in concentration of biofuels used in the soaking process leads to significant increases in swelling. The second figure further demonstrates how increasing fuel concentration affects the elastomers being studied. NBR seems to show an

increase in swelling as the concentration is elevated, while PR demonstrates a remarkable decrease by more than 50%. Fluoro-Viton A seems to exhibit statistically no change due to concentration levels, as well as virtually no change due to temperature elevations. The same case can be made for the hardness results provided as shown in the figure below.

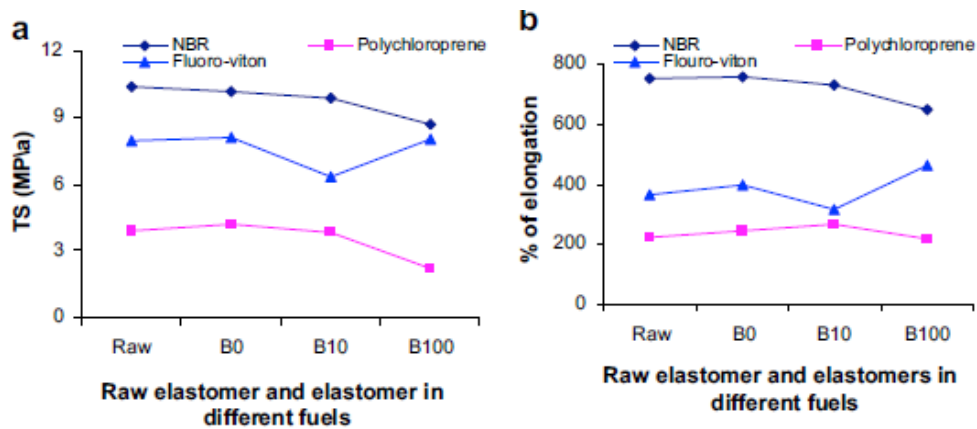


Figure 2.2 - (a) Tensile Strength and (b) Elongation of the Raw Elastomer and Elastomers from Different Fuels after Immersion at Room Temperature for 500h (Haseeb A. 2010)

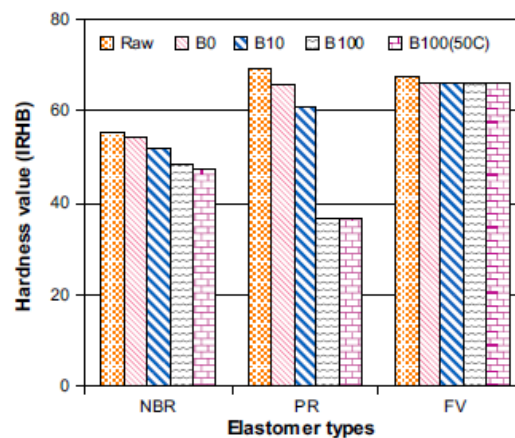


Figure 2.3 - Changes in Hardness of Elastomers in Different Blends after Immersion at Different Conditions for 500h (Haseeb A. 2010)

The previous study seems to indicate the particular vulnerability of nitrile elastomers to bio-based fuels. This is particularly of interest to our research primarily because our test specimens

comprise of nitrile based materials. The research paper written by the Defence Research Establishment Atlantic/Dockyard Laboratory (Hiltz J. 2003) provides further insight into the effects of, in this case JP-5 aviation fuel, with that of various rubbers.

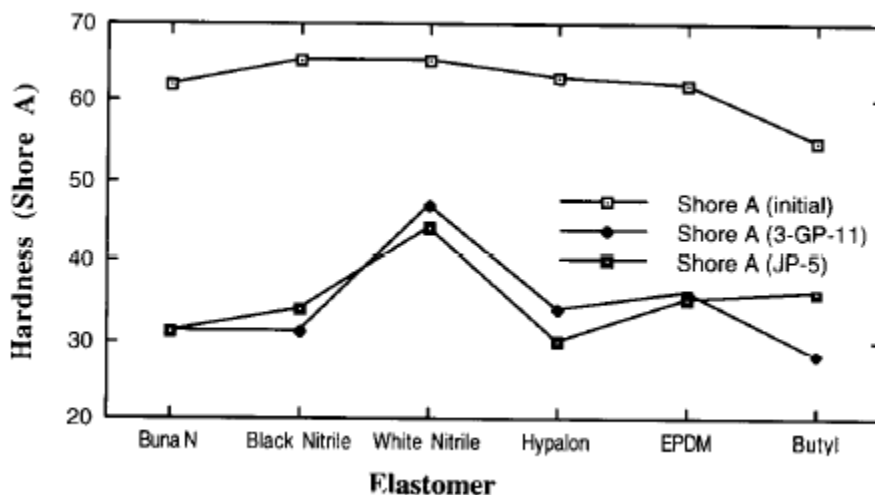


Figure 2.4 - Shore A hardness of six elastomers before and after exposure to fuels (Hiltz J. 1993)

Table 2 in the article by Hiltz (1993) shows how the hardness and weight drops after immersion in the JP-5 fuel. Focusing on the nitrile, we see that the hardness value drops nearly 50% and sheds just over 2% in weight. Keeping in mind that bio-based fuels according to Haseeb (2010) degrade nitrile polymers much more rapidly than petrol-based fuel, this material will be of particular interest during the course of the experimentation. The article written by J.A. Hiltz (1993) attempts to explain this phenomenon by stating that the “immersion of a rubber in a fluid may also result in the leaching of additives such as plasticizers from the rubber. Examination of the plots of fractional weight gain of the Buna N and black nitrile rubbers immersed in JP-5 against the square root of immersion time... indicate that the samples reached a maximum weight and then started to lose weight. Gas chromatography/ mass spectrometric analysis of a sample of JP-5 used as the immersion fluid indicated that dioctyl phthalate plasticizer was being leached from these rubbers.” (Hiltz, J.1992)

Another article titled: *Elastomer selection for bio-fuel requires a systems approach* (Micallef G. 2009) investigates biofuel effects on various elastomer compounds. In this case, the study looks at fluorosilicone and fluorocarbon elastomers using five different test fuels of varying qualities. The test that we are concerned with however is the test performed with the B30 biofuel mixture made with rapeseed oil, which is a natural methyl ester.

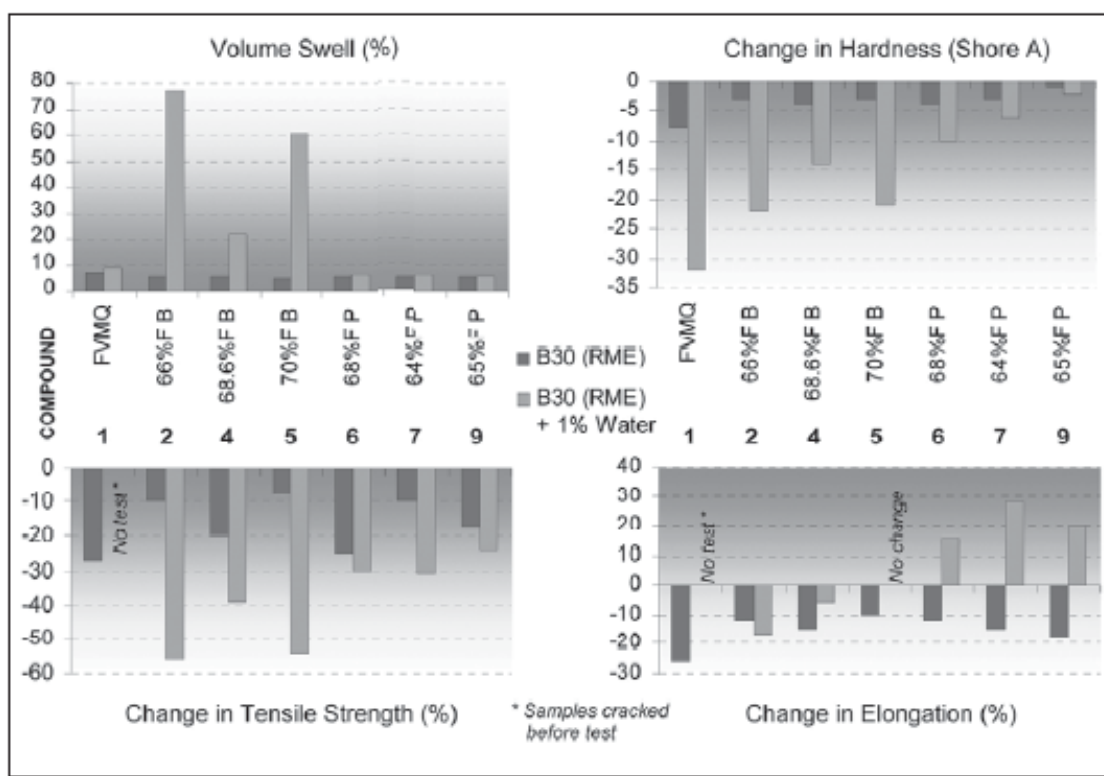


Figure 2.5 - The results of Immersion tests comparing the effect of B30 blend of bio-diesel with B30 + 1% water for 336 hours at 150C (Micallef G. 2009)

The results show a large deterioration in properties for compounds 2, 4 and 5, which are all bisphenol cured fluorocarbon. Figure 2.6 illustrates the extent of the volume change for the test pieces together with blistering of some of the compounds. It has been suggested that the water contaminant causes hydrolysis of the esters found in biodiesel and the subsequent formation of carboxylic acids. The carboxylic acids in conjunction with the metal oxides contained in bisphenol cured FKM cause the deterioration of the polymer via dehydrofluorination (Micallef G.

2009). Unlike bisphenol cured FKM peroxide cured compounds do not require metal oxides for good vulcanisation. None of the peroxide compounds in this study contain metal oxides hence the deterioration in B30 + 1% water is significantly less. The only fluorosilicone tested showed the highest deterioration in this test with the test pieces disintegrating before a stress-strain reading could be obtained. This demonstrates that it is very important for the material selection to take account of the actual working conditions and that water contamination of the diesel must be considered in the material selection (Micallef G. 2009).

We should then see trends and patterns similar to ones found in the articles above. Especially ones that involve the use of bio-based fuel composed of methyl esters. We can observe from a study performed by Chulalongkorn University (Trakarnpruk W, 2008) regarding the immersion of NBR, HNBR, NBR/PVC, acrylic rubber, co-polymer FKM, and terpolymer FKM, which are all materials used commonly in pumps, seals, fuel hoses, and filters.

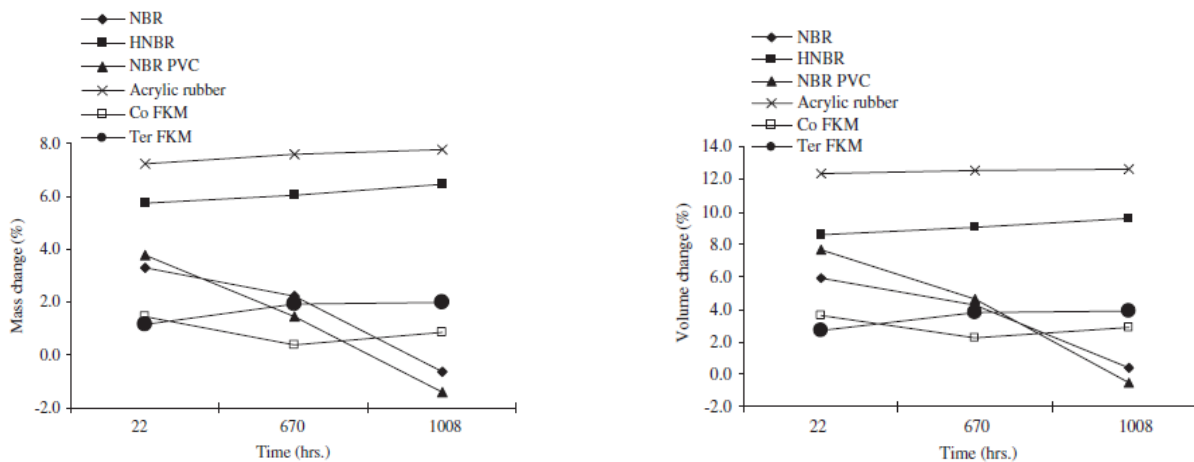


Figure 2.6 - Mass Change and Volume Change results of elastomers (Trakarnpruk W, 2008)

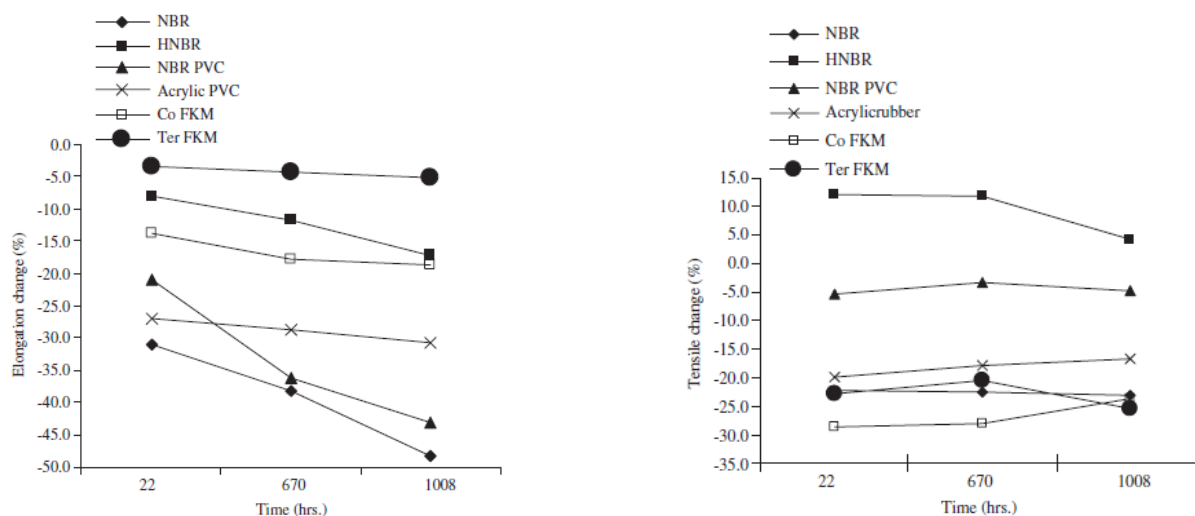


Figure 2.7 - Elongation Change and Tensile Change results of elastomers (Trakarnpruk W, 2008)

“Biodiesel was tested as a 10% blend with a base fuel (B10) to evaluate its impact on the performance of elastomers in fuel system component. This includes fuel system O-rings and hose materials. Elastomer compatibility testing includes six types of elastomers (NBR, HNBR, NBR/PVC, acrylic rubber, co-polymer FKM, and terpolymer FKM). Tests were performed at 100 1C for 23, 670, and 1008 h followed by examination (% mass change, % volume change, % hardness change, tensile change, and elongation change). Mass change and volume change of elastomers after immersion in B10 blend at 100C are presented in Figures 2.7 and 2.8. Both changes show similar trends. Among the elastomers tested, acrylic rubber shows the highest change, followed by HNBR while the fluroelastomers, co-KFM and ter-KFM show the lowest change. Acrylic rubber has carboxylic groups which can absorb oil. For NBR and NBR/PVC, they show negative change with immersion time. This is due to the absorption of oil by the elastomer and resulted in the extraction of soluble components such as plasticizers from the elastomer. Biodiesel functions as a solvent. The increase in volume or swelling resulted as the extent of liquid absorption usually exceeds that of extraction.

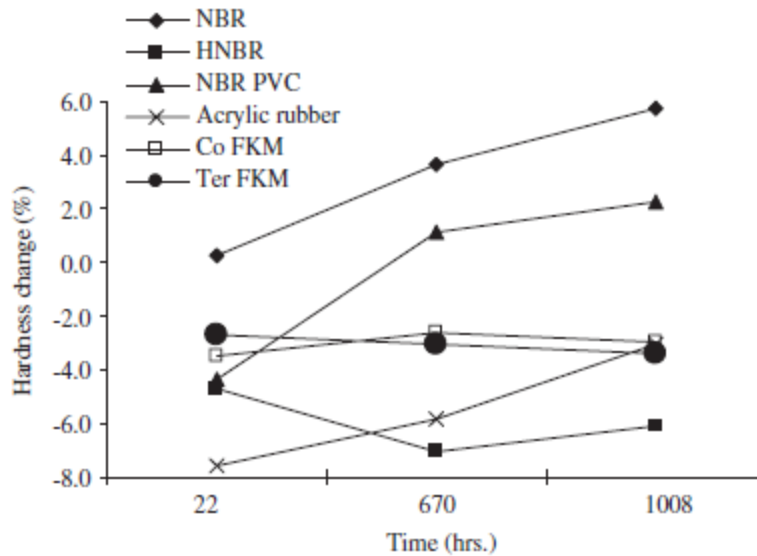


Figure 2.8 - Hardness Change of elastomers (Trakarnpruk W, 2008)

The hardness changes observed on immersions of the selected elastomers for each period of time are illustrated in Figure 2.9. Acrylic rubber and HNBR show high decrease in hardness as a consequence of high swelling. Both NBR and NBR/PVC show high increases in hardness with time. However, the hardness changes were comparable to the practical tolerances of 10–12 points of hardness quoted elsewhere (Mortaon, M. 1987). Changes in the tensile strength of the elastomers after oil immersion are shown in Figure 2.8. All elastomers except HNBR show decreased tensile strength. However, difference in tensile change was not significant (Clamroth, R. 1979). Effect of B10 on elongation change, as shown in Figure 2.8, is pronounced in the cases of NBR and NBR/PVC. Upon immersion in B10, the polymer chains tend to have reduced entanglements, the elongation at break decreased.” (Trakarnpruk, W. 2008)

CHAPTER 3

Observing Fuel Compatibility with Fuel System Materials

3.1 Overview

The purpose of the test program was to ensure that the candidate fuel will have no negative impact on engine safety, durability, or performance. Much experience in fuel compatibility research has already been compiled from ASTM, various academic institutions, military, and OEM past efforts directed at investigating fuels and fuel additives. Evaluations have included fuel sources from the oil sands, shale oil, Fischer-Tropsch synthetic kerosene and the emerging biofuel option. As the aviation industry moves towards ‘greener’ fuel substitutes (ie. fuels derived either partially or fully from renewable sources), the new fuels must be critically tested alongside either known results or currently industry active fuels to get a sense of how aircraft materials will behave once they are immersed in the new fuel system. Since using biofuels in aircraft are a relatively recent development, there were uncertainties about how the new fuel would interact with the aircraft fuel system on which it is deployed. Depending on the fuel system material, it may either exhibit no noticeable variance between different sets of fuels, or show some dissimilarity in mechanical behavior. The idea was to ensure that if there was some discernible change, that the change is minimal and within operational parameters. The parameters mentioned are outlined in ASTM D4054-09 for the wide range of materials involved, as well as the various testing procedures associated with the materials.

3.2 Test Program

3.2.1 Test Materials

Materials were chosen based on components which come in operational contact with the fuel system. Fuel system components such as seals, gaskets, hoses, pipes, fuel tanks were represented in the testing by their commonly used aerospace product. The type of testing was also outlined based on the application of the particular material in the aircraft. For instance, if the material was a sealant, then it was imperative that its' swelling or contracting attributes when in contact with fuel was noted. If the material was a fuel tank coating, then its scratch and abrasion resistivity was measured and so forth. The following table illustrates the Non-Metallic materials and their respective tests.

Table 3.1 - List of Non-Metallics

Material Type	Chemical Composition	Test Spec	Test Name	Temp
Adhesive	Epoxy Paste	ASTM D 1002	Lap Shear	93 C
	Methacrylate	ASTM D 4562	Static Shear	
Coating	Nitrile	ASTM D 3363 ASTM D 3359	Hardness(Pencil) Tape Adhesion	93 C
	Polyurethane			
Film	Teflon	ASTM D 412 ASTM D 412	Tensile Strength Elongation	71 C
	Polyethylene			93 C
	Kapton			
Foam	Polyurethane	ASTM D 412 ASTM D 412	Tensile Strength Elongation	93 C
Gasket, O-Ring	Nitrile	ASTM D 2240 ASTM D 1414 ASTM D 1414 ASTM D 395 ASTM D 471	Hardness, Shore M Tensile Strength Elongation Compression Set Volume Swell	71 C
	Fluorocarbon			153 C
	Low Temperature Fluorocarbon			163 C
Hose(Ground Refueling)	Epichlorohydrin	ASTM D 471	Volume Swell	71 C

Potting Compound	Polysulfide	ASTM D 2240 ASTM D 412 ASTM D 412 ASTM D 471	Hardness, Shore A Tensile Strength Elongation Volume Swell	71 C
Sealant	Polysulfide Dichromate Cured	ASTM D 2240 ASTM D 412 ASTM D 412 ASTM D 471	Hardness, Shore A Tensile Strength Elongation Volume Swell	93 C
	Polysulfide Manganese Cured			
	Fluorosilicone			
	Polyurethane			
	Polythioether			
	Polysulfide Lightweight			
Sealant(Groove Injection)	Fluorosilicone	ASTM D 471	Volume Swell	71 C

Table 3.2 - List of Metals

Material Specification	Test Spec	Temp
2024 T3	ASTM D 4054	93 C
6061 T6	ASTM D 4054	93 C
7075-T6 Chromate Conversion Coating	ASTM D 4054	93 C
7075-T6 Chromic Acid	ASTM D 4054	93 C
7075-T6 Sulphuric Acid Coating	ASTM D 4054	93 C
17-4 PH	ASTM D 4054	163 C
304-SS	ASTM D 4054	163 C
Inconel 625	ASTM D 4054	163 C
Inconel 718	ASTM D 4054	163 C
Monel 400	ASTM D 4054	163 C
Nickel 200	ASTM D 4054	163 C
Ti 3Al-2.5V	ASTM D 4054	163 C
Titanium 8Al-1V-1Mo	ASTM D 4054	163 C
Titanium CP70	ASTM D 4054	163 C
Waspaloy	ASTM D 4054	163 C

Tables 3.1 and 3.2 above are derived from the “short list” by the engine and aircraft OEMs and DOD found on Tables A3.2 and A3.3 in ASTM 4054-09. Table A3.2 is a list of representative non-metallic materials used in gas turbine engine and airframe fuel systems. Table A3.3 is a list

of representative metals used in gas turbine engine and airframe fuel systems. Tables A3.2 and A3.3 are comprised of materials that have been selected as representative, or worst case, for each class of material listed in Table A3.4. For example, many different polysulfide sealants are used in fuel tanks. Rather than test them all, a representative manganese dioxide cured product and a representative chromate cured product were selected for the short list. Testing material classes significantly reduced the burden from that of testing all 255 materials listed in Table A3.4 that are present in engine and airplane fuel systems.

3.2.2 Test Temperatures

The temperature column denotes the temperature at which the respective material was soaked in during the month long process. The temperatures are governed by the operational specification ASTM D 4054-09. The different temperatures were allocated depending on the type of material to be tested, and this correlates to various operational temperatures that the particular material will experience during its operational life in the aircraft. Materials were tested at the highest temperature to which it will be subjected for its specific application within an aircraft and engine fuel system. The scope of this report included temperatures of 71C, 93C, 153C and 163C.

3.2.3 Screening Tests

The tests called out in the tables above compares changes in properties of materials soaked in the new fuel (biofuel blend) to that of materials soaked in the baseline reference fuel (Jet A1). The tests are intended to be a first level screening to identify potential compatibility problems. If test results are within allowable variation as defined in the evaluation criteria given in the table below for each material, then the risk level of the new fuel was considered minimal. A set of the minimum baseline variation criteria is outlined in Table 3.3. Metallic specimens were evaluated under microscope and any signs of defects or corrosion were noted.

Table 3.3 - Evaluation Criteria

Chemical Composition	Test Spec	Test Name	Evaluation Criteria Allowable Variation
Epoxy Paste	ASTM D 1002	Lap Shear	250 psi decrease
Methacrylate	ASTM D 4562	Static Shear	
Nitrile	ASTM D 3363 ASTM D 3359	Hardness(Pencil) Tape Adhesion	1 pt decrease
Polyurethane			1 pt decrease
Teflon	ASTM D 412 ASTM D 412	Tensile Strength Elongation	150 psi decrease 15% decrease
Polyethylene	ASTM D 412 ASTM D 412	Tensile Strength Elongation	250 psi decrease 50% decrease
Kapton	ASTM D 412 ASTM D 412	Tensile Strength Elongation	1800 psi decrease 5% decrease
Polyurethane	ASTM D 412 ASTM D 412	Tensile Strength Elongation	5 psi decrease 15% decrease
Nitrile	ASTM D 2240 ASTM D 1414 ASTM D 1414 ASTM D 395 ASTM D 471	Hardness, Shore M Tensile Strength Elongation Compression Set Volume Swell	+/- 5 pts 125 psi decrease 35% decrease 5% increase +/- 10%
Fluorocarbon			
Low Temperature Fluorocarbon			
Epichlorohydrin	ASTM D 412 ASTM D 412 ASTM D 2240 ASTM D 471	Tensile Strength Elongation Hardness, Shore A Volume Swell	125 psi decrease 25% decrease +/- 5 pts +/- 5%
Polysulfide	ASTM D 2240 ASTM D 412 ASTM D 412 SAE AS5127/1 ASTM D 471	Hardness, Shore A Tensile Strength Elongation Peel Strength Volume Swell	+/- 5 pts 35 psi decrease 25% decrease 8 lb/in decrease +/- 10%
Polysulfide Dichromate Cured	SAE AS5127/1 ASTM D 2240 ASTM D 412 ASTM D 412 ASTM D 471	Peel Strength Hardness, Shore A Tensile Strength Elongation Volume Swell	8 lb/in decrease +/- 5pts 35 psi decrease 25% decrease 5% increase
Polysulfide Manganese Cured			
Fluorosilicone			
Polyurethane			
Polythioether			
Polysulfide Lightweight			
Fluorosilicone	ASTM D 471	Volume Swell	+/- 5%

3.3 Fuel Soak

Each material was exposed to fuel at its associated temperature for a period of 28 days. Non-metallic materials as listed in Table 3.1 were interrupted every 14 days to change out the fuel medium. Metallic materials as listed in Table 3.2 were interrupted every 7 days to change out the fuel medium. This was done to ensure that fresh fuel was being continuously used throughout the soaking procedure since there lay a possibility the properties of the fuel changing significantly when exposed to high temperatures for an extended period of time. The soaking was carried out for the 28 day period to confirm that the material to be tested had been thoroughly immersed and affected by its fuel environment as to simulate operational conditions.

3.4 Ovens

Soaking was done within two convection-heated ovens (Blue M Friction Aire Safety Oven HS 3804E). The ovens are designed to be explosion proof in its design as the source of heat is derived from a high velocity airflow system which creates air turbulence and friction from the air it draws, as opposed to traditional heating elements which may ignite fuel vapours emitting from the jars during the soaking process. The ovens also featured natural temperature interlock and built-in over temperature protection system, as well as an exhaust duct which continuously expels the internal gases within the oven which provides added safety. In order to conduct the soaking procedure in a safe manner, the aforementioned qualities are mandatory for testing and processing of hazardous materials such as the Jet A1 and biofuel that were used in this research.



Figure 3.1 - Blue M Friction Aire Safety Oven HS 3804E

3.5 Soaking Jars

For the soaking procedure, specimens were held in a glass mason jar of two different sizes depending on the size of the specimen. This was done so that the entirety of the specimen can be encapsulated within the volume of the jar while being soaked. A quart size jar (Ball 67000 3.5" x 3.5" x 6.9") was used for smaller specimens such as volume swell and hardness specimens, and a larger half gallon jar (Ball 68100 4.5" x 4.5" x 9") was used for larger specimens such as lap shear specimens. It is important that the entire specimen can fit within the jar since the container must have the ability to be sealed tightly during the soak procedure. Materials of different types were separated by different jars during the aging process. This is because it may be possible that components may leach out into the fuel and react with the other material specimen or component. For example, the polysulfide dichromate sealant was soaked in a separate jar from the polysulfide manganese sealant, even though they are to be soaked at the same temperature. Specimens which will undergo different tests from the same material type were also separated into different jars. This was done primarily because certain test specifications require particular

orientation within the jar during the soaking process. For example, tensile & elongation, hardness and volume swell specimens were required to be hung as per ASTM D 4054-09. However, they required different fuel levels in the mason jar and therefore they are all placed in separate containers. It is important that the appropriate fuel levels are placed within the jars to cover the testing area of the specimen. Specimens such as hardness and volume swell required its' entirely to be immersed in fuel during the aging process. However, tensile and lap shear specimens were just immersed under its neck and overlapping areas respectively. This was done to not only conserve fuel being used during the soaking process, but also to ensure that the fuel does not dangerously expand and create unsafe pressures to the sealed glass mason jar. Expansion of the fuel was shown in the figures below after a prolonged exposure to temperatures of 163 degrees Celsius (which is the highest temperature in the Test Program). Similar expansion can be expected for the 50/50 Biofuel.



Figure 3.2 - 400 mL of Jet A1 Fuel @ 163C Expansion to ~430 mL (Before and After Respectively)

In order to prevent the escape of evaporating fumes during the soaking process, the jars were required to be sealed air tight while withstanding the curing temperatures of the oven. In accordance with ASTM 4054-09, a piece of foil was placed over the mouth of the jar with an

inch overhang and then the lid was screwed into place to prevent evaporation of the fuel while aging. This method was proven to be insufficient in keeping the jars air tight, as evaporation testing demonstrated how fuel levels dropped during mock soaking periods at 163 degrees Celsius illustrated in the figure below.



Figure 3.3 - Fuel Levels Before and After Soaking at 163 C Respectively

Roughly 25 mL of the original 375 mL (approx. 7%) had seemed to have evaporated during the test. While this seemed like a trivial amount, the summation of fuel lost can become drastic as you fill the oven with 20-30 jars and they are all shedding 7% of their volume during the soaking process. This was not only a problem due to loss of fuel coming into contact with curing specimens, but also a severe safety hazard as a buildup of highly combustible vapours in an enclosed space such as an oven can cause a severe explosion.

To minimize such a catastrophic event from occurring, another sealing method was developed to keep the jars from leaking fumes. It was noticed during the evaporation test that the primary culprit to the leakage was that the foil was being torn as the lid was being screwed onto the jar. Therefore, the aluminum foil was doubled in thickness and it was tightly wrapped over the open mouth of the jar and into the jar mouth threading. High temperature Kapton tape (CGS Tape), 2

mil in thickness, was then tightly wrapped over the thread area of the jar once around. Excess tape was folded over the top face of the foil covering the jar mouth to protect the foil from being torn by the lid. The lid was then smoothly and firmly twisted over the applied tape until snug. This method was shown to exhibit absolutely zero fume leakage when being soaked at 163C in the convection oven and is the recommended practise when sealing Mason jars in preparation for high temperature soaking. The figures below illustrate the process of sealing the jars in the revised manner.



Figure 3.4 - Revised Jar Sealing Method

3.6 Types of Tests to be Performed after 28-Day Soak Period

After the soaking period reached completion, the materials listed in Tables 3.1 and 3.2 were ready to be tested for evaluation. Examples of the test to be performed on the non-metallic materials of Table 3.1 were as follows:

3.6.1 Non-Metallic Materials

The testing apparatus used for the Single Lap Shear, Tensile, Elongation, and Compression Set was the Universal Testing Machine STM-50KN by United Testing Systems Inc. It supports loading up to 11240 lbs and has a top loading speed of 20 in/min throughout the 41 inches of

travel length. Its versatility allowed the operator to add smaller load cells, customized grips, and variable loading parameters to meet the various ASTM requirements of the tests.



Figure 3.5 - United Testing Systems Inc. STM-50 kN

3.6.1.1 Lap Shear – ASTM D1002

This test method covered the determination of the apparent shear strengths of adhesives for bonding metals when tested on a standard single lap joint specimen and under specified conditions of preparation and test. In our case, the base metal was chosen to be Aluminum 2024 T3.



Figure 3.6 - Lap Shear Gripped in Tensile Machine

Prior to placing the specimen in grips, the specimen was abraded on both sides at the gripping edges to prevent the specimen from slippage during pulling. Any slipping during testing provided erroneous results that do not truly reflect the load curve of the adhesive being tested.

Another important factor to consider was the alignment of the specimen once it was being gripped in the UTM. A pair of spacers with the same thickness as the specimen was placed at the grip ends of the assembly. This was done to correct the alignment of the specimen which will be off-plane of the tensile force due to the overlap created the offset. If spacers are not employed, then the tensile force generated by the UTM multiplied by the offset distance will create a moment that will cause the tested adhesive to fail at a much more premature force than if the adhesive were to experience pure shear. Therefore, to achieve the best possible results the specimen was set up as follows.

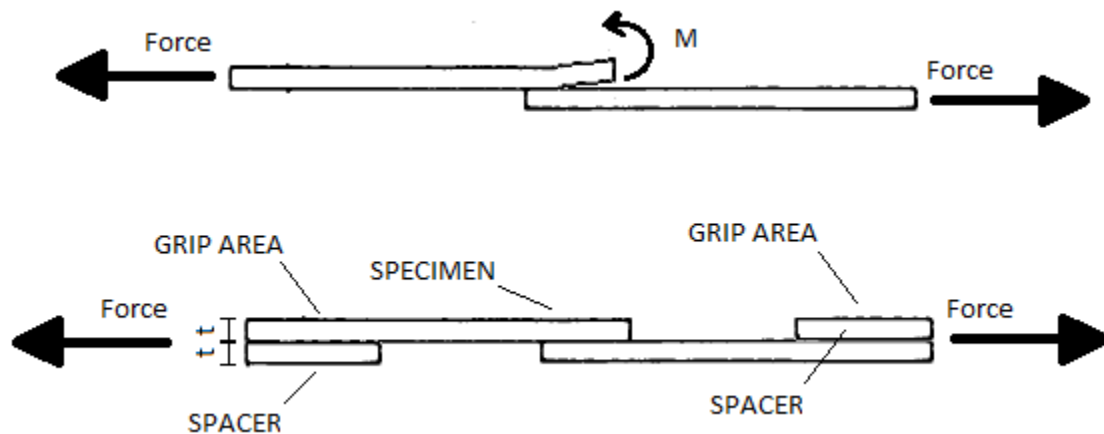


Figure 3.7 - Lap Shear Specimen without and with Spacers Respectively

The rate of loading for lap shear testing was set for 0.05 in/min and was gripped with a pair of self-aligning grips that adjusted grip strength as the specimen is being pulled.

3.6.1.2 Volume Swell – D471

This test method covered the required procedures to evaluate the comparative ability of rubber and rubber-like compositions to withstand the effect of liquids. It was designed for testing: 1) specimens of vulcanized rubber cut from standard sheets, 2) specimens cut from fabric coated with vulcanized rubber, or 3) finished articles of commerce. In our case, all of our samples were specimens of vulcanized rubber cut from standard sheets or created by molding.

Certain rubbers used in the fuel system such as gaskets, hoses, seals, sleeves, and diaphragms exhibited changes in physical properties from contact with oils and fuels. The changes in physical properties varied depending on the chemical makeup of the material, its exposure to a type of fluid, and the operating temperature at which this occurs. Properties of rubber articles deteriorate during exposure to these liquids, affecting the performance of the rubber part, which can lead to failure of the material. This test was designed to distinguish the change in mass property of the material after it has been conditioned in fuel.

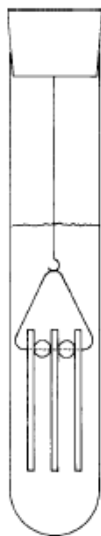


Figure 3.8 - Method of Separation of the Specimens in Fuel

Volume swell specimens were suspended and separated in the fuel medium during the conditioning procedure. This was so that the specimen surface can have sufficient contact with the fuel and therefore creates the optimal scenario for volume swelling to occur.

In order to determine the amount of volume swell which has occurred, the mass of the specimen in air and suspended in water was measured prior to, and post conditioning in the testing fuel as per ASTM D471.

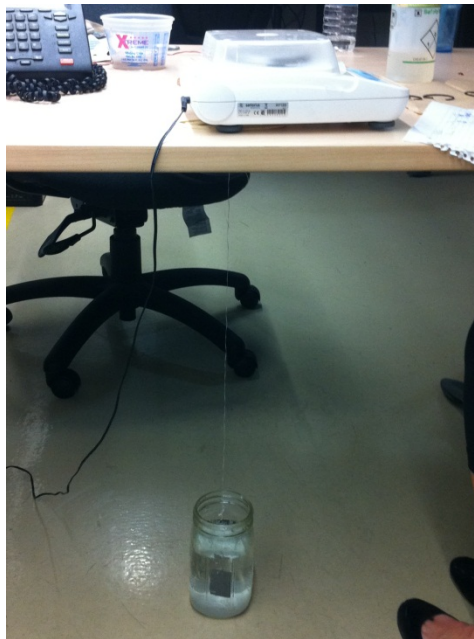


Figure 3.9 - Example of Measuring Specimen in Water

The following formula was used to determine the percentage change in volume. This equation is used with the assumption that the delta density remains negligible.

$$\Delta V, \% = \frac{(M_3 - M_4) - (M_1 - M_2)}{(M_1 - M_2)} \cdot 100$$

M_1 and M_2 are the mass of the specimen dry and wet prior to soaking and M_3 and M_4 are the mass of the specimen dry and wet post fuel conditioning to the nearest milligram.

3.6.1.3 Tensile & Elongation – D412

These test methods are used to evaluate the tensile properties of vulcanized rubbers and elastomers. Specimens tested were primarily in the shape of dumbbells, rings and straight pieces of uniform cross-sectional area. The conditions of which the specimens will be tested in have a great impact on the results of the test. Therefore, all variables such as the rate of separation, temperature, humidity, specimen geometry, were kept as consistent as possible in order to allow for results comparisons. According to ASTM D412, the rate of separation was dictated to be 20 in/min.

The geometry set ‘Die C’ was chosen to represent the dumbbell specimens for all the sealants and potting compounds in our scope of research. The dimensions of the specimen are given as follows:

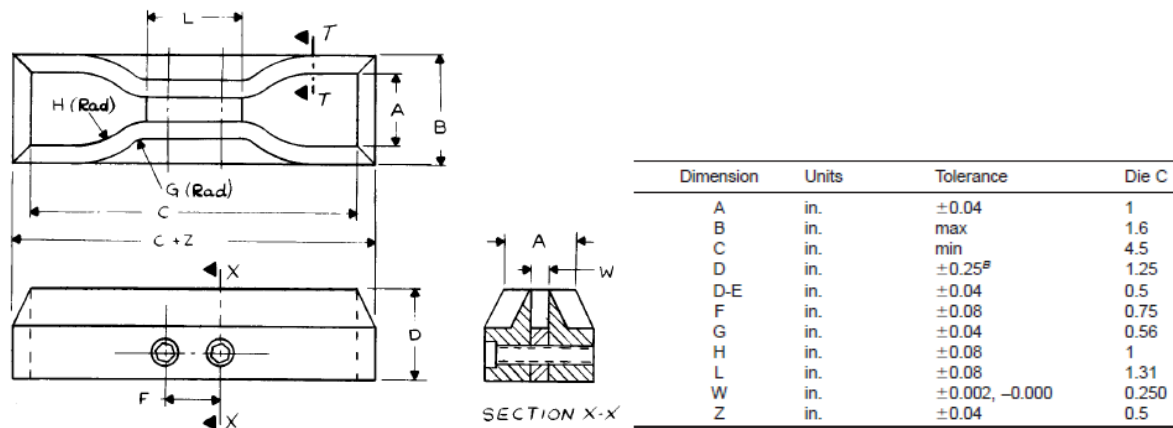


Figure 3.10 - Dumbbell Specimen Dimensions

The maximum load up to failure, and its maximum elongation was recorded by the Universal Tensile Machine. Load curves of stress vs. elongation were plotted for graphical representation.

3.6.1.4 Static Shear – D4562

This test method covers the determination of the shear strength of curing liquid adhesives used for retaining cylindrical assemblies or for locking and sealing threaded fasteners. Although

ASTM D1002 covers adhesive strength in the form of lap shear, this test method was more appropriate for the specific application mentioned above because the pin and collar motion more closely resembles practical use. This test method provided reasonably accurate information with regard to the ability of an adhesive to withstand shearing forces. It was also useful to determine the degree of cure and the effect of environment on shear strength as is in the case of this experiment.

A pin and collar specimen was used to represent the candidate adhesive to be loaded in a compressive manner. The Universal Testing Machine was employed for applying the force to the specimen. The pin and collar assembly was placed on the UTM, and loaded using a crosshead speed of 0.05 in/min. The static shear strength is found by dividing the breakaway load by the bond area as follows:

$$\text{Shear Strength} = \text{Maximum Load} / \text{Diameter} \times 3.14 \times \text{Width}$$

3.6.1.5 Tape Adhesion – D3359

This test method was developed to determine the strength of industry coatings on applicable substrates through the application of a pressure sensitive tape over slices made into the applied coating. This test method was mostly used to establish whether the adhesion of a coating to a substrate was at a generally adequate level. If a coating is to fulfill its function of protecting a substrate, it must be able to properly adhere to it during its service life. The substrate and substrate surface preparation are critical in determining the quality of the coat adhesion to the surface. If improper preparations are taken, then the coat can easily lift off the surface and fail to protect the substrate material. This was especially important in areas such as fuel tank interiors

where the metal comes in constant contact with fuel. Any failure to adequately cover the surface will lead to corrosion and possibly failure of the component prior to its expected lifetime.

The tape used was a one-inch wide semitransparent pressure sensitive tape that is specially rated for ASTM D3359 testing. This tape was used throughout the entire specimen range because the variability in adhesion strength from batch to batch should be kept nominally the same. Three inches of length was adequate for the testing procedure and provides the necessary overhand needed for the pullback.

When performing the test, an area that is free of defects and other surface imperfections was chosen and cleaned of any oils. Two cuts in the film of about 1.5 inches long that intersect near their middle with a smaller angle between 30 to 45 degrees were made. This was done using a sharp scalpel or other blade that will provide a clean and deep cut that cut through the coating all the way down to the aluminum substrate. It is important that the cut is made in one smooth and firm stroke. If an error was made then an attempt to go over the cut is not permitted as this may cause premature failure. Clean cuts can be determined by inspecting the incisions for reflection of the light from the metal substrate.

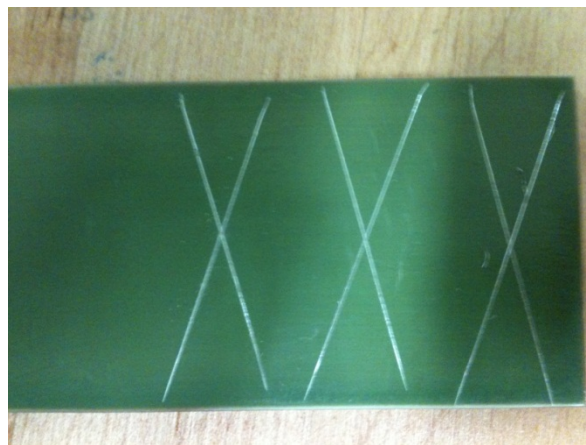


Figure 3.11 - X-Cuts Exposing the Substrate

A three inch piece of the testing tape was then removed from the roll, and applied firmly on the incision made. The centre of the tape was at the intersection made, with the tape running in the same direction as the smaller angles. The tape was then rubbed smoothly onto the cut area so that the color of the transparent tape is of uniform shade, indicating correct adhesion. An eraser was then rubbed firmly onto the tape to ensure contact.

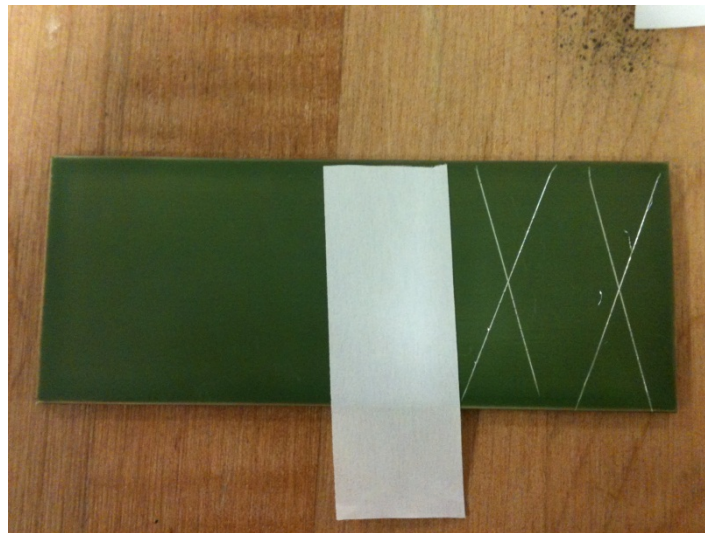


Figure 3.12 - Tape Applied onto Cut Area

Within 1-2 minutes of application, the tape was removed by seizing the free end and pulling it off rapidly, and uniformly, upon itself as close to an angle of 180 degrees as possible. The X-cut area was then inspected for removal of the coating from the substrate by the tape pull and rated by the following scale:

- 5A No peeling or removal,
- 4A Trace peeling or removal along incisions or at their intersection,
- 3A Jagged removal along incisions up to $\frac{1}{16}$ in. (1.6 mm) on either side,
- 2A Jagged removal along most of incisions up to $\frac{1}{8}$ in. (3.2 mm) on either side,
- 1A Removal from most of the area of the X under the tape, and
- 0A Removal beyond the area of the X.

3.6.1.6 Hardness –D2240

This test method is based on the penetration of an indenter when forced into the surface material under specified conditions. The indenter was either of Type M, or Type A depending on the material being tested. The indentation hardness is inversely related to the penetration and is dependent on the elastic modulus and viscoelastic behavior of the material. The test method is an empirical test and is intended primarily for control purposes. There exists no simple relationship between indentation hardness determined by this test method and any fundamental property of the material tested. Therefore, for our purposes, it was exclusively used for comparison purposes.

A hardness testing machine (Shore Micro O-Ring Hardness Tester) was used to get digital readings on the hardness of the material. Calibration was performed by testing the indentors on OEM rubber pucks of known factory hardness, which are provided with the testing apparatus.



Figure 3.13 - Hardness Testing Apparatus

To test the hardness of O-rings, an O-Ring was placed on the test bed between two placement markers. The test needle was of type M for O-Ring specimens as dictated by ASTM D2240. The test needle was raised to a specified height which is set by the Shore testing machine and latched at its top position. The latch was then released, and readings are taken. This was repeated for five different areas of the O-Ring for all the specimens and the mean result is taken.

Hardness specimens made from the sealants are tested on a level, solid surface. The test needle was swapped for a Type A indenter, and removed from the micro O-Ring testing apparatus. By hand, the indenter was smoothly and firmly pressed onto the surface of the specimen at five different locations on the specimen surface. The five positions were at least 6 mm apart from each other to get results as indicative to the entire specimen as possible. The mean result was taken.

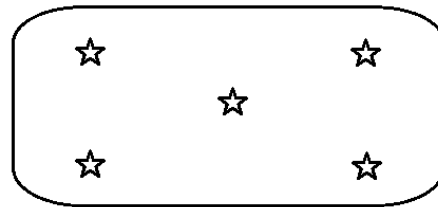


Figure 3.14 - Indent Locations on a 2"x 1" Hardness Specimen

3.6.1.7 Compression Set – D395

This test method covers the testing of rubber materials that are intended for use in compressed environments such as gaskets, or other sealing areas. The rubber gaskets in the fuel system environment will be exposed to jet fuel during operation, and therefore it must be known how the gasket will behave when a different type of fuel is introduced. The material was tested using Method B of ASTM D 395 which is the compression set under constant deflection in air.

The materials involved in the compression set testing are the O-Ring specimens indicated in the previous section. The compression device consisted of two flat steel plates with chrome finishing on the inner sides of the plates that will come in contact with the O-Rings. The surfaces contacting the O-Rings were then polished so not to introduce erroneous results when compressed. Prior to placing the specimens, the surface was cleaned of any grease, dirt, or other imperfections. Spacers are placed between the two plates so that 25% of the material thickness was being compressed. The plates between the test specimens that were compressed were made of a steel of sufficient thickness to withstand the compressive stresses without bending. The two plates were fastened together using mechanical bolts.



Figure 3.15 - Compression Plate and O-Ring Setup

The bolts are tightened incrementally one at a time so that it is brought to bear on the specimens evenly and smoothly. The test temperature was chosen depending on the soaking temperature of the O-Ring, and the test period was conducted for 70 hours. Once complete, the assembly was taken out and allowed to cool in room temperature. The specimens were then removed and allowed to rest for 30 minutes before measurements were taken of the final thickness. The compression percentage is calculated as follows:

$$C_B = [(t_o - t_i)/(t_o - t_n)] \times 100$$

where:

C_B = compression set (Test Method B) expressed as percentage of the original deflection,
 t_o = original thickness of specimen (13.1),
 t_i = final thickness of specimen (13.5), and
 t_n = thickness of the spacer bar used.

3.6.2 Metallic Materials

As per ASTM 4054-09 A3.2.9.3 and A3.2.9.4: At the conclusion of the 28 day soak cycle, the metal test specimens were removed from the test fluid, air dried, and examined visually under low power (<50x) optical magnification. The objective was to inspect for evidence of staining, deposits, surface pits, or gross corrosion. Staining was considered a benign surface phenomenon. Staining results in no appreciable weight loss or gain and indicates the formation of a passive layer that inhibits corrosion.

Subsequent to the initial examination, the metal surfaces were cleaned using acetone or alcohol and re-examined for surface pits. Following surface evaluation, metal test specimens were cross-sectioned, mounted, and polished to reveal a profile of the surface and interior. Polishing was conducted in accordance with procedures established by the evaluating laboratory. The procedures were consistent with those specified by the polishing apparatus manufacturer, and

appropriate for use on metallic alloys being evaluated as described by metallographic procedures outline in the ASTM Metals Handbook.

Mounted and polished specimens were examined at optical magnification levels between 100X and 1000X for evidence of microstructural changes, corrosion or other effects of exposure on the surface or bulk material. Observations made from specimens soaked in the reference fuel versus specimens soaked in the test fuel were compared by noting any dissimilarity between the materials.

CHAPTER 4

Synopsis of Materials and Preparations

4.1 Materials

4.1.1 Introduction

The materials introduced in this chapter are various products and base materials found commonly, and used widely in the Aerospace industry. The materials were divided into two large categories: Metallic and non-metallic materials. The metallic materials consisted of various Aluminum alloys, Titanium alloys, Steel alloys common in the industry, as well as other alloys such as Inconel and Waspaloy. Unlike the materials in the list of non-metallics, all metals were isotropic in nature. Metallic specimens were treated differently from Non-Metallic specimens throughout the research, from soaking procedure to testing requirements. All metallic specimens came pre-fabricated and preparation procedure for these specimens will not be represented.

Non-metallic materials are all other materials represented in tests. Non-metallic materials included specimens made from commonly used aircraft sealants such as PR-1422, bonding adhesives, carbon fiber composites, gaskets, bladders, film strips, paint coatings, and foams. Non-metallic materials shared very little in common with each other when compared to the metallic materials. Their characteristics ranged from being extremely elastic to extremely brittle and varied in colour much more diversely than metallic materials. Their mechanical behavior was therefore extremely varied and complex in nature. The non-metallic specimens were in general prepared from base materials, or fabricated from pre-manufactured materials. The specimens that were prepared in any way are represented in the second half of this section.

4.1.2 Non-Metallics

4.1.2.1 Epoxy Paste Adhesive - Hysol EA 9394

Hysol EA 9394 is a two-part structural paste adhesive which cures at room temperature and possesses excellent strength to 350F/ 177C and higher. Its thixotropic nature and excellent high temperature compressive strength also makes it ideal for potting, filling and liquid shim applications. The adhesive typically comes in two parts, and when mixed together it produces a thick grey paste which is easily handled.

4.1.2.2 Methacrylate Adhesive - Loctite 609

Loctite 609 provides bonding of cylindrical fitting parts such as pin and collar assemblies, screws, and bolts. The product cures anaerobically when confined in the absence of air between close fitting metal surfaces and prevents loosening and leakage from shock and vibration. Typical applications include rotor to shafts in fractional and sub fractional horsepower motors, locks, bushings, and sleeves in housings on shafts. This product is not recommended for use in pure oxygen and/or oxygen rich systems and should not be selected as a sealant for chlorine or other strong oxidizing materials. The adhesive is identified by its green colour.

4.1.2.3 Nitrile Coating - EC 776

EC 776 is a general purpose fuel resistant coating. It is a solvent-based adhesive/coating with a good adhesion to synthetic rubber, metal, glass and many plastics. EC-776SR is a variant of the same coating which includes a red dye for identification purposes. The coating when cured resists oil, gasoline and aromatic fuels. It is not recommended for use with alcohol containing fuels (gasohol) or jet fuel containing microbial organisms.

4.1.2.4 Polyurethane Coating - 825X309

825X309 is a DeSoto integral fuel tank coating which is chemically cured acid and fluid resistant urethane coating intended for the protection against fuel contaminants. These products are

designed to provide maximum protection for non-ferrous metals, against fresh or salt water, aircraft fuels, hydraulic fuels, engine oils and dilute acid solutions. It offers excellent adhesion to chemically treated surfaces and is unique in having good adhesion to titanium and stainless steel. It exhibits very good intercoat compatibility with sealants and touch-up materials when properly cleaned, even after long term exposure to fuel. This material contains photochemically reactive solvents per SCAQMD Rule 102. This coating is widely used in the aerospace industry to protect the inside of aircraft fuel tanks against corrosion from fuel contaminants or oxidation. When the parts are mixed together, the coating is a pastel green colour which cures to a dark green colour.

4.1.2.5 Teflon

Polytetrafluoroethylene, or Teflon, is a synthetic fluoropolymer of tetrafluoroethylene that finds numerous applications. Teflon is a compound consisting exclusively of carbon and fluorine and is hydrophobic in nature. Teflon also exhibits one of the lowest coefficients of friction against any solid. Due to these physical qualities, Teflon is widely used in the aerospace industry throughout many areas of an aircraft. Examples of aerospace applications include fasteners, shafts, bushes, hoses, bearings, filters, screens, connectors, exhaust systems, etc.

4.1.2.6 Polyethylene

Polyethylene, or PE, is the most common plastic available and in production. It has the chemical formula $(C_2H_4)_nH_2$ where the 'n' denotes the length of the chain. Most polyethylene grades have excellent chemical resistance, meaning that it is not attacked by strong acids or strong bases. It is also resistant to gentle oxidants and reducing agents. Applications are extremely wide ranging in an aircraft. It can be used virtually everywhere from trims, covers, hoses, tapes, tubes, fasteners, bushings, shims, screens, etc.

4.1.2.7 Kapton

Kapton is a polyimide film developed by DuPont which can remain stable in a wide range of temperatures, from -273 to $+400$ °C. Kapton insulated wiring has been widely used in civil and military aircraft because it is lighter than other insulators, and has good insulating and temperature characteristics. Kapton does however exhibit low mechanical abrasion qualities and the industry as a whole has moved away from the use of Kapton wire covers in areas where mechanical abrasion is prevalent and can lead to the possibility of short circuits. (Navick, X. 2004)

4.1.2.8 Polyurethane

Polyurethane, or PU, is a polymer composed of a chain of organic units joined by urethane links. Polyurethanes are also widely used in the aerospace industry. They are used in the manufacture of flexible, high-resilient foam seating, rigid foam insulation, seals, gaskets, electrical potting compounds, adhesives, surfaces coatings, and surface sealants. In the case of our research, polyurethane as a foam is represented as being used in fuel tanks. The polyurethane foam in the fuel tank prevents catastrophic explosions of ignited fuel vapors in the tank caused by electrical arcing, overheating of internal components, lightning strikes, or by static electrical discharge. In the event of a fuel tank rupture it mitigates fuel spray as the fuel is being contained in the foam matrix.

4.1.2.9 Nitrile O-Ring – N602-76

Nitrile rubber (NBR) is the general term for acrylonitrile butadiene terpolymer. The acrylonitrile content of nitrile sealing compounds varies considerably (18% to 50%) and influences the physical properties of the finished material. The higher the acrylonitrile content, the better the resistance to oil and fuel. At the same time, elasticity and resistance to compression set is adversely affected. In view of these opposing realities, a compromise is often drawn, and

medium acrylonitrile content selected. NBR has good mechanical properties when compared with other elastomers and high wear resistance. NBR is not resistant to weathering and ozone. See Figure 2-2. In view of these opposing realities, a compromise is again drawn and a medium acrylonitrile content selected. This material is used commonly as seals and gaskets for fuel systems and is characterized by its dark colour with shiny finish.

4.1.2.10 Fluorocarbon & L.T. Fluorocarbon O-Rings – V747 & VM128

Fluorocarbon (FKM) has excellent resistance to high temperatures, ozone, oxygen, mineral oil, synthetic hydraulic fluids, fuels, aromatics and many organic solvents and chemicals. Low temperature resistance is normally not favorable and for static applications is limited to approximately -26°C (-15°F) although in certain situations it is suitable down to -40°C (-40°F). Under dynamic conditions, the lowest service temperature is between -15°C and -18°C (5°F and 0°F). Gas permeability of the material is very low and has a good chemical resistance to fuels. Fluorocarbon is characterized by its dark colour, and LT Fluorocarbon is characterized by its dark colour with dull finish.

4.1.2.11 Hose

Epichlorohydrin (ECO) has properties similar to nitrile rubber but with better heat, oil and petrol resistance. It has a low gas permeability and better low temperature flexibility than NBR. Its resistance to acids, alkalis and ozone is excellent. However, its poor compression set limits its use as a sealing material and its corrosive effect on metals can increase tooling costs and limit metal bonding applications. Typical uses are in fuel systems, bladders, diaphragms and rollers. (EEL. 2009)

4.1.2.12 Polysulfide Sealant – CS3100

CS 3100 is a two-part polysulfide component that cures to a firm and flexible rubber. Part A is characterized by its white colour, and the curing agent is of a reddish brown colour. The mixture

prior to curing is less viscous than the other sealants explored in this report and is very easy to manipulate. The material is used for potting and sealing electrical connectors and components for protection from moisture, fuels, dirt and other contaminants. The sealant is characterized by its tan brown colour when fully cured.

4.1.2.13 Polysulfide Dichromate Cured Sealant – PR-1422

PR-1422 Class B is an aircraft integral fuel tank sealant. It has a service temperature range from -65°F (-54°C) to 250°F (121°C), with intermittent excursions up to 275°F (135°C). This material is designed for fillet sealing of fuel tanks and other aircraft fuselage sealing applications. The cured sealant maintains excellent elastomeric properties after prolonged exposure to both jet fuel and aviation gas. PR-1422 Class B is a two part, dichromate cured polysulfide compound. The uncured material is a low sag, thixotropic paste suitable for application by extrusion gun or spatula. It cures at room temperature to form a resilient sealant having excellent adhesion to common aircraft substrates. The sealant when cured is characterized by its dark colour.

4.1.2.14 Polysulfide Manganese Cured Sealant – PS 890

P/S 890 Class B is an aircraft integral fuel tank sealant. It has a service temperature range from -65°F (-54°C) to 250°F (121°C), with intermittent excursions up to 275°F (135°C). This material is designed for fillet sealing of fuel tanks and other aircraft fuselage sealing applications. The cured sealant maintains excellent elastomeric properties after prolonged exposure to both jet fuel and aviation gas. P/S 890 Class B is a two-part, manganese dioxide cured polysulfide compound. The uncured material is a low sag, thixotropic paste suitable for application by extrusion gun or spatula. It cures at room temperature to form a resilient sealant having excellent adhesion to common aircraft substrates. The sealant when cured is characterized by its light grey colour.

4.1.2.15 Fluorosilicone Sealant – Q4-2817

Q4-2817 is a one part, high strength solvent-less fluorosilicone elastomer paste. Due to its absence of a solvent it requires a longer than usual amount of time to fully cure. Q4-2817 was developed for use on equipment exposed to solvents such as jet fuel so that erosion and corrosion is mitigated. Applications include bonding or sealing of components exposed for long periods to moisture vibration, shock, fuel and solvents. The material is designed to be an excellent material for sealing aircraft fuel tanks. The material is characterized by its clay-red colour which remains the same prior to and after curing has occurred.

4.1.2.16 Polyurethane Sealant – PR-2911

PR-2911 is a two-part, polythioether polyurethane compound. The uncured sealant exhibits highly liquid properties and may be difficult to manipulate. It has a service temperature range from -65°F (-54°C) to 250°F (121°C), with intermittent excursions up to 350°F (171°C). This material is especially formulated as an elastomeric sealant for aircraft integral fuel tanks and fuel cell cavities. The cured sealant maintains excellent elastomeric properties and high elongation after prolonged exposure to both jet fuel and aviation gas. PR-2911 is an aircraft integral fuel tank sealant designed to be used over PR-2904 primer, however in our case the primer is not required as the tests will be performed independent of a substrate. The cured sealant is characterized by a dark black colour and high elastic in nature.

4.1.2.17 Polythioether Sealant – PR-1828

PR-1828 Class B is a rapid curing, primerless to most common substrates, aircraft integral fuel tank sealant. It has a service temperature range from -80°F (-62°C) to 320°F (160°C), with intermittent excursions up to 420°F (216°C). This material is designed for fillet sealing of fuel tanks and other aircraft fuselage sealing applications. The cured sealant maintains excellent elastomeric properties after prolonged exposure to both jet fuel and aviation gas. PR-1828 Class

B is a two-part, epoxy cured Permapol® P-3 polythioether compound. The uncured material is a low sag, thixotropic paste, suitable for application by extrusion gun or spatula. Unlike standard polysulfide fuel tank sealants, it can cure at low temperatures and is unaffected by changes in relative humidity. This sealant has excellent adhesion to common aircraft substrates. The cured sealant is characterized by a white pastel colour.

4.1.2.18 Polysulfide Lightweight Sealant – PR1776

PR-1776 Class B is a low density, high temperature aircraft integral fuel tank sealant. It has a service temperature range from -65°F (-54°C) to 250°F (121°C), with intermittent excursions up to 360°F (182°C). This material is designed for fillet sealing of fuel tanks and other aircraft fuselage sealing applications. It offers as much as a twenty percent weight savings, per unit volume, over traditional sealants used for these purposes. The cured sealant maintains excellent elastomeric properties after prolonged exposure to aircraft fuels both jet fuel and aviation gas, and will resist limited contact to diphosphate ester based hydraulic fluids. PR-1776 Class B is a two-part, manganese dioxide cured Permapol® P-5 modified polysulfide. The uncured material is a low sag, thixotropic paste suitable for application by extrusion gun or spatula. It cures at room temperature to form a resilient sealant having excellent adhesion to common aircraft substrates. The cured sealant is characterized by a medium grey colour.

4.1.2.19 Fluorosilicone Sealant – PR705

PR-705 is a non-curing fuel tank channel sealant. It has a service temperature range from -65°F (-54°C) to 220°F (104°C). The material is designed for sealing aircraft fuel tanks utilizing a channel/groove design with gaps up to 5 mils wide. The material offers excellent resistance to water and hydrocarbon aircraft fuels like JP-4 or JP-8. PR-705 is a one part, polysulfide compound. The material is a heavy, putty-like compound suitable for application by high pressure injection gun and is characterized by its white colour.

4.1.3 Metals

4.1.3.1 2024 T3

Good machinability and surface finish capabilities. It is a high strength material of adequate workability. This is due to its primary alloying element being copper. 2024 T3 is used extensively in the aerospace industry for a wide range of components. It largely has superseded 2017 for structural applications. Common applications are fittings, gears, shafts, bolts, fuse parts, hydraulic valve bodies, nuts, etc.

4.1.3.2 6061 T6

6061 T6 offers excellent joining characteristics, and good acceptance of applied coating. It combines relatively high strength, good workability, and high resistance to corrosion. 6061 T6 is widely available and common. It is commonly used in aircraft fittings, and structures such as wings and fuselages. Although 6061 is characteristically weaker than 2024, it offers better corrosion resistance even when the surface is abraded.

4.1.3.3 7075-T6

7075-T6 is a very high strength material used in highly stressed structural parts. It is primarily alloyed with zinc. It has strength which is comparable to many steels, and has good fatigue strength and average machinability. Compared to other aluminum alloys however, it offers less resistance to corrosion. Applications include aircraft fittings, gears, shafts, fuse parts, meter shafts and gears, regulating valve parts, etc.

4.1.3.4 *Chromate Conversion Coating, Chromic Acid & Sulphuric Acid Coating*

Acid coating is a type of conversion coating used to passivate aluminum alloys. They are primarily used as a corrosion inhibitor, or primer. The process is usually performed in an acid solution which slowly dissolves the aluminum oxide. The acid action is balanced with the oxidation rate to form a coating with nanopores. The acid used differentiates the type of

anodization between the three explored in this report. Aluminum that has been surface treated will exhibit different colour characteristics depending on the type of acid being used.

4.1.3.7 17-4 PH

17-4 Precipitation Hardening also known as Type 630 is a chromium-copper precipitation hardening stainless steel used for applications requiring high strength and a moderate level of corrosion resistance. High strength is maintained to approximately 600 degrees Fahrenheit. Alloy 17-4 PH is a precipitation hardening martensitic stainless steel with Cu and Nb/Cb additions. The grade combines high strength, hardness (up to 572°F / 300°C), and corrosion resistance. Mechanical properties can be optimized with heat treatment. Very high yield strength up to 1100-1300 MPa (160-190 ksi) can be achieved. The grade should not be used at temperatures above 572°F (300°C) or at very low temperatures. It has adequate resistance to atmospheric corrosion or in diluted acids or salts where its corrosion resistance is equivalent to Alloy 304 or 430. It has common applications in turbine blades in the aerospace industry.

4.1.3.8 304-SS

304-SS is an austenitic Cr-Ni stainless steel. Better corrosion resistance than Type 302. It has high ductility, excellent drawing, forming, and spinning properties. Essentially non-magnetic, becomes slightly magnetic when cold worked. Low carbon content means less carbide precipitation in the heat-affected zone during welding and a lower susceptibility to intergranular corrosion. It is used commonly in tubing, flexible metal hoses, oil well filter screens, etc.

4.1.3.9 Inconel 625

Inconel Filler Metal 625 is recommended for gas metal arc and gas tungsten arc welding of nickel base alloys 625 and 601, Incoloy alloys, carbon steels, low alloy steels and stainless steels. This alloy is useful for jet engine applications requiring excellent stress-rupture strength, oxidation resistance to 1200°F, plus outstanding fatigue strength and cryogenic properties. Many

engine applications include ducting systems, combustion systems, thrust reverser assemblies, fuel nozzles, afterburner parts and spray bars.

4.1.3.10 Inconel 718

Developed in the early 1960's, IN718 is still considered the material of choice for the majority of aircraft engine components with service temperatures below 1200°F (650°C). Inconel 718 is a precipitation-hardenable nickel-chromium alloy containing also significant amounts of iron, niobium, and molybdenum along with lesser amounts of aluminum and titanium. It combines corrosion resistance and high strength with outstanding weldability including resistance to postweld cracking. The alloy has excellent creep-rupture strength at temperatures to 1300°F (700°C).

4.1.3.11 Monel 400

Monel 400 is a nickel-copper alloy with high strength and excellent corrosion resistance in a range of media including sea water, hydrofluoric acid, sulfuric acid, and alkalis. Monel metal finds bulk uses in aircraft construction, especially in the making of frames and skins of components that experience great operational heating. Monel metal retains its strength at very high temperatures, allowing it to maintain its shape at high atmospheric flight speeds.

4.1.3.12 Nickel 200

Commercially pure (99.6%) wrought nickel with good mechanical properties and resistance to a range of corrosive media. Good thermal, electrical, and magnetostrictive properties.

Ferromagnetic. Used for a variety of processing equipment, particularly to maintain product purity in handling foods, synthetic fibers, and alkalis.

4.1.3.13 Ti 3Al-2.5V, Ti 8Al-1V-1Mo & Ti CP70

Titanium alloys are metals which contain a mixture of titanium and other chemical elements.

Such alloys have very high tensile strength and toughness (even at extreme temperatures). They

are light weight, have extraordinary corrosion resistance and the ability to withstand extreme temperatures.

4.1.3.16 Waspaloy

Waspaloy is an age-hardenable, nickel-based superalloy with excellent strength properties through temperatures of roughly 1800°F (980°C). Other characteristics of Waspaloy include good corrosion resistance, as well as being relatively impervious to oxidation making it well suited for service in extreme environments. Waspaloy alloy is typically used in high temperature applications, particularly in gas turbines. Components include turbine compressor blades and discs, shafts, spacers, fasteners, and other miscellaneous jet engine hardware.

4.2 Specimen Preparation

4.2.1 Tensile/Elongation Dog Bone, Hardness, and Volume Swell Specimens

4.2.1.1 The Mold: Surface Conditioning and Prior Engagements

The tensile, hardness, and volume swell specimens for the sealant materials were created using a flatbed female mold made of 6061 Aluminum. The material was chosen due to its machinability, and relative cost, however Aluminum is known to have a strong bonding characteristic to pretty much every PRC compound. Silicone or Teflon would probably be the best material to create a mold for this sort of application. However the cost benefits of manufacturing a custom mold made of these materials would be negated due to the cost outweighing the advantages.

To aid in the removal process of the specimens from the mold after they have sufficiently cured, the surface of the mold was milled to a finish of roughly 32 micro inches. This in itself is not sufficient in lifting the material off the mold. A release agent was used in conjunction with the Aluminium mold to ensure the proper removal of the specimens without damage occurring to the specimen from sticking. The nature of the release agent can vary per the personal preferences of

the research operator. However, it has been found in personal trials that the Flex-Z 6.0 (Zyvax) release agent performed appreciably better than Teflon, or silicone release agents. Zyvox also has Flex-Z 5.0 to 1.0 in its product lineup, however the 6.0 was exclusively used for the specimens created by this research operator. Using a lint-free cotton cloth, the release agent was applied thinly across all pertaining surfaces. The Flex was left to dry for 15 minutes, and another layer was applied. This was repeated for 3-5 layers depending on the material which was entering the mold. Some sealants displayed much more adhesive characteristics than others, and judgement is left to the research operator on how many layers are required.



Figure 4.1 - Flex Z 6.0 Release Agent

This arrangement worked quite well in producing consistent and good quality test samples. This was especially important for the dog bone tensile strength specimens, where the neck of the specimen is of particular interest. The volume swell and hardness tests are more forgiving in terms of the surface characteristics of the specimen. The neck area of the dog bone specimen however, required defect free conditions to provide reliable and consistent test results.

4.2.1.2 Mixing Two Part PRC Sealants

PRC sealants usually arrive as a two-part component usually 6 ounces in volume. Part A and B are contained in two separate tubes which come attached together as a semkit as shown in the figure below.

The Semkit® package

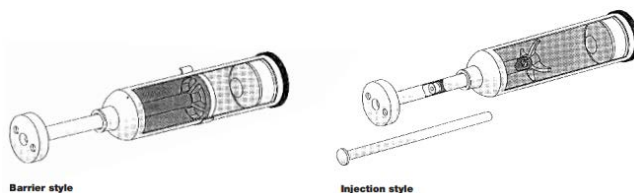


Figure 4.2 - PRC DeSoto Semkit

There are in general two different types of sealant dispensing units. One is the 'Barrier Style', and the other is the 'Injection Style'. Our experience has only come across the Injection Style, and the proper method of operation is described in the following paragraph is to describe this style only. Proper mixing was critical in order to maintain consistent specimen quality and therefore consistent specimens across the various tests. In order to get proper mixing of the two parts, Part B was first inserted about a third of the way into the Part A compartment using the injection rod to ram the compound in. A third of the Part B compound was then injected into the Part A. Part B was then inserted two thirds of the way into Part A and another third of the Part B compound was injected using the ram rod. The final third of the Part B compound was injected into the bottom third of the Part A component. The PRC mixture is now ready to be mixed, and this was accomplished by created linear back and forth extension/compression of the Part B component through the entire range of movement. Through the range of motion, the handle was twisted 180 degrees counter clockwise in a gradual motion. This ensured that the Parts A and B were being thoroughly mixed together. One compression movement followed by the extension movement is considered to be one stroke. 60 strokes within roughly 3 minutes are required to

have a thoroughly mixed even mixture. Various sealant compounds have different stroke counts or time constraints, however in general 60 strokes/ 3 minutes was common. The reason why the limit on the number of strokes was set to 60 is because excessive mixing can begin to introduce bubbles and other contaminants into the mixture. Therefore, the operator should take caution not to under mix, or over mix the sealant. If there is an issue of under mixing, it can be visible through the side of the Part A component since the casing is translucent.

After thorough mixing, the Part B component was removed by turning it clockwise, and discarded. The Part A component was now able to fit snugly into a sealant gun. An additional nozzle, which sometimes comes packaged with the semkit, can be attached to the nose of the semkit. From our observations, we have noted that the nozzle is useful for very precise application situations, such as to fill narrow channels or gaps. In the perspective of specimen preparation however, it was for the most part useless.

4.2.1.3 Filling the Molds

When filling the mold pockets with the sealant, special care was taken to avoid having any contaminants, or air pockets trapped. This was done initially by mixing sealants properly in the semkit as mentioned in the previous section. When the sealant was ready for pouring, the nozzle was first be placed as close as possible to the bottom of the mold pocket which is to be filled. The sealant gun was then be squeezed in a constant manner, while at the same time lifting the gun so that the height of the nozzle is consistently at the surface of the sealant being poured. This was done to avoid creating air pockets during pouring. The research operator should observe for any contaminants which become imbedded in the specimen mold and promptly remove them before continuation of the pouring. After filling the mold pocket, further care to remove air bubbles was taken by pressing the sealant into the mold using a plastic scraper.

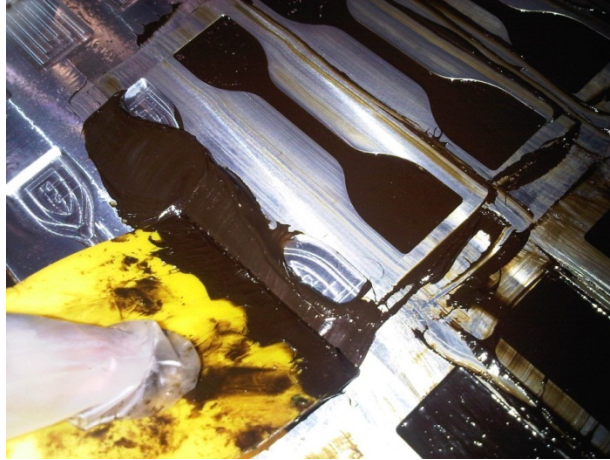


Figure 4.3 - Metal scrapers should be avoided for a number of reasons: The first being that the sealant bonds quite well to metals making cleaning difficult, and the second being that metal scrapers will damage the aluminium mold.

Extra attention was given to critical areas of the specimens being prepared such as neck regions of tensile specimens. These areas were pressed first to disperse any possibly existing bubbles to the outer grip regions, and then the rest of the specimen was pressed subsequently. Following the pressing, the scraper was placed edge first onto the surface of the mold and run across the top of the specimen to remove any excess sealant material. This process was executed in a slow manner, since sealants in general are a highly viscous material and may drag with the scraper if not careful. If the scraping revealed imperfections in the specimen, then the process of pressing and scraping was repeated until the specimen was acceptable. It should be noted that one 6 ounce sealant semkit material is enough material for 6 hardness, 9 tensile, and 6 volume swell specimens. Figures below depict acceptable specimens ready to be cured.

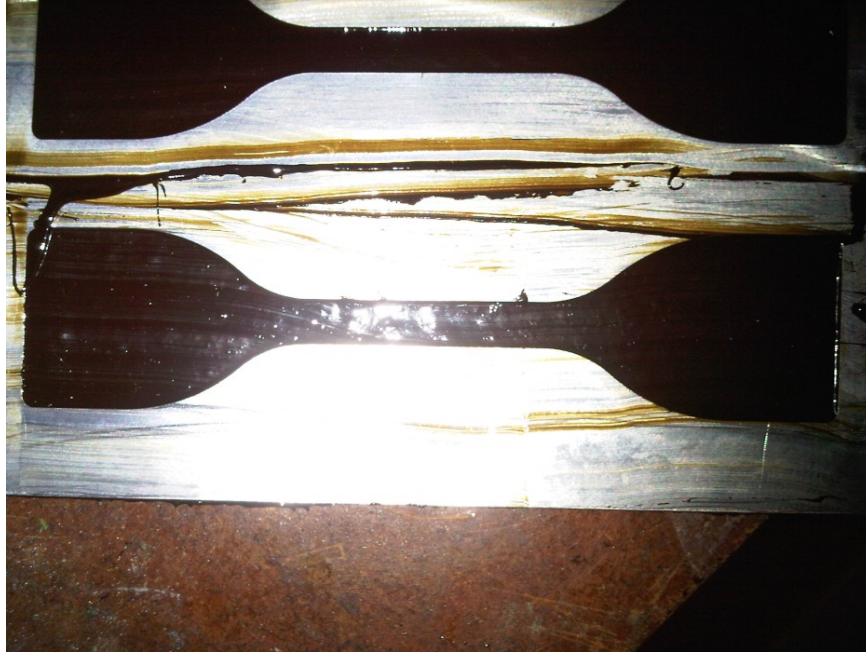


Figure 4.4 - Tensile Specimen Prepared



Figure 4.5 – Mold Completely Filled with Sealant and Scraped

4.2.2 Lap Shear: EA 9394

4.2.2.1 Surface Preparation

Hysol EA 9394 is an epoxy which was bonded to the surface of a metal substrate, in our case Aluminum 2024-T3 and tested to failure under shear stress. In this case the subject material was tested while adhered to a host material, the nature and quality of the adhesion between the two materials was just as critical as the preparation of the subject material itself. Therefore, particular care had been taken when performing the surface preparation to get acceptable and consistent results.

Before application of the adhesive on the substrate, the surface was first roughened up to increase the ability for the adhesive to bond more strongly. Using a 150J grit emery paper, the surface was evenly and sufficiently roughened up with slight application of water to aid in the sanding process. After surface roughening, the surface was made free of dirt, grease or other contaminants which exists due to material handling. Using a lint-free cloth, the surface was degreased using any common industrial degreaser. In this case, CSM-2 (Vishay Industries) was employed.



Figure 4.6 - Wiping Down with Degreaser

After the surface was degreased and allowed to air dry, the bonding area was submerged in an acetone bath and wiped with a clean lint free cloth.



Figure 4.7 - Soaking Specimens in Acetone Bath

With a clean scraper, the substrate strips were all marked at 0.5" (12.7 mm) from the leading bonding edge. This provided guidance to where the bonding area will stop, to save time and increase accuracy and consistency.

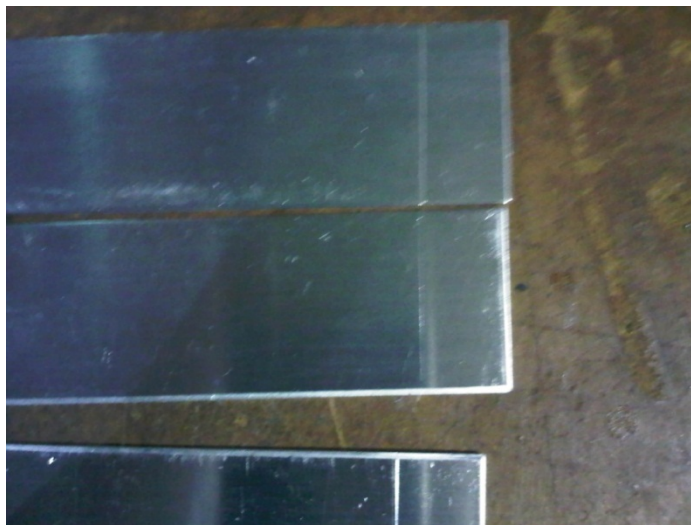


Figure 4.8 - Half Inch Mark

4.2.2.2 Adhesive Preparation and Application

The EA 9394 was mixed in accordance with OEM procedures, and applied on the bond area as outlined in the previous paragraph in accordance with OEM specifications with regards to bond thickness. A second strip was done the same, and the two bond areas were combined together. Care was taken to make sure the bond does not pass the marked lines, and that the specimens are bonded as in-line as possible since bonds that aren't straight will give erroneous results when clamped in the tensile machine. When the bond orientation is satisfactory, they were held in place by small light clips. The small light clips were only used to hold the specimen in proper orientation until we apply the required 40 psi to the specimen for curing. Excess adhesive which is squeezed out was wiped clean after being clipped.

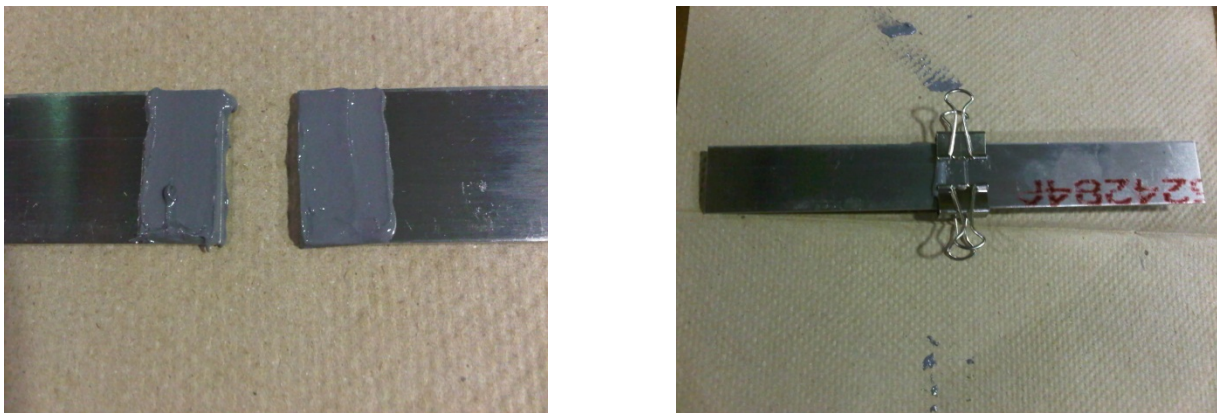


Figure 4.9 – Adhesive Applied to Bond Area and Held in Correct Orientation

After half an hour, the bonded strips were clamped to 40 psi, and further excessive adhesive squeezed out was wiped clean. Speed curing was used in the oven at 66 degrees Celsius for one hour as per OEM instructions. From this research operator's experience, speed curing for Hysol EA 9394 created a more consistent and stronger bond than room temperature curing. The final bond is represented in figure below.



Figure 4.10 - Lap Shear Bond

4.2.3. Tape Adhesion and Pencil Hardness: 825X309

4.2.3.1 Surface Preparation

The substrate used for this test material was chosen to be a 2 by 5 inch 6061 Aluminum plate.

The thickness of the plate was inconsequential as the coating behavior on the surface is the primary concern for both pencil hardness and tape adhesion tests but thicknesses between 0.06 inches to 0.1 inches would be sufficient.

In order to correctly prepare the aluminum surface to accept the coating, the surface was thoroughly degreased and wiped clean of any existing contaminants. Any industrial degreaser is acceptable, however in our case CSM-2 degreaser (Vishay Industries) was employed using a lint-free cloth. The degreased specimen was then immersed in an AlumiPrep #33 (Henkel Turco) bath containing two parts AlumiPrep and one part water. AlumiPrep is a non-flammable phosphoric acid based cleaner, brightener and pre-paint conditioner for aluminum. It was used to dissolve any remaining contaminants from the aluminum surface, as well as strip the corroded

oxide layer on the Aluminum to reveal a bare surface which bonded to the coating more willingly.



Figure 4.11 - AlumiPrep #33 Immersion

The specimen was immersed for 30 seconds, then taken out and rinsed with distilled water. Observation was done to see if the water on the substrate surface was 'beading'. Beading of the water indicated that the surface has been inadequately cleaned. If this was observed, then the cleaning process as mentioned in this paragraph was repeated until the water on the substrate surface displayed non-beading characteristics. After soaking in the AlumiPrep solution, the specimen was immersed in an Alodine 1201 solution containing a 3:1 ratio of Alodine and water respectively. Immersion in Alodine transformed the surface of the aluminum substrate into a tan color and it became a part of the aluminum surface. The Alodine solution was used primarily because it performed to offer a good substrate for both paint adhesion and corrosion resistance. The specimen was immersed in the Alodine solution for approximately 5-10 minutes before it was removed and rinsed in water.

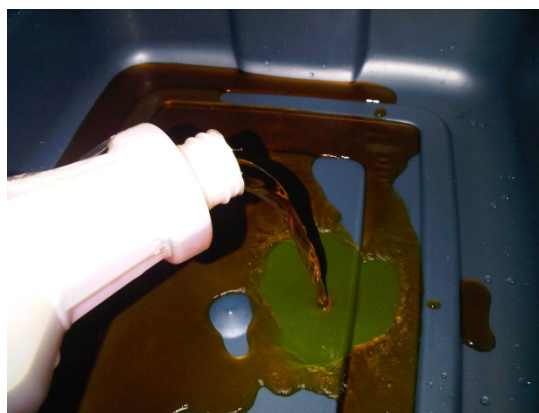
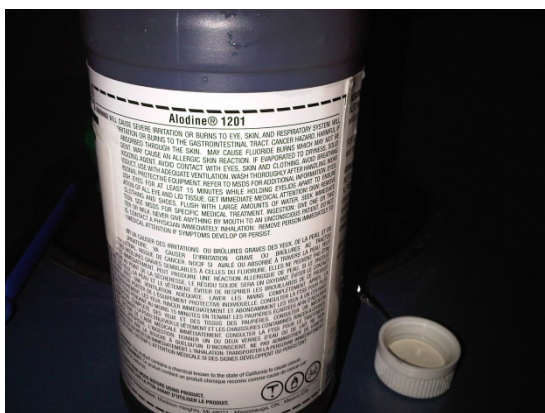


Figure 4.12 - Alodine 1201 Being Poured into Immersion Container

A thorough rinse with distilled water was necessary to remove residual Alodine coating chemical salts from the metal surface. If blistering and corrosion problems appeared under the applied coating, this was usually the result of poor rinsing. The specimen was scrutinized once more after the rinsing process to observe for any residual Alodine, as well as for an even coating of Alodine. This was easily observed as the surface exhibited consistent tan color intensity if an even coating was achieved. After observation, the specimen was allowed to air dry to be prepared for the application of 825X309. The coating was applied as soon as possible to the newly surface treated specimen, to prevent contamination of the surface from reoccurring.



Figure 4.13 - Specimen Alodine Coated

4.2.3.2 Coating Application

After mixing the coating in accordance with OEM instructions, the coating was applied to the specimen face using a sponge brush. The coating can also be applied by a bristle brush, roller brush, or spray gun depending on the operator's preference. The coating thickness was as thin and even as possible without exposing any of the under metal.

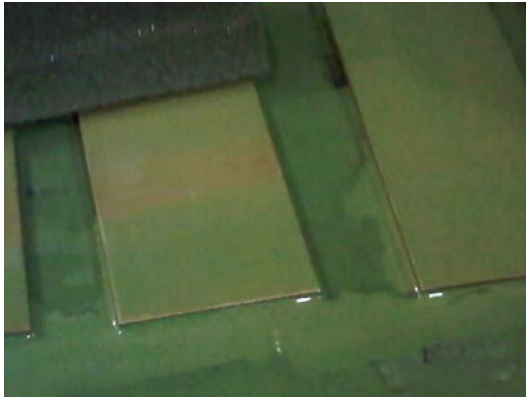


Figure 4.14 - Application of Coating



Figure 4.15 - Specimens Post Curing

This was roughly 0.8-1.2 mils thickness. All specimens were coated as consistently as possible. After the coating was applied to all the specimens, it was air cured at standard conditions (25 C @ 50% humidity) for 24 hours to dry hardness, and 14 days to ultimate cure hardness. Care had been taken so that the specimens are curing on an even level surface, and that they are not disturbed during the curing process.

4.2.4 Tape Adhesion and Pencil Hardness: EC776

4.2.4.1 Surface Preparation

The substrate used for this test material was chosen to be a 2 by 5 inch 6061 Aluminum plate. The thickness of the plate was inconsequential as the coating behavior on the surface is the primary concern for both pencil hardness and tape adhesion tests but thicknesses between 0.06 inches to 0.1 inches was sufficient.

The substrate surface has been properly cleaned and degreased in order to prepare it for the EC776 coating. The surface was degreased using an industrial degreaser and lint-free cloth. In our case, CSM-2 (Vishay Industries) was used; however any other industrial degreasing agent can be employed as long as the surface is clean of contaminants.

4.2.4.2 Coating Preparation

The coating EC776 is a general purpose, solvent based adhesive-coating with good adhesion to synthetic rubbers, metals, glass, and plastics. The coating is resistant to fuels; hence it is employed as tank coatings. The particular coating employed for our experiment was EC-776 SR, which includes a red dye in the compound. EC-776 is a clear/light amber color which makes application by visual inspection difficult. The applied coating thickness was much more easily identifiable with the SR due to the red dye in the mixture.



Figure 4.16 - EC 776 Fuel Resistant Coating

The coat application coat thickness recommended by the OEM (3M) was approximately 1 mil dry film thickness. This thickness was found difficult to achieve when applying the coating using

brushing, since the viscosity of the EC 776 straight out of the can was rated at 1200 cps (syrup consistency). In order to dilute the coating to a more usable consistency, the EC 776 coating was poured into a separate container. Methyl-Ethyl Ketone (MEK, or Butanone) was then mixed with the EC 776 until the desirable viscosity is achieved. MEK is a common industrial solvent which flash dissolves when left in standard conditions, and is recommended by the OEM to dilute the EC 776 prior to application. The amount of MEK to be mixed in is determined by the research operator, and can vary batch by batch. Proper care should be taken by the research operator when handling MEK as it is a moderate explosive, and an irritant to the eyes and nasal passages. MEK was used in well ventilated areas only, and while wearing proper safety equipment covering the eyes, nose and mouth.



Figure 4.17 - Methyl Ethyl Ketone

The mixture was applied to the substrate by dipping the bristle brush into the mixture to get a thorough soaking of the applicator. From the top of the substrate downwards, the brush is applied at a constant rate, with consistent pressure. One coating was sufficient to get the desired coating thickness. If additional thickness is required, then the research operator should wait about 10 minutes prior to applying an additional layer of coating. Streaking occurred depending on the

grade of bristle used for brush application. Much time was not spent trying to even the streaks as they smoothed out and disappeared during the curing process.



Figure 4.18 - Brush Application of EC 776

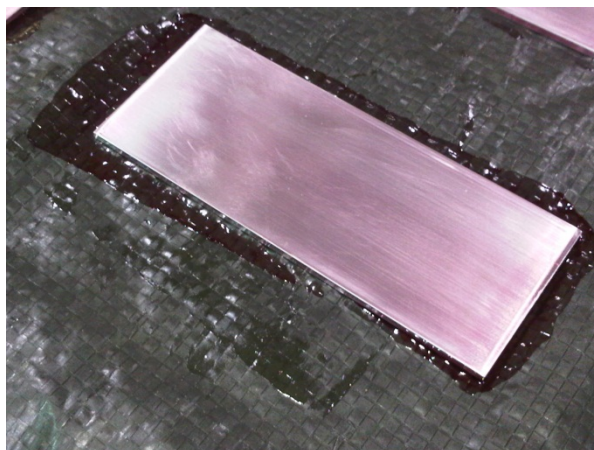


Figure 4.19 - Final Cured Specimen

It was noted that the applied thickness was thicker than the final dry film thickness since the coating lost mass as the MEK solvent dissolved from the solution. This was taken into consideration when applying the coating. EC 776 cured in standard conditions. To tack free condition it took roughly 20 minutes, and for ultimate cure the specimen was left at standard condition for 24 hours. During the curing process, tiny bubbles appeared on the coated surface of the EC 776. This was due to the MEK solvent and other solvents in the mixture escaping the compound. Much concern was not placed on these bubbles as they quickly escaped the surface entirely.

4.2.5 Static Shear: Loctite 609

4.2.5.1 Substrate Preparation

The substrate used for the static shear compression testing consisted of a pin and collar assembly. The material of the pin and collar can vary, however it was recommended by ASTM D4562 that the material be made of 12L14 steel, which has a high lead content.

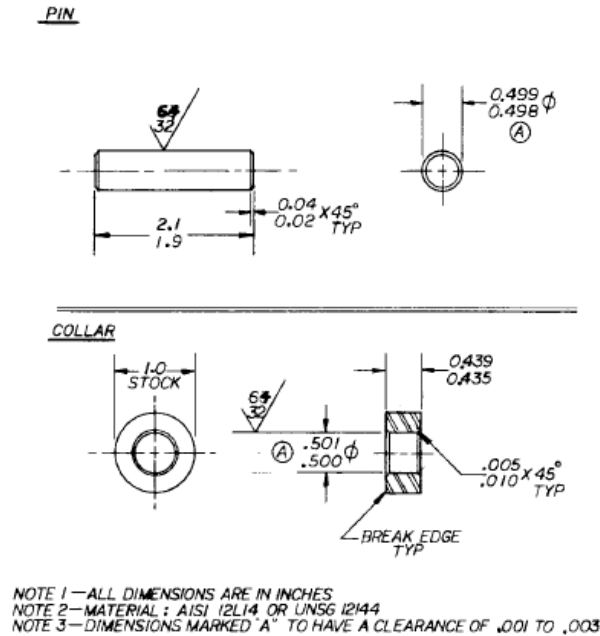


Figure 4.20 - Dimensions from ASTM D4562

The dimensions of the pin and collar were also dictated by ASTM D4562 as shown in Figure 4.20. The substrate was degreased and void of other surface contaminants prior to the bonding procedure. Surface degreasing was done by CSM-2 (Vishay Industries) with a lint-free cloth. However, other industrial degreasing agents may be employed. Extra attention had been given to the exterior of the rod piece, as well as the interior of the collar piece as these are the surfaces where the adhesive was applied. The inside of the collar was degreased using a lint-free cloth soaked in the degreasing agent and shimmied through the hole back and forth. Impurities being scrubbed off the surface became visible on the surface of the cloth indicating progress.

4.2.5.2 Application of the Adhesive

Prior to applying the Loctite 609 adhesive, the pins and collars to be bonded were assembled together to ensure that they fit correctly without exhibiting any sticks or catching between the mating pieces. Once the assembly was established, the adhesive was applied to the circumference of one side of the pin, and the entire interior of the collar piece. This was to ensure

that complete envelopment of the adhesive between the pin and collar occurred once mated. The pin was then slipped into the collar piece while turning the pin in a 180 degree rotation.



Figure 4.21 - Pin and Collar Specimen



Figure 4.22 - Specimens on Curing Rack

This sliding-rotating motion was repeated three times until the pin and collar demonstrated smooth and consistent resistance to motion. This ensures that the adhesive had been evenly spread between the pin and collar. The assembly was then placed in a curing rack of specified height by ASTM D4562. Excess adhesive material was left on the leading edge of the collar after mating the two pieces to create a fillet. If a fillet does not exist, then extra adhesive was applied to create the fillet.

Curing typically took 72 hours for our specified bond gap as defined by the OEM material data sheet. The curing rack was coated with a release agent prior to placing the specimens onto the rack, as the excess Loctite 609 bonded to the rack during curing and made removal of the specimens difficult. During the curing process, the specimens were shifted from its position periodically to ensure that the assembly does not bond to the curing rack.

4.2.6 Film Specimens: Kapton, Teflon, and Polyurethane

4.2.6.1 Specimen Preparation

The films were all cut from a larger sheet of material supplied by McMaster Carr. Using a sharp edge, such as a scalpel and a straight edge, specimen pieces were cut 6 inches by half an inch in dimension. If the edge of the cutter appears rough or worn, then it was replaced with a new cutting edge. Rough edges created uneven cuts and adversely affect the test results. The thickness of the films varied depending on the material used, but it was noted for future references. The larger sheets were taped down to a flat surface to keep it immobilised during cutting. Cuts were made with one smooth stroke, and pressed firmly through the subject material. If a mistake had been made during the cut, then another cut was made at another location. This is to prevent premature failure of the specimen during testing. Cuts were also not be made twice over the same line, as this created uneven edges which cause premature failure. Guide marks were made on the film surface using a marker or other soft felt tip to aid in the cutting process.



Figure 4.23 - Film Specimen Kapton Being Cut

4.2.7 Polyurethane Foam

4.2.7.1 Specimen Preparation

The polyurethane foam (G-15M) came prefabricated from Crest Foam Industries as a large block of material. The polyurethane block is extremely porous which made cutting using conventional means difficult. Cutting mechanically may yield poor results as well, as the cutting edge may fray and leave the surface ragged. This was critical when dealing with tensile specimens, as defects in the edge resulted in erroneous test results. Therefore, in order to produce a cutting edge that would be smooth; the block was cut using a wire heated by an electric power source.

The polyurethane block was placed on a cutting surface with 1 inch of material hanging over the surface edge. Using another metal guide on top situated 1 inch from the free surface, the heated wire was slowly run through the length of the polyurethane block. It was important to perform the cutting slowly, and consistently to get the smoothest cut possible. The cutting procedure was done in a well ventilated area with a face mask, since the heated wire cutting through the polyurethane block creates noxious fumes. After cutting an inch thick slab from the block, the slab was cut into 1 inch by 1 inch tensile specimen strips to be prepared for soaking.

4.2.7 Volume Swell Specimens: Epichlorohydrin Hose

4.2.7.1 Specimen Preparation

The volume swell specimens for the Epichlorohydrin hose material was created from a prefabricated slab in accordance with ASTM D471. Using a straight edge and a marking tool, the slab was sub-sectioned into 2" by 1" rectangular pieces and cut using a strong, sharp tool. A box cutter or shears were sufficient, as creating a perfectly straight edge was not consequential in affecting the results. A scalpel may be used with caution, as the blade may snap during the cutting process. Areas where the slab has greater thicknesses was neglected, as the thickness of the specimen was more critical to consistent results than the cut edge.

CHAPTER 5

Results

5.1 Overview

This chapter illustrates the results of all the tested materials. Some results are best depicted in graphical form, such as a strain vs. load graph, or by charts to compare results. Metallic specimens are represented by photographed images to depict the test result comparison between pre and post soaking. The tests results were categorized in order of static shear, lap shear, all the tensile tests, volume swell, rubber hardness, O-Ring compression, pencil & tape adhesion and metallic microscope images. The metallic images were taken at 40X magnification and 150X magnification respectively. Discussions of the results are presented in the following section of this chapter.

5.2 Loctite 609 Static Shear ASTM D4562

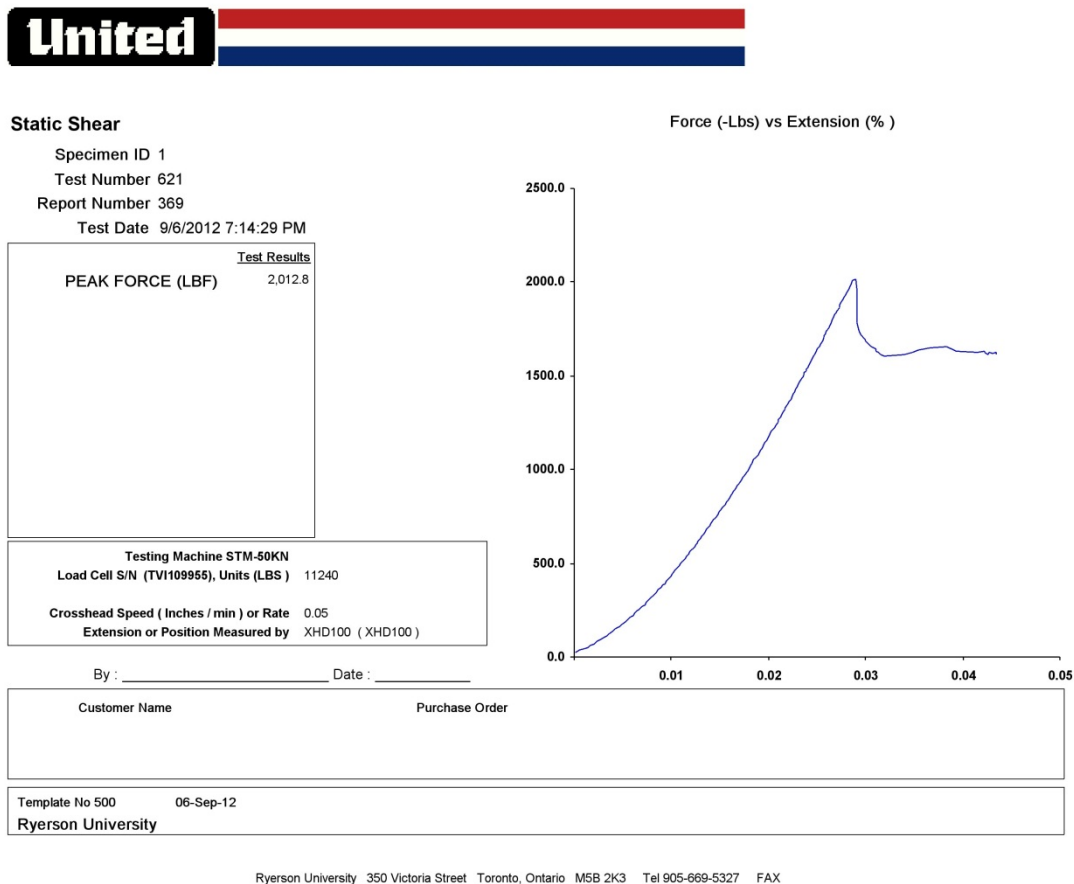


Figure 5.1 - Static Shear Test Result of Loctite 609 in Biofuel 50/50

The static shear testing was conducted on the Loctite 609 adhesive using a pin and collar specimen as described in Chapter 3. ASTM D4562 was used as the guideline for material preparation, testing procedures and the resulting calculations. The figure above is a Force (lbs) vs. Extension (%) graph which illustrates the material loading to failure. As illustrated in Figure 5.1, the failure event is recognized quite clearly as a sharp dip in loading occurs at around 0.03% elongation, and continues to sustain a constant loading at around 80% peak load. The testing was discontinued after the initial failure has occurred as the adhesive will never reach its ultimate strength. The full sets of results are referenced in Appendix B of this report.

