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FORENSIC ENGINEERING SINCE 1975

DOT Requested Analysis
of
Failed SCUBA Cylinder/Valve Assembly

Report Date
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DOT Contract
No. DTPH56-12-P-000004

RTI Matter
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ATTACHMENTS

1.0 INTRODUCTION/BACKGROUND

It was reported to RTI Group, LLC (RTI) that an Open Circuit Self-Contained-Underwater-Breathing-Apparatus (SCUBA) cylinder, valve assembly, and regulator were involved in an explosion. It was reported that the source of the explosion was the high pressure gas cylinder failing. The incident cylinder had been filled with high purity oxygen, and the explosion had resulted in a fatality and extensive property damage, both from blast effects and a fire. Since the SCUBA cylinder had been certified under regulations promulgated by the U.S. Government, the evidence recovered by the St. Petersburg Police was transferred to the United States Department of Transportation (DOT), Pipeline and Hazardous Materials Safety Administration (PHMSA), Office of Hazardous Materials Safety. Reference is made to the Code of Federal Regulations (CFR), Title 49, Parts 173 and 178.

2.0 PURPOSE

RTI was tasked through Government Contract DTPH56-12-P-000004, dated November 9, 2011, issued by Office of Acquisition Services US DOT/PHMSA/PHA-30, to perform an investigation of the evidence recovered from the subject incident to determine if non-compliance with Hazardous Materials Regulations played a part in the cylinder failure and if modification of the regulatory standards would be necessary.

Additionally, the purpose of this contract is to evaluate the ruptured DOT 3AL-3000 cylinder valve and determine the following:

1. the degree of exposure to thermal energy; and
2. evidence of oxygen contamination which may have resulted in the explosion (fire) inside the ruptured DOT 3AL cylinder.

Under the tasking directive of the contract, sub-section 3.02 "Advanced Analysis and Examination", as part of the investigation the evidence was to be subjected to a series of invasive, therefore destructive, examinations in which specific laboratory equipment would be employed, such as Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), Energy Dispersive Spectroscopy (EDS), metallography, alloy chemistry, hardness testing, and tension and compression testing.

Once completed, the evidence from physical examination and the results of the laboratory tests were subjected to an engineering evaluation to, if possible, determine the degree of exposure to thermal energy, and determine if there was evidence of contaminants or materials incompatible with oxygen that may have resulted in the incident.

3.0 INVESTIGATION

RTI performed the following: evidence inspection upon receipt on November 15, 2011; laboratory inspection of the evidence March 12-14, 2012, documented in field notes and with photographs; inspection of exemplar cylinder valves and regulator; review of the literature sources listed below; and engineering analysis.

3.1 Standards, Codes, and Open Literature

3.1.1 Standards and Codes:

a) ASTM E 8M Test Method for Tension Testing of Metallic Materials.

b) ASTM E9 Standard Test Method of Compression Testing of Metallic Materials at Room Temperature.

c) ASTM G 88 Standard Guide for Designing Systems for Oxygen Service.

d) ASTM G 93 Standard Practice for Cleaning Methods and Cleanliness Levels for Material and Equipment Used in Oxygen-Enriched Environments.

e) ASTM G 94 Standard Guide for Evaluating Metals for Oxygen Service.

f) Code of Federal Regulations, Title 49, Part 173 (Subpart G: Preparation and Packaging) and Part 178 (Subpart C: Specifications for Cylinders).

3.1.2 Open Literature

a) "Guide for Oxygen Compatibility Assessment on Oxygen Components and Systems," K. Rosales, M. Shoffstall, J. Soltzfus, NASA/TM-2007-213740, March 2007.

b) "U.S. Navy Diving Manual," SS521-AG-PRO-010 Revision 6, 0910-LP-106-0957, April 15, 2008.

c) Handbook of Compressed Gases, Third Edition, Compressed Gas Association, Inc., Chapman & Hall, 1990.

d) "Introduction to Aluminum Alloys and Tempers", Kaufman, G.J., ASM International, Materials Park, 2000.

e) "Copper-Aluminum Interaction in Fire Environments", B. Beland, C. Roy, and M. Tremblay, Fire Technology, Vol. 19, Number 1, 1983, pages 22-30.

3.2 Evidence Description

On November 15, 2011, RTI Group, LLC (RTI) received four items from the Department of Transportation (DOT), Pipeline and Hazardous Materials Safety Administration (PHMSA). These items are described as follows:

3.2.1 Yellow high pressure gas cylinder fragment, Part 1

Smaller fragment from the incident cylinder; measures approximately 30 cm by 15 cm and weighs 760 gm.

3.2.2 Yellow high pressure gas cylinder fragment, Part 2

Larger section contains the bottom, neck, and valve opening; measures approximately 60 cm by 35 cm and weighs 6,137 gm.

3.2.3 High Pressure Cylinder Valve, DIN Valve

A chrome coated metal cylinder valve with the brand "Genesis" present on the front. A pressure regulator adaptor was present in the cylinder valve outlet opening with a fractured outlet. The rubber hand closure knob was present, but separate from the valve.

3.2.4 Pressure Regulator

A cylindrical metal device having a length of 6 cm and a diameter of 4.5 cm. Attached to the regulator were:

1. Black pressure line with dial gage on high pressure side of regulator.
2. Length of green pressure line. Distal end terminates unattached.

3.3 Evidence Inspection Observations

The received evidence was inspected and photographed to document the condition in which it was received. A receipt form was executed to preserve the Chain of Custody.

3.3.1 Yellow high pressure gas cylinder, Part 1

The smaller fragment from the cylinder measured approximately 30 cm by 15 cm, and is seen in **Figure 1**. This fragment contained a portion of the upper part of the cylinder proximate to the threaded opening. The fragment was clearly fractured by a catastrophic overload failure. In the portion near the cylinder opening, the fracture transitioned into a melted/eroded area where the material appeared to have eroded or "flowed" from the interior surface of the cylinder. The erosion was most extensive at the fracture where the cylinder wall was very thin, almost terminating into a sharp edge, with increasing thickness towards the non-eroded area. The flow patterns suggest that the eroded material flowed out of the crack formed in the cylinder wall, as well as out of the valve opening. The remaining cylinder interior surface was otherwise unremarkable. The curvature of the fragment was measured using a spherometer, and resulted in a reading of up to 200 mm near a portion of the interior fracture surface, compared to the original radius of curvature of 57 mm.

Figure 1. Smaller portion of high pressure gas cylinder

Along the base of the hemispherical connection were displayed the following marks near the neck:

HY-MARK DOT-3AL 3000 OU

This is an incomplete DOT cylinder marking scheme. The remainder of the markings was found on the larger portion of the cylinder.

The cylinder fragment had on its exterior surface a full decal and part of another. The first decal, seen in **Figure 2**, appears like that used by the International Association of Nitrox and Technical Divers (IANTD), as seen in **Figure 3,** which states if the decaled cylinder has been cleaned for use with Nitrox[1] or Oxygen.

The remaining legible content of the label indicated the "Tank & Valve Have Been Cleaned For Premix, Oxygen Content 22 to 40%" was not punched out, while the "Tank & Valve Have Been Cleaned In Accordance With O_2 Service" was punched out at 2011. The month is obscured. There is no indication as to who may have stamped and applied the decal, or as to what procedure was followed to certify the cylinder was properly cleaned.

[1] Nitrogen-oxygen (NITROX) diving is a unique type of diving using nitrogen-oxygen breathing gas mixtures ranging from 75 percent nitrogen/25 percent oxygen to 60 percent nitrogen/40 percent oxygen. *U.S. Navy Diving Manual*, Chapter 10.

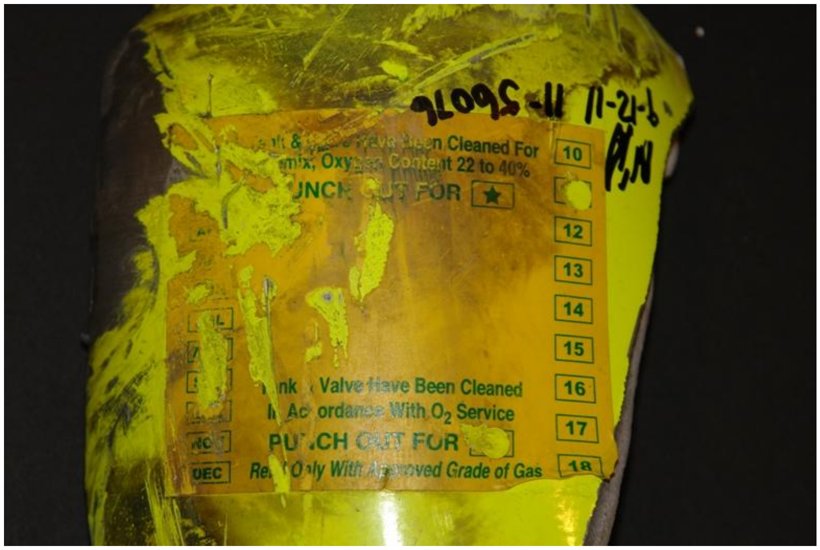

Figure 2. Label on smaller fragment.

Figure 3. Decal label from International Association Nitrox and Technical Divers[2]

[2] http://www.iantd.com/decals.html , D-3207. The web page does state that "These decals are available ONLY to Blenders or Facilities with Certified Blenders on staff."

Only a small portion of the second decal was visible, and stated “for decompression use …. IANTD/IAND, Inc.”

3.3.2 Yellow high pressure gas cylinder, Part 2

The larger fragment of the high pressure gas cylinder, seen in **Figure 4**, contained the bottom, neck, and valve opening portions.

Figure 4. Larger portion of high pressure gas cylinder

A similar erosion pattern to that found on the smaller fragment was seen near the opening at the top. Facing the interior surface with the opening up, the inside surface to the left of the opening had significant erosion extending about 20 cm below the top before transitioning to a fracture. The threads in the opening were clearly stripped with only part of the thread root visible. The pattern of erosion within the opening was uneven in depth and texture, and was different around the opening compared to along the cylinder side towards the fractures. The opening had a stippled texture whereas the areas away from the opening had distinct flow lines with perpendicular waves.

The exterior surface exhibited evidence of heat effects and darkened coloration near the cylinder top. The normally yellow paint is discolored to brown, with black material (soot) found on some of the fracture surface.

This item had the following markings near the hemispherical connection to the cylindrical body:

0001 M5422 10 07 S40 TC-3AL 207

These, together with the stamped markings found on the other fragment, create the complete DOT marking scheme as follows:

DOT-3AL 3000 OU0001 M5422 10 07 S40 TC-3AL 207 HY-MARK

These complete markings indicate as follows[3]:

DOT-3AL – This is a Department of Transportation regulated seamless cylinder made from definitely prescribed aluminum alloy requiring a minimum service pressure of 150 psig, and a maximum water capacity of 1000 lb.[4]

3000 – is the maximum service pressure in psi.

OU0001 – is the manufacturer's serial number.

M5422 – is the DOT PHMSA "M" or manufacturer's identification number. This number indicates the manufacturer was Hy-Mark Cylinders, Inc. of 305 E. Street, Hampton, VA 23661, approved June 5, 2000.

10 07 – is the originating hydrostatic test date, October 2007

S40 – indicates the cylinder is intended for SCUBA use, and can hold compressed gas that has a volume of 40 ft^3 of air at standard pressure and temperature conditions.

TC-3AL 207 – indicates the cylinder is also compliant with the Transportation Canada, identified as a 3AL container with service pressure to 207 Bar.

HY-MARK – is the manufacturer's symbol, again consistent with Hy-Mark Cylinders. Hy-Mark Cylinders, Inc. was purchased by Worthington Industries, Inc. (NYSE WOR) on June 21, 2010.[5]

This part of the cylinder contained the remaining portion of the second decal stating "OXYGEN for decompression use only – MOD 20 FSW MOD 6 MSW[6] WWW.IANTD.COM". The label

[3] *Handbook of Compressed Gases*, Chapter 4.
[4] 49 CFR 178.46(a).
[5] http://www.worthingtonindustries.com/
[6] Maximum Oxygen Depth-MOD, Feet Submerged Water-FSW, Meters Submerged Water-MSD.

indicated that the purpose of this cylinder was for oxygen use during the latter stage decompression from extremely deep diving.

3.3.3 High Pressure Cylinder Valve, DIN Valve

A label stamped into the body indicated the incident cylinder valve was manufactured by Genesis and contained a 32.6 MPa (5000 psi, 30 lb/hr) CG-1 type rupture disk. A pressure regulator adaptor was present in the opening containing a fractured outlet. A metal particle filter was evident in the opening. The rubber hand valve closure knob was present, but separated from the valve, as seen in **Figure 5**.

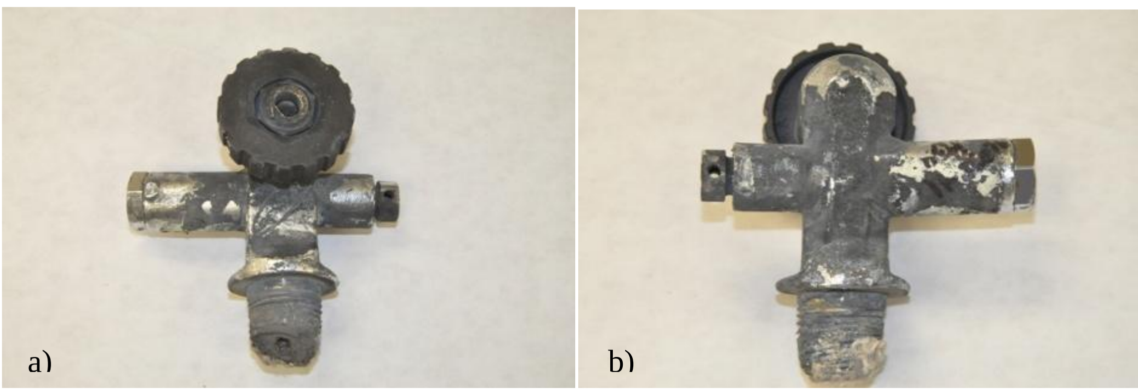

Figure 5. View of cylinder valve, a) front, b) back

3.3.4 Pressure Regulator

The incident pressure regulator was manufactured by Dive Rite, serial number 12008135. The high pressure inlet opening was occupied by the fractured end of the pressure regulator adaptor, see **Figure 6**. Attached to the regulator were:

- A black pressure line with dial gage on high pressure side of regulator; dial gage face is heat affected and the gage is illegible.
- A length of green pressure line stating "WARNING Do not exceed 250 psi (17 bar) high pressure may cause damage or personal injury"; no manufacturer was identified.

Figure 6. Cylinder valve, cylinder valve adapter, regulator and regulator assembly.

The green line was discolored (lightened to yellow white) proximate to the regulator, indicating possible exposure to high heat. There were no indications of melting or combustion. The distal portion of the outlet line was bright green and terminated without the anticipated second stage regulator.

4.0 LABORATORY TESTING

On March 12, 2012, RTI traveled to the laboratories of Anamet, Inc., an affiliated RTI company, for the purpose of conducting a laboratory examination of the incident scuba cylinder fragments, cylinder valve, and regulator, as well as an exemplar cylinder valve. RTI prepared a protocol, dated November 29, 2011, as found in **Attachment 1,** which served as the guide for all investigative activities conducted over the three day examination. The examination, which included both nondestructive and destructive procedures, was also documented by way of both still photography and videography.

4.1 Unpacking Evidence

The container of evidence, shipped from RTI's Annapolis, MD offices, remained sealed until commencement of the examination on March 12, 2012 when all attending parties were present. Items were packaged individually as seen in **Figure 7**.

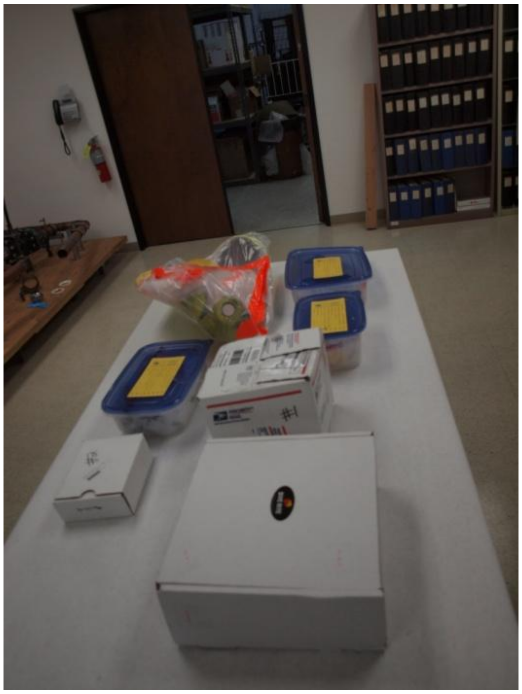

Figure 7. View of the individually packaged evidence items at Anamet after removal from the shipping container.

4.2 Disassembly and Visual Inspection

The incident cylinder valve, an exemplar cylinder valve, and the incident regulator were disassembled and photographed prior to further inspection and examination of the constituent components of each.

4.2.1 Exemplar Valve

The exemplar cylinder valve, shown in **Figure 8**, has four distinct sections. Proceeding from the left side of the valve in a clockwise direction they were: the valve stem assembly and housing, the high pressure regulator fitting, the pressure burst disk assembly, and the threaded cylinder attachment with a pick-up tube.

Figure 8. Front view of the exemplar cylinder valve. The valve stem assembly and housing is concealed by the black valve handle.

RTI first loosened and removed the locking nut securing the hard rubber valve handle grip in place. With the nut removed, the grip slid off of the 7.34 mm long threaded portion of the valve stem. Between the threaded rod and the main portion of the valve stem, a square cross section was present that provided the rubber valve handle a means for turning the valve stem. A gland nut with a smooth center bore secured the valve stem inside the valve body. The smooth bore provides for free rotation of the valve stem. An O-ring, 1.28 cm in diameter, served to seal the connection between the gland nut and the valve body, see **Figure 9**. RTI removed this nut to expose the valve stem. As it is not secured by any part other than the nut, it could be removed from the valve body simply by pulling it straight out.

Figure 9. Rear view of the partial exemplar valve stem assembly showing the gland nut, O-ring, and valve stem.

Upon removal, RTI observed the stem to be covered in a white grease-like substance, and that it incorporated two polymer bushings and two O-rings, see **Figure 10**. The stem ended in a square mandrel approximately 8.53 mm long. RTI observed the inner wall of the portion of the valve body, within which the valve stem resides, to be threaded. A threaded, square bored valve seat body resided at the inner end of this portion of the valve body. RTI removed it by reinserting the valve stem and rotating counter clockwise to unthread the valve seat body. Once removed, the valve seat body appeared to be made of bronze with a black colored coating over most of the surface area. **Figure 10** shows the valve seat body and provides orientation. The interior end incorporated a plastic valve seat.

Figure 10. Rear view of the fully disassembled exemplar valve stem assembly showing the valve seat body and its orientation in the assembly.

Referring to **Figure 11**, RTI next removed the pressure burst disk assembly, which consists of a hollow threaded plug, a 34.1 MPa (5000 psi) burst disk, and retaining rings. Threads on the plug stop short of the head by approximately 2.411 mm. The head of the plug is bored through, presumably to allow a dispersed release of excess high pressure gas should the burst disk fail. **Figure 12** shows the burst disk and retaining ring as installed in the plug. Markings on the outer surface of the assembly head indicate that the assembly is to be installed with 40.7 N-m (30 ft-lb) of torque.

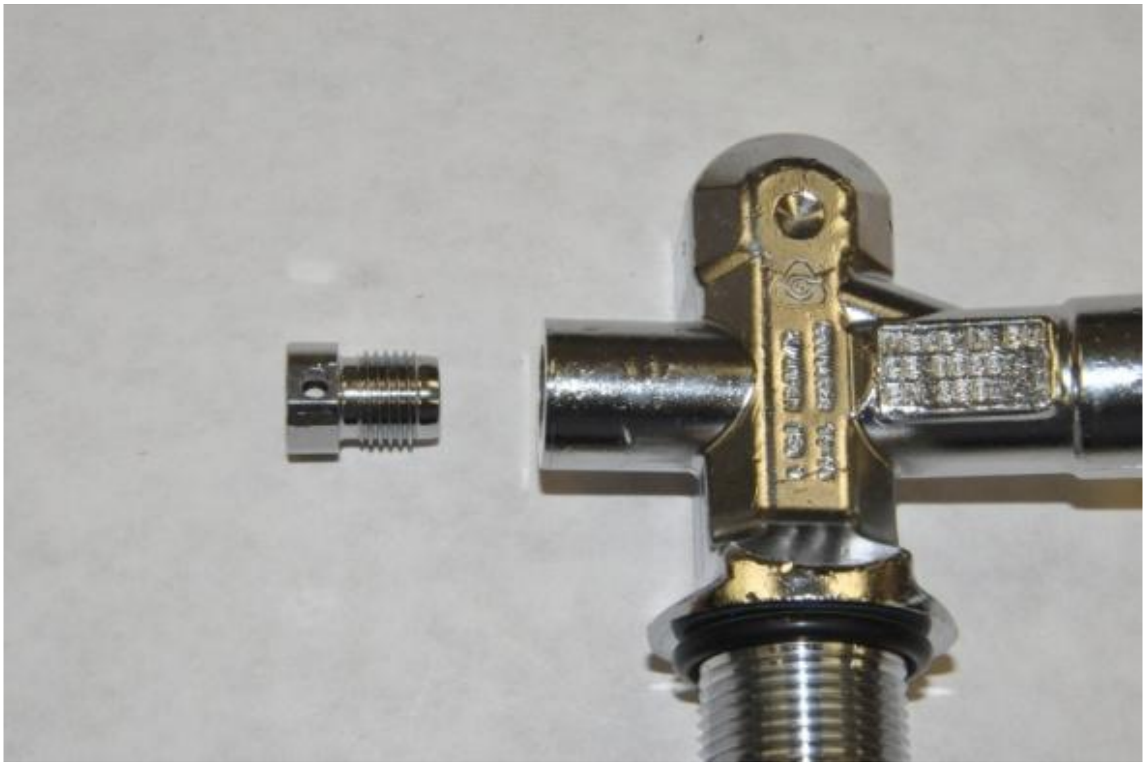

Figure 11. Rear view of the exemplar pressure burst disk assembly as removed from the valve body.

Figure 12. View of the exemplar pressure burst disk assembly showing the burst disk and retaining ring.

Finally, RTI removed the threaded protective insert into the high pressure regulator port. Removal of the insert revealed a shallow threaded bore leading to a gas supply rectangular opening proceeding down into the center of the cylinder valve body, indicated by the in **Figure 13**. Additionally, RTI observed a 1.9 mm diameter vent hole on the right side of the high pressure regulator port, indicated in **Figure 13**. This vent is approximately 7.42 mm forward of the rear inner surface of the port such that it is closed off when a fitting is fully threaded into the port.

Figure 13. Front view of the exemplar cylinder valve showing the high pressure regulator port.

The cylinder attachment consists of a straight threaded insert with an 8.05 mm diameter, 4.01 cm long dip tube fit into a center bore, see **Figure 8**. The nominal thread diameter and pitch measured as approximately 25 mm with a 2 mm pitch (1.035 inches and 13 tpi), respectively. An O-ring is provided at the cylinder mating surface.

Further detailed examination of the disassembled cylinder valve body revealed information about the path of high pressure gas from the cylinder through the valve. With the valve handle in the fully closed (inserted) position, high pressure gas flowing from the cylinder proceeds up through the pick-up tube and is directed against the valve seat to the left and the pressure burst disk to the right. As the valve is opened, the gas is allowed to flow past the valve seat and makes its way to the regulator port. This is accomplished by way of an angled bore connecting the valve stem bore to the regulator port. The rectangular cutout visible inside the regulator port is the outlet of the angled bore. The external housing of the angled bore is indicated in **Figure 14** showing the rear view of the exemplar valve.

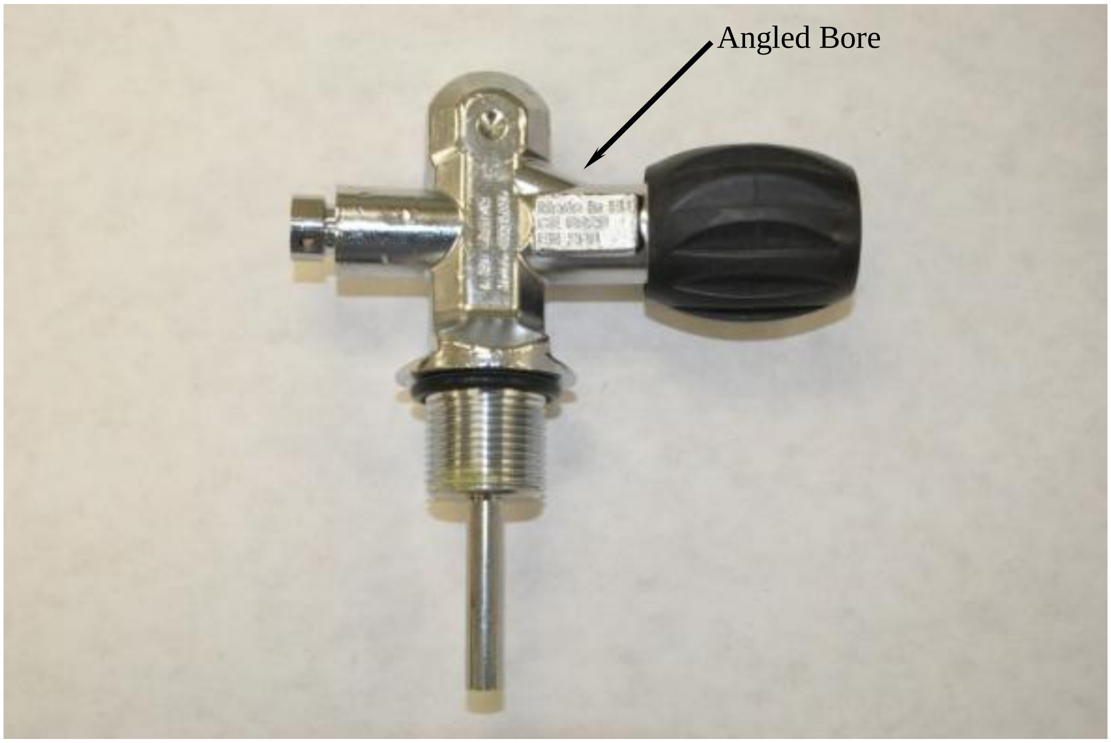

Figure 14. Rear view of the assembled exemplar cylinder valve showing the angled bore housing that connects the high pressure regulator port to the valve system assembly chamber.

4.2.2 Incident Valve

As shown in **Figure 5**, the incident valve was received with several parts missing from the valve including the locking nut; the rubber valve handle (present but damaged and no longer attached); the threaded and square segment of the valve stem to which the handle attaches (this appeared to have separated from the main body of the valve stem leaving a square fracture surface); the dip tube; and a significant portion of the cylinder neck opening threads. The entire exterior of the incident valve and its installed components appeared charred and roughened compared to the exemplar valve.

RTI began the disassembly process of the incident valve by removing the gland nut, shown in **Figure 15**, with a torque wrench fitted with an appropriately sized socket in order to measure the installation torque. The gland nut was found to be threaded into the valve body approximately finger tight as measurements showed zero installation torque. The nut made four and one sixth turns before clearing the valve body. An intact O-ring similar to that found in the exemplar remained in its intended position on the gland nut.

Figure 15. View of the incident cylinder valve gland nut showing the presence of the intact O-ring.

Removal of the gland nut allowed access to the valve stem and the valve seat body. As shown in **Figure 16**, the incident valve stem was very similar in appearance to the exemplar although one of the bushings was different in color. Compared to the exemplar valve seat body in **Figure 17**, the incident valve seat body displayed a different color coating. The incident valve seat was also coated with some material, but with a green color. All portions of the incident gland nut, the stem, the valve seat body, the plastic valve seat, and the interior of the valve stem portion of the valve body were further notable in that they were free of any apparent damage, heat effects, or discoloration as might be expected to result from fire or explosion.

Figure 16. View of the incident valve stem (top) as compared to the exemplar valve stem.

Figure 17. View of the incident valve seat body (green with white valve seat, upper) as compared to the exemplar valve seat body (black with yellow valve seat, lower).

RTI next removed the burst disk assembly of the incident valve. Compared to the gland nut, the burst disk assembly appeared tightly fit into the valve body. The installation torque was measured to be 10.17 N-m (90 in-lb). It took 5 ¾ turns to remove the assembly. While the exterior exposed surfaces of the plug had the same charred and damaged appearance as the rest of the incident valve, the interior surfaces were clean and bright and the burst disk was intact, see **Figure 18**. Correspondingly, the interior surfaces of the valve body in the area of the burst disk also proved to be clean and bright.

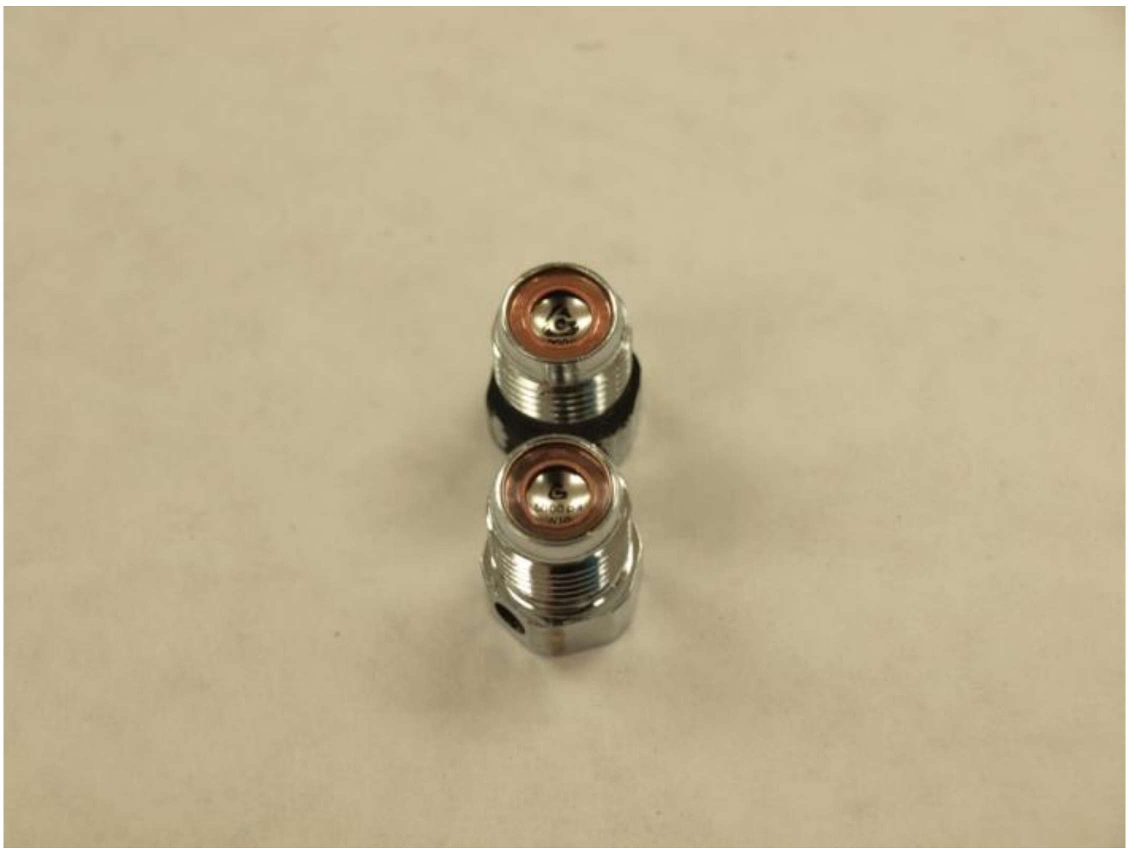

Figure 18. View of the incident burst disk assembly (upper) as compared to the exemplar burst disk assembly (lower).

During the explosion, the regulator, which attaches to the valve at the regulator port by way of a threaded adapter, broke away from the valve leaving a portion of the adapter still threaded into the valve regulator port. This adapter included a plastic handle used for tightening into the regulator port, which remained intact. As seen in **Figure 5**, the adapter broke such that the handle remained attached to the valve but the portion that threads into the regulator remained with the regulator. Simply turning the handle allowed the adapter fragment to be removed from the valve. Some soot was observed on the interior surfaces of the regulator port and the adapter fragment. Inside the regulator port, charring was seen extensively around the vent and along the bottom thread. Soot-like discoloration was observed extending into the port from the charring near the center. Otherwise, the interior of the regulator port was clean and bright, see **Figure 19**.

Figure 19. View of the incident valve high pressure regulator port showing discoloration sooting around the vent.

The valve side of the adapter fragment contained an intact O-ring and a fitting suitable for inserting a hex key. Visible on the handle was the raised text “300 BAR”, see **Figure 20**. Internal to the adapter is a metal air cup that serves as a filter between the cylinder valve and the regulator. RTI disassembled the adapter fragment and removed the air cup for further examination.

Figure 20. View of the incident valve and underside of the regulator adapter handle.

4.2.3 Incident Regulator

RTI received the incident regulator, shown in **Figure 6**, with approximately 1 m length of green hose attached to one of the low pressure ports. Attached to one of the high pressure ports was a pressure gauge at the end of a 13 cm length of black hose. Soot coated the exterior surfaces of the regulator body, pressure gauge, and black hose; and the first 53 cm of the green hose appear heat affected by discoloration.

RTI first removed the two hoses, revealing the interiors of the two ports to be clean and bright with very little evidence of soot. Next, the remaining portion of the adapter was removed. While soot covered the adaptor's exterior surface and inner bore surface, the interior of the exposed high pressure port was again clean and bright. However, the bore between the port and the regulator barrel was covered in dark soot.

Next, the cap/spring/plunger assembly, that serves in conjunction with a diaphragm to meter the high pressure gas to the low pressure side of the regulator, was removed. An O-ring and a flat plastic washer were seated in the low pressure regulator barrel and subsequently removed. Minor sooting and particulate matter were visible inside the incident regulator, on the washer and O-ring, and at the interior plunger end. As much as possible of these particulates was captured for later chemical analysis. As is seen in **Figure 21** and **Figure 22**, these components appeared to be in an overall undamaged condition.

Figure 21. View of the incident regulator with the cap/spring/plunger assembly being removed.

Figure 22. View into the low pressure portion of the incident regulator showing the O-ring and washer.

The high pressure diaphragm was revealed by removing a large set screw/fitting from the bottom of the regulator barrel using a hex key. This fitting held a spring in place that easily slipped out once the fitting was removed. Inside the chamber, a minor but noticeable amount of particulate was observed. This chamber is separated from the high pressure gas by the diaphragm and sealed to the outside by the fitting. The diaphragm chamber was separated from the regulator barrel using a strap wrench and the particulate matter found was subsequently saved for chemical analysis.

4.3 SEM Examination

A scanning electron microscope (SEM) provided high magnification imaging of metallic components selected by RTI for more detailed examination. The SEM also features the capability of analyzing small areas of the components to determine the constituent elements present. This is accomplished through energy dispersive x-ray spectroscopy (EDS) built into the microscope and provides an approximate indication of the relative concentrations of the elements present. The EDS produces a spectra plot showing the results of the analysis. The spectra plots for all EDS analysis conducted are included in **Attachment 7.**

4.3.1 Incident valve stem fracture surface.

Figure 23 is a composite view of the four corners of the fracture surface on the incident valve stem. It is notable that the majority of the fracture surface from the left edge proceeding to the right has the appearance of a ductile tensile fracture. A small remaining area along the right edge, conversely, has the appearance of a shear failure. Otherwise there is nothing remarkable about the fracture surface. EDS of the fracture surface measured high levels of copper and zinc, indicating that the valve stem was manufactured from a brass alloy.

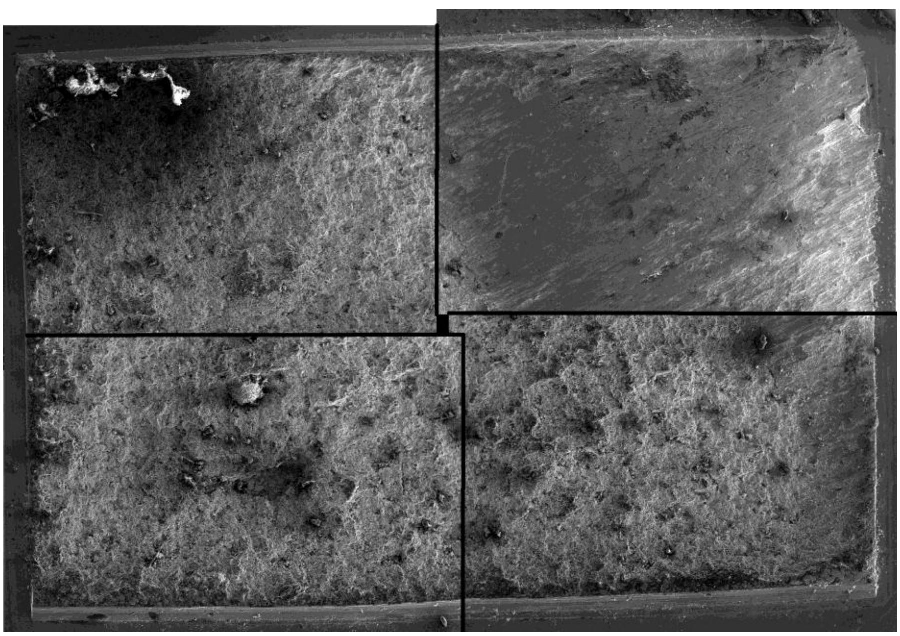

Figure 23. Composite SEM micrograph of incident valve stem fracture surface.

4.3.2 Incident pressure regulator adapter fracture surfaces

Figure 24 shows the fracture surface present on the pressure regulator adapter. As the exposed surfaces of the adapter, including the fracture surface, were covered in soot, the exact fracture morphology is not immediately apparent. Further compounding the characterization are areas that have the appearance of being mashed, or damaged, post fracture. These areas are also heavily sooted. Although there was a layer of soot on the adapter, EDS was able to measure high levels of copper and zinc which indicated that it was manufactured from a brass alloy.

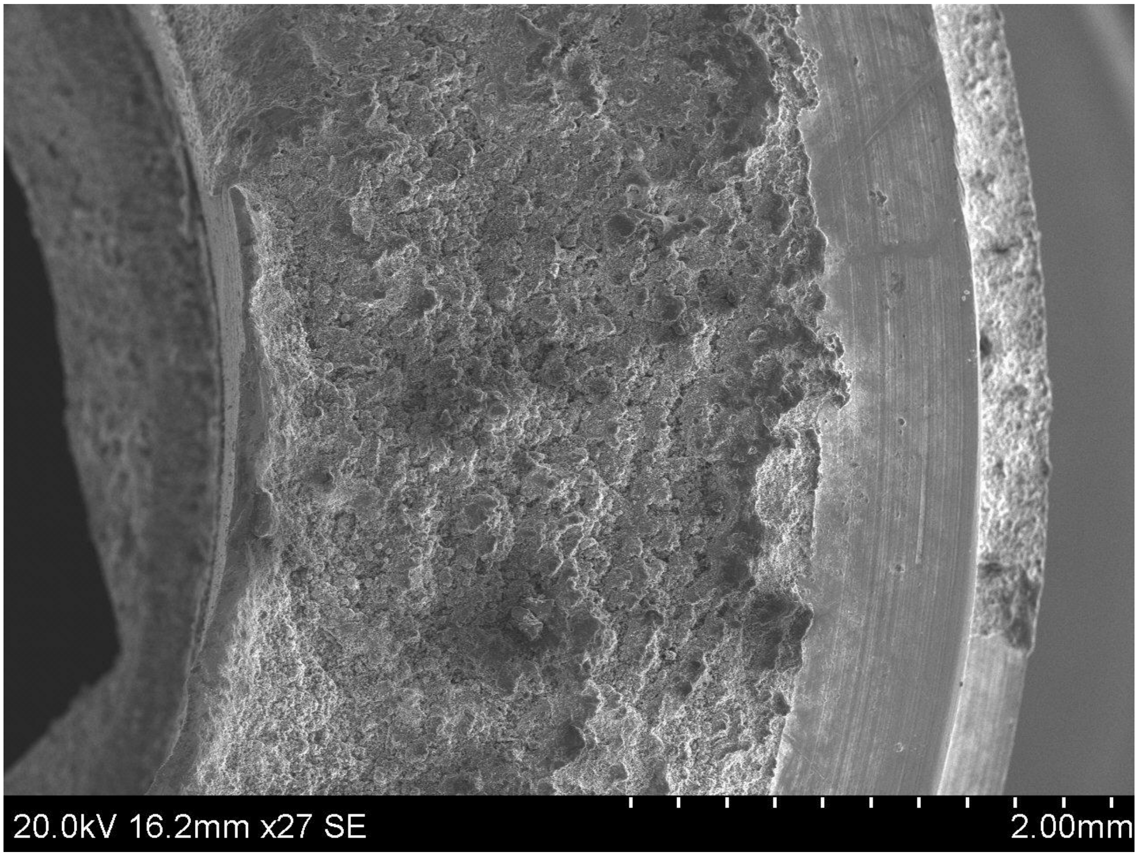

Figure 24. SEM micrograph of pressure regulator adapter fracture surface.

4.3.3 Incident pressure regulator adapter air cup

Figure 25 shows the structure of the pressure regulator adapter air cup. It is composed of numerous metallic spheres approximately 250 μm, or 0.250 mm, in size, bonded together in a process known as sintering. The random spacing between the spheres varies in size from a few microns to as much as 300 or 400 microns and acts as a filter for most particulates that might be present in the gas flow upstream of the regulator by creating a tortuous path. EDS of the air cup revealed metallic peaks of aluminum, nickel, copper, and zinc which are consistent with brass alloys.

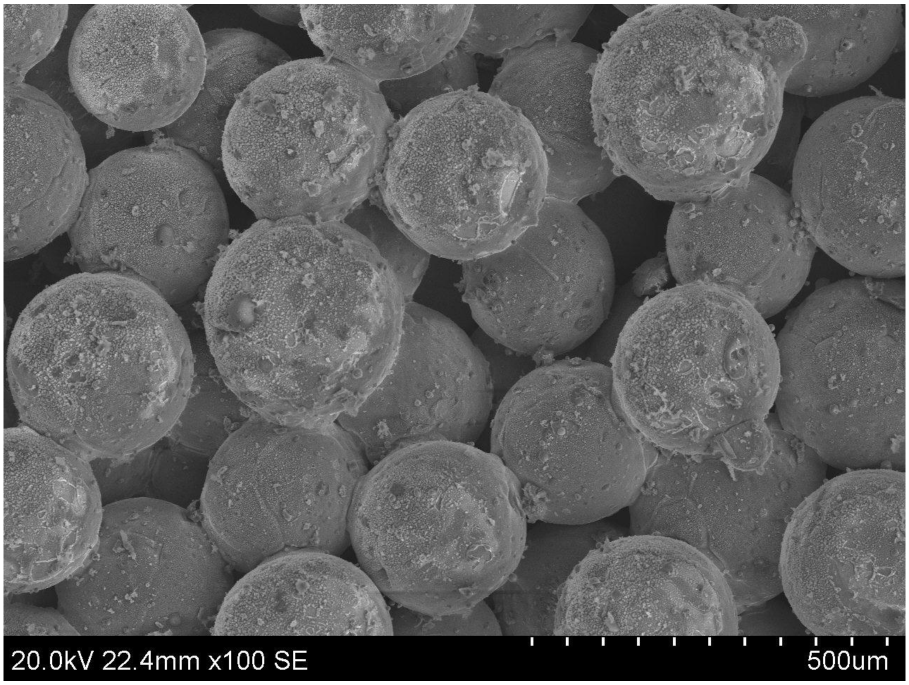

Figure 25. SEM micrograph of incident air cup structure.

4.3.4 Cylinder inside surface

A small piece of the cylinder from the larger fragment was examined in the SEM, primarily for the purpose of performing EDS on the interior surface of the cylinder. Metallic peaks were measured for aluminum and titanium.

4.3.5 Exemplar and incident valve seat bodies

Figure 26 and **Figure 27** show side by side comparison images of the exemplar and incident valve seat bodies in the threads and the smooth shaft, respectively. In **Figure 27** the extent of the coating is clearly visible on both bodies. EDS of both valve seat bodies in an uncoated area produced copper and zinc peaks indicative of brass alloys.

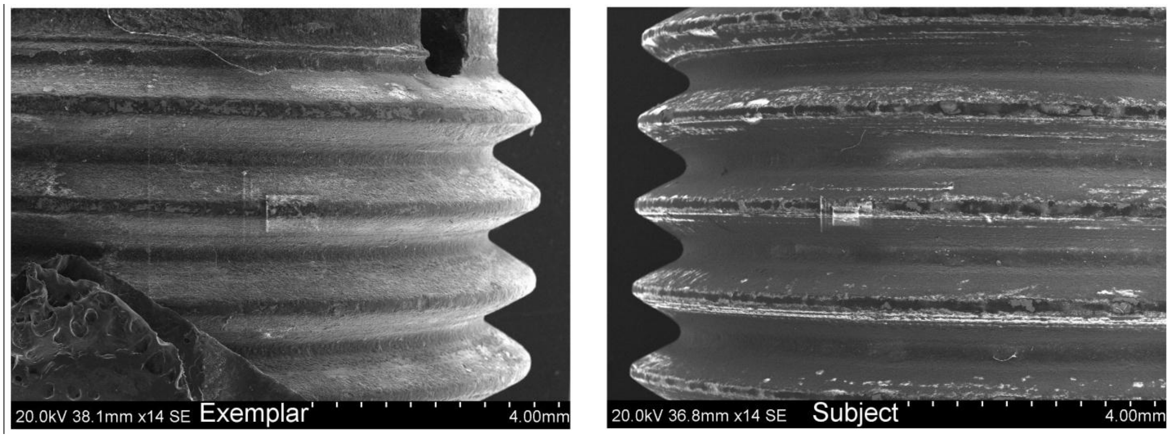

Figure 26. SEM micrographs comparing threaded portions of exemplar (left) and incident (right) valve seat bodies.

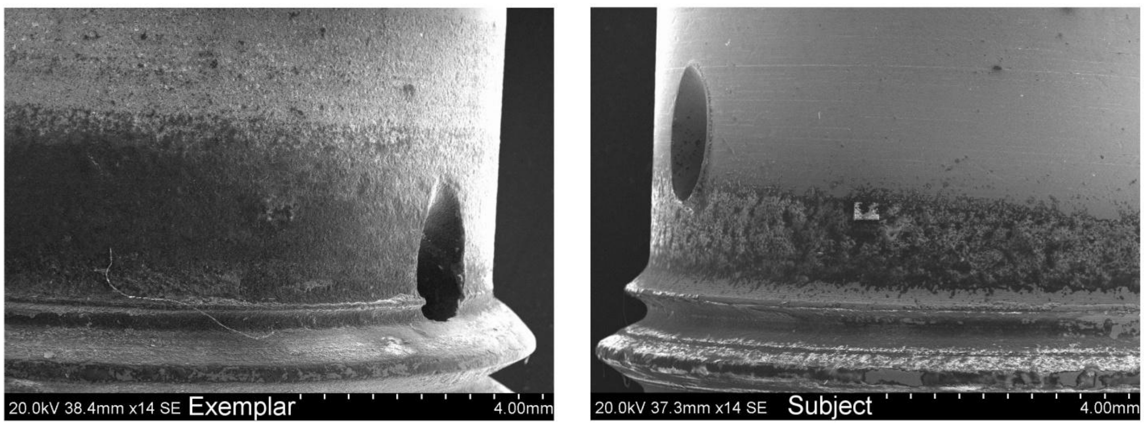

Figure 27. SEM micrographs comparing smooth portions of exemplar (left) and incident (right) valve seat bodies.

4.4 Mechanical Testing and Metallography

RTI conducted basic mechanical property testing of the cylinder material including tensile, compressive, and microhardness tests. Specimens of the cylinder material were also taken for metallographic examination.

4.4.1 Sectioning

Sectioning of the cylinder proceeded according to the established protocol, with specimens for hardness and metallography cut from the fracture edge and specimens for the tensile and compressive tests cut from a non-deformed area near the cylinder bottom. **Figure 28** shows the location of the billet cut for machining into tensile and compressive specimens. This location was chosen based on the results of spherometer measurements made of the cylinder inner curvature. It was necessary to locate an area of the cylinder, large enough to machine a full sized ASTM E-8M dog-bone specimen that had not been deformed significantly from the original curvature. Taking the specimen from such an area ensured that the cylinder material would be as close as possible to as-manufactured condition without any altering of strength properties due to deformation from the incident. **Figure 29** shows the locations of the specimens cut for hardness and metallography.

Figure 28. View of the incident cylinder showing the location of the billet removed for machining into tensile and compressive test specimens.

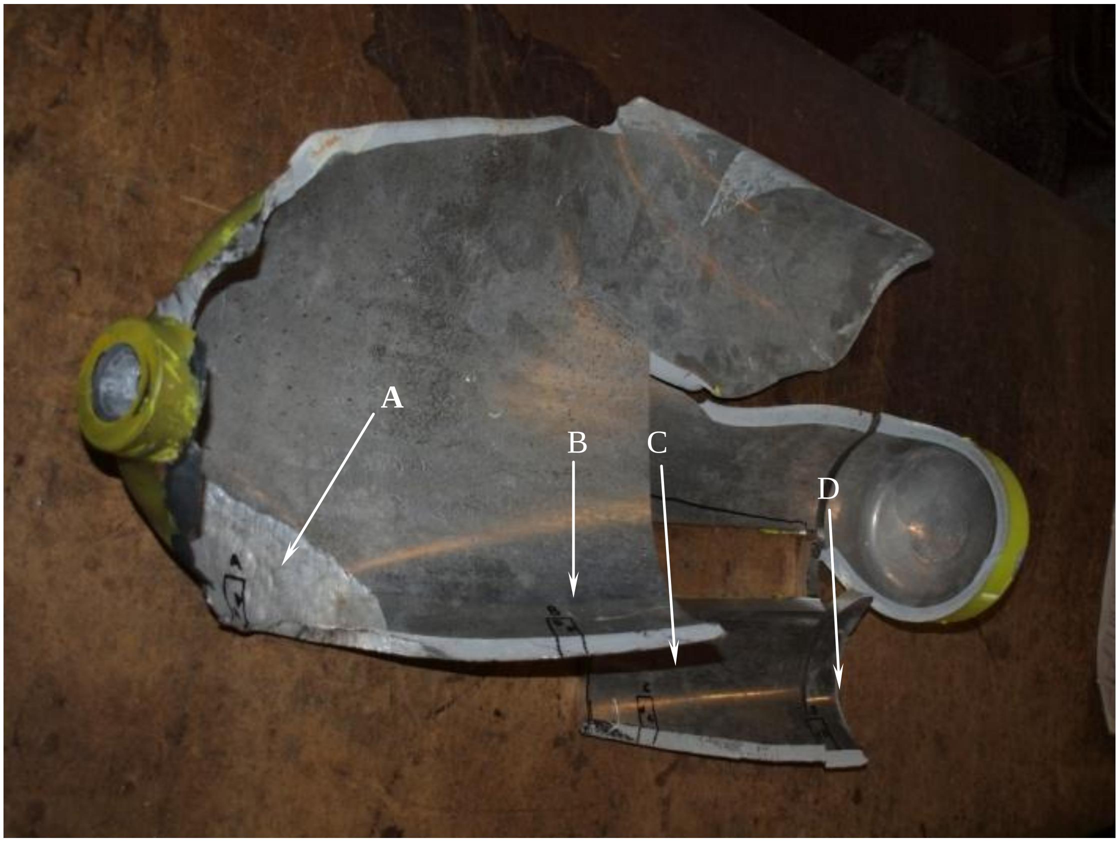

Figure 29. View of the incident cylinder showing the locations of the four metallography/microhardness specimens.

4.4.2 Machining

Specimens were machined according to ASTM E-8M and ASTM E-9 for tensile and compressive testing, respectively. Both specimens were machined such that tensile and compressive loading axes were parallel to the longitudinal axis of the cylinder. See **Figure 30** for the tensile specimen.

Figure 30. View of the tensile specimen machined from the incident tank.

4.4.3 Tensile and Compressive Testing

Both the tensile and compressive tests were conducted under quasi-static conditions. This resulted in a measured tensile yield strength of 318 MPa (46.1ksi) and a measured compressive yield strength of 347 MPa (50.3ksi). Additionally, an ultimate tensile strength of 354 MPa (51.4ksi) and tensile elongation of 15% were measured. Alcoa specifies minimum values of 290 MPa (42ksi), 345 MPa (50ksi), and 13% for the yield strength, tensile strength, and tensile elongation, respectively, for 6061-T6 aluminum.

4.4.4 Metallographic Examination

Samples A through D, as seen in **Figure 31**, were mounted and polished for metallographic examination. A weak hydrofluoric solution was used as an etchant to reveal the grain structure. The specimens were examined optically using a metallograph and images captured from various regions of all four samples. **Figure 32** and **Figure 33** show representative micrographs of samples A and D. Micrographs from all the samples were compared to a representative micrograph of 6061-T6 published in "Introduction to Aluminum Alloys and Tempers".[7] The microstructures compare favorably, confirming that the incident cylinder was manufactured from 6061-T6.

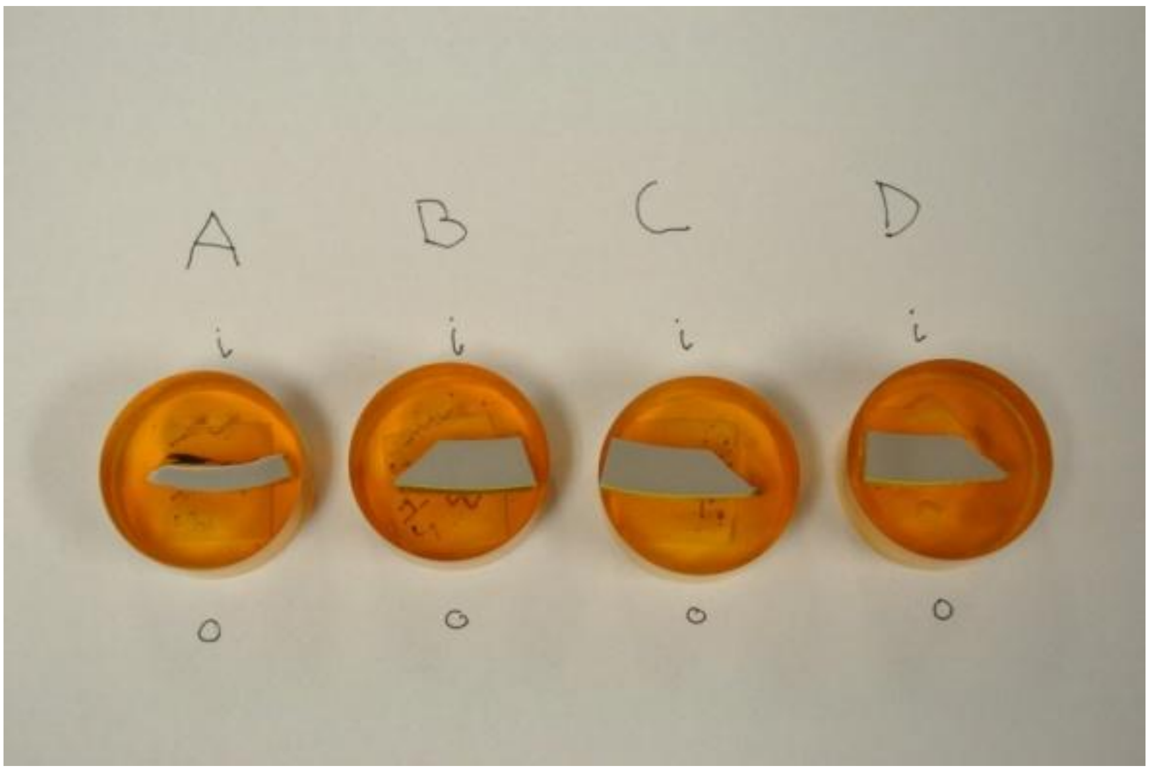

Figure 31. View of the four metallography/microhardness specimens prior to hardness testing. The "i" and "o" notations indicate the inner and outer surfaces, respectively.

[7] *Introduction to Aluminum Alloys and Tempers*, Kaufman, G.J., ASM International, Materials Park, 2000.

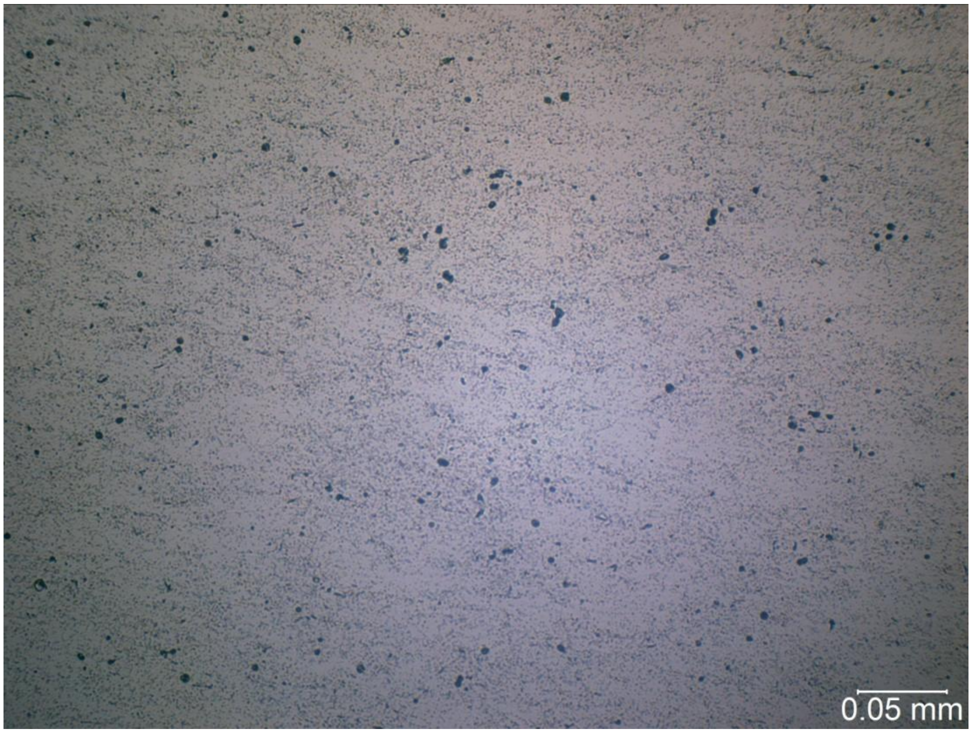

Figure 32. Sample A center 200x

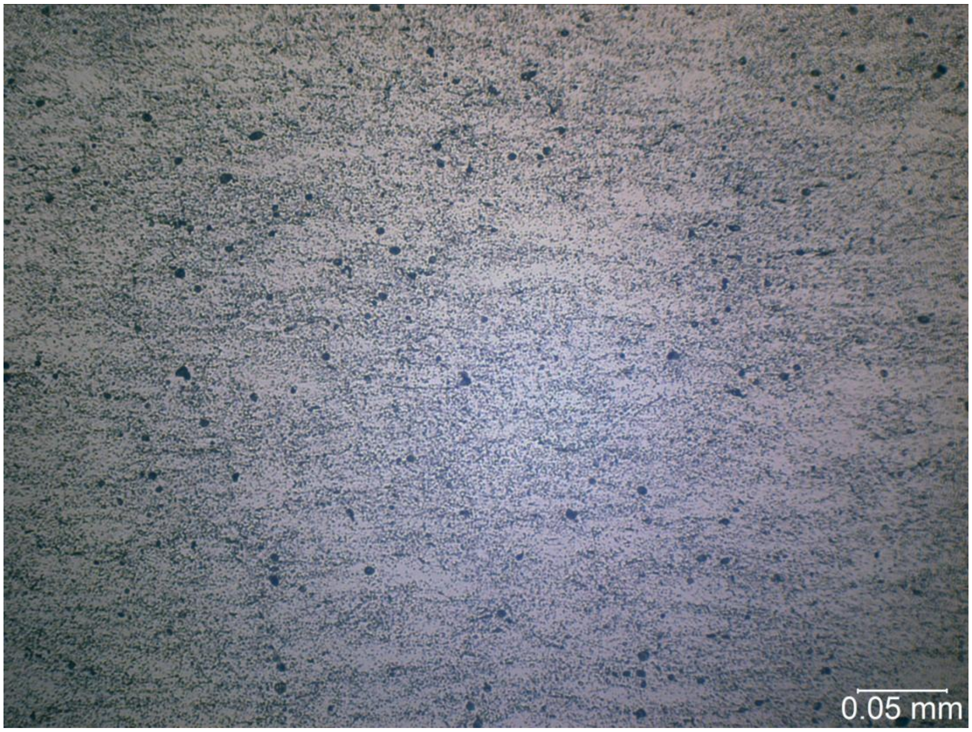

Figure 33. Sample D center 200x

4.4.5 Hardness Results

Upon completion of the metallographic examination, samples A through D were subjected to microhardness testing. Two microhardness traverses were made on each sample. One proceeded from the fracture edge across the circumference of the sample and the other proceeded from the inner to outer surfaces of the sample. A Knoop microhardness value of 120 is generally expected for 6061-T6. The microhardness measurements from sample A measured noticeably lower than the expected values. The measured values ranging from 82.7 to 110 with average values for the two traverses of 97.7 and 101.3. Sample A was taken from a section of cylinder that had undergone combustion, so the reduction in hardness is attributed to exposure heat causing over aging. Samples B through D showed measured values that were more consistent with the expected with averages of 123.8 and 126.0 for B, 119.3 and 125.8 for C, and 124.4 and 129.6 for D. The full set of results is included in **Attachment 10.**

4.5 Chemical Analysis

The level of purity of the oxygen that was allegedly contained in the incident cylinder dictates that a specific environment within the gas passages would be maintained at all times. If a contaminant is present in an oxygen rich environment, the potential for ignition increases dramatically. Wash samples using DuPont Vertrel MCA solvent were taken from: (1) the inner surface of the incident cylinder, (2) the surfaces of the incident valve and its components that are part of the gas passage, (3) the inner surface of the incident regulator green hose, (4) the interior surfaces of the incident regulator, and (5) surfaces of the exemplar valve and its components that are part of the gas passage. These samples were analyzed using Fourier Transform Infrared Spectroscopy (FTIR) for chemical composition. The samples taken from the exemplar valve were used as a control for those taken from the incident valve.

Additionally, Optical Emission Spectroscopy (OES) was performed on samples of the incident cylinder and the exemplar valve in order to specifically identify the aluminum and brass alloys, respectively, used to manufacture each.

4.5.1 FTIR Analysis

Full FTIR results are included in this report as **Attachment 8.** Other than the lubricant observed on the exemplar valve components, no substances were identified that could not be attributed to post incident sources. In other words, no unknown surface contaminants were found.

4.5.2 OES

Tables 1 and 2 contain the results of OES conducted on the cylinder and exemplar valve as compared to 6061 aluminum alloy and forging brass. The tested samples match well with the standard specifications for each alloy.

Table 1. Cylinder Valve Chemistry

Element	Cylinder Valve (wt%)	Requirements for Forging Brass UNS C37700	
		min	max
Copper (Cu)	Remainder	58.0	61.0
Iron (Fe)	0.26	-	0.30
Lead (Pb)	2.57	1.50	2.50
Nickel (Ni)	0.06	Information Only	
Phosphorus (P)	< 0.005	Information Only	
Tin (Sn)	0.21	Information Only	
Zinc (Zn)	38.47	Remainder	

Table 2. Cylinder Chemistry

Element	Tensile Specimen (wt%)	Requirements for Aluminum Alloy 6061 UNS A96061	
		min	max
Aluminum (Al)	Remainder	Remainder	
Chromium (Cr)	0.08	0.04	0.35
Copper (Cu)	0.33	0.15	0.40
Iron (Fe)	0.18	-	0.70
Lead (Pb)	< 0.005	Information Only	
Magnesium (Mg)	1.06	0.80	1.2
Manganese (Mn)	< 0.005	-	0.15
Nickel (Ni)	< 0.005	Information Only	
Silicon (Si)	0.70	0.40	0.80
Titanium (Ti)	0.01	-	0.15
Zinc (Cb)	< 0.005	-	0.25

5.0 DISCUSSION

5.1 Origin of the Explosion

The explosion has been determined to have been caused by the ignition of aluminum cylinder material and originated between the threads of the cylinder valve and the cylinder neck opening. Analysis of the cylinder dimensions and materials revealed that the cylinder was made from a material consistent with aluminum 6061-T6, and the wall thickness was appropriate. Laboratory testing failed to reveal the presence of contaminants or oxygen incompatible materials that may have auto-ignited. The resulting ignition promoted the growth and spread of further combustion of cylinder wall material. The combustion of aluminum occurred and was restricted to the inside surface of the cylinder. The heat generated was sufficient to locally soften the cylinder wall, as demonstrated by the over-aged condition of metallographic specimen "A". The combustion also reduced the wall thickness. Additionally, the heat of combustion was released into the compressed gas, causing the gas pressure to rise. The combination of weakening the cylinder wall from heat of combustion, thinning due to the combustion of the cylinder material, and the increase in gas pressure from the release of heat from combustion, caused the cylinder to rupture and explosively release its contents.

The magnitude of aluminum material eroded from the event is greatest in the threaded neck opening region, indicative of the region of most intense and/or the longest burning. The initial fracture of the cylinder occurred along the base of the threaded opening, or "neck," proximate to the ignition origin and began to grow along the perimeter of the opening base, until realigning along the cylinder axis and growing down towards the cylinder base, as indicated in **Figure 34**. Some of the fracture surfaces were either melted or covered by melted aluminum that re-solidified, but this could also be the result of the cylinder striking a hard surface which caused the cylinder to break up.

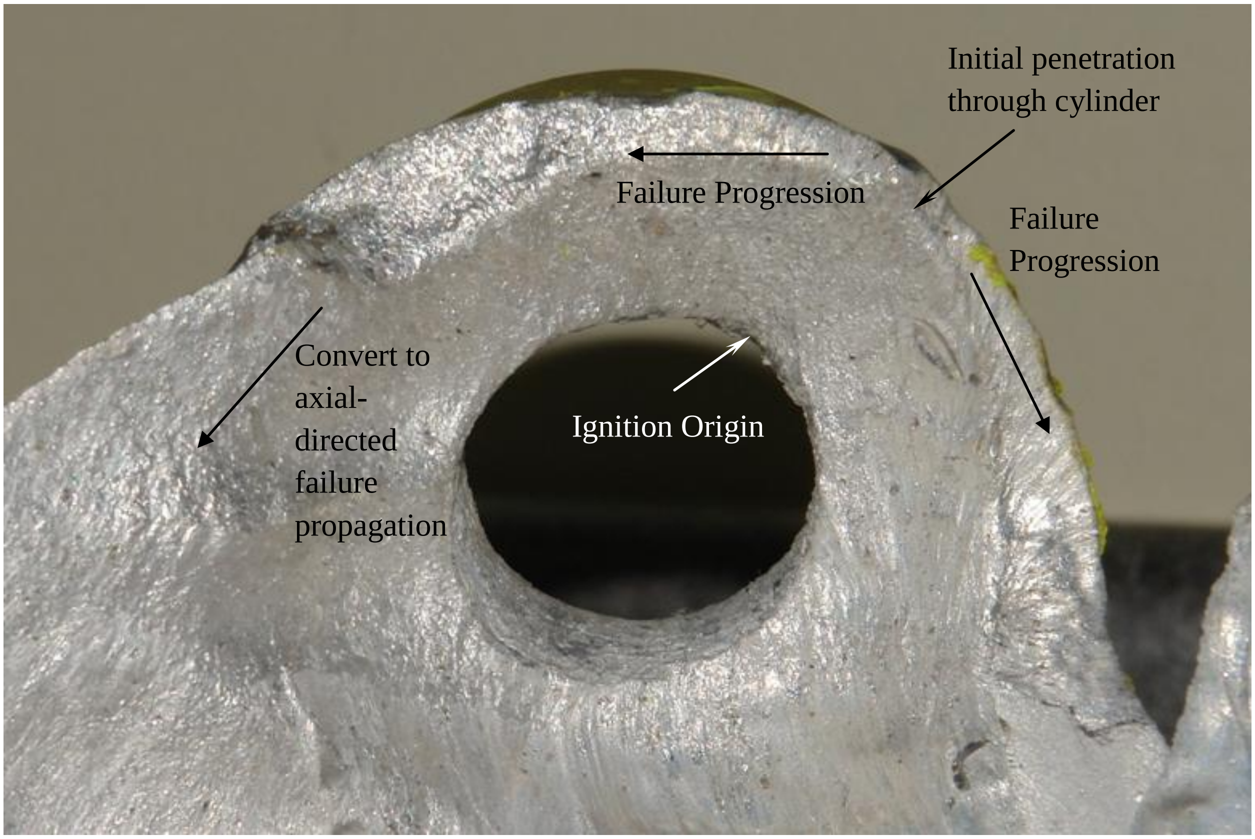

Figure 34. View showing the threaded neck opening region of the incident cylinder from the interior.

To evaluate the pattern of erosion about the cylinder opening, the depth of the threaded neck opening was measured at 30° intervals from the flat exterior top to the point where erosion seemed to stop along the threaded wall. The resulting measurements are shown in **Figure 35** in the radial diagram. The deepest erosion was set as the 0° point. The least erosion appears to have occurred at the 120°. The 120° region happened to be the area where the combustion deviated away from the opening and began to travel down the side of the cylinder interior, also being the direction where the hoop stress dominates the pattern of crack growth.

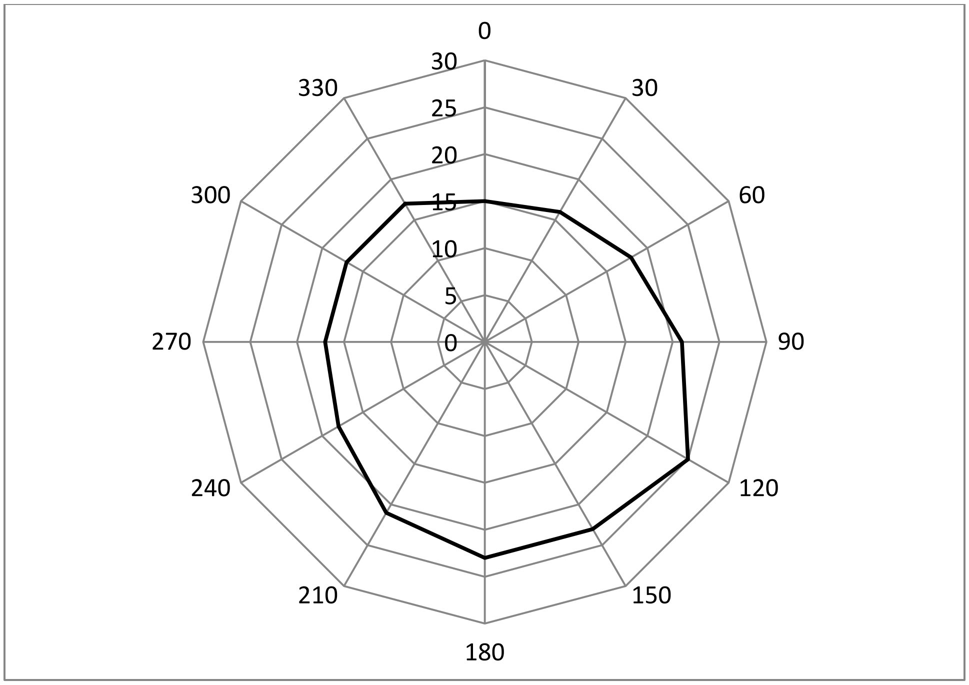

Figure 35. Depth measurements of the threaded neck cylinder opening, in mm.

The cylinder valve base also exhibits a matching pattern of erosion consistent with combustion from ignited aluminum, and alloying[8] from flowing molten aluminum, all originating from the threaded region within the threaded neck cylinder opening, as seen in **Figure 36**. There is a region along the perimeter that exhibits fracture as well as melting and reaction. The gross erosion was angled to the axial normal, indicating that once ignited, the products of combustion were expelled downward into the cylinder. The damage pattern suggests the initial ignition and resultant kindling to promoted ignition occurred within the threads closest to the edge of where the threaded neck cylinder opening bottom and cylinder valve threads meet.

The depth of the existing material below the gasket lip was also measured to evaluate the pattern of erosion. The depths were measured at 30° intervals with the 0° set coincident with the valve

[8] "*Copper-Aluminum Interaction in Fire Environments*", B. Beland, C. Roy, and M. Tremblay, Fire Technology, Vol. 19, Number 1, 1983, page 20.

outlet centerline. As seen in **Figure 37**, the region with the greatest erosion was at 30°, with the least erosion at between 180° and 240°. Superimposing the radial plot with **Figure 35** and rotating the data -60° results in a near perfect overlay as seen in **Figure 38**. The closeness of fit supports the notion that the ignition point did occur within the threaded region. The exemplar cylinder valve threads extend 25 mm from the gasket lip to the flat bottom. The smallest depth of the valve threads measured 15 mm, indicating that perhaps 10 mm of material had eroded from the threads at that point.

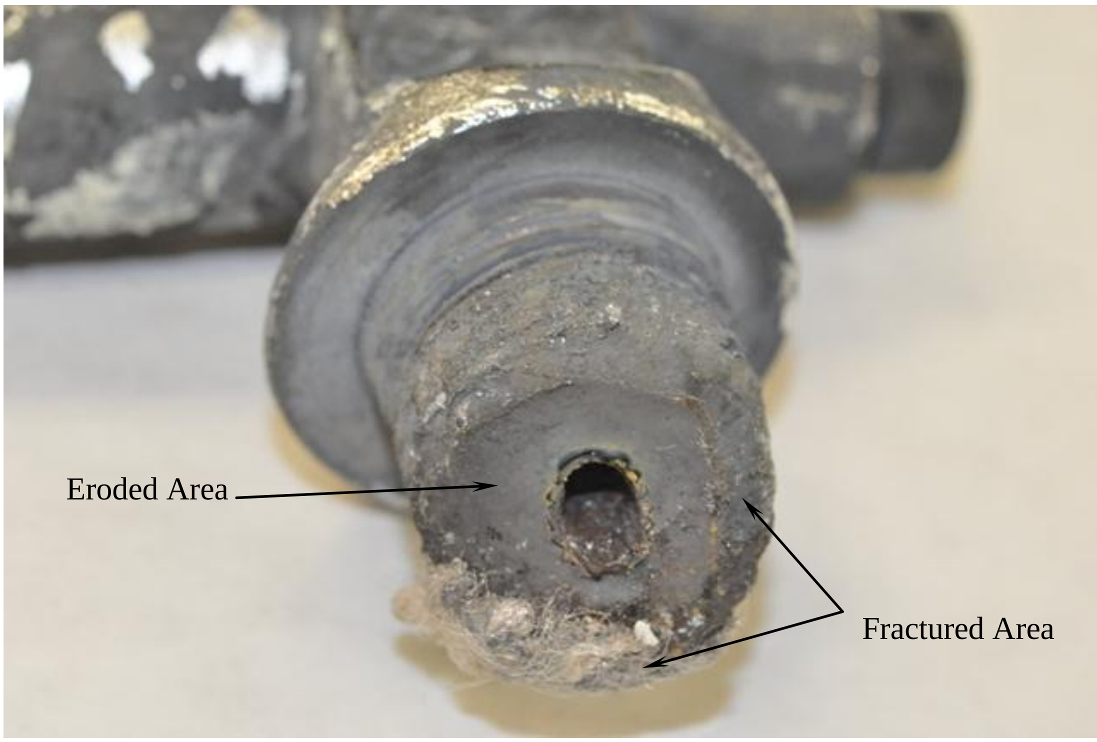

Figure 36. View of cylinder valve threaded area.

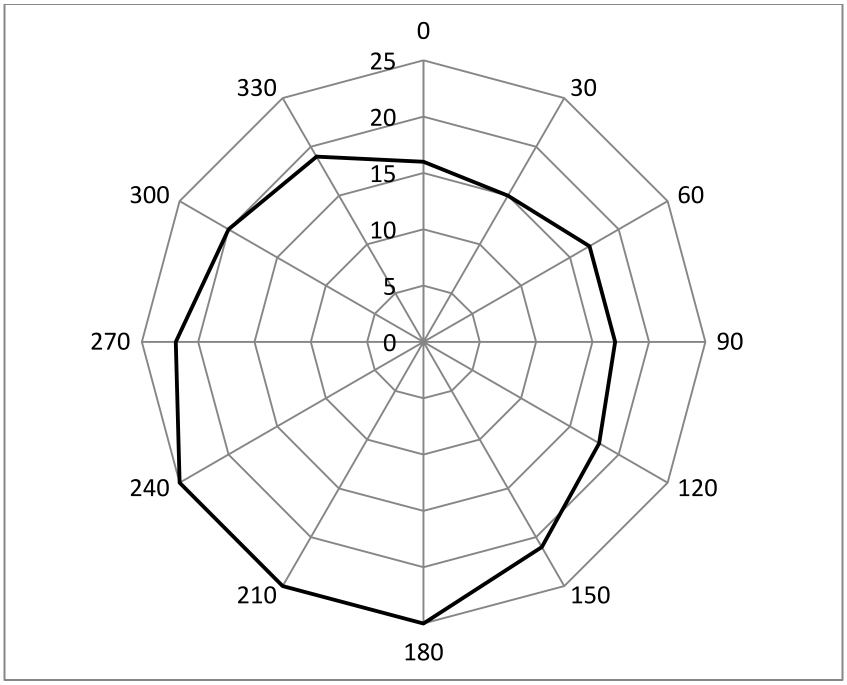

Figure 37. Depth measurements of the valve threaded area, in mm.

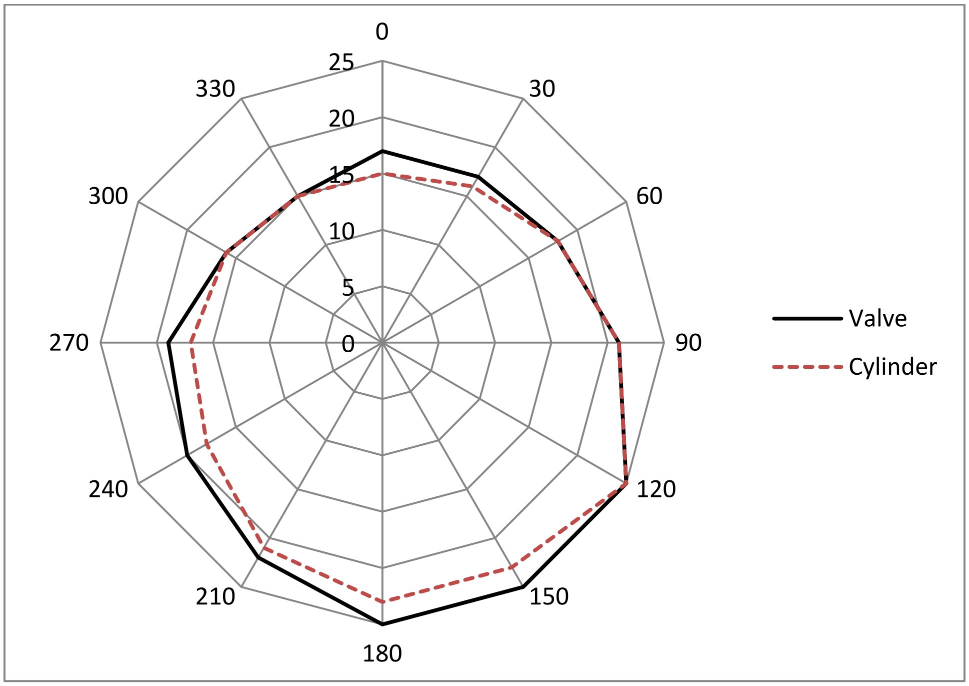

Figure 38. Comparison of measured depths, in mm. Valve depth is rotated -60° to match.

The burn pattern within the cylinder had two distinct burn zones as seen in **Figure 39**. Zone 1 matched the hemispherical geometry of the domed cylinder top with a demarcation line of between 4 cm and 5 cm from the opening center. Zone 2 extended vertically down the cylinder wall about 20 cm from the opening, and having a width of about 11 cm. A fracture divided the second burn zone, indicating this region was the area from which the crack propagated after initiating at the base of the "neck." The area in Zone 1 was due to a circumferential combustion progressing from the origin point. The burn pattern in Zone 2 is a directional effect due to gravity as the cylinder may have been on its side. Despite the fracture starting at the base of the "neck," the weakened area of Zone 2 influenced the crack to propagate in that direction as the hoop stress from internal pressure was greater in this area.

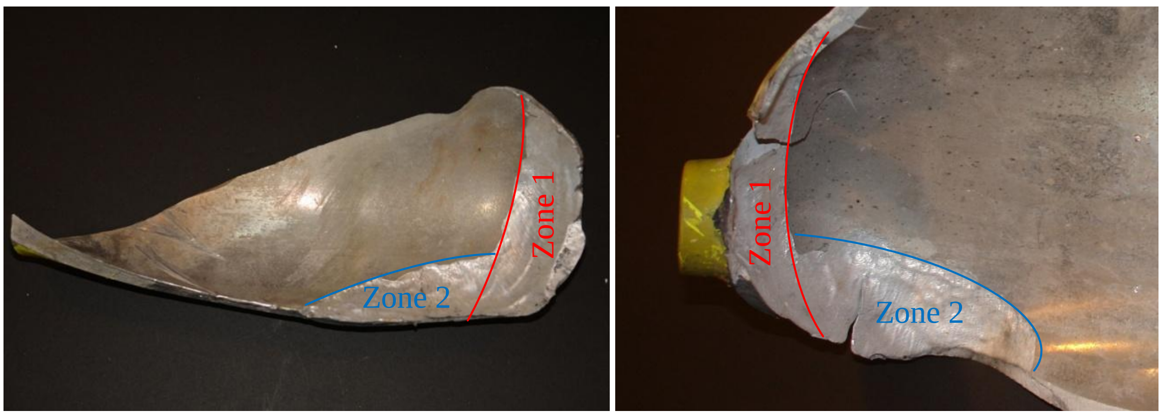

Figure 39. View of interior surface showing the two distinct burn zones.

As the aluminum was consumed, the local wall thickness was reduced; the heat weakened the aluminum; and the internal gas pressure increased from the heat energy produced by the combustion. The reaction was likely to have been more of a burning rather than explosive process. Due to this combustion process the cylinder failed at a pressure less than 38 MPa (5,500 psi)[9] as the pressure relieving burst disk in the cylinder valve was still intact after the explosion.

[9] The CG-1 burst disk is rated at 32.6 MPa ±10% (5000 psi ±10%), 38 MPa is the upper range of possible activation of the relief.

5.2 Ignition Mechanism

There are several ignition mechanisms that are possible within the incident cylinder. Some ignition mechanisms are: **promoted ignition**, where a source of heat acts to start the metal burning***;*** **friction ignition**, where the rubbing of two surfaces together generates heat; **particle impact**, where the kinetic energy of a particle striking the surface is converted to heat; **mechanical impact**, much like the particle impact, heat is generated from the transfer of kinetic energy from an object having significantly more mass and less velocity than a particle; **exposure of base metal**, where the protective oxide layer is removed to expose the base metal, which in turn, oxidizes in the oxygen enriched atmosphere generating heat; **auto ignition of contaminants or incompatible materials**, where a material, such as a hydrocarbon based lubricant, is incompatible with use in an oxygen rich environment and self-ignites to promote ignition of the metal; **heat of compression**, where the rapid filling of a low pressure vessel from a high pressure line can cause the existing gas in the low pressure chamber to be driven into a compact region and compress to an increased temperature; **charging rigid vessels**, where the kinetic energy of the gas entering a low pressure vessel is converted to heat; **electric arc**, where the discharge across gaps between conventionally powered, electrically energized objects are heated from the very high temperature arc; **static electric discharge**, like an electric arc where a competent electric discharge occurs across a gap, but the electrical potential was created by a charge difference between the objects, not by electrical energizing; and **acoustic resonance**, where the oscillations of acoustic pressure waves from flowing gas create a temperature rise within the resonant cavity.[10]

The incident cylinder valve was found closed. The extents of heat and combustion effects were limited to the entrance of the cylinder valve at the point where the pick-up tube entered the valve body. At that point in the cylinder valve and beyond, there was no evidence of heat or combustion as the valve interior wall surfaces appeared clean and without heat effects. Plastic components within the cylinder valve were spared heating as they did not suffer any melting,

[10] ASTM G 94 – 92, and Advanced Thermodynamics for Engineers, §1-7-1 Charging and Discharging Rigid Vessels.

warping, combustion, or exhibit soot. Additionally, the valve seat was at the most forward position, indicating that the valve was shut at the time of the incident. The laboratory testing also failed to reveal the presence of any identifiable materials that are non-compatible with high purity oxygen systems. It would be expected that if such a substance existed prior to the fire, remnants of the substance or its by-products would still exist.

As a result, the following ignition mechanisms can be ruled out: particle impact; incompatible materials within the cylinder valve; charging a rigid vessel; heat of compression; static electric discharge; and acoustic resonance. This leaves electric arcing, mechanical impact, exposure of base metal, promoted ignition, and friction ignition. Electric arcing and promoted ignition are ruled out as improbable, thus leaving mechanical impact, exposure of base metal and friction ignition as the most likely causes. The actual mechanism of ignition could not be determined.

5.3 Cylinder Compliance with the Federal Regulations

5.3.1 Compliance with Labeling

Compressed oxygen gas is considered a hazardous material, and is regulated under Title 49 of the Code of Federal Regulation, Part 172, Sub Chapter B. As found in the "Hazardous Materials Table," §172.101, oxygen, as a compressed gas: has a Hazard Classification or Division of 2.2 (non-flammable gas); has an Identification number of UN1072; must be label coded as 2.2 or 5.1 (oxidizer); is subject to the special provisions of §172.102 A14 and A52; and must be packaged as per §172.302 for bulk packaging, or §172.314 and 315 for non-bulk packaging, with exceptions found in §172.306. Of the exceptions provided, none provided an exception to the labeling requirements for the incident cylinder. In summary, the incident cylinder should have been minimally labeled with a diamond shaped, durable label clearly marking the contents as "oxygen" followed by a "2.2".[11] However, the Code is silent with regards to identification of the degree of cleanliness, as indicated in ASTM G 93.

[11] 49 CFR 172.407 provides the specifications for the label, §172.426 demands that an oxidizer have specific wording and Division for an oxidizer, and §172.405 modifies the oxidizer label to configure specifically to compressed oxygen gas.

In accordance with the federal regulations, the incident cylinder should have possessed a label indicating that the contents of the cylinder were compressed gas oxygen. The incident cylinder possessed two decals or labels. The first, shown in **Figure 2**, indicated that the cylinder had been cleaned in accordance with O_2 service. There is no indication as to who may have stamped and applied the decal, or as to what procedure was followed to certify the cylinder was properly cleaned. The failure to provide this information is counter to the suggestions of the Compressed Gas Association,[12] and a violation of the ASTM G 93 which states as follows:

12.2 *Package Marking*:

12.2.1 Each oxygen cleaned and packaged article shall be clearly labeled to include the following information:

12.2.1.1 The manufacturer, component identification, date cleaned, responsible department or agent,

12.2.1.2 Notification that it has been specially cleaned for oxygen service, such as oxygen cleaned, cleaned for oxygen service or specially cleaned,

12.2.1.3 Identification of cleaning method used, such as "Cleaned in accordance with ASTM G 93, Verification Type I, Test 1 through 4, Type II, Test 1, Level A, and Test 2, Level 175" or "Cleaned in accordance with ASTM G-XXX" (the manufacturer's or purchaser's specification).

The statement on the decal "Tank & Valve Have Been Cleaned In Accordance With O_2 Service" is not appropriate as it fails to indicate to what standard and level the cylinder has been cleaned, and who performed the cleaning. The decal does not provide the necessary information needed to ensure that the cylinder is appropriate for use with oxygen enriched gases. Additionally, the incident cylinder lacked the labeling as required by Federal statute. Should the incident tank have been used for Nitrox at 40% oxygen concentration or less, the IANDT label would have been sufficient and appropriate.

[12] Handbook of Compressed Gases, page 205 under section "Pressurization".

Had the requirements of proper labeling been adhered to, there would not have been a need to produce an inadequate label indicating the incident cylinder had been cleaned for oxygen use. Use of the incident cylinder prior to being labeled is unknown. The entity that allegedly cleaned the incident cylinder for oxygen use should have affixed the federally mandated label prior to allowing the incident cylinder to be used with compressed oxygen. Without further information regarding the events preceding the incident, it is impossible to determine if the inappropriate labeling played a part in the incident.

5.3.2 Compliance with Regulations for 3AL Cylinder

The requirements for a 3AL cylinder are found in Title 49 of the Code of Federal Regulations, part 178.46. The regulation dictates the cylinder material is to be similar to aluminum alloy 6061 with a T6 heat treatment with the mechanical properties having a minimum yield strength of 241 MPa (35,000 psi), a minimum tensile strength of 262 MPa (38,000 psi), and a minimum elongation of 14%. A sample of the cylinder was removed for tensile testing and compression testing. The sample was machined from the wall section having as much of the original curvature as possible to minimize the effects of work hardening from the accident. The specimen, seen in **Figure 40**, measured 12.93 mm (0.509 in) wide by 9.68 mm (0.381 in) thick by 131.75 mm (5.187 in) long. The testing performed in this investigation revealed that the cylinder material had a yield strength of 318 MPa (46,100 psi), a tensile strength of 354 MPa (51,400 psi), and an elongation of 15% – exceeding the minimum requirements of the regulation.

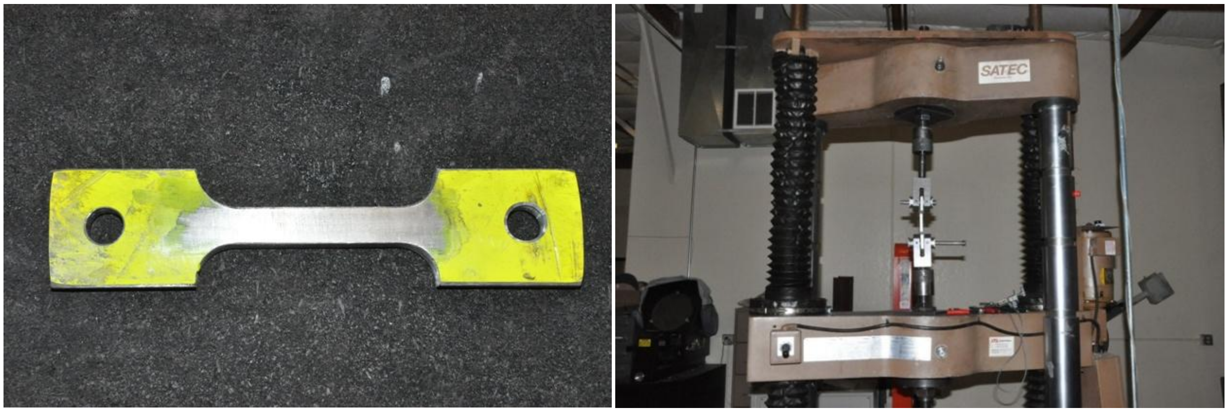

Figure 40. Tensile test specimen and tensile test.

Section 178.46(d) of the CFR provides for a minimum wall thickness. The regulation states that "The minimum wall thickness must be such that the wall stress at the minimum specified test pressure will not exceed 80 percent of the minimum yield strength nor exceed 67 percent of the minimum ultimate tensile strength as verified by physical tests in paragraph (i) of this section." The wall thickness was measured to be 9.78 mm. The prescribed minimum test pressure was 34.5 MPa (5,000 psi)[13]. Using the measured mechanical properties, the results were that the wall stress measured 63.7% of the yield stress and 57.1% of the ultimate stress, which were below the regulation maximums. The resulting analysis indicates the wall thickness of the incident cylinder exceeded the minimum required by the regulation.

A sample of the material from the tension specimen was subjected to an alloy composition analysis. The incident cylinder material was found to be consistent with aluminum 6061 with T6 temper.

[13] 49 CFR 178.46(g)(3)(iii) Five-thirds times the service pressure for cylinders having a service pressure of at least 500 psig. The incident cylinder was rated for 3,000 psi service pressure.

6.0 CONCLUSIONS

The opinions expressed in this report are based on RTI's inspection and evaluation of the evidence; and engineering analysis using generally accepted scientific and engineering methodologies. These opinions are also based on RTI's education, background, knowledge, and experience in the fields of mechanical engineering, material science, chemistry, fluid dynamics, thermodynamics, and physics.

RTI concludes, to within a reasonable degree of engineering certainty that:

1. There is no evidence to suggest that non-compliance with the hazardous materials regulations played a part in the incident cylinder failure; however, modifications to the regulatory standards may be necessary.

2. The incident cylinder was not labeled as required by the hazardous materials regulations. However, it is uncertain if the failure to properly label the incident cylinder played a part in the incident.

3. The incident cylinder failure was not due to excess thermal exposure from an external source.

4. Laboratory testing failed to reveal any evidence of contamination from an oxygen incompatible substance on the incident cylinder, cylinder valve, hoses, and regulator.

5. There were no problems evident with the incident cylinder, except for the way it was labeled.

6. There were no problems evident with the incident cylinder valve.

7. There were no problems evident with the incident regulator and pressure lines.

8. The ignition of the fire that led to an explosion originated within the threaded section of the cylinder neck opening. The actual mechanism of ignition could not be determined.

RTI reserves the right to amend or supplement this report and its conclusions or recommendations should additional information become available.

Respectfully submitted,

Richard B. Loucks, Ph.D., P.E.
Senior Mechanical Engineer

Matthew Wagenhofer, Ph.D.
Mechanical Engineer

ATTACHMENT 1

Test Protocol

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TEST PROTOCOL

November 29, 2011

RTI Matter Name: DOT – Ruptured SCUBA Cylinder

RTI Matter No.: 50151ME002

RTI Investigators:

Richard B. Loucks, Ph.D., P.E.

Matthew Wagenhofer, Ph.D.

Background:

RTI was tasked through Government Contract DTPH56-12-P-000004, dated November 9, 2011, issued by Office of Acquisition Services US DOT/PHMSA/PHA-30 to perform an investigation on a DOT 3AL-3000 cylinder involved in a fatal accident to determine if non-compliance with Hazardous Materials Regulations played a part in the cylinder failure and if modification of the regulatory standards is necessary.

Additionally, the purpose of this contract is to evaluate the ruptured DOT 3AL-3000 cylinder valve and determine the following:

- The degree of exposure to thermal energy; and
- Evidence of oxygen contamination which may have resulted in the explosion (fire) inside the ruptured DOT 3AL cylinder.

On November 15, 2011, RTI Group, LLC (RTI) received four items from the Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA). These items are described as follows:

1) Yellow high pressure gas cylinder, Part 1

Smaller fragment from the cylinder, measures approximately 12 inches by 6 inches. Fragment displays the following marks near the neck: HY-MARK DOT-3AL 3000 OU

Cylinder has one decal and part of another:

> Decal 1: "Tank & Valve Have Been Cleaned For Premix, Oxygen Content 22 to 40%" is not punched out. "Tank & Valve Have Been Cleaned In Accordance With O_2 Service" Is punched out at 2011. The month is uncertain.
>
> Decal 2 (partial): for decompression use …. IANTD/IAND, Inc.

2) Yellow high pressure gas cylinder, Part 2

Larger section contains the bottom, neck and valve opening, measures approximately 24 inches by 14 inches. This item has the following markings near the neck: 0001 M5442 10 07 S40 TC-3AL 207

This part of the cylinder contains the remaining portion of Decal 2 stating:

> Decal 2 (partial): OXYGEN for decompression use only – MOD 20 FSW MOD 6 MSW WWW.IANTD.COM

3) High Pressure Tank Valve, DIN Valve,

Manufactured by Genesis containing a 5000 psi, 30 lb/hr CG-1 type rupture disk. A pressure regulator adaptor is present in the opening which has a fractured outlet. The metal particle filter is evident in the opening. The rubber hand closure knob is present, but separate from the valve.

4) Regulator

Manufactured by Dive Rite, serial number 12008135, fitted with regulator fitting. The opening is occupied by the fractured end of the pressure regulator adaptor.

Attached to the regulator:

1. Black pressure line with dial gage on high pressure side of regulator. Dial gage face is heat affected and the gage is illegible.

2. Length of green pressure line stating "WARNING Do not exceed 250 psi (17 bar) high pressure may cause damage or personal injury" no manufacturer identified. Distal end terminates unattached. Low pressure side

Objective:

Under the tasking directive of the contract, sub-section 3.02 "Advanced Analysis and Examination", as part of the investigation the evidence is to be subjected to a series of invasive, therefore destructive, examinations in which sophisticated laboratory equipment will be employed, such as Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), Energy Dispersive Spectroscopy (EDS), metallography, alloy chemistry, hardness testing and tension and compression testing. This protocol addresses the schedule and procedures that will be performed to fulfill this task.

Date, Time and Location:

- Tuesday, December 6, 2011 at 10:00 am pacific coast time

- ANAMET, Inc.
  26102 Eden Landing Road, Suite 3
  Hayward, CA 94545-3811

- Local Contact: Kenneth Pytlewski, 800-377-7768 OR Ken@Anametinc.com

Procedure:

Phase I – Initial Examination.

Document the condition of the evidence through the use of field notes and still photography. The use of optical microscopy will be used where appropriate. This process is non-destructive and is intended to document the evidence prior to any alterations.

Phase II - Search for the presence of oxygen non-compatible substances.

An examination in search for materials typically found in SCUBA dive operations, such as silicone greases found in diving gear (dimethylsiloxane), hydrocarbon greases/oils used in diving gas compressors, perfluorinated lubricants found in Nitrox diving gear, and other lubricant materials such as Tribolube (ALI Aerospace Lubricants), Christo Lube (Lubrication Technologies, Inc.), IKV-Fluor & Zarox, etc. With the use of solvents, such as: Asahiklin AK 225 (Hydrochlorofluorocarbons); DuPont Vertrel XF, DuPont Vertrel MCA (Hydrofluorocarbon); or 3M HFE 7100, 3M HFE 71DE (Hydrofluoroether), obtain samples from within the valve gas passage area and subject the samples for FTIR analysis. The solvent will be decided upon at the time of the examination.

High Pressure Tank Valve

Subject valve and regulator will have to be disassembled to reveal any existing gasket/seal materials, provide access to components for solvent washing and sample collection. With each disassembly, each component will be documented, and then the areas upstream of the containment feature will be searched for the presence of non-oxygen compatible materials. The disassembly will proceed in the following order:

1. Test the valve closure mechanism to determine if the valve is open or closed. Mark alignment of the gland nut to the valve body prior to turning with sharpie.
2. Remove the pressure regulator adaptor.
3. Remove the CG-1 burst disk pressure relief device.
4. Remove the closure mechanism. The gland nut will be removed exposing a series of gaskets and back up rings. These will be removed to gain access to the stem and the high pressure

seat. The condition of the high pressure seat will be inspected by SEM/EDS followed by solvent wash for FTIR analysis. Components will be removed until the valve body is empty.

Samples of the valve body will be obtained for chemistry analysis to determine the alloy of the materials used.

Material from the threads of the valve will be removed and inspected under the SEM. They will be removed using a pick and collected onto carbon tape for mounting on a SEM stage. Alternately, a segment section of the threads will be cut from the valve, polished and mounted, then inspected using the SEM.

Items having been separated from the parent object will be secured within a plastic container and labeled using the scheme: Part xx followed by a lower case alpha character, e.g. "Part 3-a Gland Nut".

Pressure Regulator Adaptor

The fractured surface of the pressure regulator adaptor will be examined using the SEM to determine the mode of fracture and the presence of foreign materials. The air filter cup within the adaptor will be subjected to SEM analysis to identify both the discolored material on the filter surface and any particles that may be trapped in the filter. Subsequently, the filter will be subject to a solvent wash to determine by FTIR the presence of any contaminants.

Regulator

The high pressure hose attachment will be removed and the interior of the tubing will be inspected. The low pressure tubing will be removed and inspected. The interior of the regulator will be inspected to the extent possible from the open ports. If possible, a solvent swab will be taken though a high pressure port and subject to FTIR to determine the presence of contaminants. If contaminants are present, the regulator will be dismantled.

Tank Material

Internal surfaces of the tank will be examined for the presence of oxygen non-compatible substances. Solvent washing of the internal area will provide samples for FTIR analysis in four areas, indicated as areas “A”, “B”, “C”, and “D” and any other areas deemed of interest on the day of the examination.

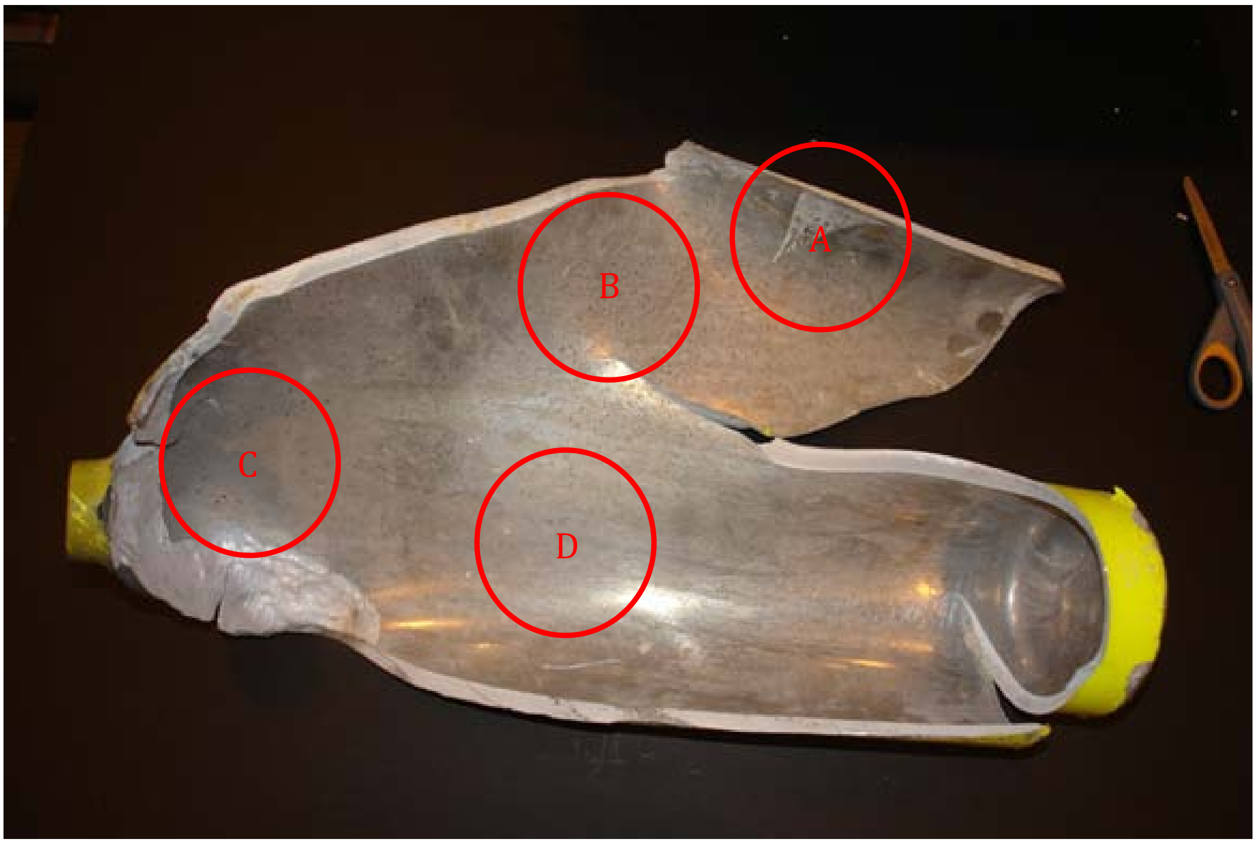


Figure 1. Solvent was areas for FTIR sampling.

Phase 3 – Mechanical properties testing of Cylinder material.

Several sections of the cylinder will be subjected to hardness testing, alloy chemistry, metallographic analysis and tension and compression testing.

Hardness traverses following the inner circumference of the tank will be made at several elevations along the length of the tank. The approximate elevations are indicated in Figure 2. The method of testing will be as follows:

1. Four sections of cylinder material of approximately 2 inches wide by 1 inch deep will be excised from the main body with the use of a liquid cooled diamond blade saw.

2. After removing the section from the main body, a ½ inch axial wide circumferentially cut section will be removed for subsequent metallographic mounting, polish and etch. This creates two sub-sub sections for evidence labeling where a lower case Roman numeral will be added to the nomenclature, e.g. “Part 1-a-i Excised section from Cylinder, Metallographic” and “Part 1-a-ii Hardness Specimen from cylinder”. See Figure 3.

3. The fracture surface from the larger section will be examined using the SEM to determine from the fracture morphology the mode of fracture, direction of crack propagation, EDS, and any other information discovered in the examination. The section will then be subjected to a Rockwell hardness test on the internal surface, not directly on the fracture surface.

4. The smaller section will be cast into a resin material with the cut surface including the fracture surface for examination. The specimen will be polished, then etched to allow examination of the grain structure. A profile of Knoop micro hardness tests will be performed at 1mm intervals in two directions: circumferentially along the mid thickness from the fracture surface for 1.5 cm; and along the radial from the internal to the external surface.

Figure 2. Approximate test sites for hardness testing and metallographic examination.

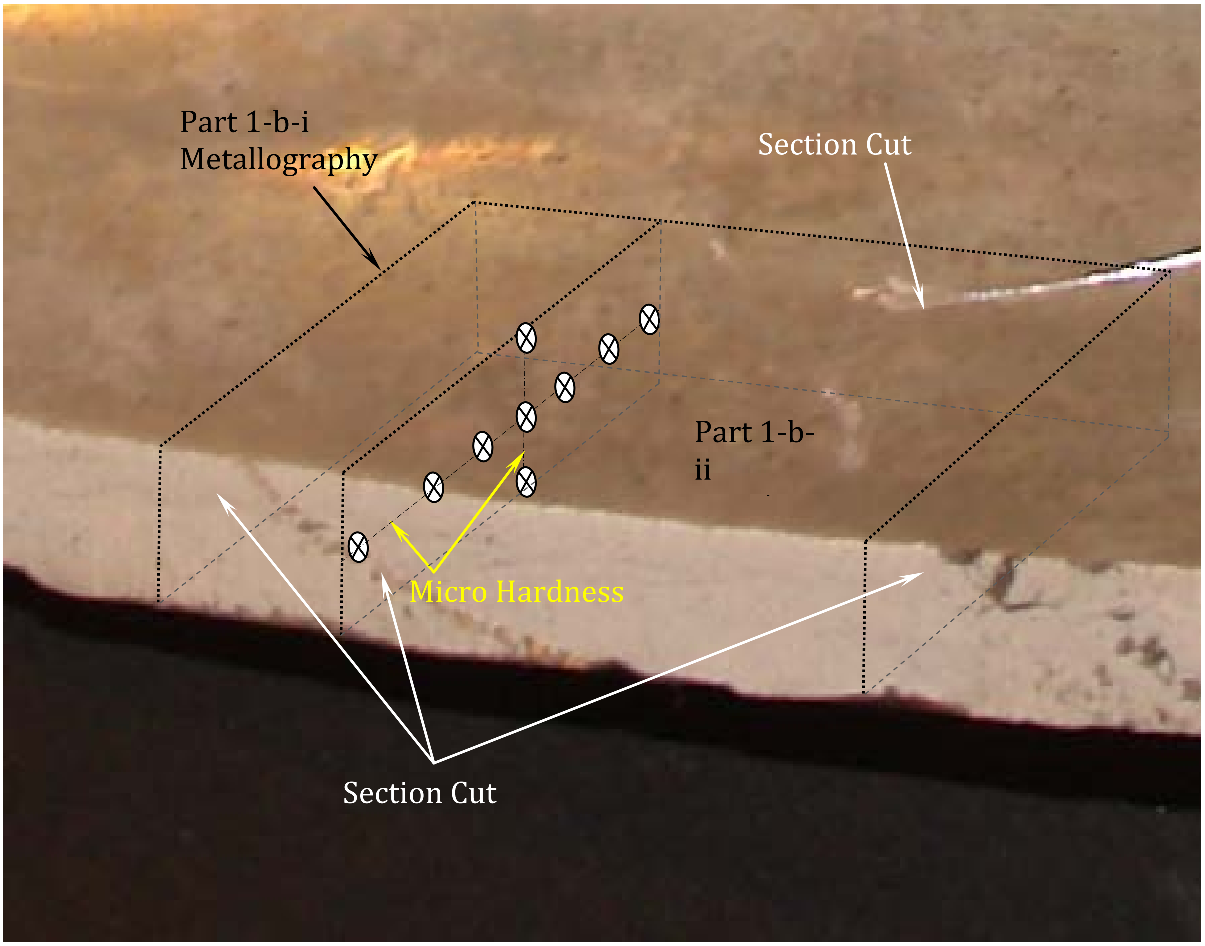


Figure 3. Hardness testing and Metallographic sectioning. ⊗ illustrate Knoop micro hardness locations along the traverse. (not to scale)

Tension and compression testing will be performed to determine the mechanical properties of the alloy. Sample material will be collected from the machined samples for chemical analysis to determine the aluminum alloy.

The tension and compression tests will be performed as follows. A spherometer will be used to measure the radius of curvature of the tank in its as-received condition. Baseline inner surface curvature measurements will be made on the intact bottom region of the tank. Further inner surface curvature measurements will be made along the length of the tank over all of the regions to determine the least deformed section of the tank. Visual inspection of the as-received tank indicates that this section is likely to correspond to that indicated in Figure 3. At least one (1) tension test specimen and two (2) compression test specimens will be machined from this region. The tension test specimen will be oriented such that the tensile axis of the specimen is parallel to the longitudinal axis of the tank. One of the compression specimens will be oriented such that the compression axis is parallel to the radial axis of the tank. The other compression specimen will be oriented such that the compression axis is parallel to the transverse axis of the tank. The transverse axis is defined by a line tangent to a circumference around the tank located at the midpoint of the tank wall. Any additional specimens for which there is sufficiently un-deformed material will duplicate these three orientations.

Dental mold compound will be used to make highly accurate replicas of the threads inside the neck of the tank prior to sectioning and mounting of the threads for metallographic and microscopic analysis. It is anticipated that the entire circumference of the threads will be replicated in two to four sections to ease removal of the molds from the inner threaded surface of the neck. Sufficient overlap will be included at both ends of each section so as to retain all details available. Measurements such as pitch, thread root depth, etc. will be made from the molds, if possible. The process will start by subjecting a portion of the threaded area to a solvent wash, the samples then subjected to FTIR analysis. Then the molding compound will be applied in quadrants with greater than 90 ° coverage. The boundaries will be indicated on the opening rim with a Sharpie and the molds labeled following the stated nomenclature.

Once the thread mold profiles are completed, the opening will be sectioned to allow SEM/EDS examination of the threaded section and subsequent metallographic mounting. A section, comprising of no more than 30 ° of radial opening on the section opposite that material still attached to the cylinder body will be sectioned. The section will be subject to SEM/EDS examination to resolve the thread/root regions for contaminants and other information. The section will then be mounted with the cut surface exposed for examination, polished and etched to reveal the grain structure, and examine for contaminants trapped beneath smeared or swaged aluminum.

Phase 4 – Collection of Evidence, logging and retrograde. Each item will be double checked to ensure it has been catalogued, logged, and properly packaged for storage. All graphs, apparatus created images, and measurements will be compiled for use in the final report.

<u>About RTI Group, LLC</u>

The RTI Group, LLC is a pioneering, global accident and failure investigation and safety management consultancy serving the legal and insurance markets. With origins dating back to 1975, RTI's forensic engineering services span comprehensive high-risk industries and transportation operations disciplines, including aviation, marine, rail, utilities, nuclear, explosion, and construction.

Headquartered in Annapolis, Maryland, RTI Group, LLC was founded in 2003 as a forensic engineering services company, with its origins dating back to 1975, by the founder of FTI Consulting, Inc. Anamet Inc., a forensic materials testing laboratory in San Francisco, California became a vital asset to RTI in 2003. In 2004, RTI founded its London office, RTI Ltd., as a wholly owned UK subsidiary that is the home office of the Aviation and Marine Departments. RTI Latin America was established in 2008 in Panama City, Panama as an extension of the London office to serve Latin America and, in particular, the Panamanian Flag State and Canal Operations. RTI opened its Bahrain branch office in April of 2011 to provide security and safety services, as well as access to other RTI disciplines in the Gulf and Middle East region. RTI continues to expand its worldwide range of analytical capabilities and services to other parts of the globe.

RTI Group, LLC
910 Bestgate Road, Suite E
Annapolis, MD 21401
ofc: +1 410 571 0712 | fax: +1 410 571 0713
www.rtiForensics.com

FORENSIC ENGINEERING SINCE 1975

February 23, 2012 Amendment to

TEST PROTOCOL
November 29, 2011

RTI Matter Name: DOT – Ruptured SCUBA Cylinder
RTI Matter No.: 50151ME002
RTI Investigators:
Richard B. Loucks, Ph.D., P.E.
Matthew Wagenhofer, Ph.D.

Under Procedure, Phase II, High Pressure Tank Valve, change item 4 and add the following items of the disassembly procedure to read as follows:

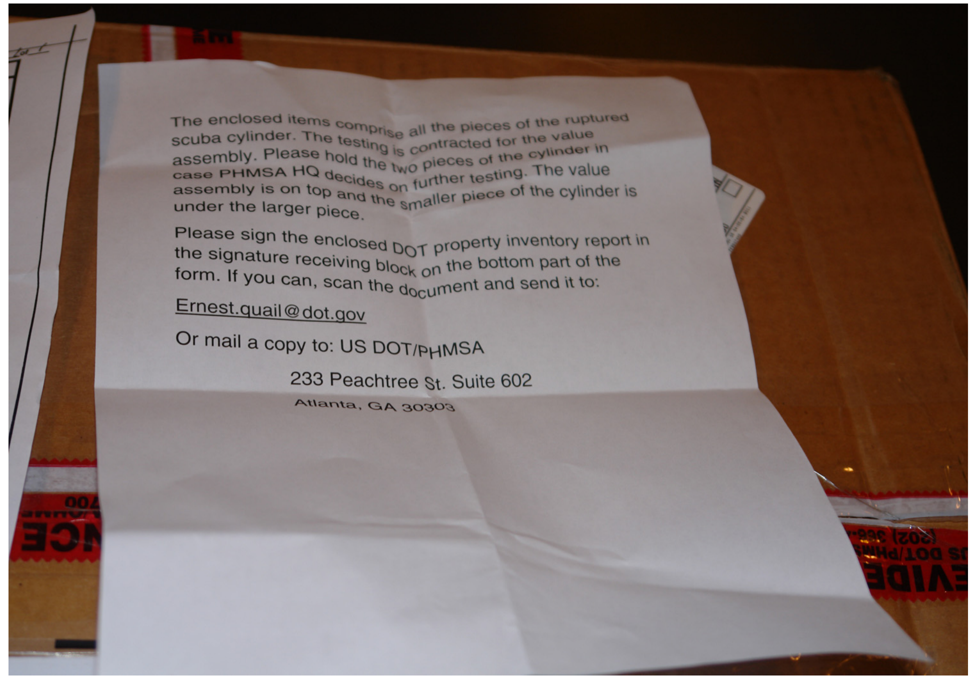
4. Remove the closure mechanism. The gland nut will be removed exposing a series of gaskets and back up rings. These will be removed to gain access to the stem and the high pressure seat.

5. Perform an electrical continuity test and measure the electrical resistance between several points on the outer and inner surfaces of the valve seat body using a multimeter.

6. The condition of the high pressure seat will be inspected by SEM/EDS followed by solvent wash for FTIR analysis. Components will be removed until the valve body is empty.

ATTACHMENT 2

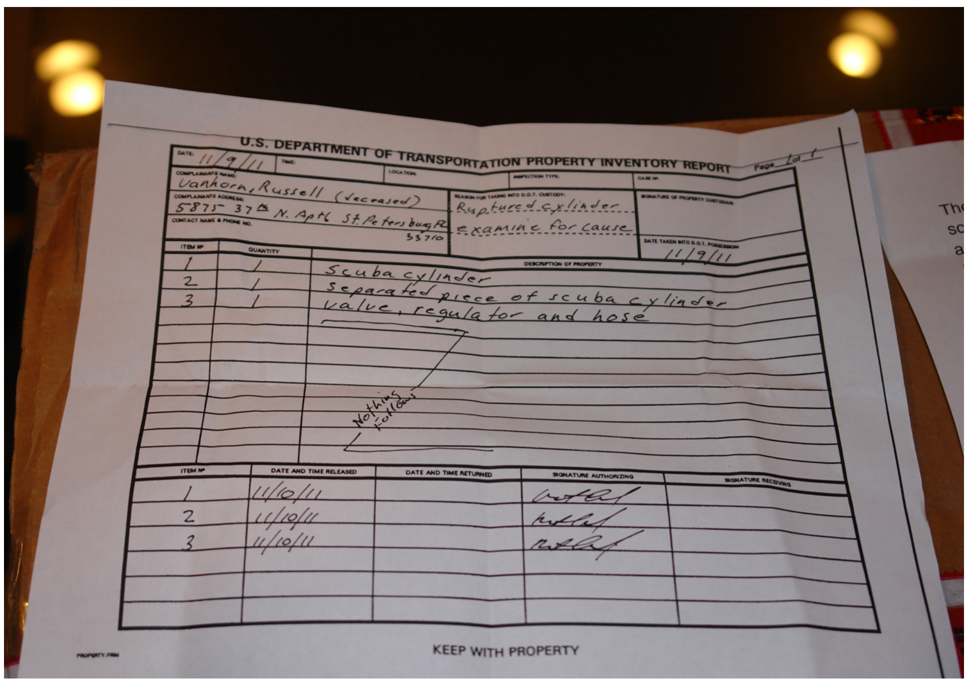
Evidence Receipt Photos


EVIDENCE
22 LBS
1 OF 1
SHIP TO:
RICHARD LOUCKS/MATHEW WAGENHOSER
410-571-0712
RTI GROUP LLC
SUITE E
910 BESTGATE ROAD
ANNAPOLIS MD 21401-3048
MD 203 9-33
UPS GROUND
TRACKING #: 1Z WR2 582 42 9167 4190
BILLING: P/P
SIGNATURE REQUIRED

The enclosed items comprise all the pieces of the ruptured scuba cylinder. The testing is contracted for the value assembly. Please hold the two pieces of the cylinder in case PHMSA HQ decides on further testing. The value assembly is on top and the smaller piece of the cylinder is under the larger piece.
Please sign the enclosed DOT property inventory report in the signature receiving block on the bottom part of the form. If you can, scan the document and send it to:
Ernest.quail@dot.gov
Or mail a copy to: US DOT/PHMSA
233 Peachtree St. Suite 602
Atlanta, GA 30303

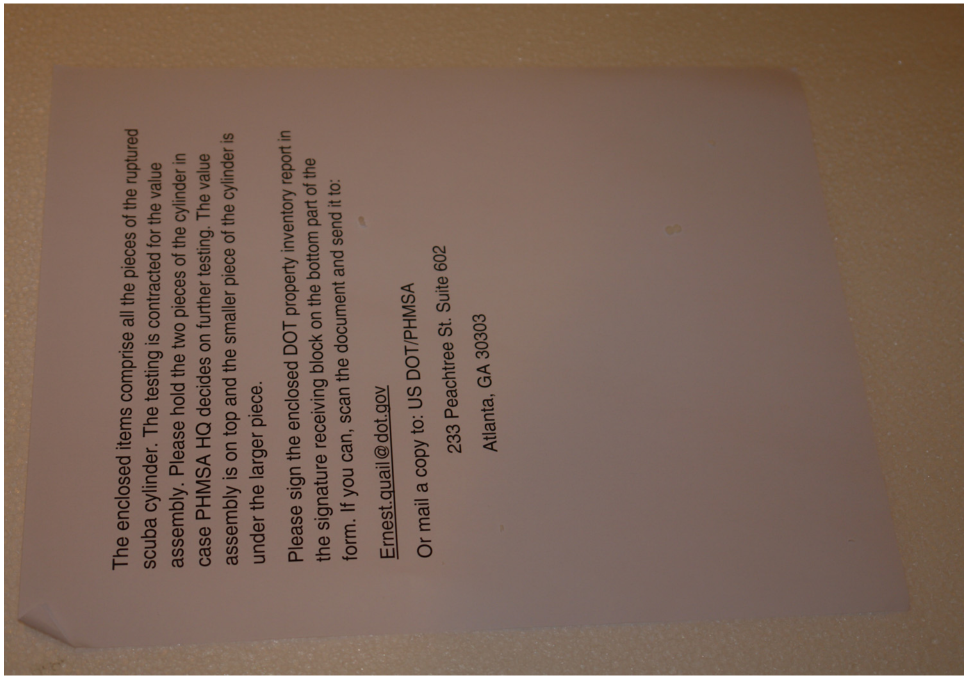
EVIDENCE

EVIDENCE
US DOT/PHMSA/OHME


U.S. DEPARTMENT OF TRANSPORTATION PROPERTY INVENTORY REPORT
KEEP WITH PROPERTY
Please sign the enclosed DOT property inventory report in the signature receiving block on the bottom part of the form. If you can, scan the document and send it to
Or mail a copy to: US DOT PHMSA
233 Peachtree St. Suite 602
EVIDENCE
MD 203 9-33
UPS GROUND
ANNAPOLIS MD 21401-3048


U.S. DEPARTMENT OF TRANSPORTATION PROPERTY INVENTORY REPORT
Page 1 of 1
11/9/11
Vanhorn, Russell (deceased)
5875 37th N. Apt 6 St Petersburg FL 33710
Ruptured cylinder
examine for cause
11/9/11
1 1 Scuba cylinder
2 1 separated piece of scuba cylinder
3 1 valve, regulator and hose
Nothing follows
1 11/10/11
2 11/10/11
3 11/10/11
KEEP WITH PROPERTY


EVIDENCE
MD 203 9-33
UPS GROUND

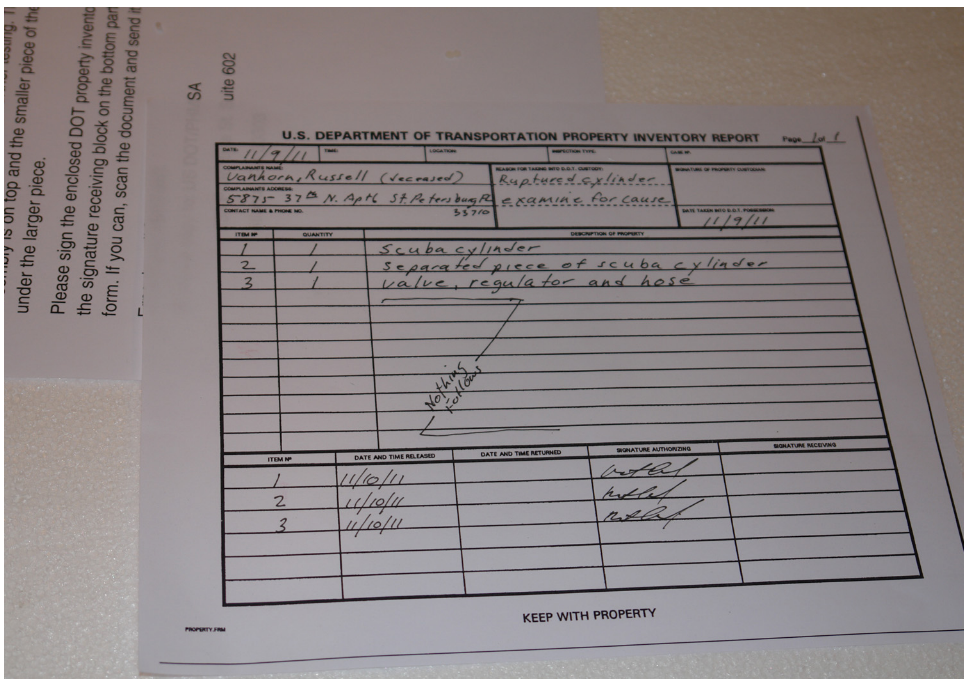


The enclosed items comprise all the pieces of the ruptured scuba cylinder. The testing is contracted for the value assembly. Please hold the two pieces of the cylinder in case PHMSA HQ decides on further testing. The value assembly is on top and the smaller piece of the cylinder is under the larger piece.