5.3 Lap Shear ASTM D1002

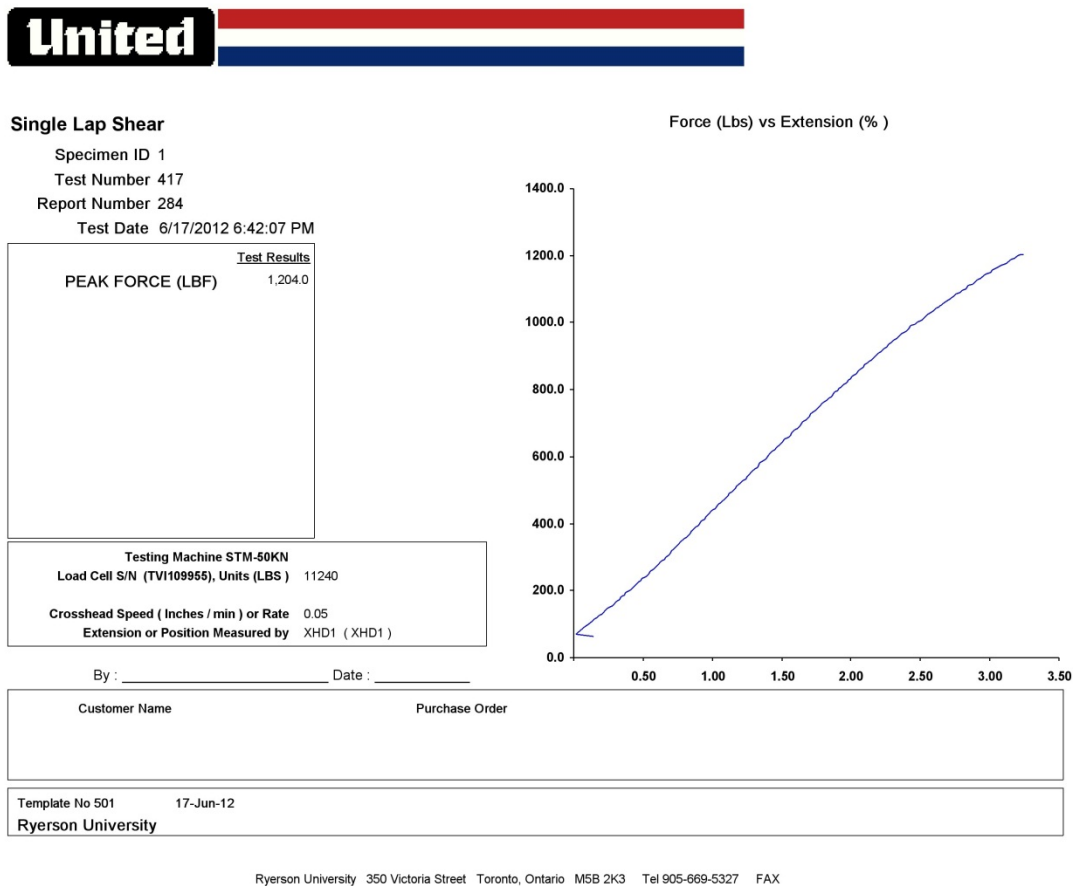


Figure 5.2 - Lap Shear Test Result of EA9394 in Jet A1

The single lap shear testing was conducted on the Hysol EA9394 adhesive using an overlapping specimen as described in Chapter 3. ASTM D1002 was used as the guideline for material preparation, testing procedures and the resulting calculations. The figure above is a Force (lbs) vs. Extension (%) graph which illustrates the material loading to failure. The testing was automatically discontinued when the load cell experienced a 20% decrease in loading. Figure 5.2 illustrates the load curve to be linear, demonstrating consistent resistance during loading to failure. This was representative of all the lap shear results observed. The full sets of results are referenced in Appendix B of this report.

5.4 Tensile ASTM D412

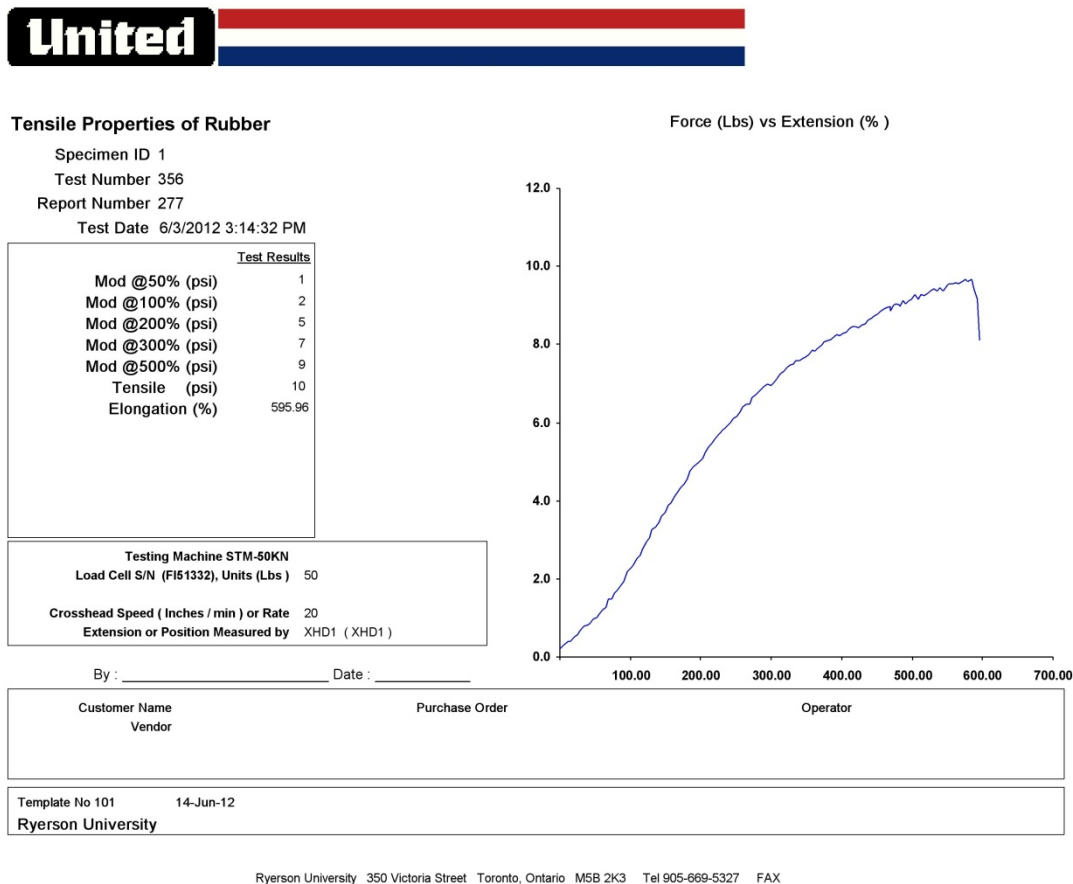


Figure 5.3 – Tensile Test Result of Polyurethane Foam in Jet A1

The tensile testing was conducted on various materials using either dog-bone or strip specimens as described in Chapter 3. ASTM D412 was used as the guideline for material preparation, testing procedures and the resulting calculations. Figure 5.3 is a Force (lbs) vs. Extension (%) graph which illustrates the material loading to failure. The testing was automatically discontinued when the load cell experienced a 20% decrease in loading which indicated material failure. Figure 5.3 shows the material loading at a greater rate in the first half of the cycle, then decreasing until failure. The load curves for the tensile specimens follow similar patterns of load rates as shown in Figure 5.3. The full sets of results are referenced in Appendix B of this report.

5.5 Volume Swell ASTM D471 and Rubber Hardness ASTM D2240

Table 5.1 - Volume Swell Result of Epichlorohydrin Hose in Jet A1

Pre-Soak			Post-Soak		
71C					
Epichlorohydrin	Dry	Wet	Dry	Wet	Volume Swell (%)
Specimen 1	3.665	1.077	3.71	1.002	4.636785162
Specimen 2	3.868	1.121	3.893	1.047	3.603931562
Specimen 3	4.004	1.161	4.009	1.082	2.954625396
Specimen 4	4.084	1.181	4.08	1.108	2.376851533
Specimen 5	3.685	1.058	3.671	0.985	2.24590788
				Avg	3.163620306

Table 5.2 - Rubber Hardness of CS3100 in Jet A1

71C						
CS3100	1	2	3	4	5	Avg
Specimen 1	42.5	41.6	42	42.3	38.9	41.46
Specimen 2	42	40	38.9	39.2	40.9	40.2
Specimen 3	40.9	43.3	42.4	43.5	44.8	42.98
Specimen 4	45.7	43.8	42.9	43.8	44.2	44.08
Specimen 5	42.8	45.3	42.9	42.6	42.6	43.24
					Avg	42.392

The volume swell and rubber hardness testing were conducted on various elastomer sets of the non-metal materials using standard 2” by 1” specimens or prefabricated configurations as described in Chapter 3. ASTM D471 was used as the guideline for material preparation, testing procedures and the resulting calculations. Table 5.1 above illustrates measured mass of the specimen suspended in air “dry” and immersed in water “wet” for both pre-soaked and post-soaked conditions. Table 5.2 illustrates measured hardness ratings on five different points of each specimen. A total of five specimens were measured to get an average reading. The full sets of results are referenced in Appendix B of this report.

5.6 Rubber Compression ASTM D395

Table 5.3 - Rubber Compression Results for Nitrile N602-70 in Jet A1

Nitrile N602-70					
Jet A1			Biofuel 50/50		
To	Ti	Compression Set (%)	To	Ti	Compression Set (%)
0.07	0.055	28.57142857	0.07	0.056	26.66666667
0.07	0.055	28.57142857	0.07	0.056	26.66666667
0.07	0.06	19.04761905	0.07	0.057	24.76190476
0.07	0.056	26.66666667	0.07	0.057	24.76190476
0.07	0.06	19.04761905	0.07	0.056	26.66666667
	Average	24.38		Average	25.91

The rubber compression testing was conducted on various elastomer o-ring materials using standard prefabricated configurations as described in Chapter 3. ASTM D395 was used as the guideline for material preparation, testing procedures and the resulting calculations. Table 5.3 above illustrates measured thickness before, and after the compression cycle has completed. A compression result as a percentage was calculated. A total of five specimens were measured to get an average reading. The full sets of results are referenced in Appendix B of this report.

5.7 Pencil Hardness ASTM D3363

Table 5.4 - Pencil Hardness Results of 825X309 in Jet A1

825X309	No scratch to Metal	No scratch on surface
Specimen 1	3H	3H
Specimen 2	4H	4H
Specimen 3	4H	3H

The pencil hardness testing was conducted on various coating materials applied on Al 6061-T6 as described in Chapter 3. ASTM D3363 was used as the guideline for material preparation, testing procedures and the resulting calculations. Table 5.4 above illustrates the pencil hardness scratch to metal and scratch to surface after the soaking cycle has completed. The rating of the

pencil hardness was compared with an uncured rating. A total of three specimens were measured to get an average reading. The full sets of results are referenced in Appendix B of this report.

5.8 Tape Adhesion ASTM D3359



Figure 5.4 - Tape Adhesion Results of 825X309 in Jet A1

The tape adhesion testing was conducted on various coating materials applied on Al 6061-T6 as described in Chapter 3. ASTM D3359 was used as the guideline for material preparation, testing procedures and the resulting calculations. Figure 5.4 above illustrates the cuts made on the coating surface to the substrate, and the tapes used for the testing. Three separate areas of cuts were made on each specimen. A total of three specimens were measured to get an average reading. The full sets of results are referenced in Appendix B of this report.

5.9 Metallic Surface Evaluation Images ASTM D4054

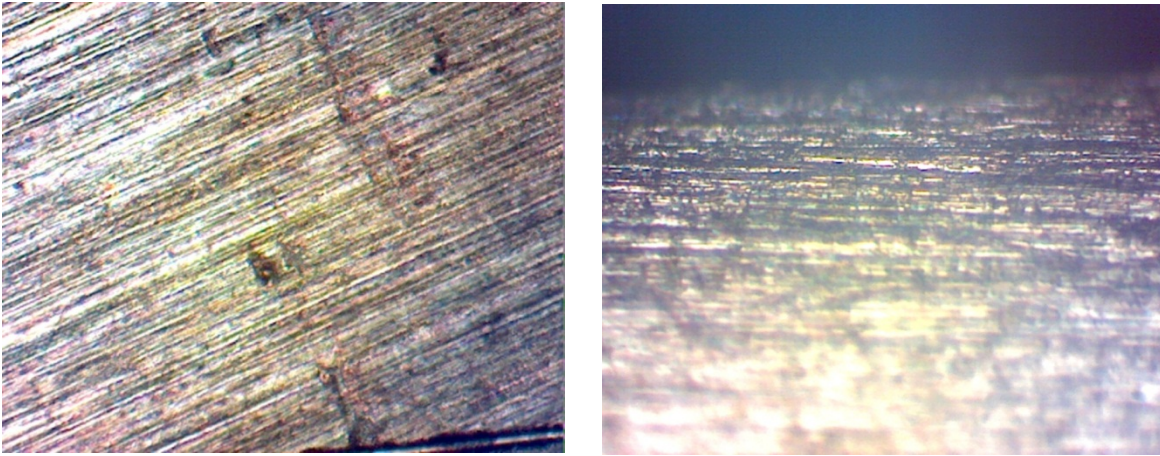


Figure 5.5 - Metallic Evaluation Results of 2024 T3 under 40X and 150X Magnification Respectively in Jet A1

The metallic surface evaluation testing was conducted on all the metal specimens investigated in this study. ASTM D4054 was used as the guideline for material preparation, testing procedures and the resulting calculations. Figure 5.5 above illustrates the surface detail of 2024 T3 when under 40X magnification and a polished cross section analysis using 150X magnification.

Overall surface defects were not present in the metals studied and a cross section revealed no corrosive effects deeper in the metal. A total of three specimens were analyzed for each material.

The full sets of results are referenced in Appendix B of this report.

CHAPTER 6

Discussions

The objective of this research was to determine the effect of mixed Biofuel/Jet A1 propellant on specimens compared to a benchmark fuel of pure Jet A1. The results as mentioned in the previous chapters are compared to baseline results which were extrapolated from Jet A1 testing, and given limiting criteria which were outlined by ASTM D4054. Each test method was evaluated using its representative ASTM procedure, and the results tabulated were from the respective standard. The results evaluated were found to be acceptable, and no items were found to egregiously violate the baseline evaluation criteria. The following section summarizes the results found and any discussions pertaining to the test performed.

6.1 Static Shear – ASTM D4562

The adhesive used for the static shear testing was Loctite 609 provided by Loctite, which is a subsidiary company of Henkel. A total of five specimens were used, with a shear area of 0.785 in². When determining the shear stress, we simply divide the observed load with the effective area as follows.

Table 6.1 - Peak Stresses of Specimens for Jet A1 and Biofuel 50/50

Specimen ID	Peak Stress Jet A1 (psi)	Peak Stress Bio 50/50 (psi)	
1	2562.8	2841.4	
2	2761.9	2766.1	
3	2496.8	2921.4	
4	2801.9	3032.3	
5	2373.2	2735.0	Allowable Criteria
Avg	2599.3	2859.3	250 psi decrease

The table above shows how Loctite 609 performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the adhesive is in contact with Biofuel 50/50, it increases the strength of the adhesive. This can clearly be nothing but a good thing in the perspective of the adhesive, and passes the allowable criteria.

6.2 Lap Shear – ASTM D1002

The lap shear specimens were tested with Hysol EA 9394 epoxy paste adhesive. A total of five specimens were used, with a shear area of 0.5 in². When determining the shear stress, we simply divide the observed load with the effective area as follows.

Table 6.2 - Peak Stresses of EA 9394 for Jet A1 and Biofuel 50/50

Specimen ID	Peak Stress Jet A1 (psi)	Peak Stress Bio 50/50 (psi)	
1	2408.0	2368.6	
2	2536.0	2389.6	
3	2463.0	2355.2	
4	2931.6	2714.6	
5	2670.0	2448.2	Allowable Criteria
Avg	2601.72	2455.24	250 psi decrease

The table above shows how the Hysol EA 9394 performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the adhesive is in contact with Biofuel 50/50, it decreases the strength of the adhesive. This is contrary to the results of Loctite 609, however the two adhesives are chemically different and a deviation of comparability can be expected. The difference of the average however is still well within the allowable baseline criteria. Therefore, the effects of the Biofuel on the adhesive are determined to be acceptable.

6.3 Polyurethane Foam – ASTM D412

Tensile and Elongation tests were performed on the Polyurethane Foam by Crest Foam Industries. Total of five specimens were used, with a cross section area of 1 in². When determining the tensile stress, we simply divide the observed load with the effective area as follows.

Table 6.3 - Peak Stresses of Polyurethane Foam for Jet A1 and Biofuel 50/50

Specimen ID	Peak Stress Jet A1 (psi)	Peak Stress Bio 50/50 (psi)	
1	10	7	
2	10	7	
3	9	8	
4	11	8	
5	10	7	Allowable Criteria
Avg	10	7	5 psi decrease

The table above shows how polyurethane foam performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it decreases in strength. The difference of the averages however is still well within the allowable baseline criteria. Therefore, the effects of the Biofuel on the foam are determined to be negligible and acceptable.

Elongation tests were also performed in conjunction with the tensile test, and the results yielded are as follows.

Table 6.4 - Peak Elongation of Polyurethane Foam for Jet A1 and Biofuel 50/50

Specimen ID	Peak Elongation Jet A1 (%)	Peak Elongation Bio 50/50 (%)	
1	595.96	351.39	
2	534.57	396.32	
3	459.94	449.91	
4	600.13	415.26	
5	658.13	379.46	Allowable Criteria
Avg	569.74	398.47	15 % decrease

The table above shows how polyurethane foam performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it decreases in elongation properties. The differences of the averages are significant enough to warrant the result to be unacceptable under the baseline criteria as outlined in the previous section. This may be due to the biofuel is making the polyurethane foam more brittle and susceptible to tearing during stretching. Another possibility could be that both elongations are extremely high, and a difference of 15% between the two fuels may be too narrow a margin to consistently achieve. Since the results were consistent, we can conclude that the results were not isolated.

6.4 Kapton Film – ASTM D412

Tensile and Elongation tests were performed on the Kapton film provided by McMaster Carr. Total of five specimens were used, with a cross section area of 0.0025 in². When determining the tensile stress, we simply divide the observed load with the effective area as follows.

Table 6.5 - Peak Stresses of Kapton Film for Jet A1 and Biofuel 50/50

Specimen ID	Peak Stress Jet A1 (psi)	Peak Stress Bio 50/50 (psi)	
1	13988.4	13252	
2	14226	14327	
3	16432.4	12014	
4	16236	16427	
5	16011.2	14677	Allowable Criteria
Avg	14949.2	14139	1800 psi decrease

The table above shows how the Kapton film performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it decreases in strength. The difference of the averages however is still well within the allowable baseline criteria. Therefore, the effects of the Biofuel on the material are determined to be negligible and acceptable.

Elongation tests were also performed in conjunction with the tensile test, and the results yielded are as follows.

Table 6.6 - Peak Elongation of Kapton Film for Jet A1 and Biofuel 50/50

Specimen ID	Peak Elongation Jet A1 (%)	Peak Elongation Bio 50/50 (%)	
1	14.86	14.80	
2	15.77	14.96	
3	24.47	11.24	
4	24.43	27.72	
5	15.77	15.28	Allowable Criteria
Avg	17.1	16.8	>25% initial

The table above shows how Kapton film performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it decreases in elongation properties. The differences of the averages are significant enough to warrant the result to be unacceptable under the baseline criteria as outlined in the previous

section. This may be due to the biofuel is making the Kapton Film more brittle and susceptible to tearing during stretching. Another possibility could be that the foams were tested at different time intervals after the soaking process has occurred and that could have had an effect on the results. Grip setup may also play a factor in the results, and may be a culprit in the premature breaking. Since the result is consistent, we can conclude that the result was not isolated.

6.5 Polyethylene Film – ASTM D412

Tensile and Elongation tests were performed on the Polyethylene film provided by McMaster Carr. Total of five specimens were used, with a cross section area of 0.0025 in². When determining the tensile stress, we simply divide the observed load with the effective area as follows.

Table 6.7 - Peak Stresses of Polyethylene Film for Jet A1 and Biofuel 50/50

Specimen ID	Peak Stress Jet A1 (psi)	Peak Stress Bio 50/50 (psi)	
1	9089	11059	
2	9303	9237	
3	9624	9605	
4	9606	9528	
5	9325	8628	Allowable Criteria
Avg	9389	9612	250 psi decrease

The table above shows how the Polyethylene film performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it increases in strength. The difference of the averages is above the allowable baseline criteria. Therefore, the effects of the Biofuel on the material are determined to be acceptable.

Elongation tests were also performed in conjunction with the tensile test, and the results yielded are as follows.

Table 6.8 - Peak Elongation of Polyethylene Film for Jet A1 and Biofuel 50/50

Specimen ID	Peak Elongation Jet A1 (%)	Peak Elongation Bio 50/50 (%)	
1	64.84	37.87	
2	77.76	61.84	
3	70.45	61.13	
4	75.03	67.13	
5	68.94	56.14	Allowable Criteria
Avg	71.40	56.82	50% decrease

The table above shows how Polyethylene film performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it decreases in elongation properties. The difference of the average however is still well within the allowable baseline criteria. Therefore, the effects of the Biofuel on the material are determined to be acceptable.

6.6 Teflon Film – ASTM D412

Tensile and Elongation tests were performed on the Teflon film provided by McMaster Carr. Total of five specimens were used, with a cross section area of 0.005 in². When determining the tensile stress, we simply divide the observed load with the effective area as follows.

Table 6.9 - Peak Stresses of Teflon Film for Jet A1 and Biofuel 50/50

Specimen ID	Peak Stress Jet A1 (psi)	Peak Stress Bio 50/50 (psi)	
1	2445	2799	
2	2543	2690	
3	2661	3039	
4	2228	2885	
5	2540	2719	Allowable Criteria
Avg	2483	2826	150 psi decrease

The table above shows how the Teflon film performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50,

it increases in strength. The difference of the averages is above the allowable baseline criteria.

Therefore, the effects of the Biofuel on the material are determined to be acceptable.

Elongation tests were also performed in conjunction with the tensile test, and the results yielded are as follows.

Table 6.10 - Peak Elongation of Teflon Film for Jet A1 and Biofuel 50/50

Specimen ID	Peak Elongation Jet A1 (%)	Peak Elongation Bio 50/50 (%)	
1	299.47	379.79	
2	395.80	258.83	
3	481.23	362.31	
4	202.10	326.08	
5	460.08	272.85	Allowable Criteria
Avg	367.74	319.97	15% decrease

The table above shows how Teflon film performs when exposed to Jet A1 and Biofuel 50/50.

The specimens tested seem to yield inconclusive data when the results between the Biofuel 50/50 are compared with Jet A1. Some results show an increase in elongation, while others indicate a decrease in elongation. The differences of the averages taken are significant enough to warrant the result to be unacceptable under the baseline criteria as outlined in the previous section. Grip setup may also play a factor in the results, and may be a culprit in the differences in elongation. The margin of failure may also be too narrow for the material being tested as both fuels show elongation over 300% and widening the acceptable margin may be necessary in ASTM D4054. The quality of the cut edge may also be a factor in the inconsistencies.

6.7 Fluorocarbon O-Ring – ASTM D1414

Tensile and Elongation tests were performed on the Fluorocarbon O-Ring provided by Parker.

Total of five specimens were used, with a cross section area of 0.0079 in². When determining the tensile stress, we simply divide the observed load with the effective area as follows.

Table 6.11 - Peak Stresses of Fluorocarbon O-Ring for Jet A1 and Biofuel 50/50

Specimen ID	Peak Stress Jet A1 (psi)	Peak Stress Bio 50/50 (psi)	
1	979	1023.9	
2	931	1046.64	
3	905	1034.38	
4	897	1044.93	
5	955	1041.75	Allowable Criteria
Avg	933.4	1038.32	125 psi decrease

The table above shows how the Fluorocarbon O-Ring performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it increases in strength. The difference of the averages is above the allowable baseline criteria. Therefore, the effects of the Biofuel on the material are determined to be acceptable.

Elongation tests were also performed in conjunction with the tensile test and were calculated using the equation:

$$\text{Ultimate elongation, \%} = [2D + G - C] \times 100$$

Where D is the grip separation of the specimen, G is the circumference of one spool, and C is the inside circumference of the specimen.

Table 6.12 - Peak Elongation of Fluorocarbon O-Ring for Jet A1 and Biofuel 50/50

Specimen ID	Peak Elongation Jet A1 (%)	Peak Elongation Bio 50/50 (%)	
1	378.15	373.4	
2	365.05	397.6	
3	371	360.4	
4	325.80	319.65	
5	375.64	409.09	Allowable Criteria
Avg	363.13	372.03	35% decrease

The table above shows how Fluorocarbon O-Ring performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it increases in elongation properties. The differences of the averages are above the allowable baseline criteria. Therefore, the effects of the Biofuel on the material are determined to be acceptable.

Hardness tests of this material passed the baseline criteria when compared to Jet A1 and the Jet A1 passes the criteria shown in Appendix A when compared to unaged specimens as dictated in ASTM D4054.

Table 6.13 - Unaged Hardness Results

Specimen	Unaged Hardness
1	77.9
2	80.3
3	79.7
4	79.0
5	74.1
Avg	78.2

Volume swell results passed under the baseline criteria when compared to the base fuel Jet A1 as shown in Appendix A. The Biofuel 50/50 results show a marginal increase in volume swell when compared to the Jet A1 fuel.

The compression set results passed under the baseline criteria when compared to the base fuel Jet A1. The Biofuel 50/50 results show a marginal increase of less than 1% in compression as opposed to the 5% criteria given by ASTM D4054 when compared to the Jet A1 fuel.

6.8 L.T. Fluorocarbon O-Ring – ASTM D1414

Tensile and Elongation tests were performed on the L.T. Fluorocarbon O-Ring provided by Parker. Total of five specimens were used, with a cross section area of 0.0079 in². When

determining the tensile stress, we simply divide the observed load with the effective area as follows.

Table 6.14 - Peak Stresses of L.T. Fluorocarbon O-Ring for Jet A1 and Biofuel 50/50

Specimen ID	Peak Stress Jet A1 (psi)	Peak Stress Bio 50/50 (psi)	
1	1395	1408	
2	1382	1533	
3	1605	1402	
4	1516	1385	
5	1417	1390	Allowable Criteria
Avg	1463	1424	125 psi decrease

The table above shows how the L.T. Fluorocarbon O-Ring performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it decreases in strength. The difference of the averages is still well within the allowable baseline criteria. Therefore, the effects of the Biofuel on the material are determined to be negligible and acceptable.

Elongation tests were also performed in conjunction with the tensile test and were calculated using the equation:

$$\text{Ultimate elongation, \%} = [2D + G - C] \times 100$$

Where D is the grip separation of the specimen, G is the circumference of one spool, and C is the inside circumference of the specimen.

Table 6.15 - Peak Elongation of L.T. Fluorocarbon O-Ring for Jet A1 and Biofuel 50/50

Specimen ID	Peak Elongation Jet A1 (%)	Peak Elongation Bio 50/50 (%)	
1	360.76	400.45	
2	419.91	460.95	
3	384.79	389.88	
4	342.01	400.66	
5	331.56	389.99	Allowable Criteria
Avg	367.81	408.39	35% decrease

The table above shows how L.T. Fluorocarbon O-Ring performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it increases in elongation properties. The differences of the averages are above the allowable baseline criteria. Therefore, the effects of the Biofuel on the material are determined to be acceptable.

Hardness tests of this material passed the baseline criteria when compared to Jet A1 shown in Appendix A and the Jet A1 passes the criteria when compared to unaged specimens as dictated in ASTM D4054.

Table 6.16 - Unaged Hardness Results

Specimen	Unaged Hardness
1	83.0
2	81.9
3	82.5
4	79.5
5	82.5
Avg	81.8

Volume swell results passed under the baseline criteria when compared to the base fuel Jet A1. However, the results from Jet A1 do not fall between the base line criteria of 0-10%. Therefore, the specimen fails the volume swell test.

The compression set results passed under the baseline criteria when compared to the base fuel Jet A1. The Biofuel 50/50 results show a marginal increase of 1% in compression in Appendix A when compared to the Jet A1 fuel compared to the 5% criteria given by ASTM D4054.

6.9 Nitrile O-Ring – ASTM D1414

Tensile and Elongation tests were performed on the Nitrile O-Ring provided by Parker. Total of five specimens were used, with a cross section area of 0.0079 in².

When determining the tensile stress, we simply divide the observed load with the effective area as follows.

Table 6.17 - Peak Stresses of Nitrile O-Ring for Jet A1 and Biofuel 50/50

Specimen ID	Peak Stress Jet A1 (psi)	Peak Stress Bio 50/50 (psi)	
1	1827	1705	
2	1775	1979	
3	1672	1861	
4	1692	1763	
5	1323	1621	Allowable Criteria
Avg	1658	1786	125 psi decrease

The table above shows how the Nitrile O-Ring performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it increases in strength. The difference of the averages is above the allowable baseline criteria. Therefore, the effects of the Biofuel on the O-Ring are determined to be acceptable.

Elongation tests were also performed in conjunction with the tensile test and were calculated using the equation:

$$\text{Ultimate elongation, \%} = [2D + G - C] \times 100$$

Where D is the grip separation of the specimen, G is the circumference of one spool, and C is the inside circumference of the specimen.

Table 6.18 - Peak Elongation of Nitrile O-Ring for Jet A1 and Biofuel 50/50

Specimen ID	Peak Elongation Jet A1 (%)	Peak Elongation Bio 50/50 (%)	
1	830.52	745.7	
2	837.6	899.98	
3	717.14	888.32	
4	741.13	848.44	
5	556.99	745.79	Allowable Criteria
Avg	736.68	825.65	35% decrease

The table above shows how Nitrile O-Ring performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it increases in elongation properties. The differences of the averages are above the allowable baseline criteria. Therefore, the effects of the Biofuel on the material are determined to be acceptable.

Hardness tests of this material passed the baseline criteria when compared to Jet A1 in Appendix A and the Jet A1 passes the criteria when compared to unaged specimens as dictated in ASTM D4054.

Table 6.19 - Unaged Hardness Results

Specimen	Unaged Hardness
1	73.5
2	76.4
3	76.9
4	73.5
5	73.1
Avg	74.6

Volume swell results passed under the baseline criteria when compared to the base fuel Jet A1. The Biofuel 50/50 results show a marginal decrease in volume swell when compared to the Jet A1 fuel.

The compression set results passed under the baseline criteria when compared to the base fuel Jet A1 in Appendix A. The Biofuel 50/50 results show a marginal increase of 1% in compression when compared to the Jet A1 fuel compared to 5% given by ASTM D4054.

6.10 CS3100 Sealant – ASTM D412

Tensile and Elongation tests were performed on the CS3100 Sealant provided by Flame Master. Total of five specimens were used, with a cross section area of 0.0186 in².

When determining the tensile stress, we simply divide the observed load with the effective area as follows.

Table 6.20 - Peak Stresses of CS3100 Sealant for Jet A1 and Biofuel 50/50

Specimen ID	Peak Stress Jet A1 (psi)	Peak Stress Bio 50/50 (psi)	
1	122	215	
2	122	249	
3	156	274	
4	153	236	
5	146	226	Allowable Criteria
Avg	140	240	35 psi decrease

The table above shows how the CS3100 Sealant performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it increases in strength. The difference of the averages is above the allowable baseline criteria. Therefore, the effects of the Biofuel on the sealant are determined to be acceptable.

Elongation tests were also performed in conjunction with the tensile test and the results are as follows.

Table 6.21 - Peak Elongation of CS3100 Sealant for Jet A1 and Biofuel 50/50

Specimen ID	Peak Elongation Jet A1 (%)	Peak Elongation Bio 50/50 (%)	
1	289.58	519.16	
2	319.98	634.48	
3	387.16	644.72	
4	424.96	627.09	
5	381.80	655.48	Allowable Criteria
Avg	360.70	655.48	25% decrease

The table above shows how CS3100 Sealant performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it increases in elongation properties. The differences of the averages are above the allowable baseline criteria. Therefore, the effects of the Biofuel on the material are determined to be acceptable.

Hardness tests of this material passed the baseline criteria when compared to Jet A1 and the Jet A1 passes the criteria when compared to unaged specimens as shown in Appendix A. The Biofuel 50/50 results showed a decrease in hardness when compared to Jet A1.

Volume swell results passed under the baseline criteria when compared to the base fuel Jet A1 as shown in Appendix A. The Biofuel 50/50 results showed a decrease in swelling when compared to Jet A1.

6.11 PR1422 Sealant – ASTM D412

Tensile and Elongation tests were performed on the PR1422 Sealant provided by PRC de Soto. Total of five specimens were used, with a cross section area of 0.0186 in².

When determining the tensile stress, we simply divide the observed load with the effective area as follows.

Table 6.22 - Peak Stresses of PR1422 Sealant for Jet A1 and Biofuel 50/50

Specimen ID	Peak Stress Jet A1 (psi)	Peak Stress Bio 50/50 (psi)	
1	315	412	
2	317	381	
3	313	401	
4	307	355	
5	310	356	Allowable Criteria
Avg	313	381	35 psi decrease

The table above shows how the PR1422 Sealant performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it increases in strength. The difference of the averages is above the allowable baseline criteria. Therefore, the effects of the Biofuel on the sealant are determined to be acceptable.

Elongation tests were also performed in conjunction with the tensile test and the results are as follows.

Table 6.23 - Peak Elongation of PR1422 Sealant for Jet A1 and Biofuel 50/50

Specimen ID	Peak Elongation Jet A1 (%)	Peak Elongation Bio 50/50 (%)	
1	603.64	590.68	
2	662.99	605.82	
3	569.59	646.98	
4	647.38	525.65	
5	437.77	523.98	Allowable Criteria
Avg	584.28	578.62	25% decrease

The table above shows how PR1422 Sealant performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it decreases in elongation properties. The difference of the average however is still well within

the allowable baseline criteria. Therefore, the effects of the Biofuel on the material are determined to be negligible and acceptable.

Hardness tests of this material passed the baseline criteria when compared to Jet A1 and the Jet A1 passes the criteria when compared to unaged specimens as shown in Appendix A. The Biofuel 50/50 results showed an increase in hardness when compared to Jet A1.

Volume swell results passed under the baseline criteria when compared to the base fuel Jet A1 as shown in Appendix A. The Biofuel 50/50 results showed a decrease in swelling when compared to Jet A1.

6.12 PR1776 Sealant – ASTM D412

Tensile and Elongation tests were performed on the PR1776 Sealant provided by PRC de Soto. Total of five specimens were used, with a cross section area of 0.0186 in².

When determining the tensile stress, we simply divide the observed load with the effective area as follows.

Table 6.24 - Peak Stresses of PR1776 Sealant for Jet A1 and Biofuel 50/50

Specimen ID	Peak Stress Jet A1 (psi)	Peak Stress Bio 50/50 (psi)	
1	228	195	
2	196	186	
3	187	181	
4	195	177	
5	217	207	Allowable Criteria
Avg	205	189	35 psi decrease

The table above shows how the PR1776 Sealant performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it decreases in strength. The difference of the averages is still well within the allowable

baseline criteria. Therefore, the effects of the Biofuel on the sealant are determined to be negligible and acceptable.

Elongation tests were also performed in conjunction with the tensile test and the results are as follows.

Table 6.25 - Peak Elongation of PR1776 Sealant for Jet A1 and Biofuel 50/50

Specimen ID	Peak Elongation Jet A1 (%)	Peak Elongation Bio 50/50 (%)	
1	320.10	398.67	
2	349.12	438.29	
3	375.60	421.93	
4	347.35	343.13	
5	424.84	347.08	Allowable Criteria
Avg	363.40	389.82	25% decrease

The table above shows how PR1776 Sealant performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it increases in elongation properties. The differences of the averages are above the allowable baseline criteria. Therefore, the effects of the Biofuel on the material are determined to be acceptable.

Hardness tests of this material passed the baseline criteria when compared to Jet A1 and the Jet A1 passes the criteria when compared to unaged specimens as shown in Appendix A. The Biofuel 50/50 results showed an increase in hardness when compared to Jet A1. Volume swell results passed under the baseline criteria when compared to the base fuel Jet A1 as shown in Appendix A. The Biofuel 50/50 results showed an increase in swelling when compared to Jet A1.

6.13 PR1828 Sealant – ASTM D412

Tensile and Elongation tests were performed on the PR1828 Sealant provided by PRC de Soto.

Total of five specimens were used, with a cross section area of 0.0186 in².

When determining the tensile stress, we simply divide the observed load with the effective area as follows.

Table 6.26 - Peak Stresses of PR1776 Sealant for Jet A1 and Biofuel 50/50

Specimen ID	Peak Stress Jet A1 (psi)	Peak Stress Bio 50/50 (psi)	
1	260	331	
2	240	280	
3	273	317	
4	254	295	
5	219	313	Allowable Criteria
Avg	249	307	35 psi decrease

The table above shows how the PR1828 Sealant performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it increases in strength. The differences of the averages are above the allowable baseline criteria. Therefore, the effects of the Biofuel on the sealant are determined to be acceptable.

Elongation tests were also performed in conjunction with the tensile test and the results are as follows.

Table 6.27 - Peak Elongation of PR1828 Sealant for Jet A1 and Biofuel 50/50

Specimen ID	Peak Elongation Jet A1 (%)	Peak Elongation Bio 50/50 (%)	
1	384.61	490.14	
2	419.32	409.38	
3	412.41	455.30	
4	385.32	447.58	
5	326.55	493.38	Allowable Criteria
Avg	385.64	459.15	25% decrease

The table above shows how PR1828 Sealant performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it increases in elongation properties. The differences of the averages are above the allowable baseline criteria. Therefore, the effects of the Biofuel on the material are determined to be acceptable.

Hardness tests of this material passed the baseline criteria when compared to Jet A1 and the Jet A1 passes the criteria when compared to unaged specimens as shown in Appendix A. The Biofuel 50/50 results decreased in hardness when compared to Jet A1.

Volume swell results passed under the baseline criteria when compared to the base fuel Jet A1 as shown in Appendix A. The Biofuel 50/50 results showed a decrease in swelling when compared to Jet A1.

6.14 PR2911 Sealant – ASTM D412

Tensile and Elongation tests were performed on the PR2911 Sealant provided by PRC de Soto. Total of five specimens were used, with a cross section area of 0.0186 in².

When determining the tensile stress, we simply divide the observed load with the effective area as follows.

Table 6.28 - Peak Stresses of PR2911 Sealant for Jet A1 and Biofuel 50/50

Specimen ID	Peak Stress Jet A1 (psi)	Peak Stress Bio 50/50 (psi)	
1	481	266	
2	494	257	
3	437	234	
4	420	298	
5	438	202	Allowable Criteria
Avg	454	251	35 psi decrease

The table above shows how the PR2911 Sealant performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it decreases in strength. The difference of the averages is not within the allowable baseline criteria. Therefore, the effects of the Biofuel on the sealant are determined to be unacceptable.

Elongation tests were also performed in conjunction with the tensile test and the results are as follows.

Table 6.29 - Peak Elongation of PR2911 Sealant for Jet A1 and Biofuel 50/50

Specimen ID	Peak Elongation Jet A1 (%)	Peak Elongation Bio 50/50 (%)	
1	1311.56	852.94	
2	1333.88	855.22	
3	1153.80	998.90	
4	1082.55	918.37	
5	987.20	761.84	Allowable Criteria
Avg	1173.80	877.45	25% decrease

The table above shows how PR2911 Sealant performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it decreases in elongation properties. The difference of the average however is not within the allowable baseline criteria. Therefore, the effects of the Biofuel on the material are determined to be unacceptable.

Hardness tests of this material passed the baseline criteria when compared to Jet A1 and the Jet A1 passes the criteria when compared to unaged specimens as shown in Appendix A. The Biofuel 50/50 results increased in hardness when compared to Jet A1.

Volume swell results passed under the baseline criteria when compared to the base fuel Jet A1 as shown in Appendix A. The Biofuel 50/50 results decreased in swelling when compared to Jet A1.

6.15 PS890 Sealant – ASTM D412

Tensile and Elongation tests were performed on the PS890 Sealant provided by PRC de Soto.

Total of five specimens were used, with a cross section area of 0.0186 in².

When determining the tensile stress, we simply divide the observed load with the effective area as follows.

Table 6.30 - Peak Stresses of PS890 Sealant for Jet A1 and Biofuel 50/50

Specimen ID	Peak Stress Jet A1 (psi)	Peak Stress Bio 50/50 (psi)	
1	277	278	
2	246	293	
3	242	256	
4	234	255	
5	250	314	Allowable Criteria
Avg	250	279	35 psi decrease

The table above shows how the PS890 Sealant performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it increases in strength. The differences of the averages are above the allowable baseline criteria. Therefore, the effects of the Biofuel on the sealant are determined to be acceptable.

Elongation tests were also performed in conjunction with the tensile test and the results are as follows.

Table 6.31 - Peak Elongation of PS890 Sealant for Jet A1 and Biofuel 50/50

Specimen ID	Peak Elongation Jet A1 (%)	Peak Elongation Bio 50/50 (%)	
1	316.88	387.40	
2	343.47	371.03	
3	298.85	347.23	
4	366.52	331.69	
5	293.23	396.72	Allowable Criteria
Avg	323.79	366.81	25% decrease

The table above shows how PS890 Sealant performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it increases in elongation properties. The differences of the averages are above the allowable baseline criteria. Therefore, the effects of the Biofuel on the material are determined to be acceptable.

Hardness tests of this material passed the baseline criteria when compared to Jet A1 and the Jet A1 passes the criteria when compared to unaged specimens as shown in Appendix A. The Biofuel 50/50 results increased in hardness when compared to Jet A1.

Volume swell results passed under the baseline criteria when compared to the base fuel Jet A1 as shown in Appendix A. The Biofuel 50/50 results decreased in swelling when compared to Jet A1.

6.16 Q4-2817 Sealant – ASTM D412

Tensile and Elongation tests were performed on the Q4-2817 Sealant provided by PRC de Soto.

Total of five specimens were used, with a cross section area of 0.0186 in².

When determining the tensile stress, we simply divide the observed load with the effective area as follows.

Table 6.32 - Peak Stresses of Q4-2817 Sealant for Jet A1 and Biofuel 50/50

Specimen ID	Peak Stress Jet A1 (psi)	Peak Stress Bio 50/50 (psi)	
1	480	478	
2	481	474	
3	435	466	
4	468	674	
5	419	399	Allowable Criteria
Avg	457	498	35 psi decrease

The table above shows how the Q4-2817 Sealant performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it increases in strength. The differences of the averages are above the allowable baseline criteria. Therefore, the effects of the Biofuel on the sealant are determined to be acceptable.

Elongation tests were also performed in conjunction with the tensile test and the results are as follows.

Table 6.33 - Peak Elongation of Q4-2817 Sealant for Jet A1 and Biofuel 50/50

Specimen ID	Peak Elongation Jet A1 (%)	Peak Elongation Bio 50/50 (%)	
1	812.31	701.39	
2	730.34	857.01	
3	664.62	882.39	
4	673.10	850.94	
5	591.26	439.75	Allowable Criteria
Avg	694.33	746.30	25% decrease

The table above shows how Q4-2817 Sealant performs when exposed to Jet A1 and Biofuel 50/50. Every specimen tested seems to indicate that when the material is in contact with Biofuel 50/50, it increases in elongation properties. The differences of the averages are above the allowable baseline criteria. Therefore, the effects of the Biofuel on the material are determined to be acceptable.

Hardness tests of this material passed the baseline criteria when compared to Jet A1 and the Jet A1 passes the criteria when compared to unaged specimens as shown in Appendix A. The Biofuel 50/50 results increased in hardness when compared to Jet A1. Volume swell results passed under the baseline criteria when compared to the base fuel Jet A1 as shown in Appendix A. The Biofuel 50/50 results decreased in swelling when compared to Jet A1.

6.17 Nitrile and Polyurethane Coating – ASTM D3363, D3359

The coatings 825X309 and EC776 both pass baseline criteria when compared to unaged and Jet A1 specimens. 825X309 showed marginally no change in hardness, with a 1 point difference between its ‘scratch to surface’ requirement between its Jet A1 and Biofuel 50/50. EC 776 on the other hand showed increased hardness across all specimens and test benchmarks by as much as 2 points. Therefore, it clearly passes its required criteria.

Table 6.34 - Unaged Pencil Hardness

	825X309 unaged	EC776 unaged
Avg Pencil Hardness	4H	HB

All tape adhesion tests show no damage done to the cut made into the applied coatings for both 825X309 and EC776 as shown in Appendix A. Results between Jet A1 and Biofuel 50/50 showed identical surface results after tape testing.

6.18 Epichlorohydrin Hose – ASTM D2240, D471

The Epichlorohydrin hose material passes volume swell tests and is well within the baseline criteria given by ASTM D4054 as shown in Appendix A. The results indicate that when Epichlorohydrin is exposed to the Biofuel 50/50 fuel it shows a decrease in volume swell when compared to Jet A1.

6.19 Fluorosilicone Groove Injection Sealant – ASTM D471

The groove injection sealant passes the volume swell test and is well within the baseline criteria given by ASTM D471 as shown in Appendix A. The results indicate that when Q4-2805 is exposed to the Biofuel 50/50 fuel it shows a decrease in volume swell when compared to Jet A1.

6.20 Metallic Specimens – ASTM D4054

All metallic specimens under 40X magnification show no visible surface corrosion as shown in Appendix A. These would be identifiable by looking for pitting, or other physical defects.

Staining and fuel residue was present for some of the metallic specimens examined, however under ASTM D4054 visual inspection criteria they are considered passive and not conducive to material failure.

The specimens were cross-sectioned, and further examined under 150X magnification as shown in Appendix A. Focus was placed on the leading edge of the cross sectioned material to examine if material corrosion has occurred through the surface of the specimen. All the metallic specimens examined show no signs of corrosion within the cross sectioned area. Therefore, the effect of the Jet A1 and Biofuel can be determined to be negligible on all the metallic specimens analyzed.

CHAPTER 7

Conclusions and Closing Statements

The purpose of this research was to determine the efficacy of a camelina based Biodiesel/Jet A1 mixture in the fuel systems components of aircrafts. Materials that have contact with the fuel during normal course of operations were scrutinized through the wide range of tests that were employed in this study. These materials included various sealants, hoses, metals, films, adhesives, potting compounds, and others. The biodiesel tests were compared to results taken from a base line fuel, which was in this case regular aviation Jet A1 fuel. Jet A1 is used as the benchmark since an extensive volume of results already exists on the effects of Jet A1 on fuel system materials due to its heavy use in the aviation industry. When comparing the results of Biofuel/Jet A1 50/50 mixture with that of regular Jet A1, we were presented with a clear image of just how the Biofuel 50/50 has an effect on aviation fuel systems.

A great deal of effort was placed on the specimen preparation portion of the research. Much of the materials that were tested for this report came as raw components that needed to be mixed, applied, molded, or manufactured in one way shape or form. Manufacturing of the specimens posed the greatest variable when determining whether or not a specimen that was tested provided accurate results or not. This was the case as specimen preparation sometimes involved multiple steps such as i) correct surface preparation and cleaning ii) priming of the bare metal iii) curing of the primer iv) application of the test material v) curing of the test material and finally vi) conditioning of the test material. Often if the material did not sufficiently meet dry testing requirements, it was due to one of those steps being improperly conducted. OEM technical data sheets were used as a basis for specimen preparations and should be used as an initial guide

when preparing any material. If proper steps were conducted in accordance with the OEM guide and test specimens still provide erroneous results, then other variations of preparations are to be explored. It is not uncommon to detract from the OEM guide, and it was found that by altering simple variables such as curing temperature and time resulted in vastly greater results.

In general, the materials showed positive results when compared between the Biofuel 50/50 and Jet A1 fuels. Results vary where the mechanical properties of some materials were enhanced when subjected to the biofuel mix, while some materials exhibited deterioration in properties after the soaking process. The reason for the variation can be related to the sheer diversity of the materials being tested and their respective chemical properties. Loctite 609 methacrylate adhesive and Hysol EA 9394 epoxy paste adhesive are good examples of the above described phenomenon, with the former exhibiting stronger shear properties after exposure to the biofuel mixture while the latter showing weaker qualities even though both meet the acceptable criteria given in ASTM D4054.

Table 7.1 - Summary of Failed Materials

Material	ASTM	Failed Requirement
Kapton Film	D412	>25% initial elongation
Teflon Film	D412	>15% allowable decrease elongation
Polyethylene Foam	D412	>15% allowable decrease elongation
PR2911 Sealant	D412	>35 psi decrease, >25% decrease elongation
VM128 O-Ring	D471	> 10% initial volume swell

There were examples of specimens which passed one set of test criteria, while concurrently failing another set of test requirements. Kapton film, Teflon film, and Polyethylene foam all pass their tensile test criteria. However, they concurrently fail their elongation benchmarks. In the case of Kapton film, the initial elongation is required to be greater than 20%, however an elongation average of 17% was reached. It was noticeably evident when looking at the resulting

data that some specimens clearly surpassed the base line criteria while some others did not. This is likely the result of variations in specimen preparation as well as the edge condition of the film to cause early failure. The Teflon film and polyethylene foam both show a marked difference between the Biofuel and Jet A1 fuels. They both fail the biofuel elongation criteria by a significant margin. The primary issue may be that both these materials show upwards of 300% elongation, yet the allowable base line variation is a 15% decrease which is a very narrow pass window. A possible solution may be to ensure that specimen geometry and condition between the Jet A1 and Biofuel 50/50 are as congruent as possible which may help to close the elongation difference. PR2911 is a specialized sealant which exhibits incredible elastic properties. Again the biofuel results yielded significantly lower results than the Jet A1 counterpart for both tensile and elongation tests. It can be that the chemical property of the polythioether polyurethane is susceptible to the Biofuel mixture. VM128 failed to meet the base line volume swell test with 32% swelling when the allowable limit is between 0 to 10%. The technical data sheet provided by the material manufacturer indicated the optimum operation temperature should be between 50 and 150 Celsius. According to ASTM D4054, the soaking temperature for VM128 was stated to be 163C. Since the soaking temperature is outside the optimal range, it may be the reason why the volume swell tests are showing erroneous results. These gaskets should be used either in a lower temperature setting between 50 and 150 Celsius, or another gasket which can tolerate the higher temperature should be employed in its place.

LIST OF APPENDICES

Static Shear ASTM D4562 - Loctite 609

Jet A1 - Test Specimens



Static Shear

Specimen ID 1
Test Number 621
Report Number 369
Test Date 9/6/2012 7:14:29 PM

Test Results
PEAK FORCE (LBF) 2,012.8

Testing Machine STM-50KN
Load Cell S/N (TVI109955), Units (LBS) 11240
Crosshead Speed (Inches / min) or Rate 0.05
Extension or Position Measured by XHD100 (XHD100)

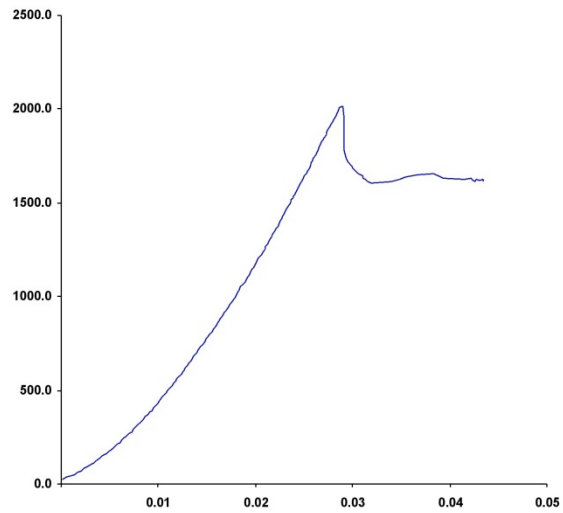
By : _____ Date : _____

Customer Name

Purchase Order

Template No 500 06-Sep-12
Ryerson University

Force (-Lbs) vs Extension (%)

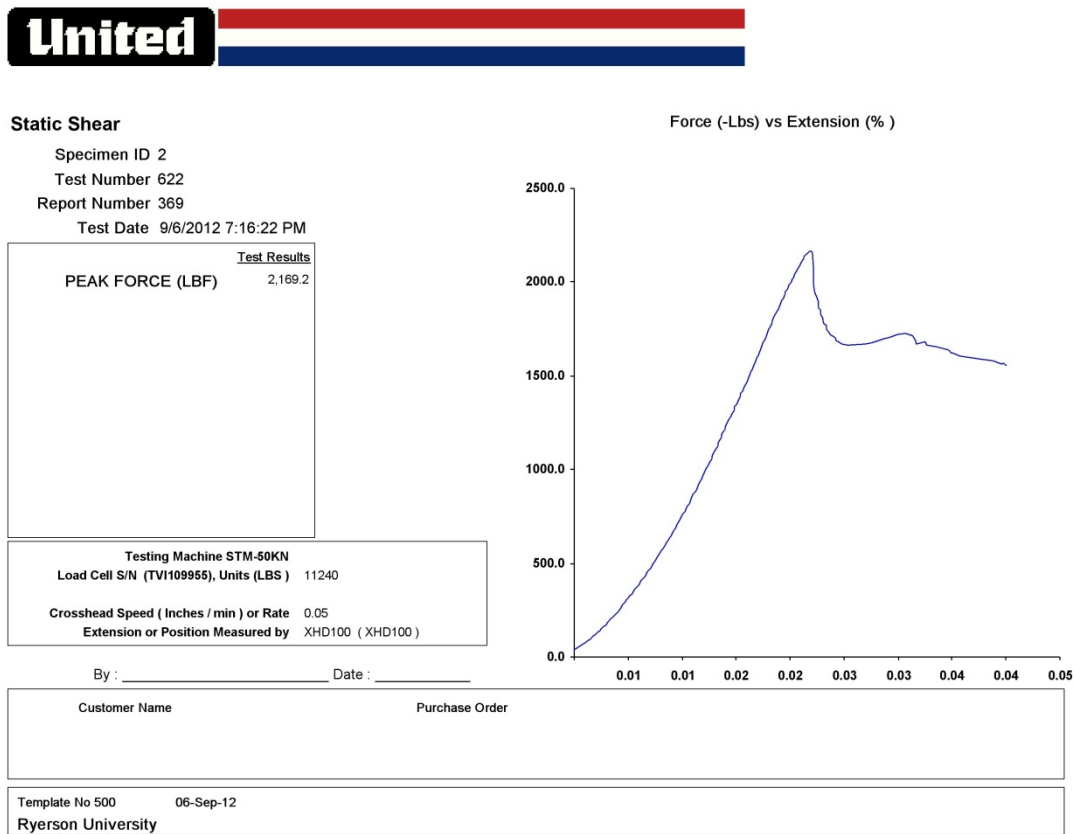


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Static Shear Loctite 609 JetA1 - Specimen 1

Static Shear ASTM D4562 - Loctite 609

Jet A1 - Test Specimens



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Static Shear Loctite 609 JetA1 - Specimen 2

Static Shear ASTM D4562 - Loctite 609

Jet A1 - Test Specimens



Static Shear

Specimen ID 3
Test Number 623
Report Number 369
Test Date 9/6/2012 7:17:50 PM

Test Results	
PEAK FORCE (LBF)	1,961.0

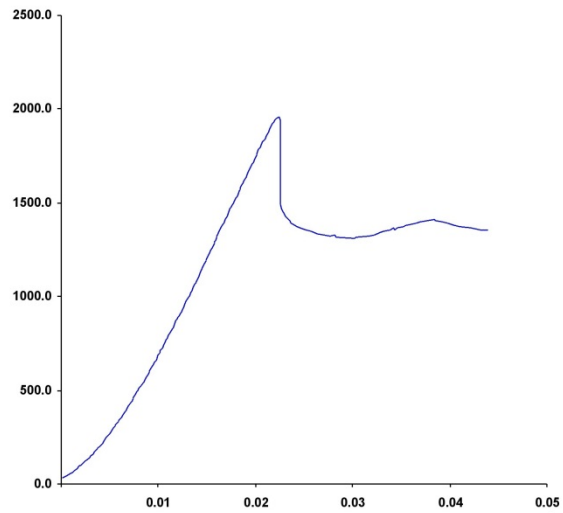
Testing Machine STM-50KN	
Load Cell S/N (TVI109955), Units (LBS)	11240
Crosshead Speed (Inches / min) or Rate	0.05
Extension or Position Measured by	XHD100 (XHD100)

By : _____ Date : _____

Customer Name	Purchase Order
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Template No 500	06-Sep-12
Ryerson University	

Force (-Lbs) vs Extension (%)

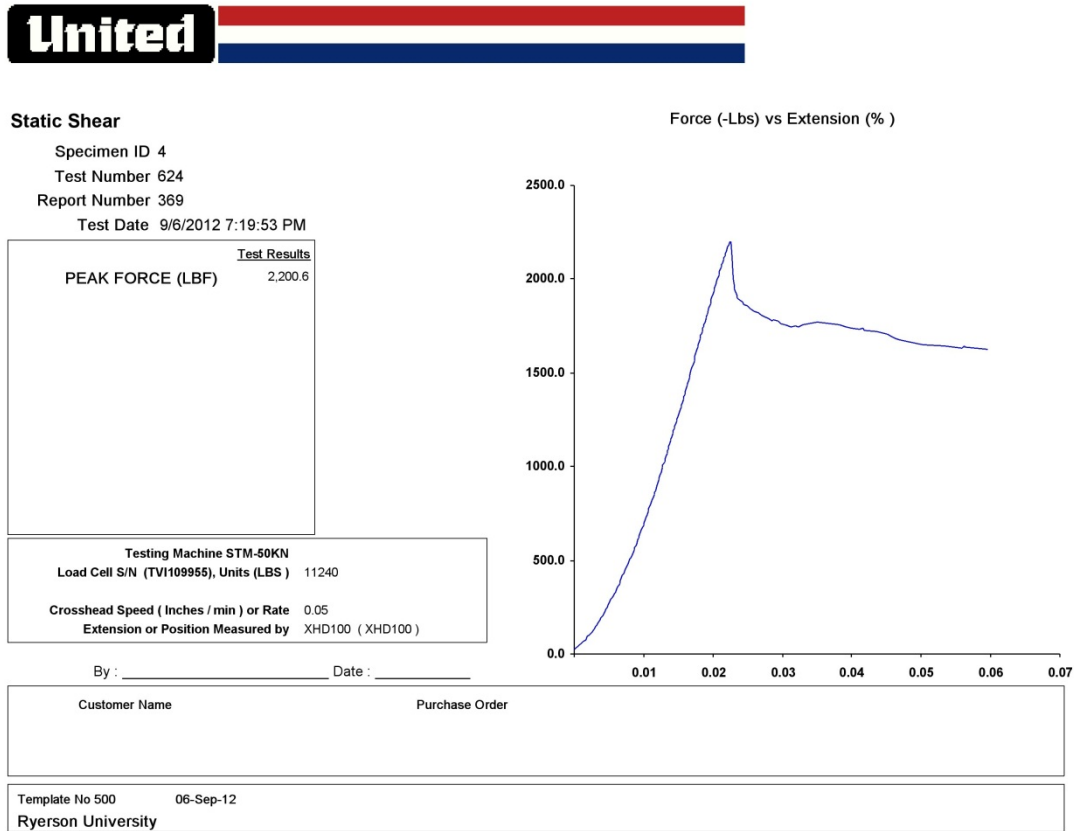


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Static Shear Loctite 609 JetA1 - Specimen 3

Static Shear ASTM D4562 - Loctite 609

Jet A1 - Test Specimens

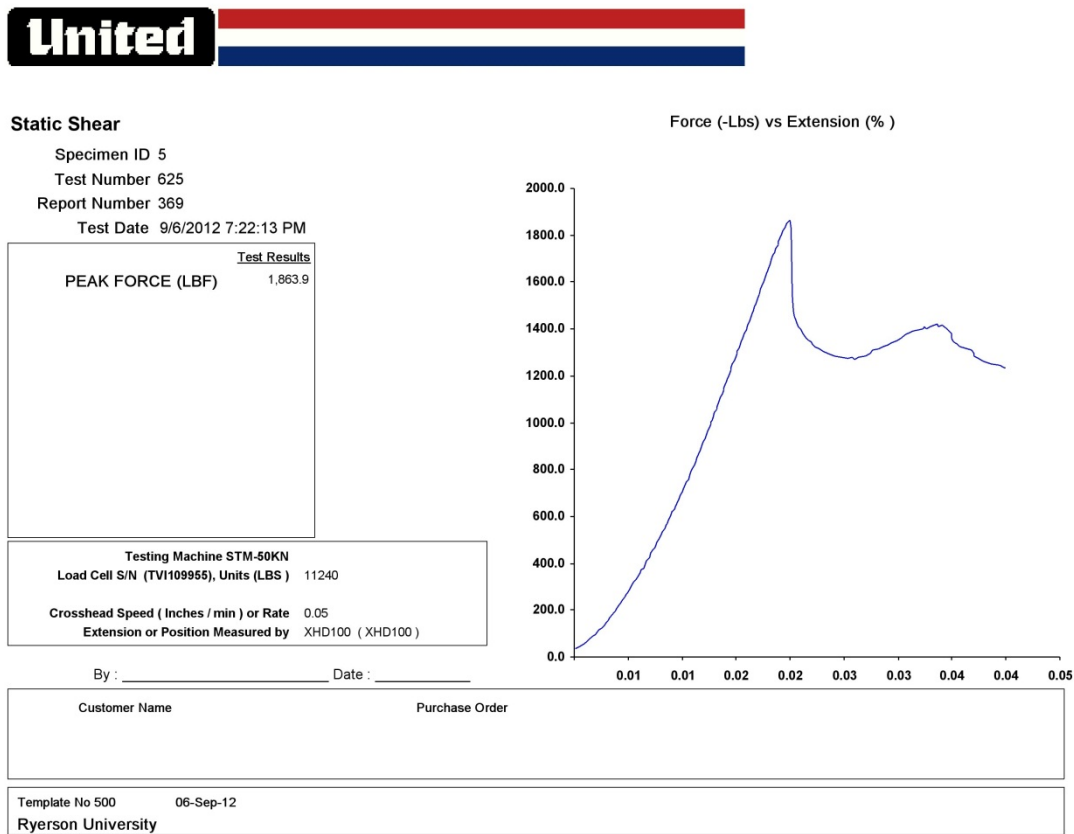


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Static Shear Loctite 609 JetA1 - Specimen 4

Static Shear ASTM D4562 - Loctite 609

Jet A1 - Test Specimens

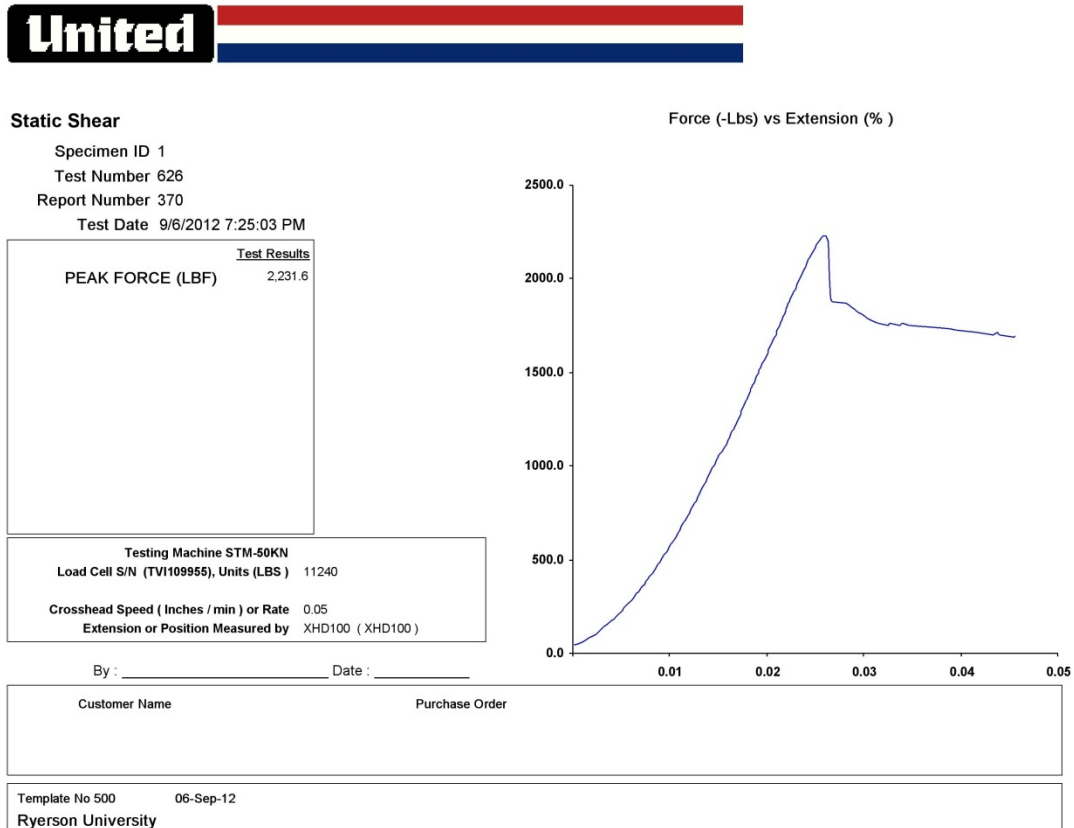


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Static Shear Loctite 609 JetA1 - Specimen 5

Static Shear ASTM D4562 - Loctite 609

Biofuel 50/50 - Test Specimens



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Static Shear Loctite 609 Bio50 – Specimen 1

Static Shear ASTM D4562 - Loctite 609

Biofuel 50/50 - Test Specimens



Static Shear

Specimen ID 2
Test Number 627
Report Number 370
Test Date 9/6/2012 7:26:52 PM

Test Results
PEAK FORCE (LBF) 2,172.5

Testing Machine STM-50KN
Load Cell S/N (TVI109955), Units (LBS) 11240
Crosshead Speed (Inches / min) or Rate 0.05
Extension or Position Measured by XHD100 (XHD100)

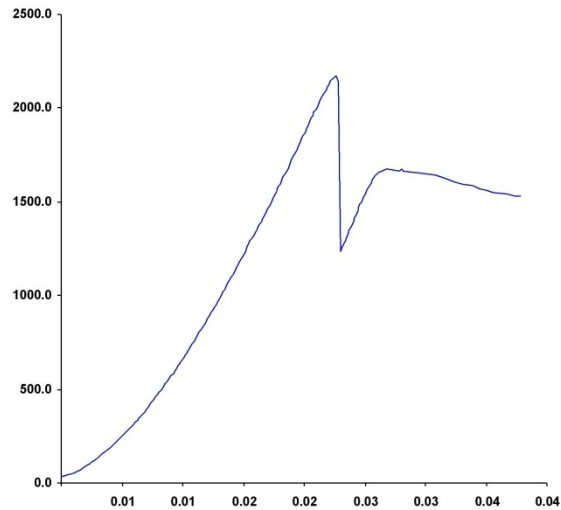
By : _____ Date : _____

Customer Name

Purchase Order

Template No 500 06-Sep-12
Ryerson University

Force (-Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Static Shear Loctite 609 Bio50 – Specimen 2

Static Shear ASTM D4562 - Loctite 609

Biofuel 50/50 - Test Specimens



Static Shear

Specimen ID 3
Test Number 628
Report Number 370
Test Date 9/6/2012 7:29:30 PM

Test Results
PEAK FORCE (LBF) 2,294.5

Testing Machine STM-50KN
Load Cell S/N (TVI109955), Units (LBS) 11240
Crosshead Speed (Inches / min) or Rate 0.05
Extension or Position Measured by XHD100 (XHD100)

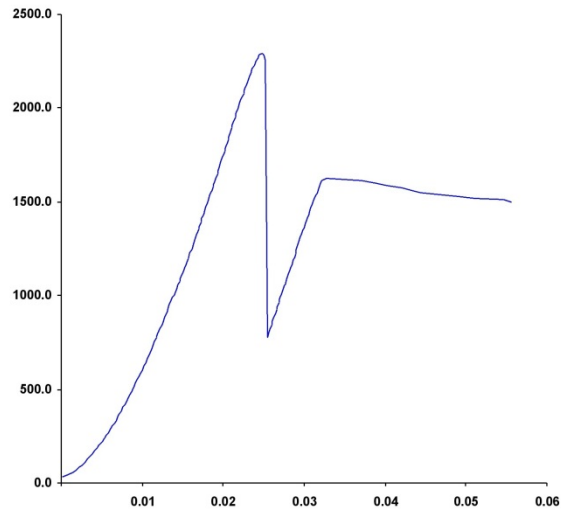
By : _____ Date : _____

Customer Name

Purchase Order

Template No 500 06-Sep-12
Ryerson University

Force (-Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Static Shear Loctite 609 Bio50 – Specimen 3

Static Shear ASTM D4562 - Loctite 609

Biofuel 50/50 - Test Specimens



Static Shear

Specimen ID 4
Test Number 631
Report Number 370
Test Date 9/6/2012 7:34:51 PM

Test Results
PEAK FORCE (LBF) 2,381.6

Testing Machine STM-50KN
Load Cell S/N (TVI109955), Units (LBS) 11240
Crosshead Speed (Inches / min) or Rate 0.05
Extension or Position Measured by XHD100 (XHD100)

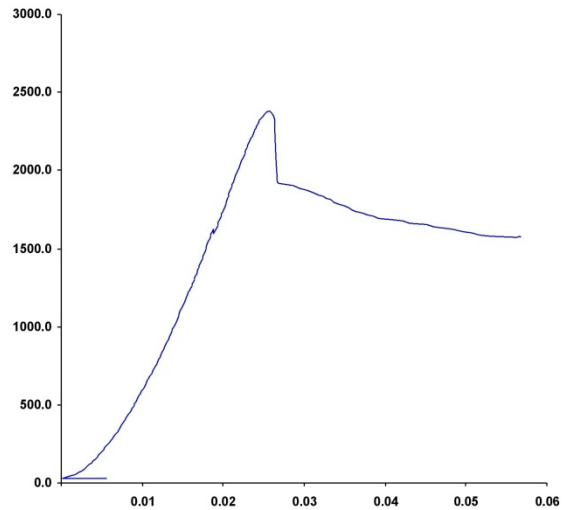
By : _____ Date : _____

Customer Name

Purchase Order

Template No 500 06-Sep-12
Ryerson University

Force (-Lbs) vs Extension (%)



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Static Shear Loctite 609 Bio50 – Specimen 4

Static Shear ASTM D4562 - Loctite 609

Biofuel 50/50 - Test Specimens



Static Shear

Specimen ID 5
Test Number 630
Report Number 370
Test Date 9/6/2012 7:32:58 PM

Test Results
PEAK FORCE (LBF) 2,148.1

Testing Machine STM-50KN
Load Cell S/N (TVI109955), Units (LBS) 11240
Crosshead Speed (Inches / min) or Rate 0.05
Extension or Position Measured by XHD100 (XHD100)

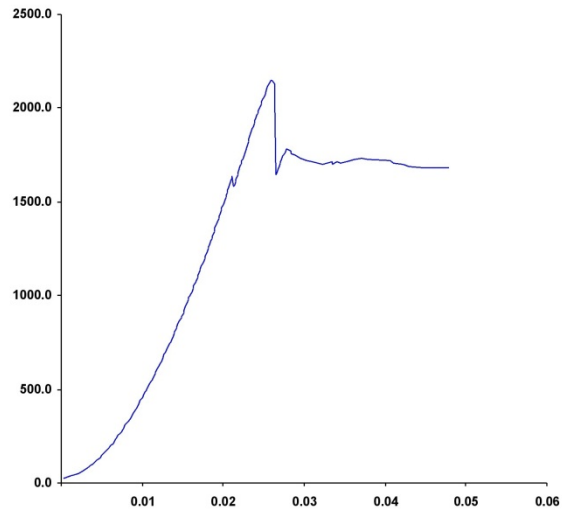
By : _____ Date : _____

Customer Name

Purchase Order

Template No 500 06-Sep-12
Ryerson University

Force (-Lbs) vs Extension (%)



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Static Shear Loctite 609 Bio50 – Specimen 5

Lap Shear ASTM D1002 – EA 9394

Jet A1 – Test Specimens



Single Lap Shear

Specimen ID 1
Test Number 417
Report Number 284
Test Date 6/17/2012 6:42:07 PM

Test Results	
PEAK FORCE (LBF)	1,204.0

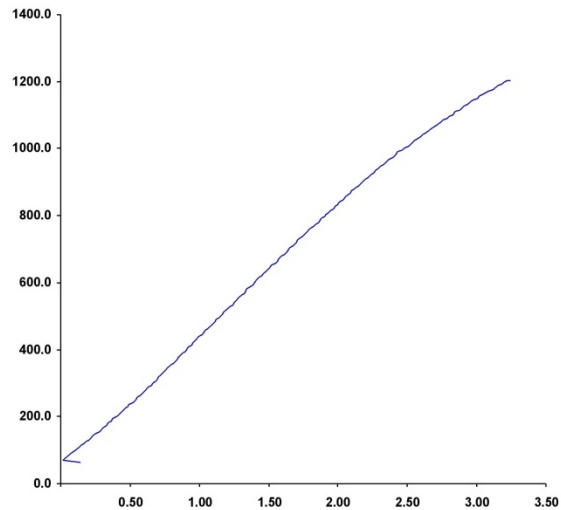
Testing Machine STM-50KN
Load Cell S/N (TVI109955), Units (LBS) 11240
Crosshead Speed (Inches / min) or Rate 0.05
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order
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Template No 501	17-Jun-12
Ryerson University	

Force (Lbs) vs Extension (%)



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Lap Shear EA 9394 JetA1 - Specimen 1

Lap Shear ASTM D1002 – EA 9394

Jet A1 – Test Specimens



Single Lap Shear

Specimen ID 2
Test Number 418
Report Number 284
Test Date 6/17/2012 6:45:00 PM

Test Results	
PEAK FORCE (LBF)	1,268.0

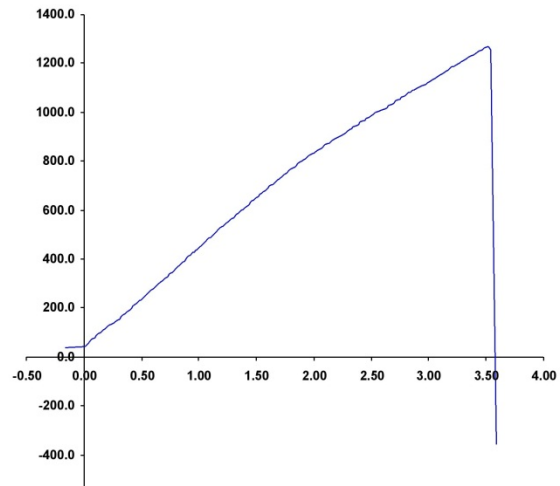
Testing Machine STM-50KN	
Load Cell S/N (TV1109955), Units (LBS)	11240
Crosshead Speed (Inches / min) or Rate	0.05
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order
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Template No 501	17-Jun-12
Ryerson University	

Force (Lbs) vs Extension (%)



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Lap Shear EA 9394 JetA1 - Specimen 2

Lap Shear ASTM D1002 – EA 9394

Jet A1 – Test Specimens



Single Lap Shear

Specimen ID 3
Test Number 419
Report Number 284
Test Date 6/17/2012 6:53:36 PM

Test Results	
PEAK FORCE (LBF)	1,231.5

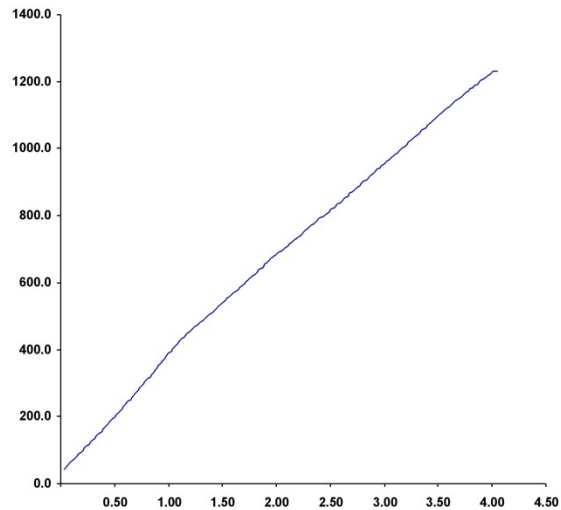
Testing Machine STM-50KN	
Load Cell S/N (TV1109955), Units (LBS)	11240
Crosshead Speed (Inches / min) or Rate	0.05
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order
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Template No 501	17-Jun-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Lap Shear EA 9394 JetA1 - Specimen 3

Lap Shear ASTM D1002 – EA 9394

Jet A1 – Test Specimens



Single Lap Shear

Specimen ID 4
Test Number 420
Report Number 284
Test Date 6/17/2012 6:55:53 PM

Test Results	
PEAK FORCE (LBF)	1,465.8

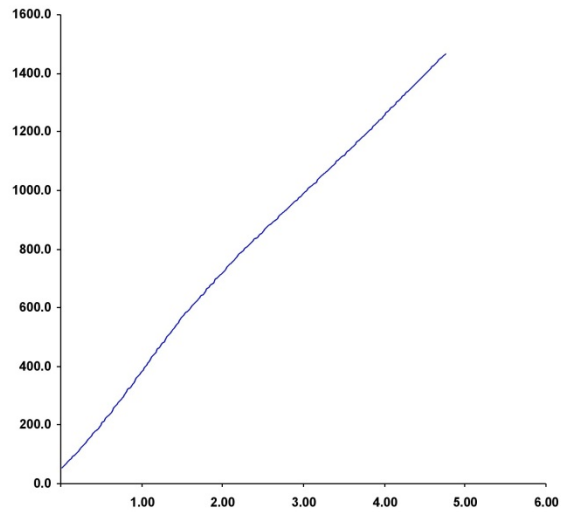
Testing Machine STM-50KN	
Load Cell S/N (TVI109955), Units (LBS)	11240
Crosshead Speed (Inches / min) or Rate	0.05
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order
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Template No 501	17-Jun-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Lap Shear EA 9394 JetA1 - Specimen 4

Lap Shear ASTM D1002 – EA 9394

Jet A1 – Test Specimens



Single Lap Shear

Specimen ID 5
Test Number 422
Report Number 284
Test Date 6/17/2012 7:00:45 PM

Test Results	
PEAK FORCE (LBF)	1,335.0

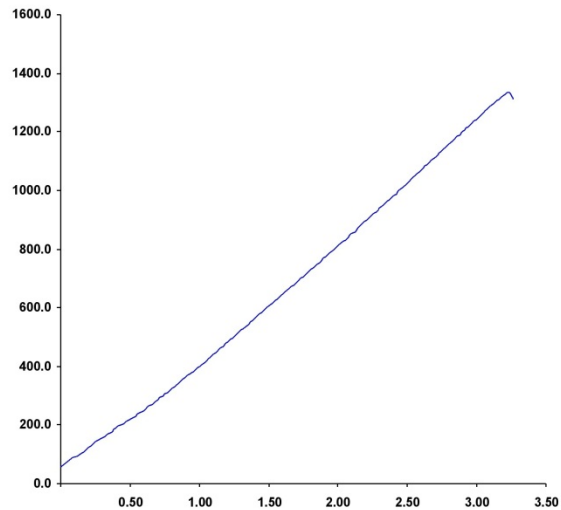
Testing Machine STM-50KN
Load Cell S/N (TVI109955), Units (LBS) 11240
Crosshead Speed (Inches / min) or Rate 0.05
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order
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Template No 501 17-Jun-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Lap Shear EA 9394 JetA1 - Specimen 5

Lap Shear ASTM D1002 – EA 9394

Biofuel 50/50 – Test Specimens



Single Lap Shear

Specimen ID 1
Test Number 595
Report Number 353
Test Date 8/14/2012 7:54:20 PM

Test Results	
PEAK FORCE (LBF)	1,184.3

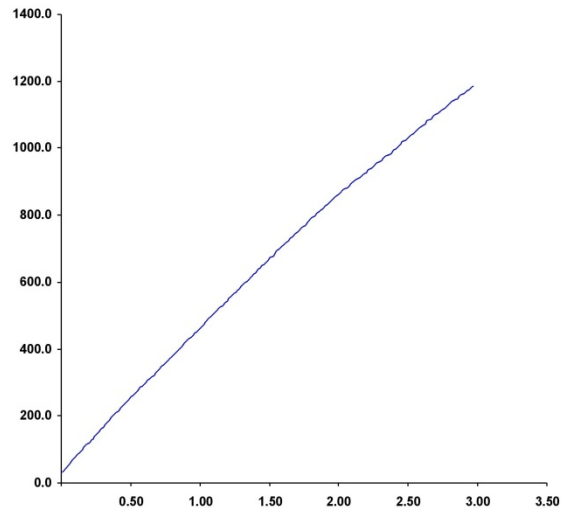
Testing Machine STM-50KN
Load Cell S/N (TV109955), Units (LBS) 11240
Crosshead Speed (Inches / min) or Rate 0.05
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order
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Template No 501 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Lap Shear EA 9394 Bio50 - Specimen 1

Lap Shear ASTM D1002 – EA 9394

Biofuel 50/50 – Test Specimens



Single Lap Shear

Specimen ID 2
Test Number 596
Report Number 353
Test Date 8/14/2012 7:58:00 PM

Test Results	
PEAK FORCE (LBF)	1,194.8

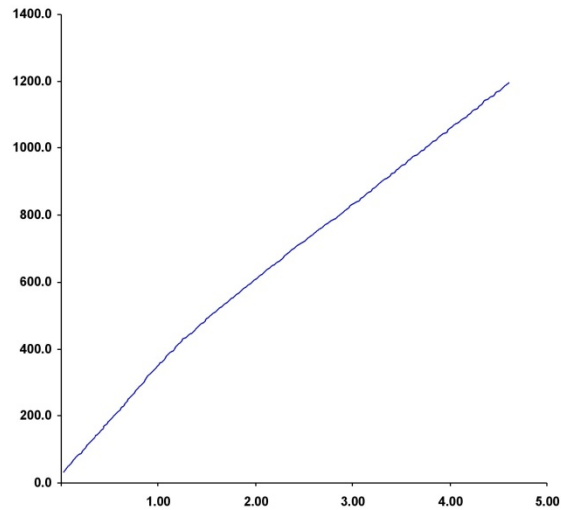
Testing Machine STM-50KN	
Load Cell S/N (TV109955), Units (LBS)	11240
Crosshead Speed (Inches / min) or Rate	0.05
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order
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Template No 501	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Lap Shear EA 9394 Bio50 - Specimen 2

Lap Shear ASTM D1002 – EA 9394

Biofuel 50/50 – Test Specimens



Single Lap Shear

Specimen ID 3
Test Number 598
Report Number 353
Test Date 8/14/2012 8:04:57 PM

Test Results	
PEAK FORCE (LBF)	1,177.6

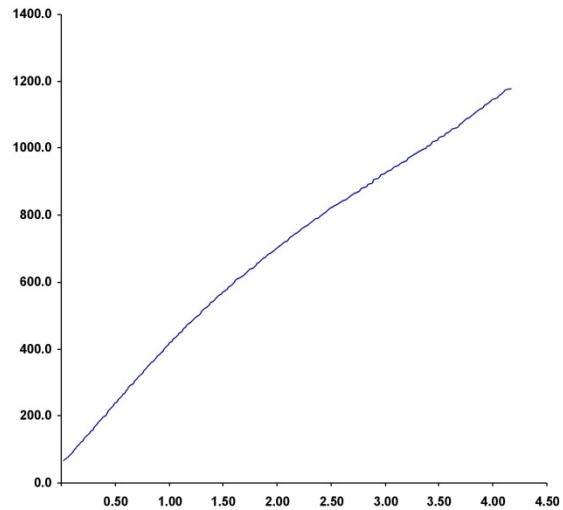
Testing Machine STM-50KN	
Load Cell S/N (TVI109955), Units (LBS)	11240
Crosshead Speed (Inches / min) or Rate	0.05
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order
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Template No 501	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Lap Shear EA 9394 Bio50 - Specimen 3

Lap Shear ASTM D1002 – EA 9394

Biofuel 50/50 – Test Specimens



Single Lap Shear

Specimen ID 4
Test Number 600
Report Number 353
Test Date 8/14/2012 8:09:23 PM

Test Results
PEAK FORCE (LBF) 1,357.3

Testing Machine STM-50KN
Load Cell S/N (TVI109955), Units (LBS) 11240
Crosshead Speed (Inches / min) or Rate 0.05
Extension or Position Measured by XHD1 (XHD1)

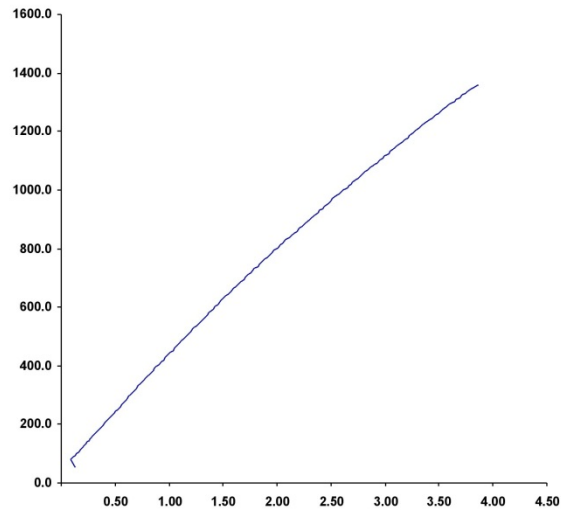
By : _____ Date : _____

Customer Name

Purchase Order

Template No 501 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Lap Shear EA 9394 Bio50 - Specimen 4

Lap Shear ASTM D1002 – EA 9394

Biofuel 50/50 – Test Specimens



Single Lap Shear

Specimen ID 5
Test Number 601
Report Number 353
Test Date 8/14/2012 8:12:03 PM

Test Results	
PEAK FORCE (LBF)	1,224.1

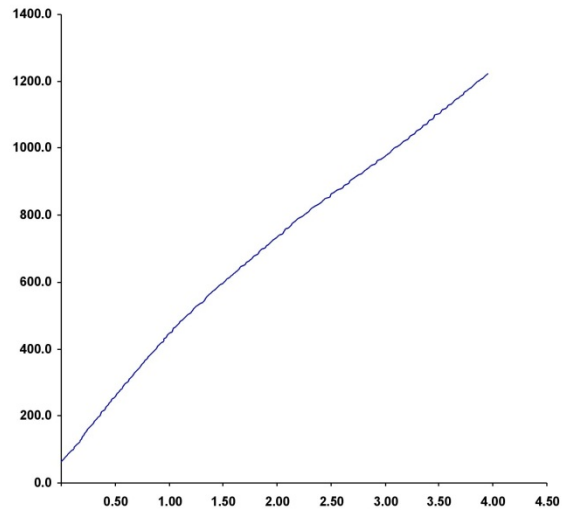
Testing Machine STM-50KN
Load Cell S/N (TVI109955), Units (LBS) 11240
Crosshead Speed (Inches / min) or Rate 0.05
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order
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Template No 501 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Lap Shear EA 9394 Bio50 - Specimen 5

Tensile ASTM D412 – Polyurethane Foam

Jet A1 – Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 356
Report Number 277
Test Date 6/3/2012 3:14:32 PM

Test Results

Mod @50% (psi)	1
Mod @100% (psi)	2
Mod @200% (psi)	5
Mod @300% (psi)	7
Mod @500% (psi)	9
Tensile (psi)	10
Elongation (%)	595.96

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

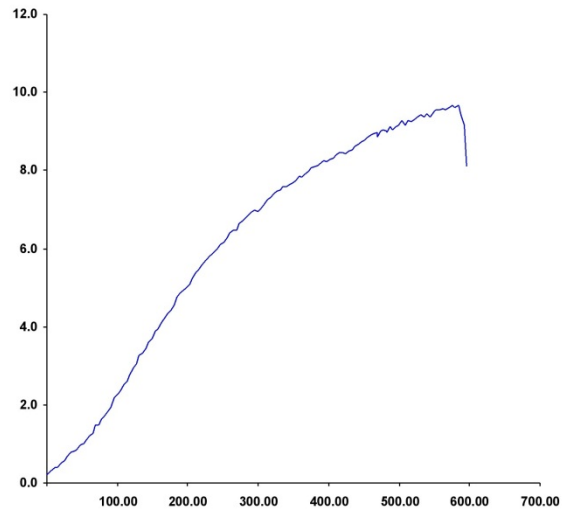
Customer Name
Vendor

Purchase Order

Operator

Template No 101 14-Jun-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Polyurethane Foam JetA1 - Specimen 1

Tensile ASTM D412 – Polyurethane Foam

Jet A1 – Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 357
Report Number 277
Test Date 6/3/2012 3:20:01 PM

Test Results

Mod @50% (psi)	1
Mod @100% (psi)	2
Mod @200% (psi)	5
Mod @300% (psi)	7
Mod @500% (psi)	10
Tensile (psi)	10
Elongation (%)	534.57

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

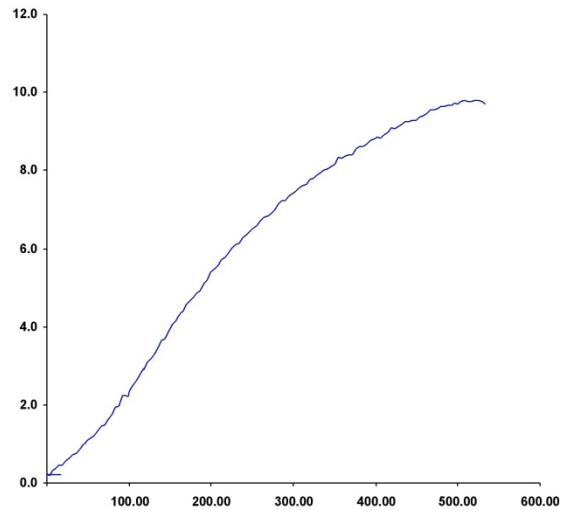
Customer Name
Vendor

Purchase Order

Operator

Template No 101 14-Jun-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Polyurethane Foam JetA1 - Specimen 2

Tensile ASTM D412 – Polyurethane Foam

Jet A1 – Test Specimens



Tensile Properties of Rubber

Specimen ID 3
Test Number 358
Report Number 277
Test Date 6/3/2012 3:25:20 PM

Test Results	
Mod @50% (psi)	1
Mod @100% (psi)	3
Mod @200% (psi)	5
Mod @300% (psi)	7
Mod @500% (psi)	9
Tensile (psi)	
Elongation (%)	459.94

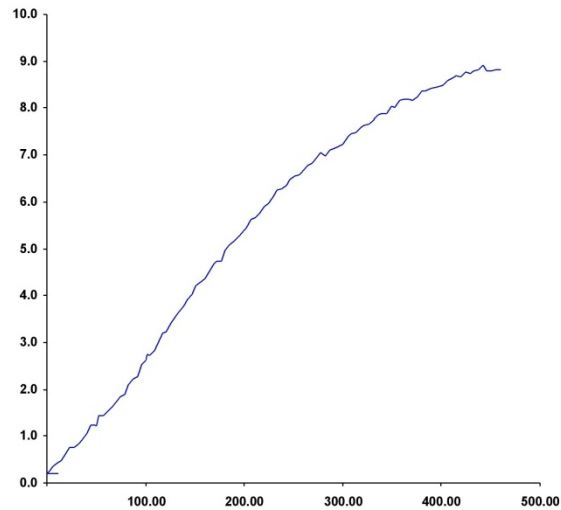
Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 14-Jun-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Polyurethane Foam JetA1 - Specimen 3

Tensile ASTM D412 – Polyurethane Foam

Jet A1 – Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 359
Report Number 277
Test Date 6/3/2012 3:32:39 PM

Test Results

Mod @50% (psi)	1
Mod @100% (psi)	3
Mod @200% (psi)	6
Mod @300% (psi)	8
Mod @500% (psi)	10
Tensile (psi)	11
Elongation (%)	600.13

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

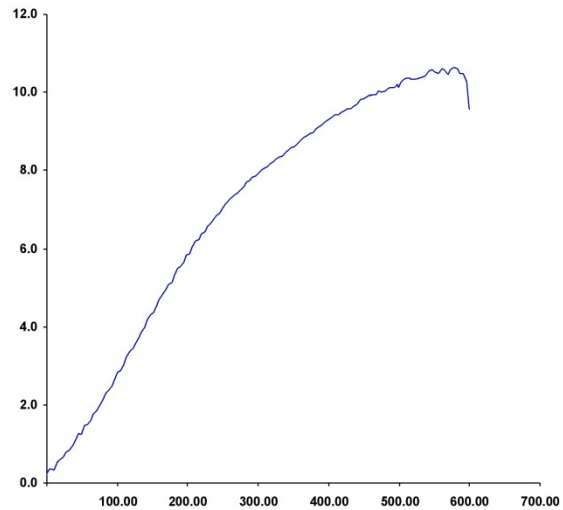
Customer Name
Vendor

Purchase Order

Operator

Template No 101 14-Jun-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Polyurethane Foam JetA1 - Specimen 4

Tensile ASTM D412 – Polyurethane Foam

Jet A1 – Test Specimens



Tensile Properties of Rubber

Specimen ID 5
Test Number 360
Report Number 277
Test Date 6/3/2012 3:34:49 PM

Test Results	
Mod @50% (psi)	1
Mod @100% (psi)	2
Mod @200% (psi)	5
Mod @300% (psi)	7
Mod @500% (psi)	10
Tensile (psi)	10
Elongation (%)	658.13

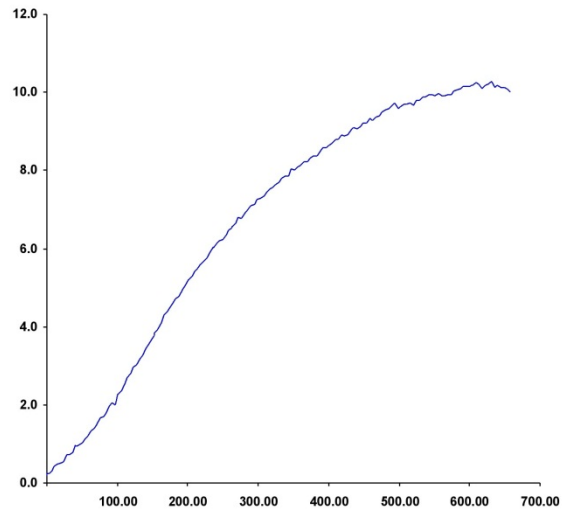
Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 14-Jun-12
Ryerson University

Force (Lbs) vs Extension (%)

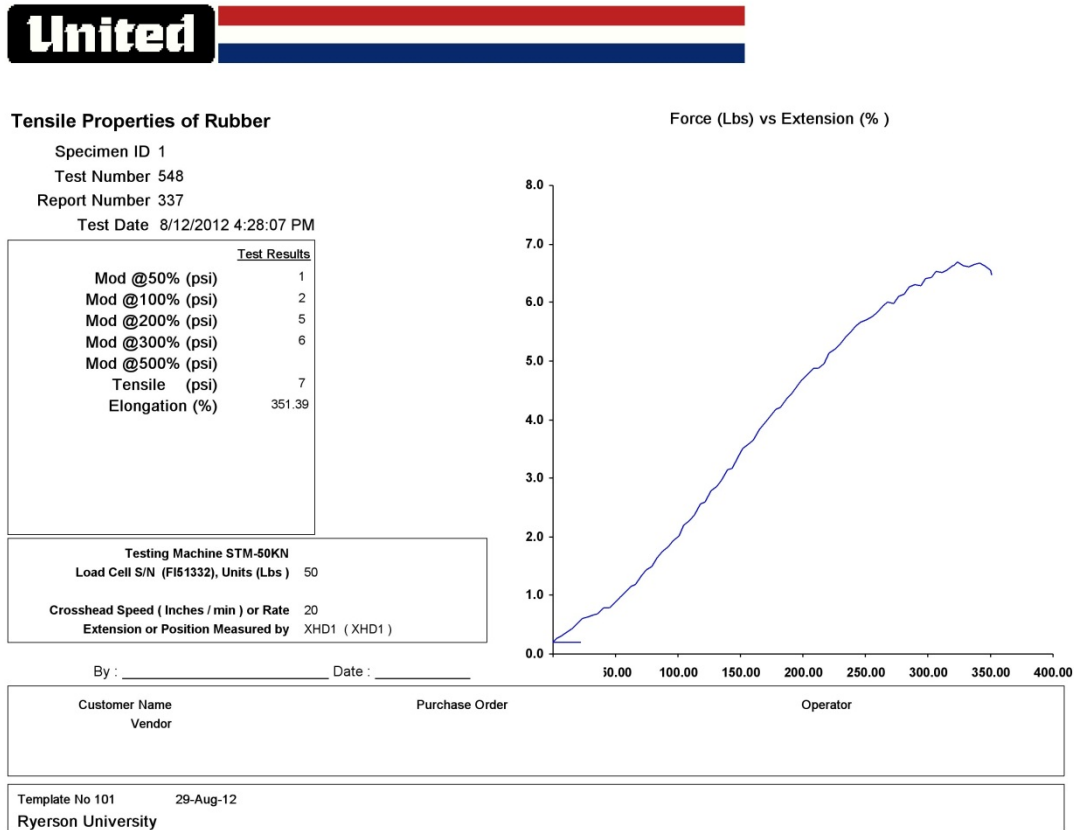


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Tensile Polyurethane Foam JetA1 - Specimen 5

Tensile ASTM D412 – Polyurethane Foam

Biofuel 50/50 – Test Specimens



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Tensile Polyurethane Foam Bio50 - Specimen 1

Tensile ASTM D412 – Polyurethane Foam

Biofuel 50/50 – Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 549
Report Number 337
Test Date 8/12/2012 4:31:13 PM

Test Results

Mod @50% (psi)	1
Mod @100% (psi)	2
Mod @200% (psi)	5
Mod @300% (psi)	7
Mod @500% (psi)	7
Tensile (psi)	396.32
Elongation (%)	

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

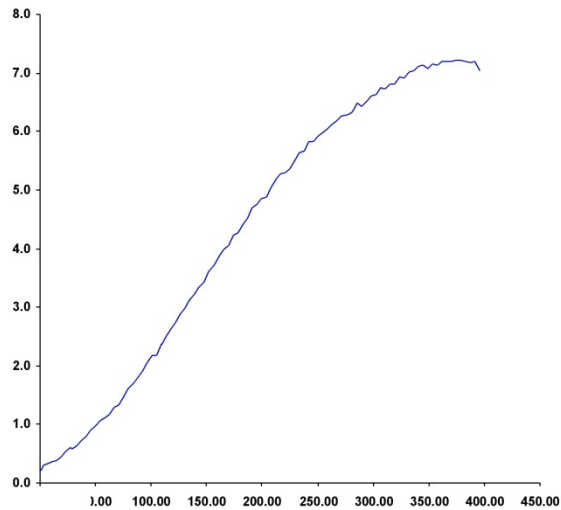
Customer Name
Vendor

Purchase Order

Operator

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)

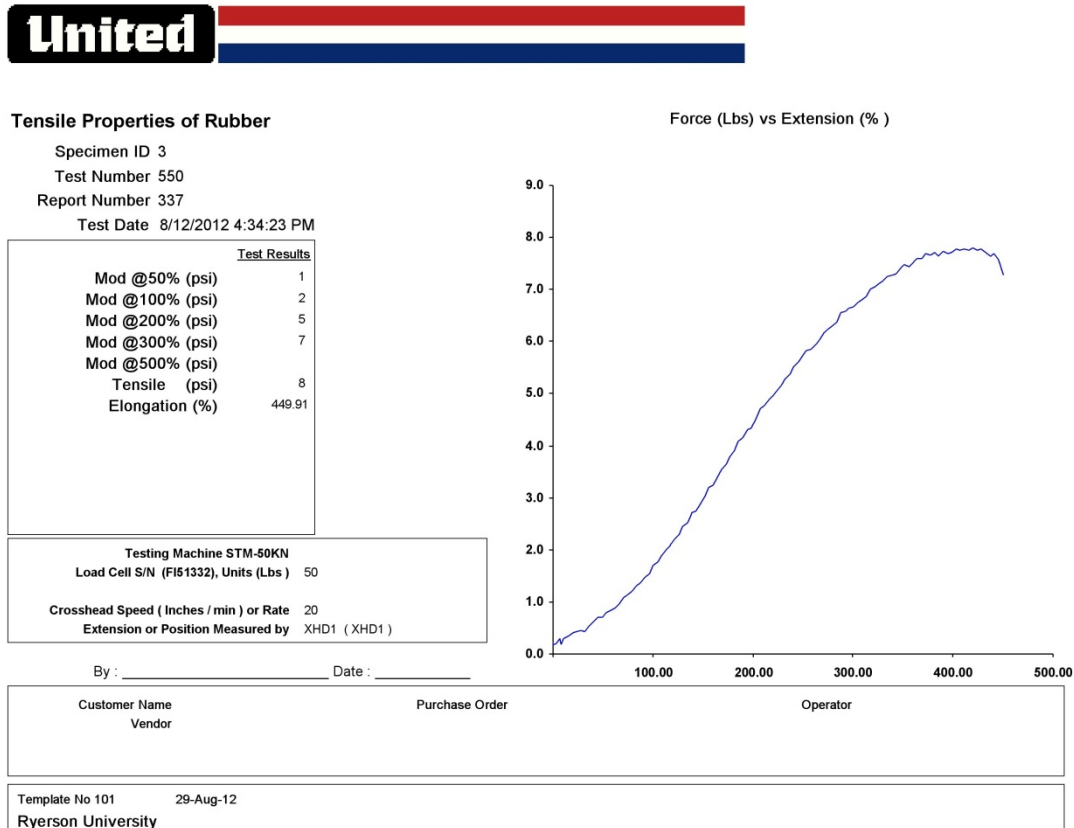


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Tensile Polyurethane Foam Bio50 - Specimen 2

Tensile ASTM D412 – Polyurethane Foam

Biofuel 50/50 – Test Specimens



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Tensile Polyurethane Foam Bio50 - Specimen 3

Tensile ASTM D412 – Polyurethane Foam

Biofuel 50/50 – Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 551
Report Number 337
Test Date 8/12/2012 4:38:11 PM

Test Results

Mod @50% (psi)	1
Mod @100% (psi)	2
Mod @200% (psi)	5
Mod @300% (psi)	8
Mod @500% (psi)	8
Tensile (psi)	8
Elongation (%)	415.26

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

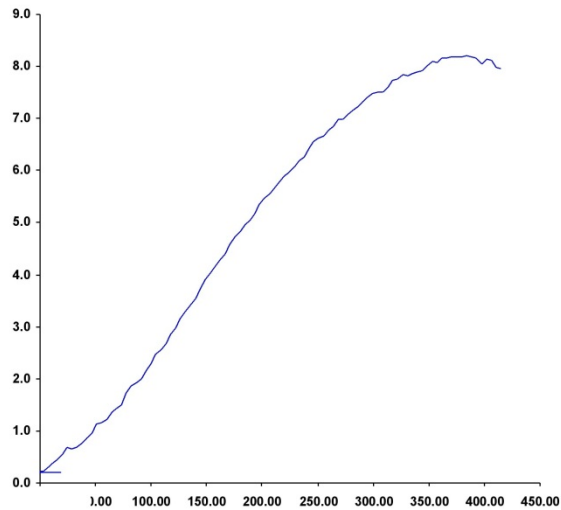
Customer Name
Vendor

Purchase Order

Operator

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)