Please sign the enclosed DOT property inventory report in the signature receiving block on the bottom part of the form. If you can, scan the document and send it to:

Ernest.quail@dot.gov

Or mail a copy to: US DOT/PHMSA
233 Peachtree St. Suite 602
Atlanta, GA 30303



U.S. DEPARTMENT OF TRANSPORTATION PROPERTY INVENTORY REPORT Page 1 of 1

DATE: 11/9/11

COMPLAINANT'S NAME: Vanhorn, Russell (deceased)

COMPLAINANT'S ADDRESS: 5875-37th N. Apt. St Petersburg FL 33710

REASON FOR TAKING INTO U.S. DOT CUSTODY: Ruptured cylinder examine for cause

DATE TAKEN INTO U.S.D.O.T. POSSESSION: 11/9/11

ITEM №	QUANTITY	DESCRIPTION OF PROPERTY
1	1	Scuba cylinder
2	1	Separated piece of scuba cylinder
3	1	valve, regulator and hose
		Nothing follows

ITEM №	DATE AND TIME RELEASED	DATE AND TIME RETURNED	SIGNATURE AUTHORIZING	SIGNATURE RECEIVING
1	11/10/11			
2	11/10/11			
3	11/10/11			

KEEP WITH PROPERTY

PROPERTY.FRM


U.S. DEPARTMENT OF TRANSPORTATION PROPERTY INVENTORY REPORT
Scuba cylinder
Separated piece of scuba cylinder
valve, regulator and hose
KEEP WITH PROPERTY
EVIDENCE


Fill-Air

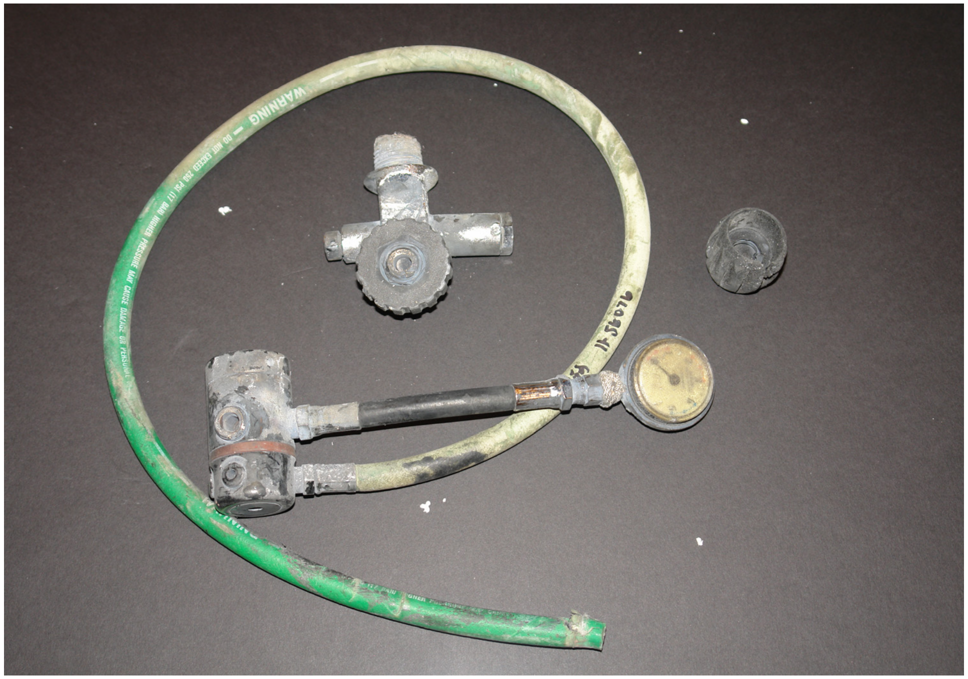

EVIDENCE


U.S. DEPARTMENT OF TRANSPORTATION PROPERTY INVENTORY REPORT
KEEP WITH PROPERTY
EVIDENCE


EVIDENCE


EVIDENCE


WARNING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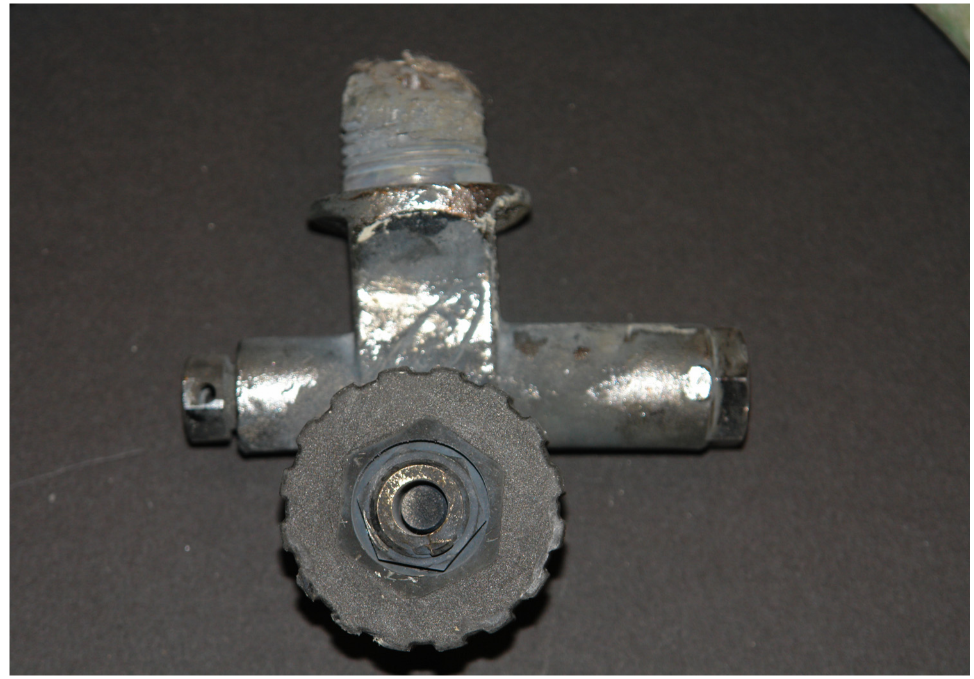

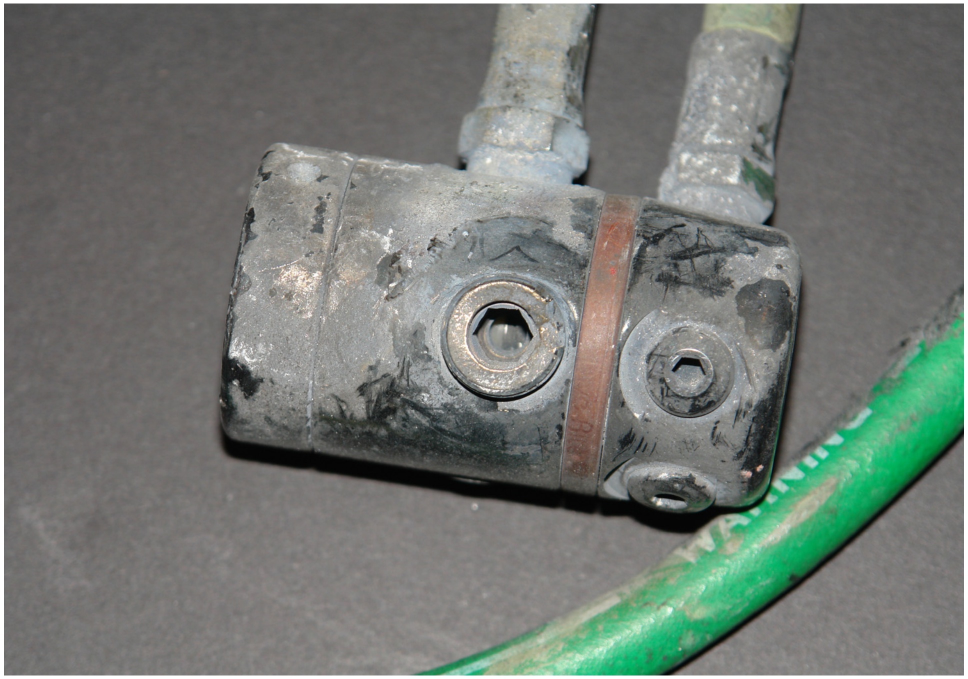
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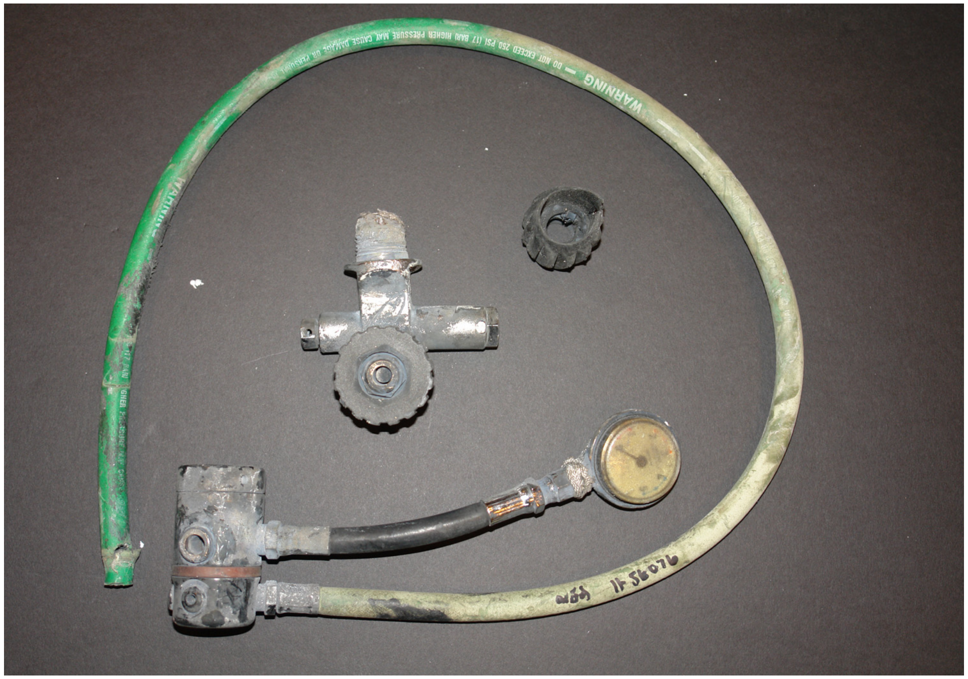
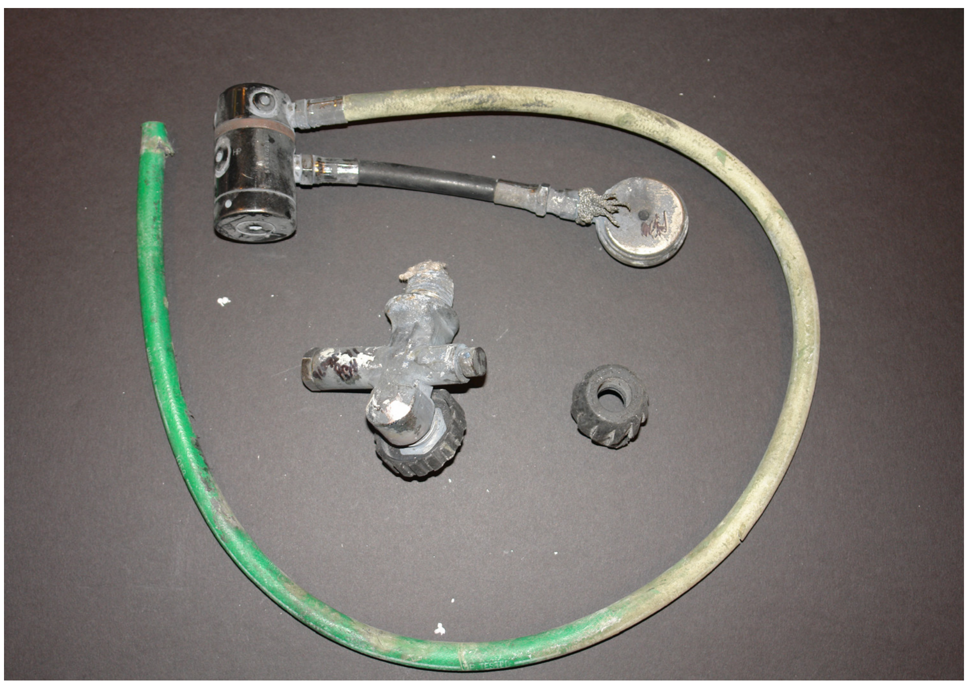

WARNING


11 56076


250 PSI (17 BAR) HIGHER PRESSURE MAY CAUSE DAMAGE OR PERSONAL


WARNING — DO NOT EXCEED 250 PSI (17 BAR) HIGHER PRESSURE MAY CAUSE





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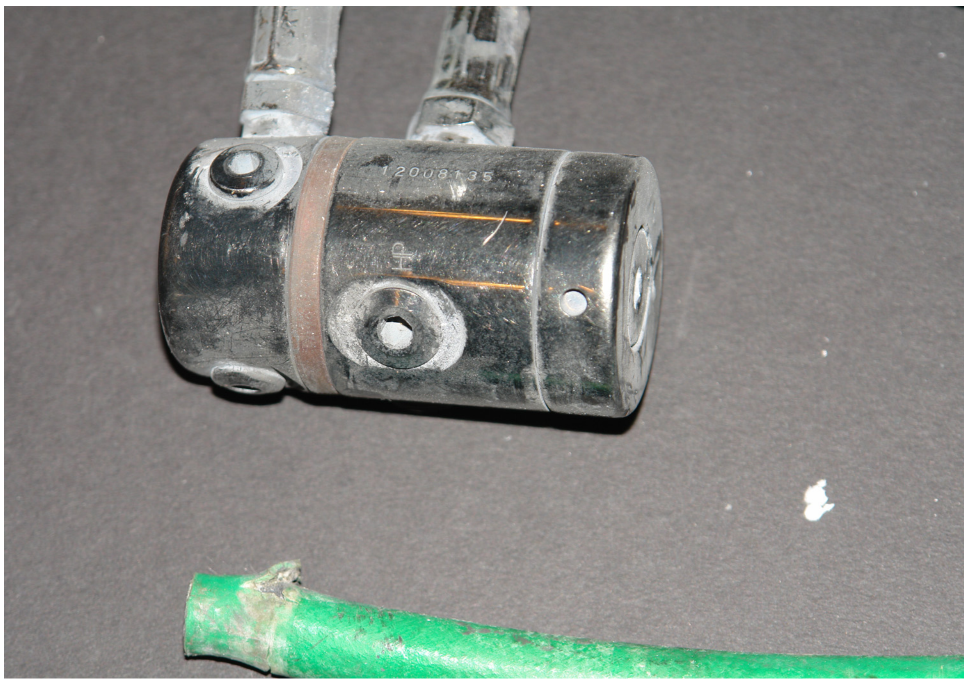
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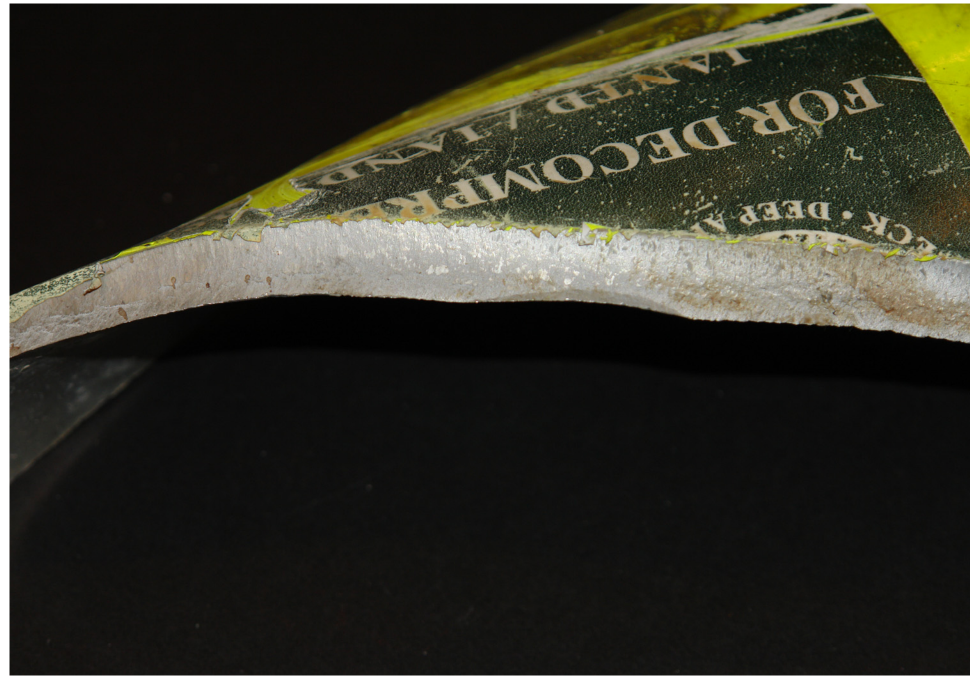
FOR DECOMPRE
IANTD / IAND, Inc.


FOR DECOMPRE


Been Cleaned
With O2 Service
Cleaned For
22 to 40%
Grade of Gas
10
12
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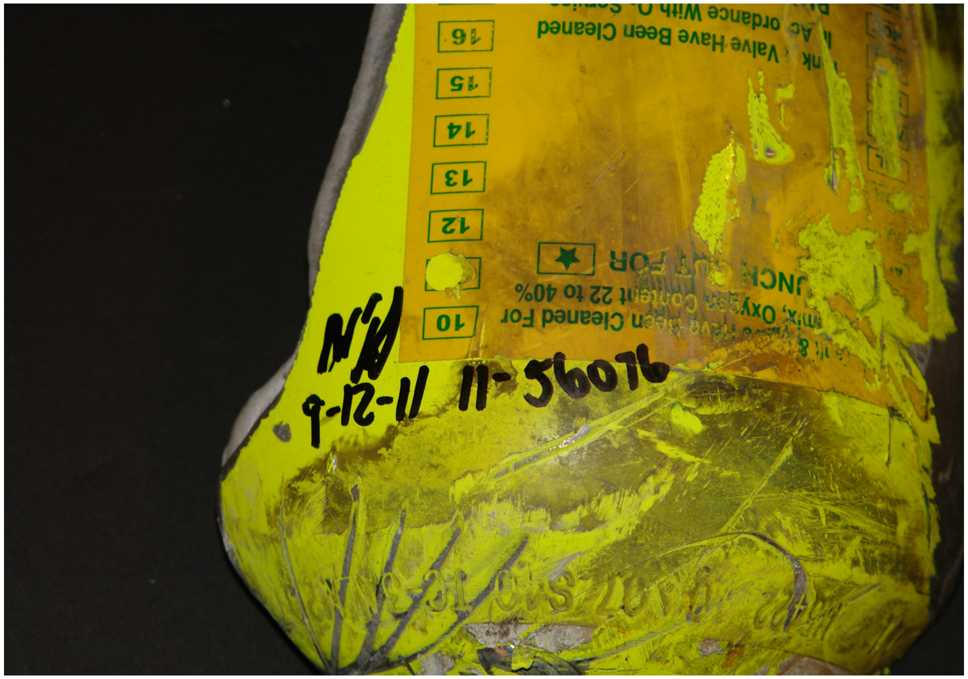
18


9-12-11 11-56076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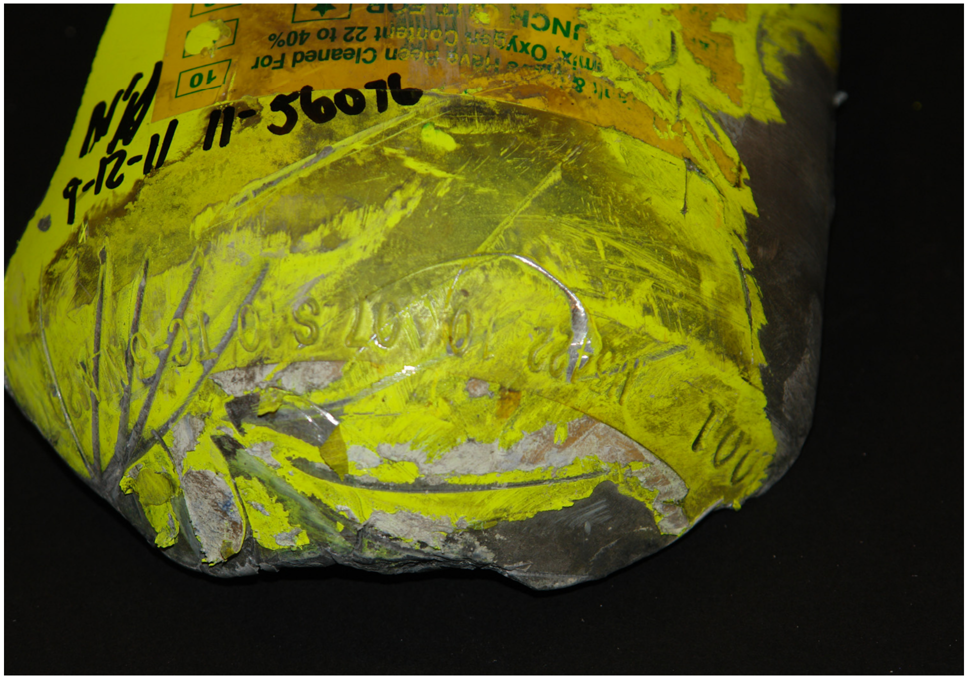
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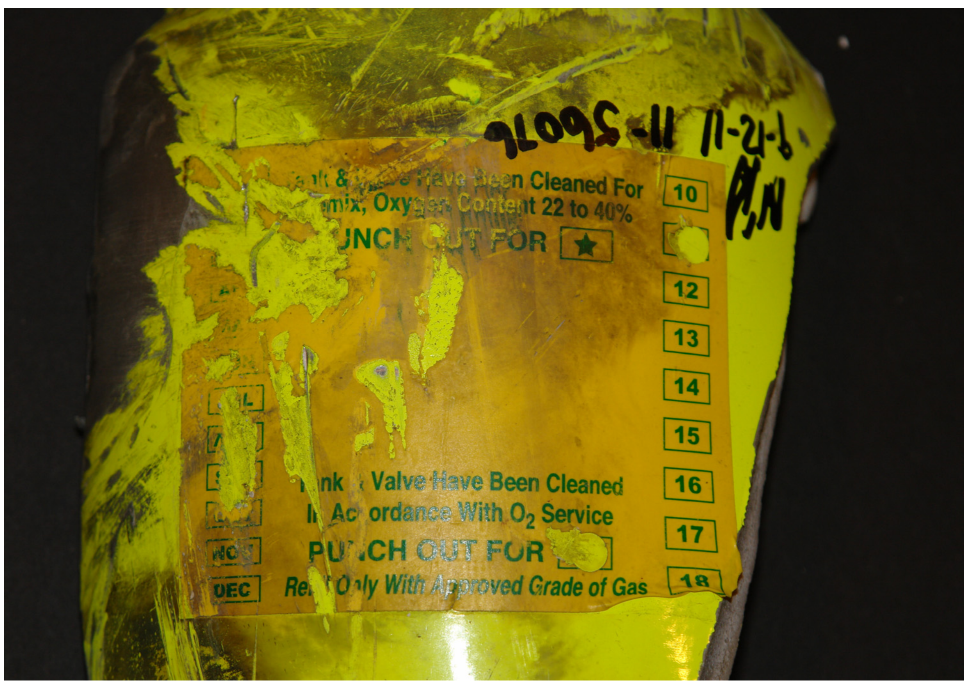
n Cleaned For
Content 22 to 40%
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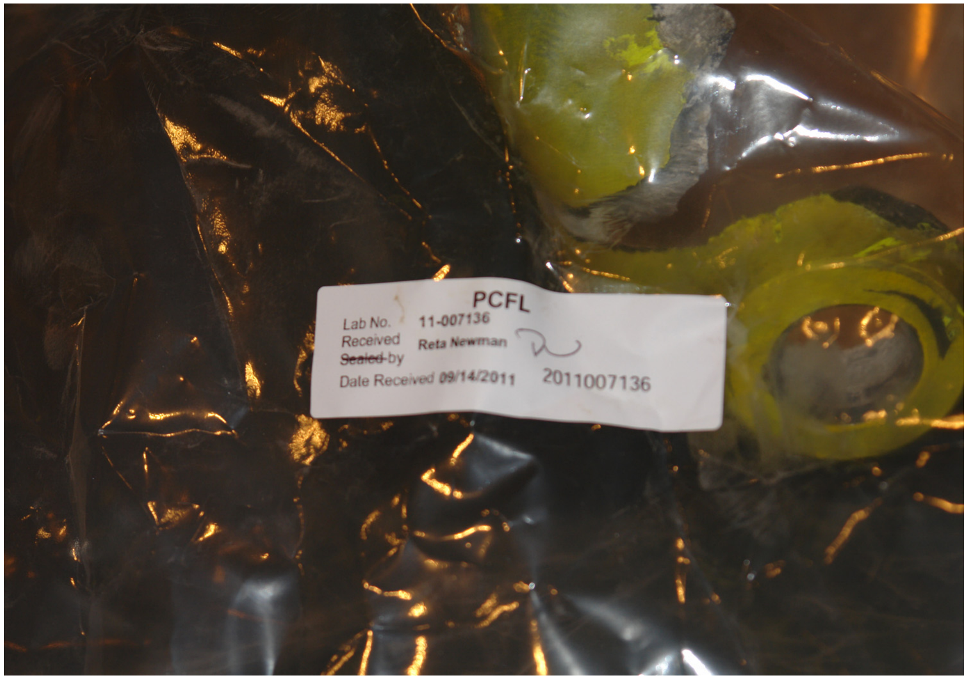
Valve Have Been Cleaned
ordance With O_2 Service
PUNCH OUT FOR
DEC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Date Received 09/14/2011
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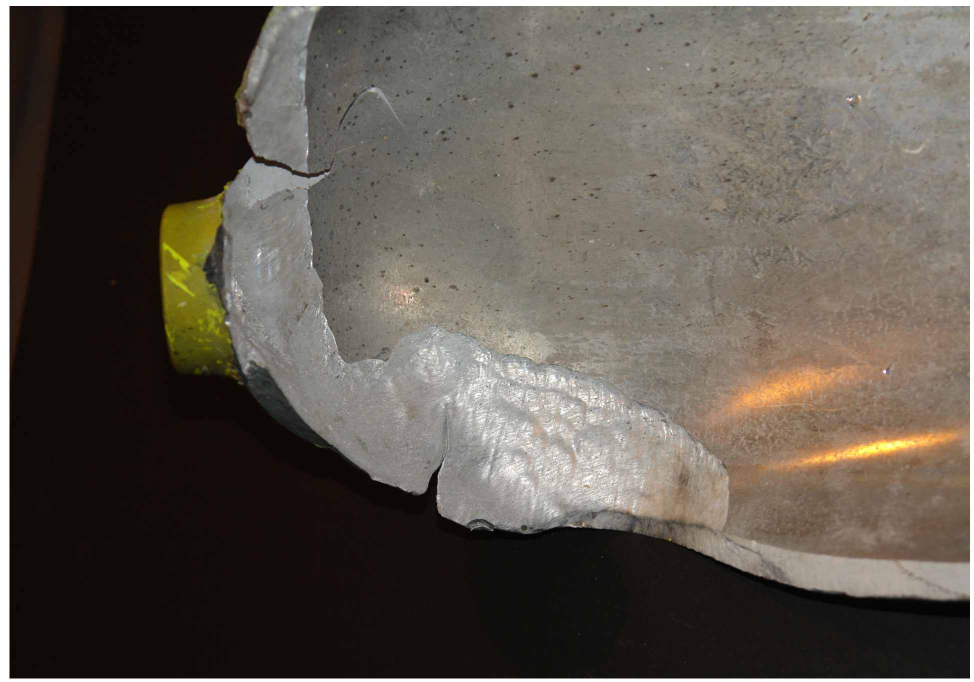
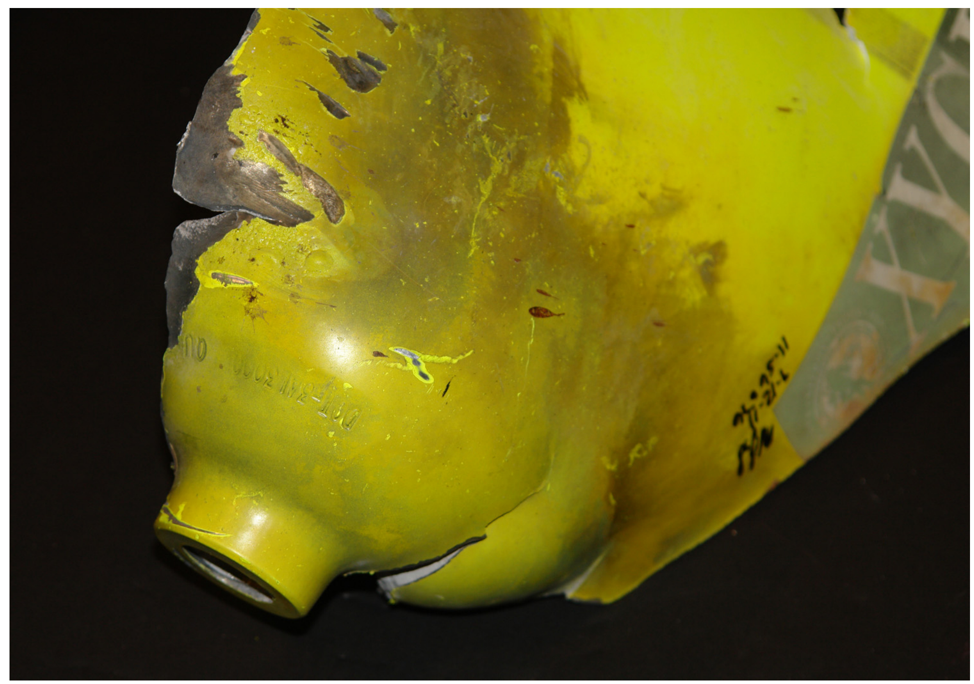
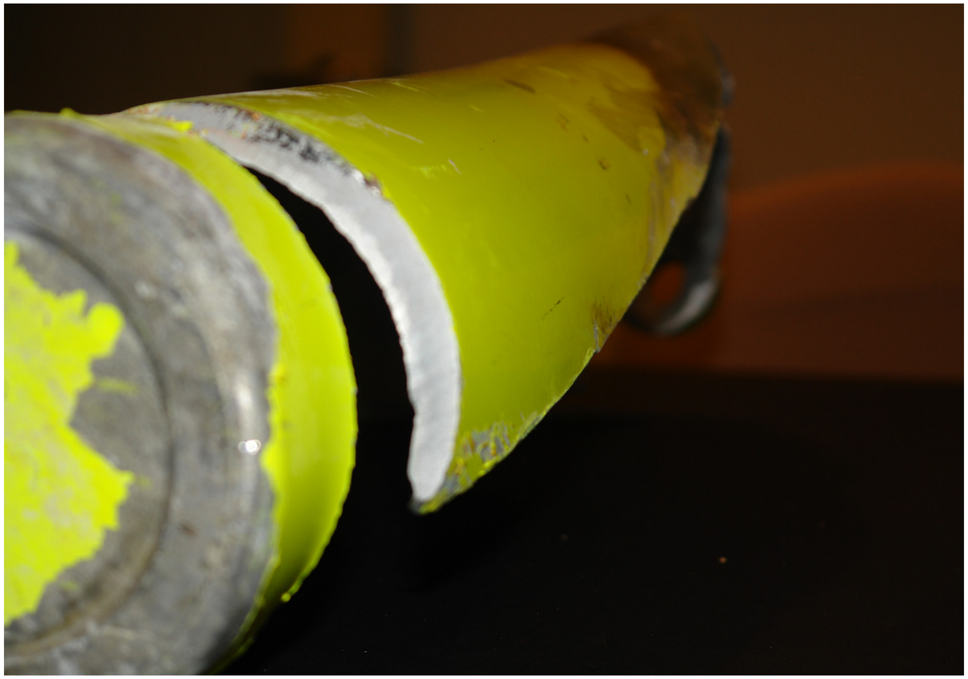
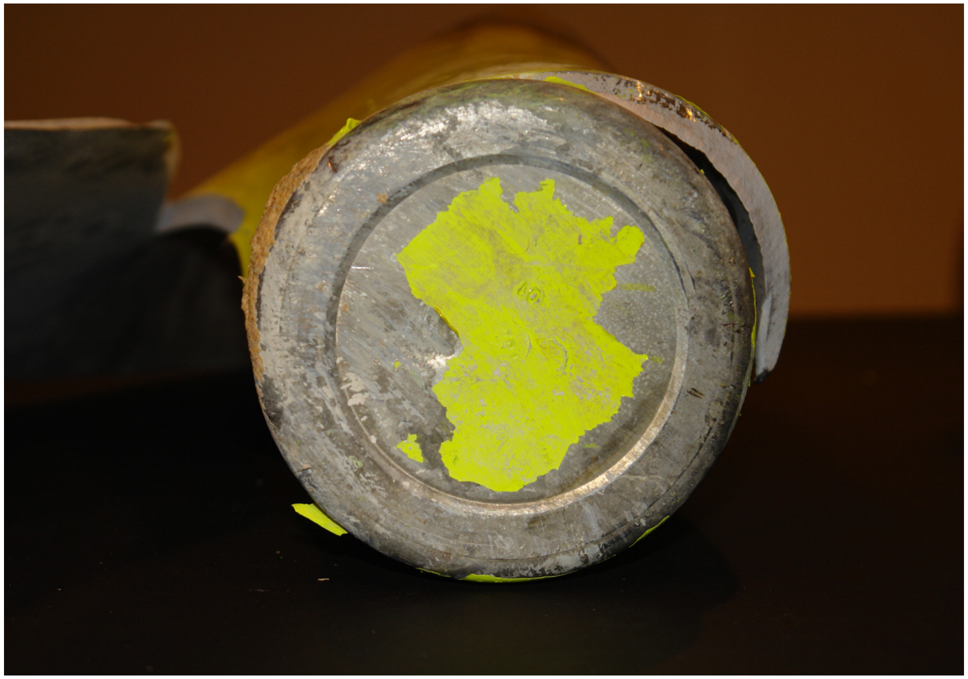


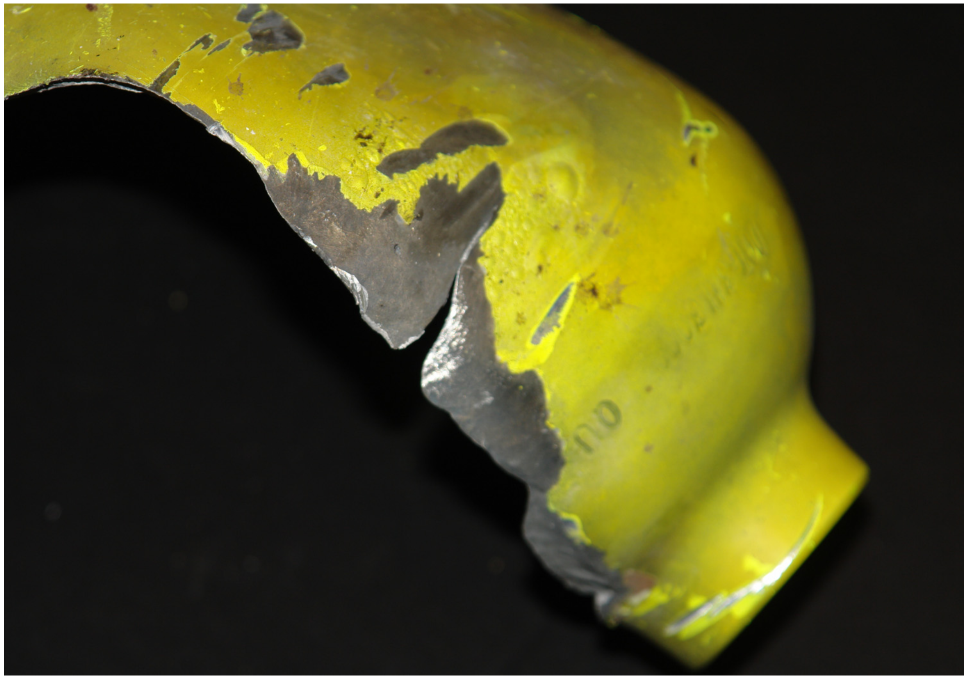

XYGEN
MOD 20 FSW
MOD 6 MSW
IANTD.COM

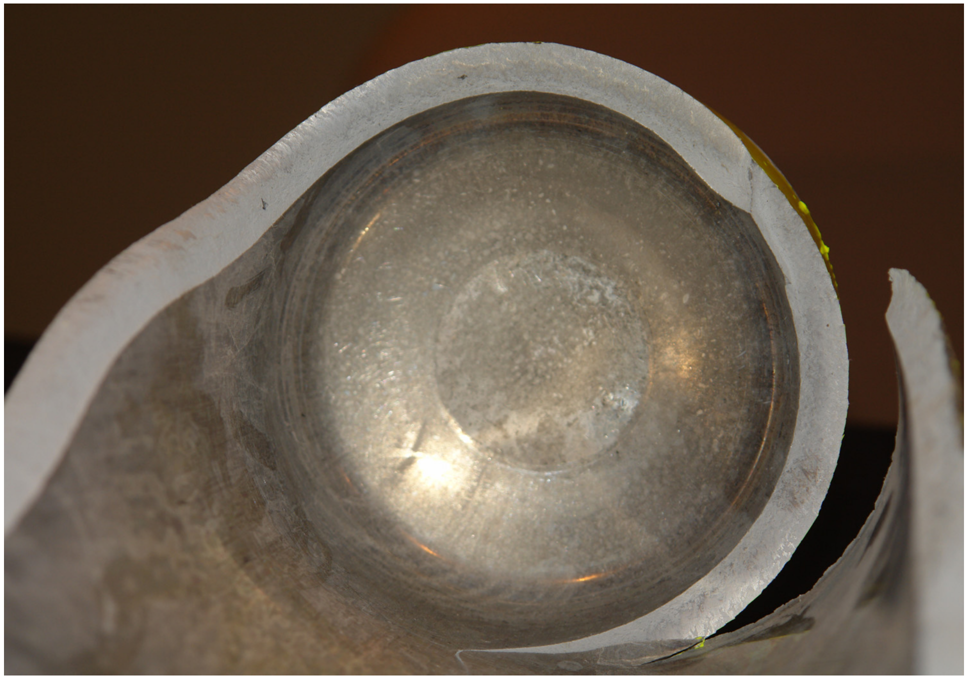
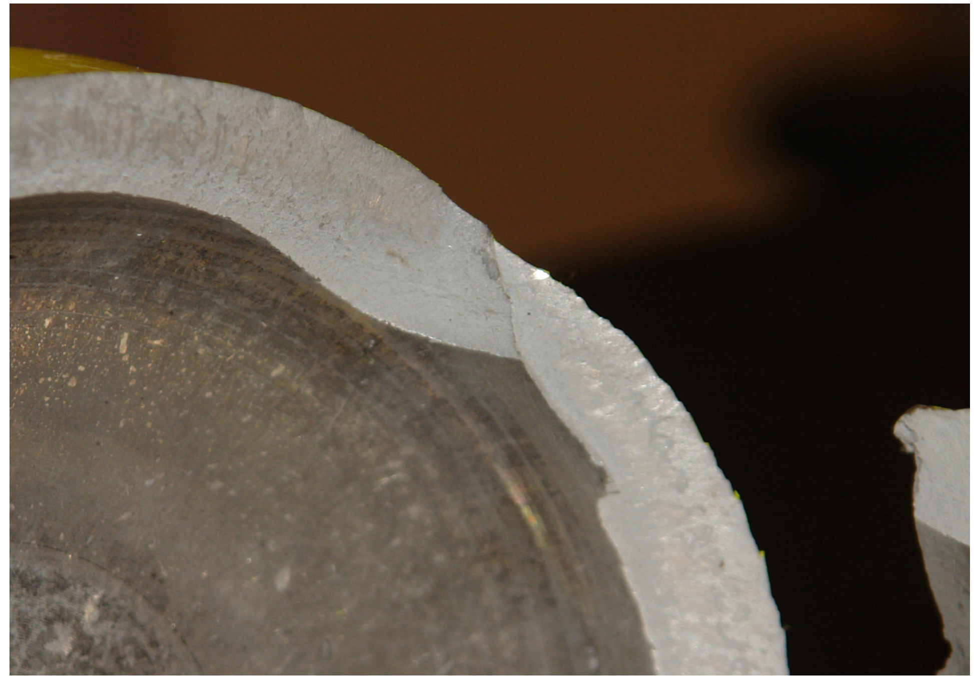
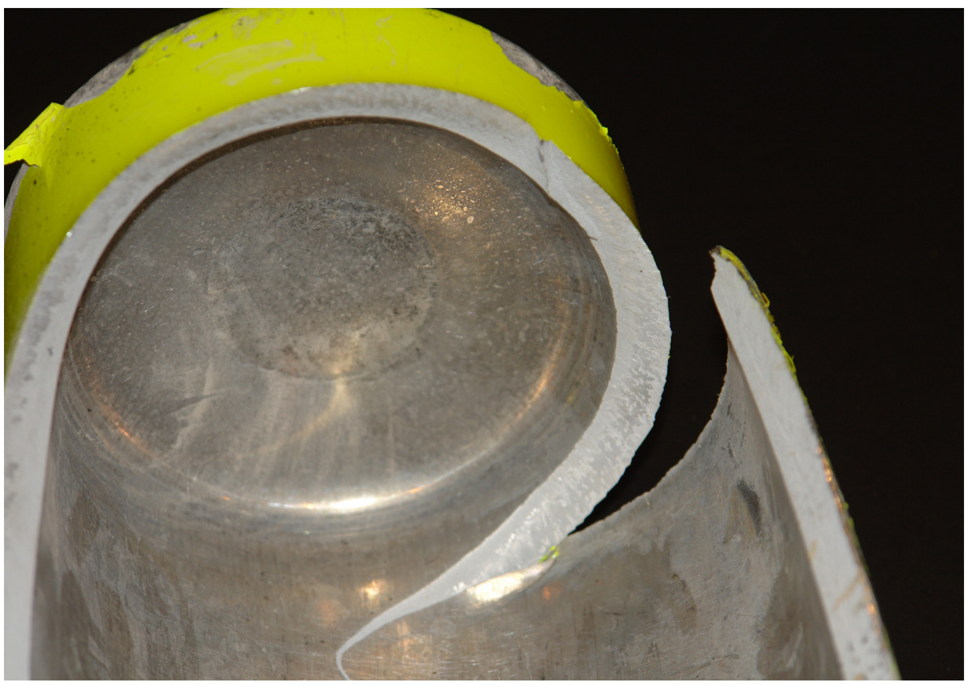

XYGEN
MOD 20 FSW
MOD 6 MSW



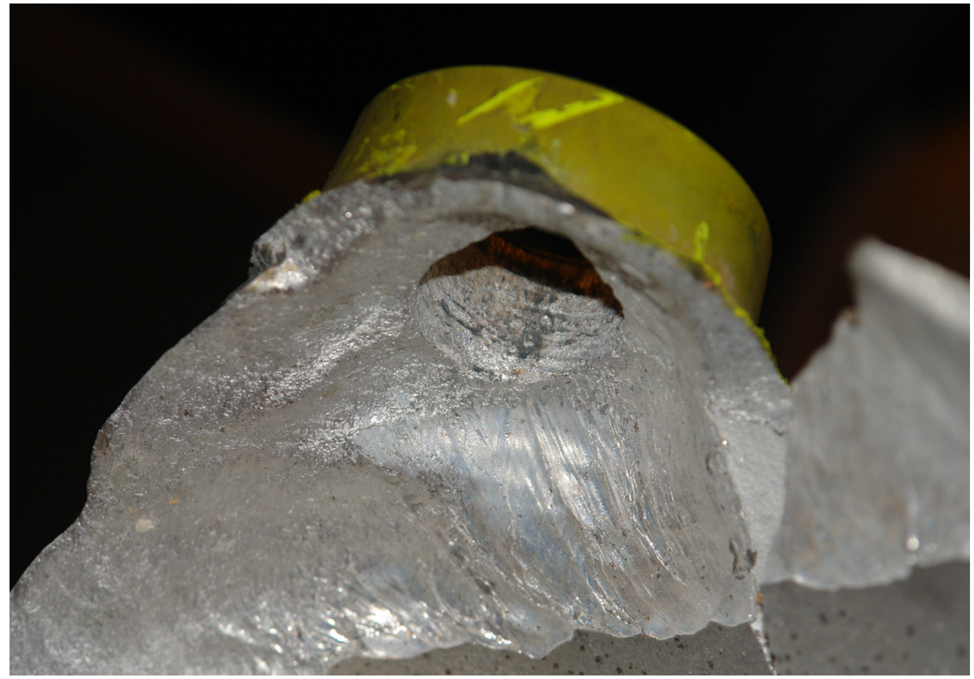
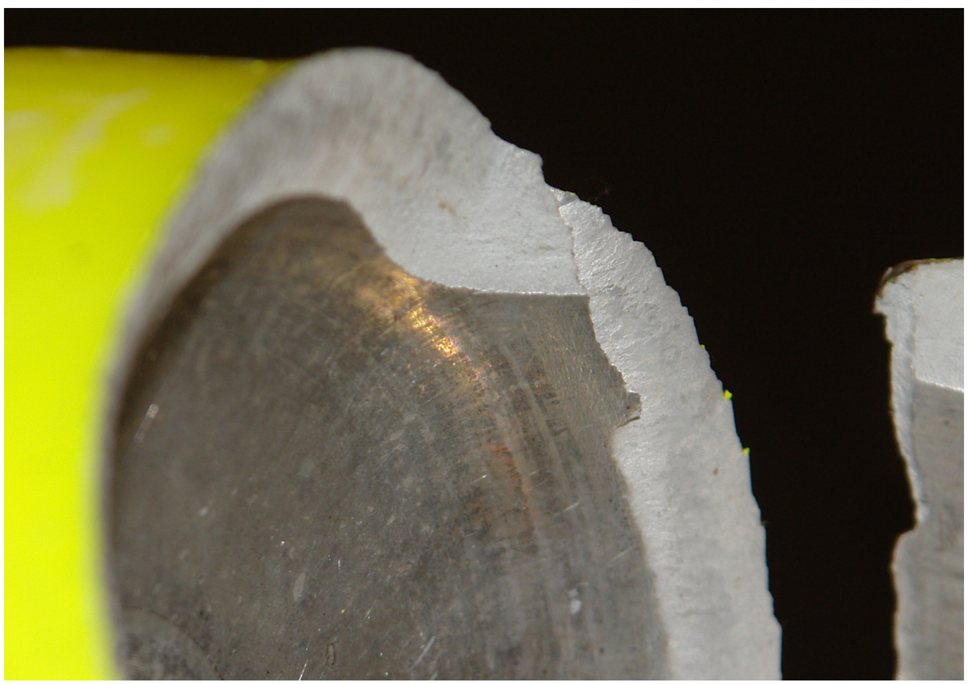
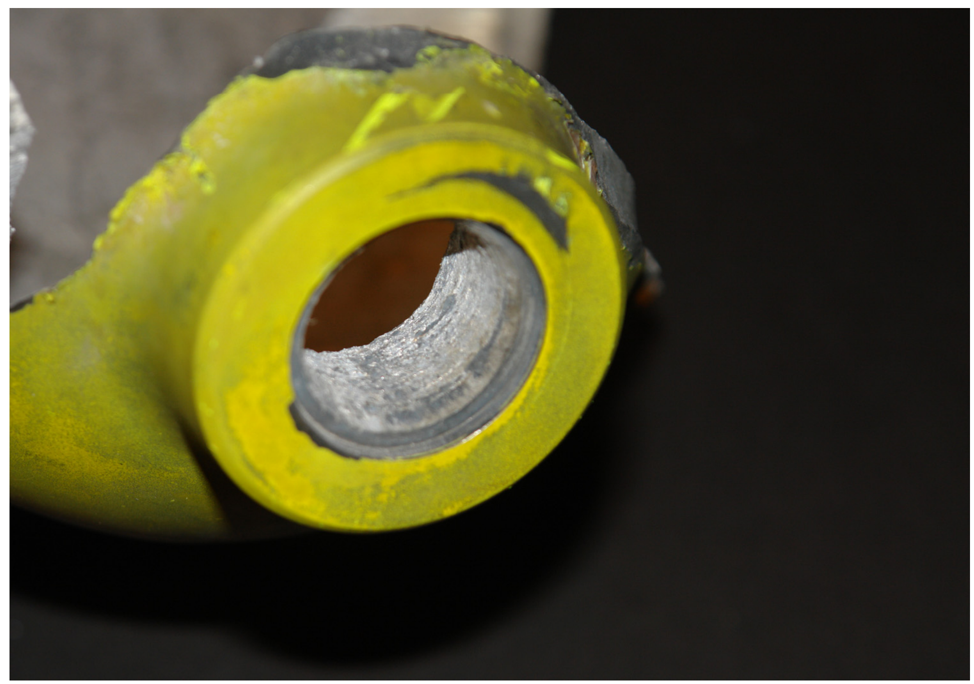





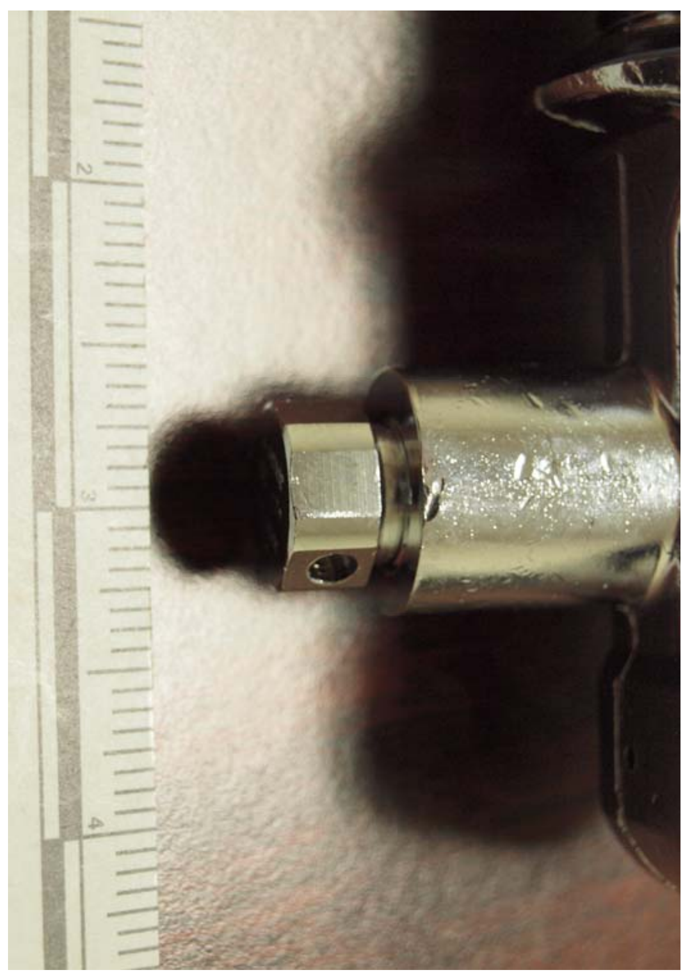




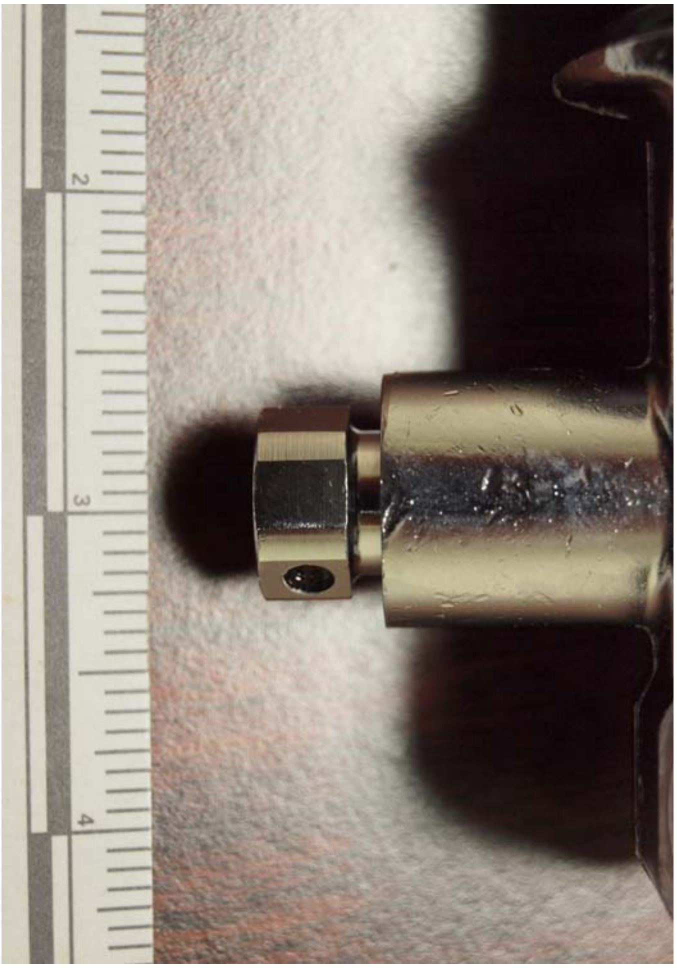


ATTACHMENT 3

Exemplar Valve Photos




2
3
4



Made in EU


5000 PSI
42- 10
30Lbf-ft


OPEN
CLOSE


OPEN
CLOSE


OPEN
CLOSE


OPEN
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OPEN
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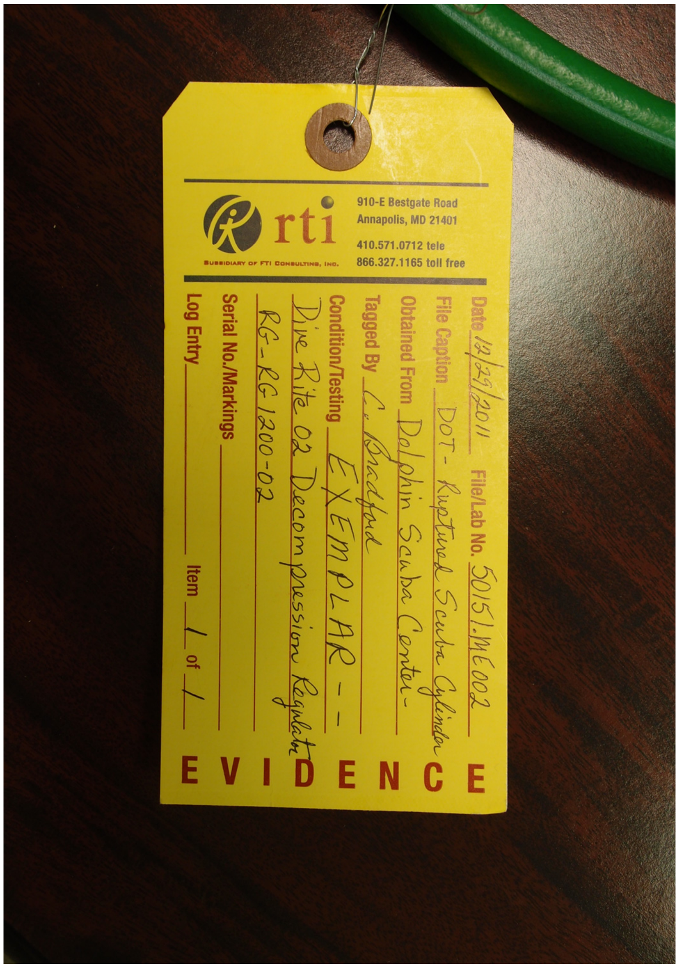
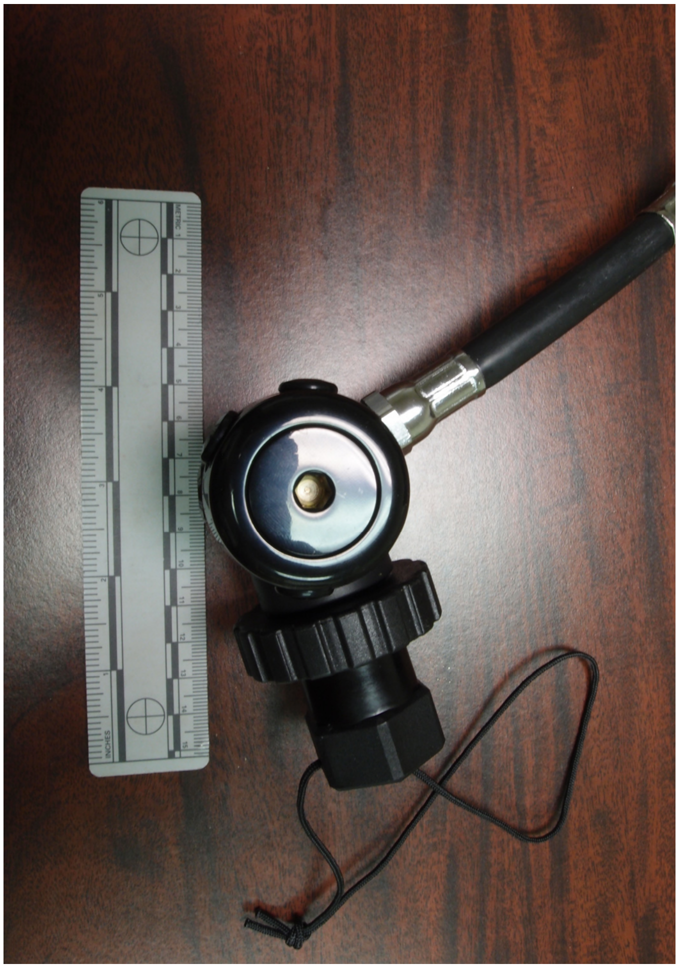
ATTACHMENT 4

Exemplar Regulator Photos


rti
SUBSIDIARY OF FTI CONSULTING, INC.
910-E Bestgate Road
Annapolis, MD 21401
410.571.0712 tele
866.327.1165 toll free
Date 12/29/2011 File/Lab No. 50151.ME002
File Caption DOT - Ruptured Scuba Cylinder
Obtained From Dolphin Scuba Center
Tagged By C. Bradford
Condition/Testing EXEMPLAR - -
Dive Rite O2 Decompression Regulator
RG-RG 1200-02
Serial No./Markings
Log Entry
Item 1 of 1
EVIDENCE


EVIDENCE


Dive Rite
CE 1463 EN 250
INCHES





Dive Rite
12106628


Dive Rite
12106628


Dive Rite


Dive Rite


Dive Rite
METRIC

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INCHES

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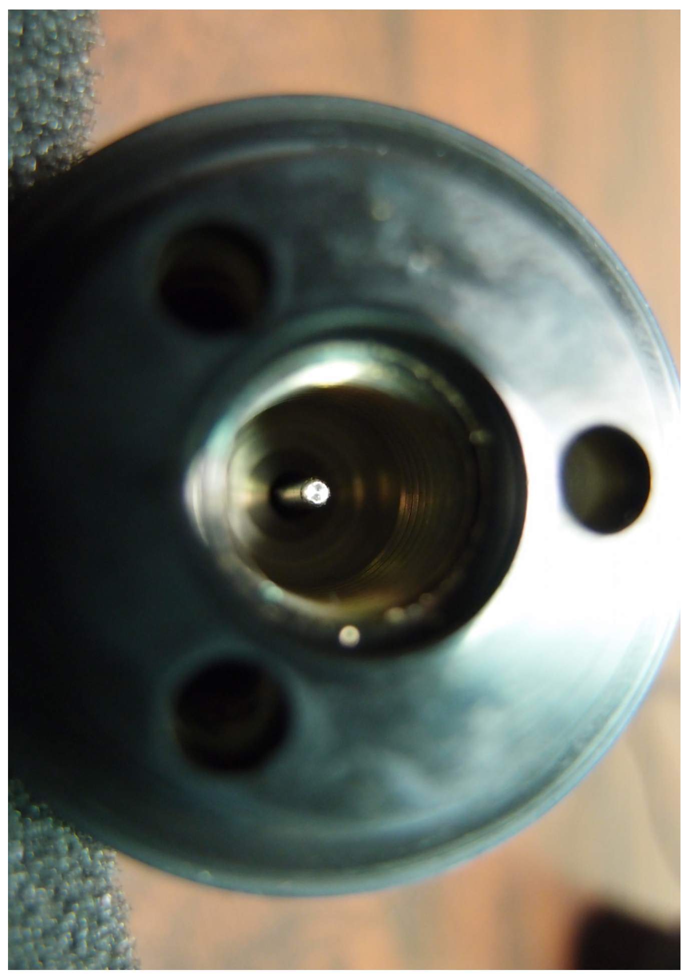
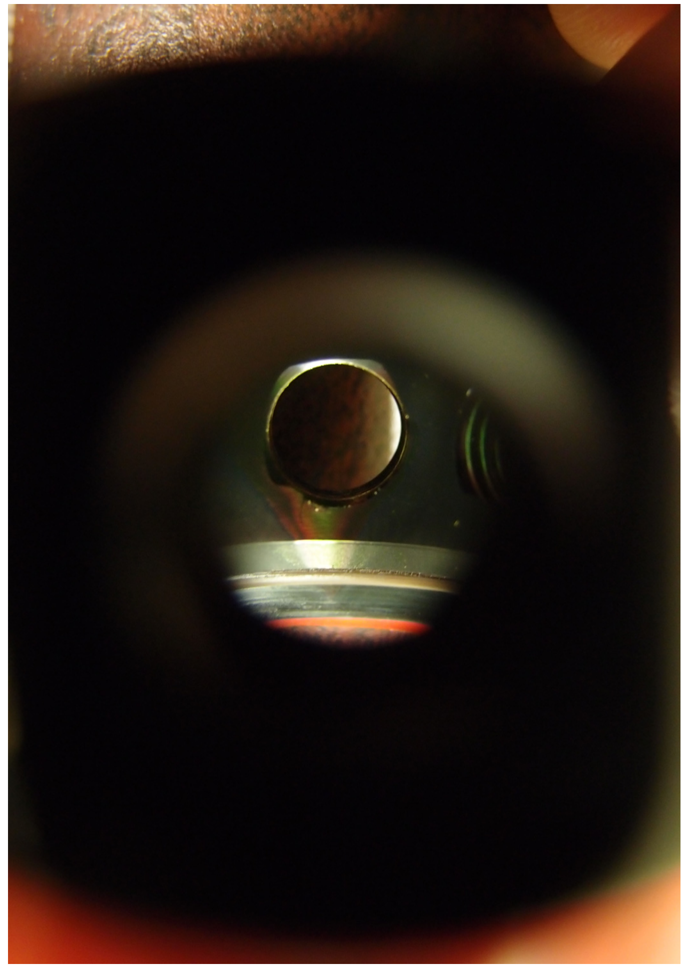
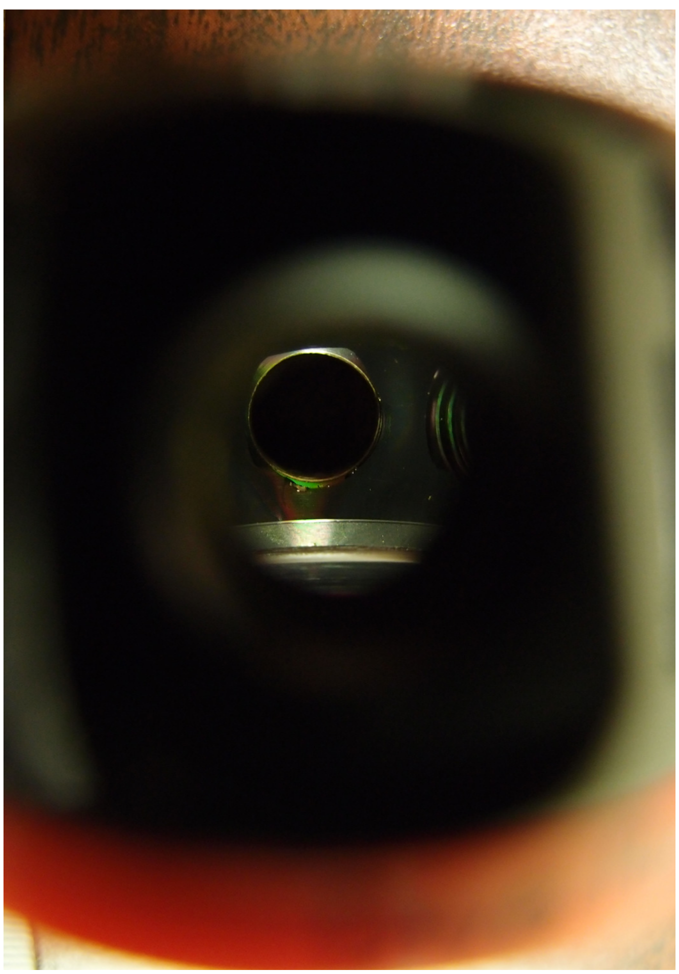
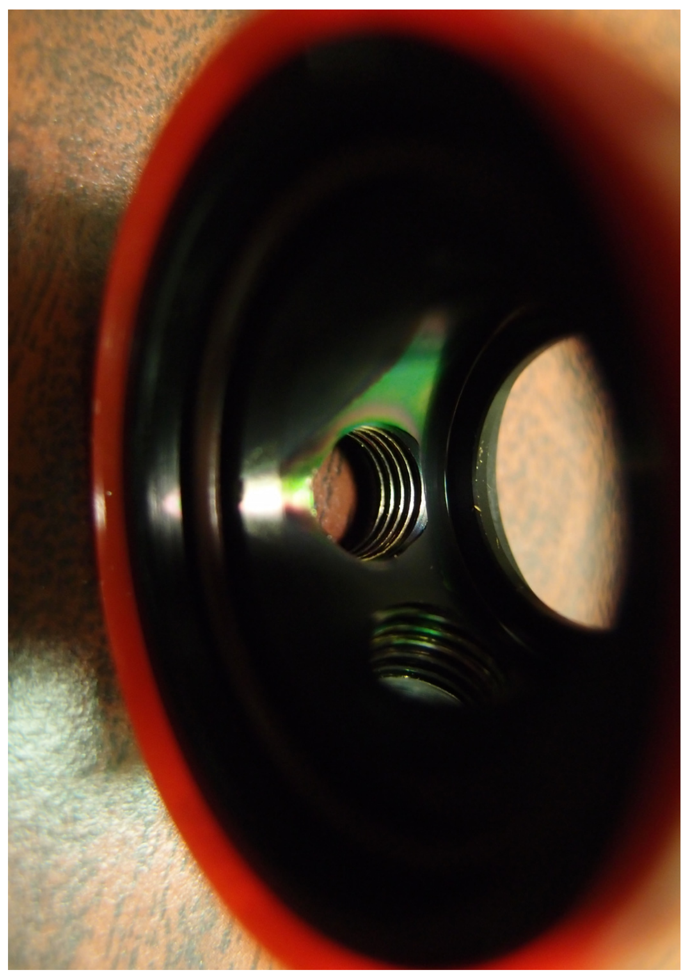


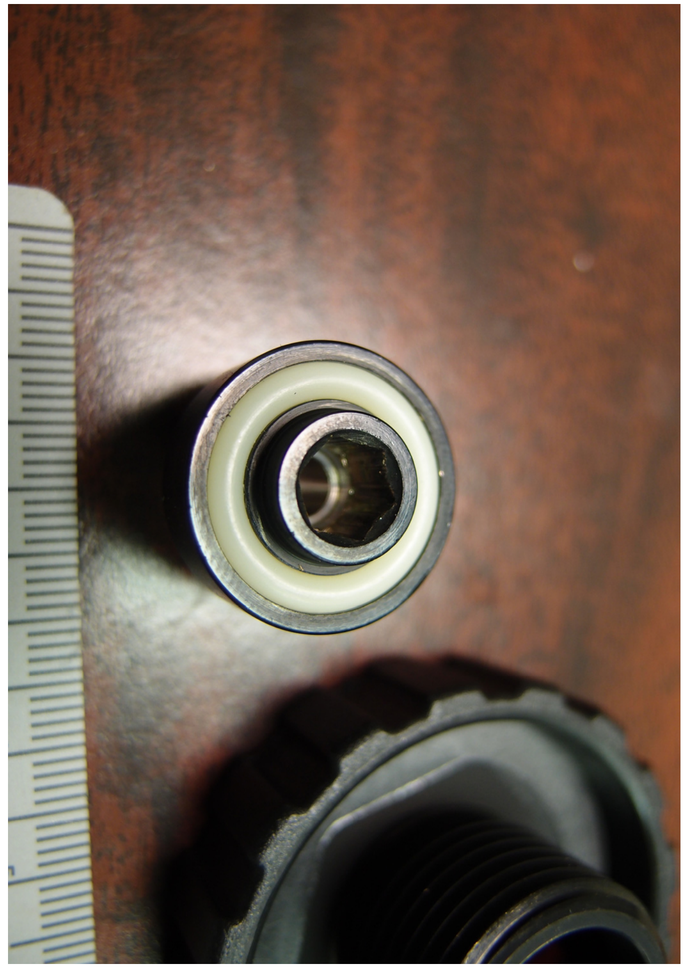

METRIC





METRIC
INCHES


METRIC
INCHES




METRIC


METRIC

ATTACHMENT 5

Testing Sign-in Sheet

Anamet, inc Materials Engineering & Laboratory Testing

26102 Eden Landing Road, suite 3 · HAYWARD, CALIFORNIA 94545 · (510) 887-8811 · Fax (510) 887-8427

Date: March 12, 2012 **Matter:** Ruptured SCUBA Cylinder

Anamet Job Number: 5004.7109 RIT Matter No: 50151ME002

Name: Matthew Wagenhofer

Company Name: RTI

Representing: DOT-PHMSA

Business Card or Contact Information

Address: 910-E Bestgate Rd, Annapolis, MD 21401

Phone: 410-571-0712

Email: matthew.wagenhofer@rti-forensics.com

Name: Adam Horsley

Company Name: PHMSA

Representing: DOT-PHMSA

U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration

ADAM HORSLEY
Attorney-Advisor
Office of the Chief Counsel

East Building, E26-202
1200 New Jersey Avenue, SE
Washington, DC 20590

Tel: 202-366-8000
Fax: 202-366-7041
adam.horsley@dot.gov

Name: BILL OLIVER

Company Name: SHERWOOD SCUBA LLC

Representing: SAME

SHERWOOD SCUBA, LLC.
1641 East Saint Andrew Place, Santa Ana, California 92705

Bill Oliver
Director of Product Development
bill@sherwoodscuba.com

TL: 714.259.4780 *ext 7000*
FX: 714.259.4789

SHERWOOD SCUBA. AKONA ADVENTURE GEAR GENESIS SCUBA

Name: NORMAN YUEN

Company Name: ANAMET

Representing: ANAMET (THIRD PARTY)

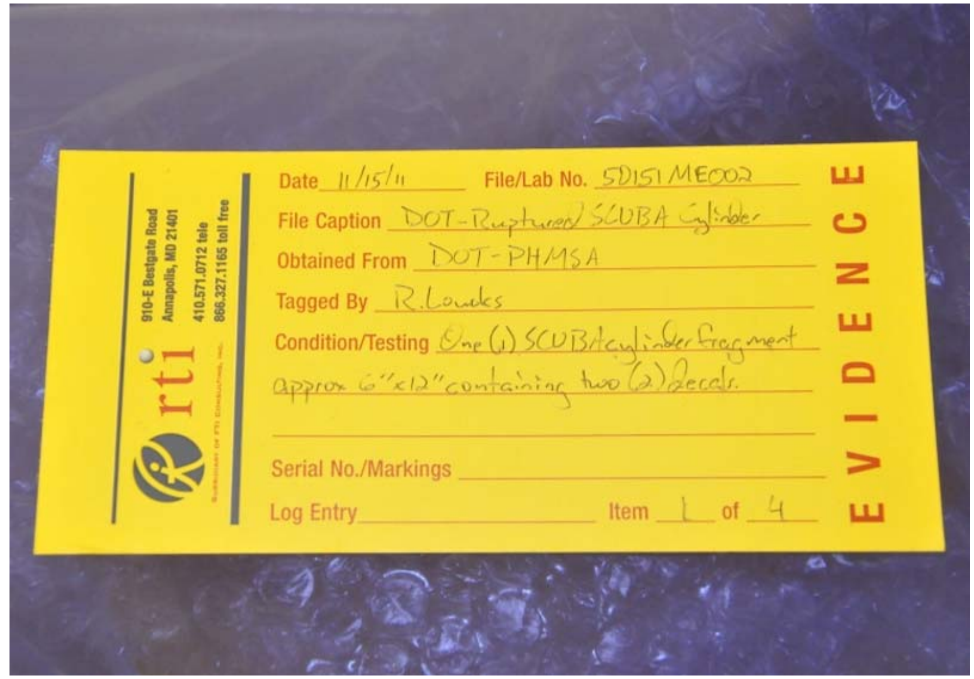
Norman Yuen
Materials Engineer
510-887-8811

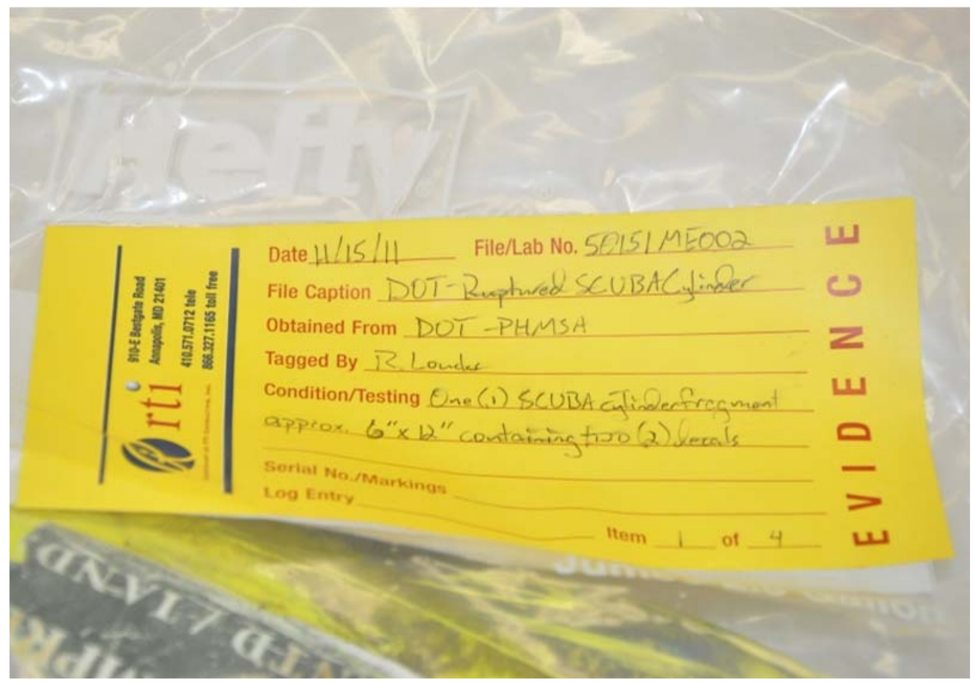
Materials Engineering
& Laboratory Testing, Since 1958
26102 Eden Landing Rd., Suite 3
Hayward, CA 94545-3811
800-377-7768 • Fax: 510-887-8427
www.anametinc.com
norman@anametinc.com

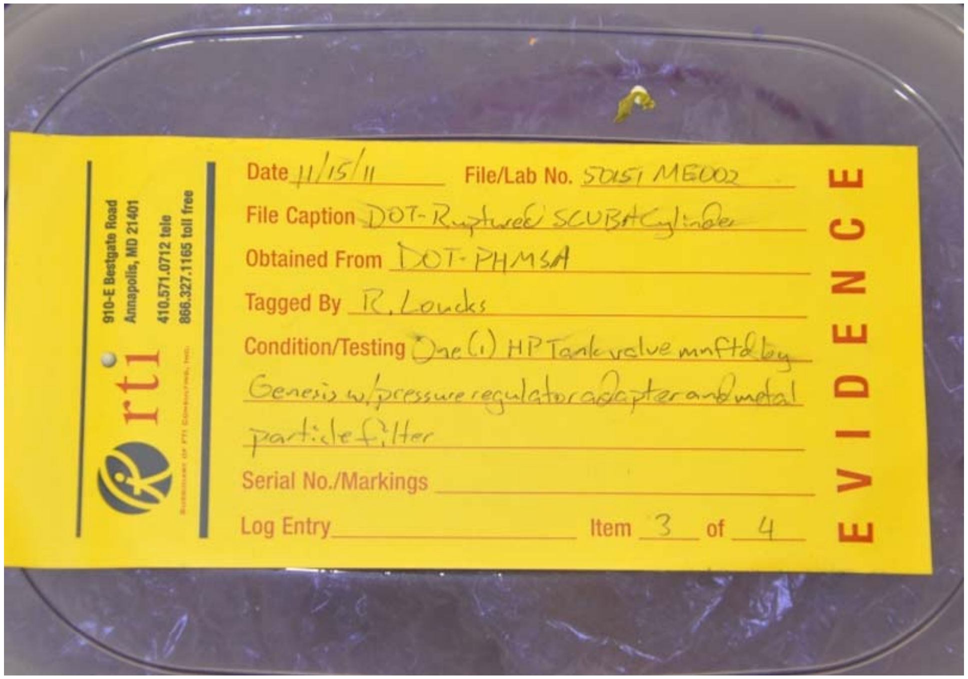
Anamet, inc

ATTACHMENT 6

Photographs from Anamet Testing


910-E Bestgate Road
Annapolis, MD 21401
410.571.0712 tele
866.327.1165 toll free
rti
Date 11/15/11 File/Lab No. 5D151ME002
File Caption DOT-Ruptured SCUBA Cylinder
Obtained From DOT-PHMSA
Tagged By R.Loucks
Condition/Testing One (1) SCUBA cylinder fragment
approx 6"x12" containing two (2) decals.
Serial No./Markings
Log Entry Item 1 of 4
EVIDENCE


Hefty
rti
910-E Bestgate Road
Annapolis, MD 21401
410.571.0712 tele
866.327.1165 toll free
Date 11/15/11 File/Lab No. 50151/ME002
File Caption DOT-Ruptured SCUBA Cylinder
Obtained From DOT-PHMSA
Tagged By R. Louder
Condition/Testing One (1) SCUBA cylinder fragment approx. 6"x 12" containing two (2) decals
Serial No./Markings
Log Entry
Item 1 of 4
EVIDENCE



rti
910-E Bestgate Road
Annapolis, MD 21401
410.571.0712 tele
866.327.1165 toll free
Date 11/15/11
File/Lab No. 50151 ME002
File Caption DOT-Ruptured SCUBA Cylinder
Obtained From DOT-PHMSA
Tagged By R. Loucks
Condition/Testing One (1) HP Tank valve mnftd by Genesis w/pressure regulator adapter and metal particle filter
Serial No./Markings
Log Entry
Item 3 of 4
EVIDENCE

rti
910-E Bestgate Road
Annapolis, MD 21401
410.571.0712 tele
866.327.1165 toll free
Date 11/15/11
File/Lab No. 50151 ME002
File Caption DOT-Ruptured SCUBA Cylinder
Obtained From DOT-PHMSA
Tagged By R. Loucks
Condition/Testing One (1) ruptured SCUBA cylinder approx. 14"x24"
Serial No./Markings
Log Entry
Item 2 of 4
EVIDENCE

rti
Date 11/15/11
File/Lab No. 50151 ME002
File Caption DOT-Ruptured SCUBA Cylinder
Obtained From DOT-PHMSA
Tagged By R. Loucks
Condition/Testing One (1) HP Tank valve mnftd by Genesis w/pressure regulator adapter and metal particle filter
Serial No./Markings
Log Entry
Item 3 of 4
EVIDENCE


Hefty
OneZip
Clicks
EVIDENCE
Date
File/Lab No.
File Caption
Obtained From
Tagged By
Condition/Testing
Serial No./Markings
Log Entry
Item
of


Hefty
EVIDENCE
rti
Date
File/Lab No.
File Caption
Obtained From
Tagged By
Condition/Testing
Serial No./Markings
Log Entry
Item 3 of 4


EVIDENCE
rti
Date 11/15/11
File/Lab No. SD151 ME062
File Caption DOT Ruptured SCUBA Cylinder
Obtained From DOT - PHMSA
Tagged By R. Lowalski
Condition/Testing
Serial No./Markings
Log Entry
Item 4 of 4


Hefty
Clicks Closed


Hefty
OneZip
Bags
Clicks Closed
Date
File/Lab No.
File Caption
Obtained From
Tagged By
Condition/Testing
Serial No./Markings
Log Entry
Item 4 of 4
EVIDENCE
rti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RITY MAIL®
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EDGEWATER MD
ZIP - e/ USPS DELIVERY
420 21037 9405 9036 99
Electronic Rate Approved
Visit us at usps.com
PRIORITY® MAIL
Mailing Box
#1


TO:
RICHARD LOUCKS
29 SHADOW POINT CT
EDGEWATER MD 21037-1212
ZIP - e/ USPS DELIVERY CONFIRMATION™
420 21037 9405 9036 9930 0052 4219 42
Electronic Rate Approved #038555749


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usps.com
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US POSTAGE
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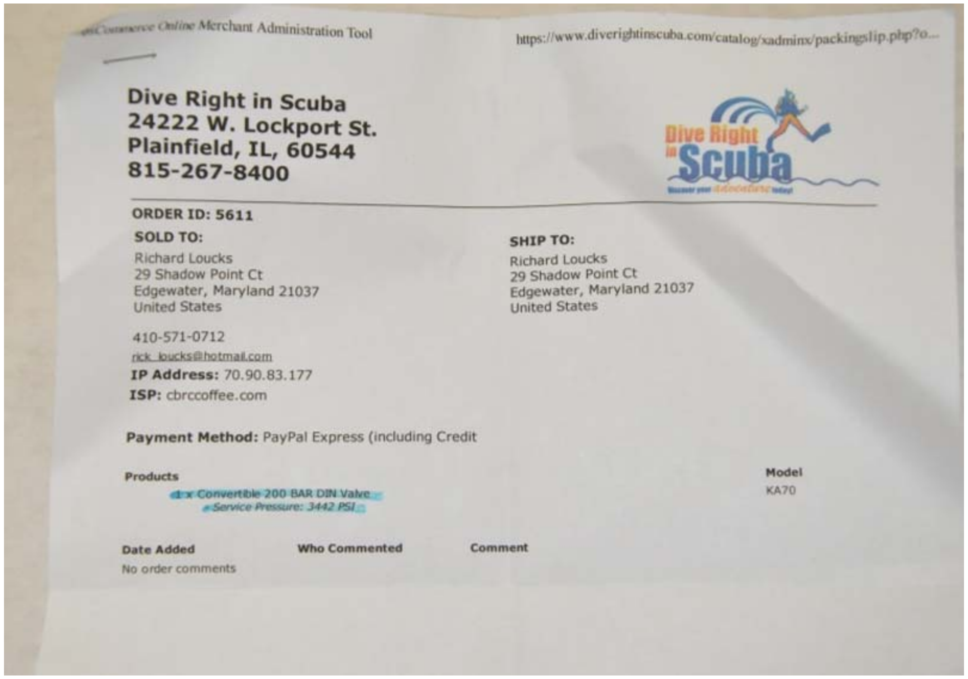
MIKE PEDERSEN
DIVE RIGHT IN SCUBA
24222 W LOCKPORT ST
PLAINFIELD IL 60544-2902
indicated in upper right han
corner.
national use affix customs declaration



osCommerce Online Merchant Administration Tool

https://www.diverightinscuba.com/catalog/xadminx/packingslip.php?o...

Dive Right in Scuba
24222 W. Lockport St.
Plainfield, IL, 60544
815-267-8400

ORDER ID: 5611

SOLD TO:
Richard Loucks
29 Shadow Point Ct
Edgewater, Maryland 21037
United States

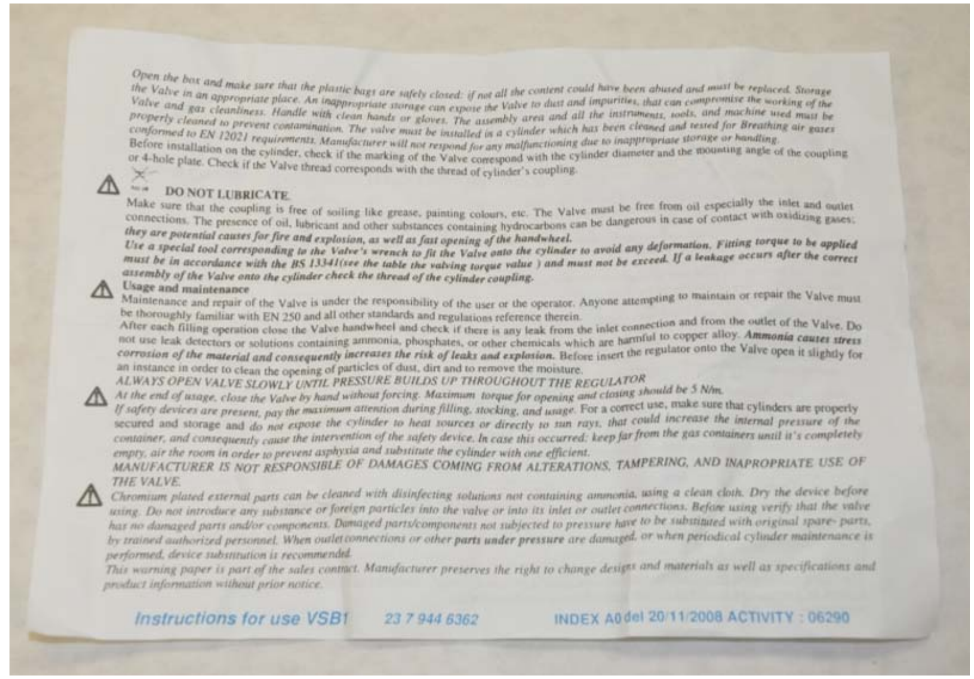
410-571-0712
rick_loucks@hotmail.com
IP Address: 70.90.83.177
ISP: cbrccoffee.com

SHIP TO:
Richard Loucks
29 Shadow Point Ct
Edgewater, Maryland 21037
United States

Payment Method: PayPal Express (including Credit

Products	Model
1 x Convertible 200 BAR DIN Valve - Service Pressure: 3442 PSI	KA70

Date Added	Who Commented	Comment
No order comments		



Open the box and make sure that the plastic bags are safely closed: if not all the content could have been abused and must be replaced. Storage the Valve in an appropriate place. An inappropriate storage can expose the Valve to dust and impurities, that can compromise the working of the Valve and gas cleanliness. Handle with clean hands or gloves. The assembly area and all the instruments, tools, and machine used must be properly cleaned to prevent contamination. The valve must be installed in a cylinder which has been cleaned and tested for Breathing air gases conformed to EN 12021 requirements. Manufacturer will not respond for any malfunctioning due to inappropriate storage or handling.
Before installation on the cylinder, check if the marking of the Valve correspond with the cylinder diameter and the mounting angle of the coupling or 4-hole plate. Check if the Valve thread corresponds with the thread of cylinder's coupling.

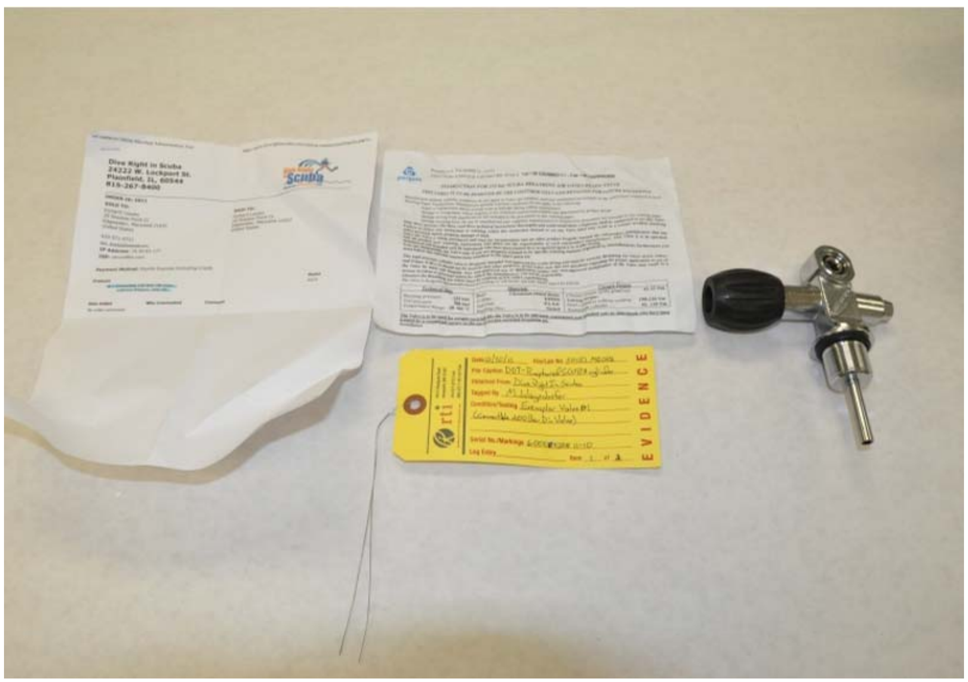
⚠ **DO NOT LUBRICATE**
Make sure that the coupling is free of soiling like grease, painting colours, etc. The Valve must be free from oil especially the inlet and outlet connections. The presence of oil, lubricant and other substances containing hydrocarbons can be dangerous in case of contact with oxidizing gases: ***they are potential causes for fire and explosion, as well as fast opening of the handwheel.***
Use a special tool corresponding to the Valve's wrench to fit the Valve onto the cylinder to avoid any deformation. Fitting torque to be applied must be in accordance with the BS 13341(see the table the valving torque value) and must not be exceed. If a leakage occurs after the correct assembly of the Valve onto the cylinder check the thread of the cylinder coupling.

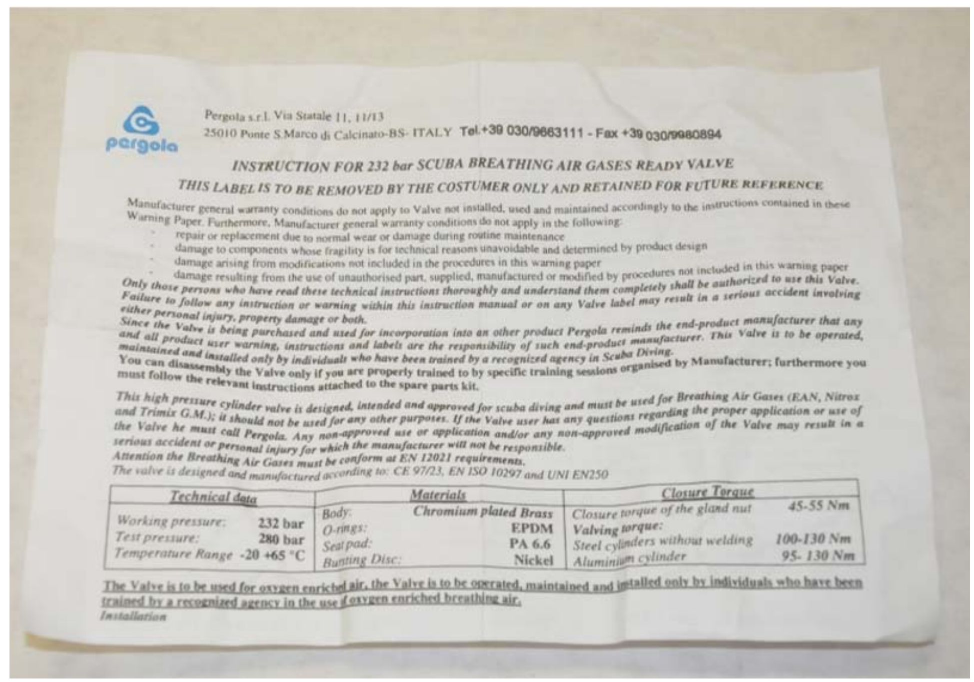
⚠ **Usage and maintenance**
Maintenance and repair of the Valve is under the responsibility of the user or the operator. Anyone attempting to maintain or repair the Valve must be thoroughly familiar with EN 250 and all other standards and regulations reference therein.
After each filling operation close the Valve handwheel and check if there is any leak from the inlet connection and from the outlet of the Valve. Do not use leak detectors or solutions containing ammonia, phosphates, or other chemicals which are harmful to copper alloy. ***Ammonia causes stress corrosion of the material and consequently increases the risk of leaks and explosion.*** Before insert the regulator onto the Valve open it slightly for an instance in order to clean the opening of particles of dust, dirt and to remove the moisture.
ALWAYS OPEN VALVE SLOWLY UNTIL PRESSURE BUILDS UP THROUGHOUT THE REGULATOR

⚠ *At the end of usage, close the Valve by hand without forcing. Maximum torque for opening and closing should be 5 N/m.*
If safety devices are present, pay the maximum attention during filling, stocking, and usage. For a correct use, make sure that cylinders are properly secured and storage *and do not expose the cylinder to heat sources or directly to sun rays, that could increase the internal pressure of the container, and consequently cause the intervention of the safety device. In case this occurred: keep far from the gas containers until it's completely empty, air the room in order to prevent asphyxia and substitute the cylinder with one efficient.*
MANUFACTURER IS NOT RESPONSIBLE OF DAMAGES COMING FROM ALTERATIONS, TAMPERING, AND INAPROPRIATE USE OF THE VALVE.

⚠ *Chromium plated external parts can be cleaned with disinfecting solutions not containing ammonia, using a clean cloth. Dry the device before using. Do not introduce any substance or foreign particles into the valve or into its inlet or outlet connections. Before using verify that the valve has no damaged parts and/or components. Damaged parts/components not subjected to pressure have to be substituted with original spare- parts, by trained authorized personnel. When outlet connections or other* ***parts under pressure*** *are damaged, or when periodical cylinder maintenance is performed, device substitution is recommended.*
This warning paper is part of the sales contract. Manufacturer preserves the right to change designs and materials as well as specifications and product information without prior notice.

Instructions for use VSB1 23 7 944 6362 INDEX A0 del 20/11/2008 ACTIVITY : 06290





pergola

Pergola s.r.l. Via Statale 11, 11/13
25010 Ponte S.Marco di Calcinato-BS- ITALY Tel.+39 030/9663111 - Fax +39 030/9980894

INSTRUCTION FOR 232 bar SCUBA BREATHING AIR GASES READY VALVE

THIS LABEL IS TO BE REMOVED BY THE COSTUMER ONLY AND RETAINED FOR FUTURE REFERENCE

Manufacturer general warranty conditions do not apply to Valve not installed, used and maintained accordingly to the instructions contained in these Warning Paper. Furthermore, Manufacturer general warranty conditions do not apply in the following:
- repair or replacement due to normal wear or damage during routine maintenance
- damage to components whose fragility is for technical reasons unavoidable and determined by product design
- damage arising from modifications not included in the procedures in this warning paper
- damage resulting from the use of unauthorised part, supplied, manufactured or modified by procedures not included in this warning paper

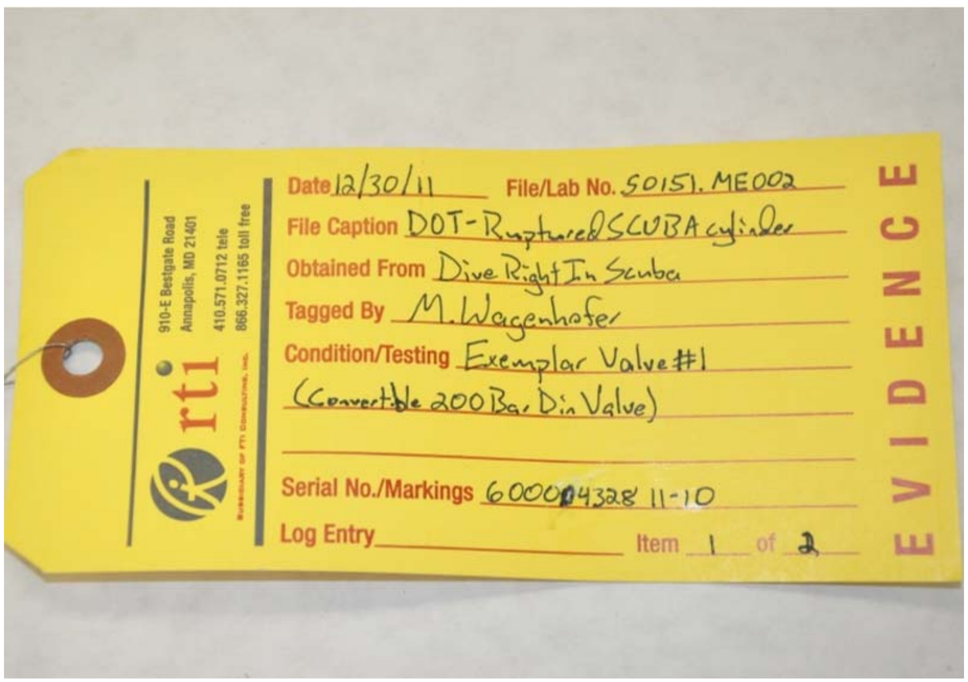
Only those persons who have read these technical instructions thoroughly and understand them completely shall be authorized to use this Valve. Failure to follow any instruction or warning within this instruction manual or on any Valve label may result in a serious accident involving either personal injury, property damage or both.
Since the Valve is being purchased and used for incorporation into an other product Pergola reminds the end-product manufacturer that any and all product user warning, instructions and labels are the responsibility of such end-product manufacturer. This Valve is to be operated, maintained and installed only by individuals who have been trained by a recognized agency in Scuba Diving.
You can disassembly the Valve only if you are properly trained to by specific training sessions organised by Manufacturer; furthermore you must follow the relevant instructions attached to the spare parts kit.

This high pressure cylinder valve is designed, intended and approved for scuba diving and must be used for Breathing Air Gases (EAN, Nitrox and Trimix G.M.); it should not be used for any other purposes. If the Valve user has any questions regarding the proper application or use of the Valve he must call Pergola. Any non-approved use or application and/or any non-approved modification of the Valve may result in a serious accident or personal injury for which the manufacturer will not be responsible.
Attention the Breathing Air Gases must be conform at EN 12021 requirements.
The valve is designed and manufactured according to: CE 97/23, EN ISO 10297 and UNI EN250

Technical data		Materials		Closure Torque	
Working pressure:	232 bar	Body:	Chromium plated Brass	Closure torque of the gland nut	45-55 Nm
Test pressure:	280 bar	O-rings:	EPDM	Valving torque:	
Temperature Range	-20 +65 °C	Seat pad:	PA 6.6	Steel cylinders without welding	100-130 Nm
		Bursting Disc:	Nickel	Aluminium cylinder	95- 130 Nm

The Valve is to be used for oxygen enriched air, the Valve is to be operated, maintained and installed only by individuals who have been trained by a recognized agency in the use of oxygen enriched breathing air.
Installation

Made In EU
CE 0029
EN 250



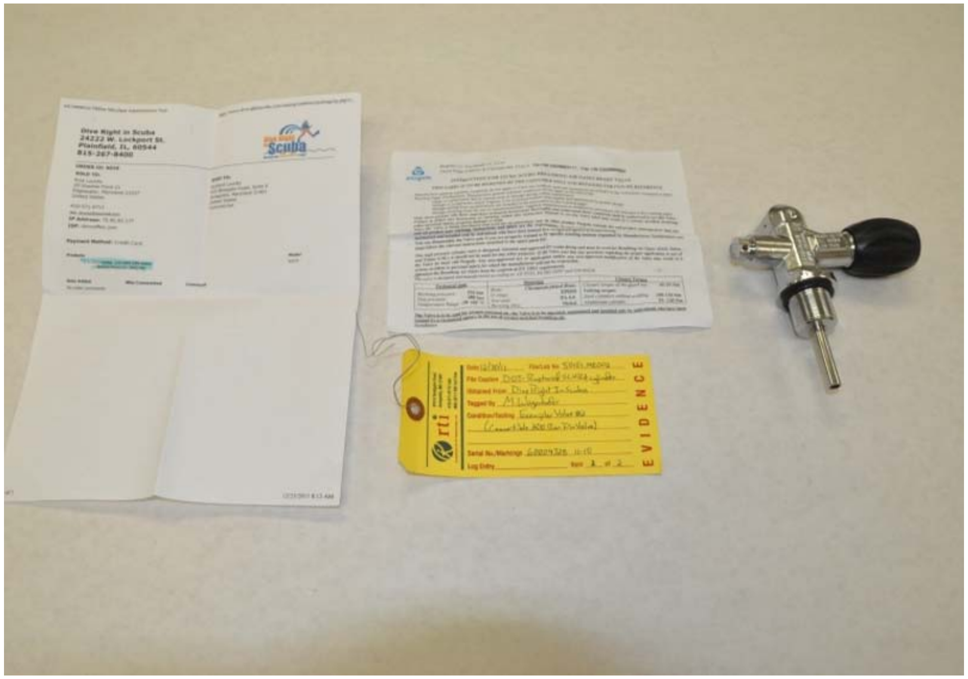
rti
910-E Bestgate Road
Annapolis, MD 21401
410.571.0712 tele
866.327.1165 toll free
Date 12/30/11
File/Lab No. 50151. ME002
File Caption DOT-Ruptured SCUBA cylinder
Obtained From Dive Right In Scuba
Tagged By M. Wagenhofer
Condition/Testing Exemplar Valve #1
(Convertible 200 Bar Din Valve)
Serial No./Markings 600004328 11-10
Log Entry
Item 1 of 2
EVIDENCE

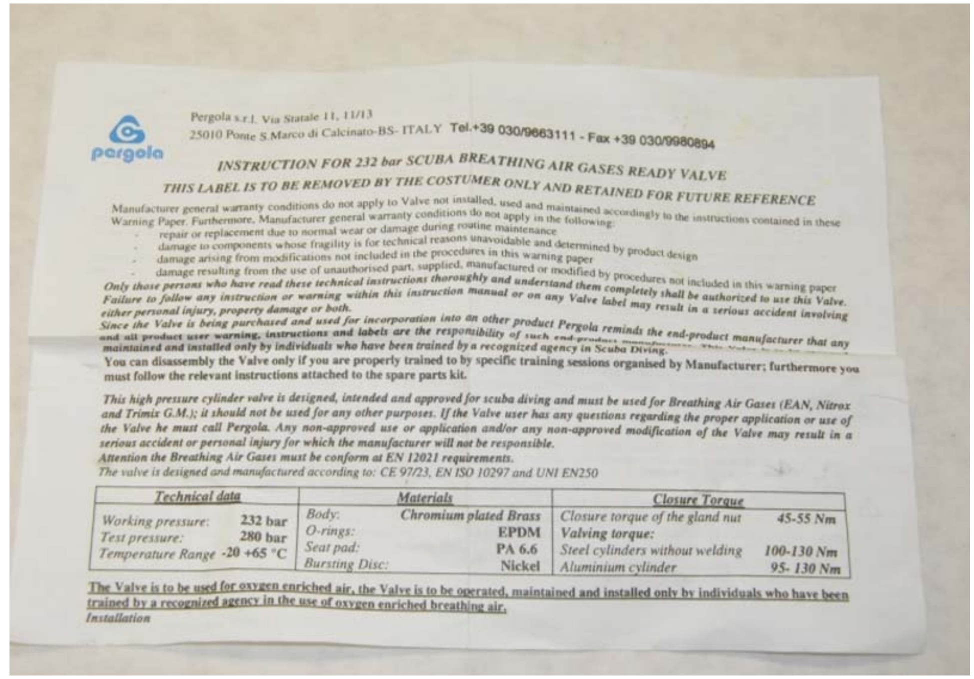

60004328 11-10

GENESIS

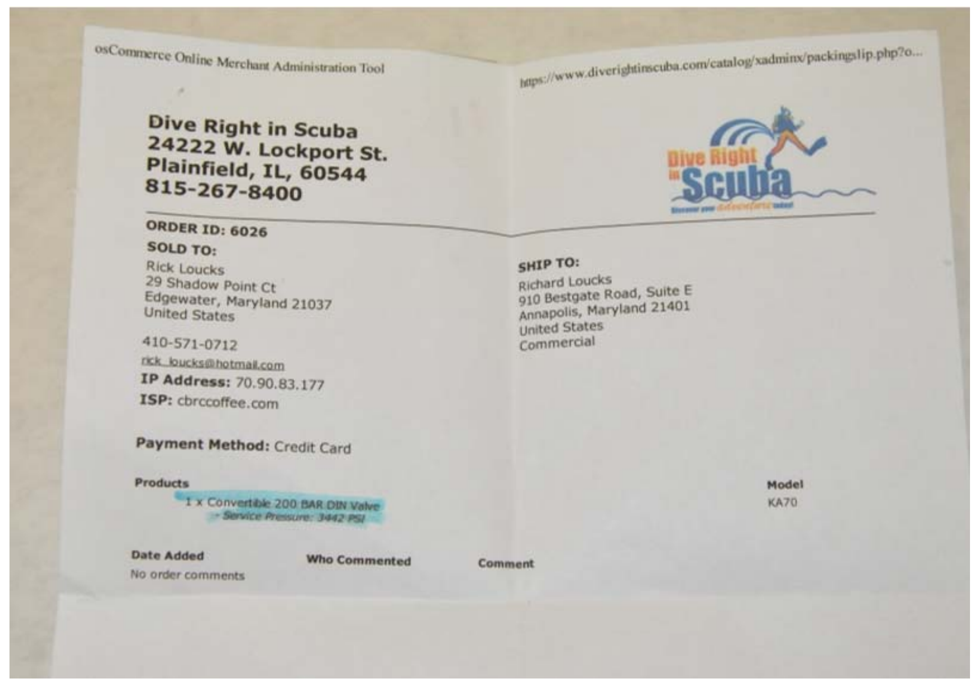
60004328 11-10

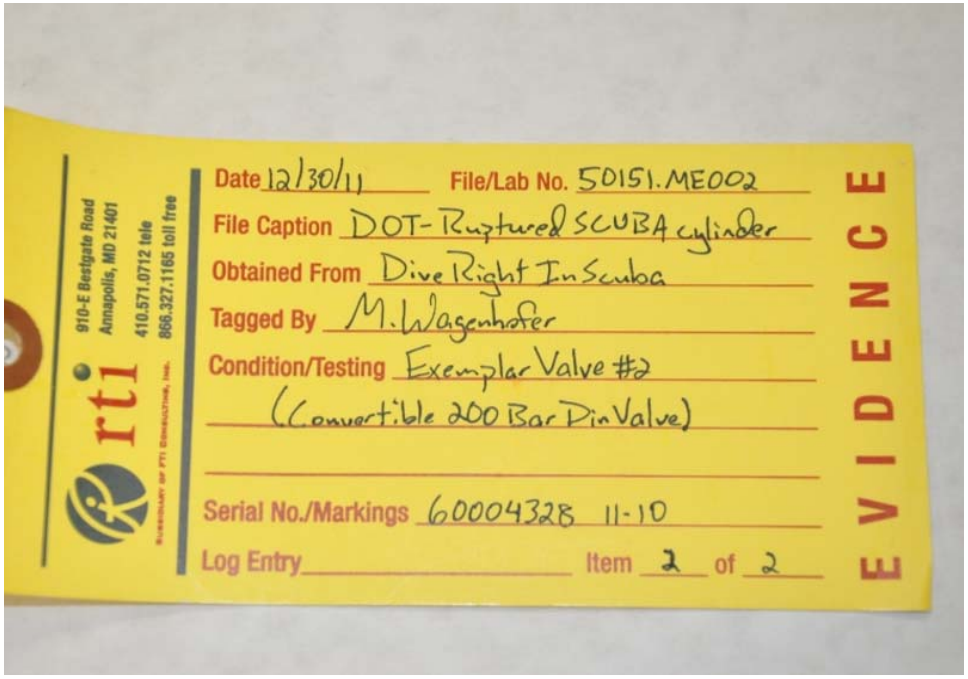
GENESIS

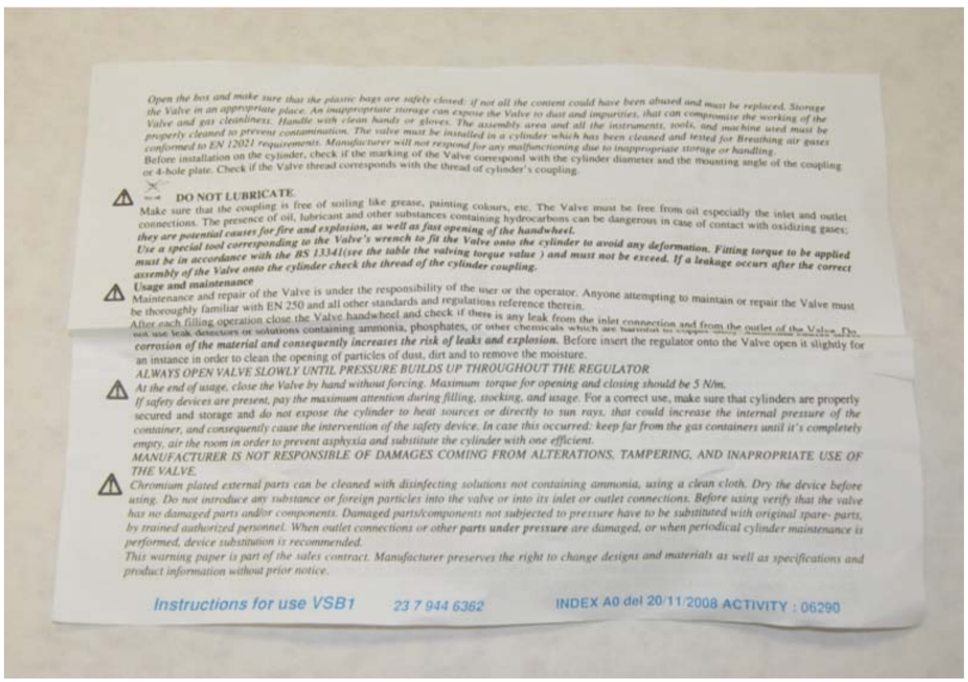



pergola
Pergola s.r.l. Via Statale 11, 11/13
25010 Ponte S.Marco di Calcinato-BS- ITALY Tel.+39 030/9663111 - Fax +39 030/9980894
INSTRUCTION FOR 232 bar SCUBA BREATHING AIR GASES READY VALVE
THIS LABEL IS TO BE REMOVED BY THE COSTUMER ONLY AND RETAINED FOR FUTURE REFERENCE
Manufacturer general warranty conditions do not apply to Valve not installed, used and maintained accordingly to the instructions contained in these Warning Paper. Furthermore, Manufacturer general warranty conditions do not apply in the following:
- repair or replacement due to normal wear or damage during routine maintenance
- damage to components whose fragility is for technical reasons unavoidable and determined by product design
- damage arising from modifications not included in the procedures in this warning paper
- damage resulting from the use of unauthorised part, supplied, manufactured or modified by procedures not included in this warning paper
Only those persons who have read these technical instructions thoroughly and understand them completely shall be authorized to use this Valve. Failure to follow any instruction or warning within this instruction manual or on any Valve label may result in a serious accident involving either personal injury, property damage or both.
Since the Valve is being purchased and used for incorporation into an other product Pergola reminds the end-product manufacturer that any and all product user warning, instructions and labels are the responsibility of such
maintained and installed only by individuals who have been trained by a recognized agency in Scuba Diving.
You can disassembly the Valve only if you are properly trained to by specific training sessions organised by Manufacturer; furthermore you must follow the relevant instructions attached to the spare parts kit.
This high pressure cylinder valve is designed, intended and approved for scuba diving and must be used for Breathing Air Gases (EAN, Nitrox and Trimix G.M.); it should not be used for any other purposes. If the Valve user has any questions regarding the proper application or use of the Valve he must call Pergola. Any non-approved use or application and/or any non-approved modification of the Valve may result in a serious accident or personal injury for which the manufacturer will not be responsible.
Attention the Breathing Air Gases must be conform at EN 12021 requirements.
The valve is designed and manufactured according to: CE 97/23, EN ISO 10297 and UNI EN250
Technical data
Working pressure: 232 bar
Test pressure: 280 bar
Temperature Range -20 +65 °C
Materials
Body: Chromium plated Brass
O-rings: EPDM
Seat pad: PA 6.6
Bursting Disc: Nickel
Closure Torque
Closure torque of the gland nut 45-55 Nm
Valving torque:
Steel cylinders without welding 100-130 Nm
Aluminium cylinder 95- 130 Nm
The Valve is to be used for oxygen enriched air, the Valve is to be operated, maintained and installed only by individuals who have been trained by a recognized agency in the use of oxygen enriched breathing air.
Installation


#2
Convertible 200 Bar Din Valve
KA70
$75.00


osCommerce Online Merchant Administration Tool
https://www.diverightinscuba.com/catalog/xadminx/packingslip.php?o...
Dive Right in Scuba
24222 W. Lockport St.
Plainfield, IL, 60544
815-267-8400
Dive Right in Scuba
ORDER ID: 6026
SOLD TO:
Rick Loucks
29 Shadow Point Ct
Edgewater, Maryland 21037
United States
410-571-0712
rick_loucks@hotmail.com
IP Address: 70.90.83.177
ISP: cbrccoffee.com
SHIP TO:
Richard Loucks
910 Bestgate Road, Suite E
Annapolis, Maryland 21401
United States
Commercial
Payment Method: Credit Card
Products
1 x Convertible 200 BAR DIN Valve
- Service Pressure: 3442 PSI
Model
KA70
Date Added
Who Commented
Comment
No order comments





Open the box and make sure that the plastic bags are safely closed: if not all the content could have been abused and must be replaced. Storage the Valve in an appropriate place. An inappropriate storage can expose the Valve to dust and impurities, that can compromise the working of the Valve and gas cleanliness. Handle with clean hands or gloves. The assembly area and all the instruments, tools, and machine used must be properly cleaned to prevent contamination. The valve must be installed in a cylinder which has been cleaned and tested for Breathing air gases conformed to EN 12021 requirements. Manufacturer will not respond for any malfunctioning due to inappropriate storage or handling.
Before installation on the cylinder, check if the marking of the Valve correspond with the cylinder diameter and the mounting angle of the coupling or 4-hole plate. Check if the Valve thread corresponds with the thread of cylinder's coupling.

⚠ DO NOT LUBRICATE
Make sure that the coupling is free of soiling like grease, painting colours, etc. The Valve must be free from oil especially the inlet and outlet connections. The presence of oil, lubricant and other substances containing hydrocarbons can be dangerous in case of contact with oxidizing gases; *they are potential causes for fire and explosion, as well as fast opening of the handwheel.*
Use a special tool corresponding to the Valve's wrench to fit the Valve onto the cylinder to avoid any deformation. Fitting torque to be applied must be in accordance with the BS 13341(see the table the valving torque value) and must not be exceed. If a leakage occurs after the correct assembly of the Valve onto the cylinder check the thread of the cylinder coupling.

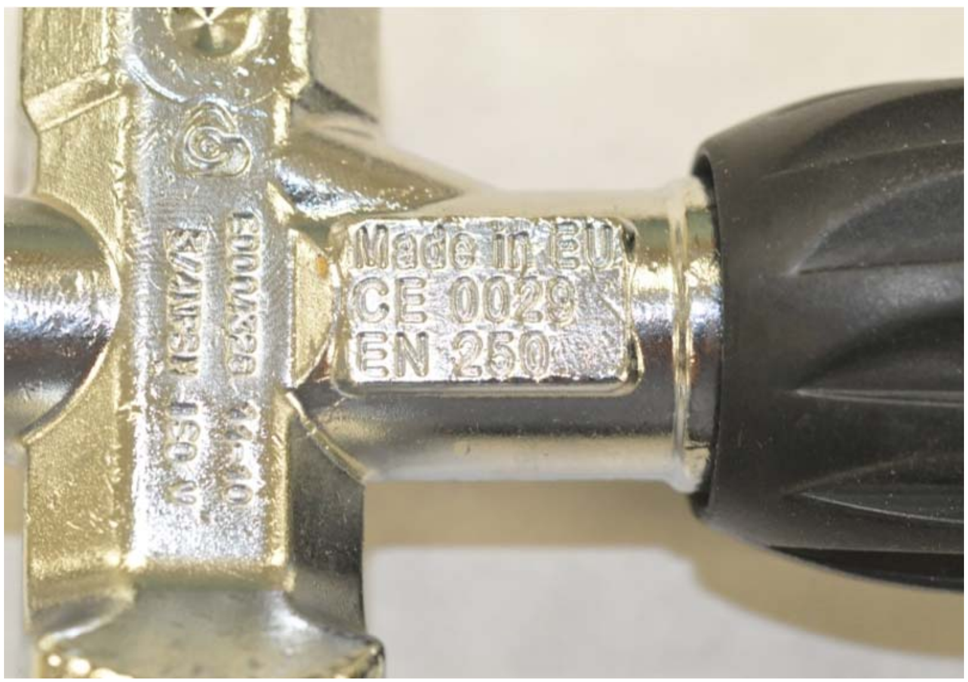
⚠ **Usage and maintenance**
Maintenance and repair of the Valve is under the responsibility of the user or the operator. Anyone attempting to maintain or repair the Valve must be thoroughly familiar with EN 250 and all other standards and regulations reference therein.
After each filling operation close the Valve handwheel and check if there is any leak from the inlet connection and from the outlet of the Valve. Do not use leak detectors or solutions containing ammonia, phosphates, or other chemicals which are [illegible] ***corrosion of the material and consequently increases the risk of leaks and explosion.*** Before insert the regulator onto the Valve open it slightly for an instance in order to clean the opening of particles of dust, dirt and to remove the moisture.
ALWAYS OPEN VALVE SLOWLY UNTIL PRESSURE BUILDS UP THROUGHOUT THE REGULATOR

⚠ *At the end of usage, close the Valve by hand without forcing. Maximum torque for opening and closing should be 5 N/m.*
If safety devices are present, pay the maximum attention during filling, stocking, and usage. For a correct use, make sure that cylinders are properly secured and storage and *do not expose the cylinder to heat sources or directly to sun rays, that could increase the internal pressure of the container, and consequently cause the intervention of the safety device. In case this occurred: keep far from the gas containers until it's completely empty, air the room in order to prevent asphyxia and substitute the cylinder with one efficient.*
MANUFACTURER IS NOT RESPONSIBLE OF DAMAGES COMING FROM ALTERATIONS, TAMPERING, AND INAPROPRIATE USE OF THE VALVE.

⚠ *Chromium plated external parts can be cleaned with disinfecting solutions not containing ammonia, using a clean cloth. Dry the device before using. Do not introduce any substance or foreign particles into the valve or into its inlet or outlet connections. Before using verify that the valve has no damaged parts and/or components. Damaged parts/components not subjected to pressure have to be substituted with original spare- parts, by trained authorized personnel. When outlet connections or other* **parts under pressure** *are damaged, or when periodical cylinder maintenance is performed, device substitution is recommended.*
This warning paper is part of the sales contract. Manufacturer preserves the right to change designs and materials as well as specifications and product information without prior notice.

Instructions for use VSB1 23 7 944 6362 INDEX A0 del 20/11/2008 ACTIVITY : 06290


Made in EU
CE 0029
EN 250

60004328 11-10

Made in EU
CE 0029
EN 250

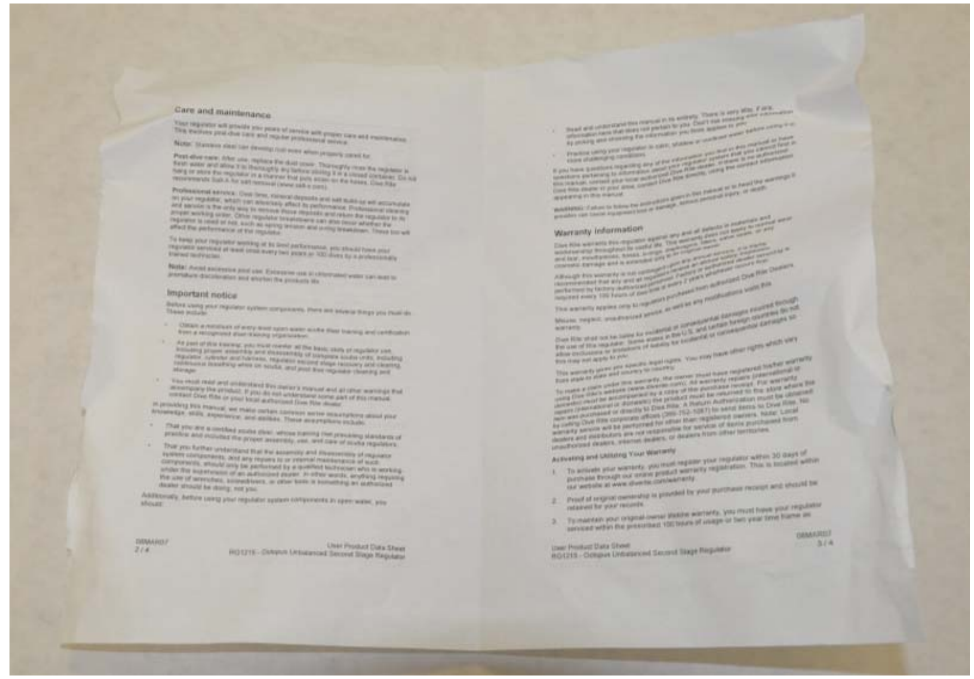
60004328 11-10

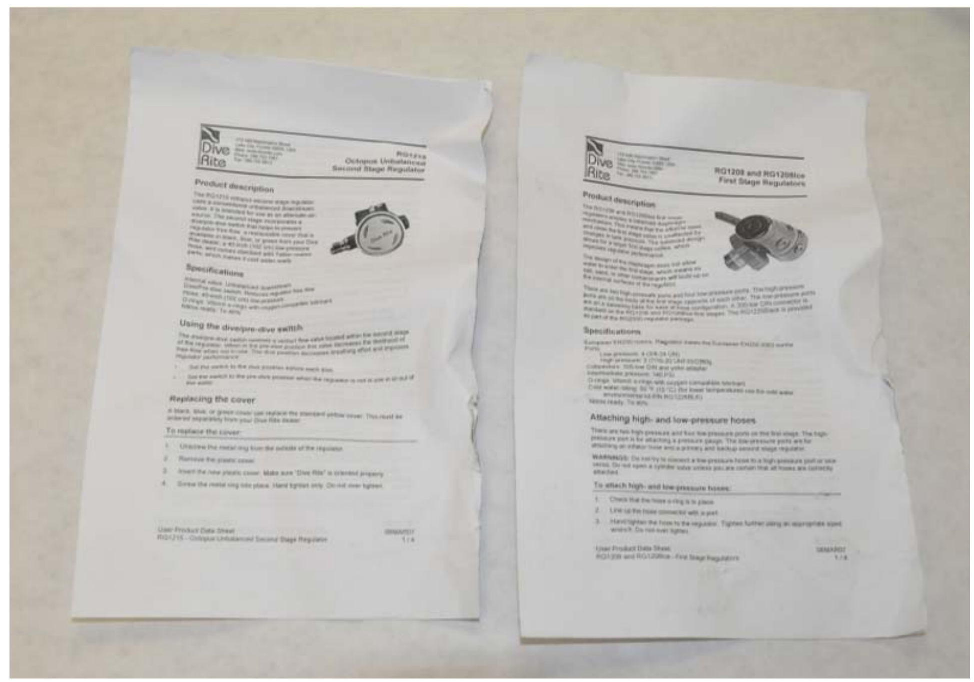

GENESIS

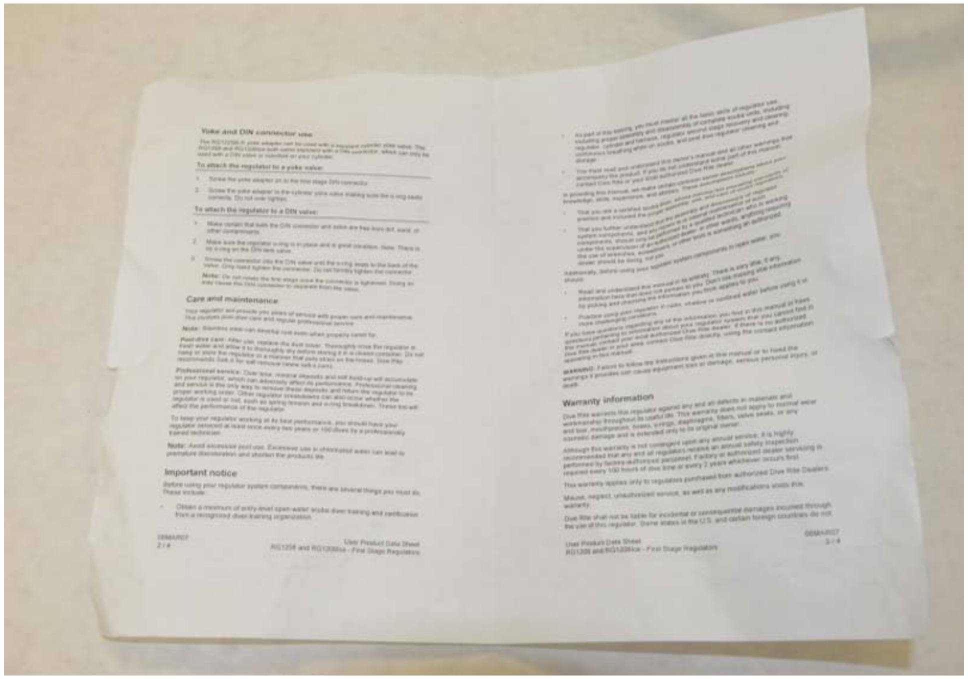

RG1200-O2
Man Serial #
12106628
DEC 29 2011
Dolphin Scuba Center of Sacramento, Inc.
DECO REG
40" GREEN
1000002874
RG RG1200-O2 L1
330.00

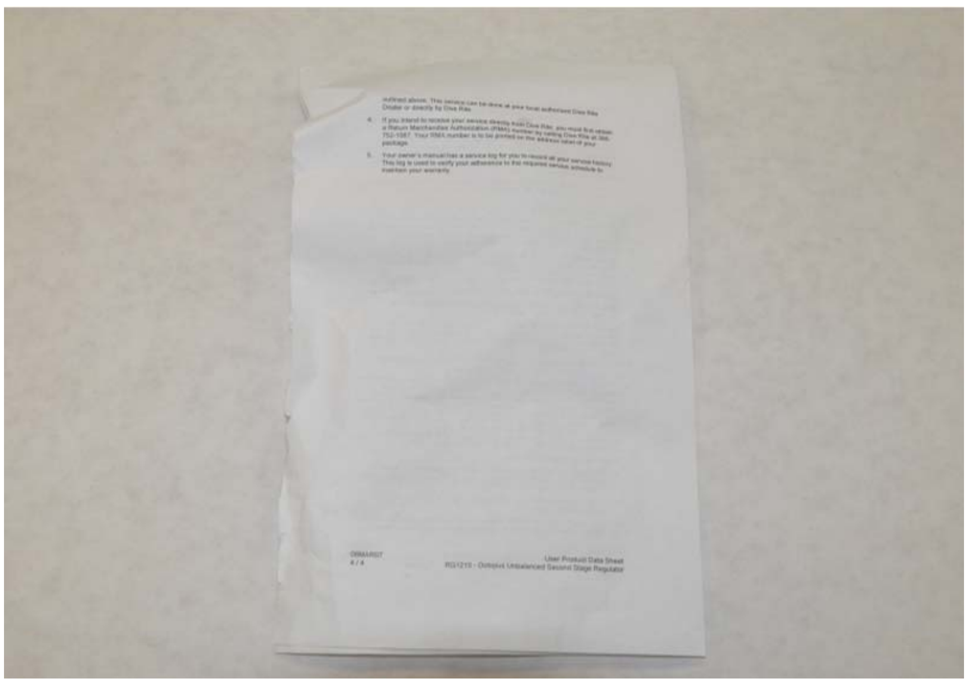

GENESIS

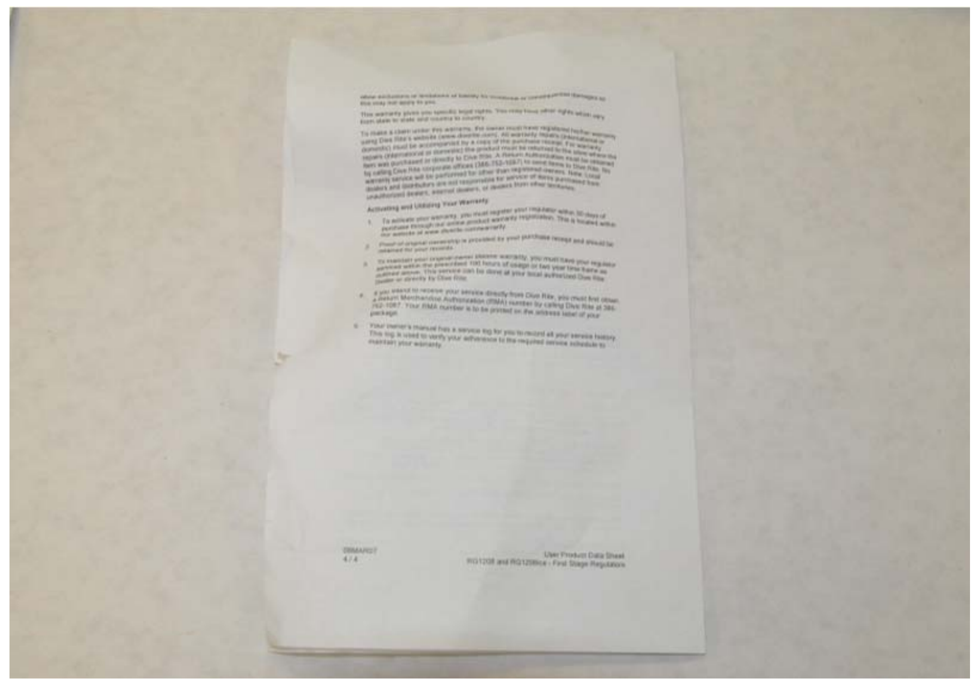

DIVE RITE





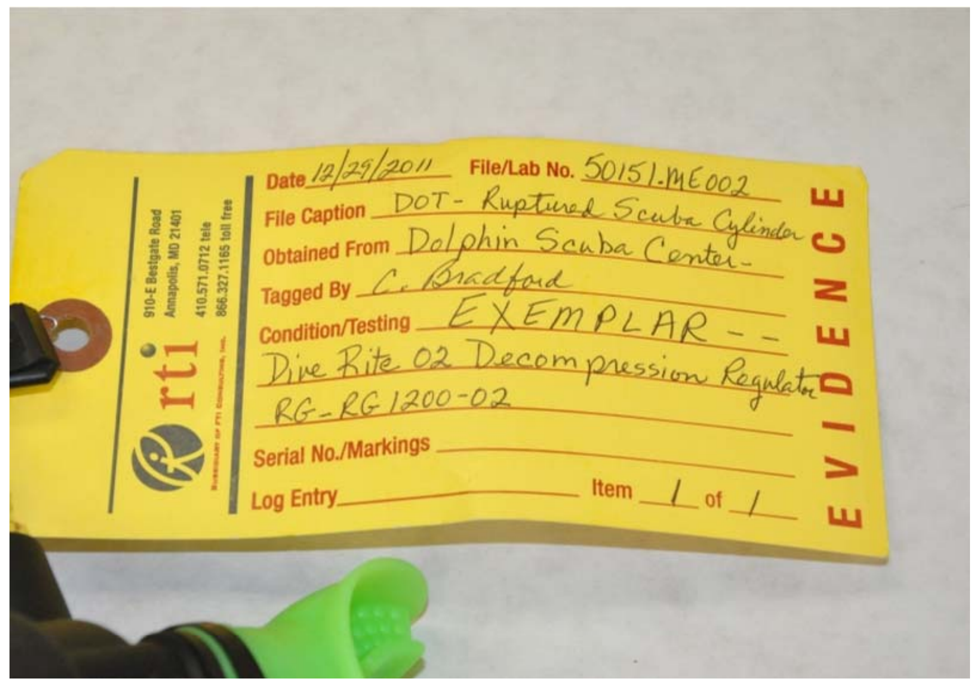







Dive Rite
WARNING
EVIDENCE


Dive Rite

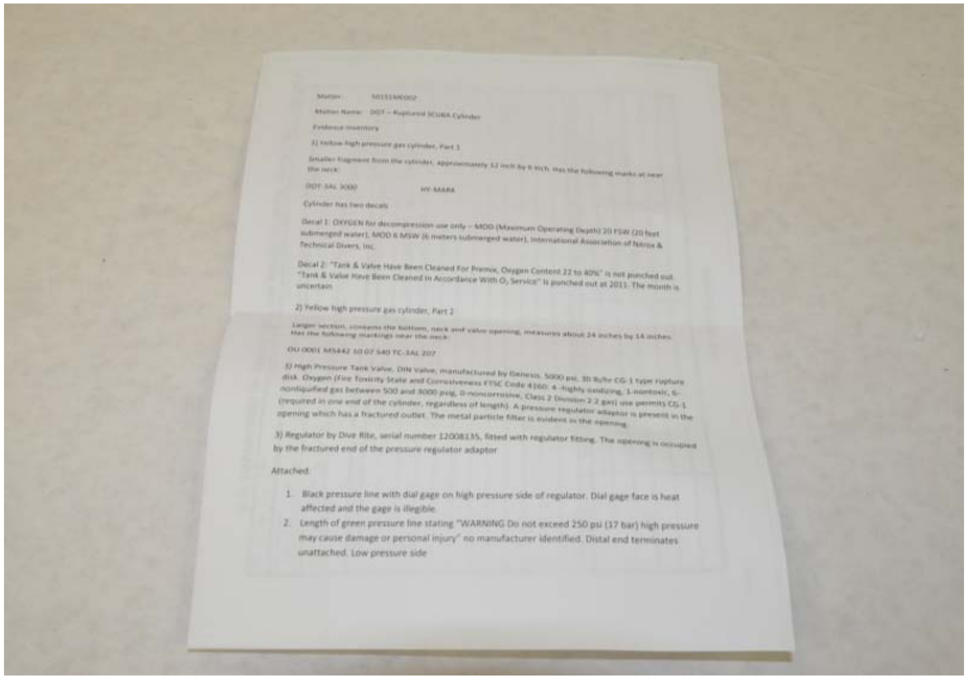

rti
910-E Bestgate Road
Annapolis, MD 21401
410.571.0712 tele
866.327.1165 toll free
Date 12/29/2011 File/Lab No. 50151.ME002
File Caption DOT- Ruptured Scuba Cylinder
Obtained From Dolphin Scuba Center
Tagged By C. Bradford
Condition/Testing EXEMPLAR --
Dive Rite O2 Decompression Regulator
RG-RG1200-02
Serial No./Markings
Log Entry
Item 1 of 1
EVIDENCE


Dive Rite
12106628
HP

Dive Rite
HP
12106628

Dive Rite
12106628
HP

CE 1463 EN 250
Dive Rite



Matter: 50151ME002

Matter Name: DOT – Ruptured SCUBA Cylinder

Evidence Inventory

1) Yellow high pressure gas cylinder, Part 1

Smaller fragment from the cylinder, approximately 12 inch by 6 inch, has the following marks at near the neck:

DOT-3AL 3000 HY-MARK

Cylinder has two decals

Decal 1: OXYGEN for decompression use only – MOD (Maximum Operating Depth) 20 FSW (20 feet submerged water), MOD 6 MSW (6 meters submerged water), International Association of Nitrox & Technical Divers, Inc.

Decal 2: "Tank & Valve Have Been Cleaned For Premix, Oxygen Content 22 to 40%" is not punched out "Tank & Valve Have Been Cleaned in Accordance With O_2 Service" is punched out at 2011. The month is uncertain

2) Yellow high pressure gas cylinder, Part 2

Larger section, contains the bottom, neck and valve opening, measures about 24 inches by 14 inches. Has the following markings near the neck:

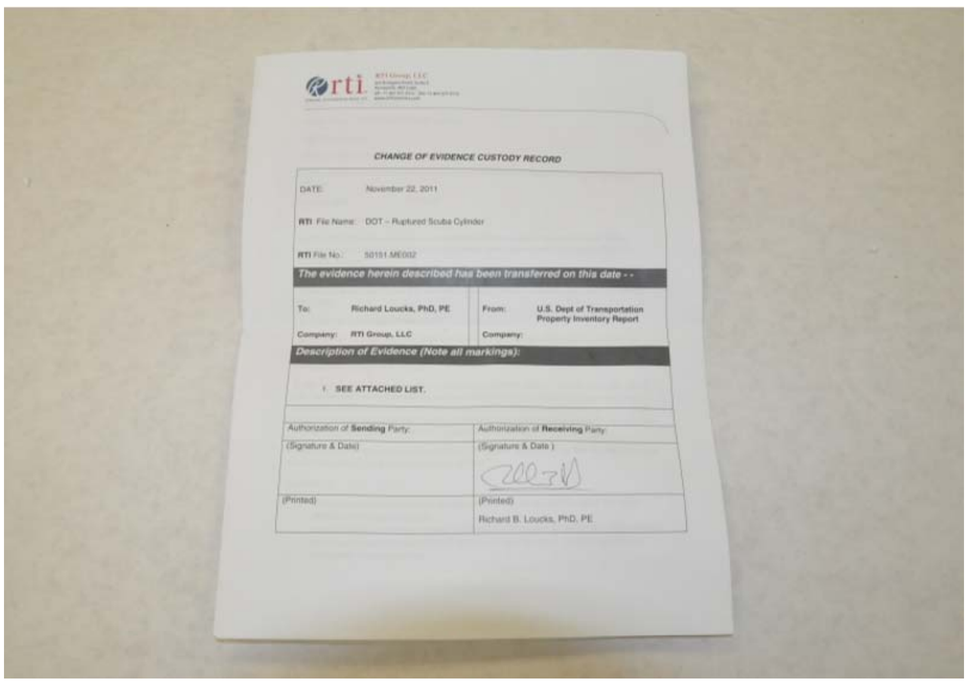
OU 0001 M5442 10 07 S40 TC-3AL 207

3) High Pressure Tank Valve, DIN Valve, manufactured by Genesis. 5000 psi, 30 lb/hr CG-1 type rupture disk. Oxygen (Fire Toxicity State and Corrosiveness FTSC Code 4160: 4 -highly oxidizing, 1-nontoxic, 6-nonliquified gas between 500 and 3000 psig, 0-noncorrosive, Class 2 Division 2.2 gas) use permits CG-1 (required in one end of the cylinder, regardless of length). A pressure regulator adaptor is present in the opening which has a fractured outlet. The metal particle filter is evident in the opening.

3) Regulator by Dive Rite, serial number 12008135, fitted with regulator fitting. The opening is occupied by the fractured end of the pressure regulator adaptor

Attached:

1. Black pressure line with dial gage on high pressure side of regulator. Dial gage face is heat affected and the gage is illegible
2. Length of green pressure line stating "WARNING Do not exceed 250 psi (17 bar) high pressure may cause damage or personal injury" no manufacturer identified. Distal end terminates unattached. Low pressure side



rti RTI Group, LLC

CHANGE OF EVIDENCE CUSTODY RECORD

DATE: November 22, 2011

RTI File Name: DOT – Ruptured Scuba Cylinder

RTI File No.: 50151.ME002

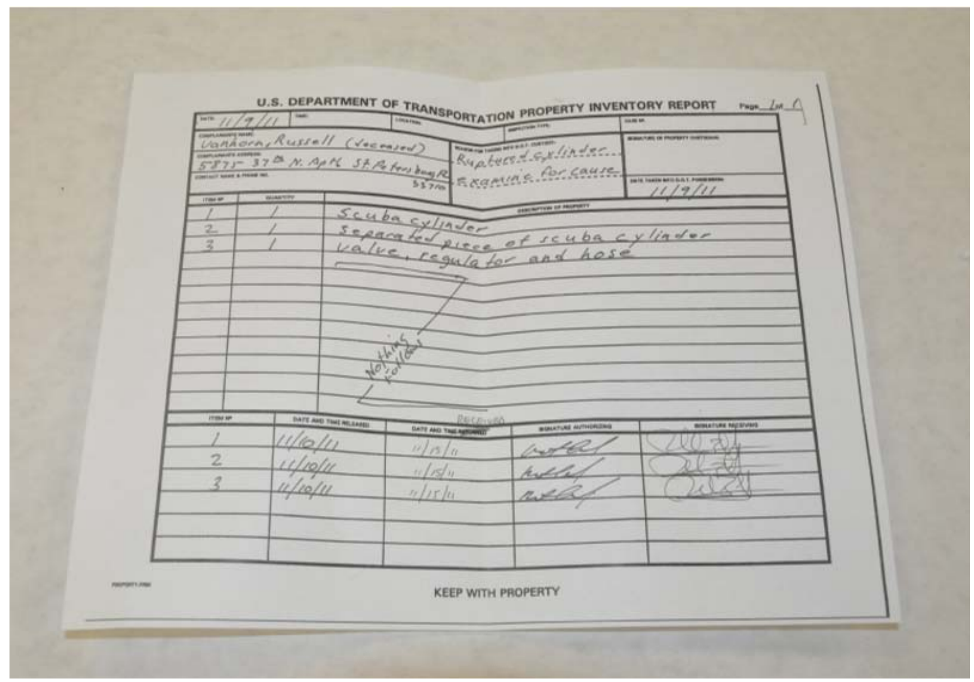
The evidence herein described has been transferred on this date - -

To:	Richard Loucks, PhD, PE	From:	U.S. Dept of Transportation Property Inventory Report
Company:	RTI Group, LLC	Company:	

Description of Evidence (Note all markings):

1. SEE ATTACHED LIST.

Authorization of Sending Party:	Authorization of Receiving Party:
(Signature & Date)	(Signature & Date) [signature]
(Printed)	(Printed) Richard B. Loucks, PhD, PE



U.S. DEPARTMENT OF TRANSPORTATION PROPERTY INVENTORY REPORT Page 1 of 1

Date: 11/9/11

Vanhorn, Russell (deceased)

5875 37th N. Apt St Petersburg FL 33710

Ruptured cylinder, examine for cause

11/9/11

Item #	Quantity	Description of Property
1	1	Scuba cylinder
2	1	separated piece of scuba cylinder
3	1	valve, regulator and hose

Nothing follows

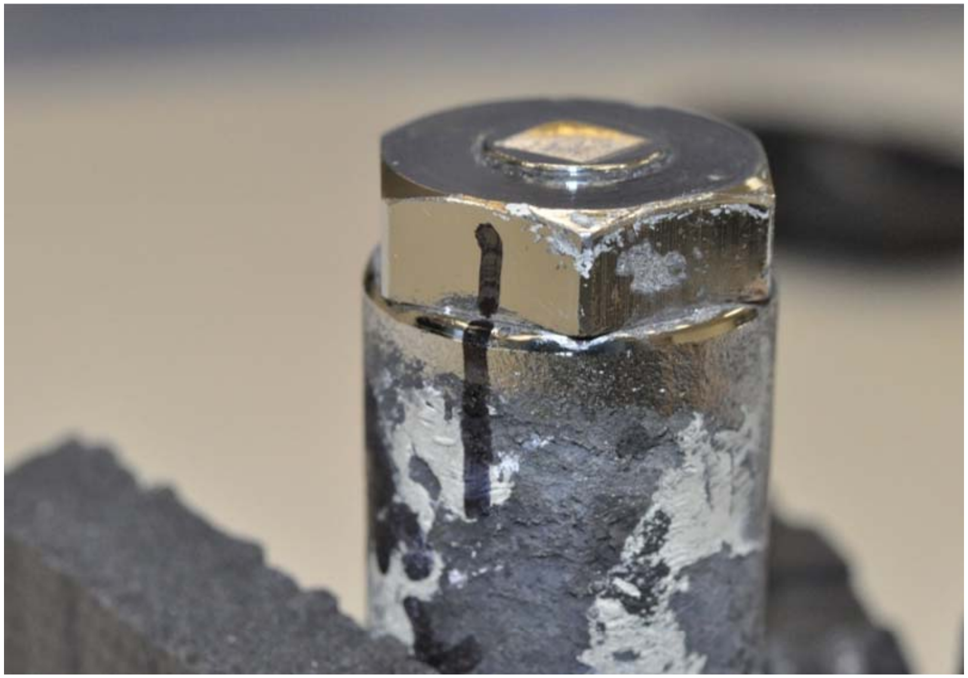
Item #	Date and Time Released	Date and Time Returned	Signature Authorizing	Signature Receiving
1	11/10/11	11/15/11	[signature]	[signature]
2	11/10/11	11/15/11	[signature]	[signature]
3	11/10/11	11/15/11	[signature]	[signature]

KEEP WITH PROPERTY





PROTO




PSI

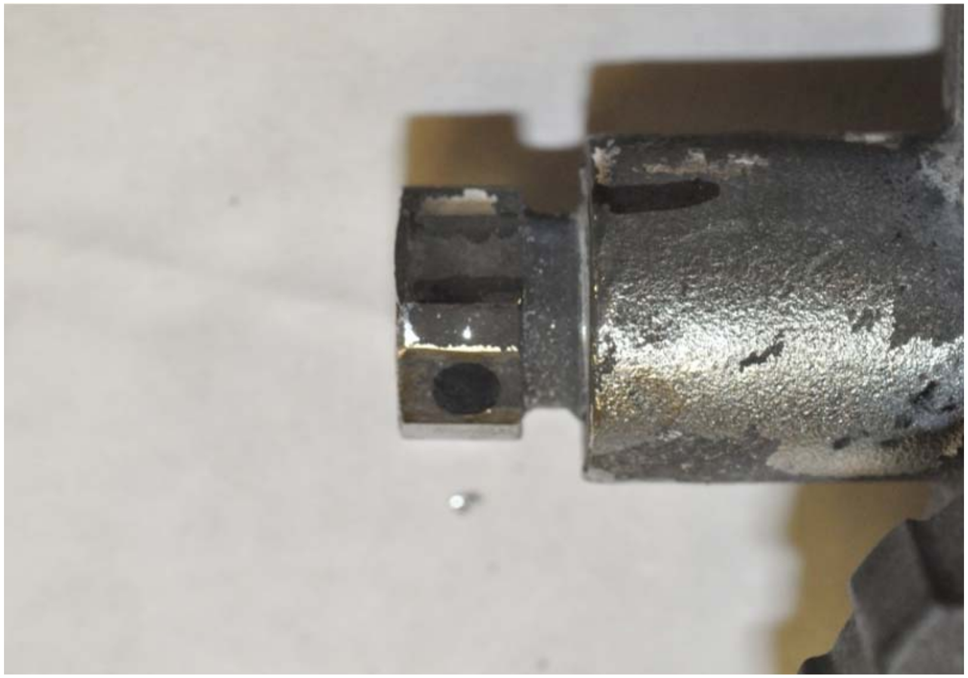

PROTO
In-Lb
cm-Kg
250 In-lb 280 cmkg

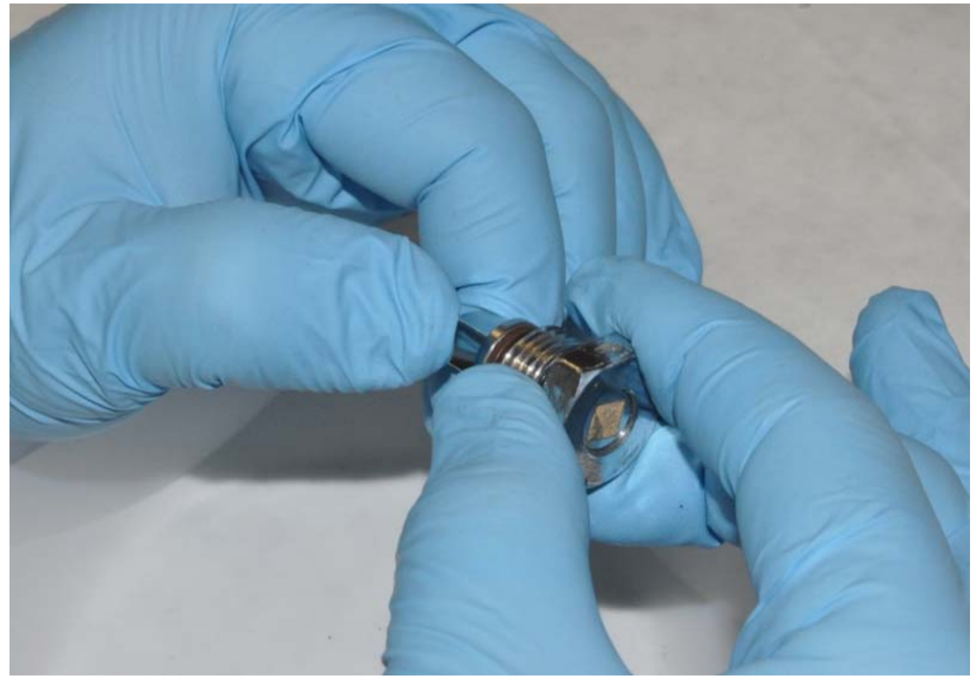

In-Lb
In-Lb
cm-Kg
cm-Kg
PROTO
MADE IN USA


PROTO


INCHES


















VALVE


GLAND NUT
RELIEF VALVE
VALVE HANDLE BODY
SEAT BODY

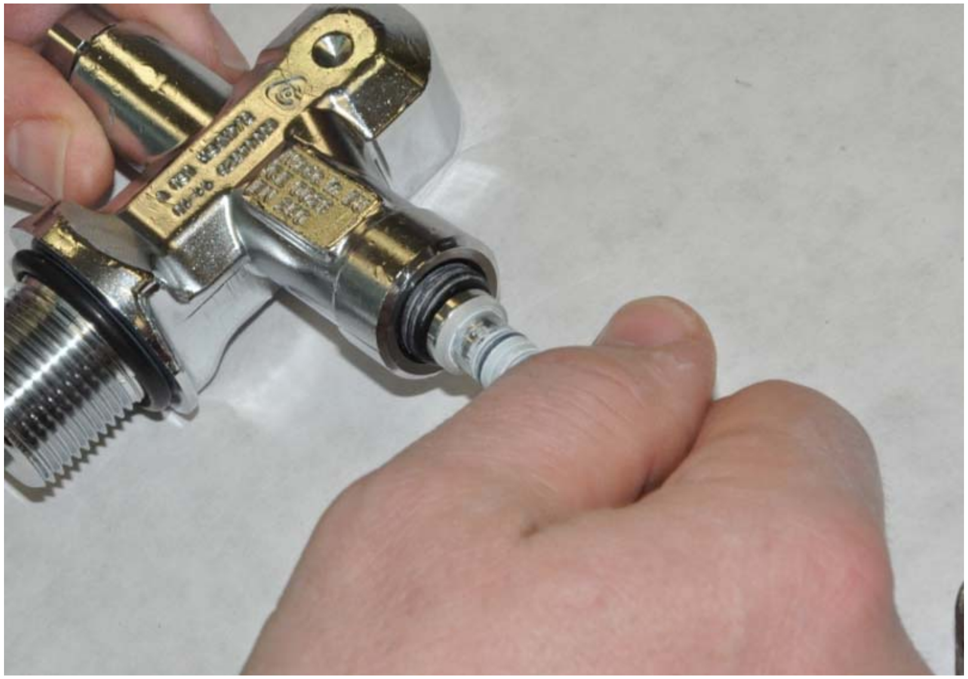







SEAT

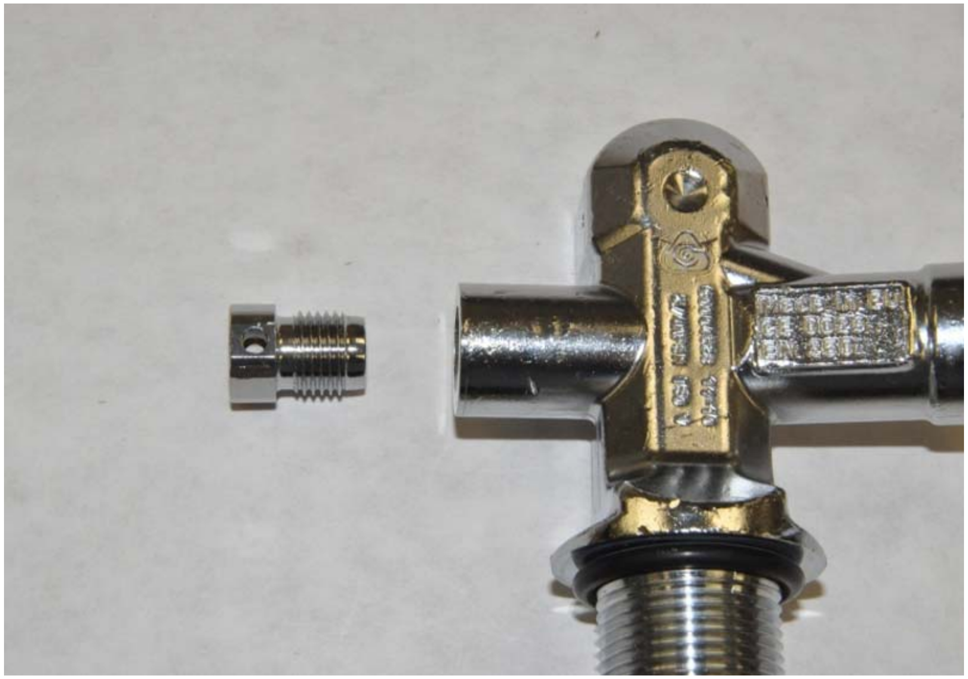

SEAT











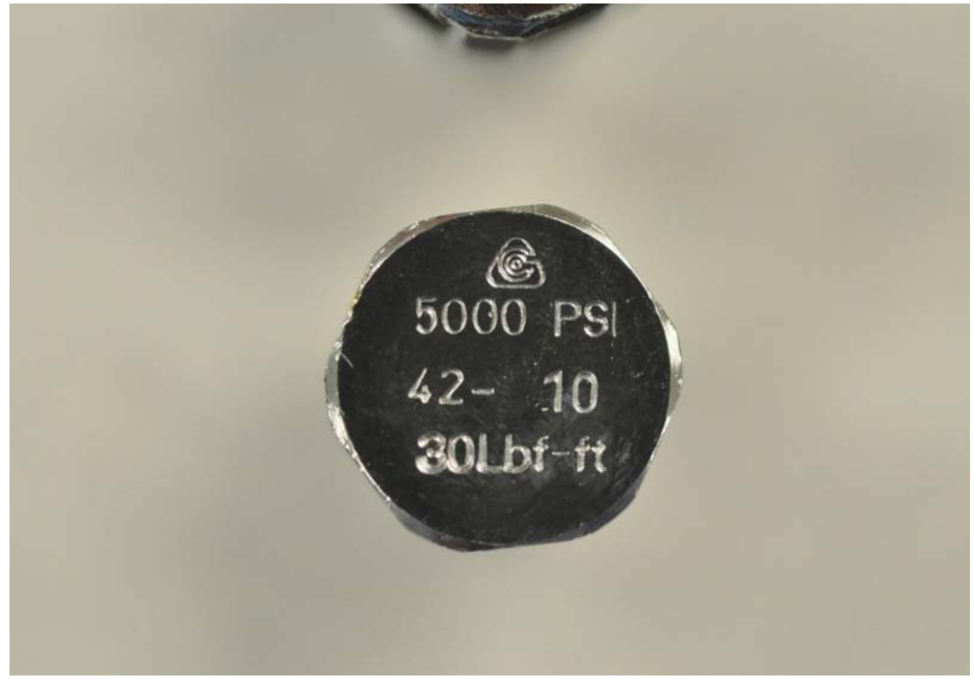






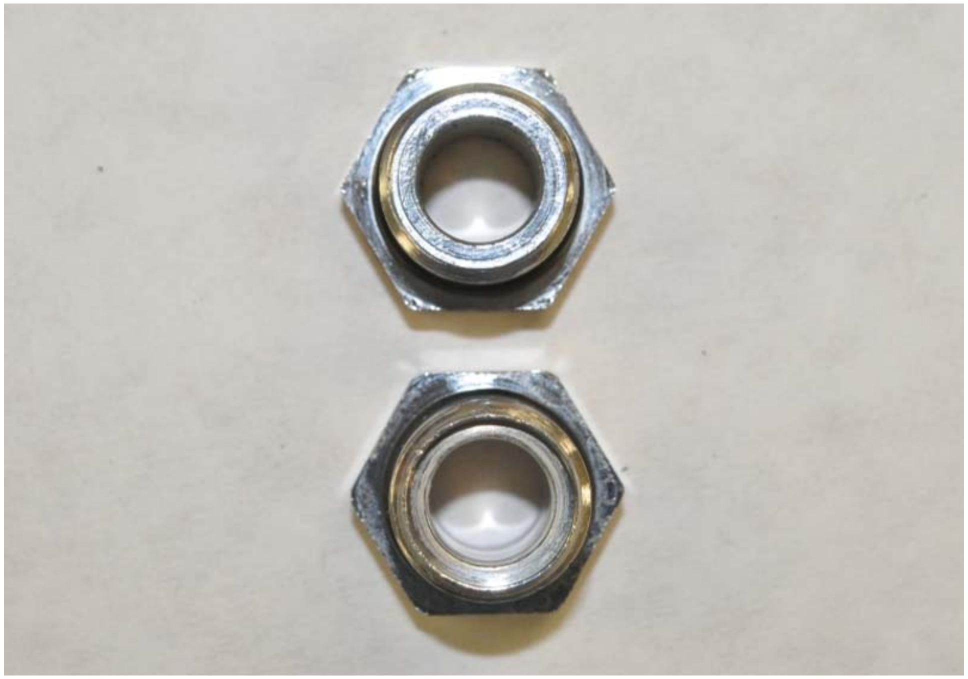


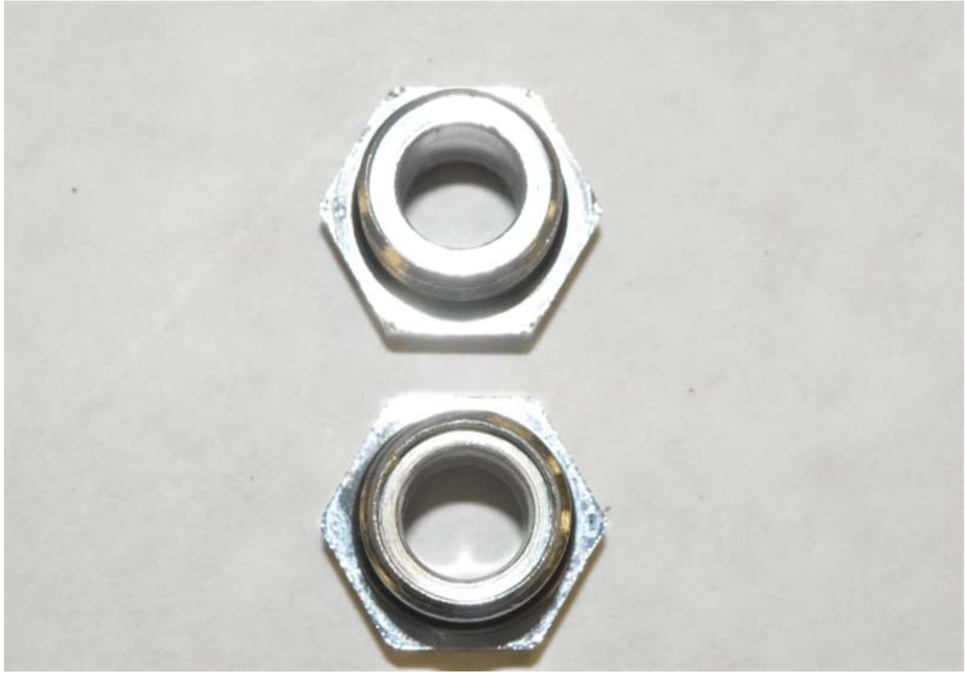


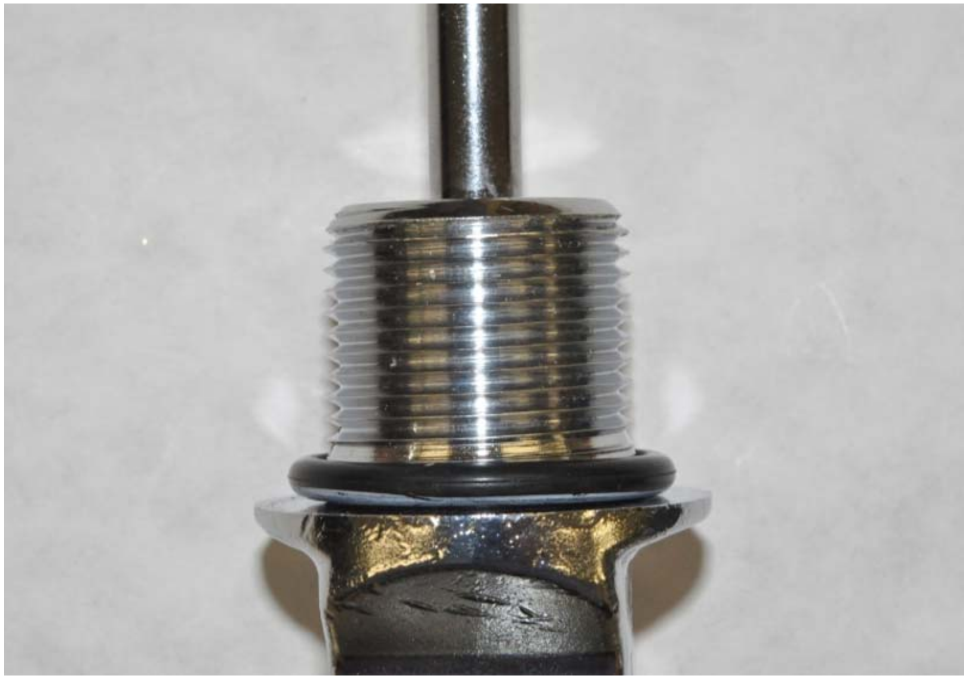
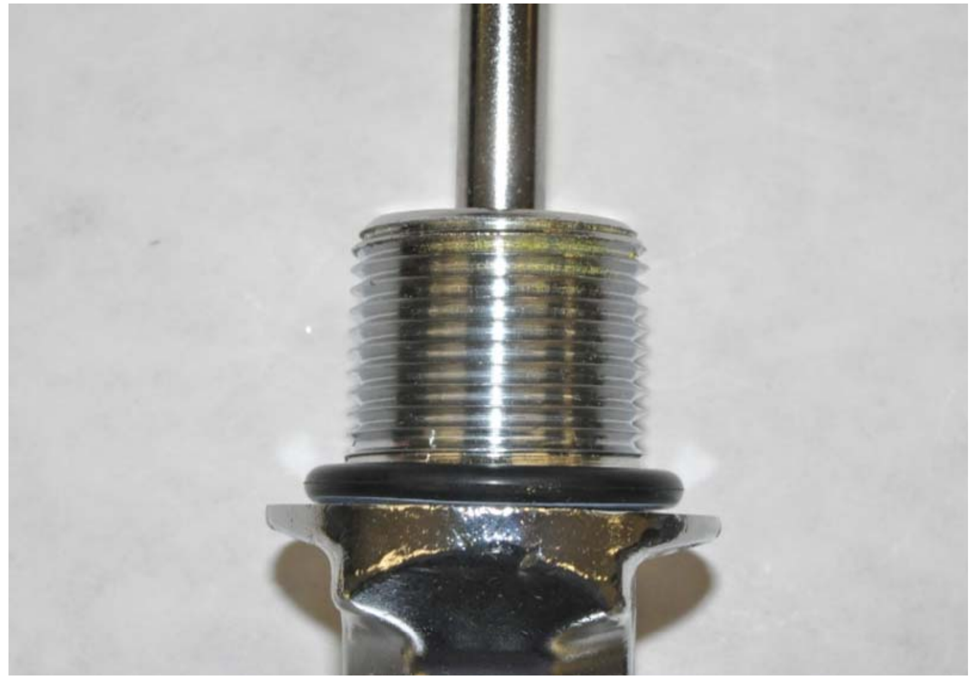

5000 PSI
42- 10
30Lbf-ft

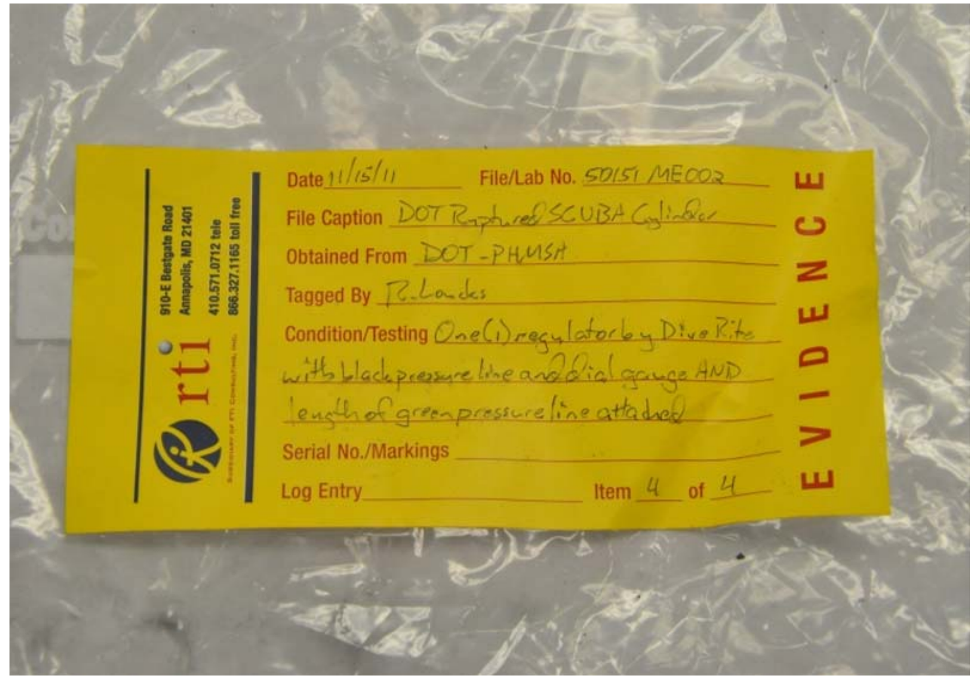

5000 psi
W10


5000psi

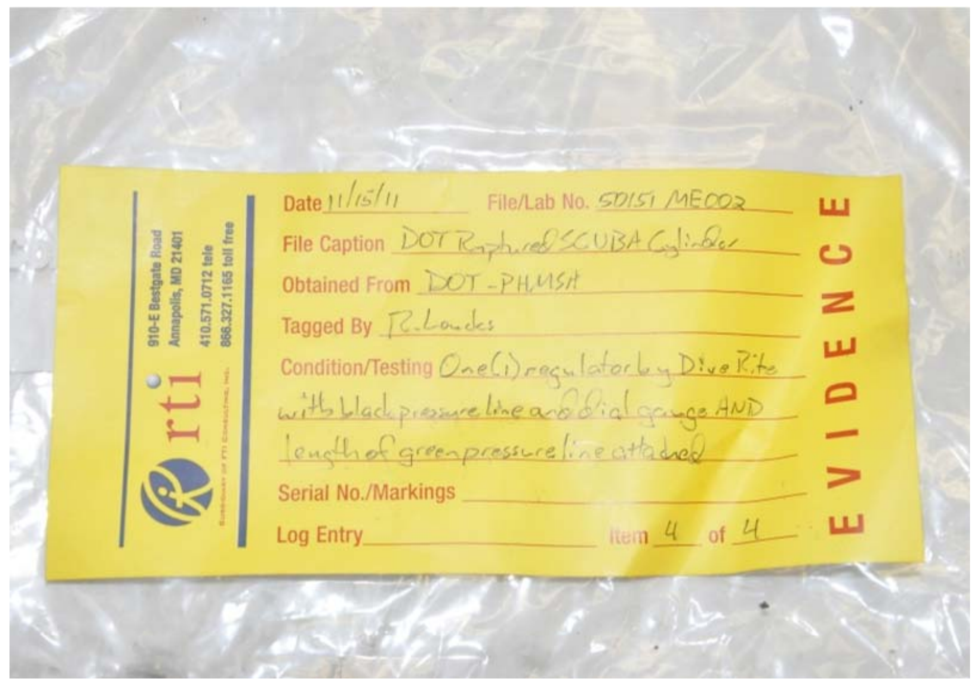







Date 11/15/11
File/Lab No. 50151 ME002
File Caption DOT Ruptured SCUBA Cylinder
Obtained From DOT-PHMSA
Tagged By
Condition/Testing One(1) regulator by Dive Rite with black pressure line and dial gauge AND length of green pressure line attached
Serial No./Markings
Log Entry
Item 4 of 4
EVIDENCE
rti
910-E Bestgate Road
Annapolis, MD 21401
410.571.0712 tele
866.327.1165 toll free



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Item 4 of 4
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rti
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866.327.1165 toll free





HP
12008135
HP

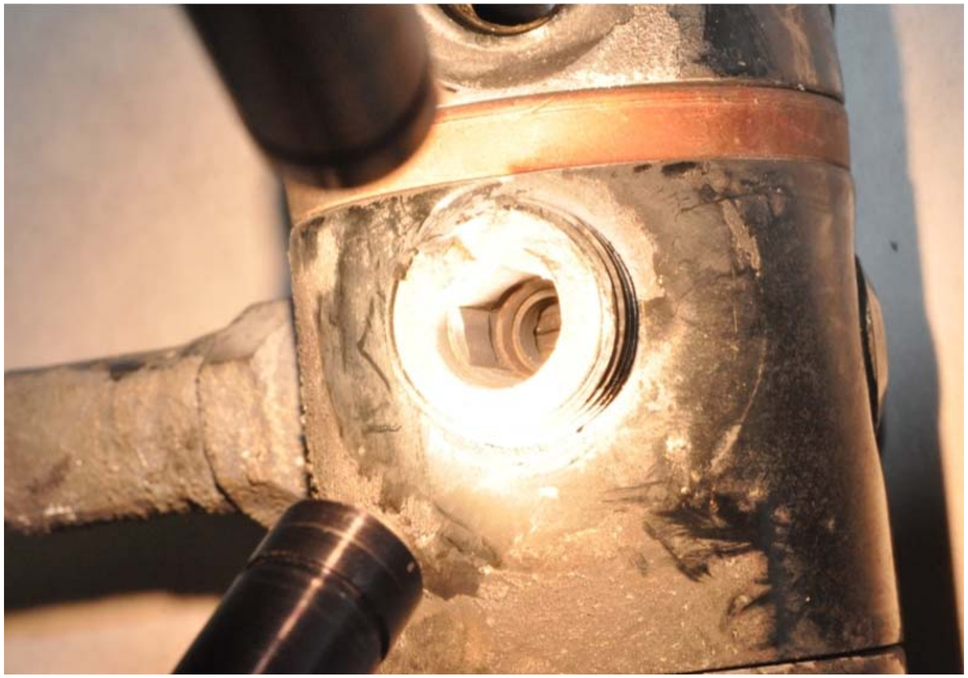


HP
12008135
HP











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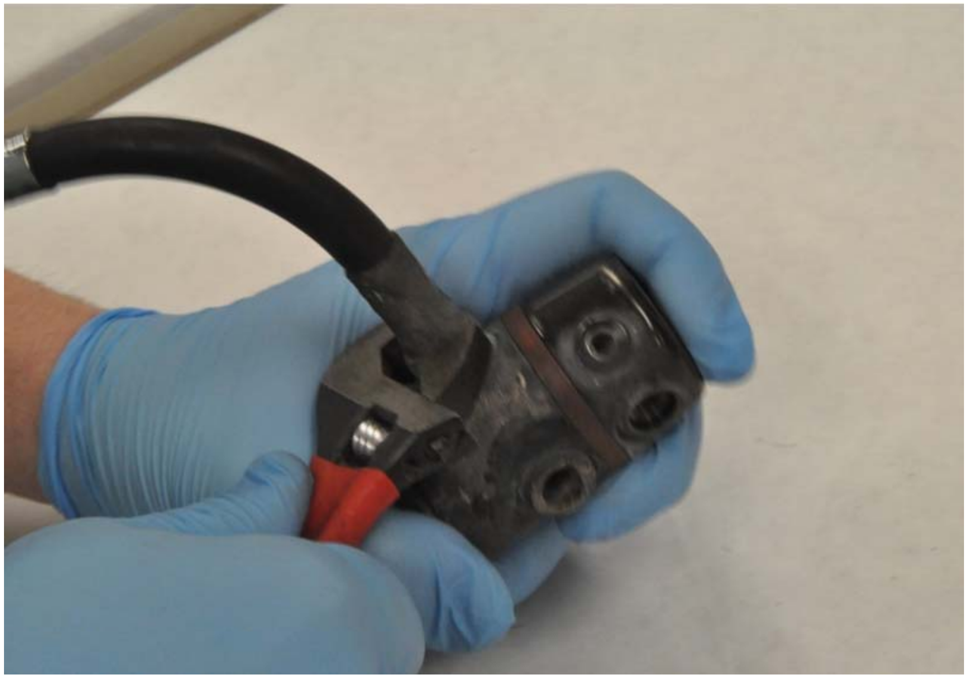


HP


HP


HP


HP





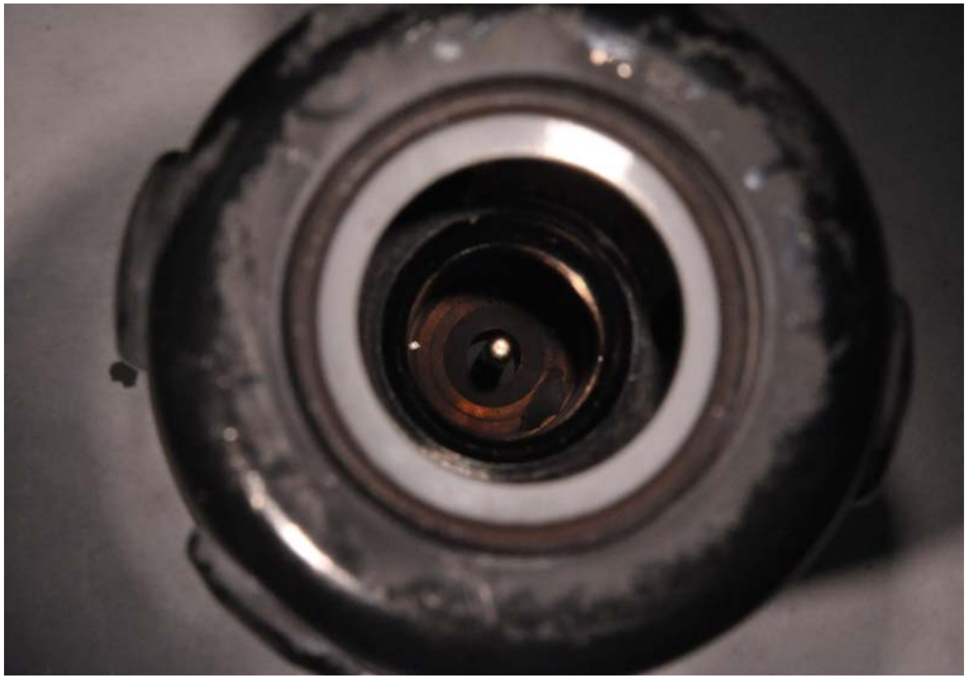






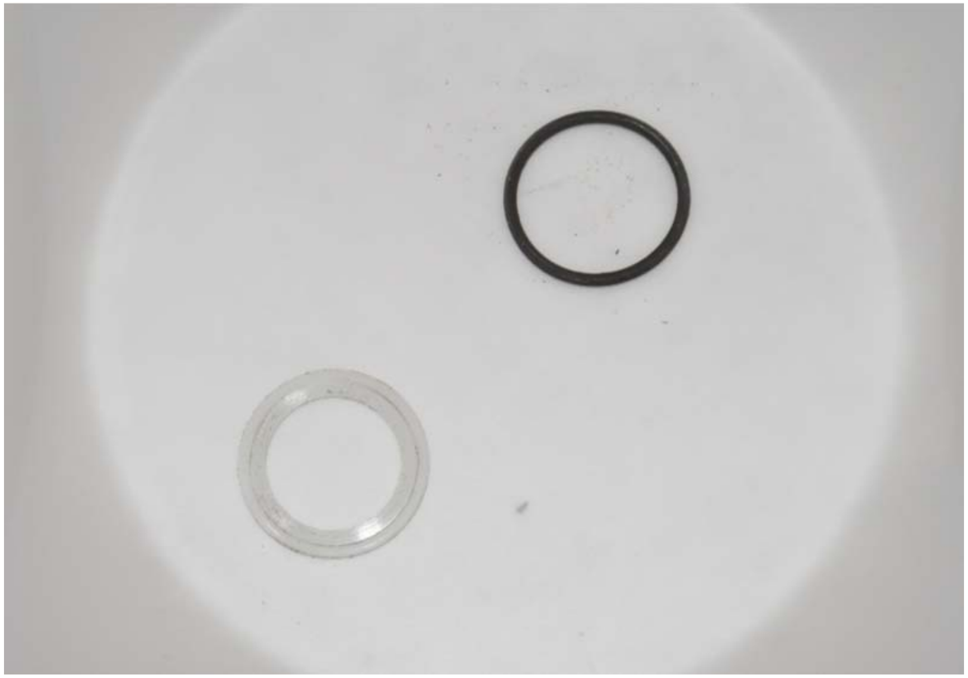


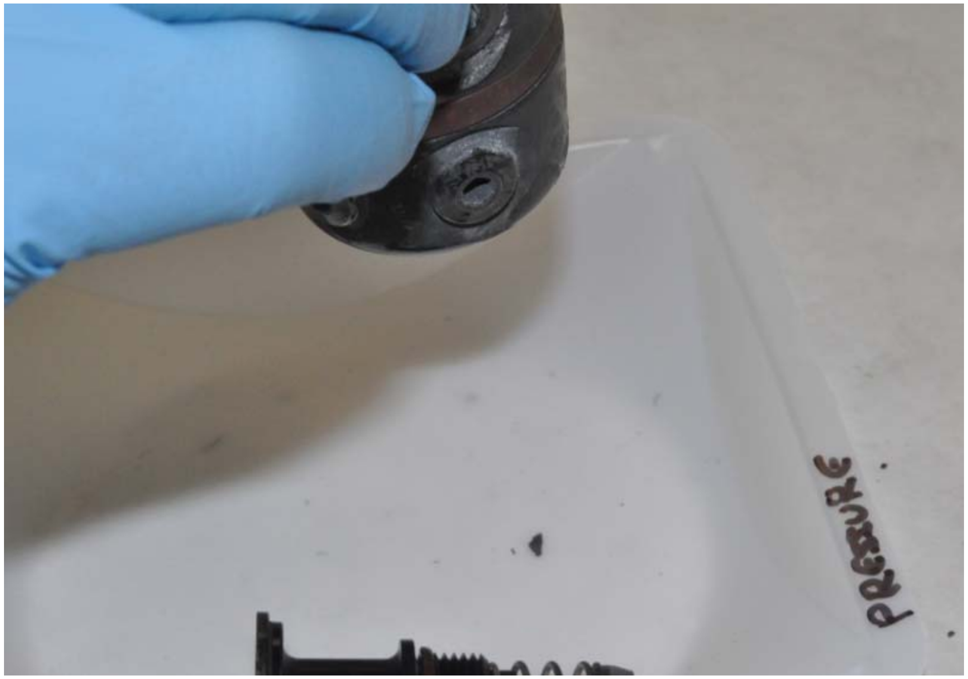









PRESSURE

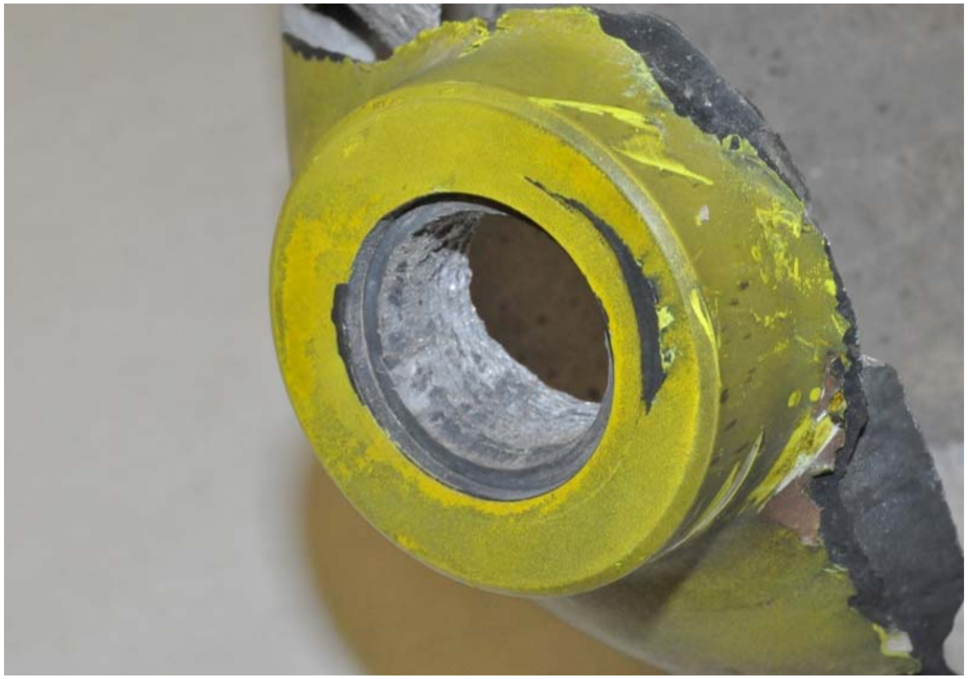


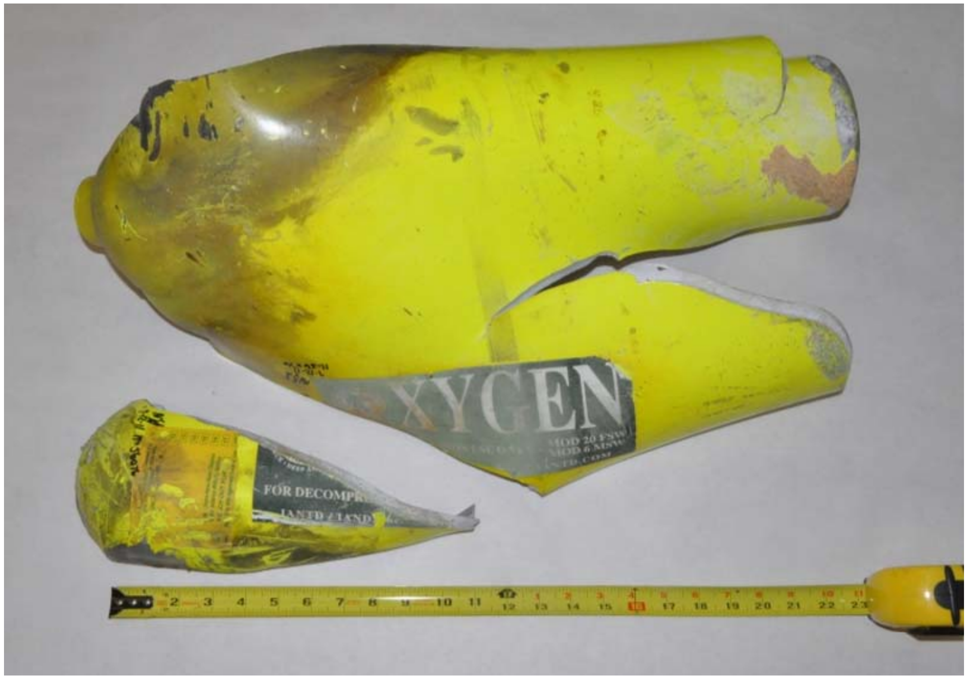










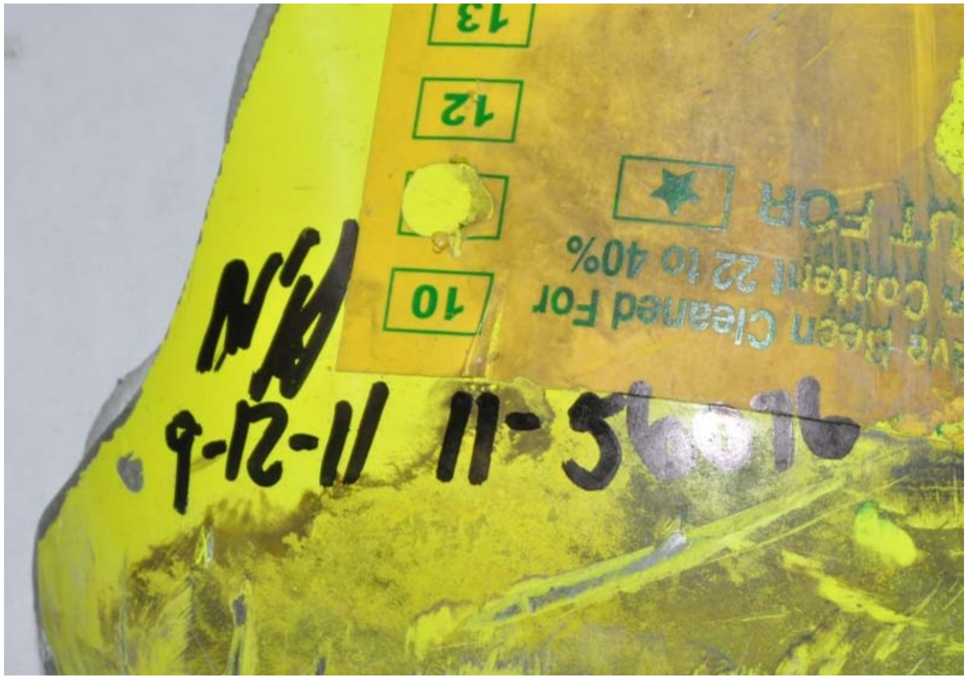


XYGEN

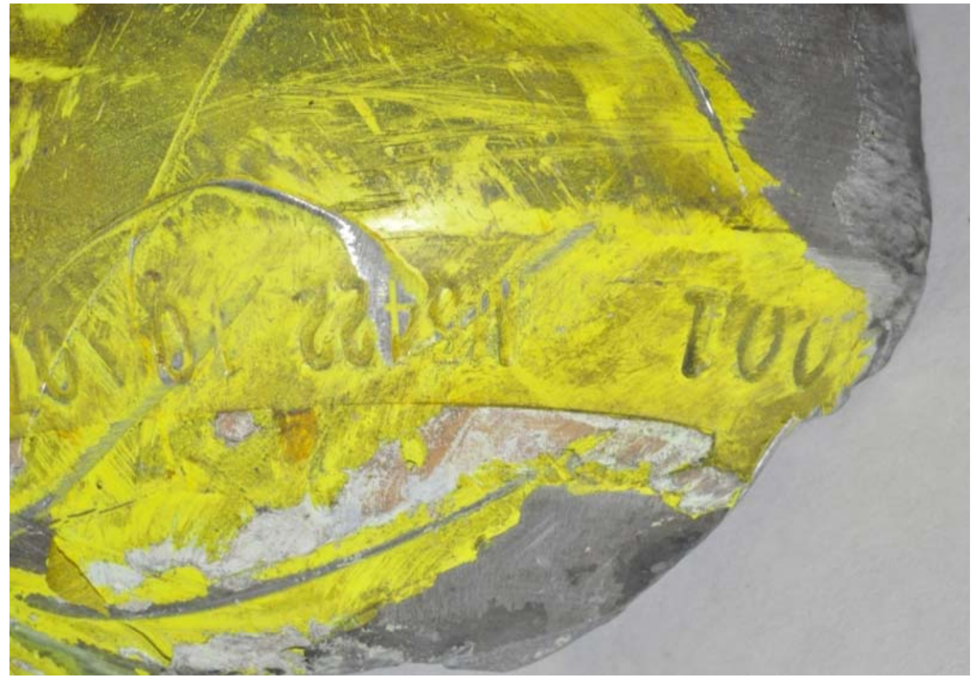

FOR DECOMPRE
IANTD / IAND, Inc.
XYG

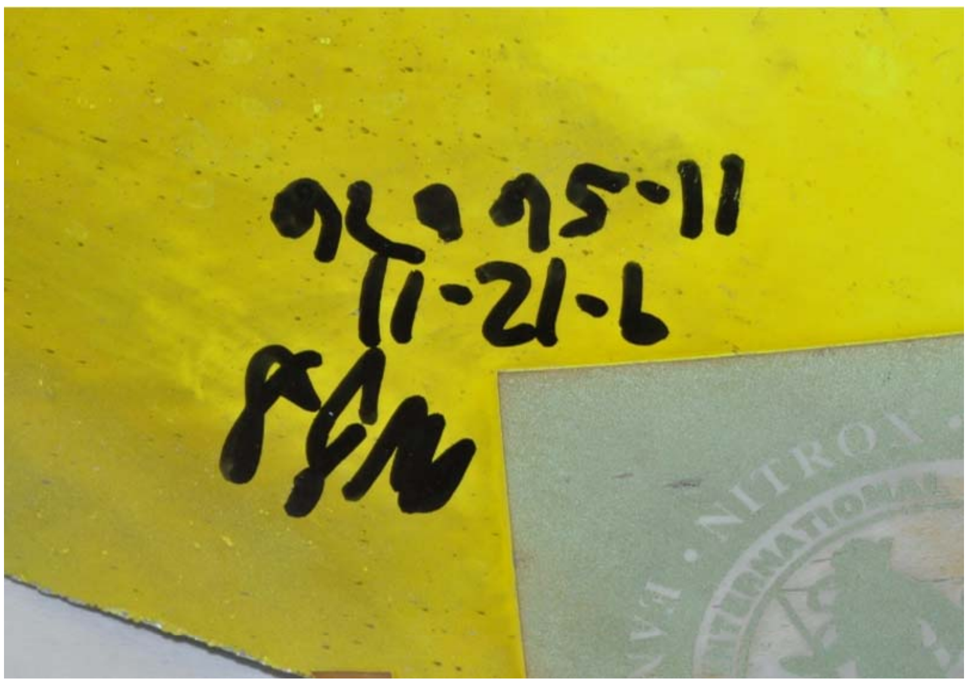

FOR DECOMPRE
IANTD / IAND, Inc.

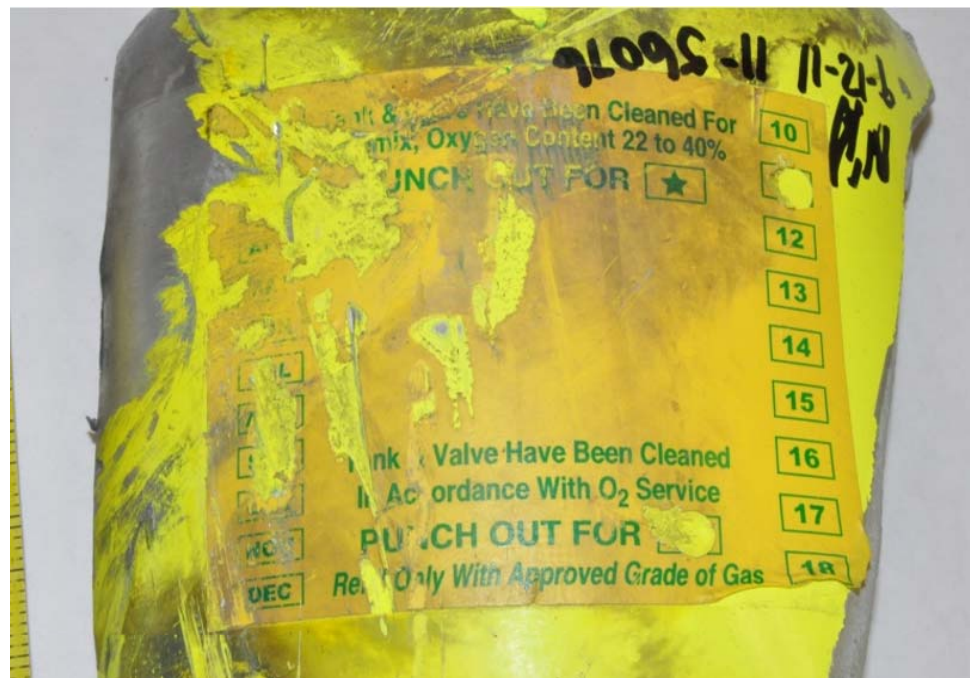

XYGEN
MOD 20 FSW
MOD 6 MSW
FOR DECOMPR

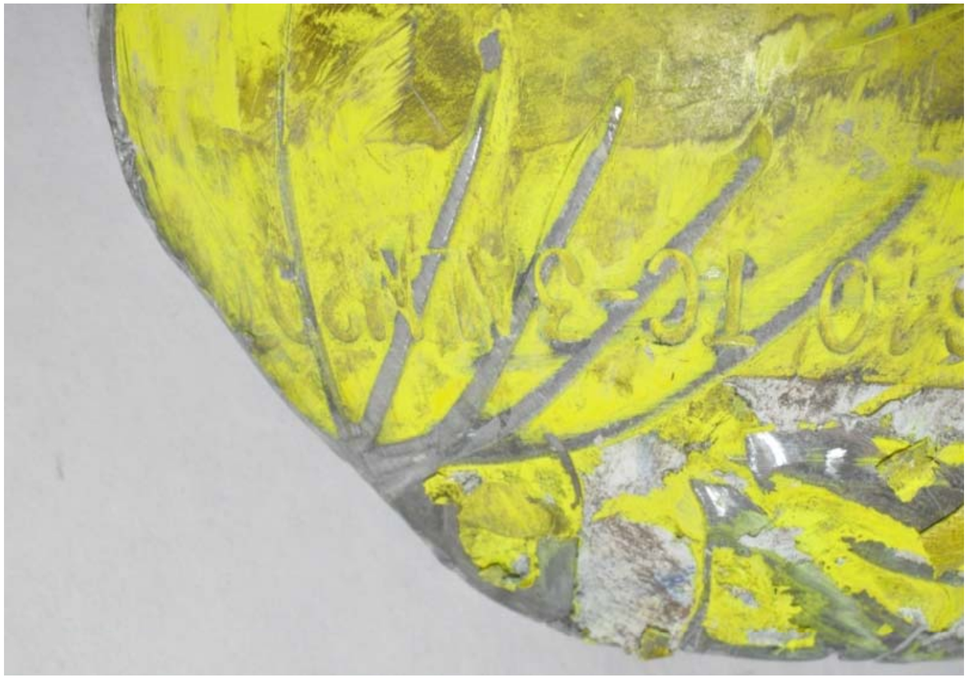

XYGEN
MOD 20 FSW
MOD 6 MSW
IANTD.COM
DECOMPRE
TD / IAND, Inc.

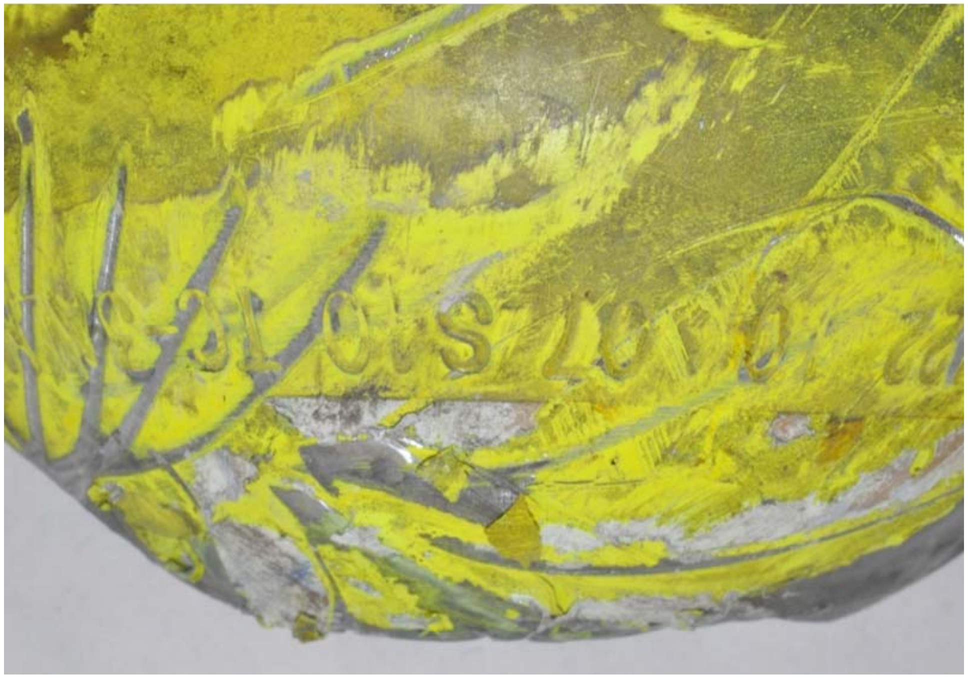

10
12
13
Content 22 to 40%
Cleaned For




NITRO


Cleaned For
Content 22 to 40%
10
12
13
14
15
16
17
Valve Have Been Cleaned
ordance With O2 Service
PUNCH OUT FOR
Only With Approved Grade of Gas
DEC



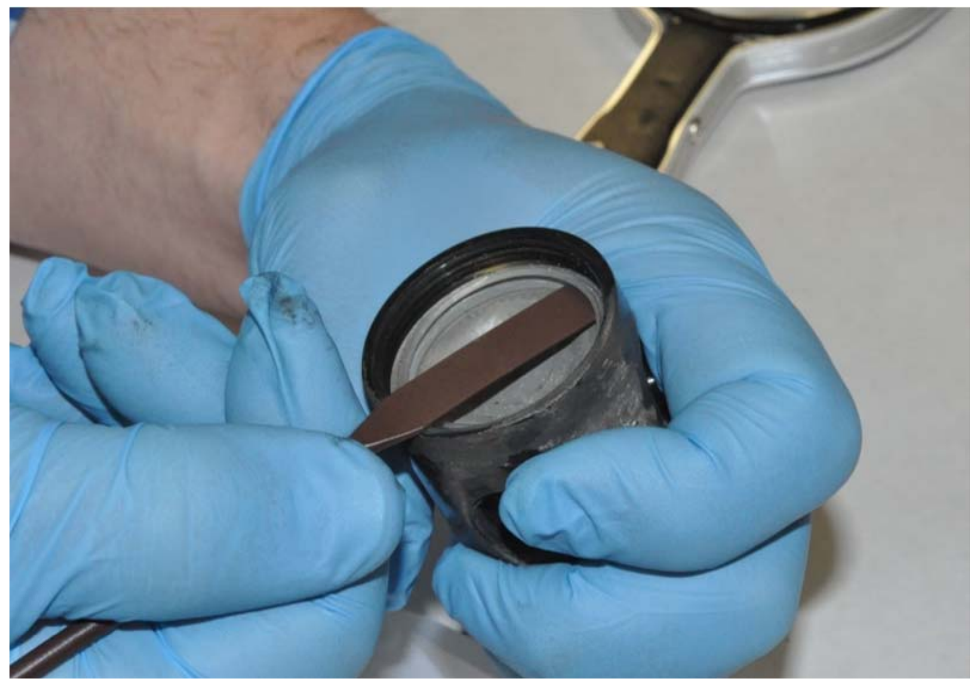








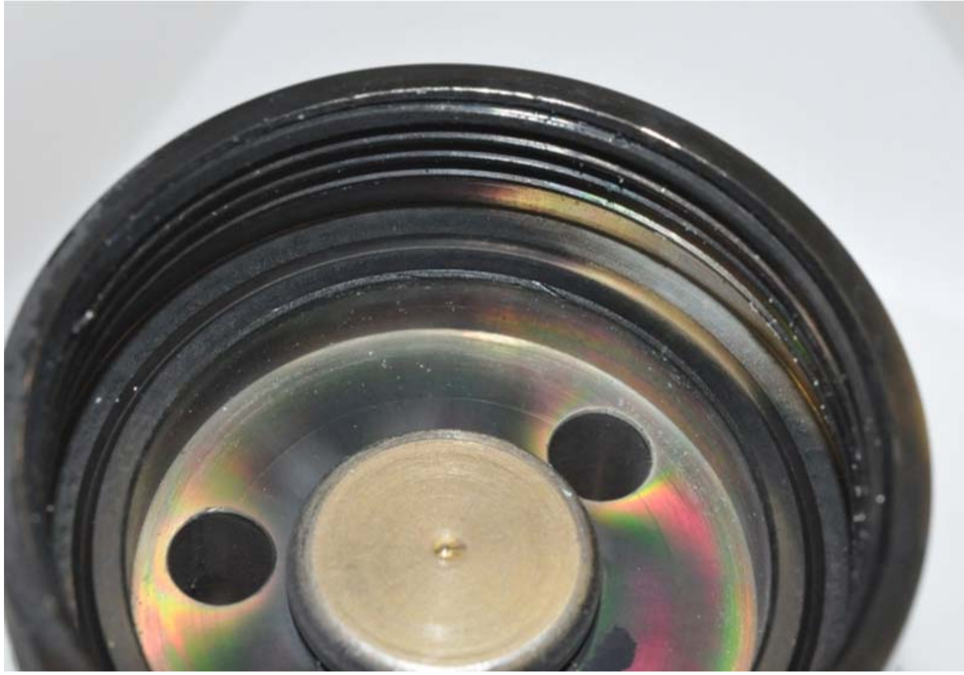

REGULAT







C1248/1





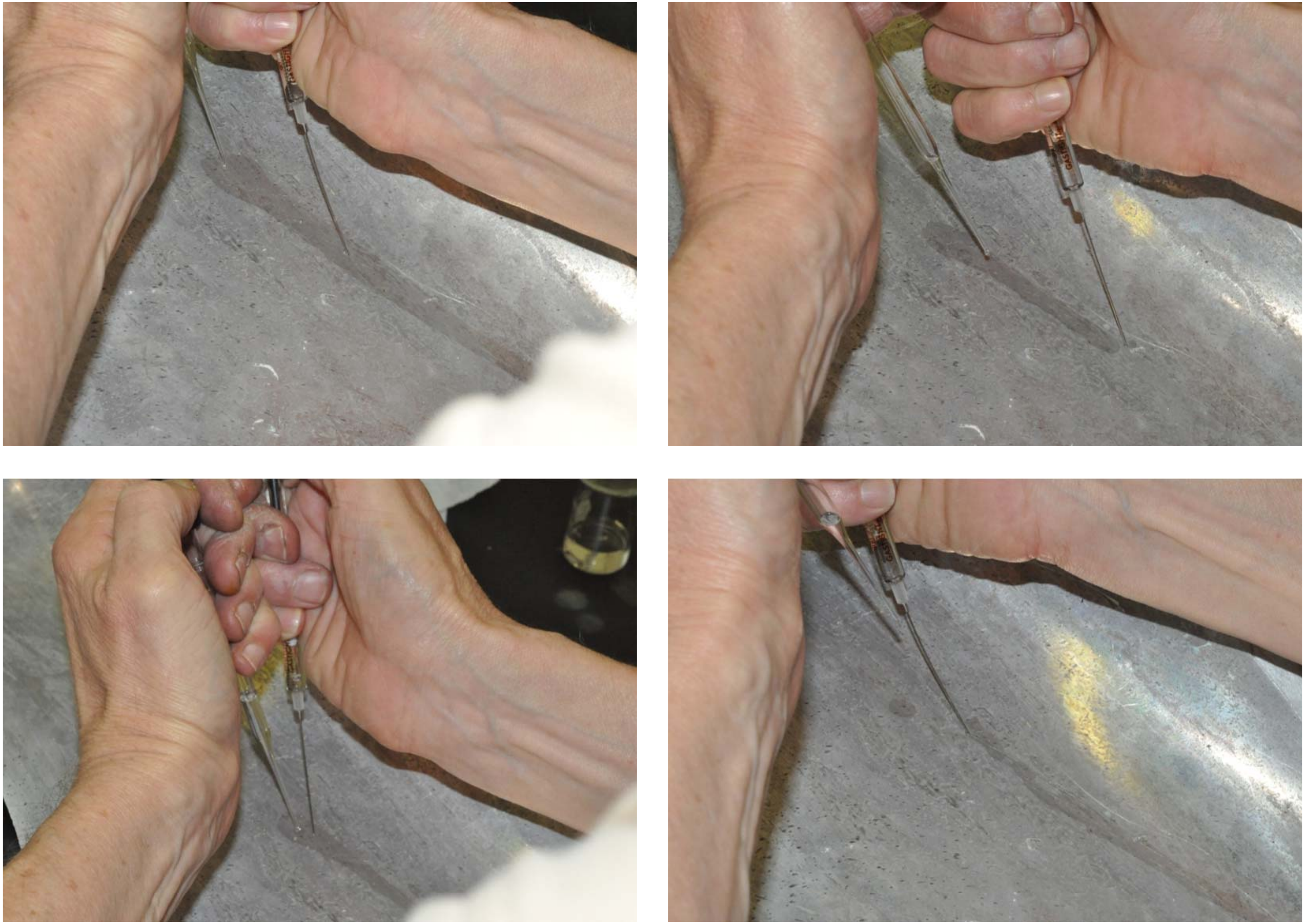


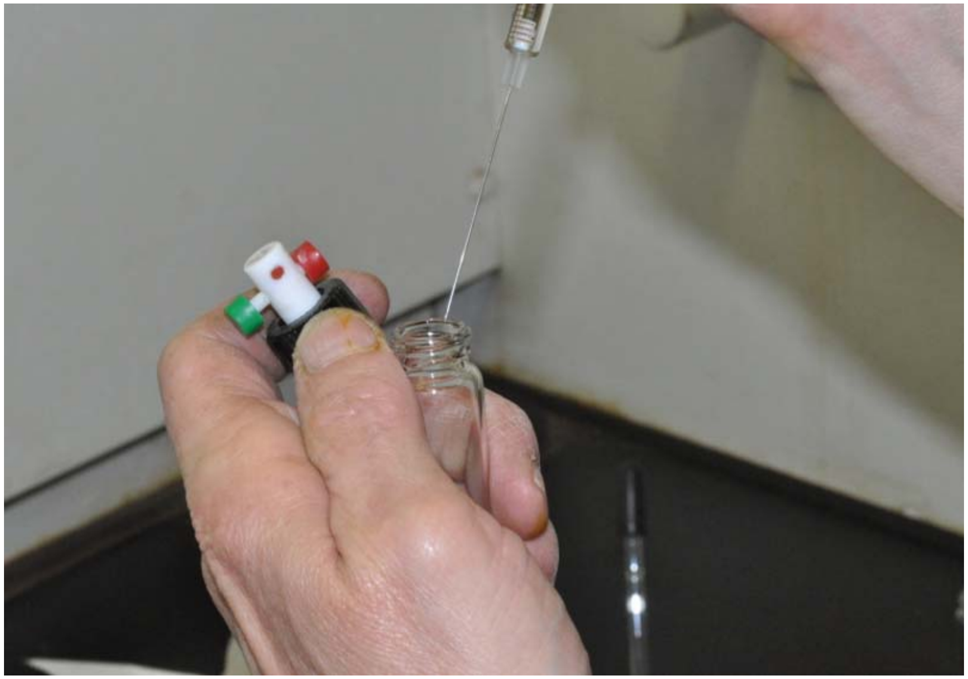






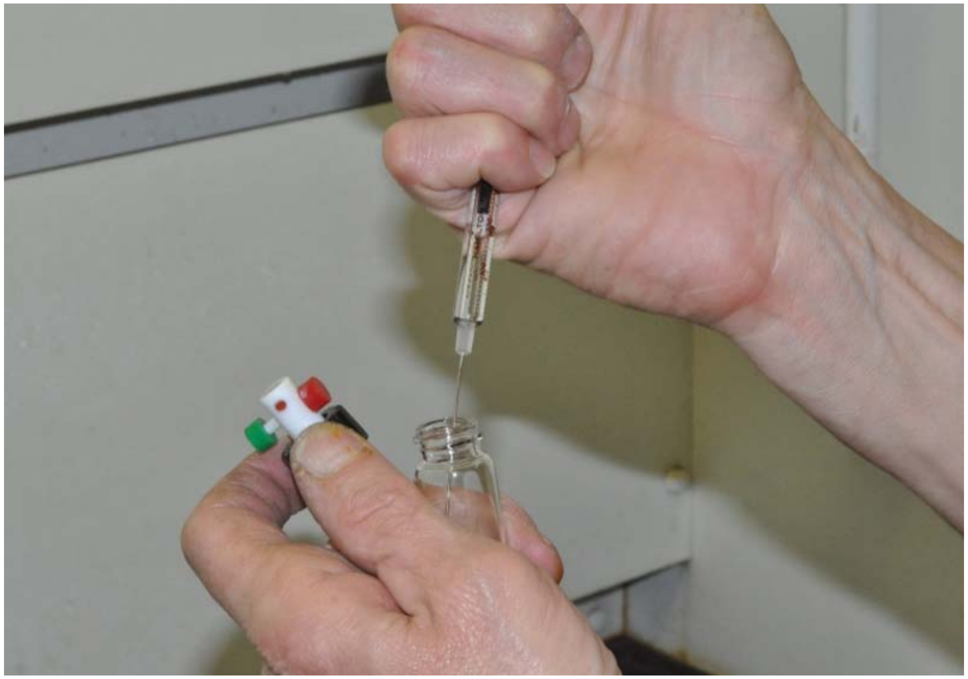


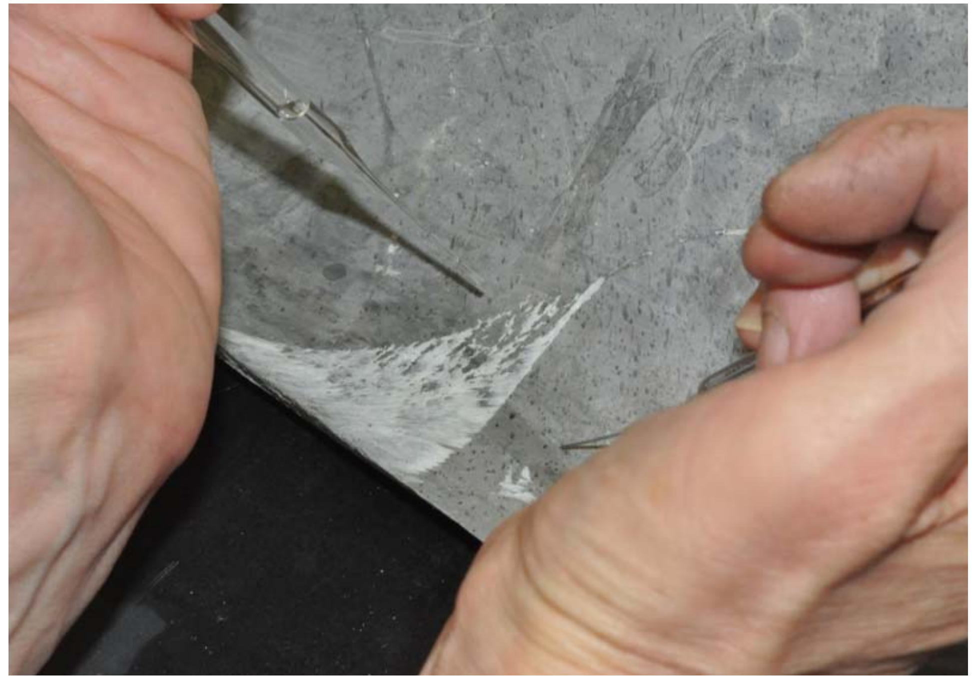


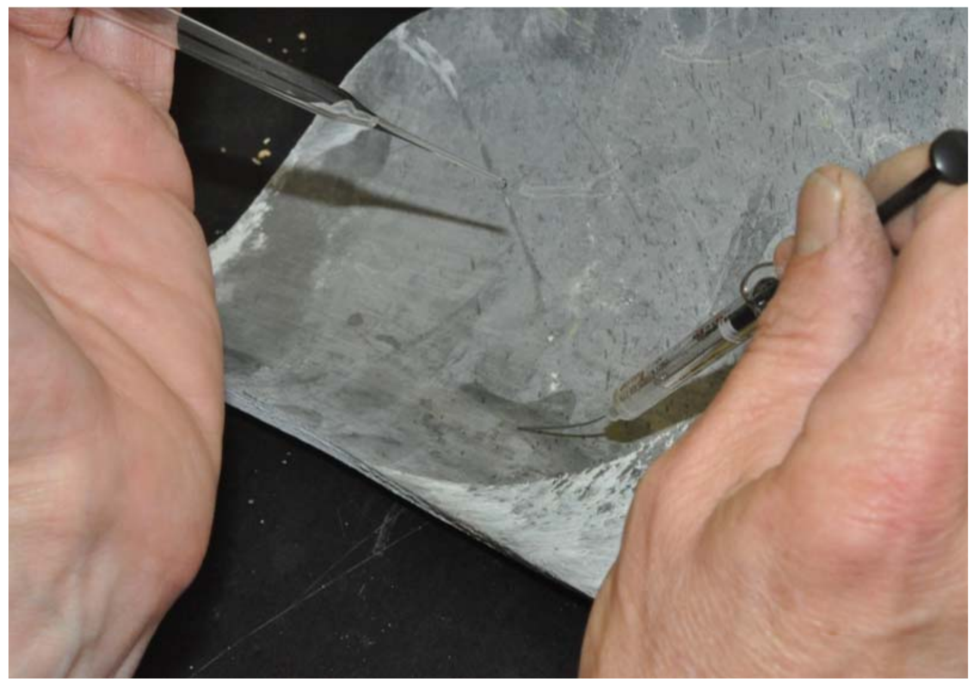




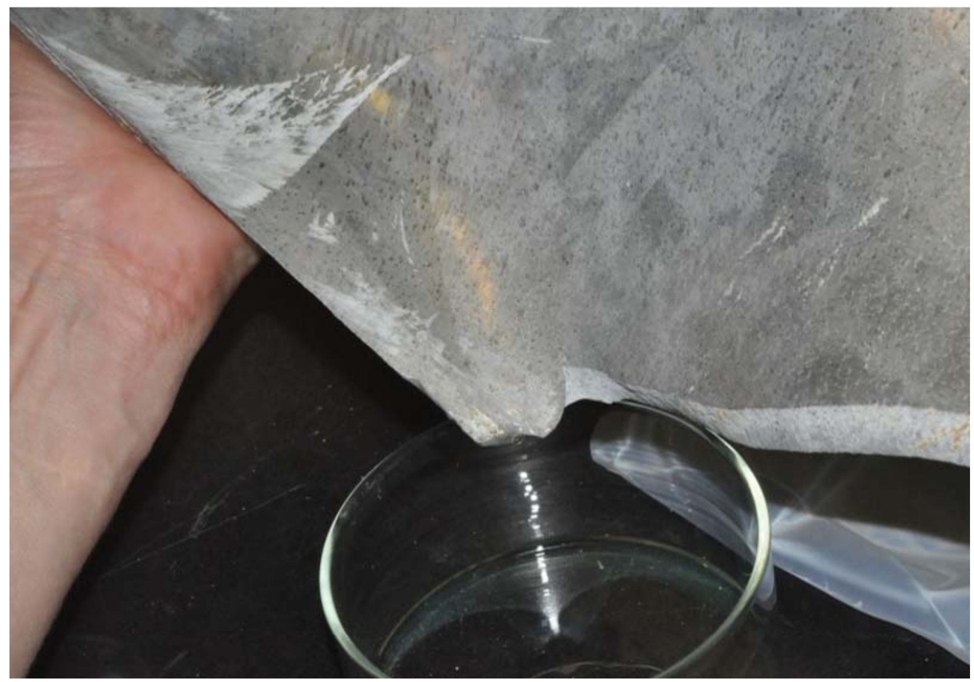


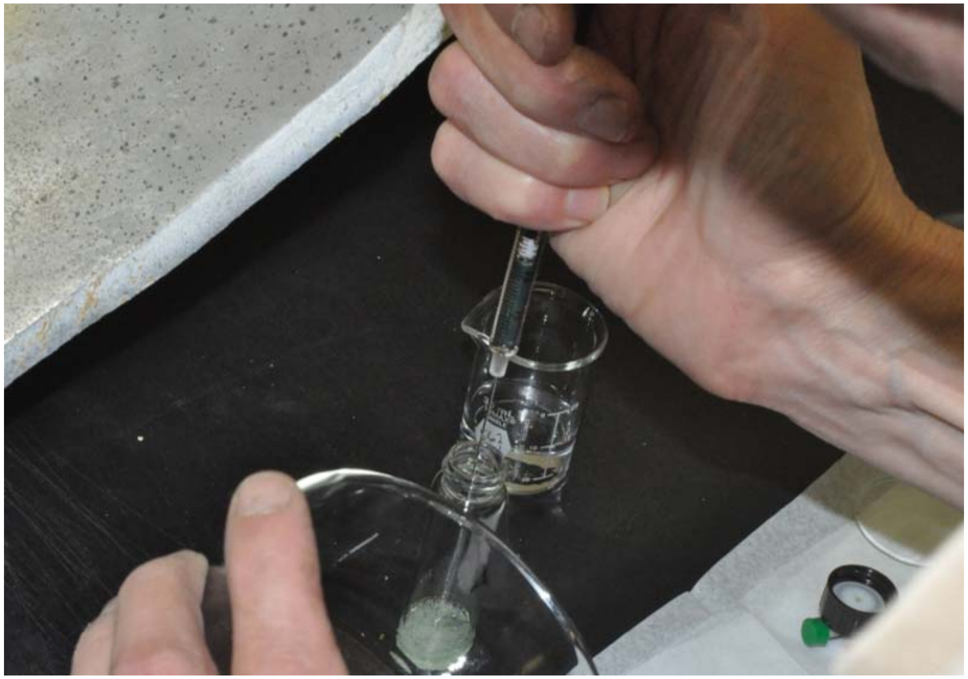
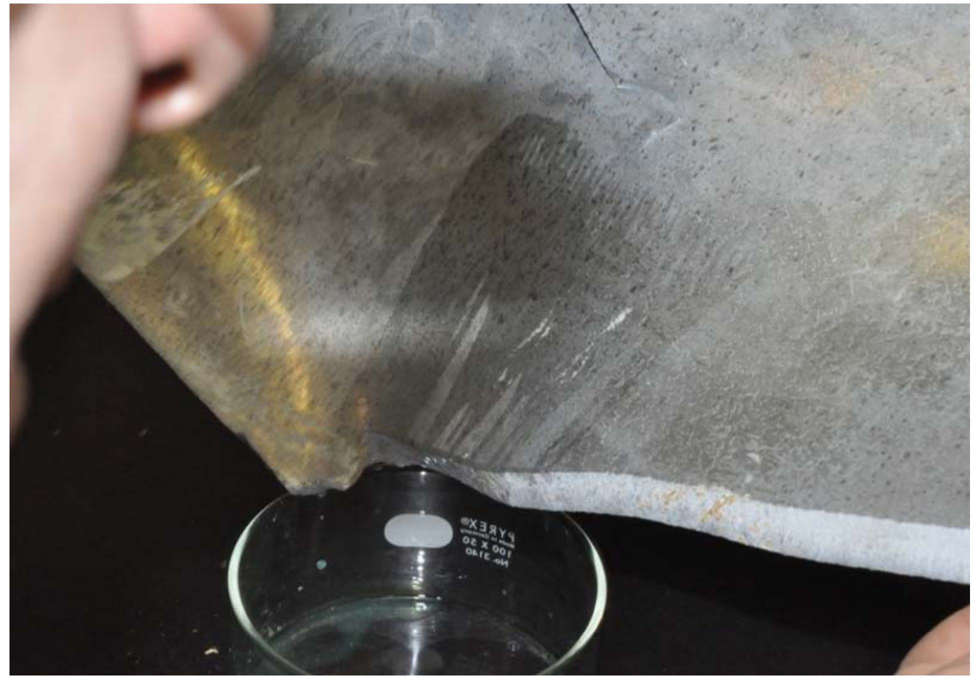


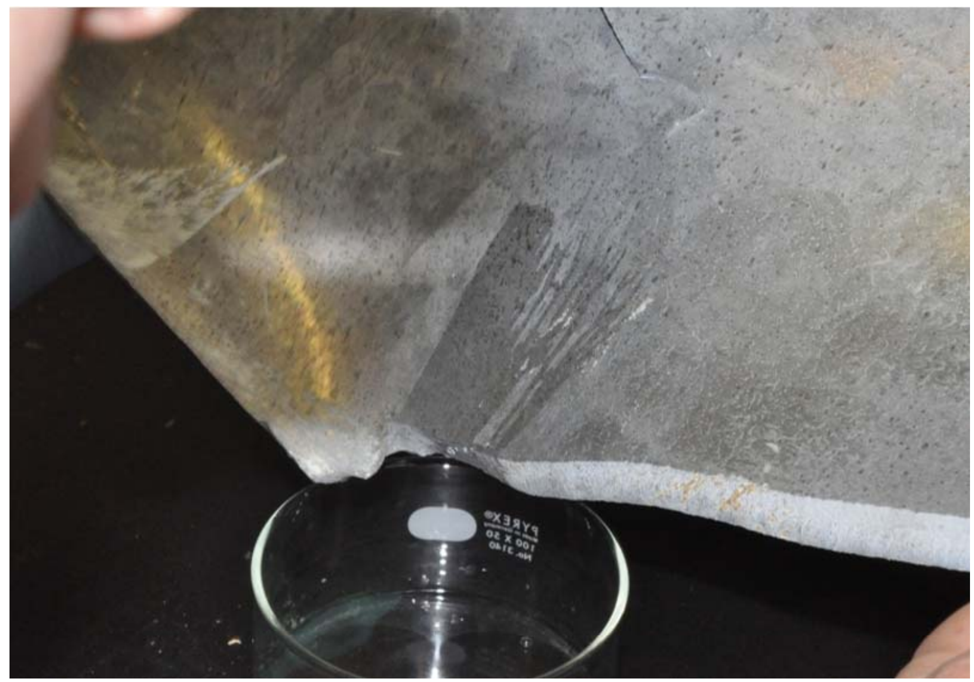



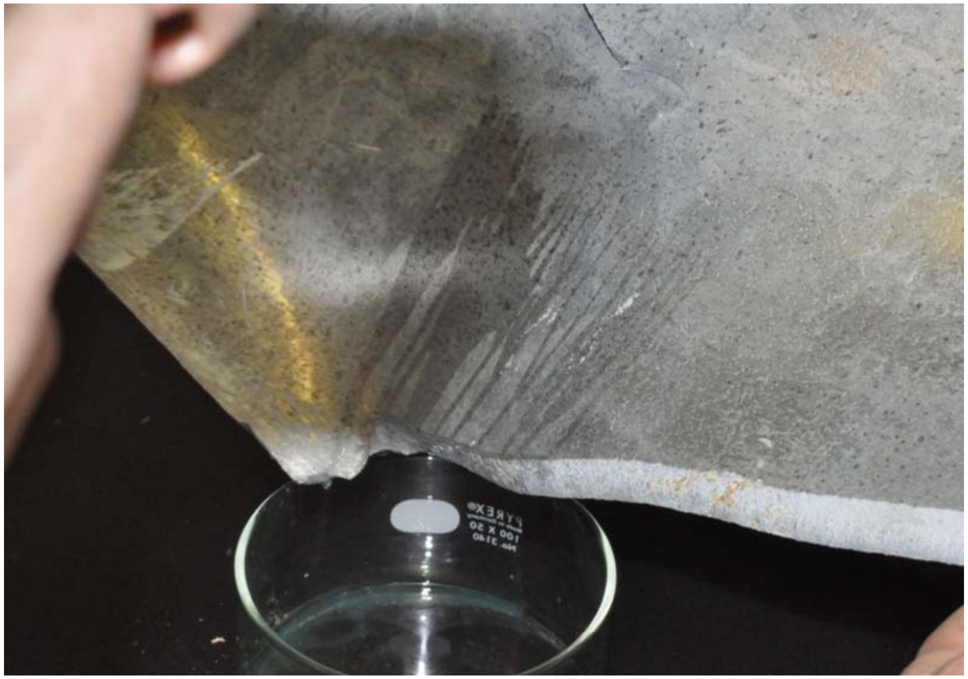


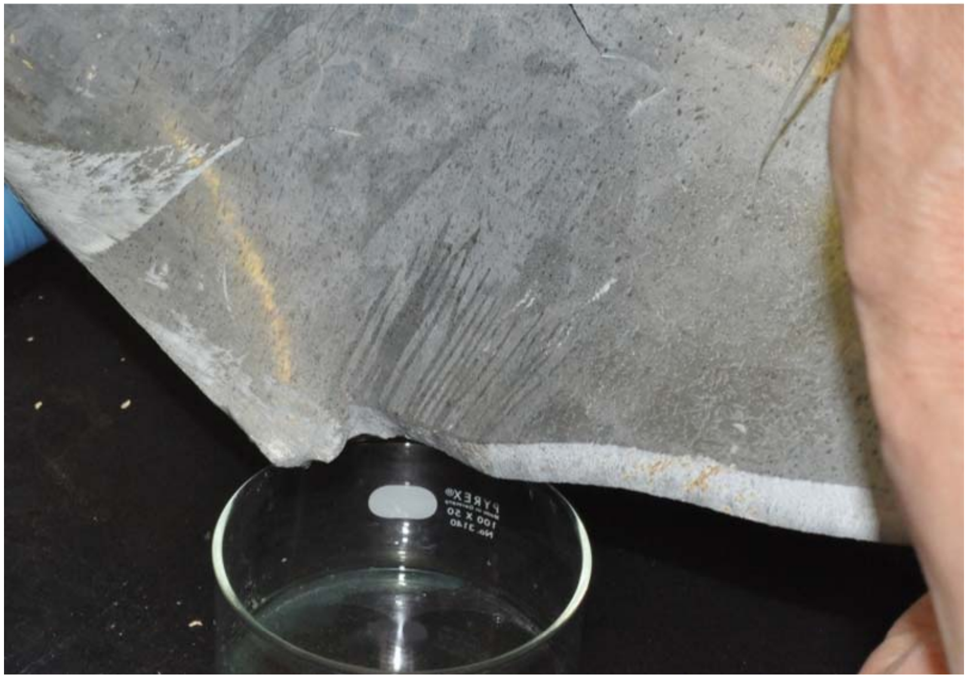
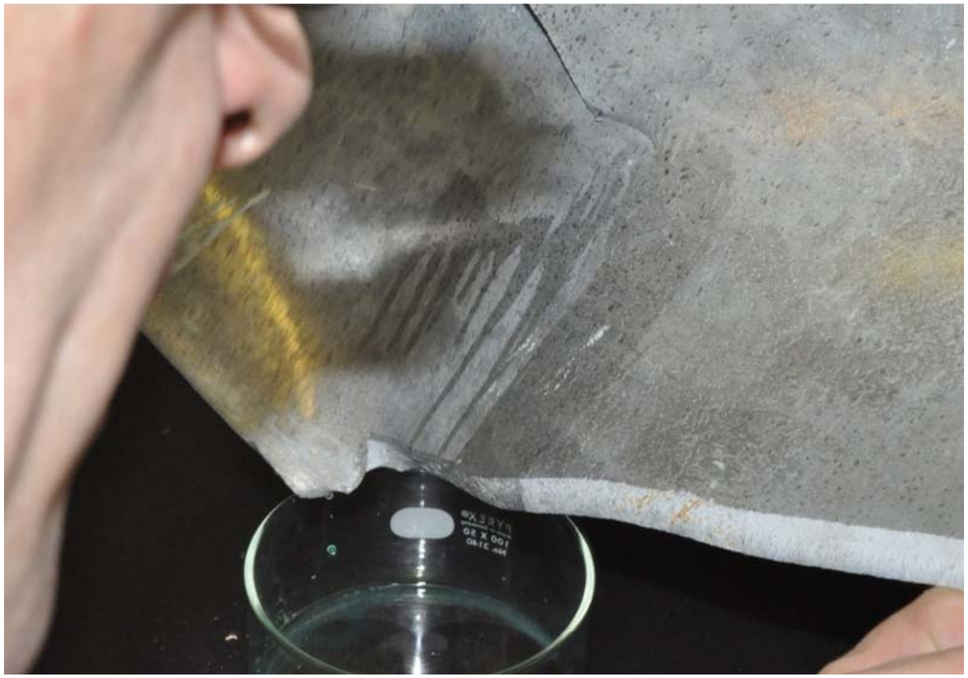


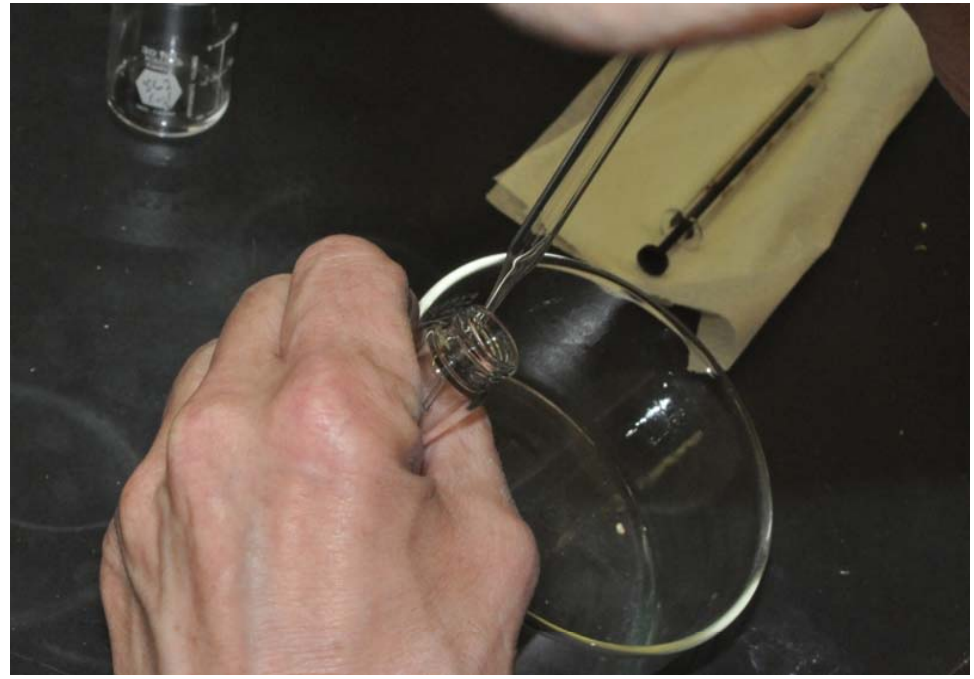



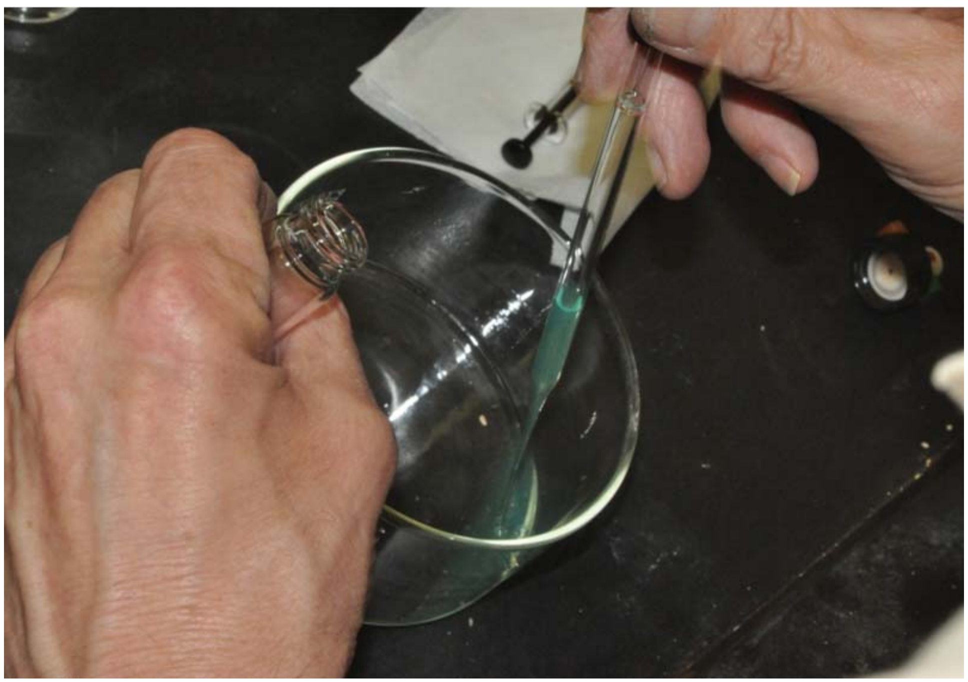



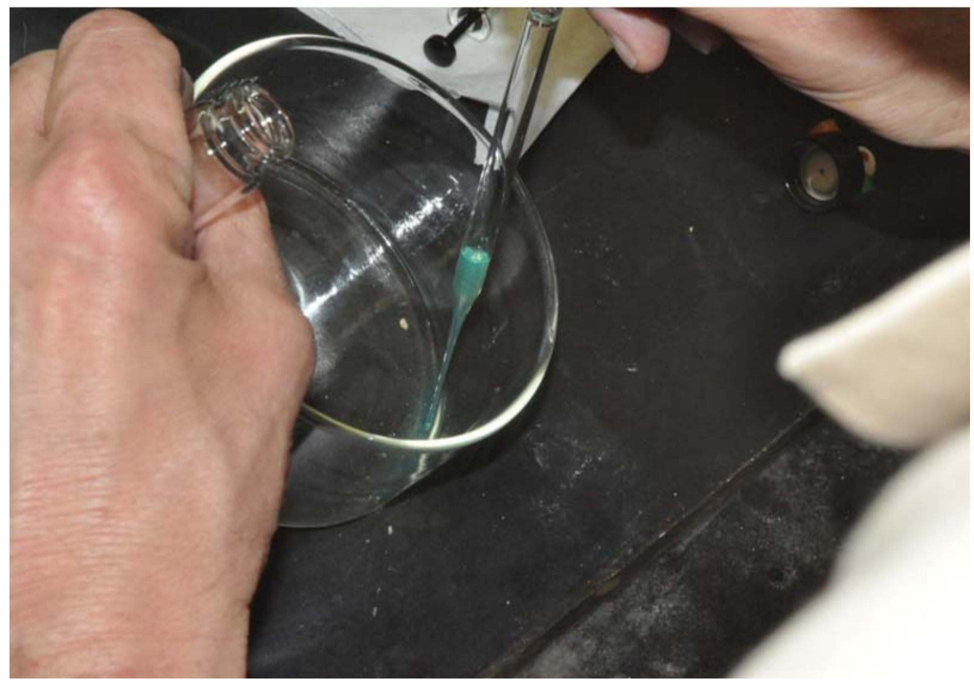




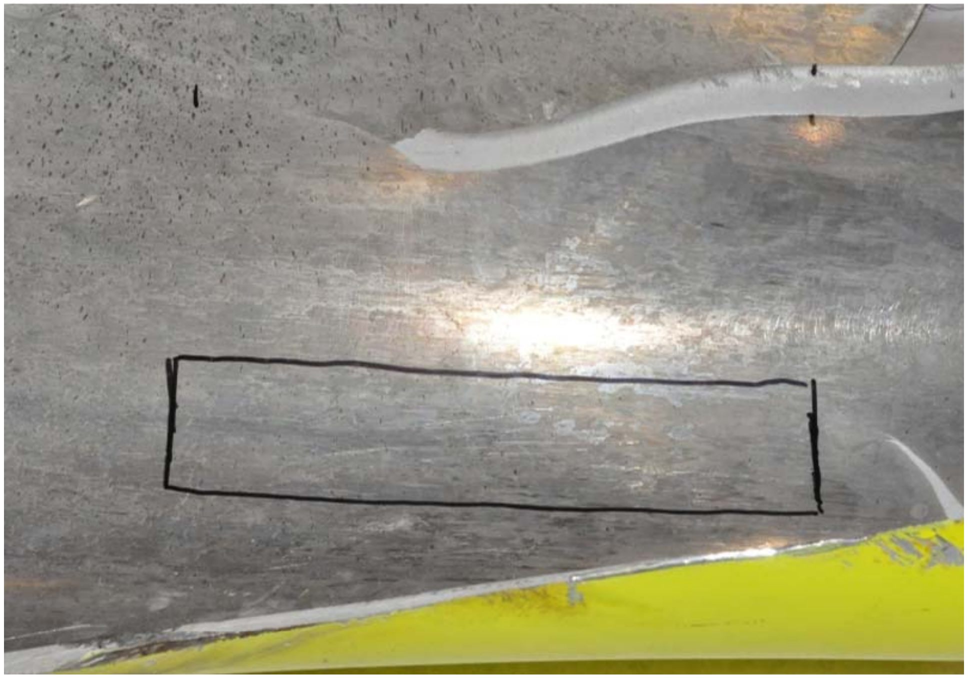





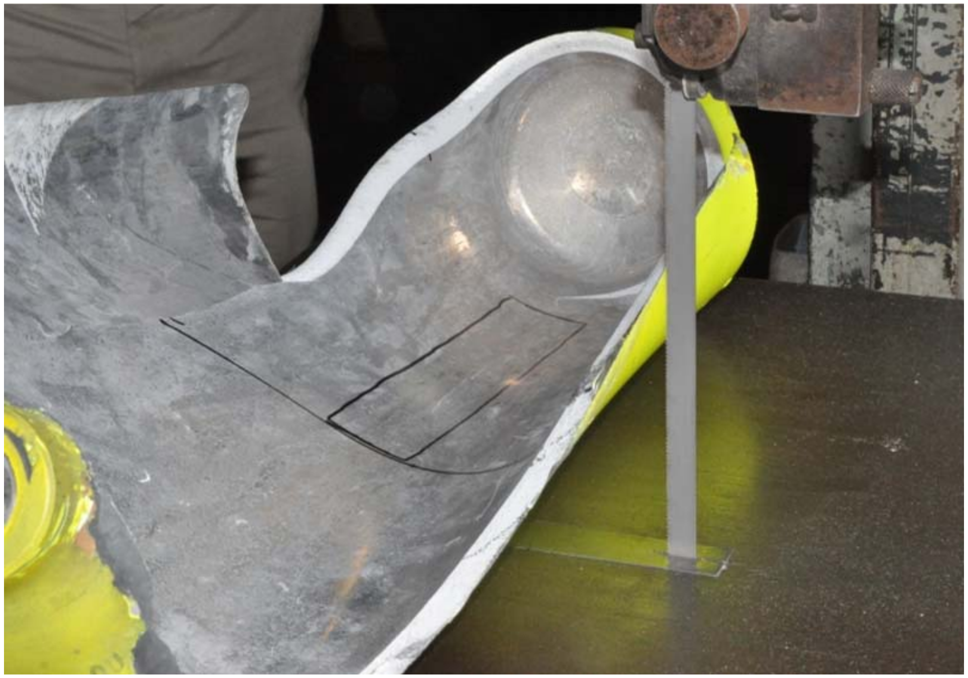





0.01mm
Mitutoyo
MUT372
Anamet, inc.
INCHES











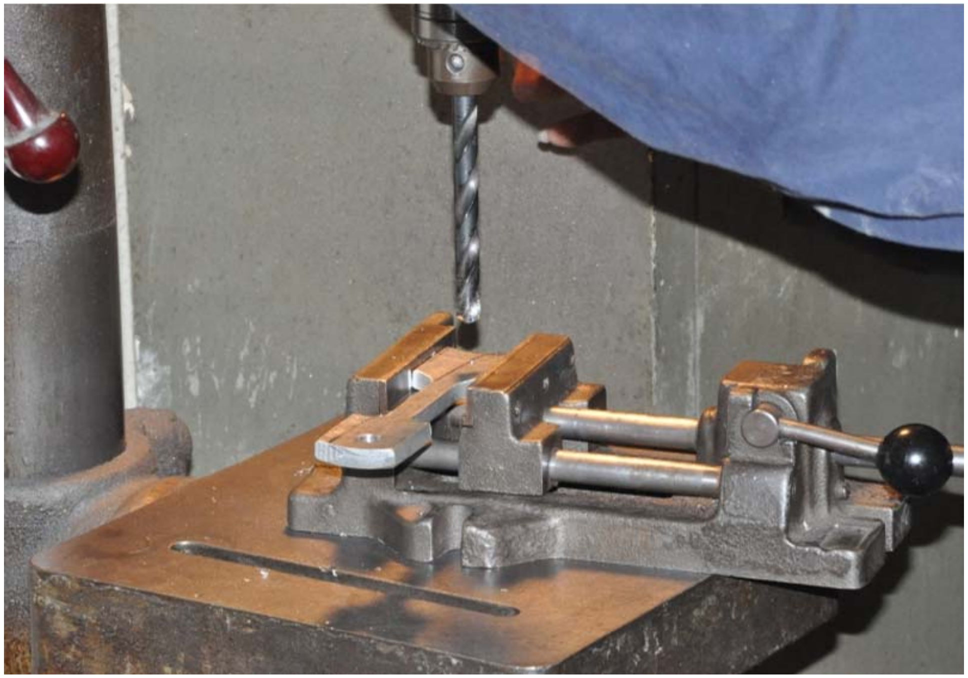




B
C


A

B







WARNING
KURT


WARNING
KURT


WARNING
KURT

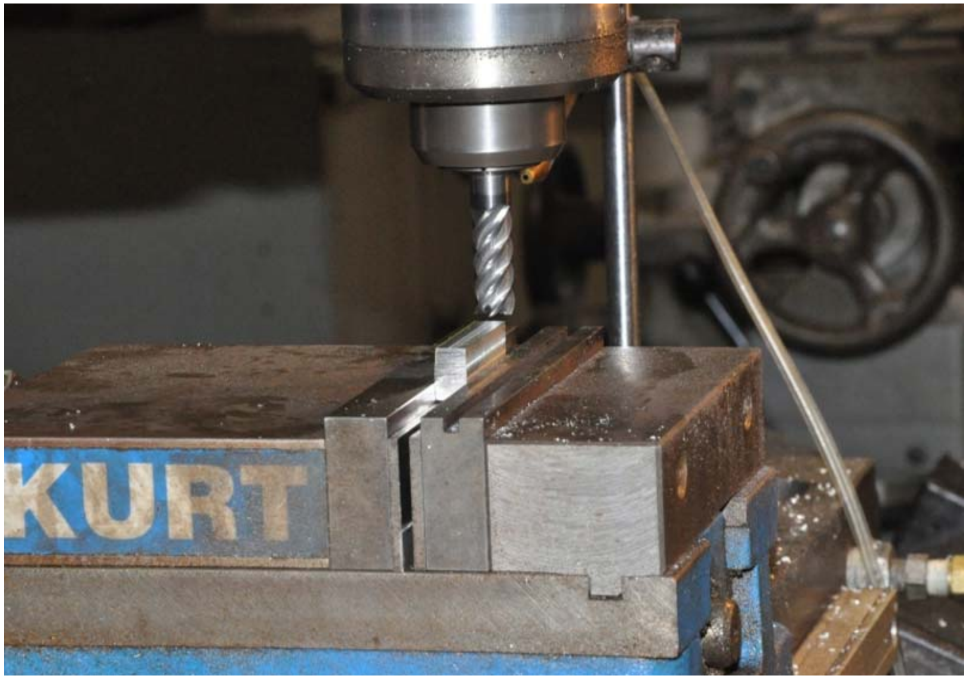

WARNING
KURT


KURT

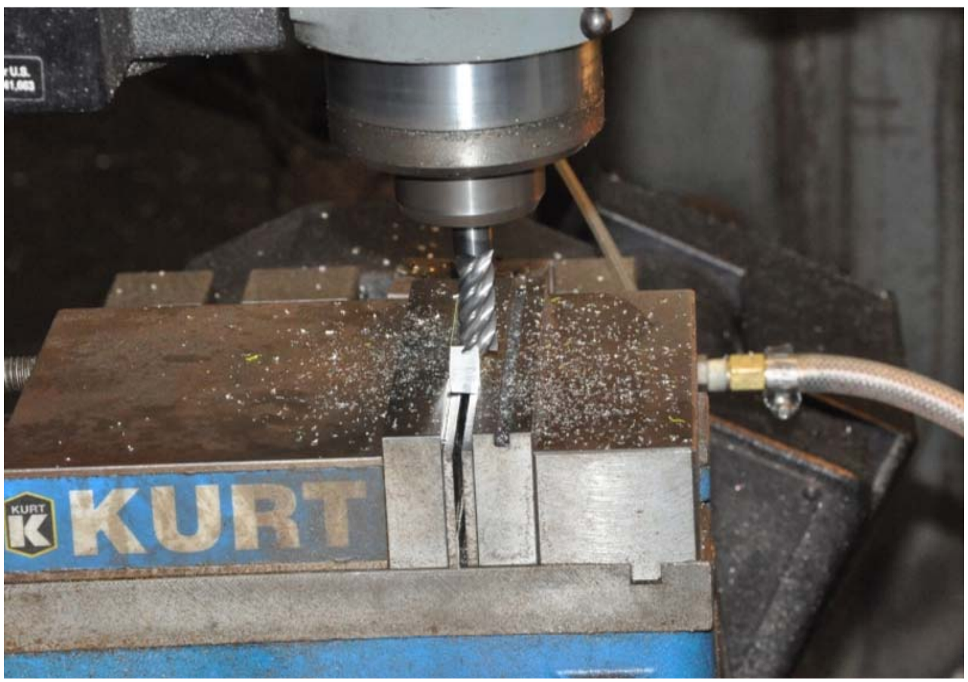

KURT


KURT


KURT


KURT


KURT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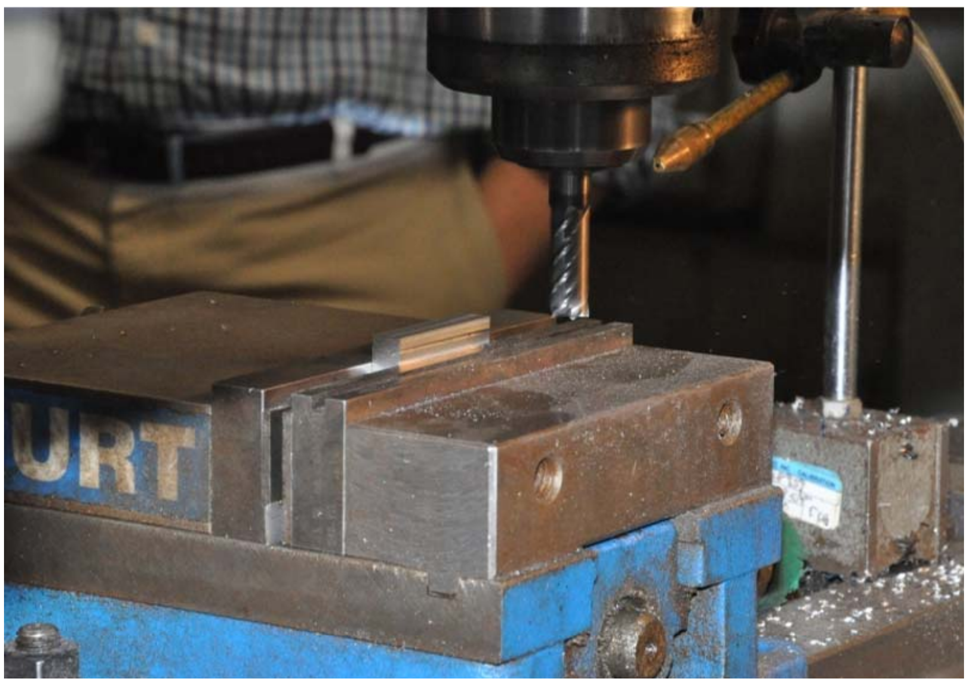
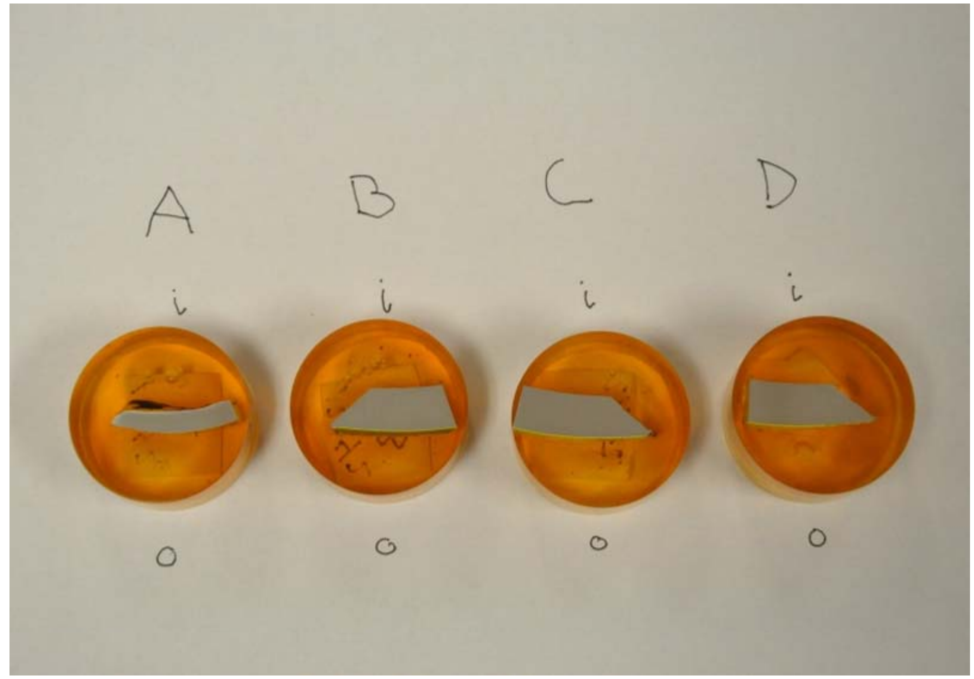
WARNING


1 676 2 STAINLESS STEEL 3 GENERAL 4 5


URT


1 676 2 STAINLESS STEEL 3 GENERAL 4 5


1 676 2 STAINLESS STEEL 3 GENERAL 4 MADE IN U.S.A 5



A
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C
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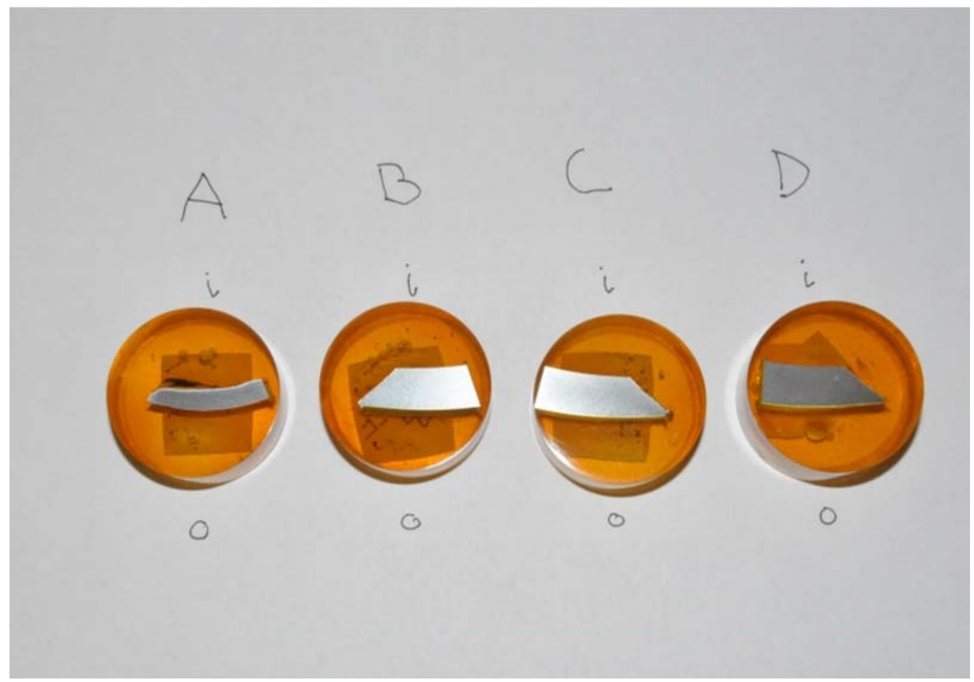

A
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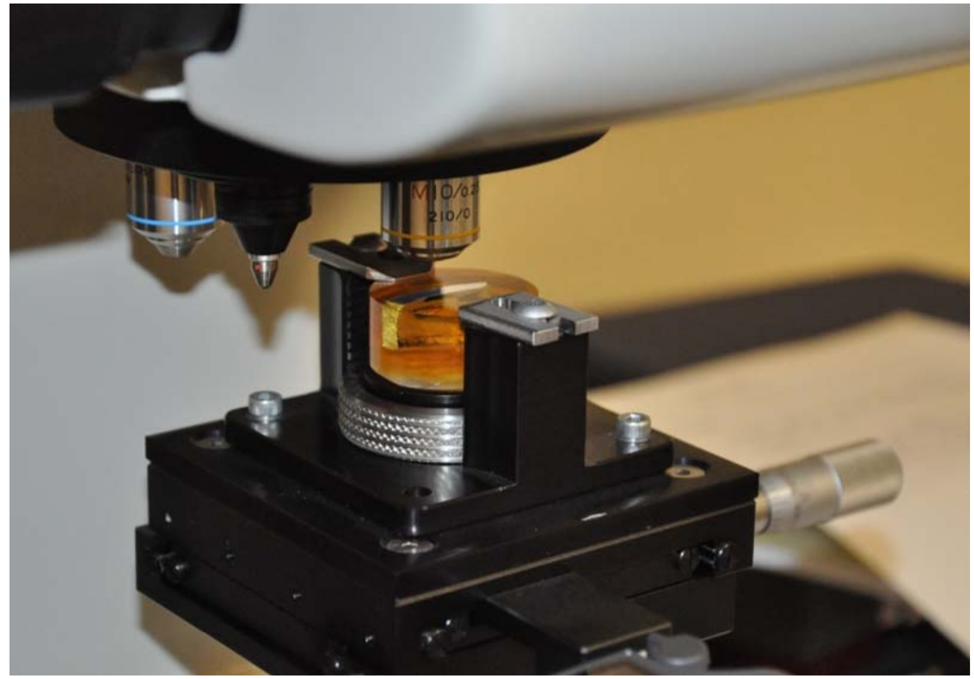


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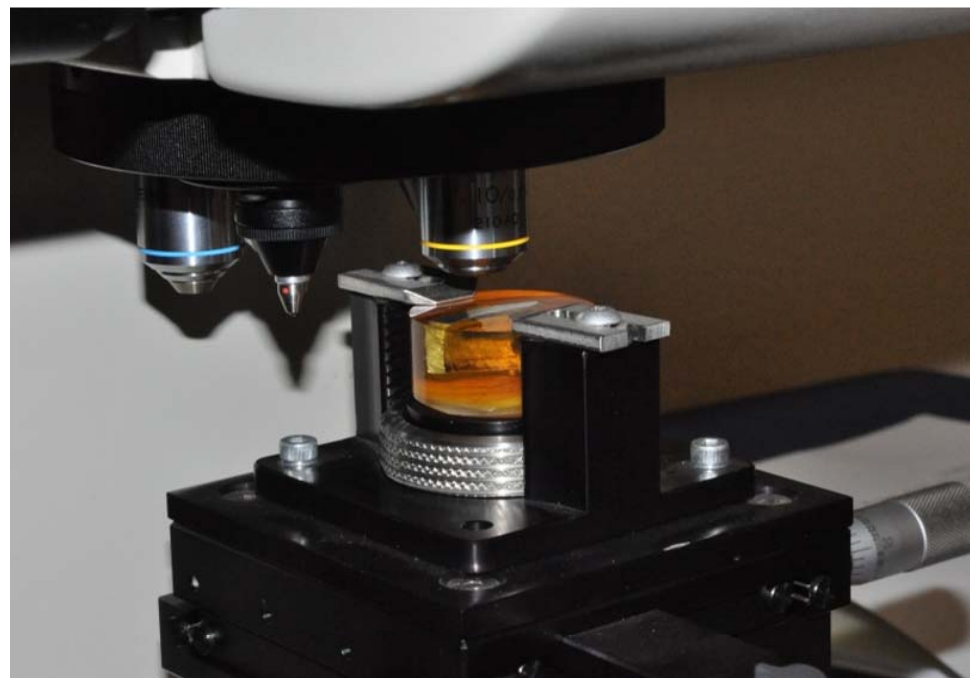


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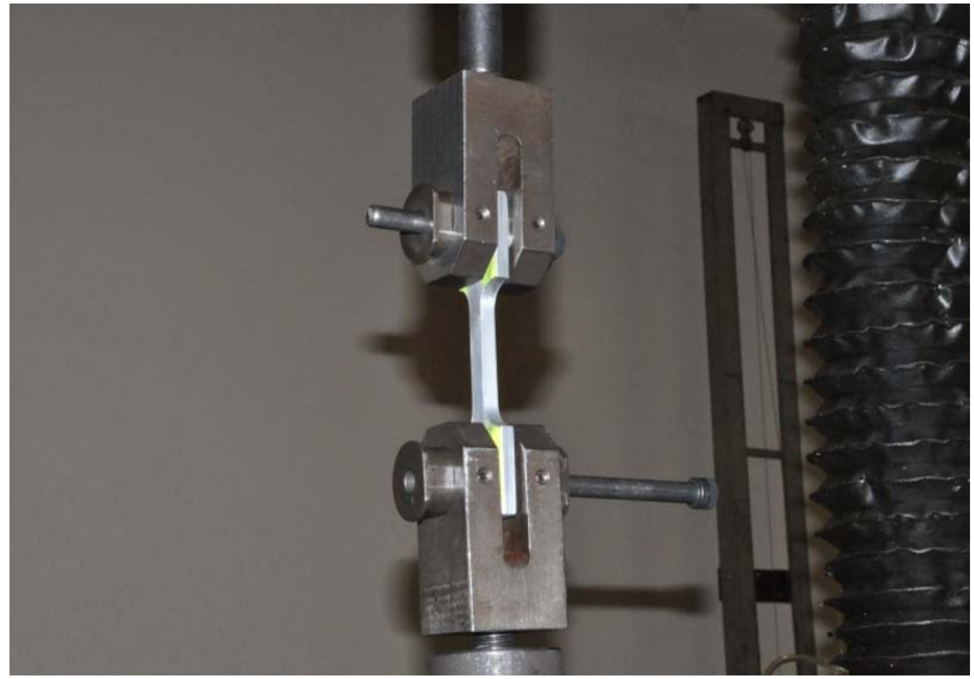

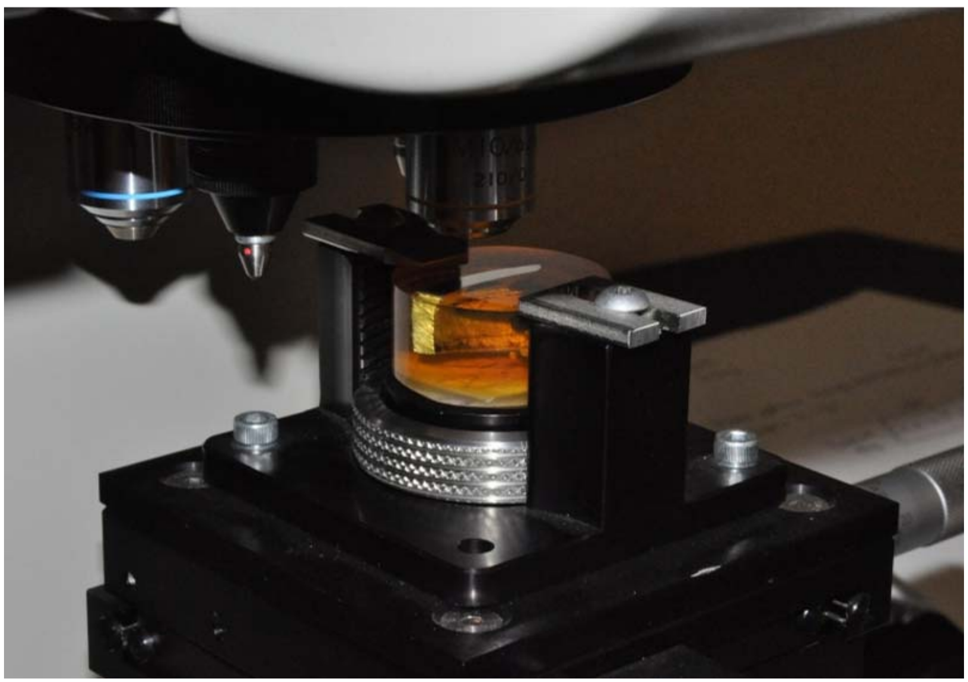

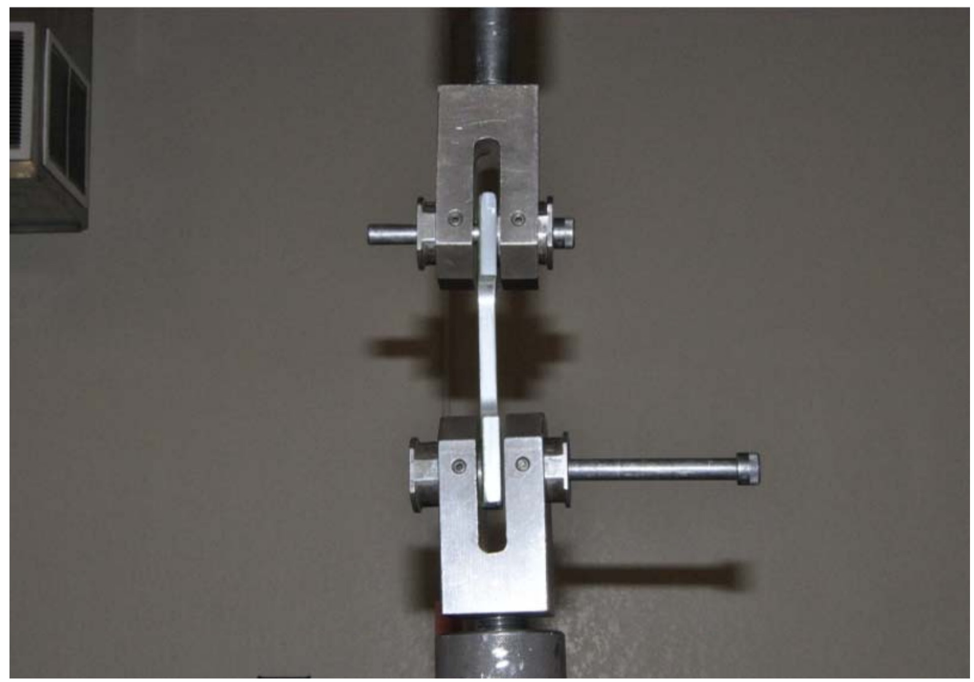

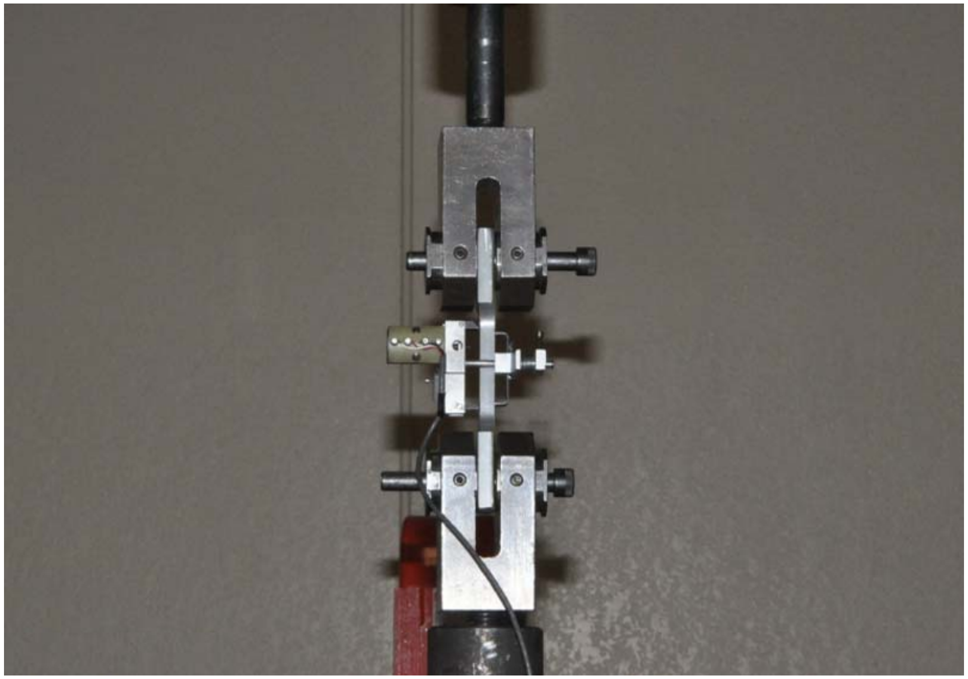
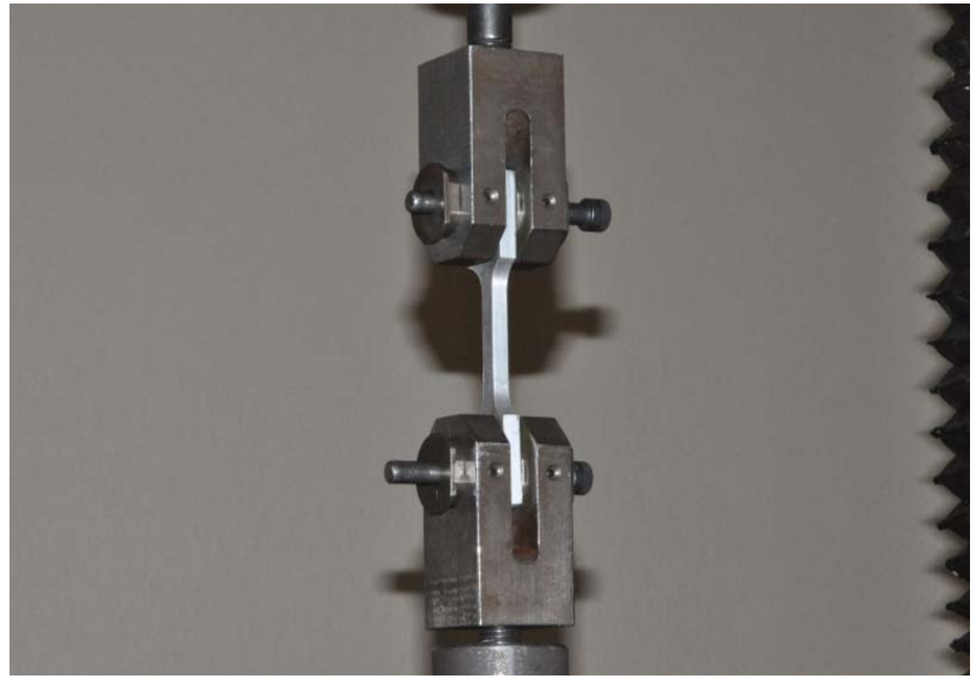
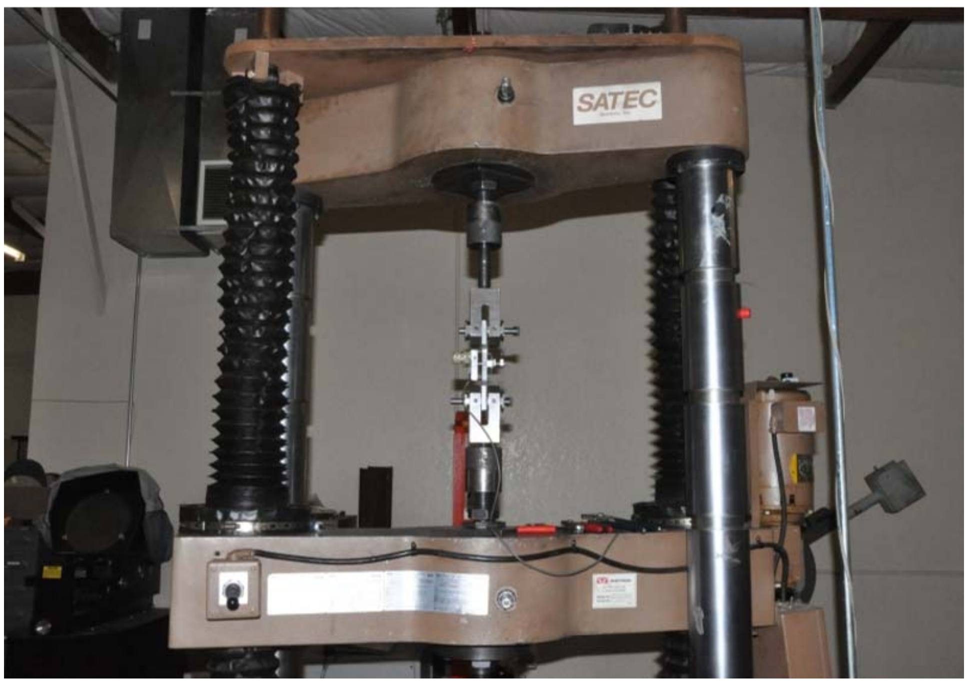
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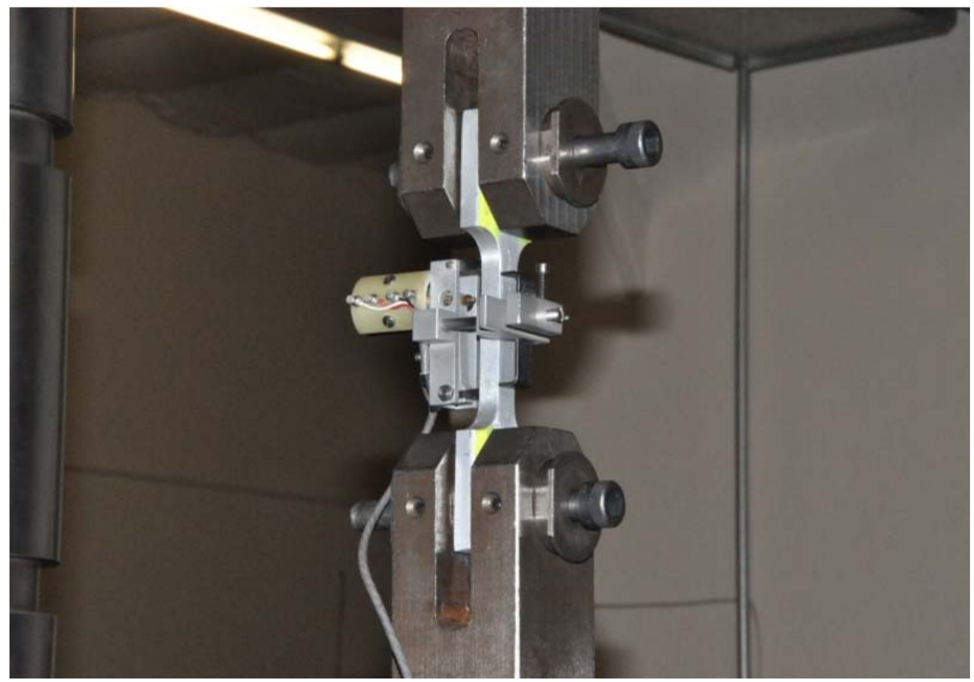