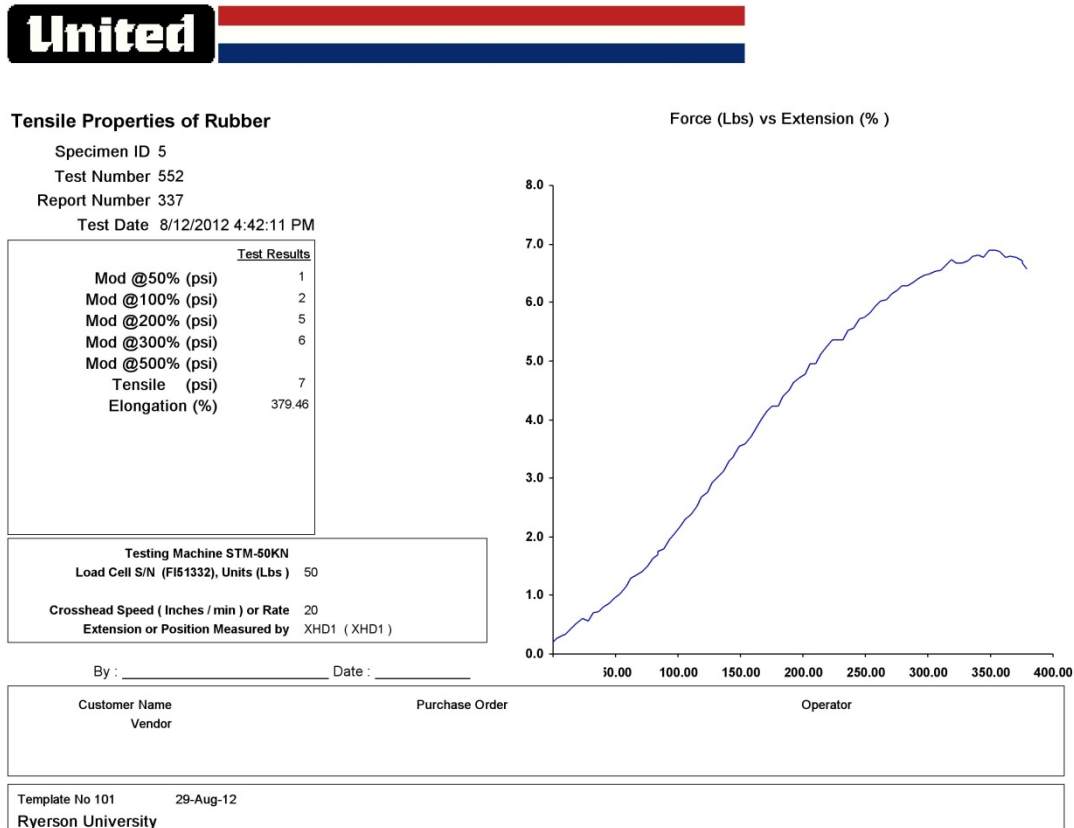


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Tensile Polyurethane Foam Bio50 - Specimen 4

Tensile ASTM D412 – Polyurethane Foam

Biofuel 50/50 – Test Specimens

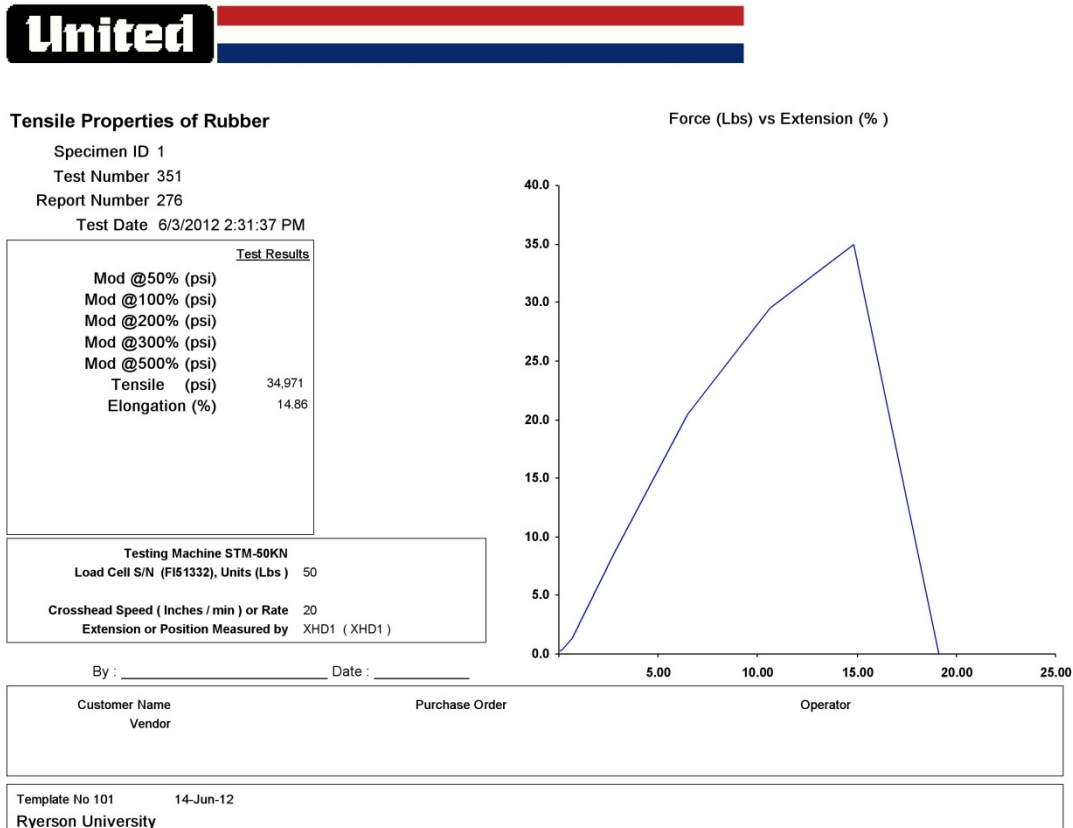


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Tensile Polyurethane Foam Bio50 - Specimen 5

Tensile ASTM D412 – Kapton Film

Jet A1 – Test Specimens



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Tensile Kapton Film JetA1 - Specimen 1

Tensile ASTM D412 – Kapton Film

Jet A1 – Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 352
Report Number 276
Test Date 6/3/2012 2:38:22 PM

Test Results

Mod @50% (psi)
Mod @100% (psi)
Mod @200% (psi)
Mod @300% (psi)
Mod @500% (psi)
Tensile (psi) 35,565
Elongation (%) 15.77

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

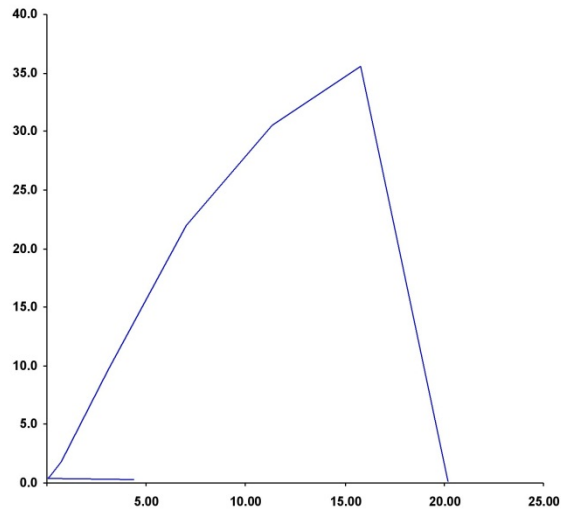
Customer Name
Vendor

Purchase Order

Operator

Template No 101 14-Jun-12
Ryerson University

Force (Lbs) vs Extension (%)

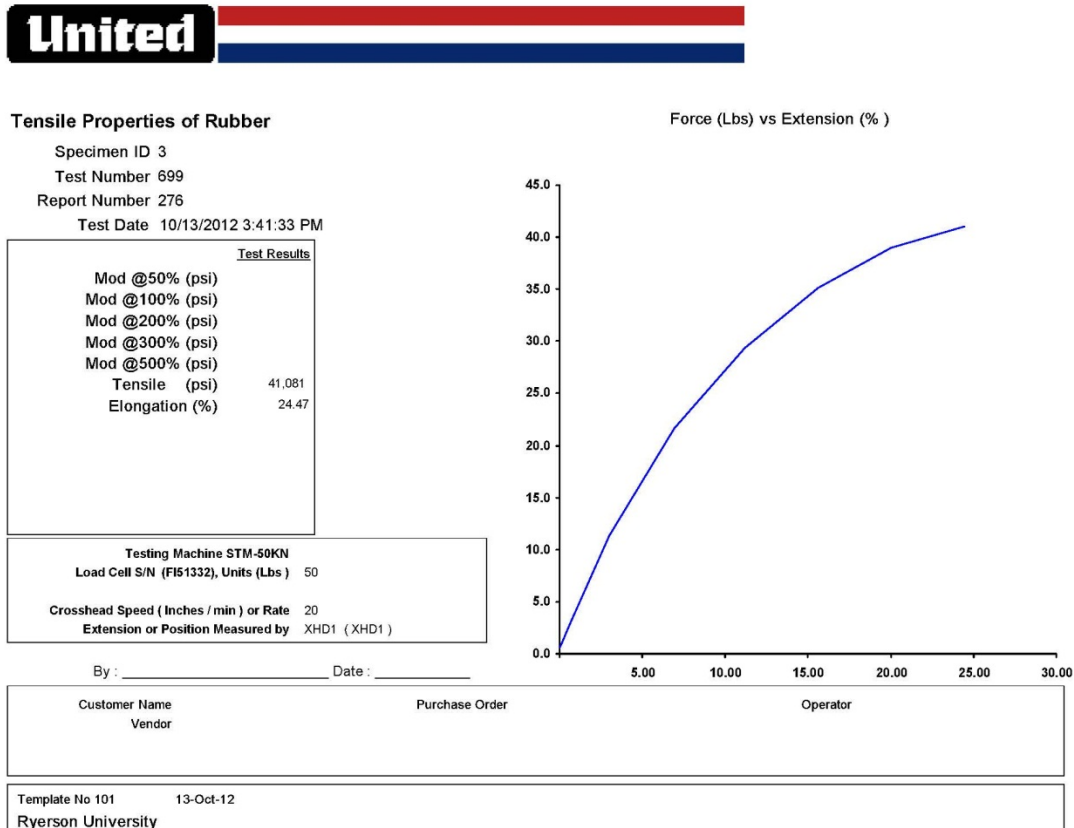


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Tensile Kapton Film JetA1 - Specimen 2

Tensile ASTM D412 – Kapton Film

Jet A1 – Test Specimens

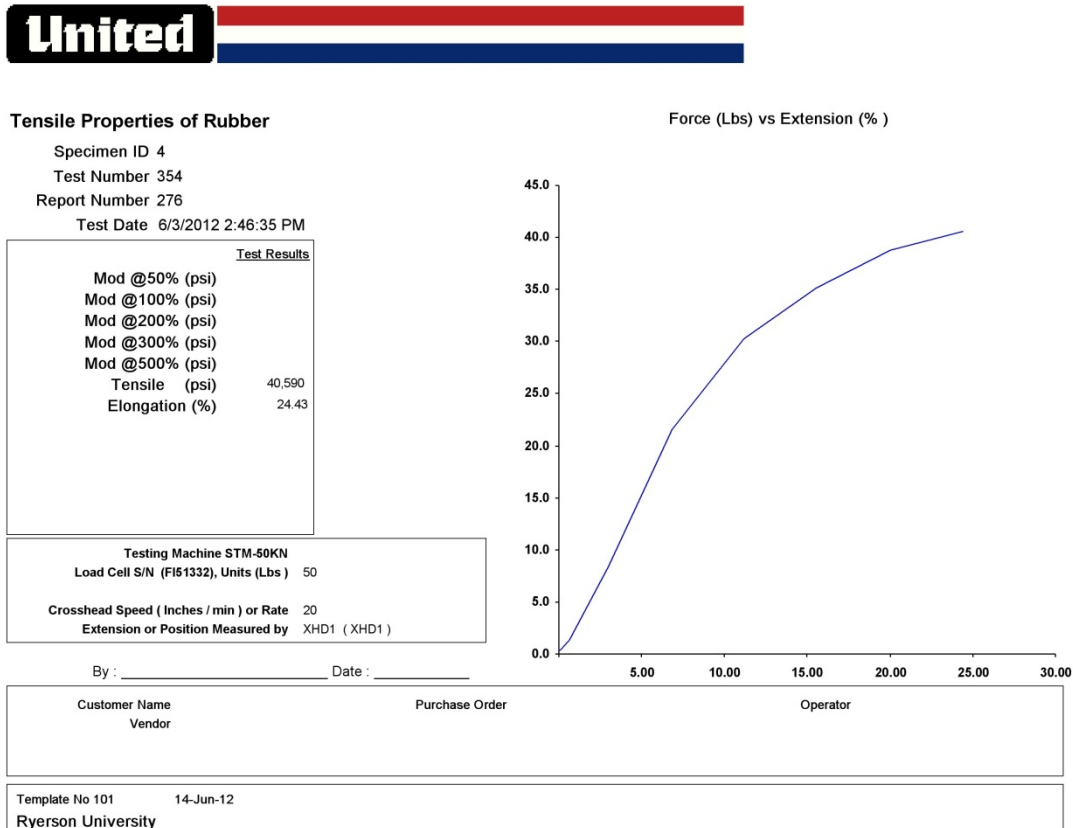


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Tensile Kapton Film JetA1 - Specimen 3

Tensile ASTM D412 – Kapton Film

Jet A1 – Test Specimens

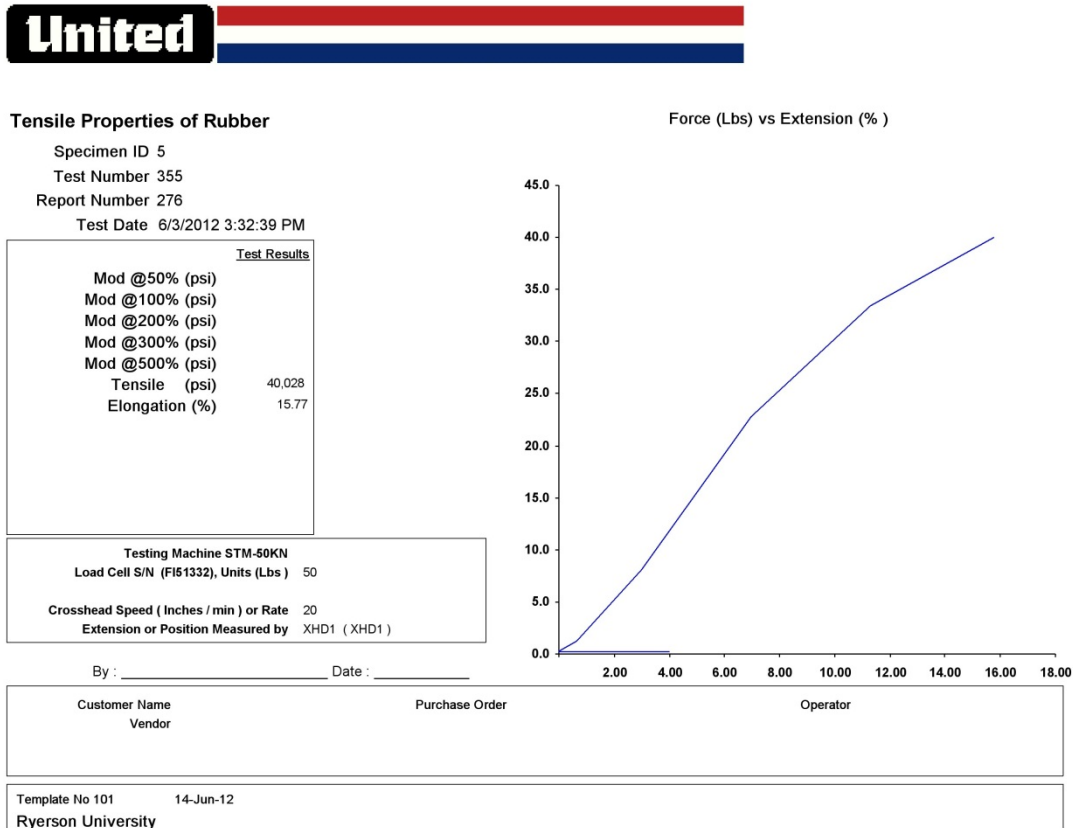


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Tensile Kapton Film JetA1 - Specimen 4

Tensile ASTM D412 – Kapton Film

Jet A1 – Test Specimens

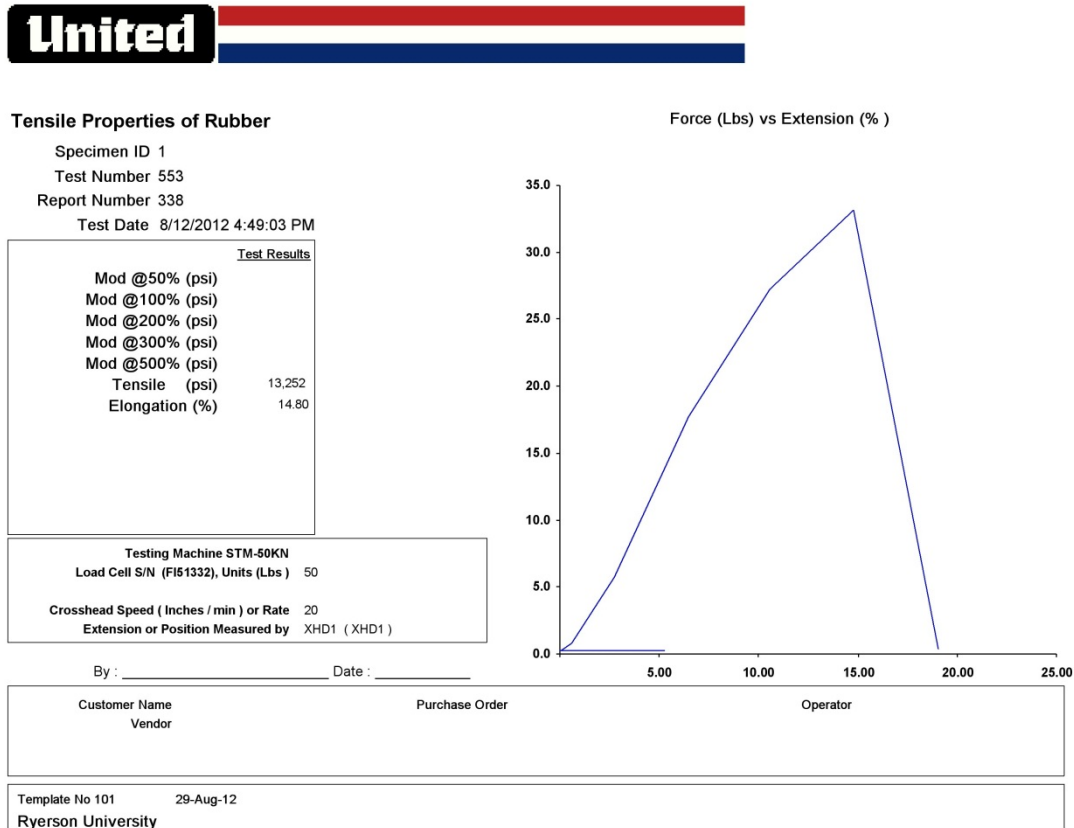


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Tensile Kapton Film JetA1 - Specimen 5

Tensile ASTM D412 – Kapton Film

Biofuel 50/50 – Test Specimens



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Tensile Kapton Film Bio50 - Specimen 1

Tensile ASTM D412 – Kapton Film

Biofuel 50/50 – Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 554
Report Number 338
Test Date 8/12/2012 4:51:45 PM

Test Results

Mod @50% (psi)
Mod @100% (psi)
Mod @200% (psi)
Mod @300% (psi)
Mod @500% (psi)
Tensile (psi) 14,327
Elongation (%) 14.96

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

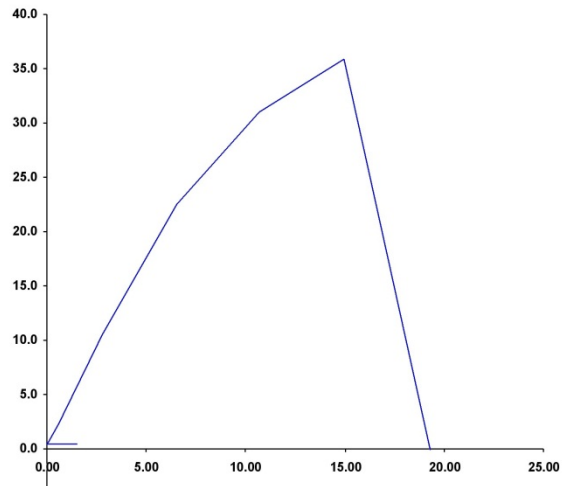
Customer Name
Vendor

Purchase Order

Operator

Template No 101 29-Aug-12
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Force (Lbs) vs Extension (%)



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Tensile Kapton Film Bio50 - Specimen 2

Tensile ASTM D412 – Kapton Film

Biofuel 50/50 – Test Specimens



Tensile Properties of Rubber

Specimen ID 3
Test Number 555
Report Number 338
Test Date 8/12/2012 4:52:59 PM

Test Results

Mod @50% (psi)
Mod @100% (psi)
Mod @200% (psi)
Mod @300% (psi)
Mod @500% (psi)
Tensile (psi) 12,014
Elongation (%) 11.24

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

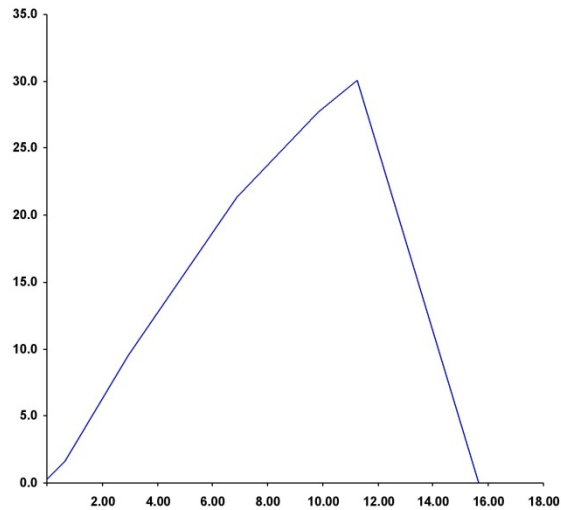
Customer Name
Vendor

Purchase Order

Operator

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)

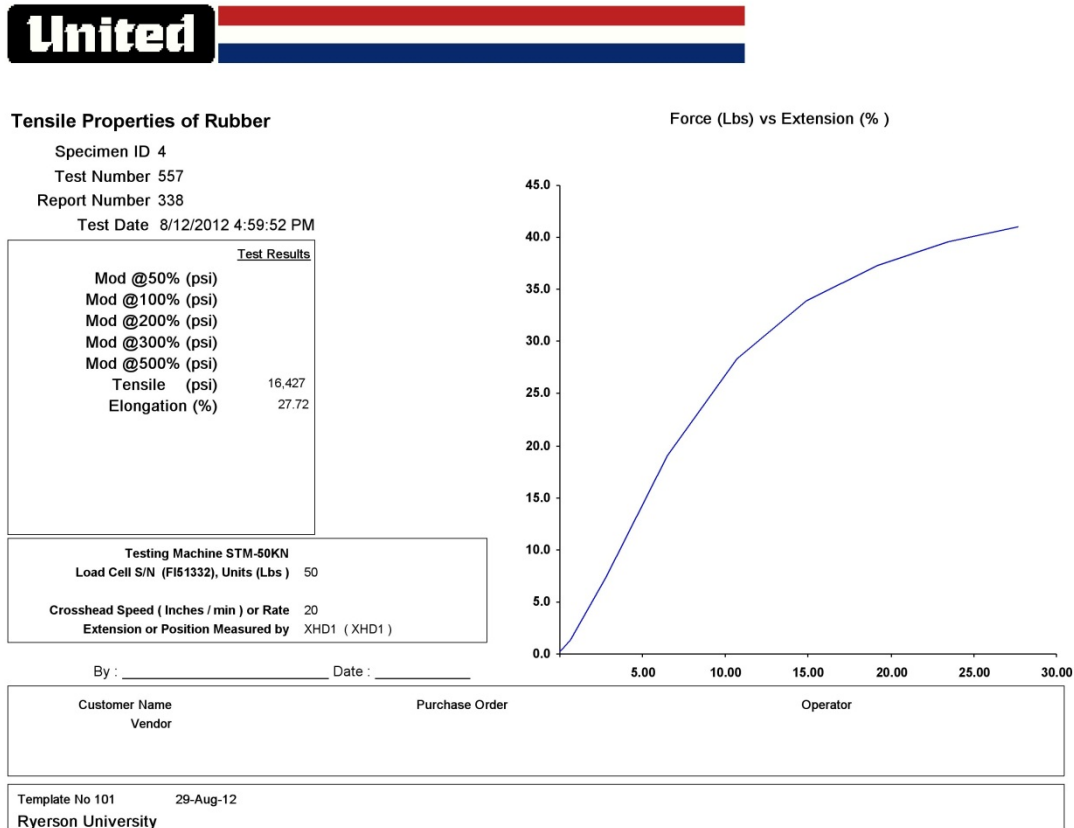


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Tensile Kapton Film Bio50 - Specimen 3

Tensile ASTM D412 – Kapton Film

Biofuel 50/50 – Test Specimens



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Tensile Kapton Film Bio50 - Specimen 4

Tensile ASTM D412 – Kapton Film

Biofuel 50/50 – Test Specimens



Tensile Properties of Rubber

Specimen ID 5
Test Number 558
Report Number 338
Test Date 8/12/2012 5:03:06 PM

Test Results

Mod @50% (psi)
Mod @100% (psi)
Mod @200% (psi)
Mod @300% (psi)
Mod @500% (psi)
Tensile (psi) 14,677
Elongation (%) 15.28

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

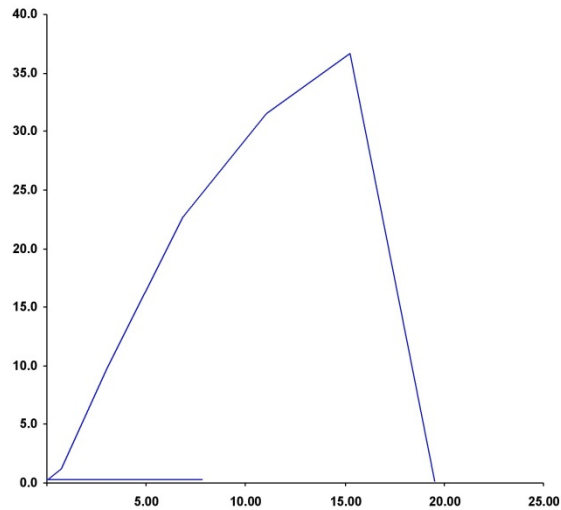
Customer Name
Vendor

Purchase Order

Operator

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



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Tensile Kapton Film Bio50 - Specimen 5

Tensile ASTM D412 – Polyethylene Film

Jet A1 – Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 249
Report Number 227
Test Date 4/7/2012 5:11:14 PM

Test Results	
Mod @50% (psi)	7.462
Mod @100% (psi)	
Mod @200% (psi)	
Mod @300% (psi)	
Mod @500% (psi)	
Tensile (psi)	9.089
Elongation (%)	64.84

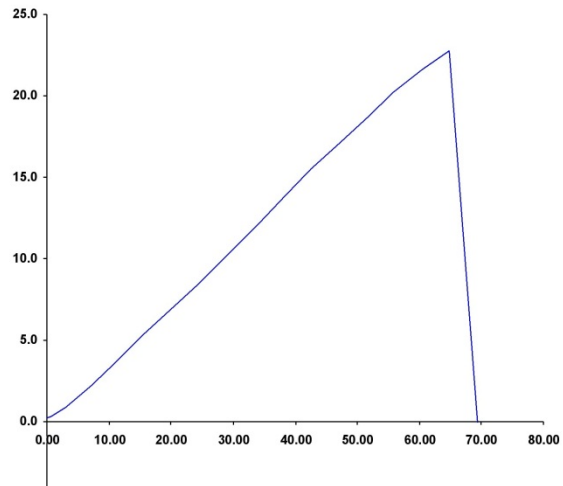
Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 07-Apr-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Polyethylene Film JetA1 - Specimen 1

Tensile ASTM D412 – Polyethylene Film

Jet A1 – Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 250
Report Number 227
Test Date 4/7/2012 5:15:45 PM

Test Results	
Mod @50% (psi)	7.065
Mod @100% (psi)	
Mod @200% (psi)	
Mod @300% (psi)	
Mod @500% (psi)	
Tensile (psi)	9,303
Elongation (%)	77.76

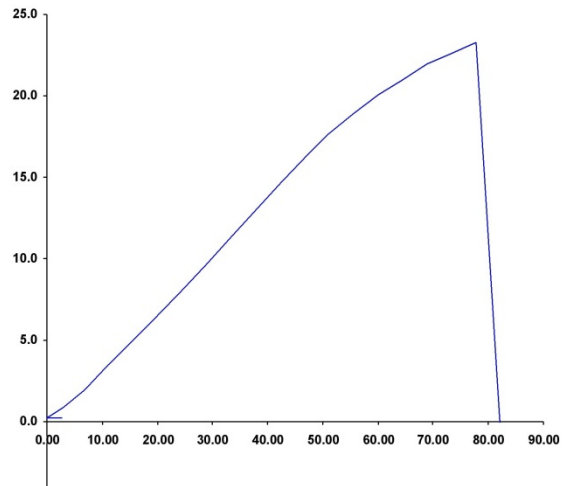
Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 07-Apr-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Polyethylene Film JetA1 - Specimen 2

Tensile ASTM D412 – Polyethylene Film

Jet A1 – Test Specimens

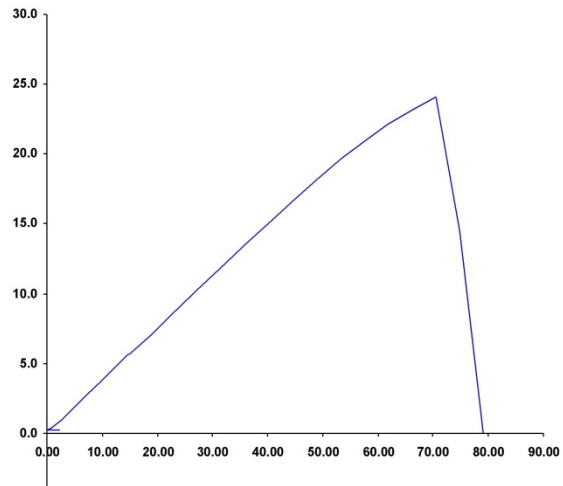


Tensile Properties of Rubber

Specimen ID 3
Test Number 251
Report Number 227
Test Date 4/7/2012 5:17:39 PM

Test Results	
Mod @50% (psi)	7.864
Mod @100% (psi)	
Mod @200% (psi)	
Mod @300% (psi)	
Mod @500% (psi)	
Tensile (psi)	9.624
Elongation (%)	70.45

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)



By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 07-Apr-12
Ryerson University

Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Polyethylene Film JetA1 - Specimen 3

Tensile ASTM D412 – Polyethylene Film

Jet A1 – Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 252
Report Number 227
Test Date 4/7/2012 5:20:52 PM

Test Results	
Mod @50% (psi)	7.970
Mod @100% (psi)	
Mod @200% (psi)	
Mod @300% (psi)	
Mod @500% (psi)	
Tensile (psi)	9.606
Elongation (%)	75.03

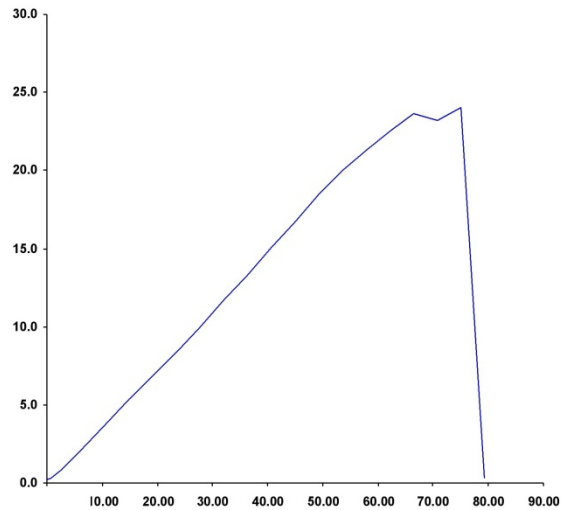
Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 07-Apr-12
Ryerson University

Force (Lbs) vs Extension (%)



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Tensile Polyethylene Film JetA1 - Specimen 4

Tensile ASTM D412 – Polyethylene Film

Jet A1 – Test Specimens



Tensile Properties of Rubber

Specimen ID 5

Test Number 253

Report Number 227

Test Date 4/7/2012 5:22:44 PM

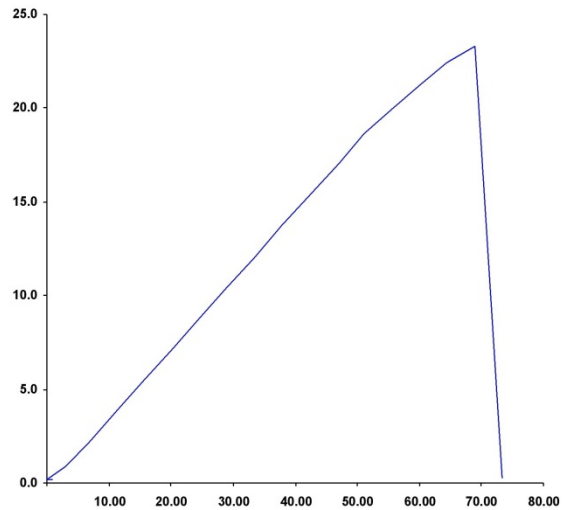
Test Results	
Mod @50% (psi)	7.454
Mod @100% (psi)	
Mod @200% (psi)	
Mod @300% (psi)	
Mod @500% (psi)	
Tensile (psi)	9,325
Elongation (%)	68.94

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	07-Apr-12
Ryerson University	



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Tensile Polyethylene Film JetA1 - Specimen 5

Tensile ASTM D412 – Polyethylene Film

Biofuel 50/50 – Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 701
Report Number 293
Test Date 10/13/2012 3:57:33 PM

Test Results

Mod @50% (psi)
Mod @100% (psi)
Mod @200% (psi)
Mod @300% (psi)
Mod @500% (psi)
Tensile (psi) 11,059
Elongation (%) 37.87

Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

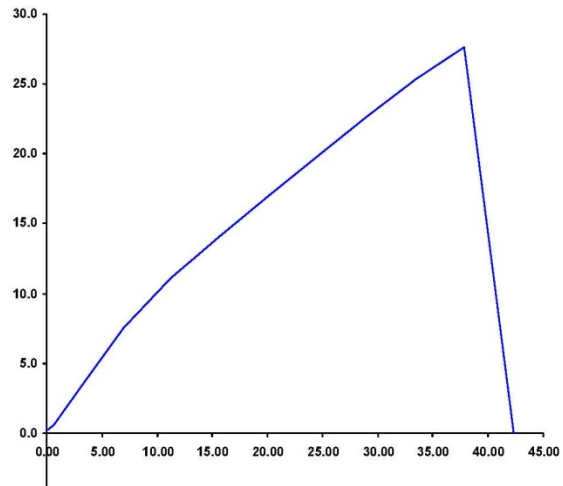
Customer Name
Vendor

Purchase Order

Operator

Template No 101 13-Oct-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Polyethylene Film Bio50 - Specimen 1

Tensile ASTM D412 – Polyethylene Film

Biofuel 50/50 – Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 467
Report Number 293
Test Date 7/20/2012 4:33:39 PM

Test Results	
Mod @50% (psi)	8.227
Mod @100% (psi)	
Mod @200% (psi)	
Mod @300% (psi)	
Mod @500% (psi)	
Tensile (psi)	9.237
Elongation (%)	61.84

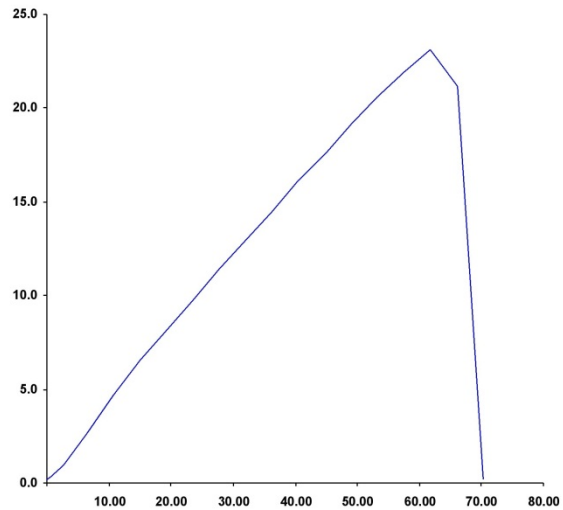
Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



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Tensile Polyethylene Film Bio50 - Specimen 2

Tensile ASTM D412 – Polyethylene Film

Biofuel 50/50 – Test Specimens



Tensile Properties of Rubber

Specimen ID 3
Test Number 468
Report Number 293
Test Date 7/20/2012 4:35:28 PM

Test Results	
Mod @50% (psi)	8,589
Mod @100% (psi)	
Mod @200% (psi)	
Mod @300% (psi)	
Mod @500% (psi)	
Tensile (psi)	9,605
Elongation (%)	61.13

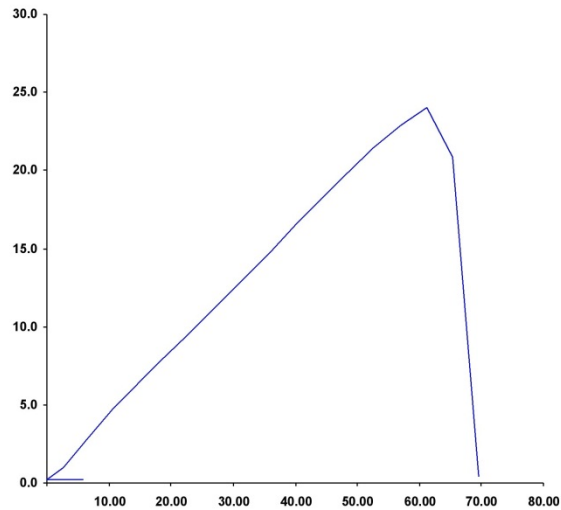
Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Polyethylene Film Bio50 - Specimen 3

Tensile ASTM D412 – Polyethylene Film

Biofuel 50/50 – Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 469
Report Number 293
Test Date 7/20/2012 4:38:01 PM

Test Results

Mod @50% (psi)	7.793
Mod @100% (psi)	
Mod @200% (psi)	
Mod @300% (psi)	
Mod @500% (psi)	
Tensile (psi)	9,528
Elongation (%)	67.13

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

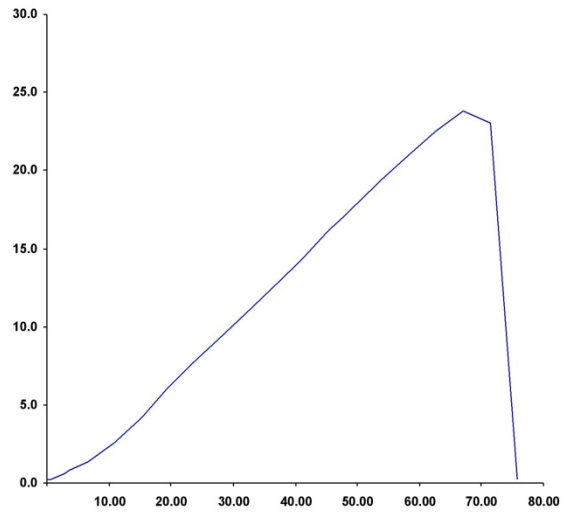
Customer Name
Vendor

Purchase Order

Operator

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Polyethylene Film Bio50 - Specimen 4

Tensile ASTM D412 – Polyethylene Film

Biofuel 50/50 – Test Specimens



Tensile Properties of Rubber

Specimen ID 5
Test Number 470
Report Number 293
Test Date 7/20/2012 4:41:57 PM

Test Results

Mod @50% (psi)	8,003
Mod @100% (psi)	
Mod @200% (psi)	
Mod @300% (psi)	
Mod @500% (psi)	
Tensile (psi)	8,628
Elongation (%)	56.14

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

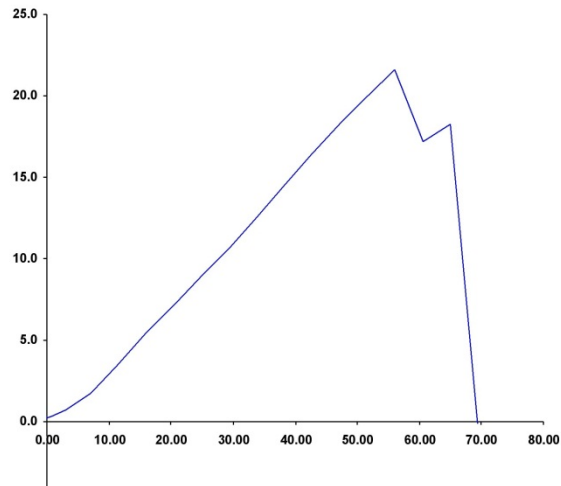
Customer Name
Vendor

Purchase Order

Operator

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Polyethylene Film Bio50 - Specimen 5

Tensile ASTM D412 – Teflon Film

Jet A1 – Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 243
Report Number 226
Test Date 4/7/2012 4:40:54 PM

Test Results

Mod @50% (psi)	1,772
Mod @100% (psi)	1,920
Mod @200% (psi)	2,236
Mod @300% (psi)	-29
Mod @500% (psi)	
Tensile (psi)	2,445
Elongation (%)	299.47

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

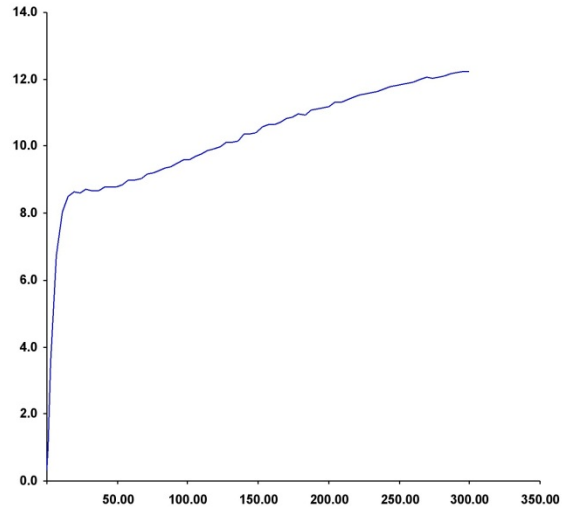
Customer Name
Vendor

Purchase Order

Operator

Template No 101 07-Apr-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Teflon Film JetA1 - Specimen 1

Tensile ASTM D412 – Teflon Film

Jet A1 – Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 244
Report Number 226
Test Date 4/7/2012 4:44:34 PM

Test Results	
Mod @50% (psi)	1,749
Mod @100% (psi)	1,910
Mod @200% (psi)	2,220
Mod @300% (psi)	2,431
Mod @500% (psi)	
Tensile (psi)	2,543
Elongation (%)	395.80

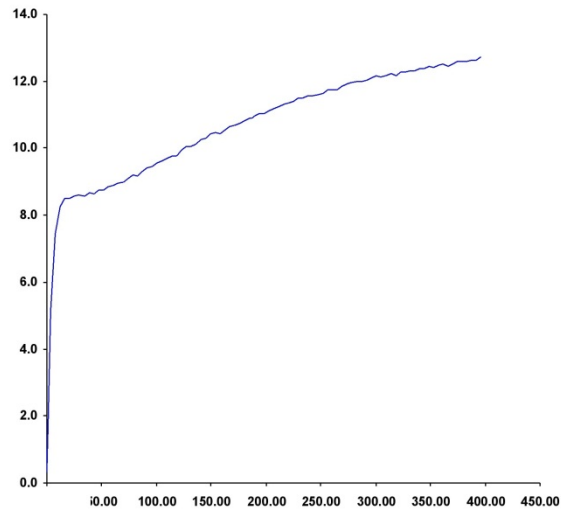
Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 07-Apr-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Teflon Film JetA1 - Specimen 2

Tensile ASTM D412 – Teflon Film

Jet A1 – Test Specimens



Tensile Properties of Rubber

Specimen ID 3
Test Number 245
Report Number 226
Test Date 4/7/2012 4:49:06 PM

Test Results

Mod @50% (psi)	1,797
Mod @100% (psi)	1,951
Mod @200% (psi)	2,282
Mod @300% (psi)	2,488
Mod @500% (psi)	
Tensile (psi)	2,661
Elongation (%)	481.23

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

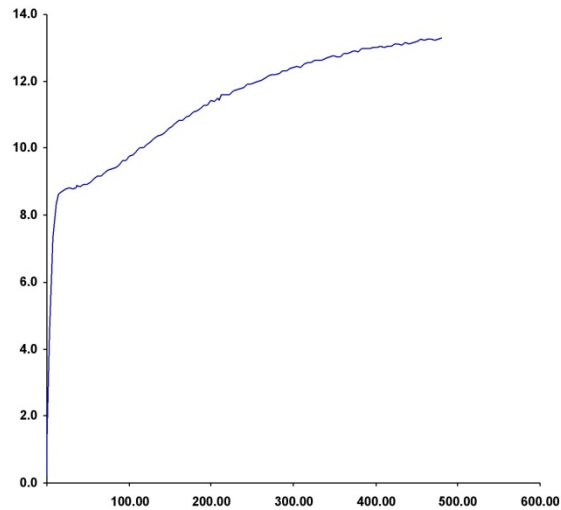
Customer Name
Vendor

Purchase Order

Operator

Template No 101 07-Apr-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Teflon Film JetA1 - Specimen 3

Tensile ASTM D412 – Teflon Film

Jet A1 – Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 248
Report Number 226
Test Date 4/7/2012 4:57:34 PM

Test Results	
Mod @50% (psi)	1,765
Mod @100% (psi)	1,934
Mod @200% (psi)	2,228
Mod @300% (psi)	
Mod @500% (psi)	
Tensile (psi)	2,228
Elongation (%)	202.10

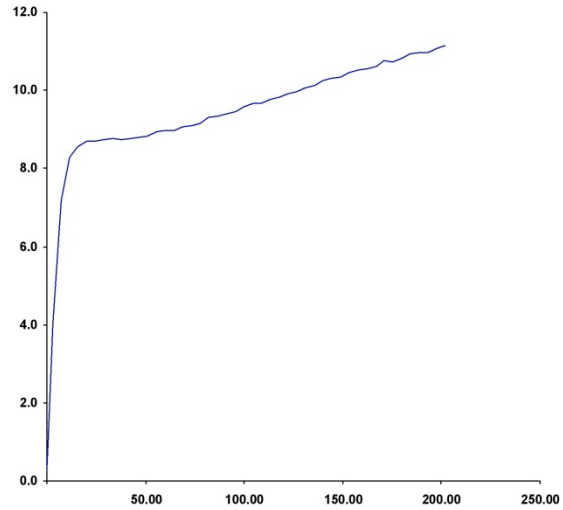
Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 07-Apr-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Teflon Film JetA1 - Specimen 4

Tensile ASTM D412 – Teflon Film

Jet A1 – Test Specimens



Tensile Properties of Rubber

Specimen ID 5
Test Number 247
Report Number 226
Test Date 4/7/2012 4:35:31 PM

Test Results	
Mod @50% (psi)	1,678
Mod @100% (psi)	1,838
Mod @200% (psi)	2,151
Mod @300% (psi)	2,380
Mod @500% (psi)	
Tensile (psi)	2,540
Elongation (%)	460.08

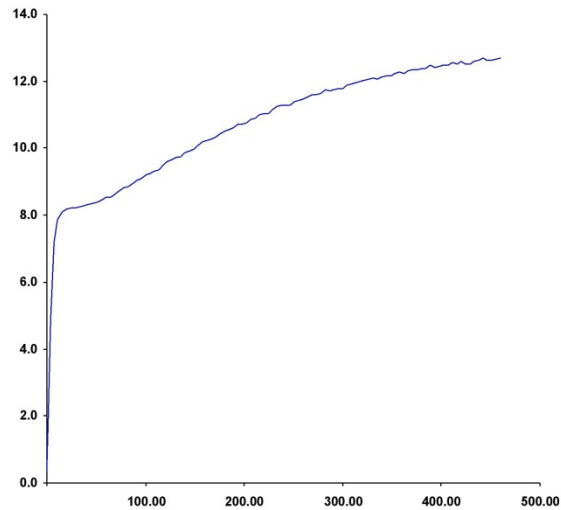
Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 07-Apr-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Teflon Film JetA1 - Specimen 5

Tensile ASTM D412 – Teflon Film

Bofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1

Test Number 471

Report Number 294

Test Date 7/20/2012 4:45:26 PM

Test Results

Mod @50% (psi)	1,966
Mod @100% (psi)	2,121
Mod @200% (psi)	2,476
Mod @300% (psi)	2,771
Mod @500% (psi)	
Tensile (psi)	2,799
Elongation (%)	379.79

Testing Machine STM-50KN

Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20

Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

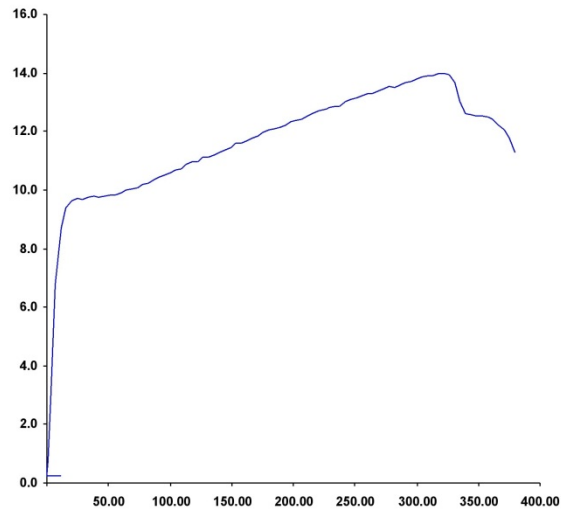
Customer Name
Vendor

Purchase Order

Operator

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Teflon Film Bio50 - Specimen 1

Tensile ASTM D412 – Teflon Film

Bofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 472
Report Number 294
Test Date 7/20/2012 4:48:13 PM

Test Results	
Mod @50% (psi)	1,984
Mod @100% (psi)	2,154
Mod @200% (psi)	2,513
Mod @300% (psi)	
Mod @500% (psi)	
Tensile (psi)	2,690
Elongation (%)	258.83

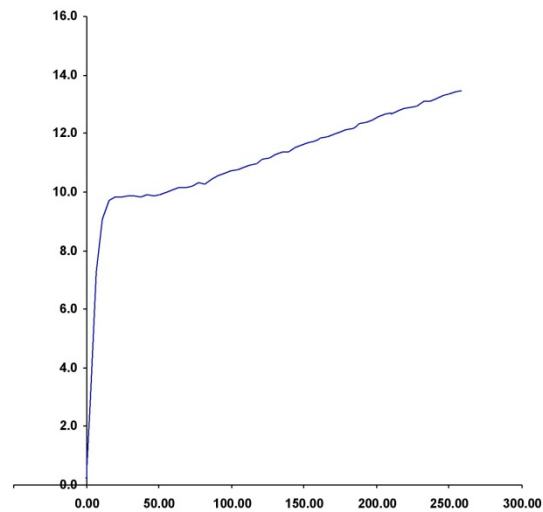
Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Teflon Film Bio50 - Specimen 2

Tensile ASTM D412 – Teflon Film

Bofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 3
Test Number 473
Report Number 294
Test Date 7/20/2012 4:50:35 PM

Test Results

Mod @50% (psi)	2.028
Mod @100% (psi)	2.177
Mod @200% (psi)	2.569
Mod @300% (psi)	2.901
Mod @500% (psi)	
Tensile (psi)	3.039
Elongation (%)	362.31

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

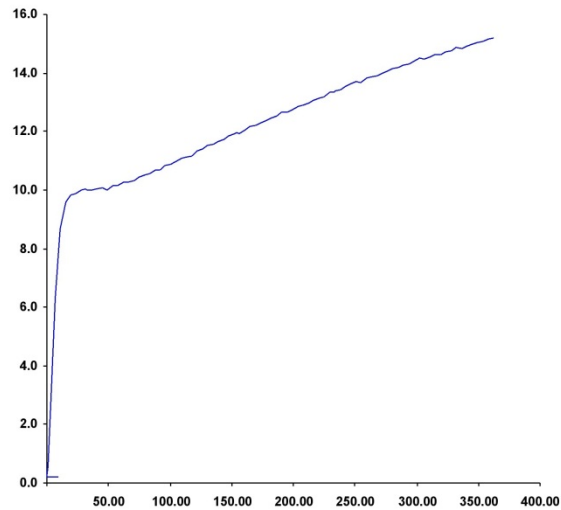
Customer Name
Vendor

Purchase Order

Operator

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Teflon Film Bio50 - Specimen 3

Tensile ASTM D412 – Teflon Film

Bofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 4

Test Number 474

Report Number 294

Test Date 7/20/2012 4:52:51 PM

Test Results

Mod @50% (psi)	1,991
Mod @100% (psi)	2,142
Mod @200% (psi)	2,502
Mod @300% (psi)	2,839
Mod @500% (psi)	
Tensile (psi)	2,885
Elongation (%)	326.08

Testing Machine STM-50KN

Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20

Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

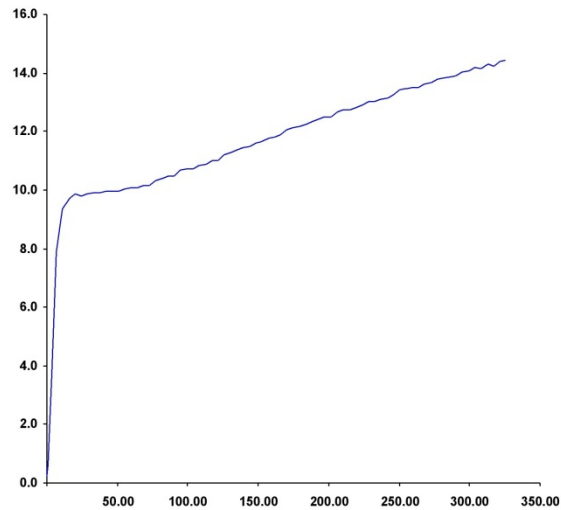
Customer Name
Vendor

Purchase Order

Operator

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Teflon Film Bio50 - Specimen 4

Tensile ASTM D412 – Teflon Film

Bofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 5
Test Number 475
Report Number 294
Test Date 7/20/2012 4:55:57 PM

Test Results	
Mod @50% (psi)	1,981
Mod @100% (psi)	2,125
Mod @200% (psi)	2,496
Mod @300% (psi)	
Mod @500% (psi)	
Tensile (psi)	2,719
Elongation (%)	272.85

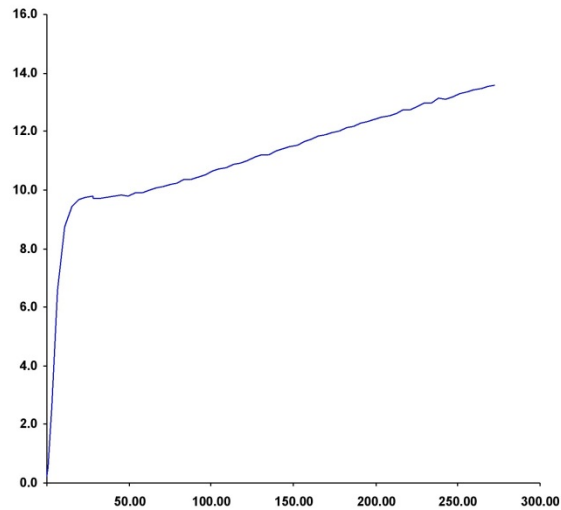
Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Teflon Film Bio50 - Specimen 5

Tensile ASTM D412 – Fluorocarbon O-Ring

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 361
Report Number 278
Test Date 6/3/2012 3:45:58 PM

Test Results

Mod @50% (psi)	213
Mod @100% (psi)	355
Mod @200% (psi)	688
Mod @300% (psi)	
Mod @500% (psi)	
Tensile (psi)	979
Elongation (%)	292.76

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

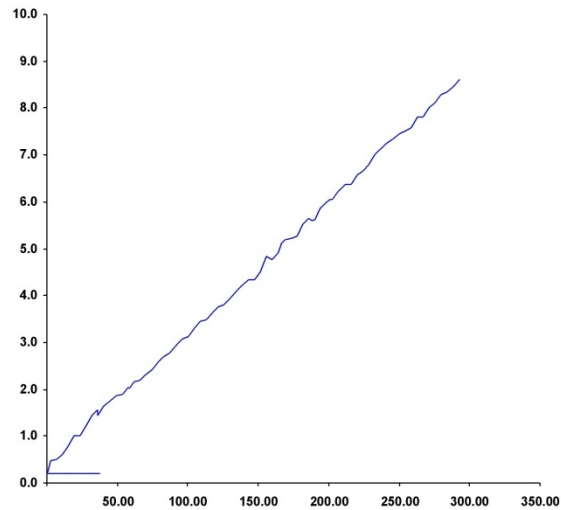
Customer Name
Vendor

Purchase Order

Operator

Template No 101 14-Jun-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Fluorocarbon O-Ring JetA1 - Specimen 1

Tensile ASTM D412 – Fluorocarbon O-Ring

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 362
Report Number 278
Test Date 6/3/2012 3:47:55 PM

Test Results	
Mod @50% (psi)	202
Mod @100% (psi)	349
Mod @200% (psi)	662
Mod @300% (psi)	
Mod @500% (psi)	
Tensile (psi)	931
Elongation (%)	286.33

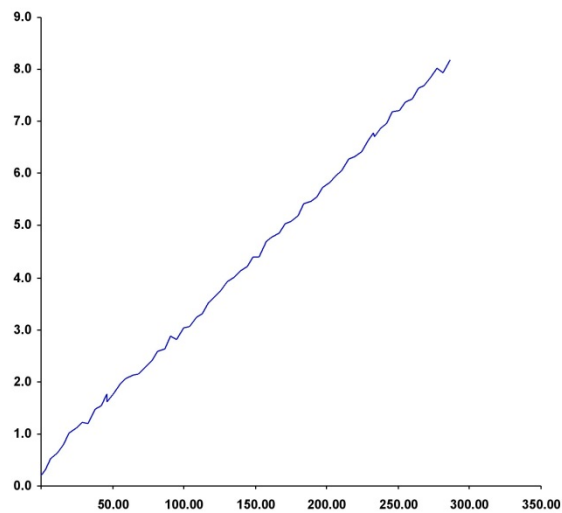
Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	14-Jun-12
Ryerson University	

Force (Lbs) vs Extension (%)

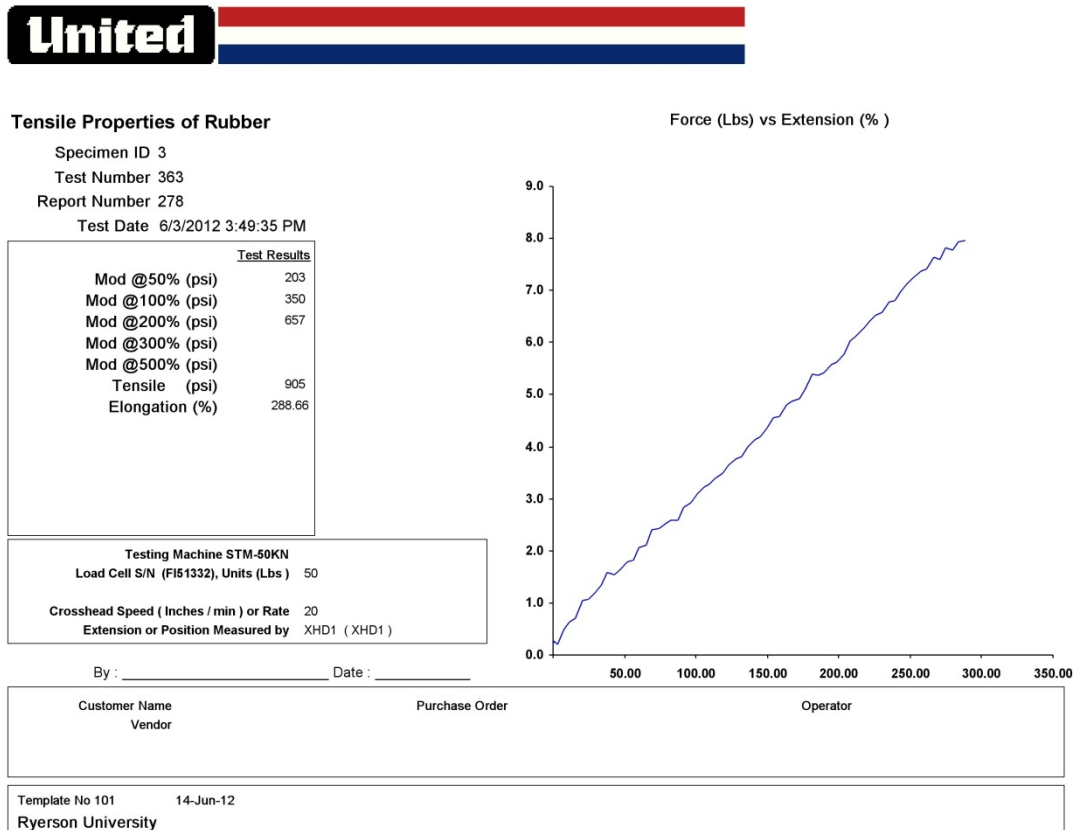


Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Fluorocarbon O-Ring JetA1 - Bio50 Specimen 2

Tensile ASTM D412 – Fluorocarbon O-Ring

Jet A1 - Test Specimens

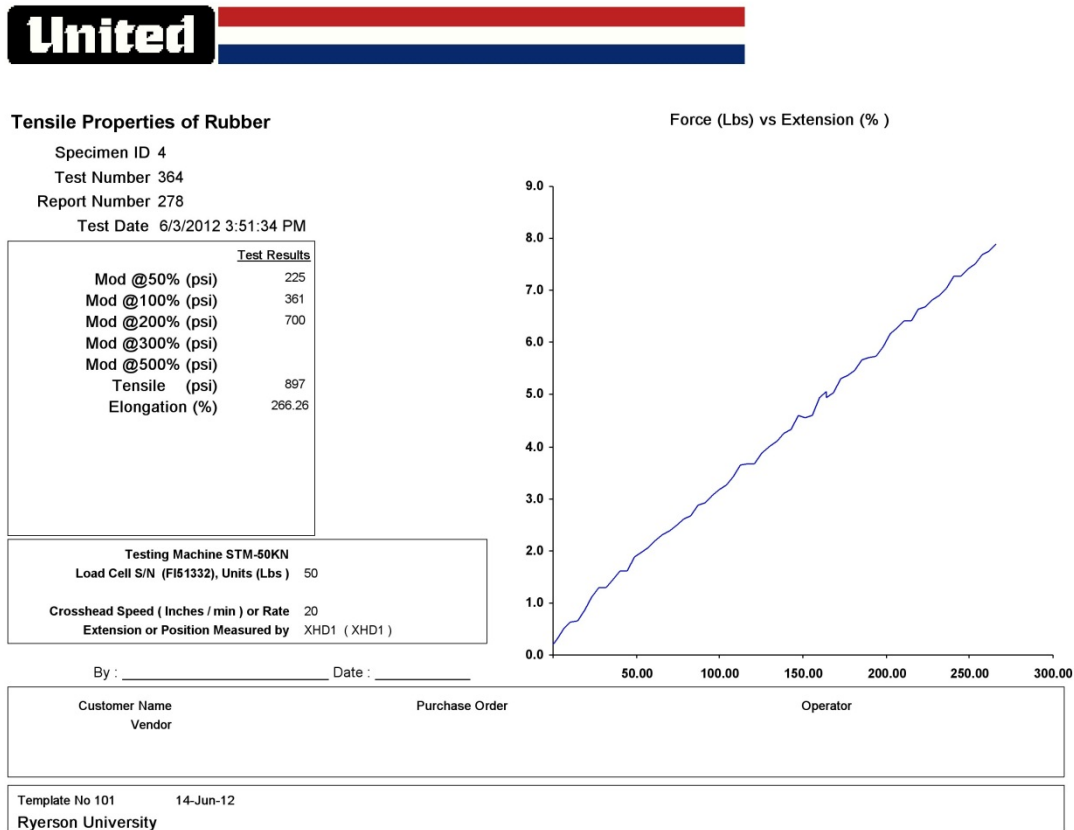


Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Fluorocarbon O-Ring JetA1 - Specimen 3

Tensile ASTM D412 – Fluorocarbon O-Ring

Jet A1 - Test Specimens

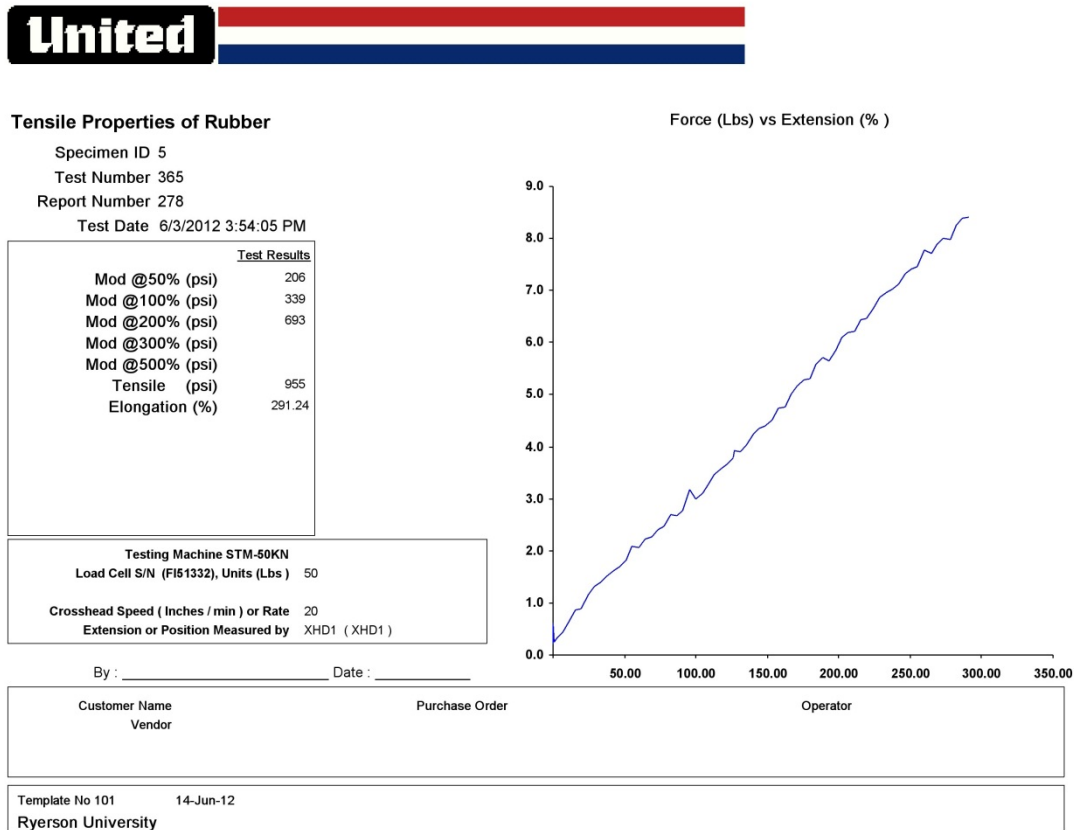


Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Fluorocarbon O-Ring JetA1 - Specimen 4

Tensile ASTM D412 – Fluorocarbon O-Ring

Jet A1 - Test Specimens



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Fluorocarbon O-Ring JetA1 - Specimen 5

Tensile ASTM D412 – Fluorocarbon O-Ring

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 559
Report Number 339
Test Date 8/12/2012 5:15:18 PM

Test Results

Mod @50% (psi)	23
Mod @100% (psi)	37
Mod @200% (psi)	70
Mod @300% (psi)	-1
Mod @500% (psi)	
Tensile (psi)	102
Elongation (%)	299.33

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

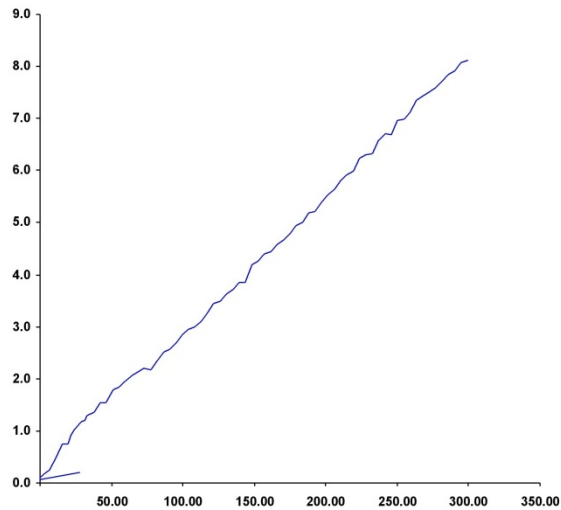
Customer Name
Vendor

Purchase Order

Operator

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Fluorocarbon O-Ring Bio50 - Specimen 1

Tensile ASTM D412 – Fluorocarbon O-Ring

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 560
Report Number 339
Test Date 8/12/2012 5:17:10 PM

Test Results	
Mod @50% (psi)	23
Mod @100% (psi)	39
Mod @200% (psi)	71
Mod @300% (psi)	104
Mod @500% (psi)	
Tensile (psi)	105
Elongation (%)	307.98

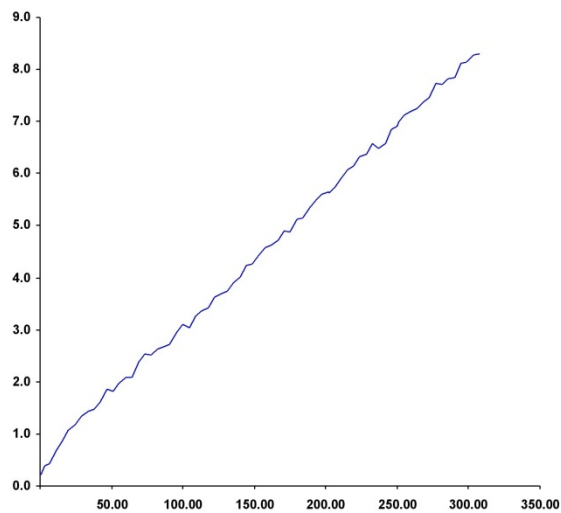
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)

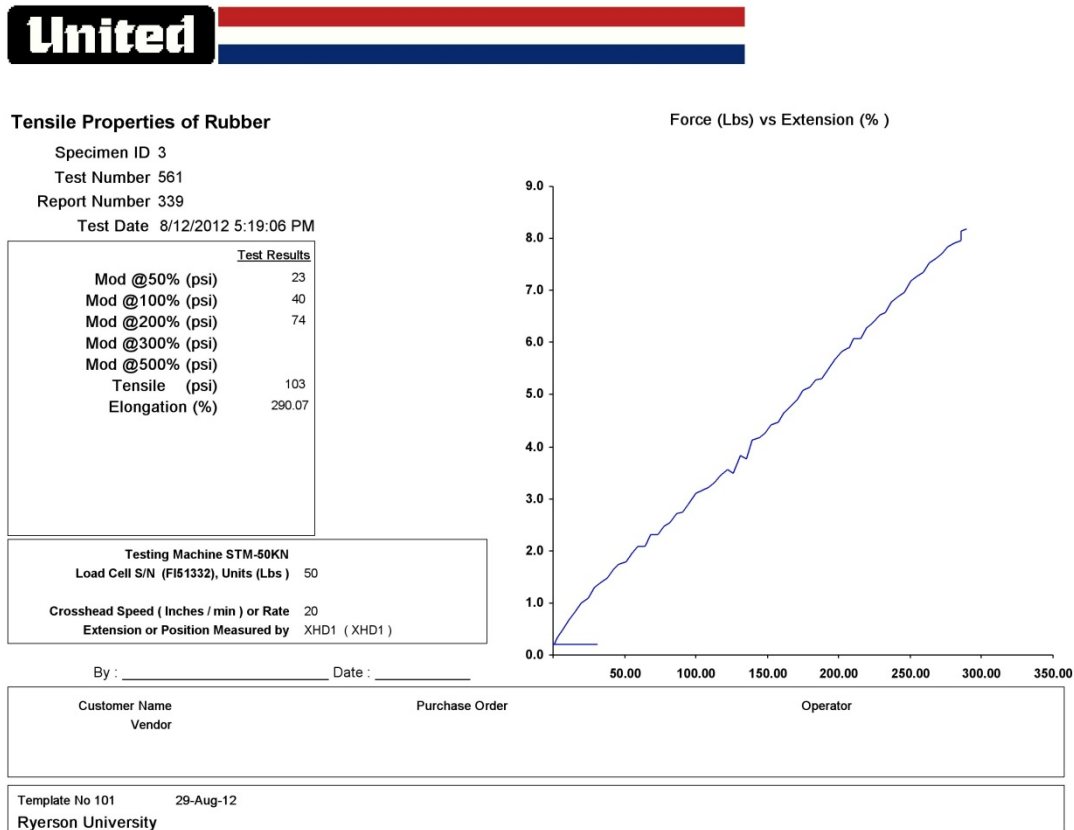


Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Fluorocarbon O-Ring Bio50 - Specimen 2

Tensile ASTM D412 – Fluorocarbon O-Ring

Biofuel 50/50 - Test Specimens



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Fluorocarbon O-Ring Bio50 - Specimen 3

Tensile ASTM D412 – Fluorocarbon O-Ring

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 562
Report Number 339
Test Date 8/12/2012 5:20:31 PM

Test Results	
Mod @50% (psi)	26
Mod @100% (psi)	41
Mod @200% (psi)	79
Mod @300% (psi)	
Mod @500% (psi)	
Tensile (psi)	104
Elongation (%)	270.10

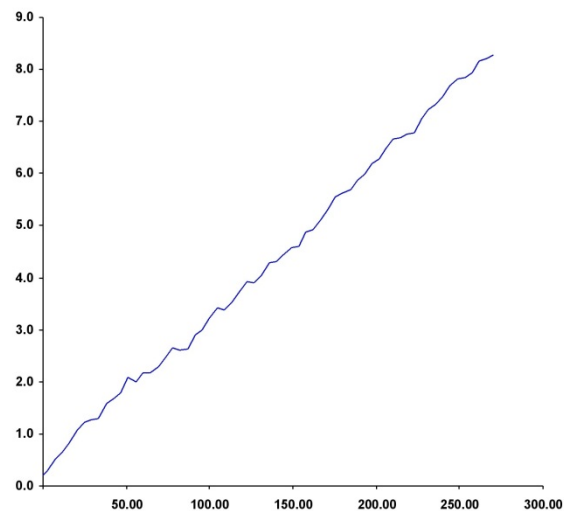
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Fluorocarbon O-Ring Bio50 - Specimen 4

Tensile ASTM D412 – Fluorocarbon O-Ring

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 5
Test Number 563
Report Number 339
Test Date 8/12/2012 5:23:17 PM

Test Results	
Mod @50% (psi)	22
Mod @100% (psi)	37
Mod @200% (psi)	70
Mod @300% (psi)	101
Mod @500% (psi)	
Tensile (psi)	104
Elongation (%)	312.30

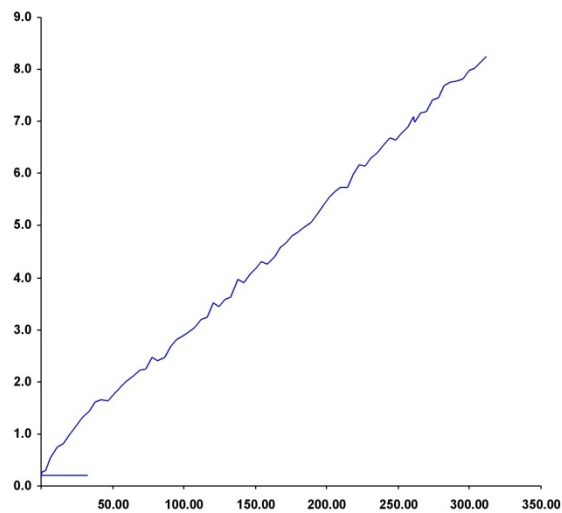
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Fluorocarbon O-Ring Bio50 - Specimen 5

Tensile ASTM D412 – Low Temperature Fluorocarbon O-Ring

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 263
Report Number 234
Test Date 4/7/2012 7:55:32 PM

Test Results

Mod @50% (psi)	210
Mod @100% (psi)	384
Mod @200% (psi)	869
Mod @300% (psi)	1,395
Mod @500% (psi)	
Tensile (psi)	1,395
Elongation (%)	300.64

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

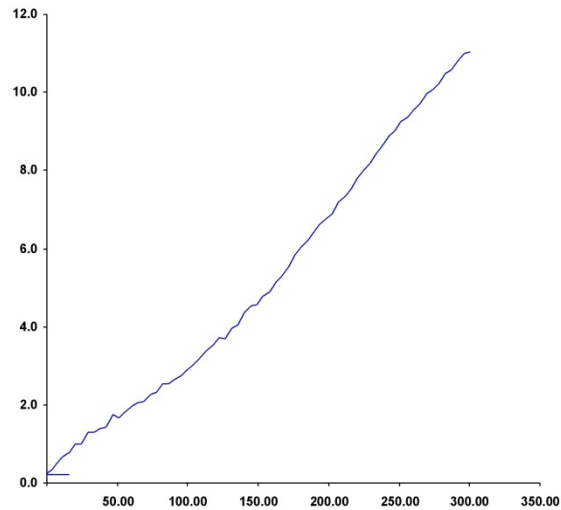
Customer Name
Vendor

Purchase Order

Operator

Template No 101 07-Apr-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile L.T. Fluorocarbon O-Ring JetA1 - Specimen 1

Tensile ASTM D412 – Low Temperature Fluorocarbon O-Ring

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 268
Report Number 234
Test Date 4/7/2012 7:58:57 PM

Test Results	
Mod @50% (psi)	225
Mod @100% (psi)	393
Mod @200% (psi)	899
Mod @300% (psi)	
Mod @500% (psi)	
Tensile (psi)	1,382
Elongation (%)	287.68

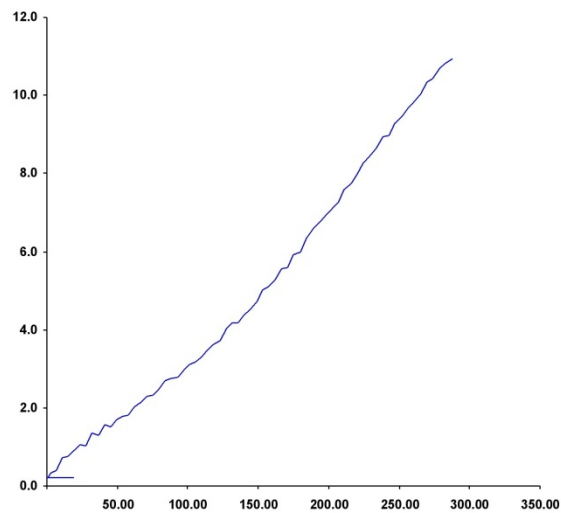
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 07-Apr-12
Ryerson University

Force (Lbs) vs Extension (%)

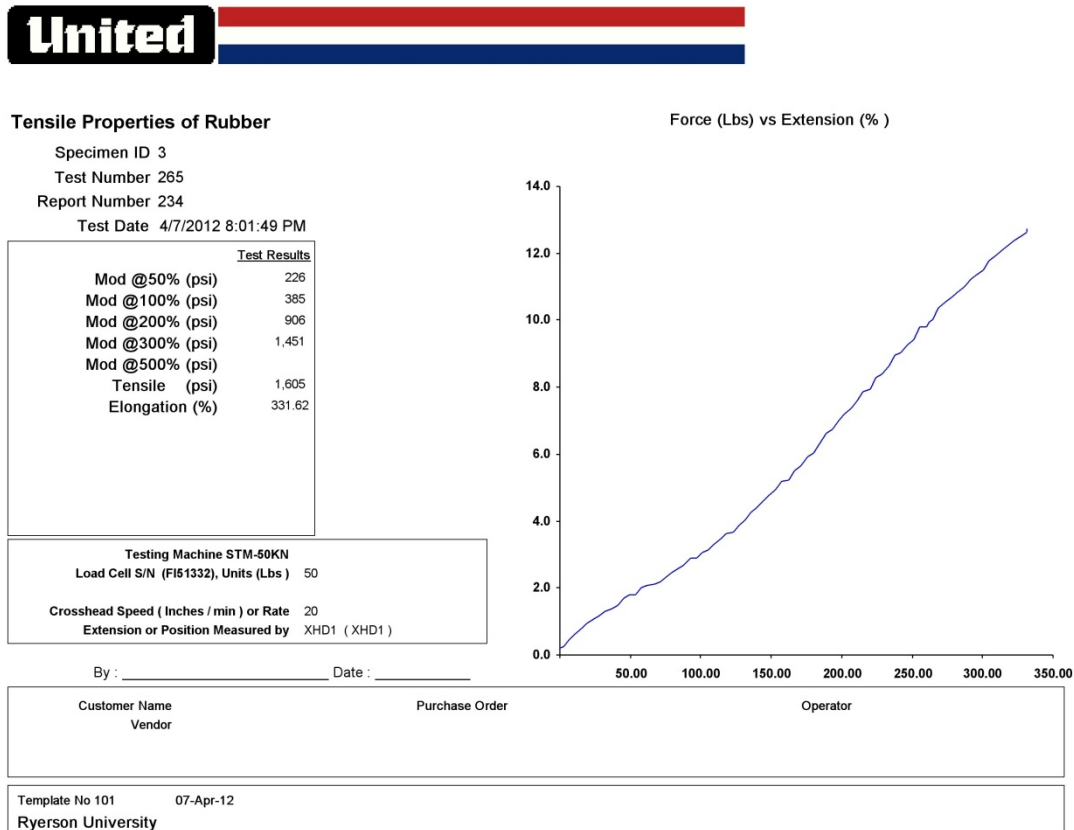


Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile L.T. Fluorocarbon O-Ring JetA1 - Specimen 2

Tensile ASTM D412 – Low Temperature Fluorocarbon O-Ring

Jet A1 - Test Specimens



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile L.T. Fluorocarbon O-Ring JetA1 - Specimen 3

Tensile ASTM D412 – Low Temperature Fluorocarbon O-Ring

Jet A1 - Test Specimens

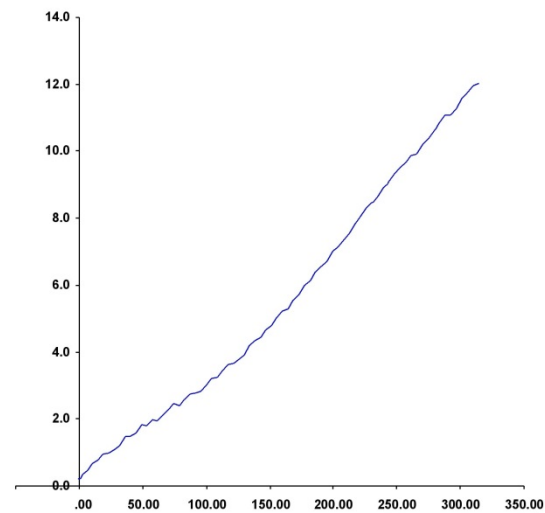


Tensile Properties of Rubber

Specimen ID 4
Test Number 266
Report Number 234
Test Date 4/7/2012 8:02:58 PM

Test Results	
Mod @50% (psi)	229
Mod @100% (psi)	385
Mod @200% (psi)	899
Mod @300% (psi)	1,458
Mod @500% (psi)	
Tensile (psi)	1,516
Elongation (%)	314.57

Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)



By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	07-Apr-12
Ryerson University	

Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile L.T. Fluorocarbon O-Ring JetA1 - Specimen 4

Tensile ASTM D412 – Low Temperature Fluorocarbon O-Ring

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 5
Test Number 267
Report Number 234
Test Date 4/7/2012 8:06:51 PM

Test Results	
Mod @50% (psi)	246
Mod @100% (psi)	403
Mod @200% (psi)	929
Mod @300% (psi)	
Mod @500% (psi)	
Tensile (psi)	1,417
Elongation (%)	291.98

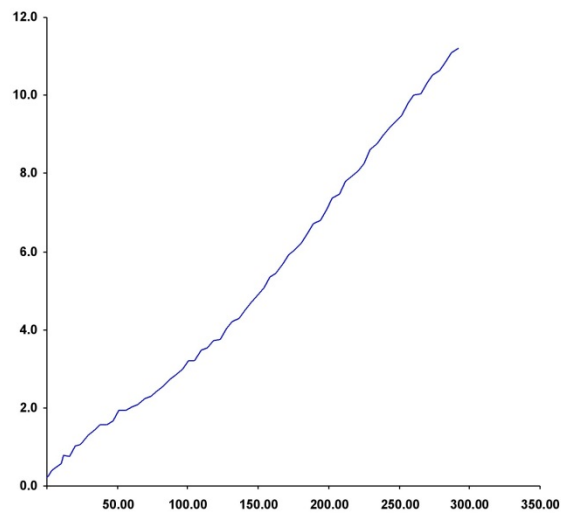
Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	07-Apr-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile L.T. Fluorocarbon O-Ring JetA1 - Specimen 5

Tensile ASTM D412 – Low Temperature Fluorocarbon O-Ring

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 430
Report Number 286
Test Date 6/30/2012 10:18:56 AM

Test Results

Mod @50% (psi)	203
Mod @100% (psi)	340
Mod @200% (psi)	744
Mod @300% (psi)	1,214
Mod @500% (psi)	
Tensile (psi)	1,267
Elongation (%)	313.95

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

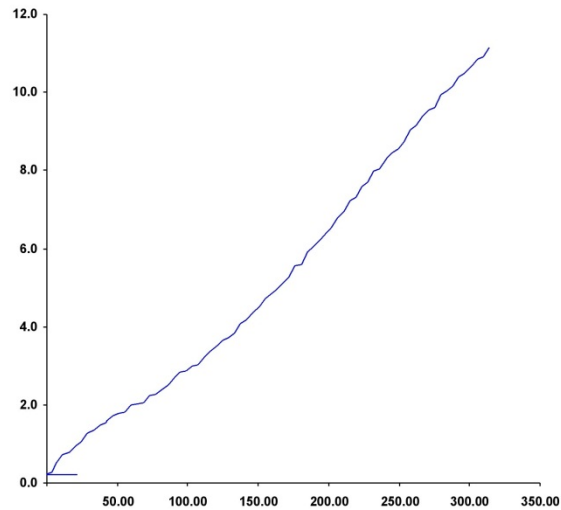
Customer Name
Vendor

Purchase Order

Operator

Template No 101 30-Jun-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile L.T. Fluorocarbon O-Ring Bio50 - Specimen 1

Tensile ASTM D412 – Low Temperature Fluorocarbon O-Ring

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 431
Report Number 286
Test Date 6/30/2012 10:21:13 AM

Test Results	
Mod @50% (psi)	194
Mod @100% (psi)	334
Mod @200% (psi)	757
Mod @300% (psi)	1,229
Mod @500% (psi)	
Tensile (psi)	1,380
Elongation (%)	343.65

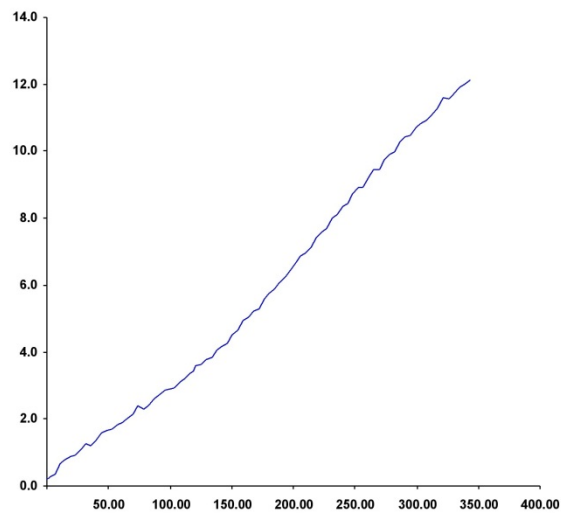
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	30-Jun-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile L.T. Fluorocarbon O-Ring Bio50 - Specimen 2

Tensile ASTM D412 – Low Temperature Fluorocarbon O-Ring

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 3
Test Number 432
Report Number 286
Test Date 6/30/2012 10:22:41 AM

Test Results	
Mod @50% (psi)	188
Mod @100% (psi)	352
Mod @200% (psi)	787
Mod @300% (psi)	1,250
Mod @500% (psi)	
Tensile (psi)	1,261
Elongation (%)	308.11

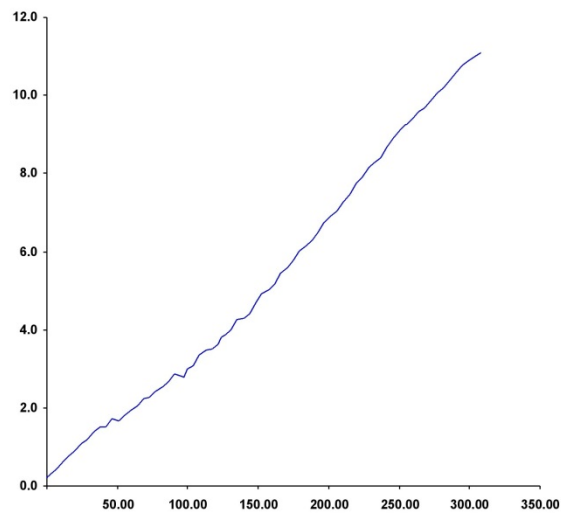
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 30-Jun-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile L.T. Fluorocarbon O-Ring Bio50 - Specimen 3

Tensile ASTM D412 – Low Temperature Fluorocarbon O-Ring

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 434
Report Number 286
Test Date 6/30/2012 10:24:54 AM

Test Results	
Mod @50% (psi)	200
Mod @100% (psi)	351
Mod @200% (psi)	762
Mod @300% (psi)	1,219
Mod @500% (psi)	
Tensile (psi)	1,246
Elongation (%)	313.05

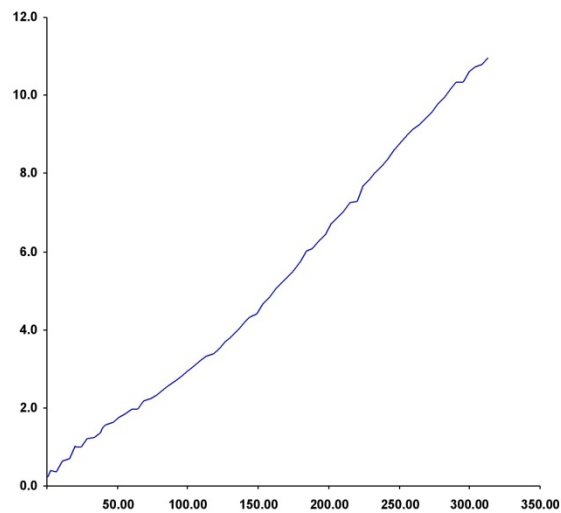
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	30-Jun-12
Ryerson University	

Force (Lbs) vs Extension (%)

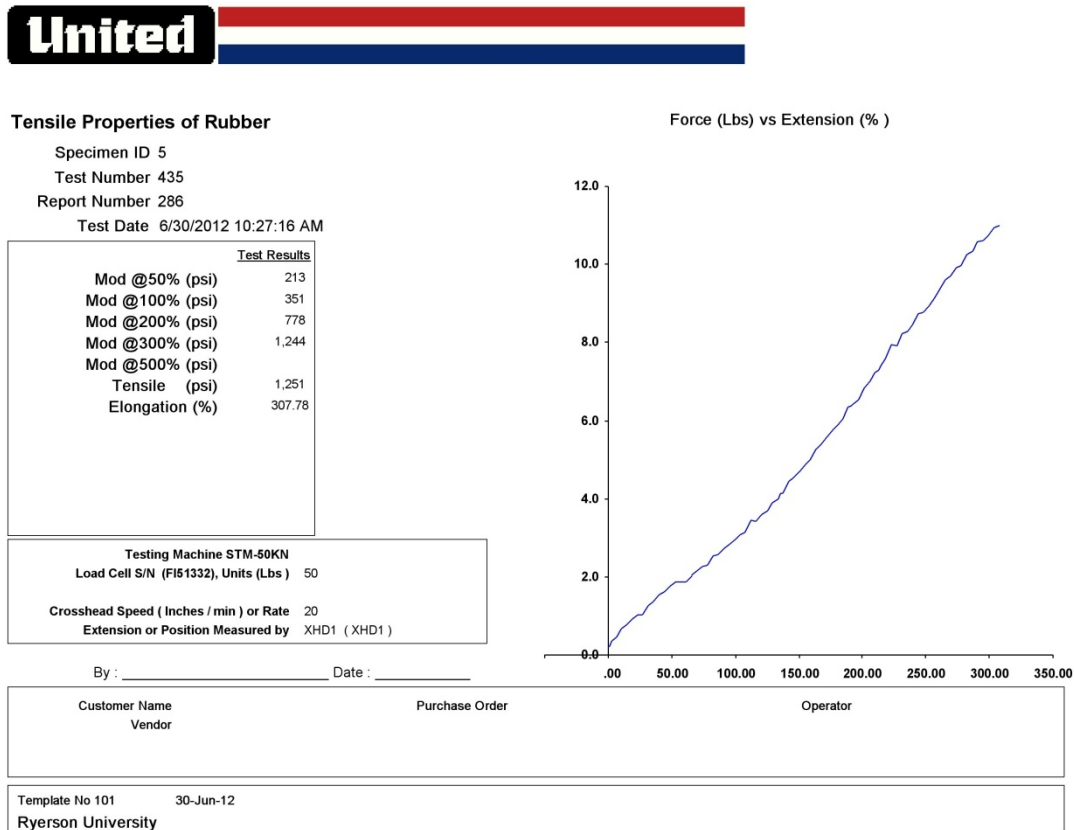


Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile L.T. Fluorocarbon O-Ring Bio50 - Specimen 4

Tensile ASTM D412 – Low Temperature Fluorocarbon O-Ring

Biofuel 50/50 - Test Specimens



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile L.T. Fluorocarbon O-Ring Bio50 - Specimen 5

Tensile ASTM D412 – Nitrile O-Ring

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 258
Report Number 232
Test Date 4/7/2012 7:17:12 PM

Test Results

Mod @50% (psi)	199
Mod @100% (psi)	284
Mod @200% (psi)	579
Mod @300% (psi)	955
Mod @500% (psi)	1,643
Tensile (psi)	1,827
Elongation (%)	551.93

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

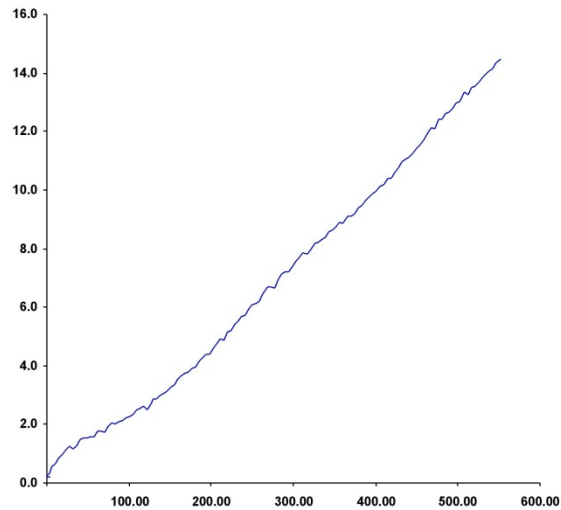
Customer Name
Vendor

Purchase Order

Operator

Template No 101 07-Apr-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Nitrile O-Ring JetA1 - Specimen 1

Tensile ASTM D412 – Nitrile O-Ring

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 2

Test Number 259

Report Number 232

Test Date 4/7/2012 7:20:32 PM

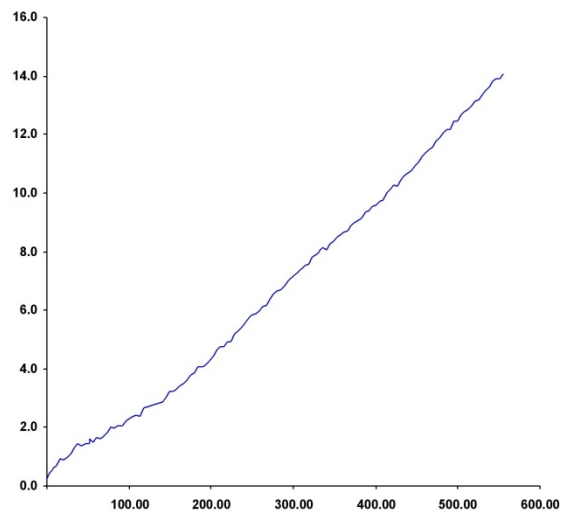
Test Results	
Mod @50% (psi)	184
Mod @100% (psi)	288
Mod @200% (psi)	562
Mod @300% (psi)	910
Mod @500% (psi)	1,597
Tensile (psi)	1,775
Elongation (%)	555.33

Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	07-Apr-12
Ryerson University	

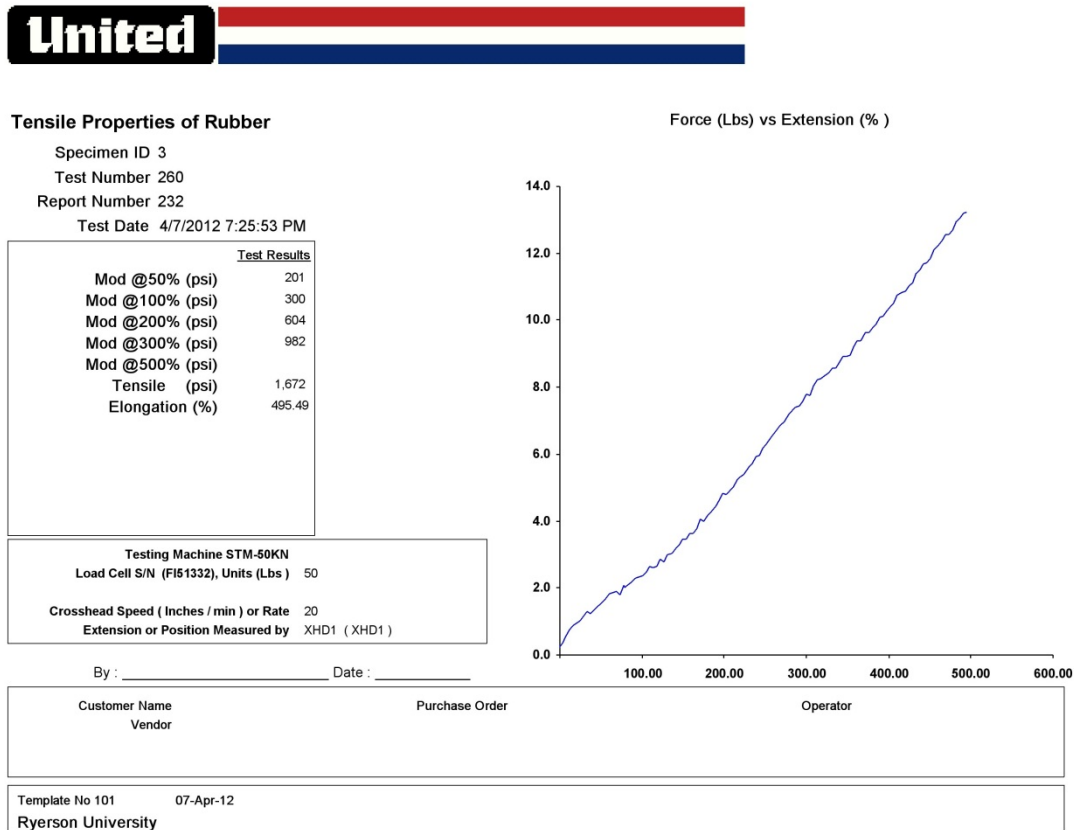


Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Nitrile O-Ring JetA1 - Specimen 2

Tensile ASTM D412 – Nitrile O-Ring

Jet A1 - Test Specimens



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Nitrile O-Ring JetA1 - Specimen 3

Tensile ASTM D412 – Nitrile O-Ring

Jet A1 - Test Specimens



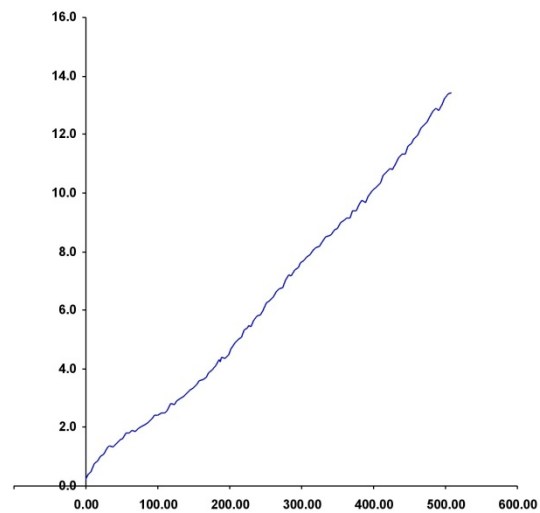
Tensile Properties of Rubber

Specimen ID 4
Test Number 261
Report Number 232
Test Date 4/7/2012 7:27:07 PM

Test Results	
Mod @50% (psi)	205
Mod @100% (psi)	303
Mod @200% (psi)	591
Mod @300% (psi)	974
Mod @500% (psi)	1,689
Tensile (psi)	1,692
Elongation (%)	507.54

Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____



Customer Name	Purchase Order	Operator
Vendor		

Template No 101	07-Apr-12
Ryerson University	

Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Nitrile O-Ring JetA1 - Specimen 4

Tensile ASTM D412 – Nitrile O-Ring

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 5
Test Number 262
Report Number 232
Test Date 4/7/2012 7:40:33 PM

Test Results	
Mod @50% (psi)	210
Mod @100% (psi)	312
Mod @200% (psi)	593
Mod @300% (psi)	966
Mod @500% (psi)	
Tensile (psi)	1,323
Elongation (%)	415.02

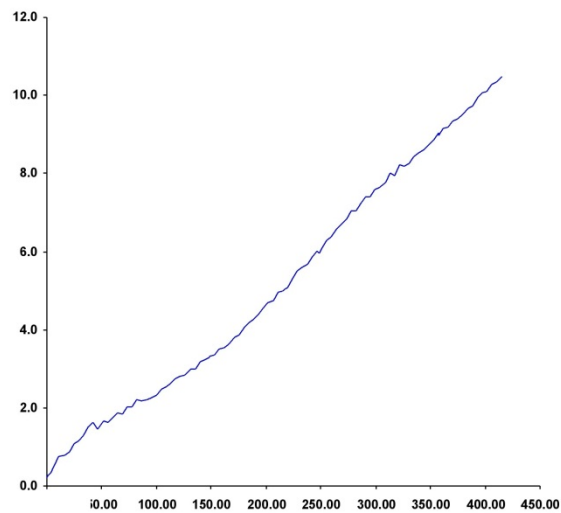
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	07-Apr-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Nitrile O-Ring JetA1 - Specimen 5

Tensile ASTM D412 – Nitrile O-Ring

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 436
Report Number 287
Test Date 7/6/2012 8:06:28 PM

Test Results

Mod @50% (psi)	213
Mod @100% (psi)	310
Mod @200% (psi)	632
Mod @300% (psi)	1,025
Mod @500% (psi)	
Tensile (psi)	1,705
Elongation (%)	477.14