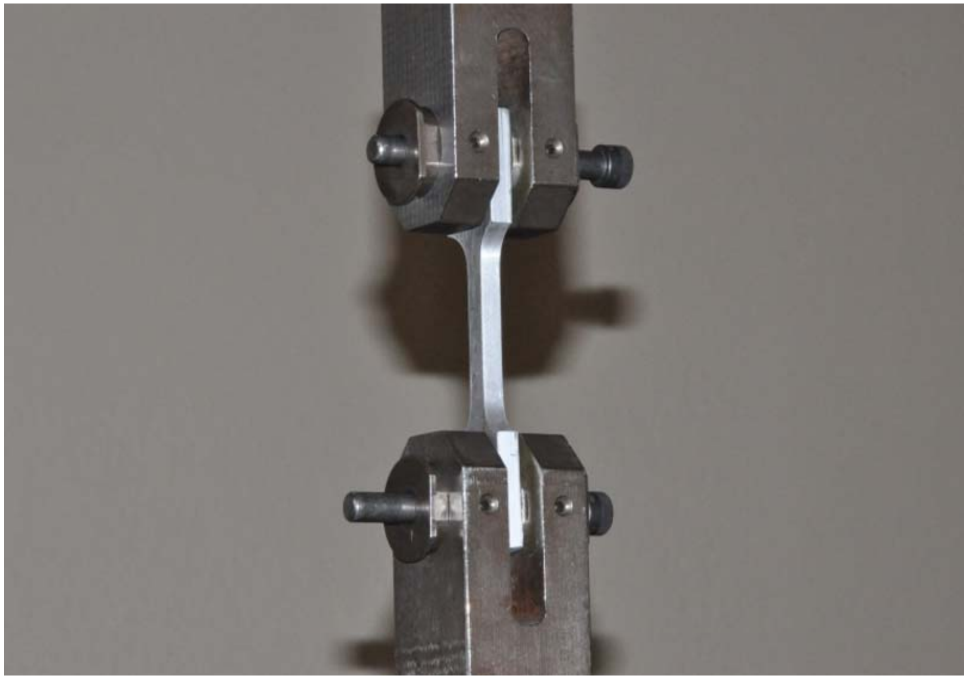
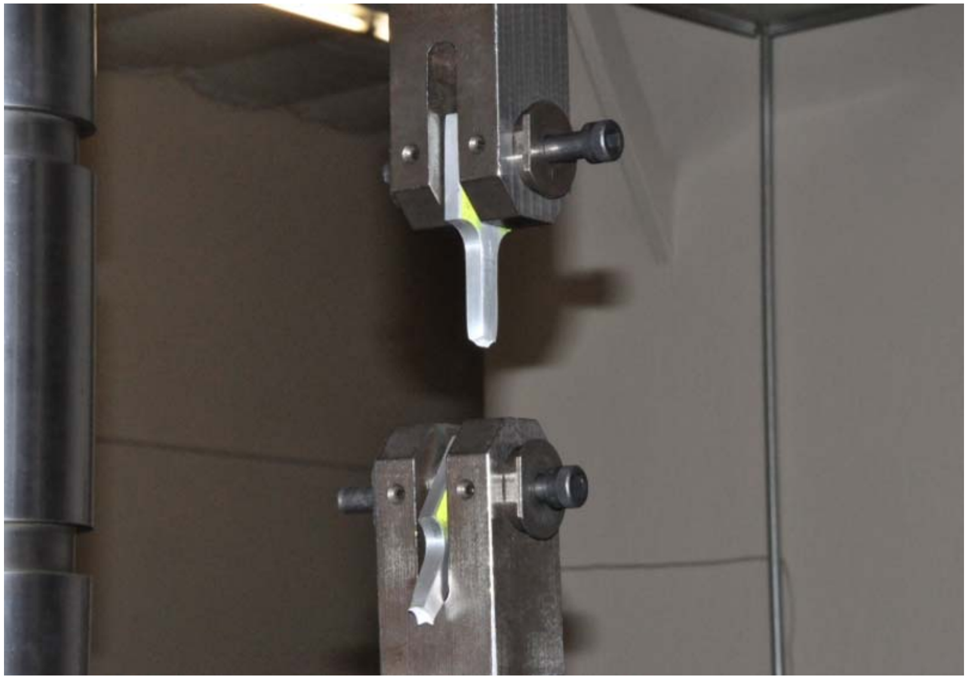
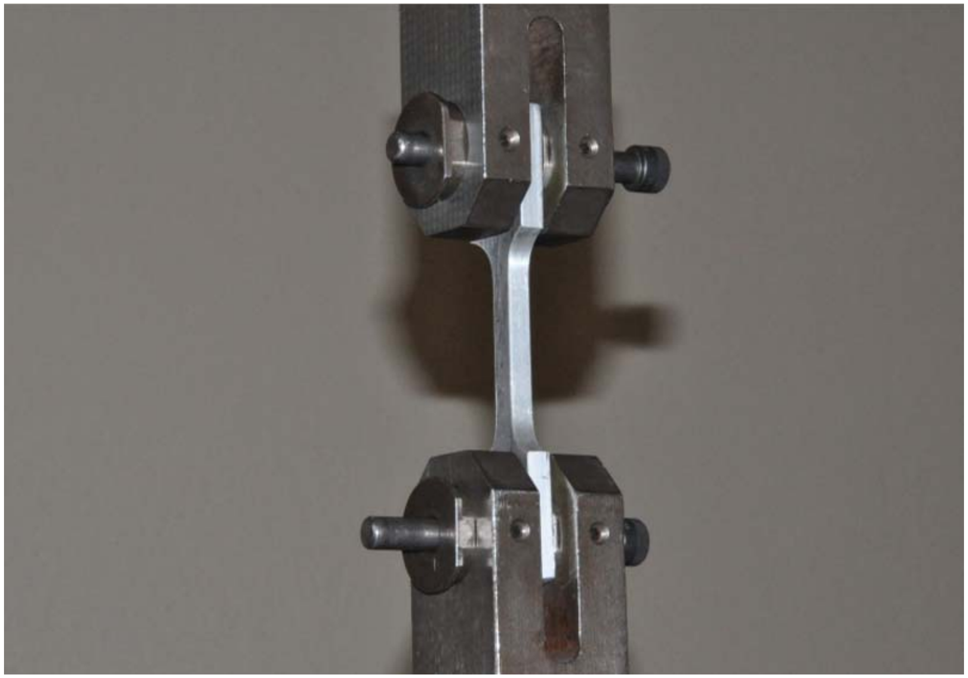
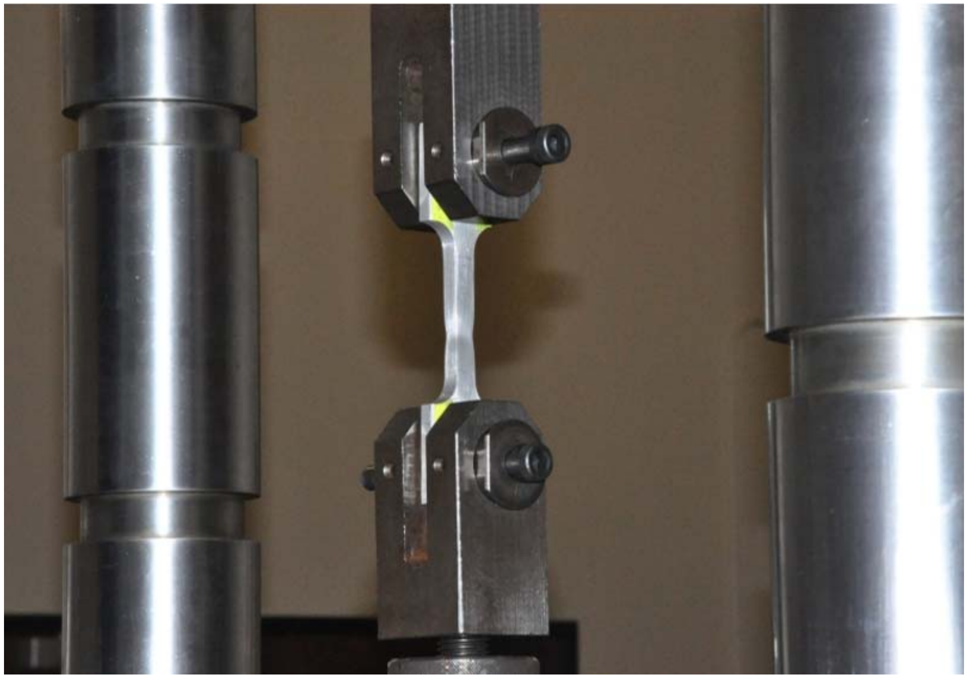

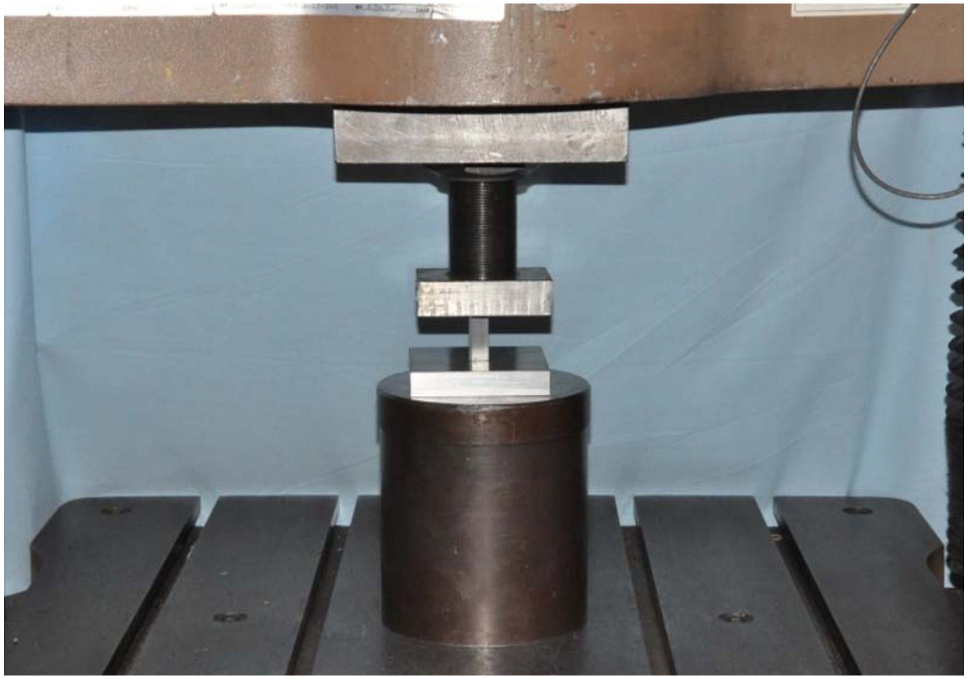
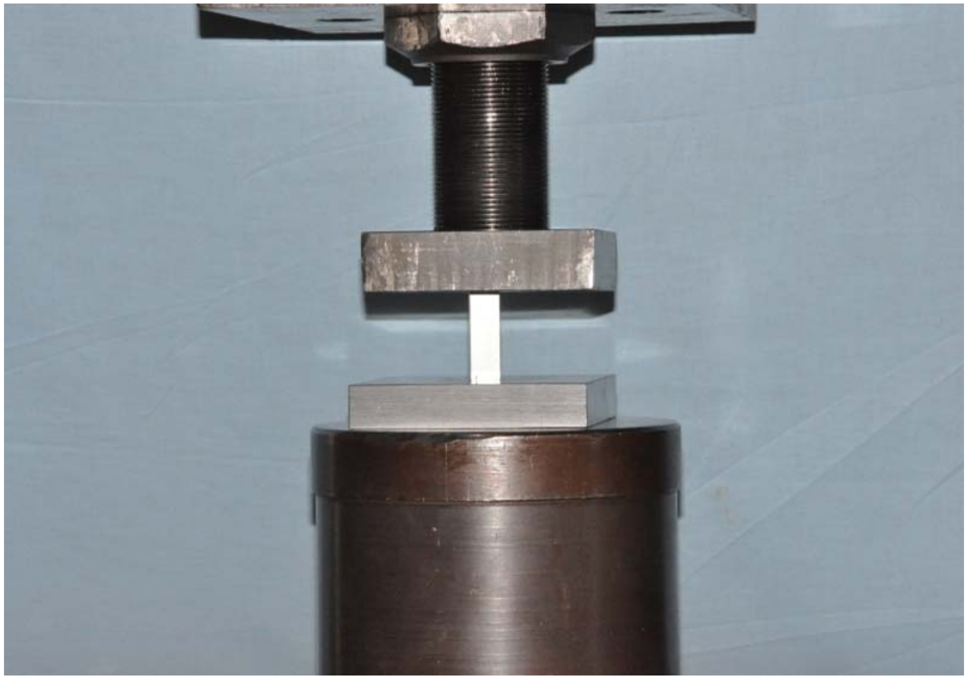
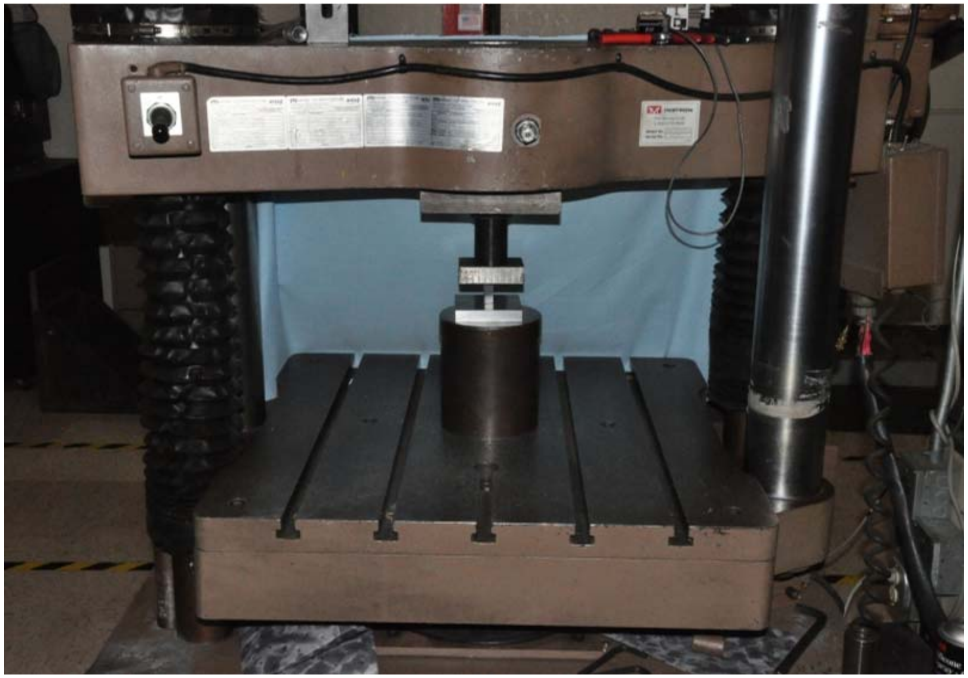
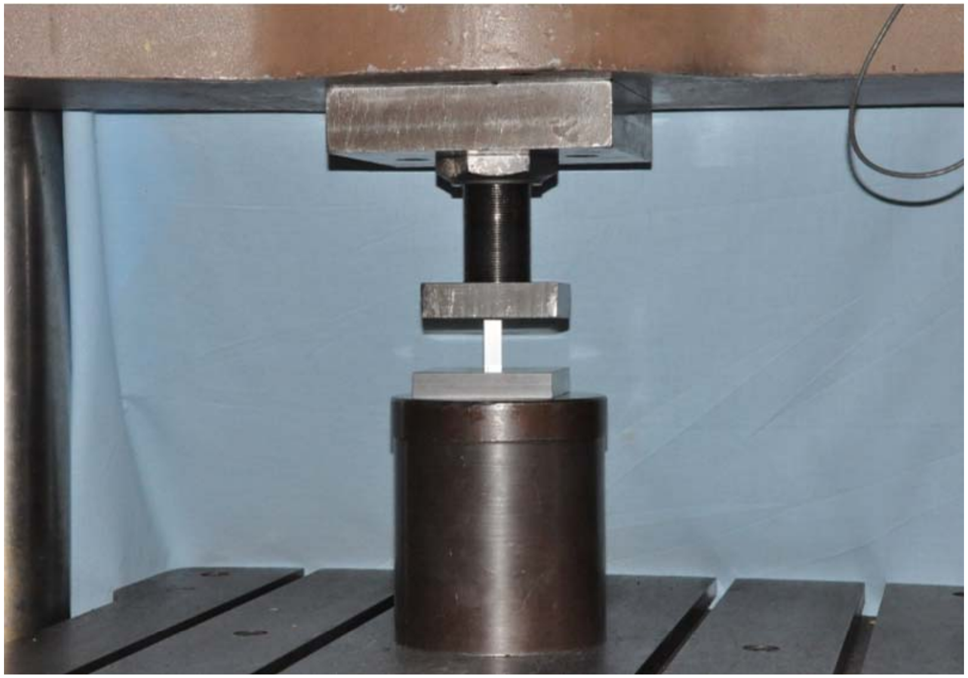

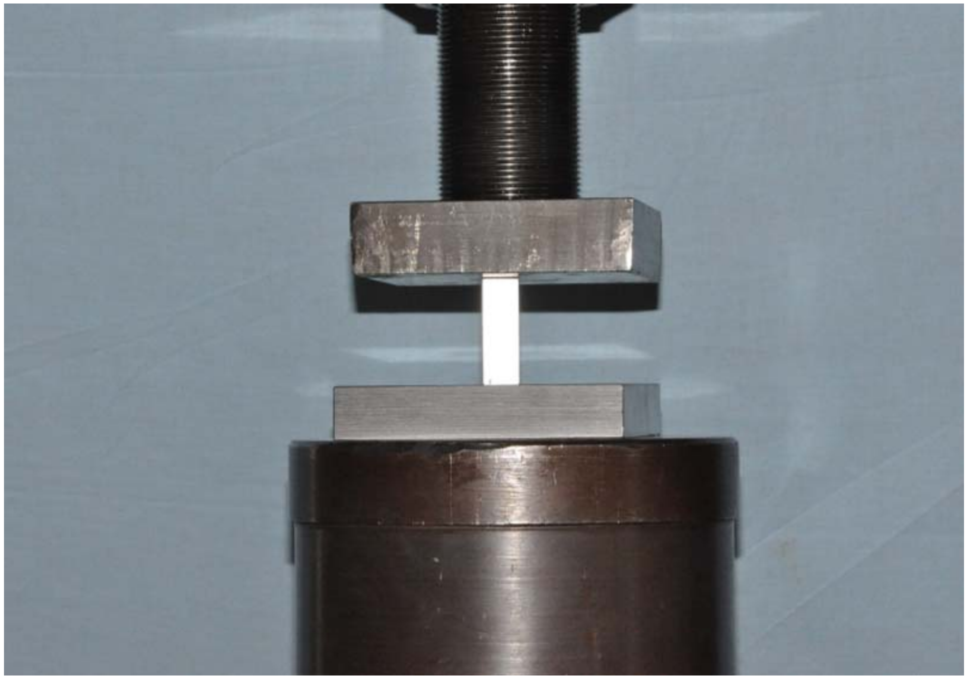
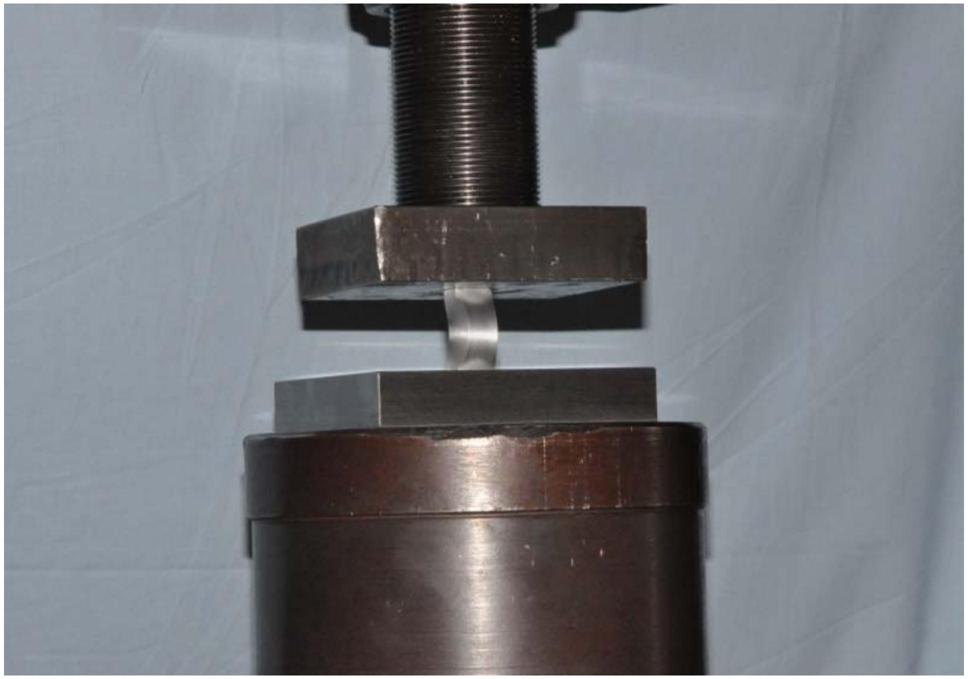
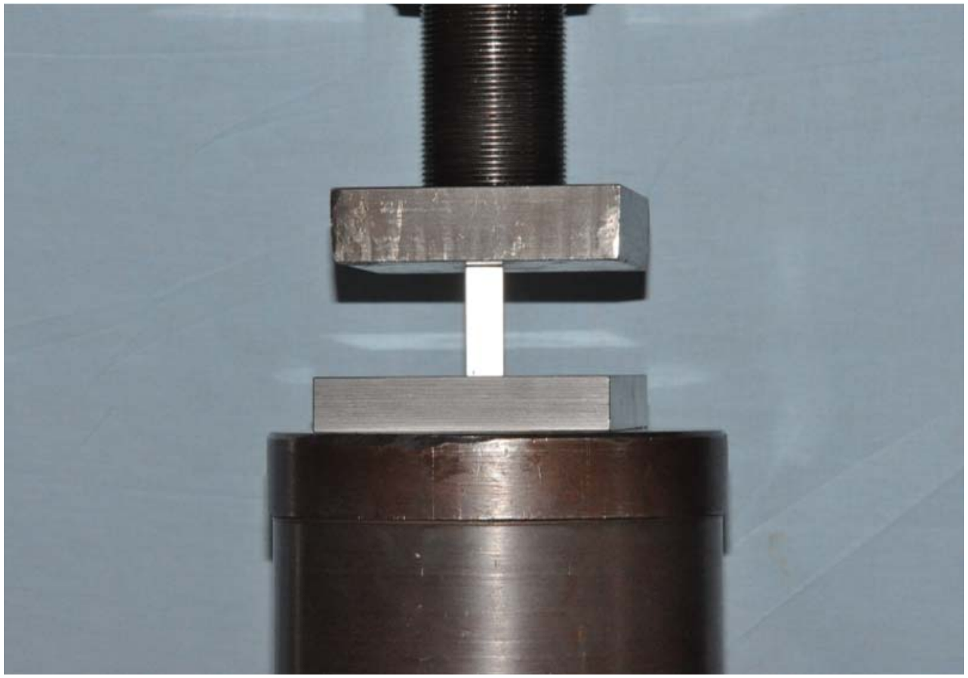


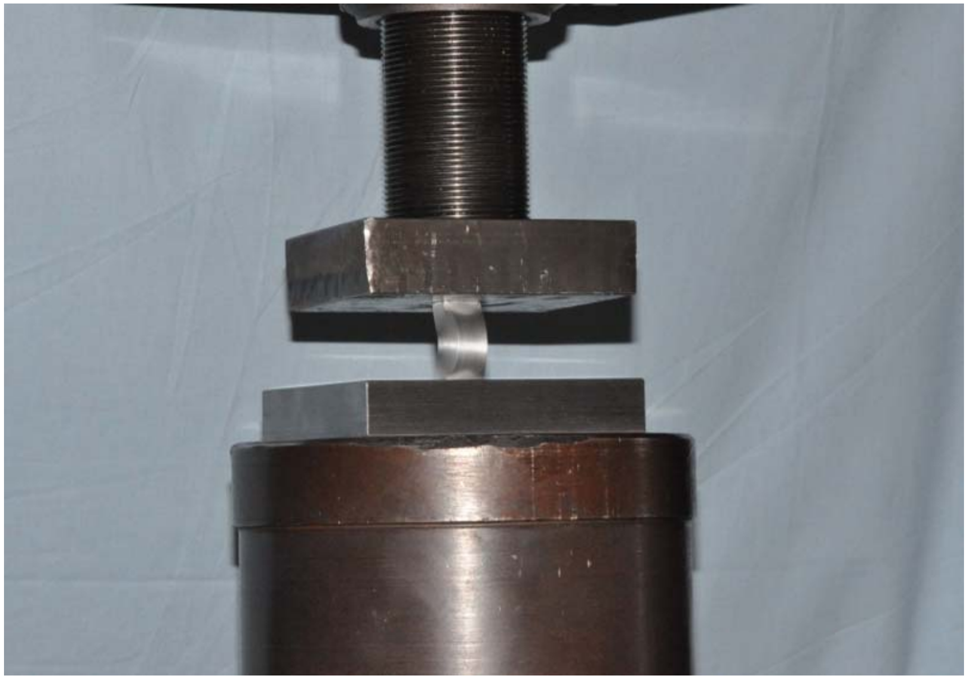


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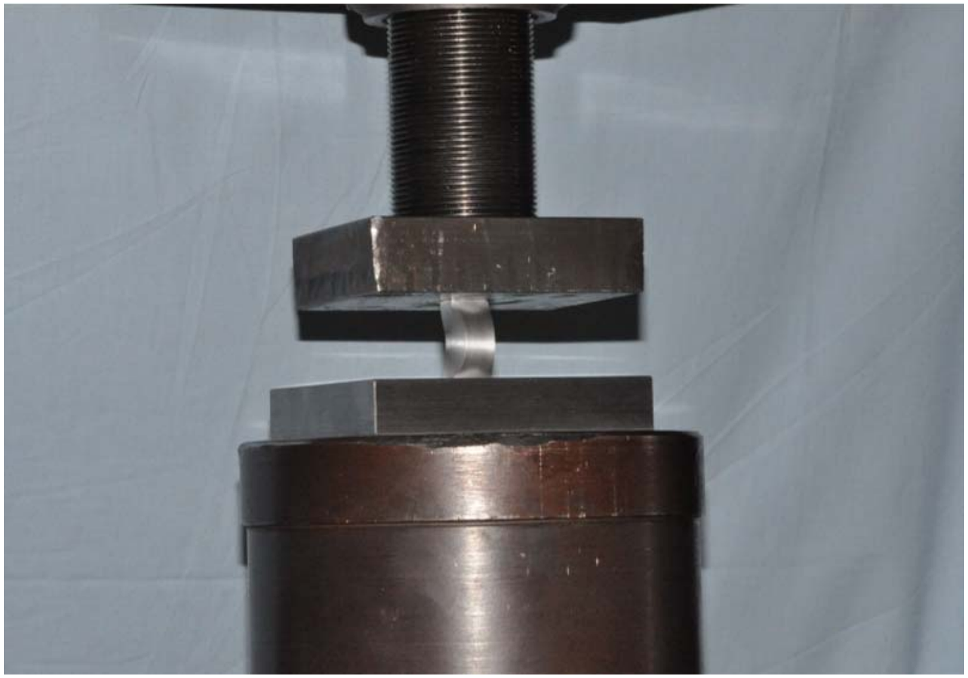


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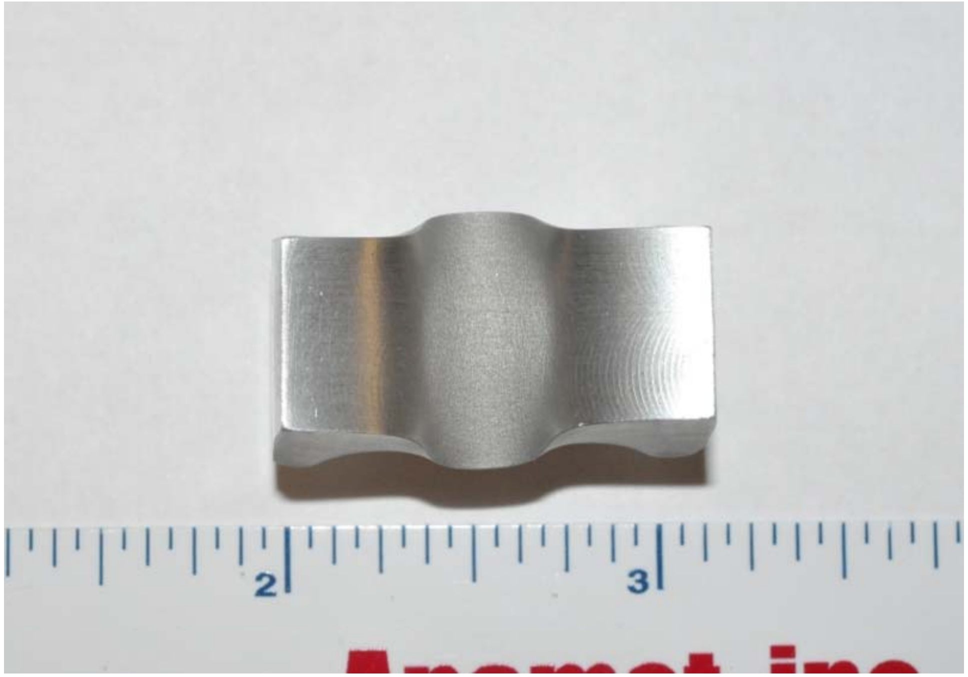
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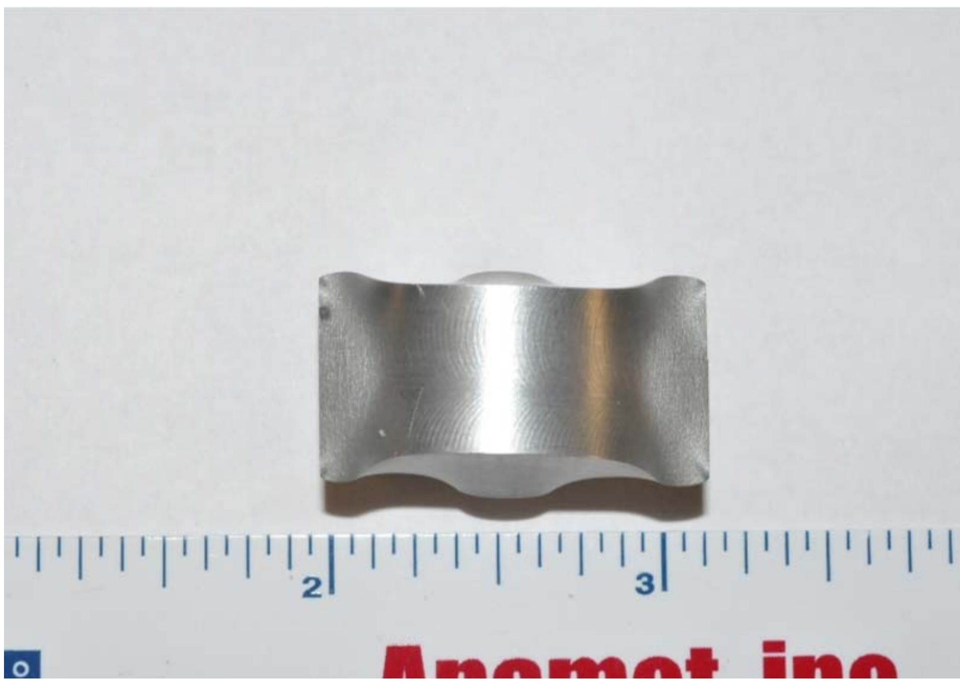
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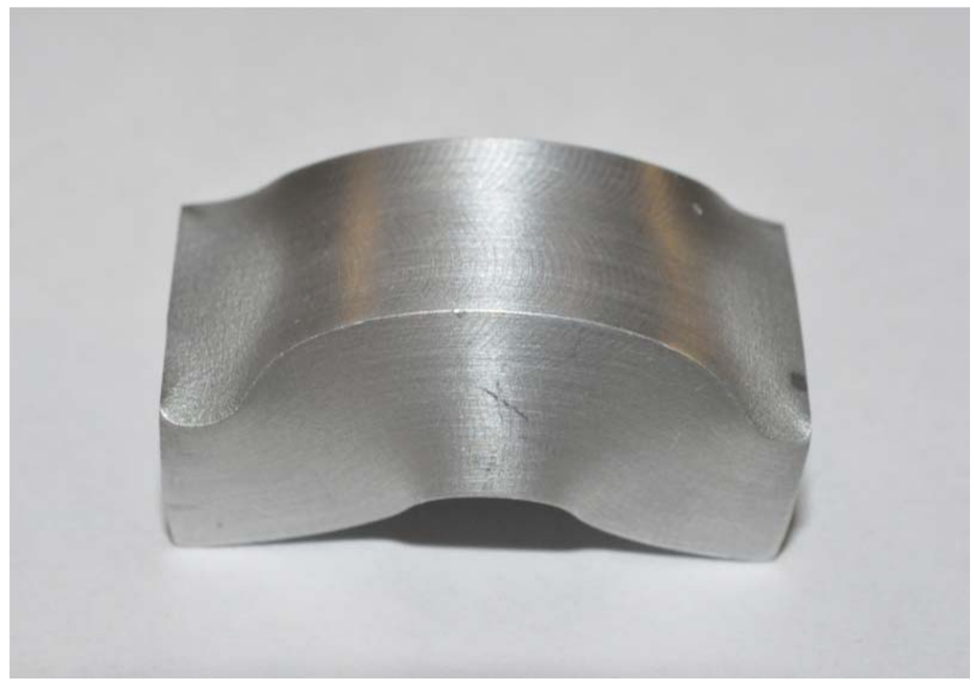




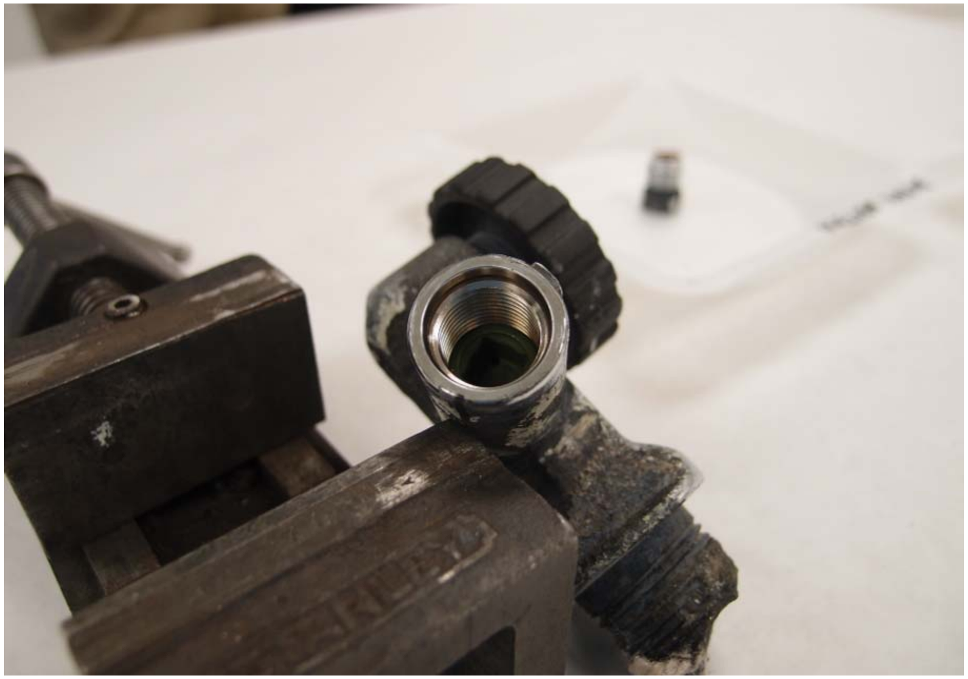






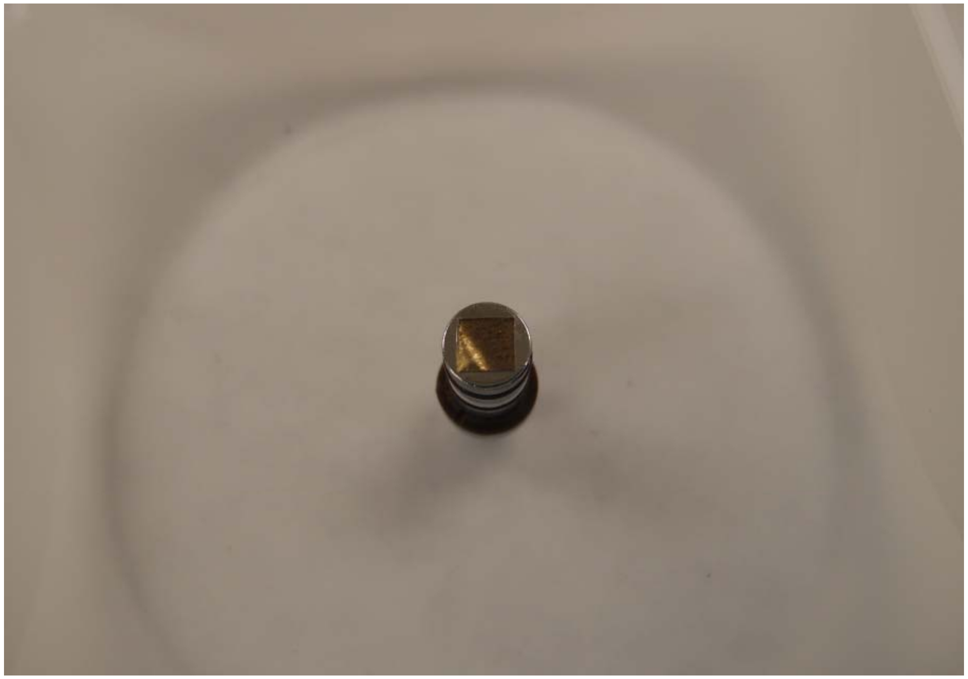







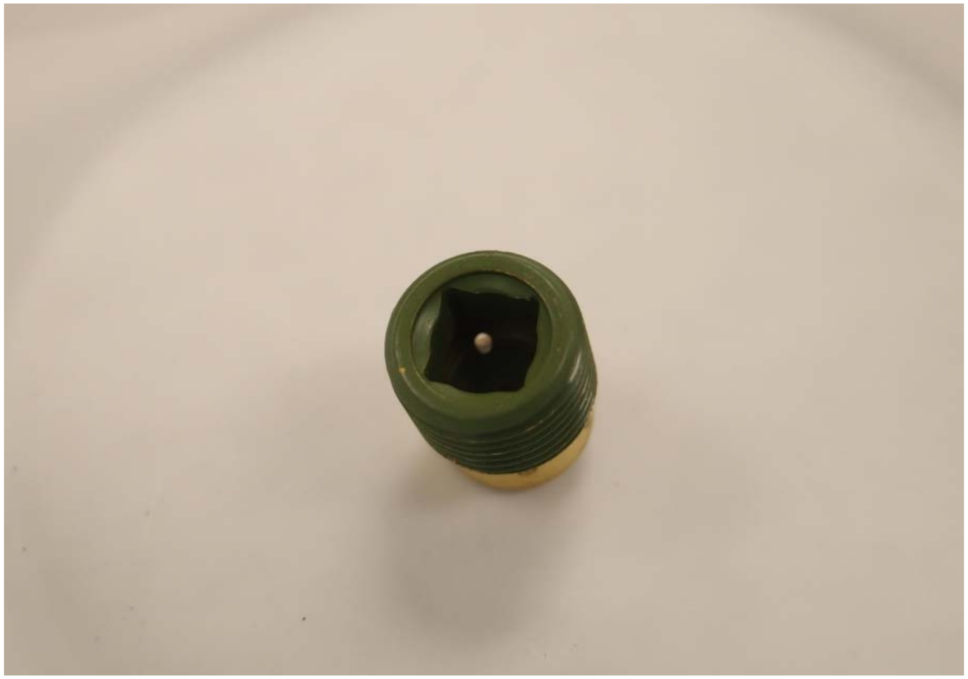









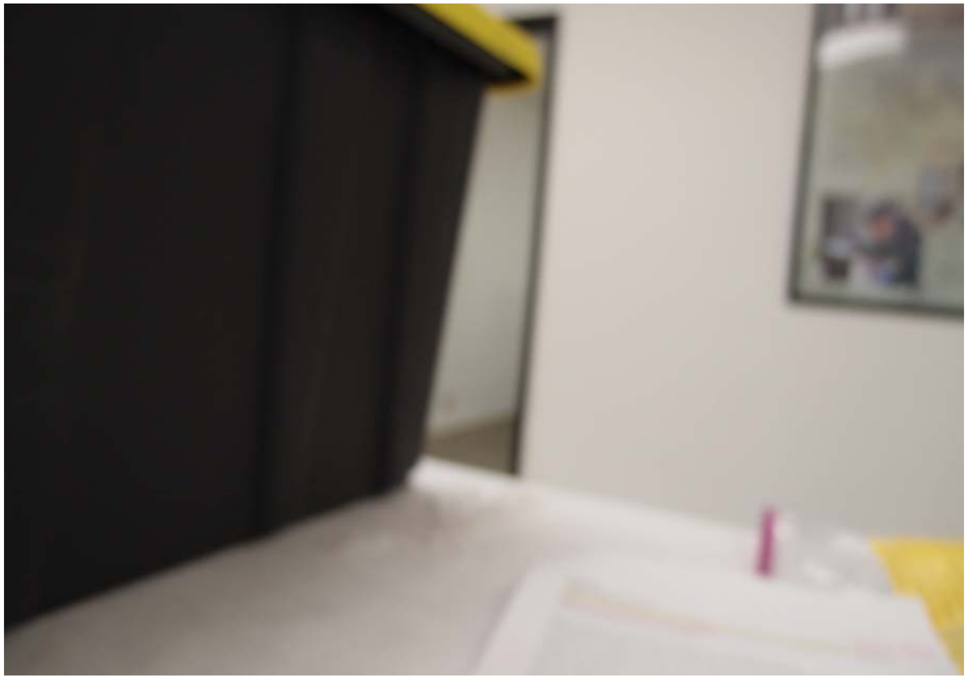








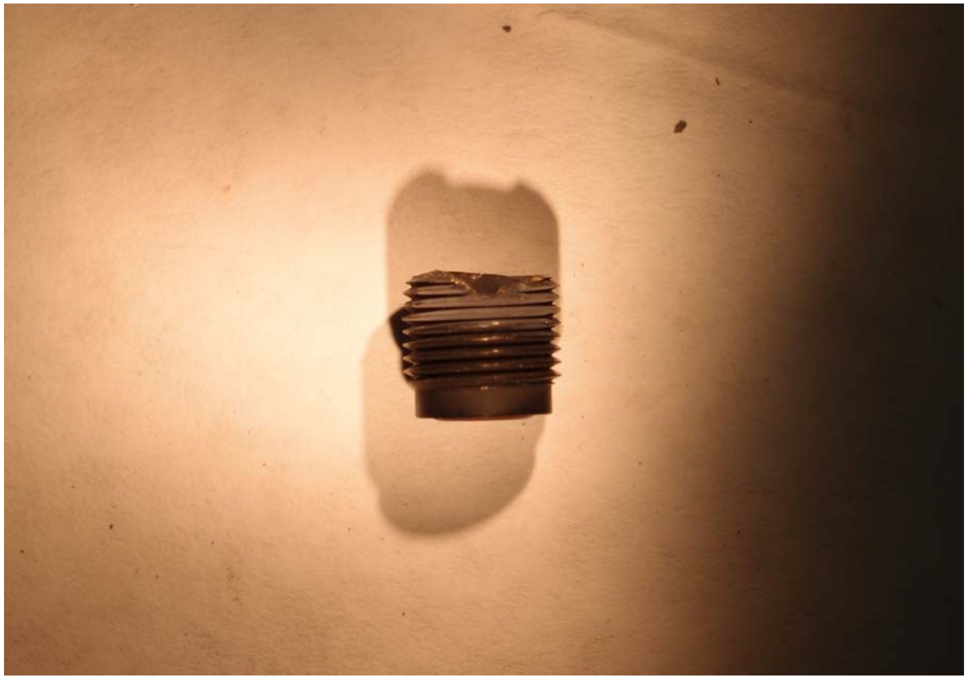
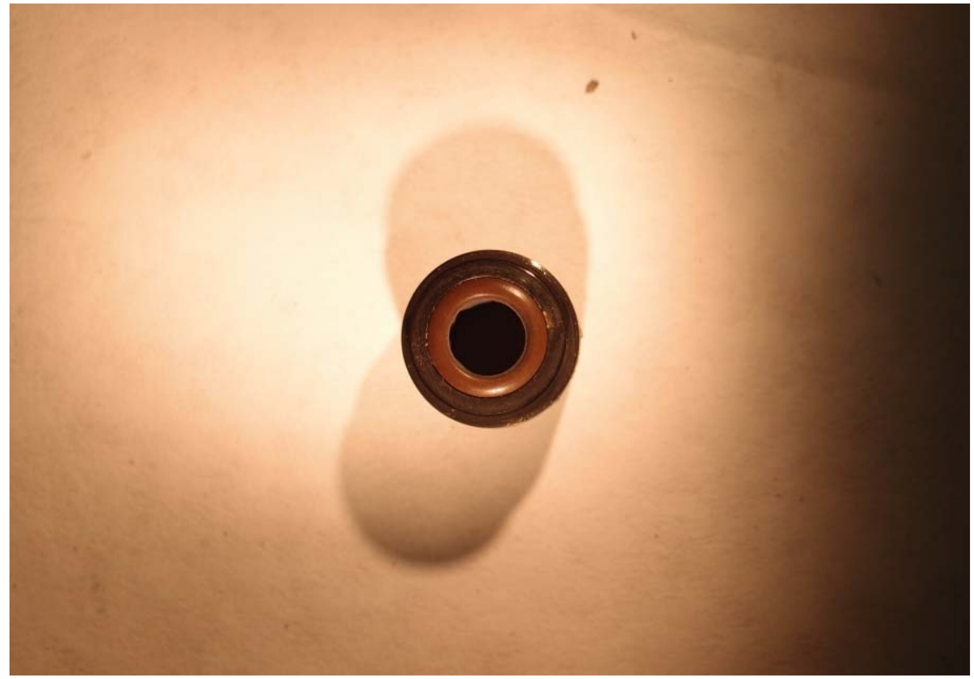
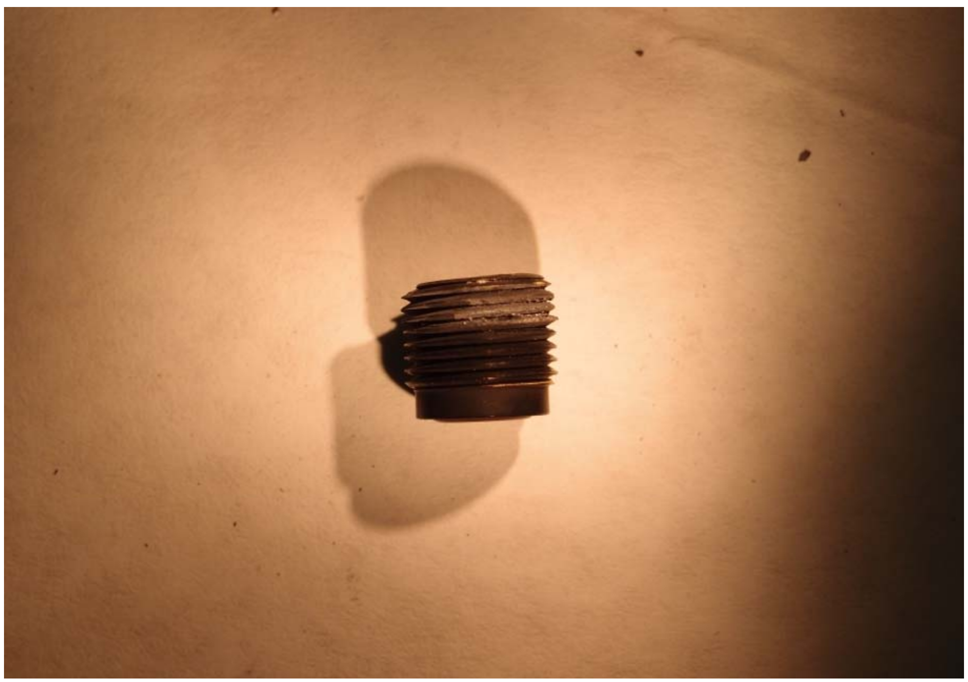
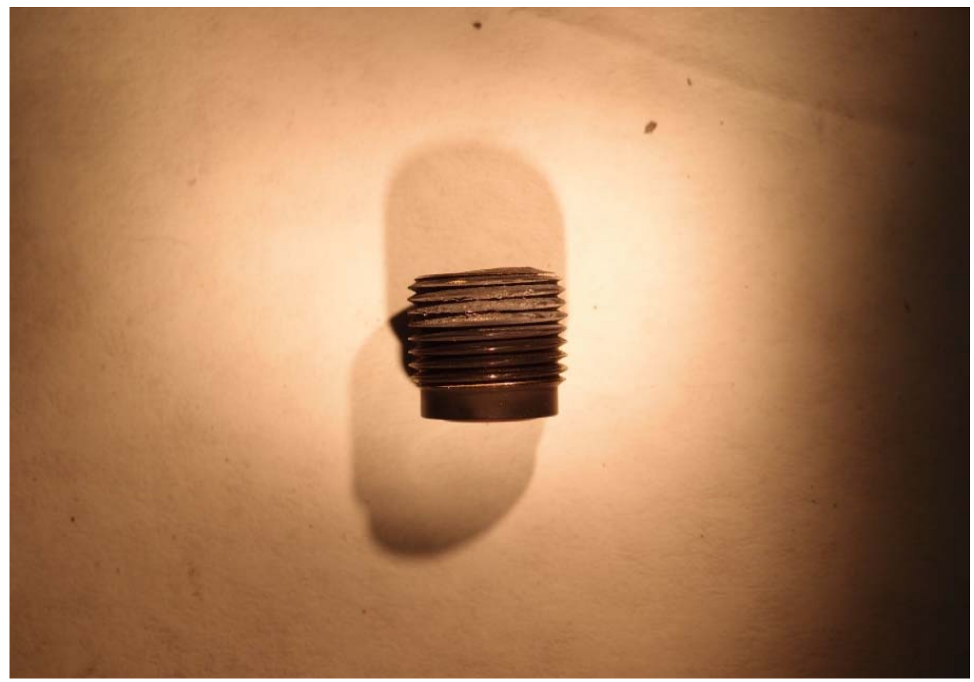

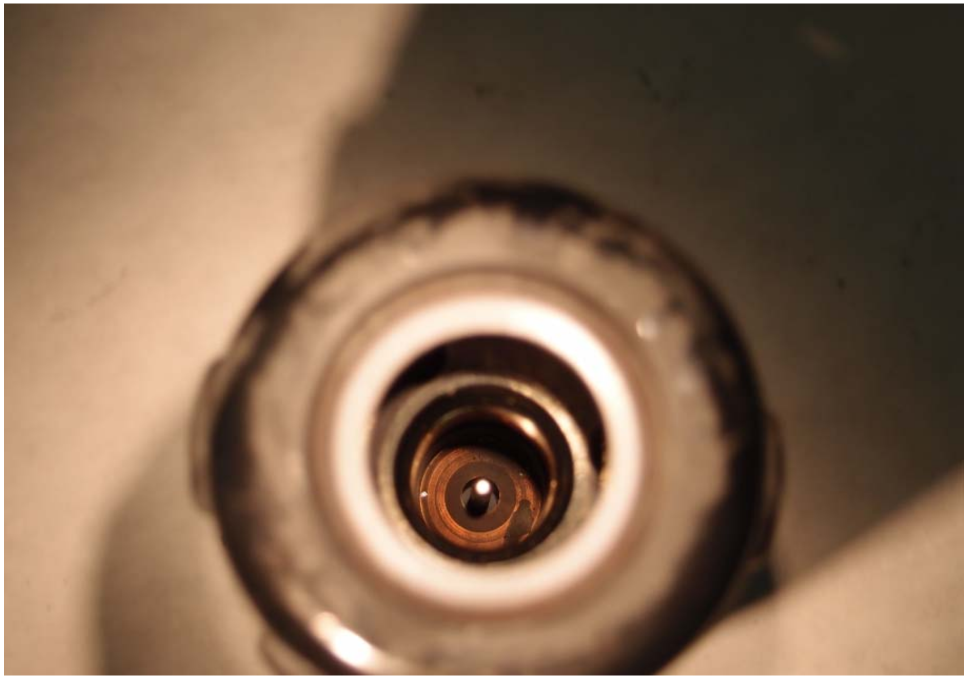

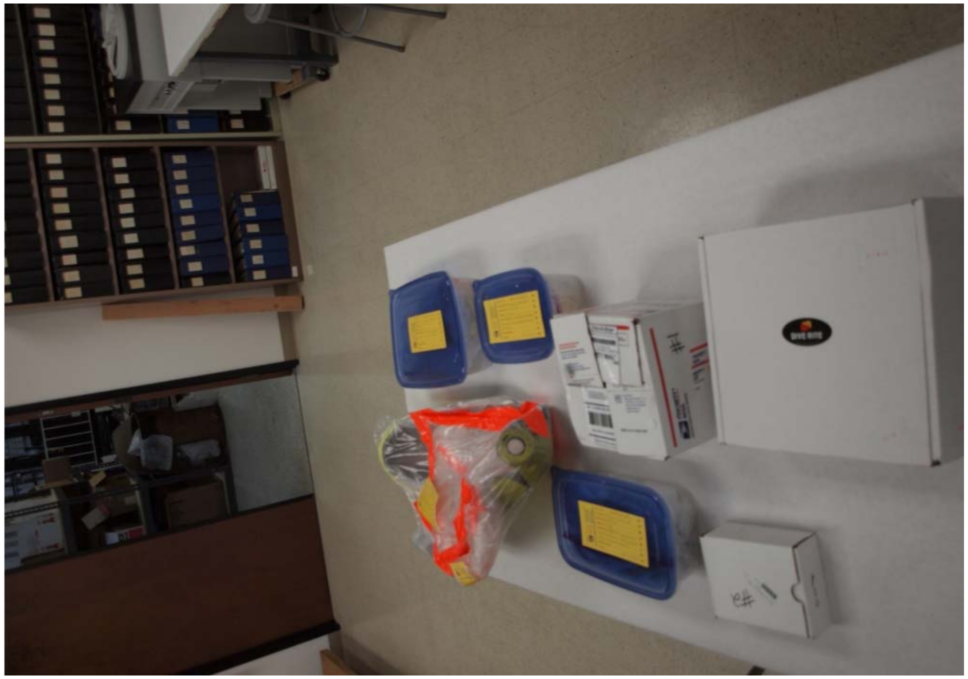


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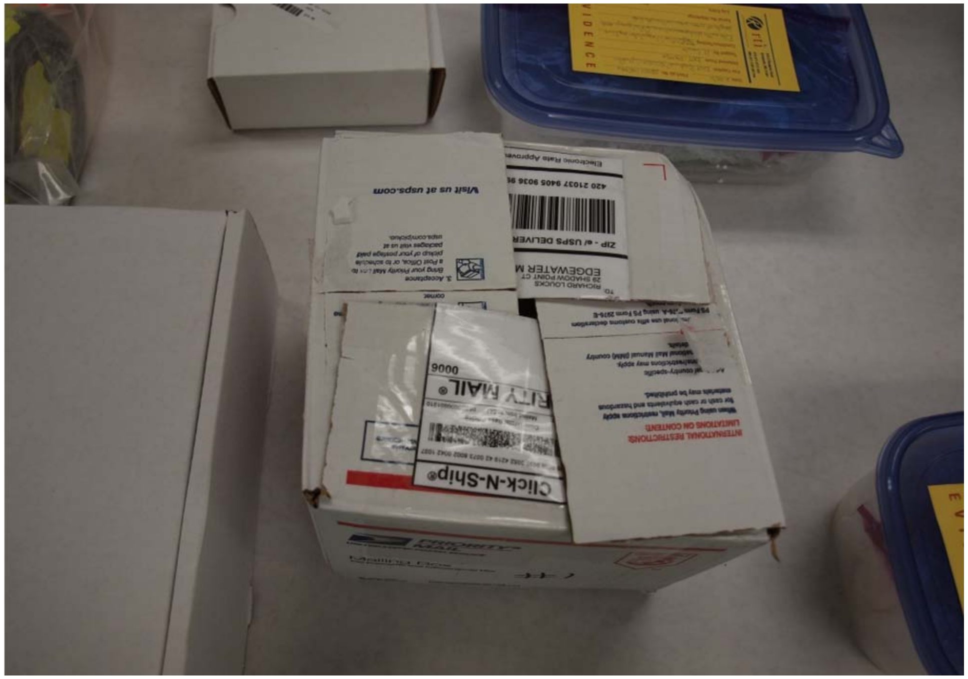
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DIVE RITE
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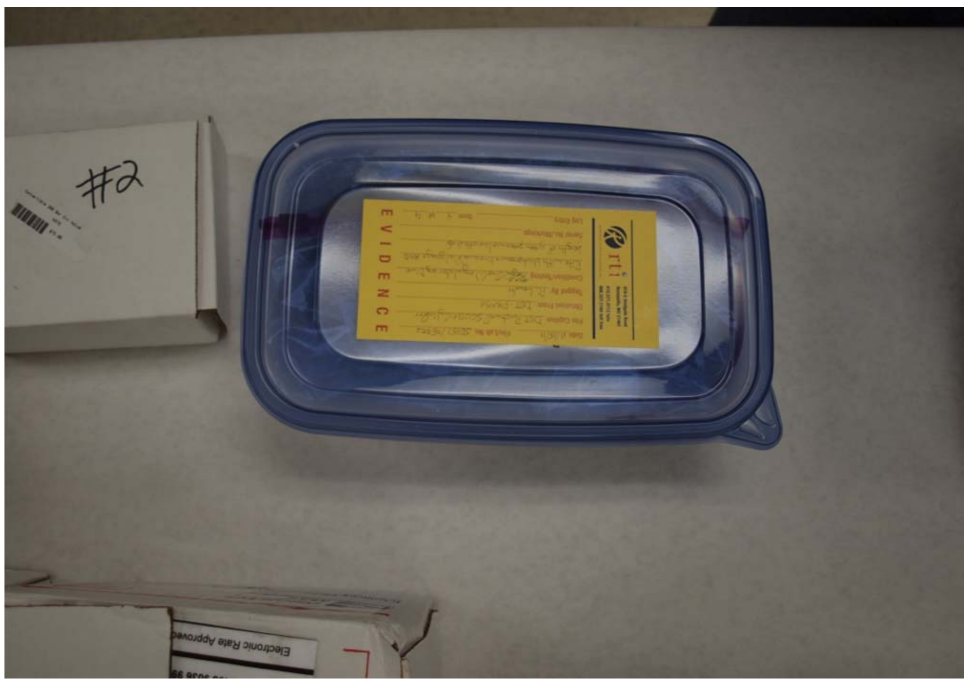
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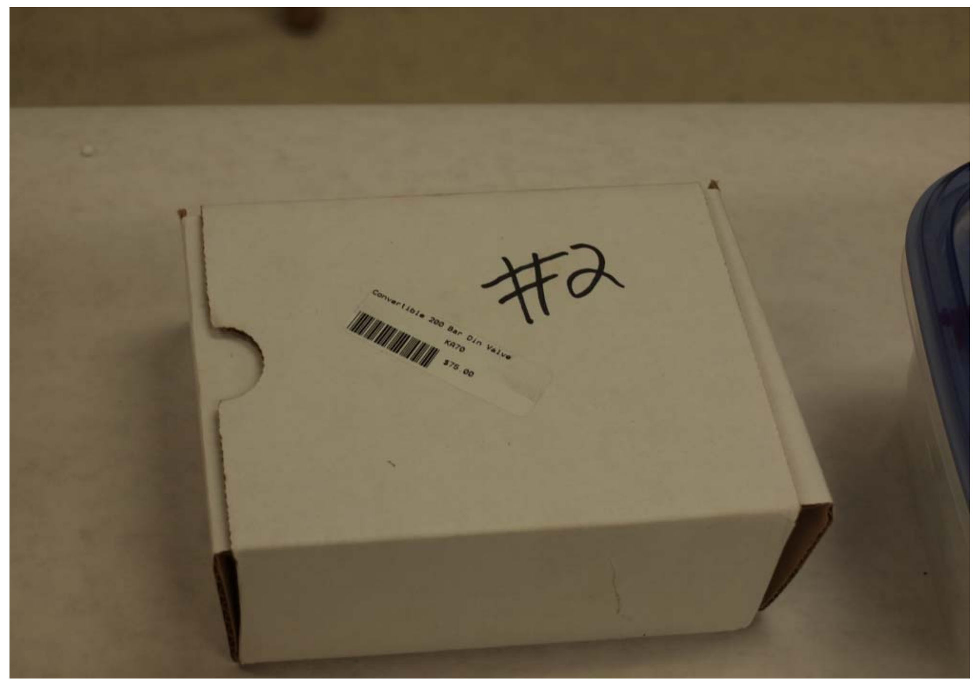
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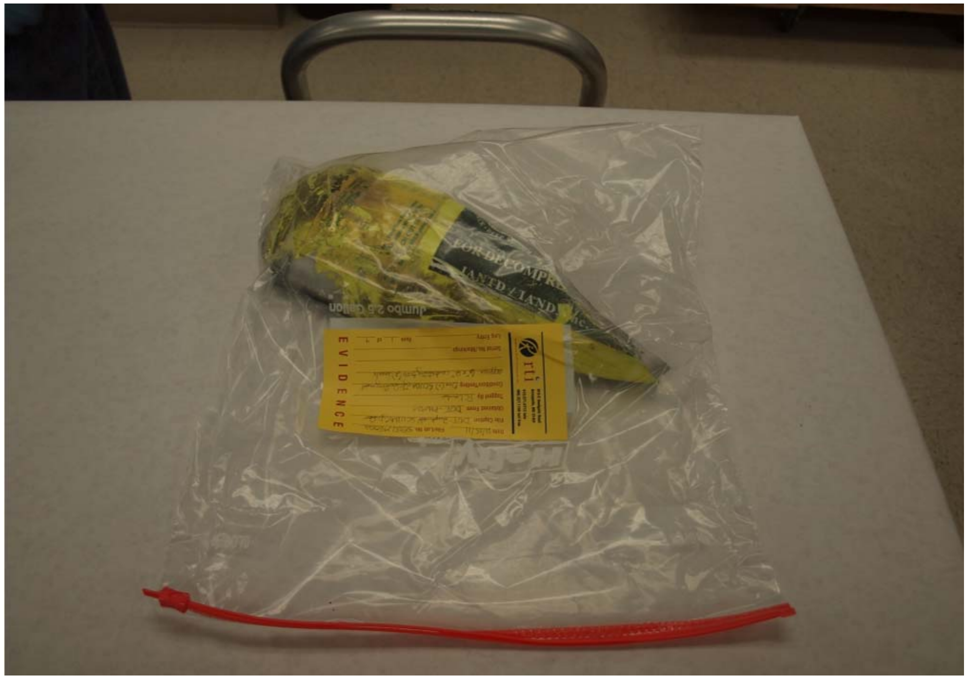
$75.00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EVIDENCE
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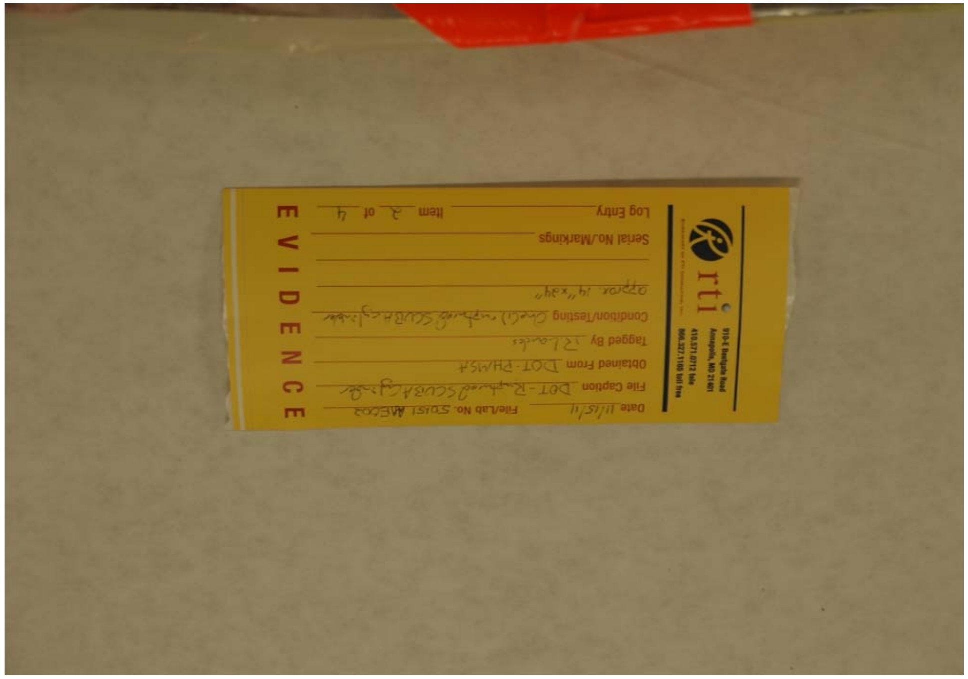


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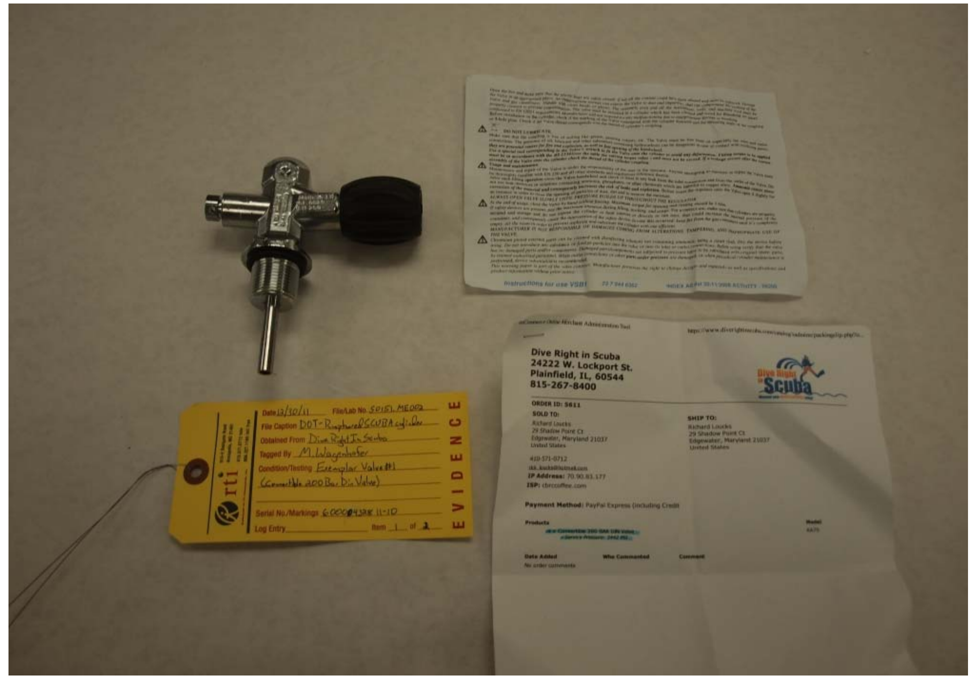

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Obtained From Dive Right In Scuba
Tagged By M. Wagenhofer
Condition/Testing Exemplar Valve #1
(Convertible 200 Bar Din Valve)
Serial No./Markings
Log Entry
Item 1 of 2
EVIDENCE
rti
Dive Right in Scuba
24222 W. Lockport St.
Plainfield, IL, 60544
815-267-8400
ORDER ID: 5611
SOLD TO:
SHIP TO:
Richard Loucks
29 Shadow Point Ct
Edgewater, Maryland 21037
United States
410-571-0712
IP Address: 70.90.81.177
ISP: cbrccoffee.com
Payment Method: PayPal Express (including Credit
Products
Model
Date Added
Who Commented
Comment
No order comments

OneZip
Bags
EVIDENCE
rti
Date
File/Lab No.
File Caption
Obtained From
Tagged By
Condition/Testing
Serial No./Markings
Log Entry
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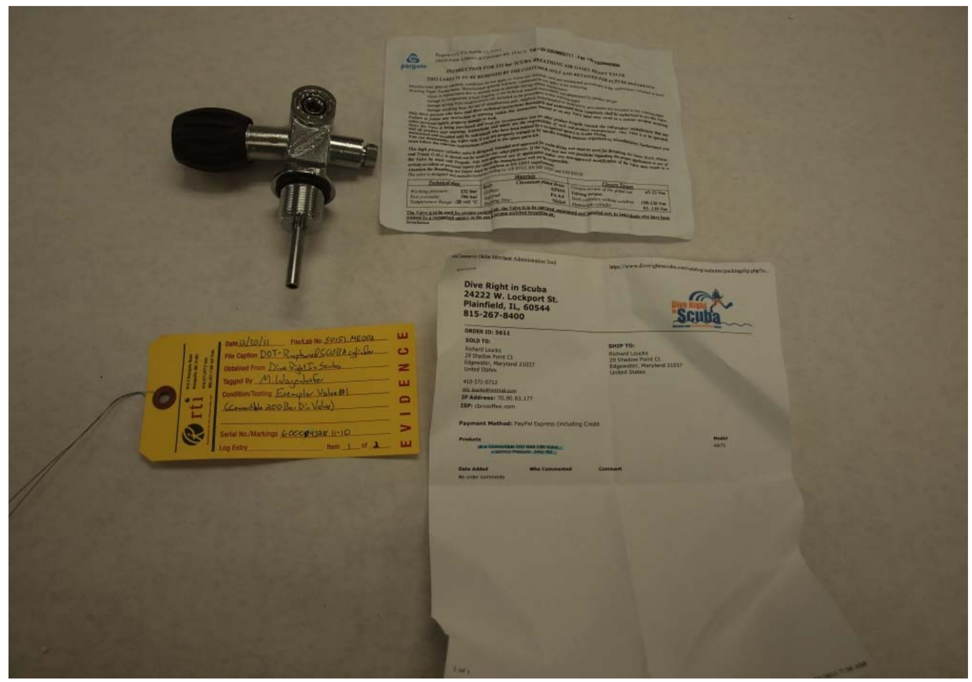

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24222 W. Lockport St.
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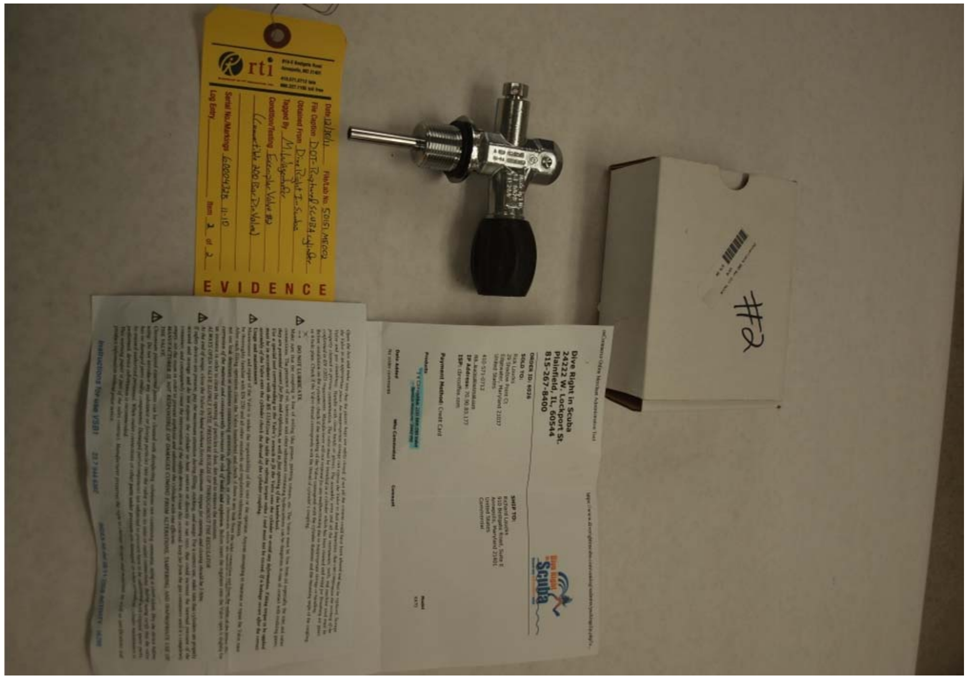
815-267-8400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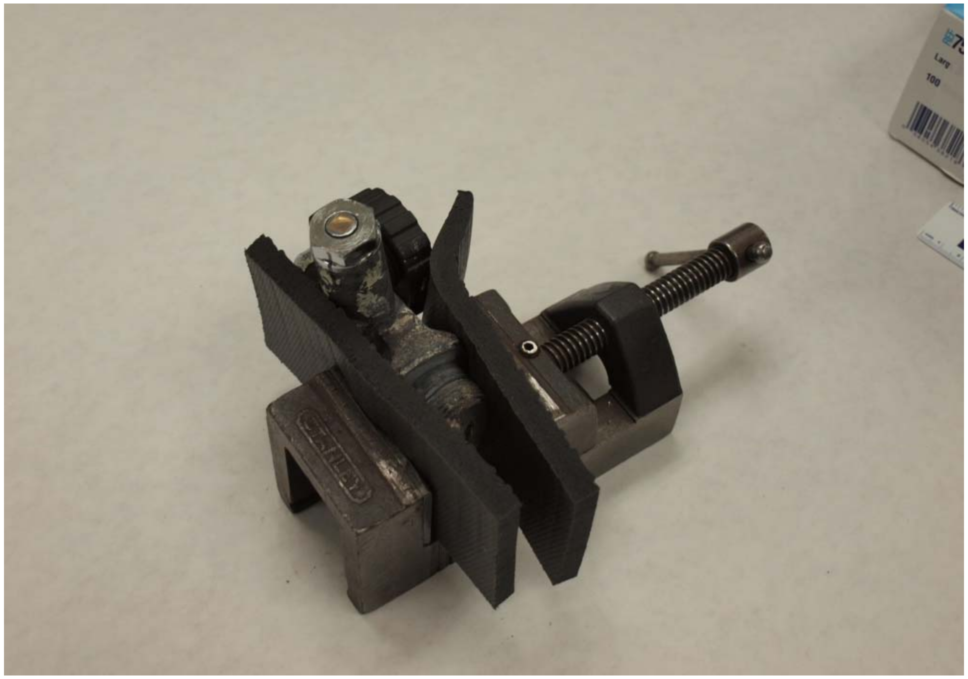
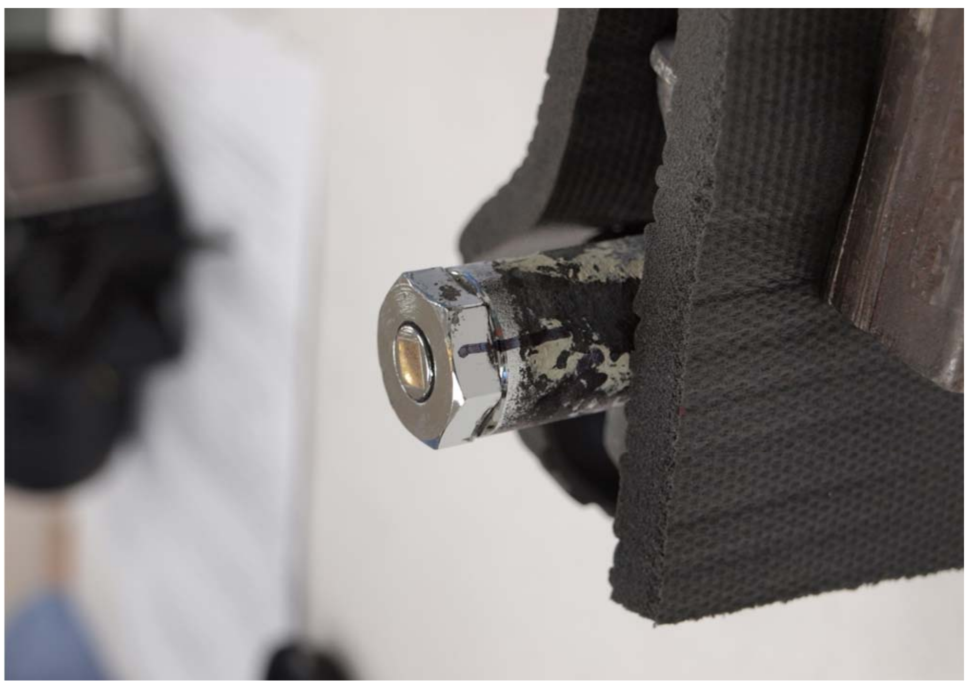
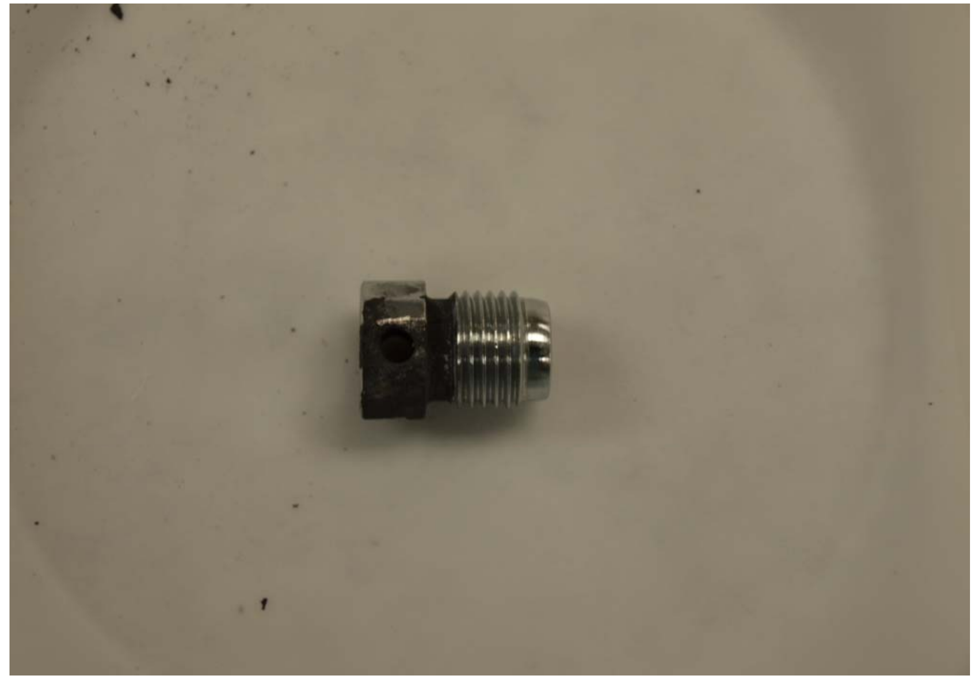


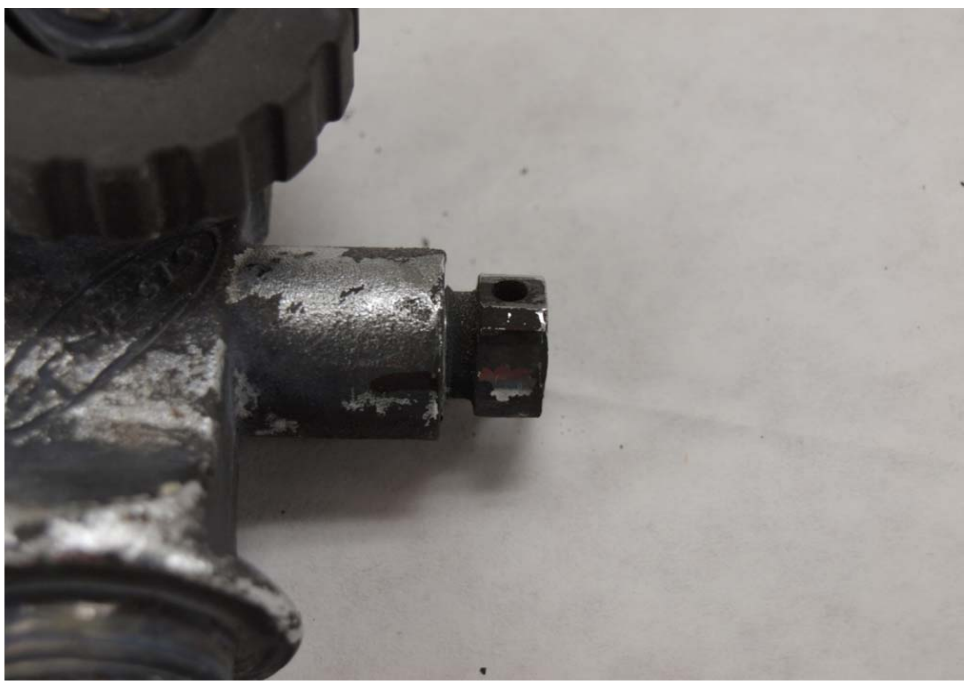


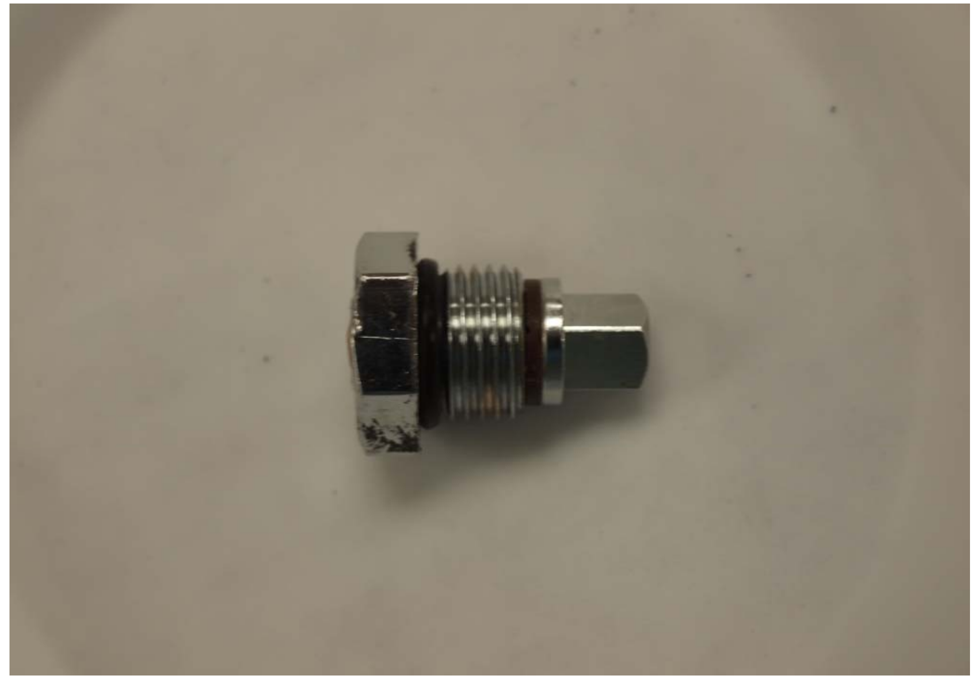


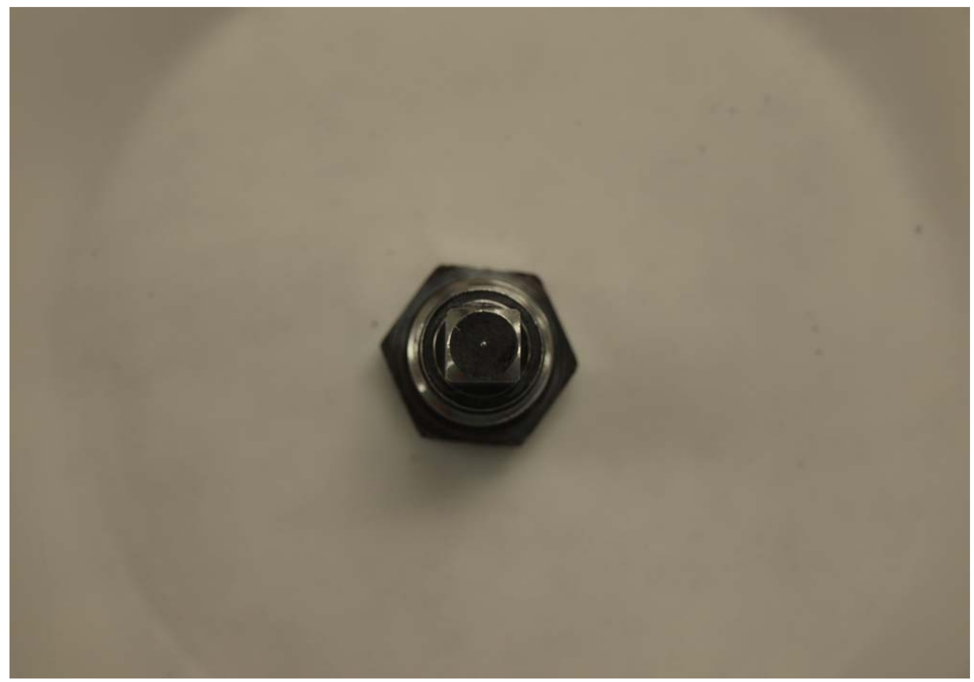


RELIEF VALVE
GLAND NUT





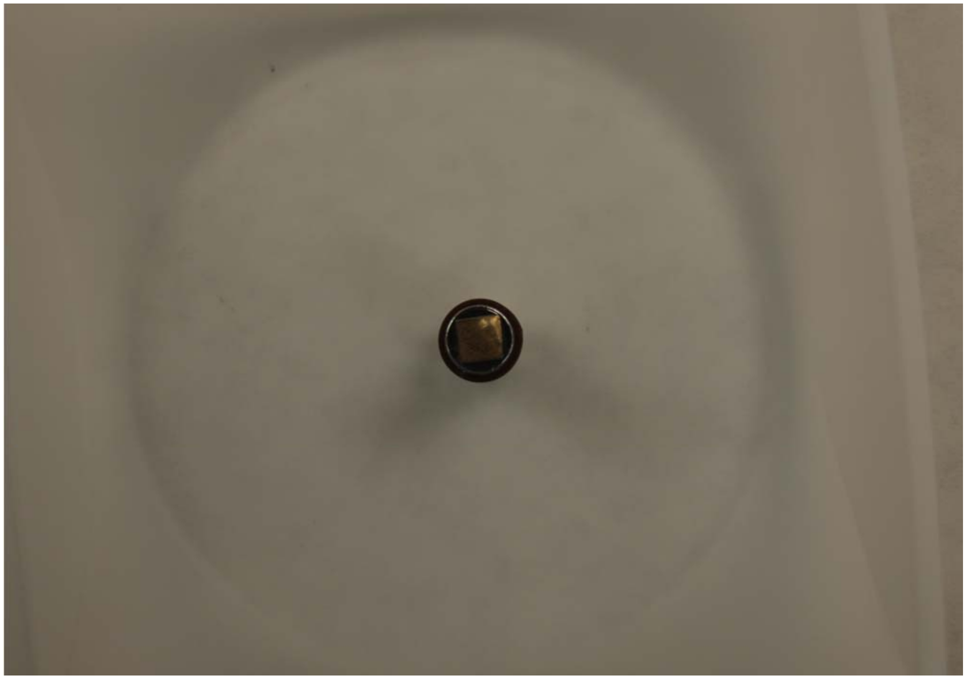
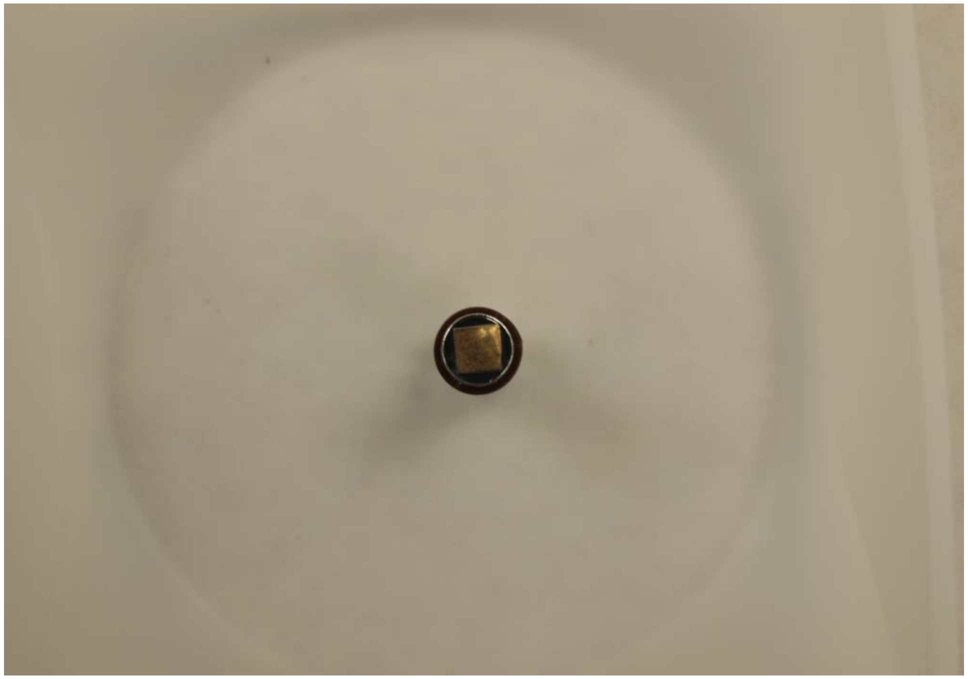
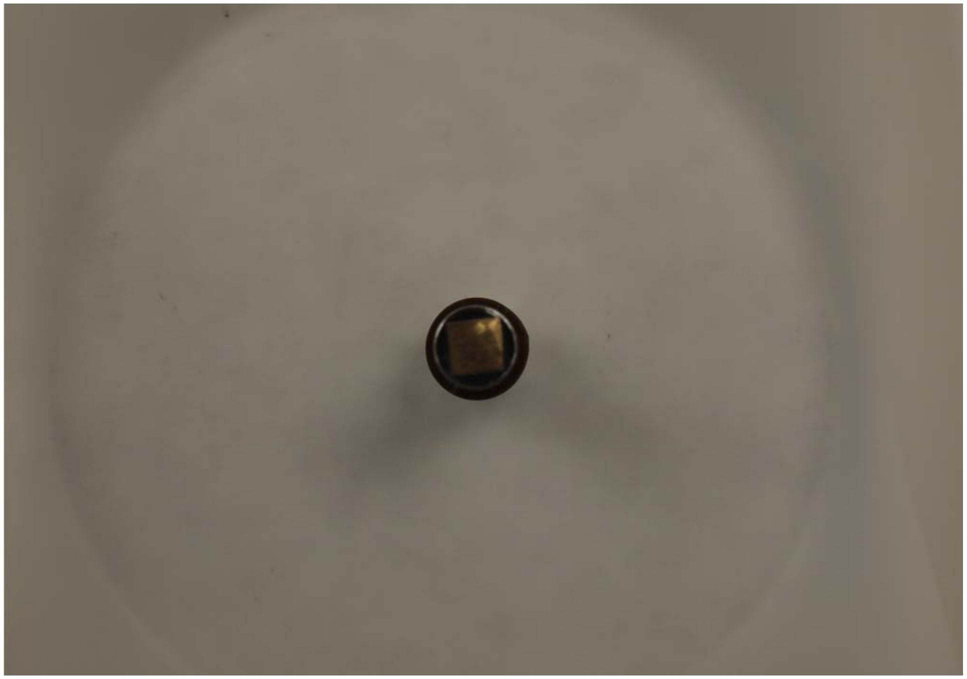
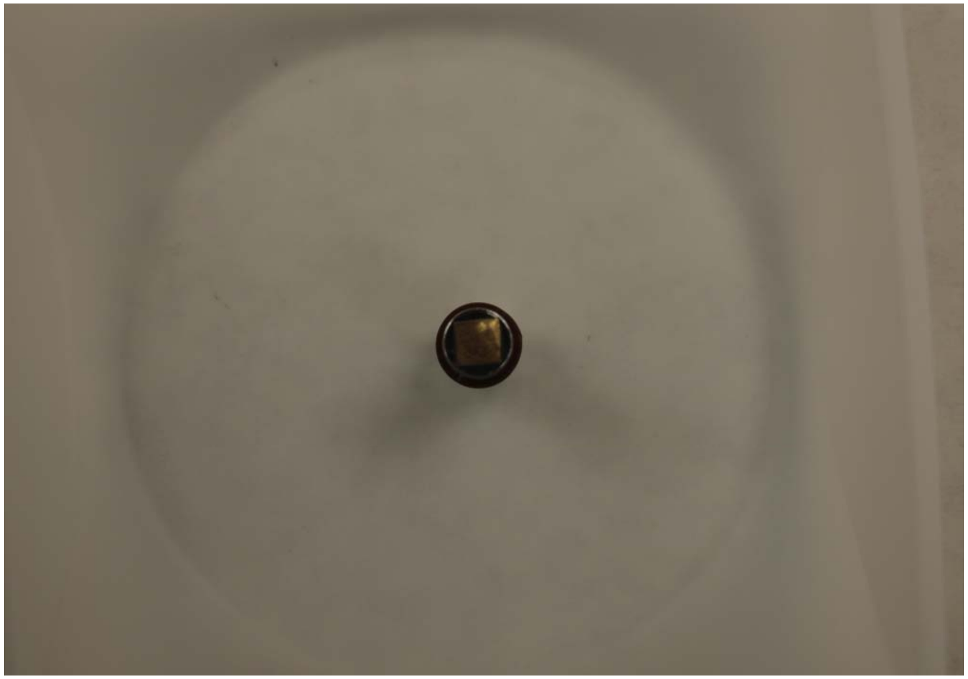



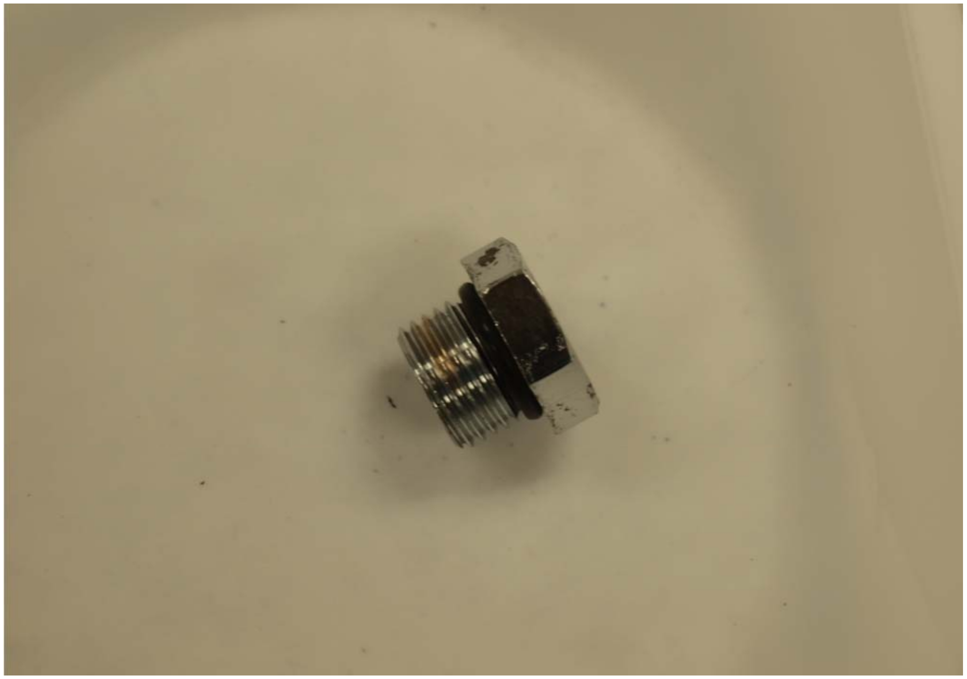
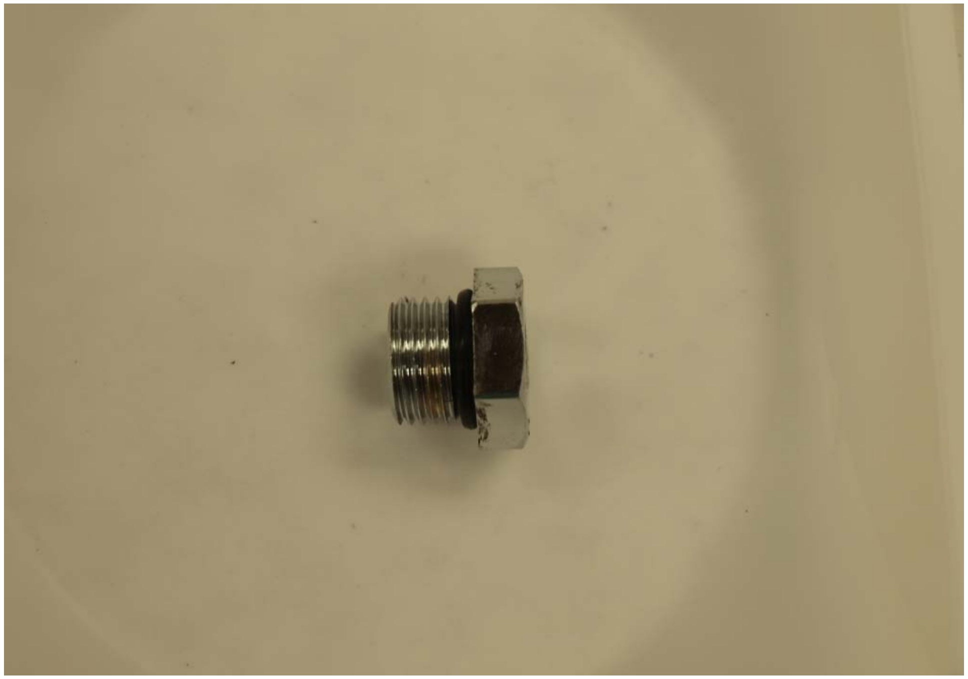
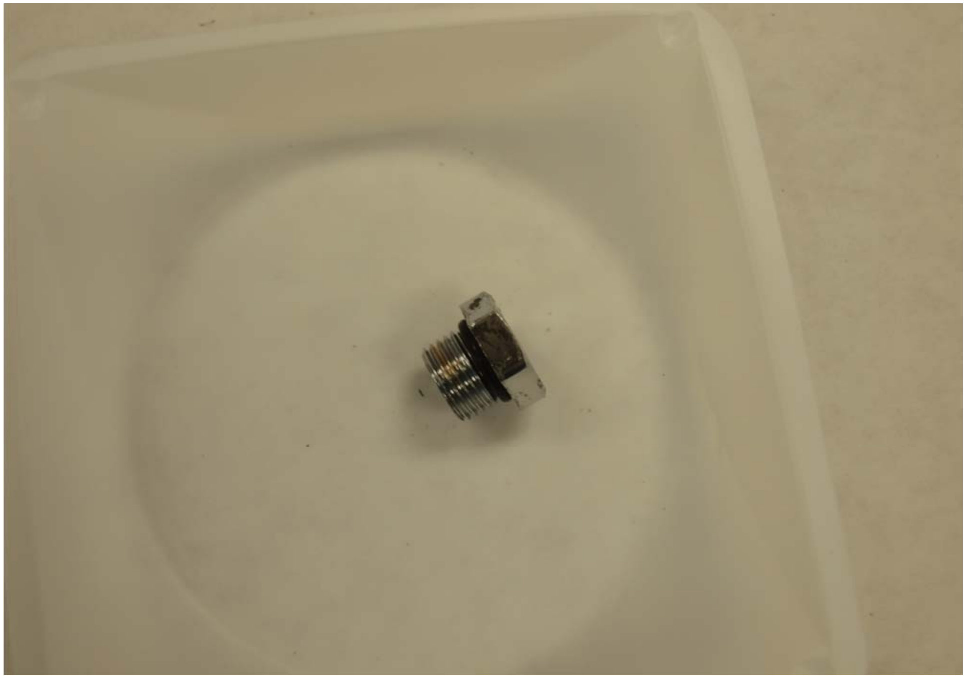
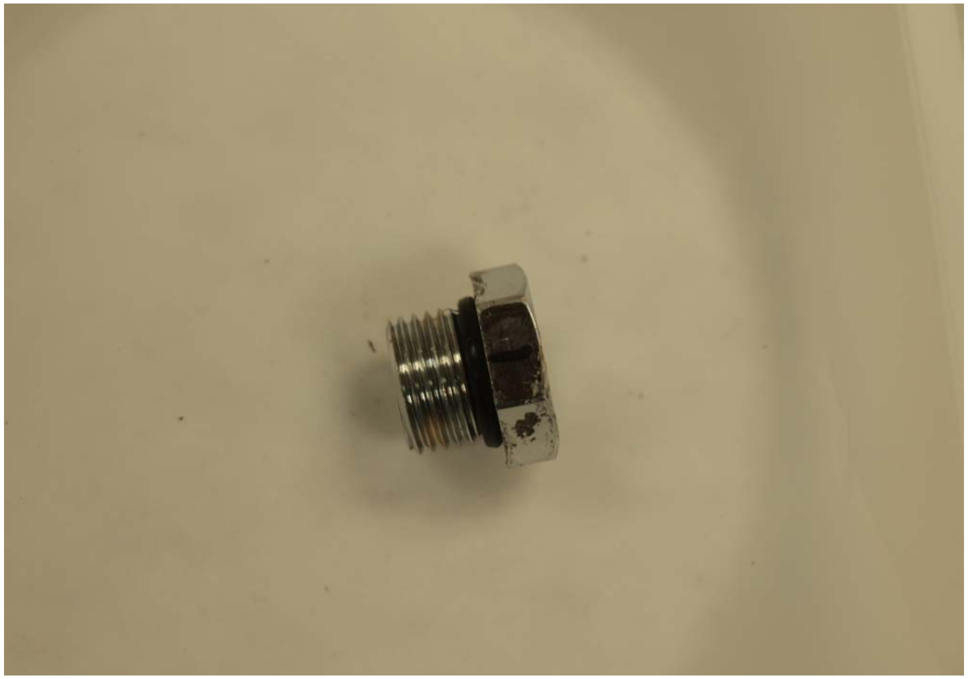


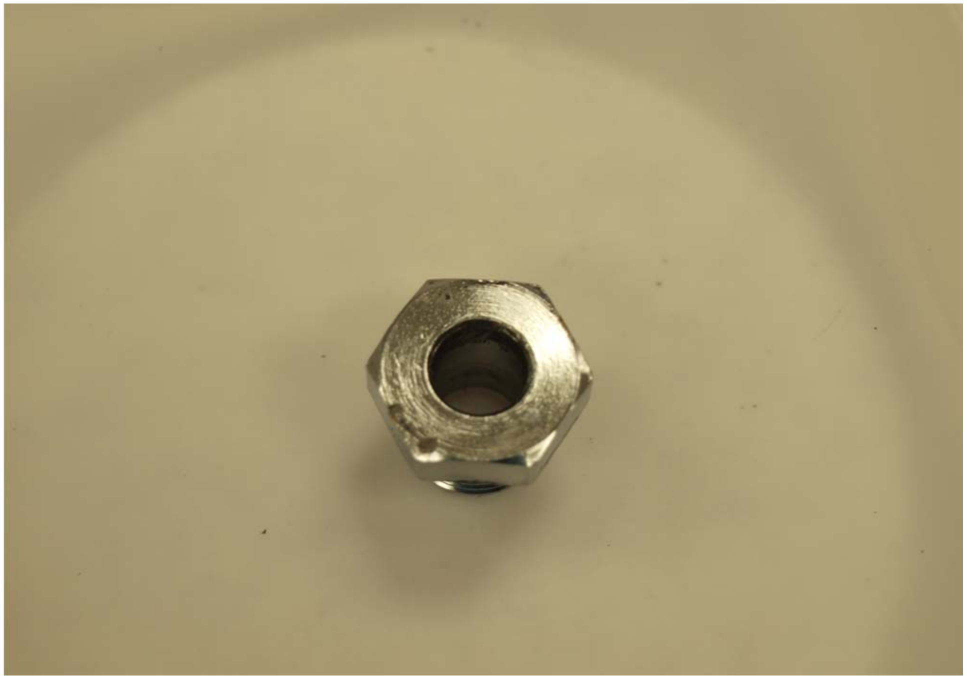
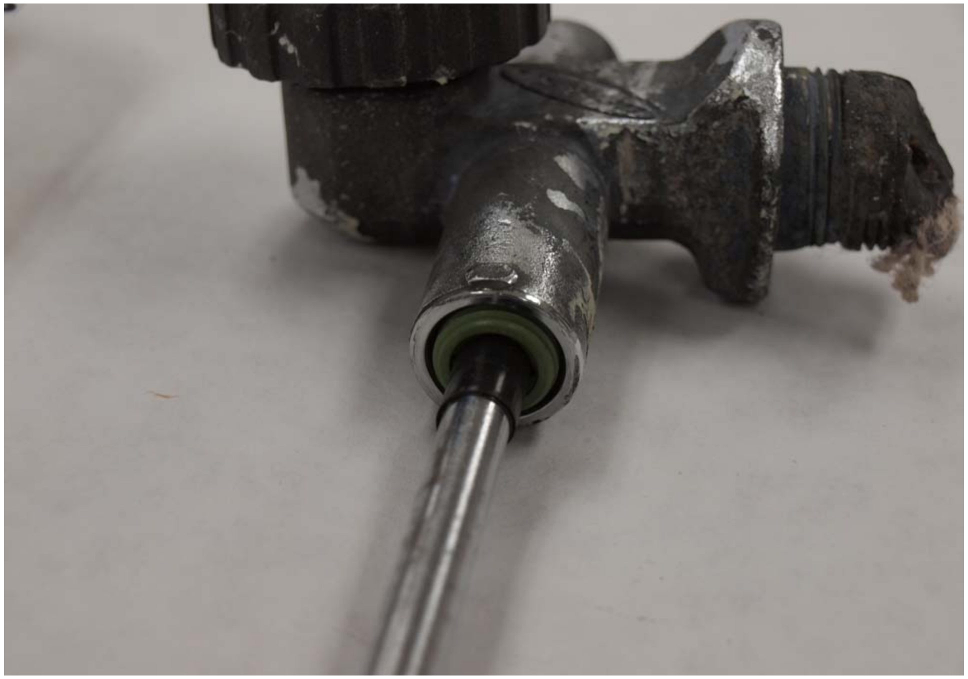
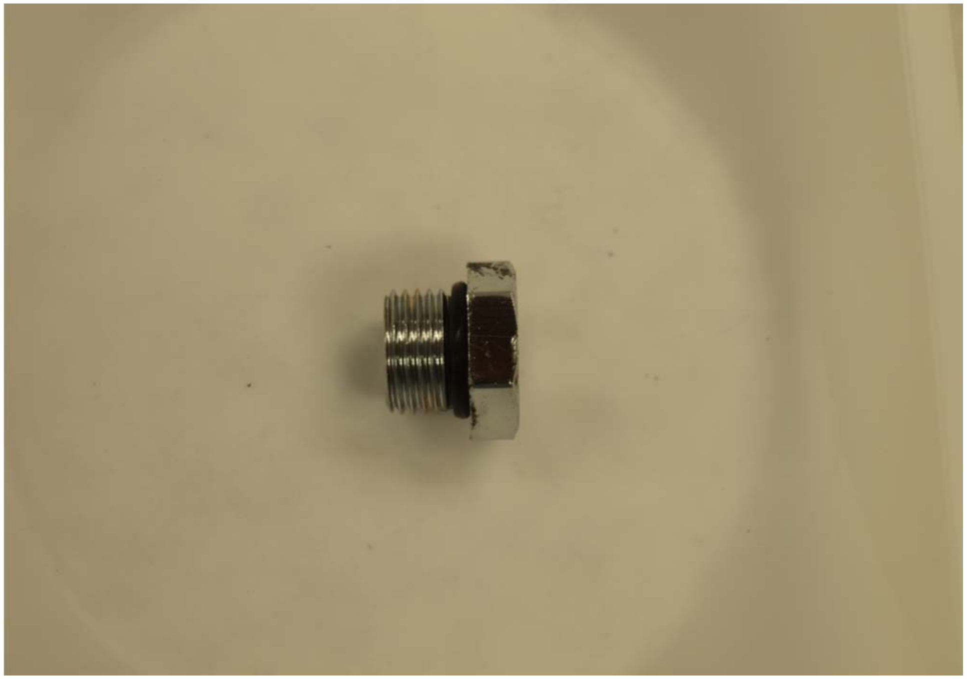




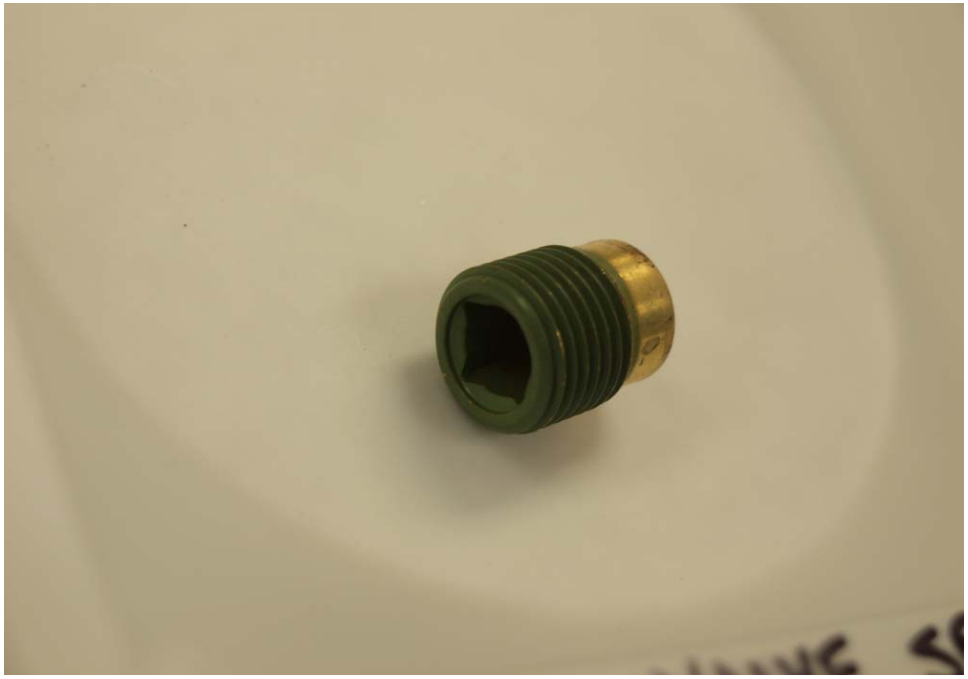
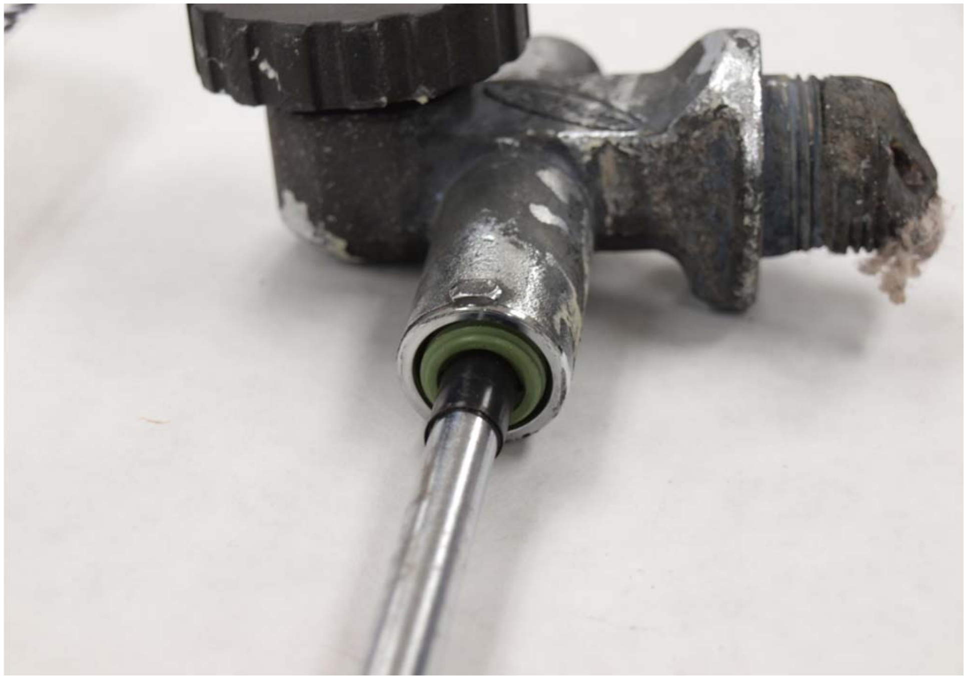
VALVE HANDLE BODY

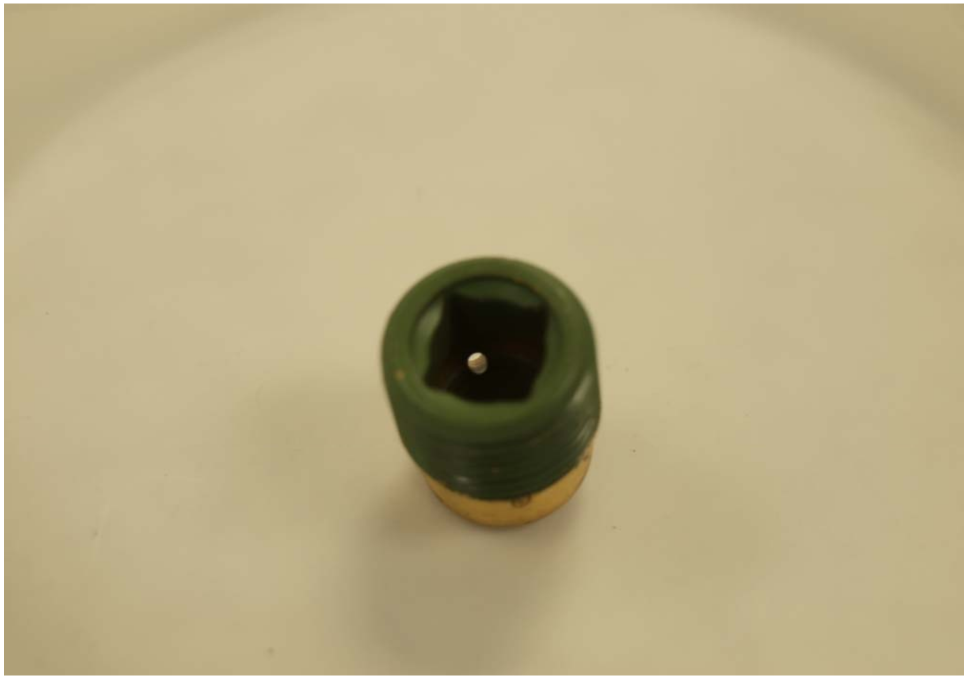







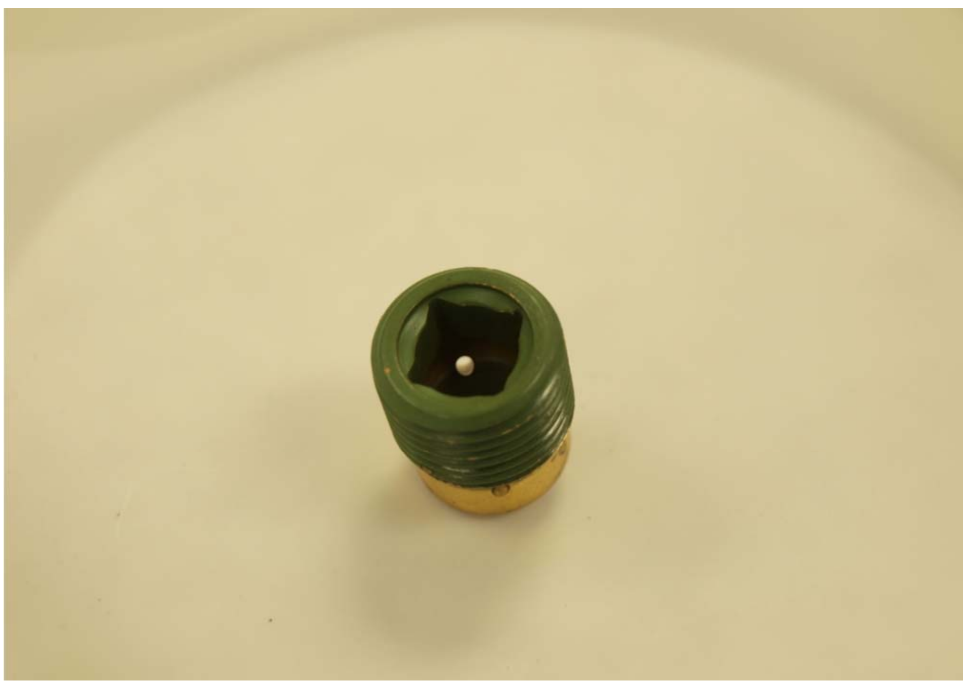








VALVE


GLAND NUT
RELIEF VALVE
VALVE HANDLE BODY
VALVE SEAT BODY

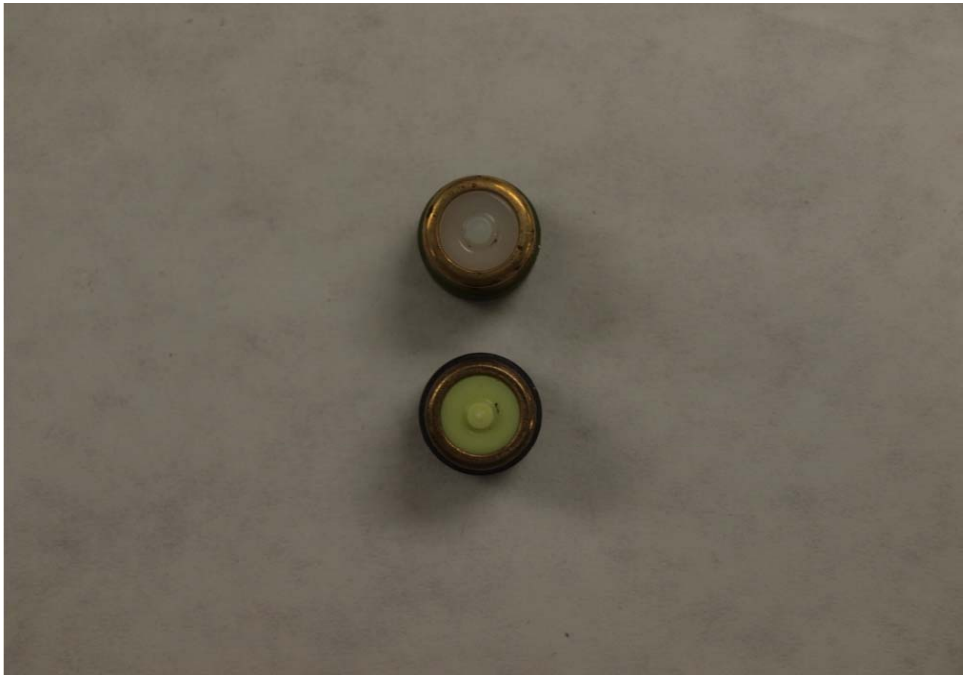
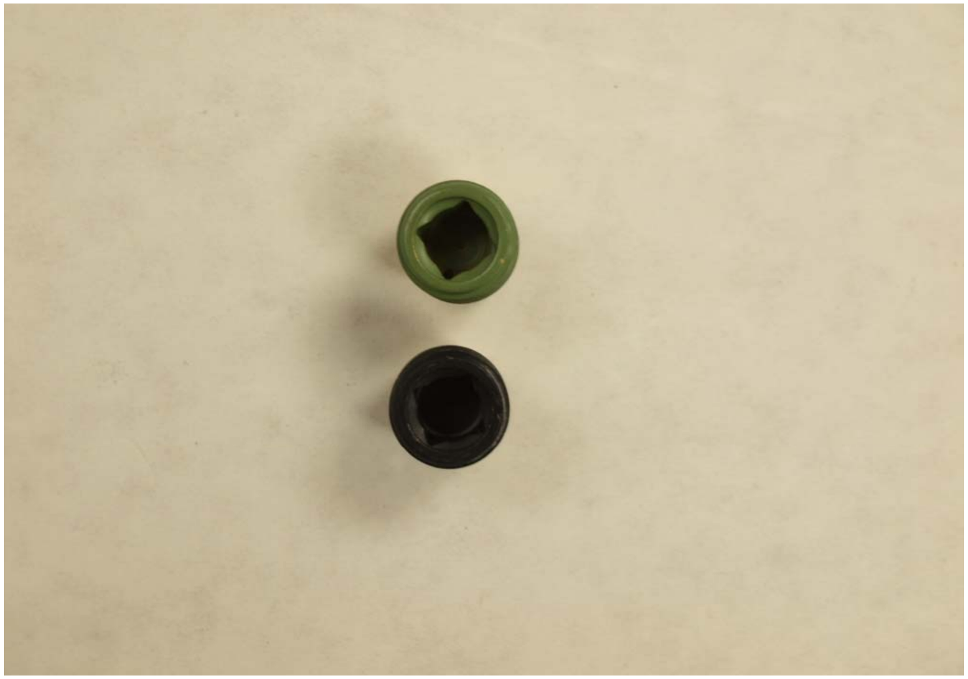


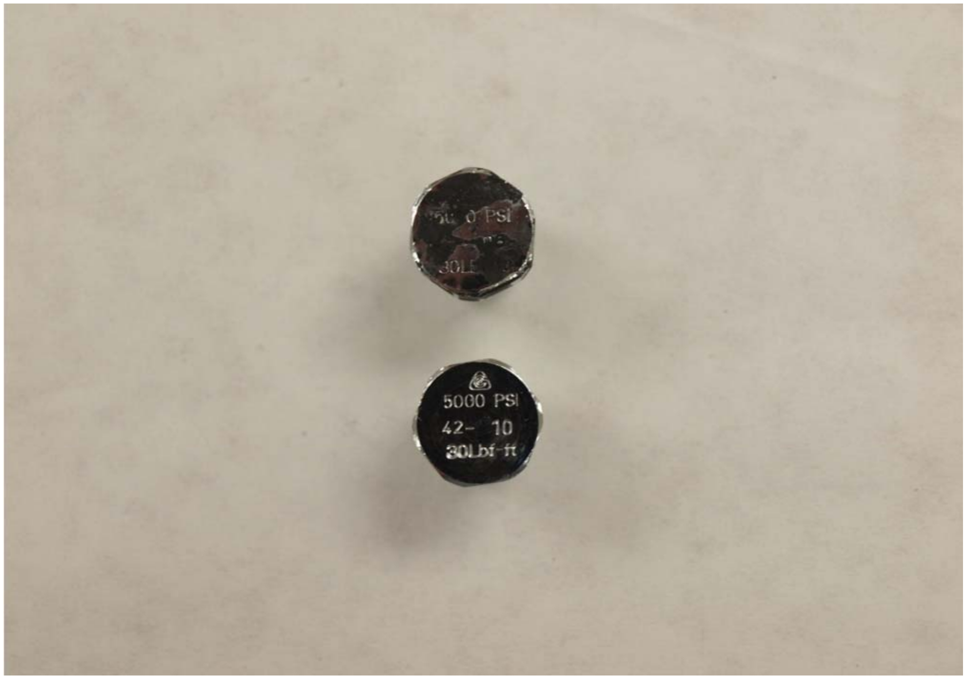






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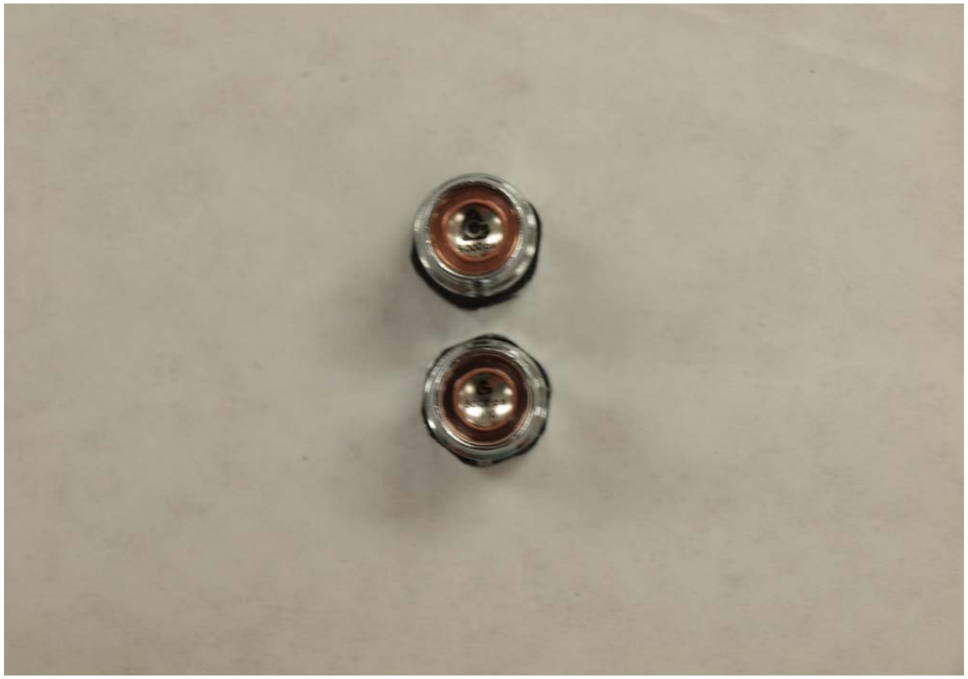

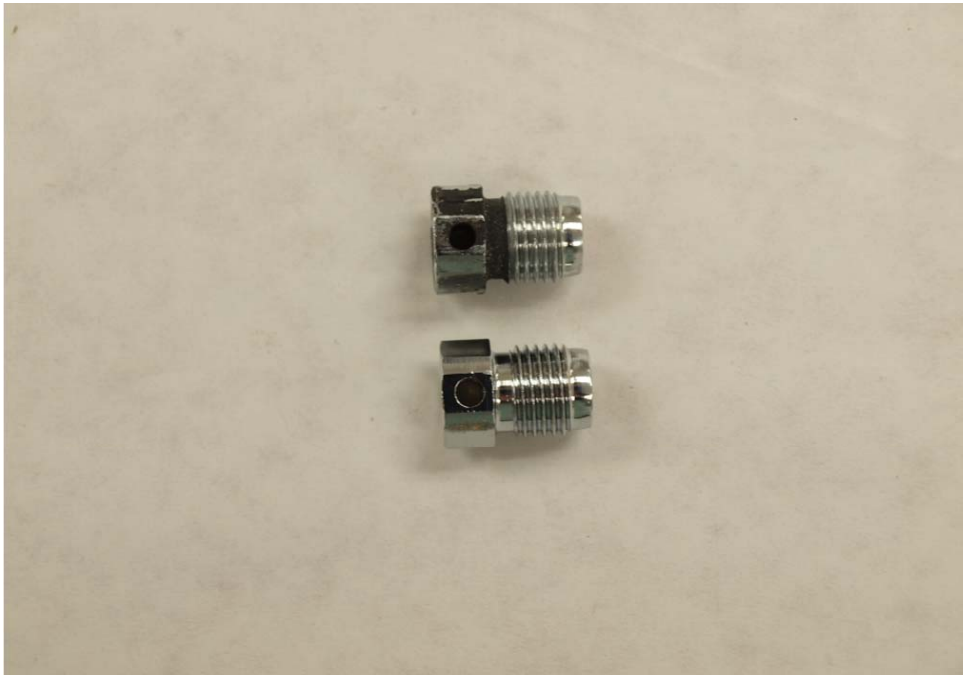


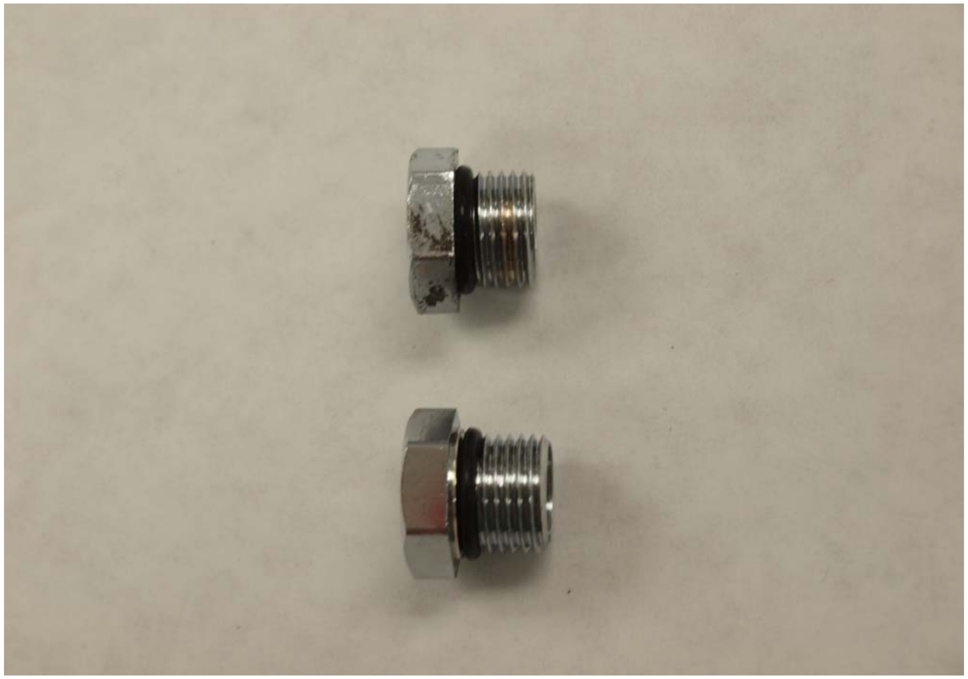
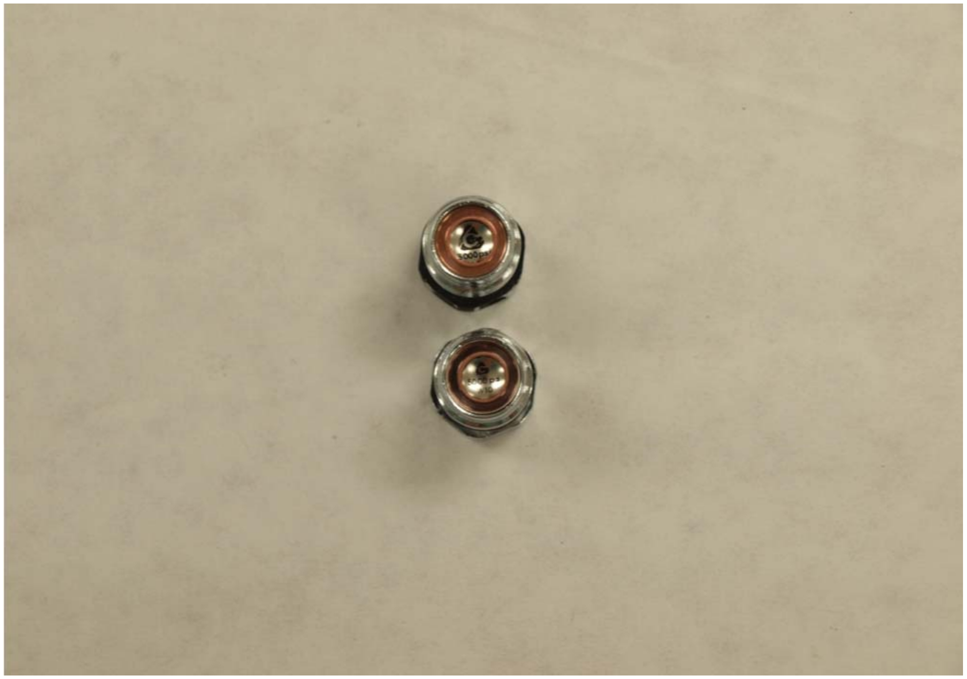





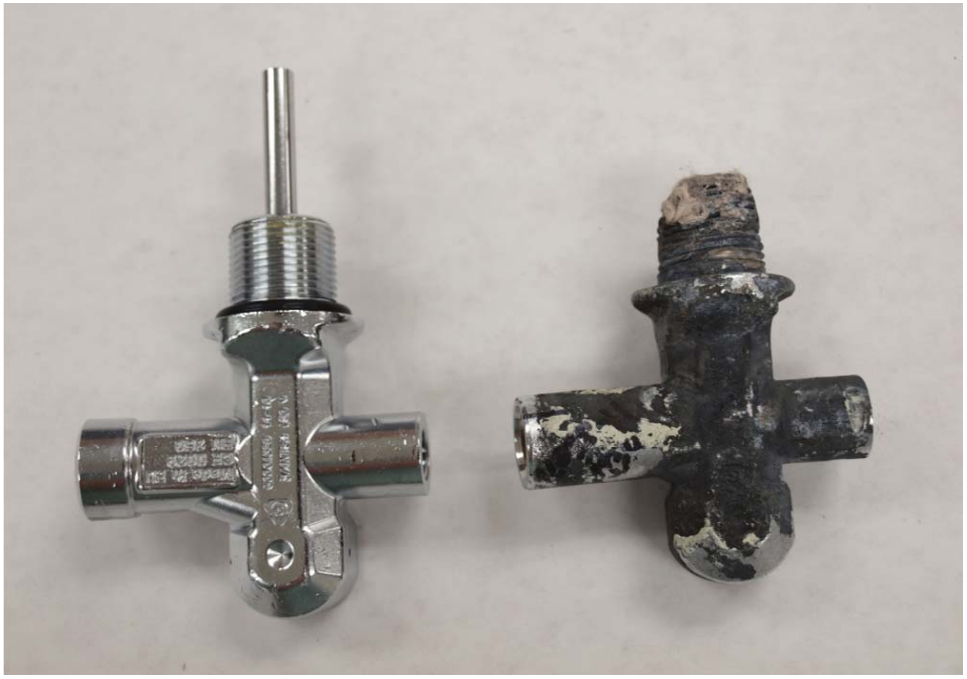


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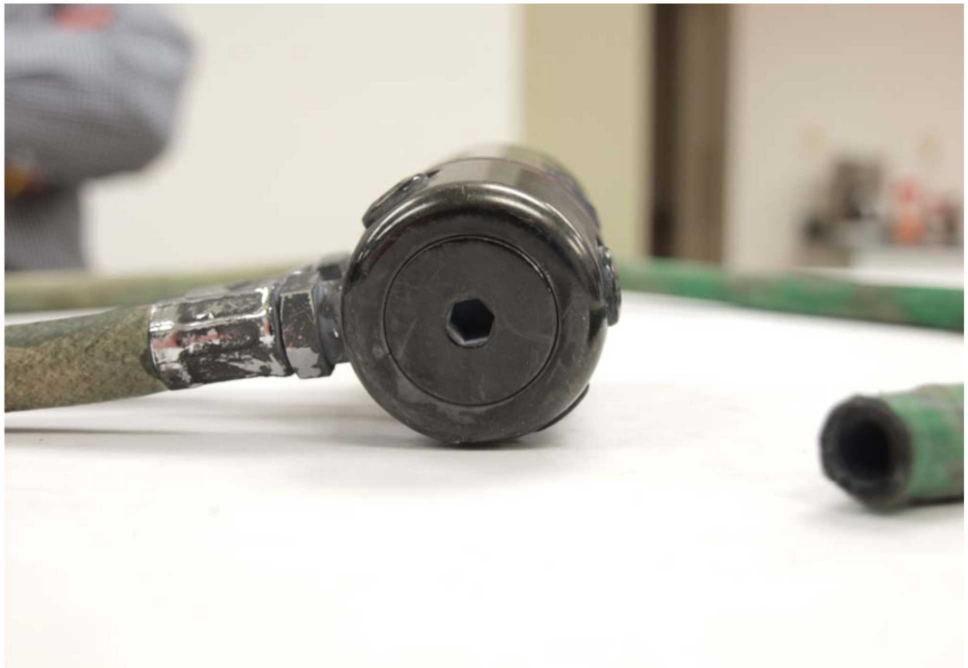




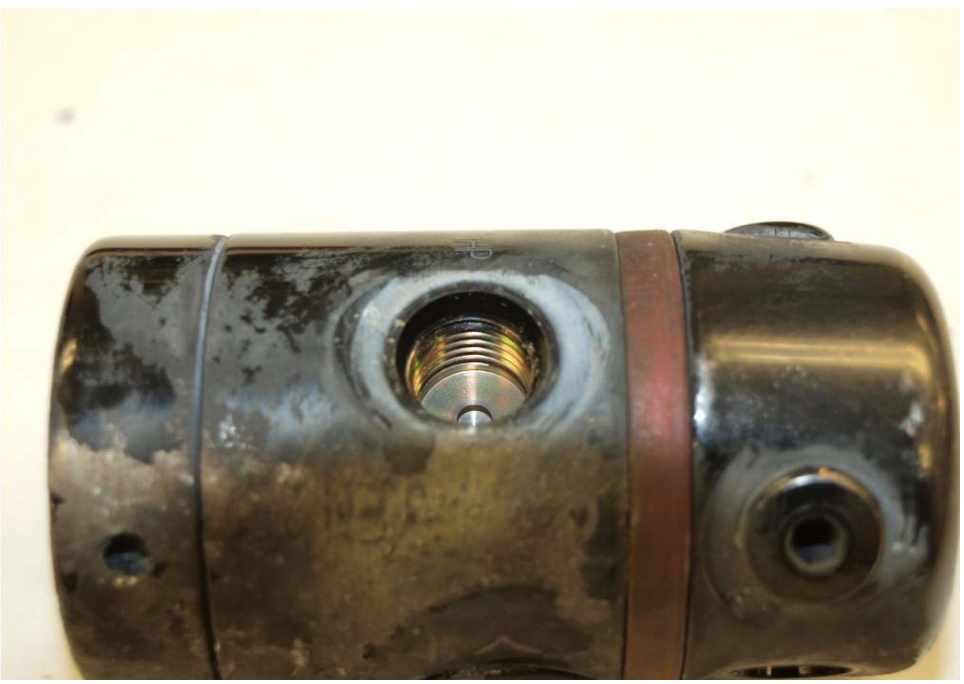





HP

HP


HP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HP








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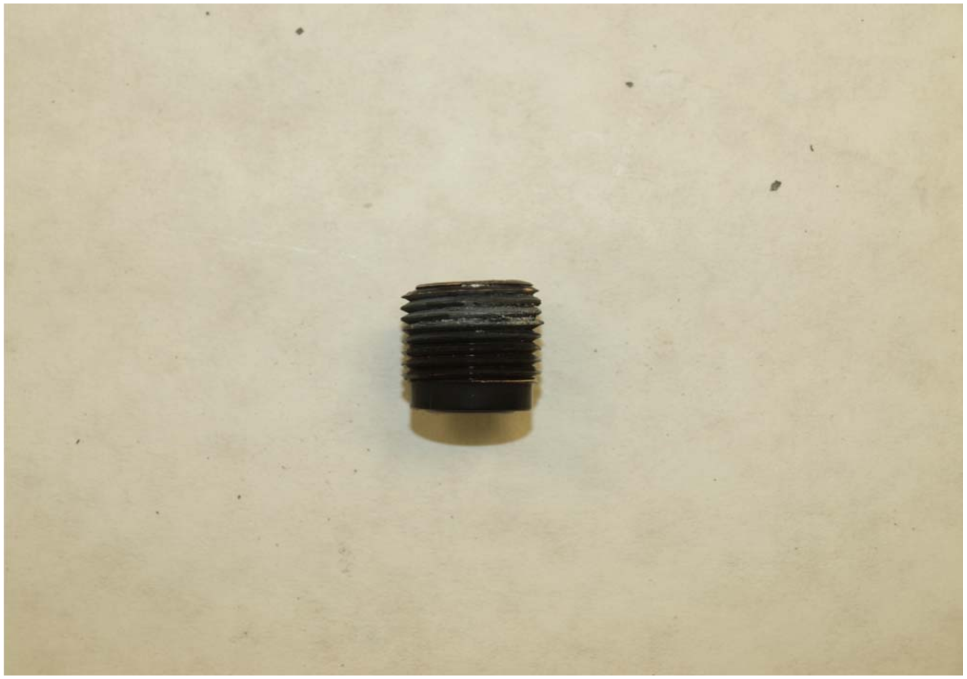









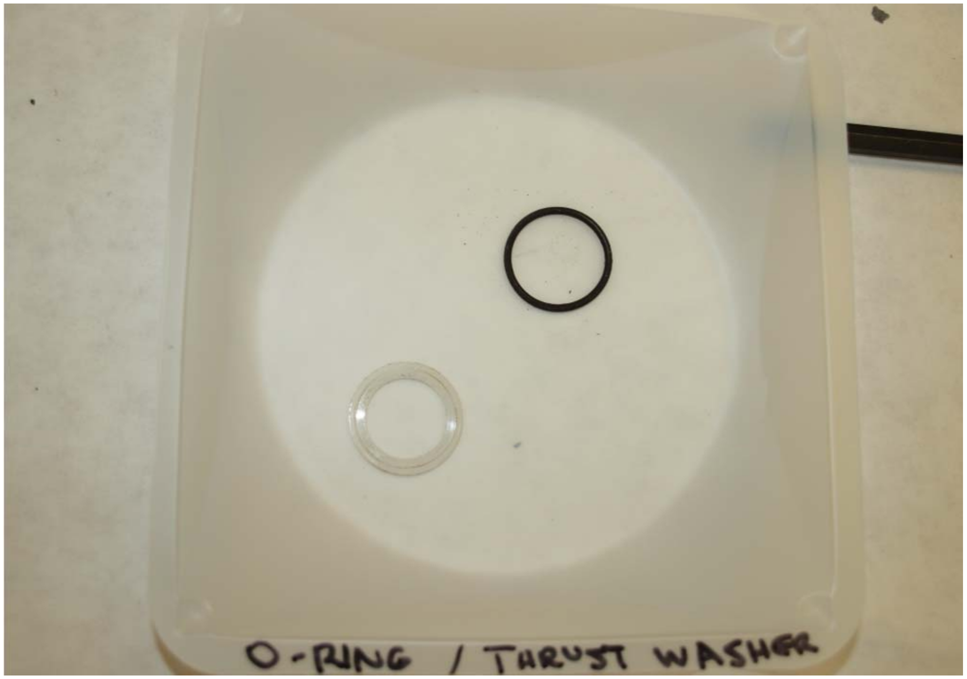
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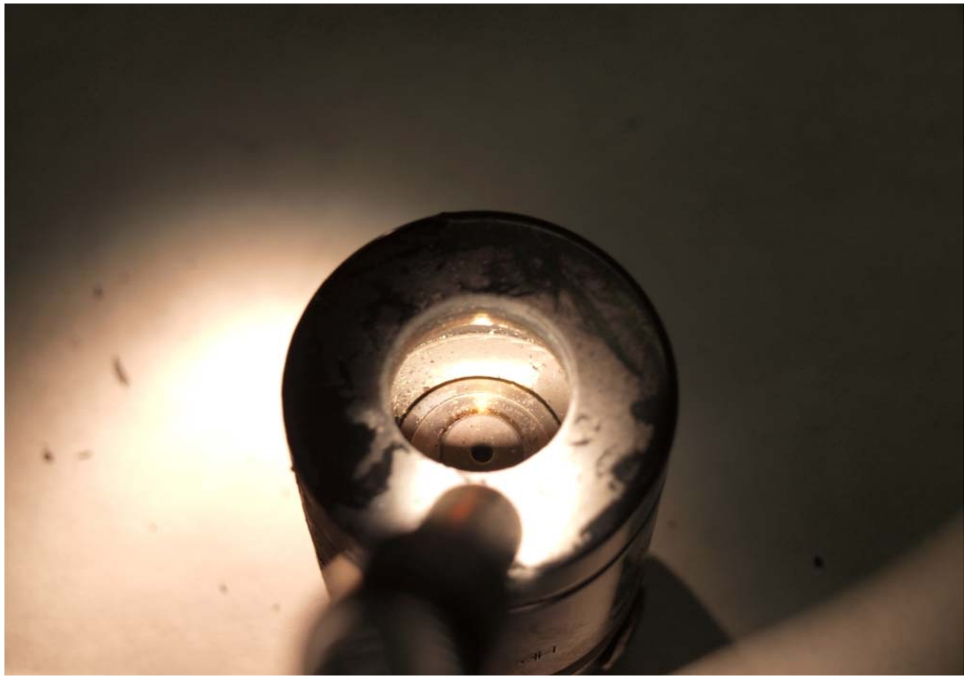


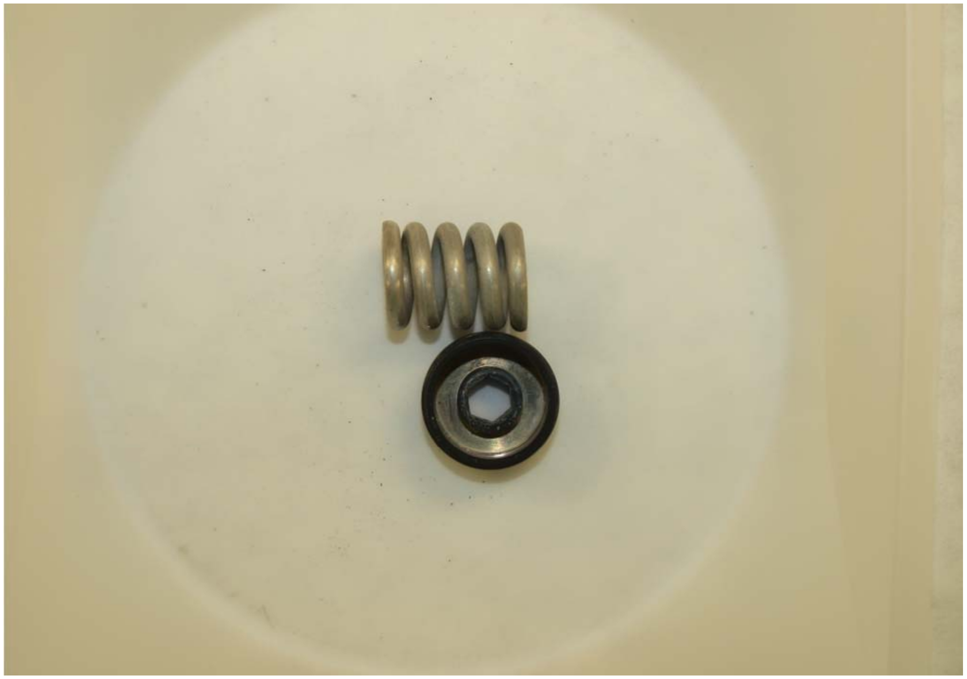




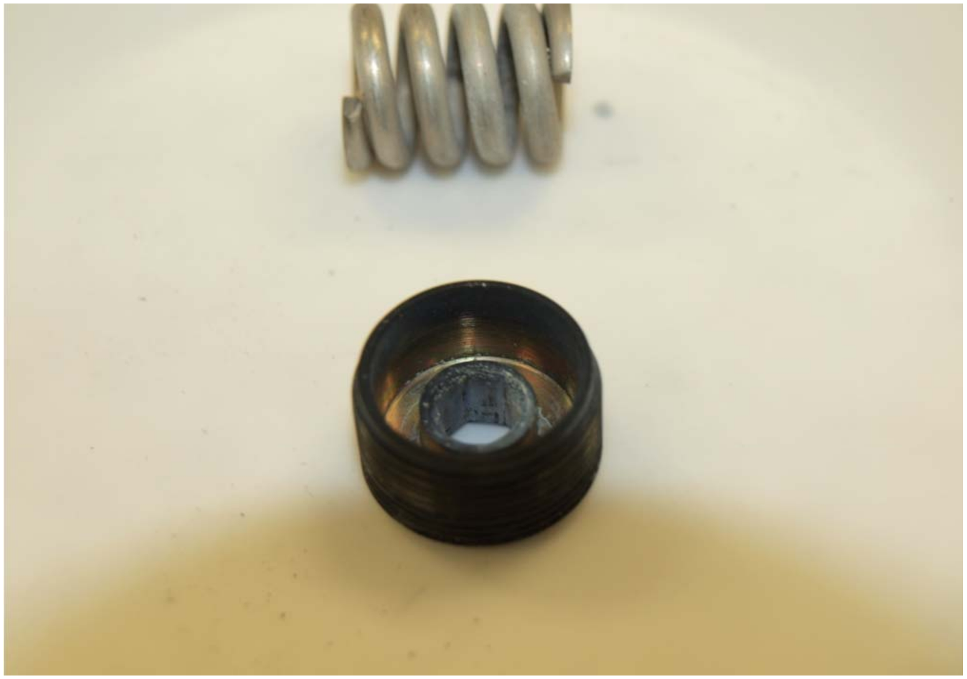
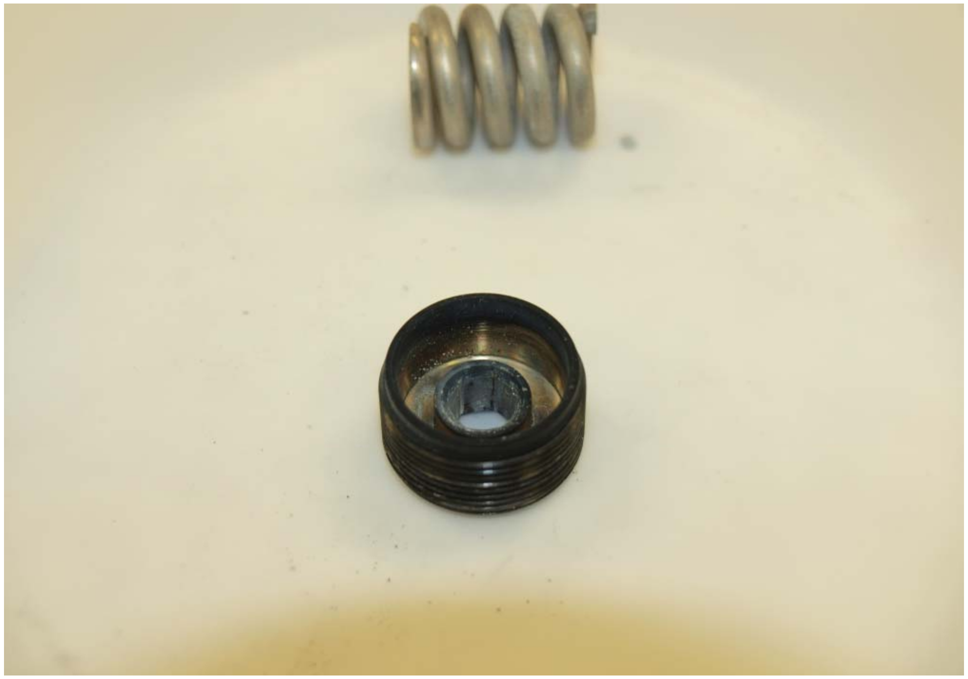

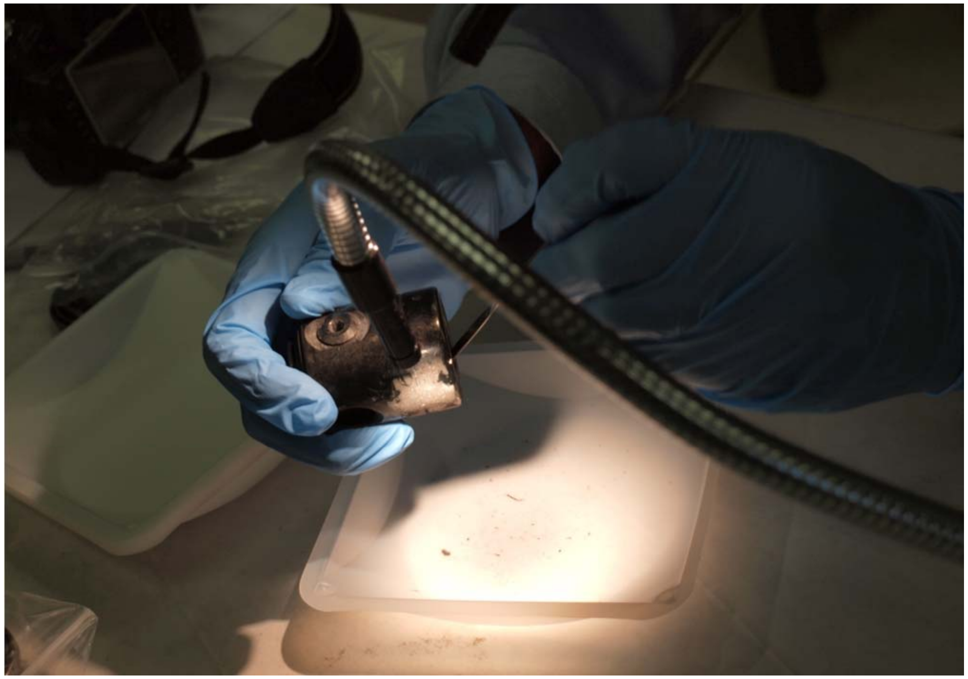

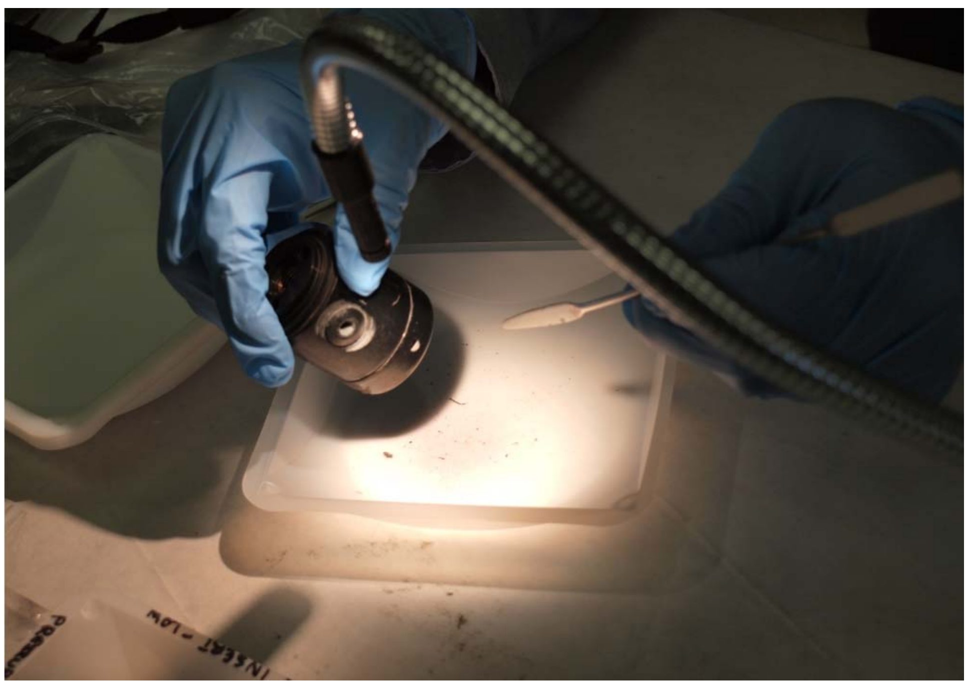


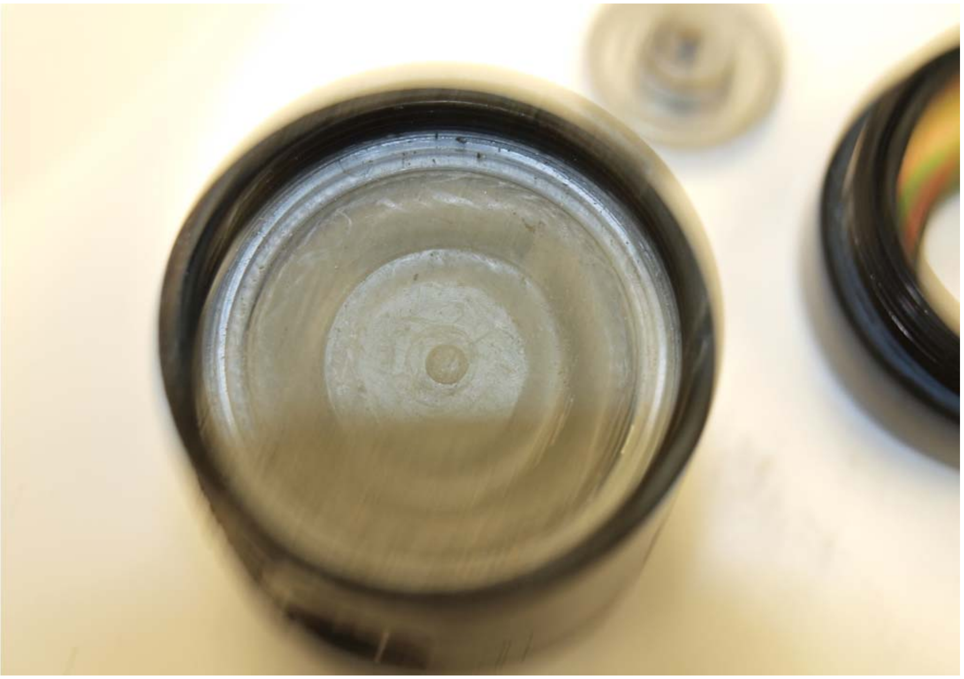


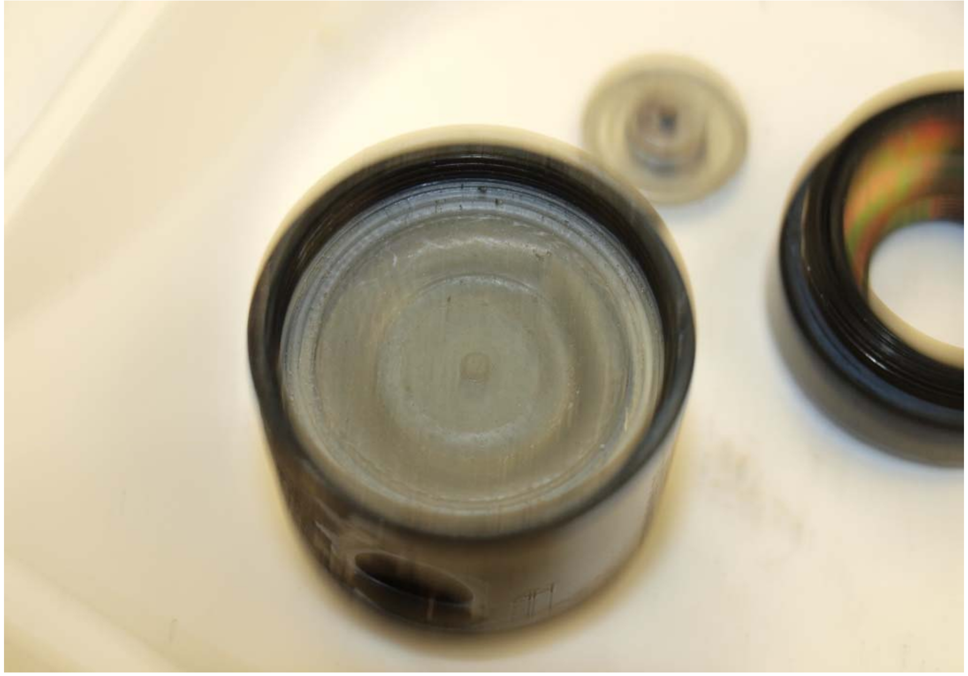




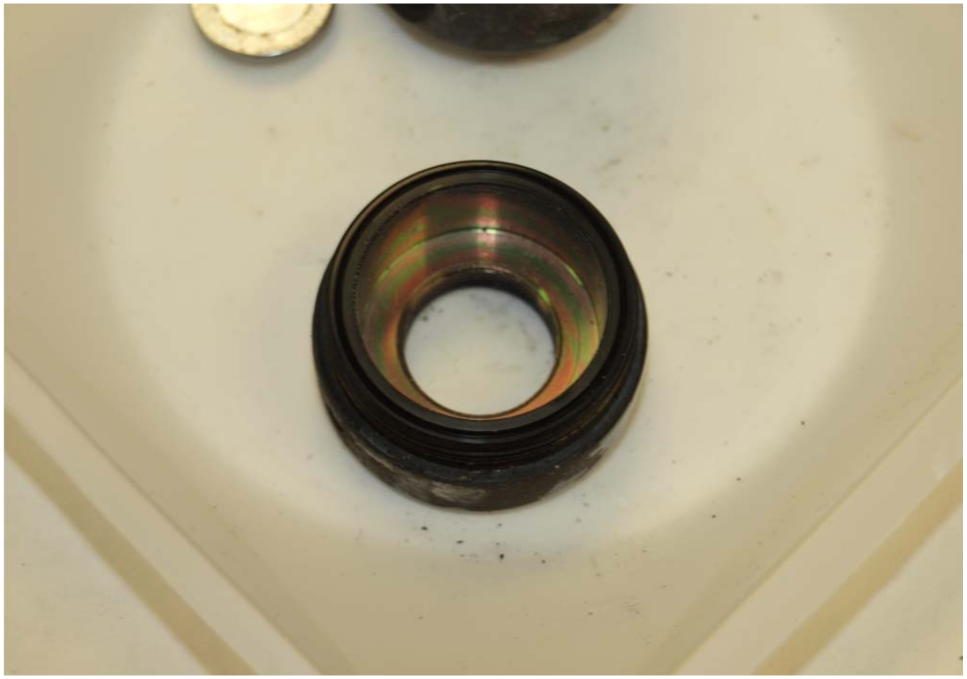

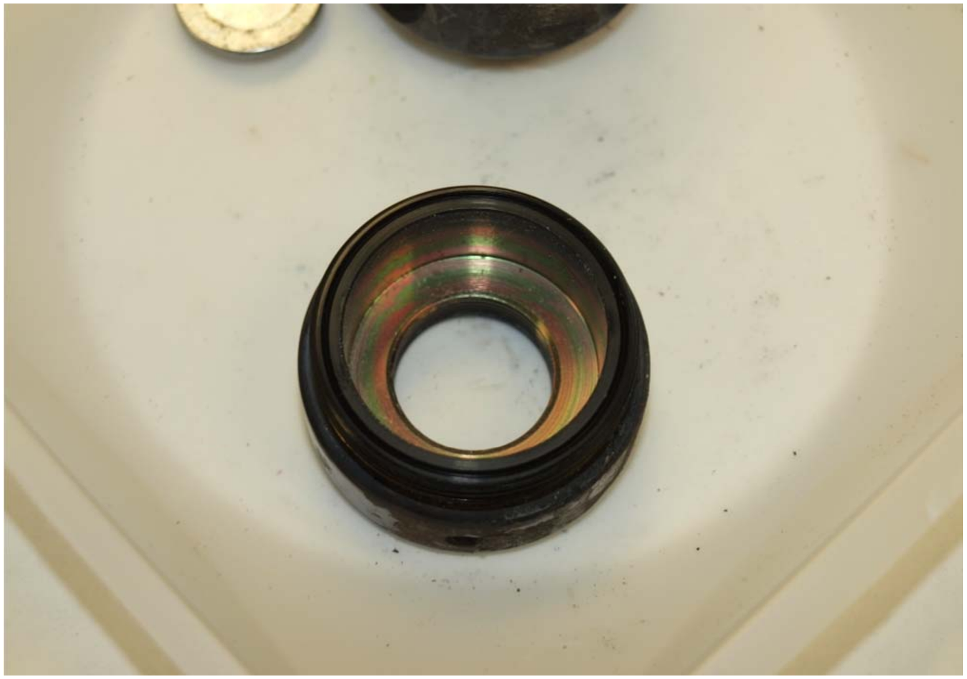



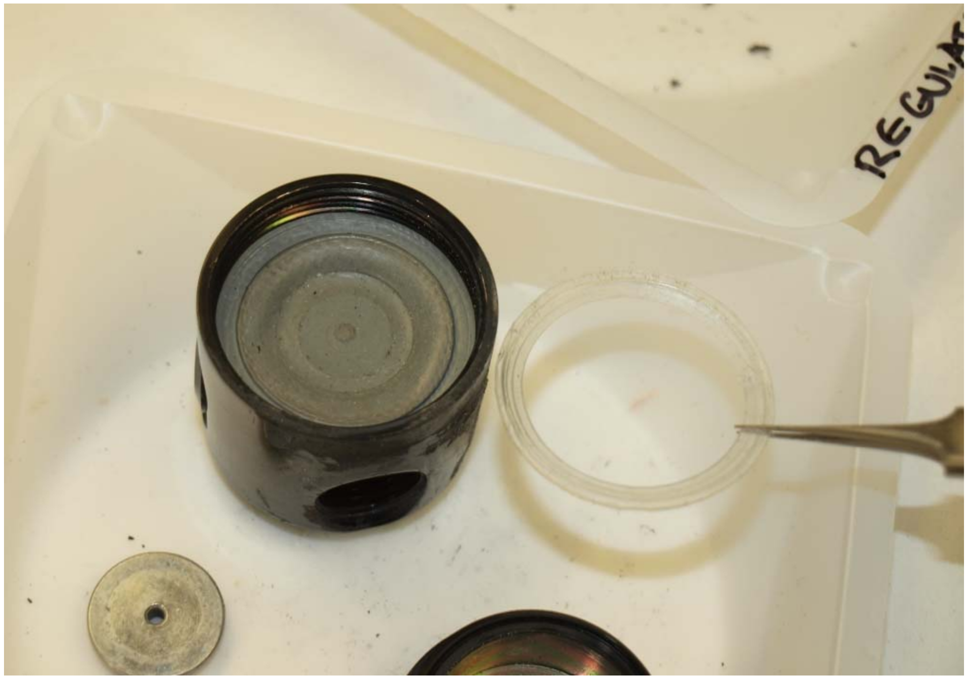

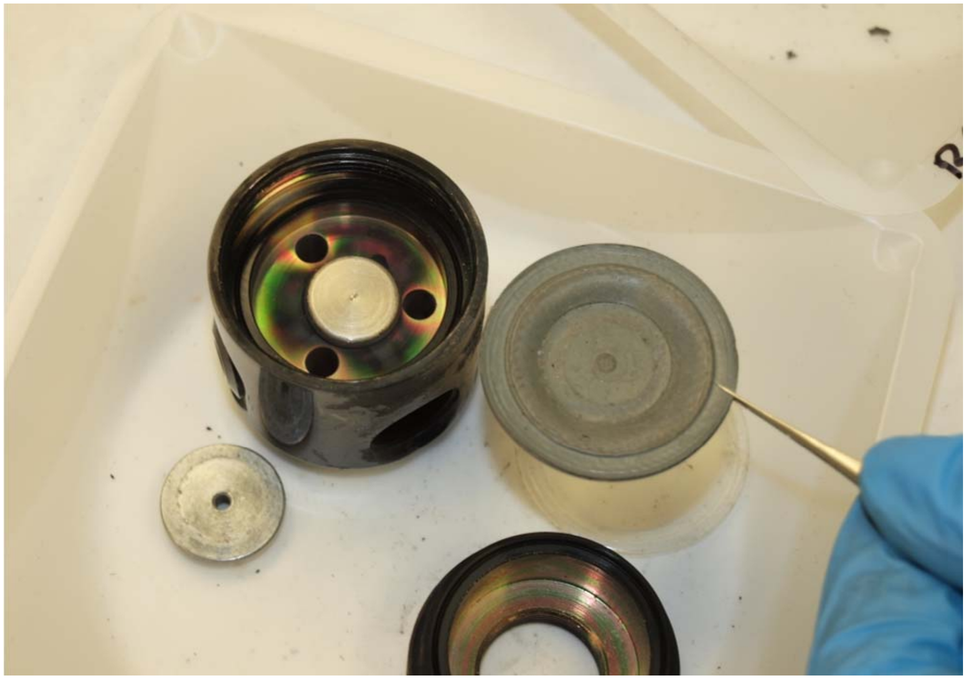


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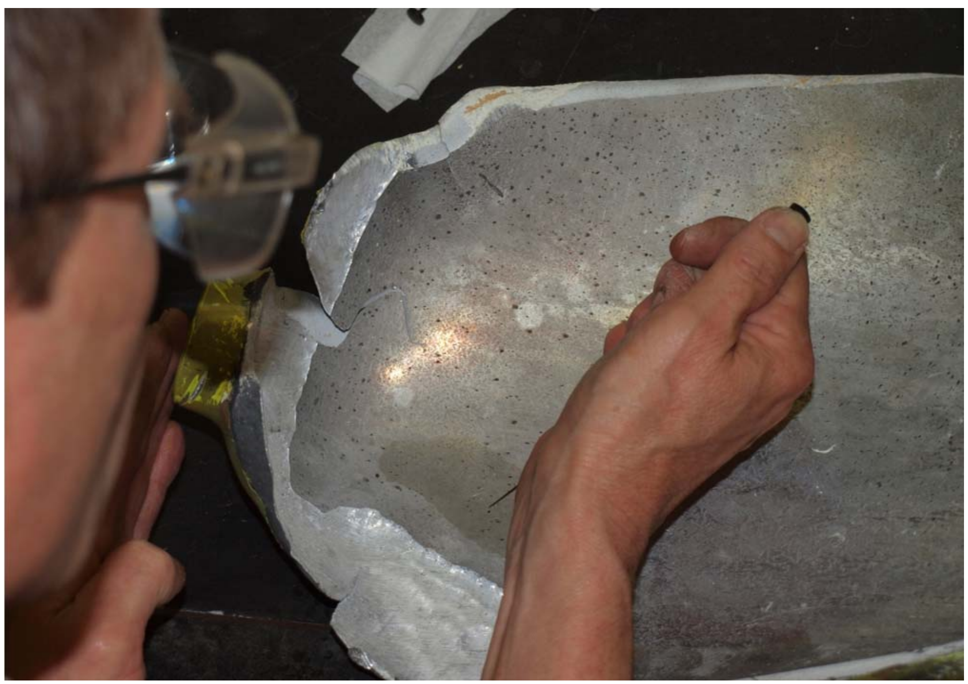
BASE



























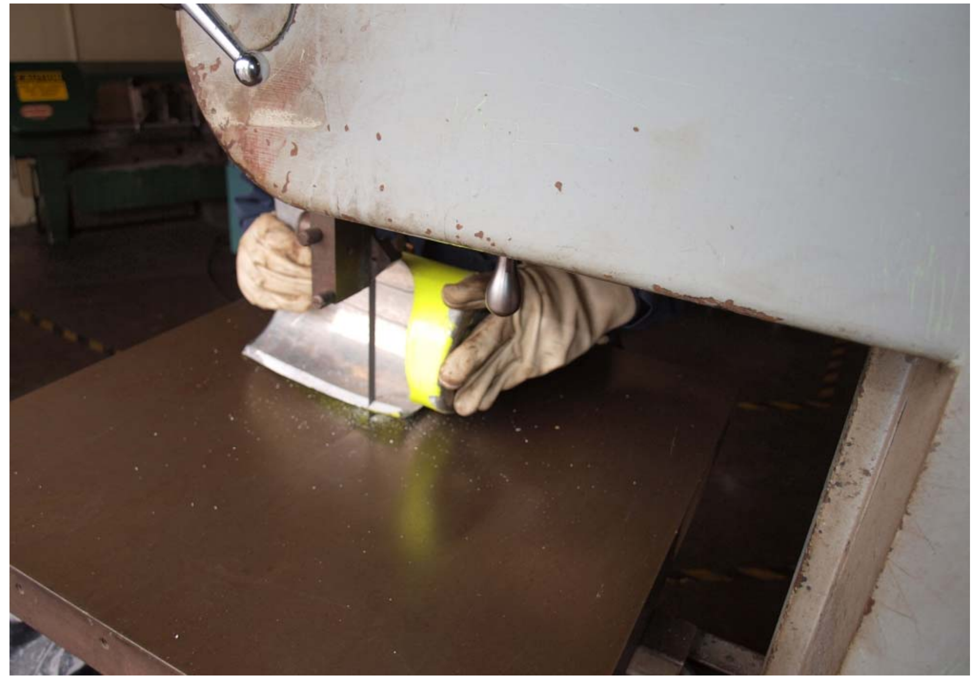










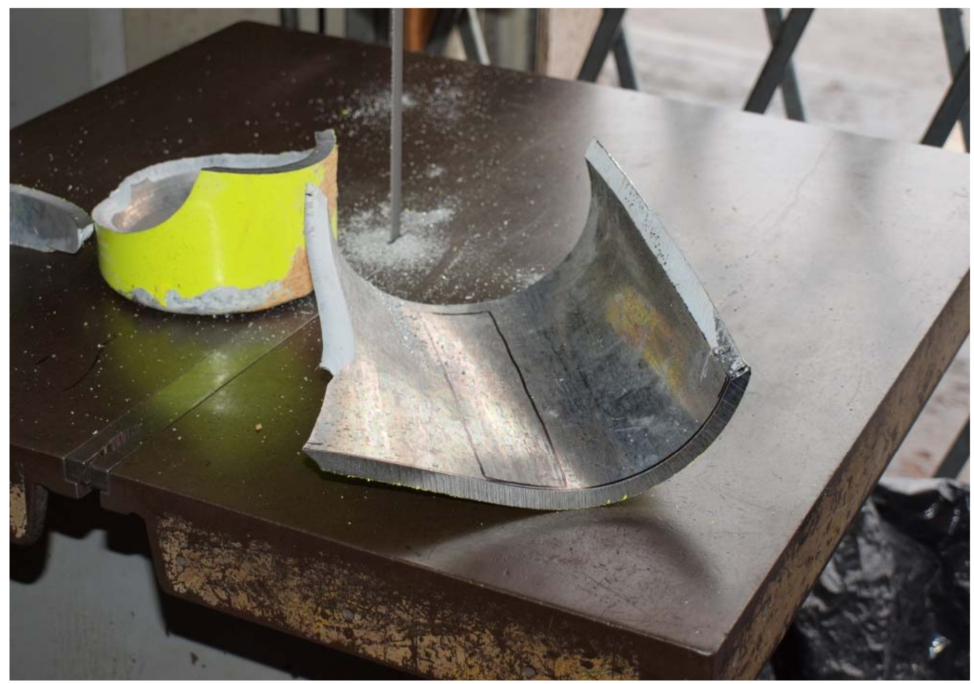






To CLEAN
USE A Brush
NOT THE
AIR Hose!





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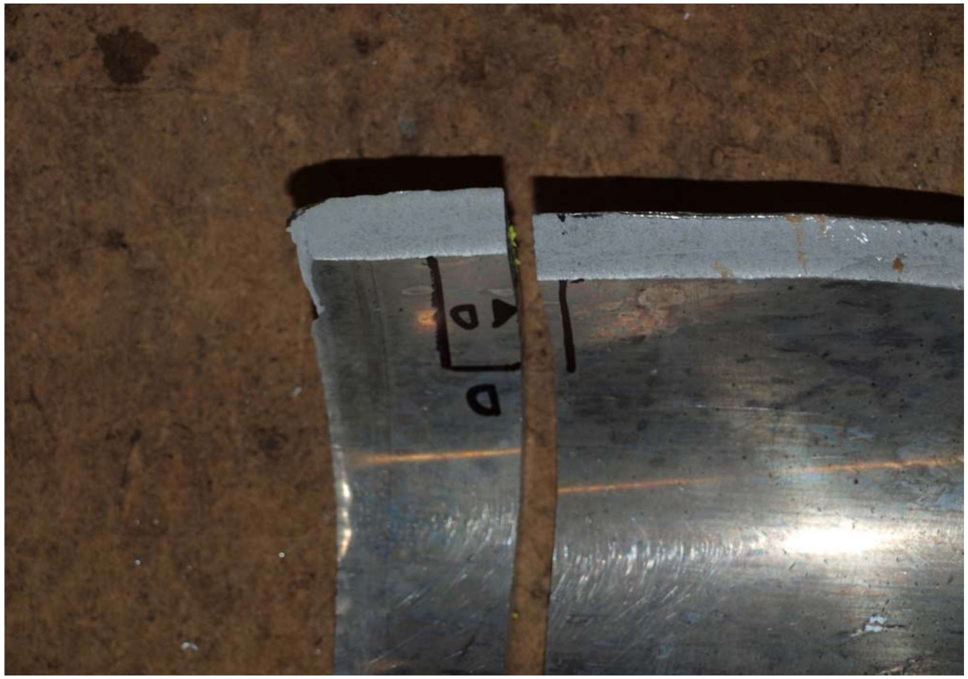



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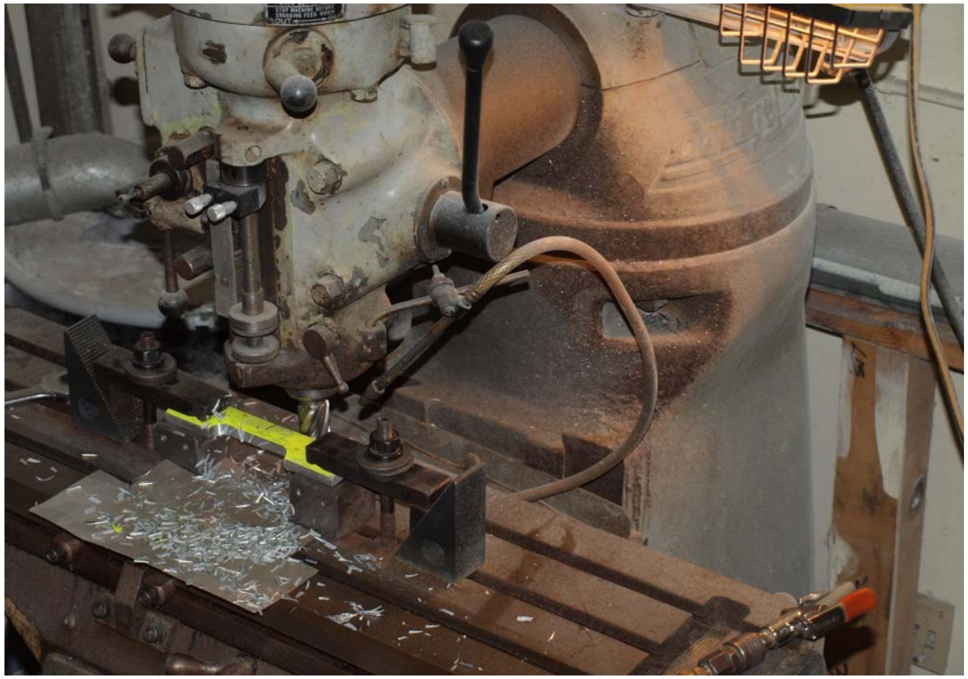
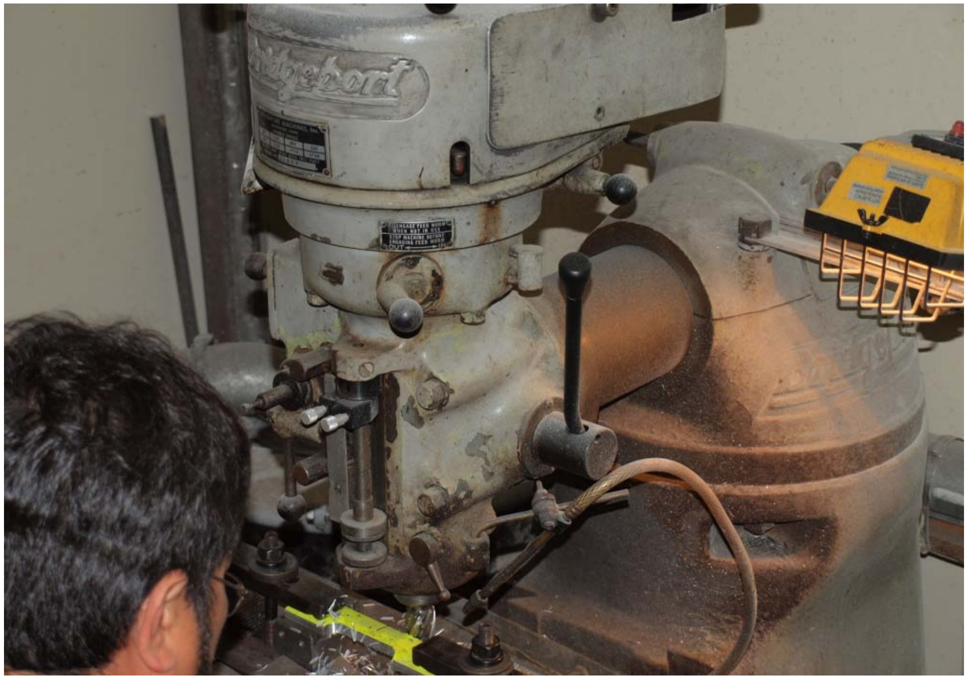





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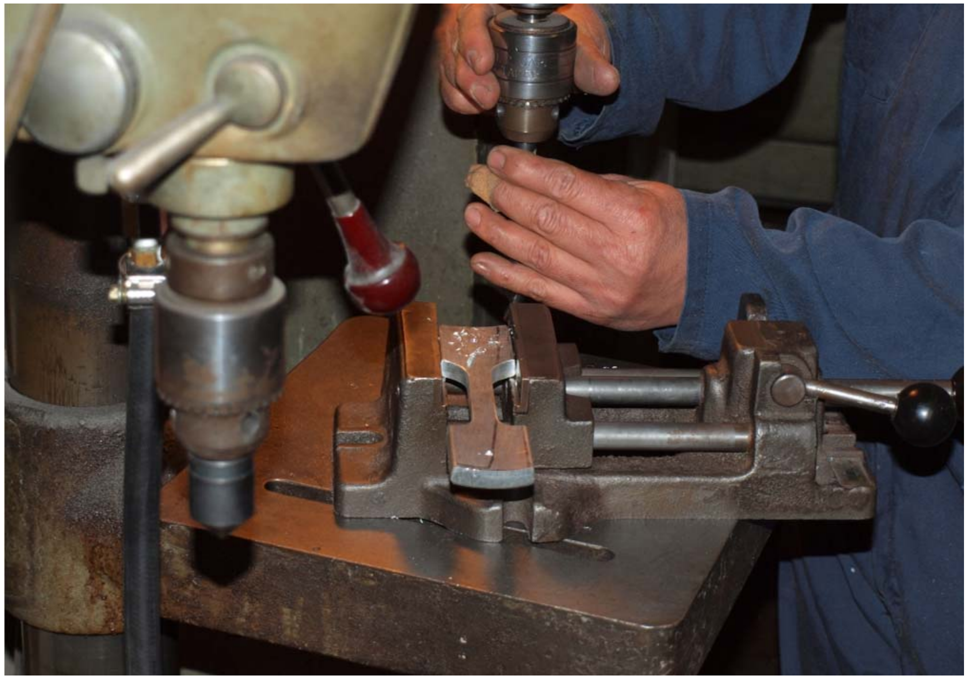


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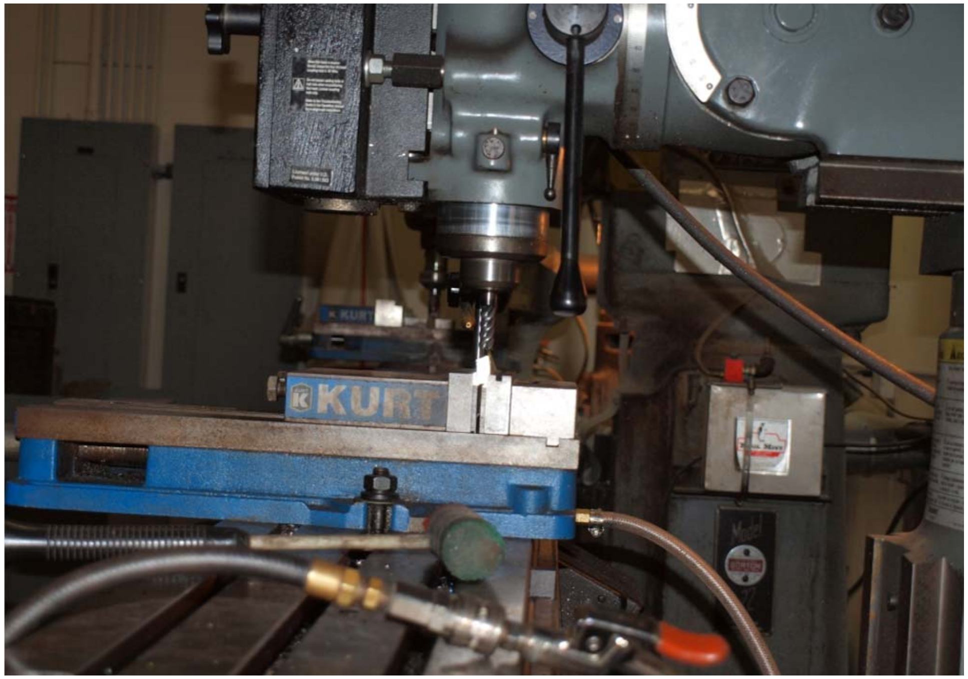
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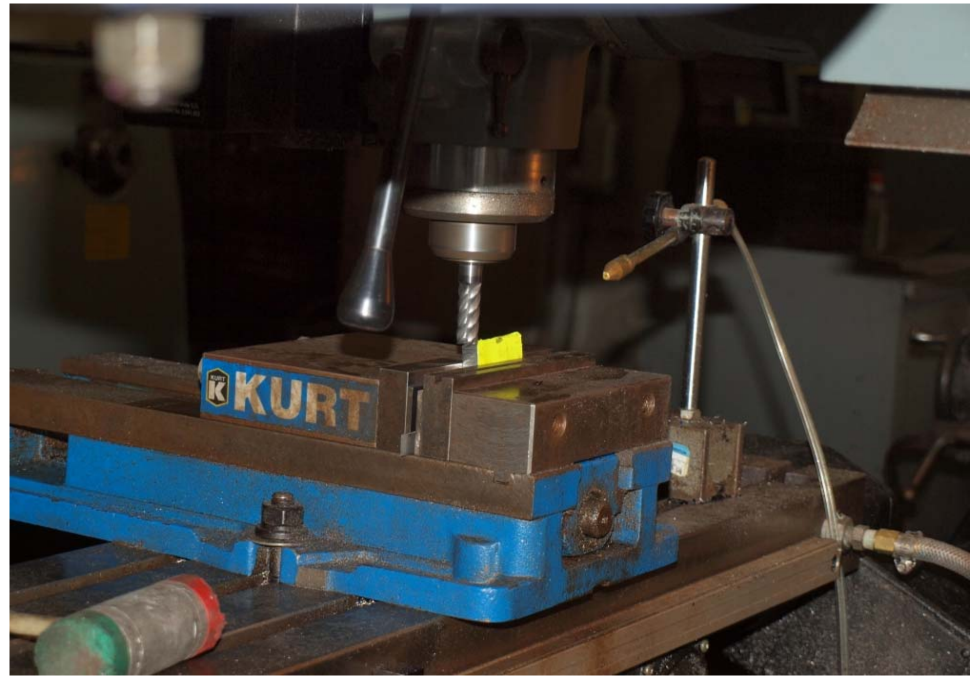
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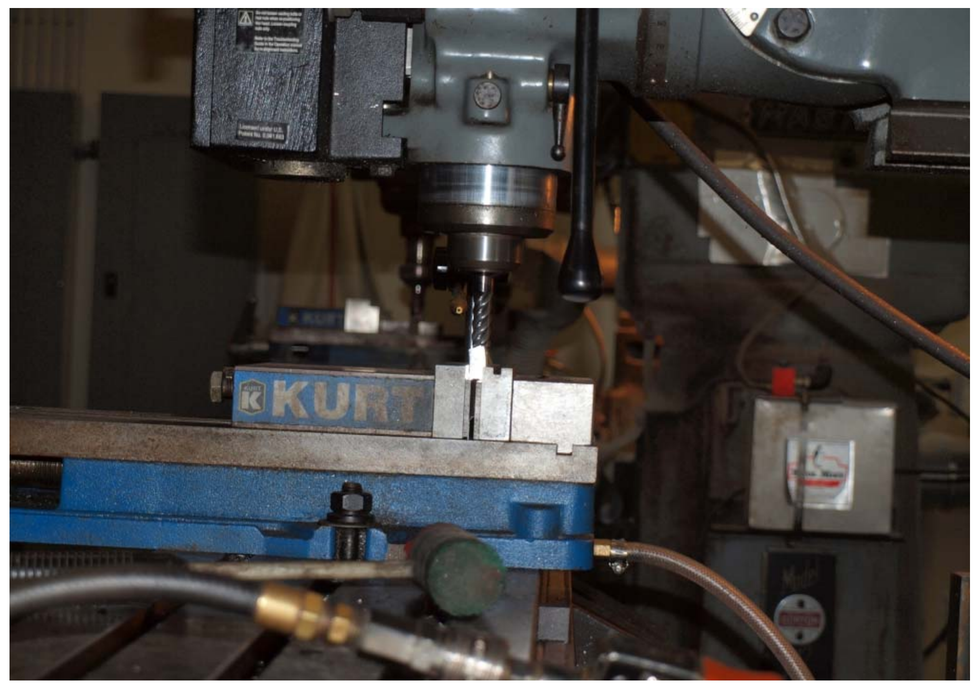
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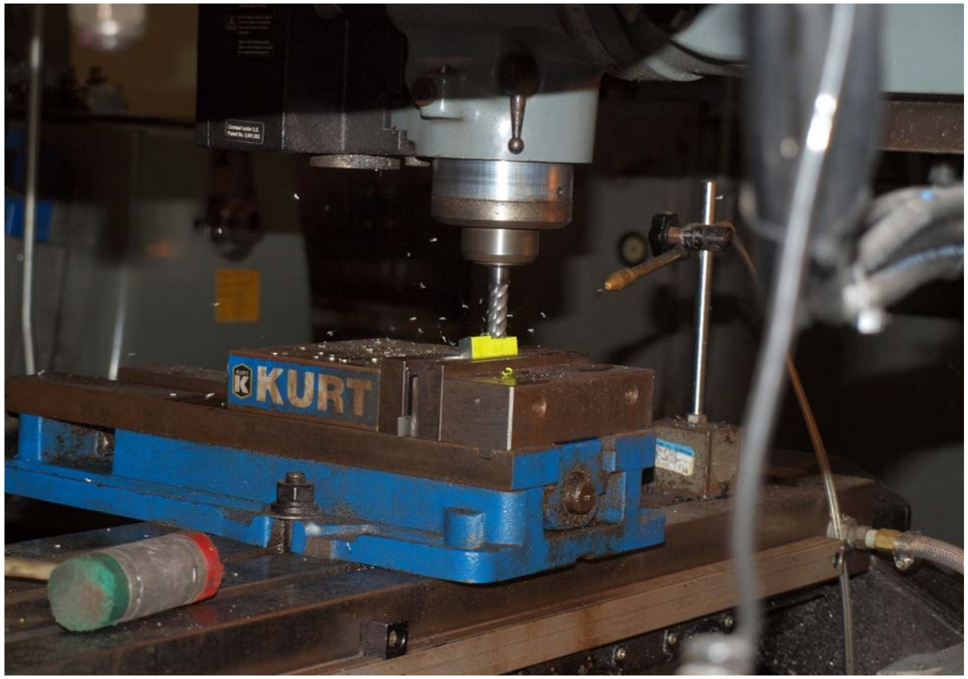
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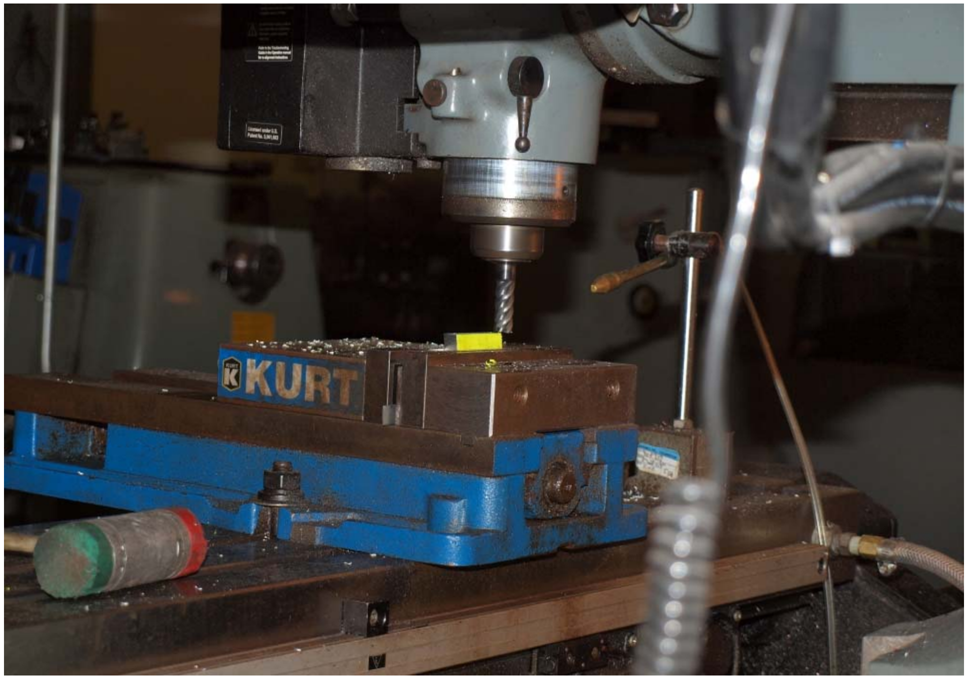
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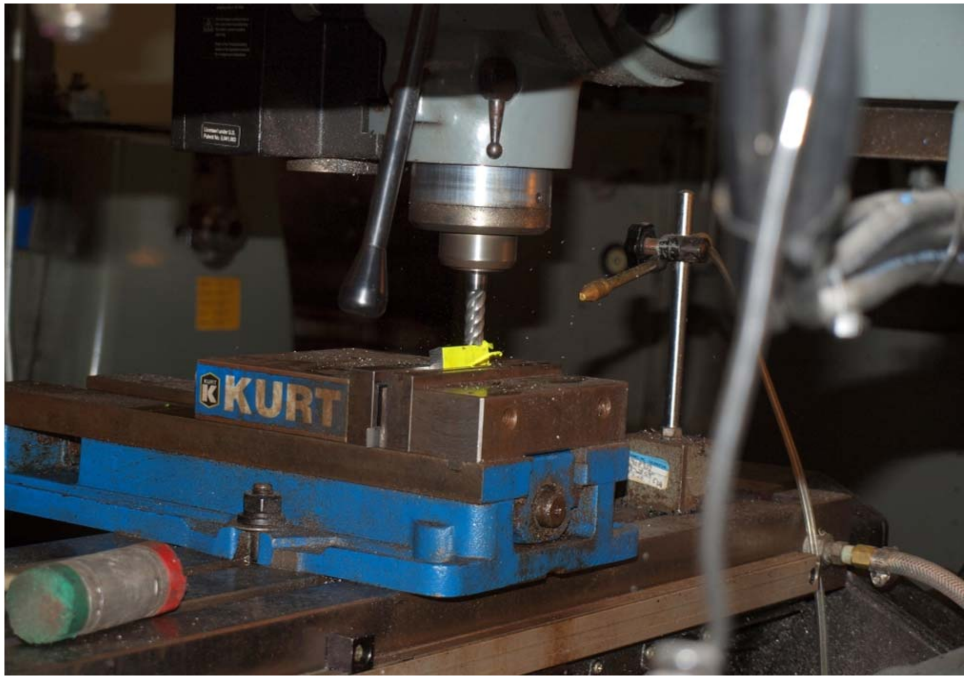
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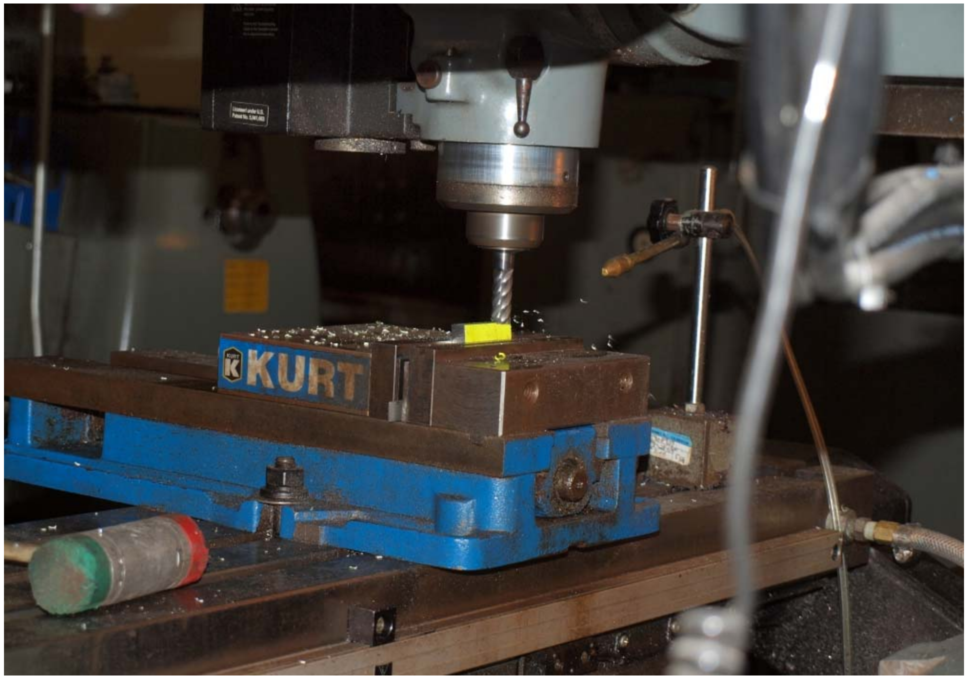
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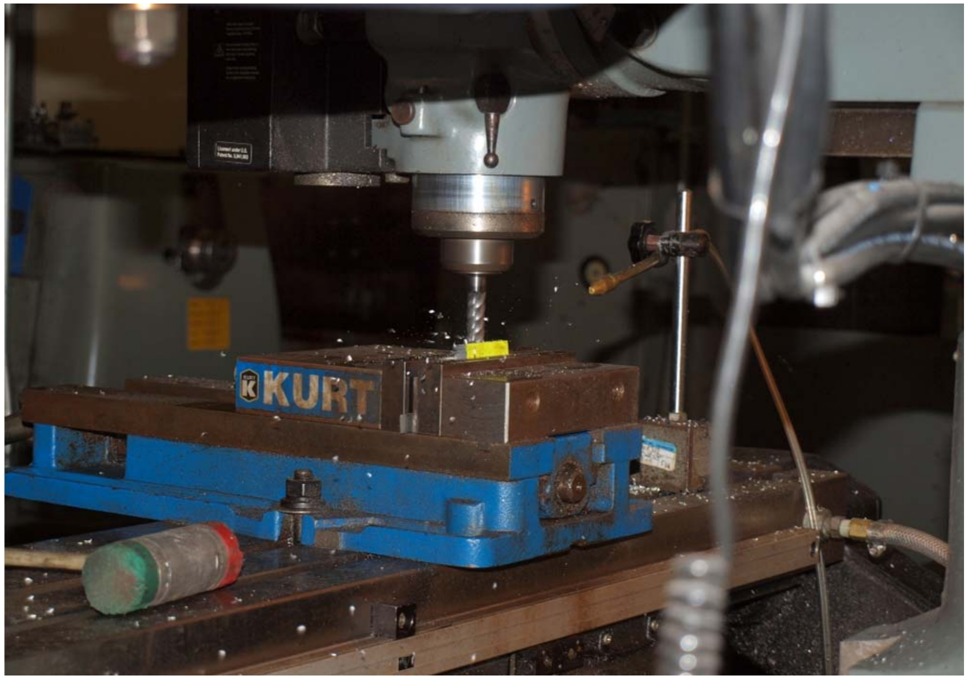
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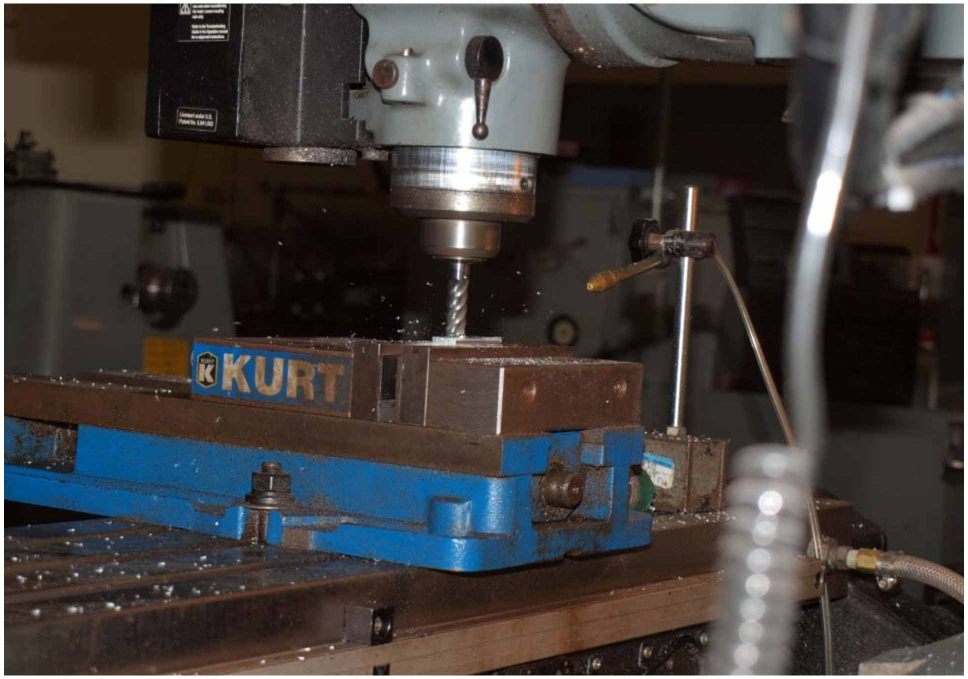
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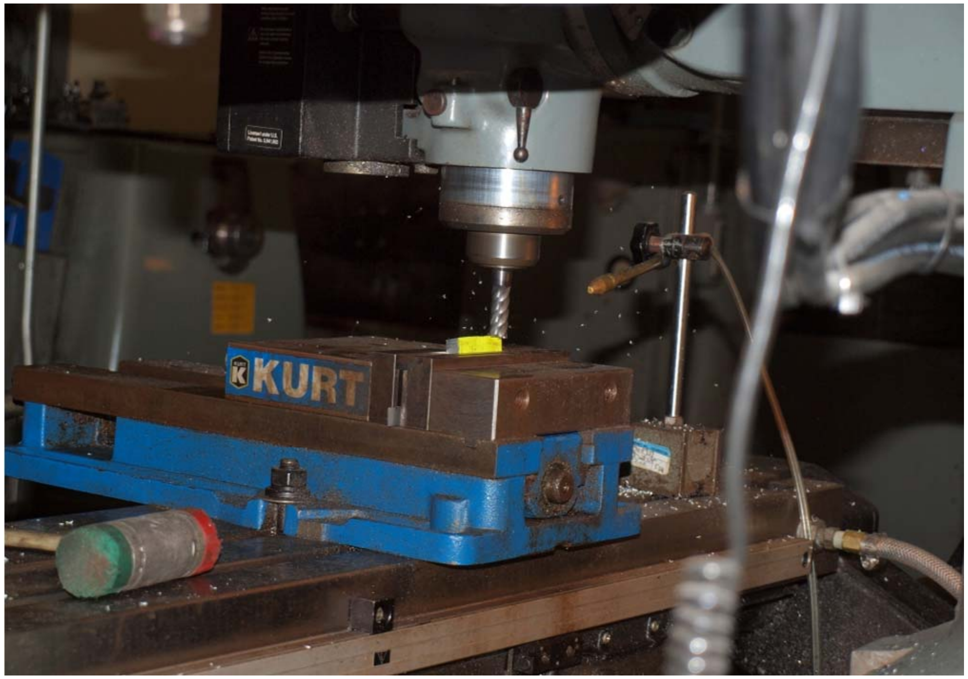
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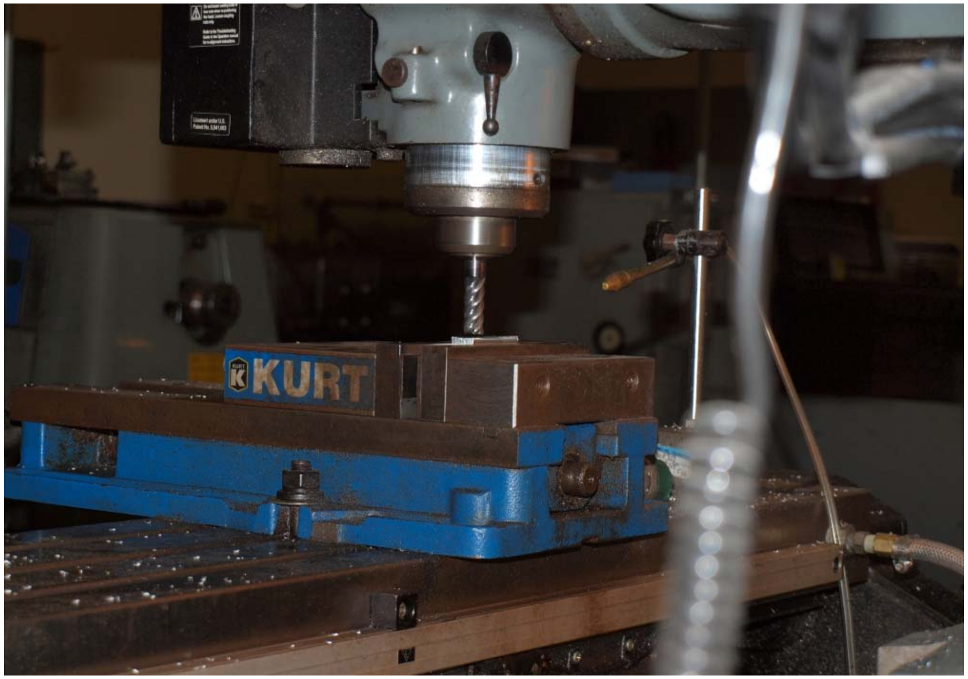
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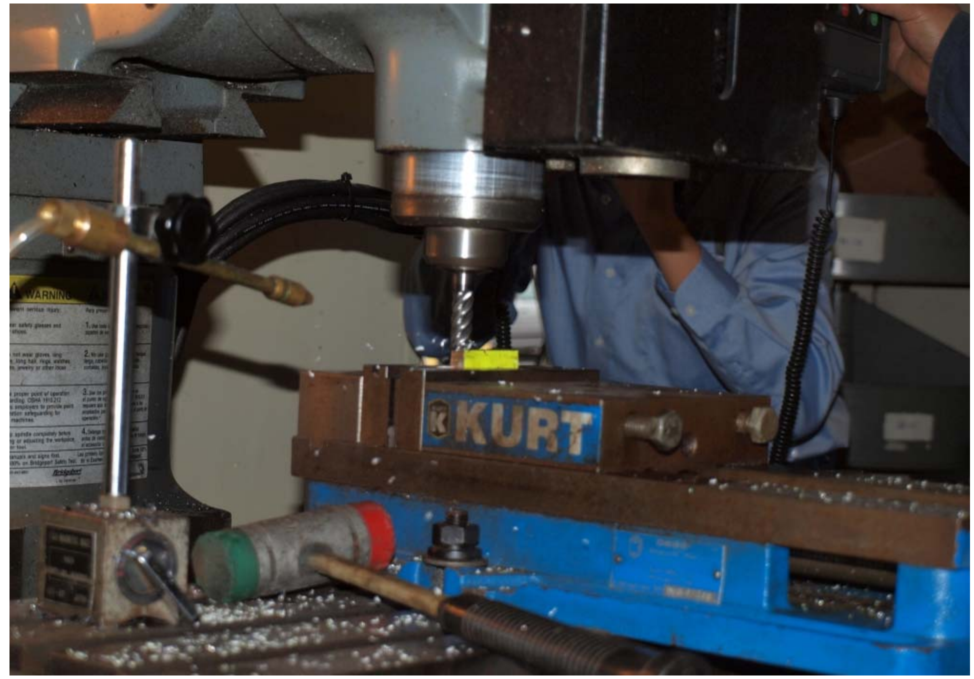
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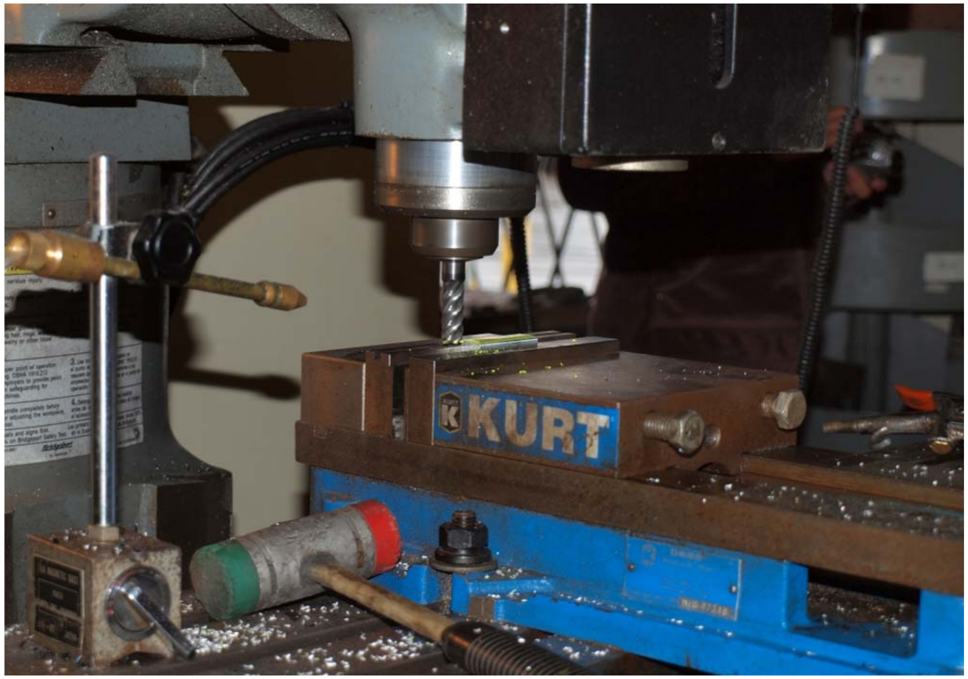
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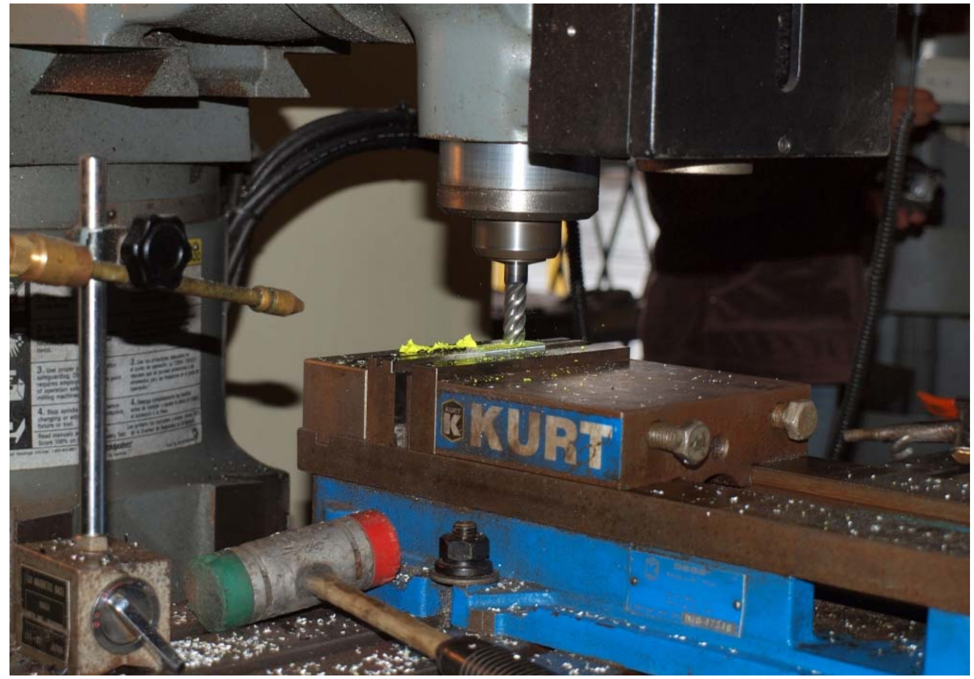
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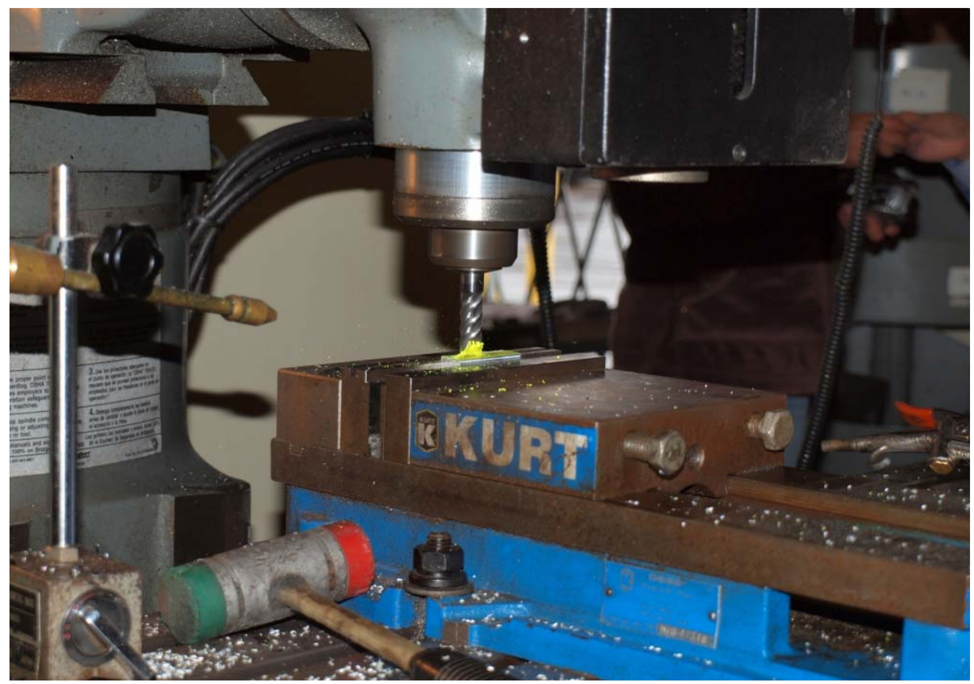
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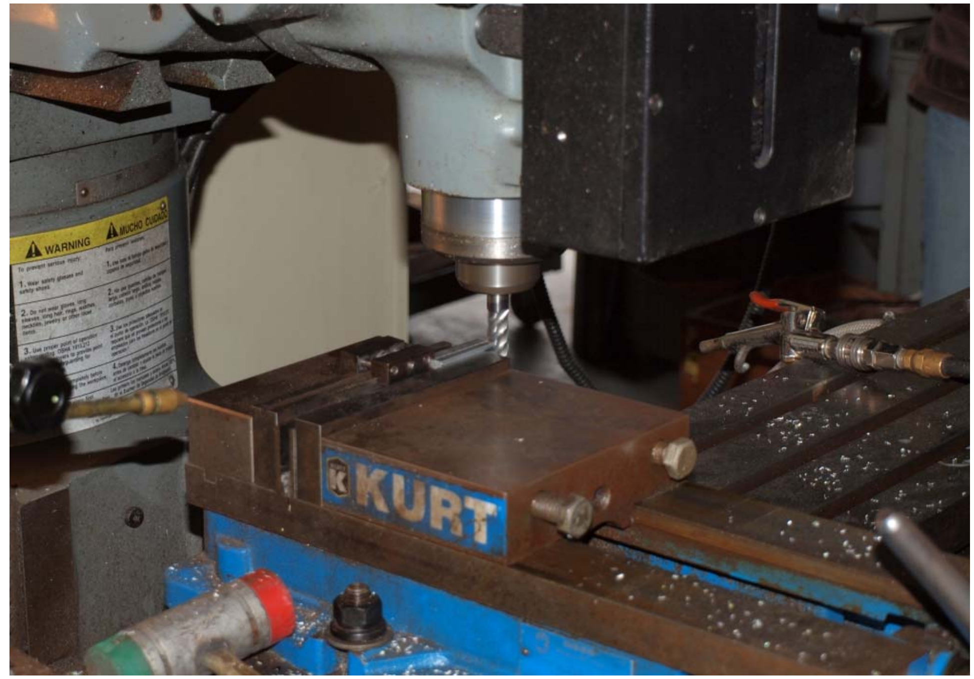
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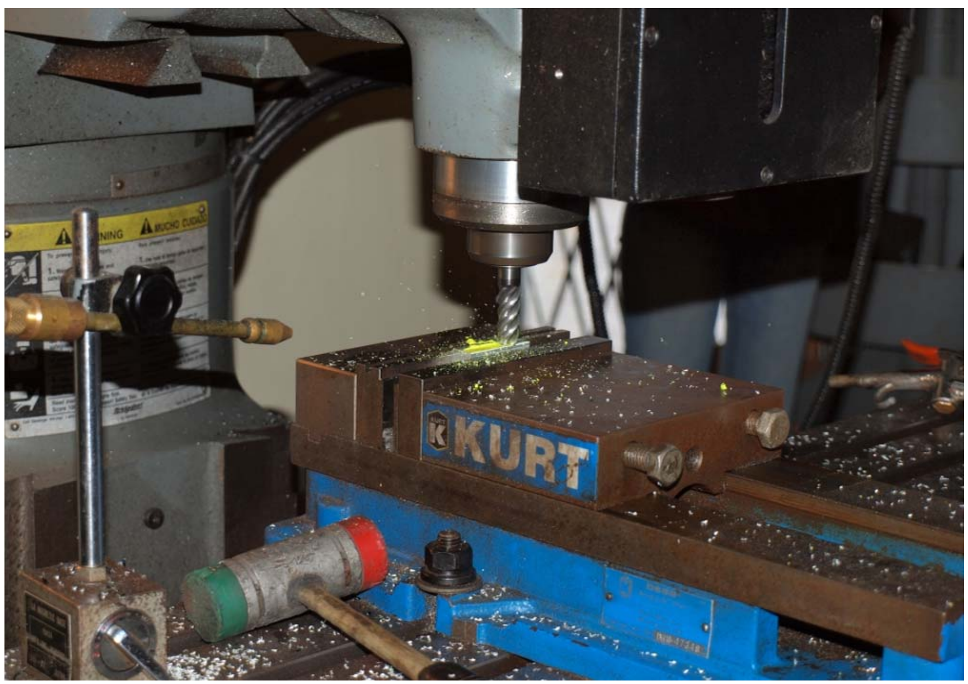
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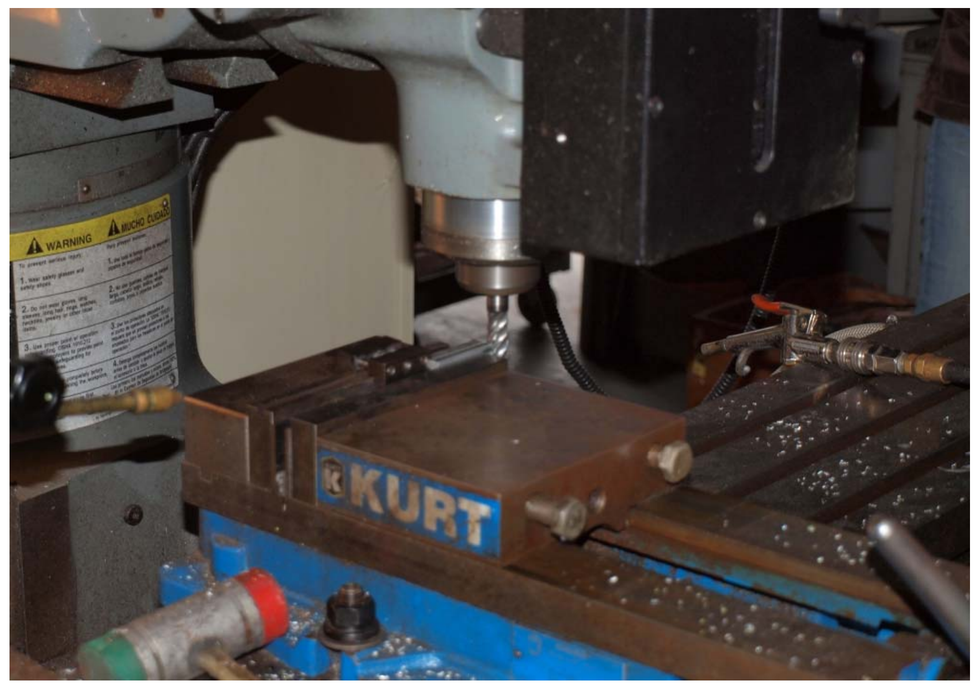
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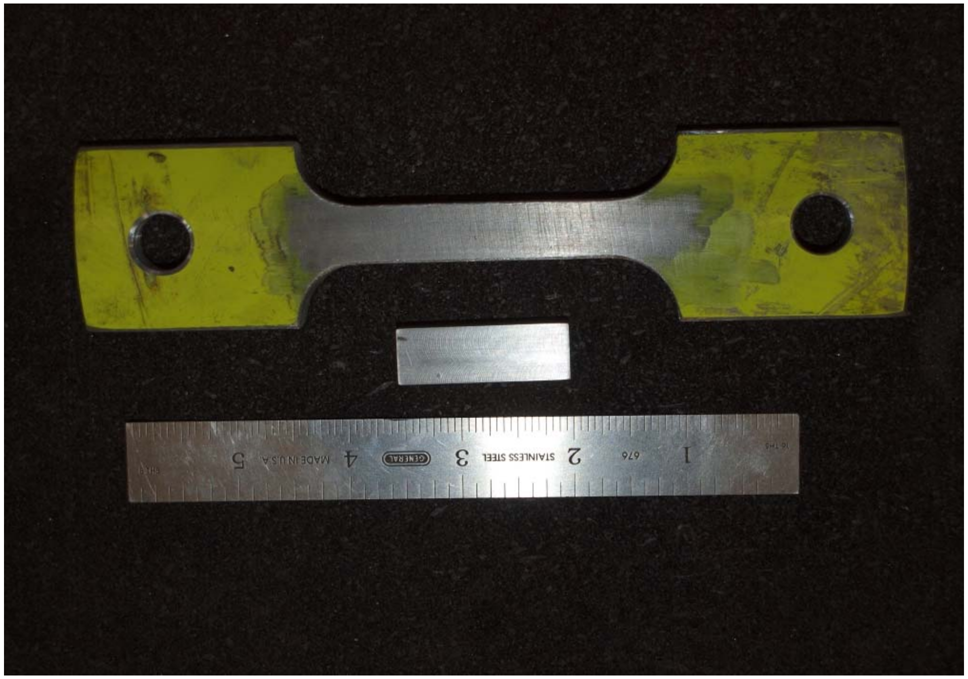


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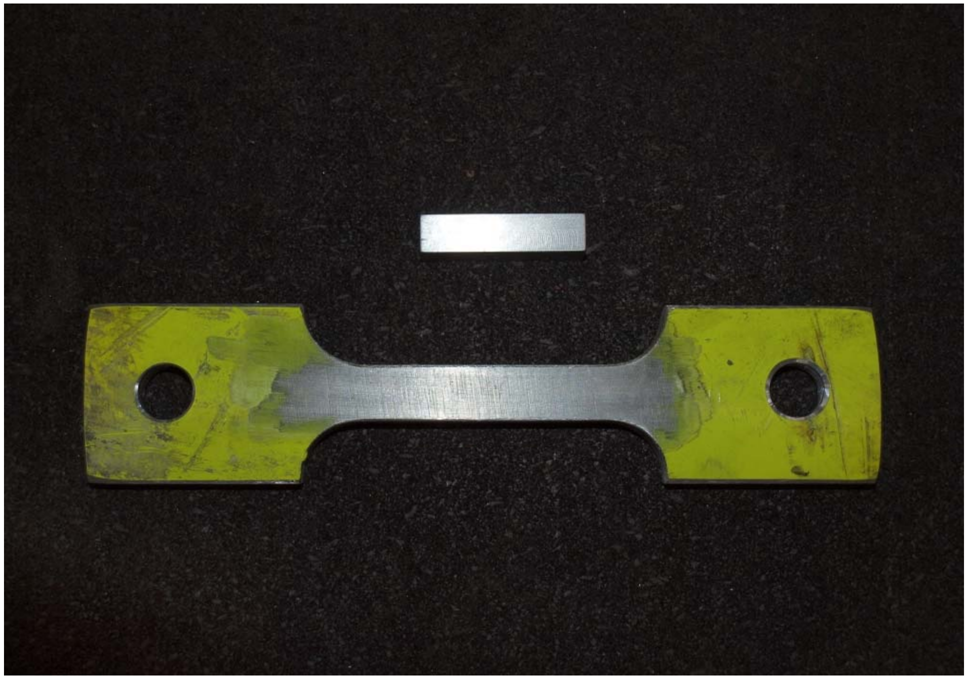

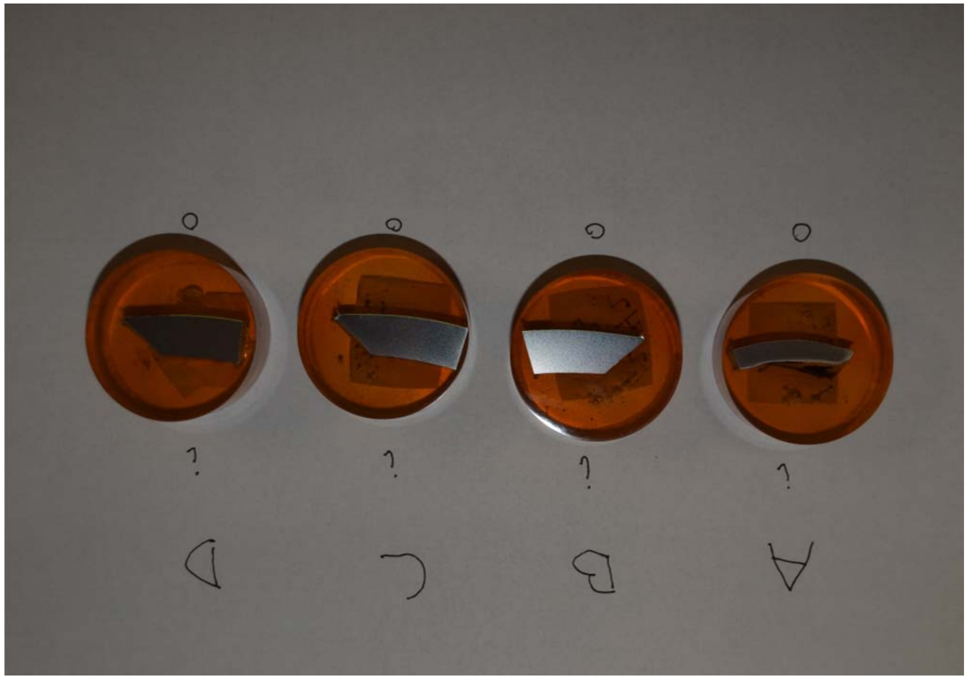

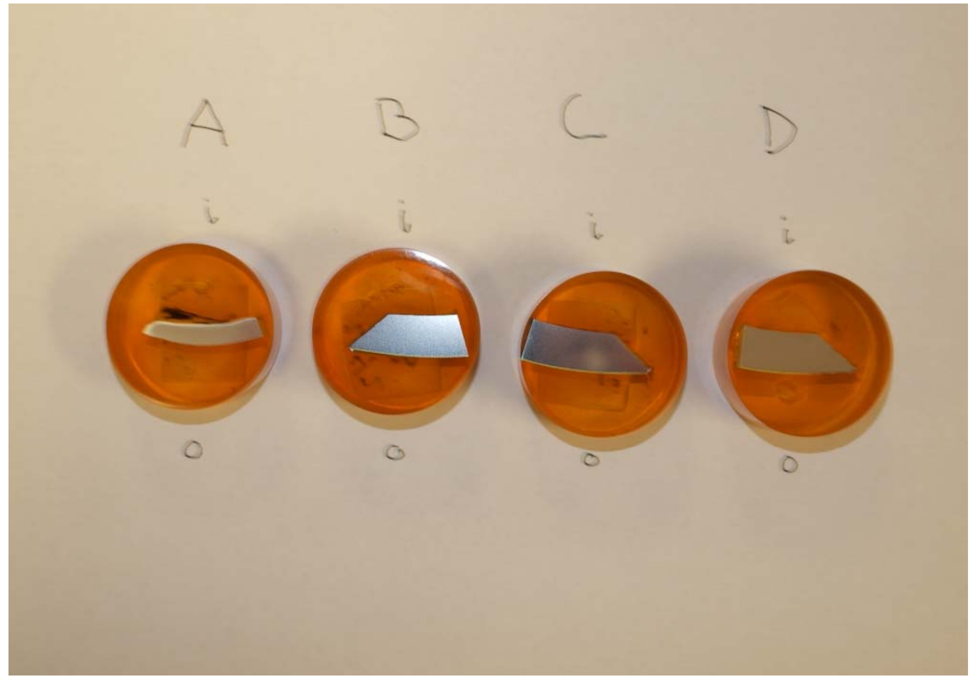
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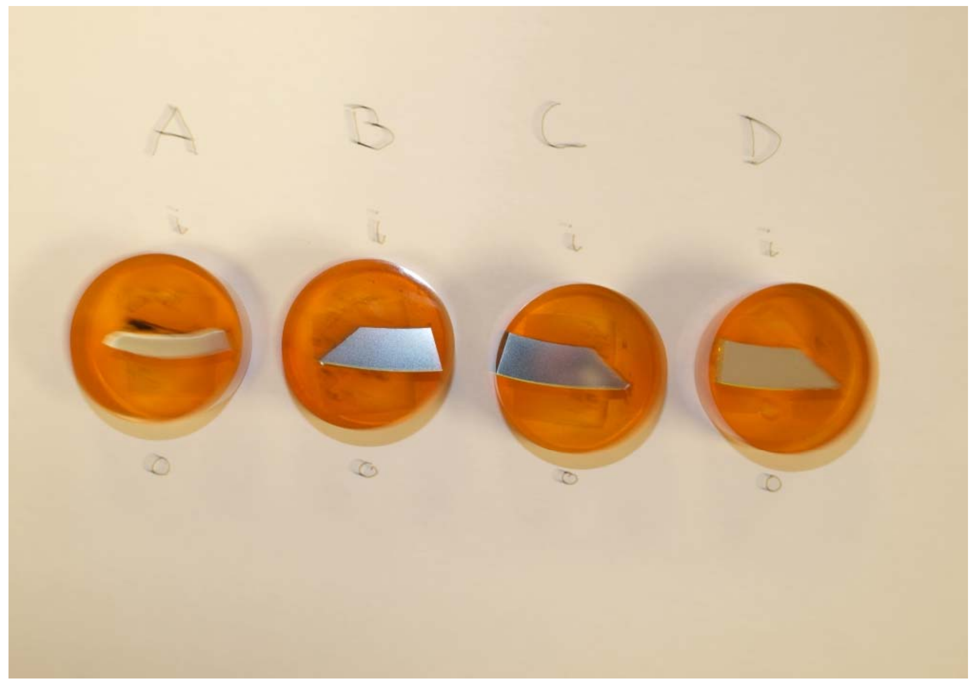
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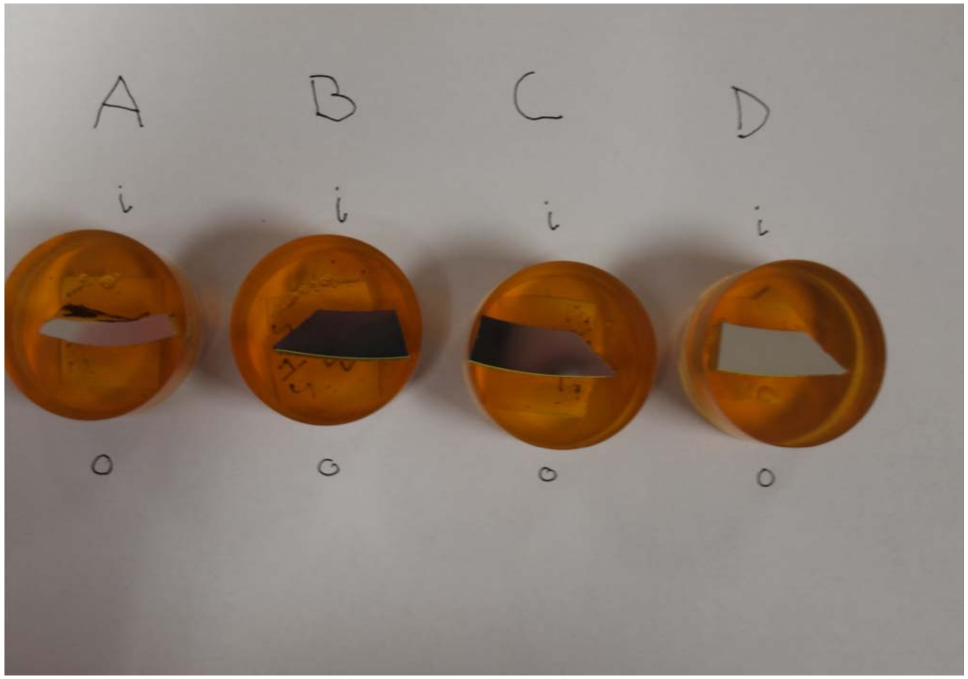
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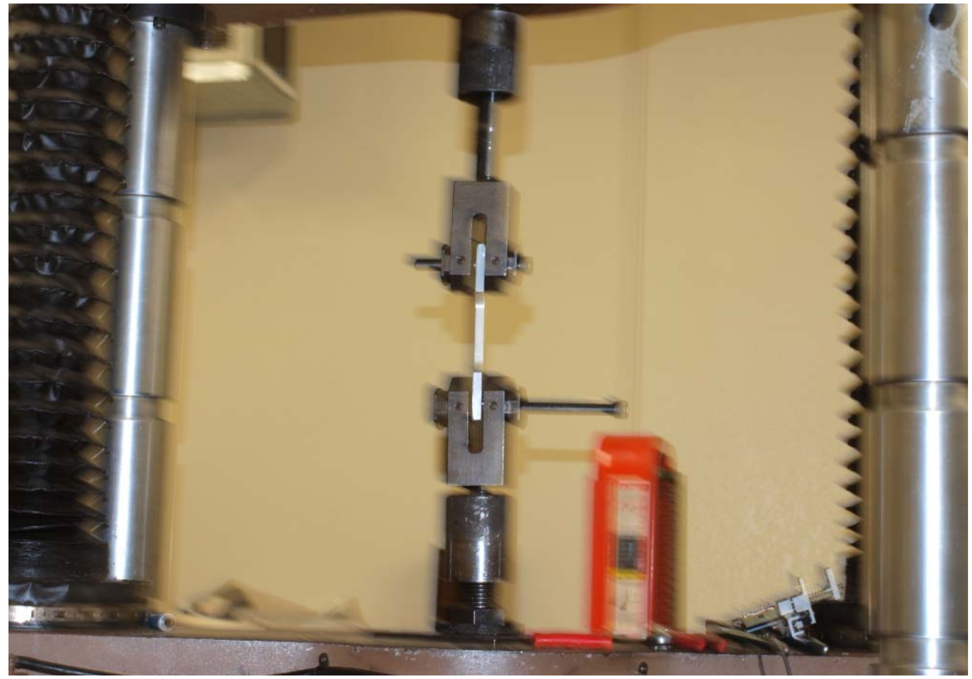

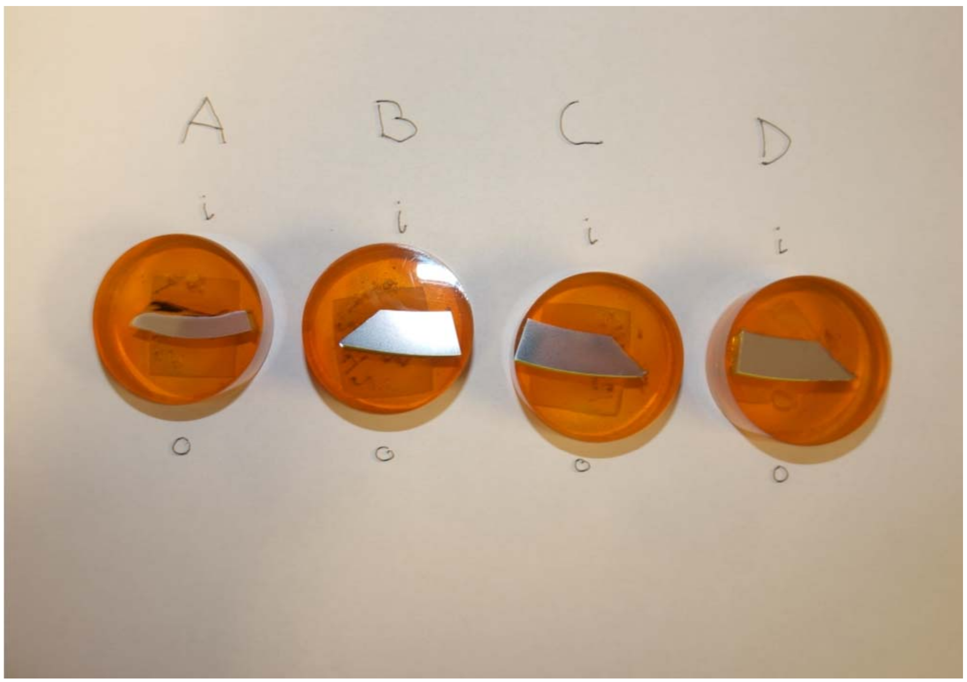
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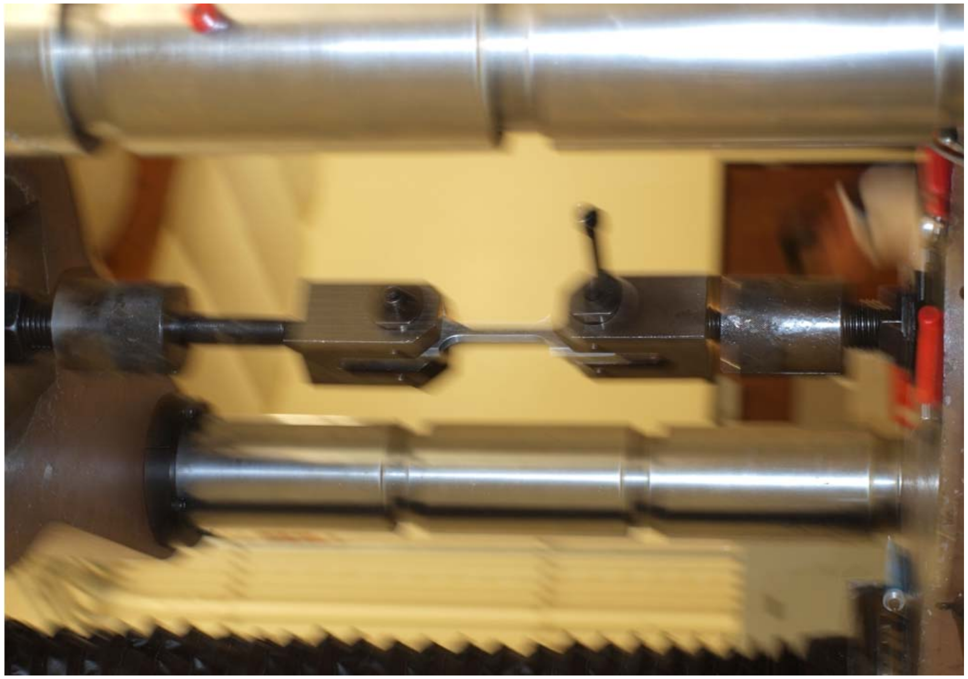

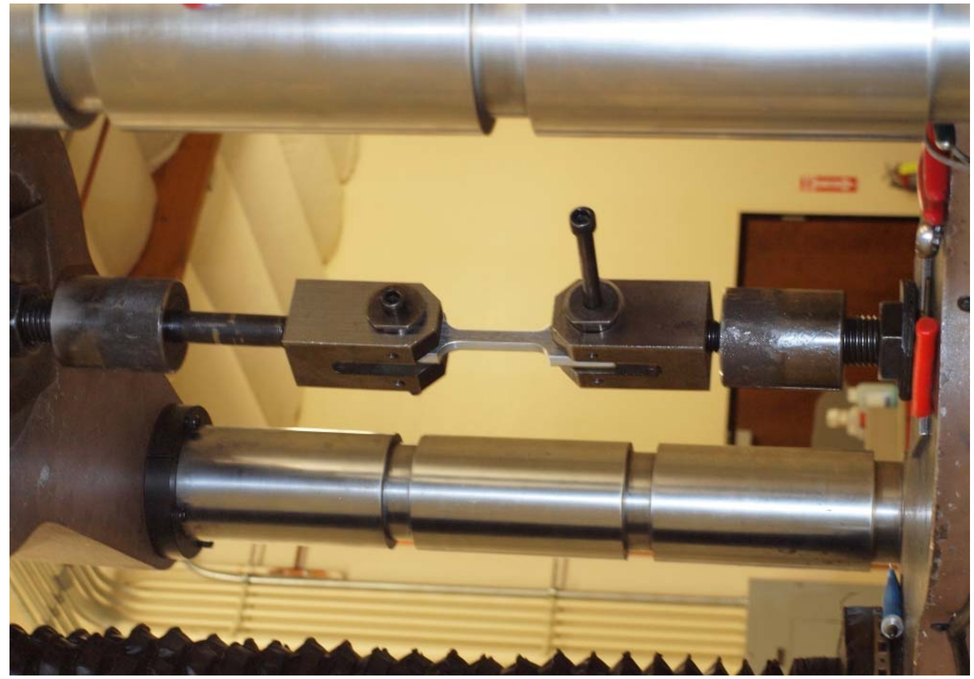

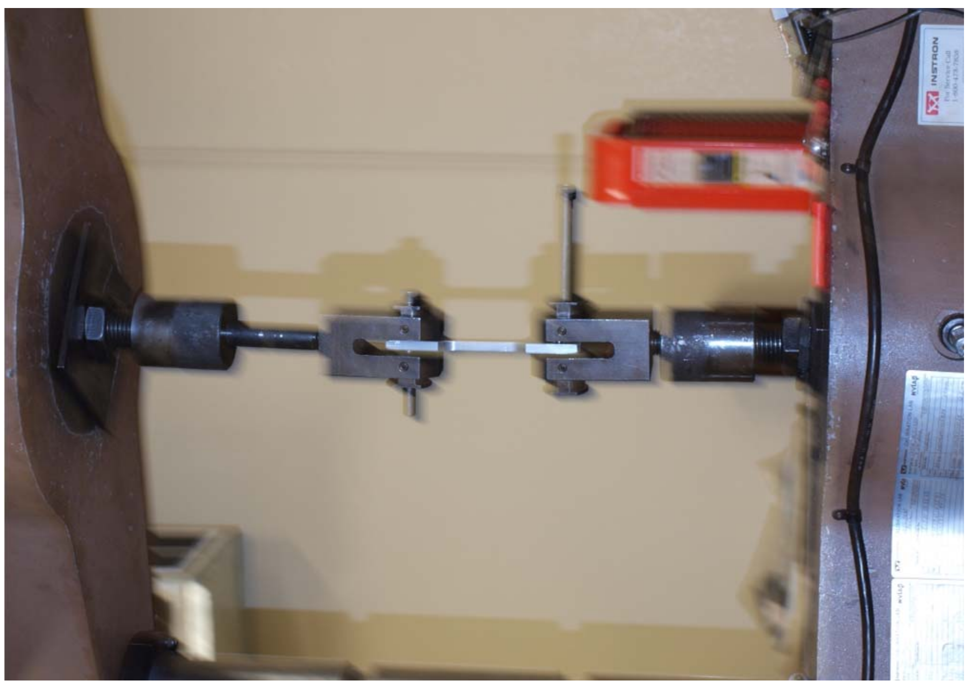
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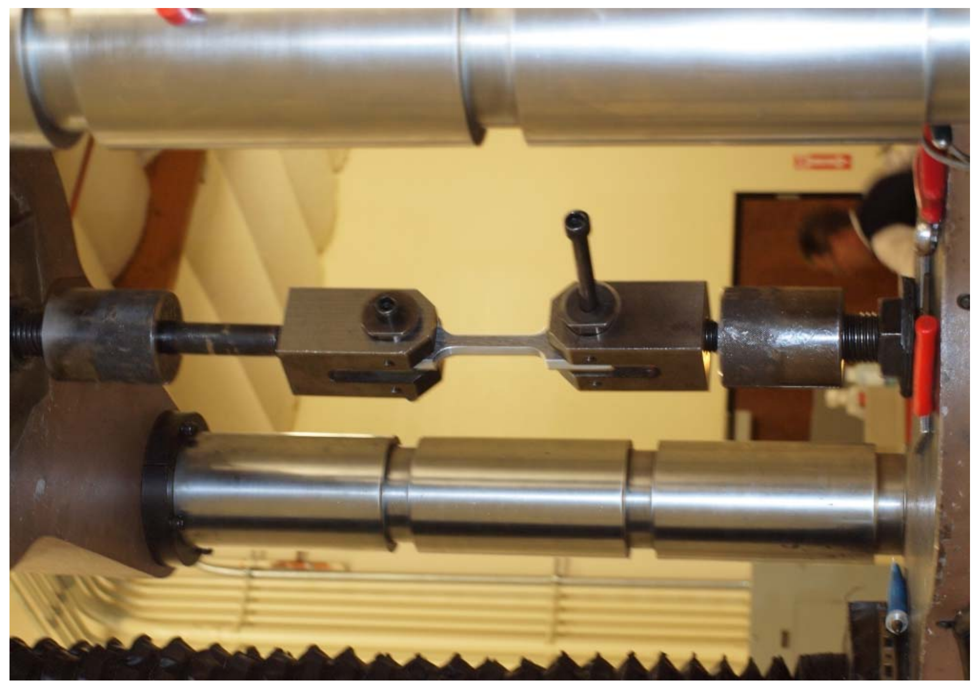

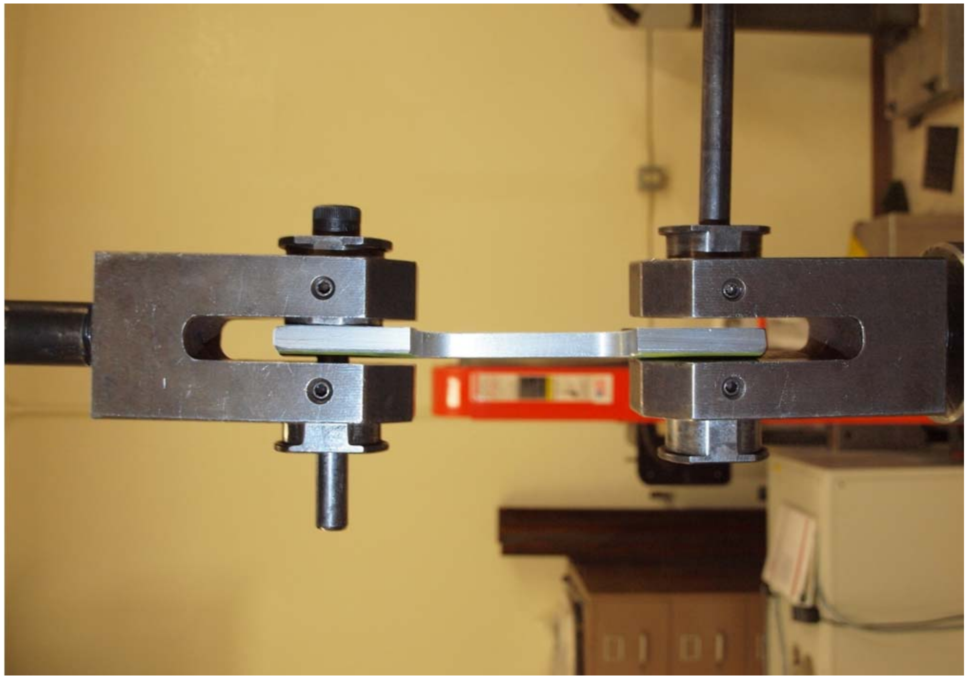
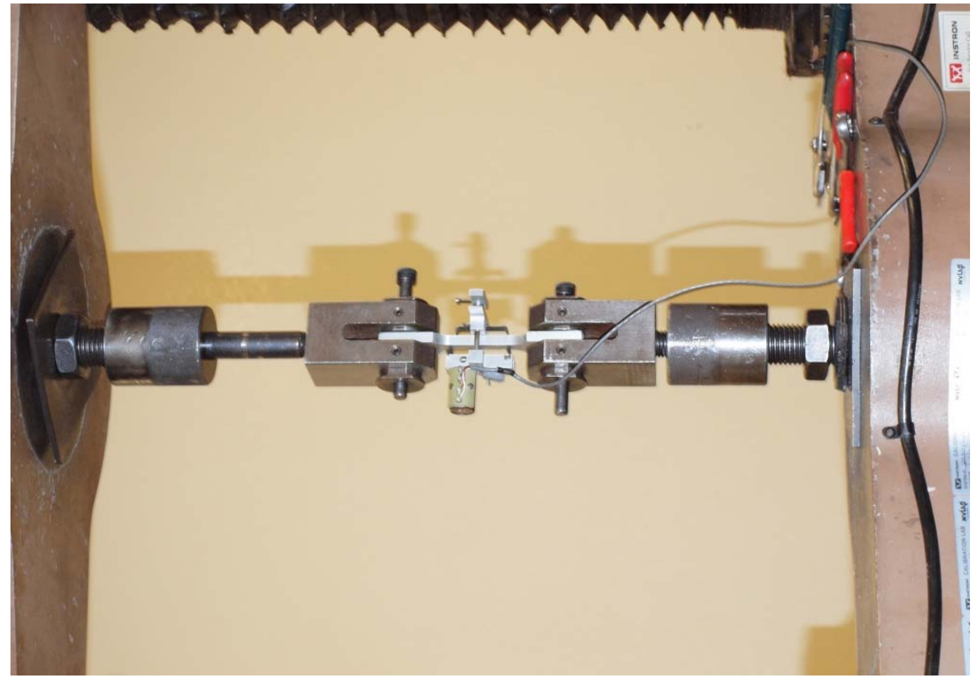
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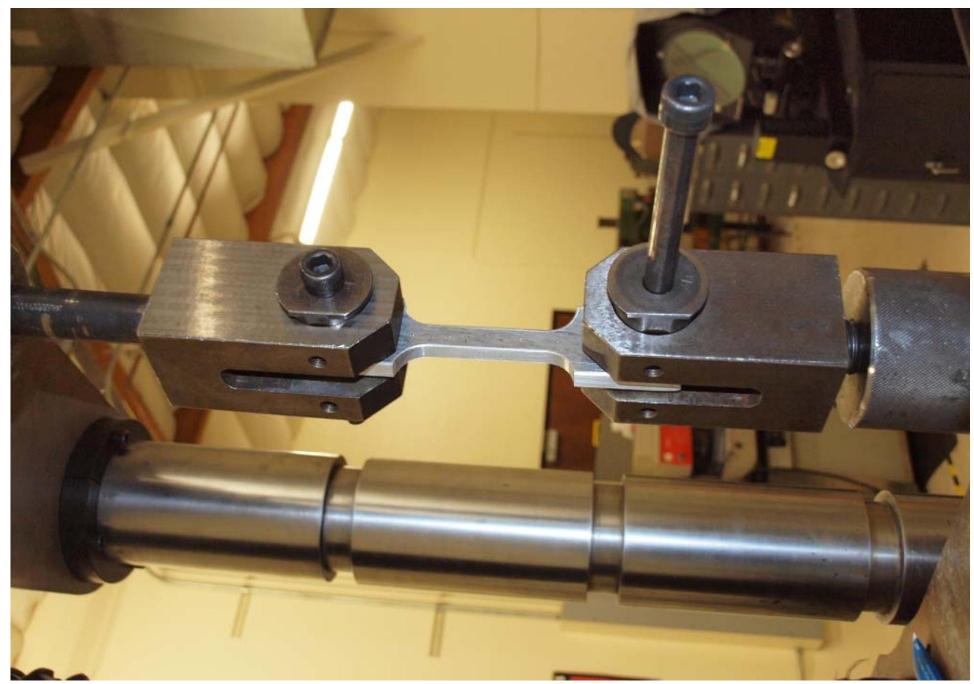