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

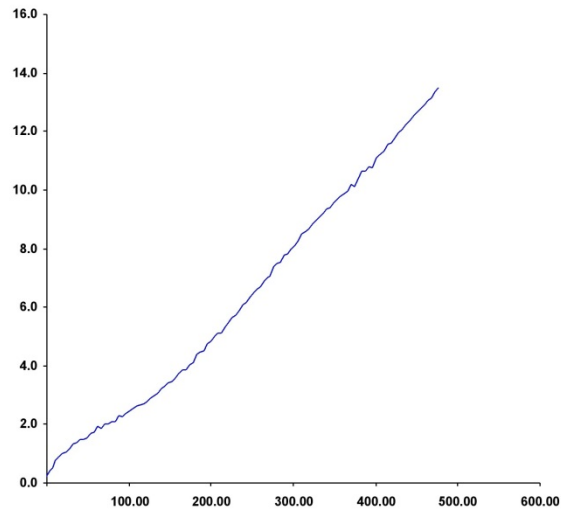
Customer Name
Vendor

Purchase Order

Operator

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)

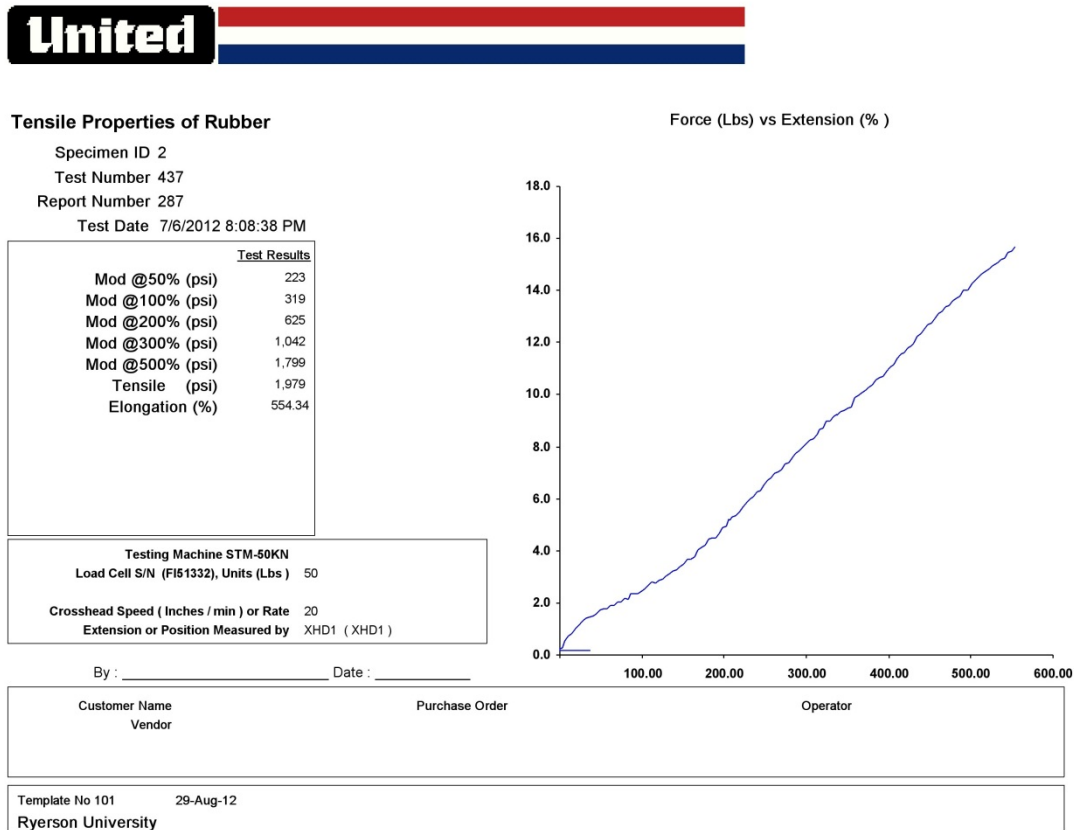


Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Nitrile O-Ring Bio50 - Specimen 1

Tensile ASTM D412 – Nitrile O-Ring

Biofuel 50/50 - Test Specimens

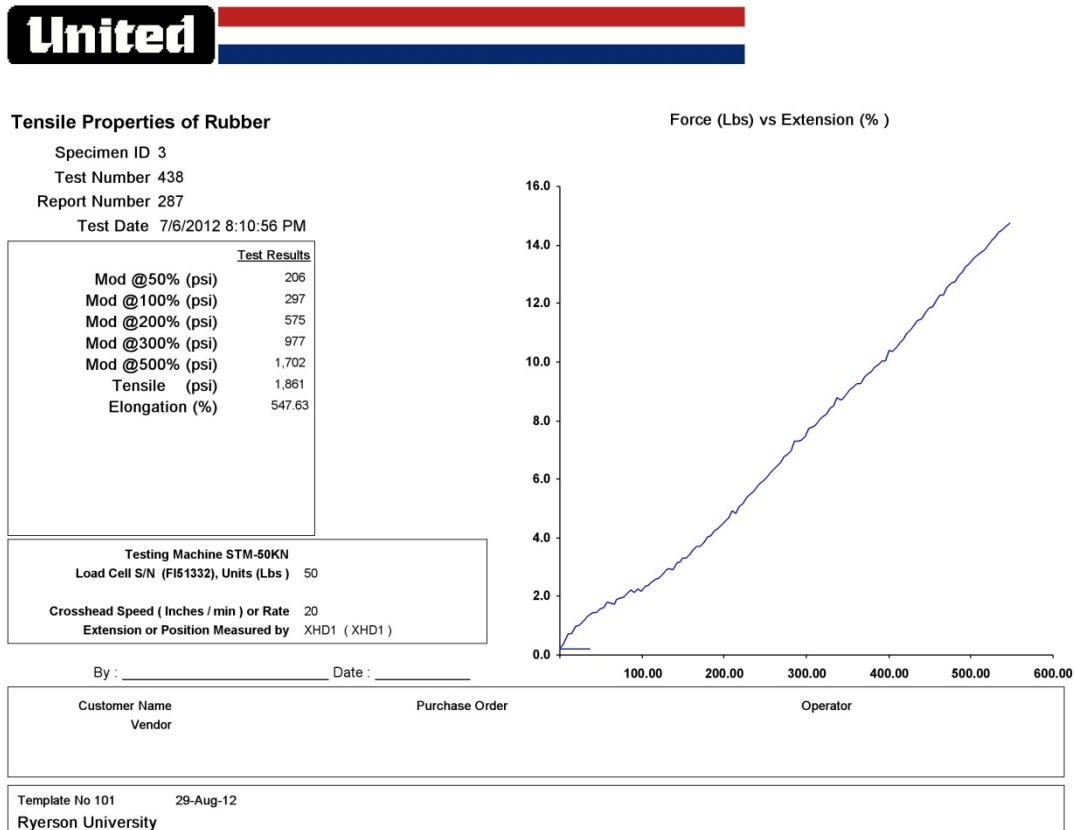


Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Nitrile O-Ring Bio50 - Specimen 2

Tensile ASTM D412 – Nitrile O-Ring

Biofuel 50/50 - Test Specimens



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Nitrile O-Ring Bio50 - Specimen 3

Tensile ASTM D412 – Nitrile O-Ring

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 439
Report Number 287
Test Date 7/6/2012 8:13:00 PM

Test Results	
Mod @50% (psi)	206
Mod @100% (psi)	284
Mod @200% (psi)	562
Mod @300% (psi)	945
Mod @500% (psi)	1,681
Tensile (psi)	1,763
Elongation (%)	527.67

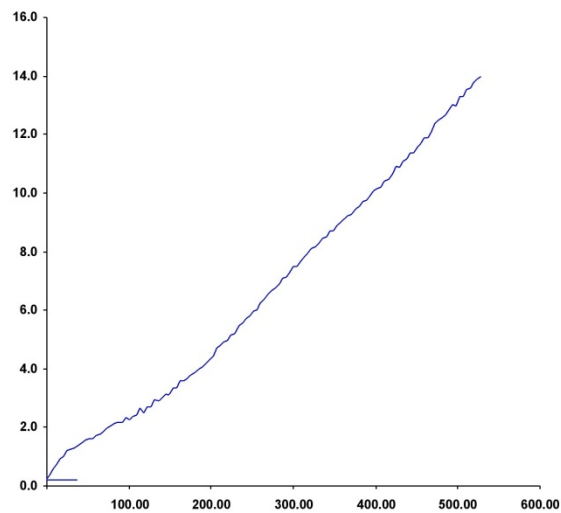
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Nitrile O-Ring Bio50 - Specimen 4

Tensile ASTM D412 – Nitrile O-Ring

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 5
Test Number 440
Report Number 287
Test Date 7/6/2012 8:16:39 PM

Test Results	
Mod @50% (psi)	209
Mod @100% (psi)	308
Mod @200% (psi)	598
Mod @300% (psi)	994
Mod @500% (psi)	
Tensile (psi)	1,621
Elongation (%)	476.51

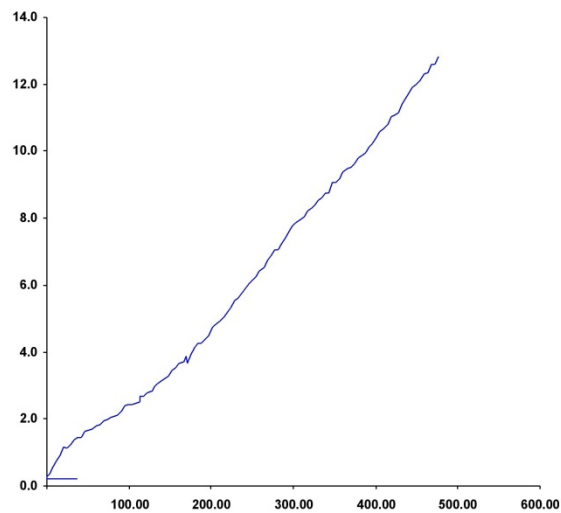
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Nitrile O-Ring Bio50 - Specimen 5

Tensile ASTM D412 – CS3100

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 238
Report Number 225
Test Date 4/7/2012 3:07:06 PM

Test Results	
Mod @50% (psi)	46
Mod @100% (psi)	62
Mod @200% (psi)	99
Mod @300% (psi)	
Mod @500% (psi)	
Tensile (psi)	122
Elongation (%)	289.58

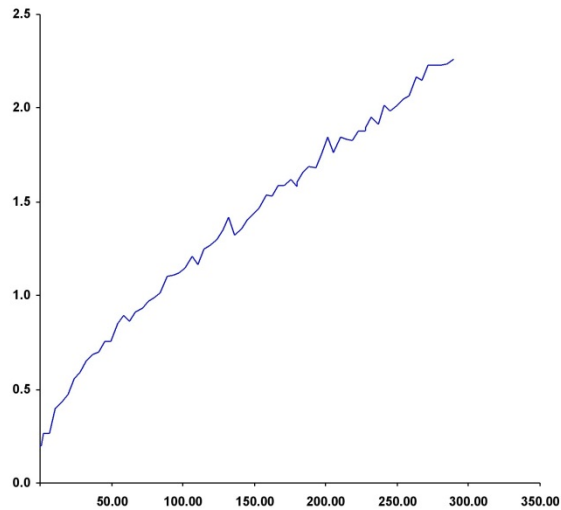
Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 07-Apr-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile CS3100 JetA1 - Specimen 1

Tensile ASTM D412 – CS3100

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 239
Report Number 225
Test Date 4/7/2012 3:11:17 PM

Test Results	
Mod @50% (psi)	41
Mod @100% (psi)	60
Mod @200% (psi)	89
Mod @300% (psi)	117
Mod @500% (psi)	
Tensile (psi)	122
Elongation (%)	319.98

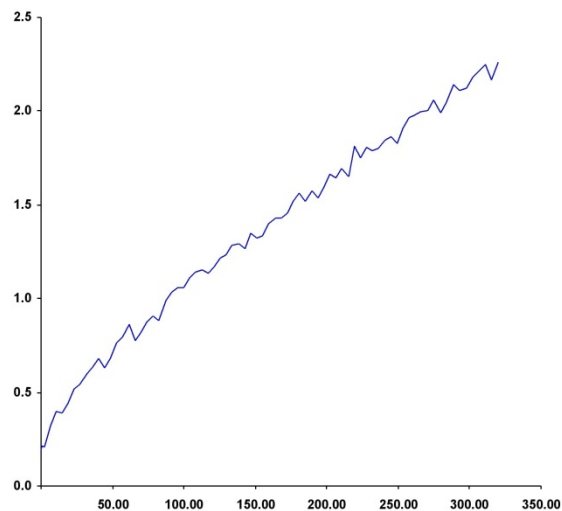
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 07-Apr-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile CS3100 JetA1 - Specimen 2

Tensile ASTM D412 – CS3100

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 3
Test Number 240
Report Number 225
Test Date 4/7/2012 3:17:08 PM

Test Results	
Mod @50% (psi)	44
Mod @100% (psi)	64
Mod @200% (psi)	100
Mod @300% (psi)	131
Mod @500% (psi)	
Tensile (psi)	156
Elongation (%)	387.16

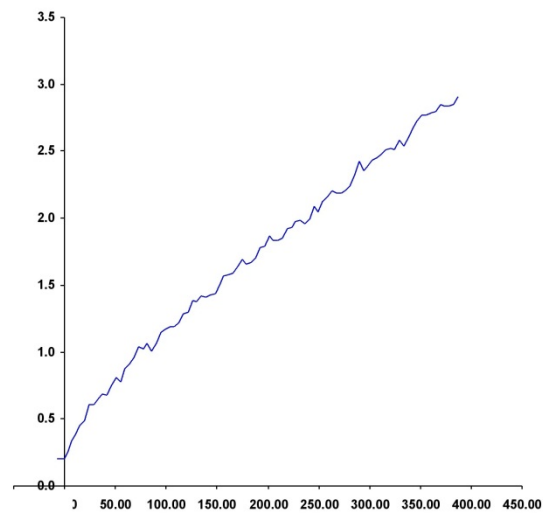
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 07-Apr-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile CS3100 JetA1 - Specimen 3

Tensile ASTM D412 – CS3100

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 241
Report Number 225
Test Date 4/7/2012 3:21:43 PM

Test Results	
Mod @50% (psi)	41
Mod @100% (psi)	59
Mod @200% (psi)	86
Mod @300% (psi)	118
Mod @500% (psi)	
Tensile (psi)	153
Elongation (%)	424.96

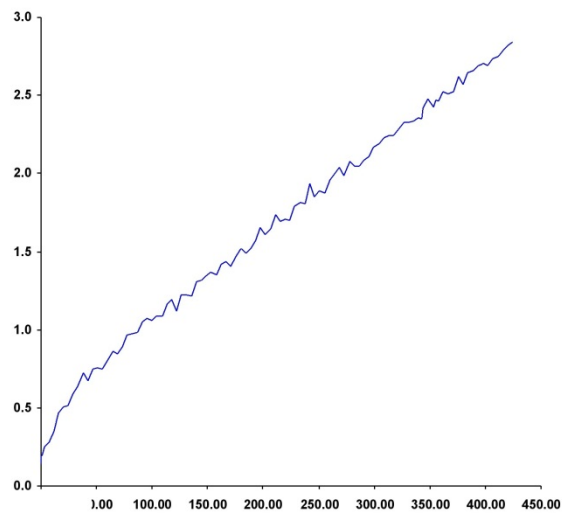
Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	07-Apr-12
Ryerson University	

Force (Lbs) vs Extension (%)

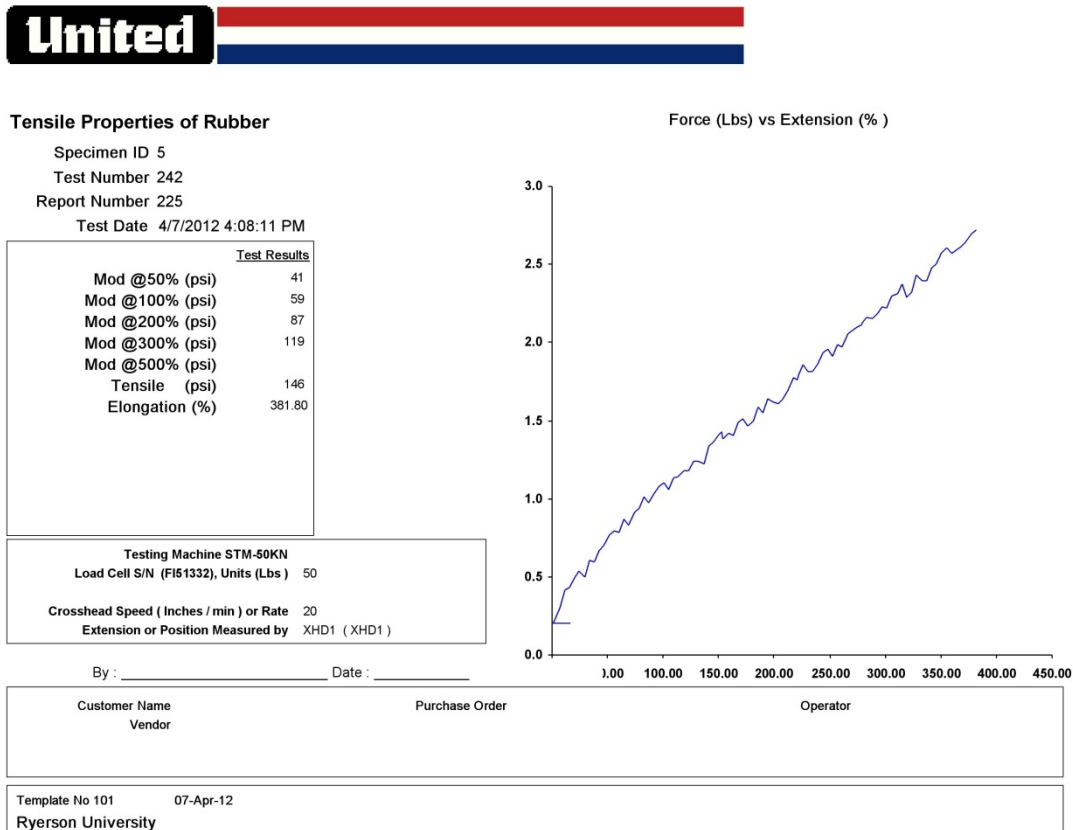


Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile CS3100 JetA1 - Specimen 4

Tensile ASTM D412 – CS3100

Jet A1 - Test Specimens



Tensile CS3100 JetA1 - Specimen 5

Tensile ASTM D412 – CS3100

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 461
Report Number 292
Test Date 7/20/2012 3:44:44 PM

Test Results	
Mod @50% (psi)	52
Mod @100% (psi)	71
Mod @200% (psi)	110
Mod @300% (psi)	143
Mod @500% (psi)	208
Tensile (psi)	215
Elongation (%)	519.16

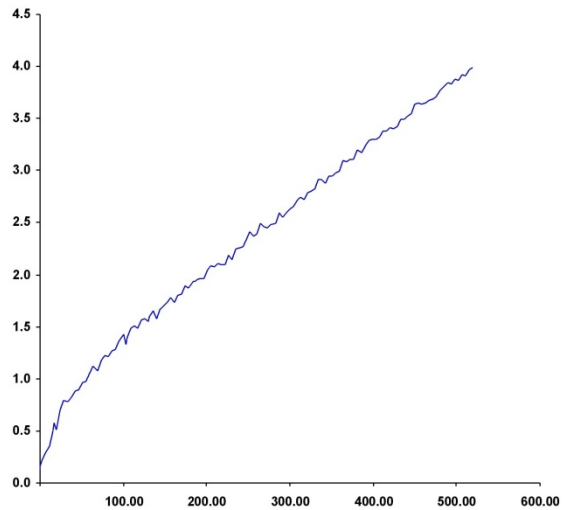
Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile CS3100 Bio50 - Specimen 1

Tensile ASTM D412 – CS3100

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 462
Report Number 292
Test Date 7/20/2012 4:17:45 PM

Test Results	
Mod @50% (psi)	51
Mod @100% (psi)	73
Mod @200% (psi)	103
Mod @300% (psi)	136
Mod @500% (psi)	206
Tensile (psi)	249
Elongation (%)	634.48

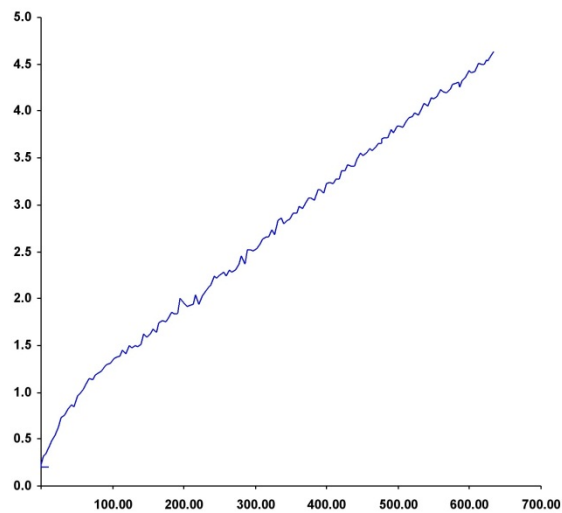
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile CS3100 Bio50 - Specimen 2

Tensile ASTM D412 – CS3100

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 3
Test Number 463
Report Number 292
Test Date 7/20/2012 4:19:16 PM

Test Results	
Mod @50% (psi)	59
Mod @100% (psi)	84
Mod @200% (psi)	120
Mod @300% (psi)	158
Mod @500% (psi)	222
Tensile (psi)	274
Elongation (%)	644.72

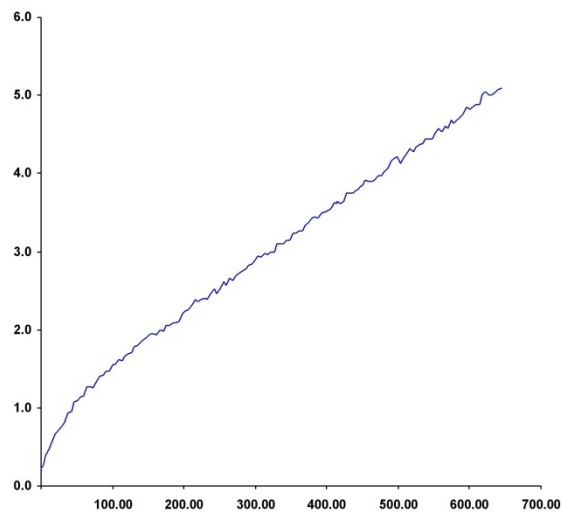
Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile CS3100 Bio50 - Specimen 3

Tensile ASTM D412 – CS3100

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 464
Report Number 292
Test Date 7/20/2012 4:21:17 PM

Test Results	
Mod @50% (psi)	55
Mod @100% (psi)	71
Mod @200% (psi)	103
Mod @300% (psi)	135
Mod @500% (psi)	194
Tensile (psi)	236
Elongation (%)	627.09

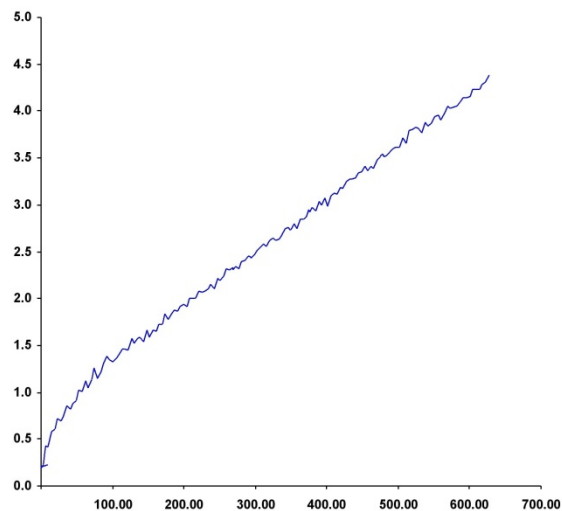
Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile CS3100 Bio50 - Specimen 4

Tensile ASTM D412 – CS3100

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 5
Test Number 465
Report Number 292
Test Date 7/20/2012 4:25:39 PM

Test Results	
Mod @50% (psi)	48
Mod @100% (psi)	70
Mod @200% (psi)	99
Mod @300% (psi)	124
Mod @500% (psi)	183
Tensile (psi)	226
Elongation (%)	655.48

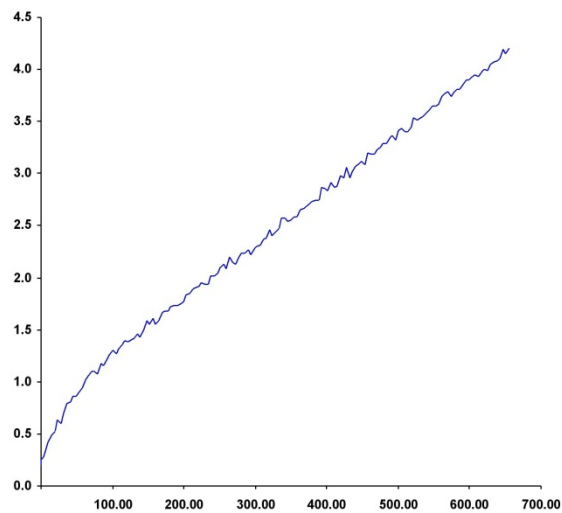
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile CS3100 Bio50 - Specimen 5

Tensile ASTM D412 – PR1422

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 309
Report Number 267
Test Date 6/2/2012 12:27:23 PM

Test Results

Mod @50% (psi)	106
Mod @100% (psi)	142
Mod @200% (psi)	192
Mod @300% (psi)	227
Mod @500% (psi)	289
Tensile (psi)	315
Elongation (%)	603.64

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

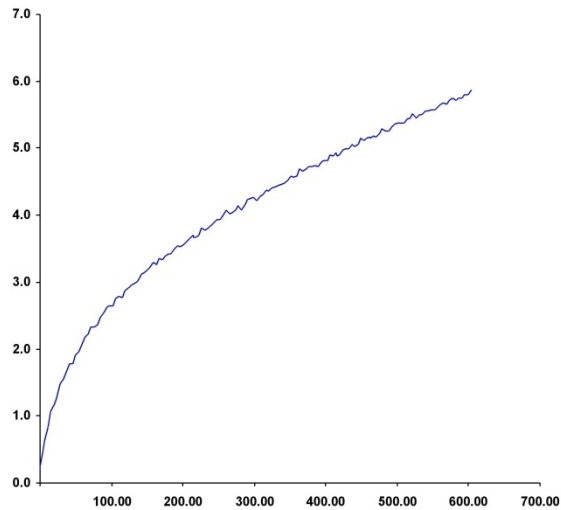
Customer Name
Vendor

Purchase Order

Operator

Template No 101 02-Jun-12
Ryerson University

Force (Lbs) vs Extension (%)

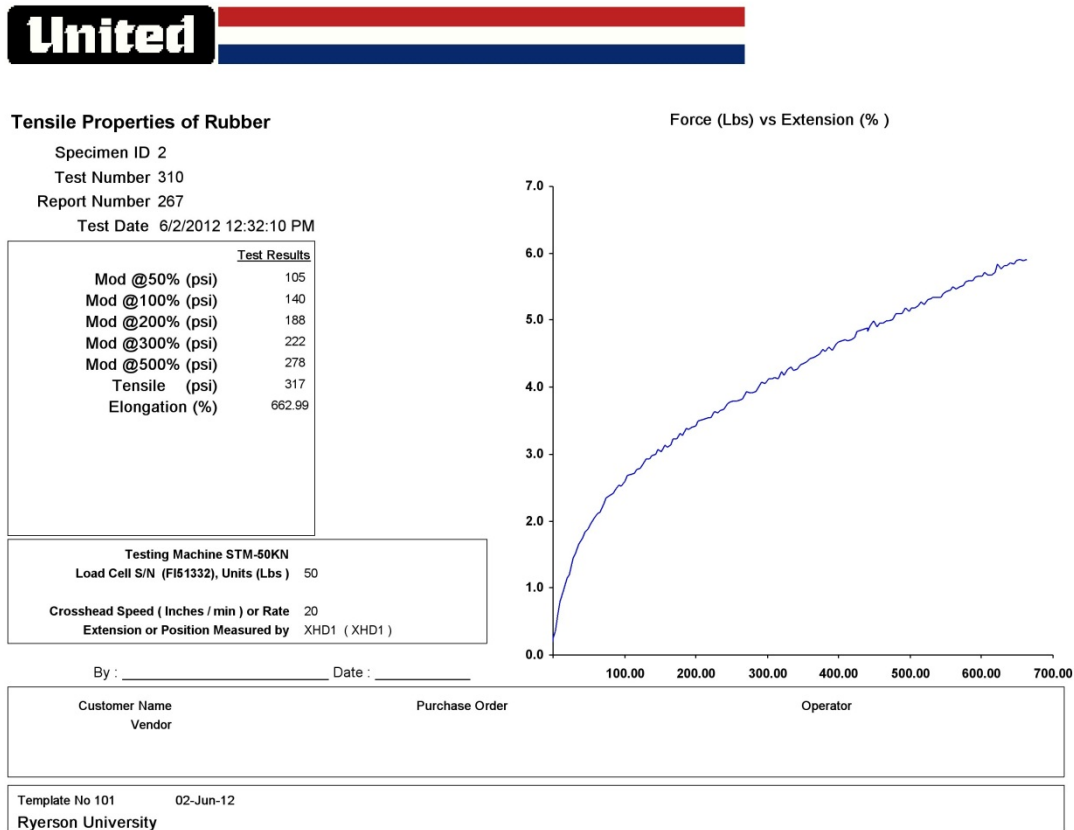


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Tensile PR1422 JetA1 - Specimen 1

Tensile ASTM D412 – PR1422

Jet A1 - Test Specimens



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Tensile PR1422 JetA1 - Specimen 2

Tensile ASTM D412 – PR1422

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 3
Test Number 311
Report Number 267
Test Date 6/2/2012 12:33:47 PM

Test Results	
Mod @50% (psi)	105
Mod @100% (psi)	147
Mod @200% (psi)	192
Mod @300% (psi)	233
Mod @500% (psi)	294
Tensile (psi)	313
Elongation (%)	569.59

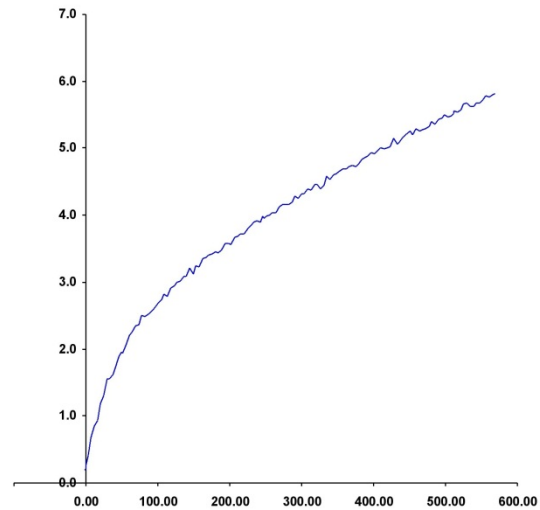
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 02-Jun-12
Ryerson University

Force (Lbs) vs Extension (%)



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Tensile PR1422 JetA1 - Specimen 3

Tensile ASTM D412 – PR1422

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 312
Report Number 267
Test Date 6/2/2012 12:37:01 PM

Test Results	
Mod @50% (psi)	102
Mod @100% (psi)	134
Mod @200% (psi)	178
Mod @300% (psi)	214
Mod @500% (psi)	271
Tensile (psi)	307
Elongation (%)	647.38

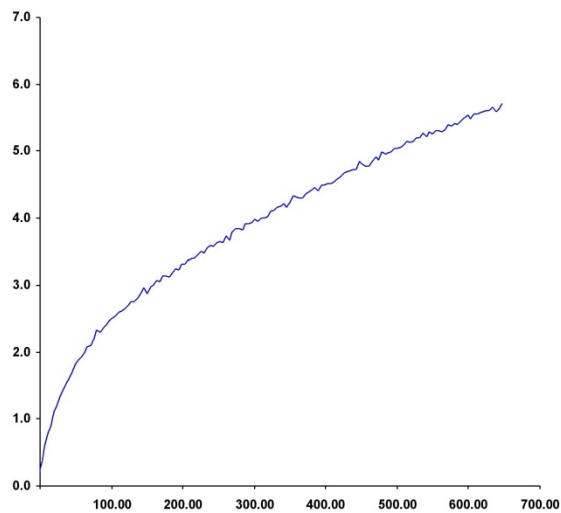
Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	02-Jun-12
Ryerson University	

Force (Lbs) vs Extension (%)



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Tensile PR1422 JetA1 - Specimen 4

Tensile ASTM D412 – PR1422

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 5
Test Number 313
Report Number 267
Test Date 6/2/2012 12:38:48 PM

Test Results	
Mod @50% (psi)	111
Mod @100% (psi)	155
Mod @200% (psi)	215
Mod @300% (psi)	261
Mod @500% (psi)	
Tensile (psi)	310
Elongation (%)	437.77

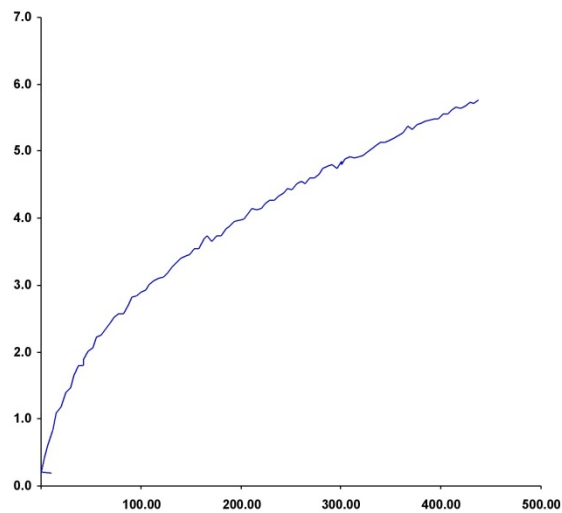
Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	02-Jun-12
Ryerson University	

Force (Lbs) vs Extension (%)



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Tensile PR1422 JetA1 - Specimen 5

Tensile ASTM D412 – PR1422

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 538
Report Number 335
Test Date 8/12/2012 4:00:50 PM

Test Results

Mod @50% (psi)	133
Mod @100% (psi)	184
Mod @200% (psi)	247
Mod @300% (psi)	294
Mod @500% (psi)	379
Tensile (psi)	412
Elongation (%)	590.68

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

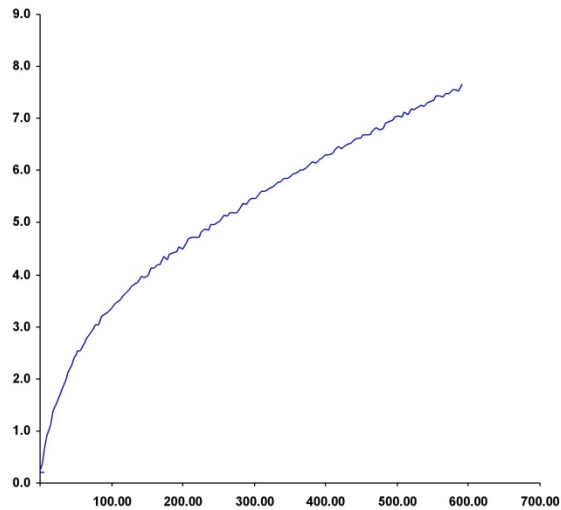
Customer Name
Vendor

Purchase Order

Operator

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



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Tensile PR1422 Bio50- Specimen 1

Tensile ASTM D412 – PR1422

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 539
Report Number 335
Test Date 8/12/2012 4:02:26 PM

Test Results	
Mod @50% (psi)	133
Mod @100% (psi)	175
Mod @200% (psi)	233
Mod @300% (psi)	275
Mod @500% (psi)	349
Tensile (psi)	381
Elongation (%)	605.82

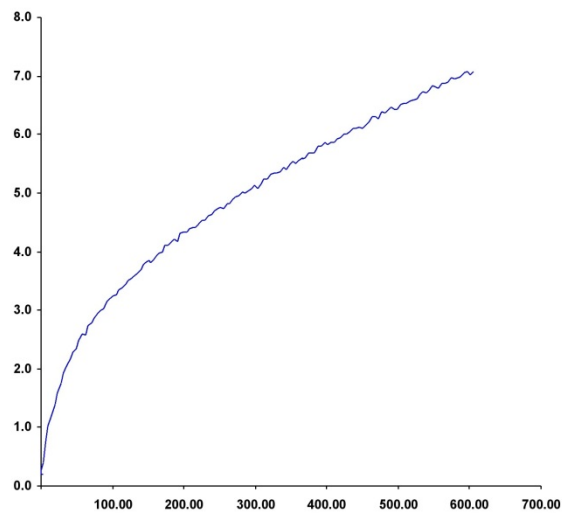
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)

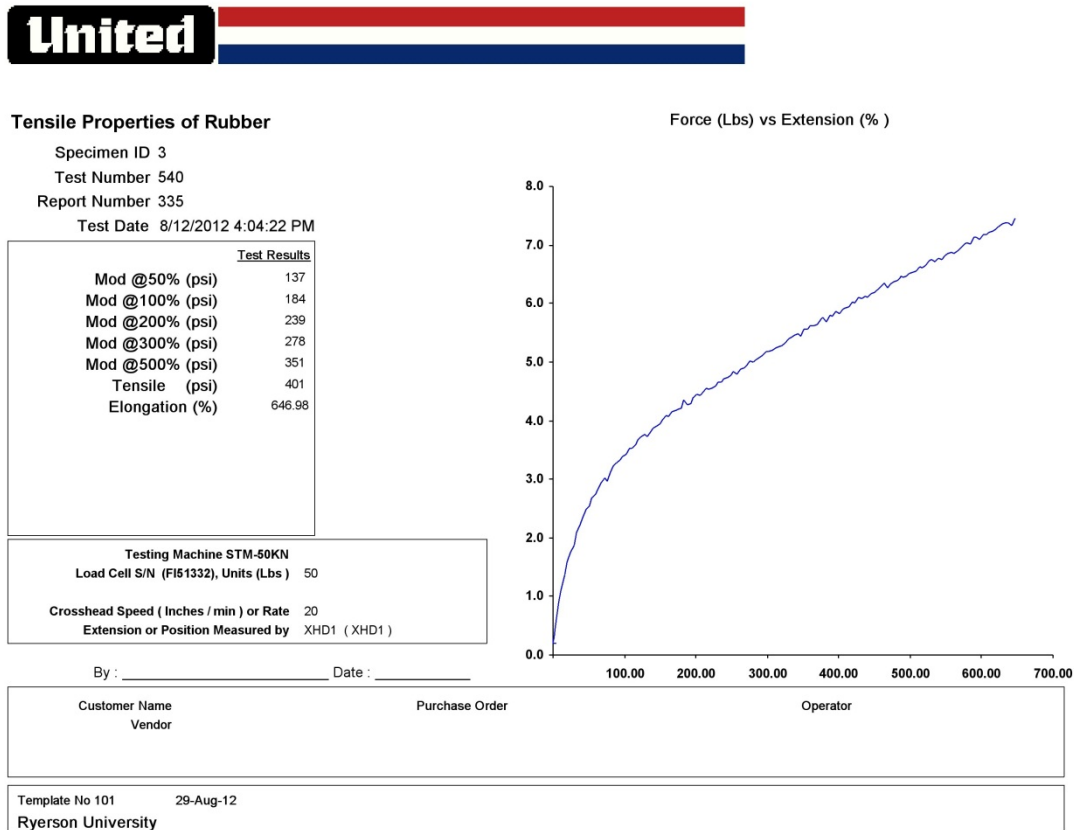


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Tensile PR1422 Bio50- Specimen 2

Tensile ASTM D412 – PR1422

Biofuel 50/50 - Test Specimens



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Tensile PR1422 Bio50- Specimen 3

Tensile ASTM D412 – PR1422

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 541
Report Number 335
Test Date 8/12/2012 4:05:43 PM

Test Results	
Mod @50% (psi)	138
Mod @100% (psi)	182
Mod @200% (psi)	236
Mod @300% (psi)	276
Mod @500% (psi)	348
Tensile (psi)	355
Elongation (%)	525.65

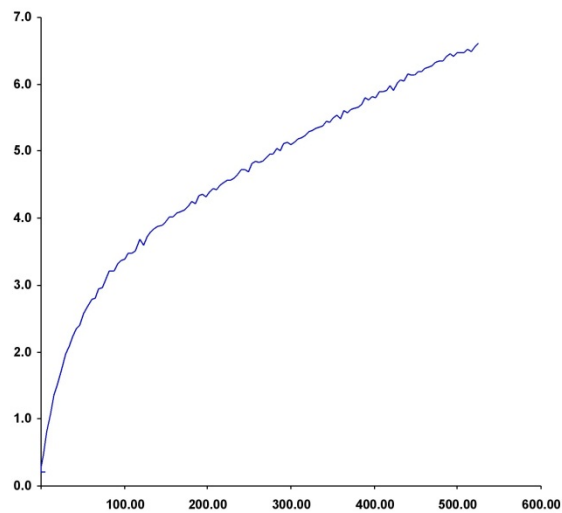
Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)

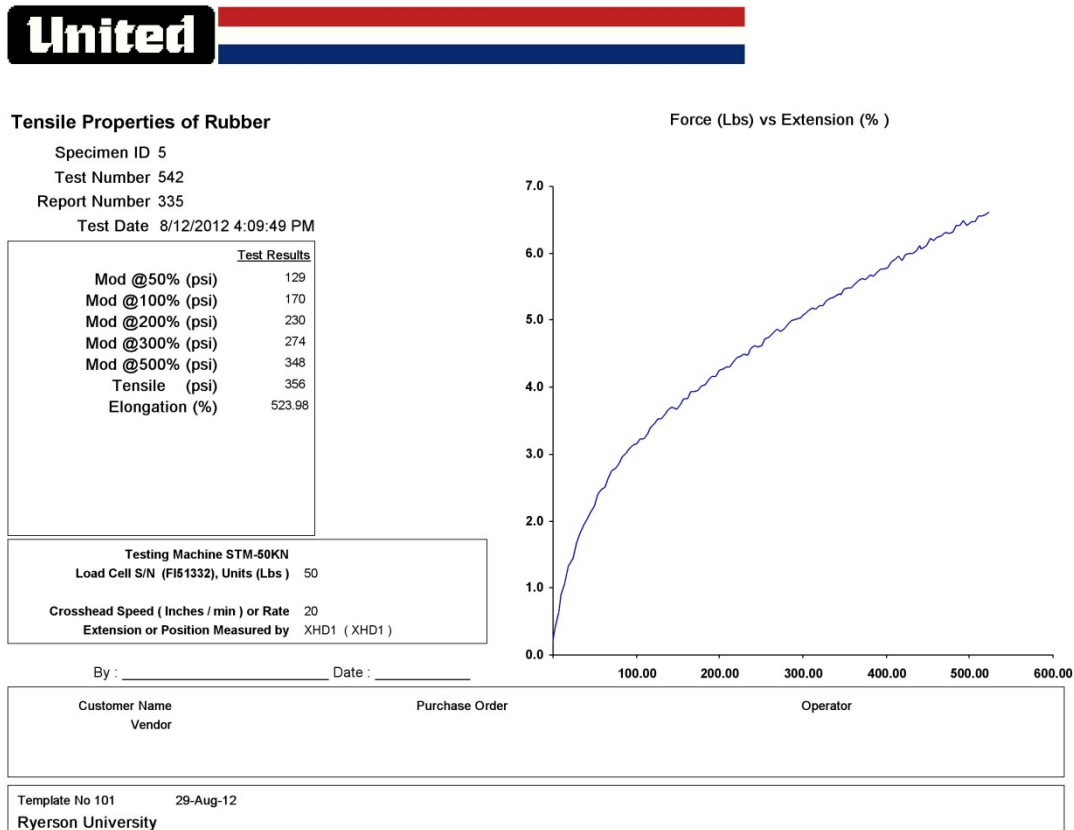


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Tensile PR1422 Bio50- Specimen 4

Tensile ASTM D412 – PR1422

Biofuel 50/50 - Test Specimens

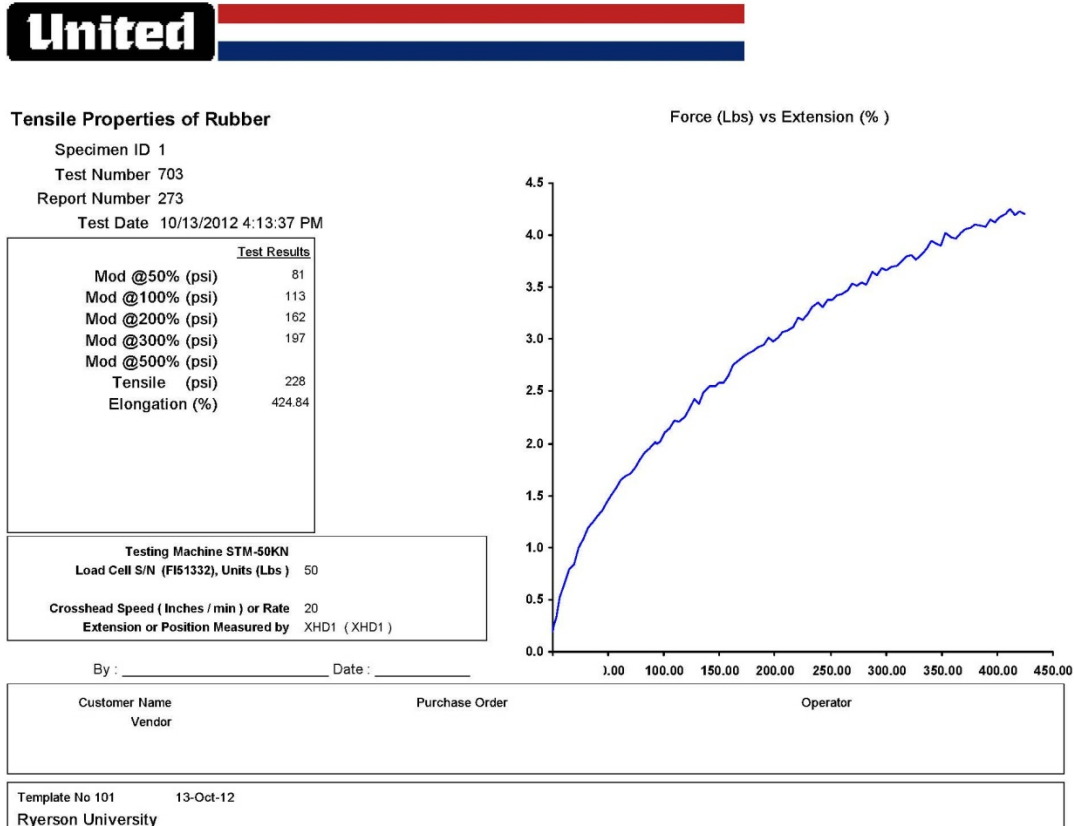


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Tensile PR1422 Bio50- Specimen 5

Tensile ASTM D412 – PR1776

Jet A1 - Test Specimens



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Tensile PR1776 JetA1 - Specimen 1

Tensile ASTM D412 – PR1776

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 335
Report Number 273
Test Date 6/2/2012 2:04:05 PM

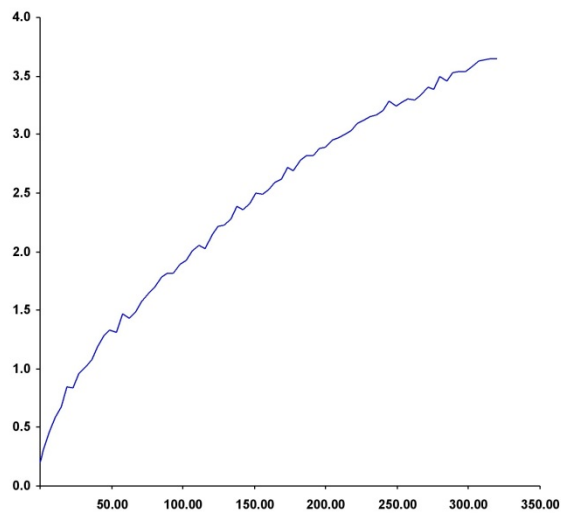
Test Results	
Mod @50% (psi)	70
Mod @100% (psi)	103
Mod @200% (psi)	156
Mod @300% (psi)	192
Mod @500% (psi)	
Tensile (psi)	196
Elongation (%)	320.10

Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	02-Jun-12
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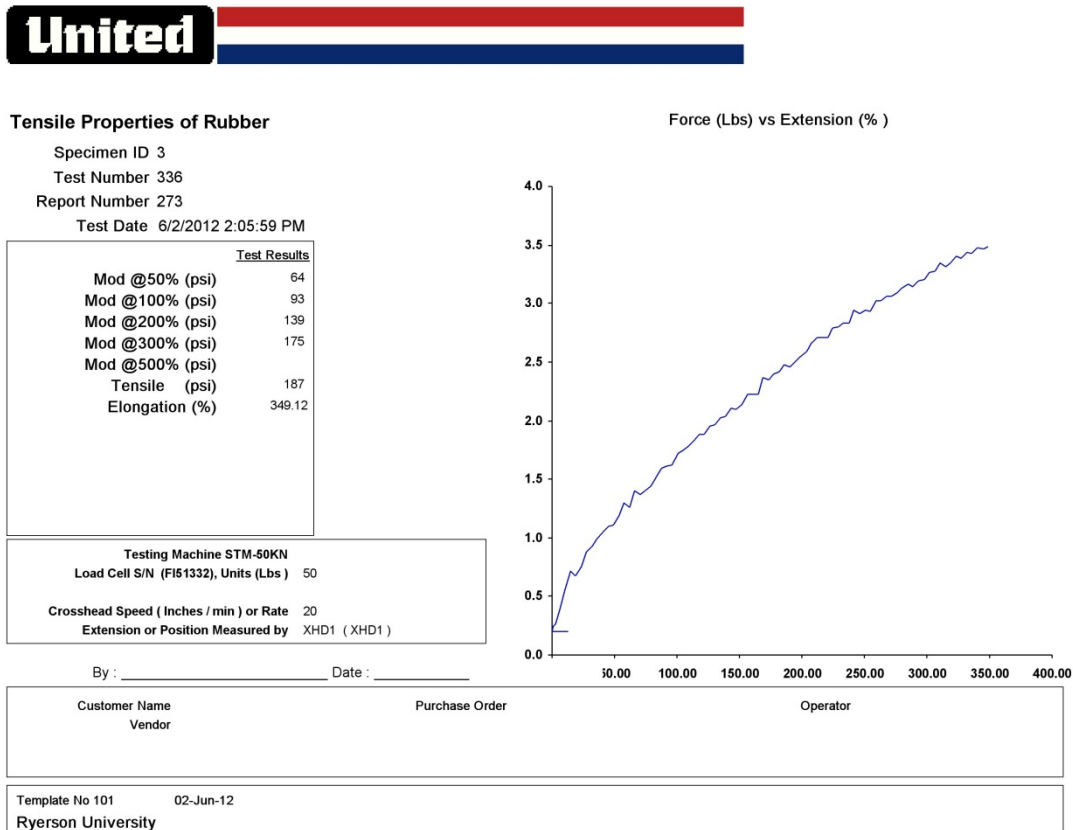


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Tensile PR1776 JetA1 - Specimen 2

Tensile ASTM D412 – PR1776

Jet A1 - Test Specimens



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Tensile PR1776 JetA1 - Specimen 3

Tensile ASTM D412 – PR1776

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 337
Report Number 273
Test Date 6/2/2012 2:07:26 PM

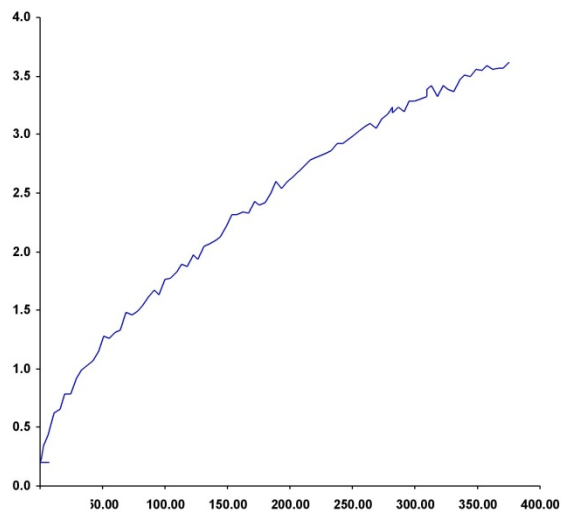
Test Results	
Mod @50% (psi)	69
Mod @100% (psi)	95
Mod @200% (psi)	142
Mod @300% (psi)	177
Mod @500% (psi)	
Tensile (psi)	195
Elongation (%)	375.60

Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	02-Jun-12
Ryerson University	



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Tensile PR1776 JetA1 - Specimen 4

Tensile ASTM D412 – PR1776

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 5
Test Number 338
Report Number 273
Test Date 6/2/2012 2:09:02 PM

Test Results	
Mod @50% (psi)	77
Mod @100% (psi)	114
Mod @200% (psi)	169
Mod @300% (psi)	206
Mod @500% (psi)	
Tensile (psi)	217
Elongation (%)	347.35

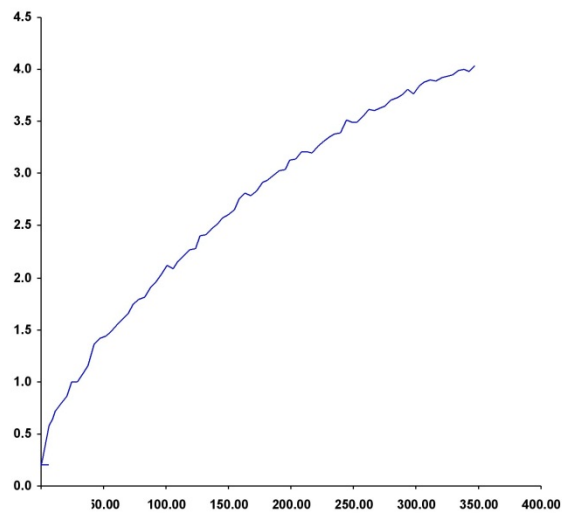
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 02-Jun-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR1776 JetA1 - Specimen 5

Tensile ASTM D412 – PR1776

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 511
Report Number 330
Test Date 8/12/2012 2:29:22 PM

Test Results

Mod @50% (psi)	66
Mod @100% (psi)	100
Mod @200% (psi)	144
Mod @300% (psi)	174
Mod @500% (psi)	
Tensile (psi)	195
Elongation (%)	398.67

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

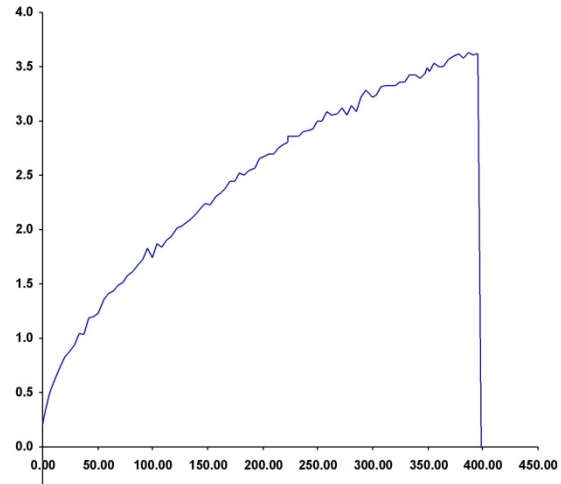
Customer Name
Vendor

Purchase Order

Operator

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR1776 Bio50 - Specimen 1

Tensile ASTM D412 – PR1776

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 512
Report Number 330
Test Date 8/12/2012 2:31:44 PM

Test Results	
Mod @50% (psi)	65
Mod @100% (psi)	85
Mod @200% (psi)	129
Mod @300% (psi)	156
Mod @500% (psi)	
Tensile (psi)	186
Elongation (%)	438.29

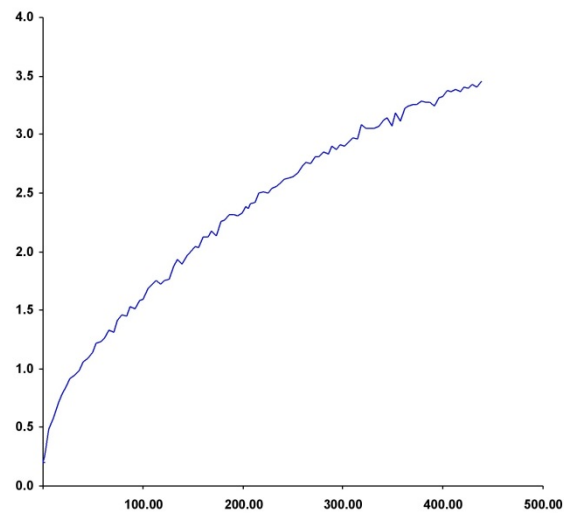
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR1776 Bio50 - Specimen 2

Tensile ASTM D412 – PR1776

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 3
Test Number 513
Report Number 330
Test Date 8/12/2012 2:33:45 PM

Test Results	
Mod @50% (psi)	64
Mod @100% (psi)	87
Mod @200% (psi)	131
Mod @300% (psi)	157
Mod @500% (psi)	
Tensile (psi)	181
Elongation (%)	421.93

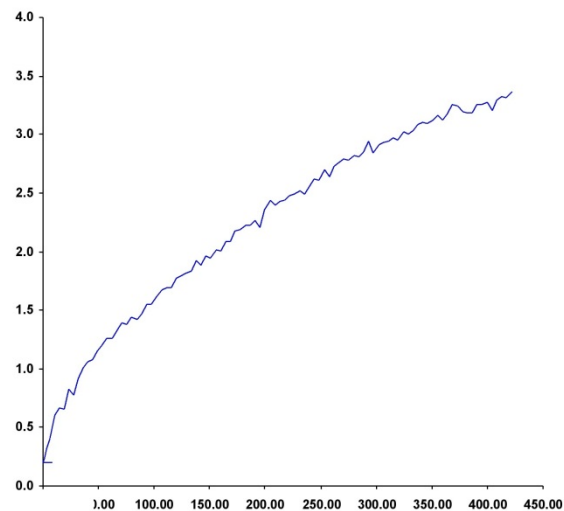
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR1776 Bio50 - Specimen 3

Tensile ASTM D412 – PR1776

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 514
Report Number 330
Test Date 8/12/2012 2:36:23 PM

Test Results	
Mod @50% (psi)	68
Mod @100% (psi)	95
Mod @200% (psi)	137
Mod @300% (psi)	167
Mod @500% (psi)	
Tensile (psi)	177
Elongation (%)	343.13

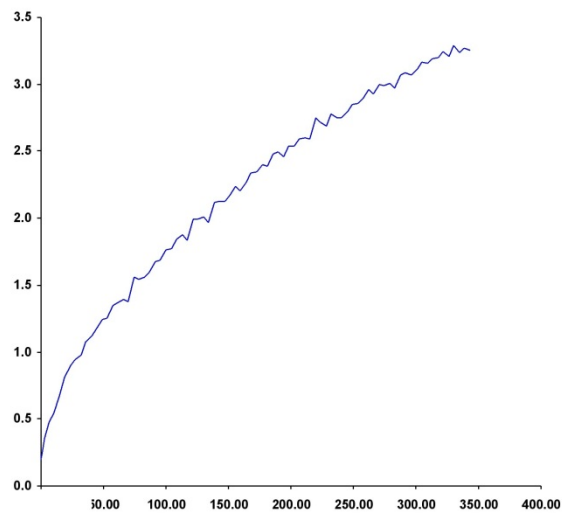
Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR1776 Bio50 - Specimen 4

Tensile ASTM D412 – PR1776

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 5
Test Number 515
Report Number 330
Test Date 8/12/2012 2:40:09 PM

Test Results	
Mod @50% (psi)	81
Mod @100% (psi)	108
Mod @200% (psi)	160
Mod @300% (psi)	192
Mod @500% (psi)	
Tensile (psi)	207
Elongation (%)	347.08

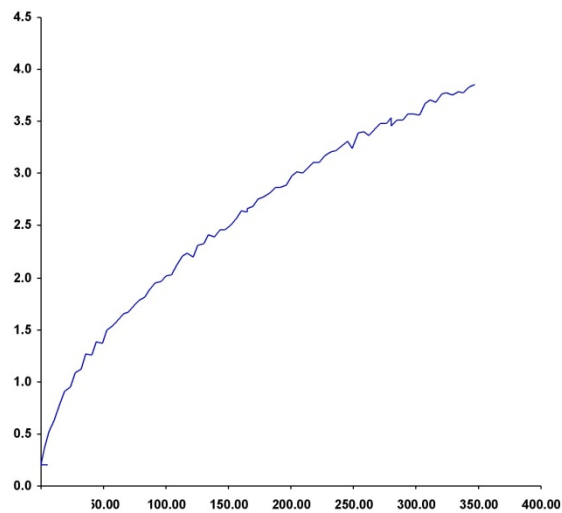
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



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Tensile PR1776 Bio50 - Specimen 5

Tensile ASTM D412 – PR1828

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1

Test Number 329

Report Number 272

Test Date 6/2/2012 1:46:26 PM

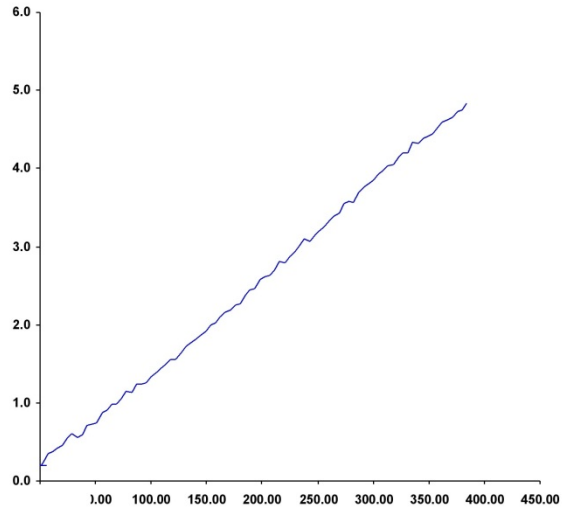
Test Results	
Mod @50% (psi)	40
Mod @100% (psi)	71
Mod @200% (psi)	140
Mod @300% (psi)	207
Mod @500% (psi)	
Tensile (psi)	260
Elongation (%)	384.61

Testing Machine STM-50KN	
Load Cell S/N (FI61332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	02-Jun-12
Ryerson University	



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Tensile PR1828 JetA1 - Specimen 1

Tensile ASTM D412 – PR1828

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 330
Report Number 272
Test Date 6/2/2012 1:51:31 PM

Test Results	
Mod @50% (psi)	48
Mod @100% (psi)	69
Mod @200% (psi)	136
Mod @300% (psi)	192
Mod @500% (psi)	
Tensile (psi)	240
Elongation (%)	419.32

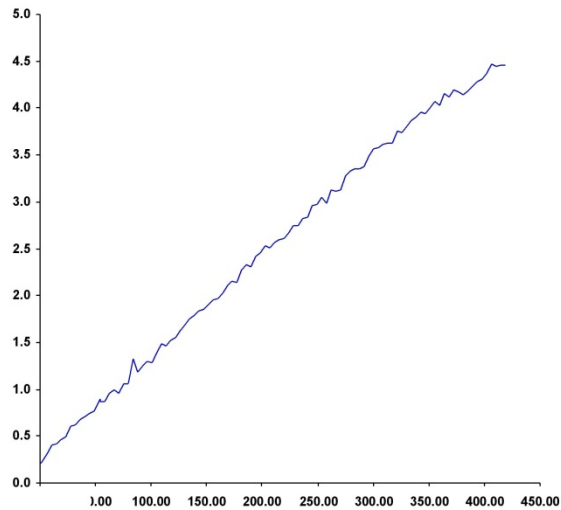
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 02-Jun-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR1828 JetA1 - Specimen 2

Tensile ASTM D412 – PR1828

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 3
Test Number 331
Report Number 272
Test Date 6/2/2012 1:53:59 PM

Test Results	
Mod @50% (psi)	46
Mod @100% (psi)	71
Mod @200% (psi)	142
Mod @300% (psi)	208
Mod @500% (psi)	
Tensile (psi)	273
Elongation (%)	412.41

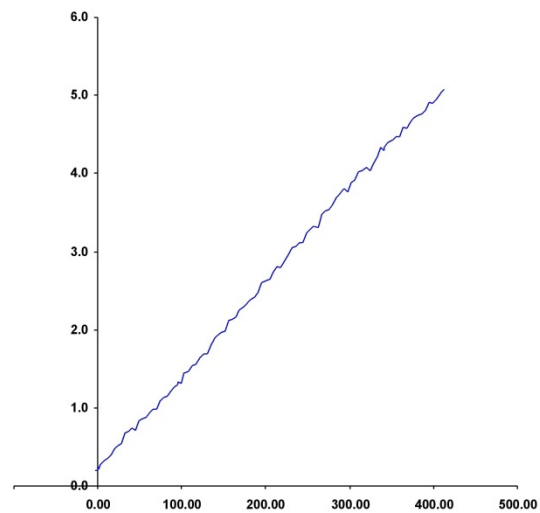
Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	02-Jun-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR1828 JetA1 - Specimen 3

Tensile ASTM D412 – PR1828

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 332
Report Number 272
Test Date 6/2/2012 1:56:58 PM

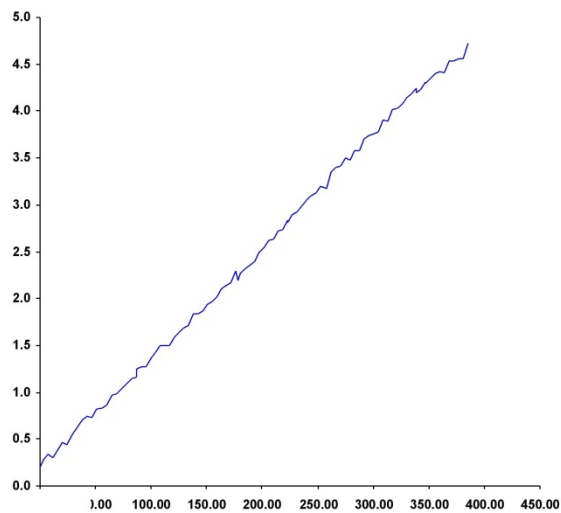
Test Results	
Mod @50% (psi)	44
Mod @100% (psi)	76
Mod @200% (psi)	137
Mod @300% (psi)	202
Mod @500% (psi)	
Tensile (psi)	254
Elongation (%)	385.32

Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	02-Jun-12
Ryerson University	



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR1828 JetA1 - Specimen 4

Tensile ASTM D412 – PR1828

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 5
Test Number 333
Report Number 272
Test Date 6/2/2012 2:00:04 PM

Test Results	
Mod @50% (psi)	44
Mod @100% (psi)	77
Mod @200% (psi)	137
Mod @300% (psi)	204
Mod @500% (psi)	
Tensile (psi)	219
Elongation (%)	326.55

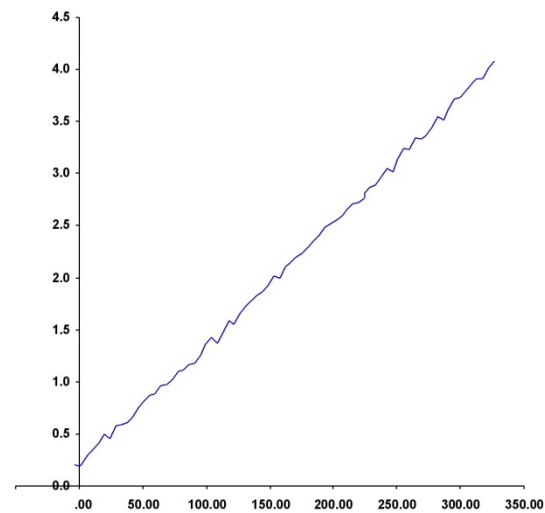
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 02-Jun-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR1828 JetA1 - Specimen 5

Tensile ASTM D412 – PR1828

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 516
Report Number 331
Test Date 8/12/2012 2:44:05 PM

Test Results

Mod @50% (psi)	52
Mod @100% (psi)	90
Mod @200% (psi)	164
Mod @300% (psi)	231
Mod @500% (psi)	
Tensile (psi)	331
Elongation (%)	490.14

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

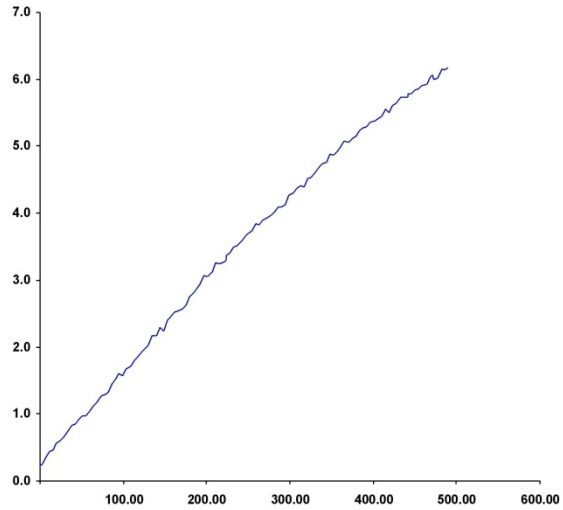
Customer Name
Vendor

Purchase Order

Operator

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR1828 Bio50 - Specimen 1

Tensile ASTM D412 – PR1828

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 517
Report Number 331
Test Date 8/12/2012 2:46:08 PM

Test Results	
Mod @50% (psi)	46
Mod @100% (psi)	83
Mod @200% (psi)	157
Mod @300% (psi)	213
Mod @500% (psi)	
Tensile (psi)	280
Elongation (%)	409.38

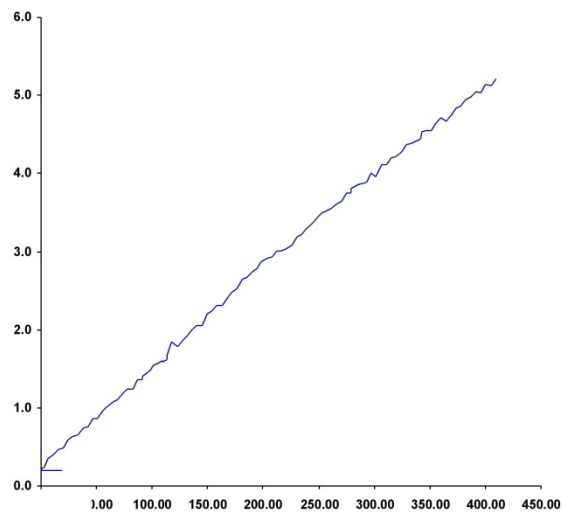
Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)

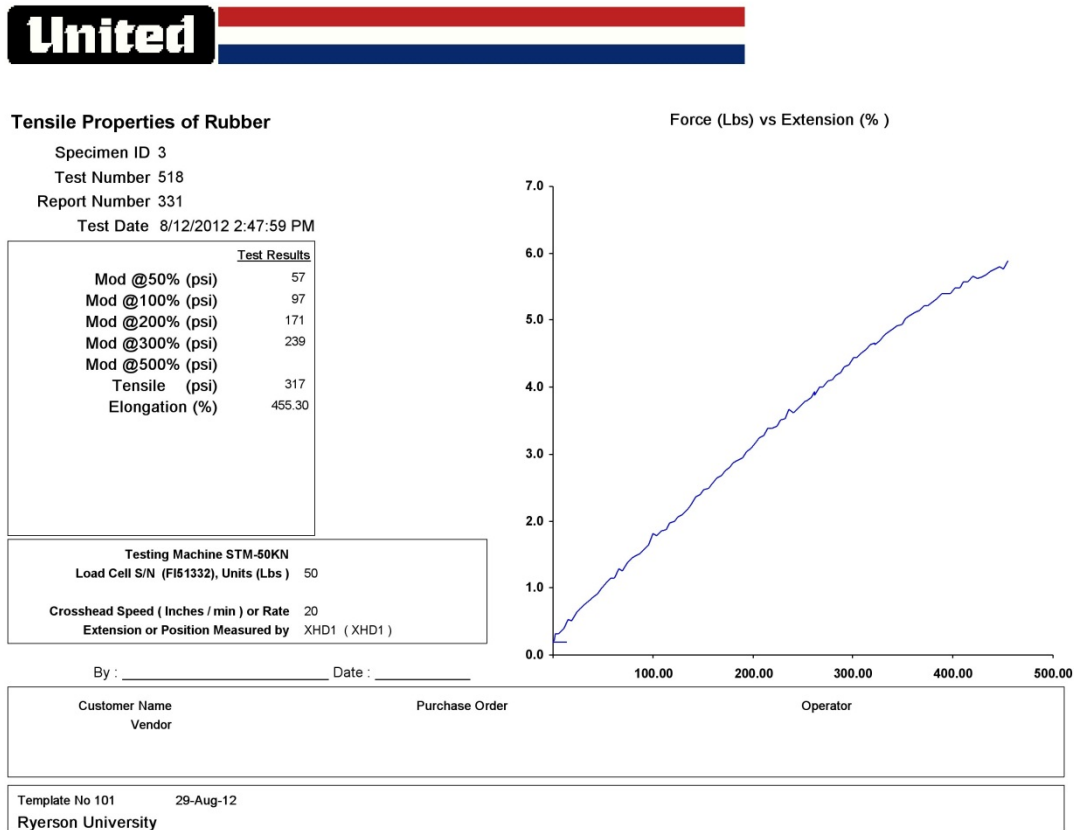


Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR1828 Bio50 - Specimen 2

Tensile ASTM D412 – PR1828

Biofuel 50/50 - Test Specimens



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR1828 Bio50 - Specimen 3

Tensile ASTM D412 – PR1828

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 519
Report Number 331
Test Date 8/12/2012 2:50:19 PM

Test Results	
Mod @50% (psi)	51
Mod @100% (psi)	85
Mod @200% (psi)	157
Mod @300% (psi)	216
Mod @500% (psi)	
Tensile (psi)	295
Elongation (%)	447.58

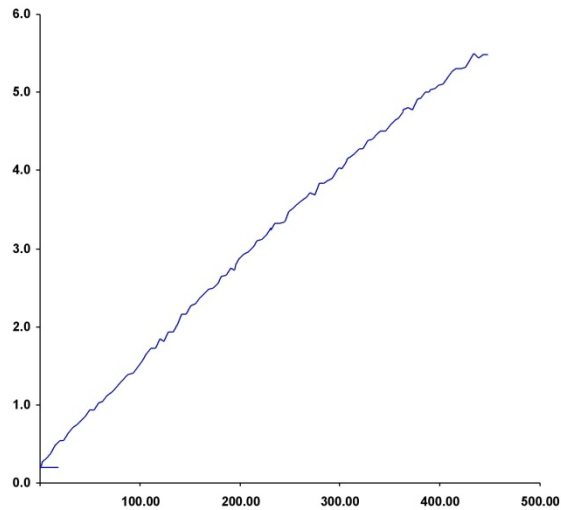
Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR1828 Bio50 - Specimen 4

Tensile ASTM D412 – PR1828

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 5
Test Number 520
Report Number 331
Test Date 8/12/2012 2:52:34 PM

Test Results	
Mod @50% (psi)	49
Mod @100% (psi)	84
Mod @200% (psi)	154
Mod @300% (psi)	218
Mod @500% (psi)	
Tensile (psi)	313
Elongation (%)	493.38

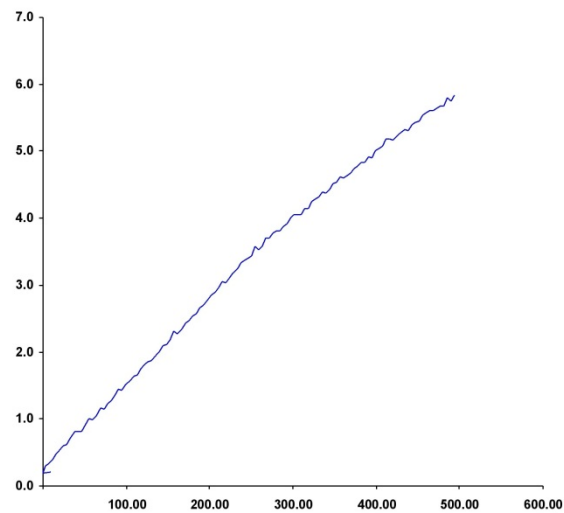
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR1828 Bio50 - Specimen 5

Tensile ASTM D412 – PR2911

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 425
Report Number 285
Test Date 6/30/2012 9:35:13 AM

Test Results

Mod @50% (psi)	136
Mod @100% (psi)	169
Mod @200% (psi)	204
Mod @300% (psi)	233
Mod @500% (psi)	293
Tensile (psi)	481
Elongation (%)	1,311.56

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

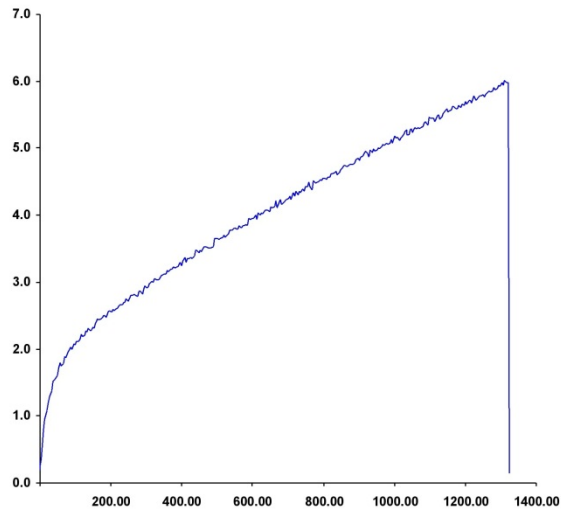
Customer Name
Vendor

Purchase Order

Operator

Template No 101 30-Jun-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR2911 JetA1 - Specimen 1

Tensile ASTM D412 – PR2911

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 426
Report Number 285
Test Date 6/30/2012 9:37:46 AM

Test Results	
Mod @50% (psi)	136
Mod @100% (psi)	169
Mod @200% (psi)	206
Mod @300% (psi)	239
Mod @500% (psi)	300
Tensile (psi)	494
Elongation (%)	1,333.88

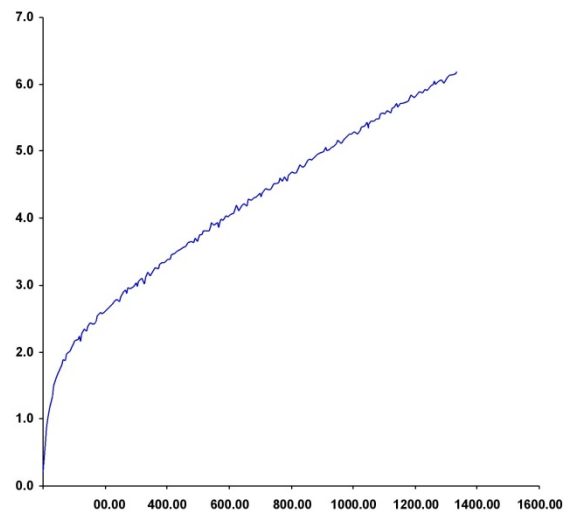
Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	30-Jun-12
Ryerson University	

Force (Lbs) vs Extension (%)

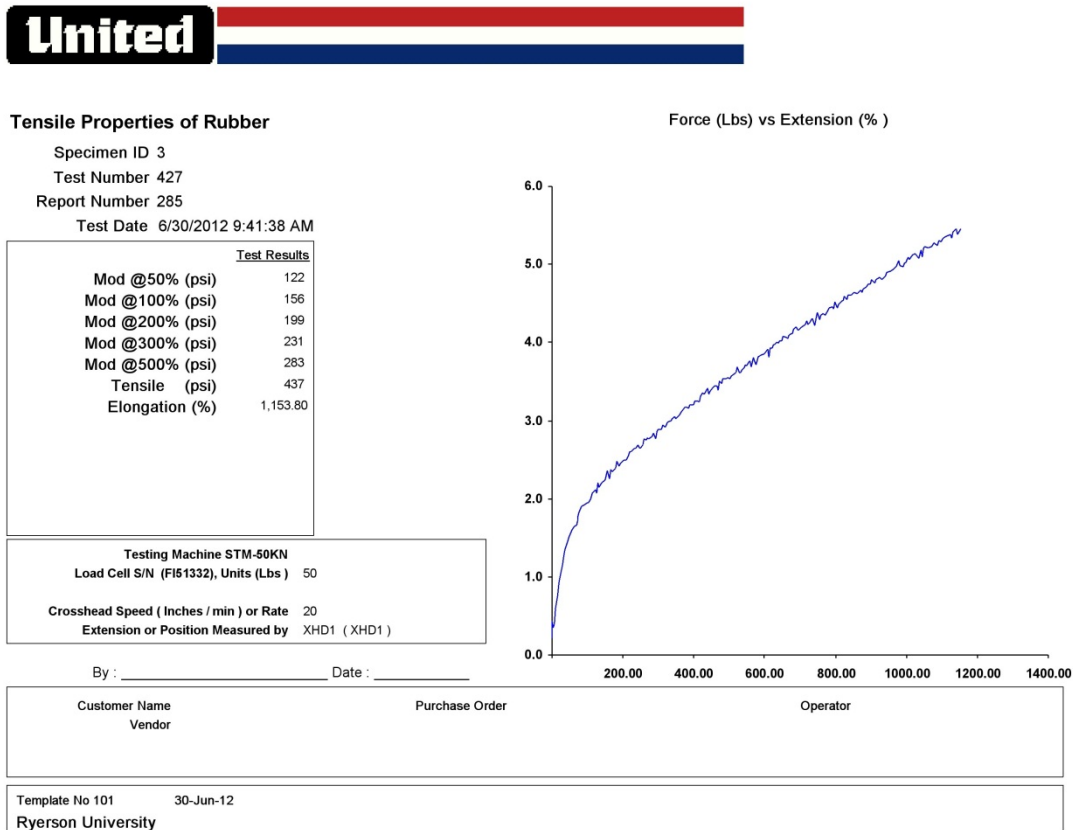


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Tensile PR2911 JetA1 - Specimen 2

Tensile ASTM D412 – PR2911

Jet A1 - Test Specimens

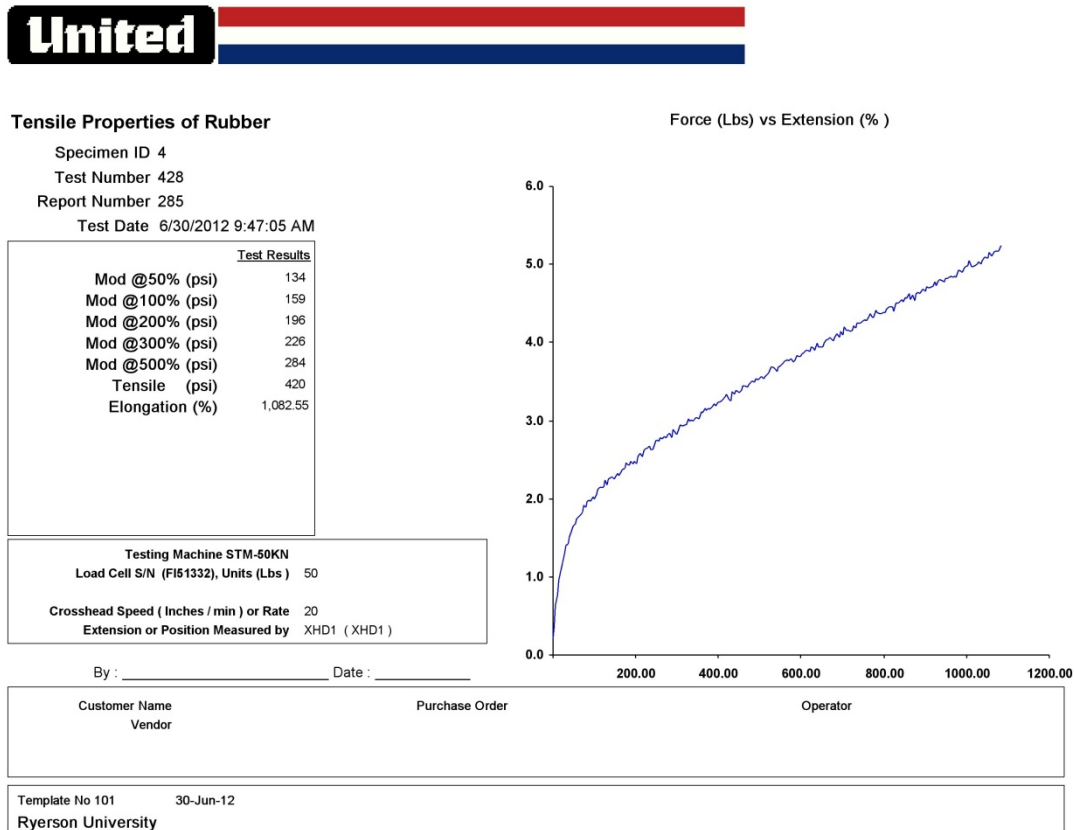


Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR2911 JetA1 - Specimen 3

Tensile ASTM D412 – PR2911

Jet A1 - Test Specimens

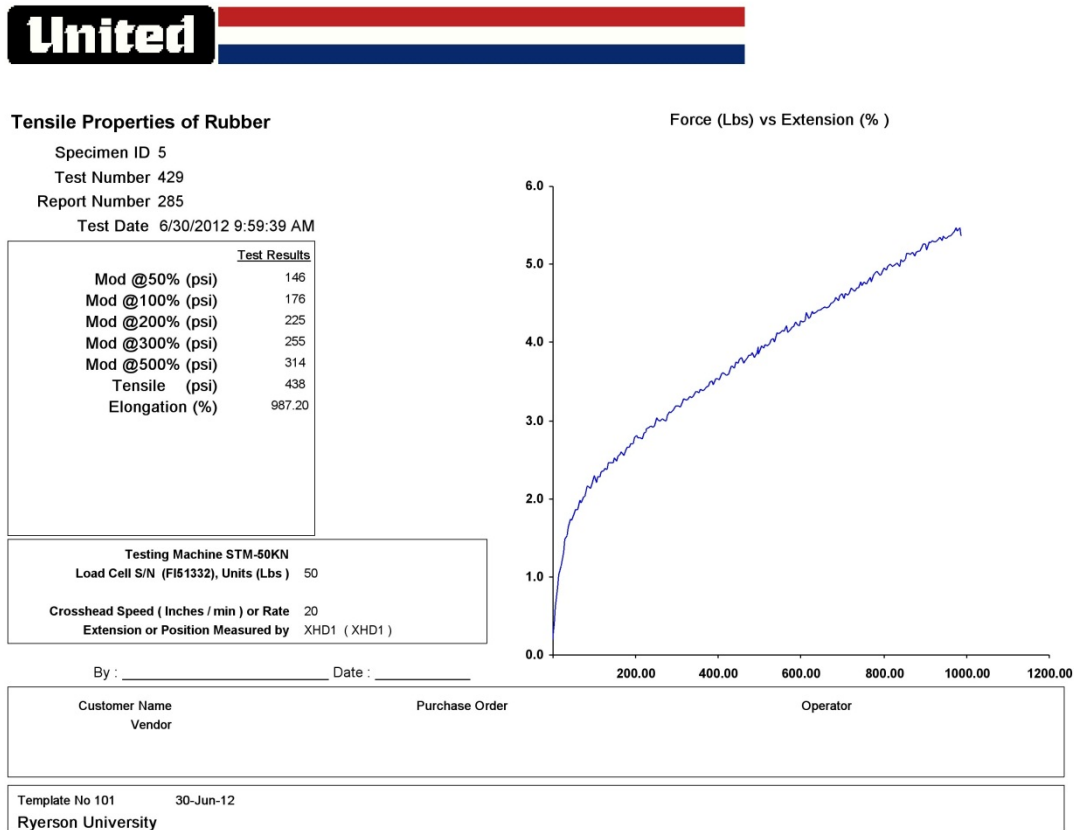


Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR2911 JetA1 - Specimen 4

Tensile ASTM D412 – PR2911

Jet A1 - Test Specimens



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR2911 JetA1 - Specimen 5

Tensile ASTM D412 – PR2911

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 521
Report Number 332
Test Date 8/12/2012 3:05:54 PM

Test Results

Mod @50% (psi)	88
Mod @100% (psi)	114
Mod @200% (psi)	140
Mod @300% (psi)	161
Mod @500% (psi)	199
Tensile (psi)	266
Elongation (%)	852.94

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

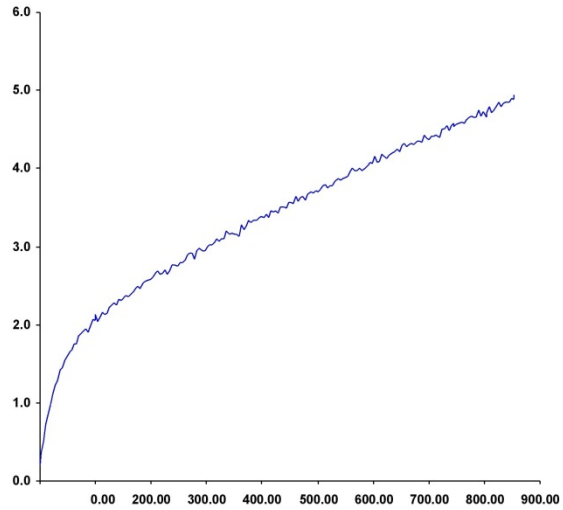
Customer Name
Vendor

Purchase Order

Operator

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)

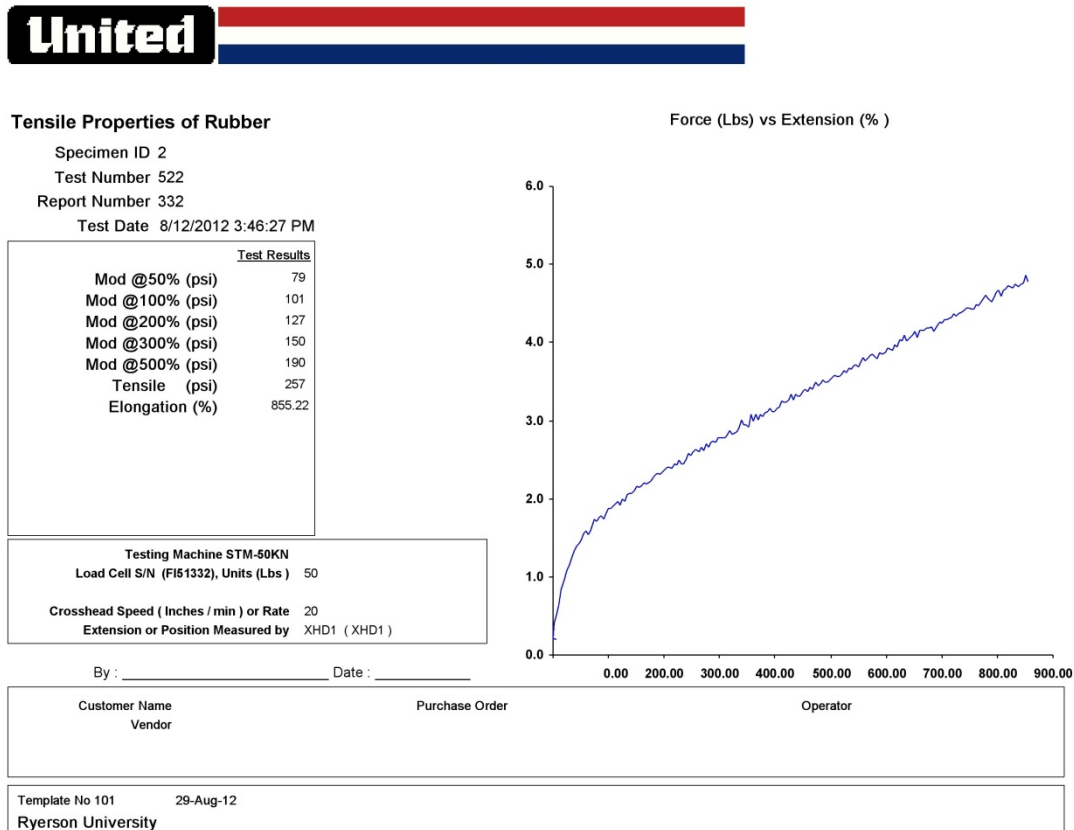


Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR2911 Bio50 - Specimen 1

Tensile ASTM D412 – PR2911

Biofuel 50/50 - Test Specimens



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR2911 Bio50 - Specimen 2

Tensile ASTM D412 – PR2911

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 3
Test Number 523
Report Number 332
Test Date 8/12/2012 3:12:38 PM

Test Results	
Mod @50% (psi)	65
Mod @100% (psi)	83
Mod @200% (psi)	107
Mod @300% (psi)	121
Mod @500% (psi)	156
Tensile (psi)	234
Elongation (%)	998.90

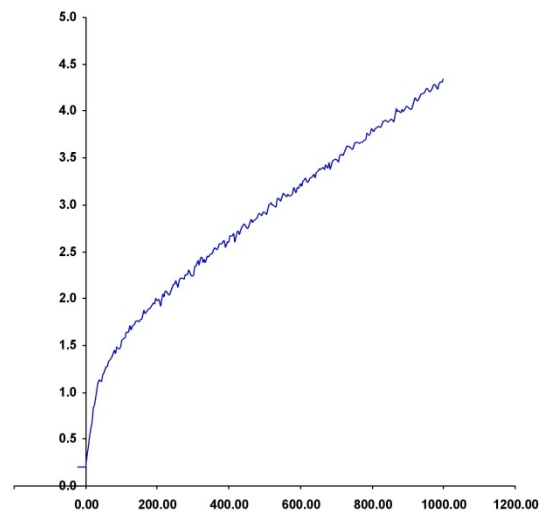
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR2911 Bio50 - Specimen 3

Tensile ASTM D412 – PR2911

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 524
Report Number 332
Test Date 8/12/2012 3:15:14 PM

Test Results	
Mod @50% (psi)	99
Mod @100% (psi)	123
Mod @200% (psi)	154
Mod @300% (psi)	175
Mod @500% (psi)	219
Tensile (psi)	298
Elongation (%)	918.37

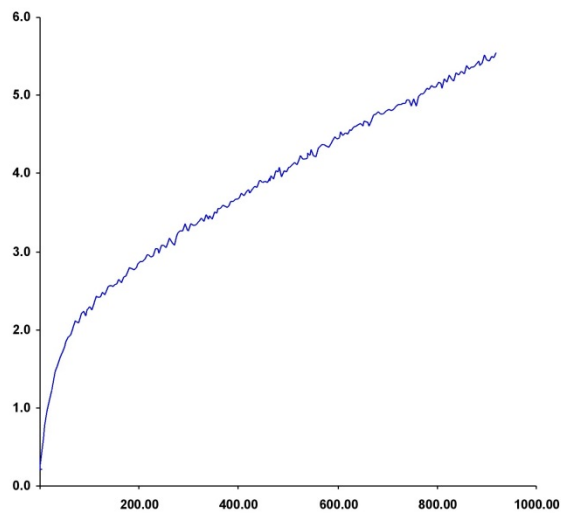
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)

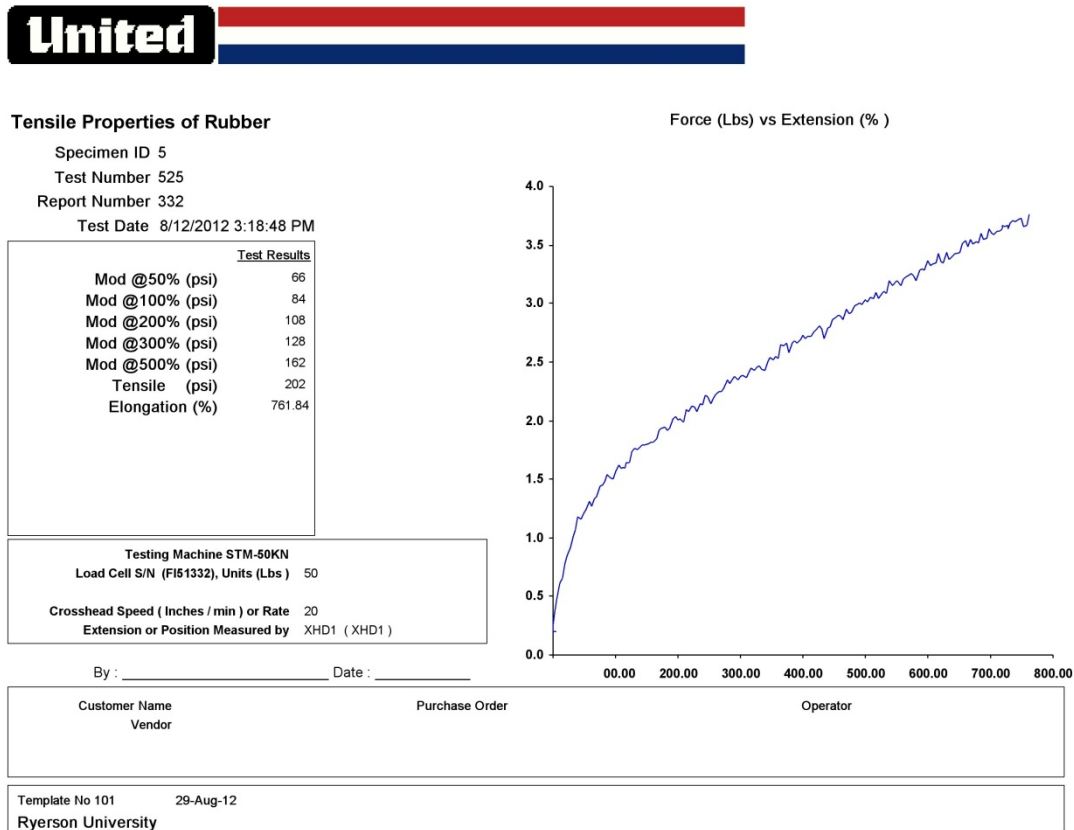


Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR2911 Bio50 - Specimen 4

Tensile ASTM D412 – PR2911

Biofuel 50/50 - Test Specimens



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PR2911 Bio50 - Specimen 5

Tensile ASTM D412 – PS890

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1

Test Number 314

Report Number 268

Test Date 6/2/2012 12:51:28 PM

Test Results

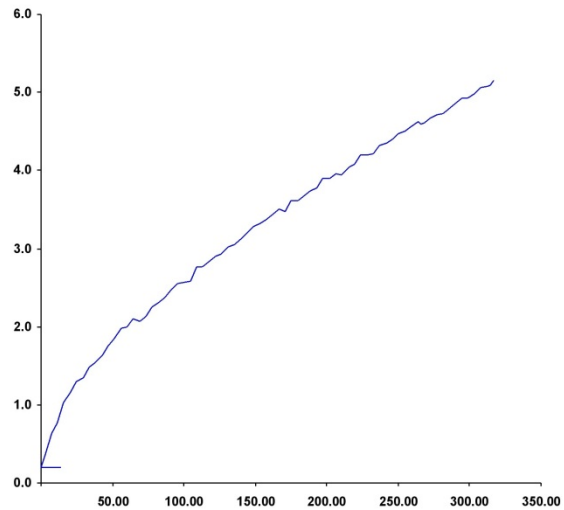
Mod @50% (psi)	99
Mod @100% (psi)	139
Mod @200% (psi)	209
Mod @300% (psi)	268
Mod @500% (psi)	
Tensile (psi)	277
Elongation (%)	316.88

Testing Machine STM-50KN

Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20

Extension or Position Measured by XHD1 (XHD1)



By : _____ Date : _____

Customer Name
Vendor

Purchase Order

Operator

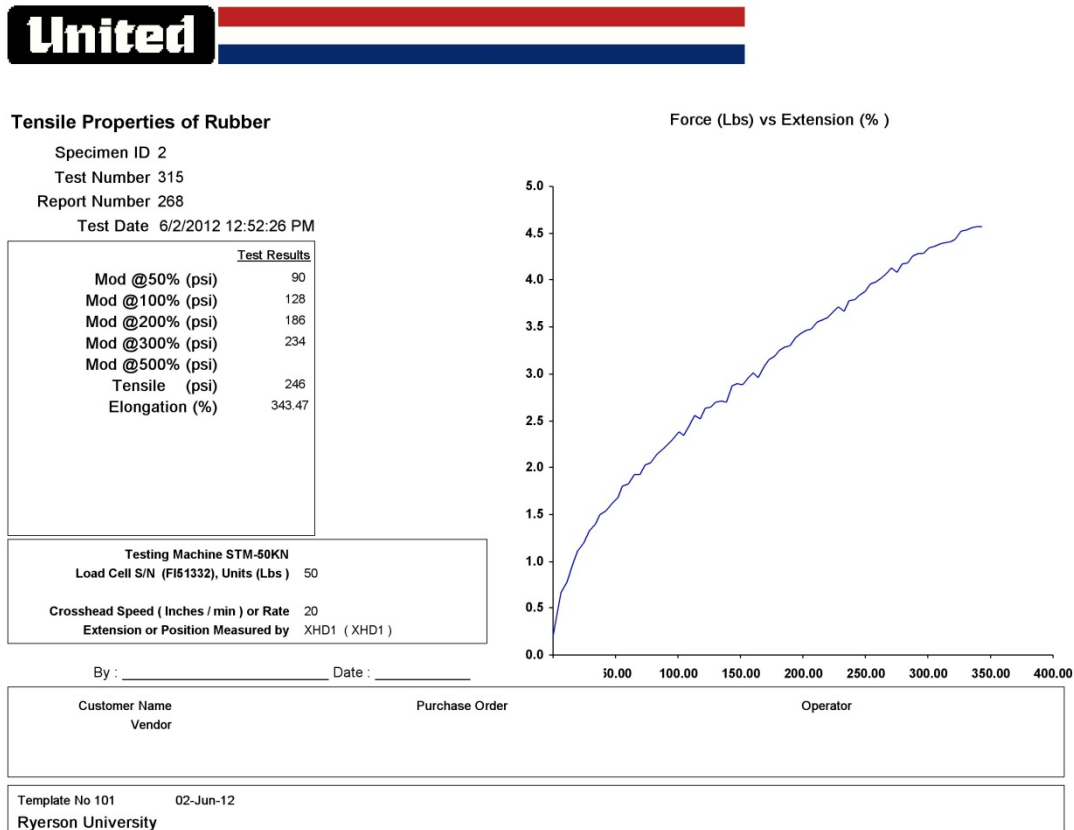
Template No 101 02-Jun-12
Ryerson University

Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PS890 JetA1 - Specimen 1

Tensile ASTM D412 – PS890

Jet A1 - Test Specimens



Tensile PS890 JetA1 - Specimen 2

Tensile ASTM D412 – PS890

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 3
Test Number 316
Report Number 268
Test Date 6/2/2012 1:06:53 PM

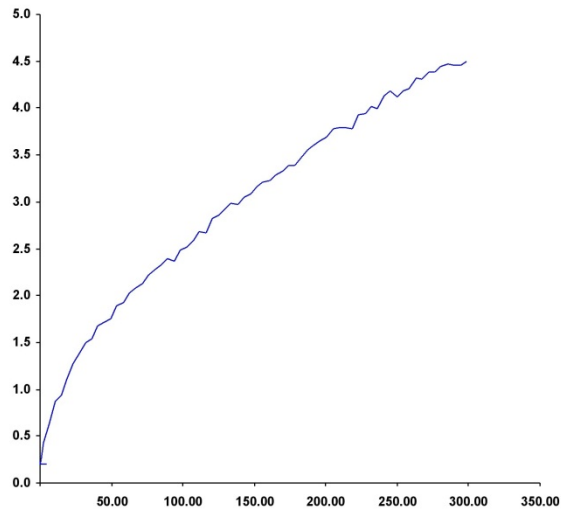
Test Results	
Mod @50% (psi)	102
Mod @100% (psi)	136
Mod @200% (psi)	198
Mod @300% (psi)	10
Mod @500% (psi)	
Tensile (psi)	242
Elongation (%)	298.85

Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	02-Jun-12
Ryerson University	



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PS890 JetA1 - Specimen 3

Tensile ASTM D412 – PS890

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 317
Report Number 268
Test Date 6/2/2012 1:10:08 PM

Test Results	
Mod @50% (psi)	79
Mod @100% (psi)	111
Mod @200% (psi)	165
Mod @300% (psi)	212
Mod @500% (psi)	
Tensile (psi)	234
Elongation (%)	366.52

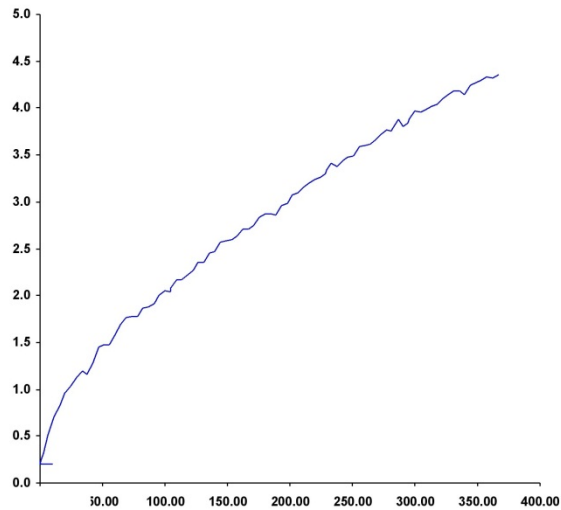
Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	02-Jun-12
Ryerson University	

Force (Lbs) vs Extension (%)

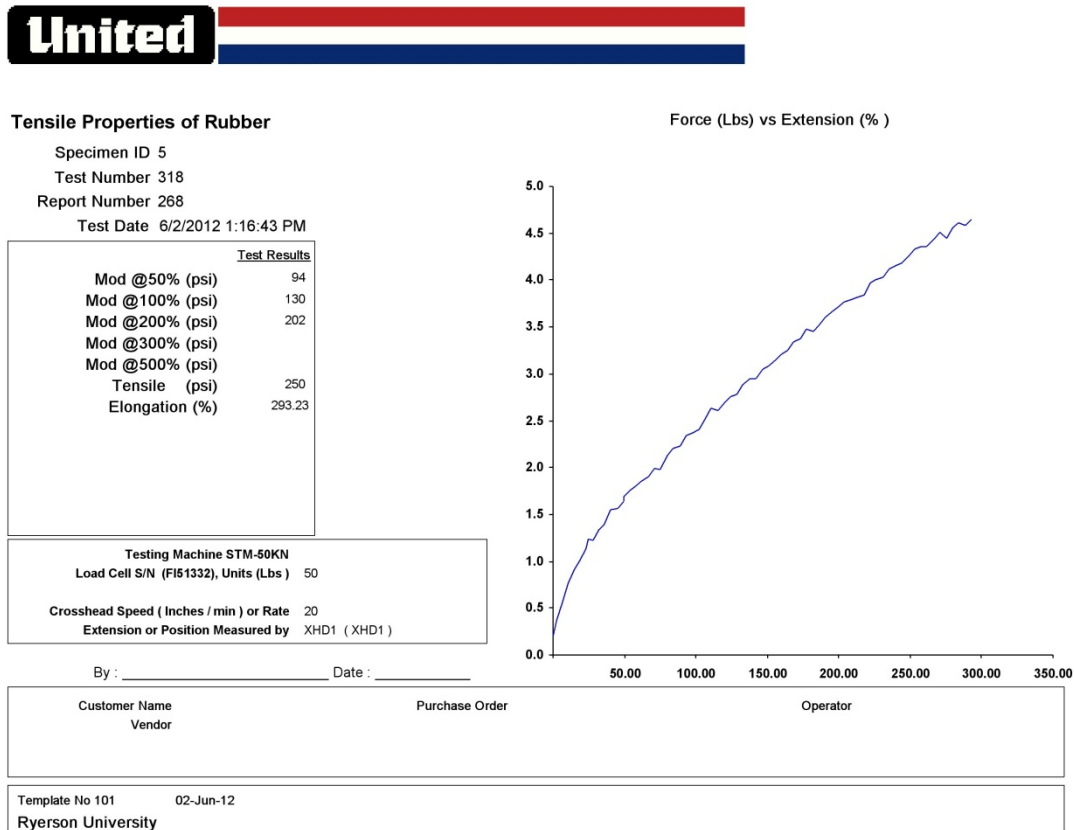


Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PS890 JetA1 - Specimen 4

Tensile ASTM D412 – PS890

Jet A1 - Test Specimens



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PS890 JetA1 - Specimen 5

Tensile ASTM D412 – PS890

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 543
Report Number 336
Test Date 8/12/2012 4:10:48 PM

Test Results

Mod @50% (psi)	97
Mod @100% (psi)	138
Mod @200% (psi)	197
Mod @300% (psi)	245
Mod @500% (psi)	
Tensile (psi)	278
Elongation (%)	387.40

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

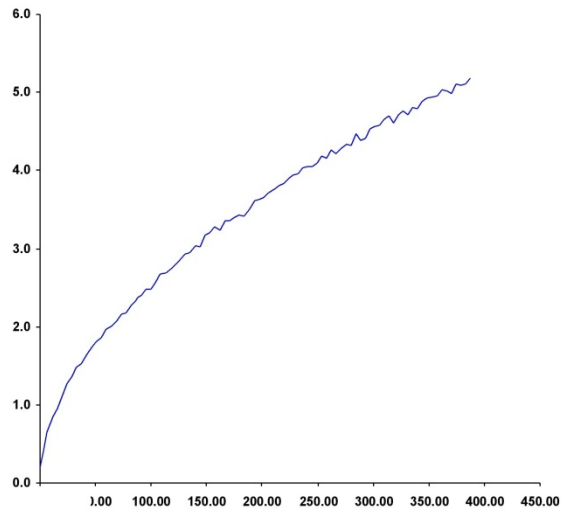
Customer Name
Vendor

Purchase Order

Operator

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PS890 Bio50 - Specimen 1

Tensile ASTM D412 – PS890

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 544
Report Number 336
Test Date 8/12/2012 4:12:45 PM

Test Results	
Mod @50% (psi)	107
Mod @100% (psi)	151
Mod @200% (psi)	215
Mod @300% (psi)	266
Mod @500% (psi)	
Tensile (psi)	293
Elongation (%)	371.03

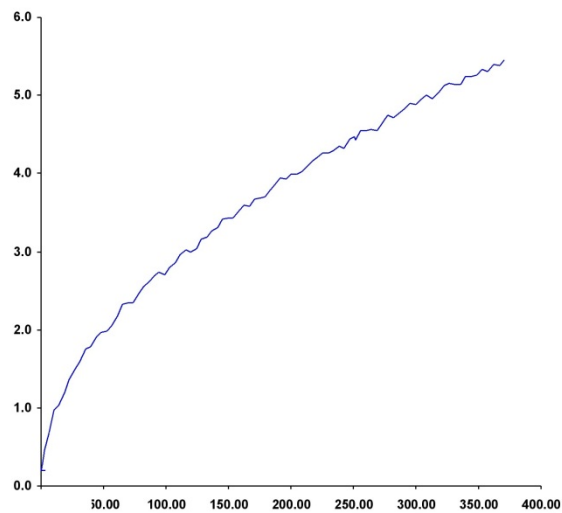
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PS890 Bio50 - Specimen 2

Tensile ASTM D412 – PS890

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 3
Test Number 545
Report Number 336
Test Date 8/12/2012 4:15:06 PM

Test Results	
Mod @50% (psi)	101
Mod @100% (psi)	133
Mod @200% (psi)	193
Mod @300% (psi)	242
Mod @500% (psi)	
Tensile (psi)	256
Elongation (%)	347.23

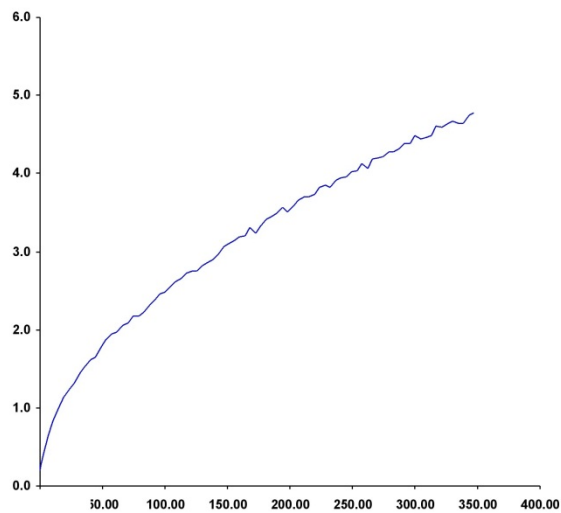
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PS890 Bio50 - Specimen 3

Tensile ASTM D412 – PS890

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 546
Report Number 336
Test Date 8/12/2012 4:16:25 PM

Test Results	
Mod @50% (psi)	111
Mod @100% (psi)	142
Mod @200% (psi)	197
Mod @300% (psi)	242
Mod @500% (psi)	
Tensile (psi)	255
Elongation (%)	331.69

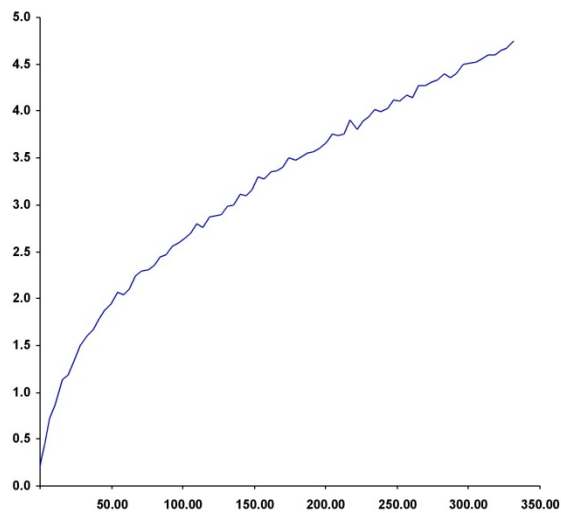
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PS890 Bio50 - Specimen 4

Tensile ASTM D412 – PS890

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 5
Test Number 547
Report Number 336
Test Date 8/12/2012 4:18:42 PM

Test Results	
Mod @50% (psi)	116
Mod @100% (psi)	160
Mod @200% (psi)	222
Mod @300% (psi)	278
Mod @500% (psi)	
Tensile (psi)	314
Elongation (%)	396.72

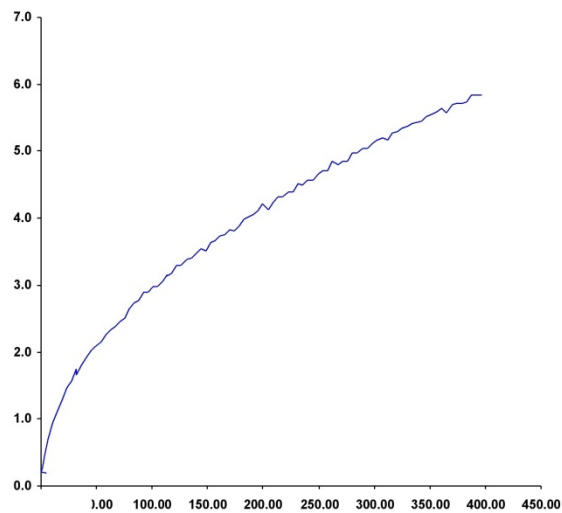
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile PS890 Bio50 - Specimen 5

Tensile ASTM D412 – Q4-2817

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 339
Report Number 274
Test Date 6/2/2012 2:12:12 PM

Test Results

Mod @50% (psi)	29
Mod @100% (psi)	37
Mod @200% (psi)	52
Mod @300% (psi)	83
Mod @500% (psi)	313
Tensile (psi)	480
Elongation (%)	812.31

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

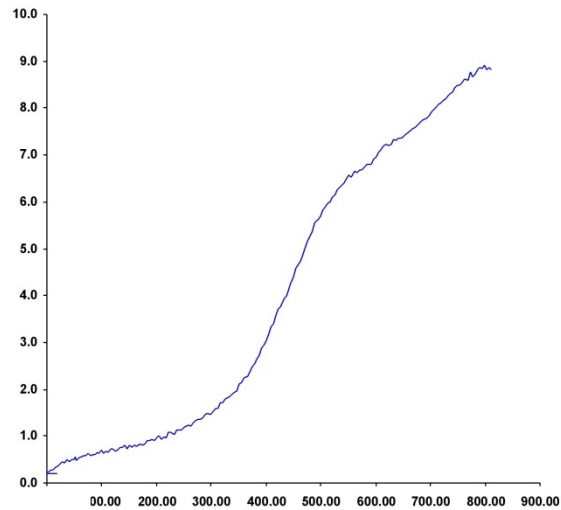
Customer Name
Vendor

Purchase Order

Operator

Template No 101 02-Jun-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Q4-2817 JetA1 - Specimen 1

Tensile ASTM D412 – Q4-2817

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 2
Test Number 340
Report Number 274
Test Date 6/2/2012 2:14:53 PM

Test Results	
Mod @50% (psi)	54
Mod @100% (psi)	77
Mod @200% (psi)	130
Mod @300% (psi)	198
Mod @500% (psi)	345
Tensile (psi)	481
Elongation (%)	730.34

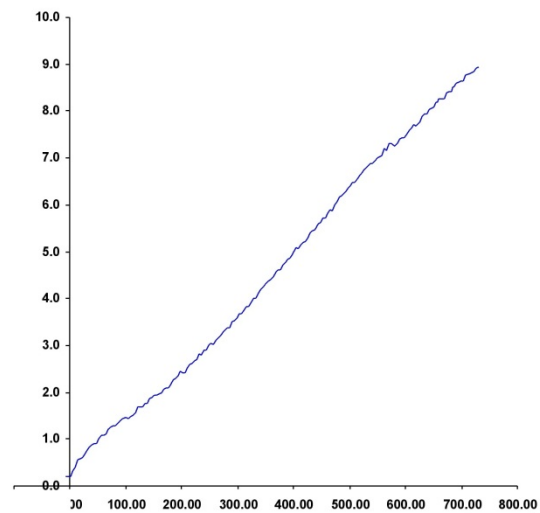
Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	02-Jun-12
Ryerson University	

Force (Lbs) vs Extension (%)

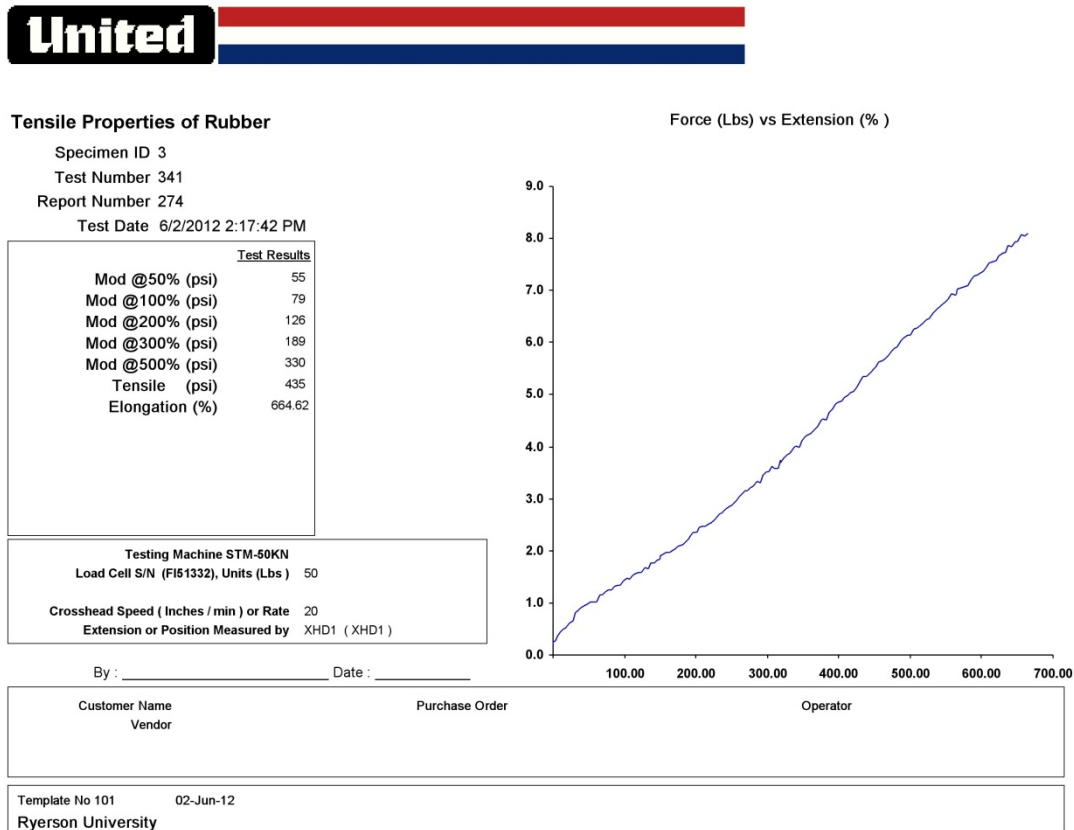


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Tensile Q4-2817 JetA1 - Specimen 2

Tensile ASTM D412 – Q4-2817

Jet A1 - Test Specimens



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Tensile Q4-2817 JetA1 - Specimen 3

Tensile ASTM D412 – Q4-2817

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 342
Report Number 274
Test Date 6/2/2012 2:20:24 PM

Test Results	
Mod @50% (psi)	29
Mod @100% (psi)	32
Mod @200% (psi)	48
Mod @300% (psi)	65
Mod @500% (psi)	199
Tensile (psi)	468
Elongation (%)	673.10

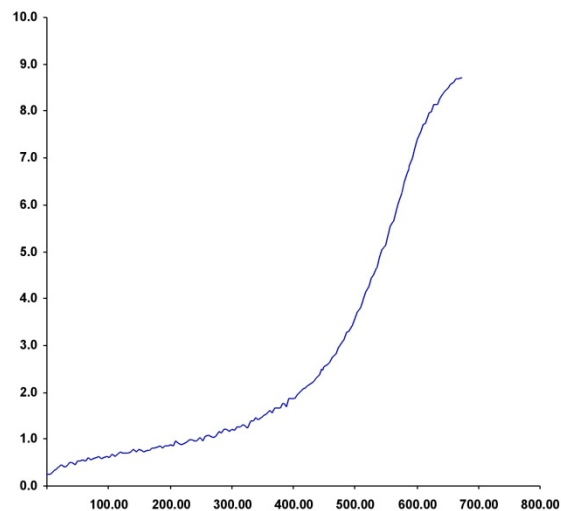
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101 02-Jun-12
Ryerson University

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Q4-2817 JetA1 - Specimen 4

Tensile ASTM D412 – Q4-2817

Jet A1 - Test Specimens



Tensile Properties of Rubber

Specimen ID 5
Test Number 343
Report Number 274
Test Date 6/2/2012 4:29:40 PM

Test Results	
Mod @50% (psi)	54
Mod @100% (psi)	74
Mod @200% (psi)	137
Mod @300% (psi)	200
Mod @500% (psi)	353
Tensile (psi)	419
Elongation (%)	591.26

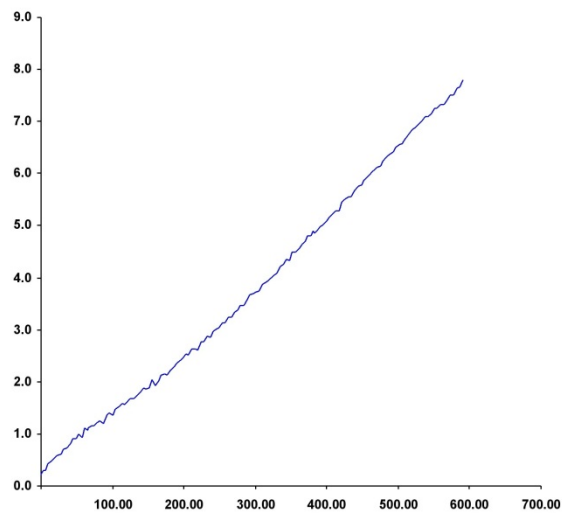
Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	02-Jun-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Q4-2817 JetA1 - Specimen 5

Tensile ASTM D412 – Q4-2817

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 1
Test Number 531
Report Number 334
Test Date 8/12/2012 3:29:54 PM

Test Results

Mod @50% (psi)	28
Mod @100% (psi)	32
Mod @200% (psi)	47
Mod @300% (psi)	64
Mod @500% (psi)	147
Tensile (psi)	478
Elongation (%)	701.39

Testing Machine STM-50KN
Load Cell S/N (FI61332), Units (Lbs) 50

Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

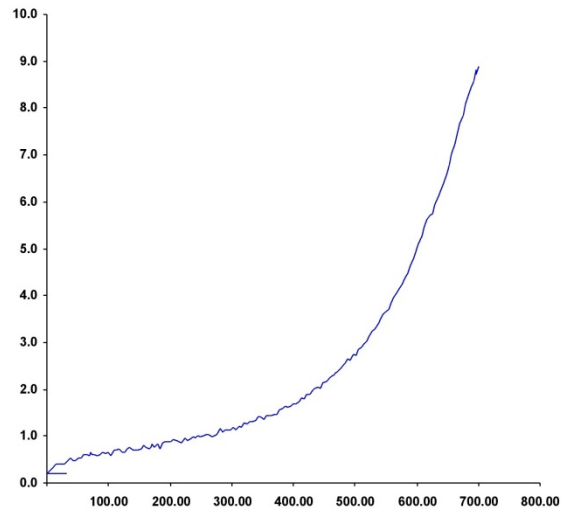
Customer Name
Vendor

Purchase Order

Operator

Template No 101 29-Aug-12
Ryerson University

Force (Lbs) vs Extension (%)

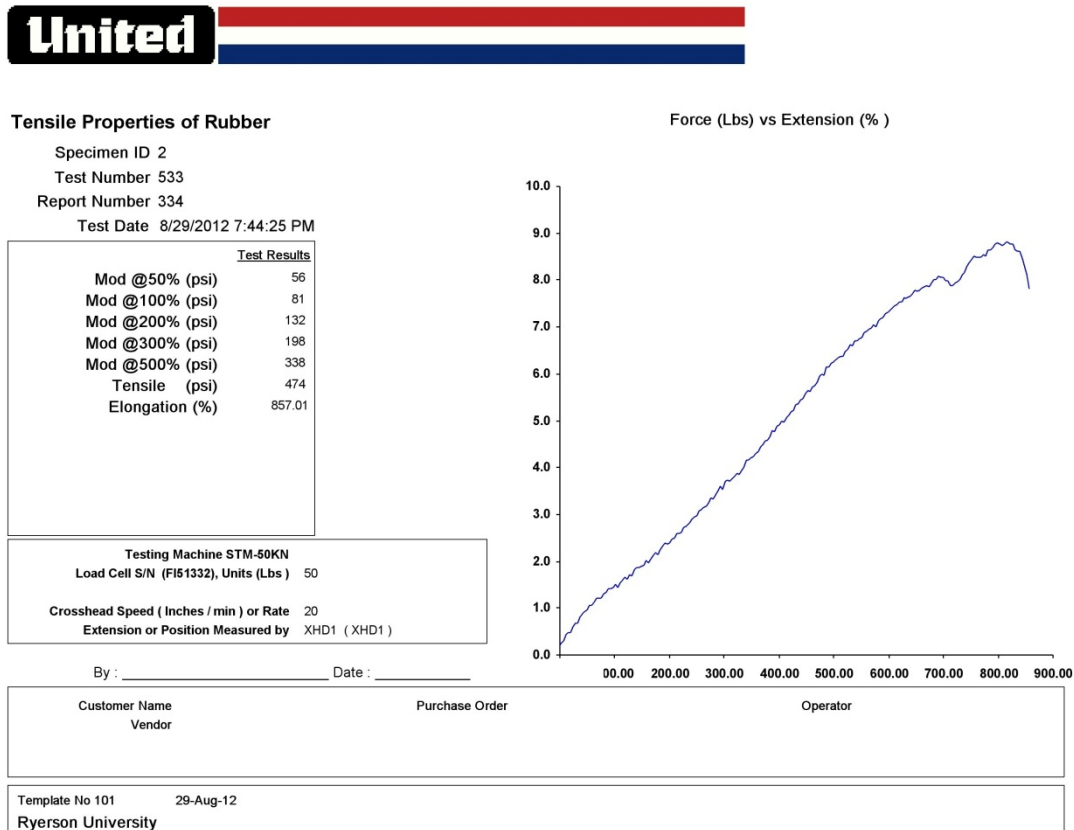


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Tensile Q4-2817 Bio50 - Specimen 1

Tensile ASTM D412 – Q4-2817

Biofuel 50/50 - Test Specimens



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Tensile Q4-2817 Bio50 - Specimen 2

Tensile ASTM D412 – Q4-2817

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 3
Test Number 534
Report Number 334
Test Date 8/12/2012 3:39:40 PM

Test Results	
Mod @50% (psi)	28
Mod @100% (psi)	35
Mod @200% (psi)	45
Mod @300% (psi)	60
Mod @500% (psi)	144
Tensile (psi)	466
Elongation (%)	882.39

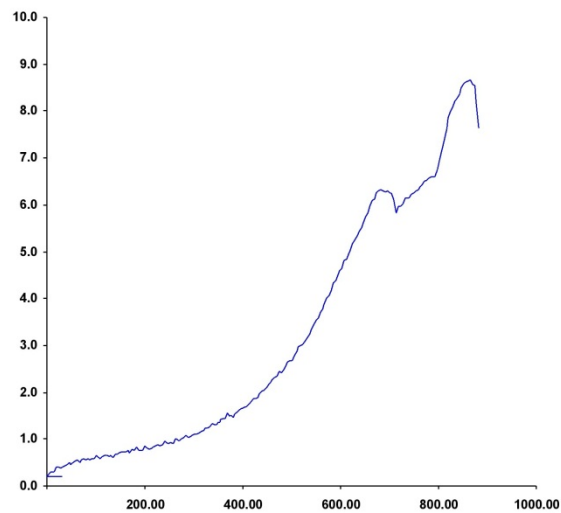
Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Q4-2817 Bio50 - Specimen 3

Tensile ASTM D412 – Q4-2817

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 4
Test Number 535
Report Number 334
Test Date 8/12/2012 5:03:07 PM

Test Results	
Mod @50% (psi)	27
Mod @100% (psi)	31
Mod @200% (psi)	44
Mod @300% (psi)	55
Mod @500% (psi)	124
Tensile (psi)	674
Elongation (%)	850.94

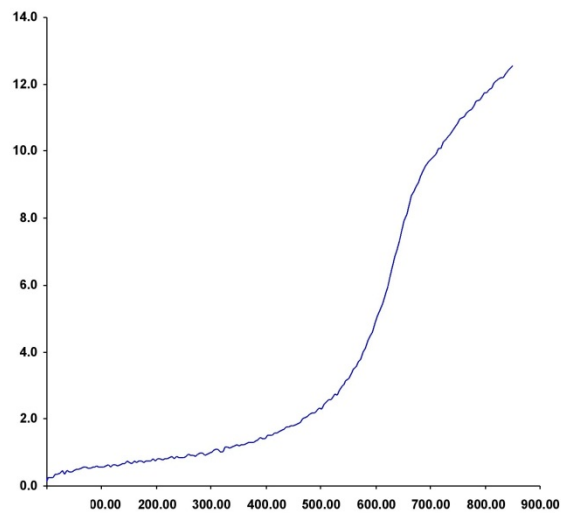
Testing Machine STM-50KN	
Load Cell S/N (FI51332), Units (Lbs)	50
Crosshead Speed (Inches / min) or Rate	20
Extension or Position Measured by	XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Q4-2817 Bio50 - Specimen 4

Tensile ASTM D412 – Q4-2817

Biofuel 50/50 - Test Specimens



Tensile Properties of Rubber

Specimen ID 5
Test Number 537
Report Number 334
Test Date 8/12/2012 3:57:11 PM

Test Results	
Mod @50% (psi)	75
Mod @100% (psi)	107
Mod @200% (psi)	177
Mod @300% (psi)	262
Mod @500% (psi)	
Tensile (psi)	399
Elongation (%)	439.75

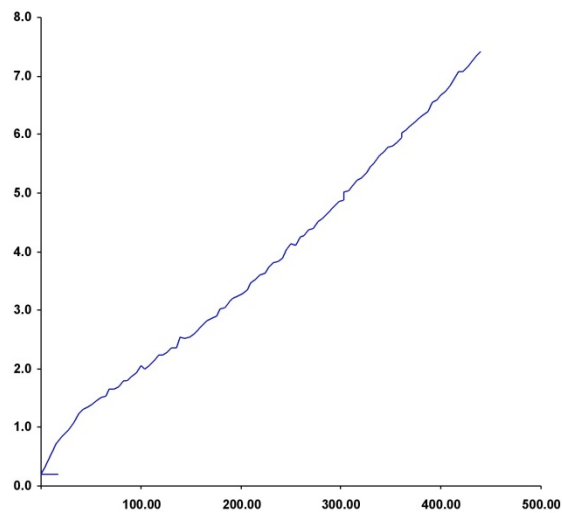
Testing Machine STM-50KN
Load Cell S/N (FI51332), Units (Lbs) 50
Crosshead Speed (Inches / min) or Rate 20
Extension or Position Measured by XHD1 (XHD1)

By : _____ Date : _____

Customer Name	Purchase Order	Operator
Vendor		

Template No 101	29-Aug-12
Ryerson University	

Force (Lbs) vs Extension (%)



Ryerson University 350 Victoria Street Toronto, Ontario M5B 2K3 Tel 905-669-5327 FAX

Tensile Q4-2817 Bio50 - Specimen 5

Volume Swell ASTM D471

Jet A1

Pre-Soak			Post-Soak		
Epichlorohydrin	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	3.665	1.077	3.71	1.002	4.636785162
Specimen 2	3.868	1.121	3.893	1.047	3.603931562
Specimen 3	4.004	1.161	4.009	1.082	2.954625396
Specimen 4	4.084	1.181	4.08	1.108	2.376851533
Specimen 5	3.685	1.058	3.671	0.985	2.24590788
				Avg	3.163620306
CS3100	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	2.811	1.206	2.545	1.066	-7.85046729
Specimen 2	2.754	1.199	2.485	1.048	-7.588424437
Specimen 3	3.086	1.34	2.808	1.18	-6.758304696
Specimen 4	2.768	1.203	2.515	1.05	-6.389776358
Specimen 5	2.986	1.302	2.71	1.124	-5.819477435
				Avg	-6.881290043
Q4-2805	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	4.98	1.399	5.237	1.241	11.58894164
Specimen 2	4.601	1.282	4.855	1.153	11.53962037
Specimen 3	4.419	1.2	4.646	1.069	11.12146629
Specimen 4	4.347	1.203	4.589	1.077	11.70483461
Specimen 5	4.59	1.277	4.885	1.143	12.94898883
				Avg	11.78077035
N602-70	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	0.332	0.097	0.31	0.074	0.425531915
Specimen 2	0.33	0.099	0.306	0.072	1.298701299
Specimen 3	0.331	0.097	0.317	0.078	2.136752137
Specimen 4	0.334	0.096	0.31	0.075	-1.260504202
Specimen 5	0.333	0.098	0.309	0.075	-0.425531915
				Avg	0.434989847
VM128	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	0.474	0.218	0.536	0.196	32.8125
Specimen 2	0.473	0.219	0.535	0.196	33.46456693
Specimen 3	0.476	0.221	0.535	0.197	32.54901961

Volume Swell ASTM D471

Jet A1

Specimen 4	0.473	0.216	0.533	0.195	31.51750973
Specimen 5	0.477	0.217	0.535	0.195	30.76923077
				Avg	32.22256541
PR1422	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	2.542	0.707	3.014	0.85	17.92915531
Specimen 2	2.73	0.788	2.89	0.769	9.217301751
Specimen 3	2.87	0.797	2.754	0.72	-1.881331404
Specimen 4	2.984	0.872	2.59	0.647	-8.001893939
Specimen 5	2.412	0.872	2.433	0.628	17.20779221
				Avg	6.894204786
PS890	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	3.321	1.248	3.308	1.17	3.13555234
Specimen 2	3.458	1.3	3.397	1.246	-0.324374421
Specimen 3	3.057	1.124	2.996	1.092	-1.500258665
Specimen 4	3.05	1.122	2.946	1.053	-1.815352697
Specimen 5	3.095	1.127	3.045	1.067	0.508130081
				Avg	0.000739328
Q4-2817	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	3.654	1.58	3.623	1.563	-0.675024108
Specimen 2	3.592	1.528	3.563	1.508	-0.436046512
Specimen 3	3.474	1.479	3.456	1.447	0.701754386
Specimen 4	3.475	1.482	3.447	1.446	0.401404917
Specimen 5	3.45	1.475	3.429	1.449	0.253164557
				Avg	0.049050648
PR2911	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	1.12	0.113	1.179	0.124	4.766633565
Specimen 2	1.182	0.099	1.247	0.135	2.677746999
Specimen 3	1.215	0.128	1.283	0.137	5.427782889
Specimen 4	1.288	0.13	1.361	0.149	4.663212435
Specimen 5	1.283	0.134	1.352	0.145	5.047867711
				Avg	4.51664872
PR 1828	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	2.839	0.867	2.9	0.862	3.346855984

Volume Swell ASTM D471

Jet A1

Specimen 2	2.83	0.878	2.875	0.86	3.227459016
Specimen 3	2.814	0.871	2.862	0.857	3.190941843
Specimen 4	2.955	0.909	2.997	0.896	2.688172043
Specimen 5	2.831	0.873	2.881	0.864	3.013278856
				Avg	3.093341548
PR 1776	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	2.388	0.53	2.354	0.462	1.82992465
Specimen 2	2.321	0.52	2.249	0.455	-0.388672959
Specimen 3	2.325	0.519	2.295	0.447	2.325581395
Specimen 4	2.338	0.538	2.281	0.458	1.277777778
Specimen 5	2.338	0.522	2.277	0.454	0.385462555
				Avg	1.086014684
Fluorocarbon O-Ring	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	0.499	0.178	0.544	0.189	10.59190031
Specimen 2	0.496	0.165	0.537	0.178	8.459214502
Specimen 3	0.499	0.176	0.544	0.188	10.21671827
Specimen 4	0.51	0.176	0.553	0.189	8.982035928
Specimen 5	0.491	0.168	0.534	0.175	11.14551084
				Avg	9.879075969

Volume Swell ASTM D471

Biofuel 50/50

Pre-Soak			Post-Soak		
Epichlorohydrin	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	3.419	1.004	3.435	1.043	-0.952380952
Specimen 2	3.54	1.04	3.55	1.085	-1.4
Specimen 3	3.505	1.037	3.524	1.075	-0.769854133
Specimen 4	3.582	1.06	3.588	1.135	-2.73592387
Specimen 5	3.525	1.043	3.546	1.114	-2.014504432
				Avg	-1.574532677
CS3100	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	3.165	1.37	2.825	1.188	-8.802228412
Specimen 2	2.814	1.211	2.513	1.015	-6.550218341
Specimen 3	3.073	1.321	2.732	1.126	-8.333333333
Specimen 4	3.075	1.325	2.738	1.145	-8.971428571
Specimen 5	2.86	1.224	2.552	1.075	-9.718826406
				Avg	-8.475207013
Q4-2805	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	4.765	1.29	5.064	1.284	8.776978417
Specimen 2	4.39	1.209	4.798	1.091	16.5356806
Specimen 3	4.025	1.085	4.003	1.004	2.006802721
Specimen 4	3.854	1.035	4.016	1.079	4.185881518
Specimen 5	4.135	1.085	4.327	1.052	7.37704918
				Avg	7.776478488
N602-70	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	0.338	0.042	0.305	0.031	-7.432432432
Specimen 2	0.336	0.048	0.313	0.034	-3.125
Specimen 3	0.334	0.041	0.313	0.033	-4.436860068
Specimen 4	0.335	0.046	0.315	0.037	-3.806228374
Specimen 5	0.338	0.046	0.316	0.034	-3.424657534
				Avg	-4.445035682
VM128	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	0.472	0.218	0.503	0.174	29.52755906
Specimen 2	0.474	0.219	0.506	0.175	29.80392157
Specimen 3	0.476	0.221	0.503	0.173	29.41176471

Volume Swell ASTM D471

Biofuel 50/50

Specimen 4	0.473	0.216	0.498	0.169	28.0155642
Specimen 5	0.477	0.22	0.503	0.172	28.79377432
				Avg	29.11051677
PR1422	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	2.522	0.759	2.518	0.713	2.382302893
Specimen 2	2.89	0.854	2.903	0.831	1.768172888
Specimen 3	2.545	0.751	2.474	0.706	-1.449275362
Specimen 4	2.971	0.892	2.807	0.802	-3.559403559
Specimen 5	2.556	0.764	2.489	0.708	-0.613839286
				Avg	-0.294408485
PS890	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	2.734	1.024	2.922	1.104	6.315789474
Specimen 2	3.034	1.155	2.603	0.993	-14.3161256
Specimen 3	3.315	1.259	3.24	1.199	-0.729571984
Specimen 4	3.195	1.194	2.936	1.106	-8.545727136
Specimen 5	3.058	1.139	3.057	1.164	-1.354872329
				Avg	-3.726101515
Q4-2817	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	3.405	1.48	3.489	1.517	2.441558442
Specimen 2	3.712	1.589	3.575	1.566	-5.369759774
Specimen 3	3.477	1.502	3.42	1.487	-2.126582278
Specimen 4	3.655	1.589	3.646	1.575	0.242013553
Specimen 5	3.546	1.533	3.34	1.466	-6.905116741
				Avg	-2.34357736
PR2911	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	1.215	0.124	1.233	0.138	0.366636114
Specimen 2	1.078	0.102	1.101	0.128	-0.307377049
Specimen 3	1.166	0.121	1.262	0.134	7.942583732
Specimen 4	1.207	0.108	1.206	0.149	-3.821656051
Specimen 5	1.234	0.119	1.258	0.153	-0.896860987
				Avg	0.656665152
PR 1828	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	2.956	0.869	2.896	0.879	-3.35409679

Volume Swell ASTM D471

Biofuel 50/50

Specimen 2	2.953	0.866	2.984	0.912	-0.718735026
Specimen 3	2.798	0.82	2.837	0.874	-0.758341759
Specimen 4	2.957	0.864	3.035	0.901	1.958910655
Specimen 5	2.847	0.824	3.036	0.895	5.832921404
				Avg	0.592131697
PR 1776	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	2.29	0.468	2.36	0.467	3.896816685
Specimen 2	2.357	0.474	2.581	0.484	11.36484334
Specimen 3	2.524	0.513	2.828	0.571	12.23272004
Specimen 4	2.828	0.595	2.578	0.49	-6.493506494
Specimen 5	2.542	0.508	2.259	0.462	-11.6519174
				Avg	1.869791232
Fluorocarbon O-Ring	Dry	Wet	Dry	Wet	Volume Swell
Specimen 1	0.493	0.181	0.53	0.181	11.85897436
Specimen 2	0.498	0.187	0.519	0.173	11.25401929
Specimen 3	0.512	0.189	0.525	0.175	8.359133127
Specimen 4	0.492	0.187	0.52	0.173	13.7704918
Specimen 5	0.513	0.189	0.524	0.174	8.024691358
				Avg	10.65346199

Rubber Hardness ASTM D2240

Jet A1

CS3100	1	2	3	4	5	Avg
Specimen 1	42.5	41.6	42	42.3	38.9	41.46
Specimen 2	42	40	38.9	39.2	40.9	40.2
Specimen 3	40.9	43.3	42.4	43.5	44.8	42.98
Specimen 4	45.7	43.8	42.9	43.8	44.2	44.08
Specimen 5	42.8	45.3	42.9	42.6	42.6	43.24
					Avg	42.392
Nitrile O-Ring	1	2	3	4	5	Avg
Specimen 1	76.3	76	76.5	75.7	74.8	75.86
Specimen 2	76.8	75	73.5	75.5	74.6	75.08
Specimen 3	77.6	77.2	76.1	75.7	75.6	76.44
Specimen 4	74.3	72.9	74.2	73.5	73.3	73.64
Specimen 5	76.5	75.3	75	74.9	78	75.94
					Avg	75.392
LT Fluoro O-Ring	1	2	3	4	5	Avg
Specimen 1	82.4	85.1	84.4	81	84.6	83.5
Specimen 2	81.4	84.4	85.1	84	82.9	83.56
Specimen 3	84.6	84.8	84.8	84.6	84.8	84.72
Specimen 4	84.5	84.3	84.4	83.7	84.8	84.34
Specimen 5	83	81.8	83.9	84.3	84.7	83.54
					Avg	83.932
PR1422	1	2	3	4	5	Avg
Specimen 1	55.7	56.4	54.6	57.6	57.5	56.36
Specimen 2	56.6	54.9	52.4	53.8	57.1	54.96
Specimen 3	55.9	54.7	55.9	55.7	55.7	55.58
Specimen 4	53.4	55.8	54.4	56.2	56.6	55.28
Specimen 5	55.7	54.2	52.8	54.3	54.7	54.34
					Avg	55.304
PS890	1	2	3	4	5	Avg
Specimen 1	58.1	57.4	56	55.3	53.9	56.14
Specimen 2	58.2	56.2	55.5	54.6	52.1	55.32
Specimen 3	61.1	57.5	59.6	54.4	59.1	58.34
Specimen 4	56.6	57.3	53.9	55.6	55.8	55.84
Specimen 5	55.7	56	53.6	56.2	58.3	55.96

Rubber Hardness ASTM D2240

Jet A1

					Avg	56.32
Q4-2817	1	2	3	4	5	Avg
Specimen 1	42.4	39.1	40.1	37.3	39.5	39.68
Specimen 2	39.2	41.6	43.4	43	41.9	41.82
Specimen 3	44.9	41.4	39.8	40.9	41.7	41.74
Specimen 4	42.4	42	41.4	40.4	42.4	41.72
Specimen 5	40.5	42.3	42.1	40.4	39.9	41.04
					Avg	41.2
PR 1776	1	2	3	4	5	Avg
Specimen 1	42.9	44.3	43.9	45.3	45.8	44.44
Specimen 2	46.1	45.3	45.2	45.6	46.1	45.66
Specimen 3	45.5	46.4	44.8	43.6	45.5	45.16
Specimen 4	47.5	47.1	45.7	44.7	45.7	46.14
Specimen 5	48	48.8	46.2	47.8	48.8	47.92
					Avg	45.864
PR 1828	1	2	3	4	5	Avg
Specimen 1	48.3	48.9	45.1	44.9	44.5	46.34
Specimen 2	44.7	46.5	45.4	43.8	45.4	45.16
Specimen 3	45.5	44.4	43.9	46.3	47.1	45.44
Specimen 4	47.1	46.5	43.1	43.8	47.3	45.56
Specimen 5	48.1	44.8	46.2	44.8	47	46.18
					Avg	45.736
PR 2911	1	2	3	4	5	Avg
Specimen 1	50.2	61.8	52.7	48.8	60.8	54.86
Specimen 2	57.1	55	61.1	59.9	60.9	58.8
Specimen 3	55.9	49.7	52.4	56.7	50	52.94
Specimen 4	53.1	50.3	52.8	55.6	52.9	52.94
Specimen 5	56.2	51	52.1	58.4	51.9	53.92
					Avg	54.692
Fluorocarb O-Ring	1	2	3	4	5	Avg
Specimen 1	78.6	79	78.4	75.5	78.8	78.06
Specimen 2	76.5	79.6	79.9	78.4	78.4	78.56
Specimen 3	76.8	76.5	75	75.3	77.3	76.18

Rubber Hardness ASTM D2240

Jet A1

Specimen 4	75.7	75	76.8	76.1	76.2	75.96
Specimen 5	75.4	74.6	72.3	75.1	77.1	74.9
					Avg	76.732

Rubber Hardness ASTM D2240

Biofuel 50/50

CS3100	1	2	3	4	5	Avg
Specimen 1	40.6	41.9	42.5	39.9	39	40.78
Specimen 2	39.8	41.5	38.2	38.1	39.9	39.5
Specimen 3	41.1	41.8	40.4	40.6	39.5	40.68
Specimen 4	41.9	41.9	40.7	39.6	39.9	40.8
Specimen 5	42.2	41.5	40.4	40	39.9	40.8
					Avg	40.512
N602-76	1	2	3	4	5	Avg
Specimen 1	76.7	72.7	71.9	77	70.1	73.68
Specimen 2	78.6	76.3	79	77.9	74.5	77.26
Specimen 3	73.8	73.9	78.3	77.2	77.8	76.2
Specimen 4	77.2	75	74.7	78	78	76.58
Specimen 5	76	74.7	75.4	74.3	78.1	75.7
					Avg	75.884
LT Fluoro VM128	1	2	3	4	5	Avg
Specimen 1	80.4	80.6	79.2	80.1	80.2	80.1
Specimen 2	75.4	80.2	81.1	82	81.4	80.02
Specimen 3	79.8	80.3	80.8	80.3	80.6	80.36
Specimen 4	79.9	79	81.1	80.6	80.4	80.2
Specimen 5	79.6	79.5	80.3	80.5	79.9	79.96
					Avg	80.128
PR1422	1	2	3	4	5	Avg
Specimen 1	58	54.6	63	61.6	61.7	59.78
Specimen 2	60	57.2	56.7	61.7	62.8	59.68
Specimen 3	61.4	54.5	59.9	53.3	54.5	56.72
Specimen 4	60.9	55.4	60.6	59.1	55.3	58.26
Specimen 5	57.6	55.4	59	58.8	55	57.16
					Avg	58.32
PS890	1	2	3	4	5	Avg
Specimen 1	48.7	54.2	59	57.6	55.3	54.96
Specimen 2	58.3	54.7	59.7	56.6	55.9	57.04
Specimen 3	59.7	59.6	57.9	57.1	58.4	58.54
Specimen 4	60.3	59.1	58.9	60.9	59.1	59.66
Specimen 5	57.3	57.3	57	52.4	59	56.6

Rubber Hardness ASTM D2240

Biofuel 50/50

					Avg	57.36
Q4-2817	1	2	3	4	5	Avg
Specimen 1	39.7	43.5	41.9	41.5	44.2	42.16
Specimen 2	43.3	43.3	40.7	43.9	41.8	42.6
Specimen 3	44	43.1	39.2	45.3	43.9	43.1
Specimen 4	44	44.4	40.3	43.9	45.6	43.64
Specimen 5	39.7	40.2	37.1	42.9	39.6	39.9
					Avg	42.28
PR 1776	1	2	3	4	5	Avg
Specimen 1	44.2	50.4	47.8	46.9	44.5	46.76
Specimen 2	51.4	46.6	47.9	47.8	49.3	48.6
Specimen 3	47	44.8	49.1	43	46.8	46.14
Specimen 4	45.8	44	50.1	48.1	47	47
Specimen 5	44.9	47.4	45.2	47.3	40.5	45.06
					Avg	46.712
PR 1828	1	2	3	4	5	Avg
Specimen 1	43.7	39.6	39.1	43.7	44.5	42.12
Specimen 2	43.3	42.8	45.1	43.2	43	43.48
Specimen 3	45.4	45.5	42.3	44.2	43.2	44.12
Specimen 4	46.1	45.6	40.2	42.1	43.8	43.56
Specimen 5	44.4	41.3	40.3	39.9	42.7	41.72
					Avg	43
PR 2911	1	2	3	4	5	Avg
Specimen 1	58.8	62.8	59.5	62.1	54.5	59.54
Specimen 2	62.1	53.7	52.1	62.3	58.6	57.76
Specimen 3	58.3	55	53.3	61.4	60.8	57.76
Specimen 4	53.2	56.9	59.7	55.6	61.9	57.46
Specimen 5	54.7	54	52.2	61.5	58.8	56.24
					Avg	57.752
Fluorocarb O-Ring	1	2	3	4	5	Avg
1	76.7	72.7	71.9	77	70.1	73.68
2	78.6	76.3	79	77.9	74.5	77.26

Rubber Hardness ASTM D2240

Biofuel 50/50

3	73.8	73.9	78.3	77.2	77.8	76.2
4	77.2	75	74.7	78	78	76.58
5	76	74.7	75.4	74.3	78.1	75.7
					Avg	75.884

O-Ring Compression ASTM D395

Nitrile N602-70						
Jet A1				Bio50		
To	Ti	Compression Set		To	Ti	Compression Set
0.07	0.055	28.57142857		0.07	0.056	26.66666667
0.07	0.055	28.57142857		0.07	0.056	26.66666667
0.07	0.06	19.04761905		0.07	0.057	24.76190476
0.07	0.056	26.66666667		0.07	0.057	24.76190476
0.07	0.06	19.04761905		0.07	0.056	26.66666667
	Average	24.38			Average	25.91
Fluorocarbon LT VM128						
Jet A1				Bio50		
To	Ti	Compression Set		To	Ti	Compression Set
0.075	0.054	36.52173913		0.074	0.051	40.7079646
0.074	0.056	31.85840708		0.074	0.054	35.39823009
0.074	0.054	35.39823009		0.074	0.054	35.39823009
0.074	0.053	37.16814159		0.074	0.052	38.9380531
0.074	0.051	40.7079646		0.074	0.053	37.16814159
	Average	36.33			Average	37.52
Fluorocarbon V747						
Jet A1				Bio50		
To	Ti	Compression Set		To	Ti	Compression Set
0.075	0.044	53.91304348		0.075	0.042	57.39130435
0.075	0.039	62.60869565		0.075	0.04	60.86956522
0.075	0.041	59.13043478		0.075	0.045	52.17391304
0.075	0.041	59.13043478		0.075	0.042	57.39130435
0.075	0.047	48.69565217		0.075	0.041	59.13043478
	Average	56.70			Average	57.39

Pencil Hardness and Tape Adhesion ASTM D3363 and D3359 – Jet A1

825X309	No scratch to Metal	No scratch on surface
Specimen 1	3H	3H
Specimen 2	4H	4H
Specimen 3	4H	3H
EC776		
Specimen 1	B	2B
Specimen 2	B	2B
Specimen 3	HB	B

Pencil Hardness 825X309 & EC776 JetA1

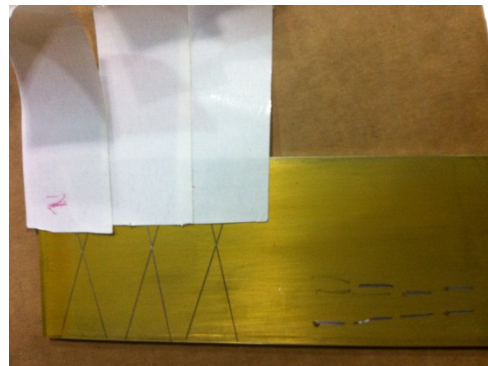
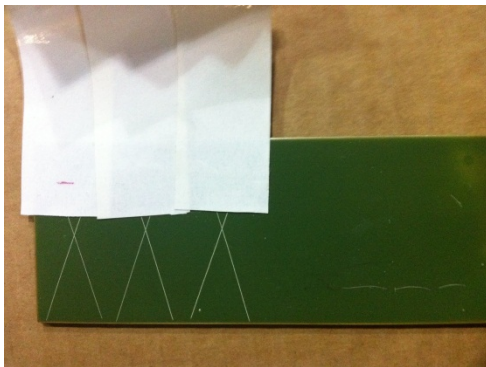


Tape Adhesion and Scratch Hardness 825X309 & EC776 Respectively JetA1

Pencil Hardness and Tape Adhesion ASTM D3363 and D3359 - Bio 50/50

825X309	No scratch to Metal	No scratch on surface
Specimen 1	3H	3H
Specimen 2	3H	3H
Specimen 3	3H	3H
EC776		
Specimen 1	HB	HB
Specimen 2	HB	HB
Specimen 3	F	F

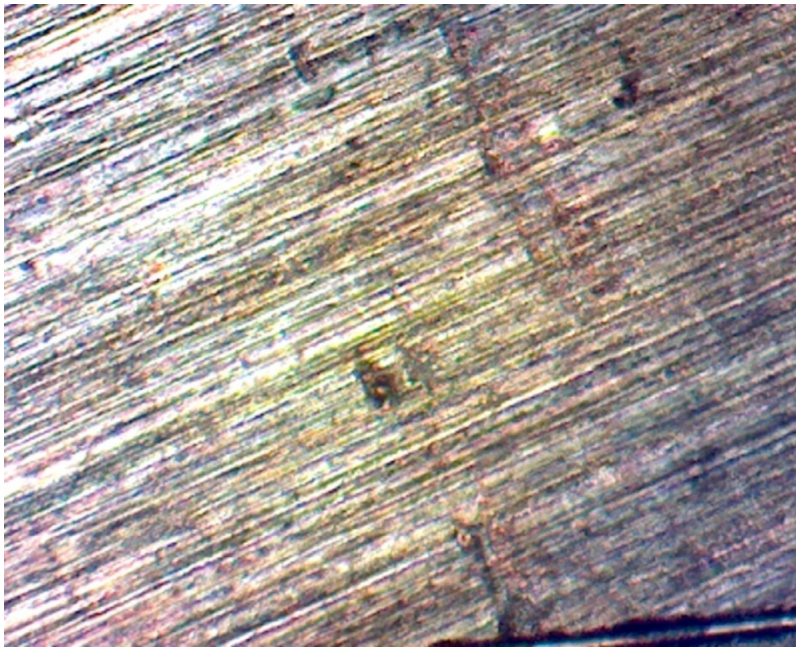
Pencil Hardness 825X309 & EC776 Bio50



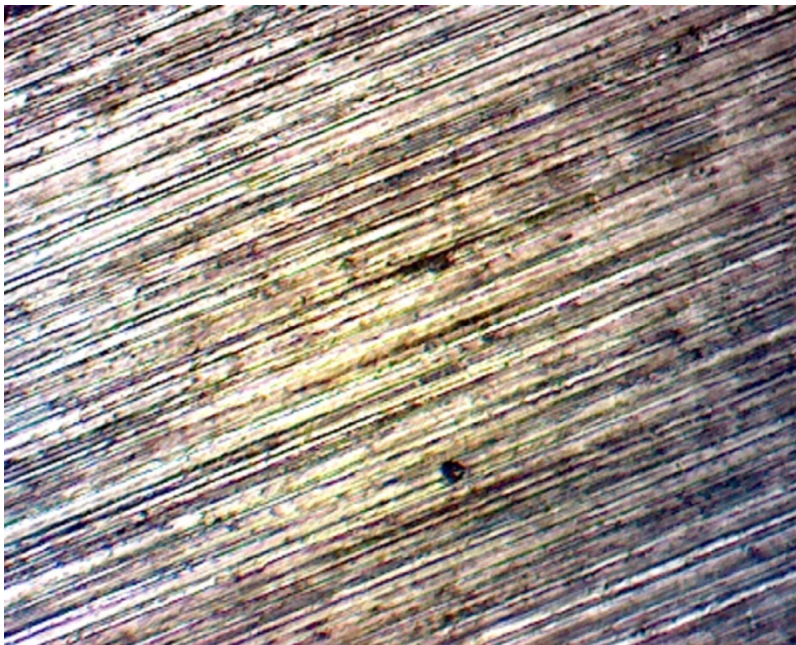
Tape Adhesion and Scratch Hardness 825X309 & EC776 Respectively Bio50

Metallic Surface Evaluation Images 40X ASTM D4054

Jet A1 – 2024 T3



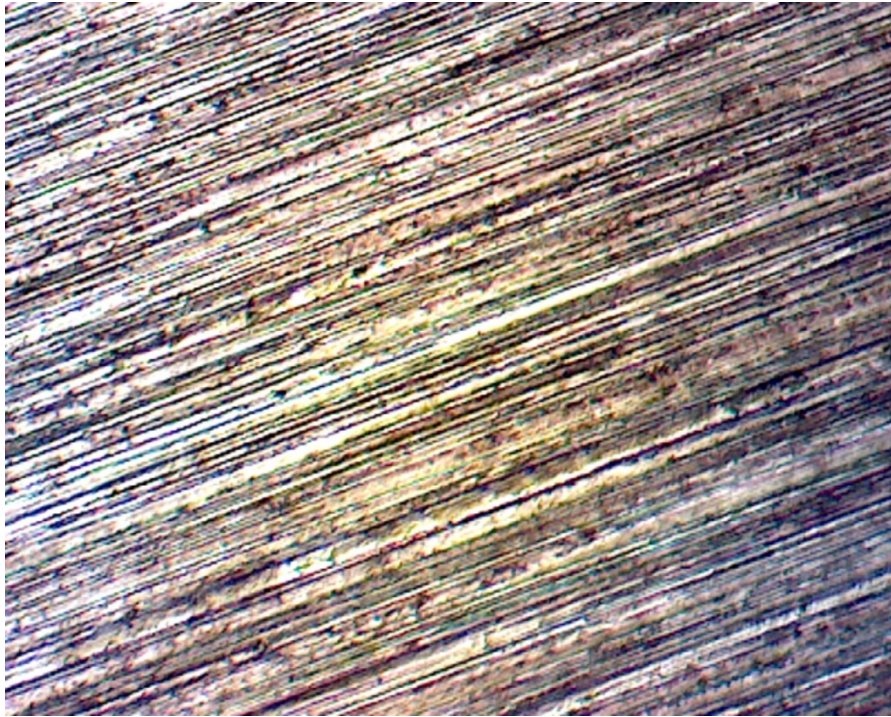
2024T3 JetA1 40X Magnification - Specimen 1



2024T3 JetA1 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

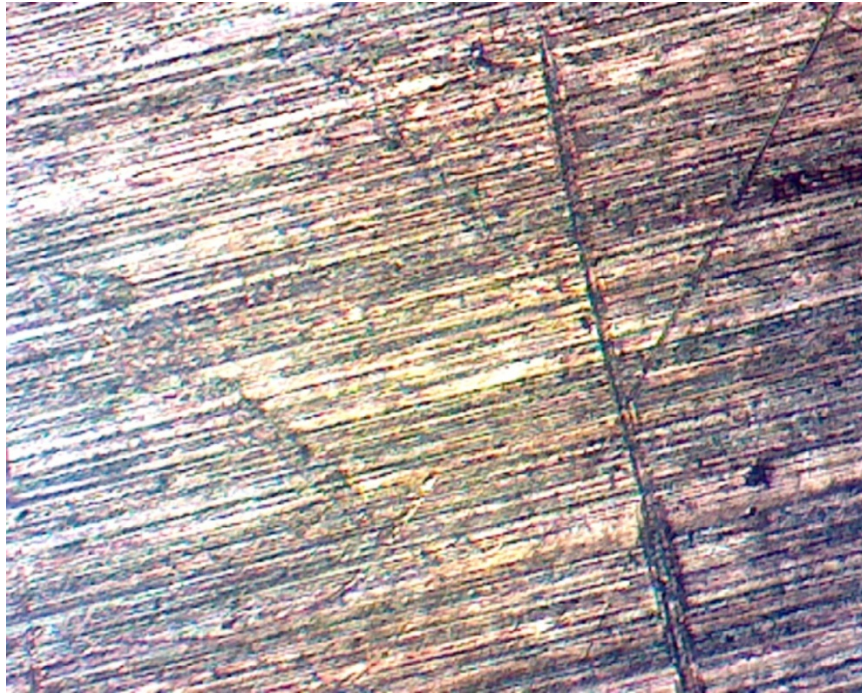
Jet A1 – 2024 T3



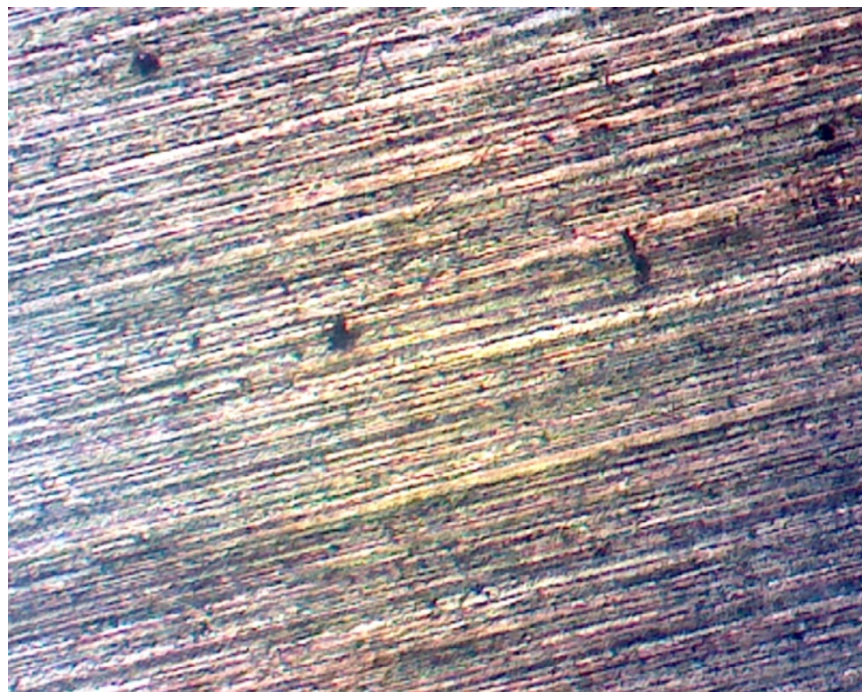
2024T3 JetA1 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Biofuel 50/50 – 2024 T3



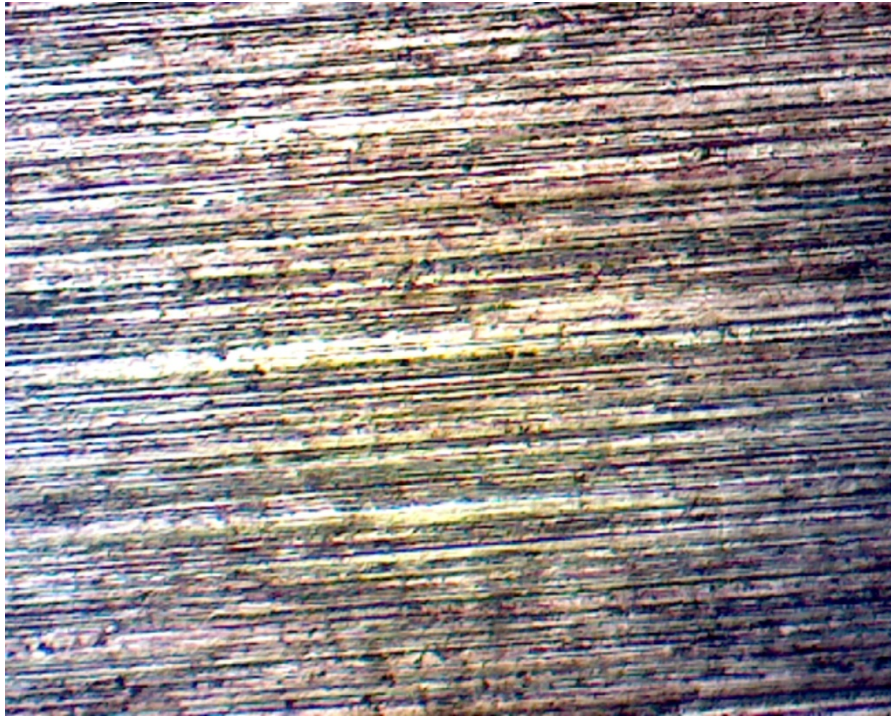
2024T3 Bio50 40X Magnification - Specimen 1



2024T3 Bio50 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

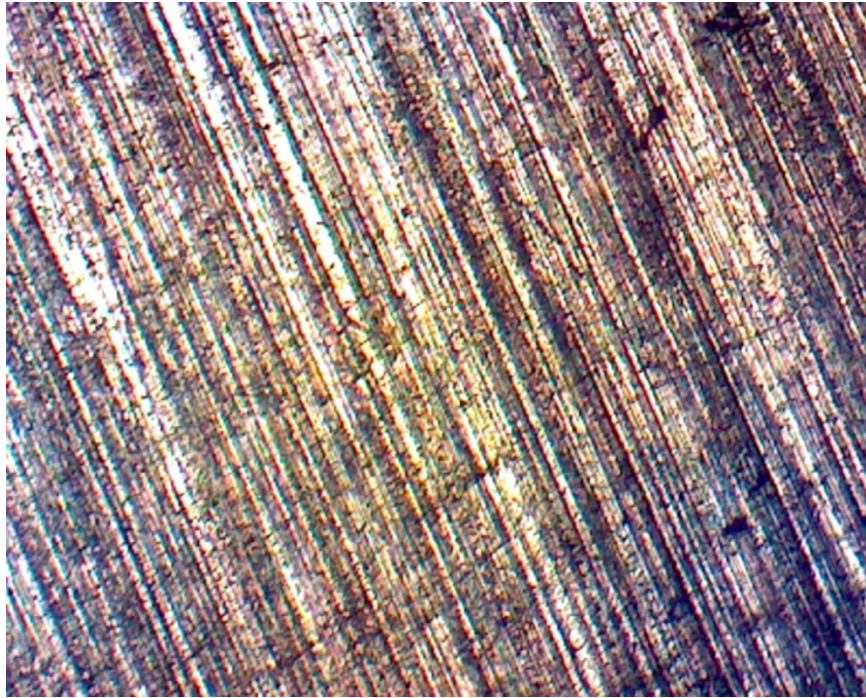
Biofuel 50/50 – 2024 T3



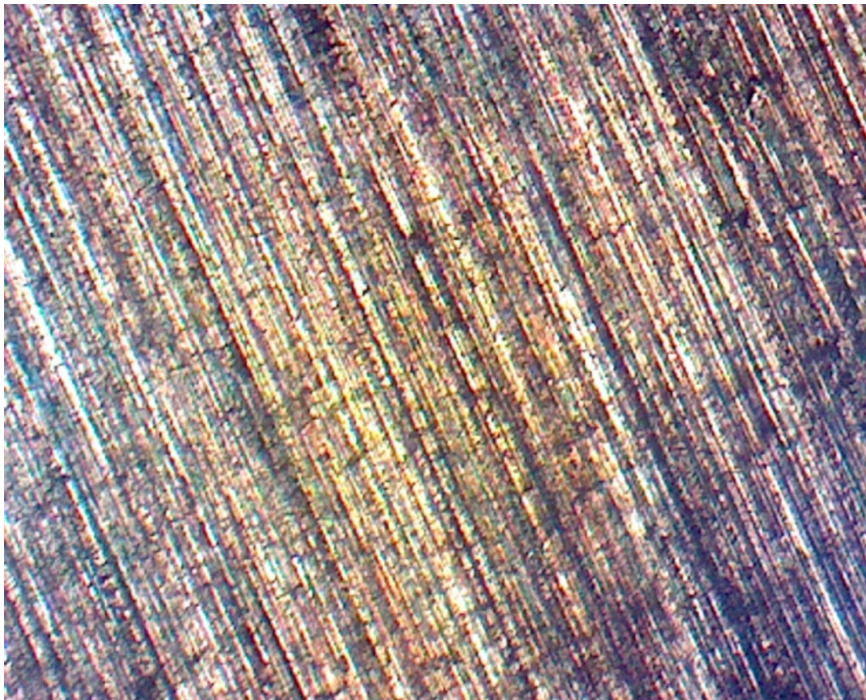
2024T3 Bio50 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Jet A1 – 6061 T6



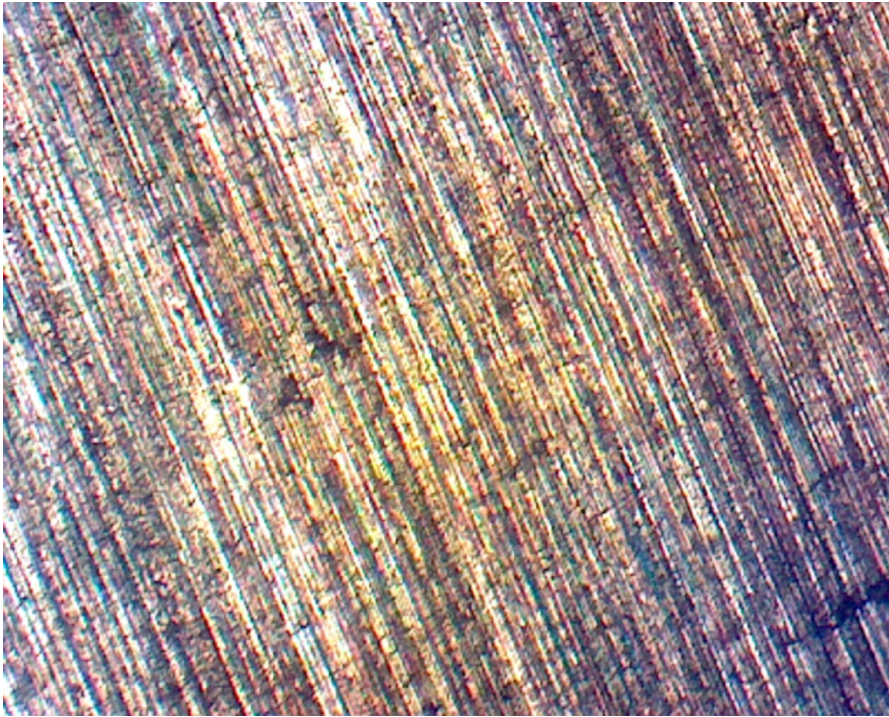
6061T6 JetA1 40X Magnification - Specimen 1



6061T6 JetA1 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

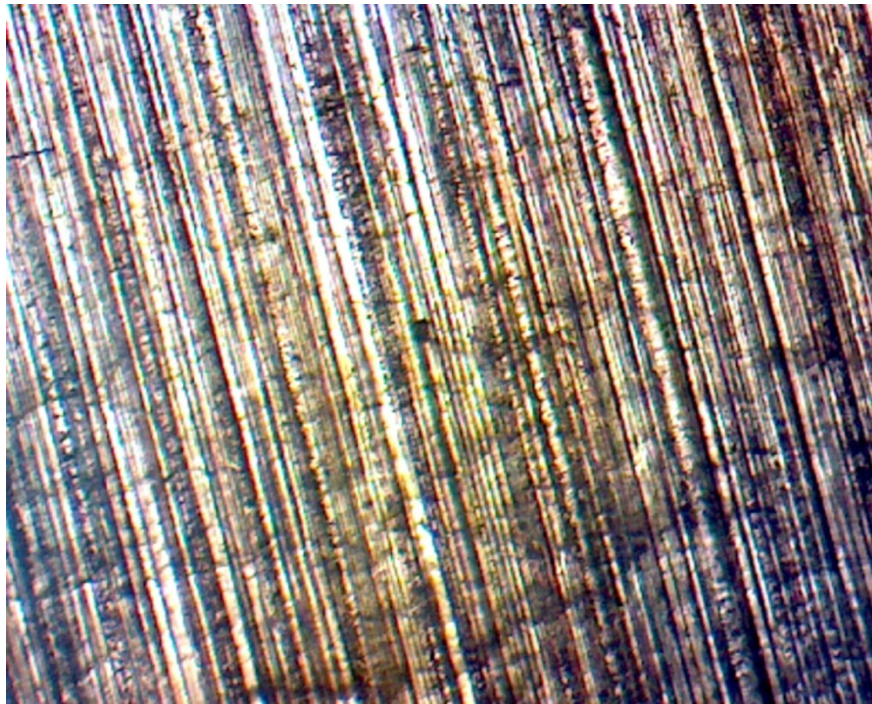
Jet A1 – 6061 T6



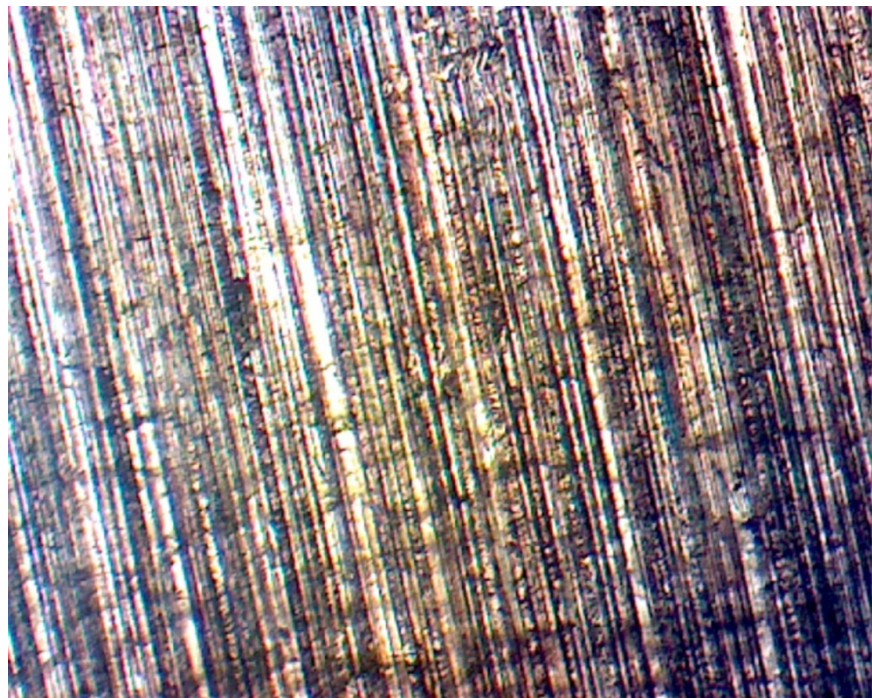
6061T6 JetA1 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Biofuel 50/50 – 6061 T6



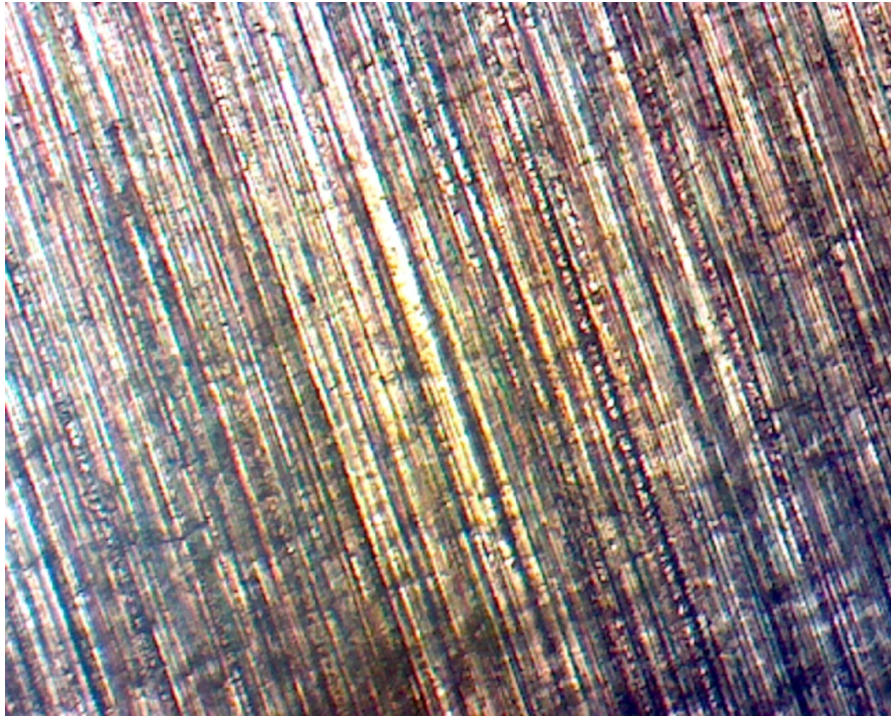
6061T6 Bio50 40X Magnification - Specimen 1



6061T6 Bio50 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

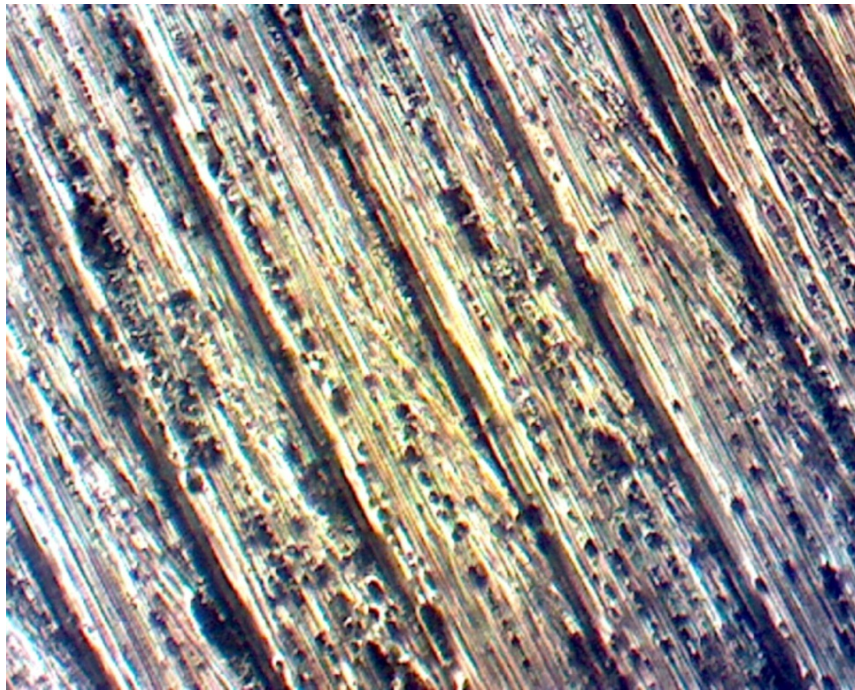
Biofuel 50/50 – 6061 T6



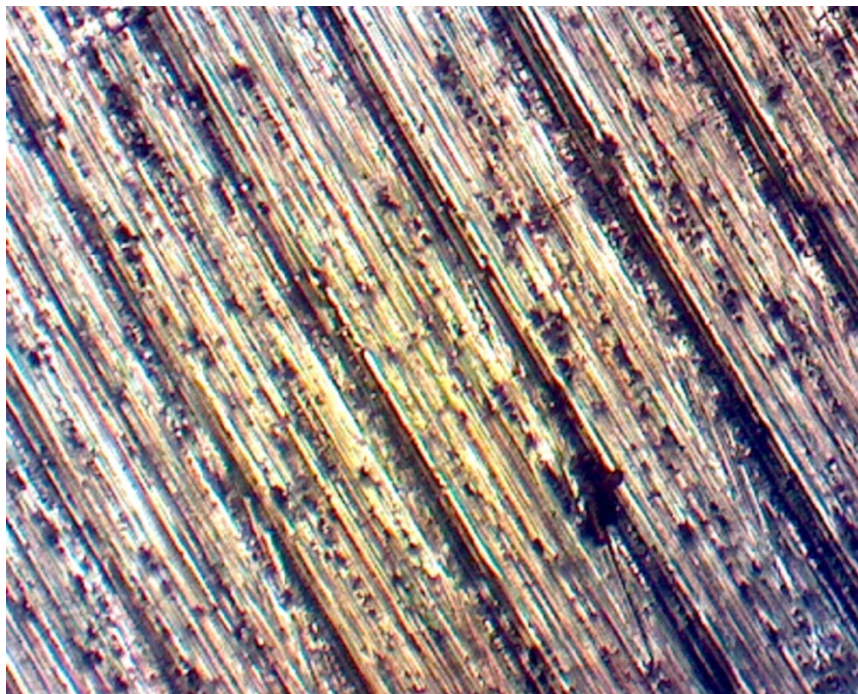
6061T6 Bio50 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Jet A1 – 7076 Chromate Conversion Coating



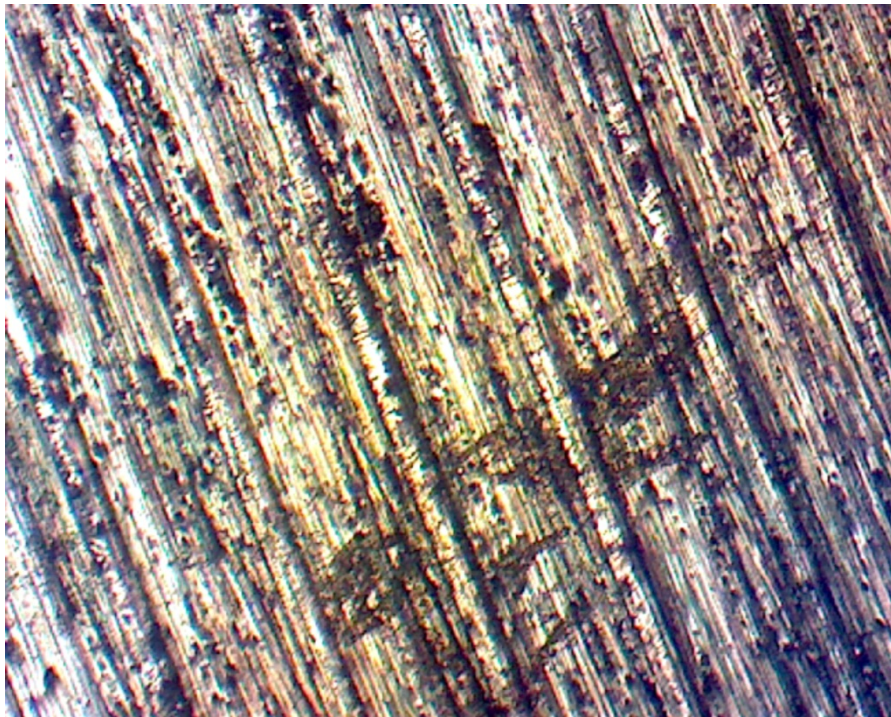
7076 Chromate Coating JetA1 40X Magnification - Specimen 1



7076 Chromate Coating JetA1 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

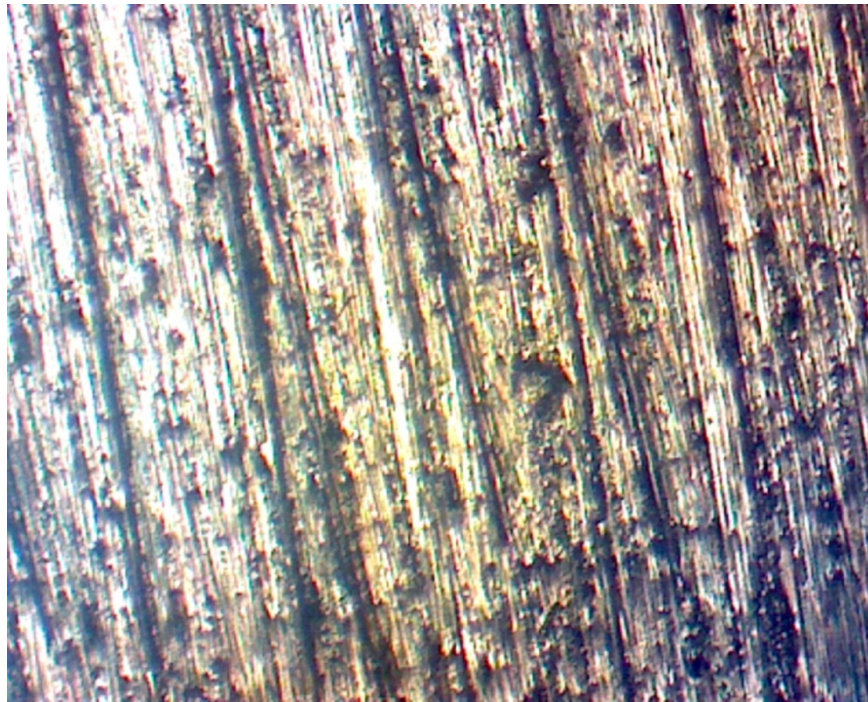
Jet A1 – 7076 Chromate Conversion Coating



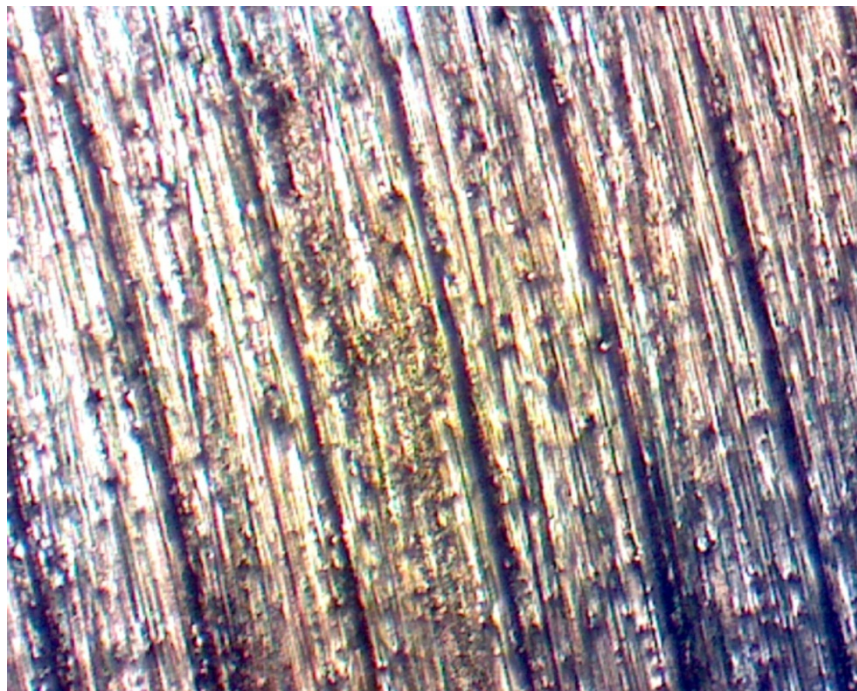
7076 Chromate Coating JetA1 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Biofuel 50/50 – 7076 Chromate Conversion Coating



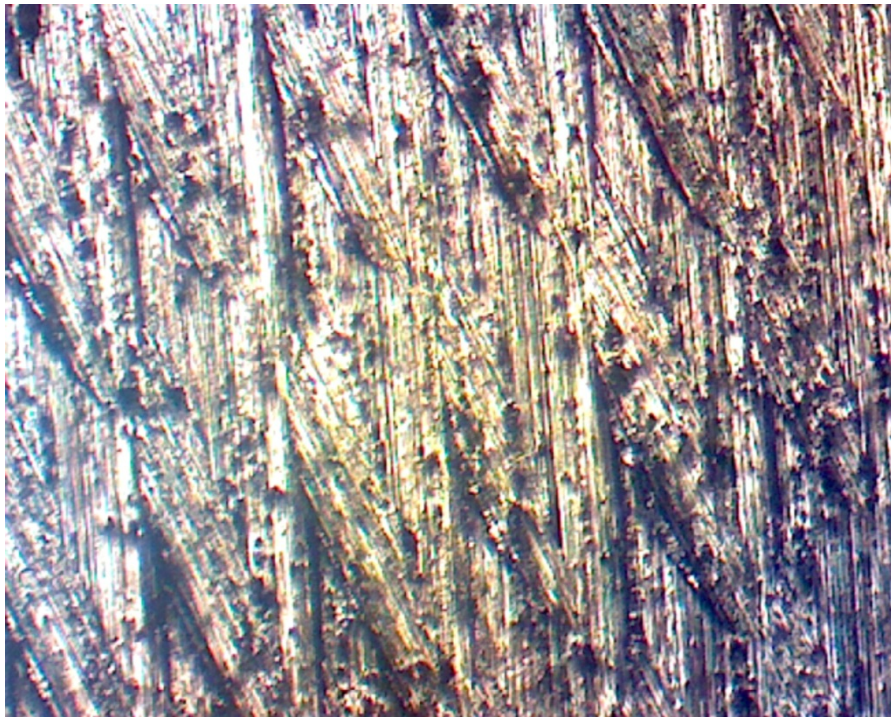
7076 Chromate Coating Bio50 40X Magnification - Specimen 1



7076 Chromate Coating Bio50 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

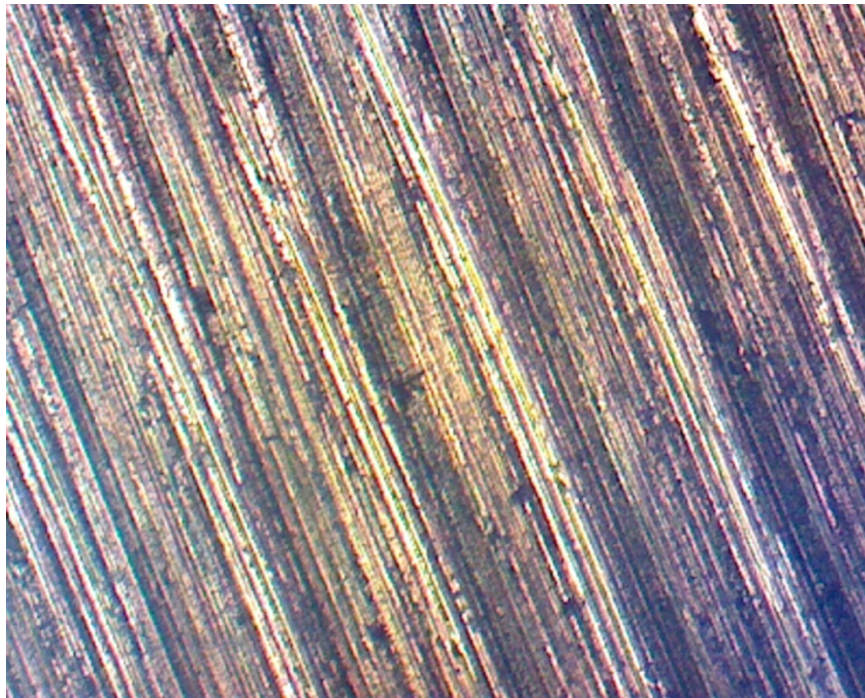
Biofuel 50/50 – 7076 Chromate Conversion Coating



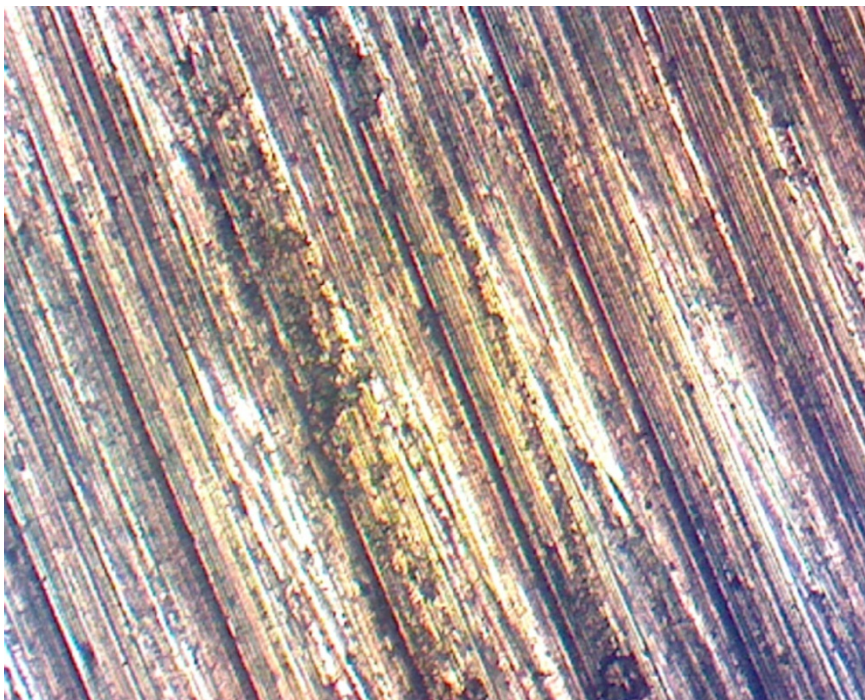
7076 Chromate Coating Bio50 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Jet A1 – 7076 Chromic Acid Coating



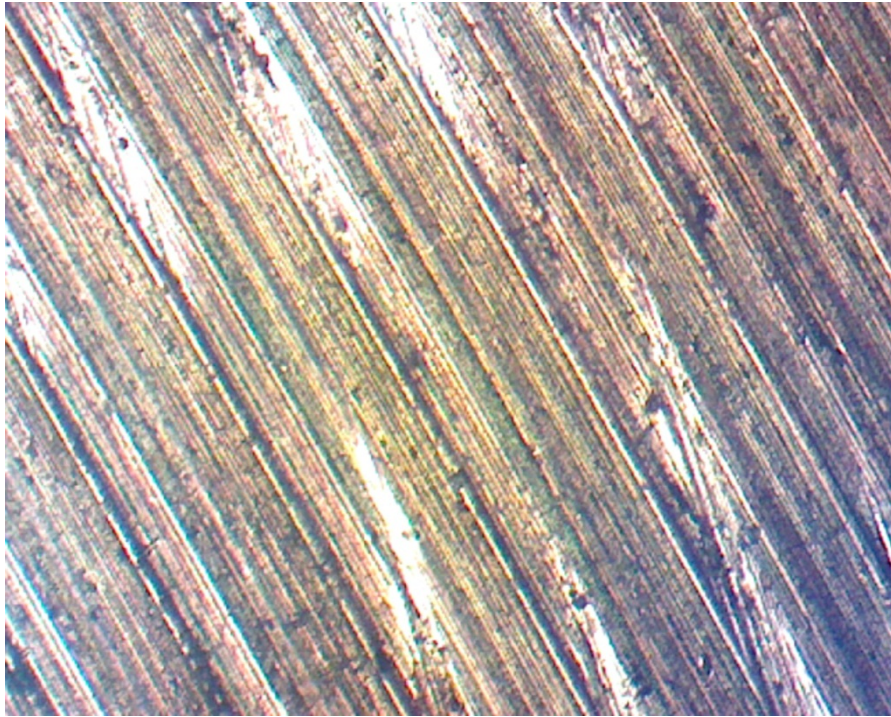
7076 Chromic Acid Coating JetA1 40X Magnification - Specimen 1



7076 Chromic Acid Coating JetA1 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

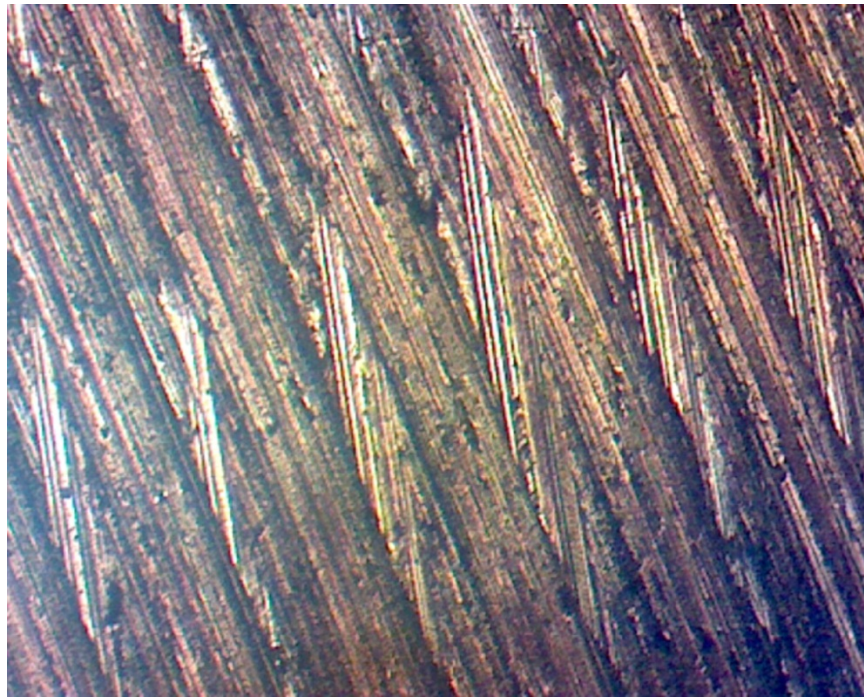
Jet A1 – 7076 Chromic Acid Coating



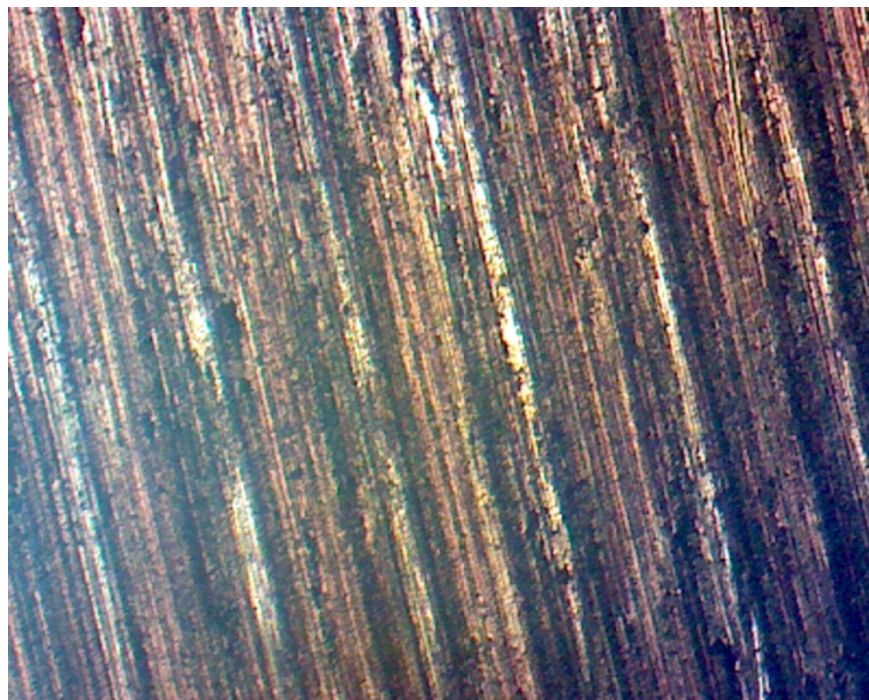
7076 Chromic Acid Coating JetA1 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Biofuel 50/50 – 7076 Chromic Acid Coating



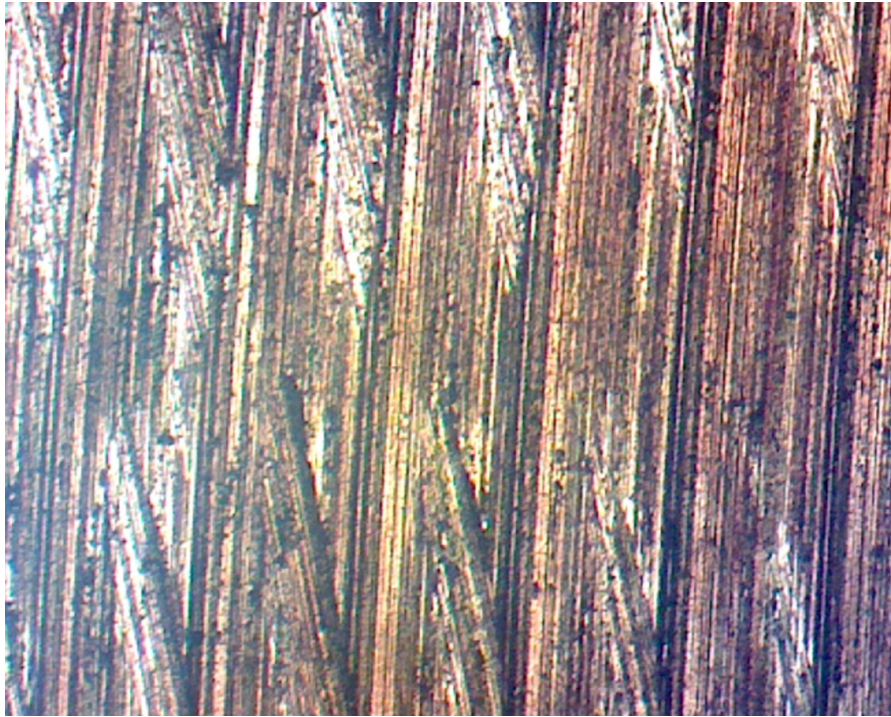
7076 Chromic Acid Coating Bio50 40X Magnification - Specimen 1



7076 Chromic Acid Coating Bio50 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

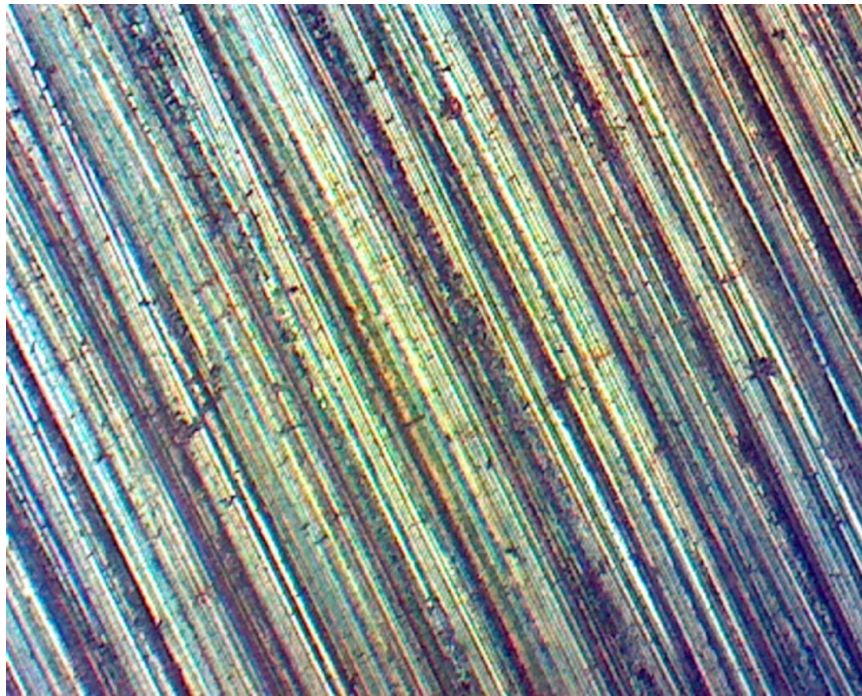
Biofuel 50/50 – 7076 Chromic Acid Coating