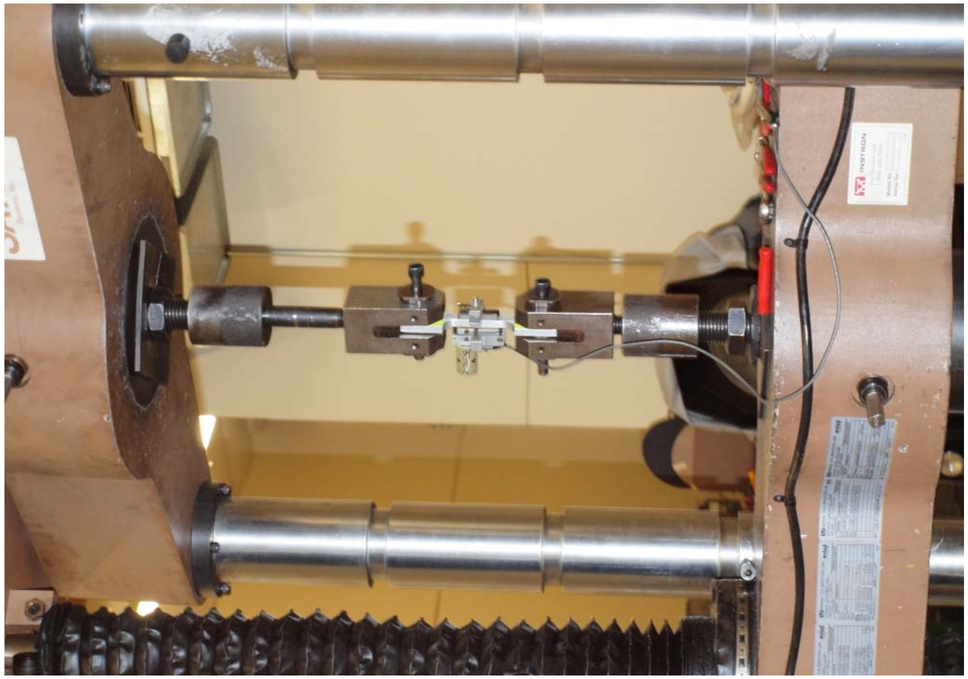

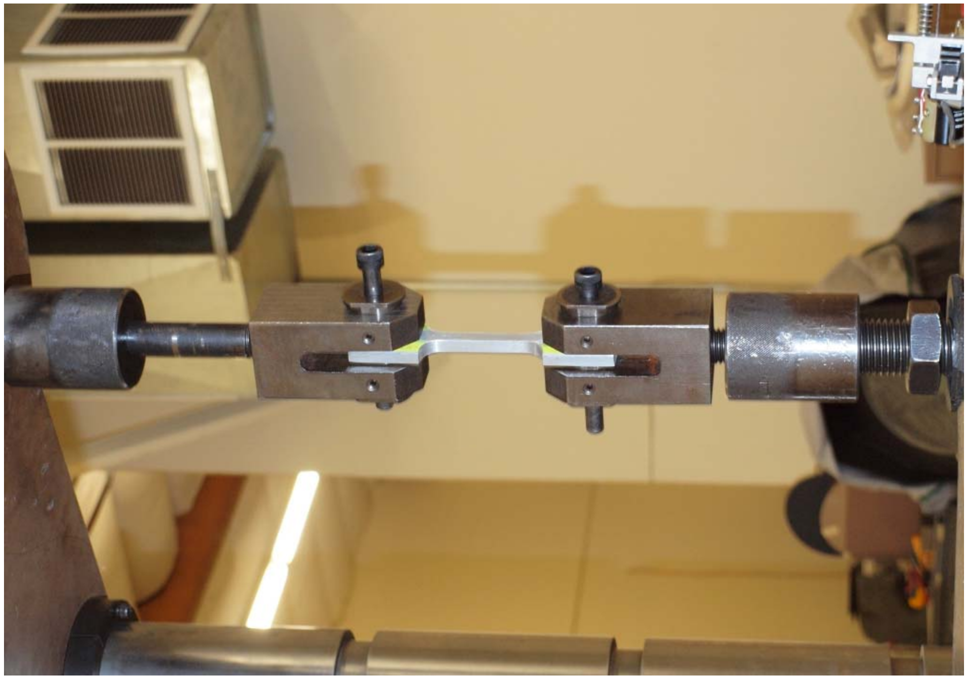

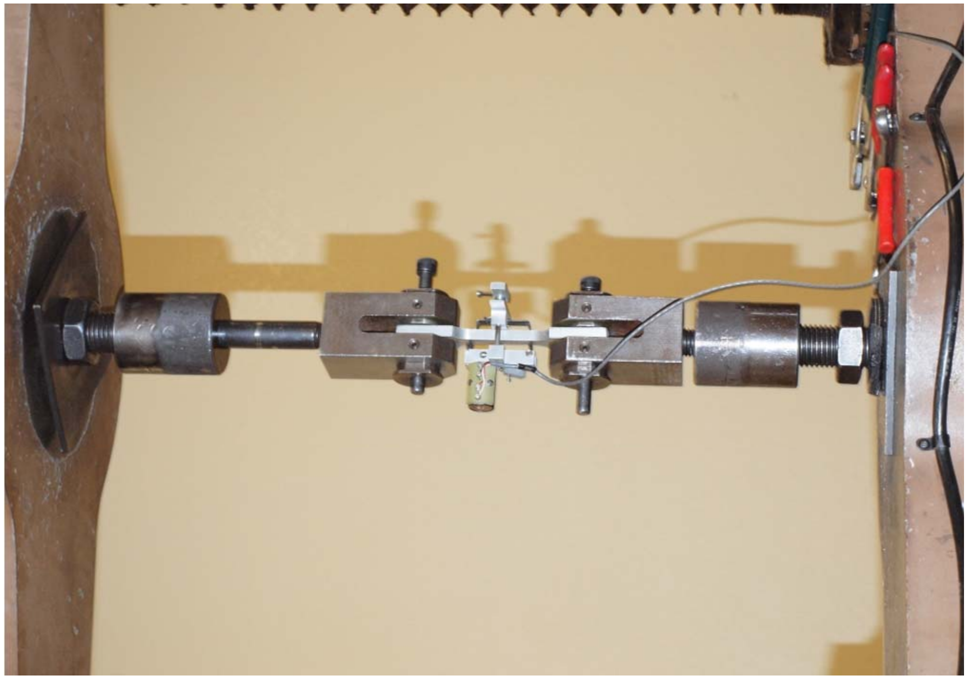

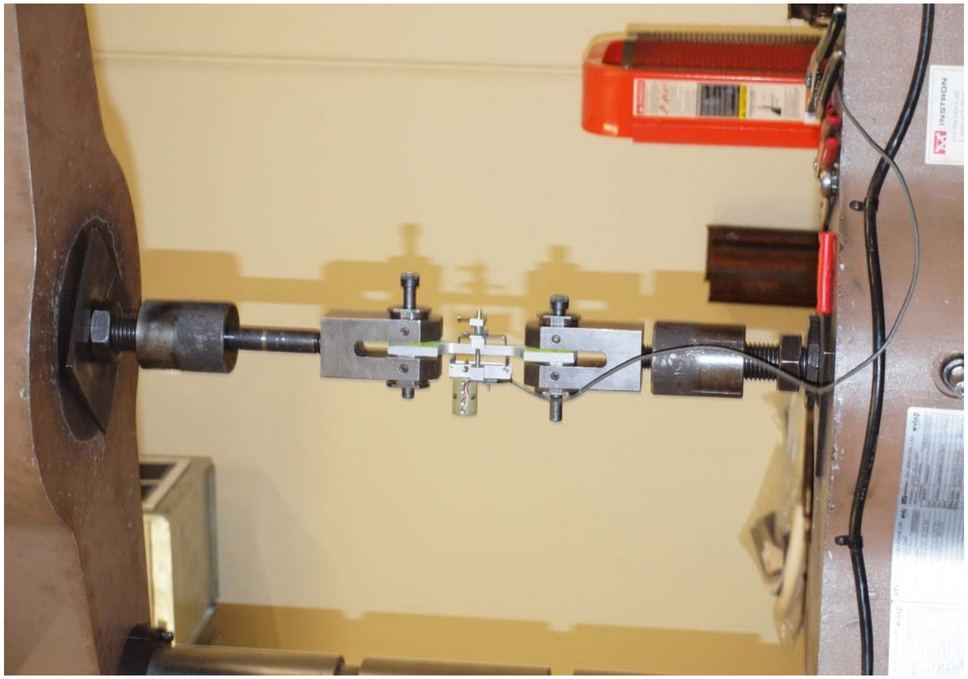

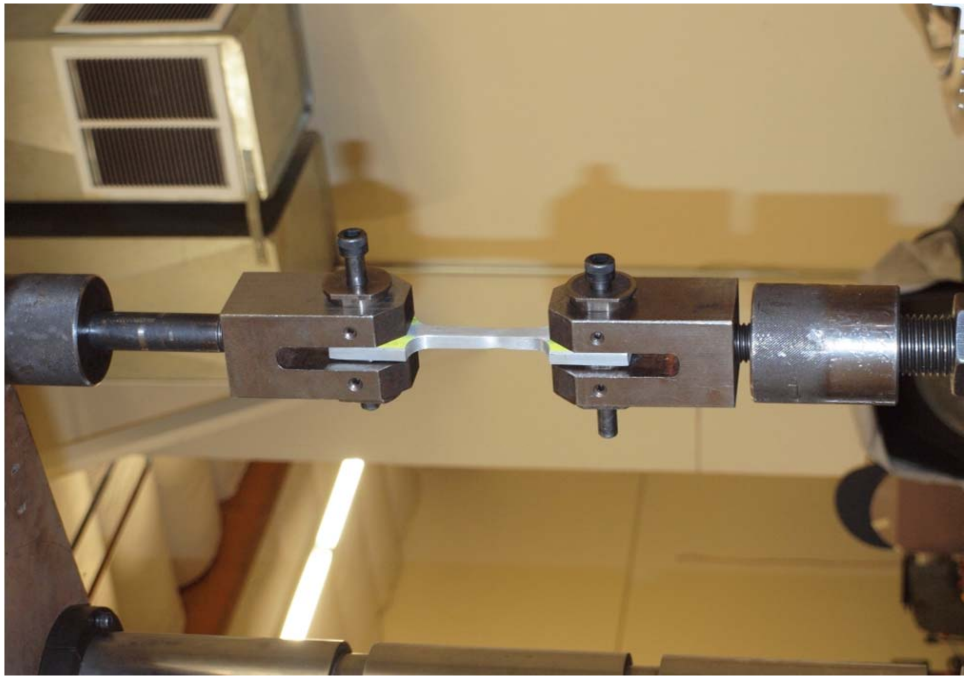
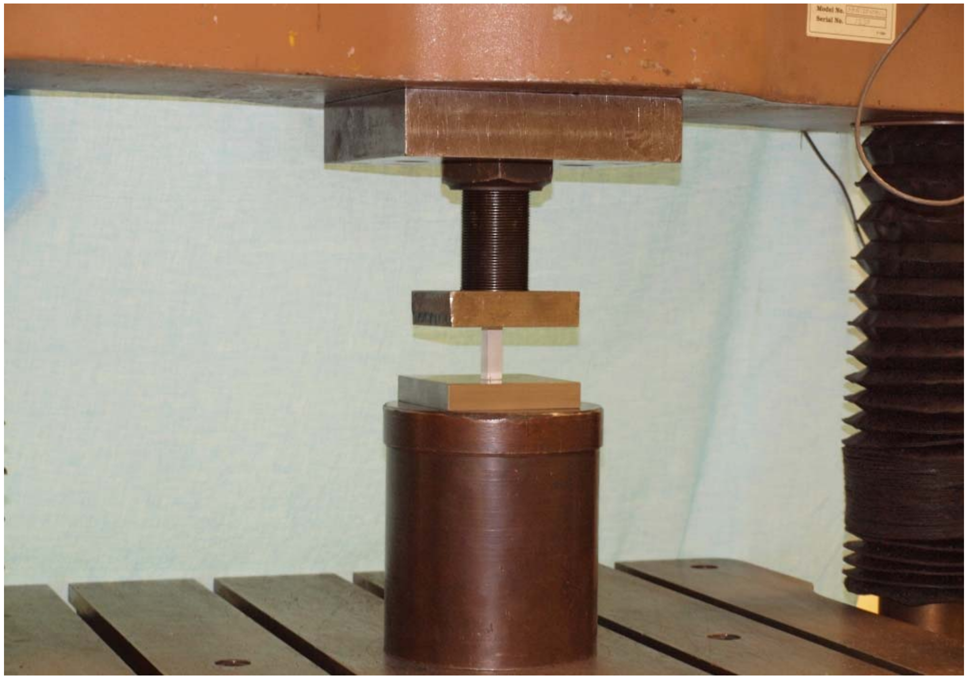
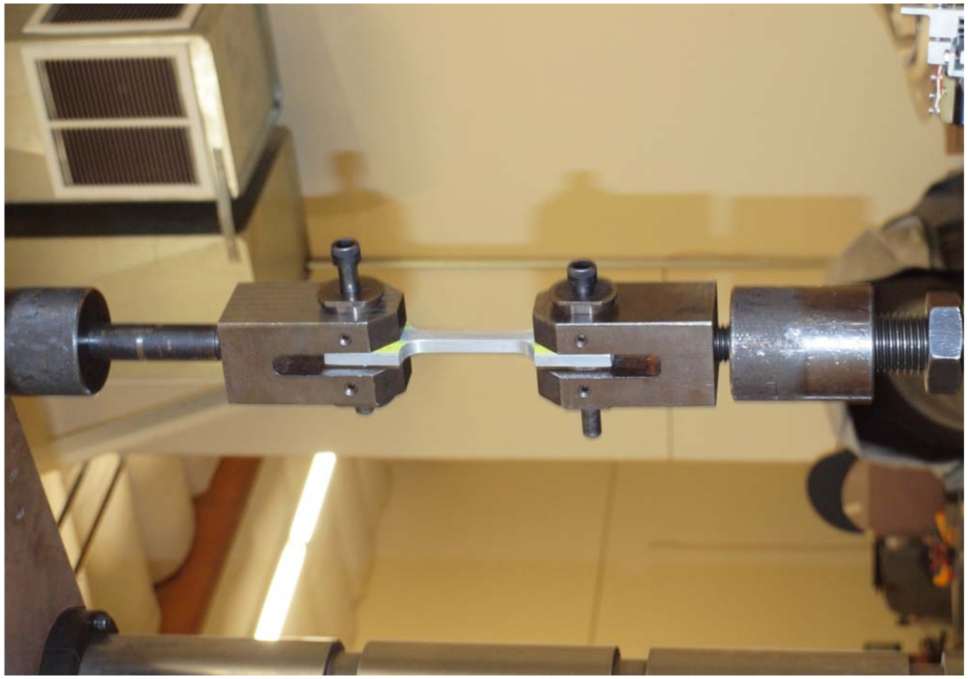
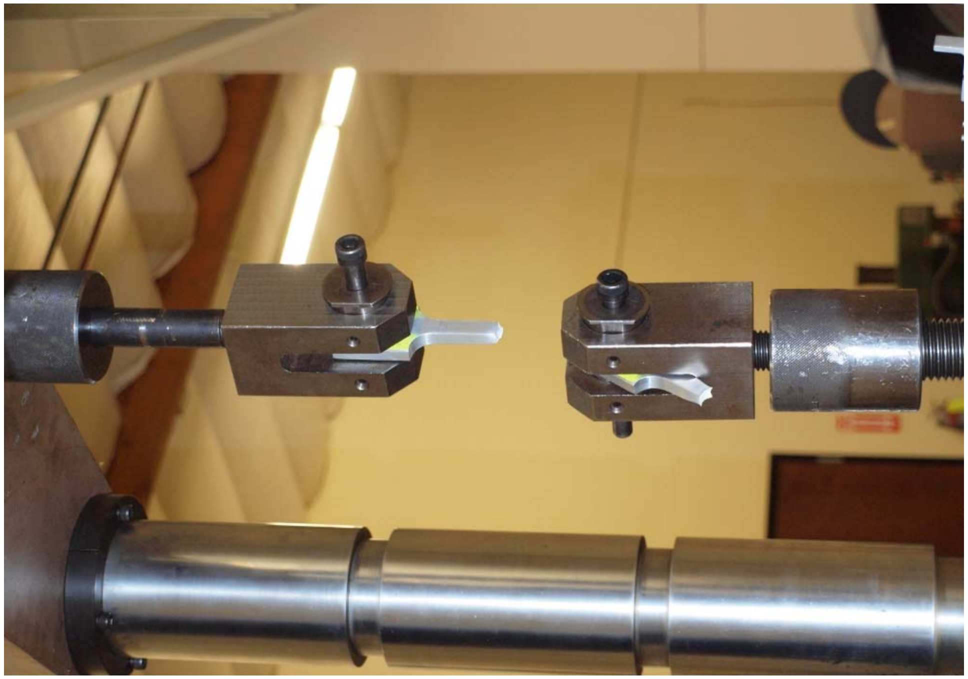

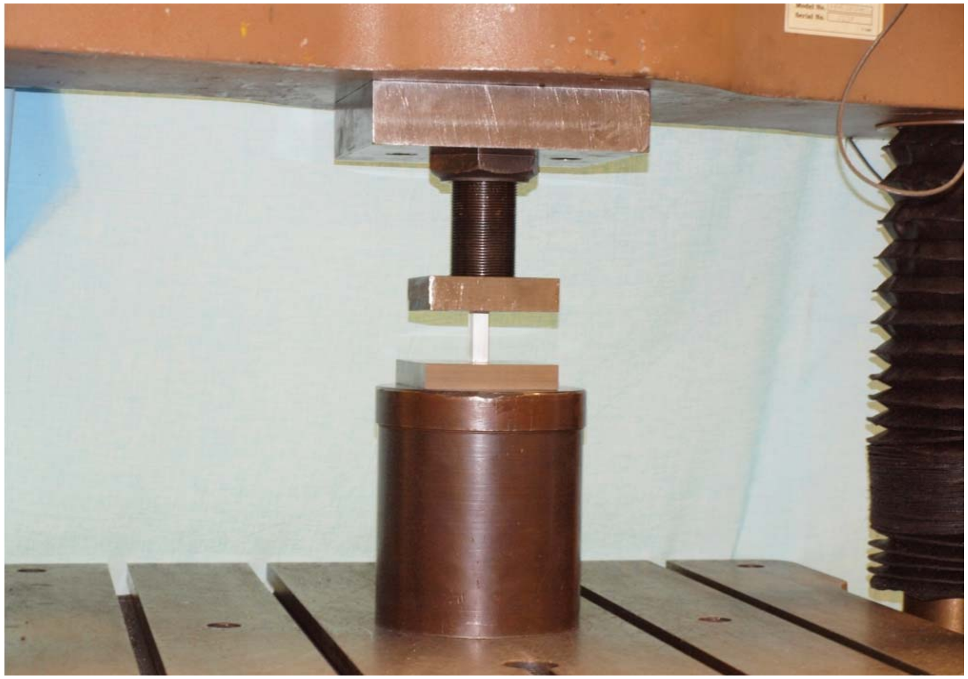

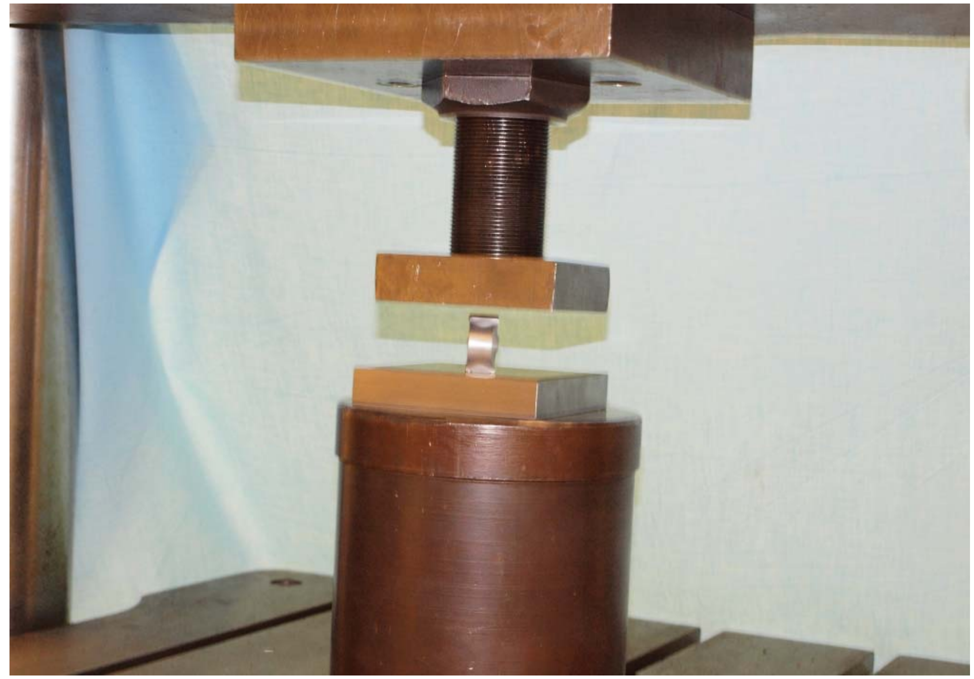

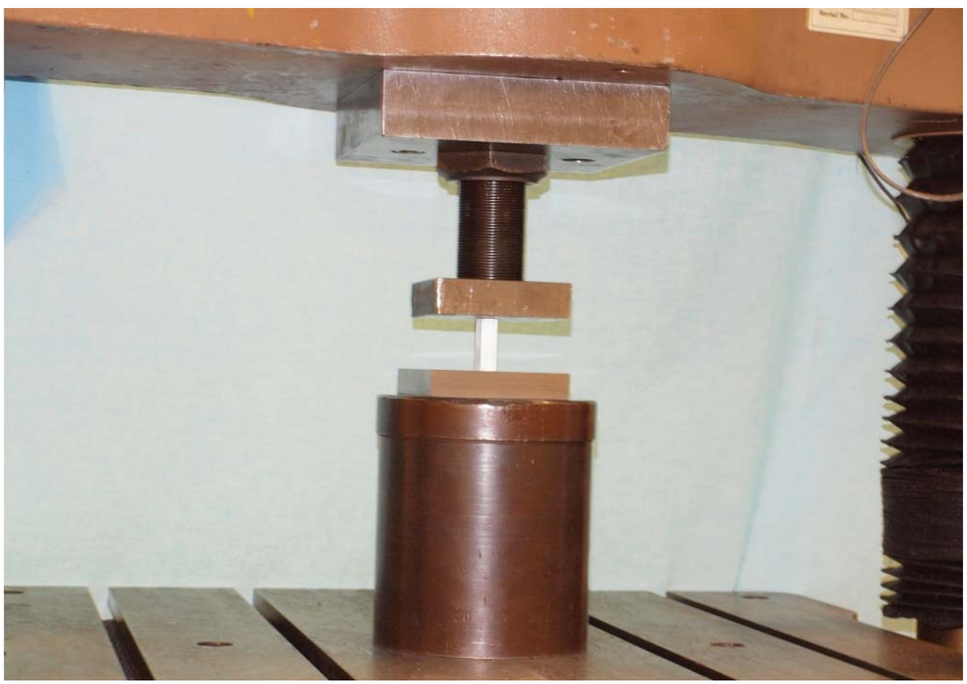

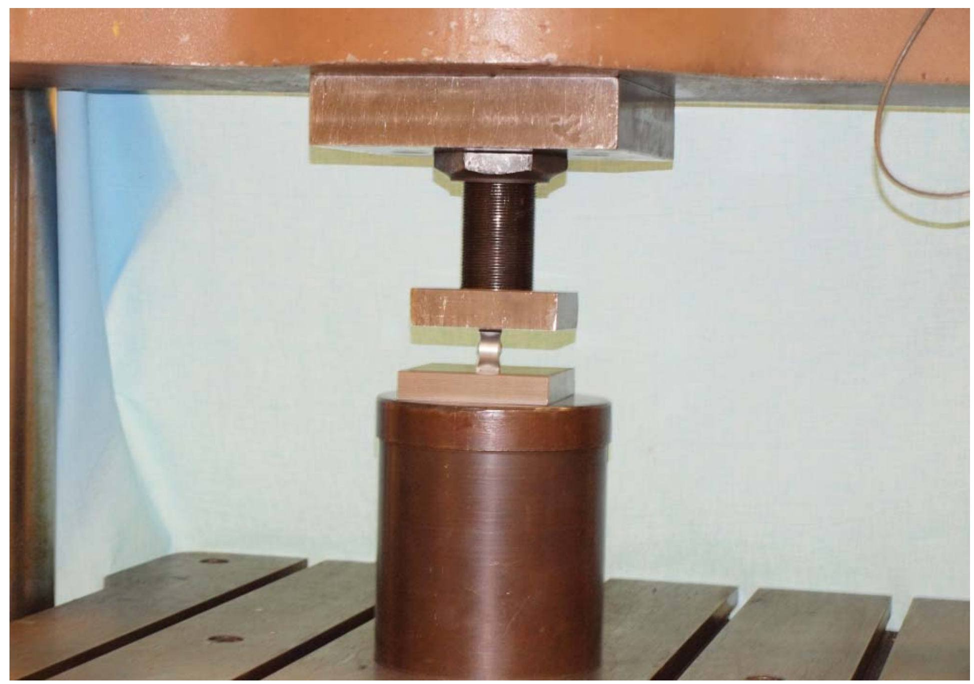

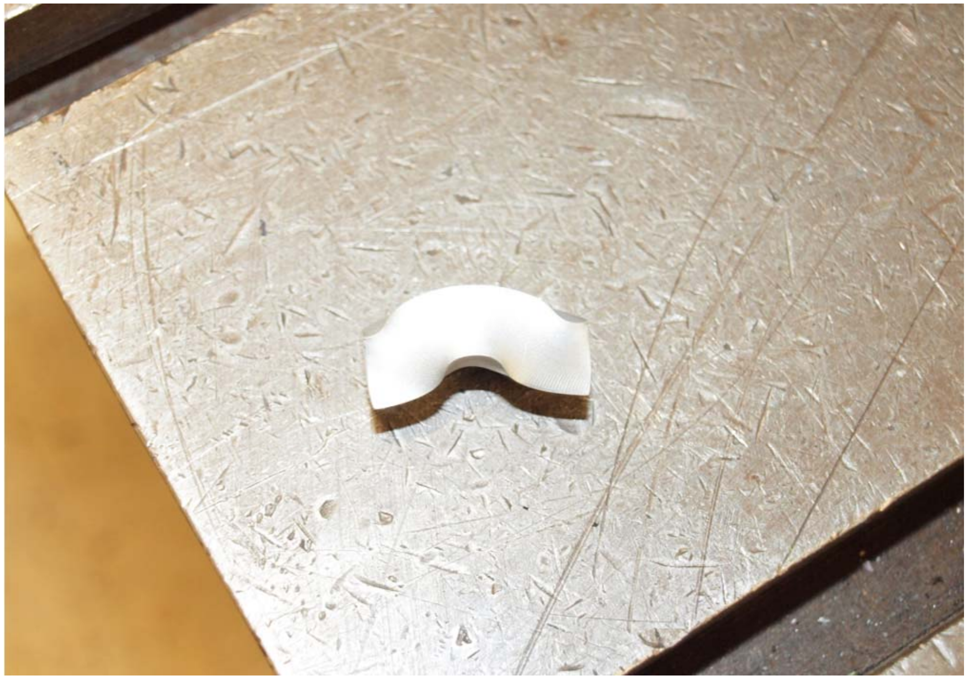


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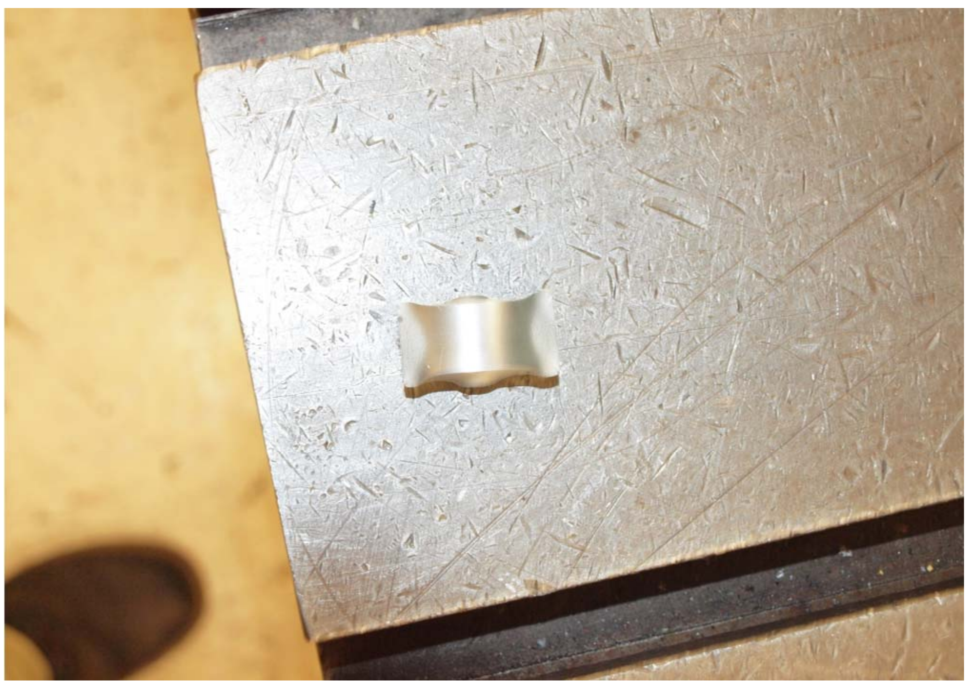

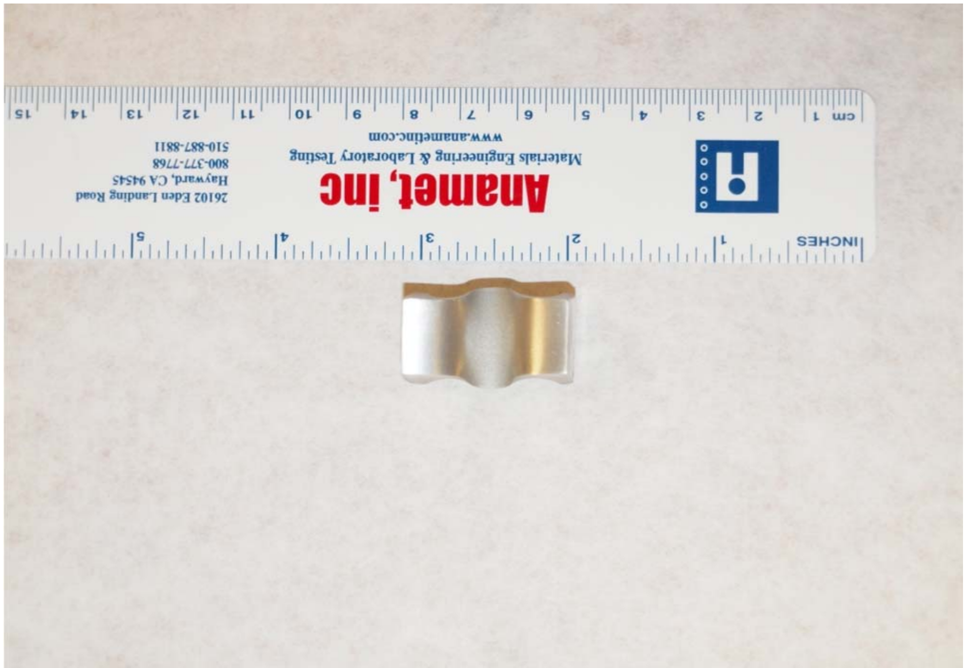
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ADAPTER


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ADAPTER


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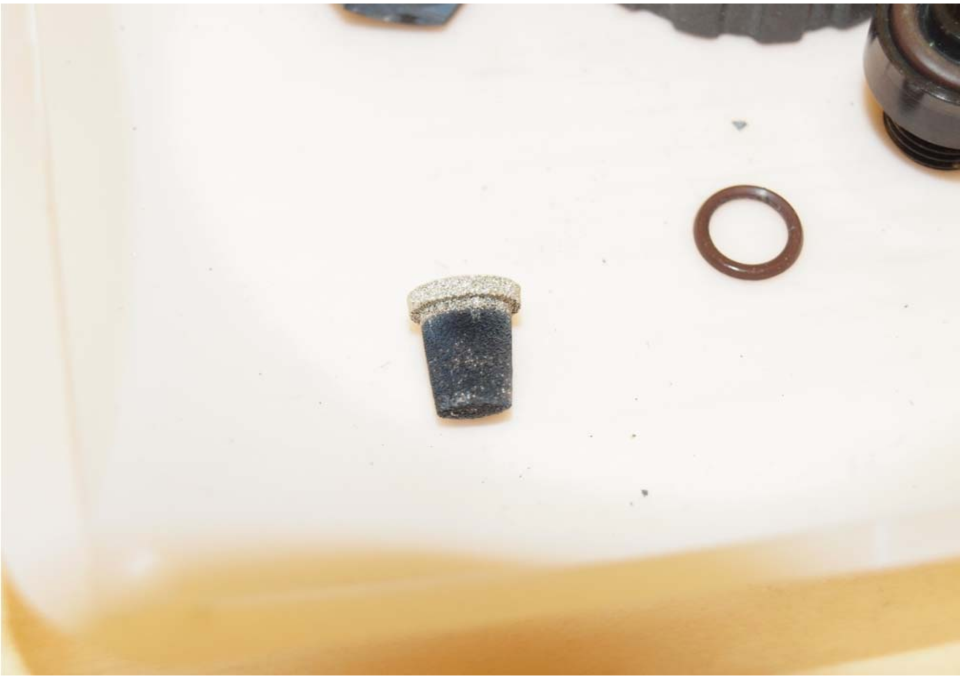
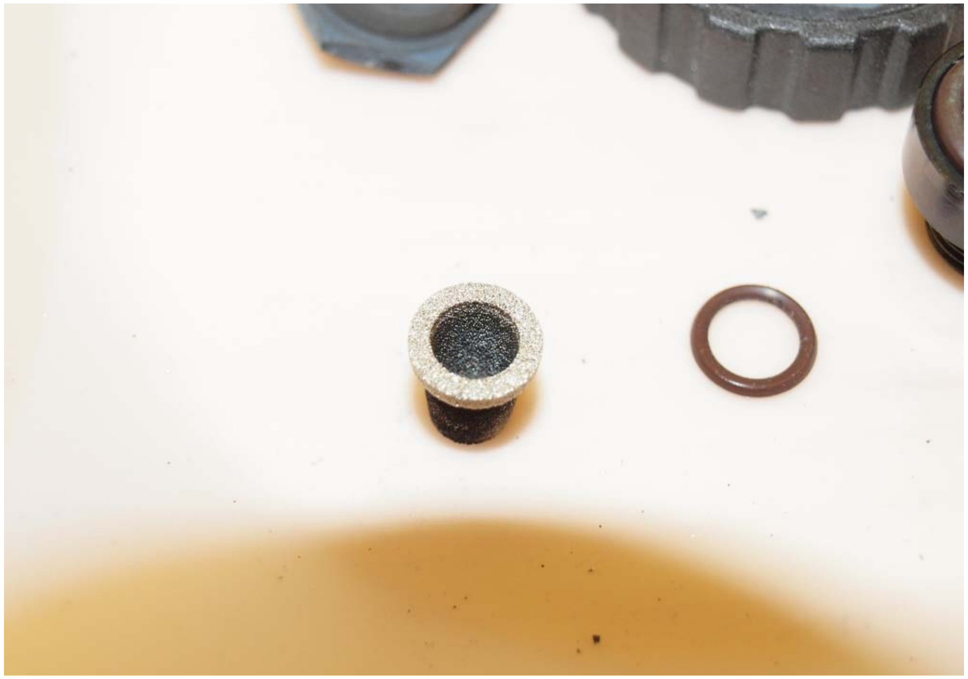

ATTACHMENT 7

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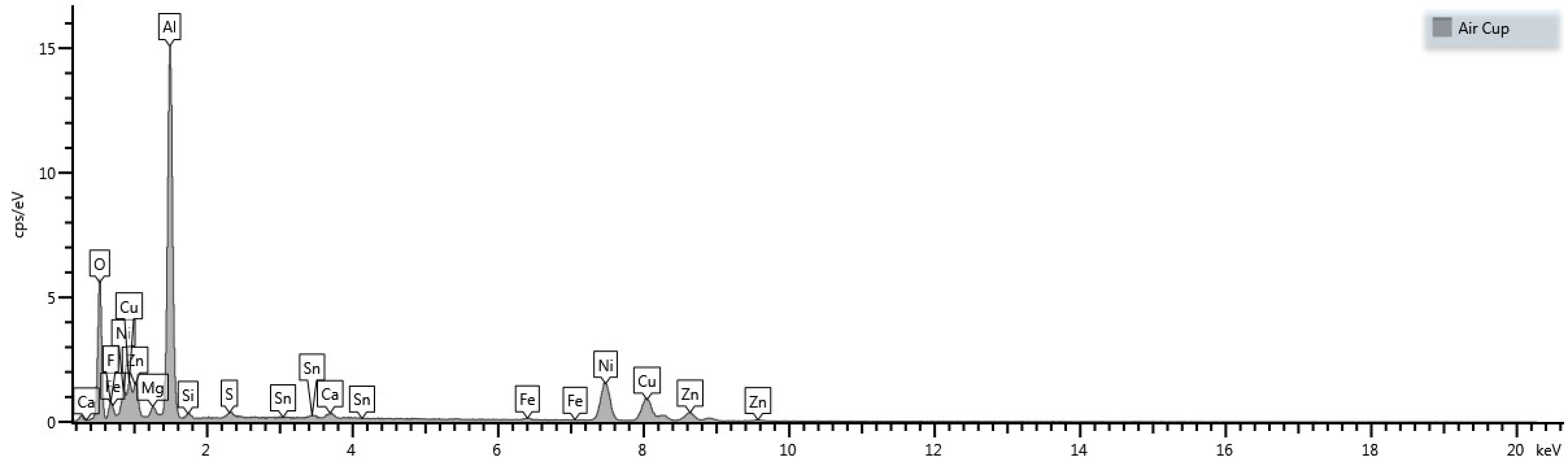

Air Cup
cps/eV
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16
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20
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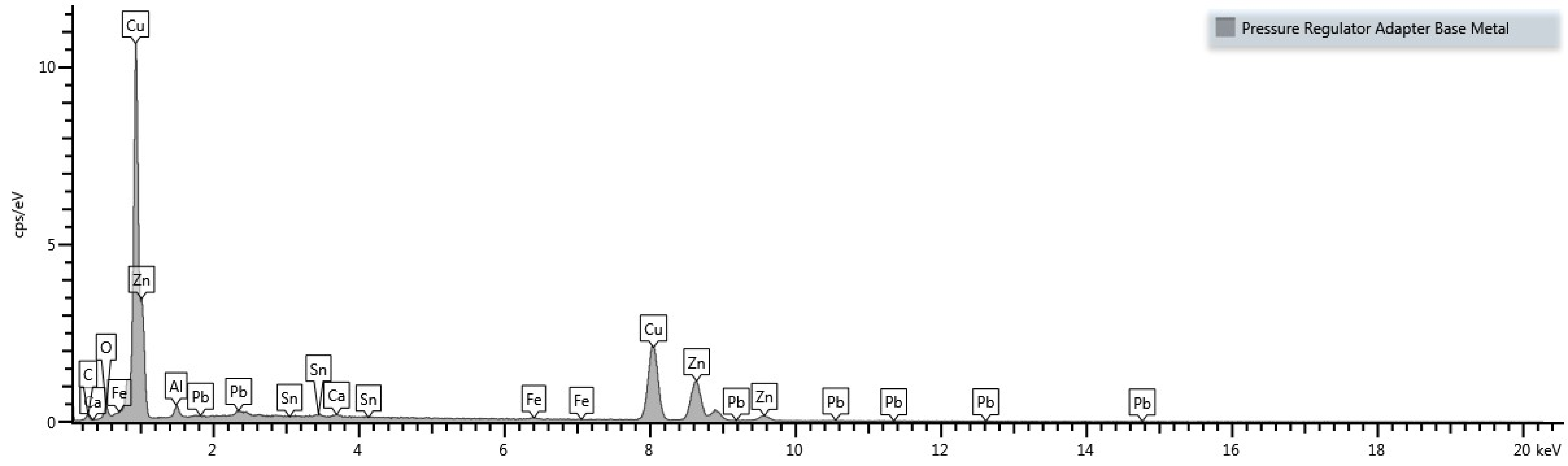

Pressure Regulator Adapter Base Metal
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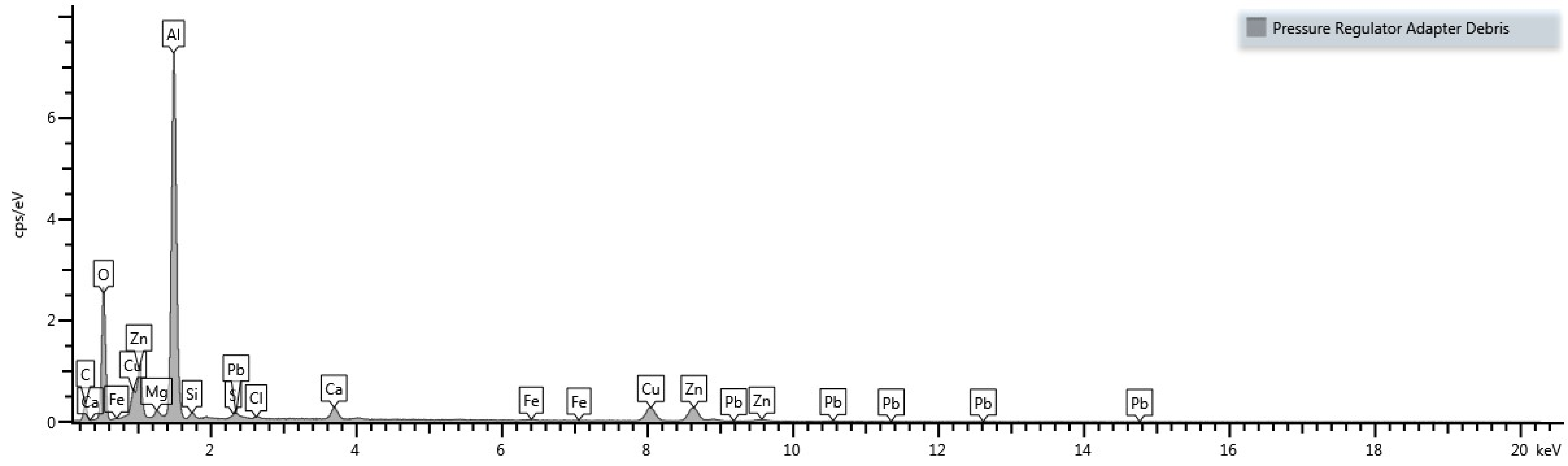

Pressure Regulator Adapter Debris
cps/eV
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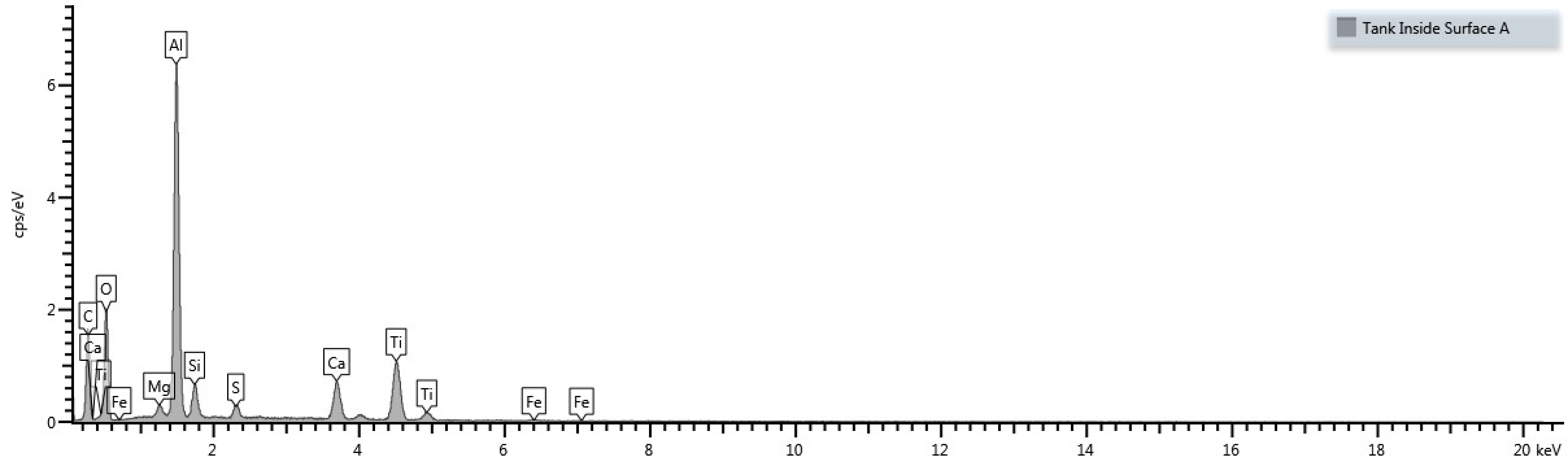
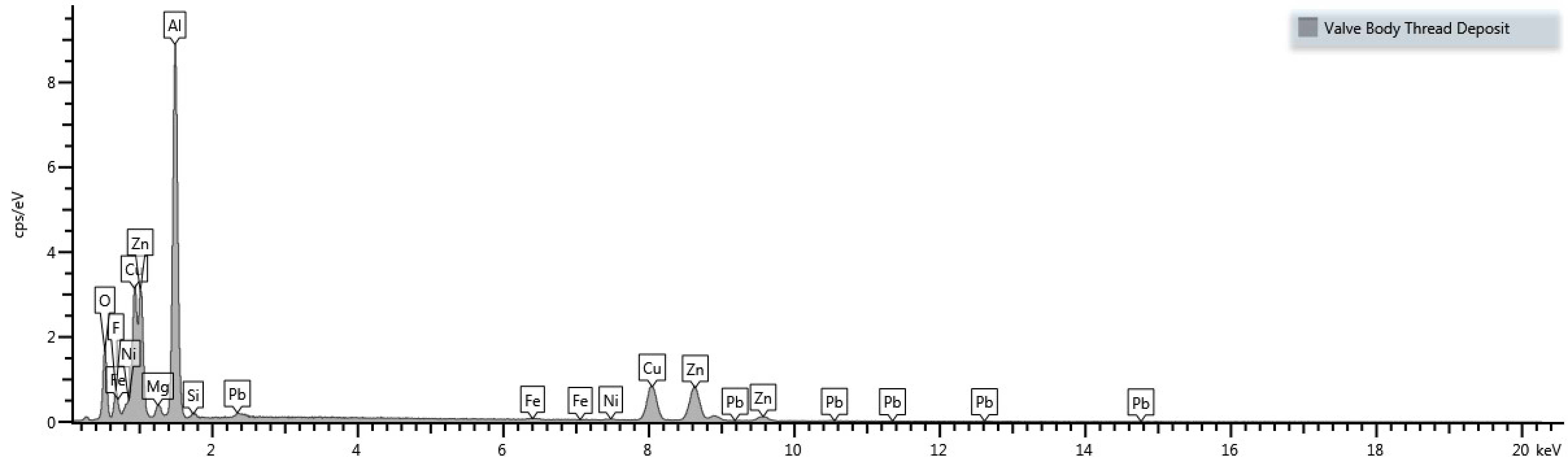
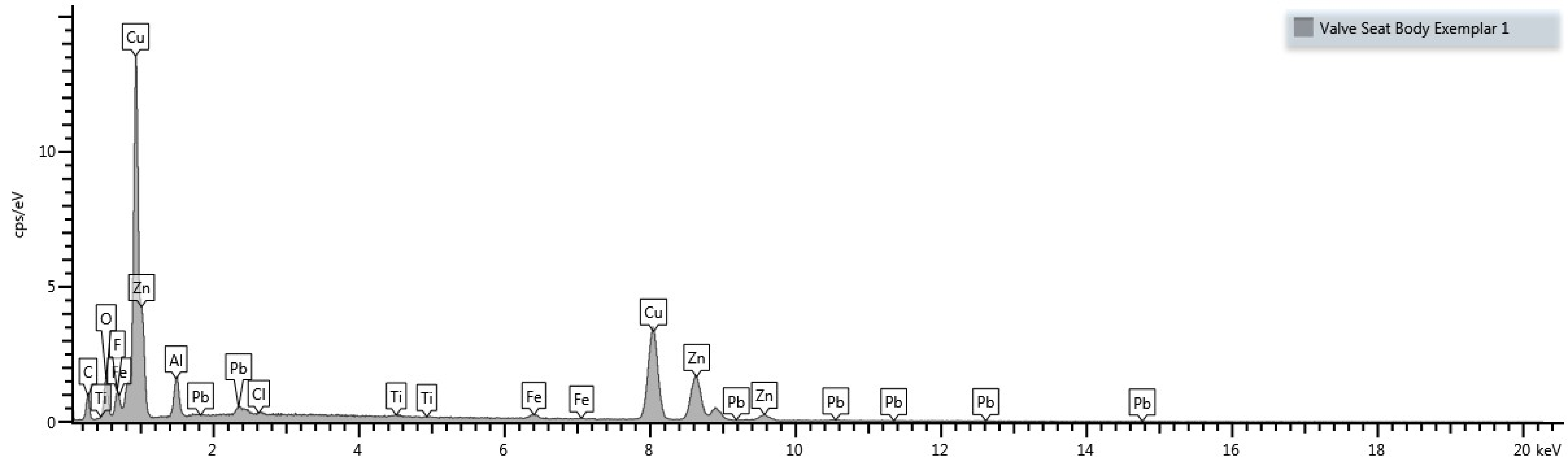
8
10
12
14
16
18
20

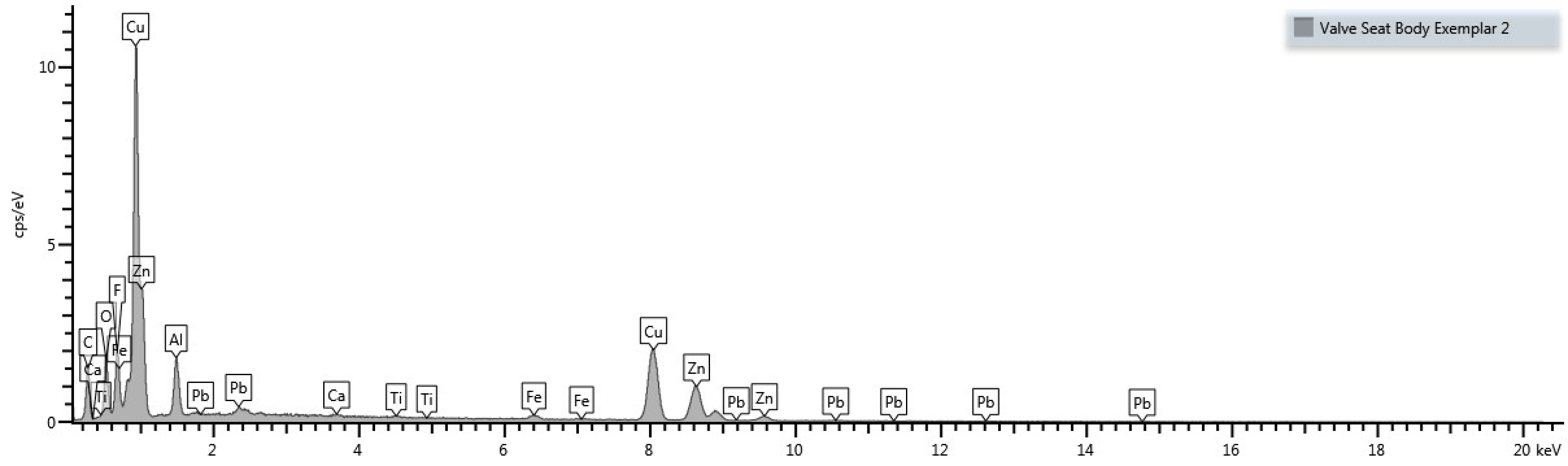


Tank Inside Surface A
cps/eV
6
4
2
0
Al
O
C
Ca
Ti
Fe
Mg
Si
S
Ca
Ti
Ti
Fe
Fe
2
4
6
8
10
12
14
16
18
20 keV

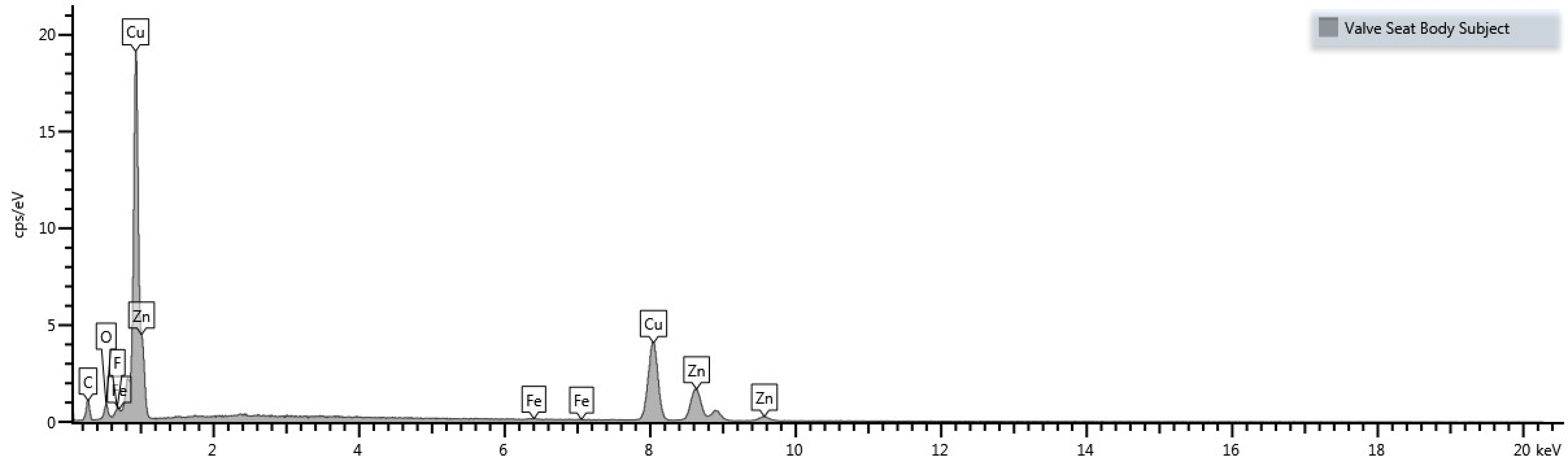

Valve Body Thread Deposit
cps/eV
Al
Zn
Cu
O
F
Ni
Fe
Mg
Si
Pb
Fe
Fe
Ni
Cu
Zn
Pb
Zn
Pb
Pb
Pb
Pb
0
2
4
6
8
10
12
14
16
18
20 keV



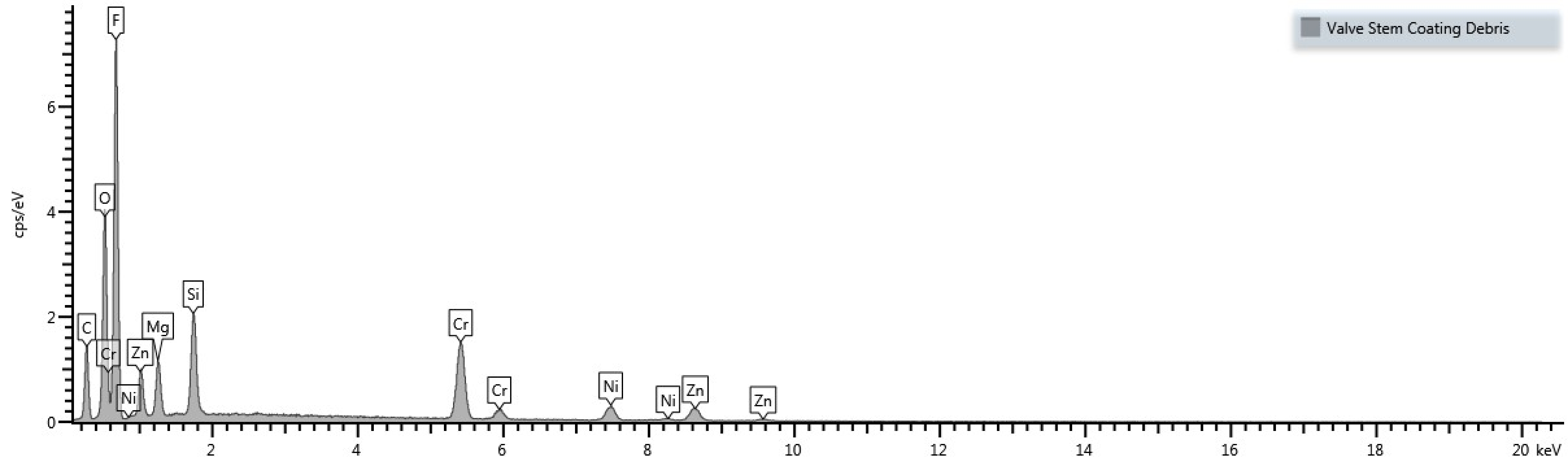
Valve Seat Body Exemplar 1
cps/eV
Cu
Zn
O
F
C
Ti
Fe
Al
Pb
Pb
Cl
Ti
Ti
Fe
Fe
Cu
Zn
Pb
Zn
Pb
Pb
Pb
Pb
0
5
10
2
4
6
8
10
12
14
16
18
20 keV



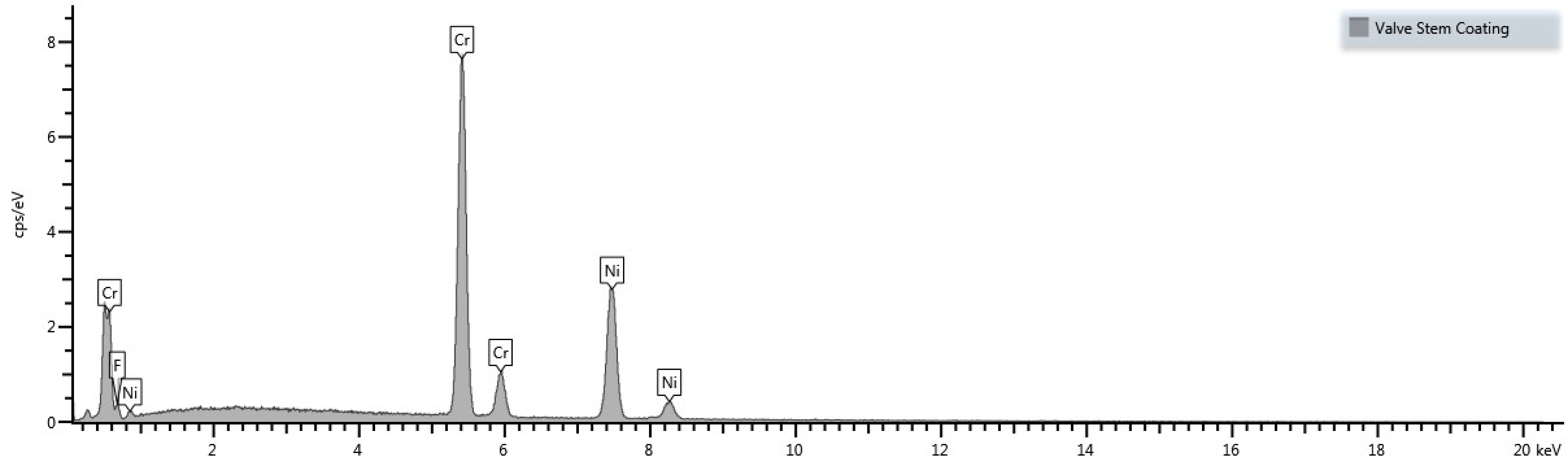
Valve Seat Body Exemplar 2
cps/eV
10
5
0
Cu
Zn
F
O
C
Fe
Ca
Ti
Al
Pb
Pb
Ca
Ti
Ti
Fe
Fe
Cu
Zn
Pb
Zn
Pb
Pb
Pb
Pb
2
4
6
8
10
12
14
16
18
20 keV



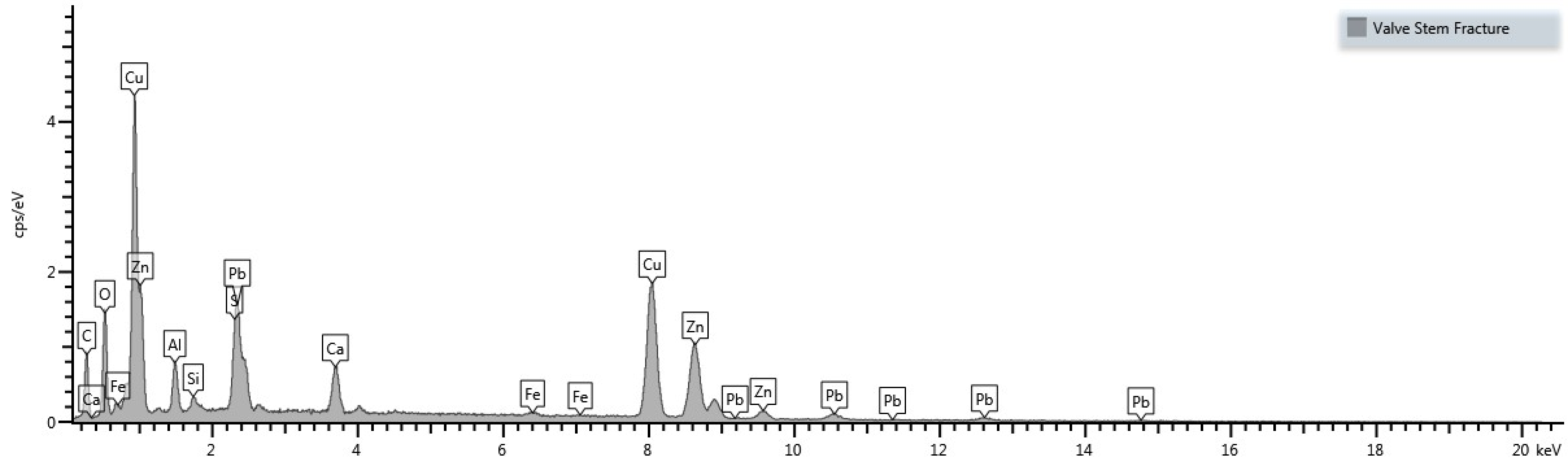
Valve Seat Body Subject
cps/eV
20
15
10
5
0
Cu
Zn
O
F
Fe
C
Fe
Fe
Cu
Zn
Zn
2
4
6
8
10
12
14
16
18
20 keV



Valve Stem Coating Debris
cps/eV
F
O
C
Cr
Zn
Mg
Ni
Si
Cr
Cr
Ni
Ni
Zn
Zn
0
2
4
6
2
4
6
8
10
12
14
16
18
20 keV



Valve Stem Coating
cps/eV
8
6
4
2
0
Cr
Cr
F
Ni
Cr
Ni
Ni
2
4
6
8
10
12
14
16
18
20 keV



Valve Stem Fracture
cps/eV
keV
Cu
Zn
O
C
Ca
Fe
Al
Si
Pb
S
Ca
Fe
Fe
Cu
Zn
Pb
Zn
Pb
Pb
Pb
Pb

Air Cup

Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Default Standard	Standard Calibration Date
O	K_series	5.20	0.01749	26.49	0.23	SiO2	Yes	
F	K_series	1.06	0.00208	4.44	0.17	CaF2	Yes	
Mg	K_series	0.10	0.00063	1.00	0.06	MgO	Yes	
Al	K_series	3.65	0.02623	31.48	0.19	Al2O3	Yes	
Si	K_series	0.05	0.00038	0.49	0.04	SiO2	Yes	
S	K_series	0.05	0.00046	0.39	0.04	FeS2	Yes	
Ca	K_series	0.08	0.00069	0.42	0.04	Wollastonite	Yes	
Fe	K_series	0.06	0.00064	0.36	0.06	Fe	Yes	
Ni	K_series	2.69	0.02688	15.99	0.18	Ni	Yes	
Cu	K_series	1.94	0.01937	12.33	0.20	Cu	Yes	
Zn	K_series	0.90	0.00901	5.85	0.18	Zn	Yes	
Sn	L_series	0.11	0.00106	0.75	0.09	Sn	Yes	
Total:				100.00				

Pressure Regulator Adapter Debris

Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Default Standard	Standard Calibration Date
C				88.47				
O	K_series	2.37	0.00797	7.56	0.07	SiO2	Yes	
Mg	K_series	0.03	0.00021	0.04	0.00	MgO	Yes	
Al	K_series	1.75	0.01260	1.86	0.01	Al2O3	Yes	
Si	K_series	0.03	0.00025	0.03	0.00	SiO2	Yes	
S	K_series	0.02	0.00015	0.02	0.00	FeS2	Yes	
Cl	K_series	0.01	0.00010	0.01	0.00	NaCl	Yes	
Ca	K_series	0.11	0.00101	0.12	0.00	Wollastonite	Yes	
Fe	K_series	0.02	0.00019	0.02	0.00	Fe	Yes	
Cu	K_series	0.58	0.00579	0.79	0.02	Cu	Yes	
Zn	K_series	0.73	0.00730	1.00	0.02	Zn	Yes	
Pb	M_series	0.07	0.00067	0.08	0.01	PbTe	Yes	
Total:				100.00				

Pressure Regulator Adapter Base Metal

Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Default Standard	Standard Calibration Date
Cu	K_series	4.63	0.04633	60.35	0.37	Cu	Yes	
Zn	K_series	3.05	0.03054	39.65	0.37	Zn	Yes	
Total:				100.00				

Tank Inside Surface A

Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Default Standard	Standard Calibration Date
O	K_series	1.94	0.00654	48.57	0.47	SiO2	Yes	
Mg	K_series	0.05	0.00032	0.98	0.09	MgO	Yes	
Al	K_series	1.54	0.01103	27.92	0.30	Al2O3	Yes	
Si	K_series	0.14	0.00111	3.30	0.12	SiO2	Yes	
S	K_series	0.07	0.00064	1.42	0.08	FeS2	Yes	
Ca	K_series	0.33	0.00294	5.13	0.12	Wollastonite	Yes	
Ti	K_series	0.65	0.00647	12.37	0.21	Ti	Yes	
Fe	K_series	0.02	0.00016	0.30	0.10	Fe	Yes	
Total:				100.00				

Valve Body Thread Deposit

Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Default Standard	Standard Calibration Date
C				86.25				
O	K_series	1.54	0.00519	4.77	0.08	SiO2	Yes	
F	K_series	0.83	0.00164	0.90	0.03	CaF2	Yes	
Mg	K_series	0.07	0.00049	0.09	0.00	MgO	Yes	
Al	K_series	2.14	0.01535	2.38	0.01	Al2O3	Yes	
Si	K_series	0.03	0.00021	0.03	0.00	SiO2	Yes	
Fe	K_series	0.03	0.00025	0.03	0.01	Fe	Yes	
Ni	K_series	0.04	0.00036	0.04	0.01	Ni	Yes	
Cu	K_series	1.80	0.01795	2.42	0.03	Cu	Yes	
Zn	K_series	2.20	0.02201	2.98	0.04	Zn	Yes	
Pb	M_series	0.09	0.00079	0.10	0.01	PbTe	Yes	
Total:				100.00				

Valve Seat Body Exemplar 1

Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Default Standard	Standard Calibration Date
Cu	K_series	7.32	0.07318	62.01	0.36	Cu	Yes	
Zn	K_series	4.50	0.04498	37.99	0.36	Zn	Yes	
Total:				100.00				

Valve Seat Body Exemplar 2

Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Default Standard	Standard Calibration Date
Cu	K_series	4.45	0.04453	62.57	0.42	Cu	Yes	
Zn	K_series	2.67	0.02672	37.43	0.42	Zn	Yes	
Total:				100.00				

Valve Seat Body

Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Default Standard	Standard Calibration Date
Cu	K_series	8.82	0.08822	66.03	0.36	Cu	Yes	
Zn	K_series	4.55	0.04553	33.97	0.36	Zn	Yes	
Total:				100.00				

Valve Stem Fracture

Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Default Standard	Standard Calibration Date
Cu	K_series	3.93	0.03926	59.43	0.40	Cu	Yes	
Zn	K_series	2.69	0.02688	40.57	0.40	Zn	Yes	
Total:				100.00				

Valve Stem Coating

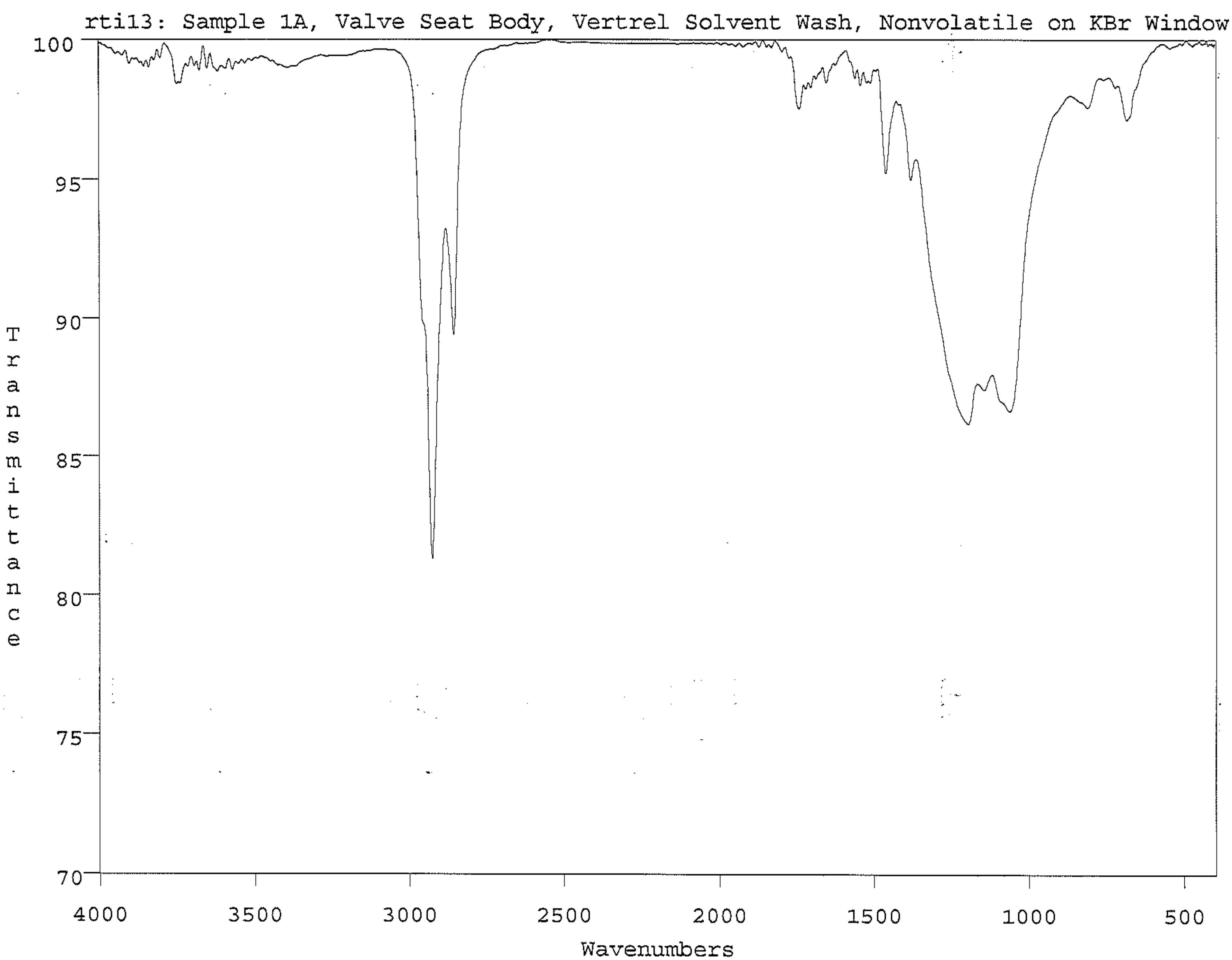
Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Default Standard	Standard Calibration Date
Cr	K_series	6.39	0.06390	54.35	0.24	Cr	Yes	
Ni	K_series	4.98	0.04982	45.65	0.24	Ni	Yes	
Total:				100.00				

Valve Stem Coating Debris

Element	Line Type	Apparent Concentration	k Ratio	Wt%	Wt% Sigma	Standard Label	Default Standard	Standard Calibration Date
O	K_series	3.66	0.01233	16.22	0.17	SiO2	Yes	
F	K_series	9.72	0.01908	53.47	0.24	CaF2	Yes	
Mg	K_series	0.27	0.00180	4.22	0.08	MgO	Yes	
Si	K_series	0.48	0.00377	5.15	0.07	SiO2	Yes	
Cr	K_series	1.23	0.01235	10.83	0.11	Cr	Yes	
Ni	K_series	0.46	0.00457	3.97	0.10	Ni	Yes	
Zn	K_series	0.65	0.00653	6.15	0.16	Zn	Yes	
Total:				100.00				

ATTACHMENT 8

FTIR Spectra and Tables



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Suite 3
Hayward, CA 94545

rti13: Sample 1A, Valve Seat Body, Vertrel Solvent Wash, Nonvolatile on KBr Window

Peak Pick

cm-1	Intensity
682.844	97.145
758.073	98.587
810.154	97.588
1060.916	86.651
1143.860	87.411
1195.941	86.189
1379.190	95.000
1460.206	95.249
1541.221	98.361
1651.171	98.477
1739.902	97.539
2854.828	89.382
2924.270	81.

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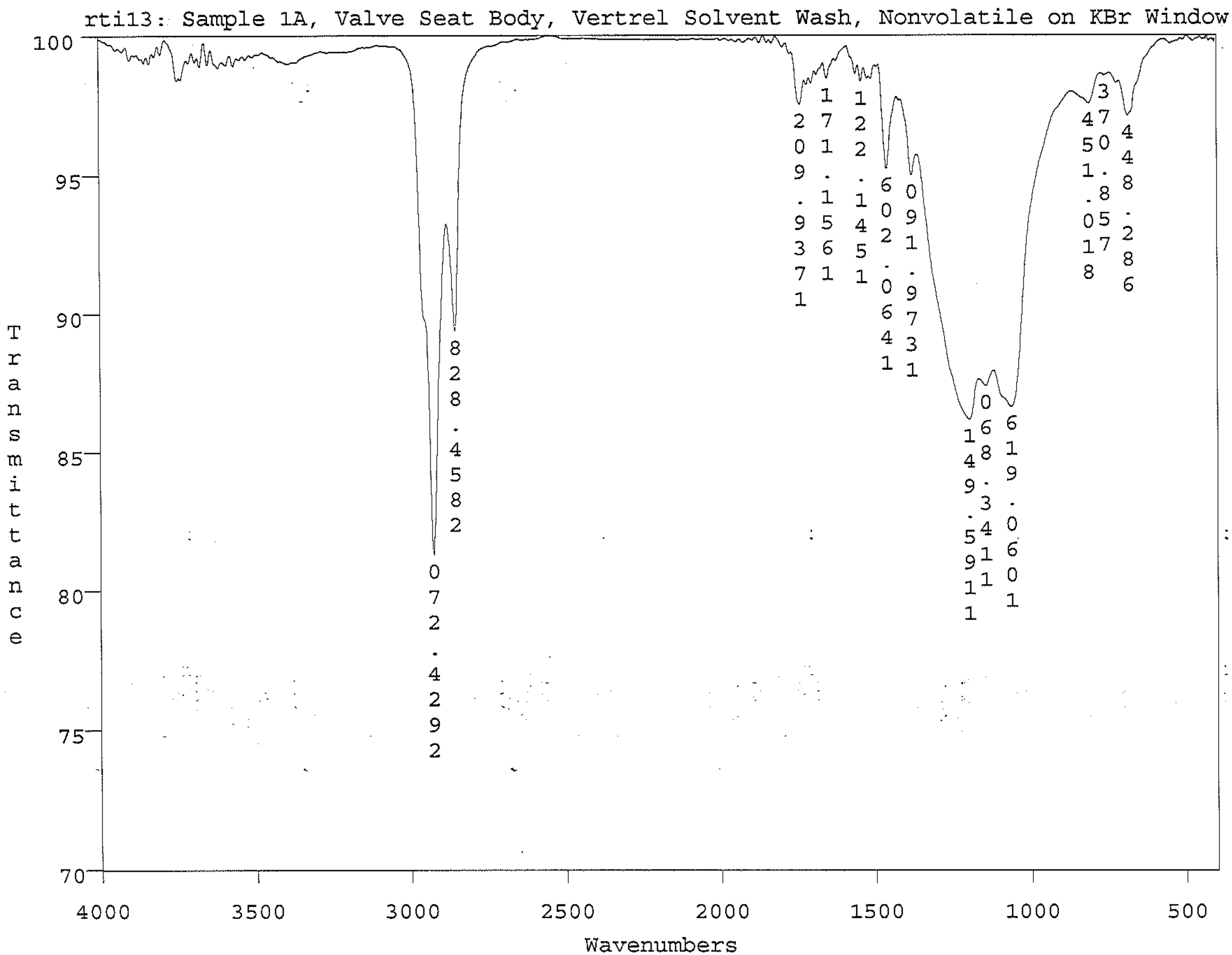

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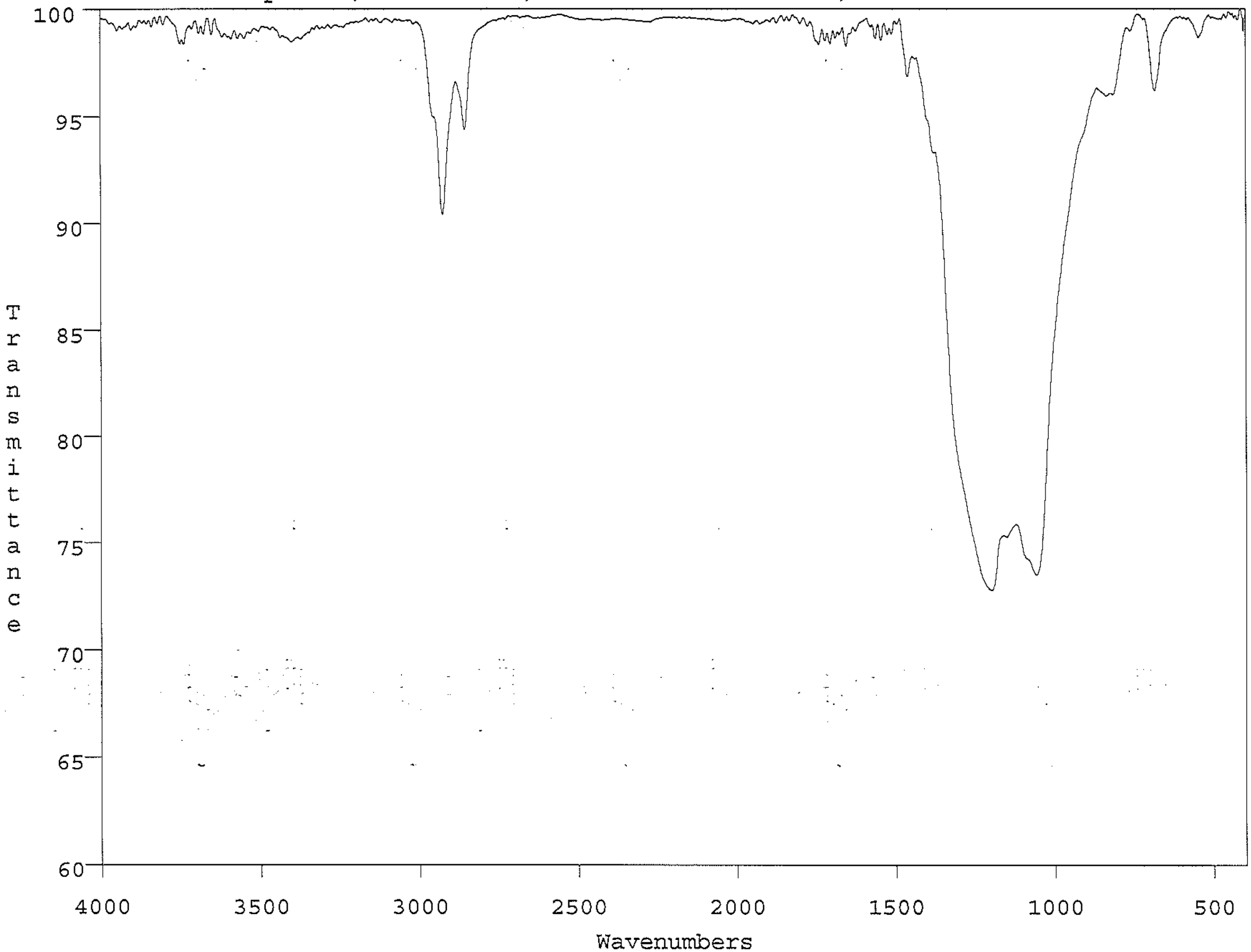
rti16: Sample 1B, Valve Stem, Vertrel Solvent Wash, Nonvolatile on KBr Window



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rti16: Sample 1B, Valve Stem, Vertrel Solvent Wash, Nonvolatile on KBr Window

Peak Pick

cm-1	Intensity
543.960	98.684
682.844	96.214
814.012	96.021
835.230	95.959
1057.058	73.497
1149.647	75.275
1197.870	72.778
1377.262	93.322
1460.206	96.877
2266.502	99.411
2854.828	94.397
2924.270	90.390
3396.859	98.

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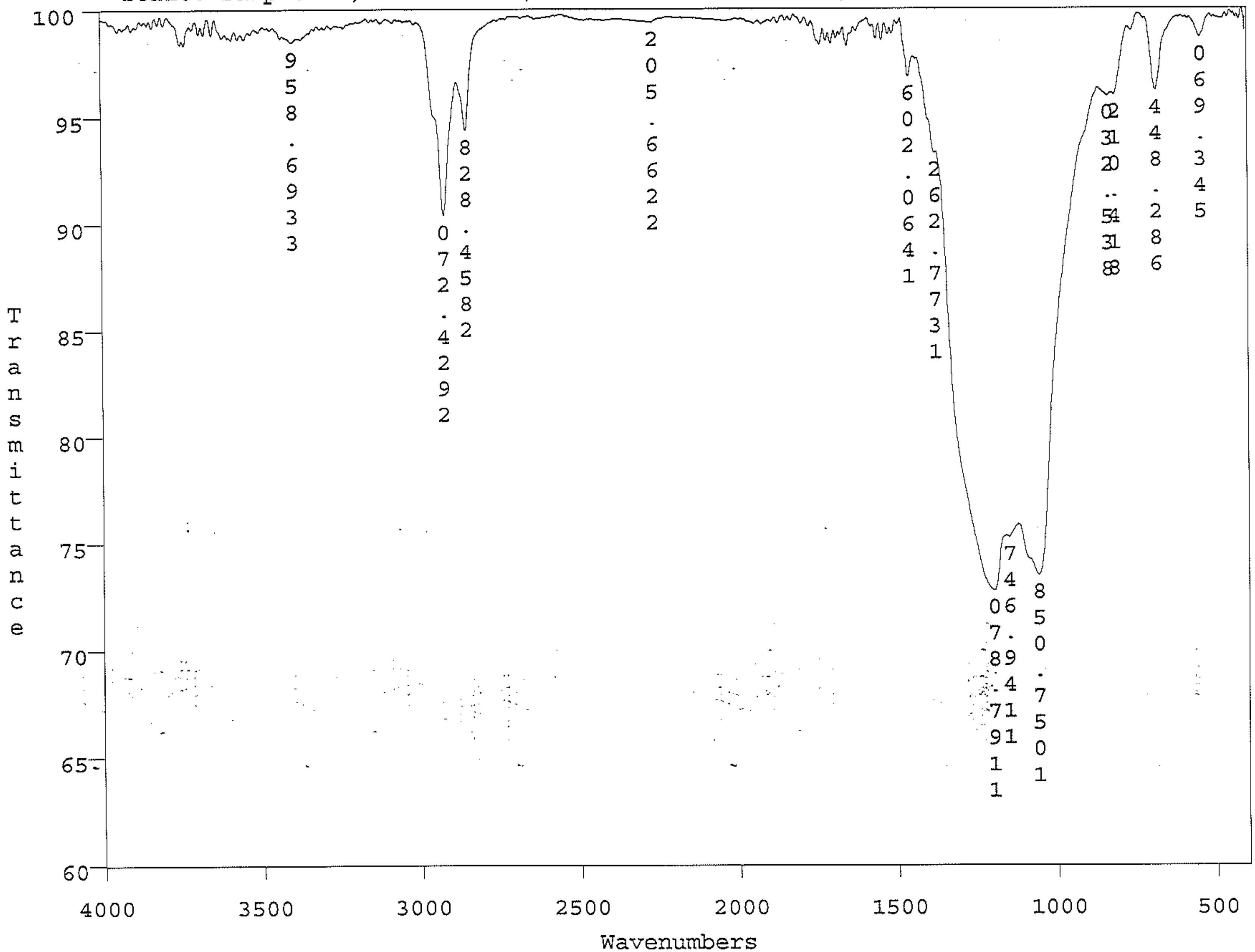
rti16: Sample 1B, Valve Stem, Vertrel Solvent Wash, Nonvolatile on KBr Window



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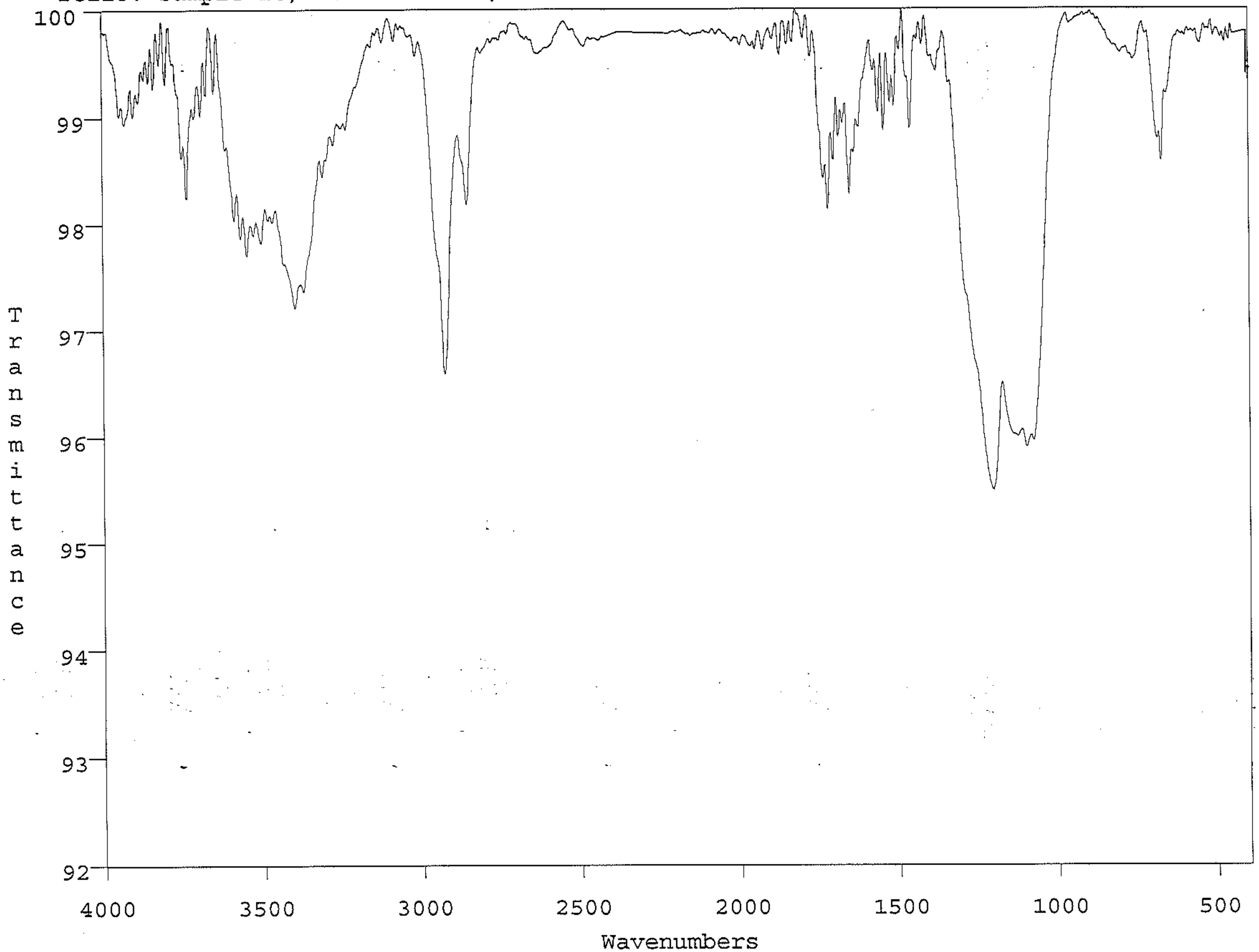
rti18: Sample 1C, Relief Valve, Vertel Solvent Wash of Burst Disc Face, NV on KBr Win.



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rti18: Sample 1C, Relief Valve, Vertrel Solvent Wash of Burst Disc Face, NV on KBr Win.

Peak Pick

cm-1	Intensity
443.656	99.768
671.270	98.586
682.844	98.798
1074.418	95.965
1095.637	95.901
1124.571	96.004
1201.728	95.499
1377.262	99.428
1460.206	98.891
1510.358	99.099
1521.932	99.133
1543.150	98.878
1560.511	99.039
1622.237	98.900
1637.668	98.660
1651.171	98.278
1672.389	98.943
1685.892	98.812
1701.323	98.596
1718.684	98.134
1734.115	98.424
1845.993	99.674
1869.141	99.576
1921.222	99.623
2218.278	99.777
2854.828	98.181
2926.199	96.592
3234.829	98.885
3250.260	98.898
3273.407	98.737
3294.626	98.601
3308.128	98.442
3367.925	97.361
3396.859	97.207
3431.580	97.620
3466.301	98.015
3479.804	98.034
3501.022	97.823
3526.098	97.892
3547.316	97.704
3566.606	97.865
3585.895	98.033
3614.829	98.698
3649.550	99.232
3674.626	99.212
3691.987	99.016
3713.205	98.989
3736.352	98.246
3751.784	98.621
3801.936	99.317
3821.226	99.495
3840.515	99.270
3855.947	99.326
3904.170	99.004
3931.175	98.936
3946.607	99.010

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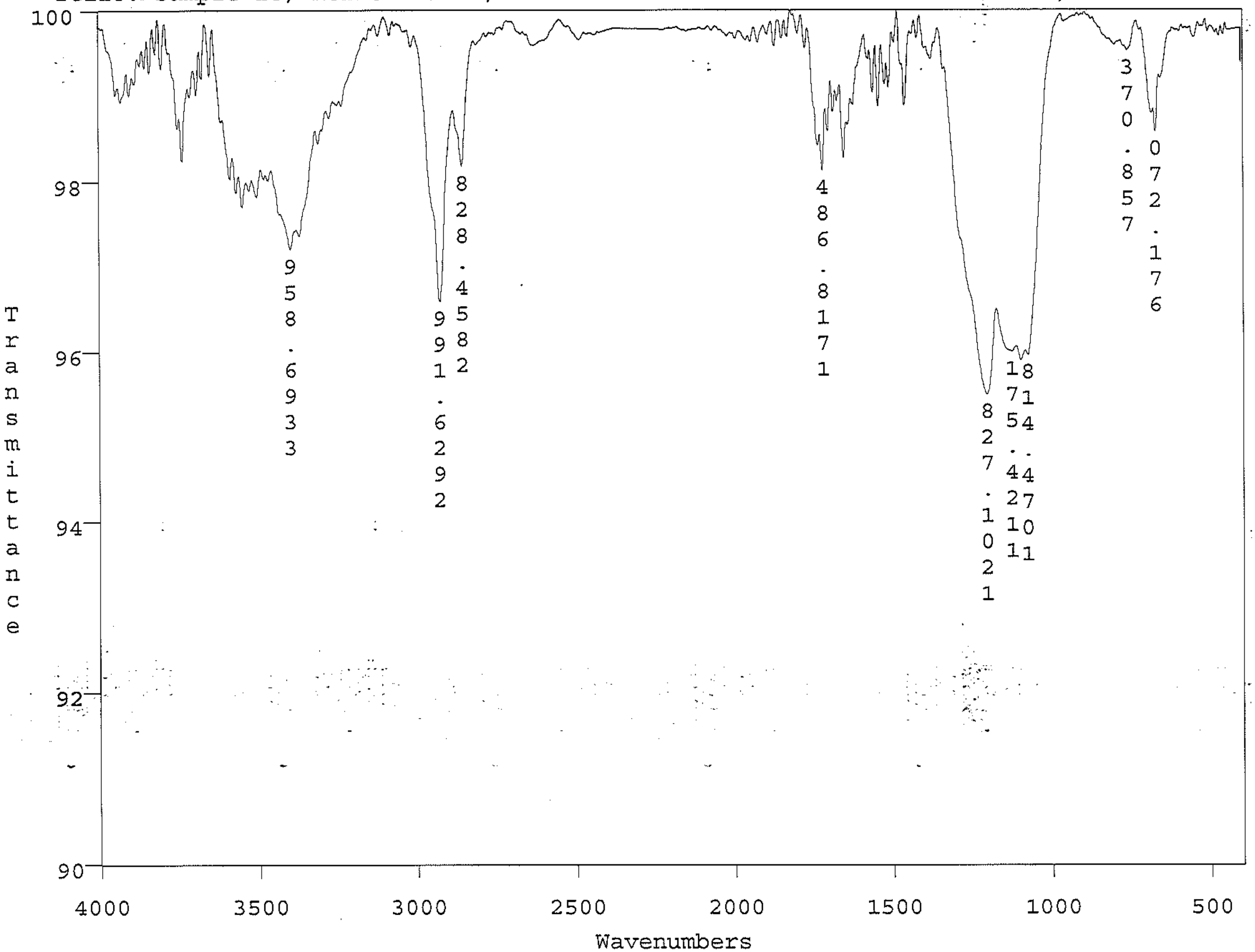
rti18: Sample 1C, Relief Valve, Vertel Solvent Wash of Burst Disc Face, NV on KBr Win.



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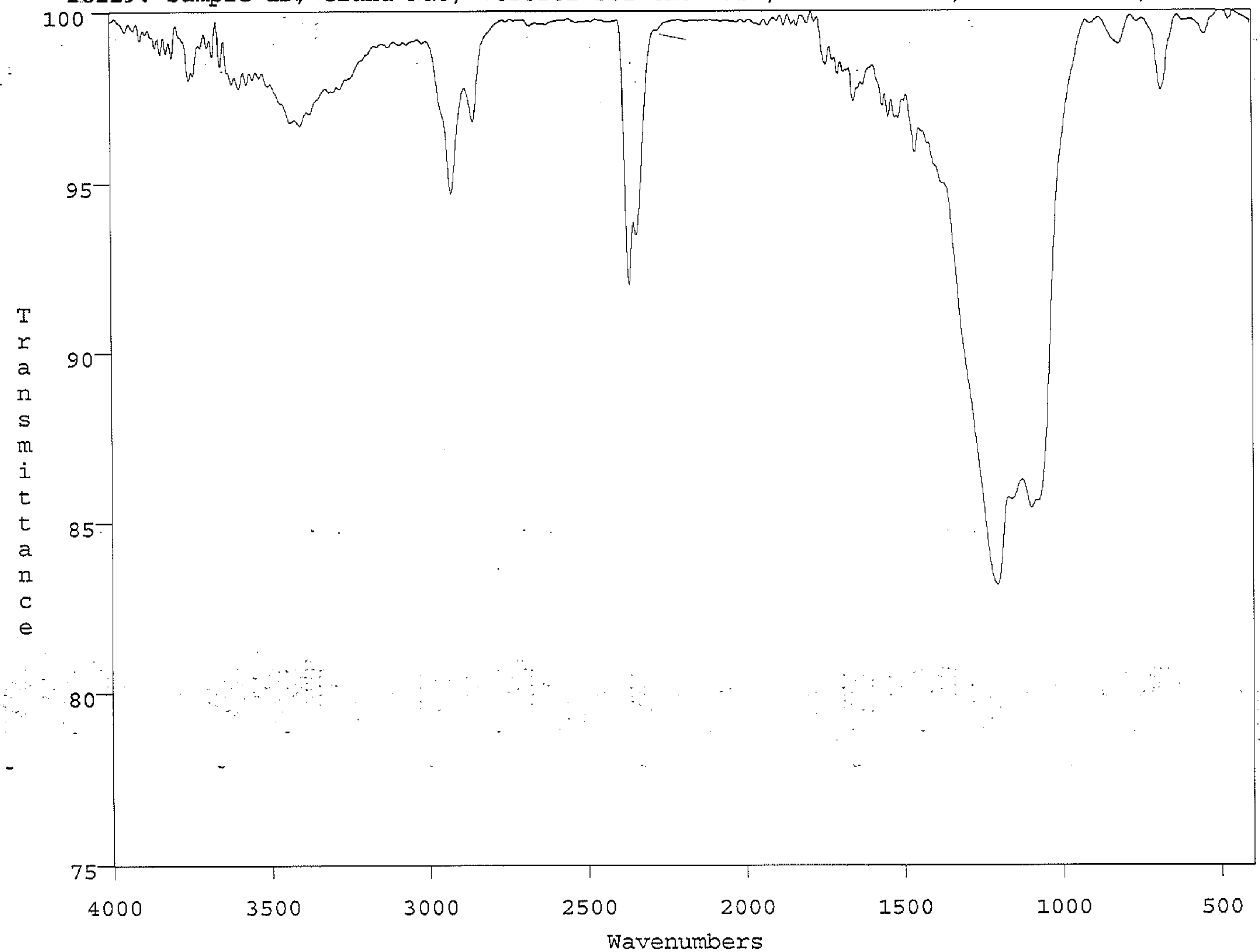
rti19: Sample 1D, Gland Nut, Vertrel Solvent Wash, Inside Bore, Nonvolatile, KBr Win.



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rti19: Sample 1D, Gland Nut, Vertrel Solvent Wash, Inside Bore, Nonvolatile, KBr Win.

Peak Pick

cm-1	Intensity
545.889	99.330
682.844	97.724
815.941	99.044
1074.418	85.645
1095.637	85.436
1157.363	85.698
1203.657	83.176
1373.404	94.989
1458.277	95.905
1512.287	96.897
1543.150	96.916
1560.511	97.256
1653.100	97.378
1703.252	98.177
1739.902	98.445
2339.801	93.465
2362.949	92.006
2854.828	96.791
2924.270	94.679
3273.407	97.757
3369.854	97.022
3400.717	96.685
3431.580	96.771
3502.951	97.837
3529.956	98.083
3570.464	97.884
3593.611	97.777
3616.758	97.898
3653.408	98.401

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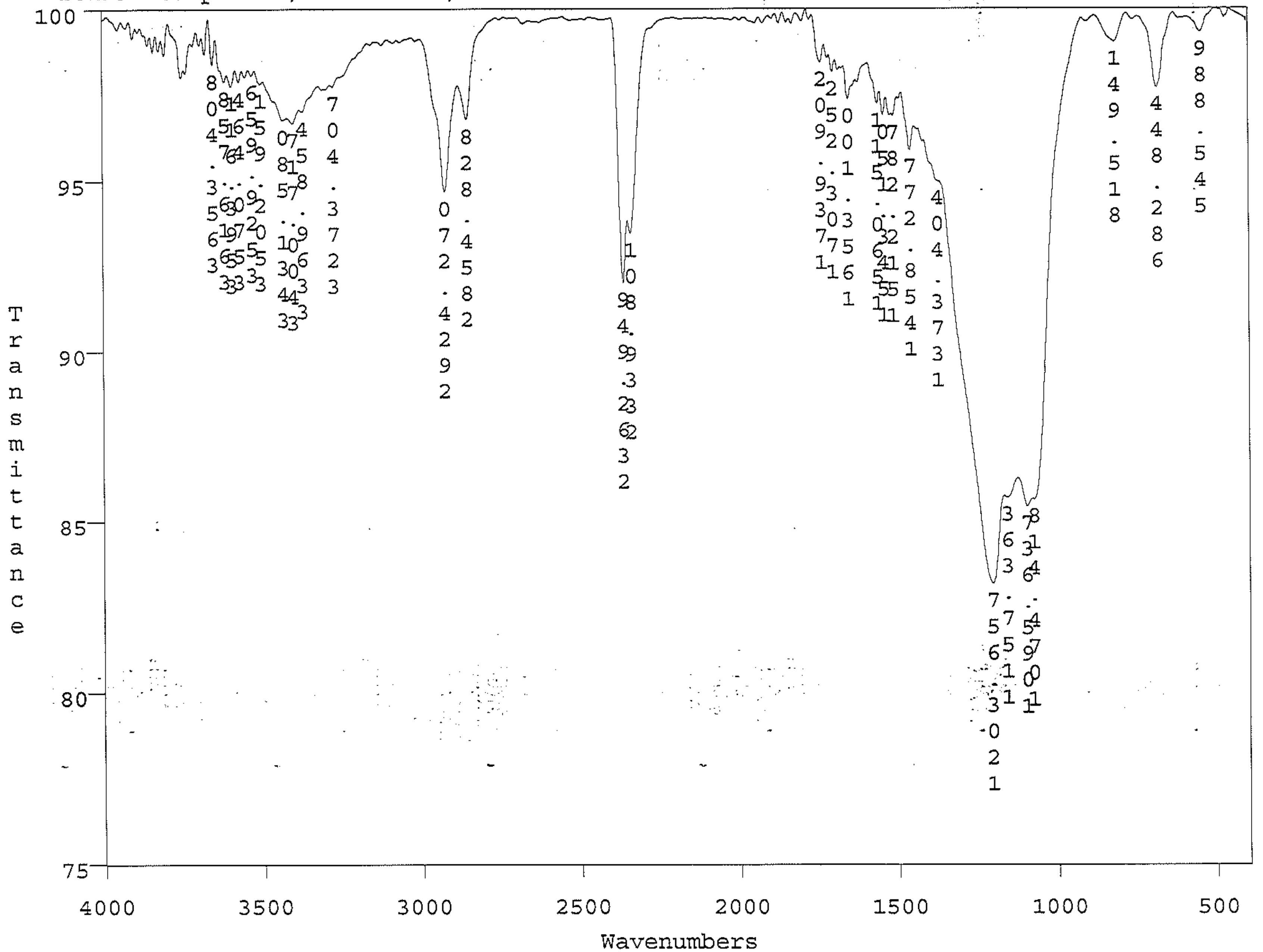
rti19: Sample 1D, Gland Nut, Vertrel Solvent Wash, Inside Bore, Nonvolatile, KBr Win.



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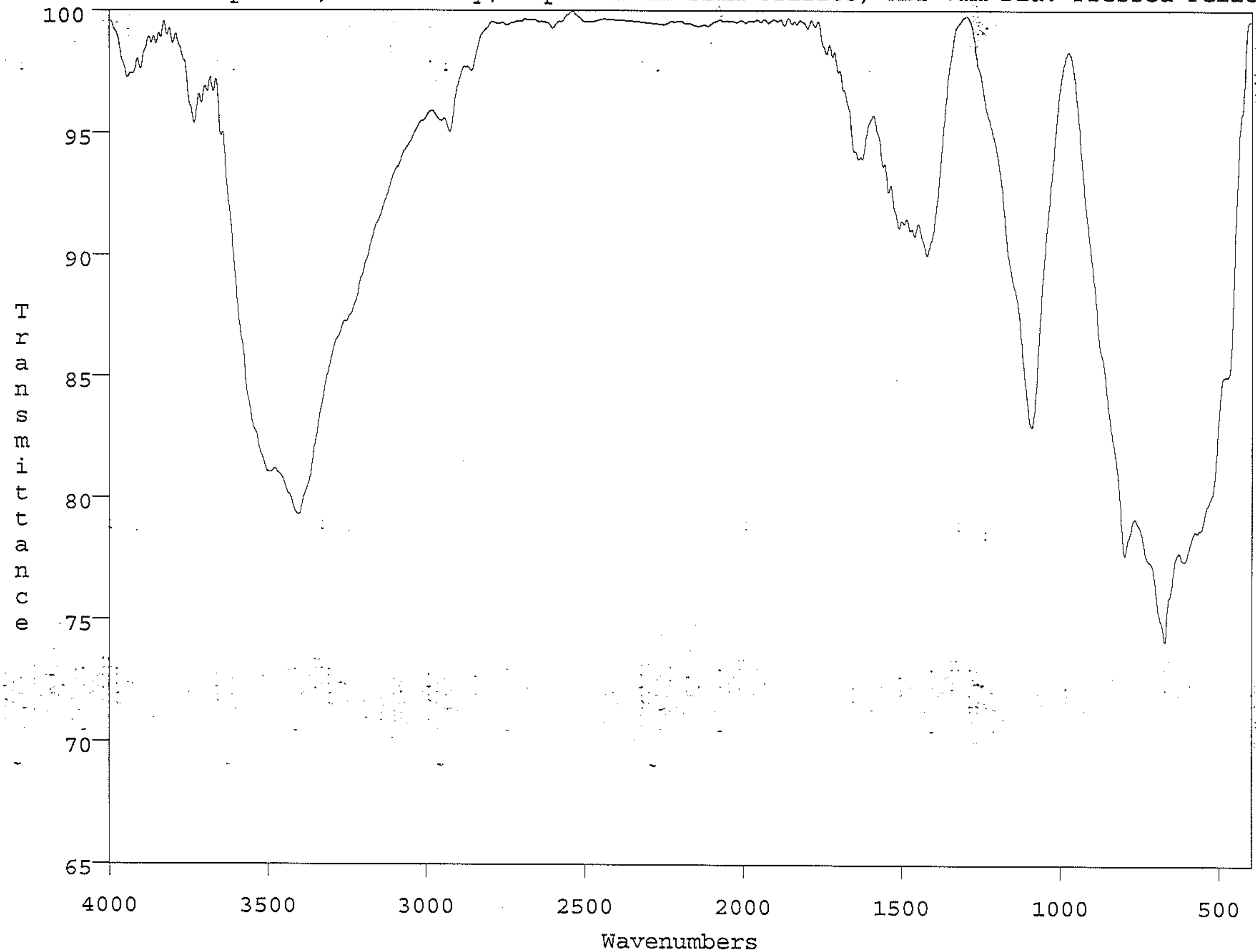
Hayward, CA 94545

rti20: Sample 1E, Valve Body, Deposits in 22mm Orifice, KBr 7mm Dia. Pressed Pellet



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rti20: Sample 1E, Valve Body, Deposits in 22mm Orifice, KBr 7mm Dia. Pressed Pellet

Peak Pick

cm-1	Intensity
472.590	85.026
559.392	78.681
569.037	78.581
609.544	77.419
669.341	74.131
796.651	77.661
1089.850	82.921
1419.698	90.008
1458.277	90.791
1471.779	91.021
1491.069	91.282
1506.500	91.124
1539.292	92.603
1622.237	93.976
1635.739	93.956
2924.270	95.062
2953.204	95.507
3252.189	87.260
3402.646	79.297
3489.448	81.045
3495.235	81.050
3647.621	94.900
3672.697	96.718
3709.347	96.225
3732.495	95.403

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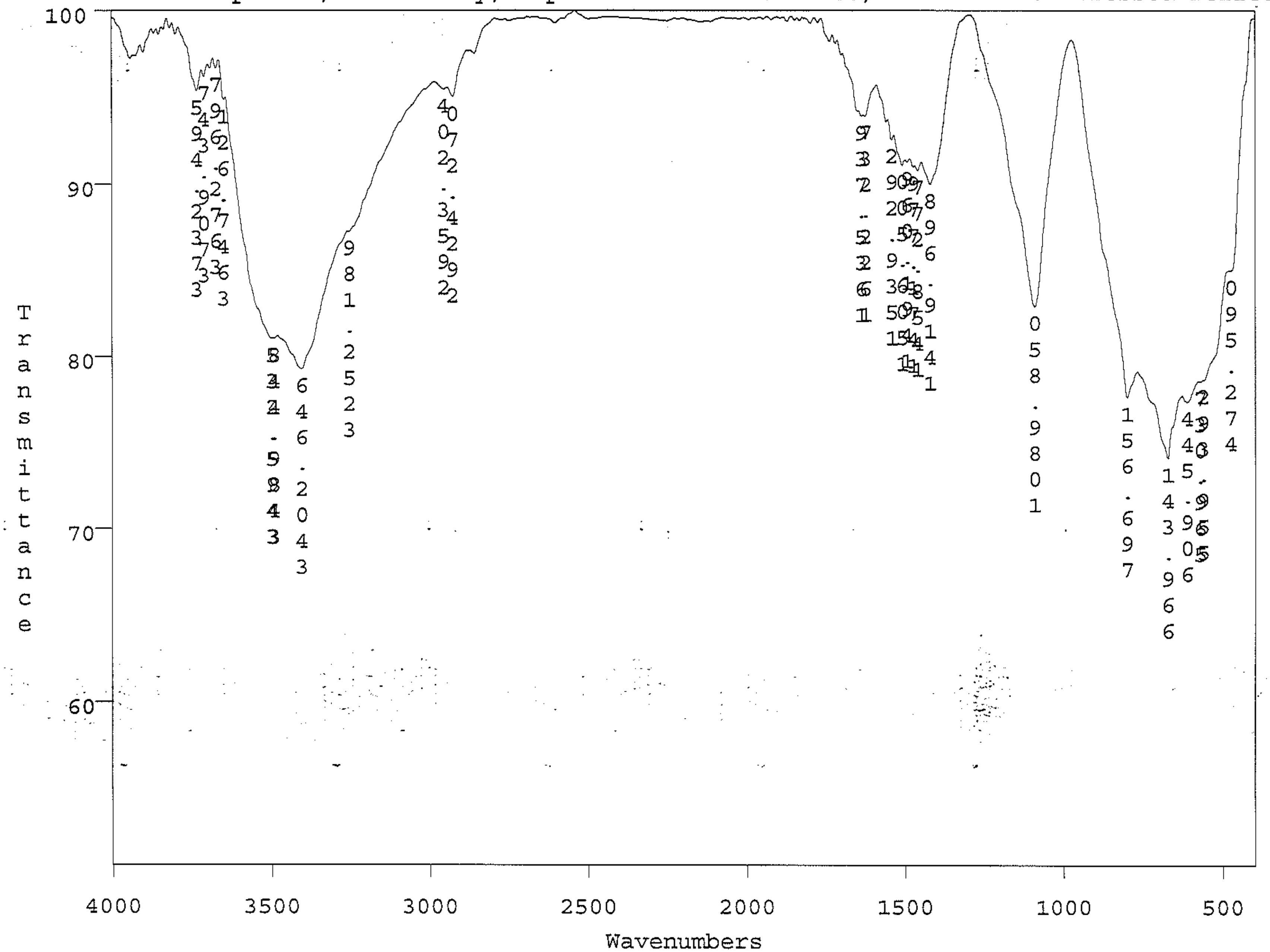
rti20: Sample 1E, Valve Body, Deposits in 22mm Orifice, KBr 7mm Dia. Pressed Pellet



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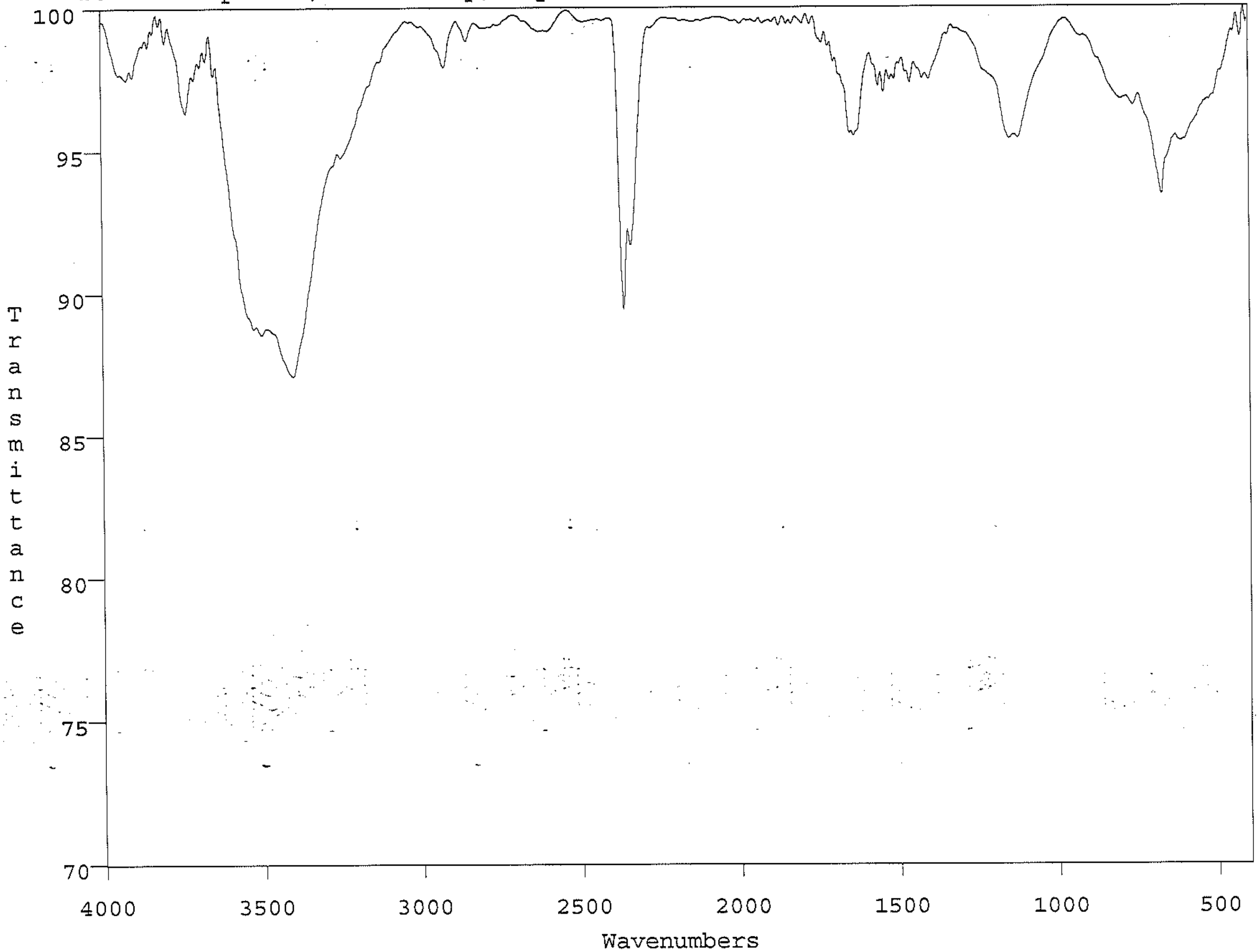
rti21: Sample 1E, Valve Body, Deposits in 18mm Orifice, KBr 7mm Dia. Pressed Pellet



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rti21: Sample 1E, Valve Body, Deposits in 18mm Orifice, KBr 7mm Dia. Pressed Pellet

Peak Pick

cm-1	Intensity
422.437	98.943
596.042	95.375
607.615	95.310
671.270	93.447
758.073	96.561
796.651	96.781
1118.784	95.427
1145.789	95.400
1400.409	97.495
1419.698	97.523
1458.277	97.372
1508.429	97.482
1541.221	97.028
1558.582	97.252
1635.739	95.520
1649.242	95.608
2339.801	91.698
2361.020	89.454
2852.899	98.850
2922.341	97.939
3248.331	94.768
3404.575	87.096
3481.733	88.771
3501.022	88.562
3526.098	88.766
3647.621	97.642
3734.423	96.350
3902.241	97.595
3921.530	97.513

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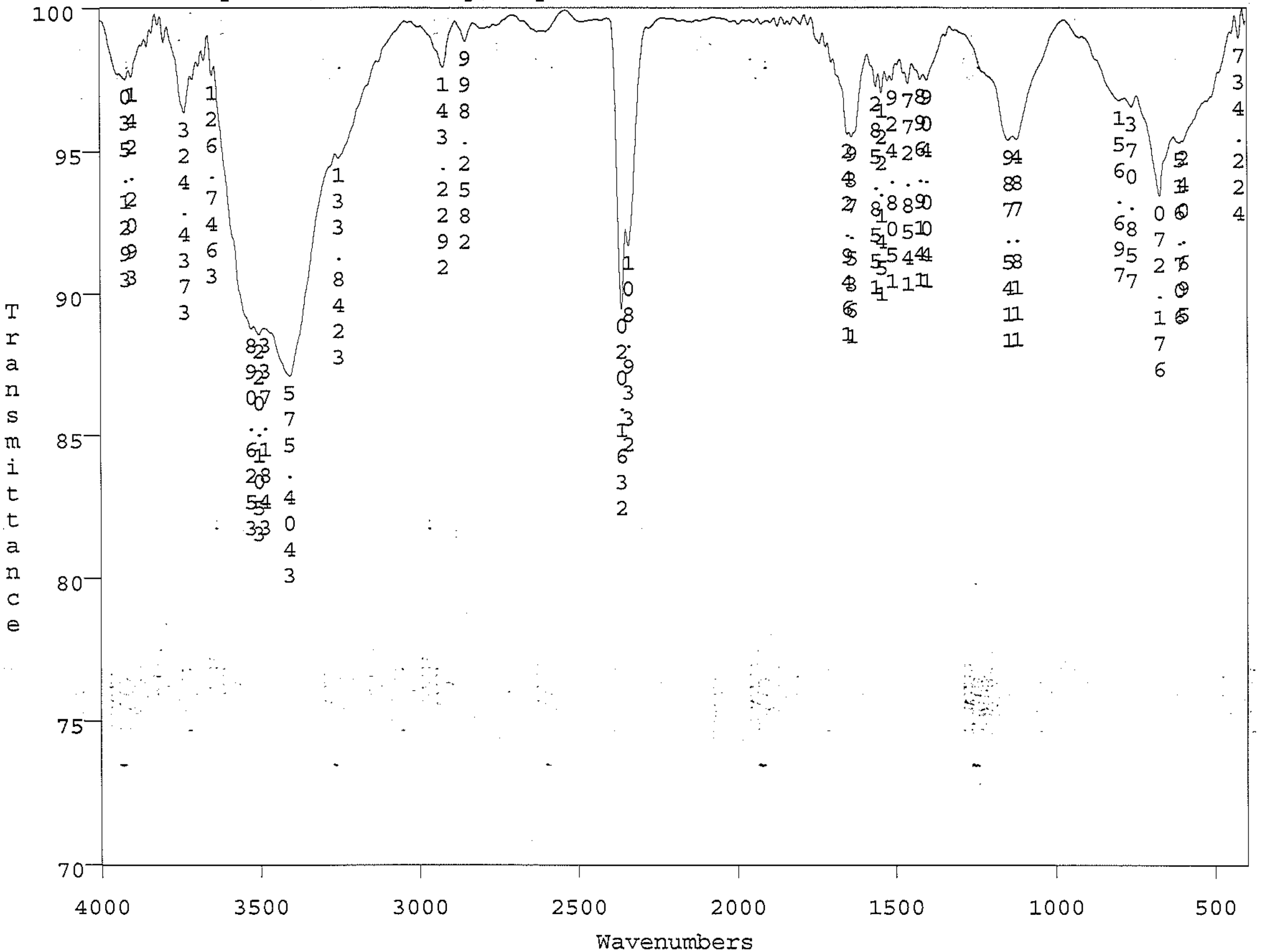
rti21: Sample 1E, Valve Body, Deposits in 18mm Orifice, KBr 7mm Dia. Pressed Pellet



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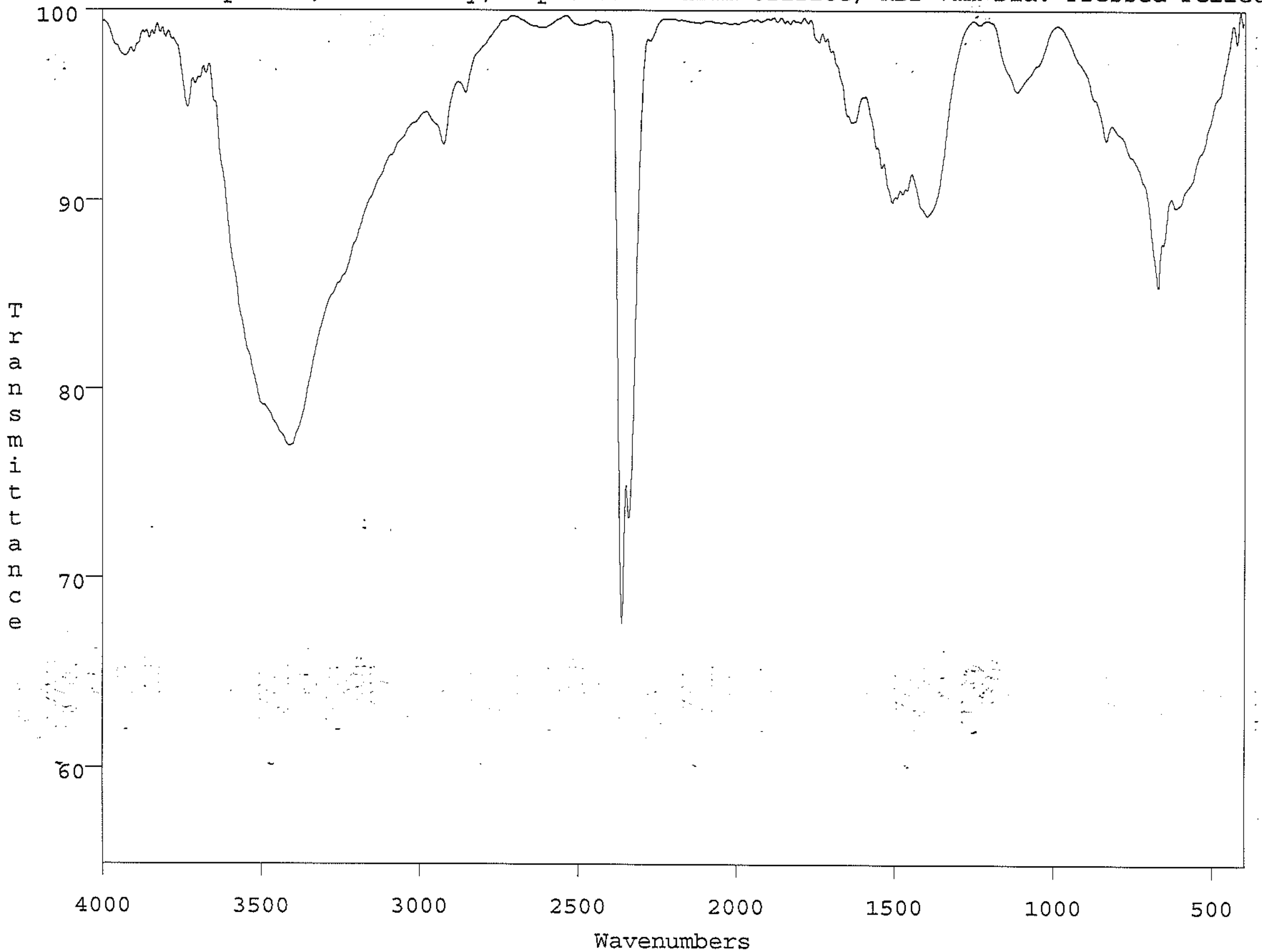
Suite 3
Hayward, CA 94545

rti22: Sample 1E, Valve Body, Deposits in 12mm Orifice, KBr 7mm Dia. Pressed Pellet



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rti22: Sample 1E, Valve Body, Deposits in 12mm Orifice, KBr 7mm Dia. Pressed Pellet

Peak Pick

cm-1	Intensity
615.331	89.666
653.910	87.717
669.341	85.472
833.301	93.219
1114.926	95.778
1398.480	89.220
1460.206	90.588
1473.708	90.390
1492.998	90.177
1506.500	89.946
1541.221	91.788
2339.801	73.177
2361.020	67.608
2488.330	99.234
2854.828	95.691
2922.341	92.964
3410.362	76.995
3732.495	94.923
3931.175	97.618

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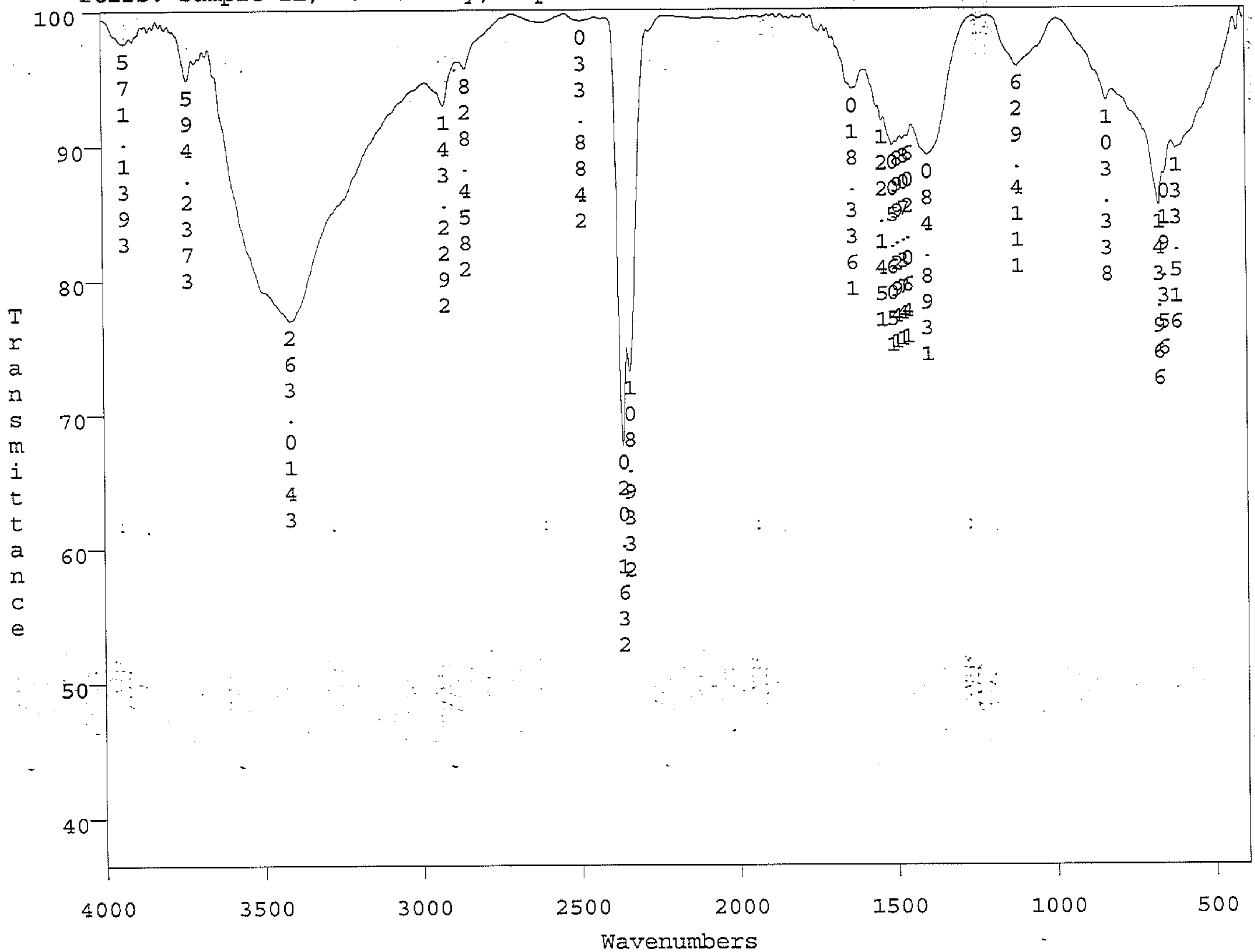
rti22: Sample 1E, Valve Body, Deposits in 12mm Orifice, KBr 7mm Dia. Pressed Pellet



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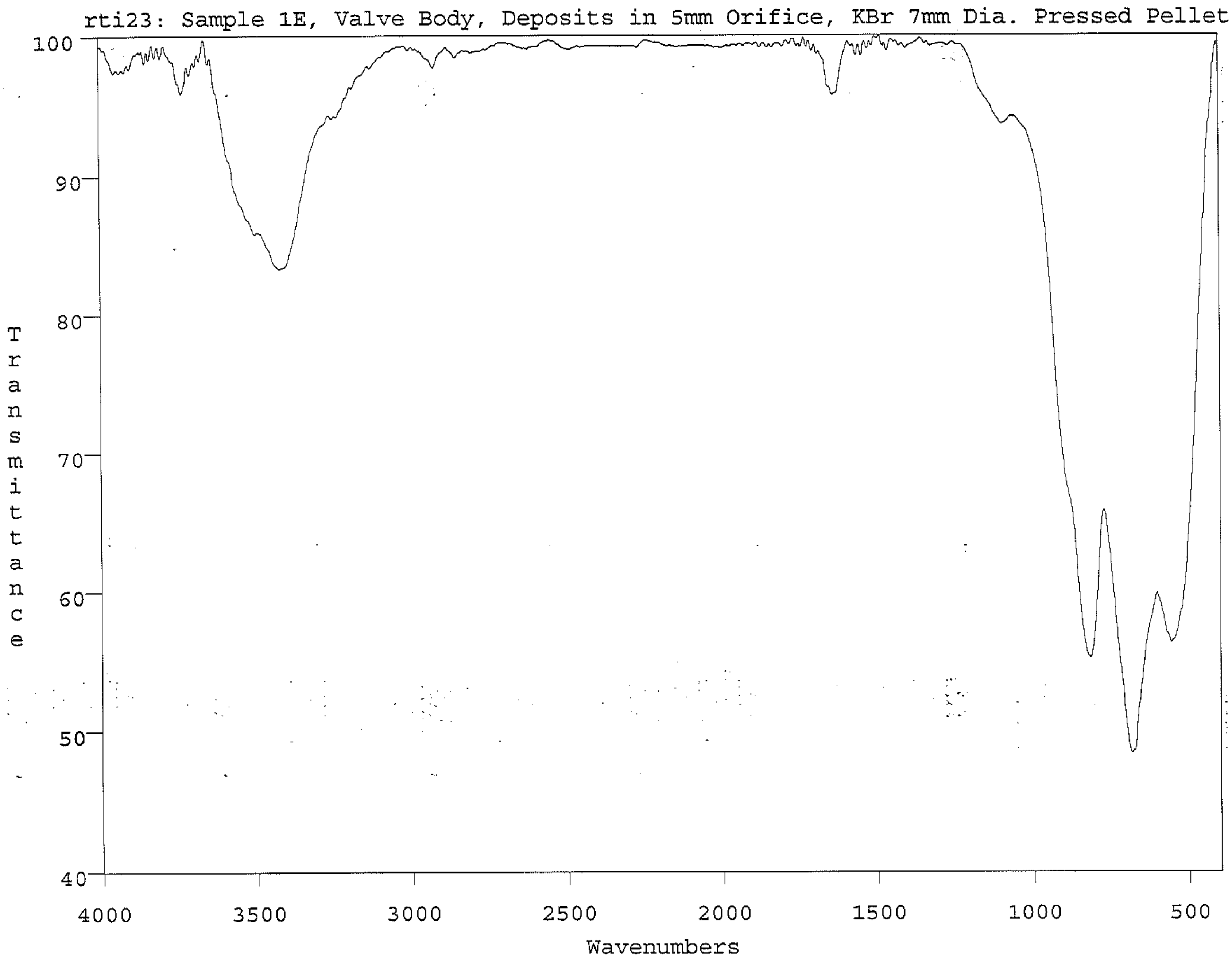

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rti23: Sample 1E, Valve Body, Deposits in 5mm Orifice, KBr 7mm Dia. Pressed Pellet

Peak Pick

cm-1	Intensity
555.534	56.381
673.199	48.593
680.915	48.417
814.012	55.303
1093.708	93.706
2922.341	97.746
3418.078	83.340
3499.093	85.836

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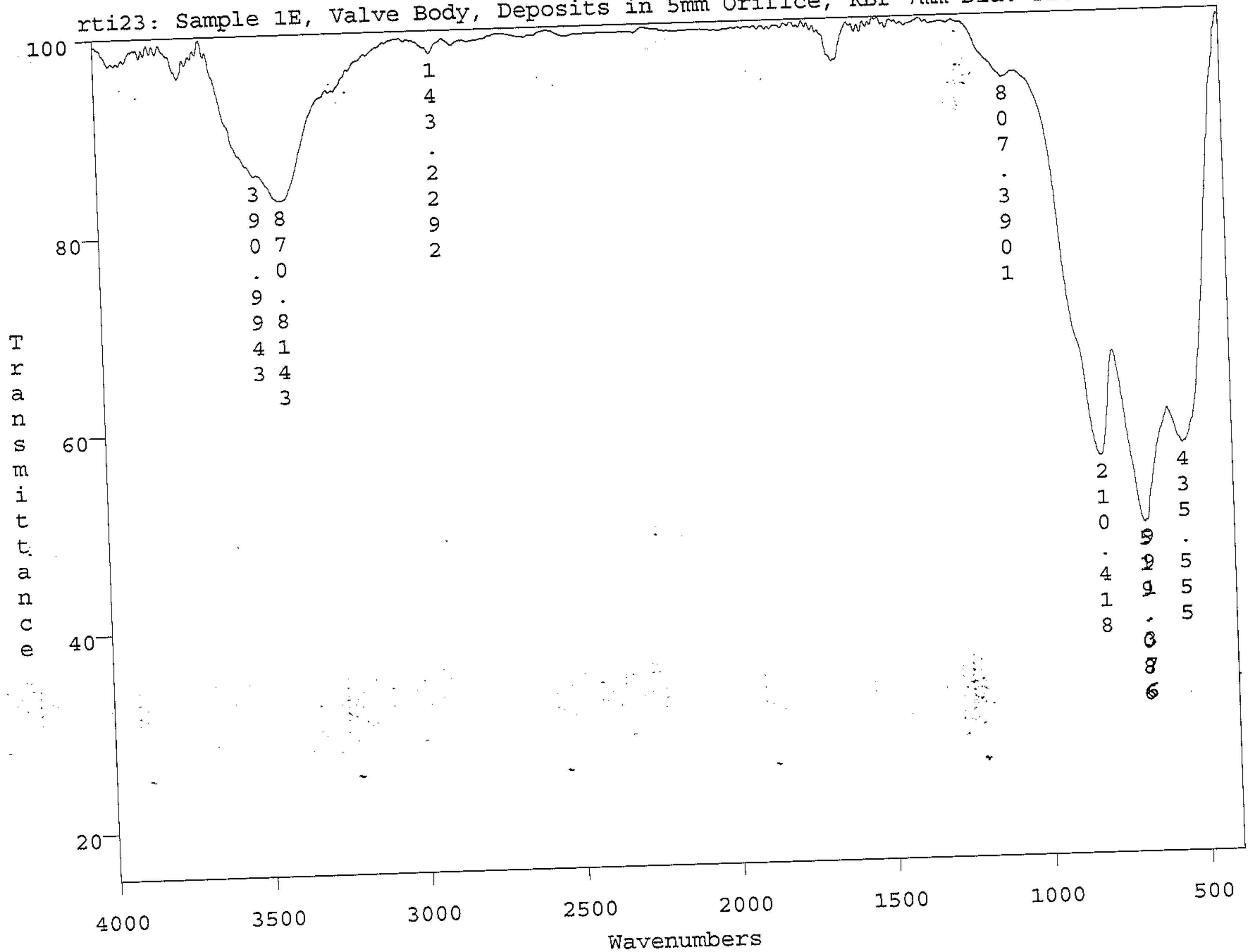
rti23: Sample 1E, Valve Body, Deposits in 5mm Orifice, KBr 7mm Dia. Pressed Pellet



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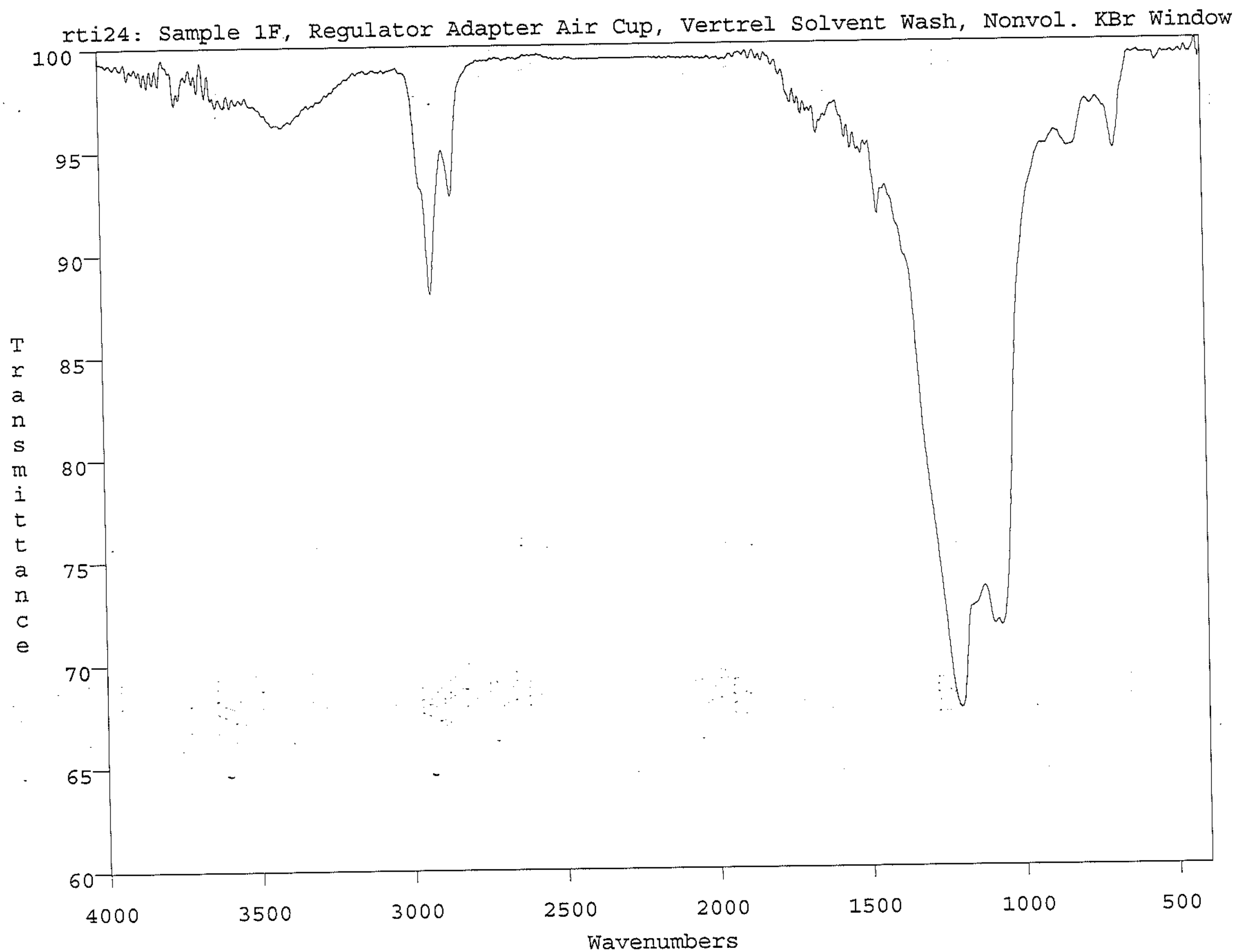

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rti24: Sample 1F, Regulator Adapter Air Cup, Vertrel Solvent Wash, Nonvol. KBr Window

Peak Pick

cm-1	Intensity
686.702	94.744
760.001	96.914
837.159	94.872
1070.560	71.579
1093.708	71.675
1205.586	67.608
1458.277	91.678
1508.429	94.592
1543.150	94.853
1560.511	95.370
1653.100	95.596
2447.822	99.328
2854.828	92.745
2924.270	87.973
3591.682	97.128

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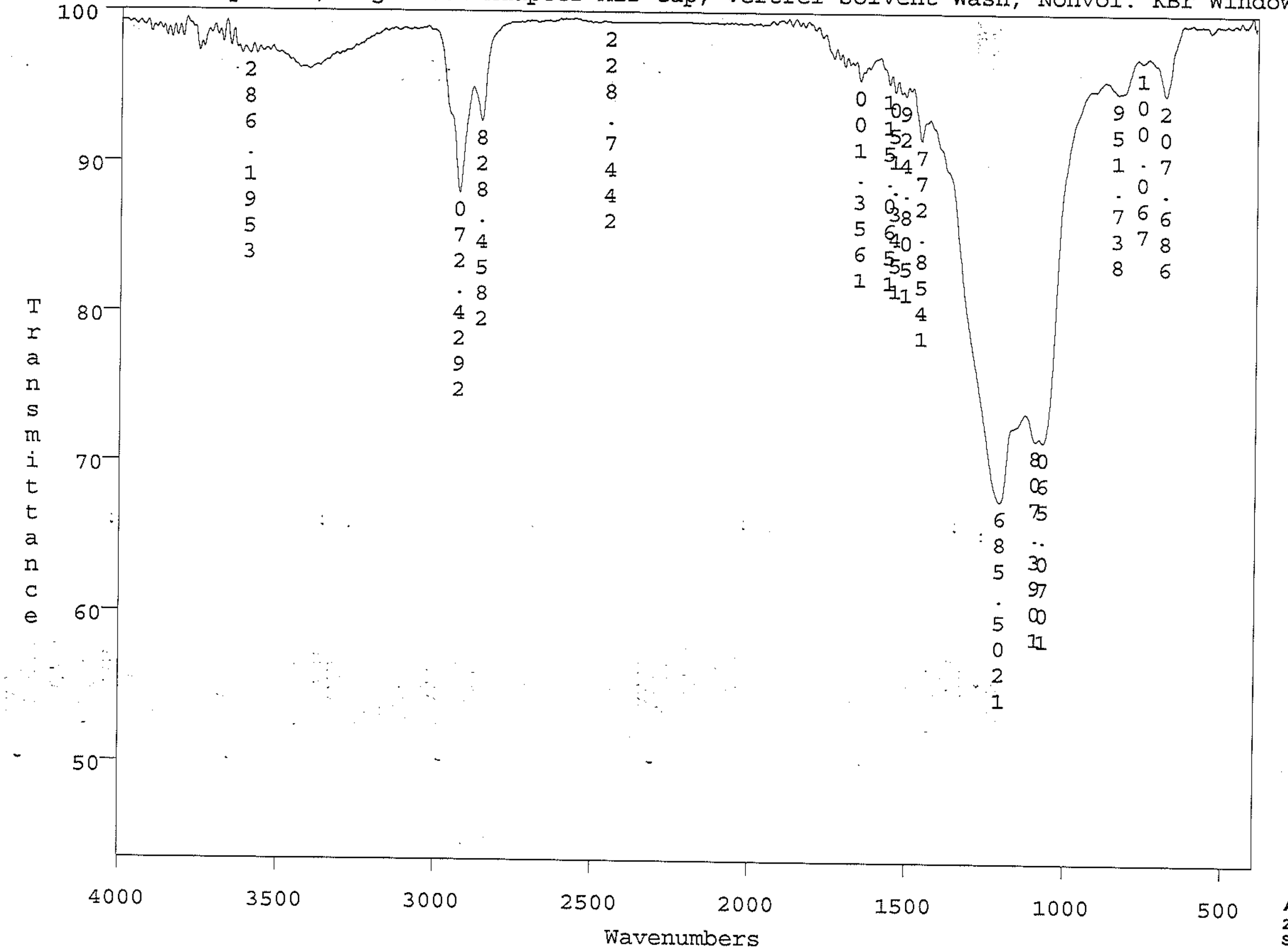
rti24: Sample 1F, Regulator Adapter Air Cup, Vertrel Solvent Wash, Nonvol. KBr Window



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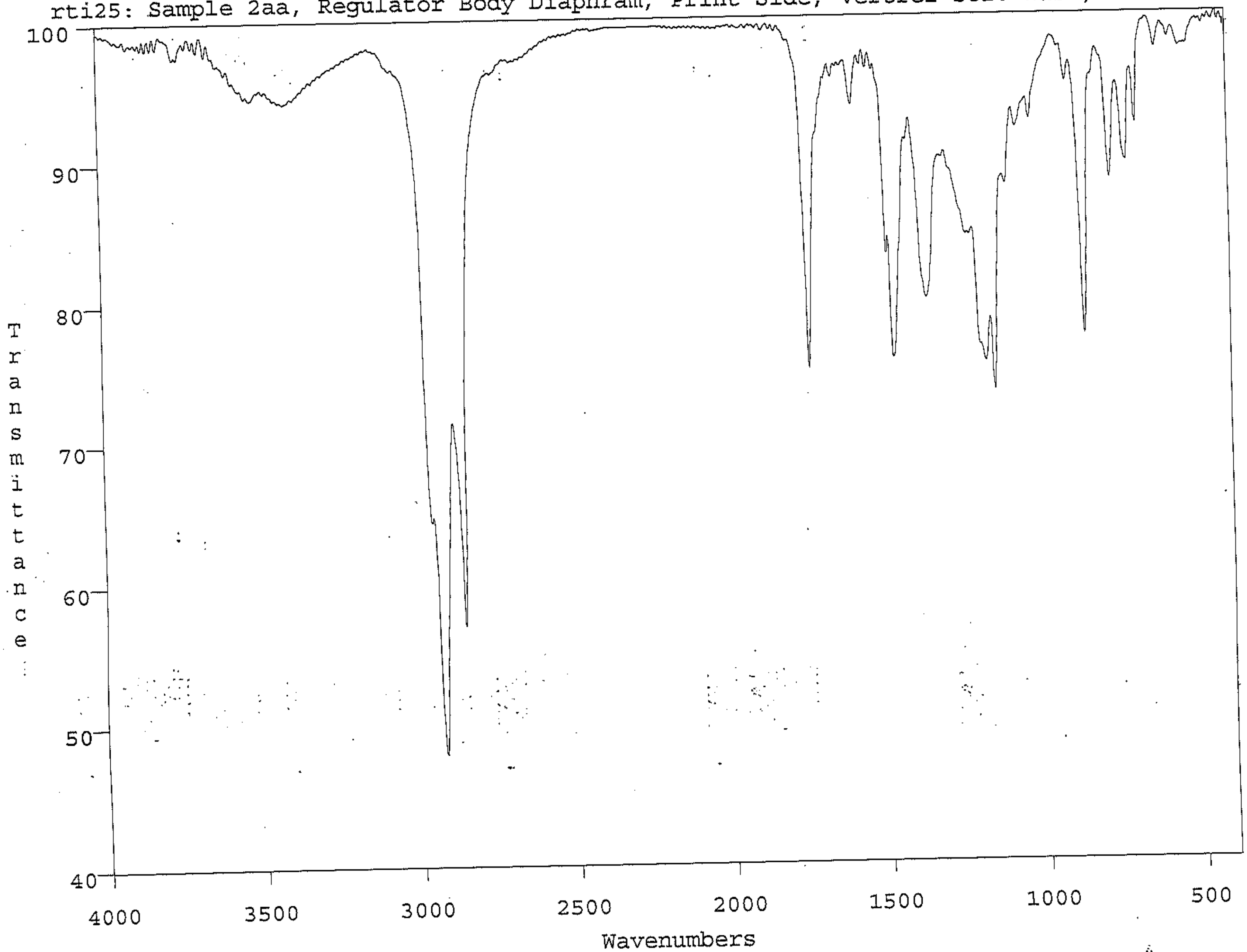
rti25: Sample 2aa, Regulator Body Diaphram, Print Side, Vertrel Sol. Wash, NV KBr Win.