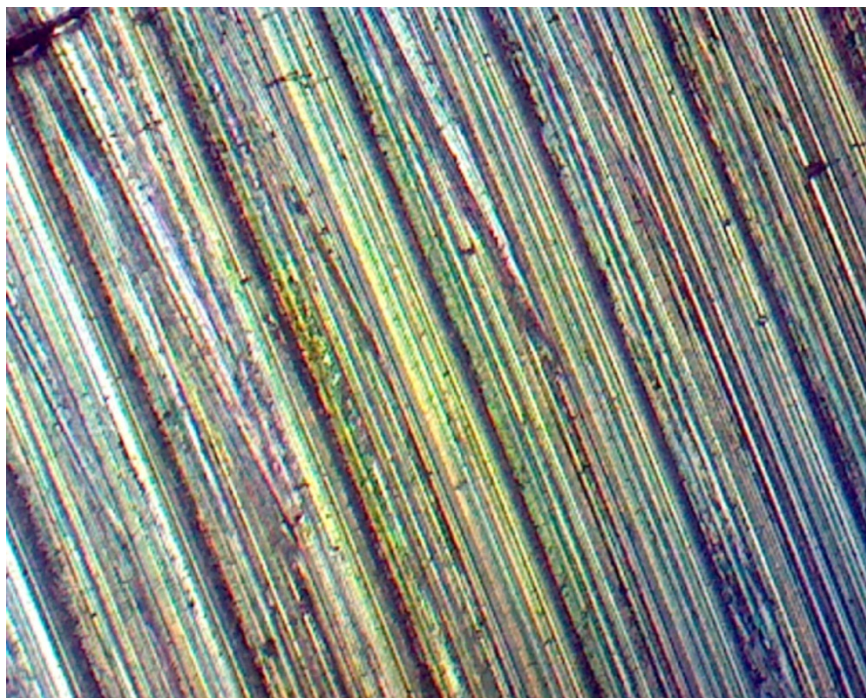
7076 Chromic Acid Coating Bio50 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Jet A1 – 7076 Sulfuric Acid Coating



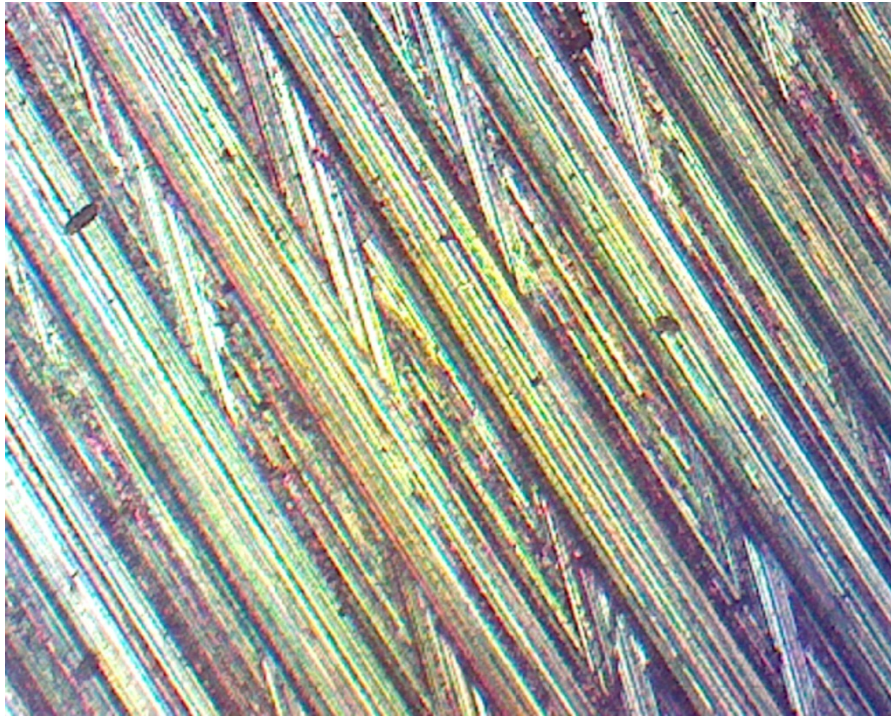
7076 Sulfuric Acid Coating JetA1 40X Magnification - Specimen 1



7076 Sulfuric Acid Coating JetA1 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

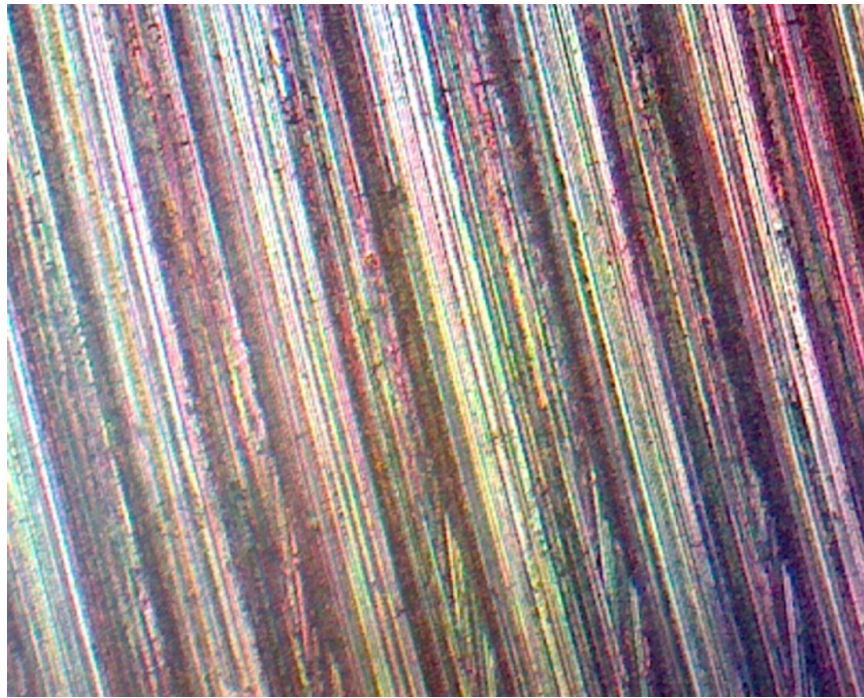
Jet A1 – 7076 Sulfuric Acid Coating



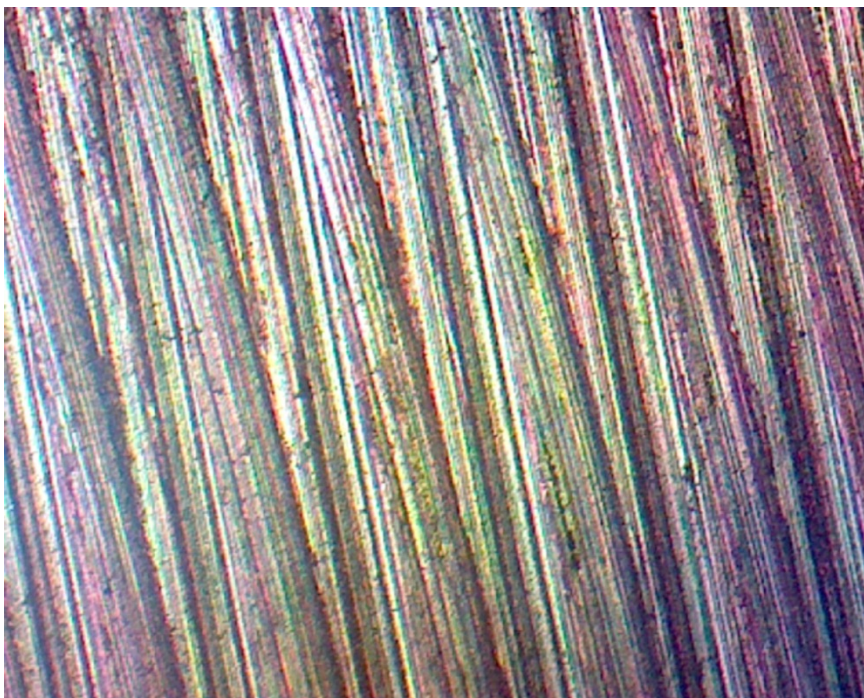
7076 Sulfuric Acid Coating JetA1 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Biofuel 50/50 – 7076 Sulfuric Acid Coating



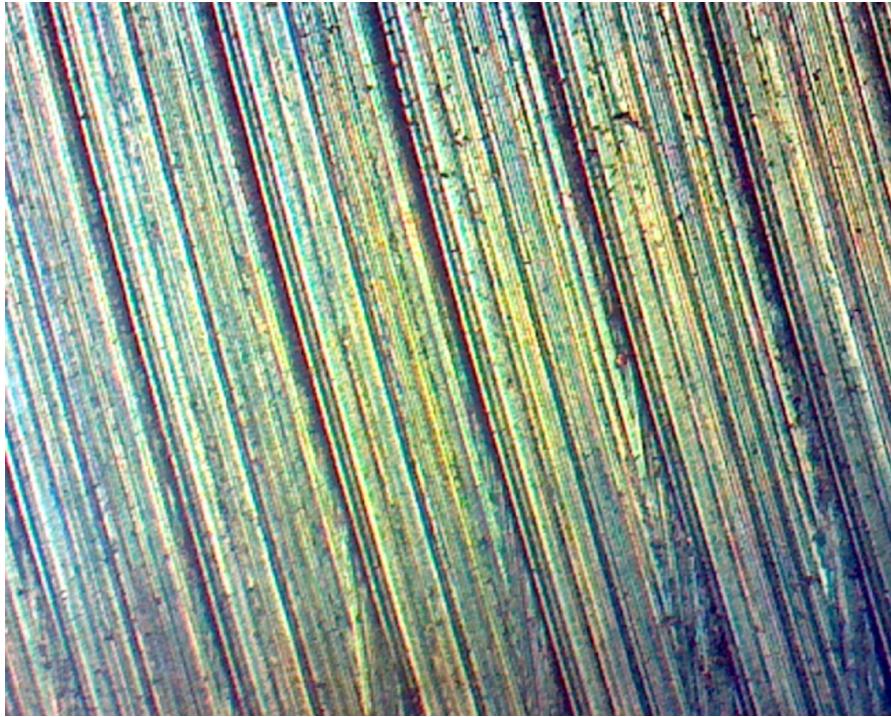
7076 Sulfuric Acid Coating Bio50 40X Magnification - Specimen 1



7076 Sulfuric Acid Coating Bio50 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

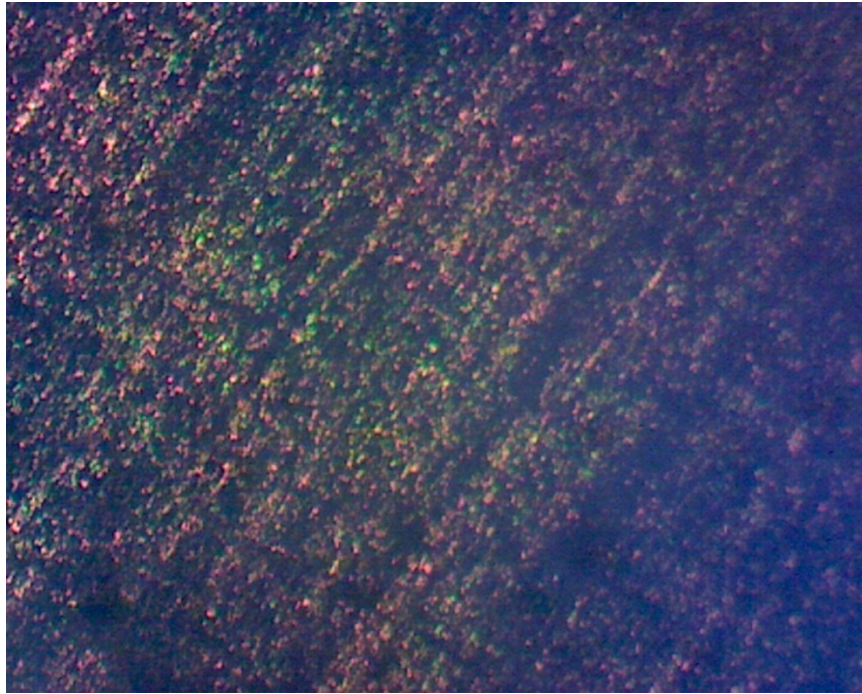
Biofuel 50/50 – 7076 Sulfuric Acid Coating



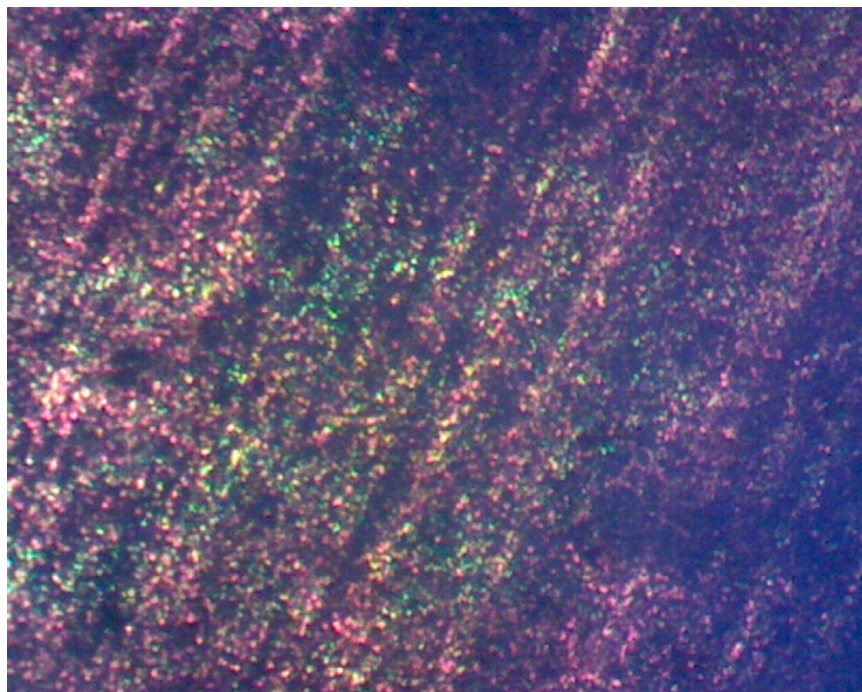
7076 Sulfuric Acid Coating Bio50 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Jet A1 – 17-4



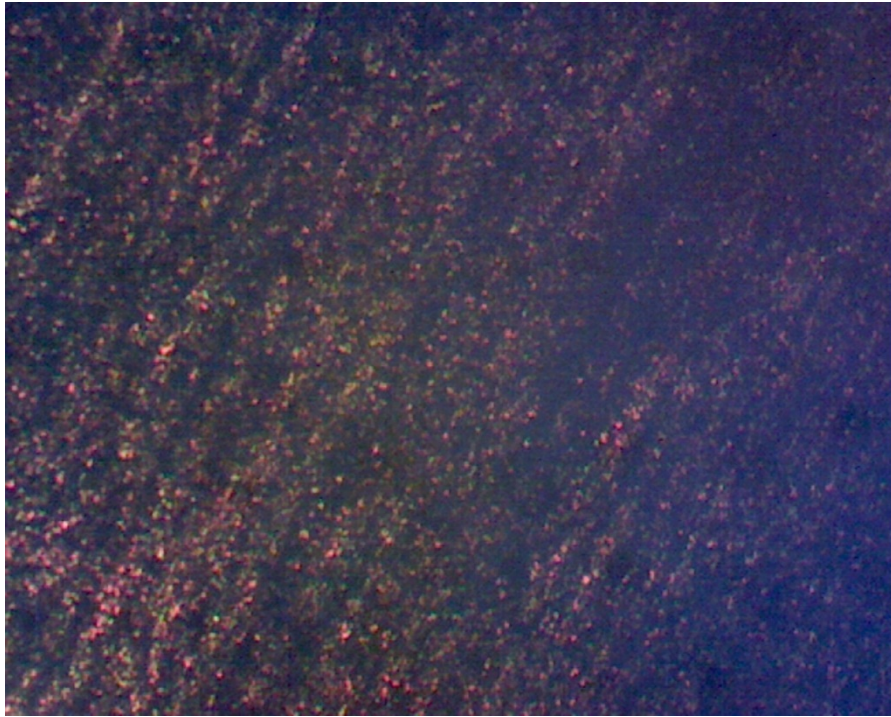
17-4 JetA1 40X Magnification - Specimen 1



17-4 JetA1 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

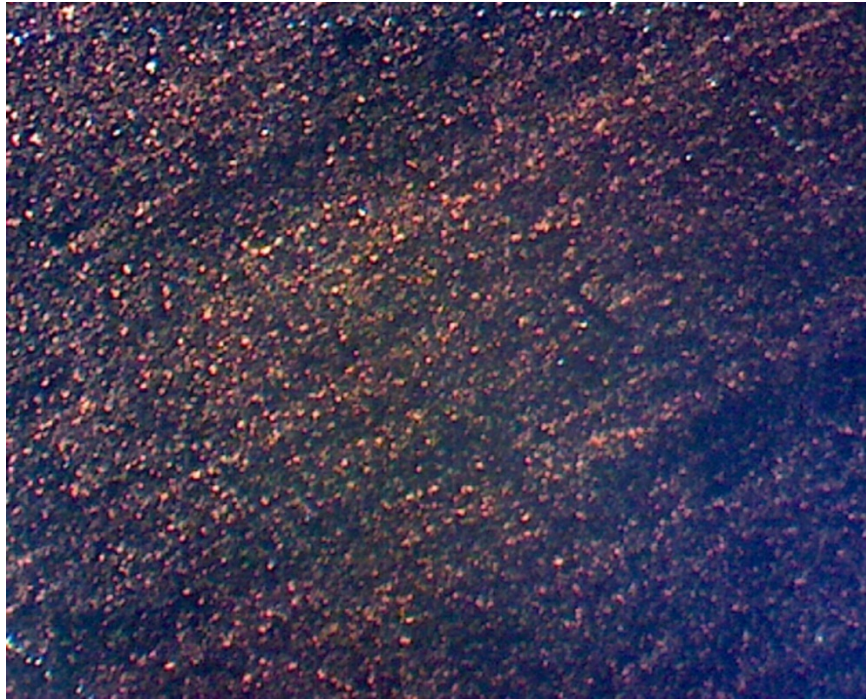
Jet A1 – 17-4



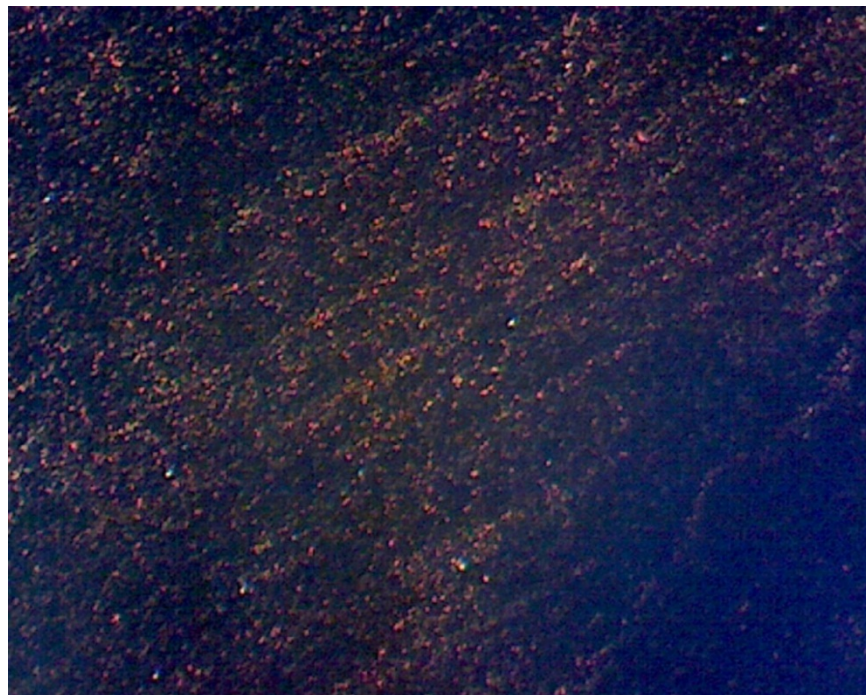
17-4 JetA1 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Biofuel 50/50 – 17-4



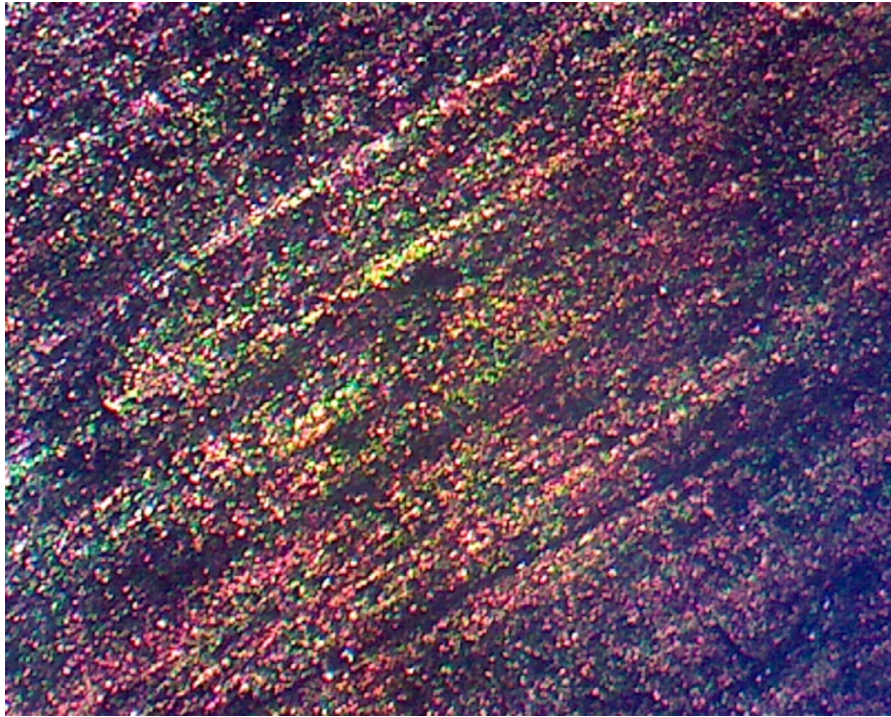
17-4 Bio50 40X Magnification - Specimen 1



17-4 Bio50 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

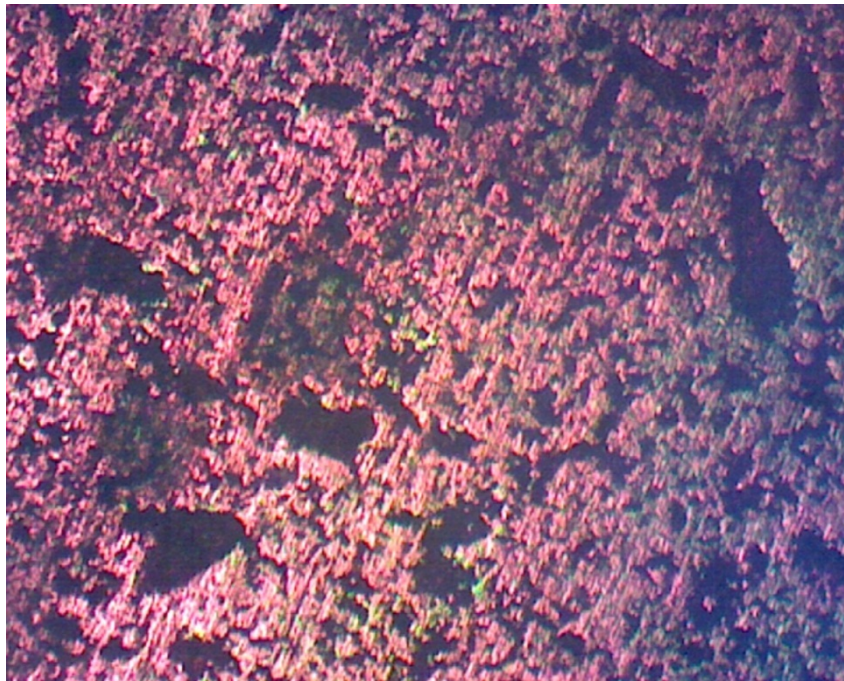
Biofuel 50/50 – 17-4



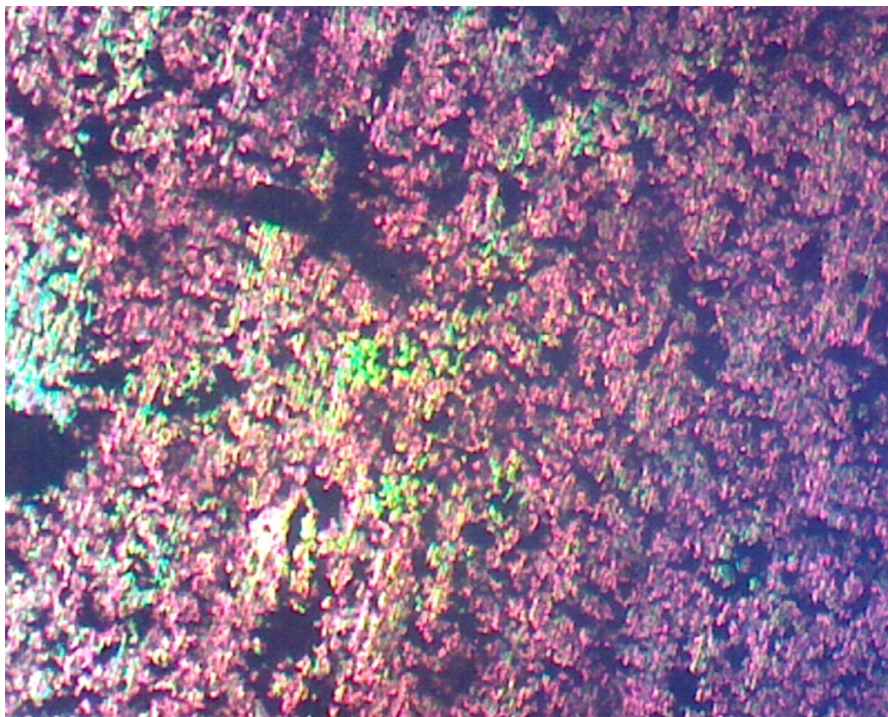
17-4 Bio50 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Jet A1 – 304-SS



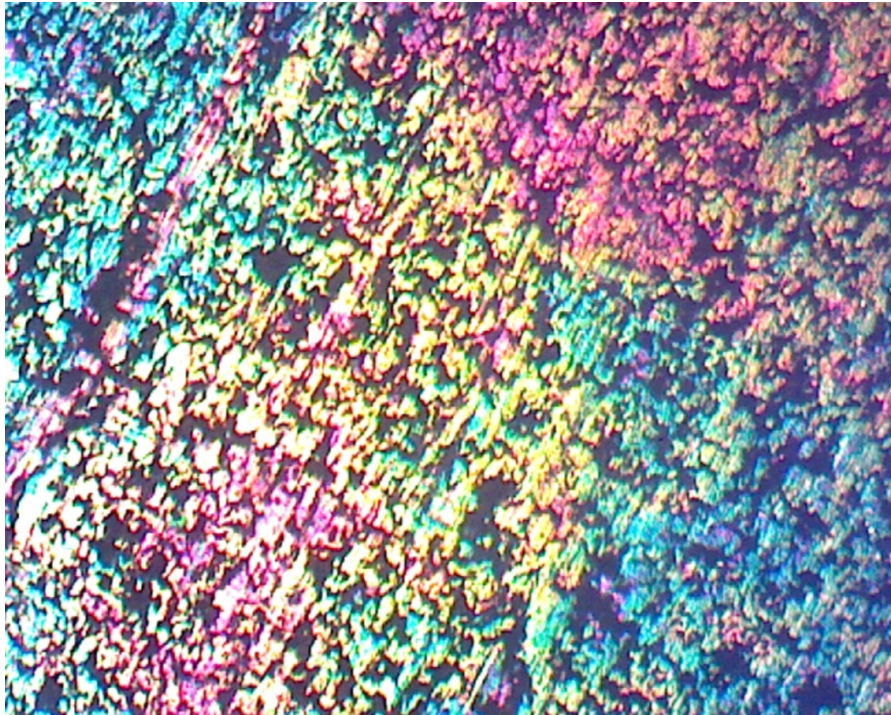
304-SS JetA1 40X Magnification - Specimen 1



304-SS JetA1 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

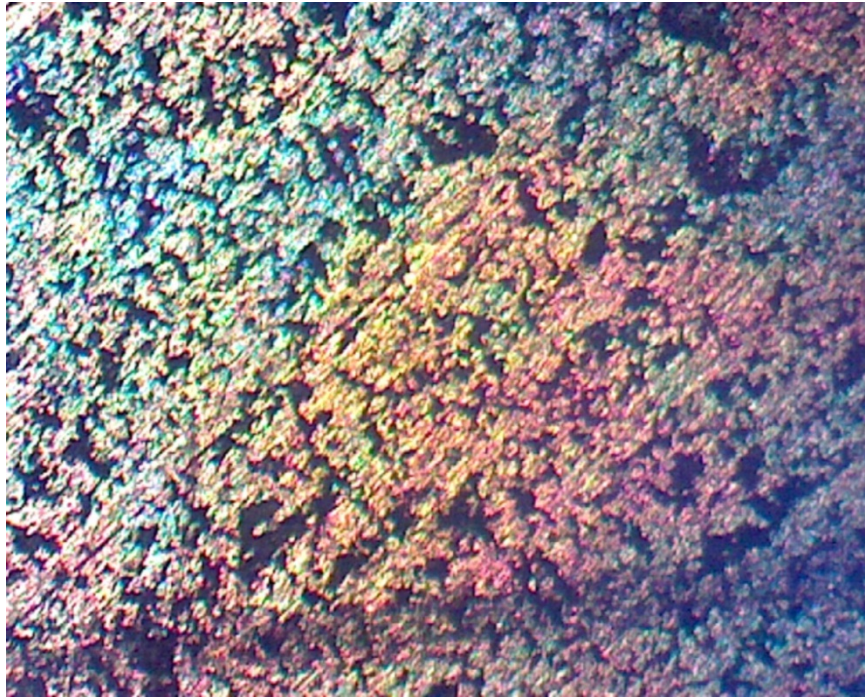
Jet A1 – 304-SS



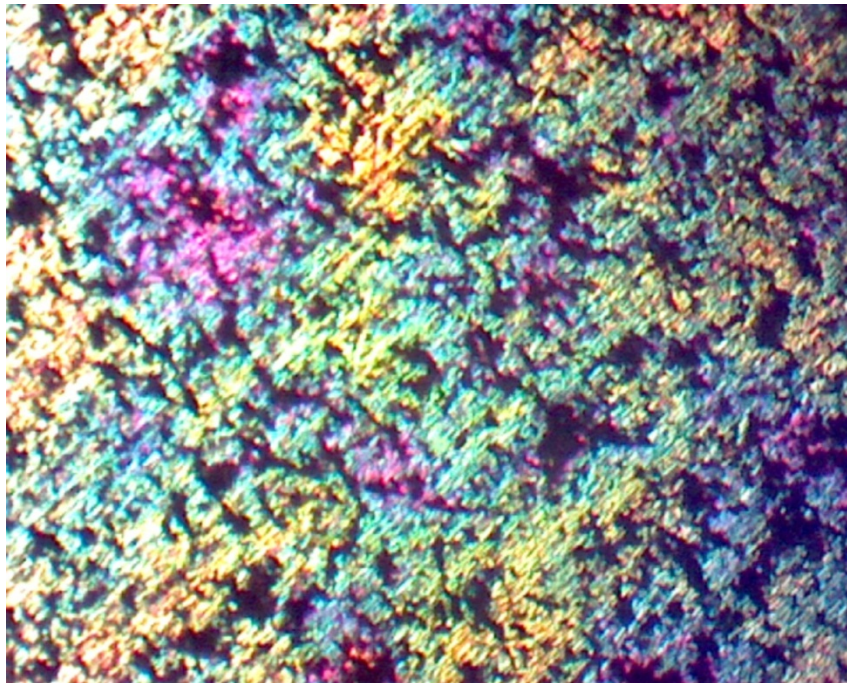
304-SS JetA1 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Biofuel 50/50 – 304-SS



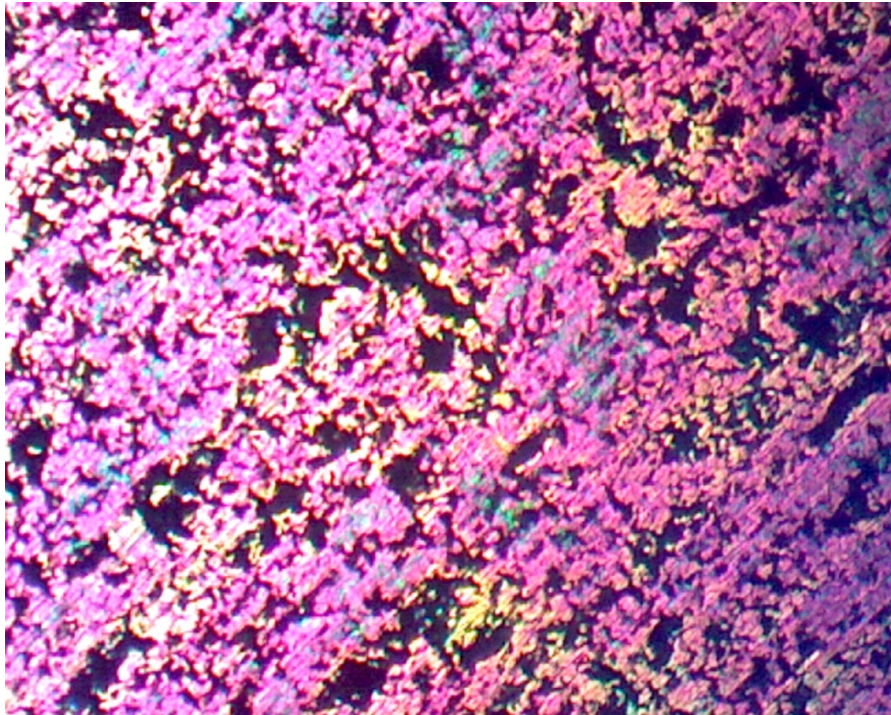
304-SS Bio50 40X Magnification - Specimen 1



304-SS Bio50 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

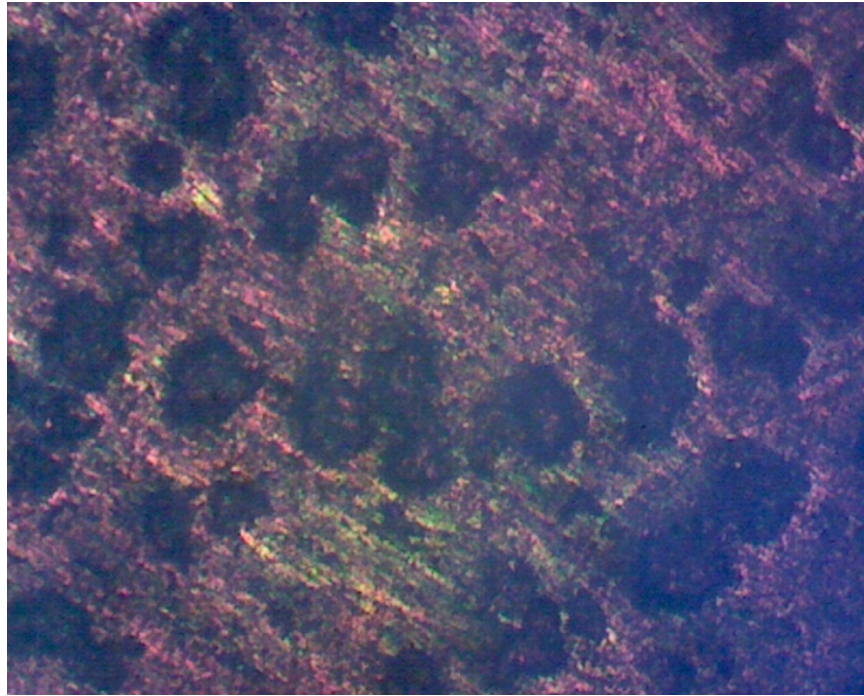
Biofuel 50/50 – 304-SS



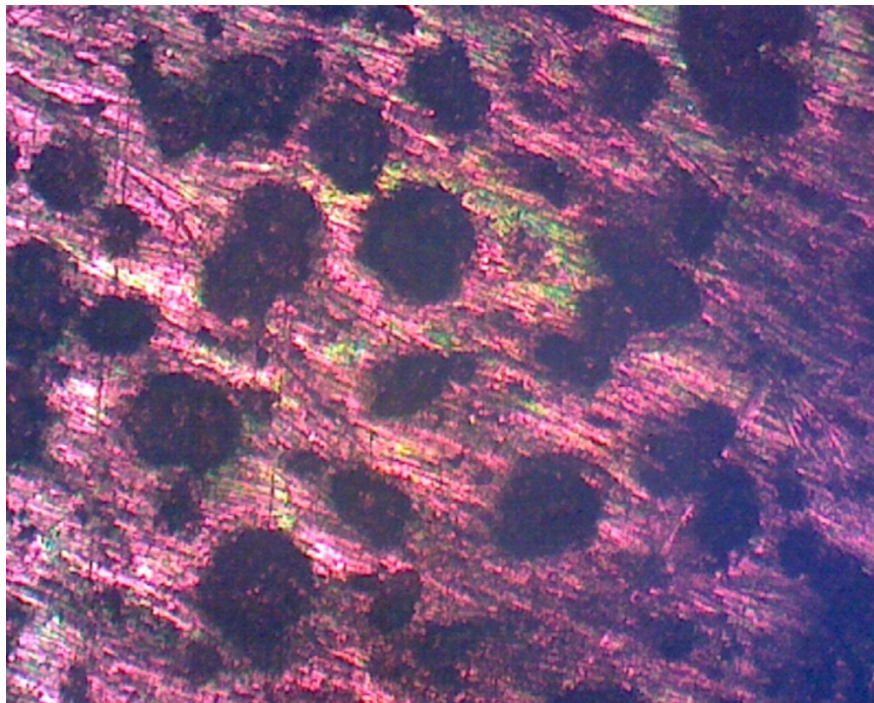
304-SS Bio50 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Jet A1 – Inconel 625



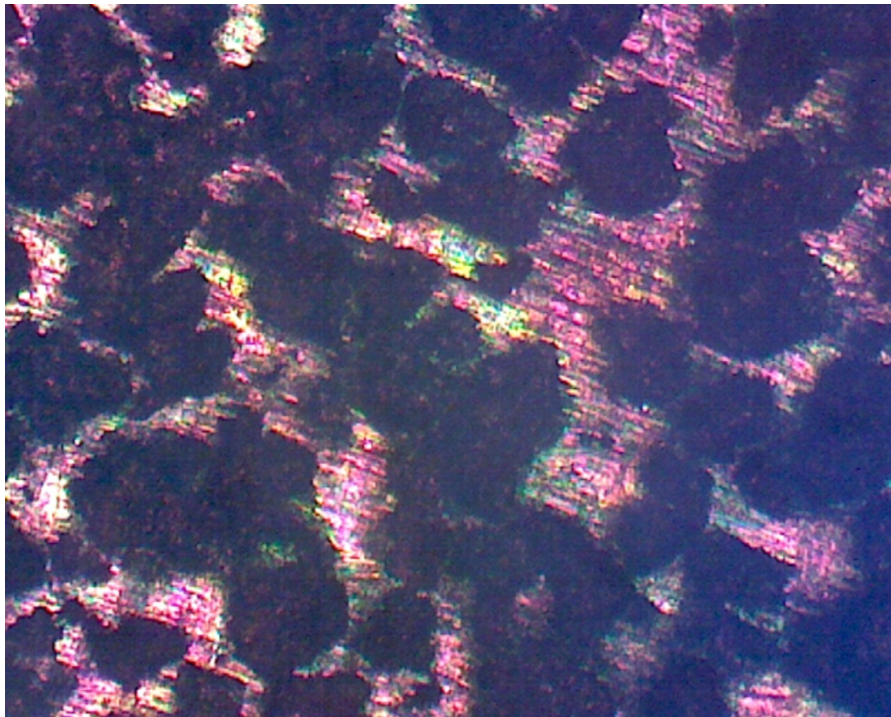
Inconel 625 JetA1 40X Magnification - Specimen 1



Inconel 625 JetA1 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

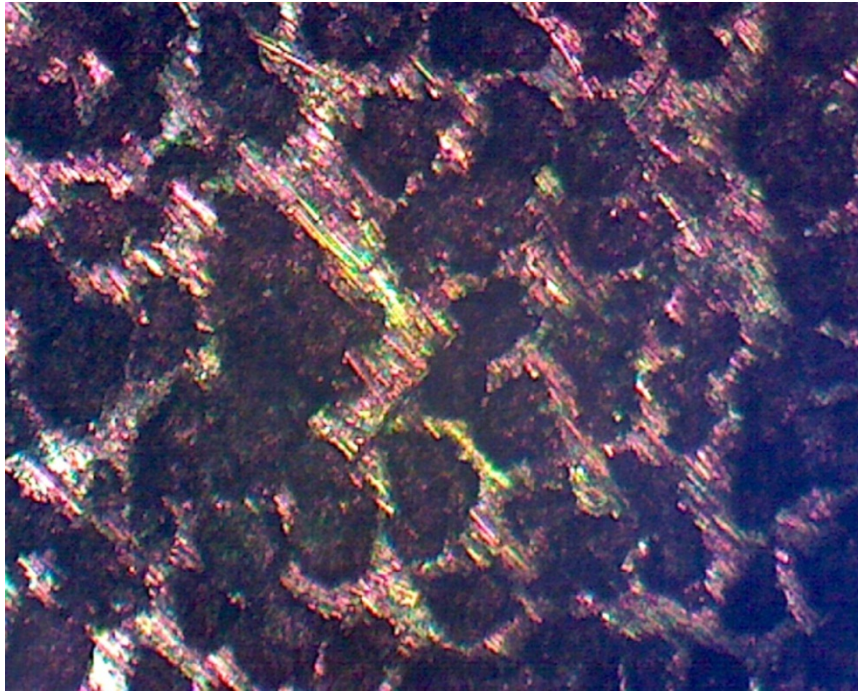
Jet A1 – Inconel 625



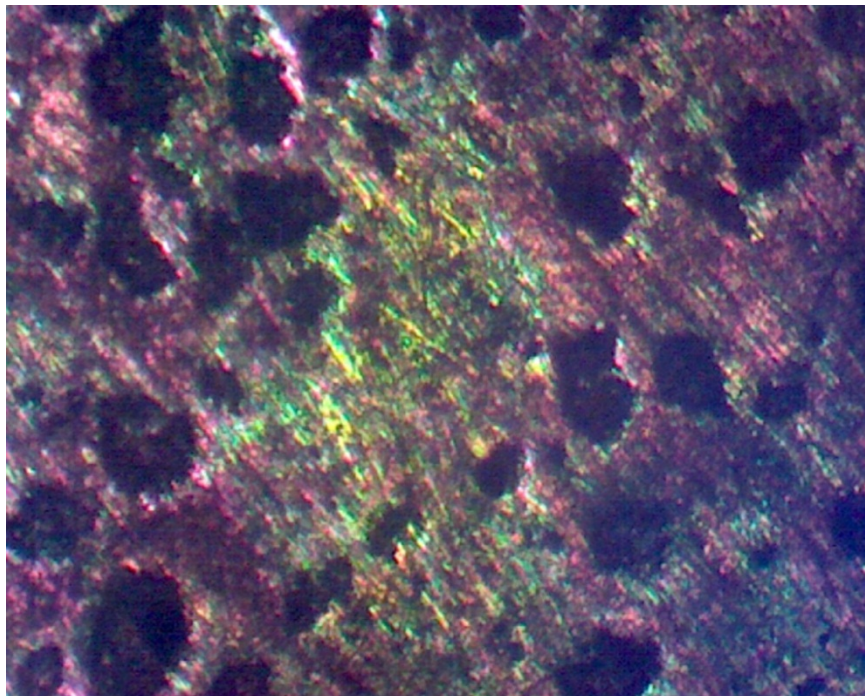
Inconel 625 JetA1 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Biofuel 50/50 – Inconel 625



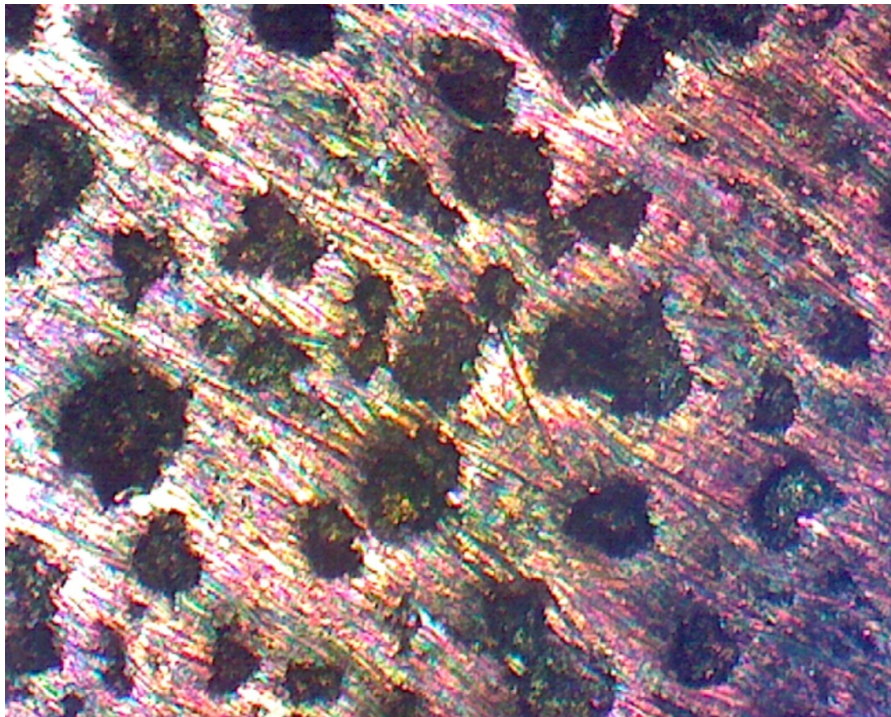
Inconel 625 Bio50 40X Magnification - Specimen 1



Inconel 625 Bio50 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

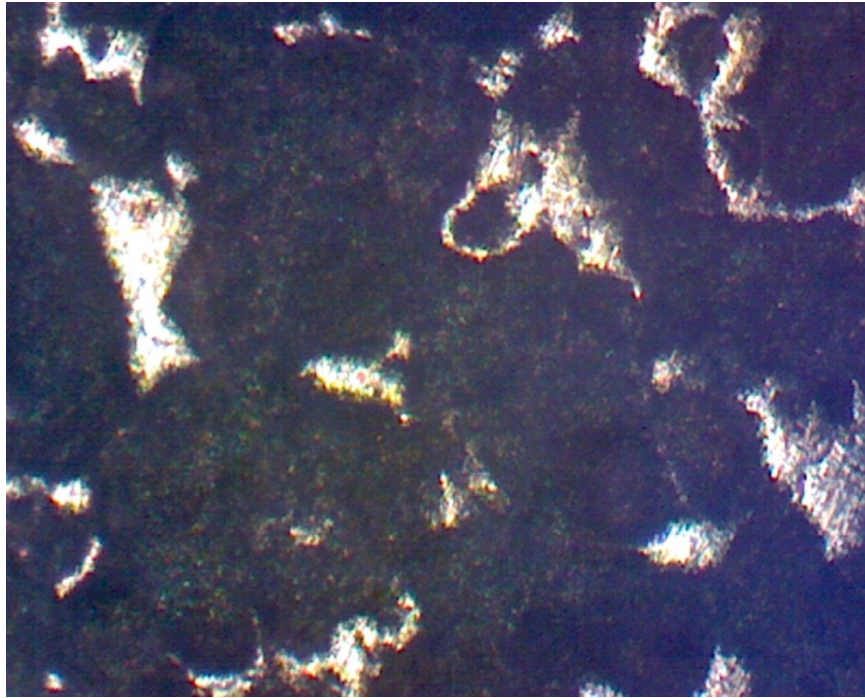
Biofuel 50/50 – Inconel 625



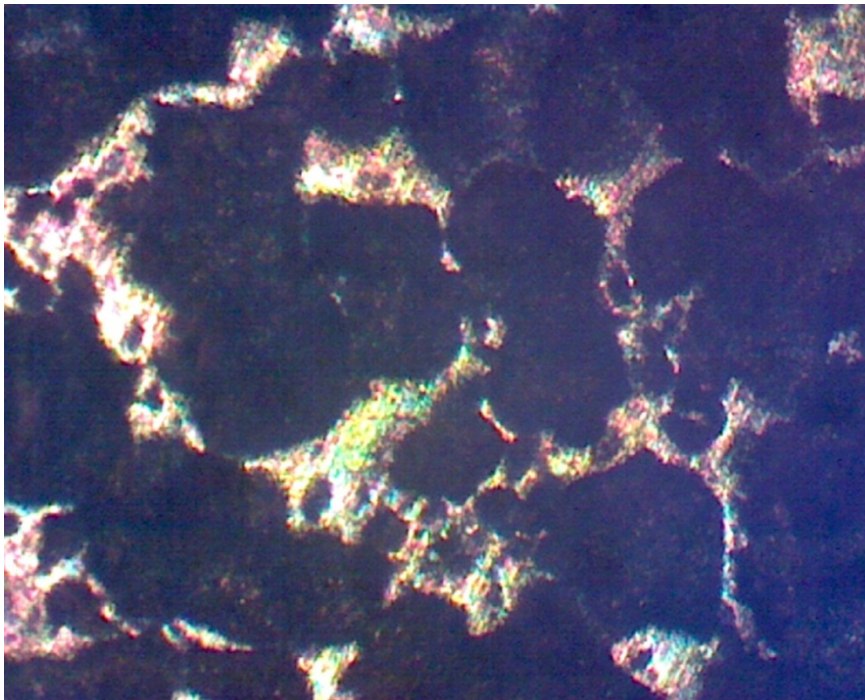
Inconel 625 Bio50 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Jet A1 – Inconel 718



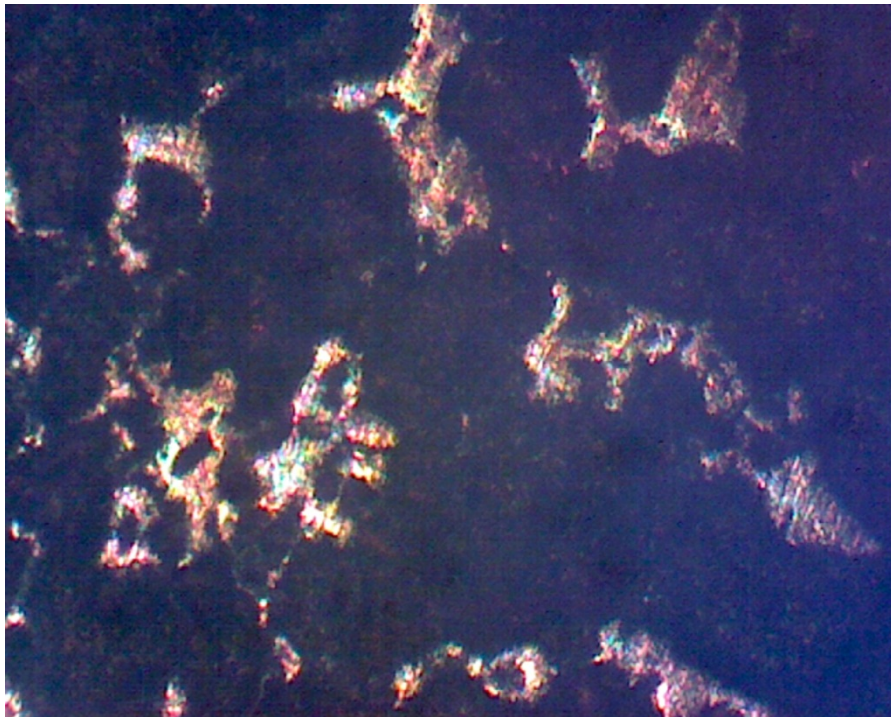
Inconel 718 JetA1 40X Magnification - Specimen 1



Inconel 718 JetA1 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

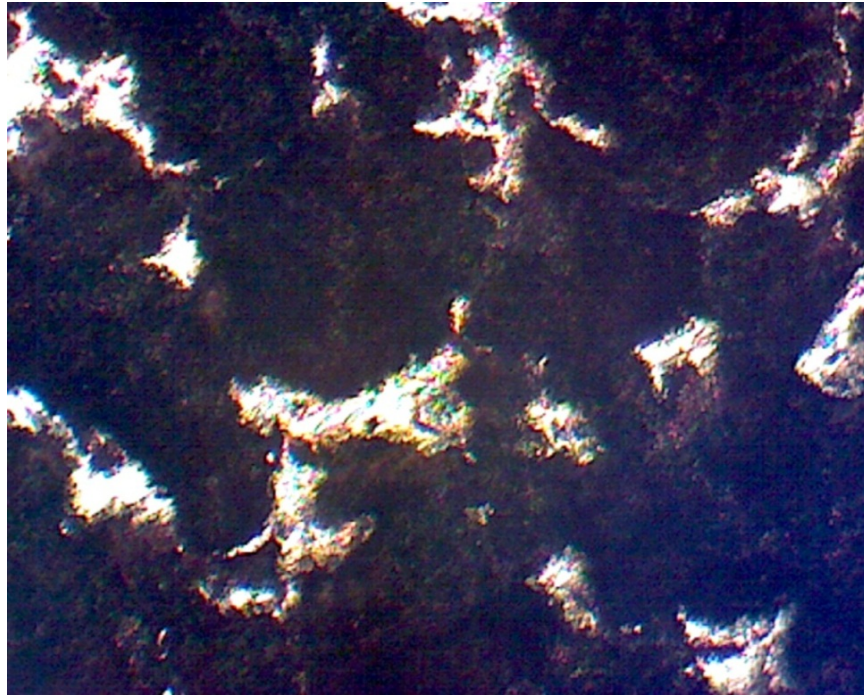
Jet A1 – Inconel 718



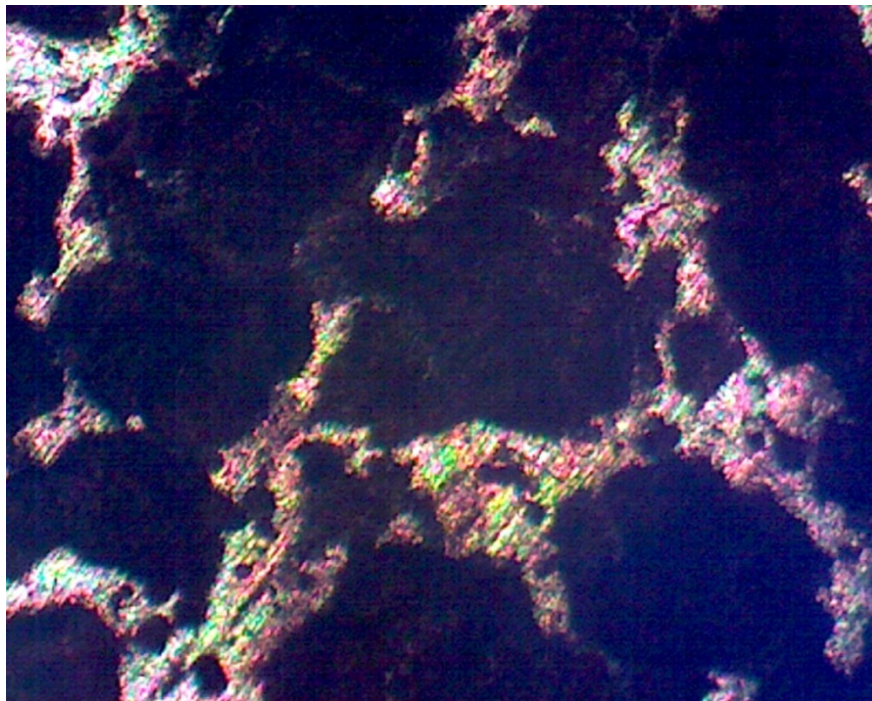
Inconel 718 JetA1 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Biofuel 50/50 – Inconel 718



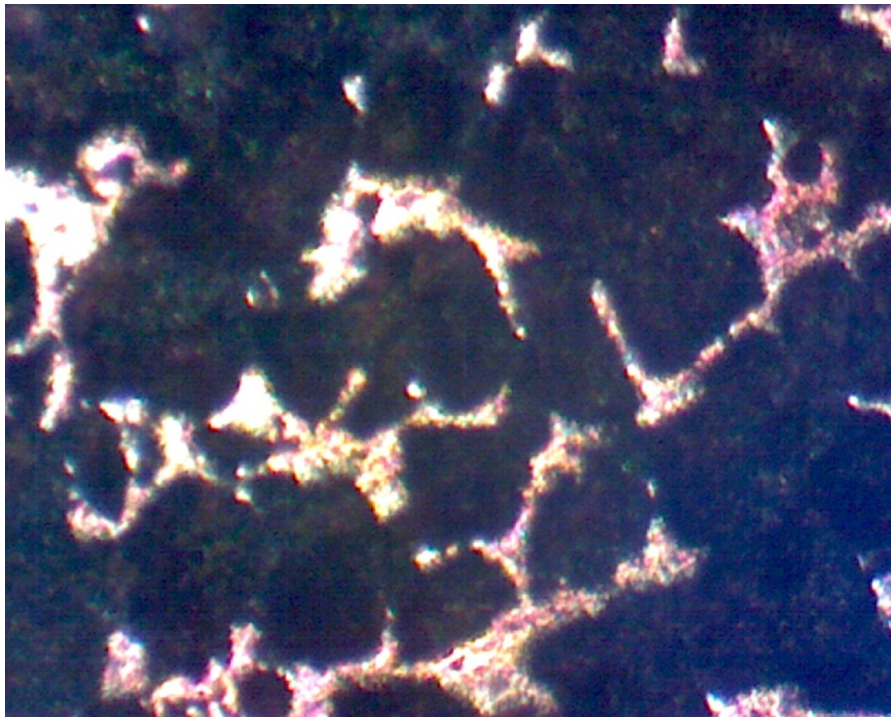
Inconel 718 Bio50 40X Magnification - Specimen 1



Inconel 718 Bio50 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

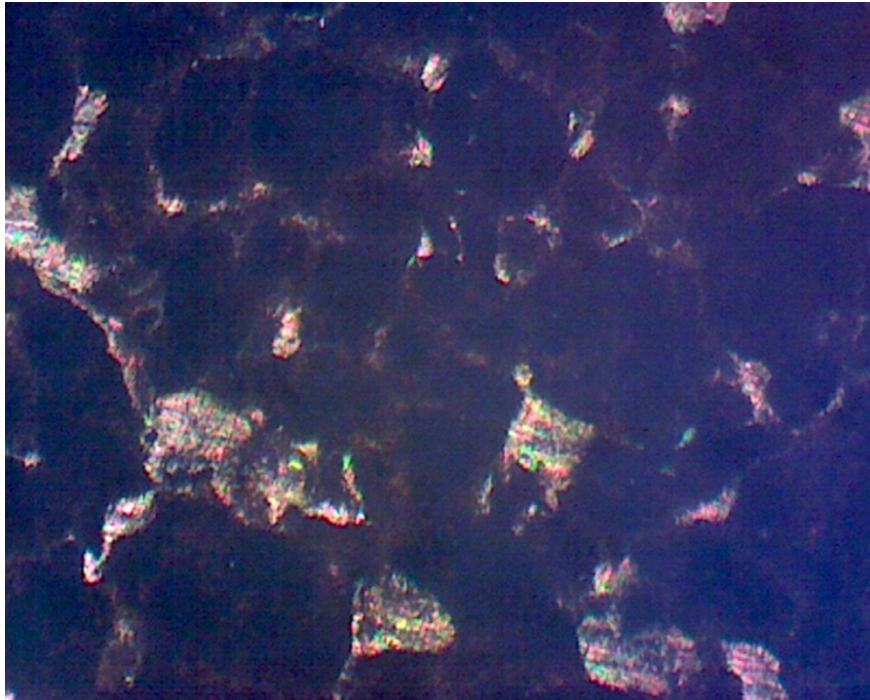
Biofuel 50/50 – Inconel 718



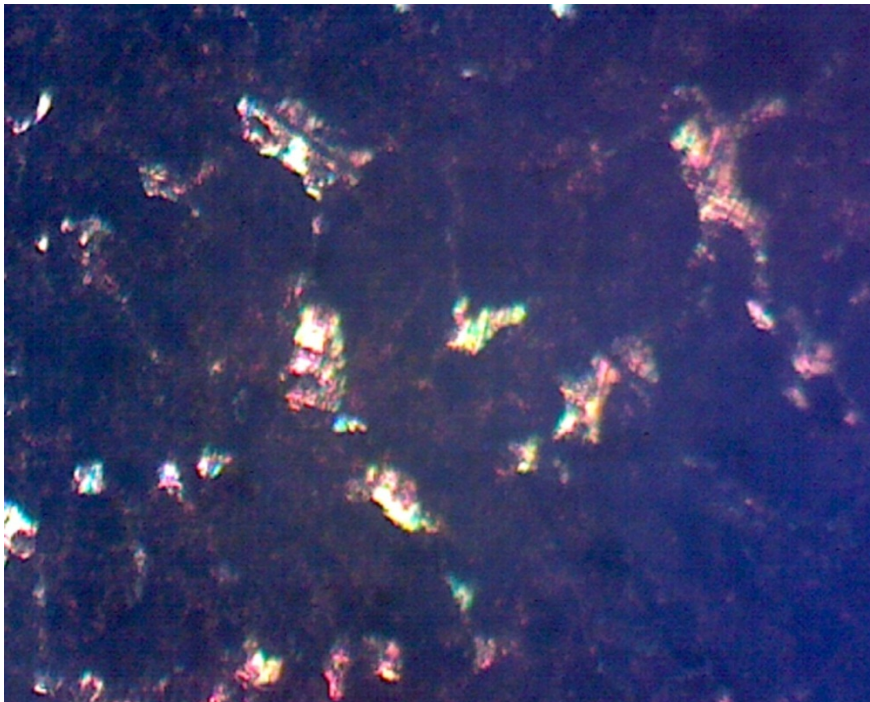
Inconel 718 Bio50 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Jet A1 – Monel 400



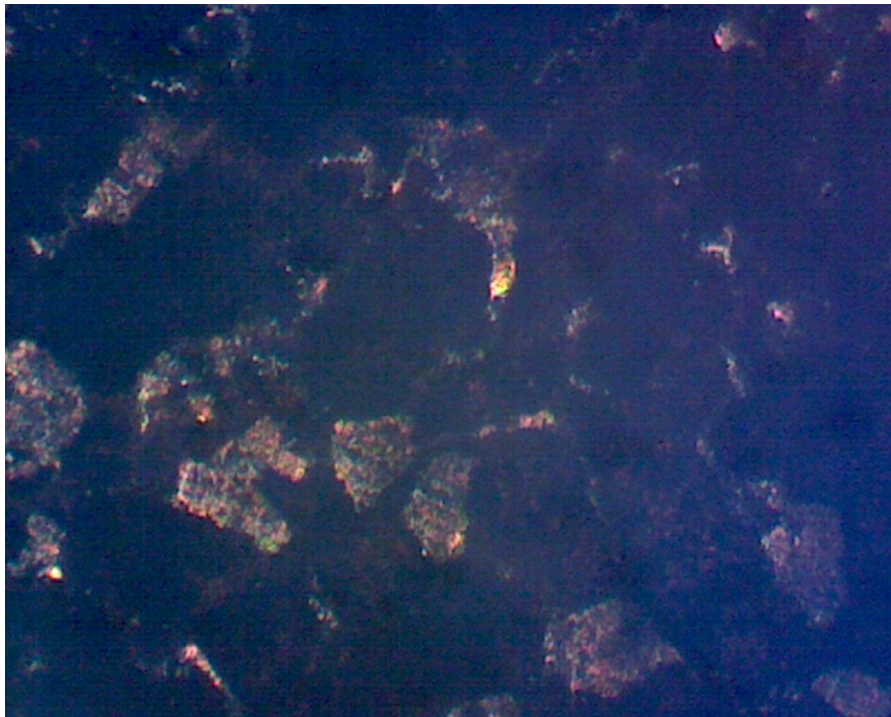
Monel 400 JetA1 40X Magnification - Specimen 1



Monel 400 JetA1 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

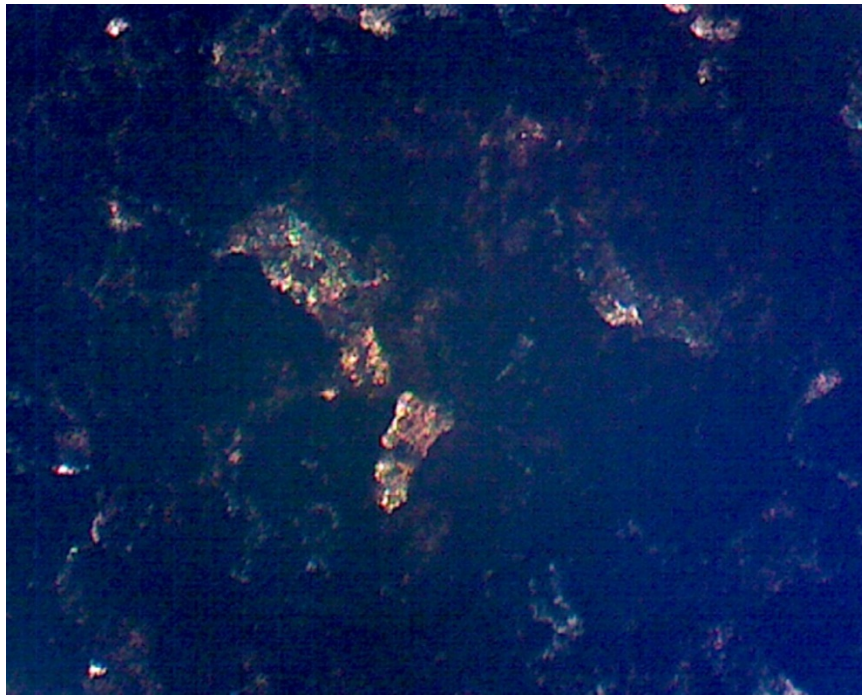
Jet A1 – Monel 400



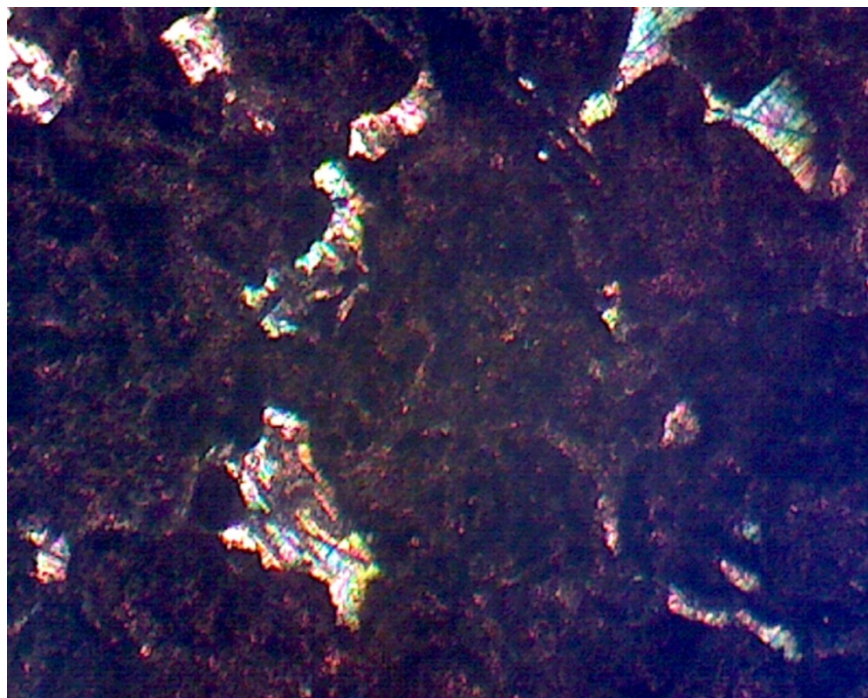
Monel 400 JetA1 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Biofuel 50/50 – Monel 400



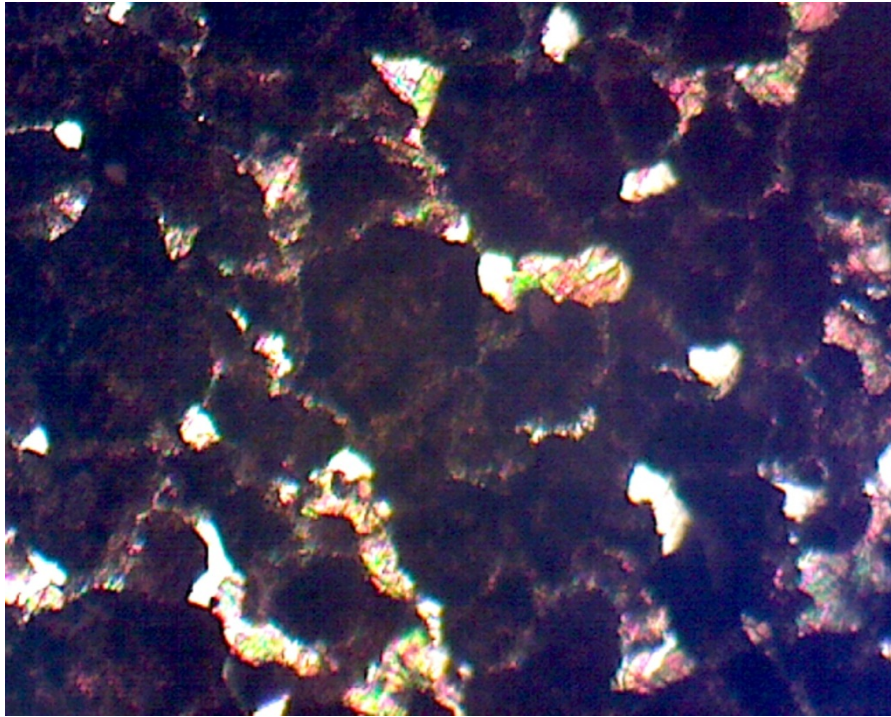
Monel 400 Bio50 40X Magnification - Specimen 1



Monel 400 Bio50 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

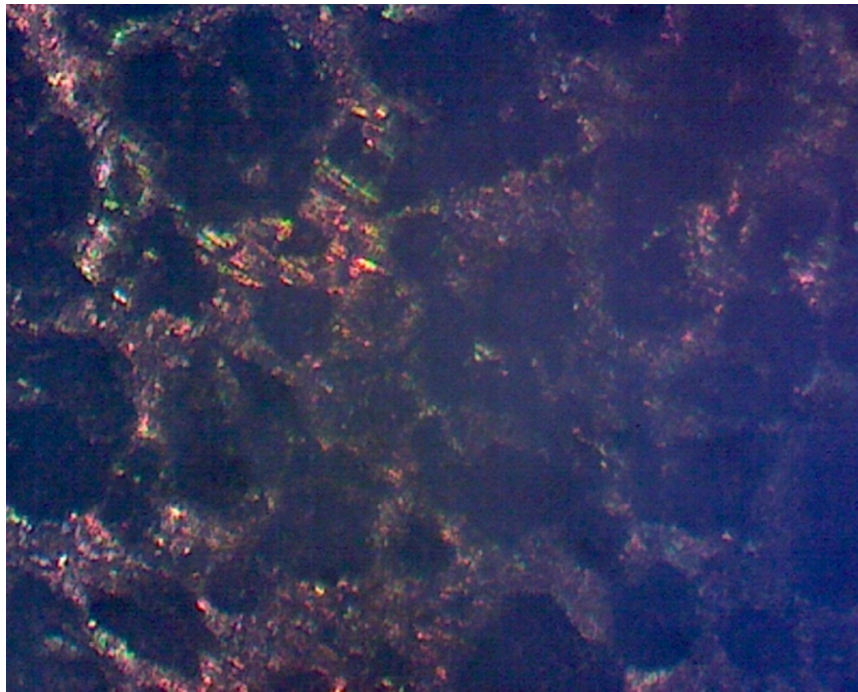
Biofuel 50/50 – Monel 400



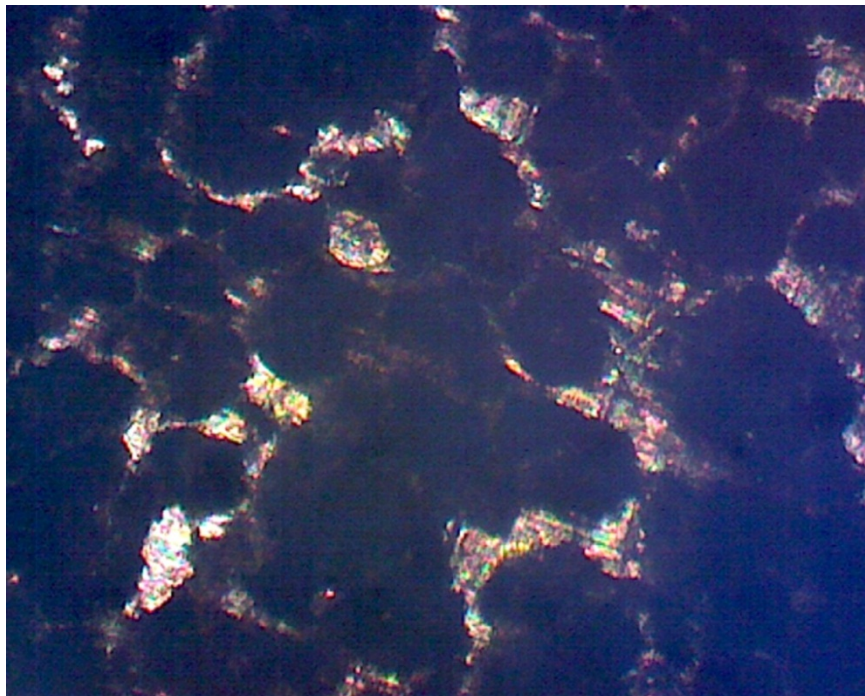
Monel 400 Bio50 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Jet A1 – Nickel 200



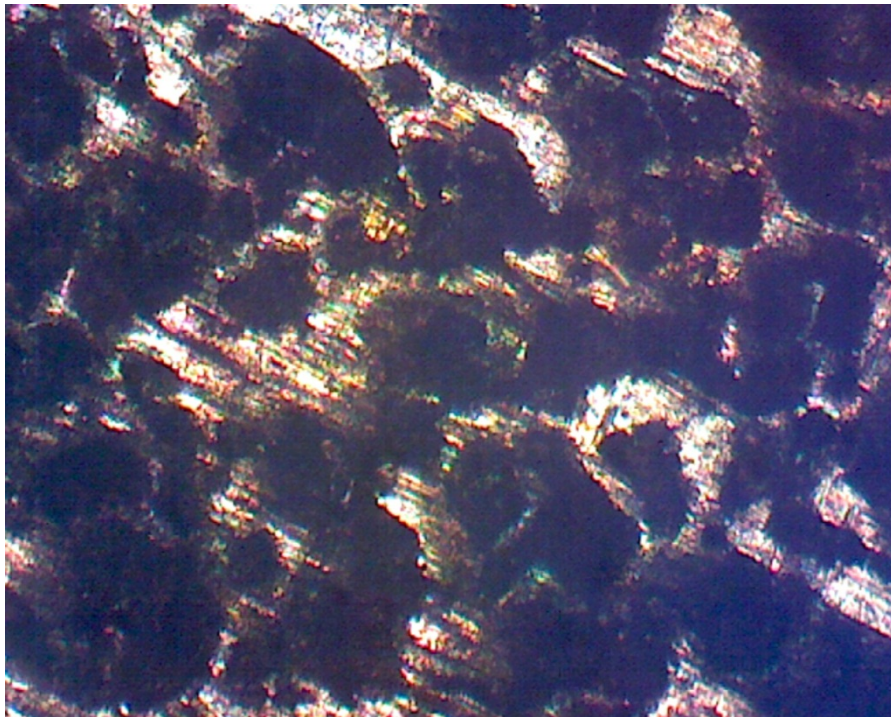
Nickel 200 JetA1 40X Magnification - Specimen 1



Nickel 200 JetA1 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

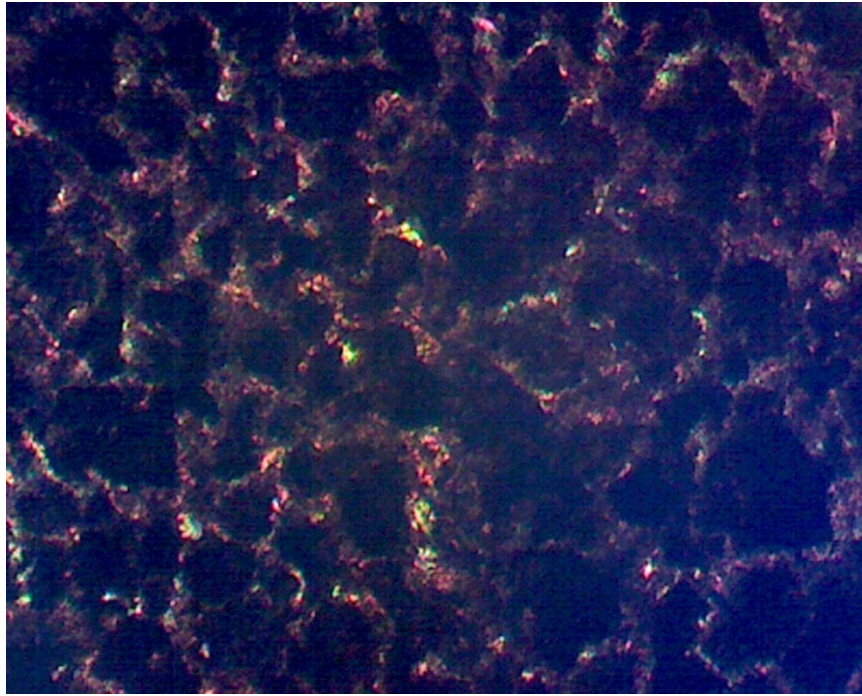
Jet A1 – Nickel 200



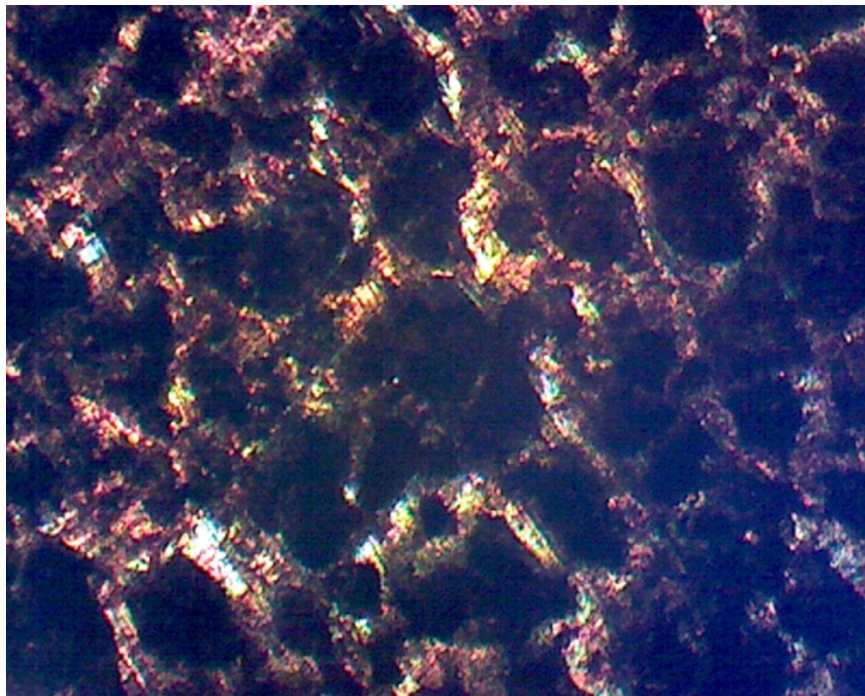
Nickel 200 JetA1 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Biofuel 50/50 – Nickel 200



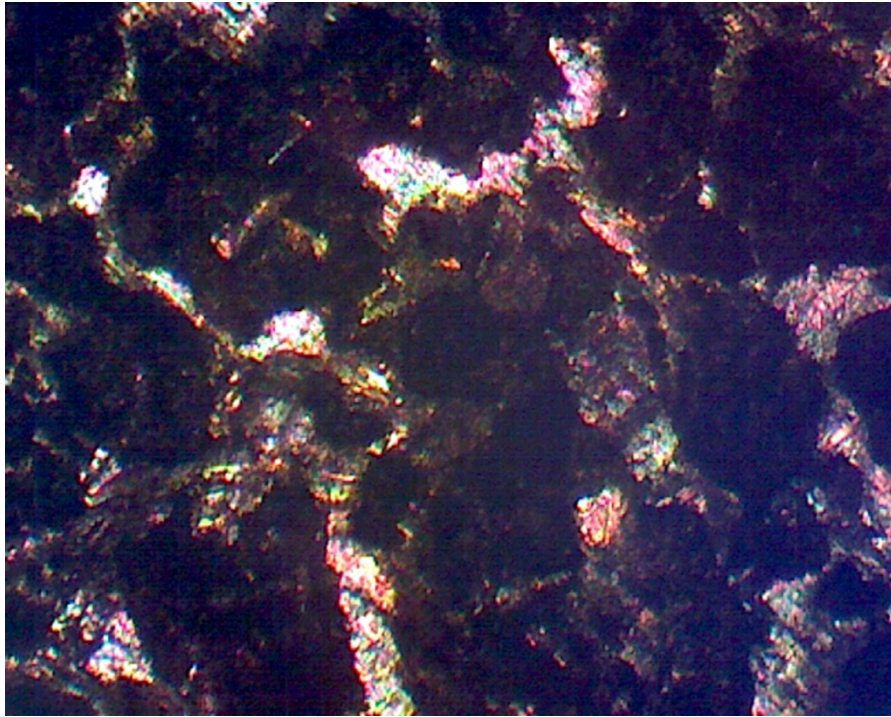
Nickel 200 Bio50 40X Magnification - Specimen 1



Nickel 200 Bio50 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

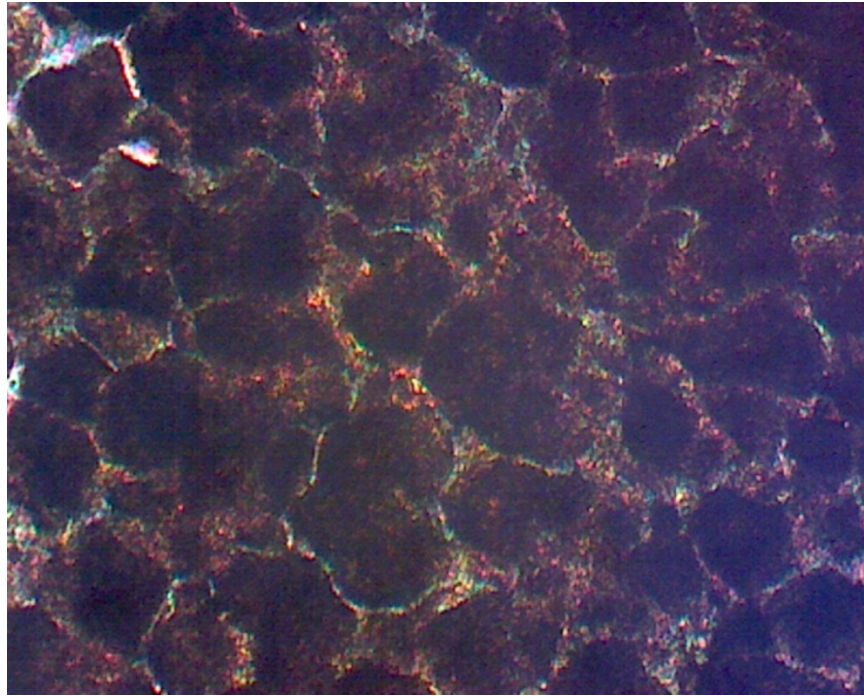
Biofuel 50/50 – Nickel 200



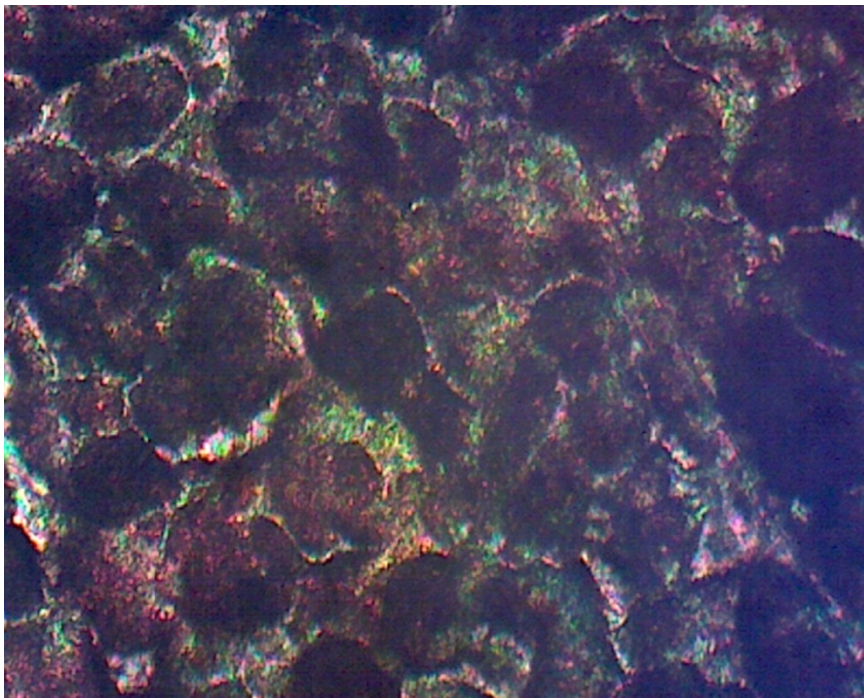
Nickel 200 Bio50 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Jet A1 – Ti 3Al-2.5V



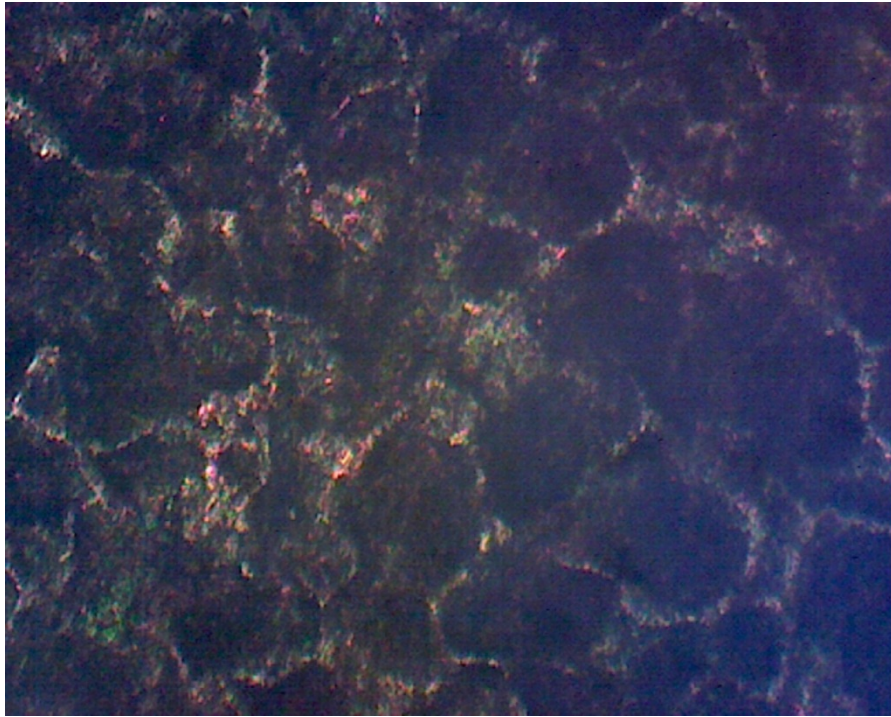
Ti 3Al-2.5V JetA1 40X Magnification - Specimen 1



Ti 3Al-2.5V JetA1 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

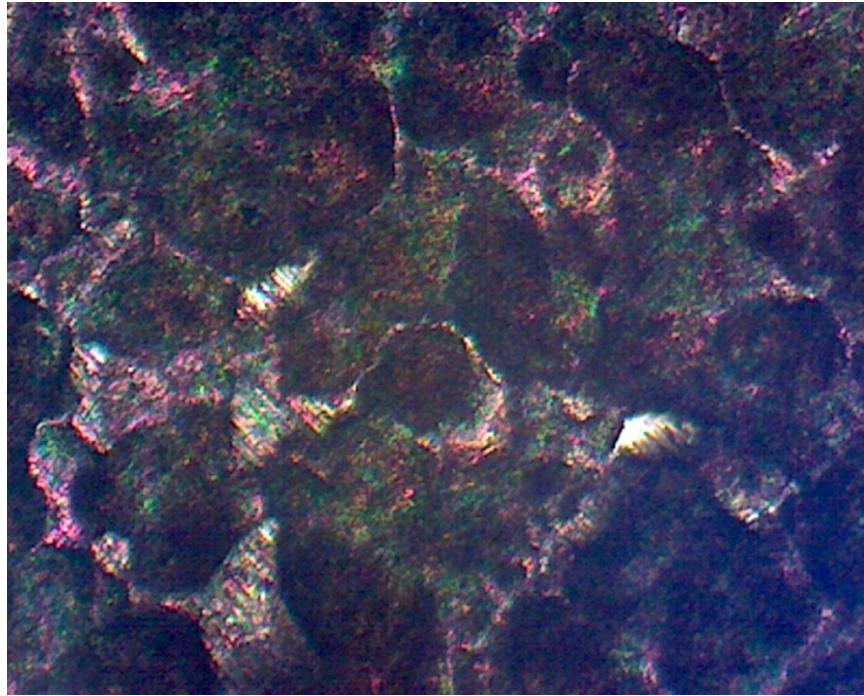
Jet A1 – Ti 3Al-2.5V



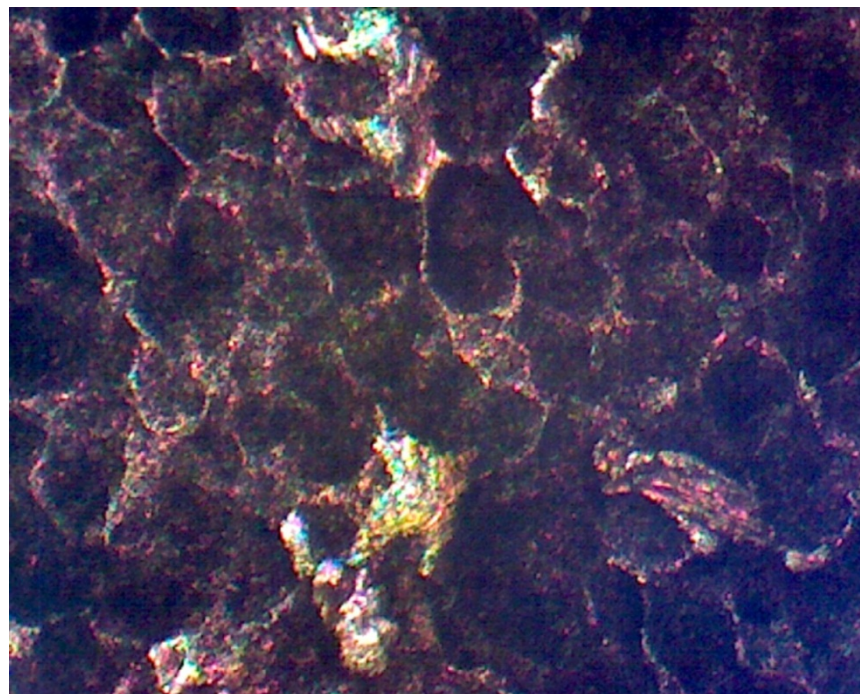
Ti 3Al-2.5V JetA1 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Biofuel 50/50 – Ti 3Al-2.5V



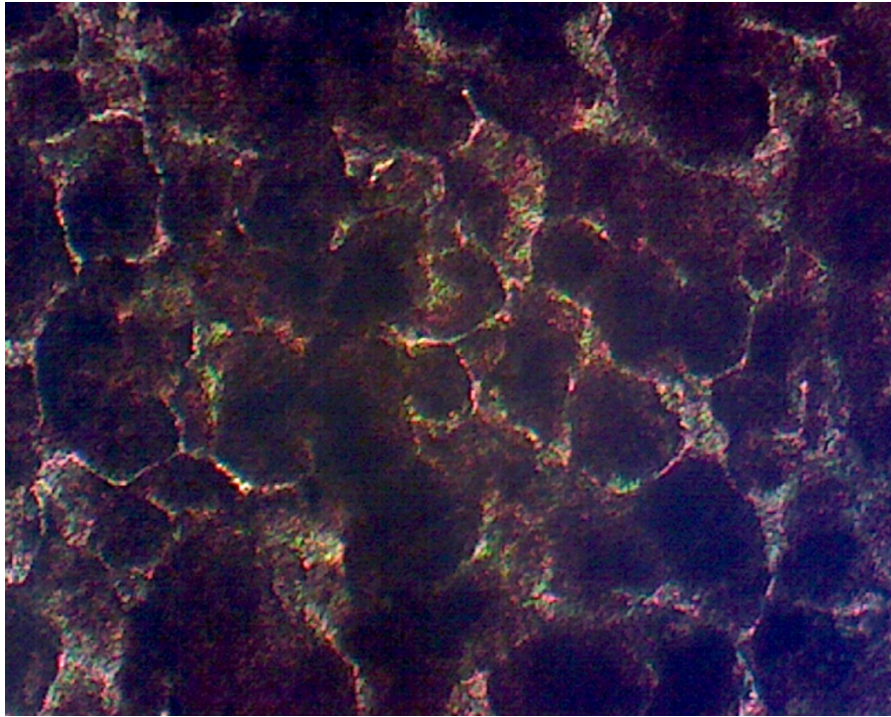
Ti 3Al-2.5V Bio50 40X Magnification - Specimen 1



Ti 3Al-2.5V Bio50 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

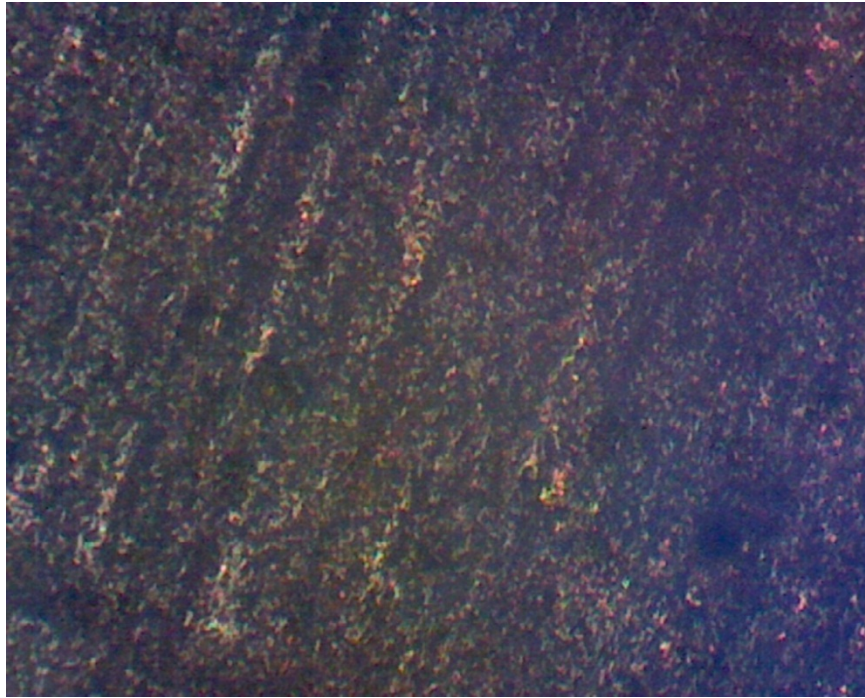
Biofuel 50/50 – Ti 3Al-2.5V



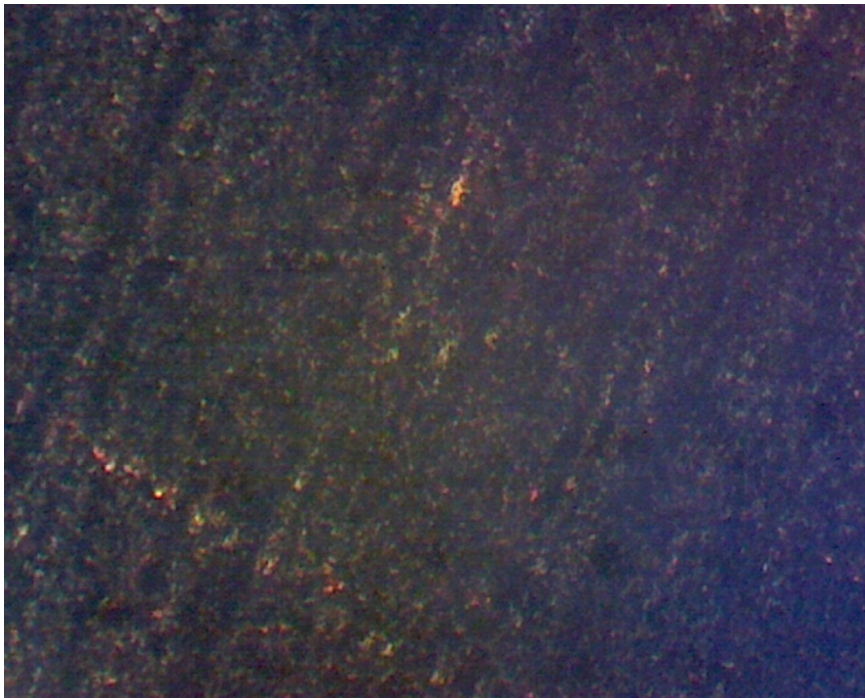
Ti 3Al-2.5V Bio50 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Jet A1 – Ti 8Al-1V-1Mo



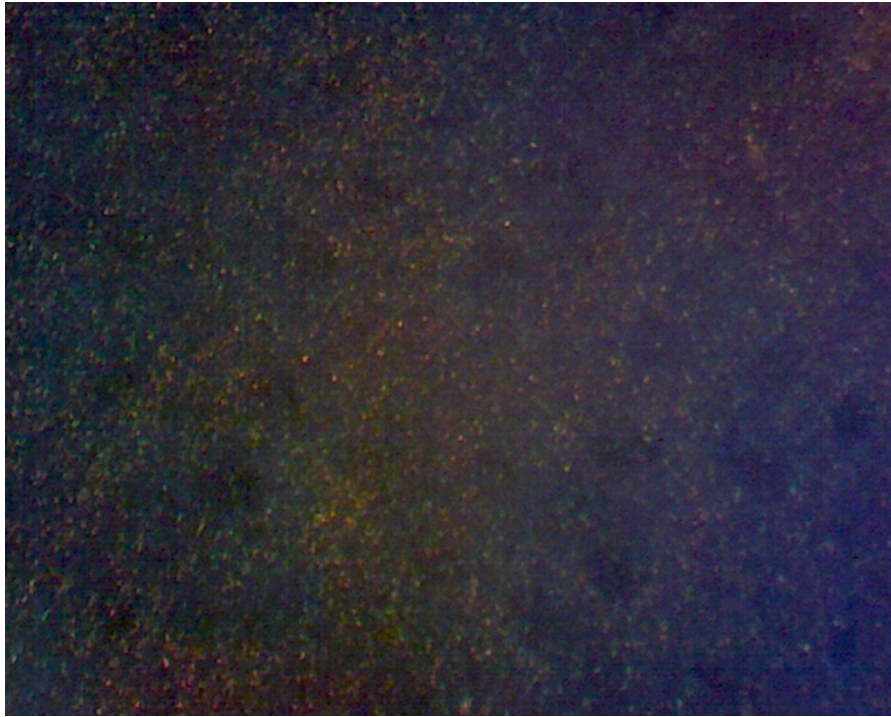
Ti 8Al-1V-1Mo JetA1 40X Magnification - Specimen 1



Ti 8Al-1V-1Mo JetA1 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

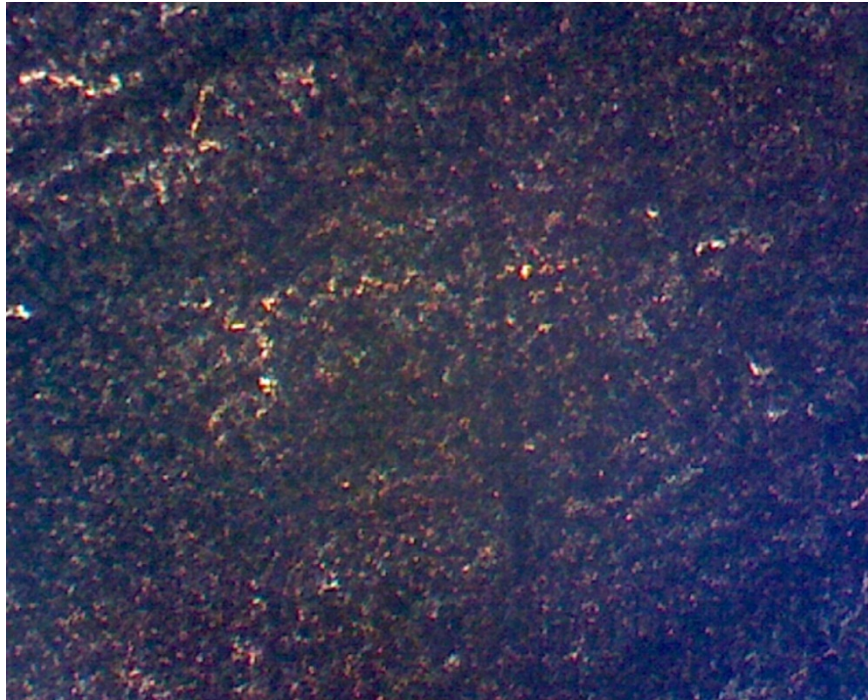
Jet A1 – Ti 8Al-1V-1Mo



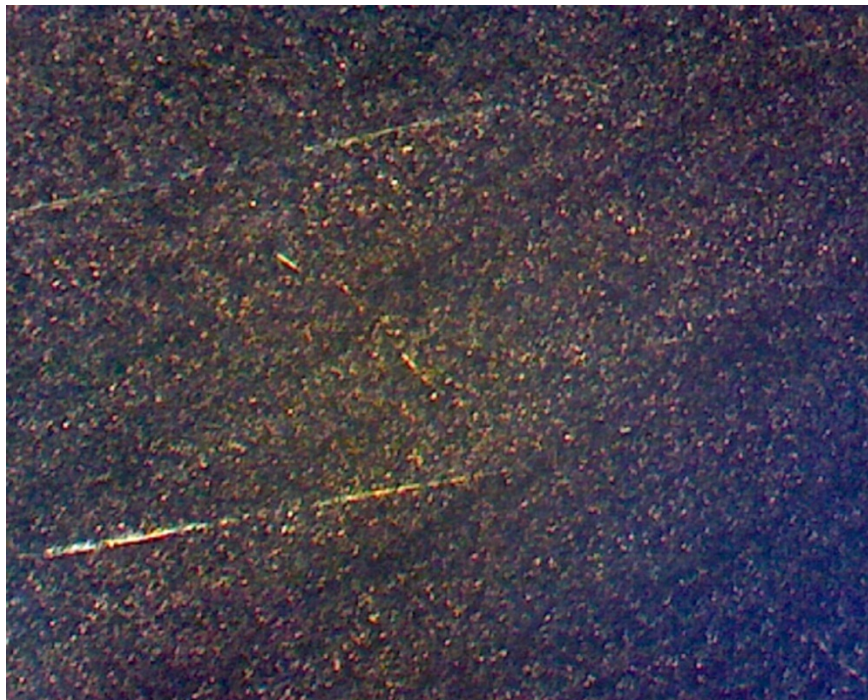
Ti 8Al-1V-1Mo JetA1 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Biofuel 50/50 – Ti 8Al-1V-1Mo



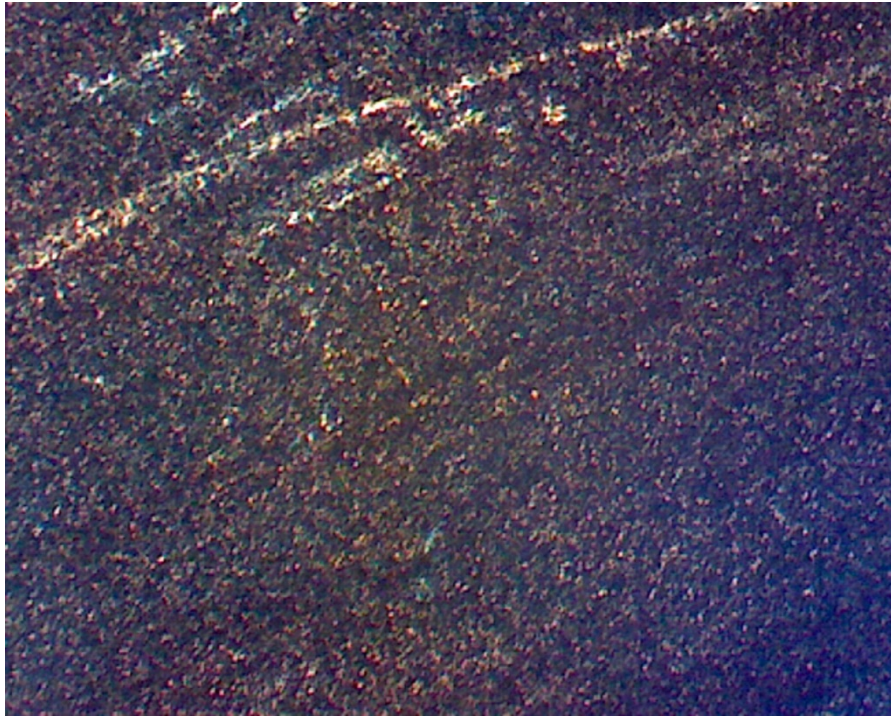
Ti 8Al-1V-1Mo Bio50 40X Magnification - Specimen 1



Ti 8Al-1V-1Mo Bio50 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

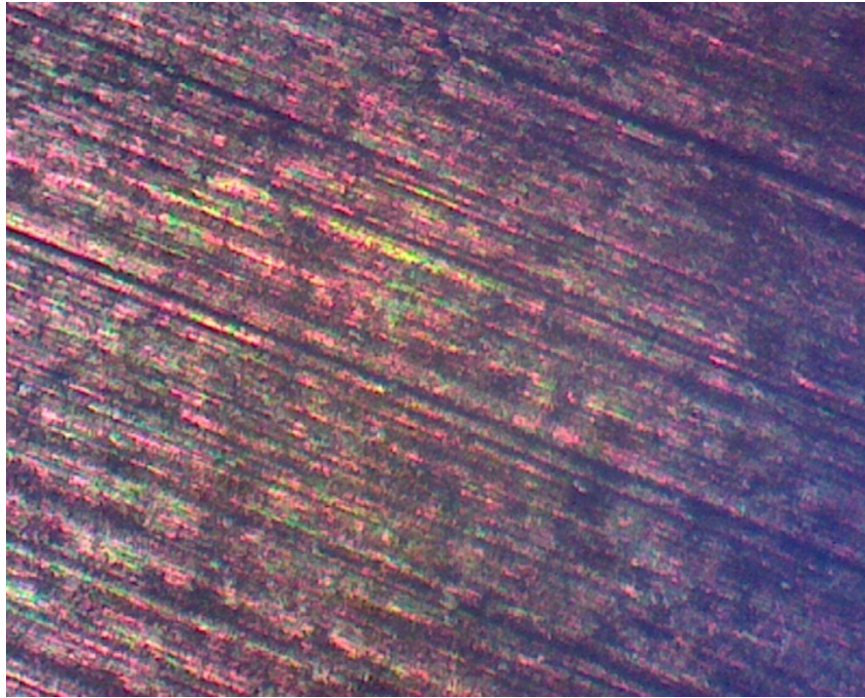
Biofuel 50/50 – Ti 8Al-1V-1Mo



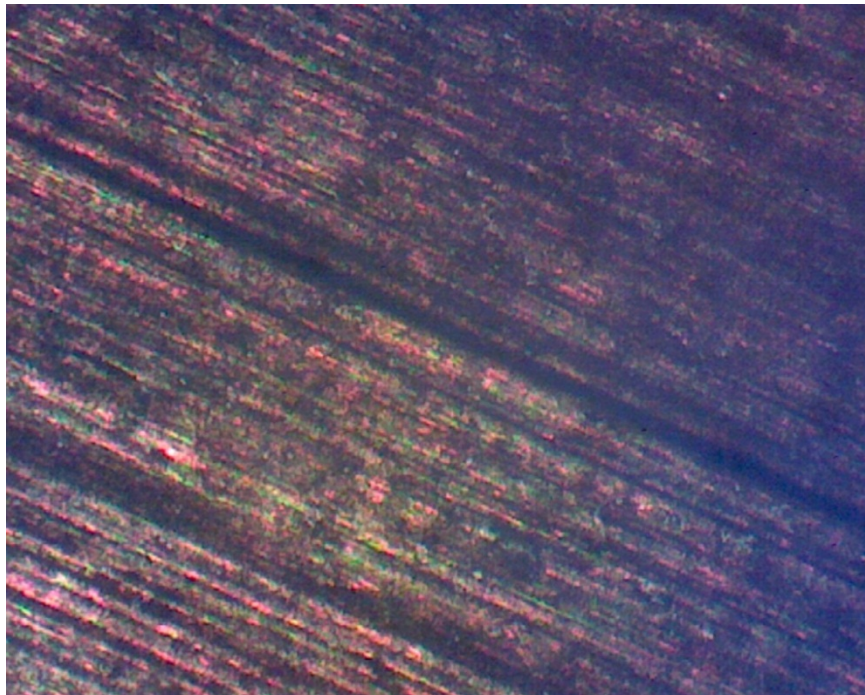
Ti 8Al-1V-1Mo Bio50 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Jet A1 – Titanium CP70



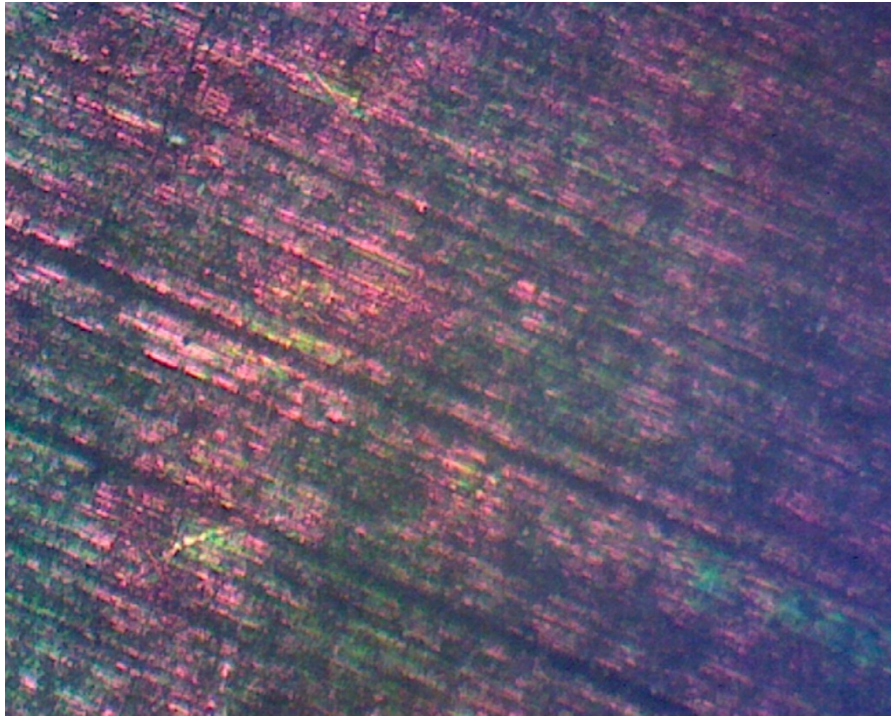
Titanium CP70 JetA1 40X Magnification - Specimen 1



Titanium CP70 JetA1 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

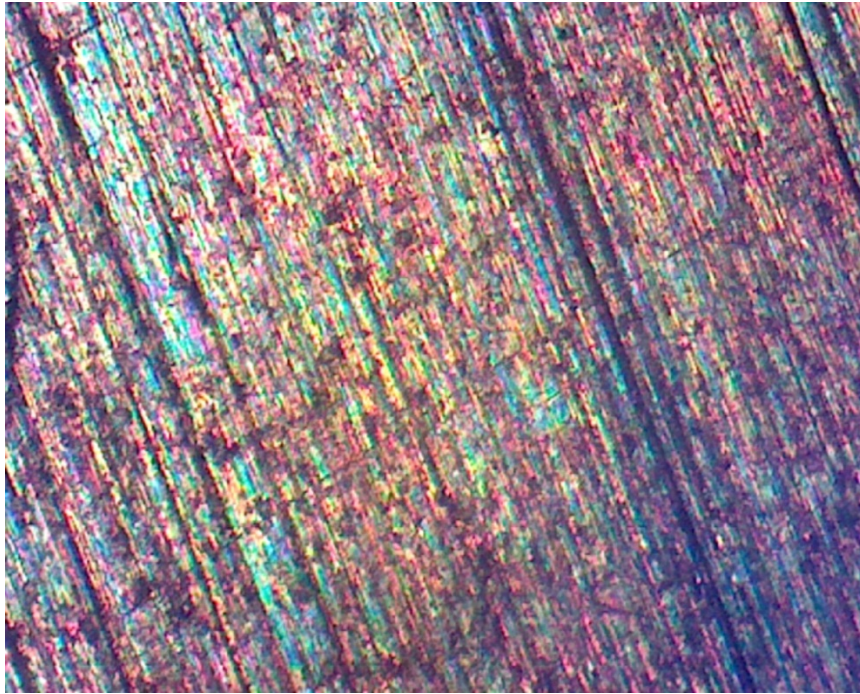
Jet A1 – Titanium CP70



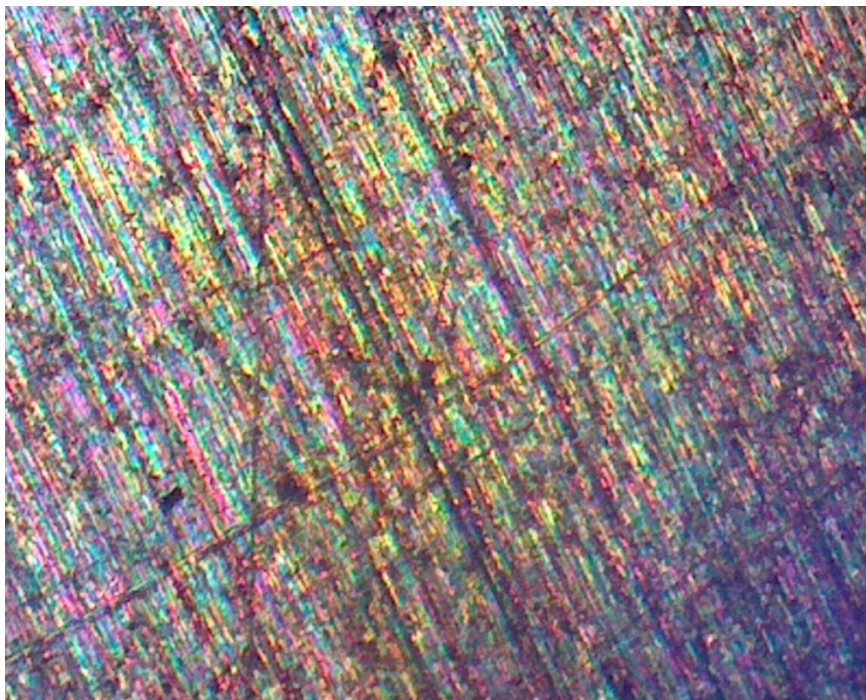
Titanium CP70 JetA1 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Biofuel 50/50 – Titanium CP70



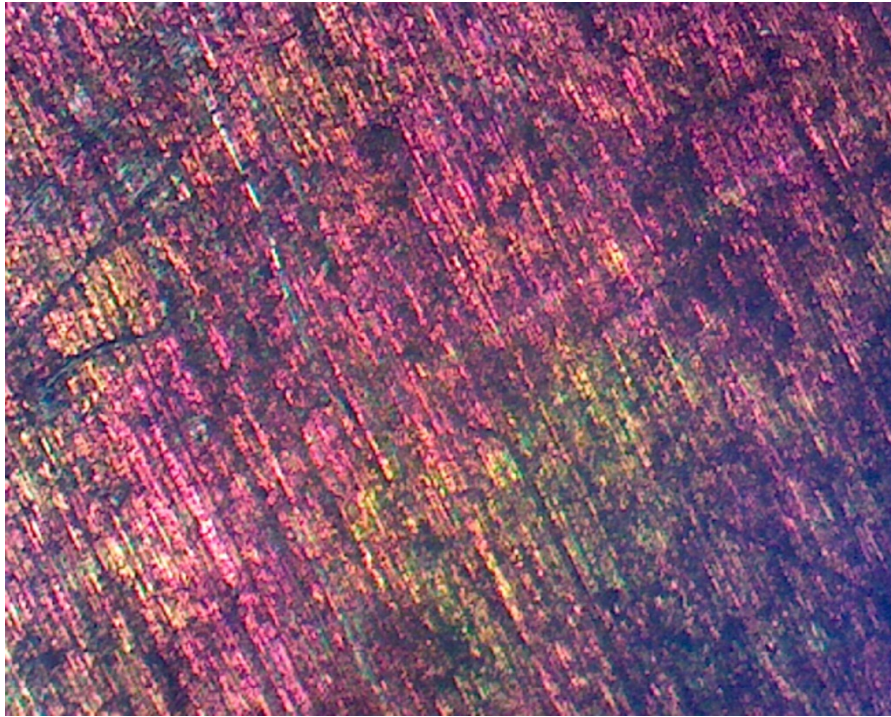
Titanium CP70 Bio50 40X Magnification - Specimen 1



Titanium CP70 Bio50 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

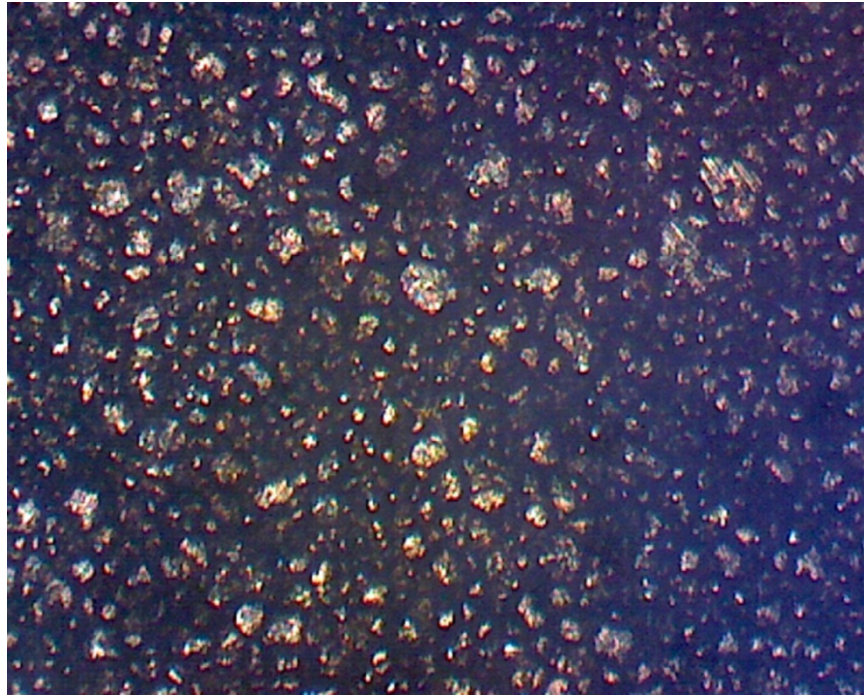
Biofuel 50/50 – Titanium CP70



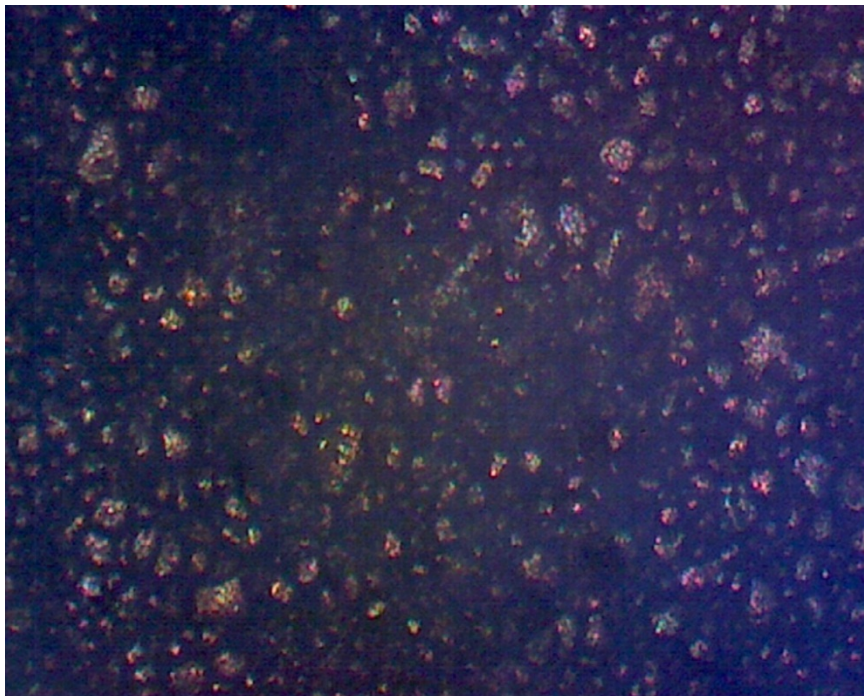
Titanium CP70 Bio50 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Jet A1 – Waspaloy



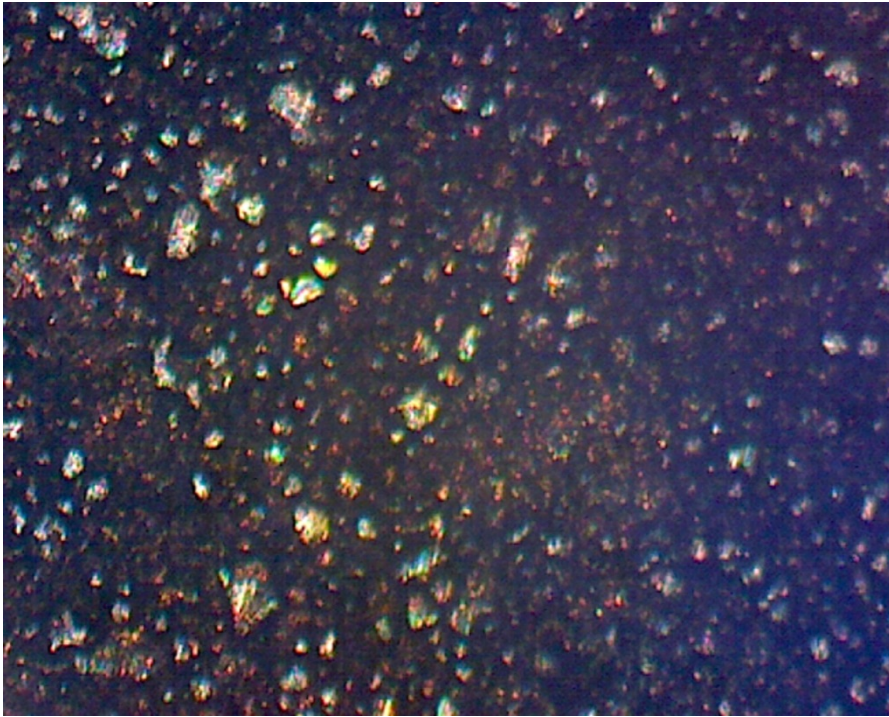
Waspaloy JetA1 40X Magnification - Specimen 1



Waspaloy JetA1 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

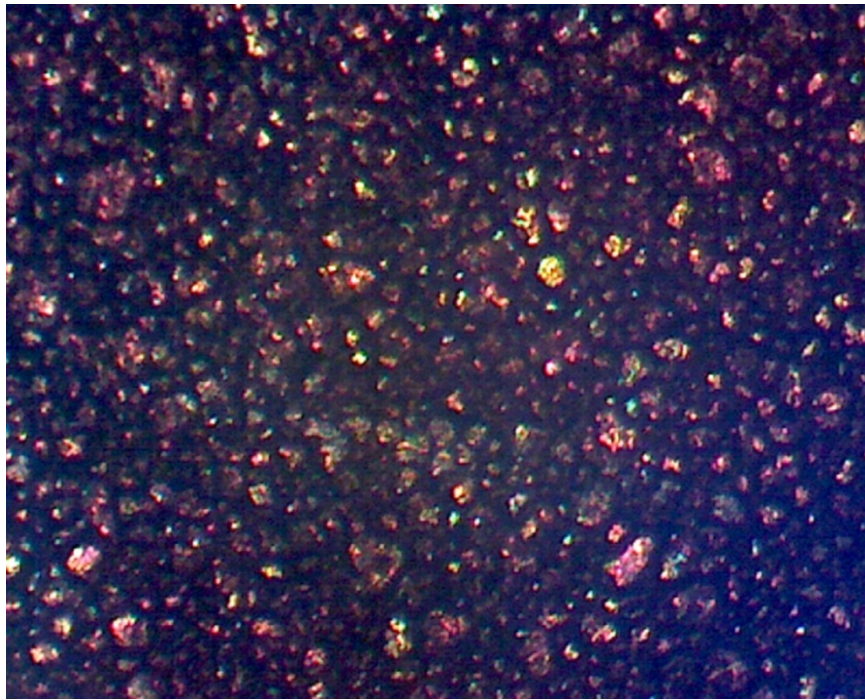
Jet A1 – Waspaloy



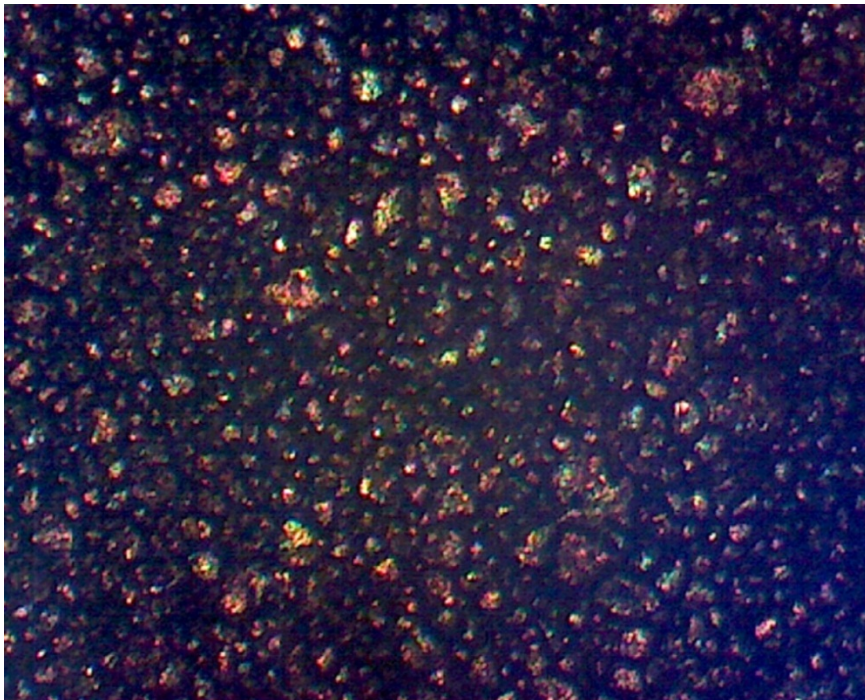
Waspaloy JetA1 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 40X ASTM D4054

Biofuel 50/50 – Waspaloy



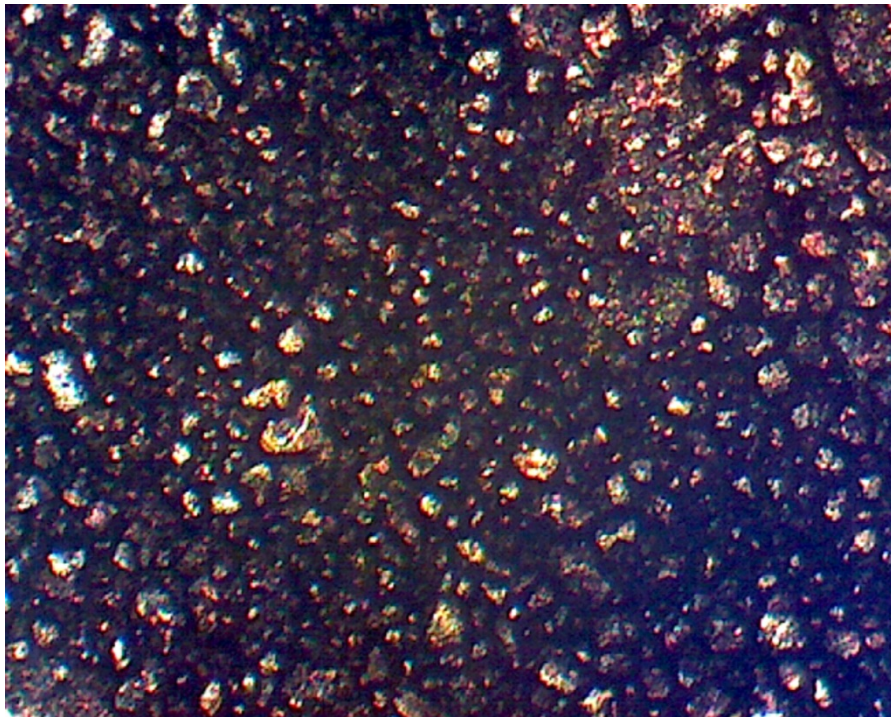
Waspaloy Bio50 40X Magnification - Specimen 1



Waspaloy Bio50 40X Magnification - Specimen 2

Metallic Surface Evaluation Images 40X ASTM D4054

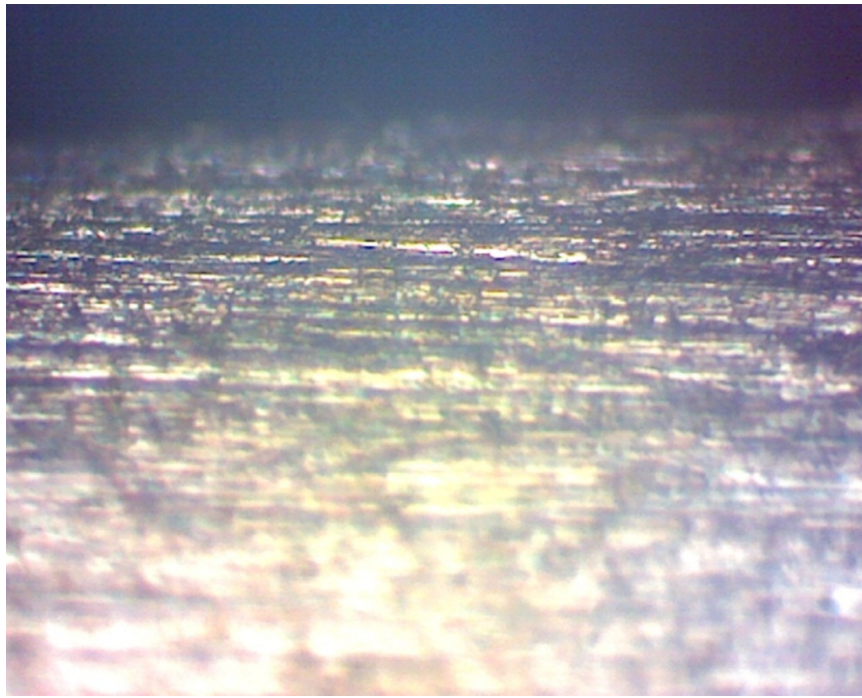
Biofuel 50/50 – Waspaloy



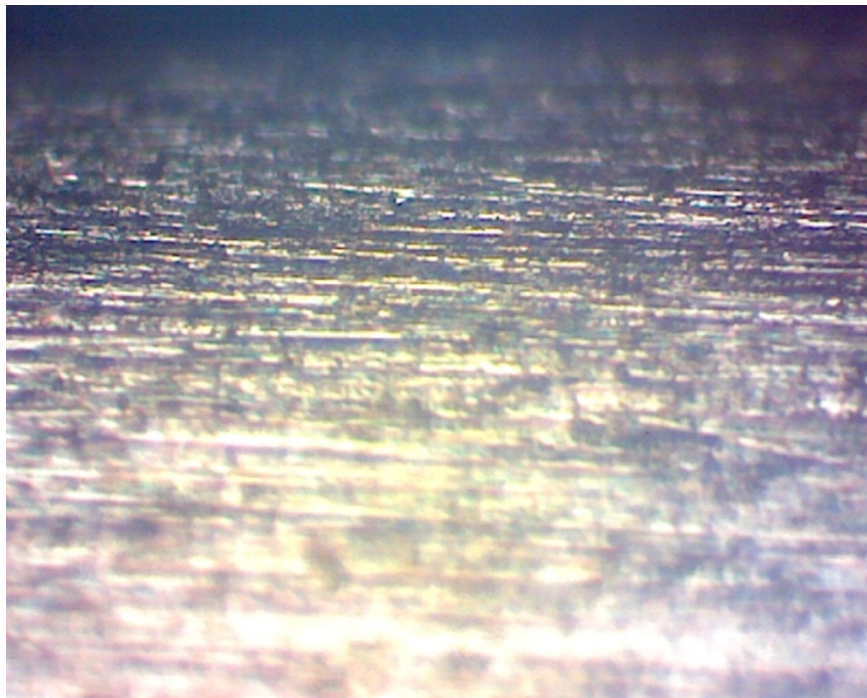
Waspaloy Bio50 40X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Jet A1 – 2024 T3



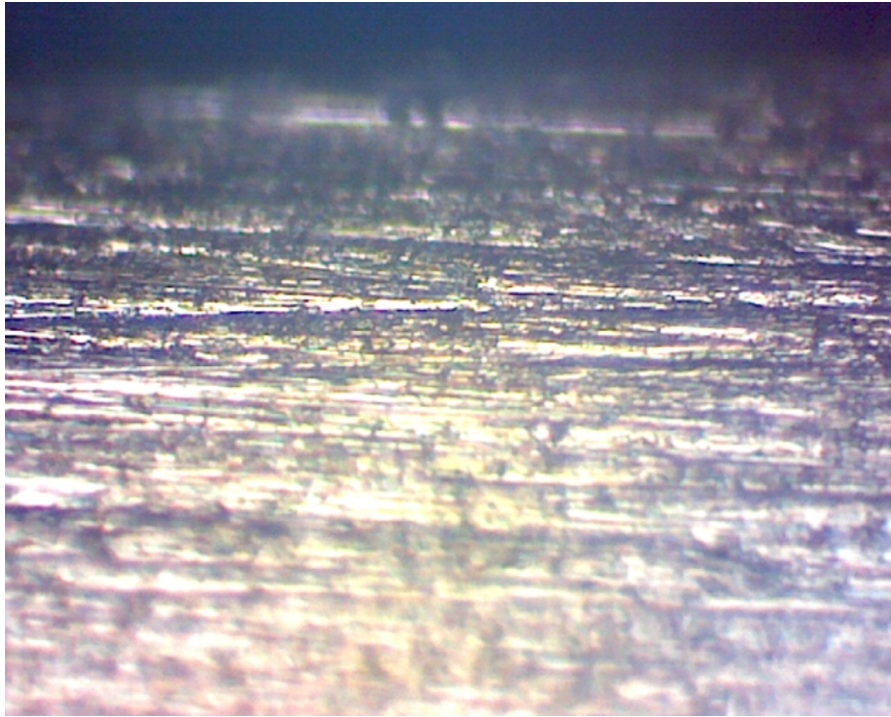
2024T3 JetA1 150X Magnification - Specimen 1



2024T3 JetA1 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

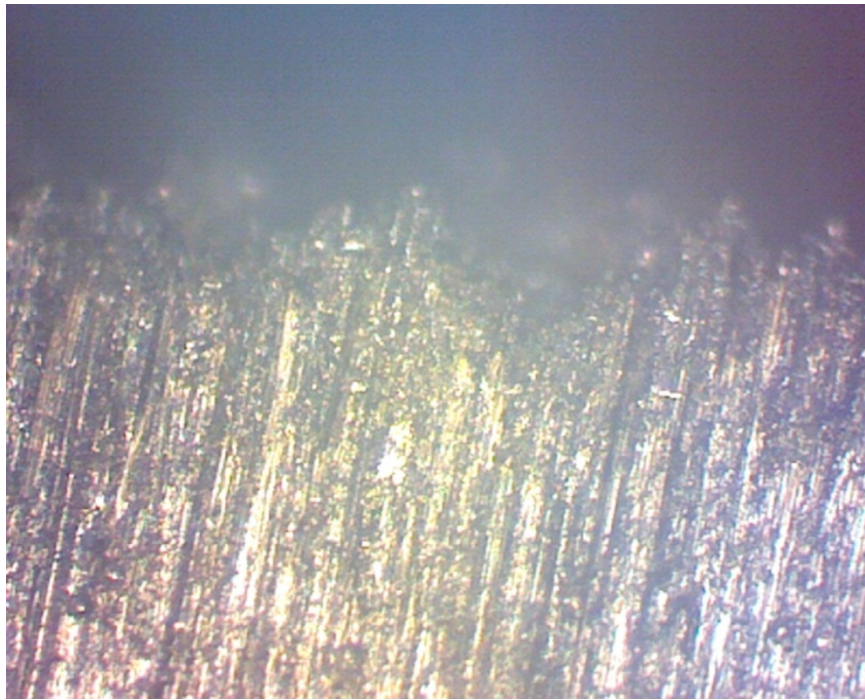
Jet A1 – 2024 T3



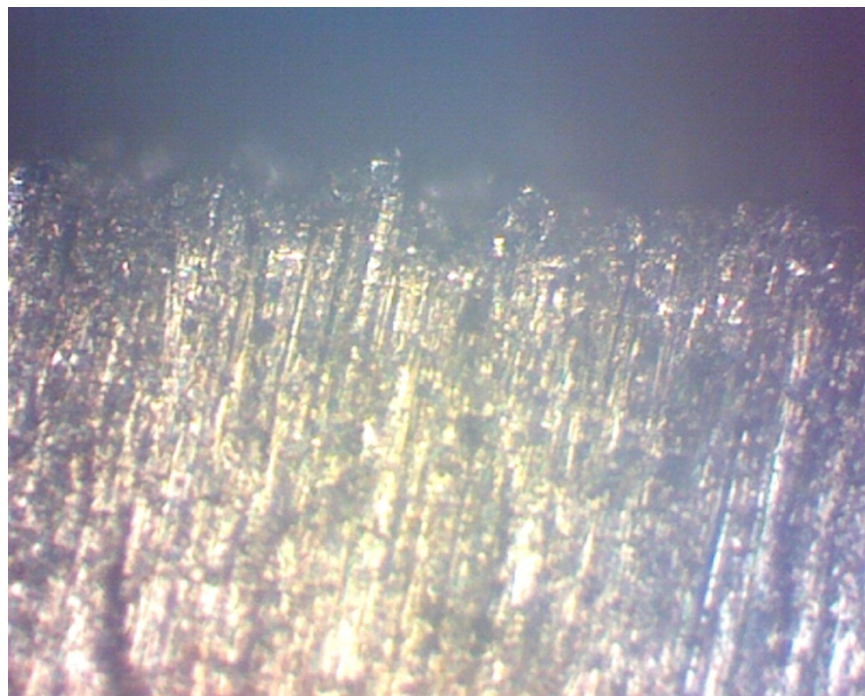
2024T3 JetA1 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Biofuel 50/50 – 2024 T3



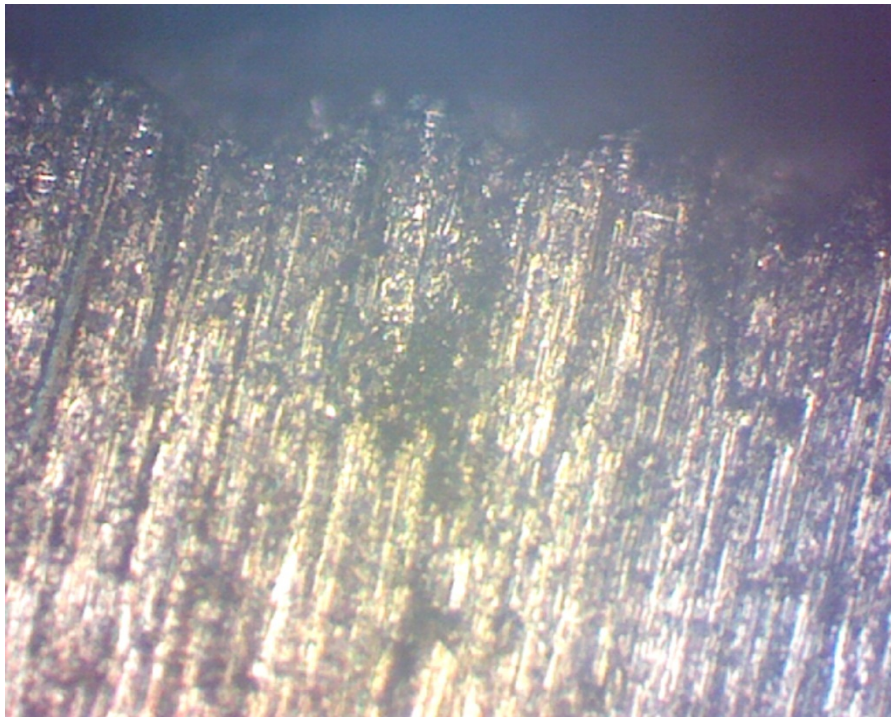
2024T3 Bio50 150X Magnification - Specimen 1



2024T3 Bio50 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

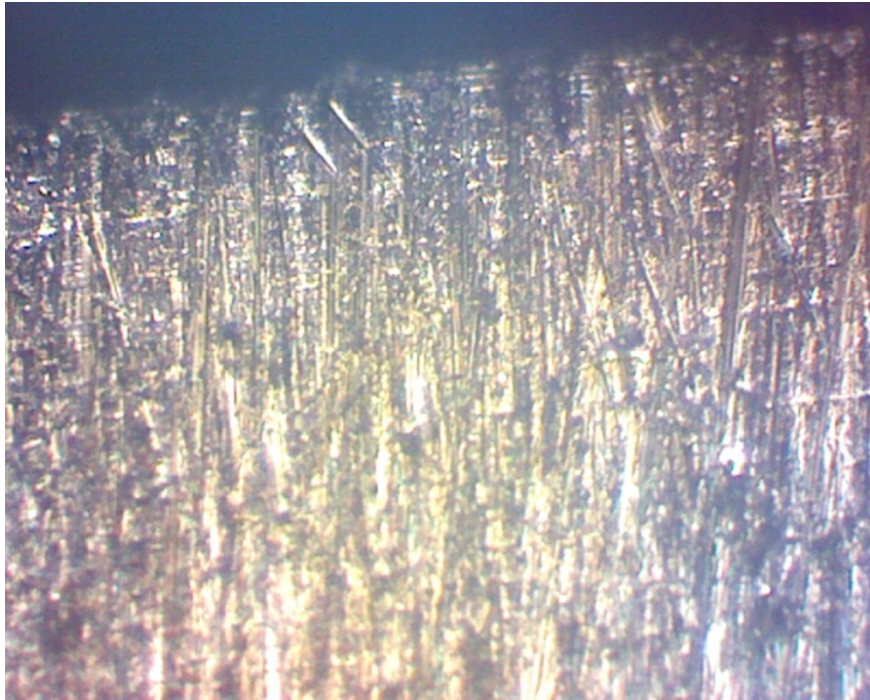
Biofuel 50/50 – 2024 T3



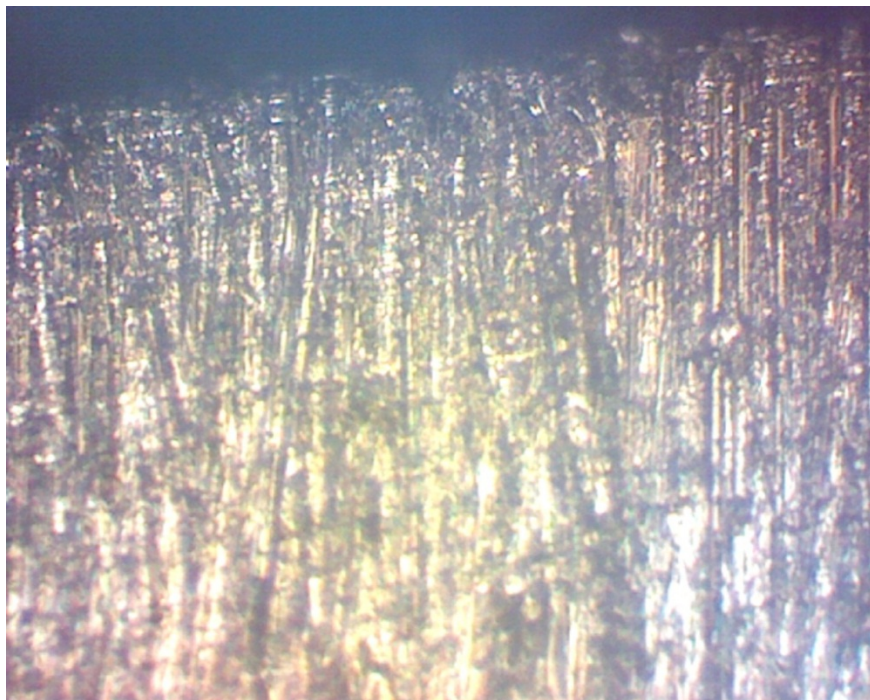
2024T3 Bio50 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Jet A1 – 6061 T6



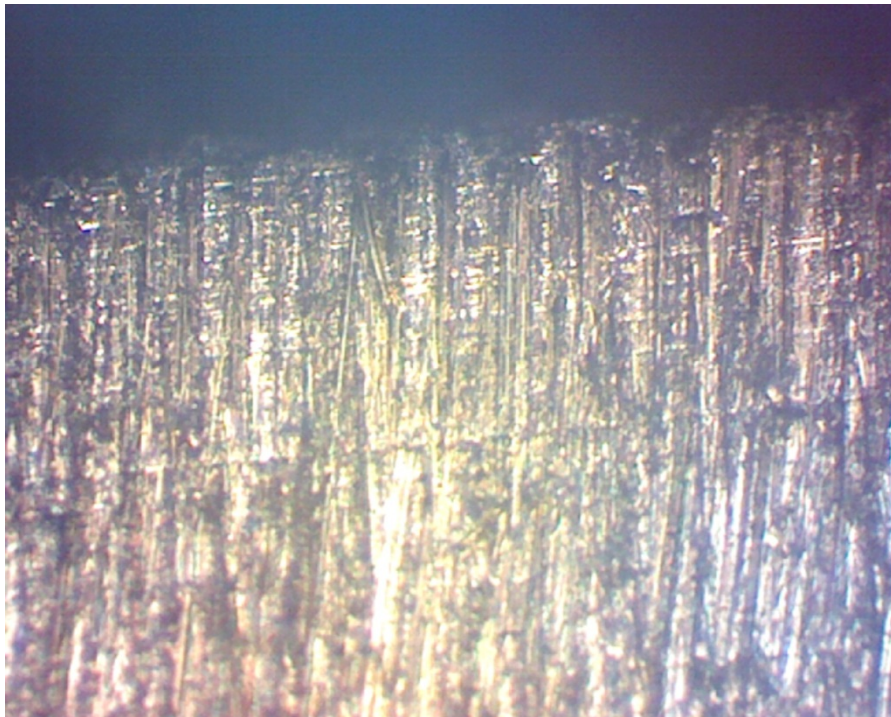
6061T6 JetA1 150X Magnification - Specimen 1



6061T6 JetA1 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

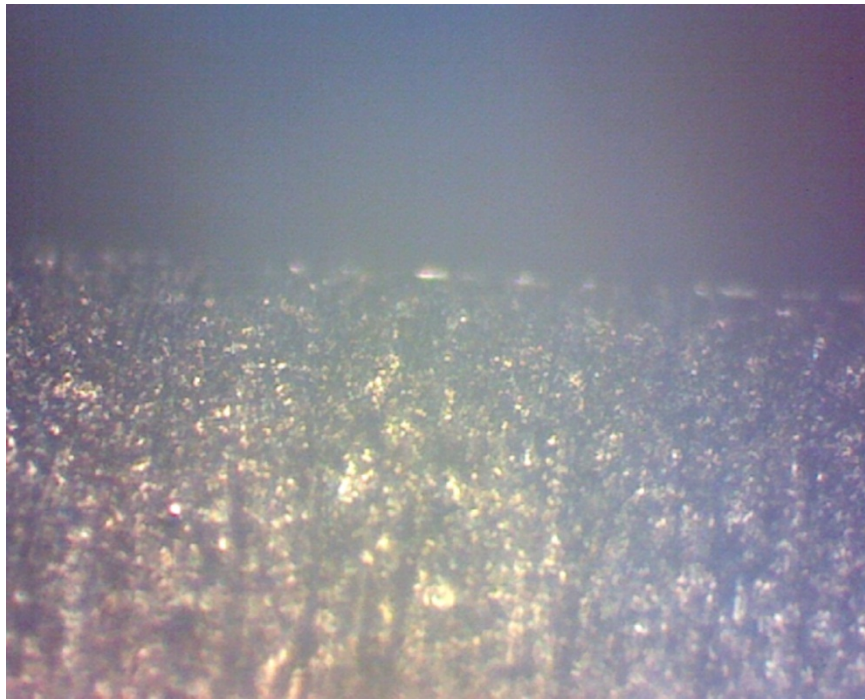
Jet A1 – 6061 T6



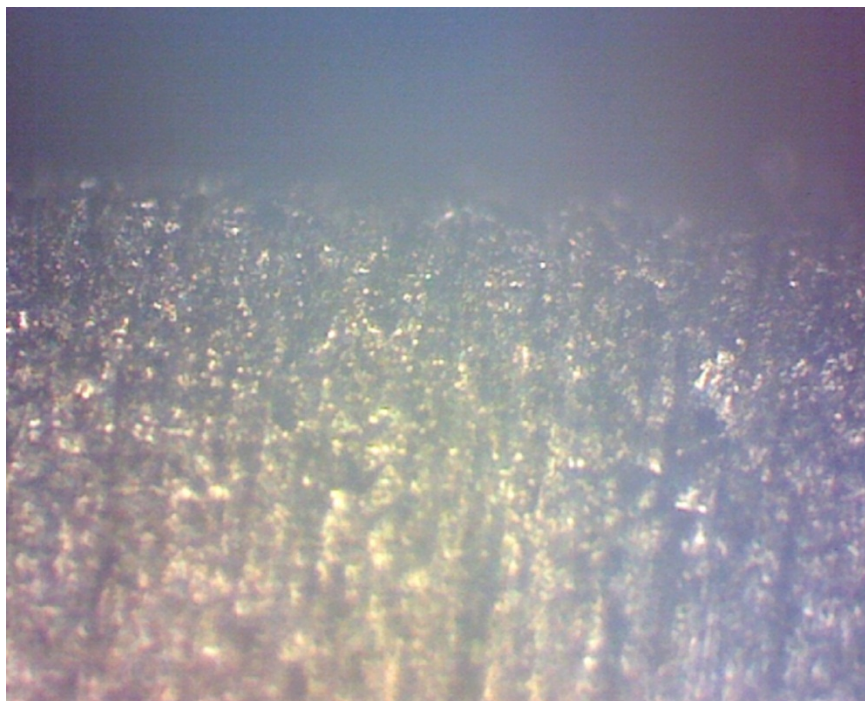
6061T6 JetA1 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Biofuel 50/50 – 6061 T6



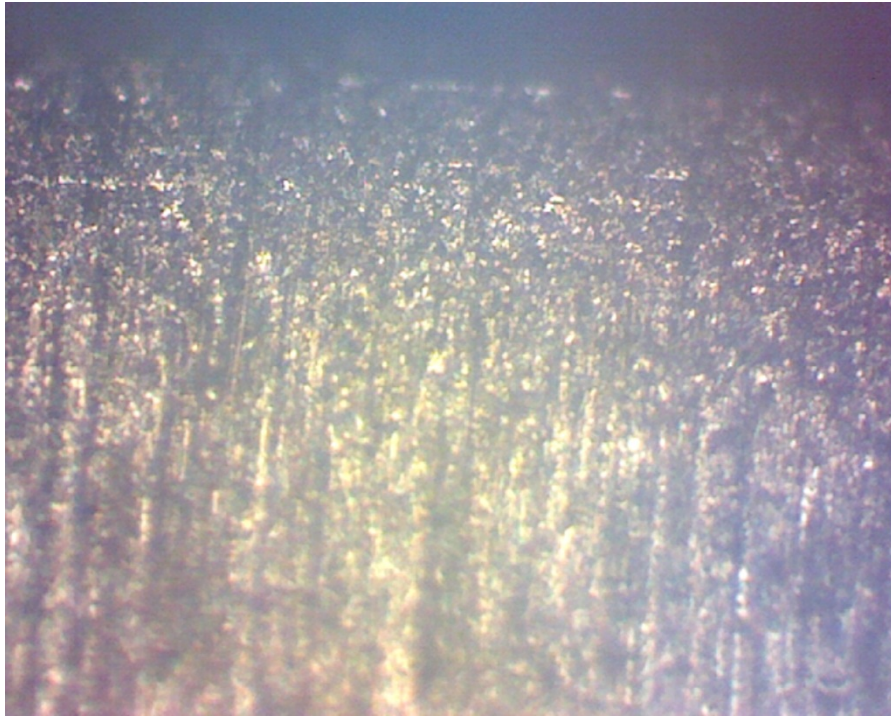
6061T6 Bio50 150X Magnification - Specimen 1



6061T6 Bio50 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

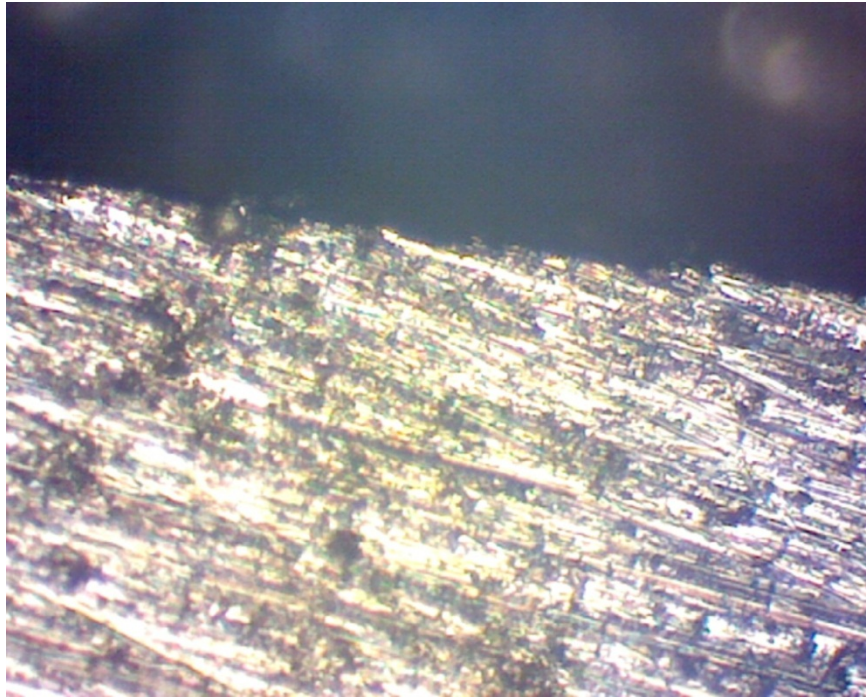
Biofuel 50/50 – 6061 T6



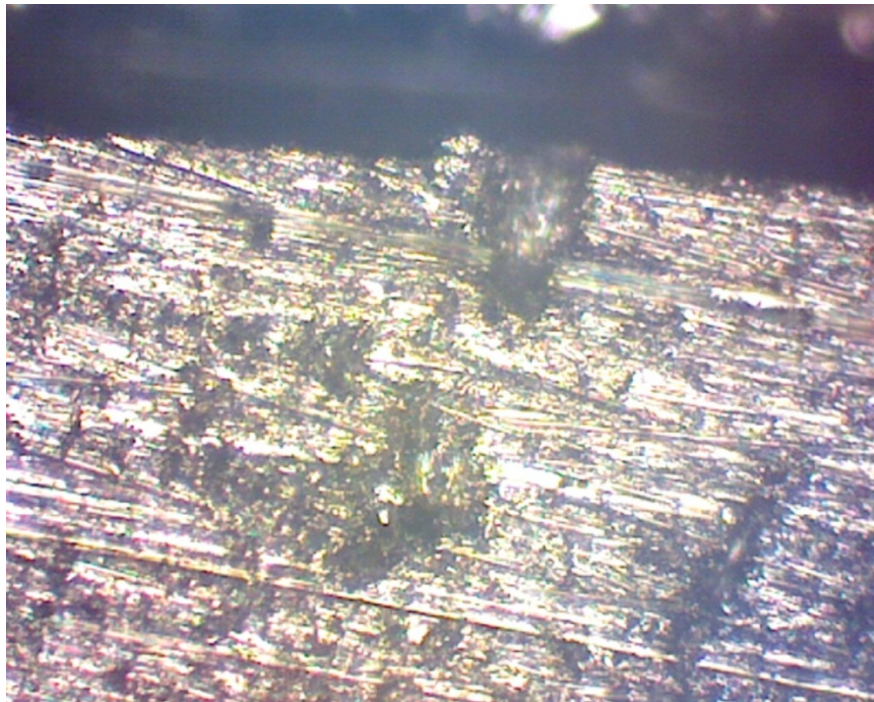
6061T6 Bio50 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Jet A1 – 7076 Chromate Coated



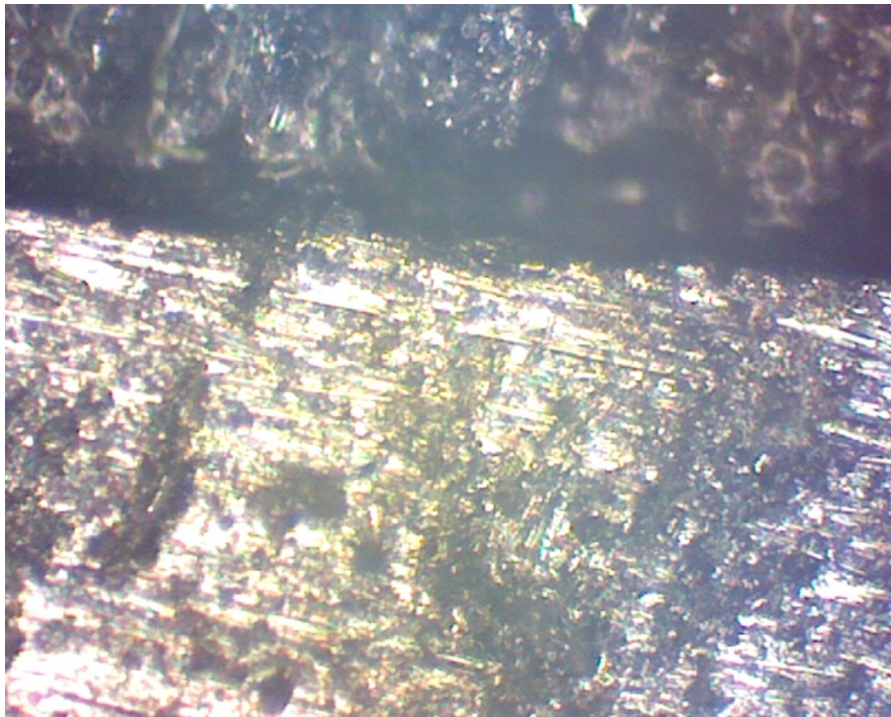
7076 Chromate Coated JetA1 150X Magnification - Specimen 1



7076 Chromate Coated JetA1 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

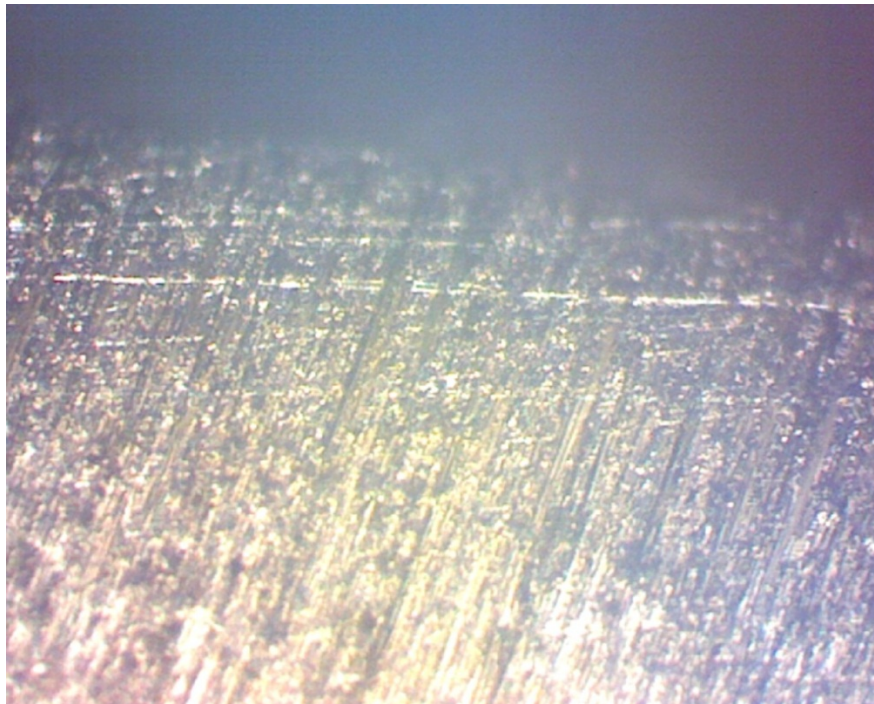
Jet A1 – 7076 Chromate Coated



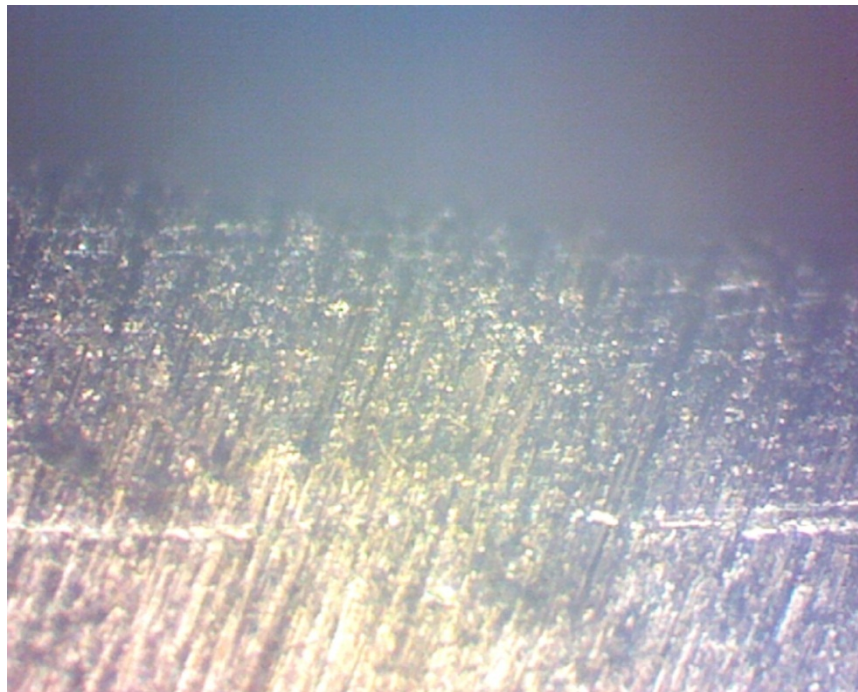
7076 Chromate Coated JetA1 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Biofuel 50/50 – 7076 Chromate Coated



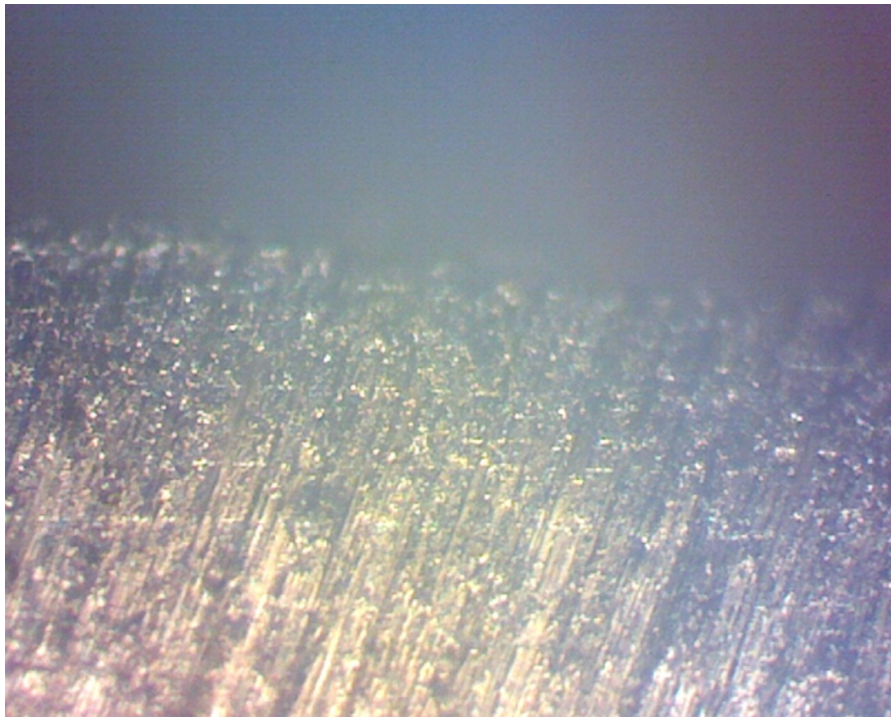
7076 Chromate Coated Bio50 150X Magnification - Specimen 1



7076 Chromate Coated Bio50 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

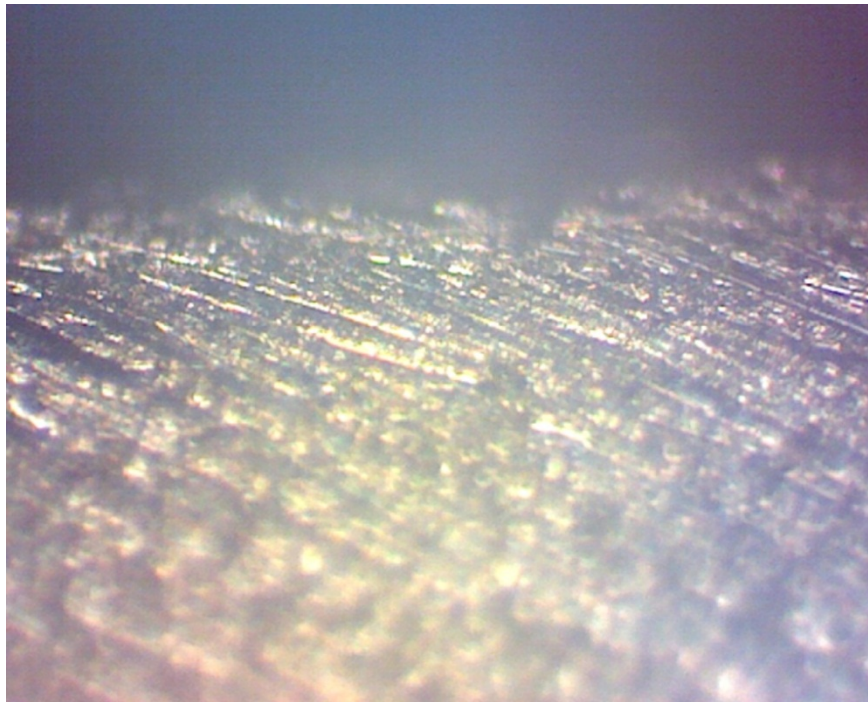
Biofuel 50/50 – 7076 Chromate Coated



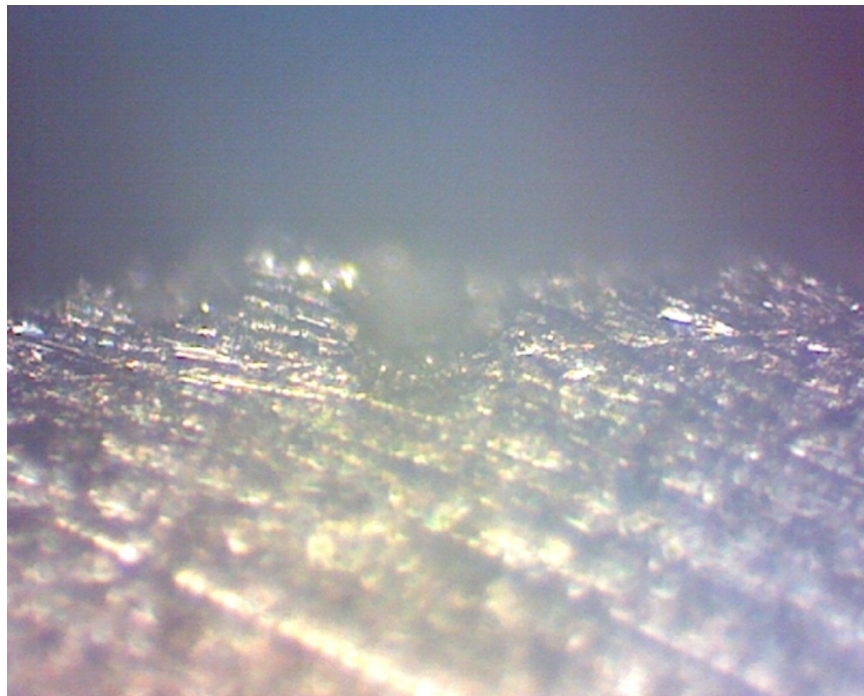
7076 Chromate Coated Bio50 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Jet A1 – 7076 Chromic Acid



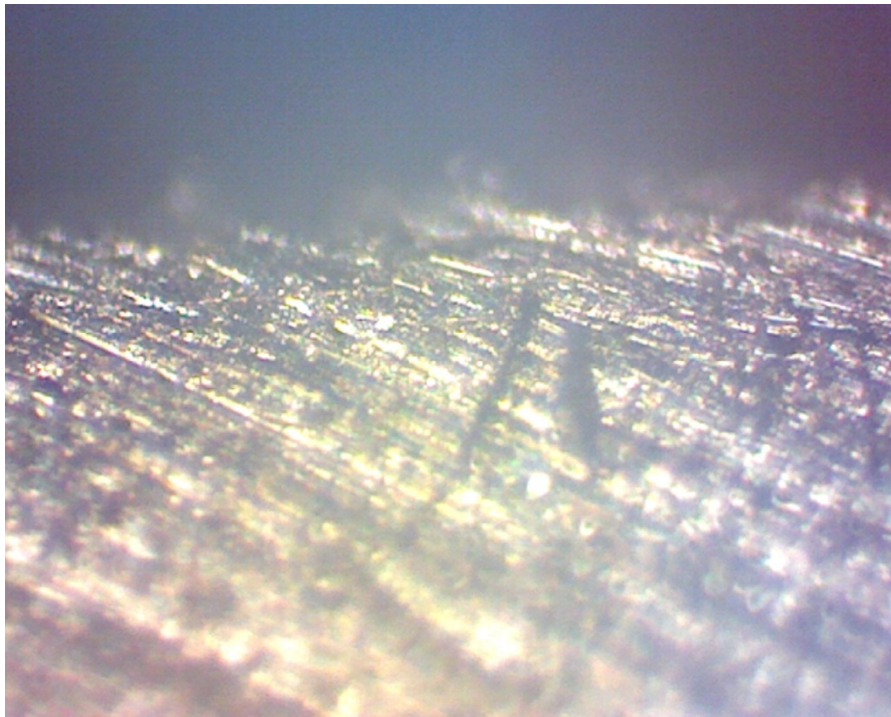
7076 Chromic Acid JetA1 150X Magnification - Specimen 1



7076 Chromic Acid JetA1 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

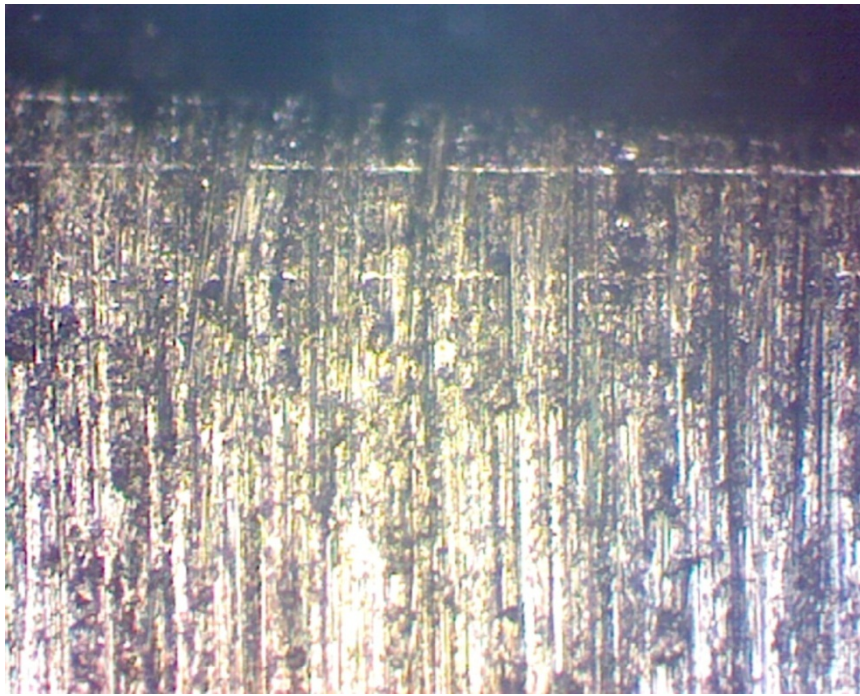
Jet A1 – 7076 Chromic Acid



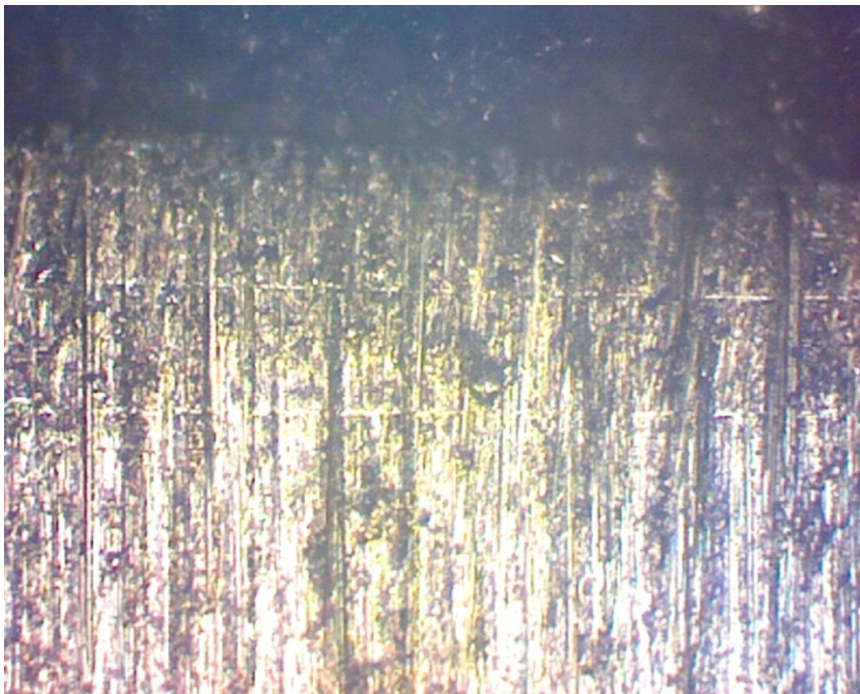
7076 Chromic Acid JetA1 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Biofuel 50/50 – 7076 Chromic Acid



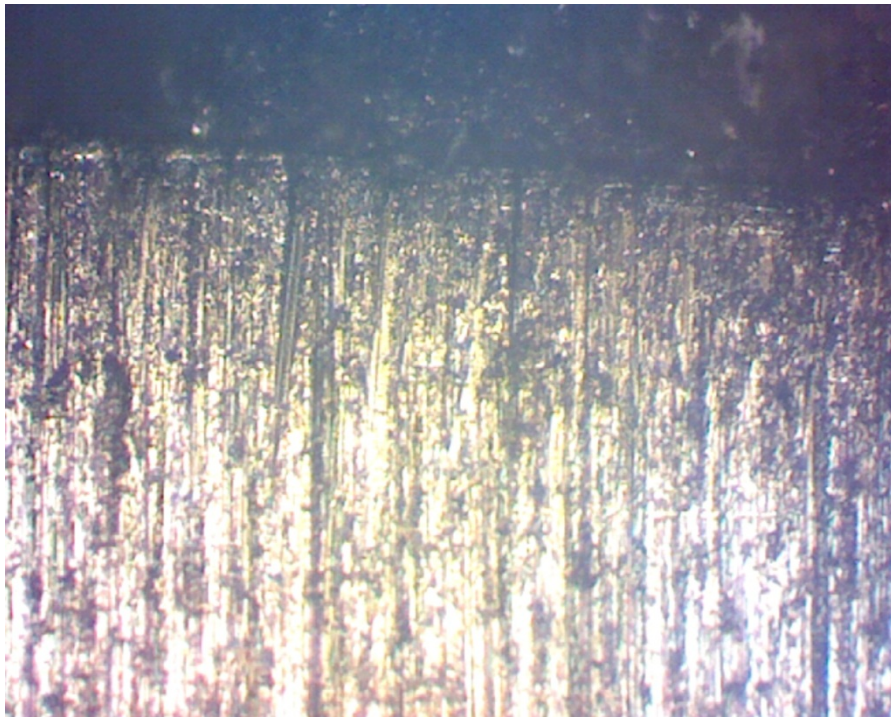
7076 Chromic Acid Bio50 150X Magnification - Specimen 1



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Metallic Surface Evaluation Images 150X ASTM D4054

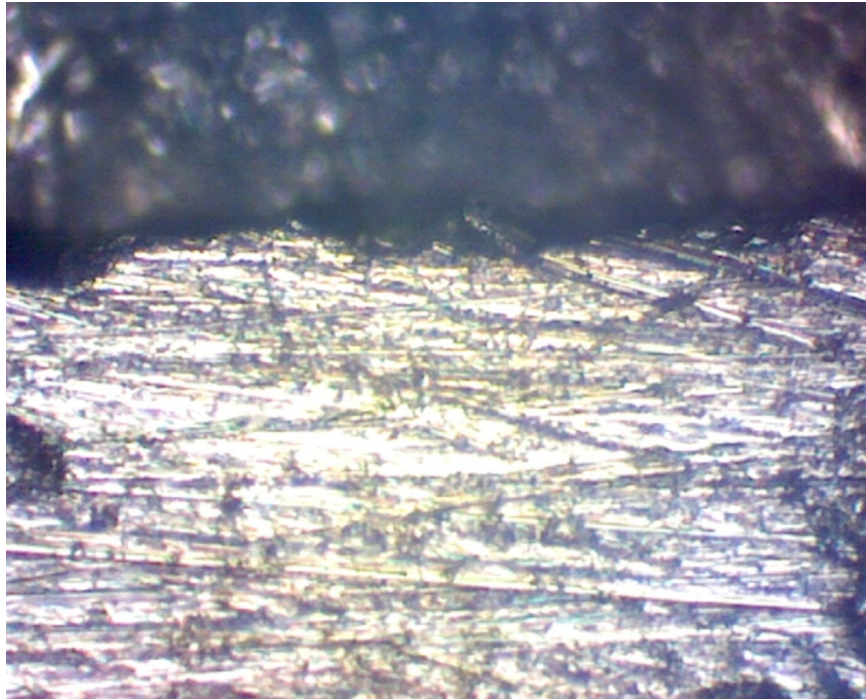
Biofuel 50/50 – 7076 Chromic Acid



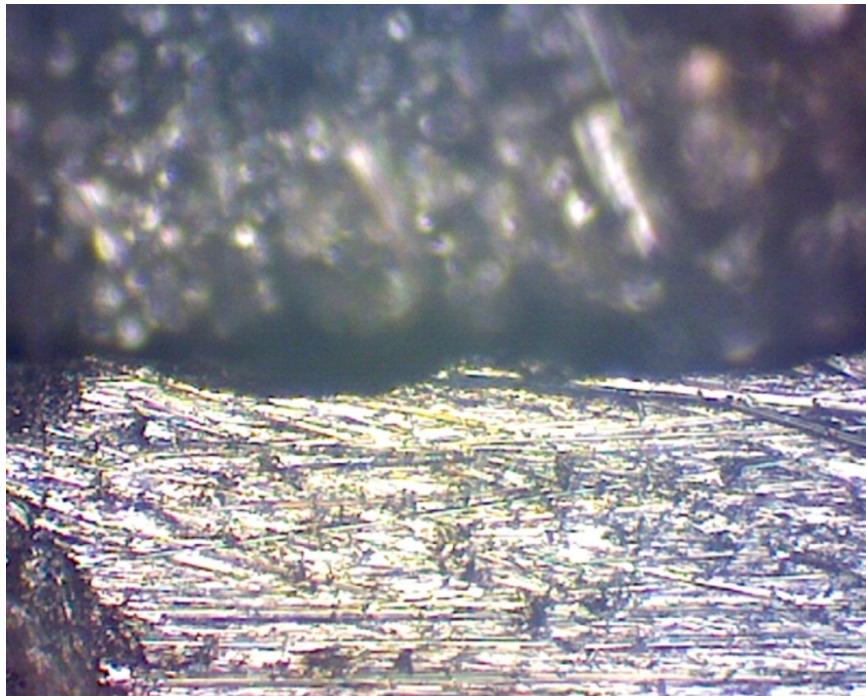
7076 Chromic Acid Bio50 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Jet A1 – 7076 Sulfuric Acid



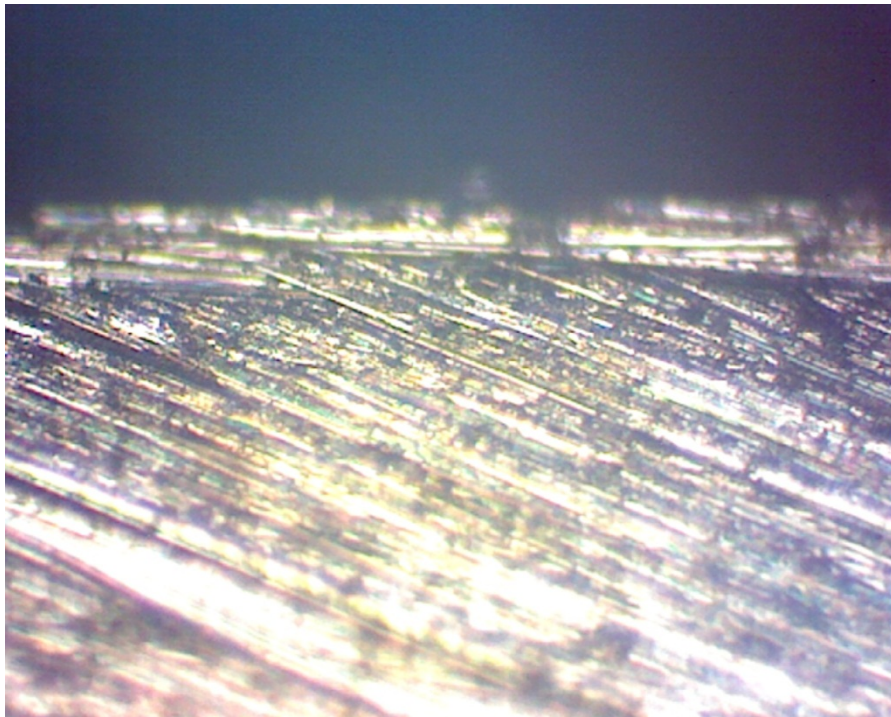
7076 Sulfuric Acid JetA1 150X Magnification - Specimen 1



7076 Sulfuric Acid JetA1 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

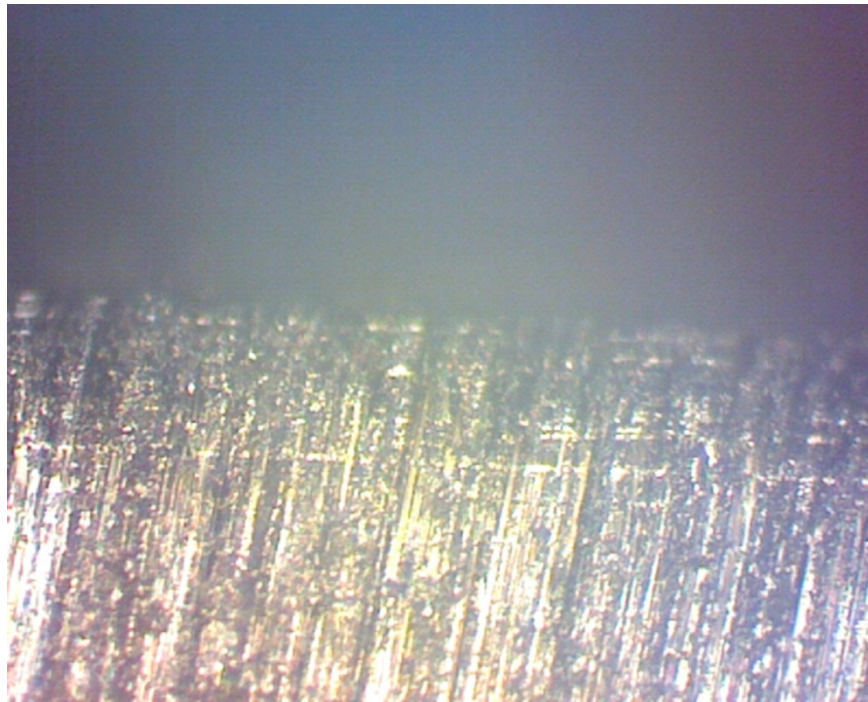
Jet A1 – 7076 Sulfuric Acid



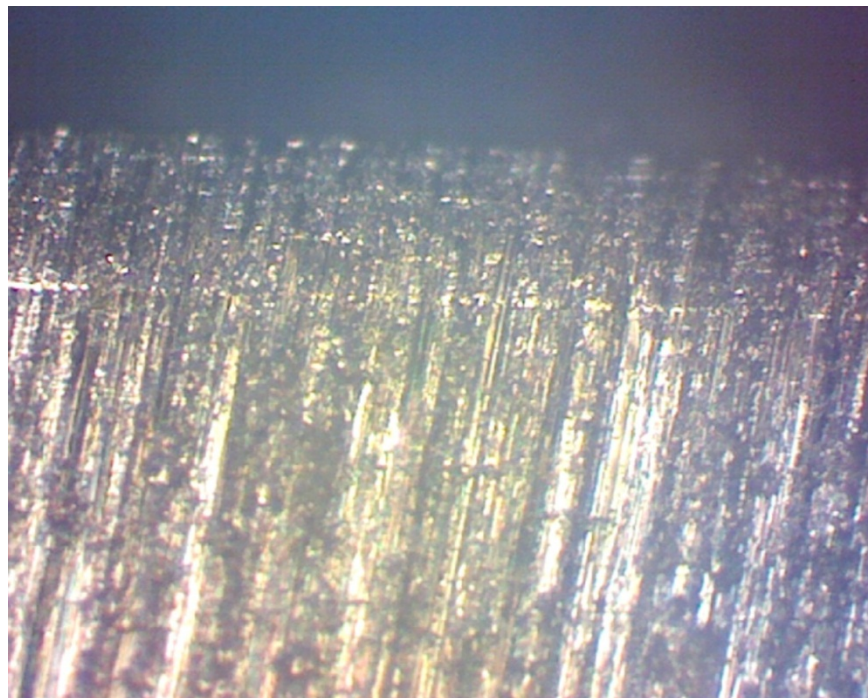
7076 Sulfuric Acid JetA1 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Biofuel 50/50 – 7076 Sulfuric Acid



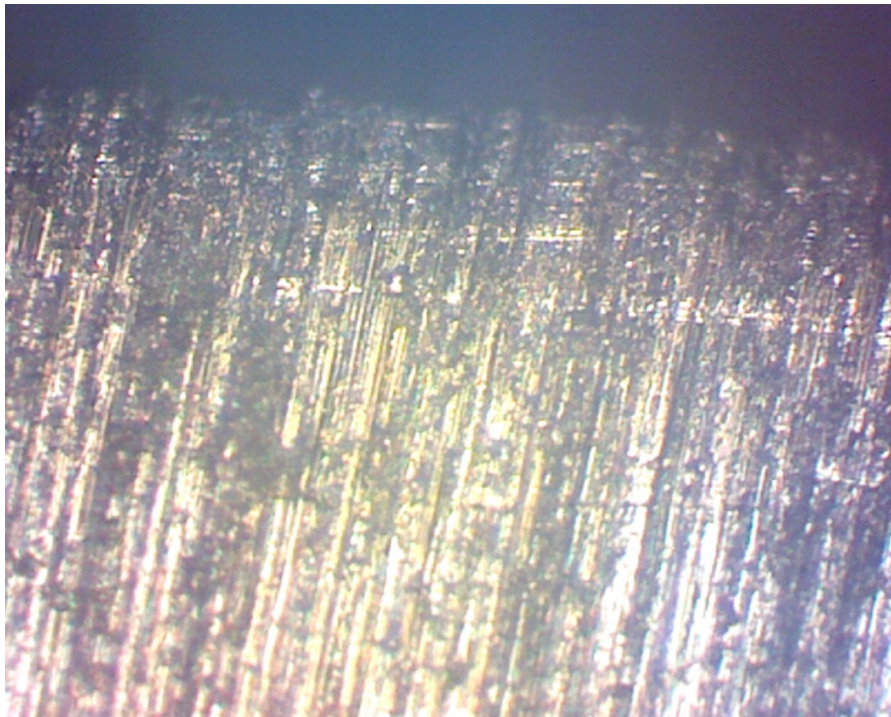
7076 Sulfuric Acid Bio50 150X Magnification - Specimen 1



7076 Sulfuric Acid Bio50 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

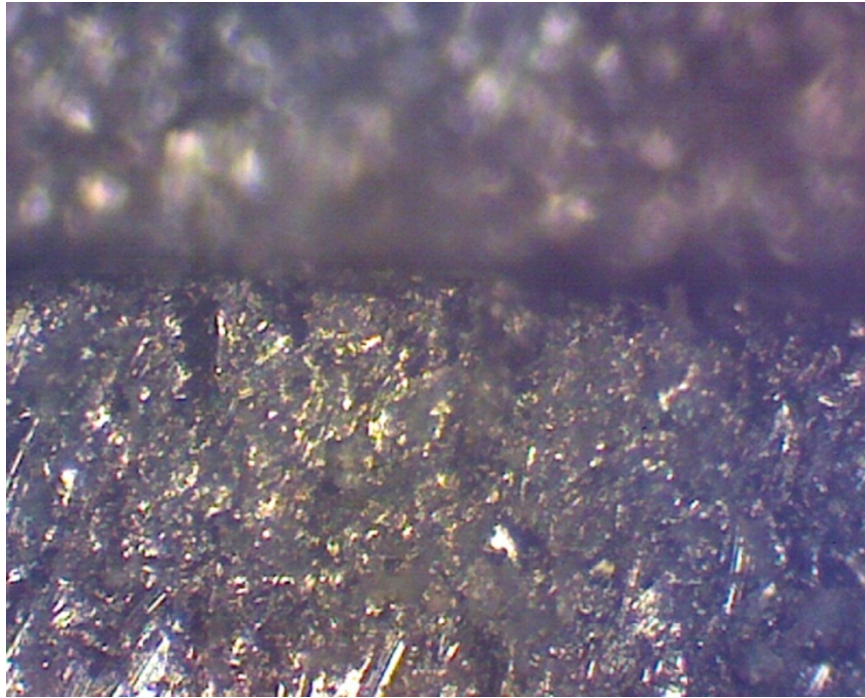
Biofuel 50/50 – 7076 Sulfuric Acid



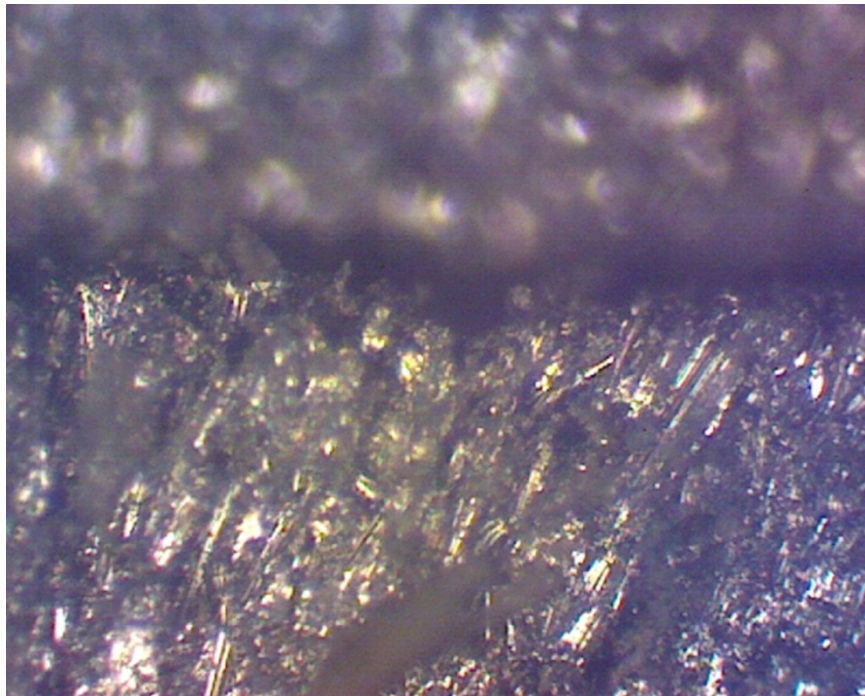
7076 Sulfuric Acid Bio50 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Jet A1 – 17-4



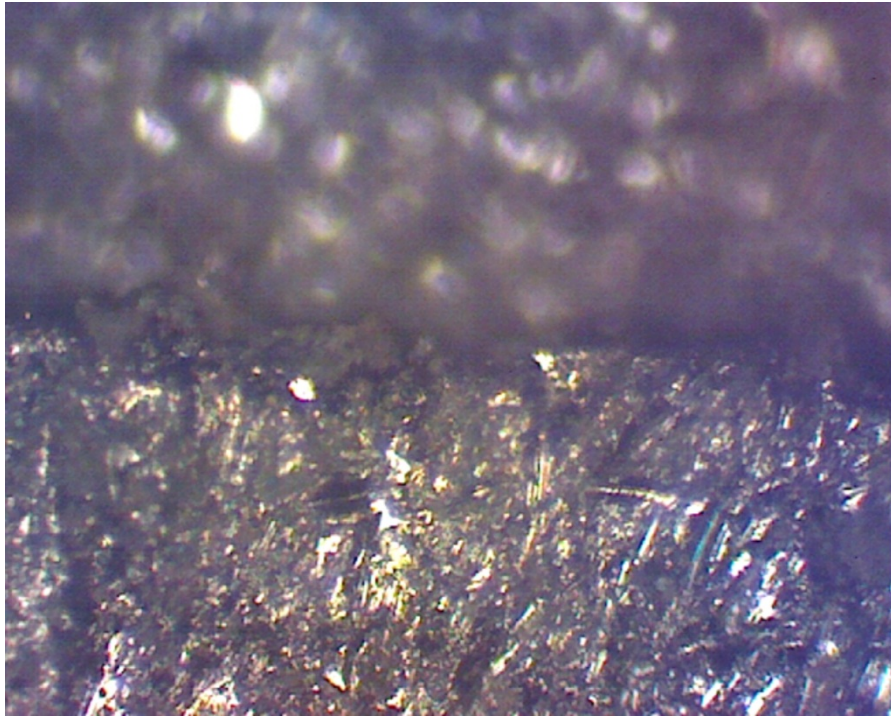
17-4 JetA1 150X Magnification - Specimen 1



17-4 JetA1 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

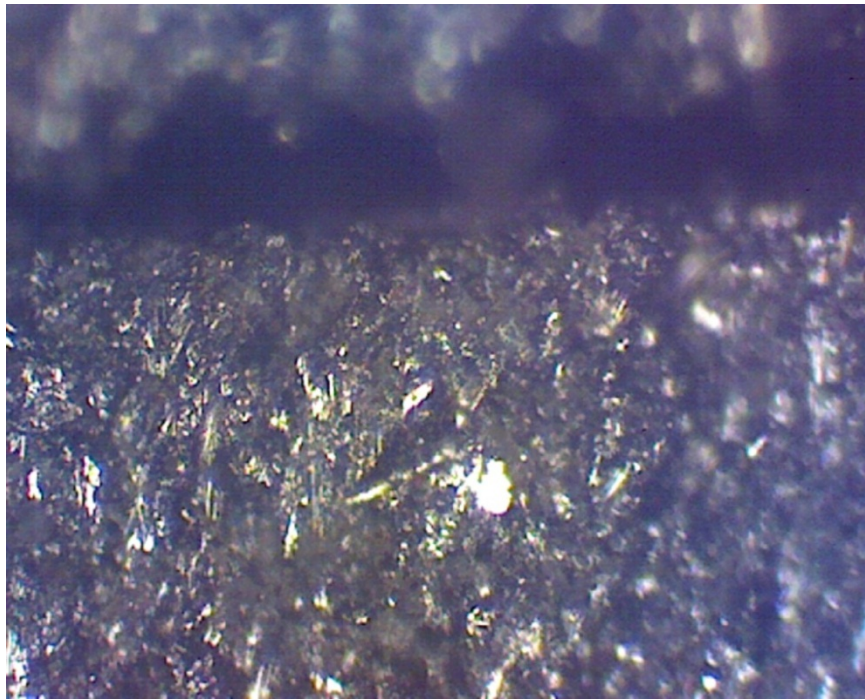
Jet A1 – 17-4



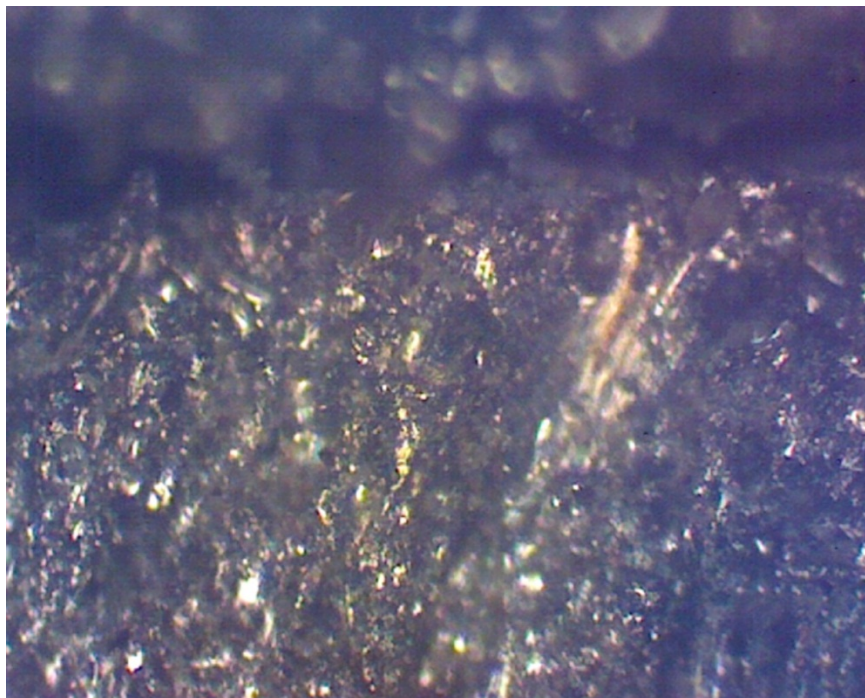
17-4 JetA1 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Biofuel 50/50 – 17-4



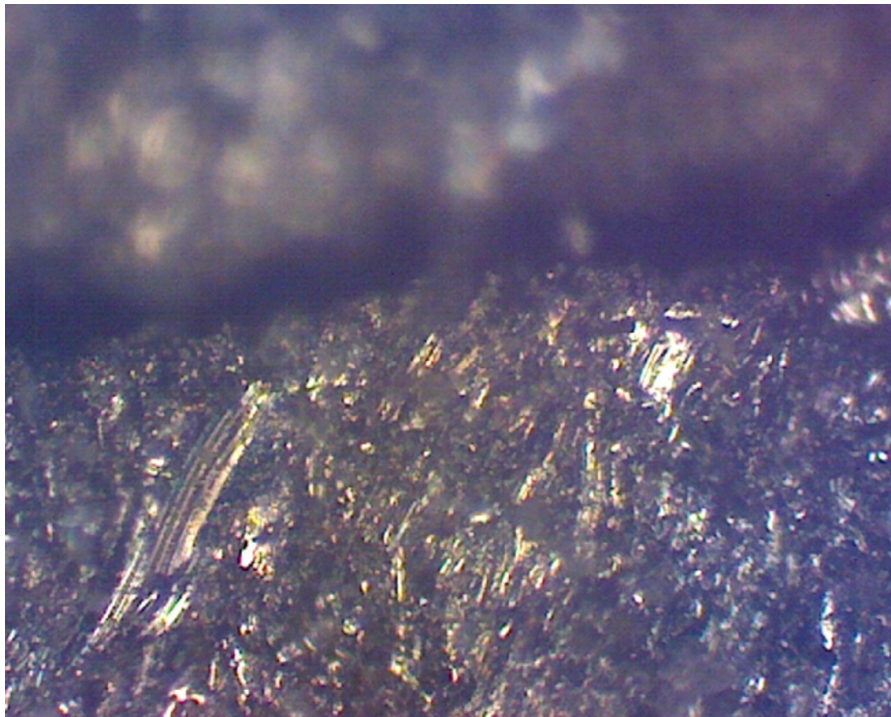
17-4 Bio50 150X Magnification - Specimen 1



17-4 Bio50 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

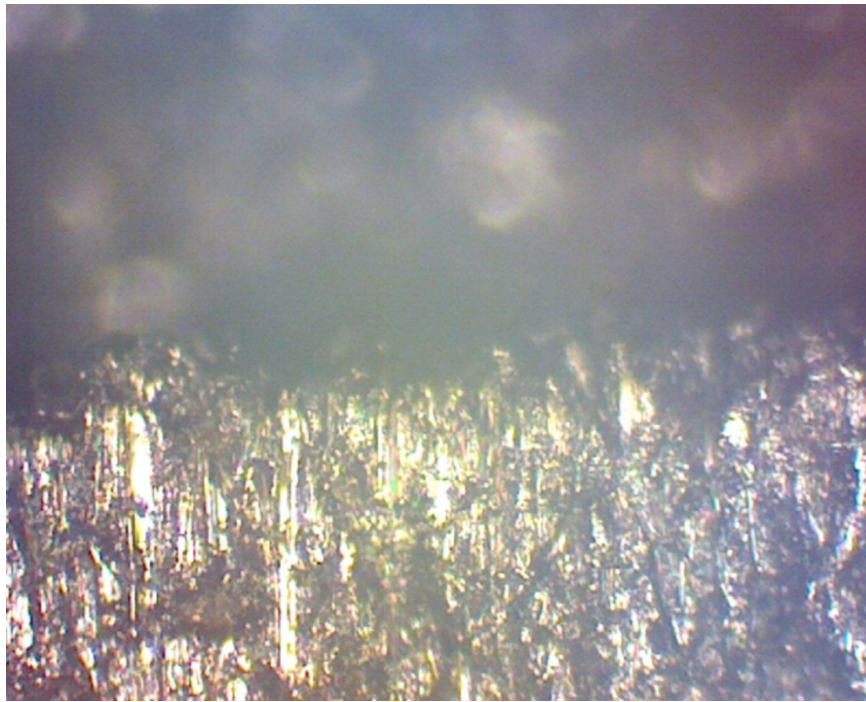
Biofuel 50/50 – 17-4



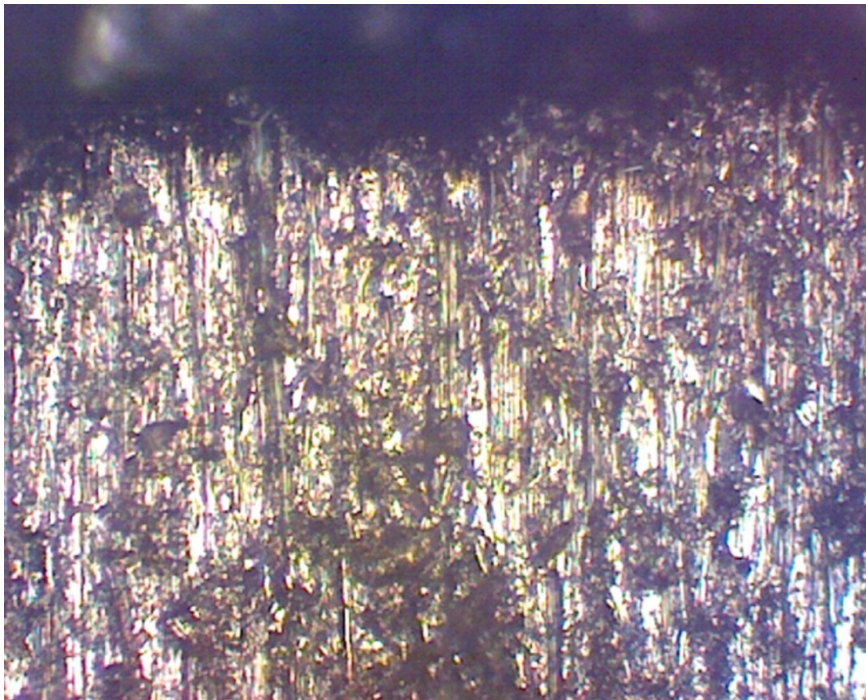
17-4 Bio50 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Jet A1 – 304-SS