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rti25: Sample 2aa, Regulator Body Diaphram, Print Side, Vertrel Sol. Wash, NV. KBr Win.

Peak Pick

cm-1	Intensity
623.047	97.557
688.631	92.171
721.423	89.474
773.504	88.250
860.306	77.270
908.530	95.211
1024.266	92.540
1068.632	91.967
1105.281	87.935
1145.789	73.379
1172.794	75.417
1192.084	76.620
1222.947	84.430
1234.520	84.444
1305.891	89.886
1361.830	79.935
1417.769	91.168
1467.922	75.781
1487.211	83.156
1541.221	96.318
1589.445	93.689
1651.171	95.670
1736.044	75.074
2850.970	57.049
2918.483	47.863
2953.204	64.333
3402.646	94.197
3464.372	94.978
3508.738	94.489

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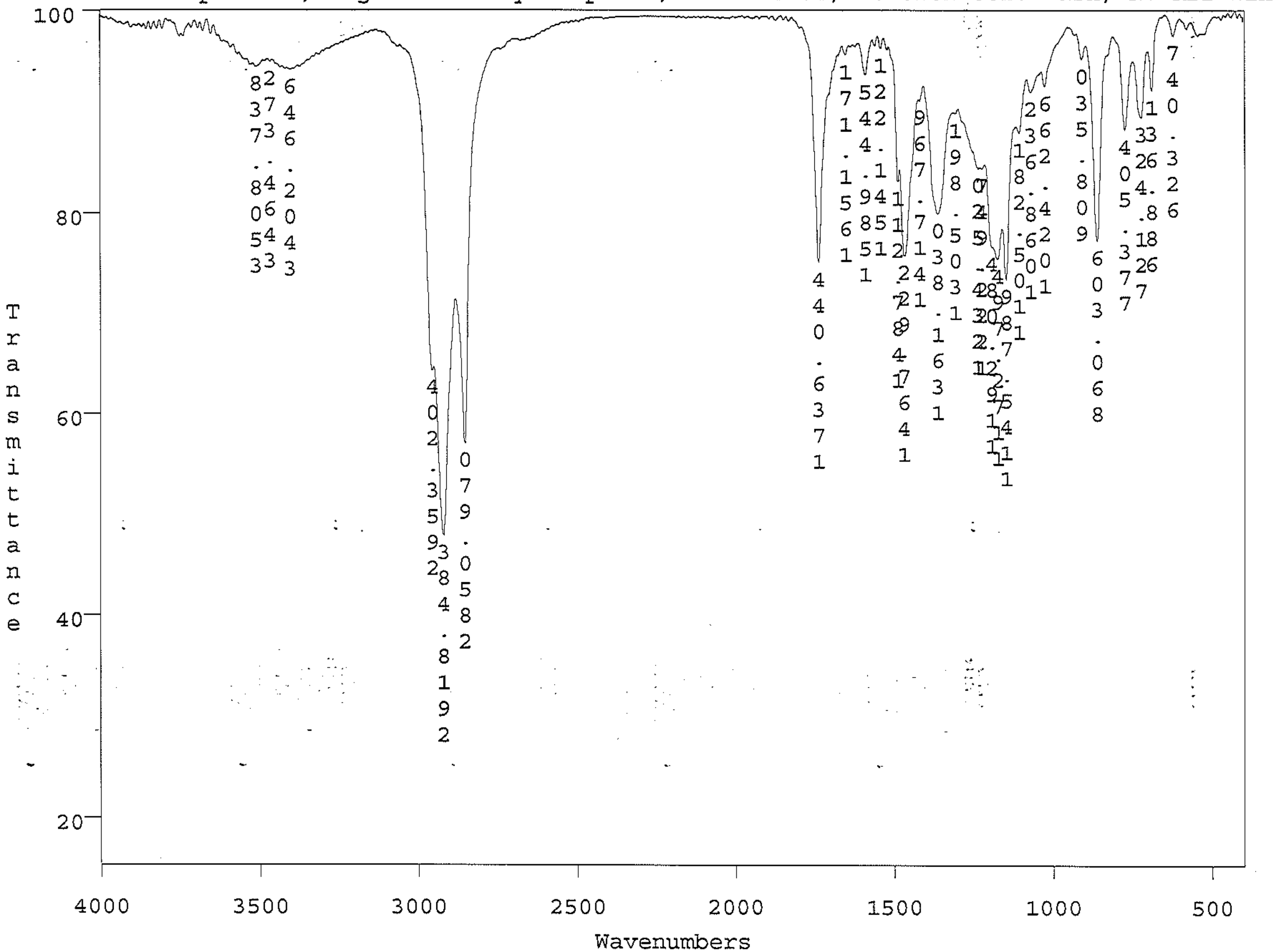
rti25: Sample 2aa, Regulator Body Diaphram, Print Side, Vertrel Sol. Wash, NV KBr Win.



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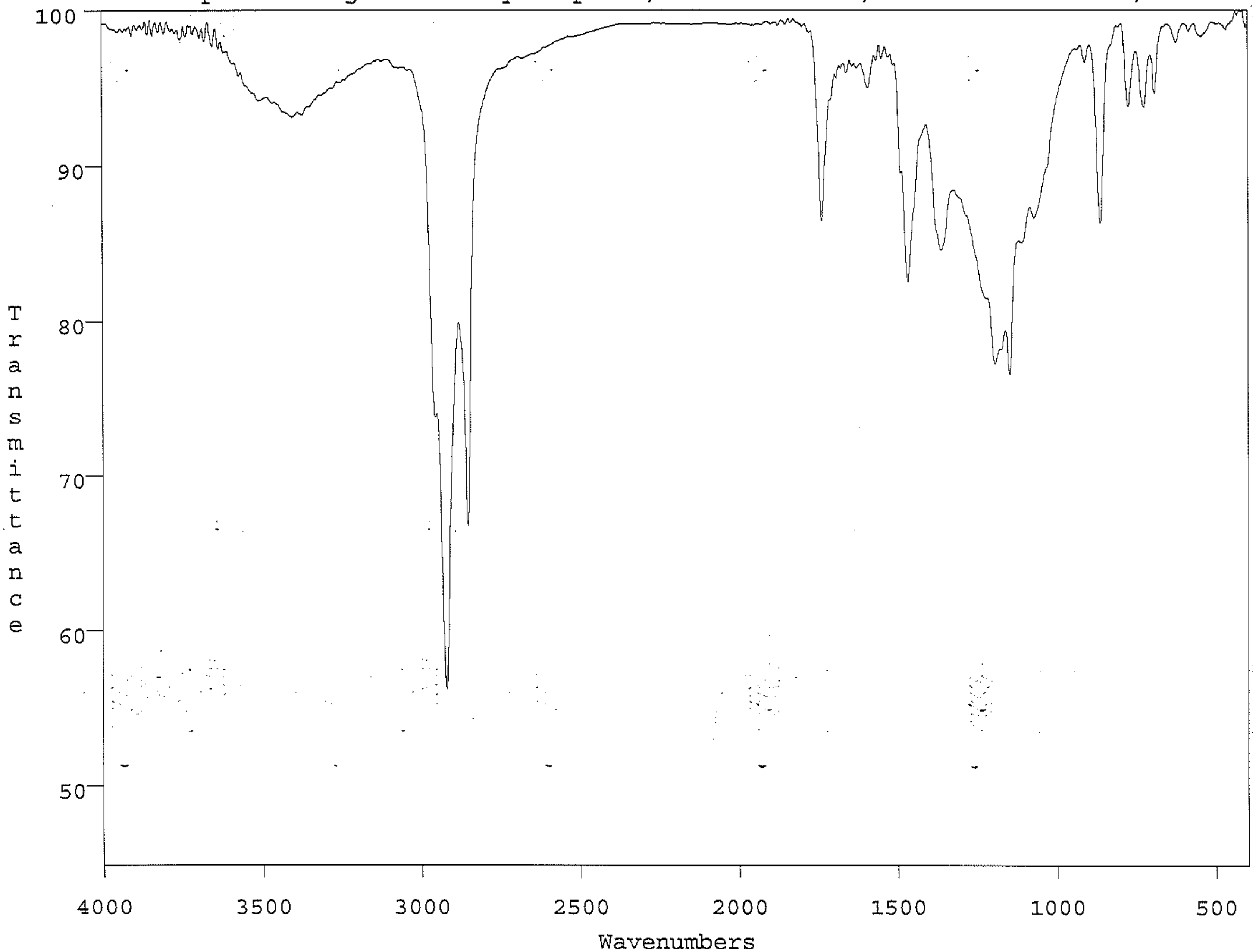
rti26: Sample 2aa Regulator Body Diaphram, NonPrint Side, Vertrel Sol. Wash, NV KBr W.



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rti26: Sample 2aa, Regulator Body Diaphram, NonPrint Side, Vertrel Sol. Wash, NV. KBr W.

Peak Pick

cm-1	Intensity
621.118	97.968
688.631	94.699
721.423	93.801
771.575	93.849
860.306	86.330
908.530	96.665
1068.632	86.687
1107.210	85.095
1145.789	76.582
1172.794	78.203
1192.084	77.264
1219.089	81.480
1359.901	84.587
1464.064	82.557
1589.445	95.044
1736.044	86.494
2850.970	66.752
2918.483	56.234
2953.204	73.773
3369.854	93.335
3402.646	93.188

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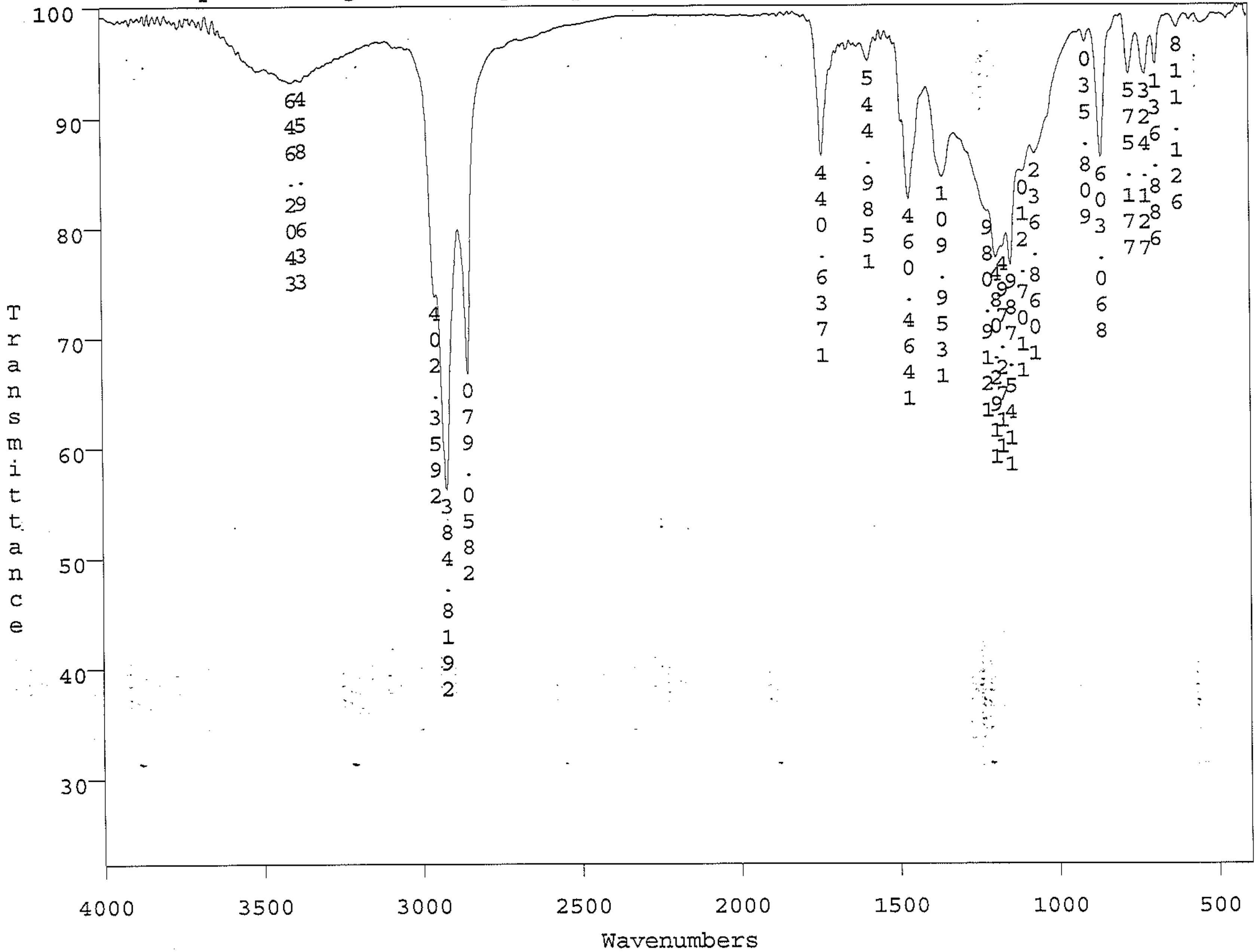
rti26: Sample 2aa Regulator Body Diaphram, NonPrint Side, Vertrel Sol. Wash, NV KBr W.



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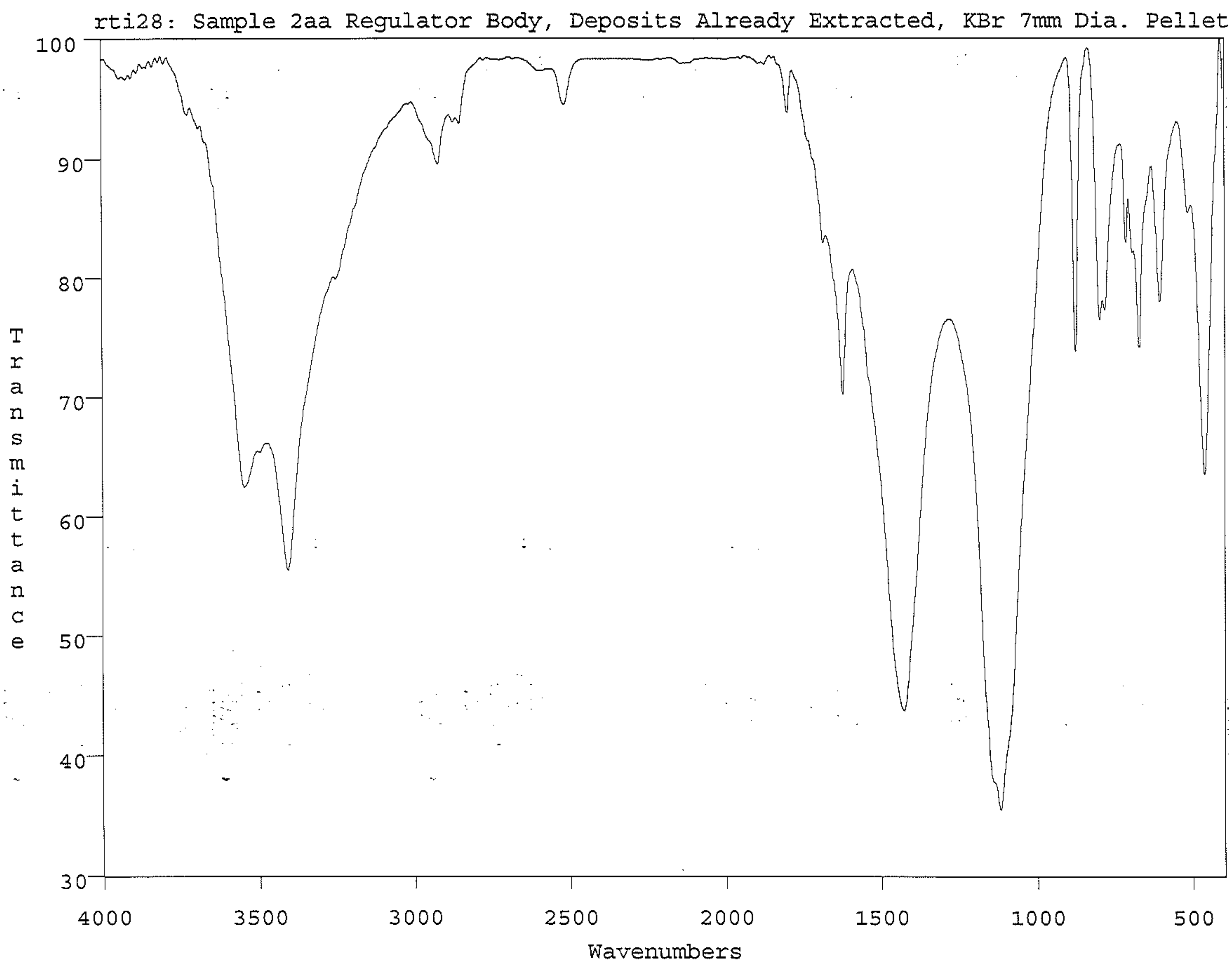

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rti28: Sample 2aa, Regulator Body, Deposits Already Extracted, KBr 7mm Dia. Pellet

Peak Pick

cm-1	Intensity
461.016	63.526
513.097	85.530
603.758	78.020
669.341	74.244
711.778	82.990
779.291	77.341
796.651	76.518
873.809	73.853
1116.855	35.481
1425.485	43.766
1622.237	70.243
1683.963	82.970
1797.770	93.845
2235.639	98.212
2513.406	94.536
2920.412	89.589
3248.331	79.940
3406.504	55.517
3495.235	65.438
3499.093	65.446
3545.388	62.429

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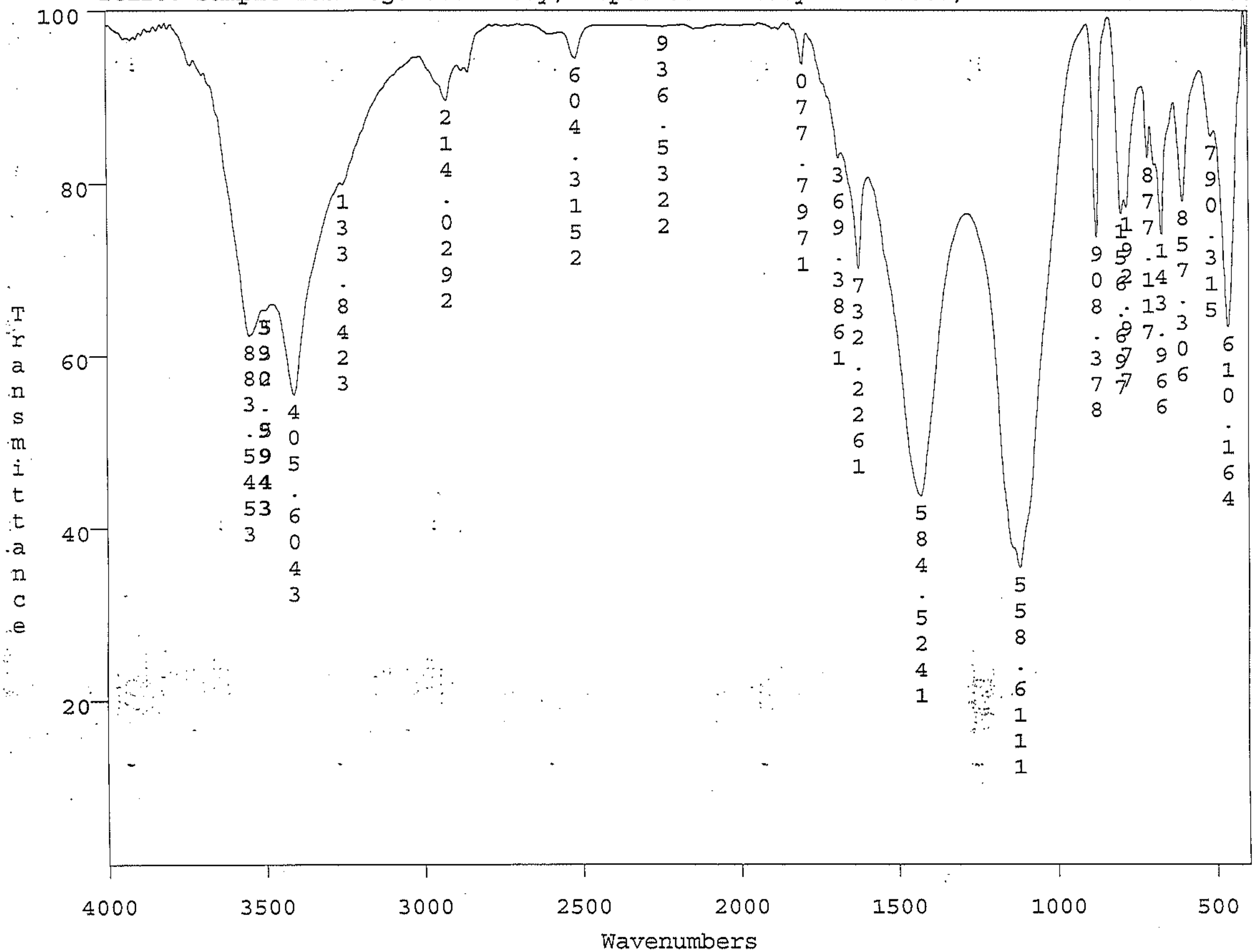
rti28: Sample 2aa Regulator Body, Deposits Already Extracted, KBr 7mm Dia. Pellet



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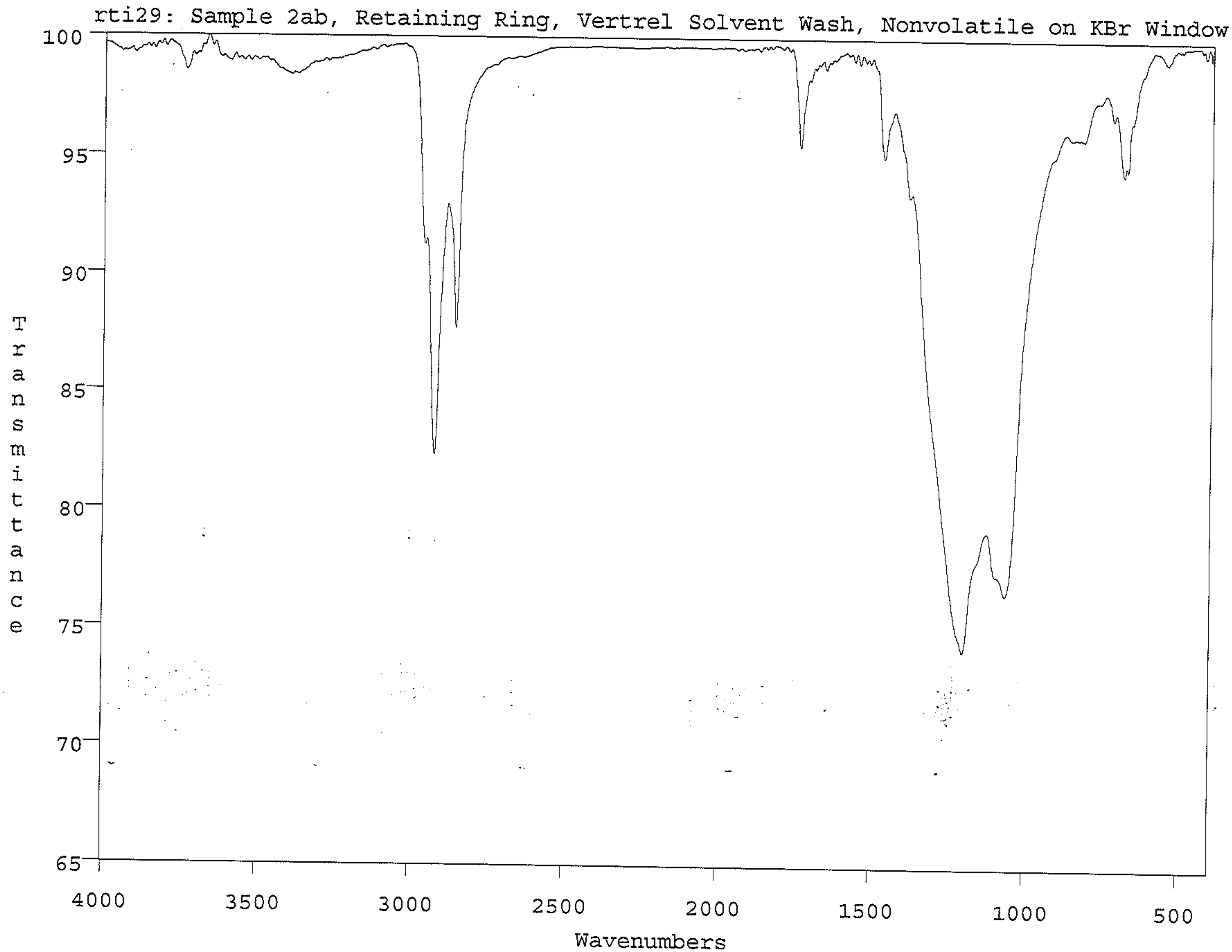

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rti29: Sample 2ab, Retaining Ring, Vertrel Solvent Wash, Nonvolatile on KBr Window

Peak Pick

cm-1	Intensity
545.889	99.122
682.844	94.381
717.565	96.737
814.012	95.855
833.301	95.920
850.662	95.897
1060.916	76.535
1093.708	77.338
1197.870	74.131
1377.262	93.386
1462.135	95.041
1736.044	95.463
2235.639	99.589
2850.970	87.683
2918.483	82.325
2953.204	91.288
3734.423	98.547

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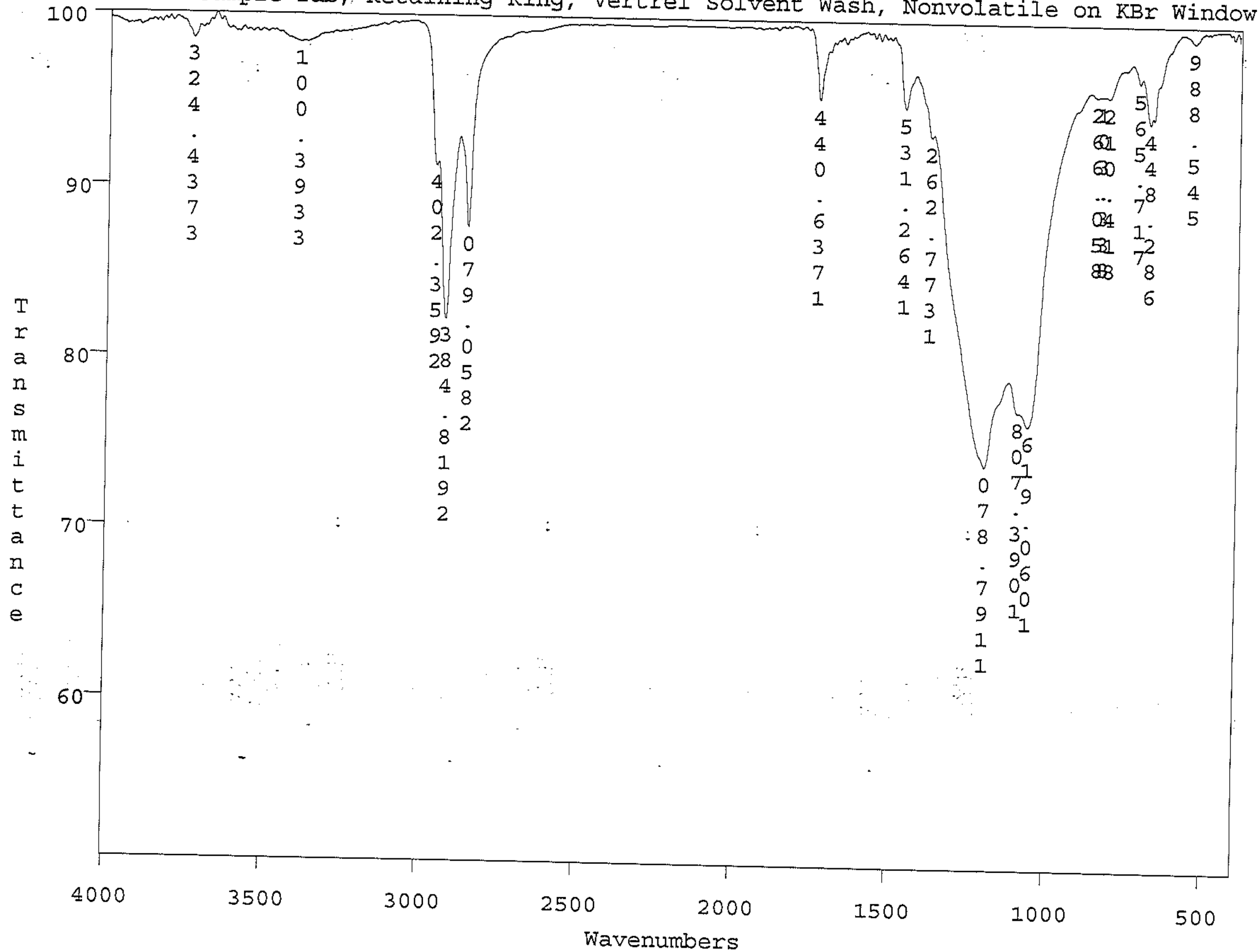
rti29: Sample 2ab, Retaining Ring, Vertrel Solvent Wash, Nonvolatile on KBr Window



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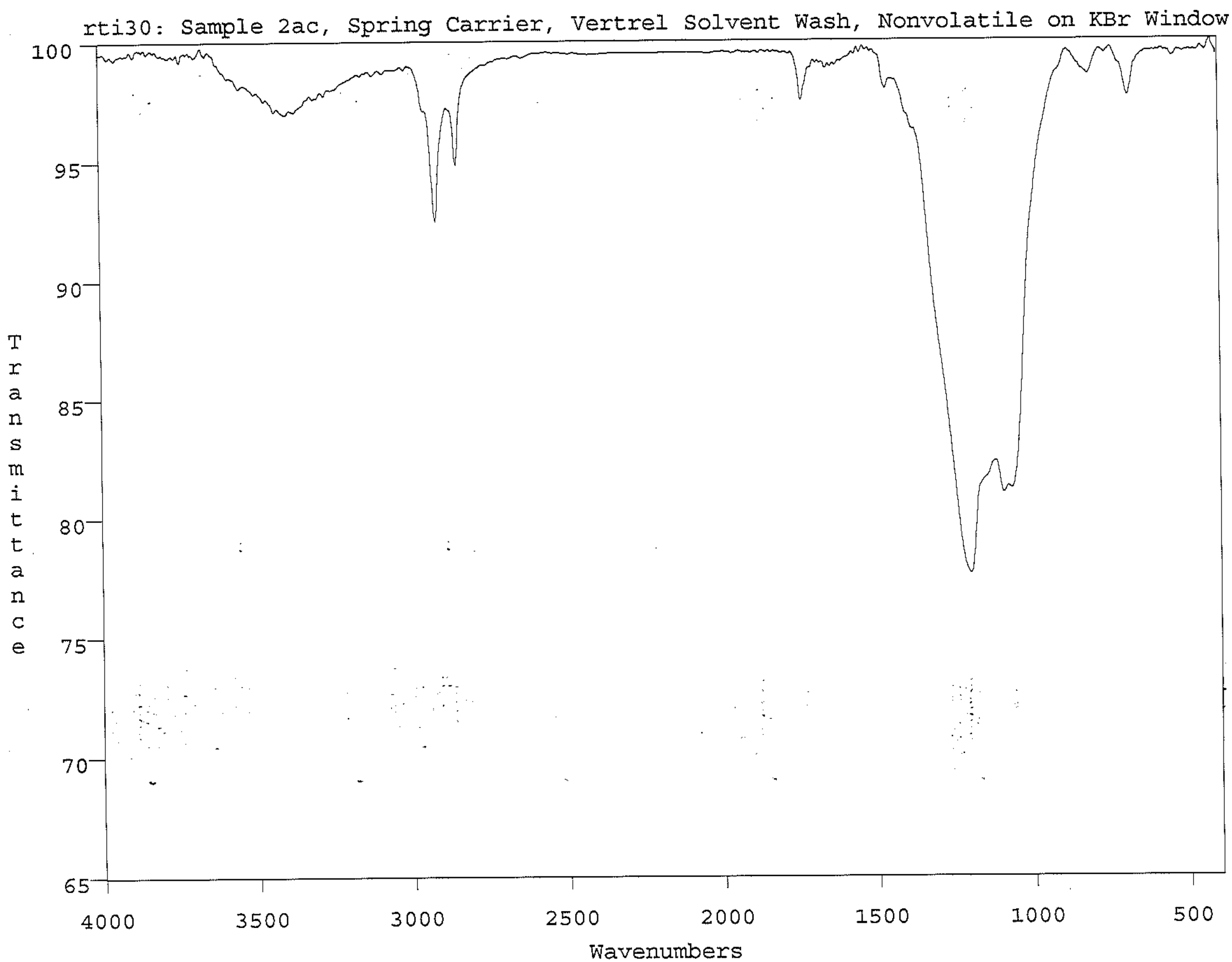

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Rti30: Sample 2ac, Spring Carrier, Vertrel Solvent Wash, Nonvolatile on KBr Window

Peak Pick

cm-1	Intensity
684.773	97.660
814.012	98.556
1068.632	81.201
1093.708	81.014
1201.728	77.625
1462.135	97.971
1736.044	97.500
2197.060	99.503
2849.041	94.870
2916.554	92.490
3271.478	97.757
3367.925	97.079
3396.859	96.975
3433.509	97.086
3545.388	98.080

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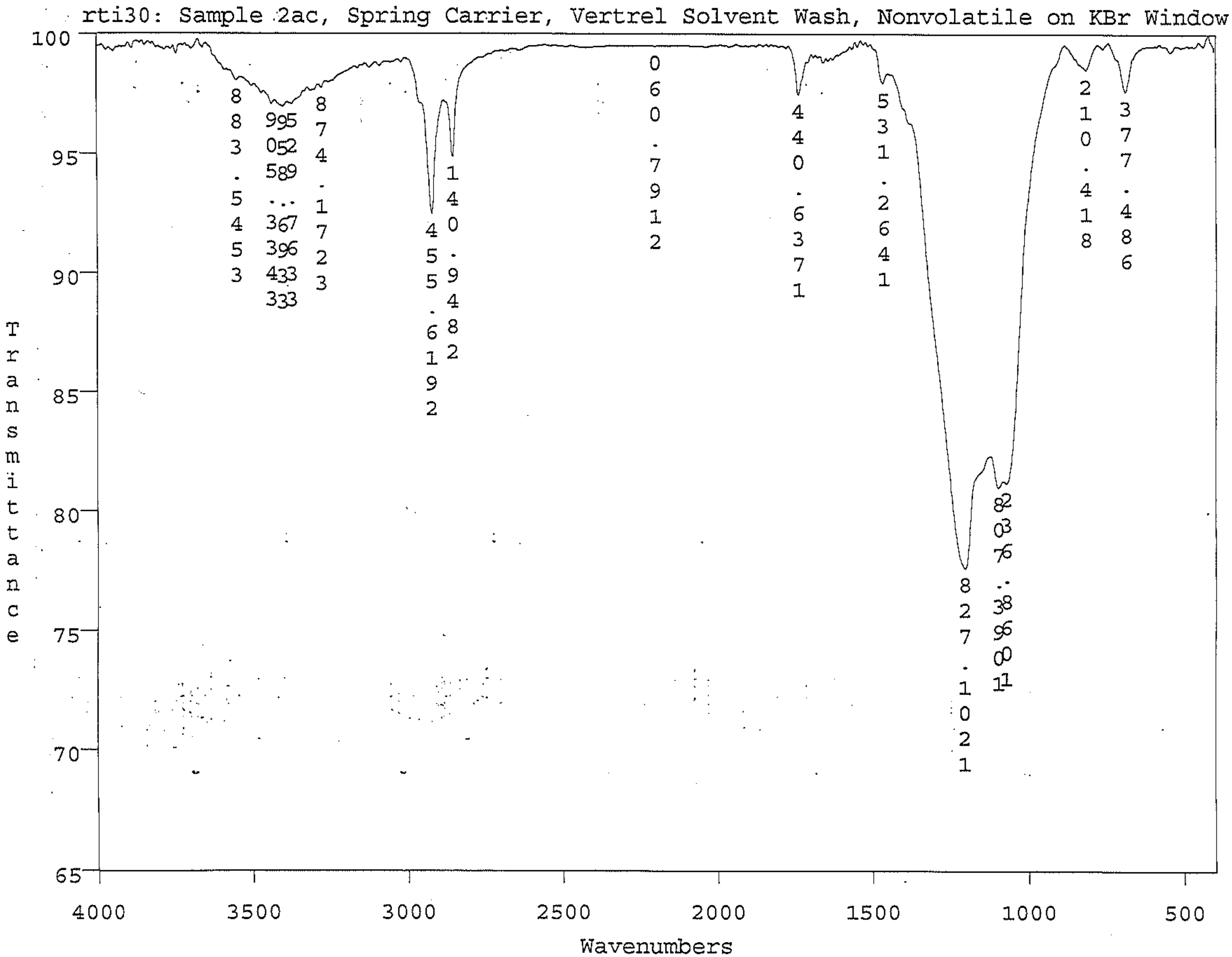

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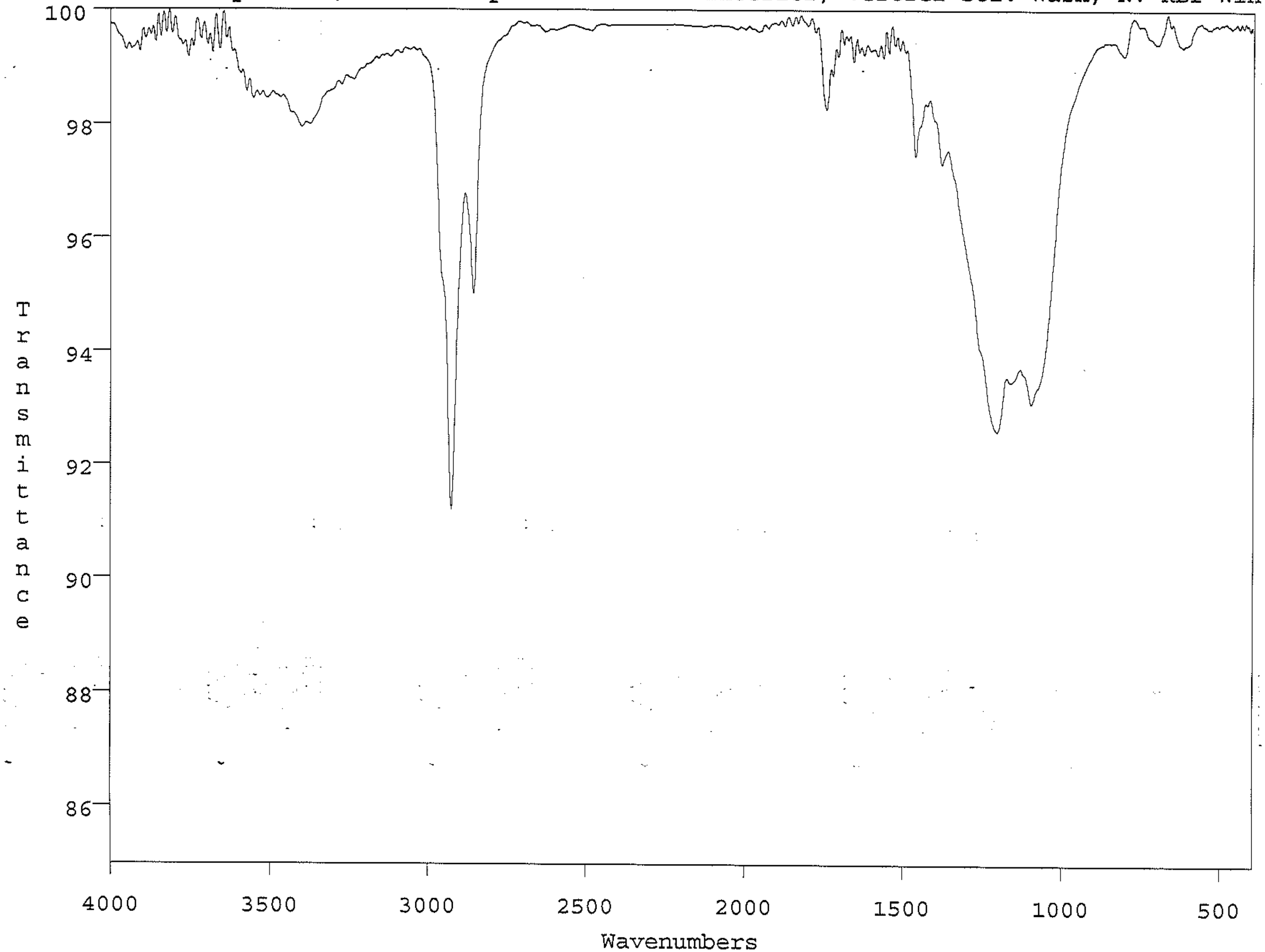
rti34: Sample 2ad, Metal Diaphram Retainer Interior, Vertrel Sol. Wash, NV KBr Win.



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rti34: Sample 2ad, Metal Diaphram Retainer Inserior, Vertrel Sol. Wash, NV KBr Win.

Peak Pick

cm-1	Intensity
696.347	99.427
804.367	99.222
1095.637	93.099
1161.221	93.472
1203.657	92.607
1377.262	97.311
1460.206	97.450
1741.831	98.270
2430.462	99.727
2854.828	95.020
2924.270	91.201
3232.900	98.787
3271.478	98.693
3371.783	97.998
3396.859	97.951
3466.301	98.463
3506.809	98.455
3549.245	98.450
3570.464	98.568
3657.266	99.313

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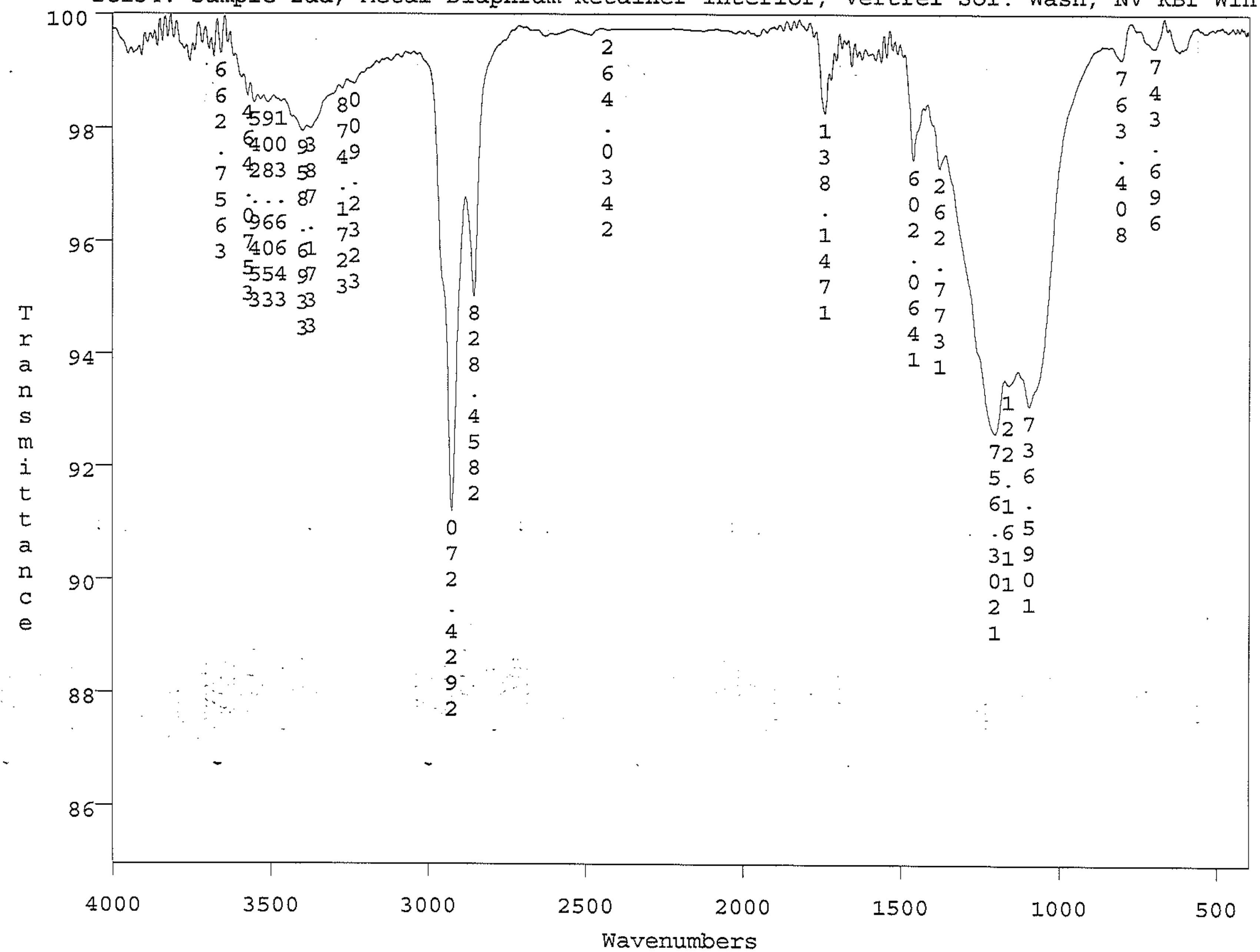
rti34: Sample 2ad, Metal Diaphram Retainer Interior, Vertrel Sol. Wash, NV KBr Win.



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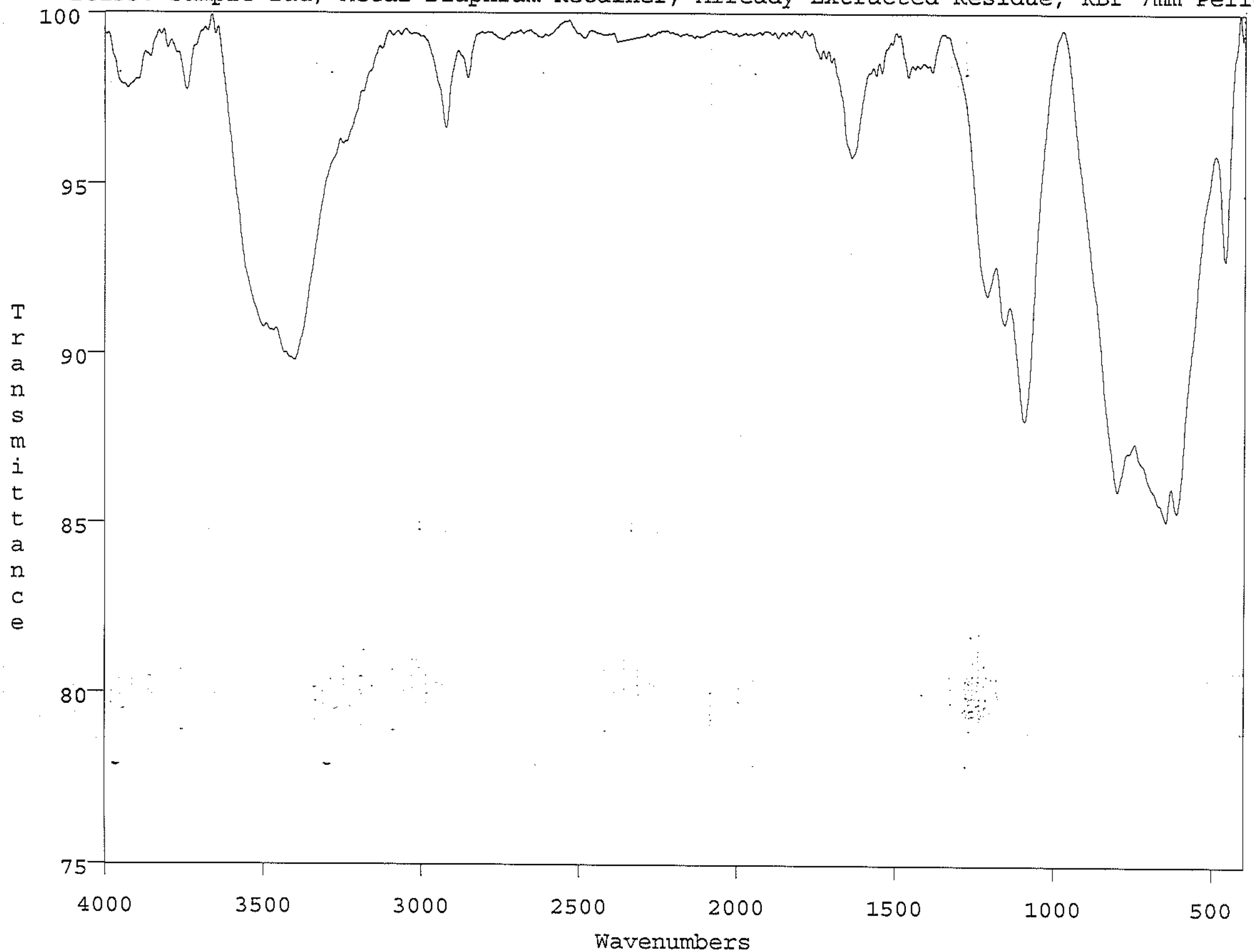
rti35: Sample 2ad, Metal Diaphram Retainer, Already Extracted Residue, KBr 7mm Pellet



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rti35: Sample 2ad, Metal Diaphram Retainer, Already Extracted Residue, KBr 7mm Pellet

Peak Pick

cm-1	Intensity
459.087	92.809
611.473	85.362
644.265	85.114
667.412	85.603
761.930	87.125
796.651	85.995
1091.779	88.051
1155.434	90.919
1209.444	91.755
1460.206	98.182
1637.668	95.821
2382.238	99.177
2852.899	98.124
2922.341	96.654
3248.331	96.189
3400.717	89.806
3414.220	89.878
3433.509	90.020
3466.301	90.670
3477.875	90.690
3499.093	90.778
3740.210	97.771
3927.317	97.818

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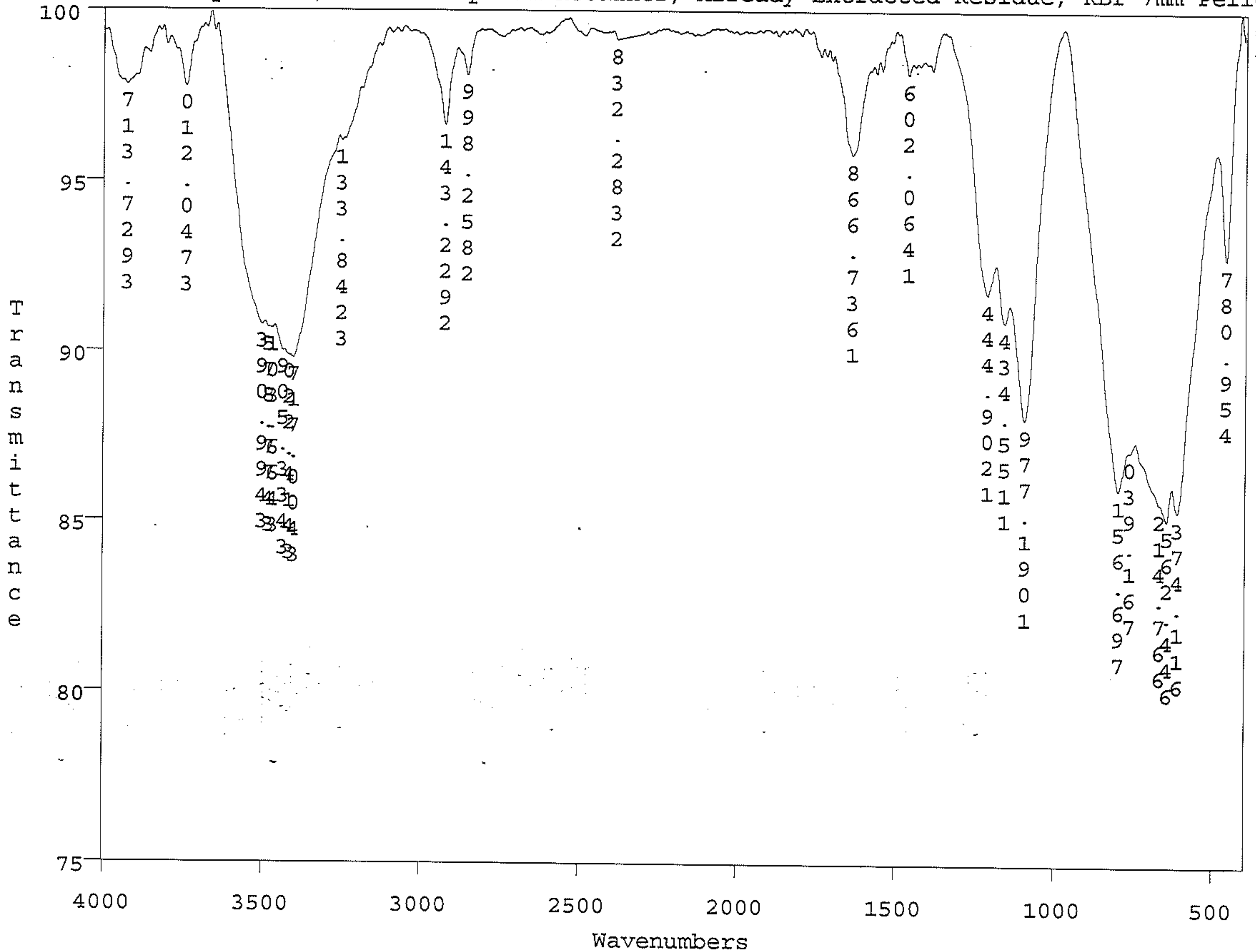
rti35: Sample 2ad, Metal Diaphram Retainer, Already Extracted Residue, KBr 7mm Pellet



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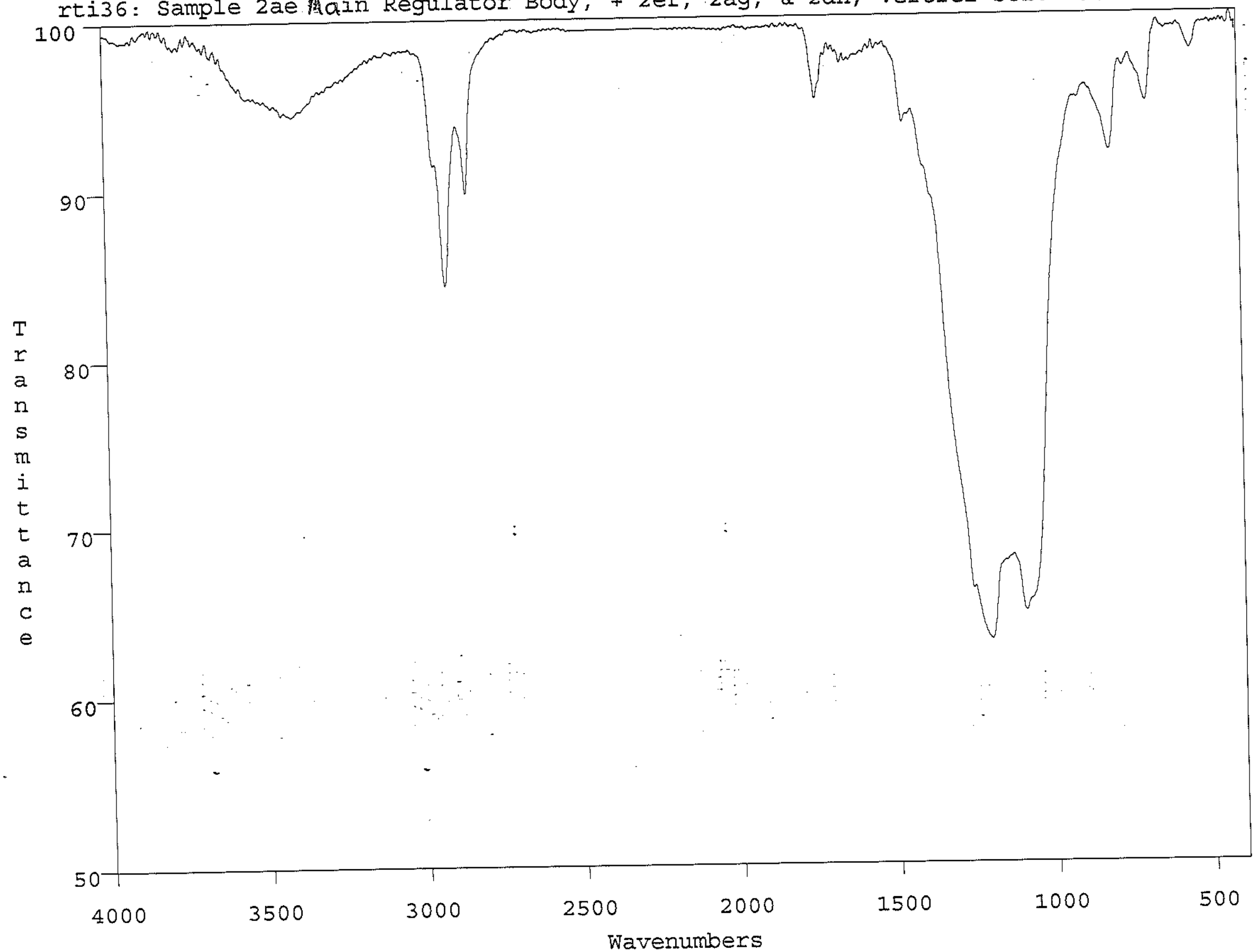
rti36: Sample 2ae Main Regulator Body, + 2ef, 2ag, & 2ah, Vertrel Sol. Wash NV KBr Win



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rti36: Sample 2ae, Main Regulator Body, + 2ef, 2ag, & 2ah, Vertrel Sol. Wash NV KBr Win

Peak Pick

cm-1	Intensity
545.889	97.827
688.631	94.798
808.225	91.938
1091.779	64.741
1151.576	67.699
1201.728	63.096
1257.667	66.077
1462.135	93.694
1737.973	95.146
2521.122	99.299
2852.899	89.780
2922.341	84.327
3400.717	94.414

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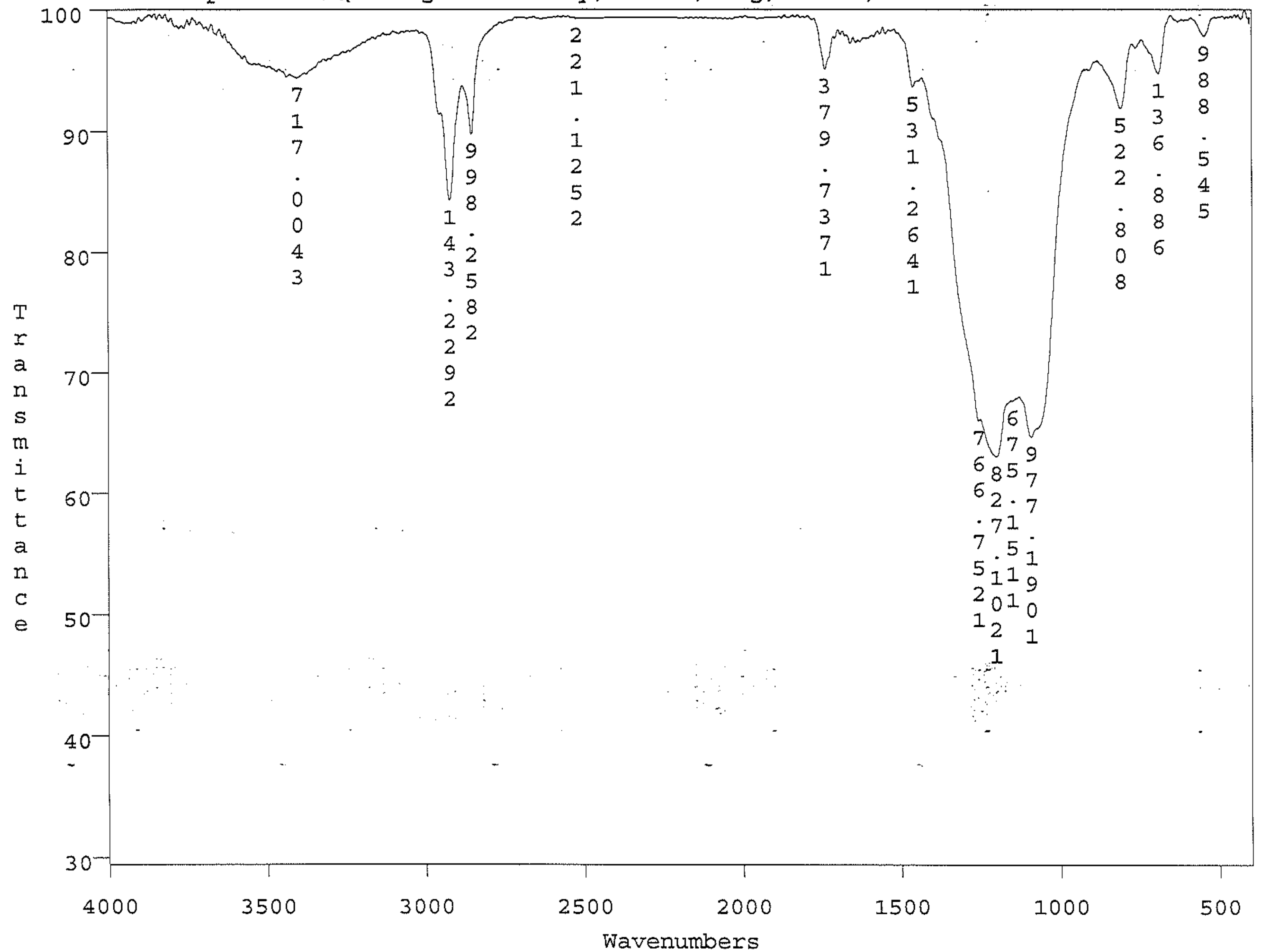
rti36: Sample 2ae Main Regulator Body, + 2ef, 2ag, & 2ah, Vertrel Sol. Wash NV KBr Win



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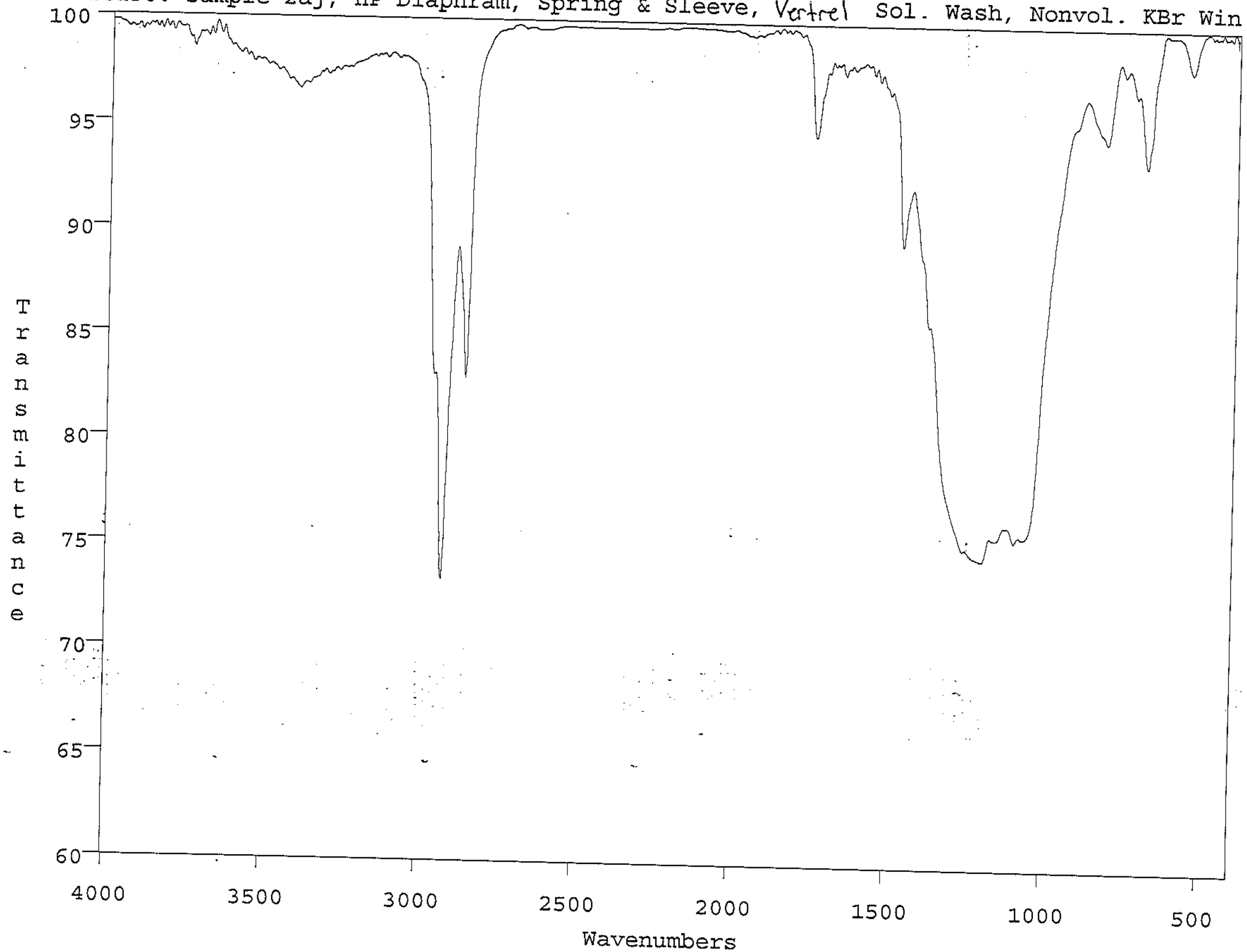
rti38: Sample 2aj, HP Diaphram, Spring & Sleeve, Vertrel Sol. Wash, Nonvol. KBr Win.



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rti38: Sample 2aj, HP Diaphram Spring & Sleeve, Vertrel So. Wash, Nonvol.KBr Win.

Peak Pick

cm-1	Intensity
543.960	98.031
684.773	93.521
814.012	94.619
1068.632	75.719
1095.637	75.548
1120.713	76.233
1151.576	75.640
1163.149	75.643
1197.870	74.613
1259.596	75.111
1375.333	85.745
1460.206	89.564
1743.760	94.687
2854.828	82.940
2924.270	73.282
2953.204	83.106
3396.859	96.628

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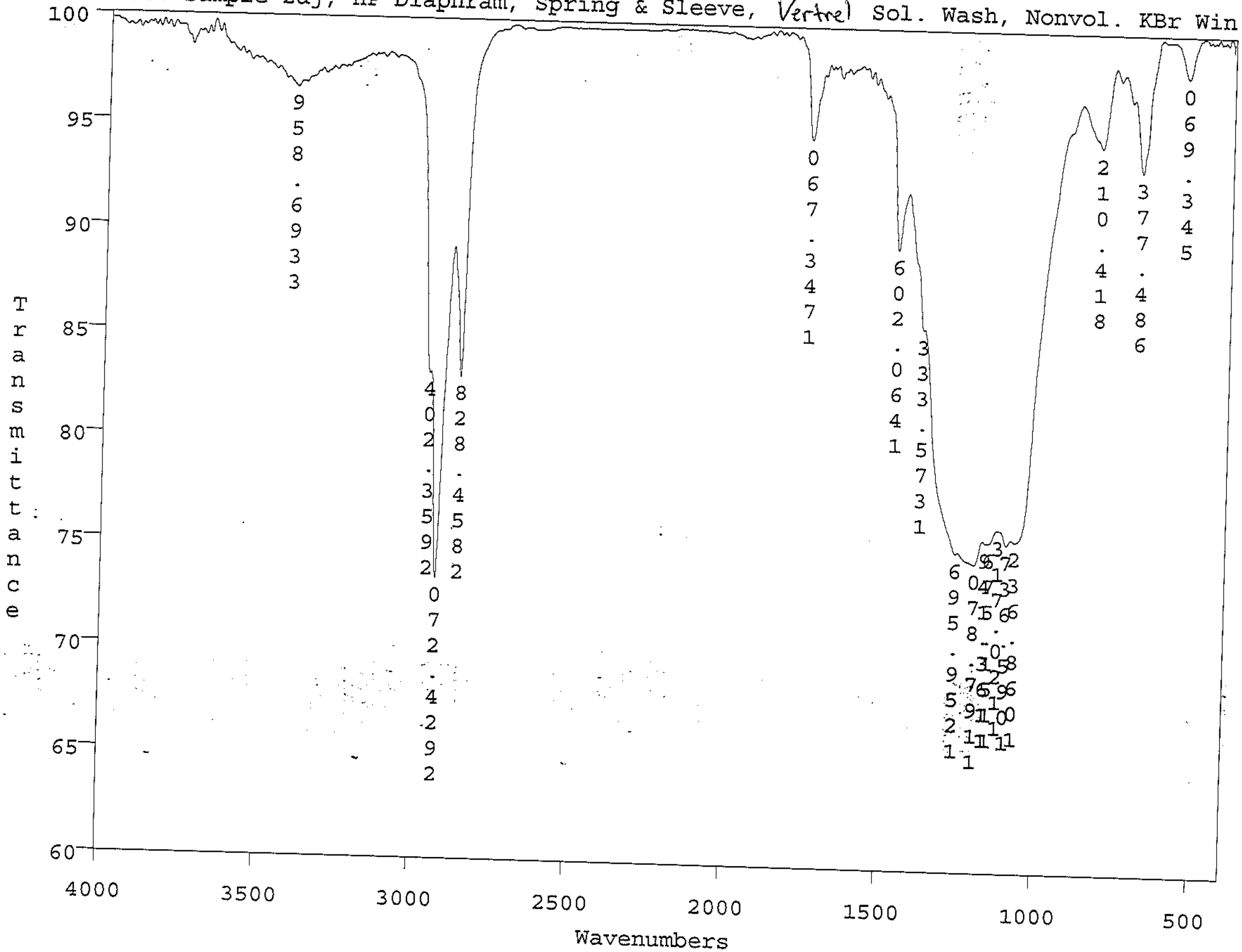
rti38: Sample 2aj, HP Diaphram, Spring & Sleeve, Vertrel Sol. Wash, Nonvol. KBr Win.



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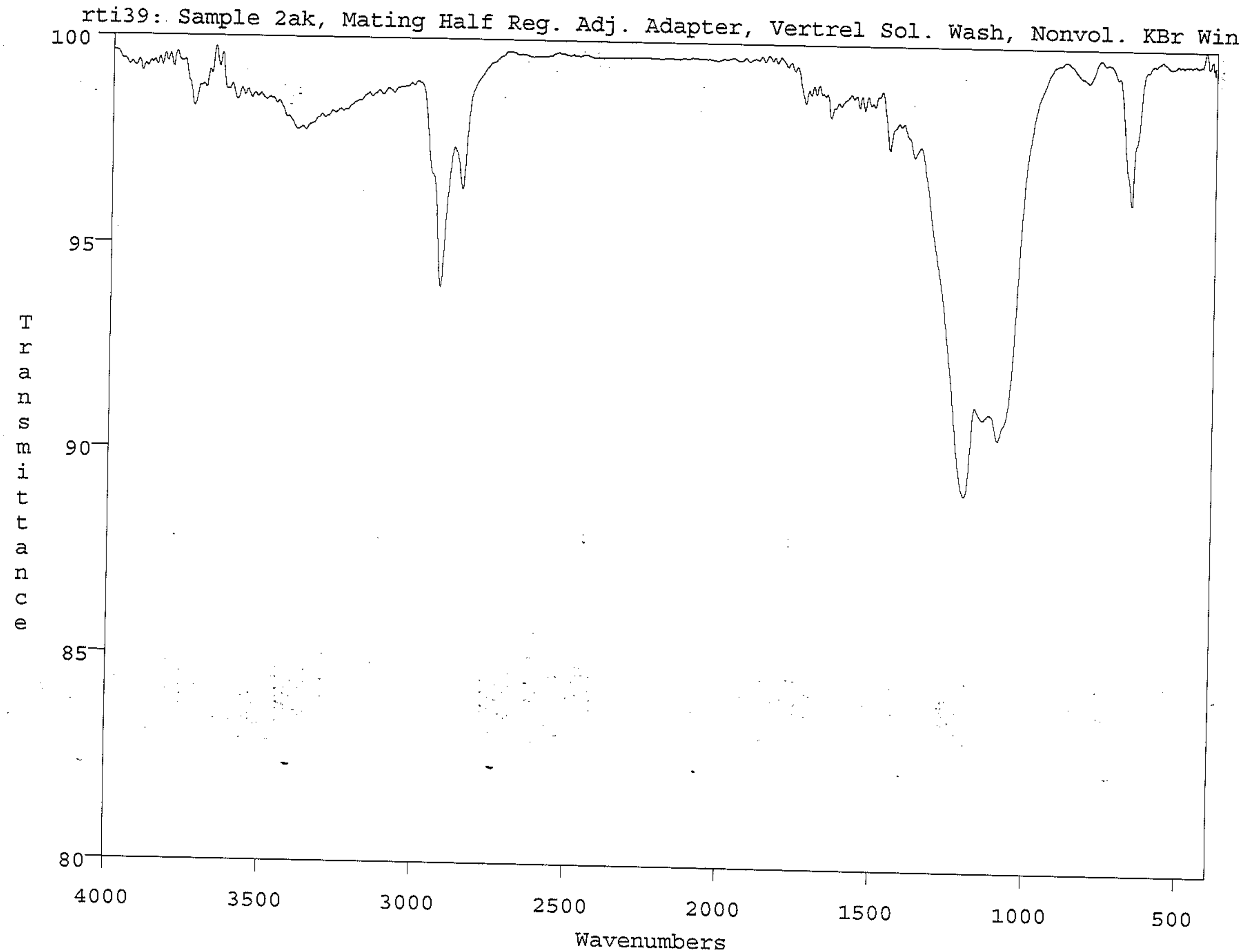

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rti39: Sample 2ak, Mating Half Reg. Adj. Adapter, Vertrel Sol. Wash, Nonvol. KBr Win.

Peak Pick

cm-1	Intensity
669.341	96.284
812.083	99.212
1095.637	90.485
1145.789	90.975
1201.728	89.125
1377.262	97.347
1421.627	98.080
1458.277	97.511
1543.150	98.450
1653.100	98.255
1737.973	98.595
2434.319	99.611
2852.899	96.376
2922.341	93.989
3082.442	98.687
3117.163	98.644
3248.331	98.239
3273.407	98.184
3308.128	98.067
3369.854	97.764
3396.859	97.776
3595.540	98.477
3734.423	98.307

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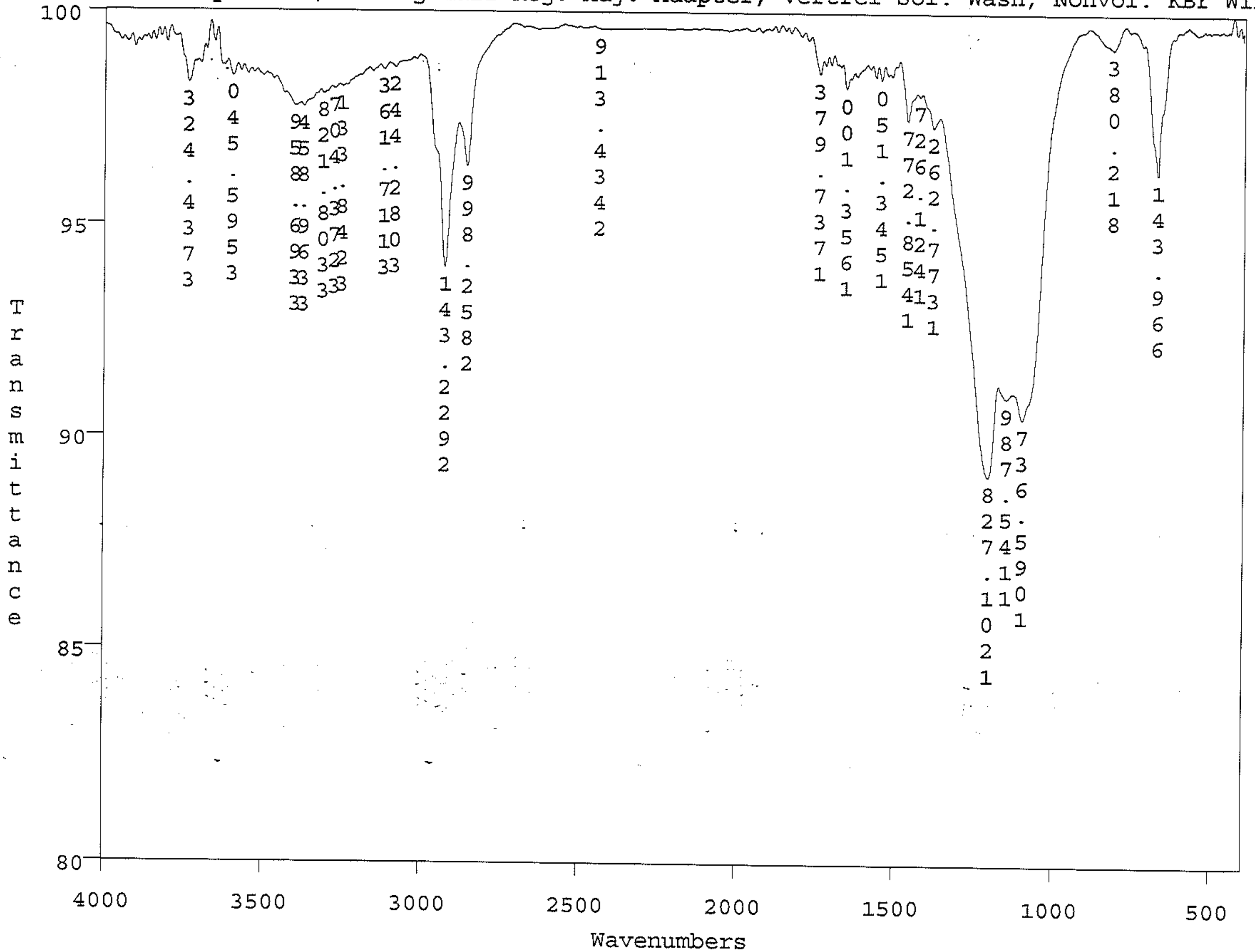
rti39: Sample 2ak, Mating Half Reg. Adj. Adapter, Vertrel Sol. Wash, Nonvol. KBr Win.



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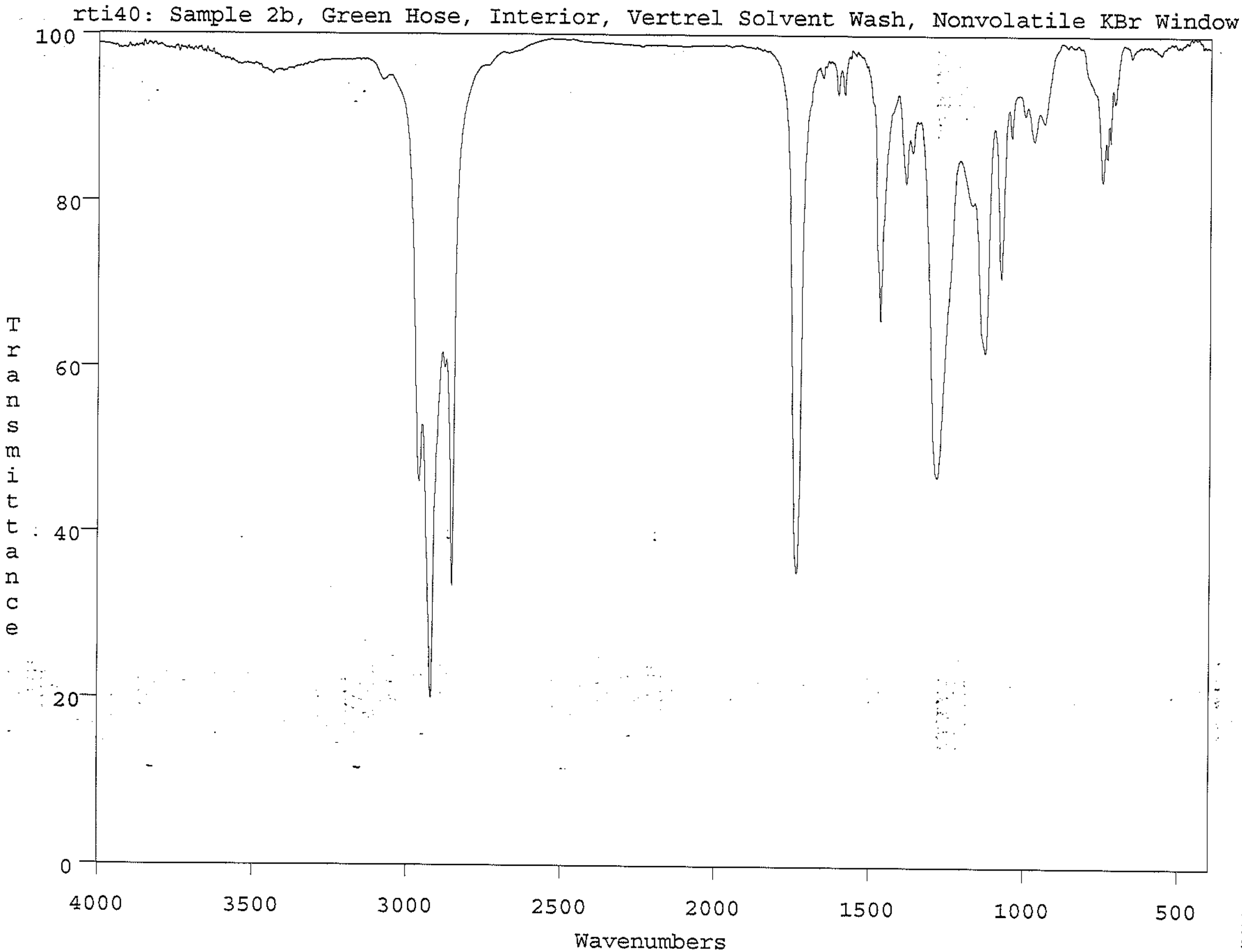

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rti40: Sample 2b, Green House, Vertrel Solvent Wash, Nonvolatile KBr Window

Peak Pick

cm-1	Intensity
729.138	85.525
744.570	82.613
933.606	89.677
966.398	87.583
1039.697	87.862
1072.489	70.997
1124.571	61.880
1165.078	79.807
1278.886	46.841
1359.901	86.092
1381.119	82.351
1464.064	65.823
1579.800	92.981
1601.018	93.018
1732.186	35.242
2849.041	33.452
2874.117	59.904
2918.483	19.953
2957.062	46.042
3078.585	94.566

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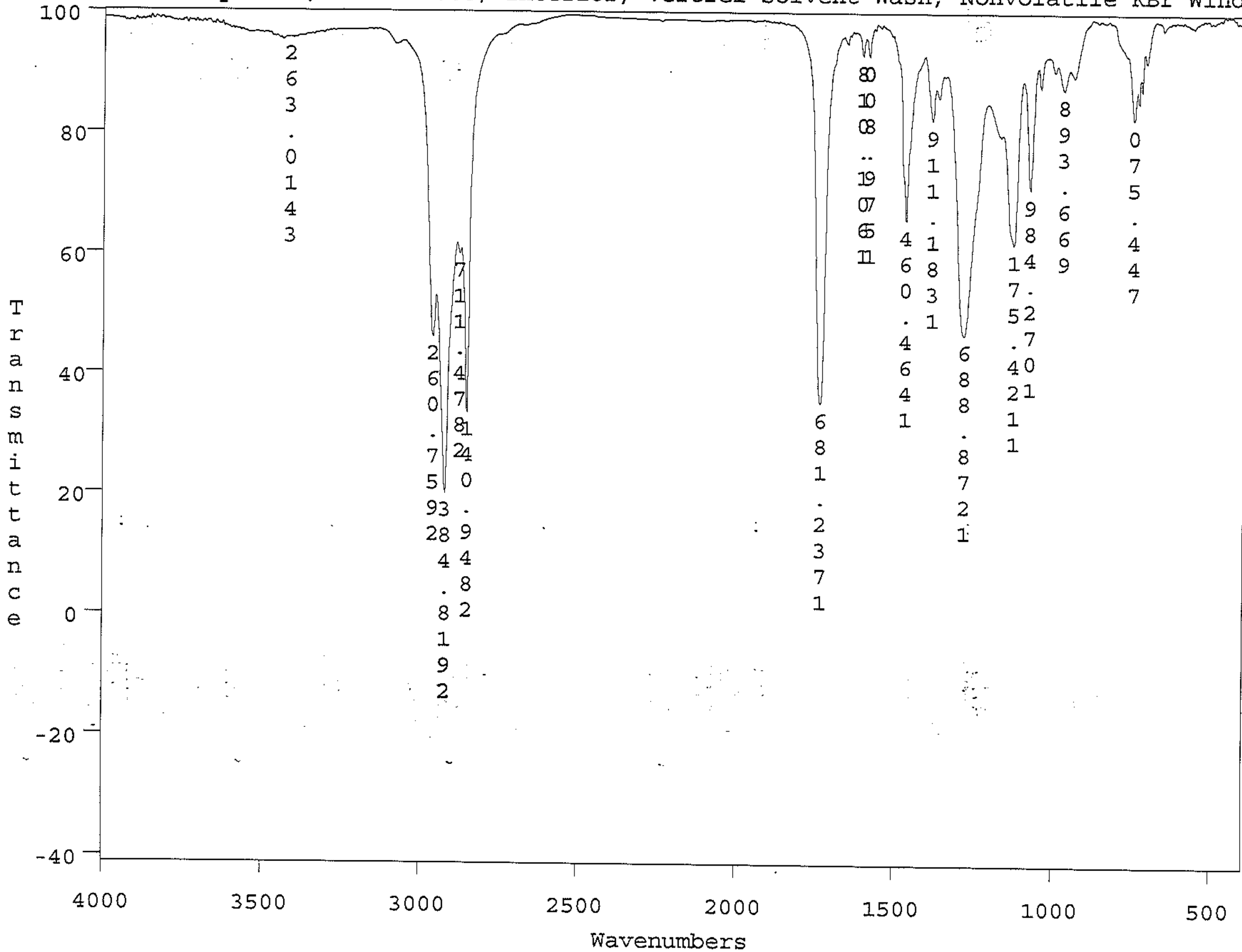
rti40: Sample 2b, Green Hose, Interior, Vertrel Solvent Wash, Nonvolatile KBr Window



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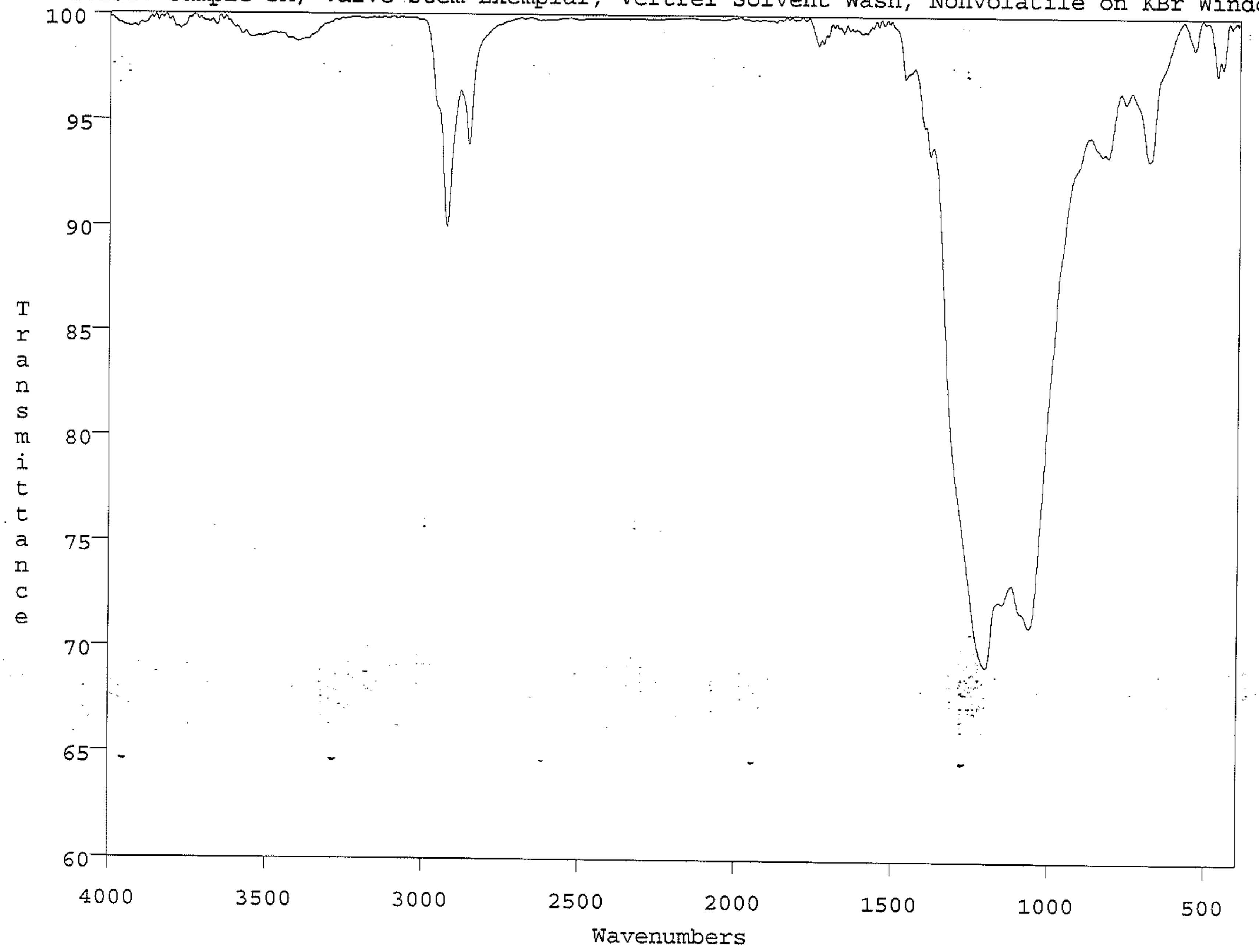
rti31: Sample 3A, Valve Stem Exemplar, Vertrel Solvent Wash, Nonvolatile on KBr Window



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rti31: Sample 3A, Valve Stem Exemplar, Vertrel Solvent Wash, Nonvolatile on KBr Window

Peak Pick

cm-1	Intensity
451.371	97.659
466.803	97.327
540.103	98.577
682.844	93.309
758.073	95.996
814.012	93.469
833.301	93.542
1060.916	71.068
1147.718	72.184
1197.870	69.183
1381.119	93.498
1400.409	94.825
1462.135	97.115
2852.899	93.863
2922.341	89.955
3400.717	98.720

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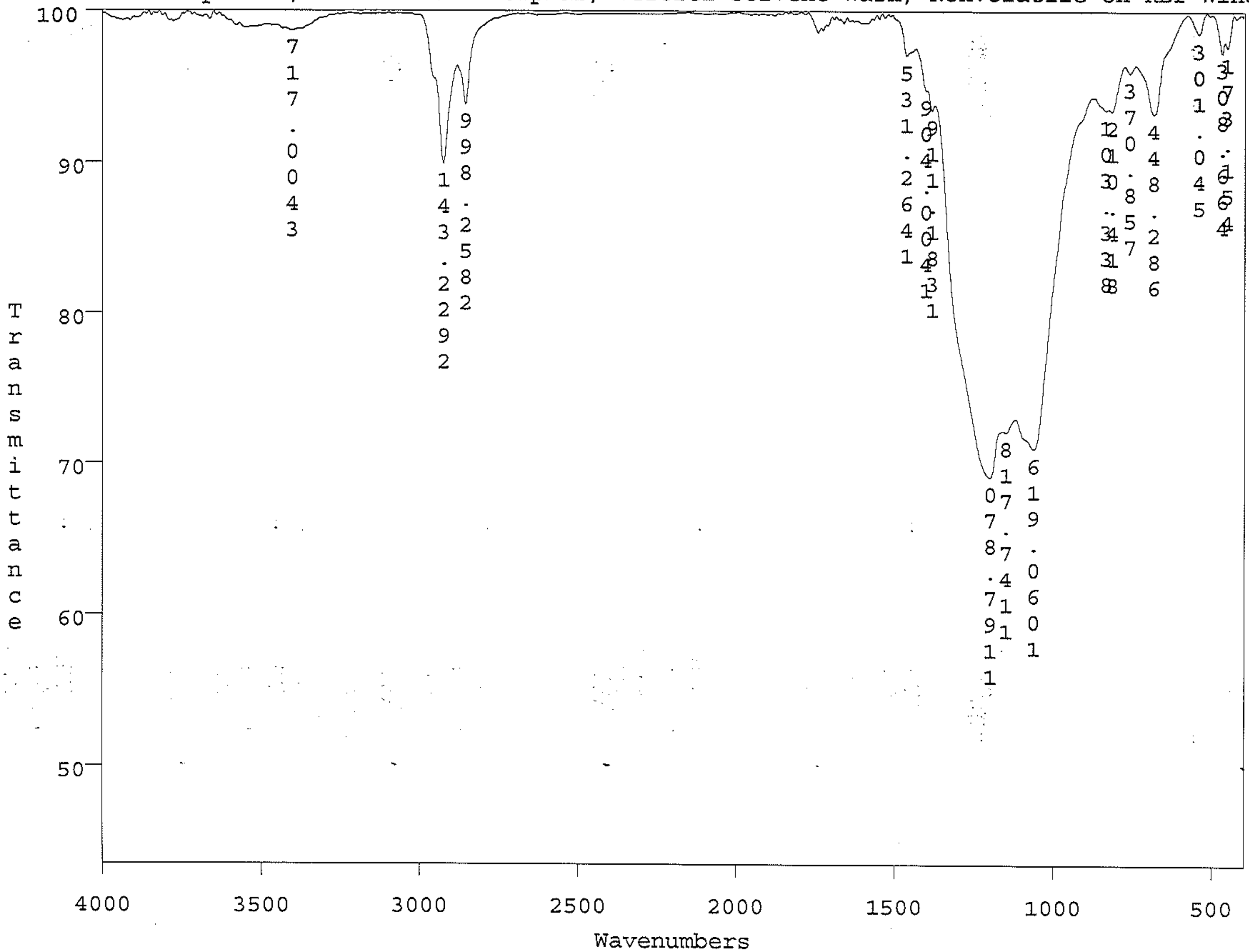
rti31: Sample 3A, Valve Stem Exemplar, Vertrel Solvent Wash, Nonvolatile on KBr Window



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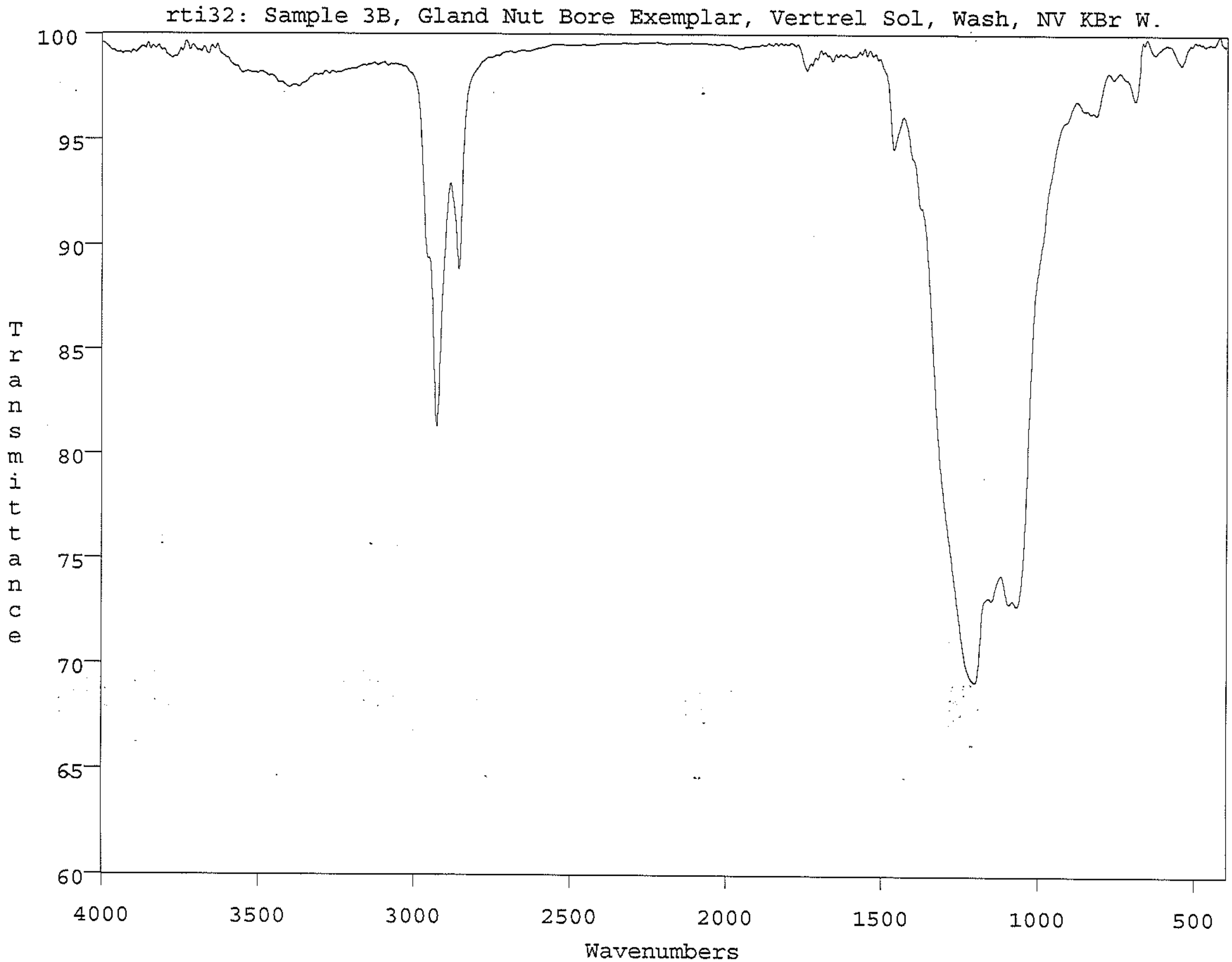

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rti32: Sample 3B, Gland Nut Bore Exemplar, Vertrel Sol. Wash, NV KBr W.

Peak Pick

cm-1	Intensity
543.960	98.639
624.976	99.142
690.560	96.959
758.073	97.952
814.012	96.246
1068.632	72.812
1091.779	72.922
1147.718	73.085
1201.728	69.183
1462.135	94.589
2854.828	88.836
2924.270	81.294
2953.204	89.372
3367.925	97.504
3398.788	97.493

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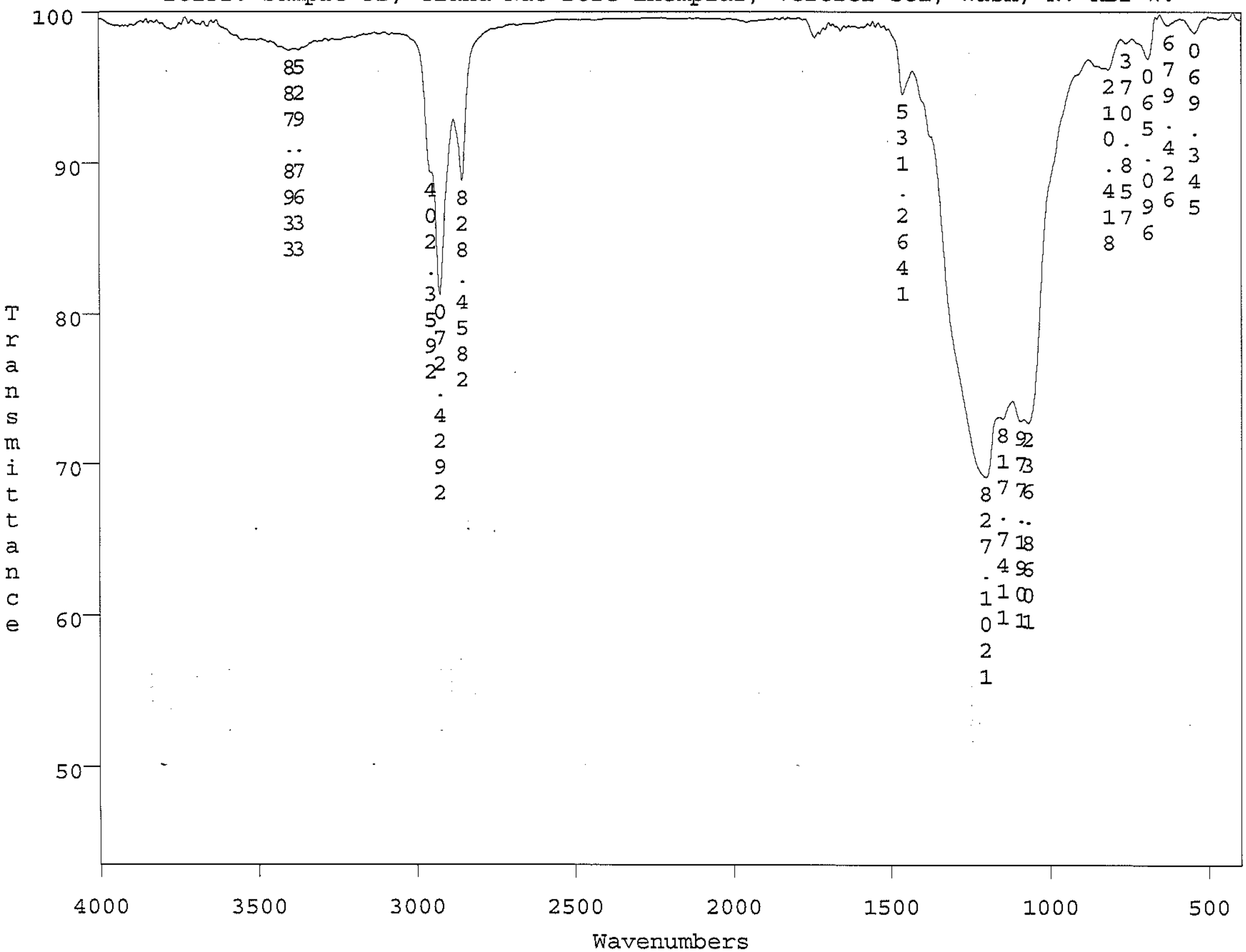
rti32: Sample 3B, Gland Nut Bore Exemplar, Vertrel Sol, Wash, NV KBr W.



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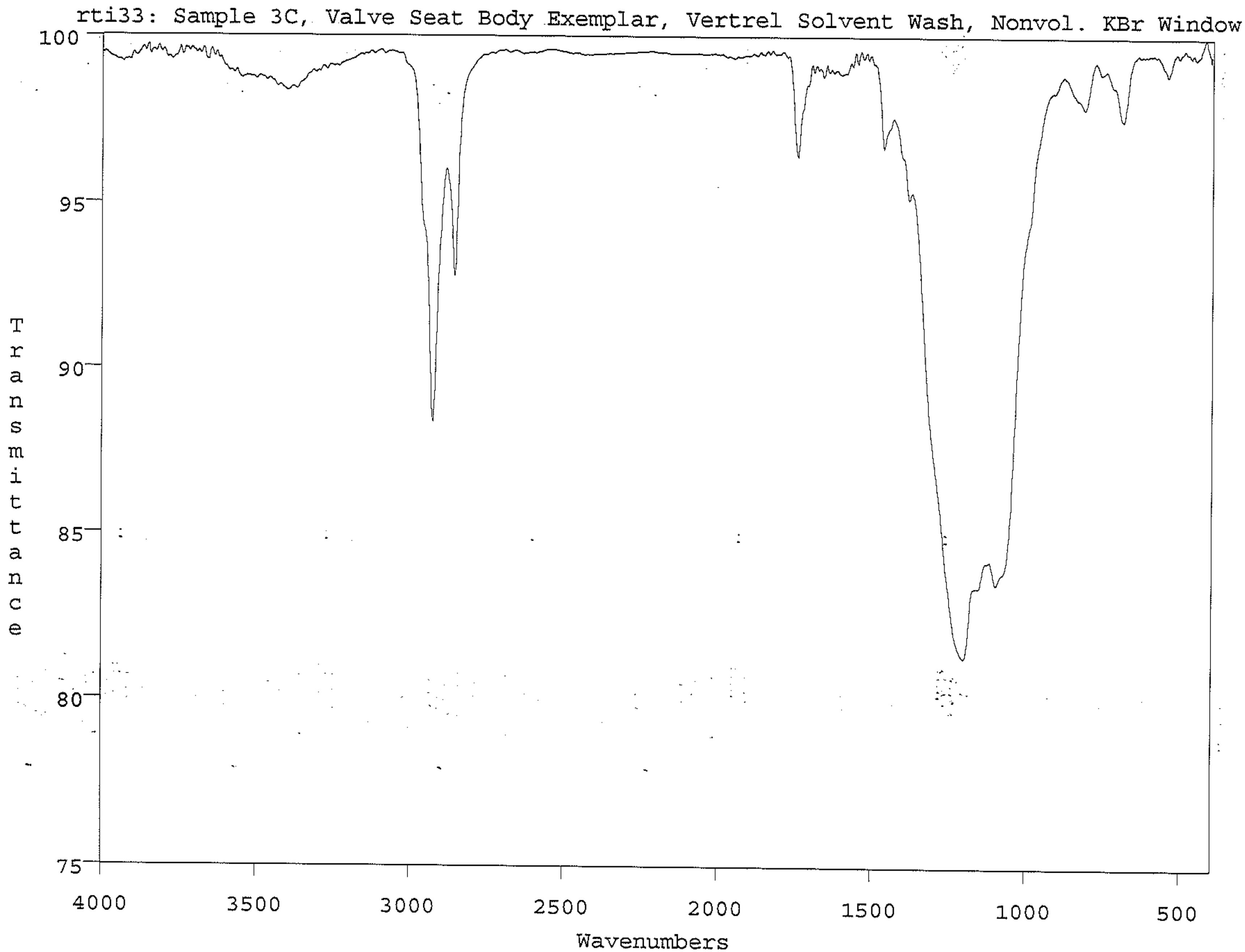

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rti33 Sample 3C, Valve Seat Body Exemplar, Vertrel Solvent Wash, Nonvol. KBr Window

Peak Pick

cm-1	Intensity
542.032	98.881
686.702	97.533
758.073	98.928
812.083	97.886
1095.637	83.494
1124.571	84.158
1153.505	83.394
1199.799	81.283
1379.190	95.147
1462.135	96.675
1741.831	96.429
2854.828	92.791
2924.270	88.342
3367.925	98.421
3398.788	98.362
3501.022	98.706

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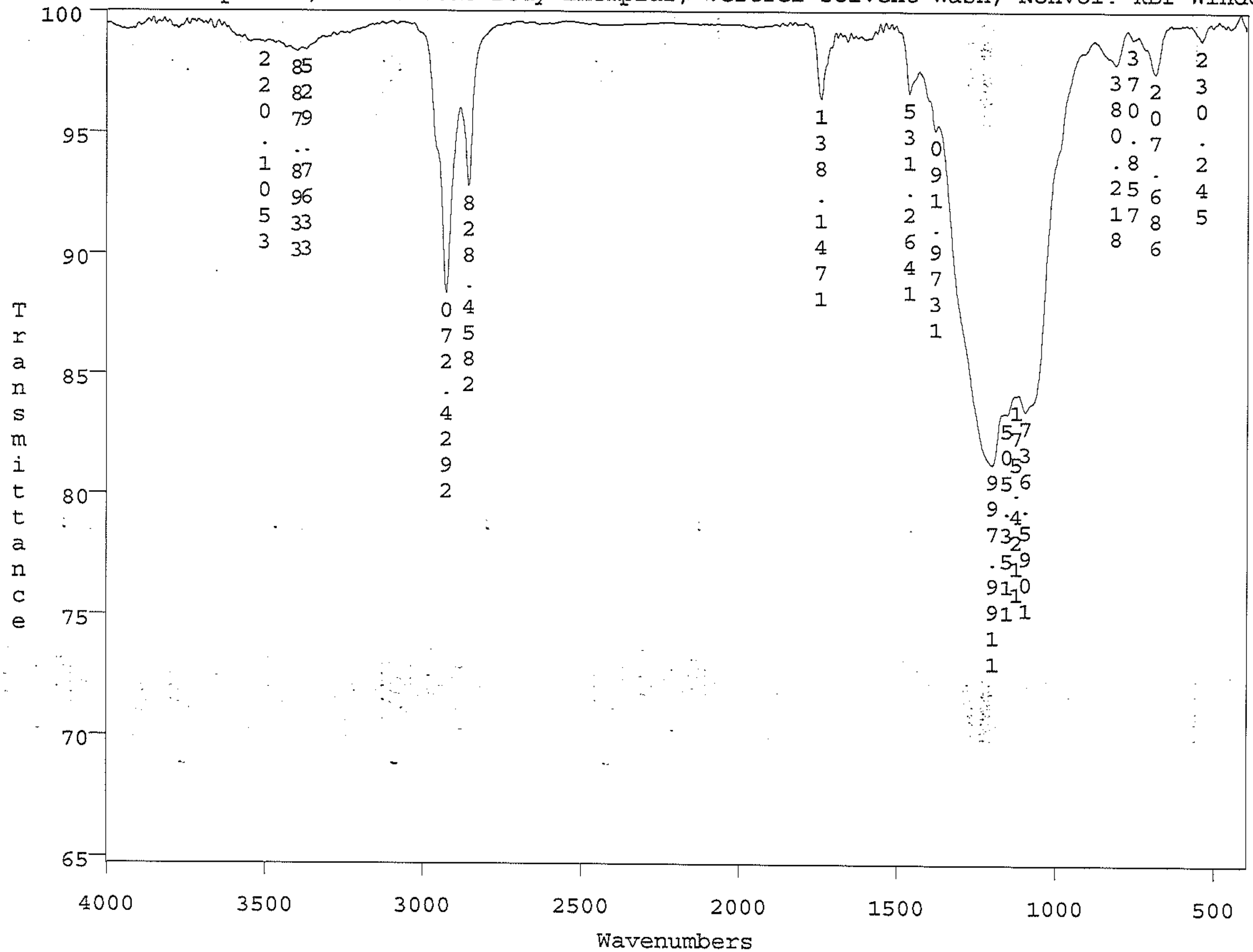
rti33: Sample 3C, Valve Seat Body Exemplar, Vertrel Solvent Wash, Nonvol. KBr Window



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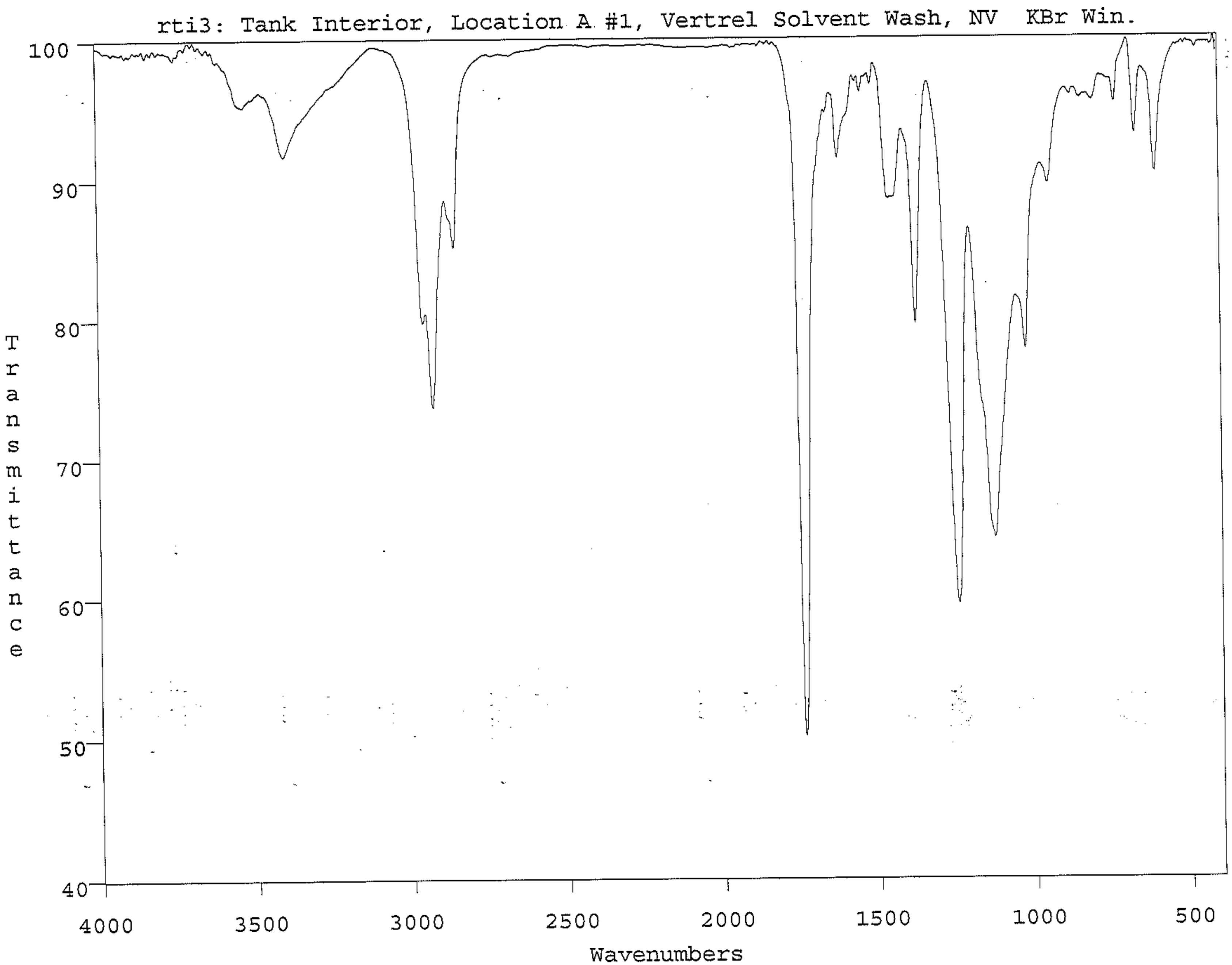

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rti3: Tank Interior, Location A #1, Vertrel Solvent Wash, NV KBr Win.