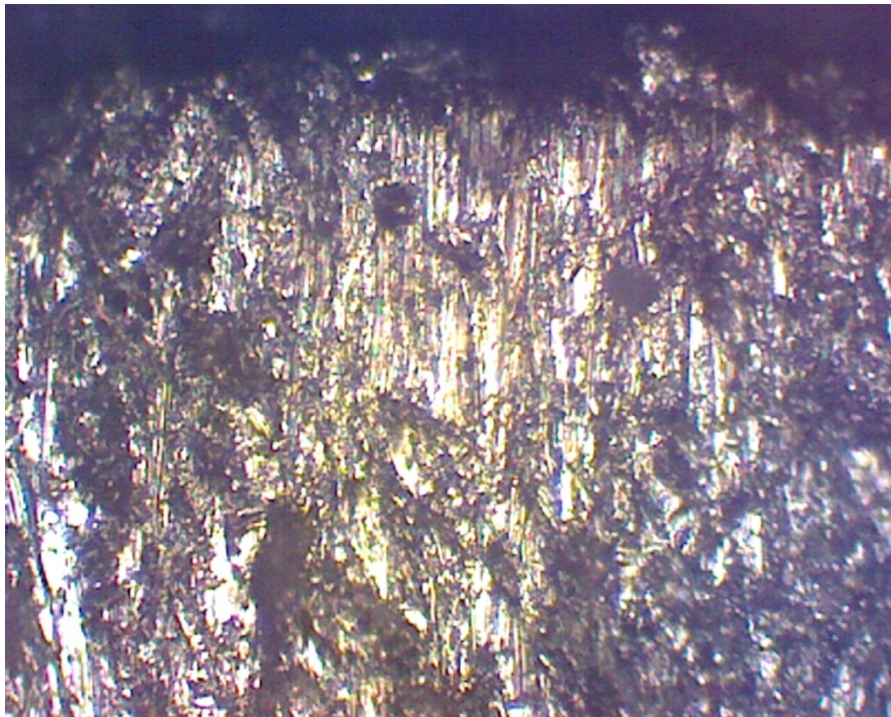
304-SS JetA1 150X Magnification - Specimen 1



304-SS JetA1 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

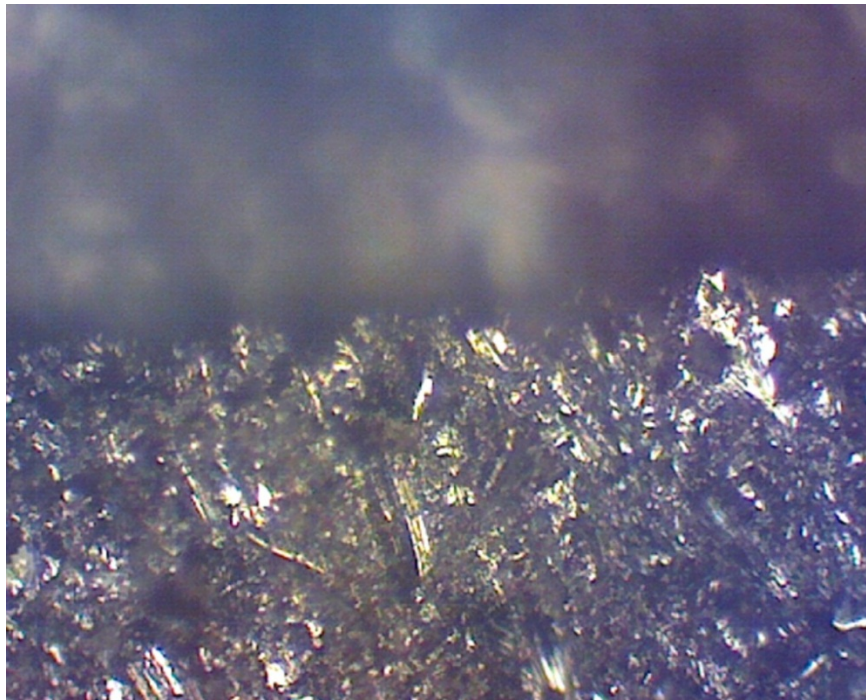
Jet A1 – 304-SS



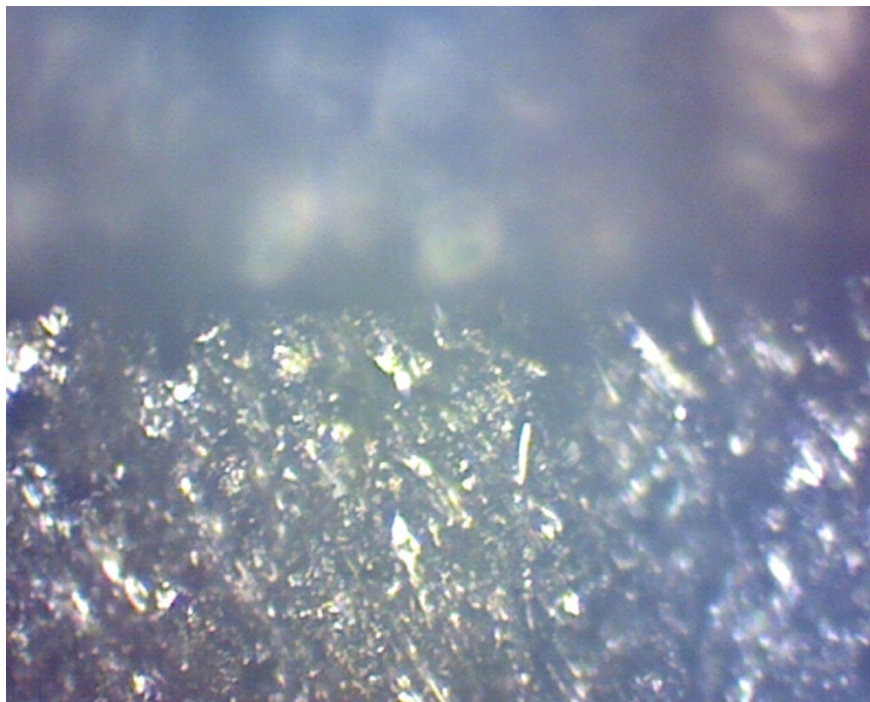
304-SS JetA1 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Biofuel 50/50 – 304-SS



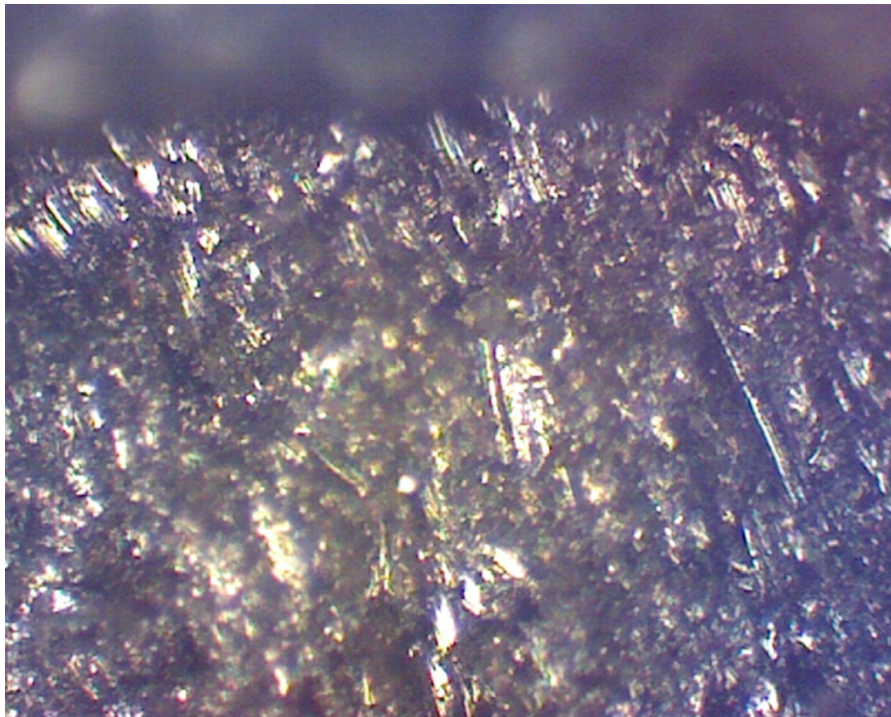
304-SS Bio50 150X Magnification - Specimen 1



304-SS Bio50 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

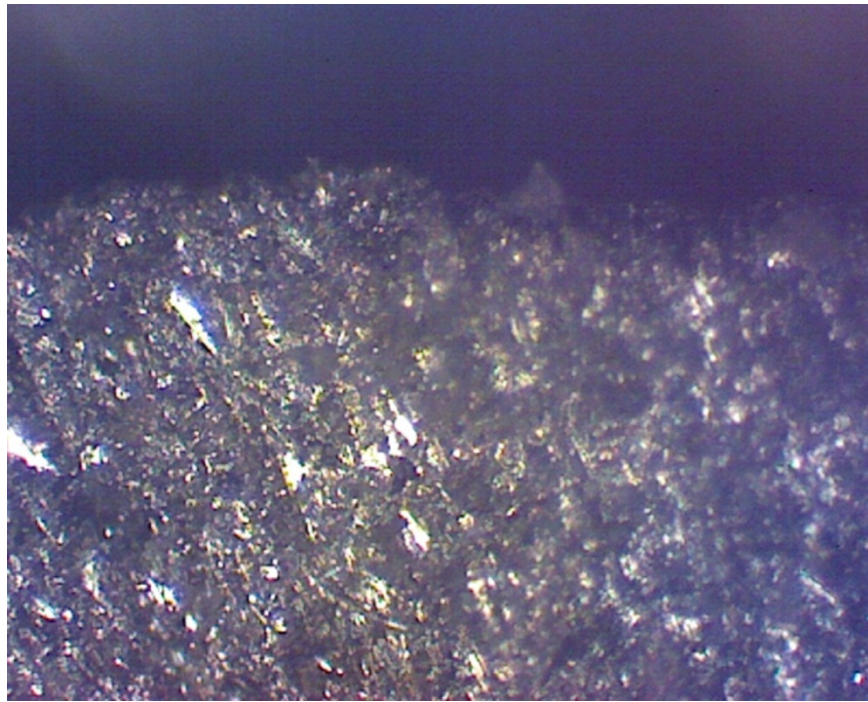
Biofuel 50/50 – 304-SS



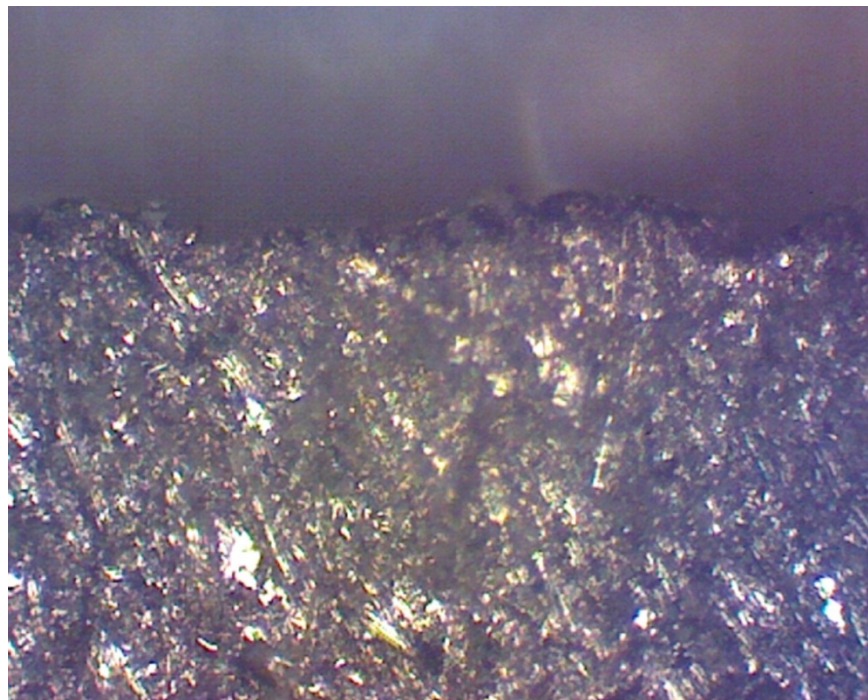
304-SS Bio50 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Jet A1 – Inconel 625



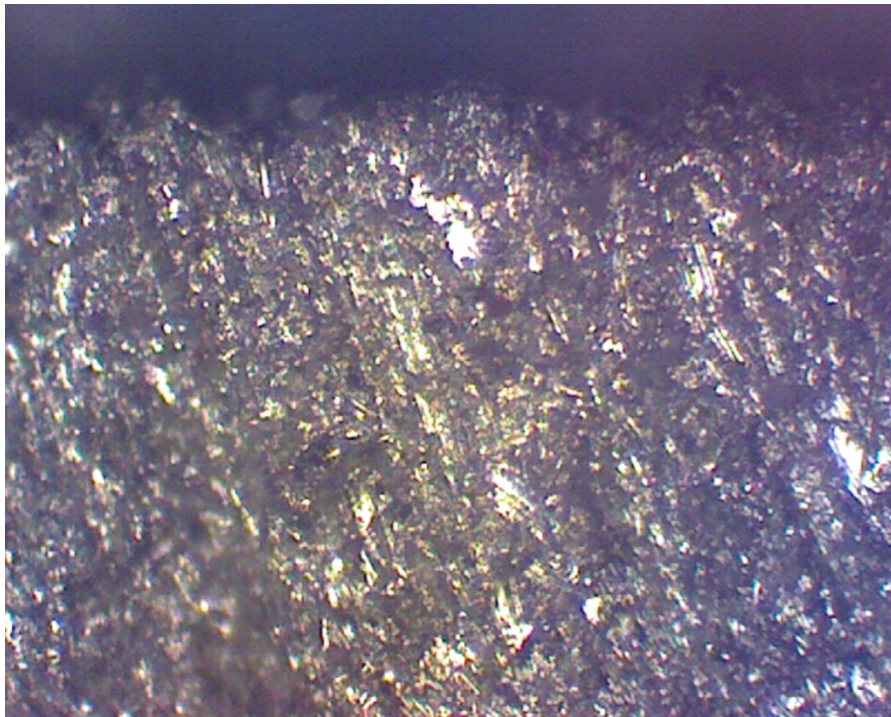
Inconel 625 JetA1 150X Magnification - Specimen 1



Inconel 625 JetA1 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

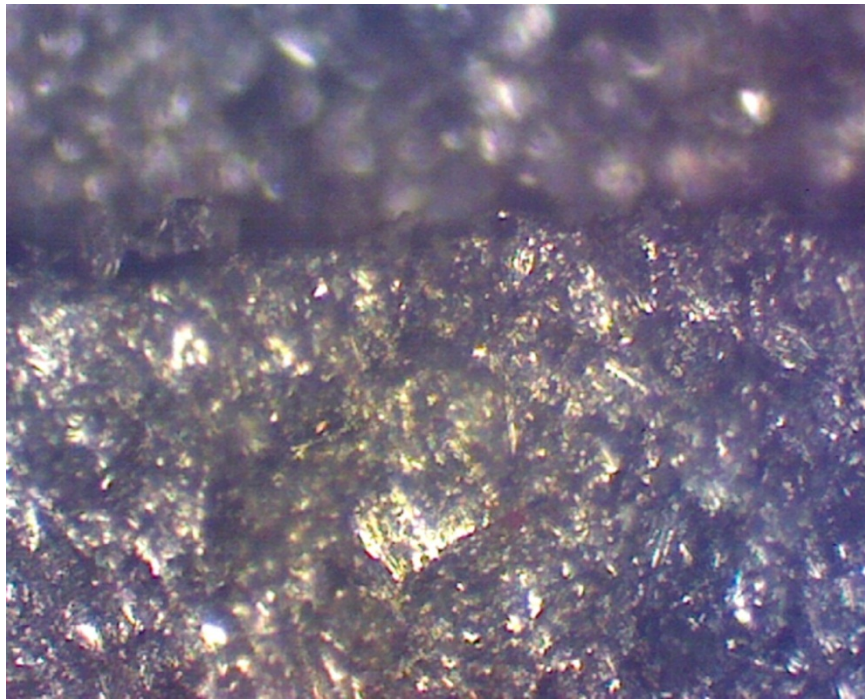
Jet A1 – Inconel 625



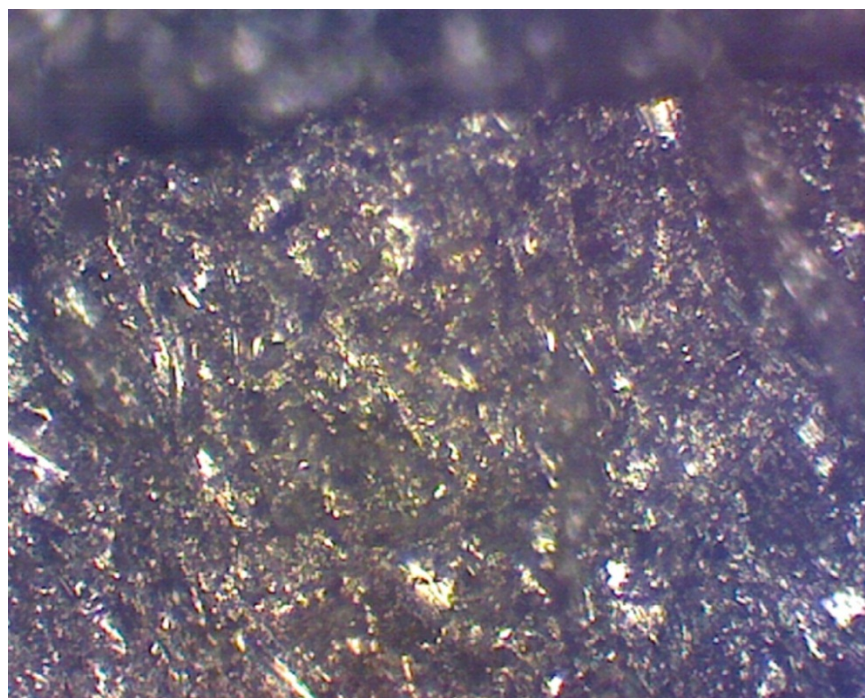
Inconel 625 JetA1 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Biofuel 50/50 – Inconel 625



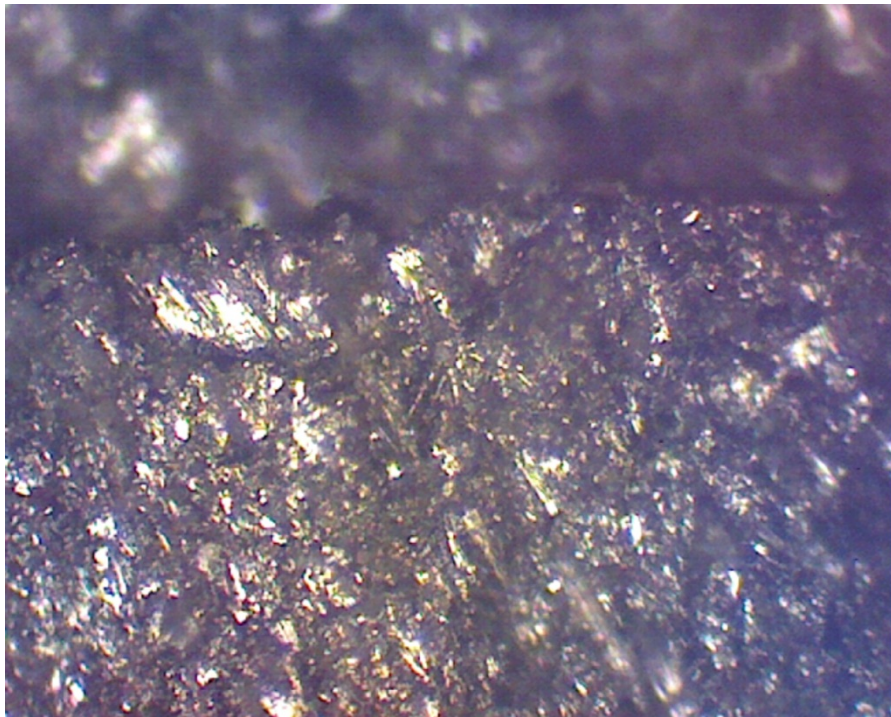
Inconel 625 Bio50 150X Magnification - Specimen 1



Inconel 625 Bio50 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

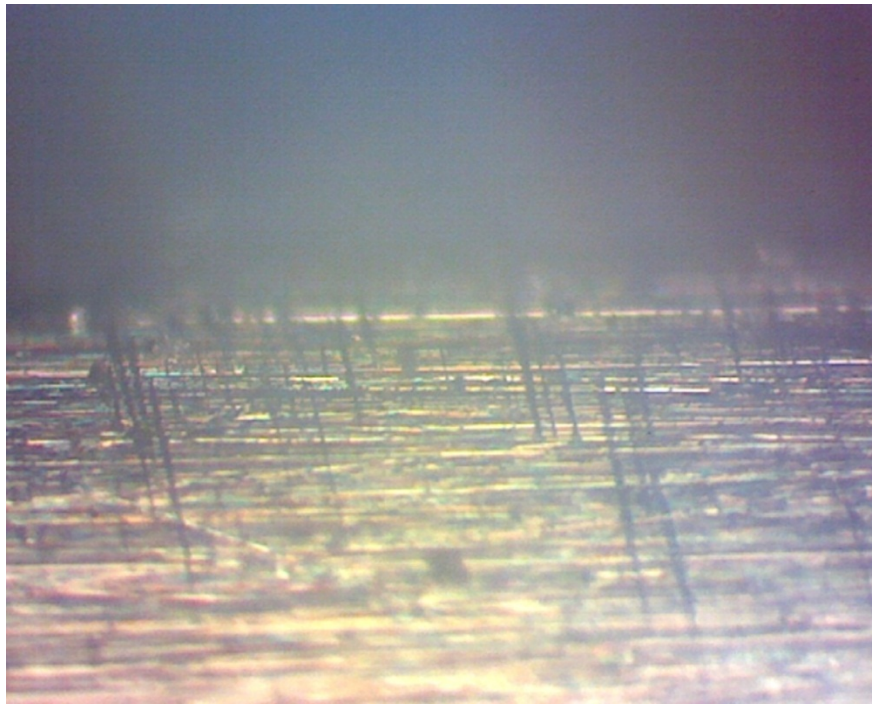
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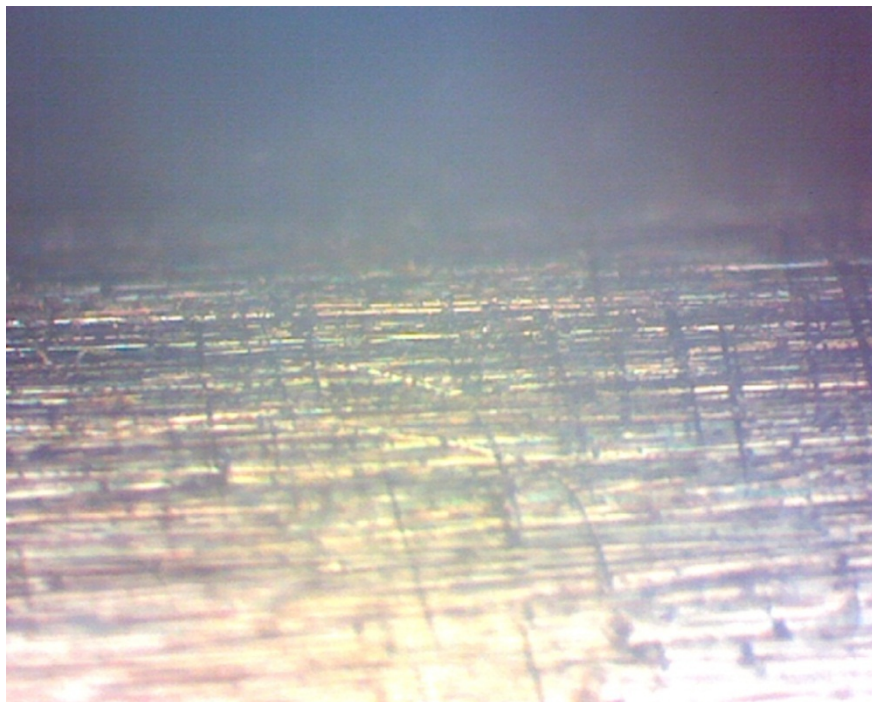
Inconel 625 Bio50 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Jet A1 – Inconel 718



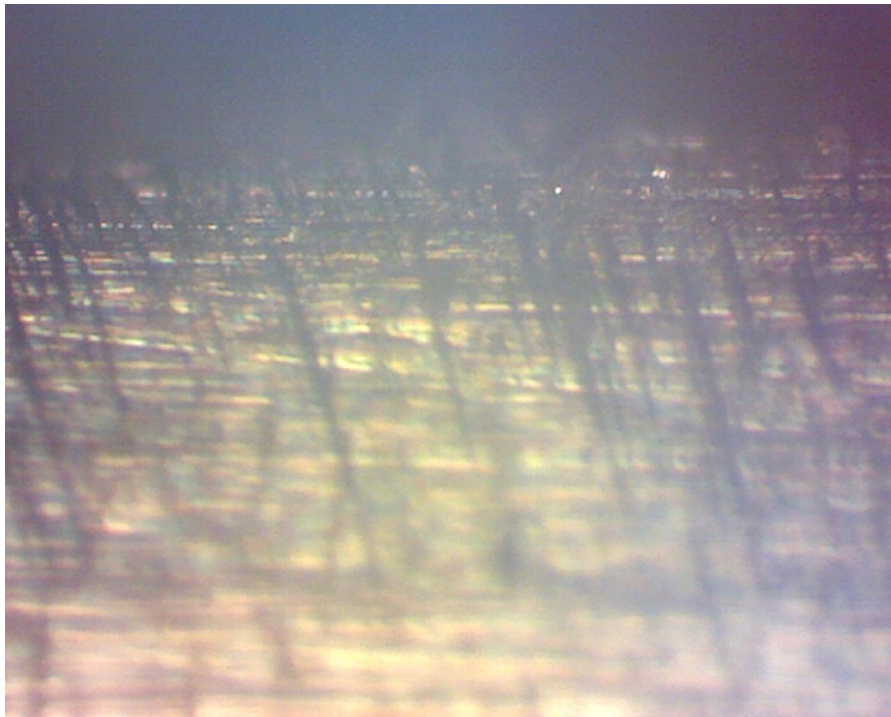
Inconel 718 JetA1 150X Magnification - Specimen 1



Inconel 718 JetA1 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

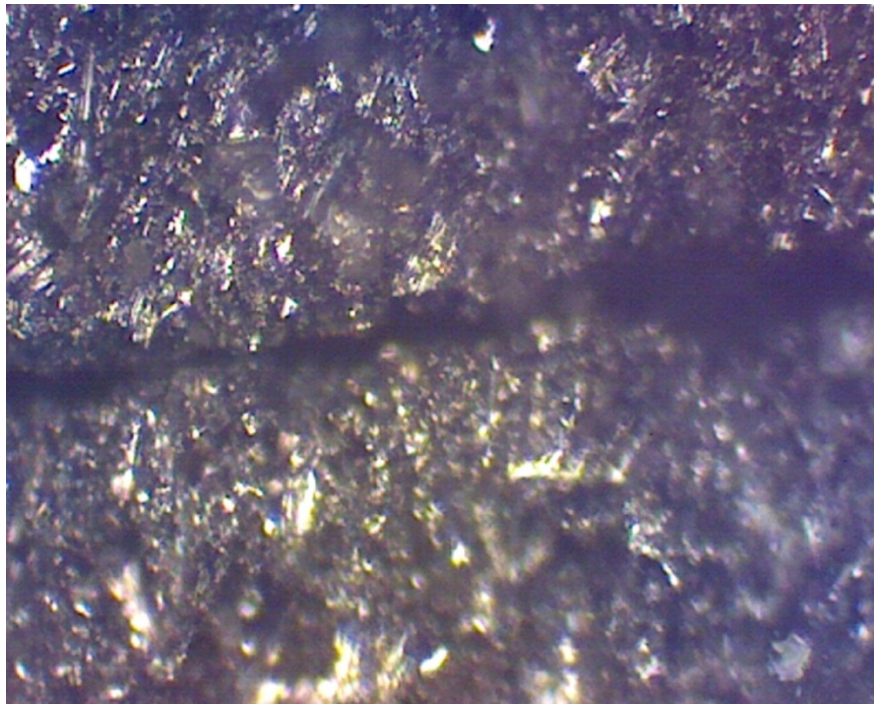
Jet A1 – Inconel 718



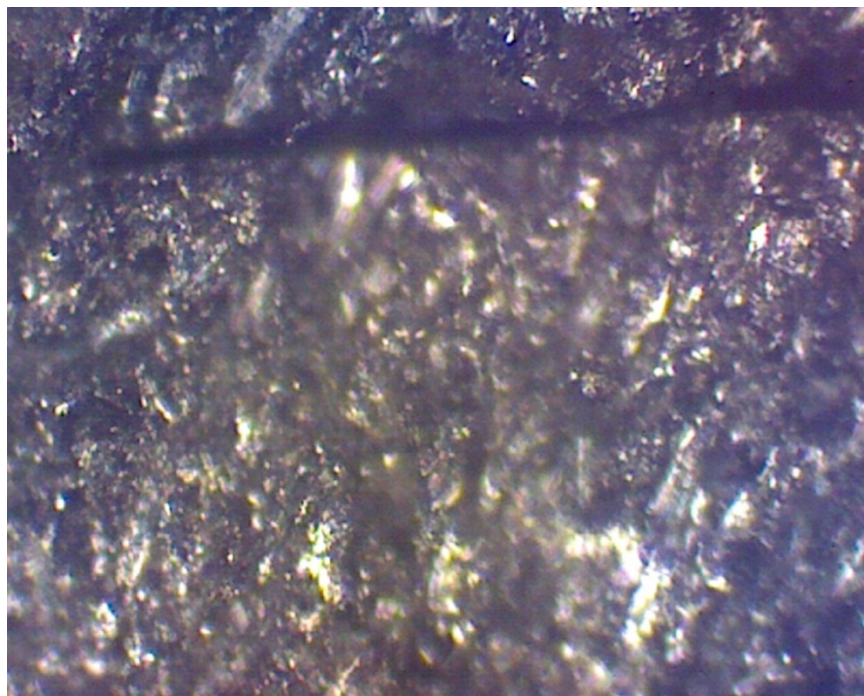
Inconel 718 JetA1 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Biofuel 50/50 – Inconel 718



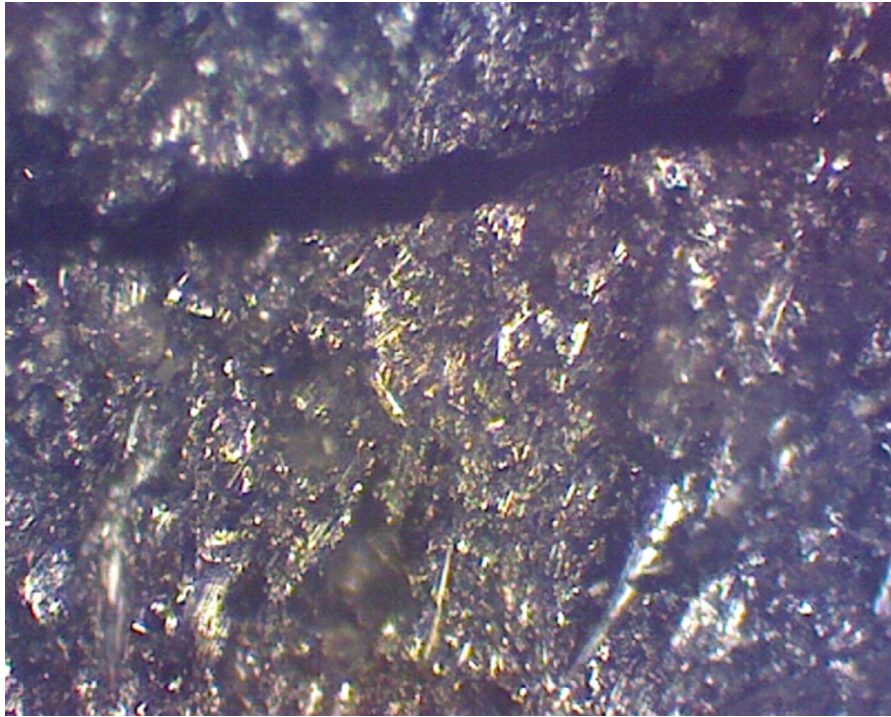
Inconel 718 Bio50 150X Magnification - Specimen 1



Inconel 718 Bio50 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

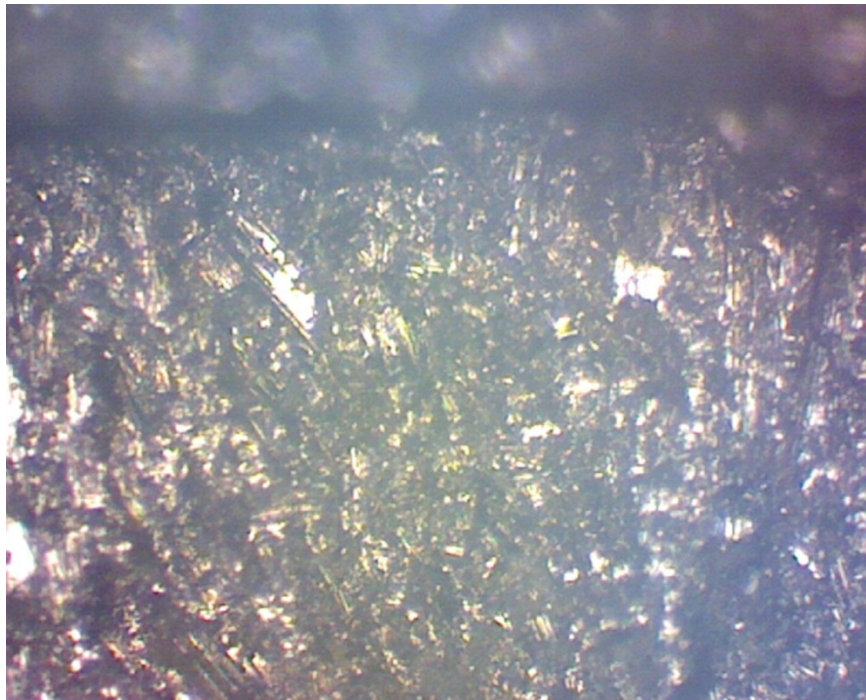
Biofuel 50/50 – Inconel 718



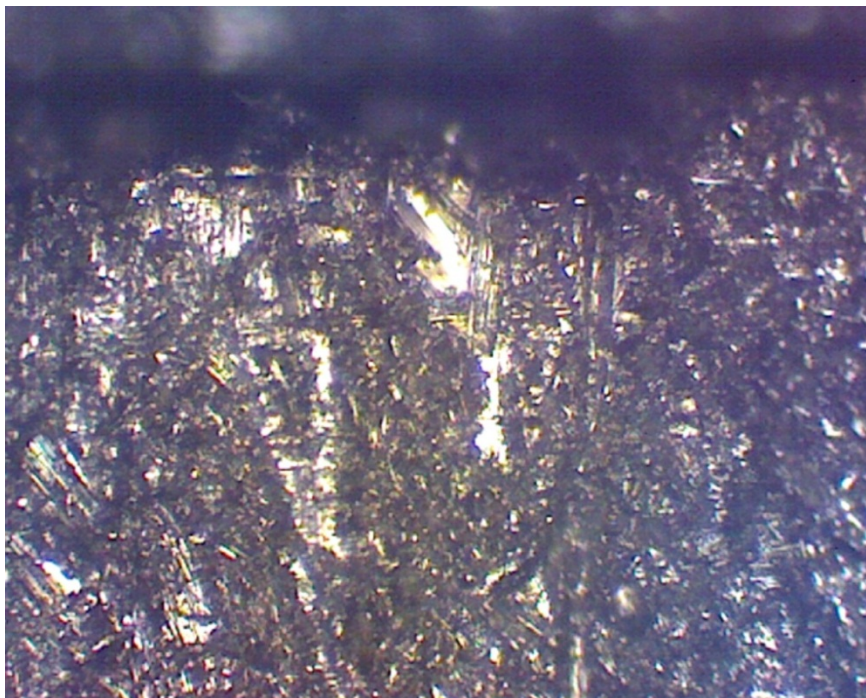
Inconel 718 Bio50 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Jet A1 – Monel 400



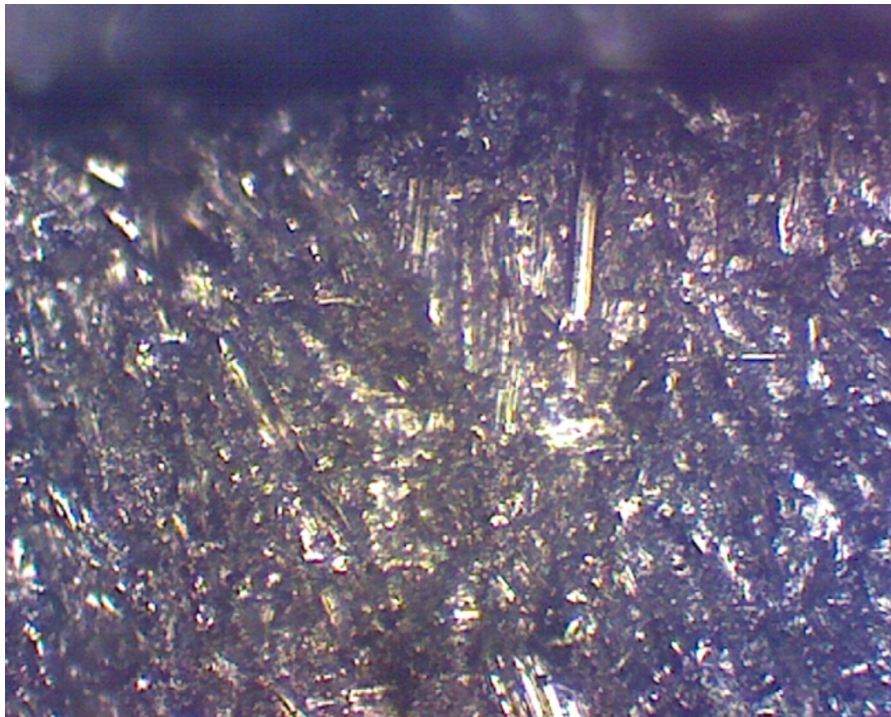
Monel 400 JetA1 150X Magnification - Specimen 1



Monel 400 JetA1 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

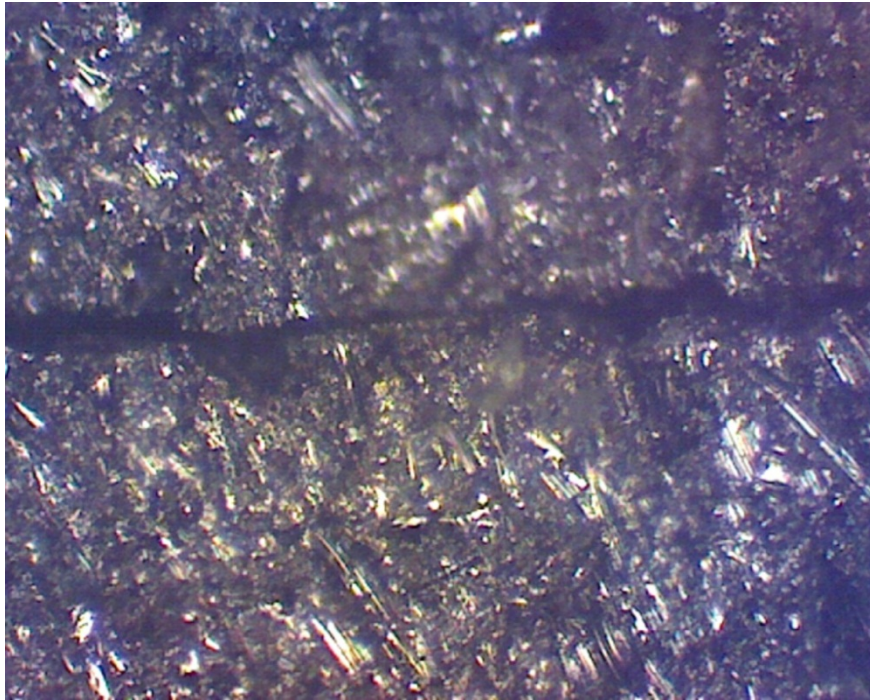
Jet A1 – Monel 400



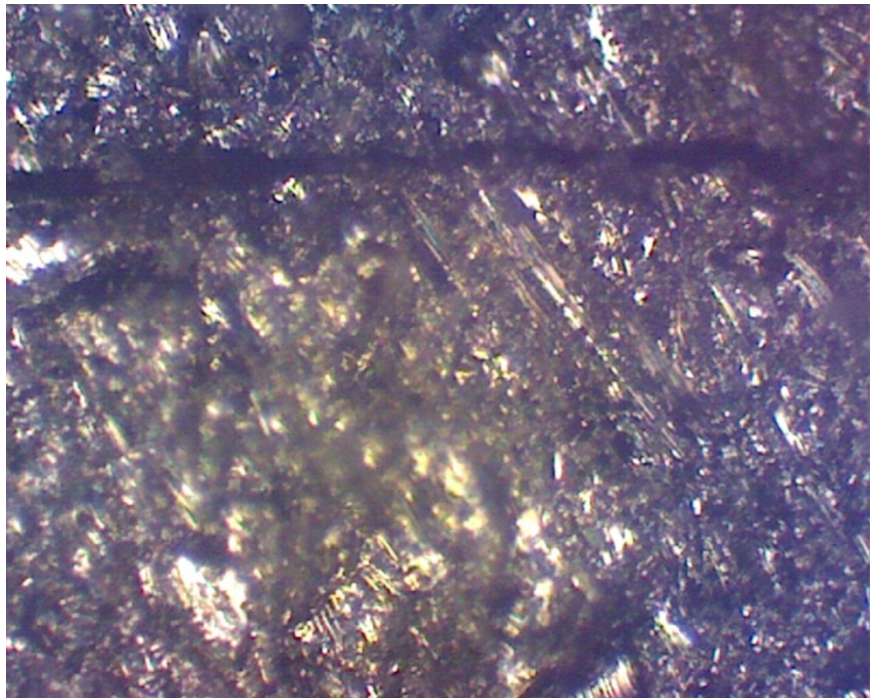
Monel 400 JetA1 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Biofuel 50/50 – Monel 400



Monel 400 Bio50 150X Magnification - Specimen 1



Monel 400 Bio50 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

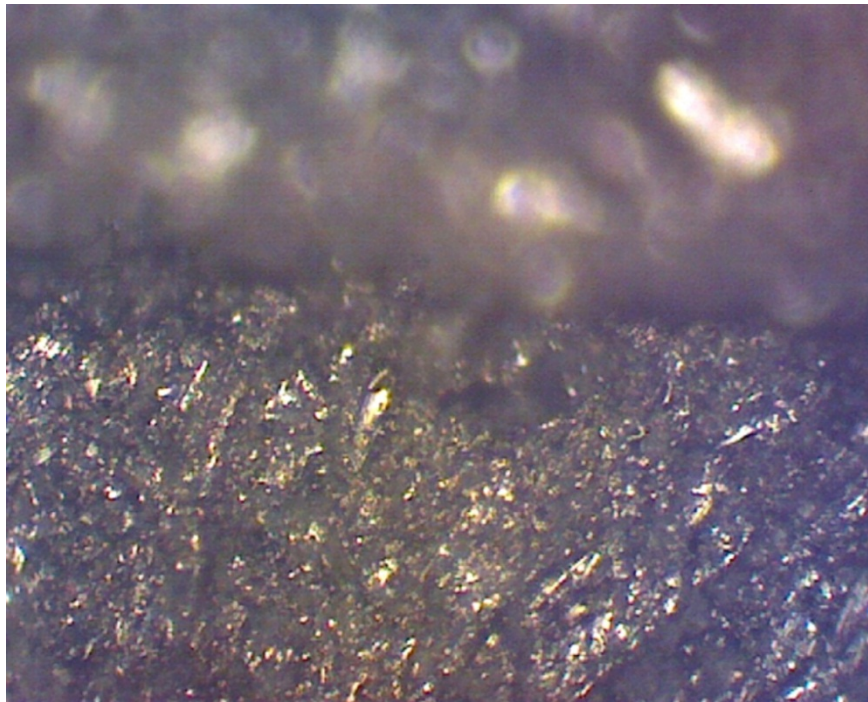
Biofuel 50/50 – Monel 400



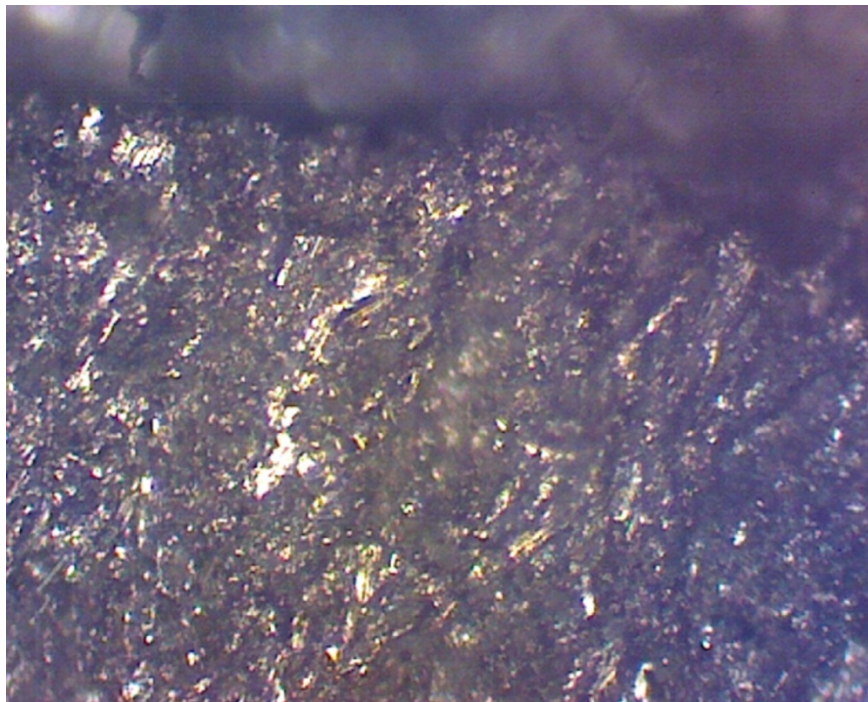
Monel 400 Bio50 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Jet A1 – Nickel 200



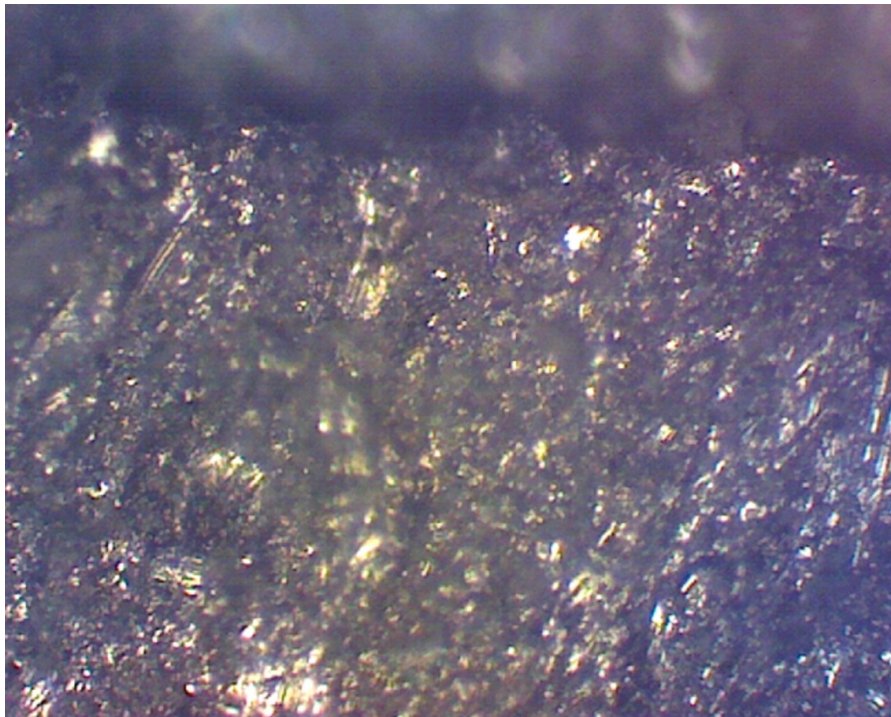
Nickel 200 JetA1 150X Magnification - Specimen 1



Nickel 200 JetA1 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

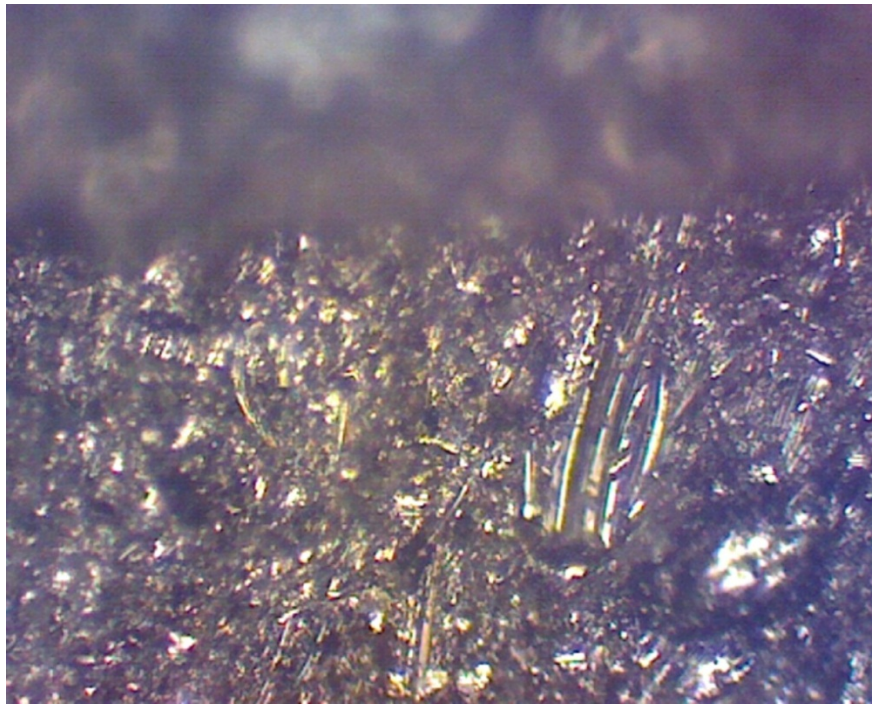
Jet A1 – Nickel 200



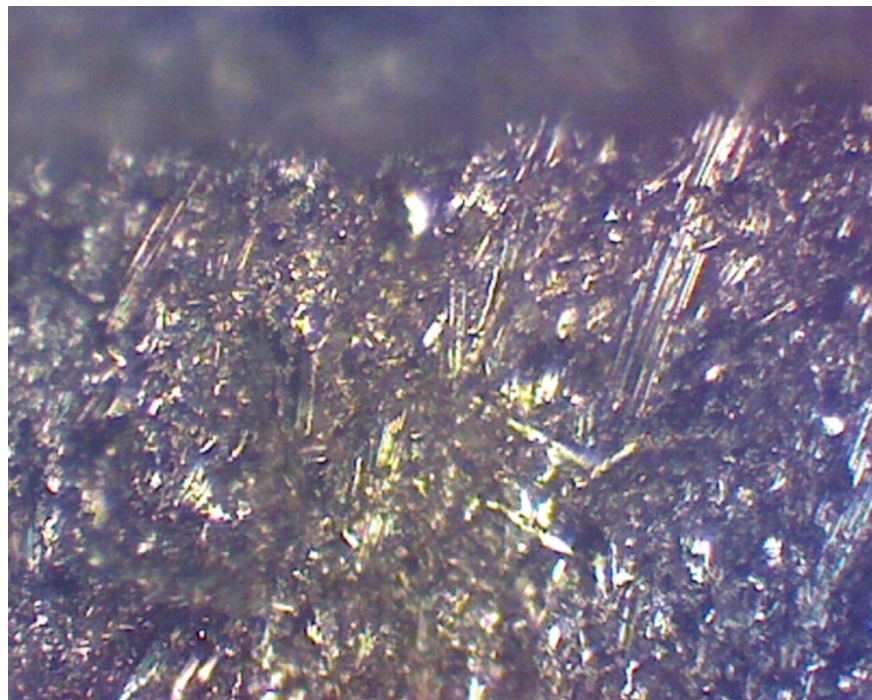
Nickel 200 JetA1 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Biofuel 50/50 – Nickel 200



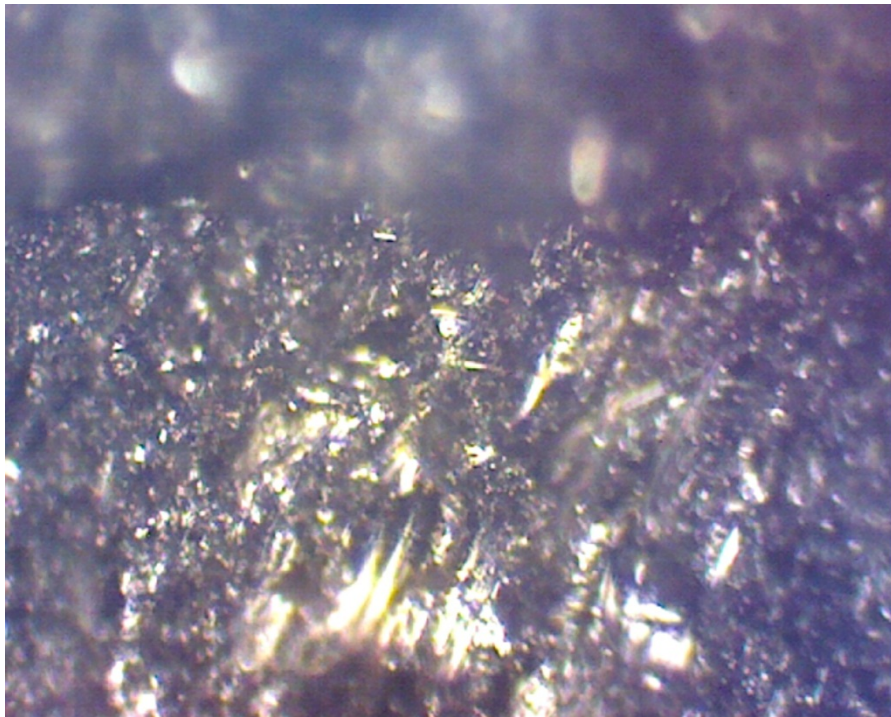
Nickel 200 Bio50 150X Magnification - Specimen 1



Nickel 200 Bio50 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

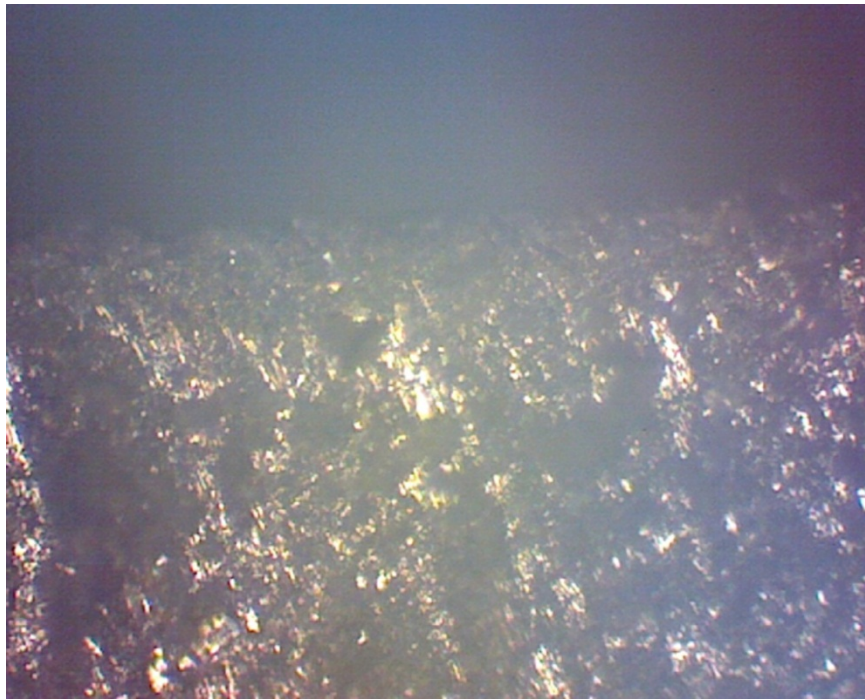
Biofuel 50/50 – Nickel 200



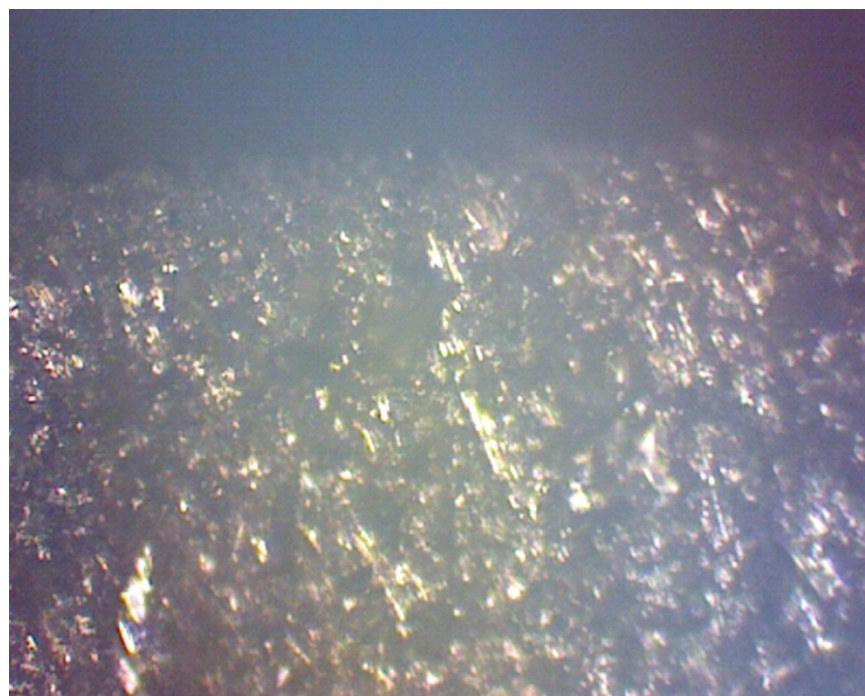
Nickel 200 Bio50 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Jet A1 – Titanium 3Al-2.5V



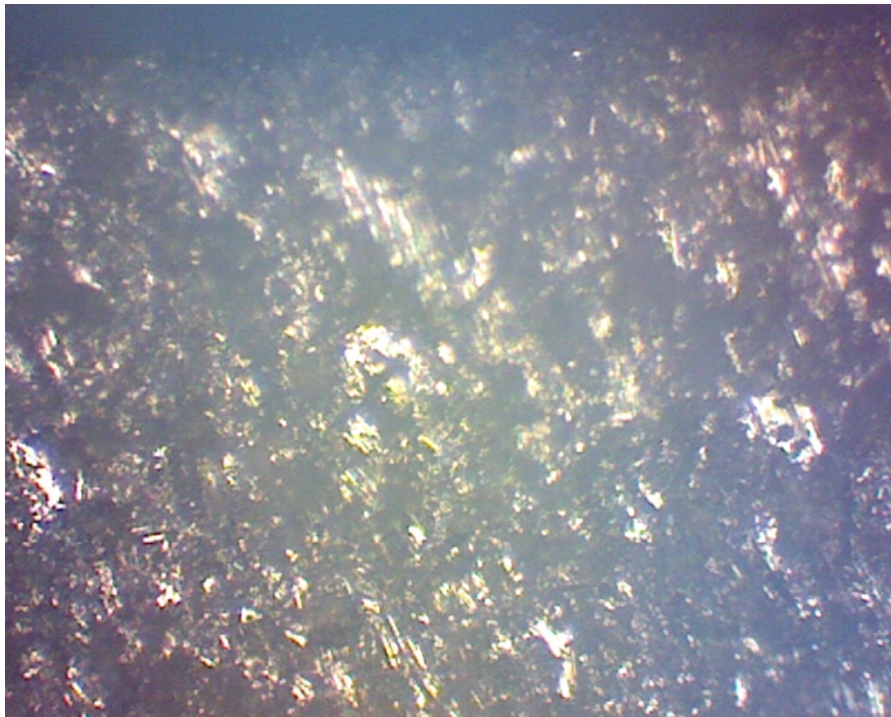
Titanium 3Al-2.5V JetA1 150X Magnification - Specimen 1



Titanium 3Al-2.5V JetA1 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

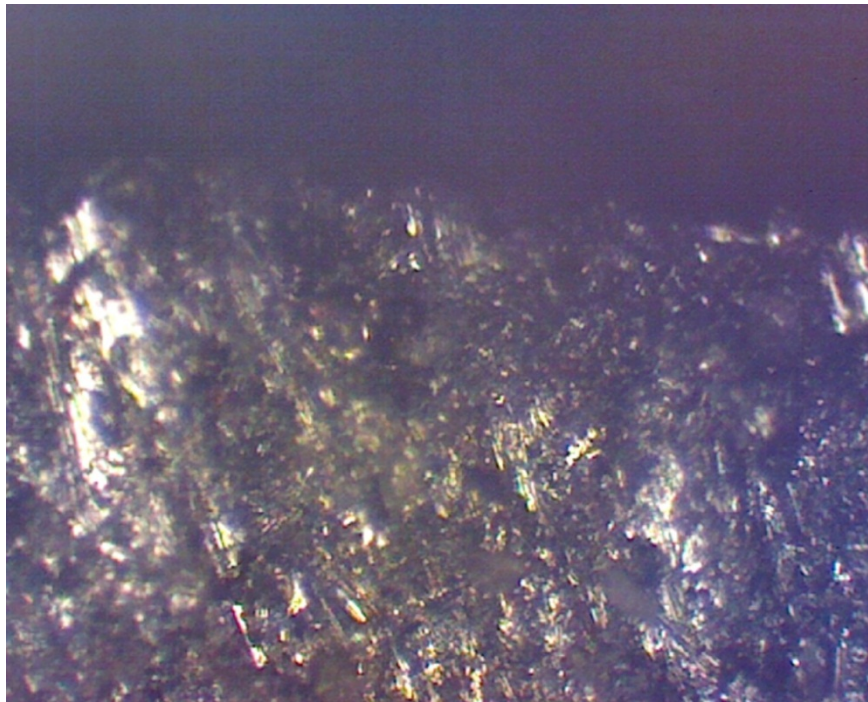
Jet A1 – Titanium 3Al-2.5V



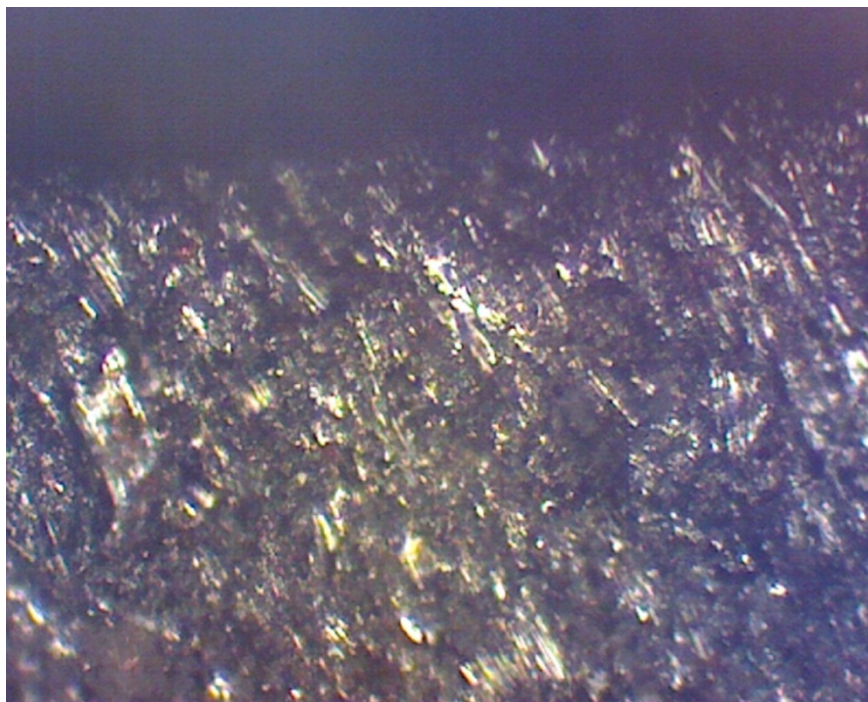
Titanium 3Al-2.5V JetA1 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Biofuel 50/50 – Titanium 3Al-2.5V



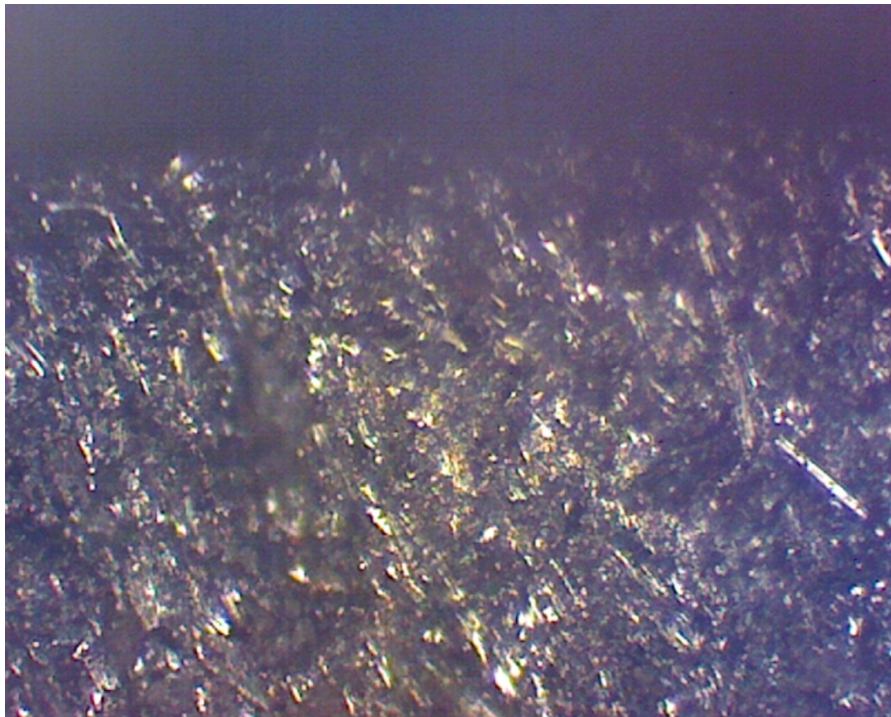
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Titanium 3Al-2.5V Bio50 150X Magnification - Specimen 2

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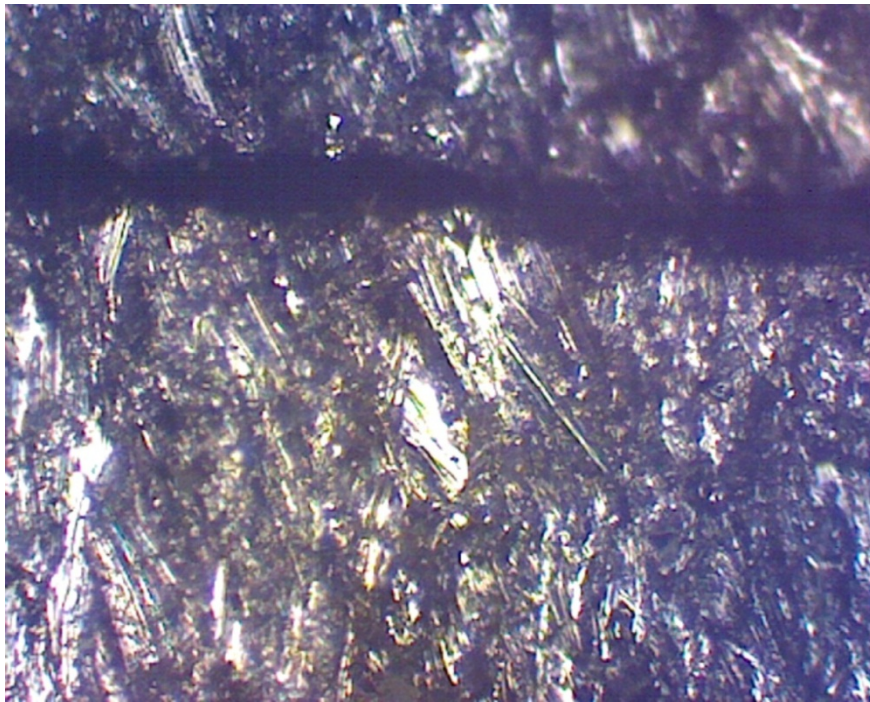
Biofuel 50/50 – Titanium 3Al-2.5V



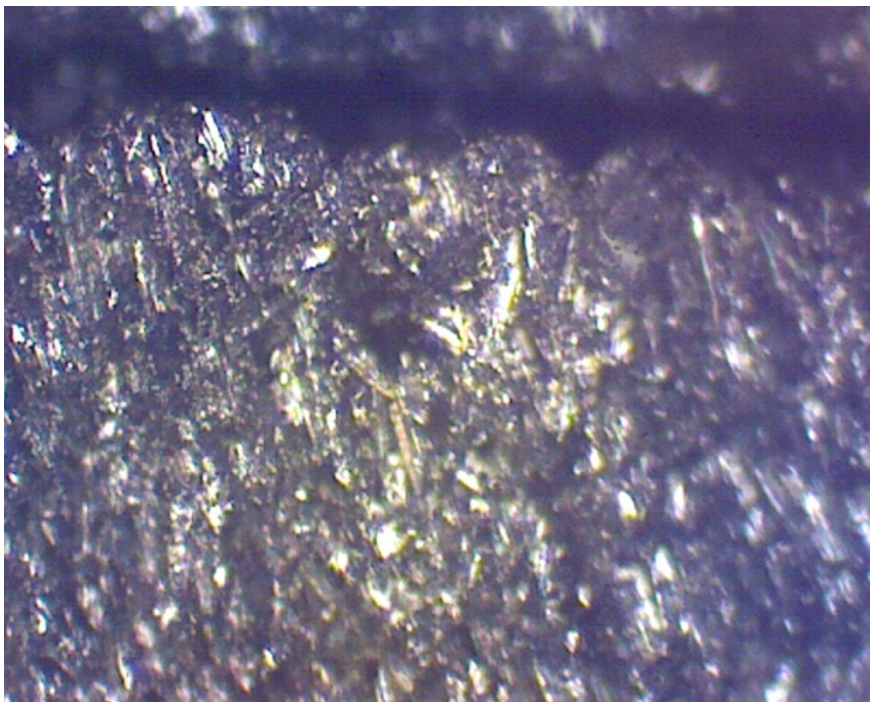
Titanium 3Al-2.5V Bio50 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Jet A1 – Titanium 8Al-1V-1Mo



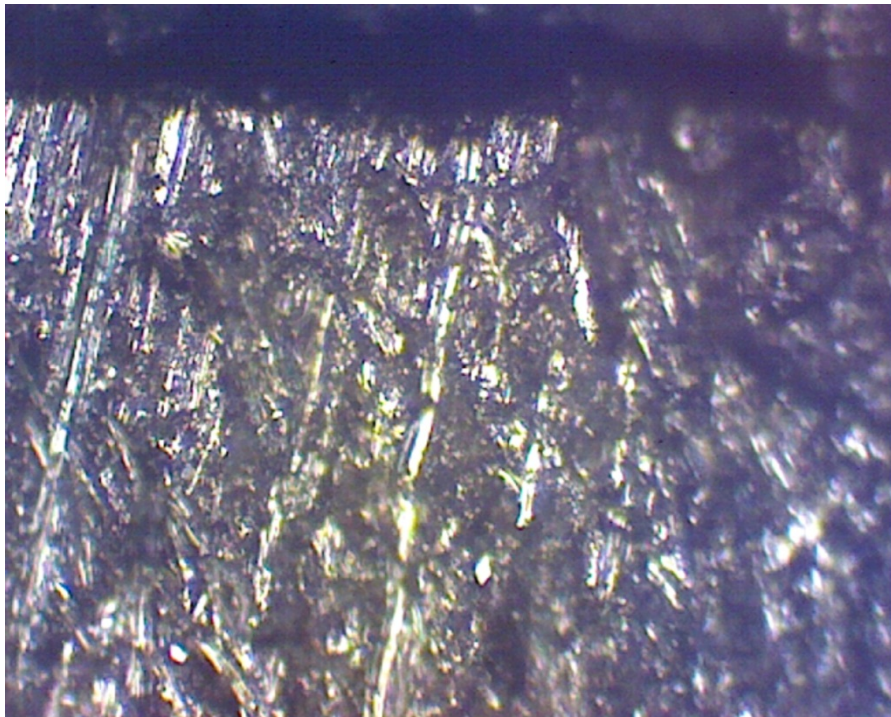
Titanium 8Al-1V-1Mo JetA1 150X Magnification - Specimen 1



Titanium 8Al-1V-1Mo JetA1 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

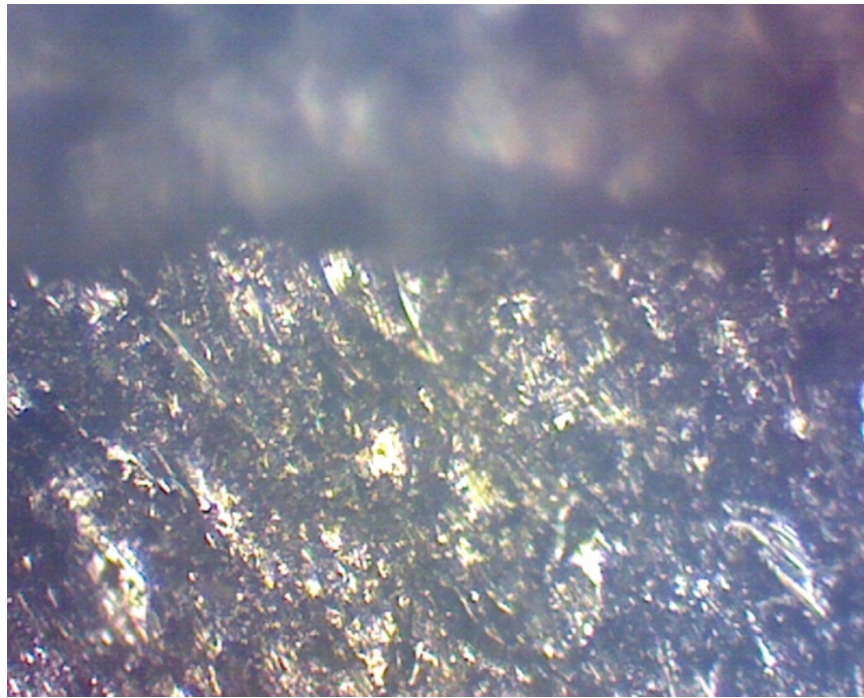
Jet A1 – Titanium 8Al-1V-1Mo



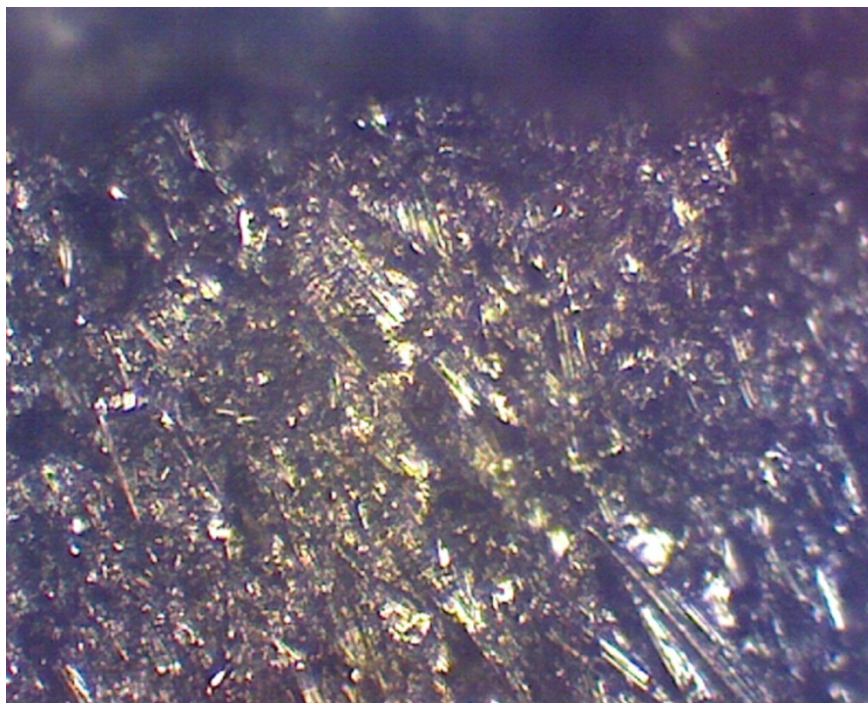
Titanium 8Al-1V-1Mo JetA1 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Biofuel 50/50 – Titanium 8Al-1V-1Mo



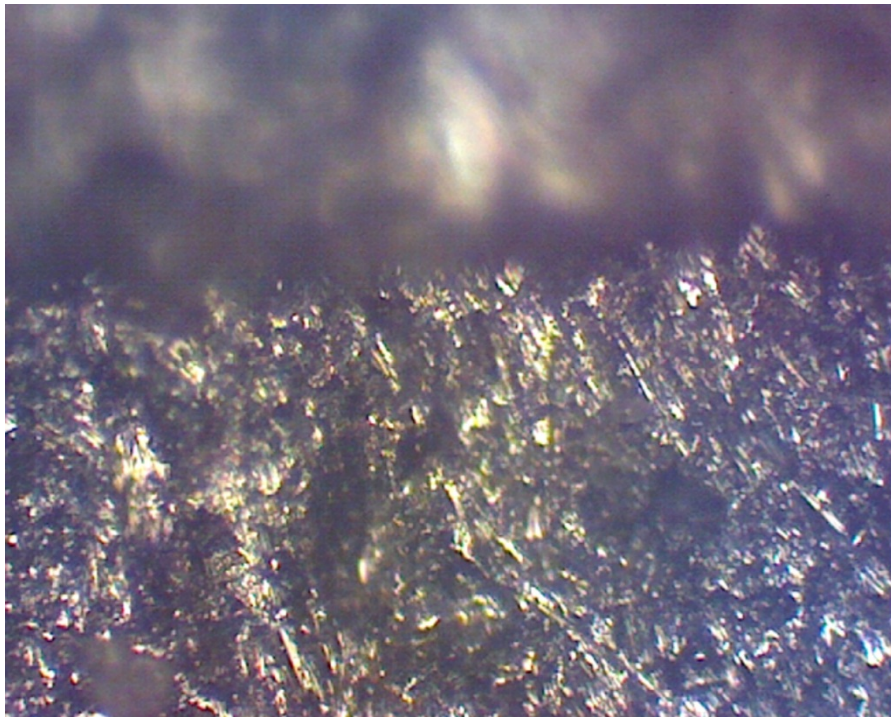
Titanium 8Al-1V-1Mo Bio50 150X Magnification - Specimen 1



Titanium 8Al-1V-1Mo Bio50 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

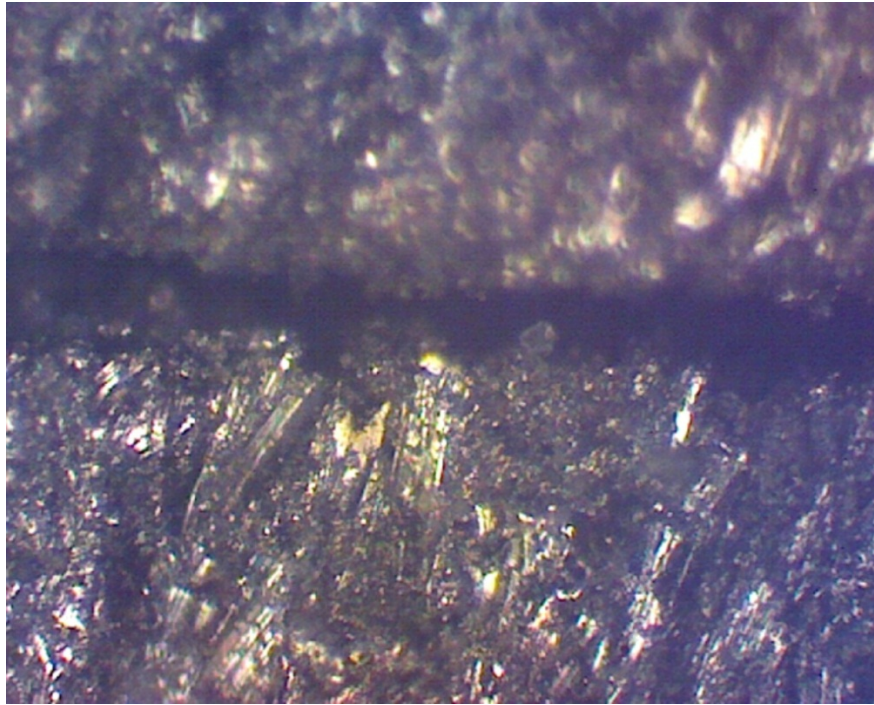
Biofuel 50/50 – Titanium 8Al-1V-1Mo



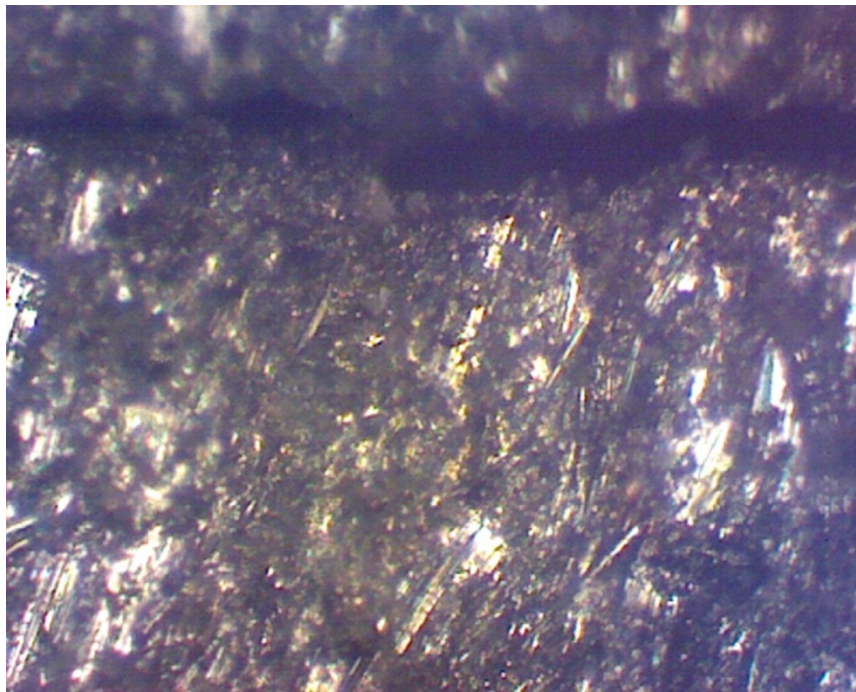
Titanium 8Al-1V-1Mo Bio50 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Jet A1 – Titanium CP70



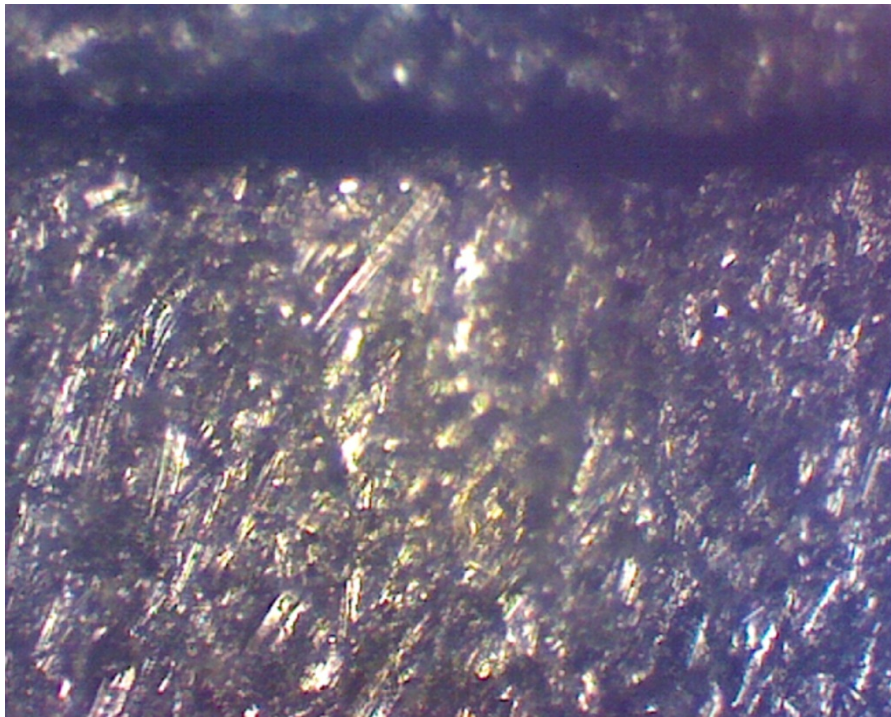
Titanium CP70 JetA1 150X Magnification - Specimen 1



Titanium CP70 JetA1 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

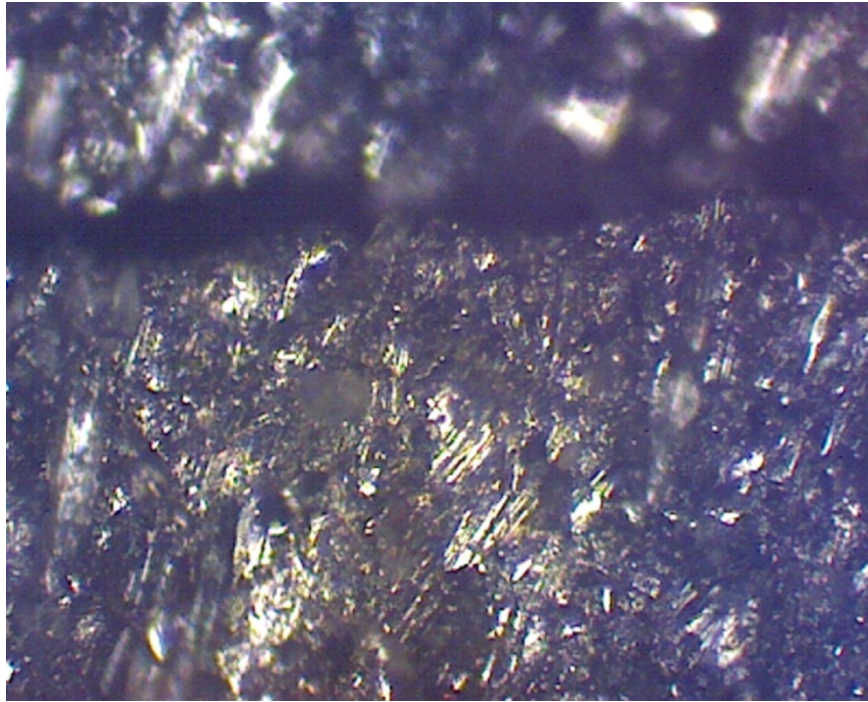
Jet A1 – Titanium CP70



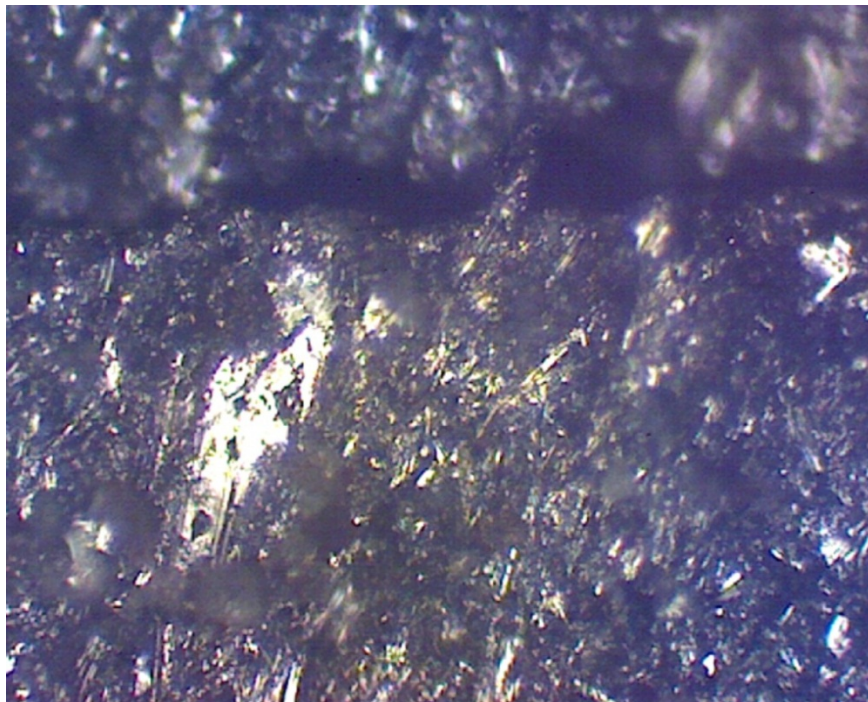
Titanium CP70 JetA1 150X Magnification - Specimen 3

Metallic Surface Evaluation Images 150X ASTM D4054

Biofuel 50/50 – Titanium CP70



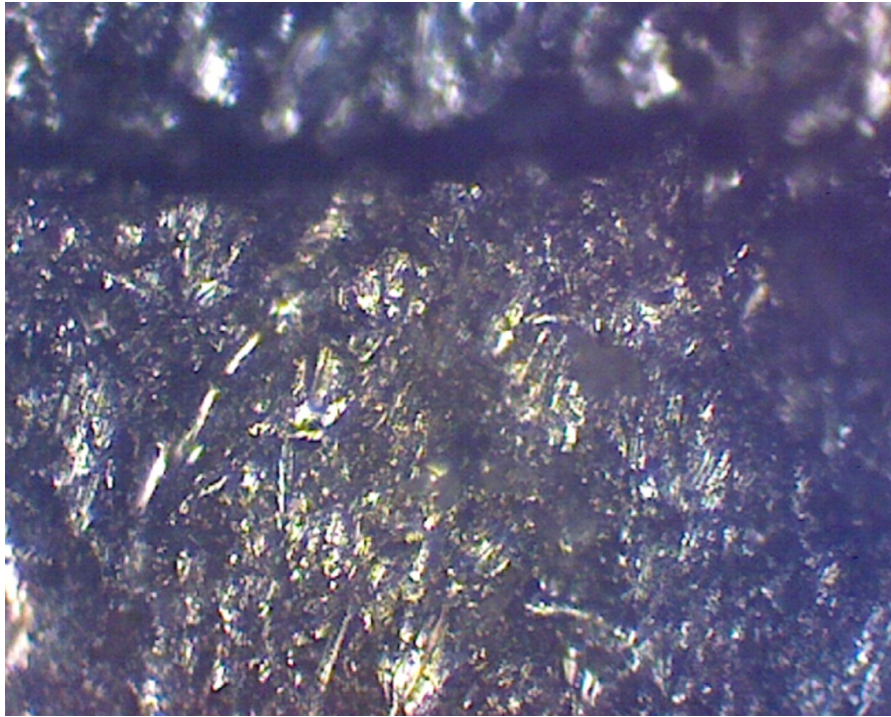
Titanium CP70 Bio50 150X Magnification - Specimen 1



Titanium CP70 Bio50 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

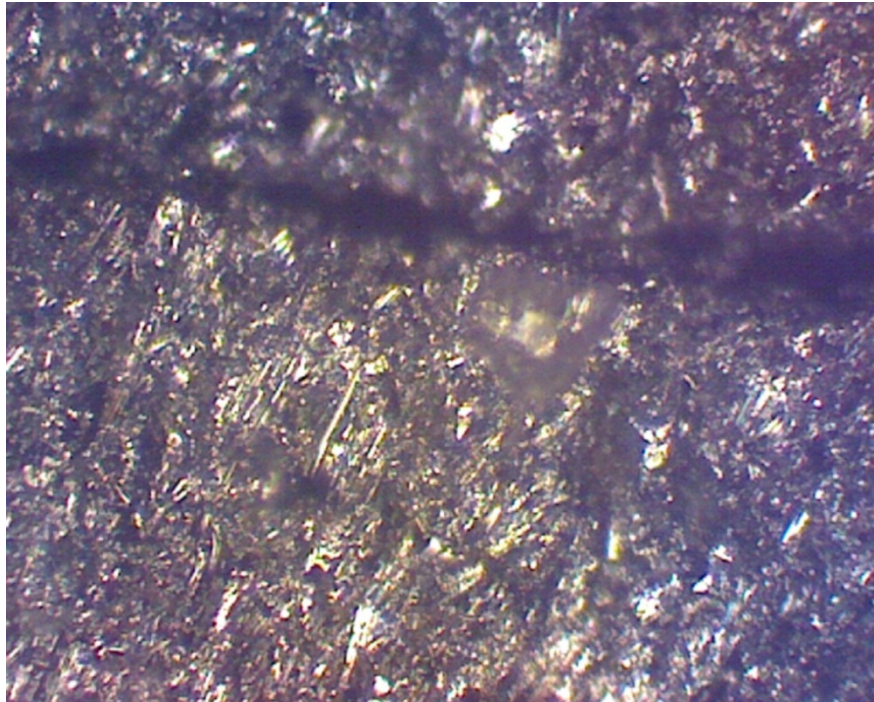
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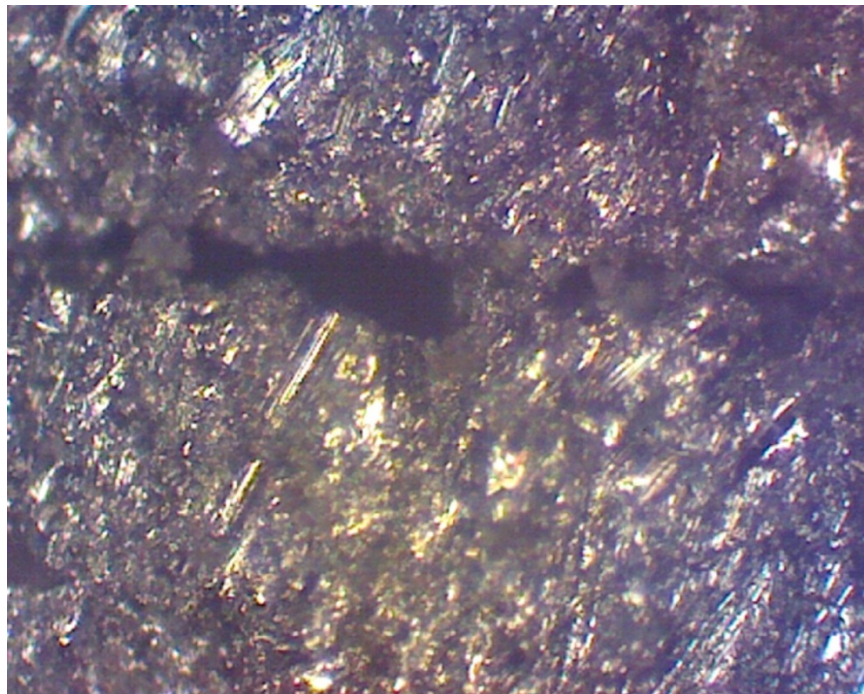
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Metallic Surface Evaluation Images 150X ASTM D4054

Jet A1 – Waspaloy



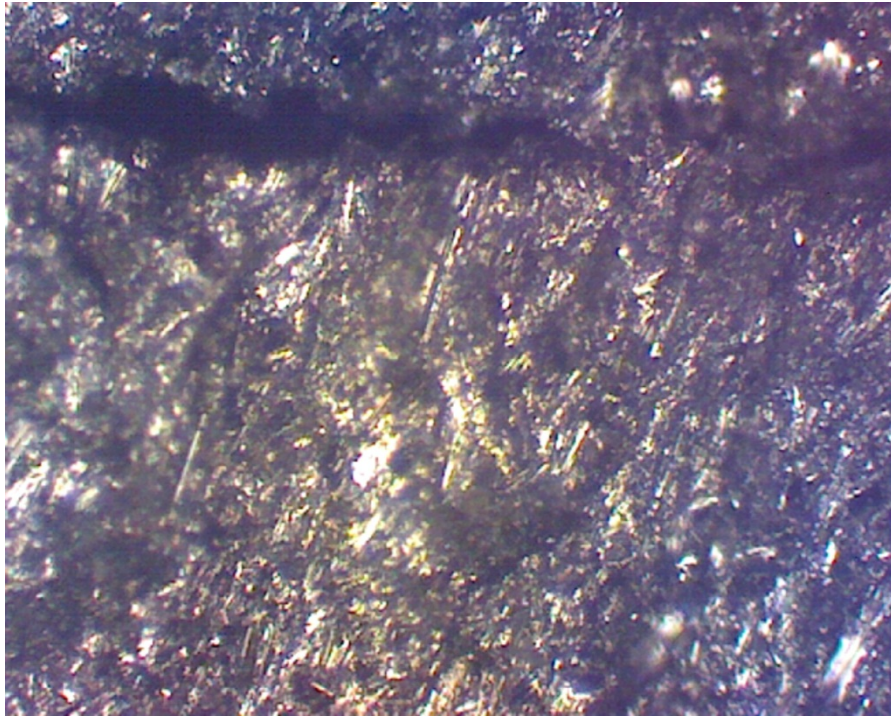
Waspaloy JetA1 150X Magnification - Specimen 1



Waspaloy JetA1 150X Magnification - Specimen 2

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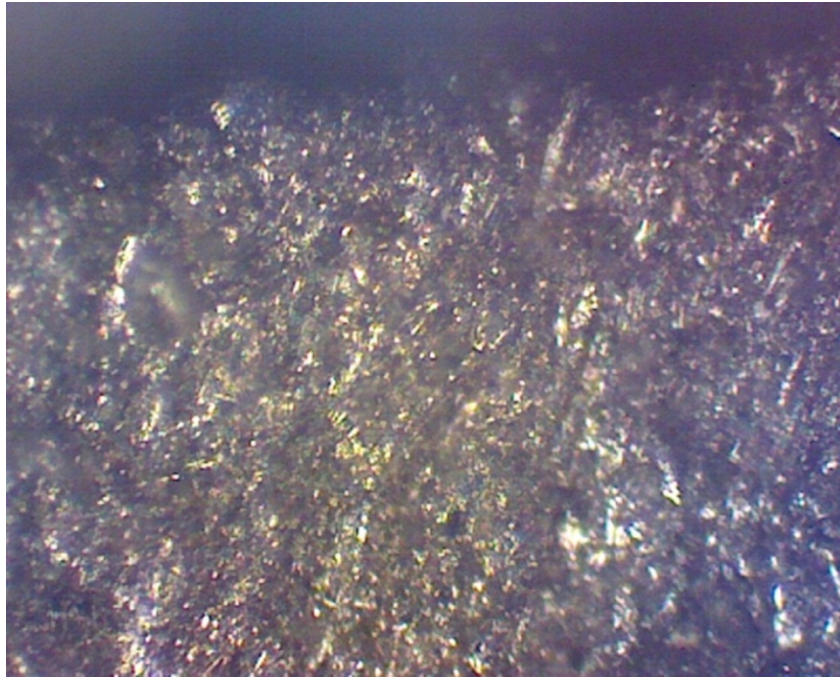
Jet A1 – Waspaloy



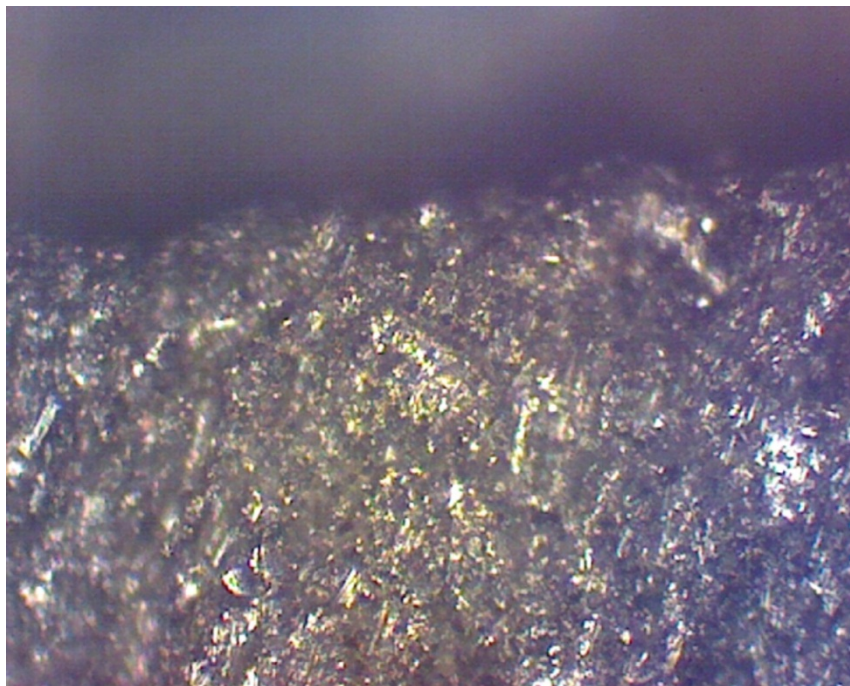
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Metallic Surface Evaluation Images 150X ASTM D4054

Biofuel 50/50 – Waspaloy



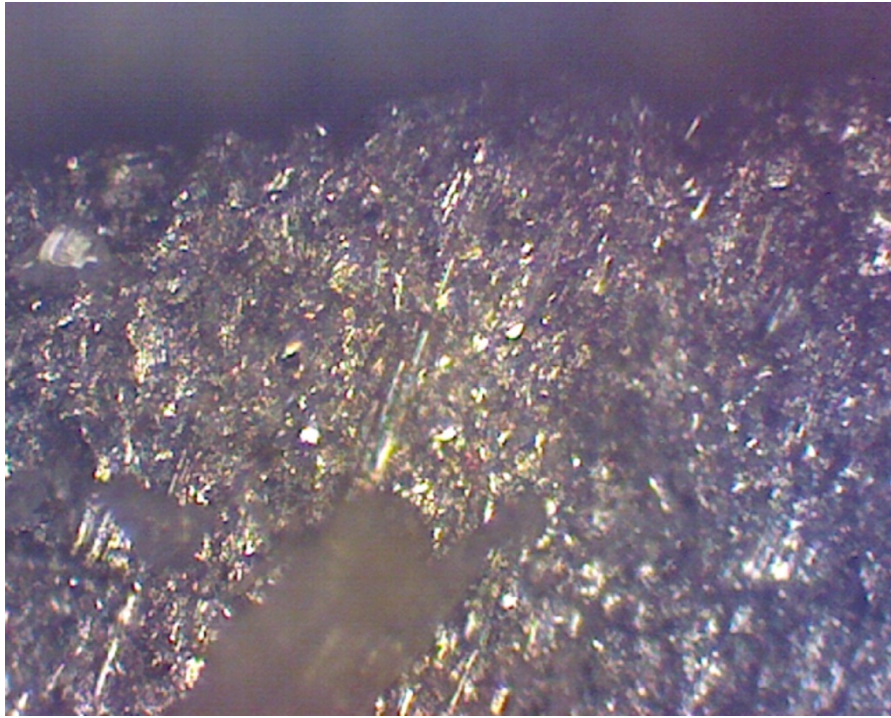
Waspaloy Bio50 150X Magnification - Specimen 1



Waspaloy Bio50 150X Magnification - Specimen 2

Metallic Surface Evaluation Images 150X ASTM D4054

Biofuel 50/50 – Waspaloy



Waspaloy Bio50 150X Magnification - Specimen 3

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- [1] **ASTM D395** – Rubber Property – Compression Set
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