Peak Pick

cm-1	Intensity
601.829	90.418
665.484	93.168
731.067	95.388
802.438	95.529
841.017	95.698
873.809	95.923
947.108	89.608
1022.337	77.777
1124.571	64.231
1240.307	59.544
1373.404	79.607
1440.916	88.656
1448.632	88.620
1456.348	88.560
1545.079	96.138
1620.308	91.486
1736.044	50.119
2854.828	85.217
2926.199	73.687
2957.062	79.725
3396.859	91.737
3528.027	95.267

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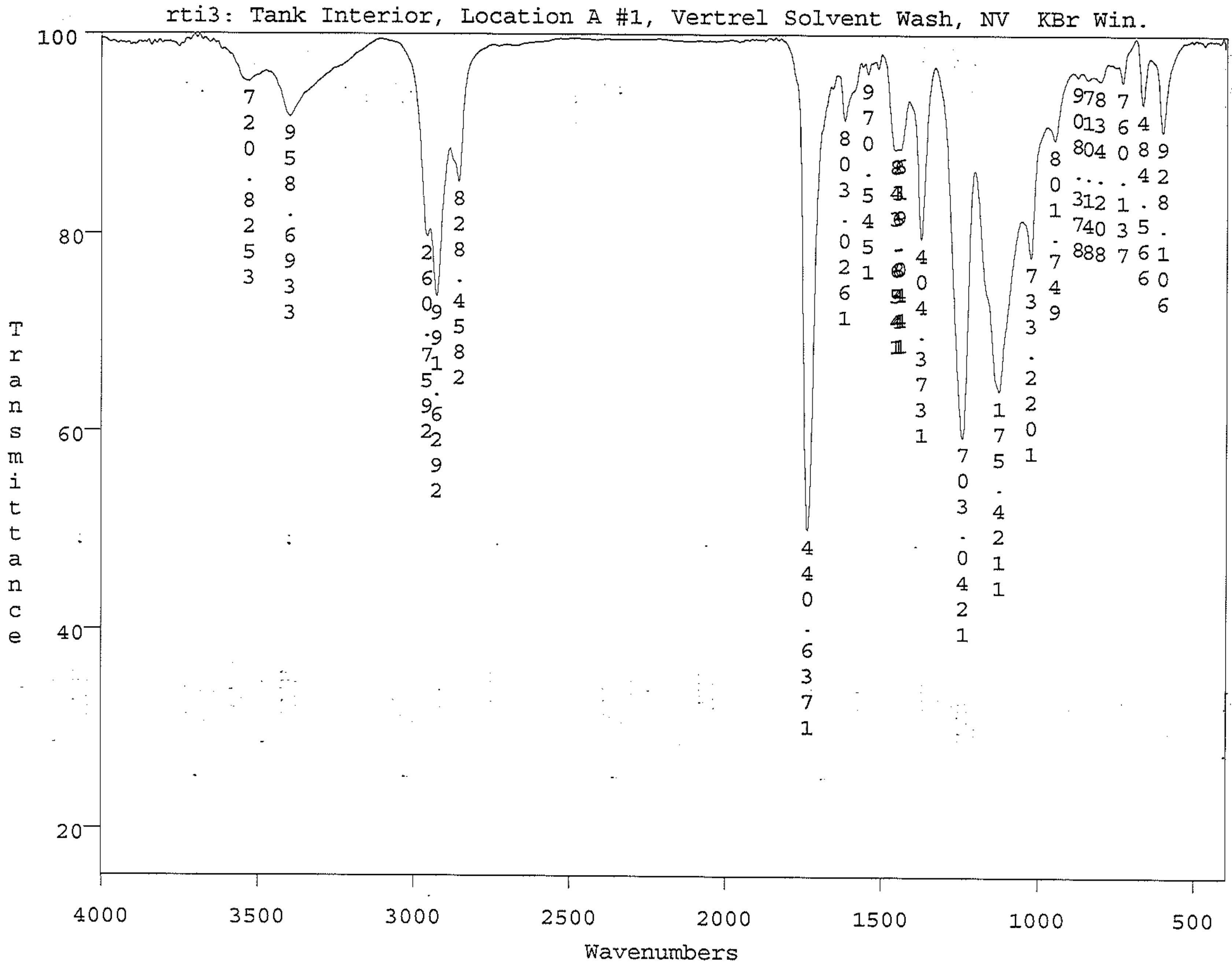

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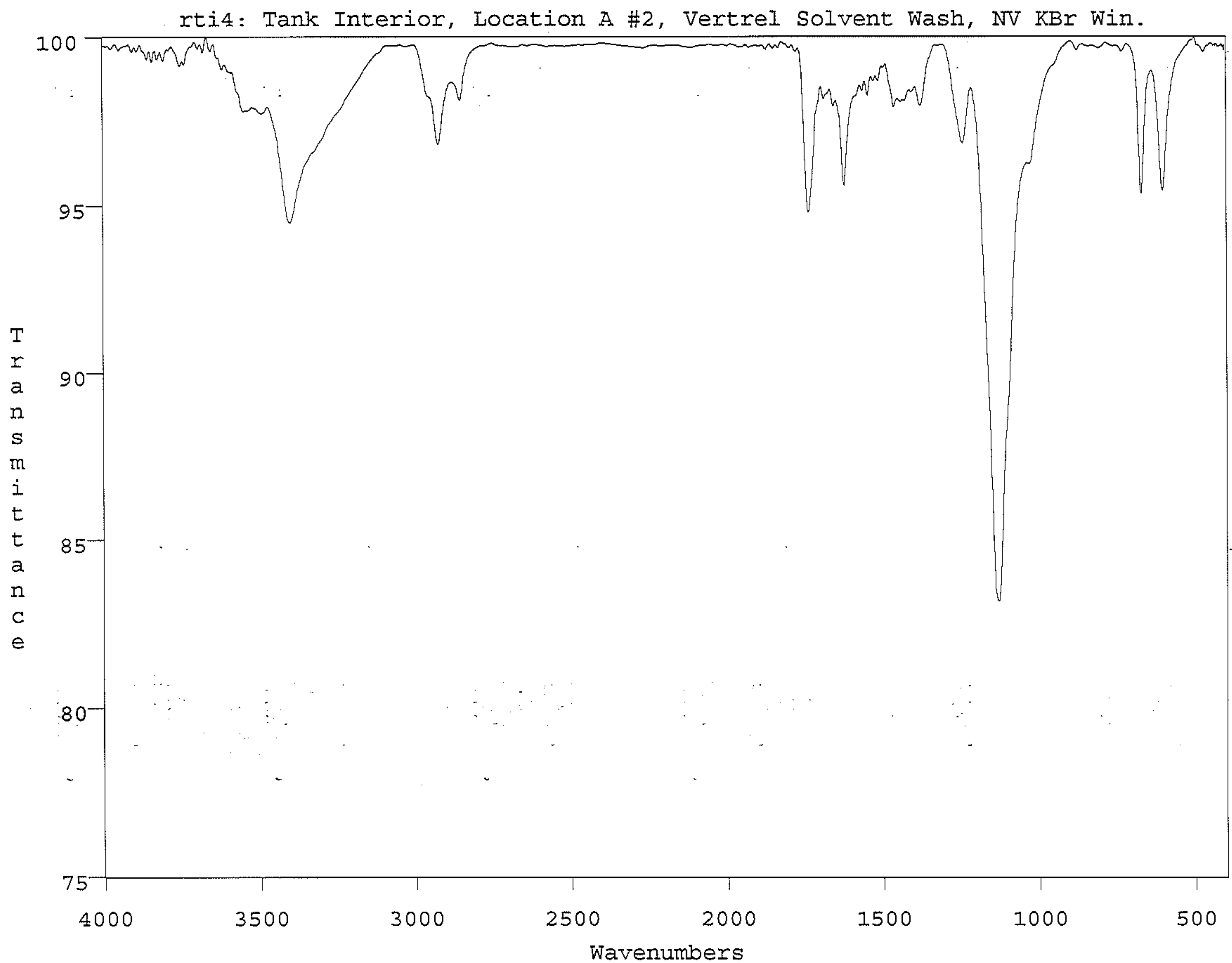

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Peak Pick

rti4: Tank Interior, Location A #2, Vertrel Solvent Wash, NV KBr Win.

cm-1	Intensity
599.900	95.465
669.341	95.361
1026.195	96.256
1128.429	83.176
1240.307	96.868
1375.333	97.976
1438.988	98.096
1460.206	97.947
1545.079	98.271
1562.440	98.419
1620.308	95.612
1655.029	97.964
1685.892	98.167
1736.044	94.791
2852.899	98.133
2922.341	96.825
3398.788	94.484
3489.448	97.750
3547.316	97.809

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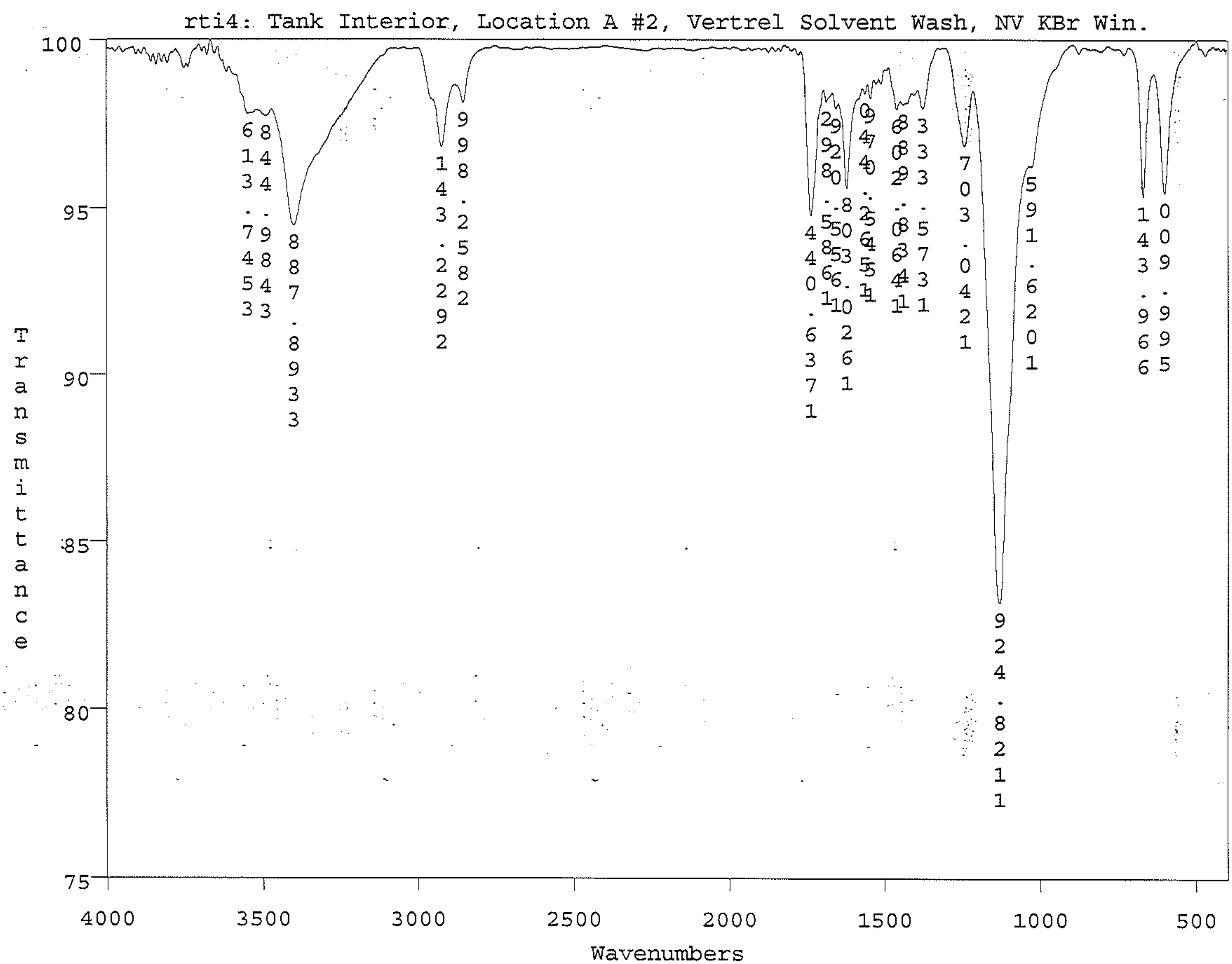

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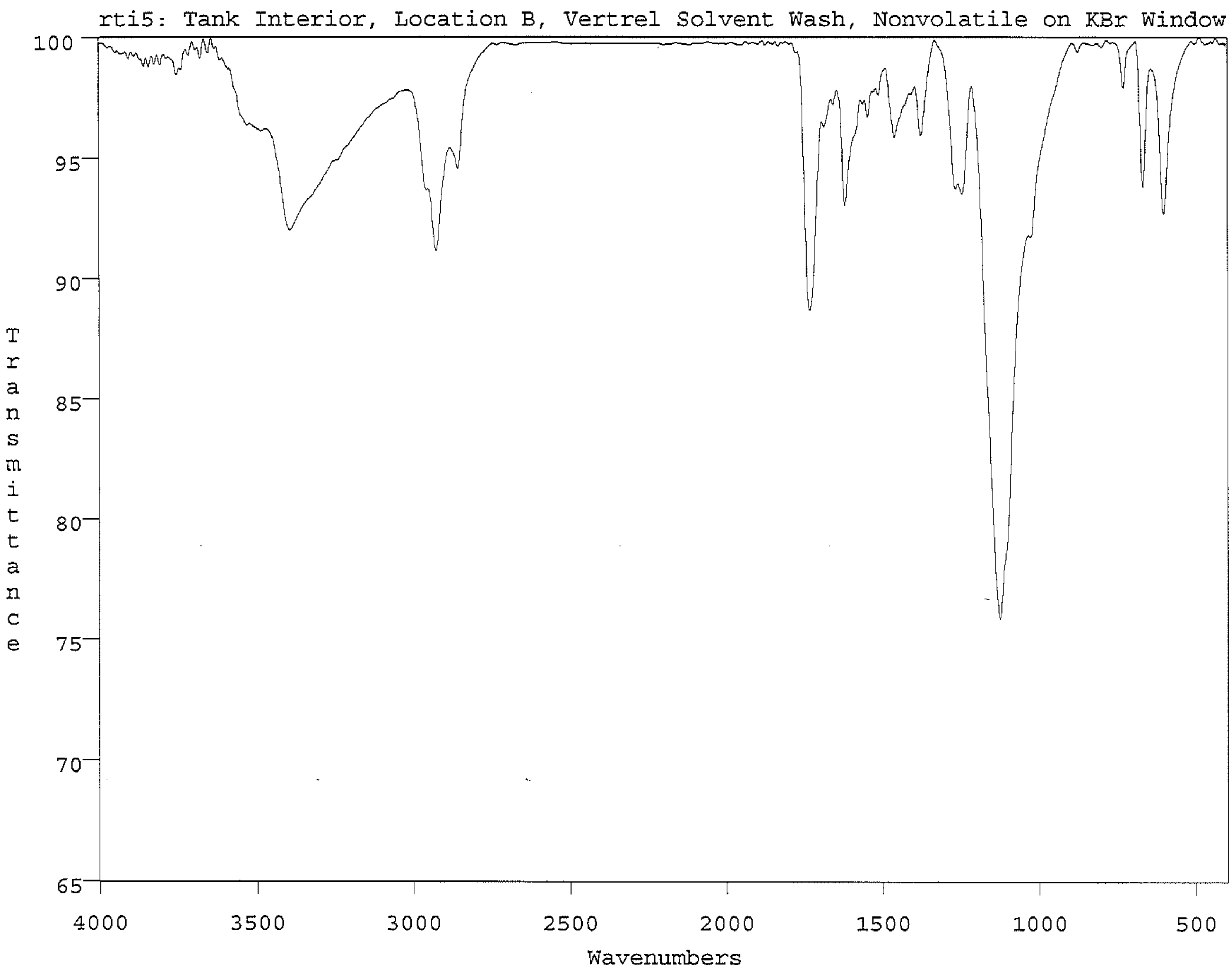

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rti5: Tank Interior, Location B, Vertrel Solvent Wash, Nonvolatile on KBr Window

Peak Pick

cm-1	Intensity
599.900	92.708
665.484	93.842
729.138	97.942
1024.266	91.736
1122.642	75.858
1244.165	93.558
1263.454	93.764
1375.333	95.965
1458.277	95.893
1510.358	97.643
1545.079	96.713
1618.379	93.055
1655.029	97.245
1685.892	96.298
1732.186	88.727
2854.828	94.573
2924.270	91.150
2953.204	93.715
3391.073	92.028
3483.662	96.150
3528.027	96.391

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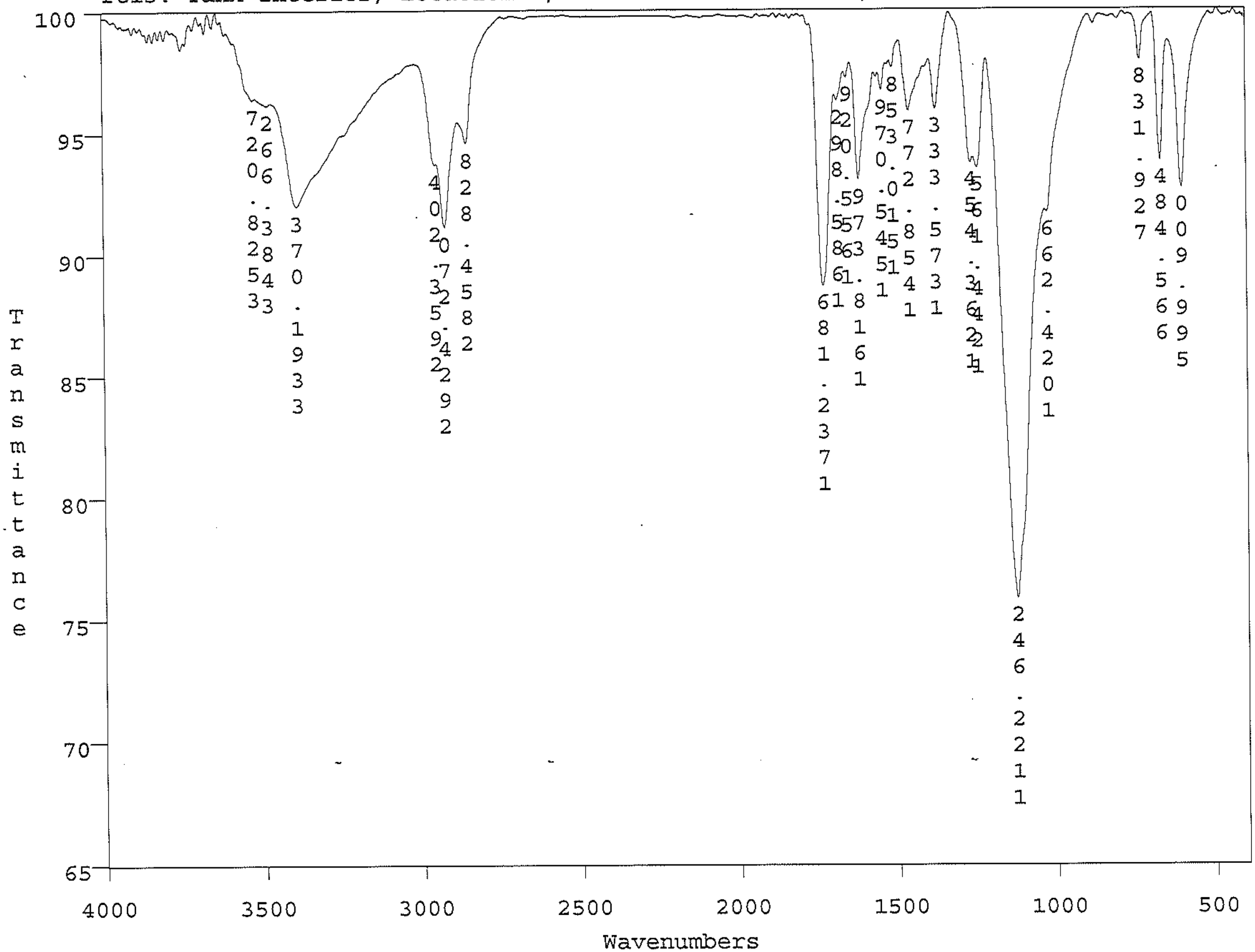
rti5: Tank Interior, Location B, Vertrel Solvent Wash, Nonvolatile on KBr Window



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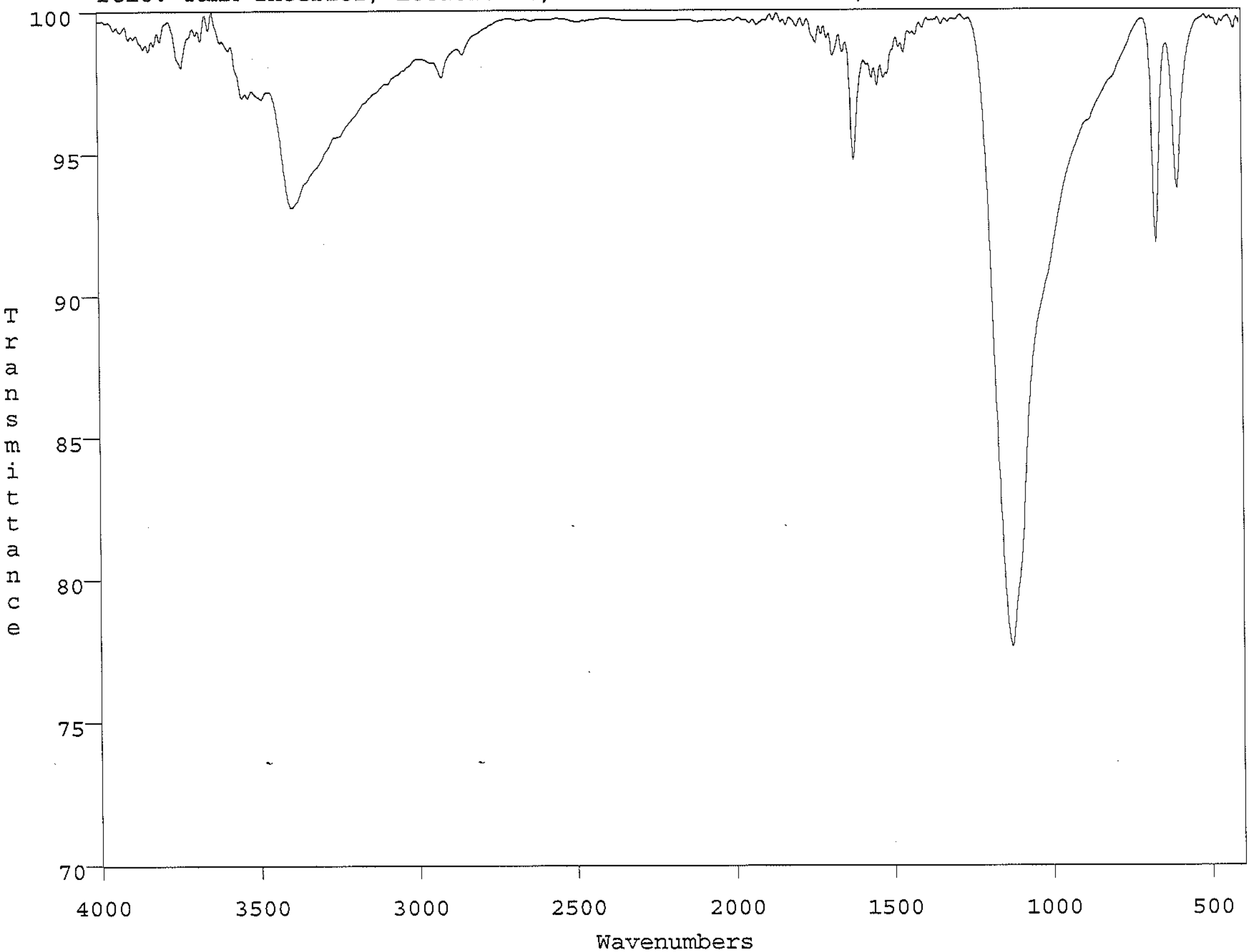
rti6: Tank Interior, Location C, Vertrel Solvent Wash, Nonvolatile on KBr Window



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rti6: Tank Interior, Location C, Vertrel Solvent Wash, Nonvolatile on KBr Window

Peak Pick

cm-1	Intensity
599.900	93.755
667.412	91.852
1124.571	77.625
1521.932	97.645
1543.150	97.390
1560.511	97.654
1618.379	94.768
1683.963	98.435
2849.041	98.485
2914.625	97.676
3086.300	97.442
3391.073	93.116
3483.662	96.936
3526.098	96.980
3545.388	96.965
3738.281	98.056

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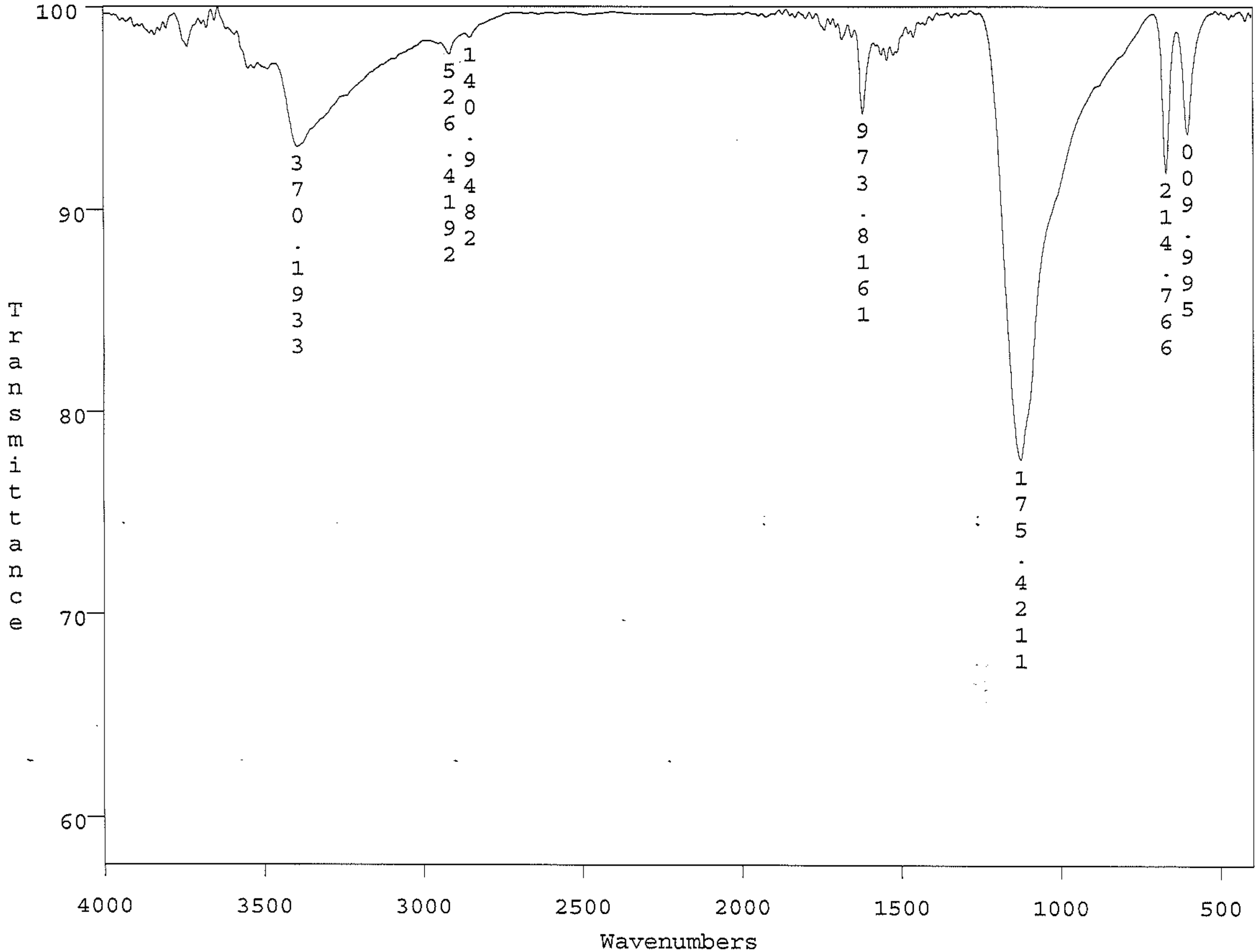
rti6: Tank Interior, Location C, Vertrel Solvent Wash, Nonvolatile on KBr Window



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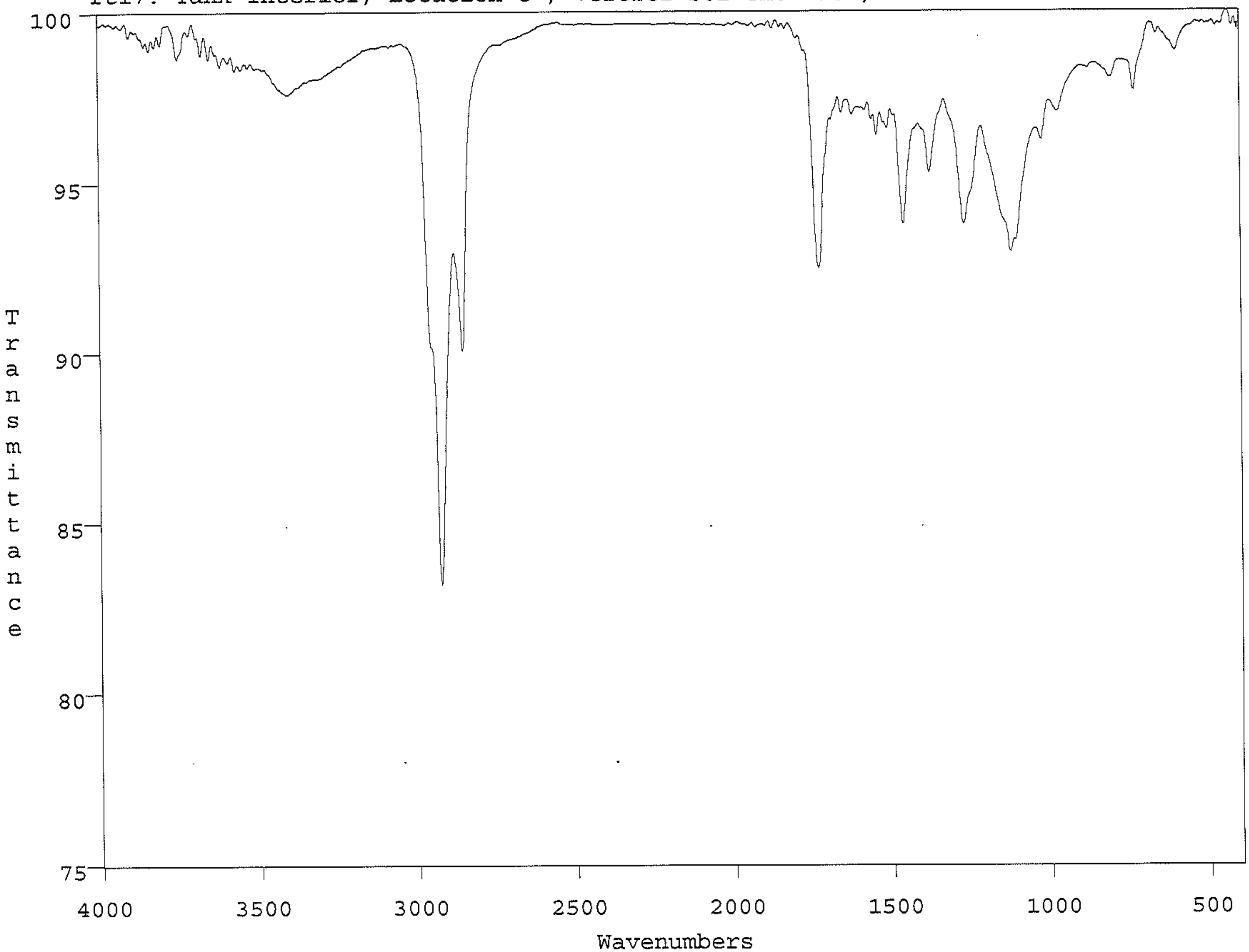
rti7: Tank Interior, Location C', Vertrel Solvent Wash, Nonvolatile on KBr Window



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rti7: Tank Interior, Location C', Vertrel Solvent Wash, Nonvolatile on KBr Window

Peak Pick

cm-1	Intensity
597.971	98.840
729.138	97.693
802.438	98.063
873.809	98.332
970.256	97.083
1022.337	96.265
1103.352	93.333
1118.784	92.972
1267.312	93.795
1377.262	95.292
1460.206	93.798
1491.069	96.952
1510.358	96.585
1543.150	96.390
1558.582	96.847
1579.800	97.110
1620.308	96.992
1653.100	97.037
1726.399	92.504
2389.954	99.644
2854.828	90.072
2924.270	83.176
3402.646	97.600
3504.880	98.363
3528.027	98.402
3549.245	98.337
3568.535	98.309
3589.753	98.543
3614.829	98.434
3651.479	98.634
3676.555	98.766
3749.855	98.662

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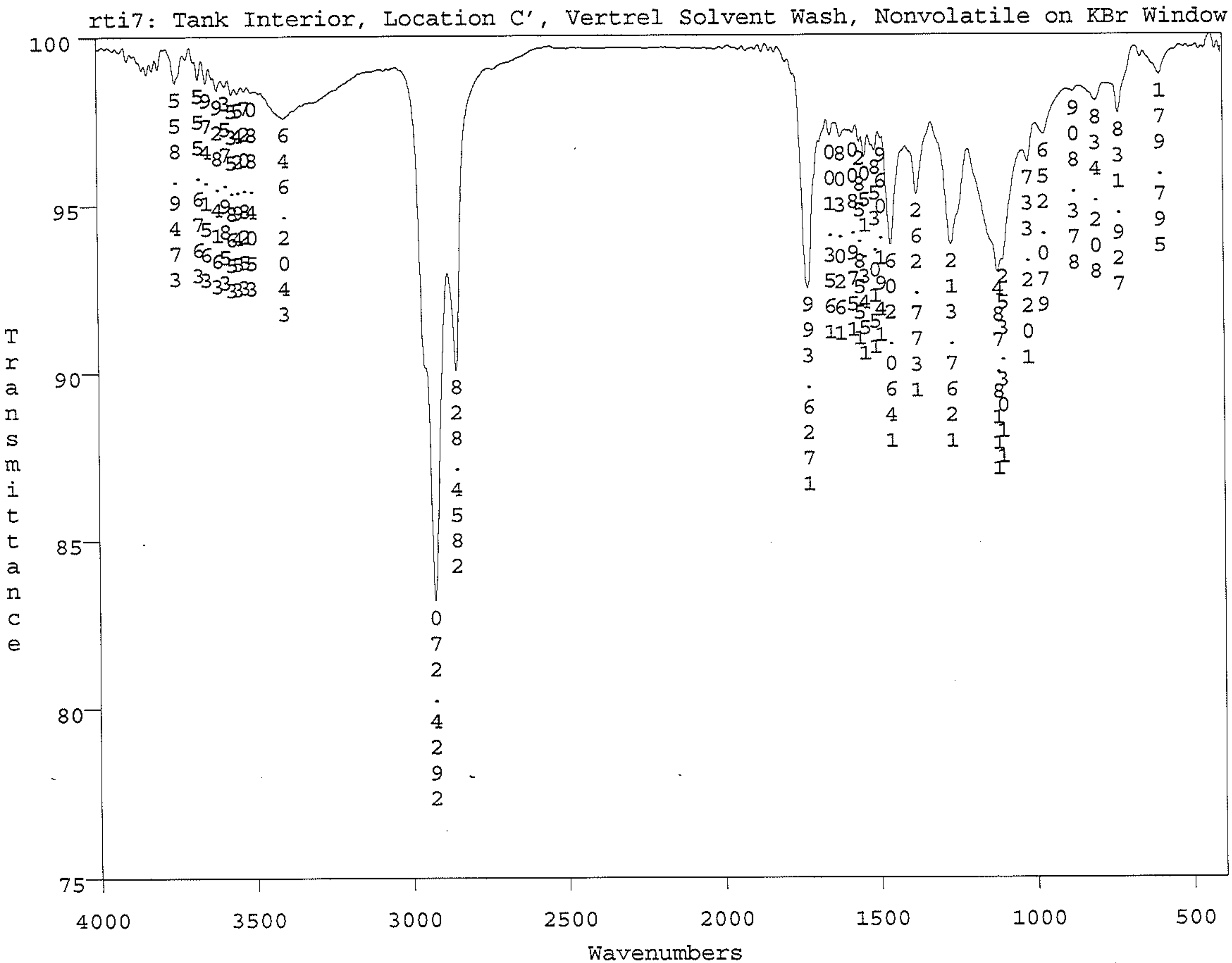

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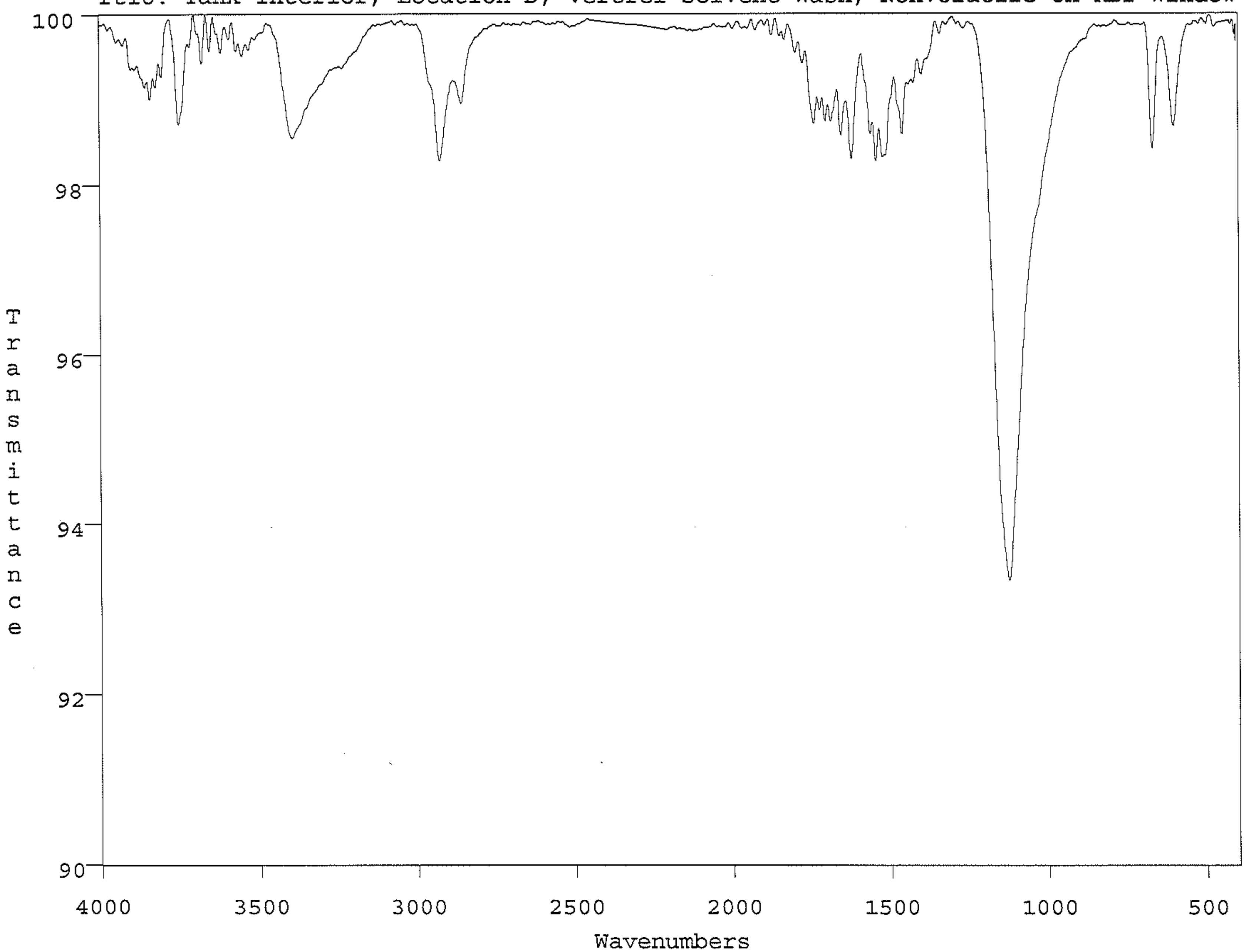
rti8: Tank Interior, Location D, Vertrel Solvent Wash, Nonvolatile on KBr Window



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rti8: Tank Interior, Location D, Vertrel Solvent Wash, Nonvolatile on KBr Window

Peak Pick

cm-1	Intensity
470.661	99.845
599.900	98.681
667.412	98.423
1122.642	93.325
1398.480	99.296
1458.277	98.600
1512.287	98.343
1520.003	98.326
1541.221	98.277
1558.582	98.593
1620.308	98.300
1653.100	98.581
1683.963	98.744
1701.323	98.745
1718.684	98.877
1737.973	98.717
1772.694	99.426
2852.899	98.957
2922.341	98.280
3232.900	99.368
3389.144	98.555
3549.245	99.517
3616.758	99.555
3651.479	99.568
3676.555	99.429
3749.855	98.711
3803.865	99.274
3823.155	99.143
3840.515	99.006
3855.947	99.146

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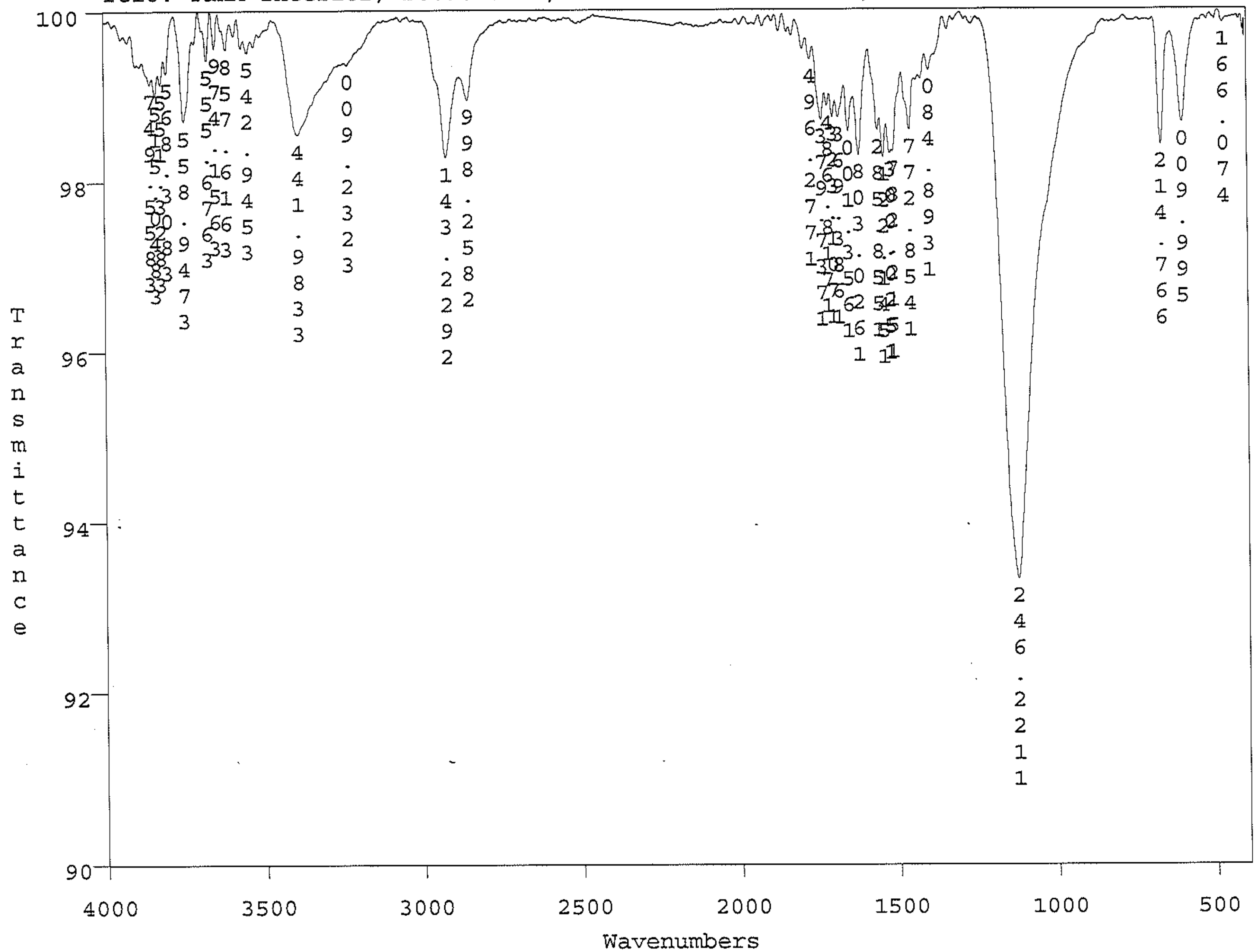
rti8: Tank Interior, Location D, Vertrel Solvent Wash, Nonvolatile on KBr Window



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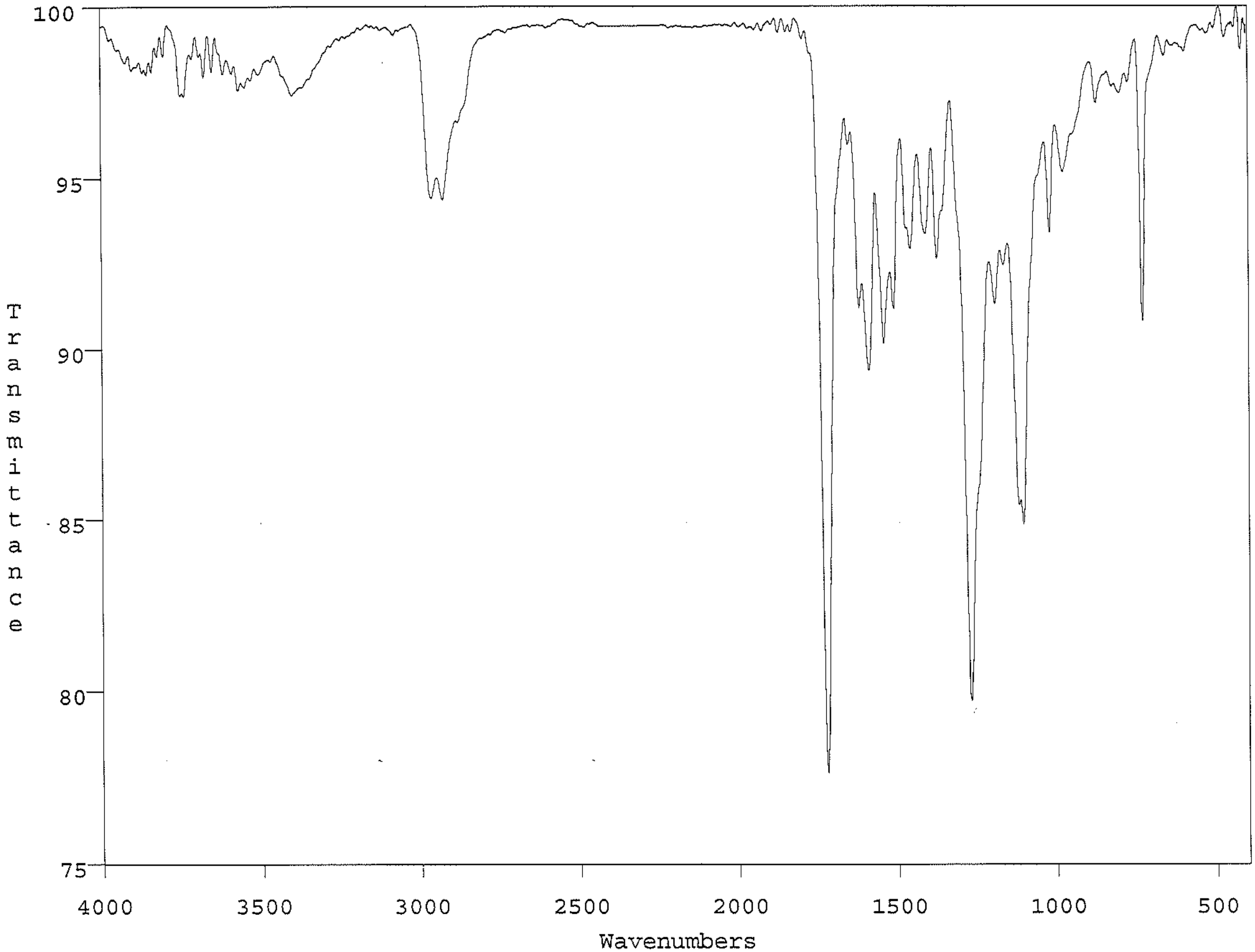
rti9: Tank Exterior, Yellow Paint, Vertrel Solvent Extracted, Nonvolatile, KBr Window



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rti9: Tank Exterior, Yellow Paint, Vertrel Solvent Extracted, Nonvolatile, KBr Window

Peak Pick

cm-1	Intensity
729.138	90.829
773.504	97.788
800.509	97.476
871.880	97.200
977.971	95.182
1018.479	93.422
1103.352	84.868
1116.855	85.421
1165.078	92.464
1192.084	91.327
1269.241	79.733
1375.333	92.659
1410.053	93.387
1458.277	92.927
1510.358	91.200
1543.150	90.170
1589.445	89.369
1620.308	91.228
1653.100	95.969
1720.612	77.625
2434.319	99.436
2926.199	94.379
2962.848	94.410
3400.717	97.430
3504.880	98.035
3549.245	97.663
3568.535	97.563
3616.758	98.049
3651.479	98.117
3676.555	97.959

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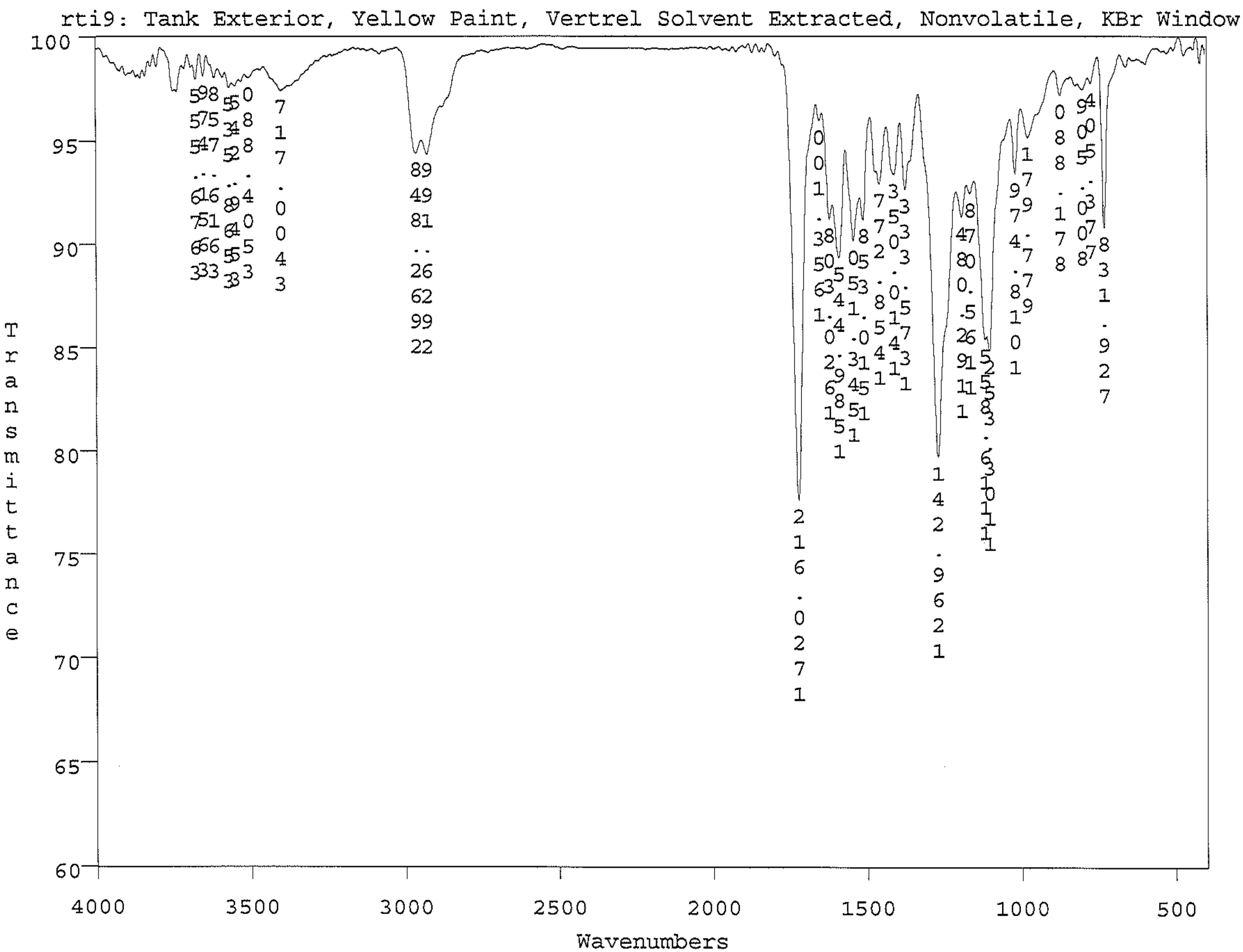

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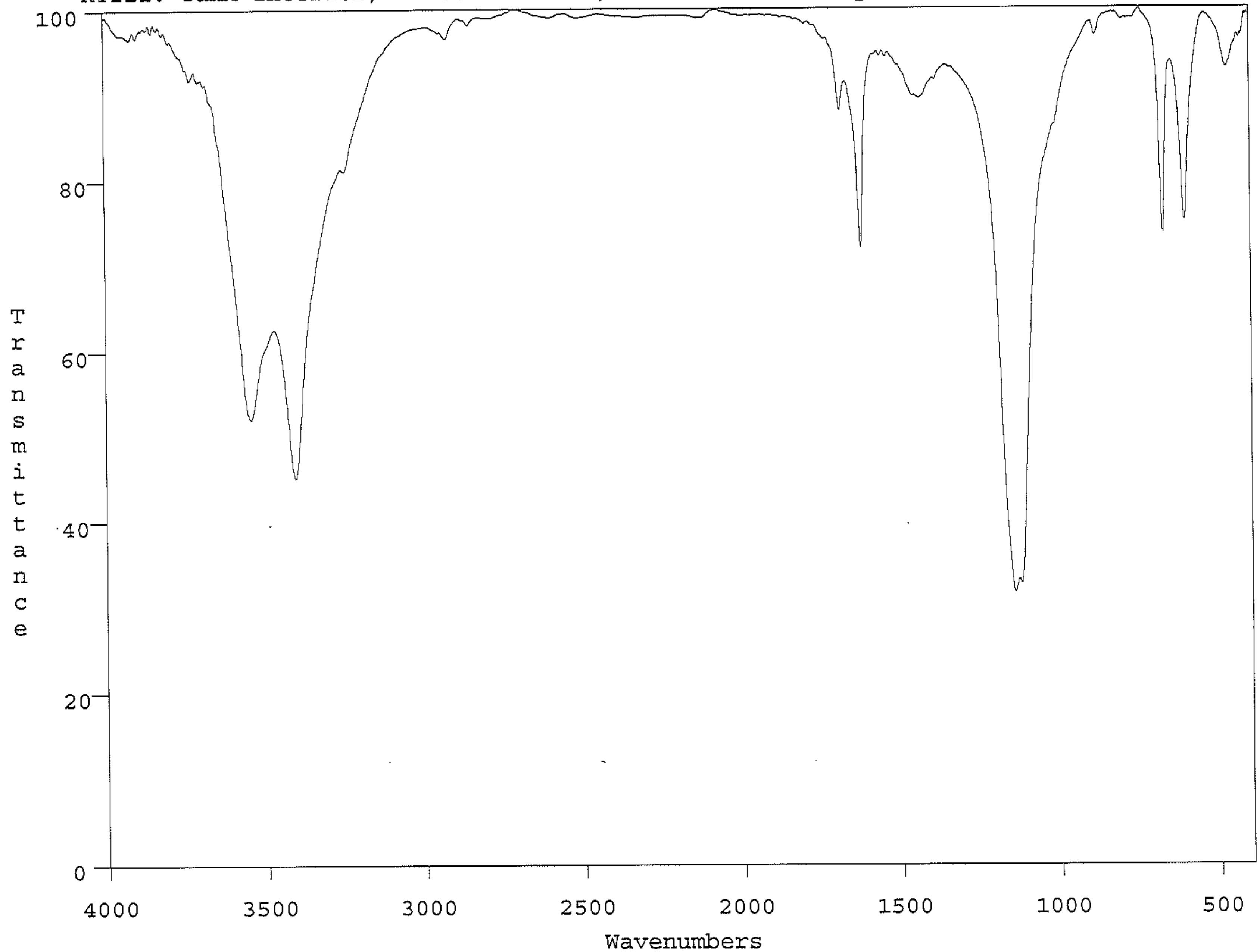
RTI11: Tank Interior, White Material, Six Inches to Right of Location A, KBr Pellet



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RTI11: Tank Interior, White Material, Six Inches to Right of Location A, KBr Pellet

Peak Pick

cm-1	Intensity
468.732	93.197
601.829	75.992
669.341	75.271
877.667	96.985
1122.642	32.869
1140.002	31.821
1437.059	89.619
1622.237	73.297
1685.892	88.542
2507.619	99.052
2852.899	98.296
2922.341	96.645
3248.331	81.157
3406.504	45.254
3545.388	52.166
3728.637	92.022
3919.601	96.711

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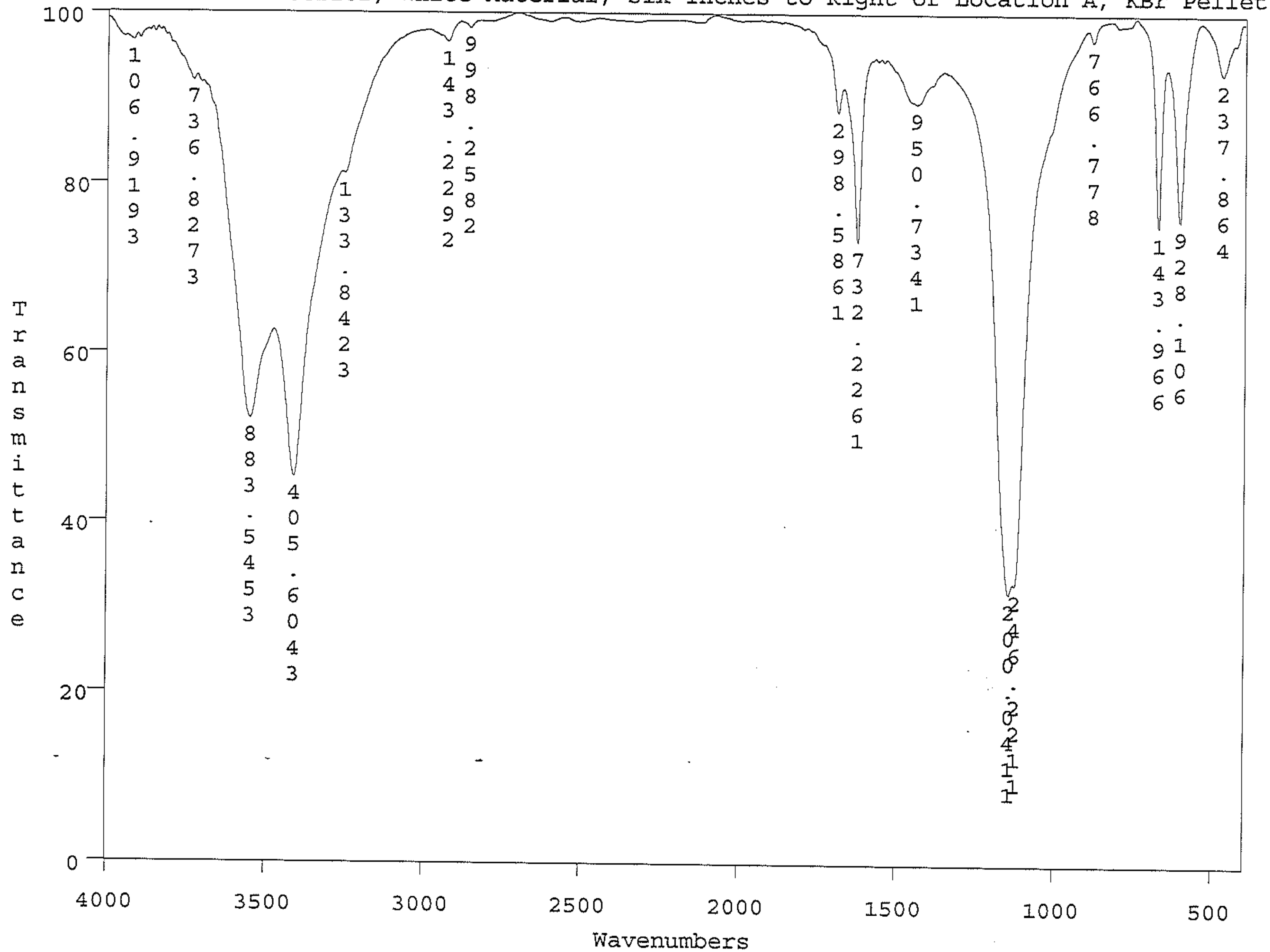
RTI11: Tank Interior, White Material, Six Inches to Right of Location A, KBr Pellet



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26102 Eden Landing Road Suite 3·Hayward CA 94545(510)887-8811-Fax (510)887-8427

March 22, 2012 Lab. No. 5004.7109 RTI Group

FTIR Spectra Characterization

Sample	Part No.	Spectrum No.	Characterization
Tank Interior	Loc. A, #1	rti3	vinyl acetate and ester type polymers + calcium sulfate
Tank Interior	Location A, #2	rti4	calcium sulfate + ester type polymer
Tank Interior	Location B	rti5	calcium sulfate + ester type polymers
Tank Interior	Location C	rti6	calcium sulfate
Tank Interior	Location C’	rti7	terephthalate type polyester
Tank Interior	Location D	rti8	calcium sulfate
Tank Exterior	Yellow Paint	rti9	terephthalate type polyester
Tank Interior	White material 6” to right of Location A	rti11	calcium sulfate
Valve Seat Body	1A	rti13	fluoro-polymer
Valve Stem	1B	rti16	fluoro-polymer (fluorine confirmed by EDS)
Relief Valve	1C	rti18	fluoro-polymer
Gland Nut	1D	rti19	fluoro-polymer
Valve Body	1E, 22mm orifice	rti20	silicate(s) + ammonium salt + oxides
Valve Body	1E, 18mm orifice	rti21	silicate(s) + ammonium salt + oxides
Valve Body	1E, 12mm orifice	rti22	silicate(s) + ammonium salt + oxides
Valve Body	1E, 5mm orifice	rti23	oxides
Regulator Adapter Air Cup	1F	rti24	fluoro-polymer
Regulator Body Diaphragm	2aa, Print Side	rti25	aromatic ester
Regulator Body Diaphragm	2aa, Non-Print Side	rti26	aromatic ester
Regulator Body	2aa, Non-Print Side	rti28	calcium sulfate + calcium carbonate

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FTIR Spectra Characterization

Sample	Part No.	Spectrum No.	Characterization
Retaining Ring	2ab	rti29	fluoro-polymer + ester
Spring Carrier	2ac	rti30	fluoro-polymer
Metal Diaphragm Retainer, Interior	2ad	rti34	fluoro-polymer + ester
Metal Diaphragm Retainer	2ad	rti35	fluoro-polymer + silicate(s) + oxides
Main Regulator Body	2ae, 2ef, 2ag, & 2ah	rti36	fluoro-polymer + ester
High Pressure Diaphragm & Adjustment Sleeve	2aj'	rti38	fluoro-polymer + ester
Mating Half regulator Adjuster Adapter	2ak	rti39	fluoro-polymer
Green Hose, Interior	2b	rti40	phthalate type ester
Valve Stem Exemplar	3A	rti31	fluoro-polymer
Gland Nut Bore Exemplar	3B	rti32	fluoro-polymer
Valve Seat Body Exemplar	3C	rti33	fluoro-polymer + ester

Submitted by:

Harold R. Harlan,
Director, Organic Chemistry Laboratories

ATTACHMENT 9

Micrographs with HF Etch and Kellers Etch
Micrograph images, in order of appearance

HF Etch

Sample A Center 50x
Sample A Center 200x
Sample A Fracture 50x
Sample A Fracture 200x
Sample A Inside Surface 50x
Sample A Inside Surface 200x

Sample B Center 50x
Sample B Center 200x
Sample B Fracture 50x
Sample B Fracture 200x

Sample C Center 50x
Sample C Center 200x
Sample C Fracture 50x
Sample C Fracture 200x

Sample D Center 50x
Sample D Center 200x
Sample D Fracture 50x
Sample D Fracture 200x
Sample D Outside Surface 50x
Sample D Outside Surface 200x

Attachment 9, continued

Kellers Etch

Sample A Center 50x
Sample A Center 200x
Sample A Fracture 50x
Sample A Fracture 200x
Sample A Inside Surface 50x
Sample A Inside Surface 200x

Sample B Center 50x
Sample B Center 200x
Sample B Fracture 50x
Sample B Fracture 200x

Sample C Center 50x
Sample C Center 200x
Sample C Fracture 50x
Sample C Fracture 200x

Sample D Center 50x
Sample D Center 200x
Sample D Fracture 50x
Sample D Fracture 200x
Sample D Outside Surface 50x
Sample D Outside Surface 200x


0.05 mm


0.25 mm


0.05 mm


0.25 mm


0.05 mm


0.25 mm


0.05 mm


0.25 mm


0.05 mm


0.25 mm


0.05 mm


0.25 mm


0.05 mm


0.25 mm


0.05 mm

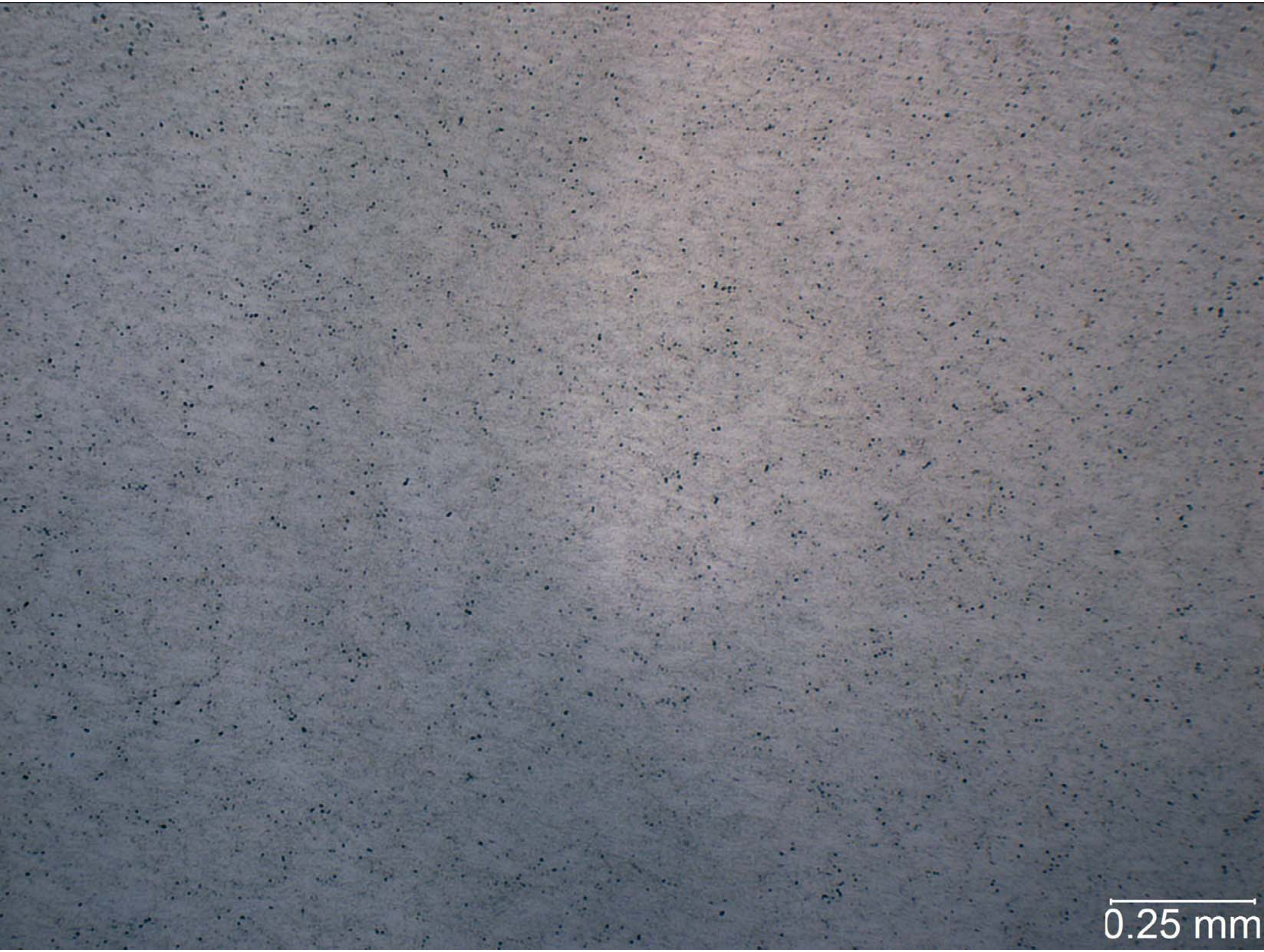

0.25 mm

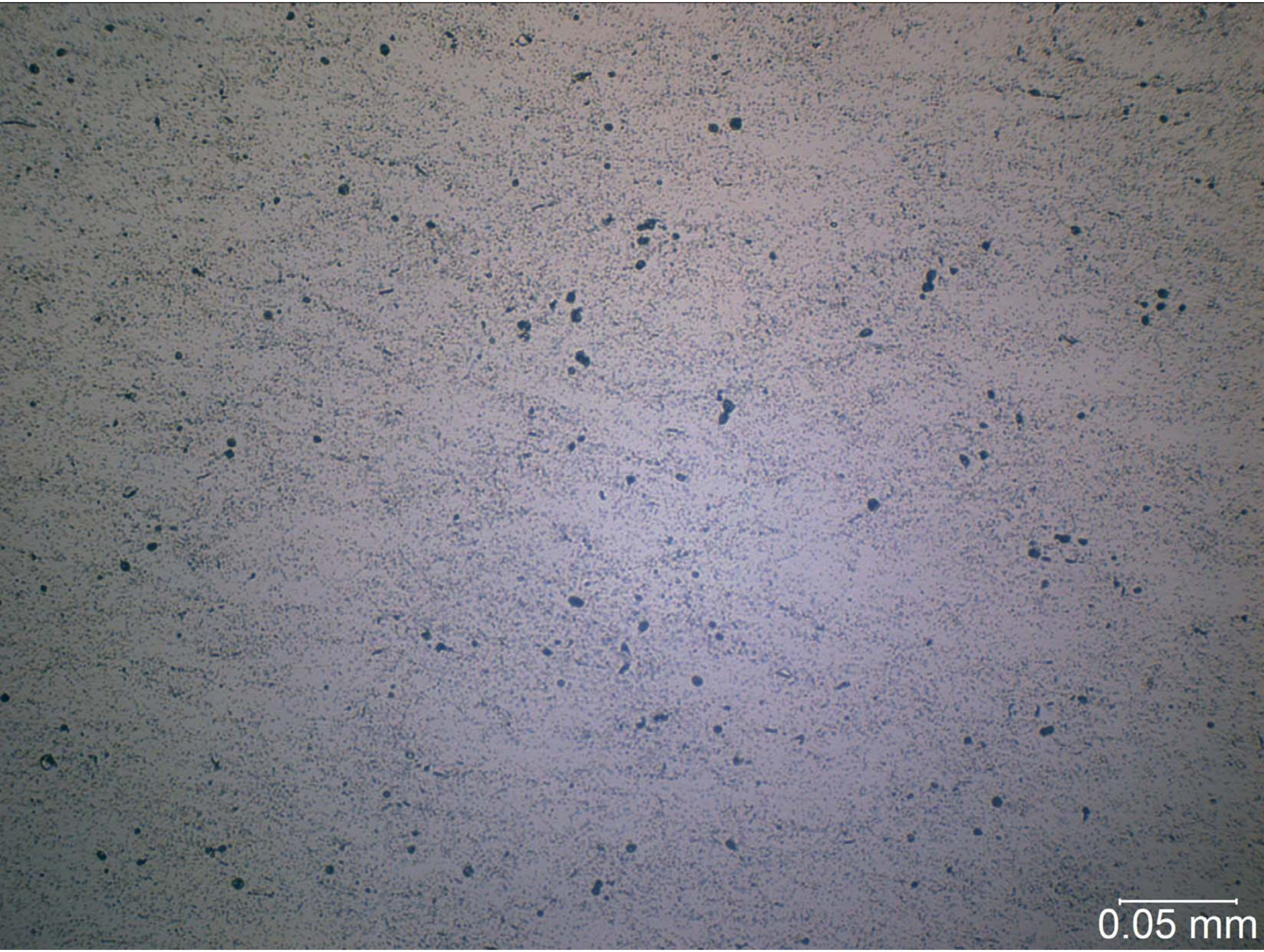

0.05 mm

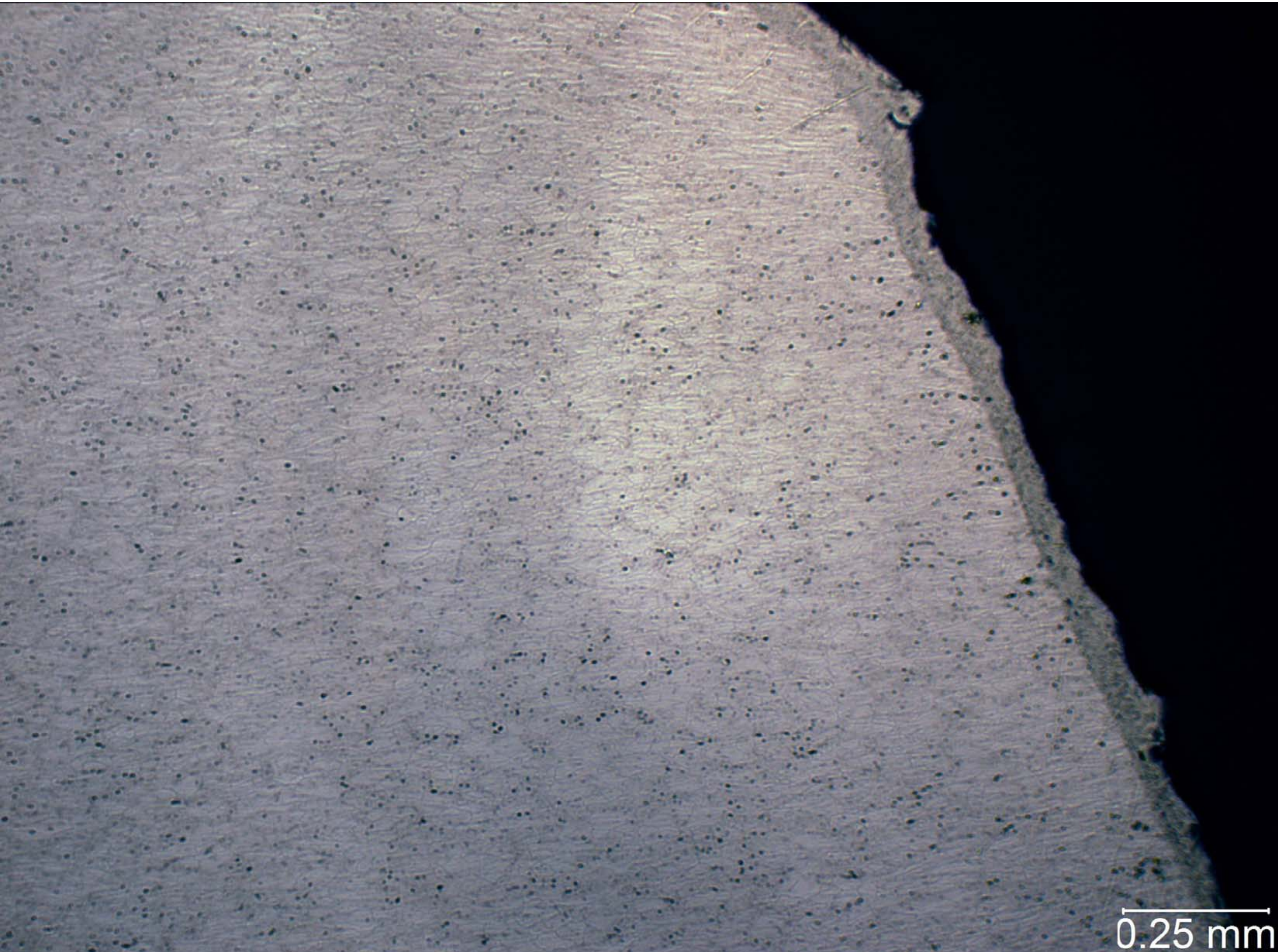

0.25 mm

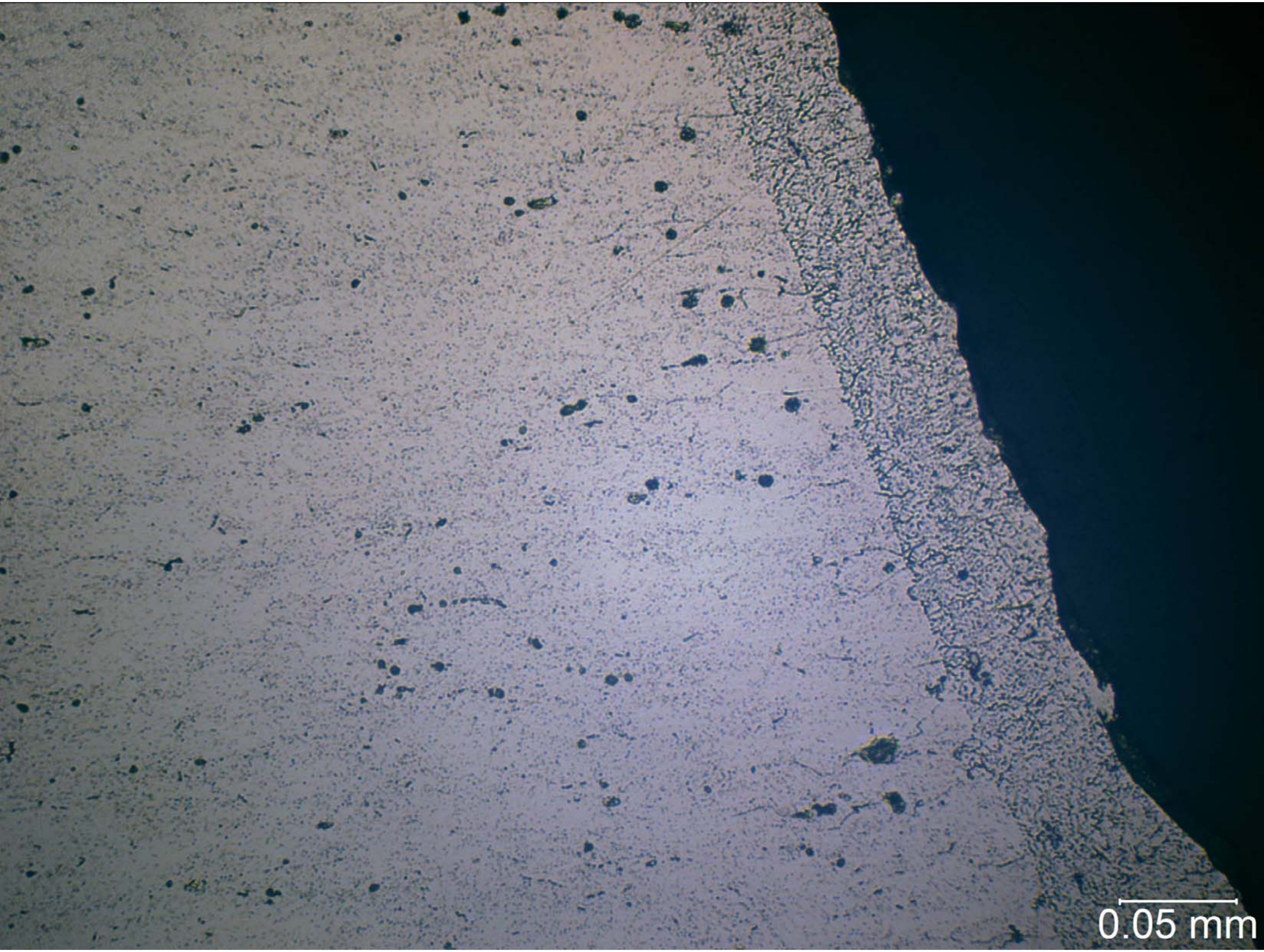

0.05 mm

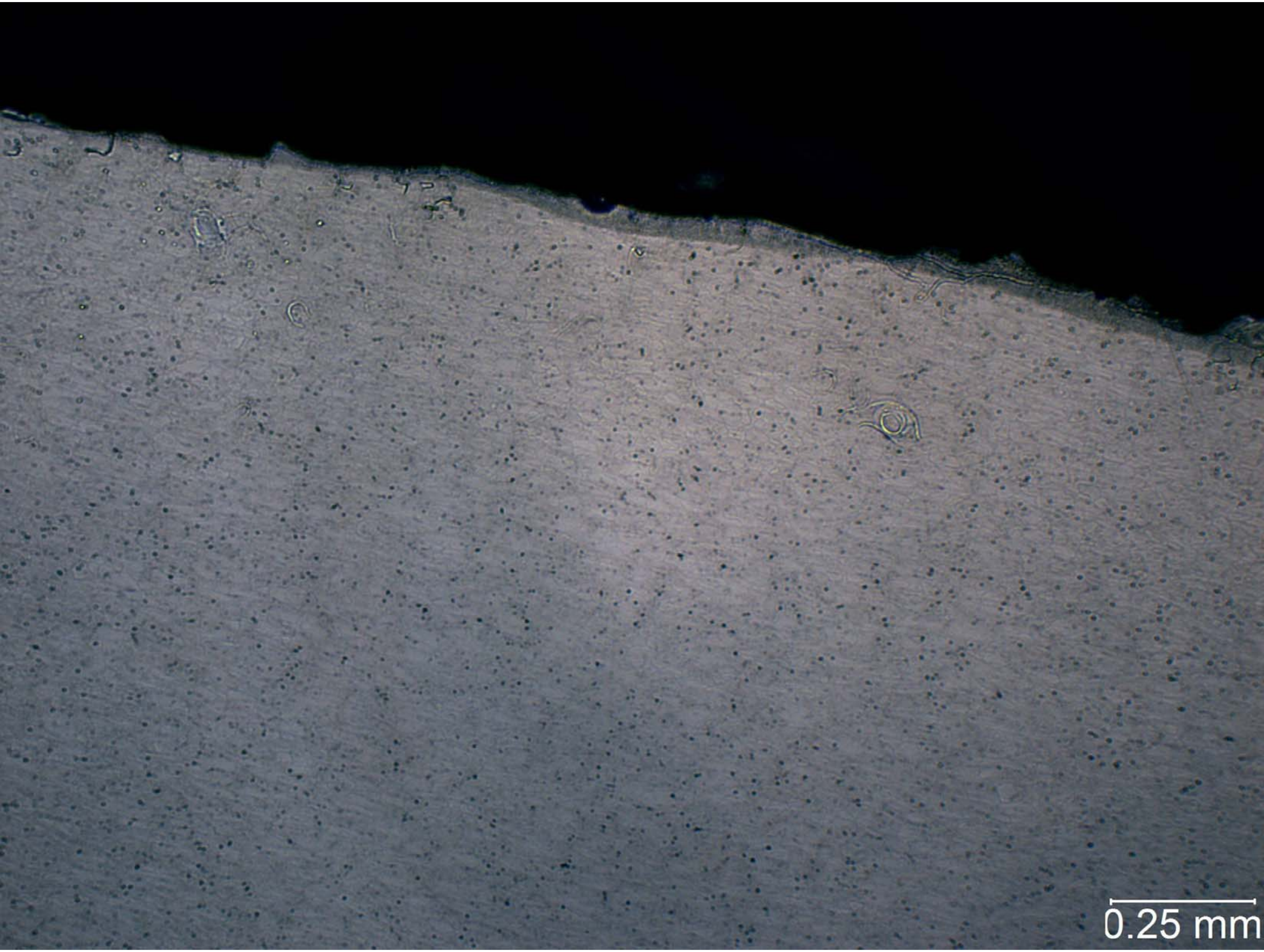

0.25 mm

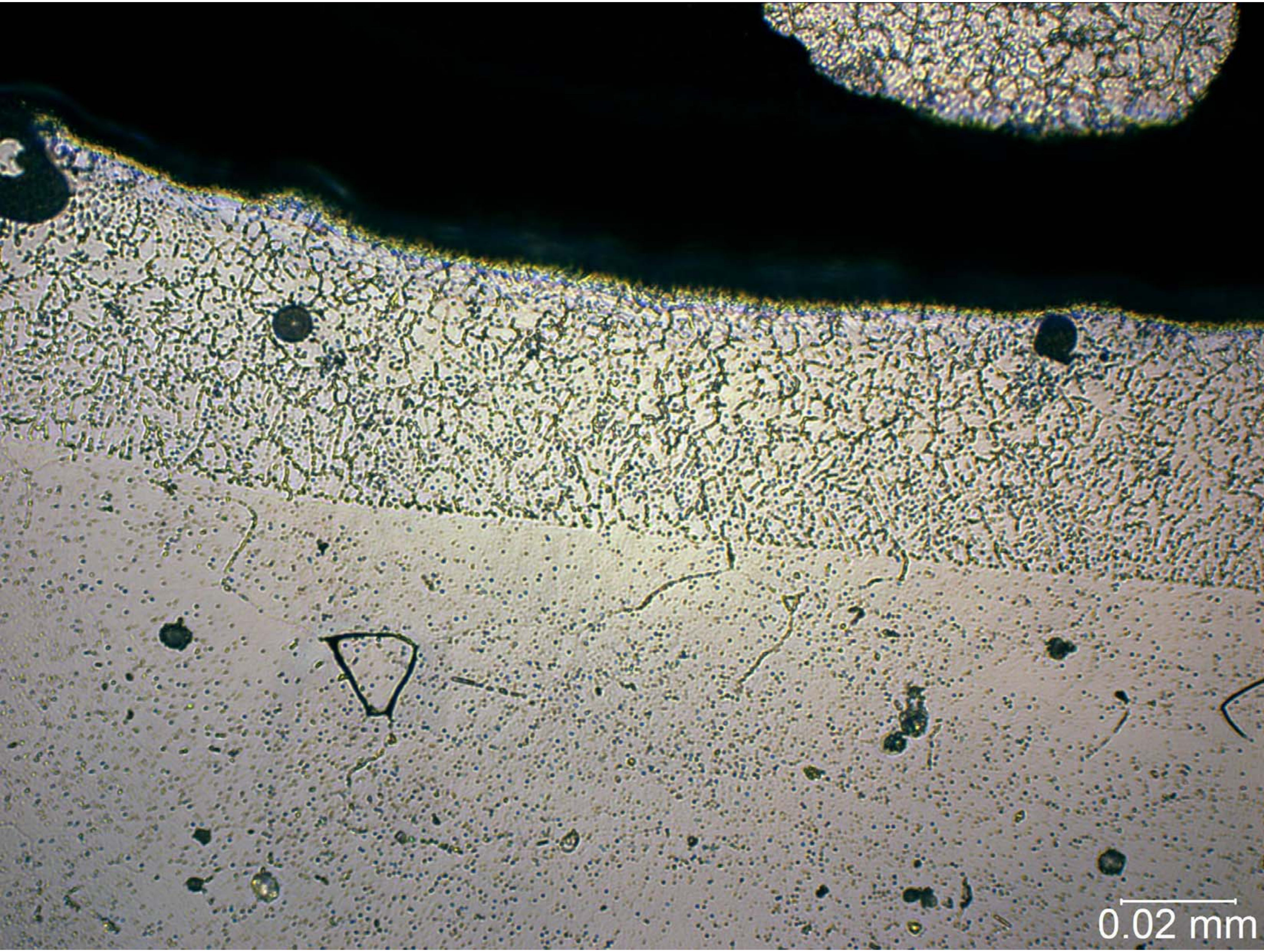

0.25 mm


0.05 mm


0.25 mm


0.05 mm


0.25 mm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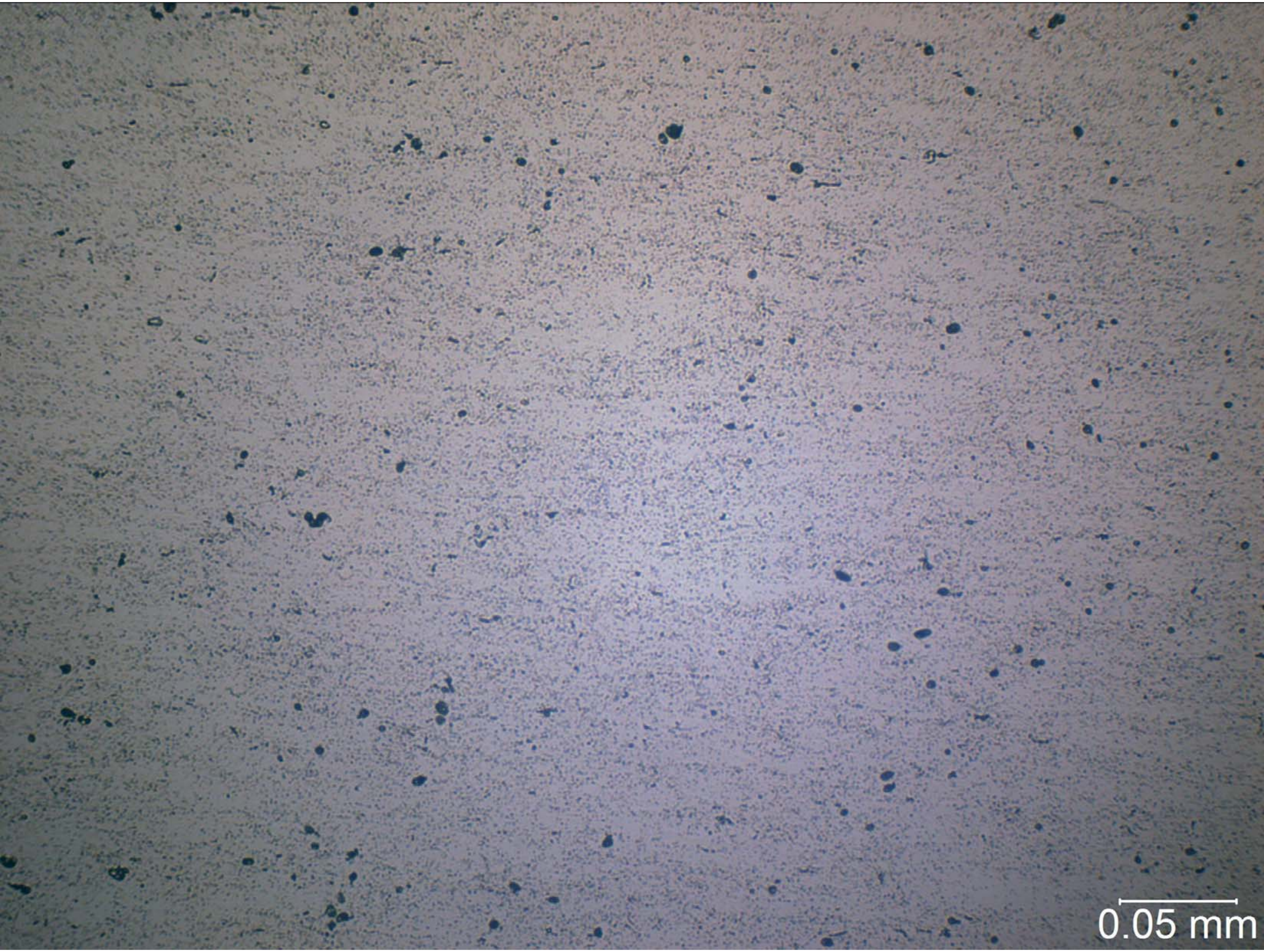
0.25 mm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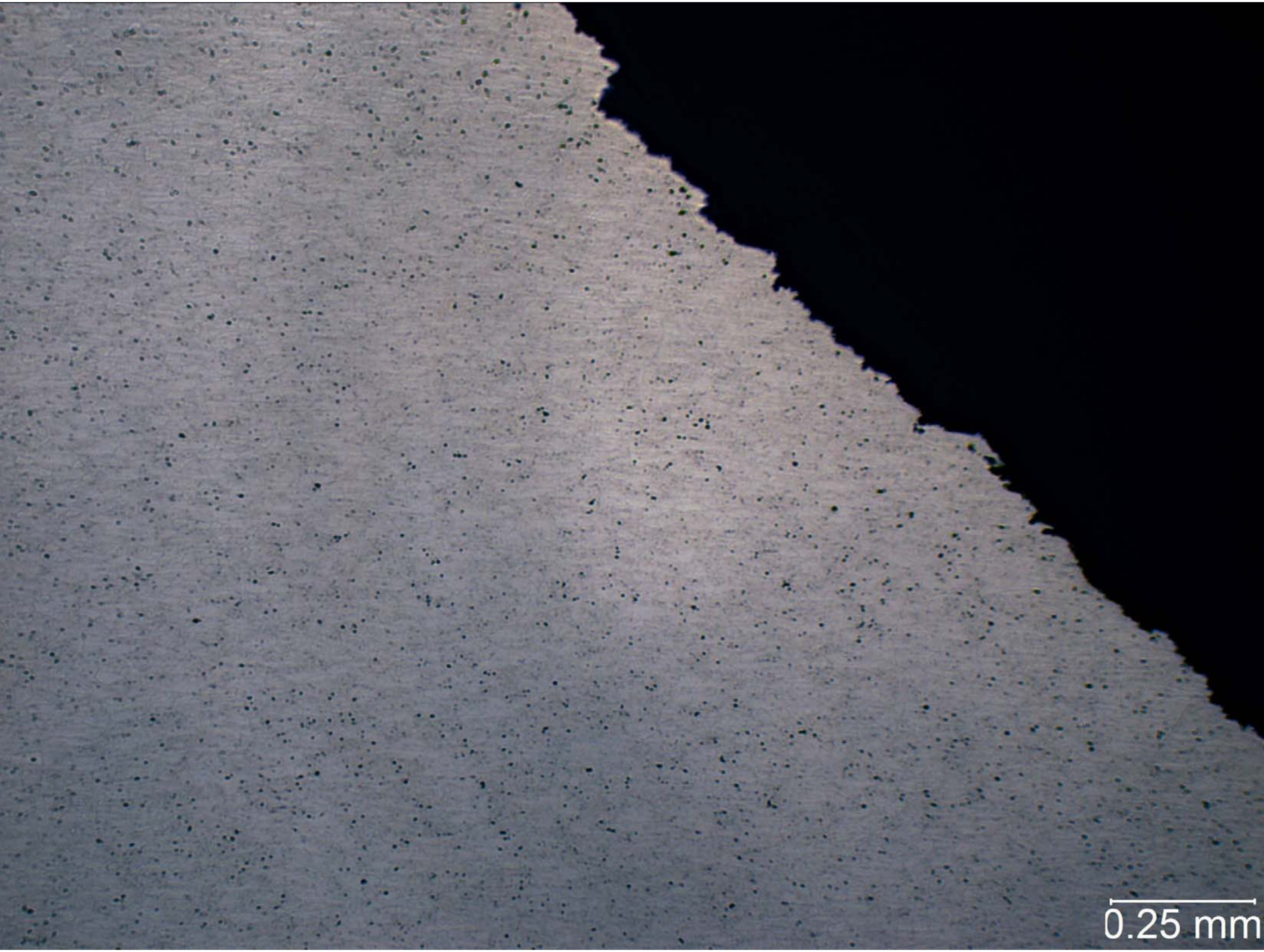
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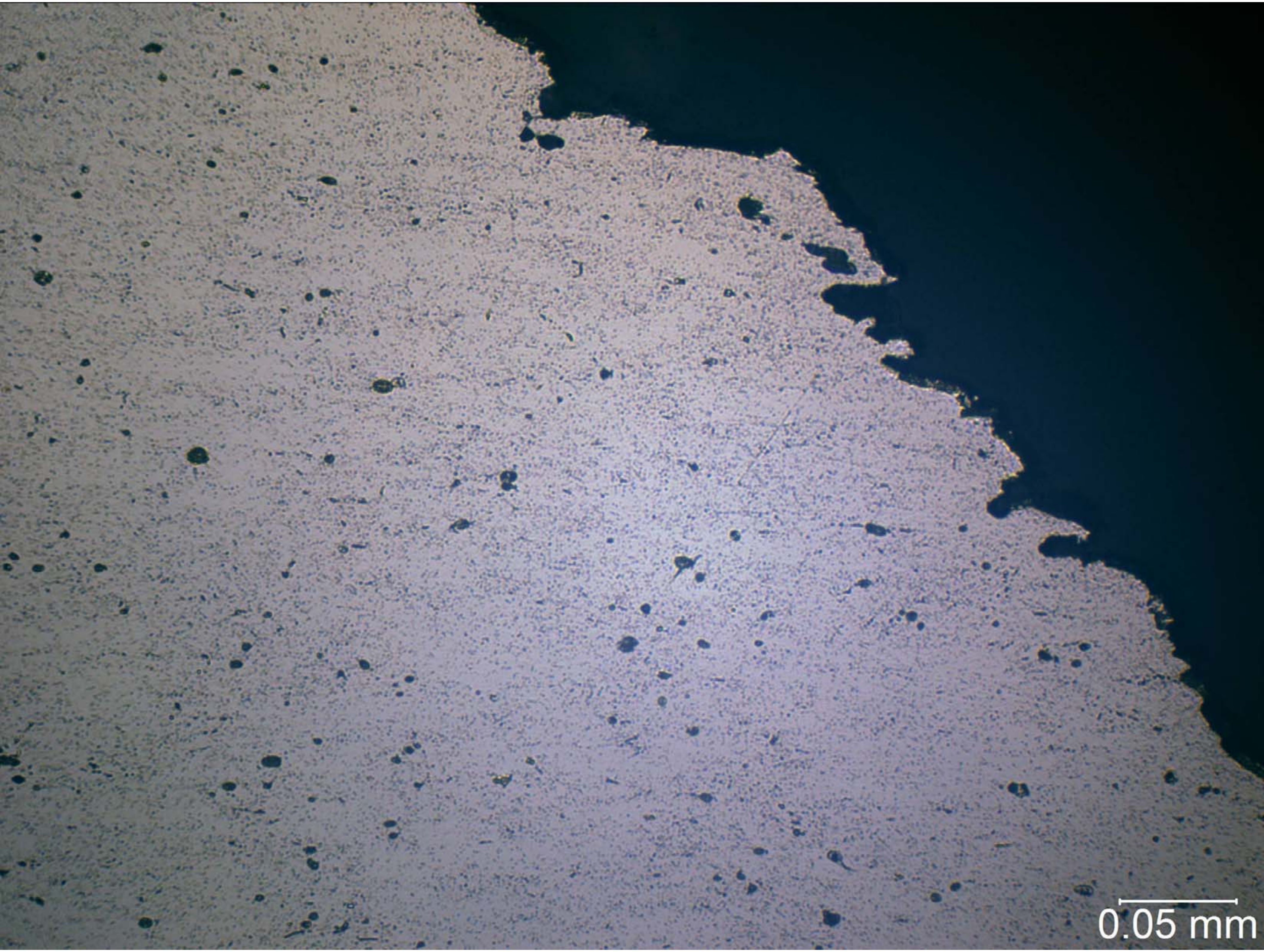
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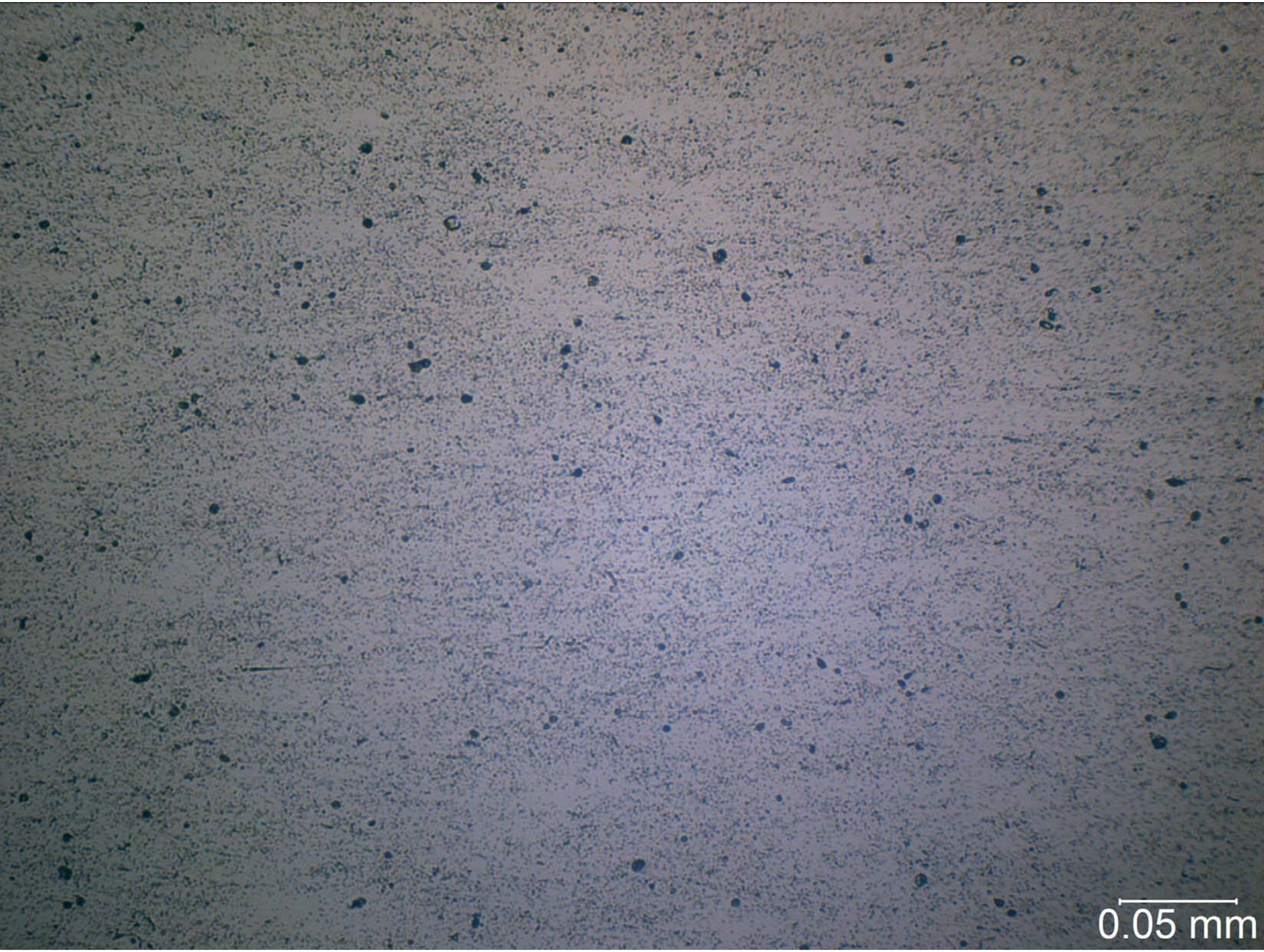
0.25 mm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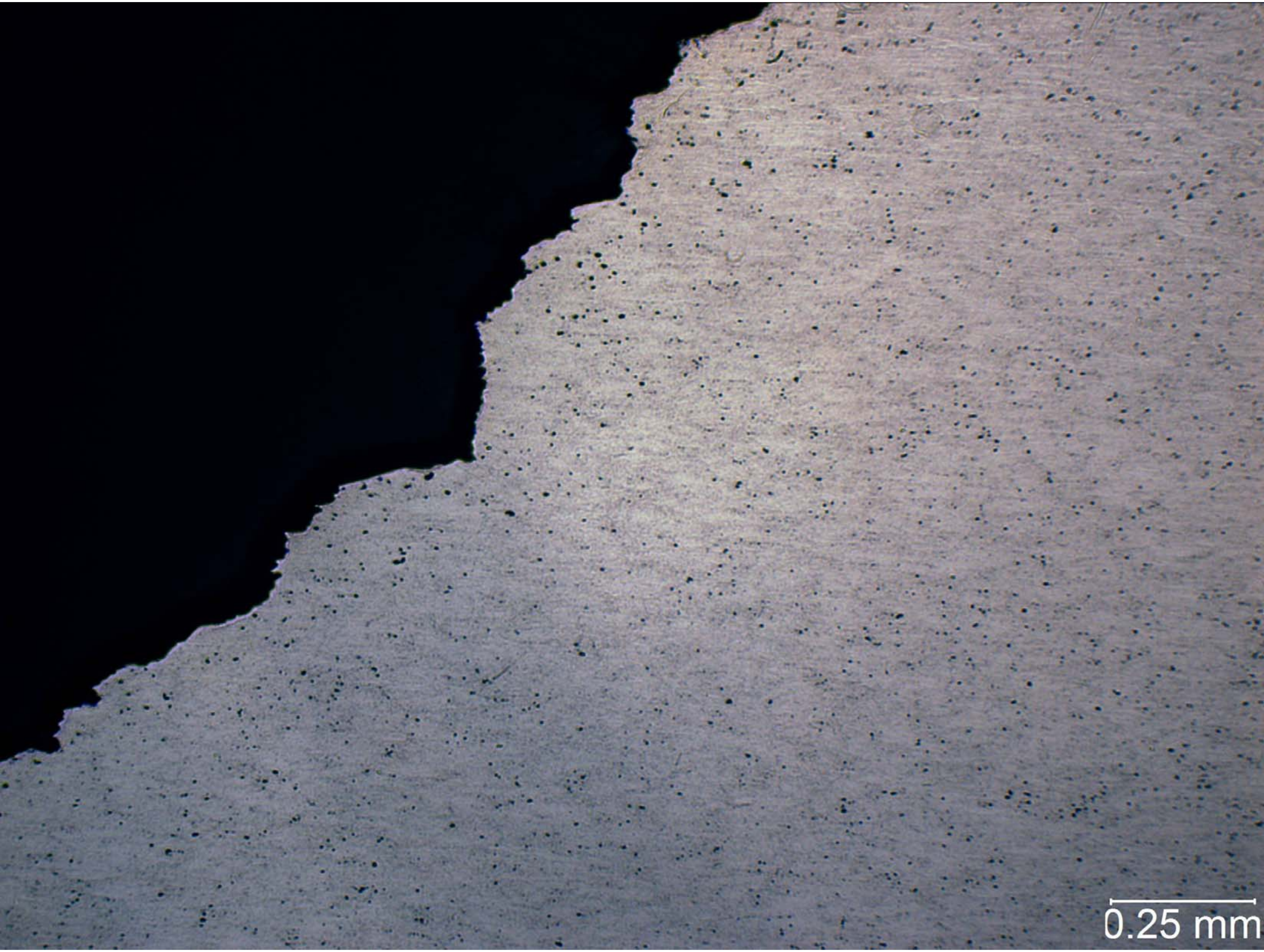
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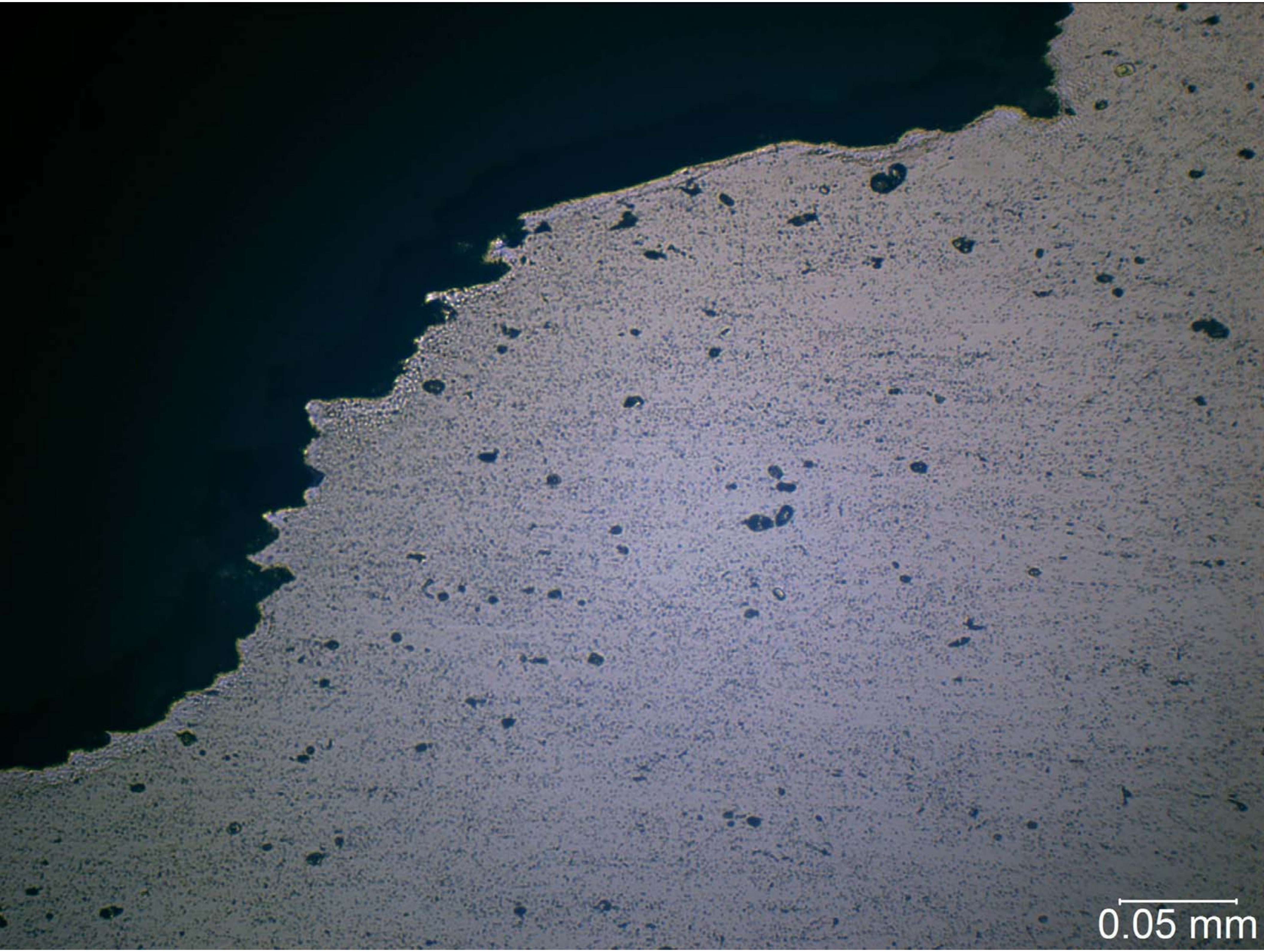
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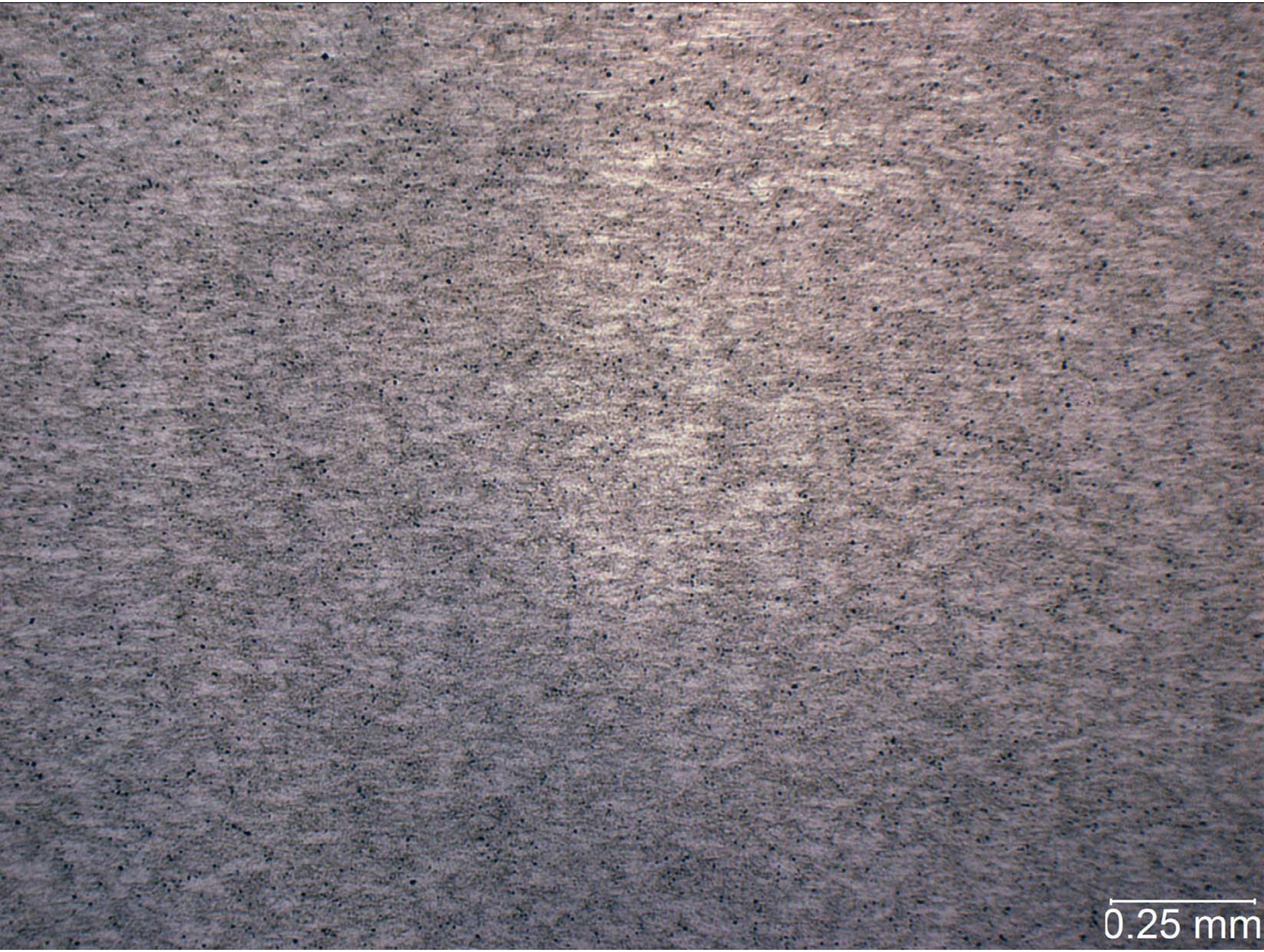
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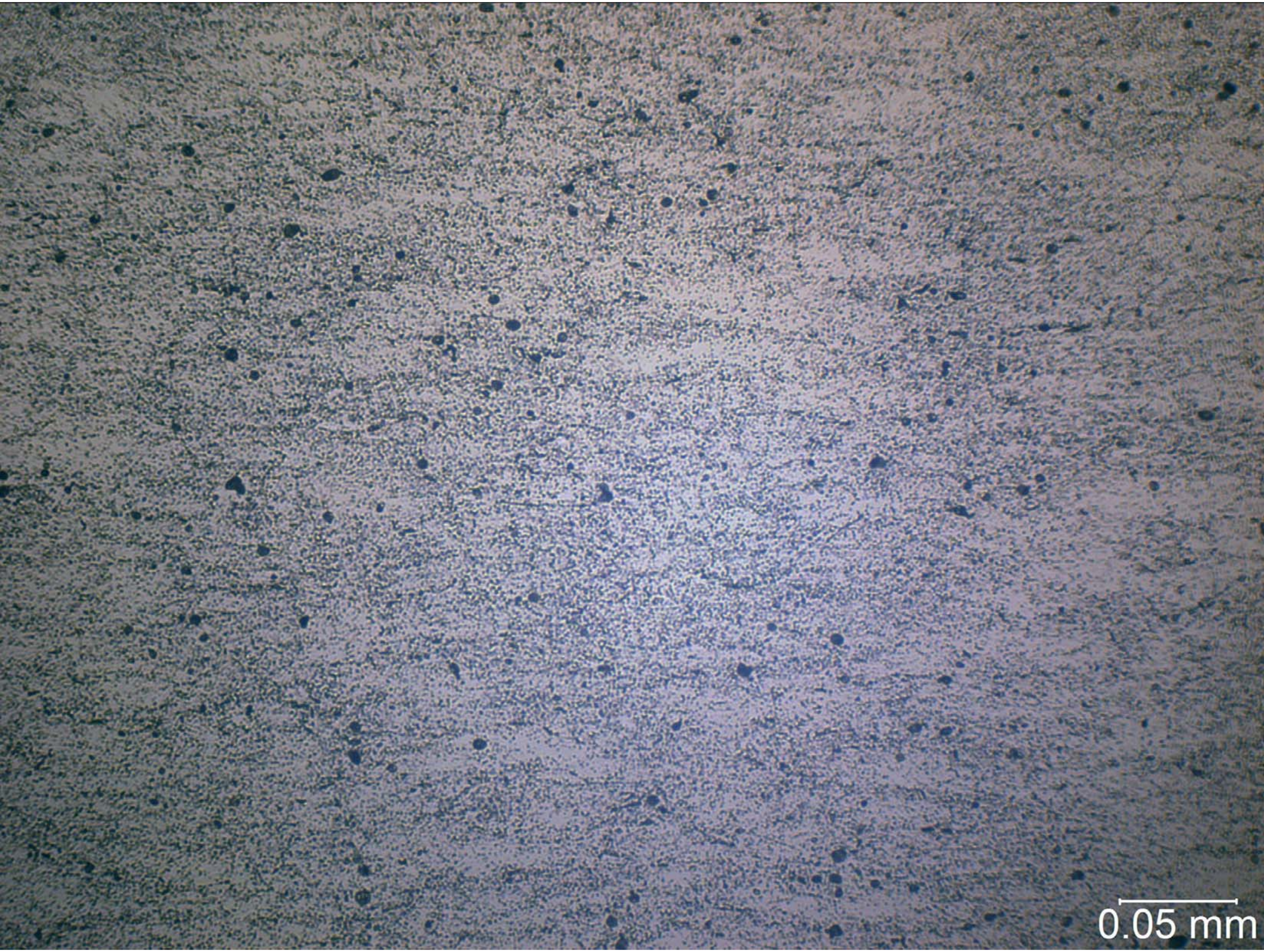
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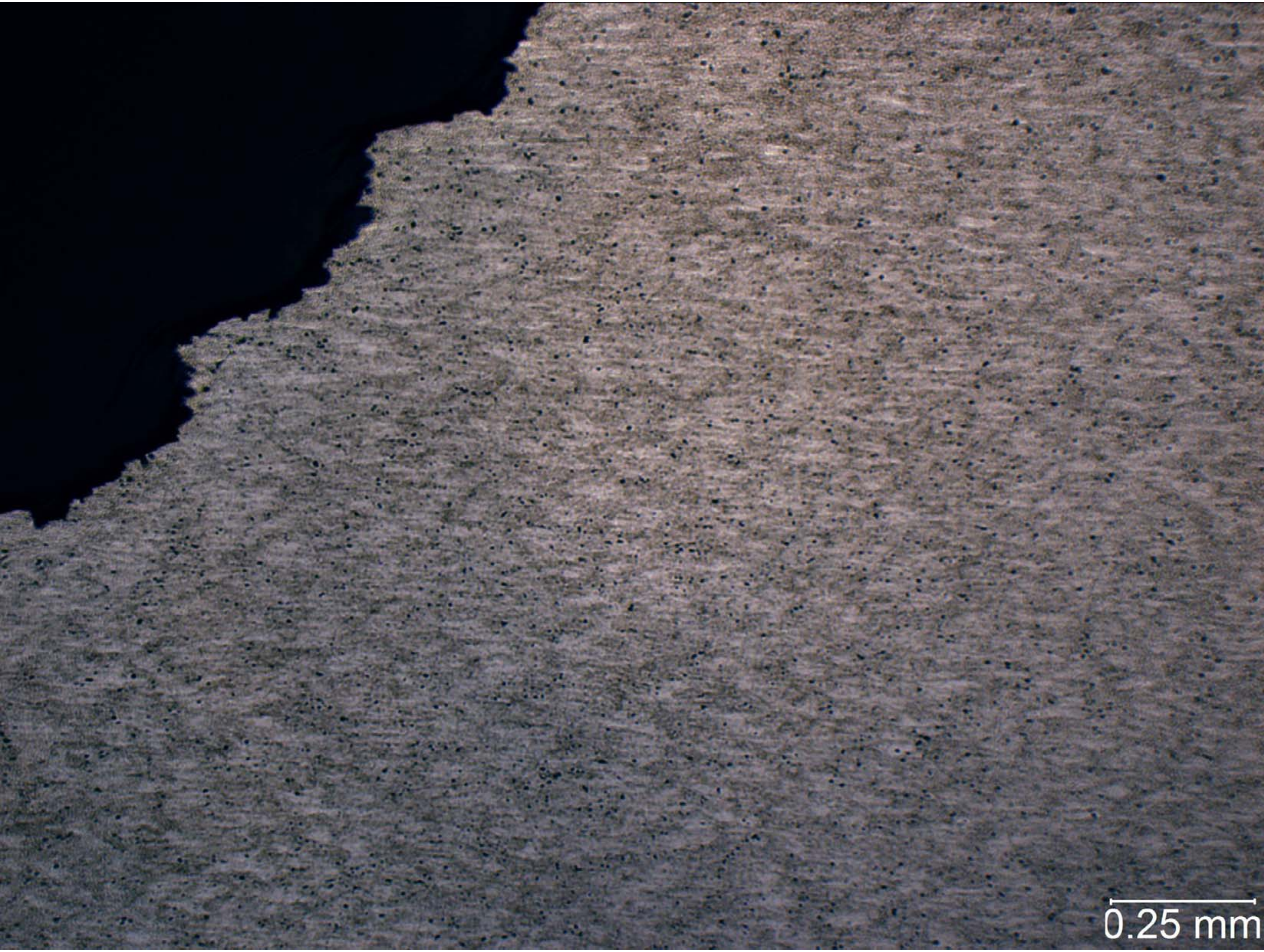
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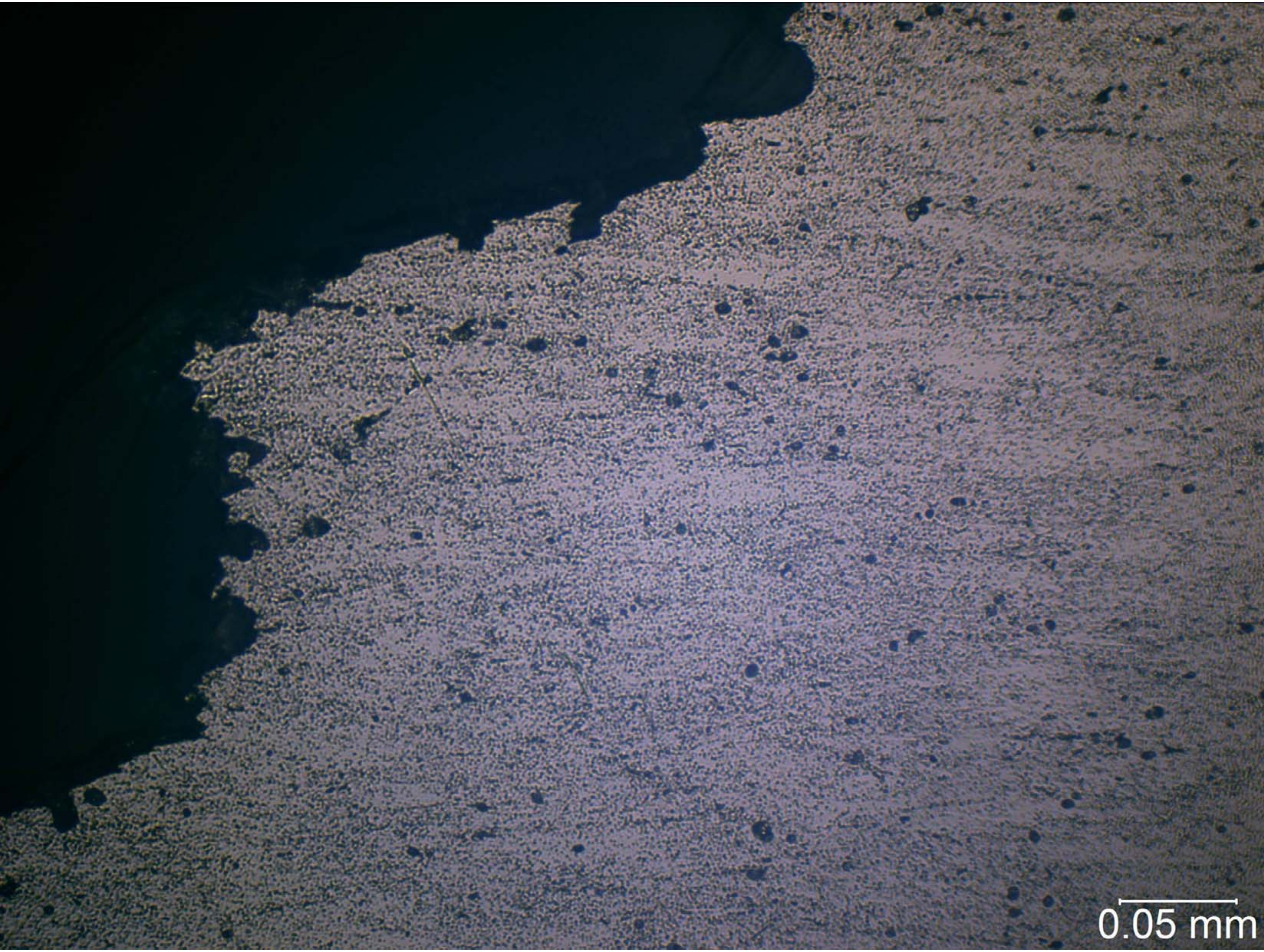
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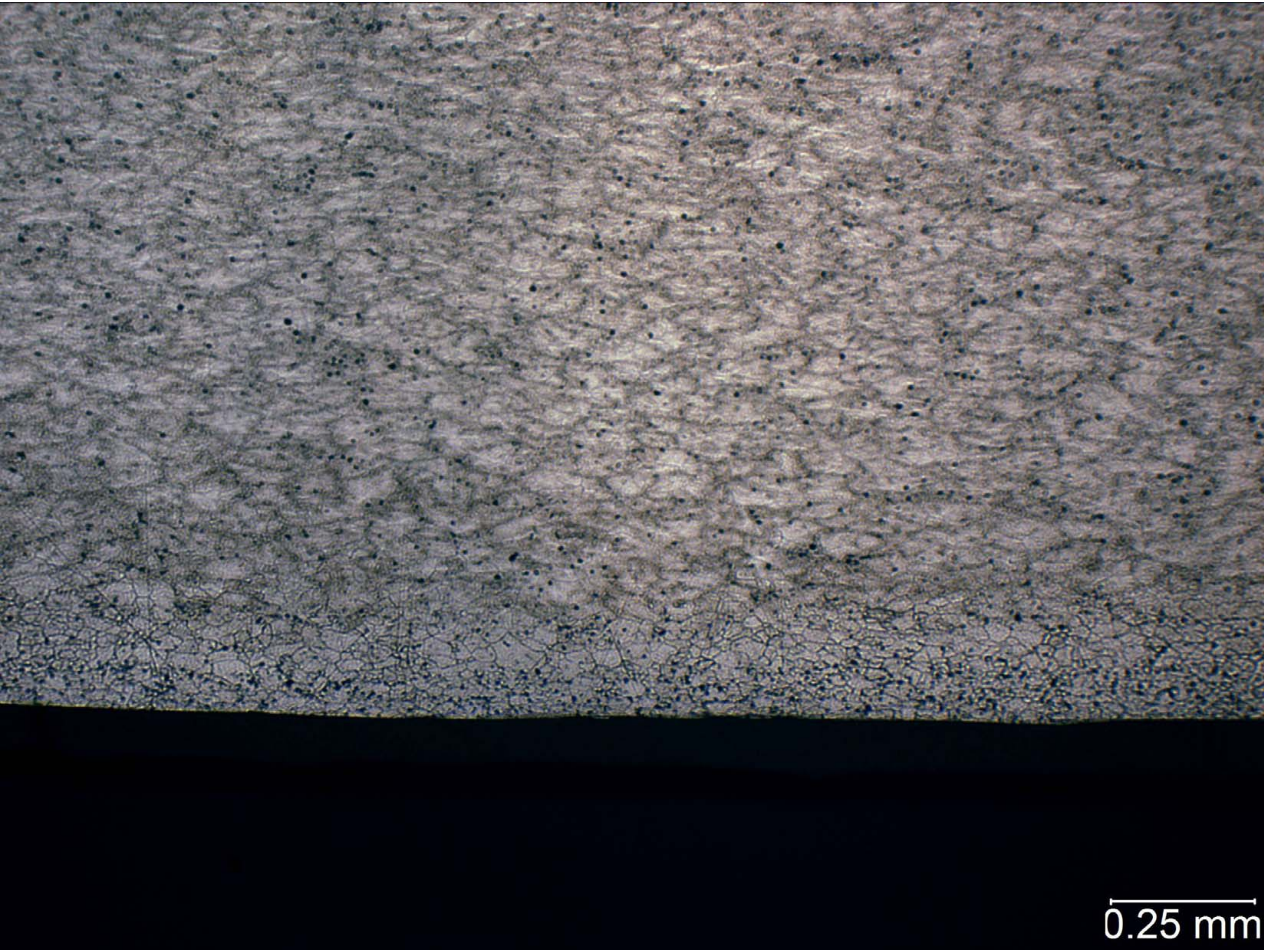
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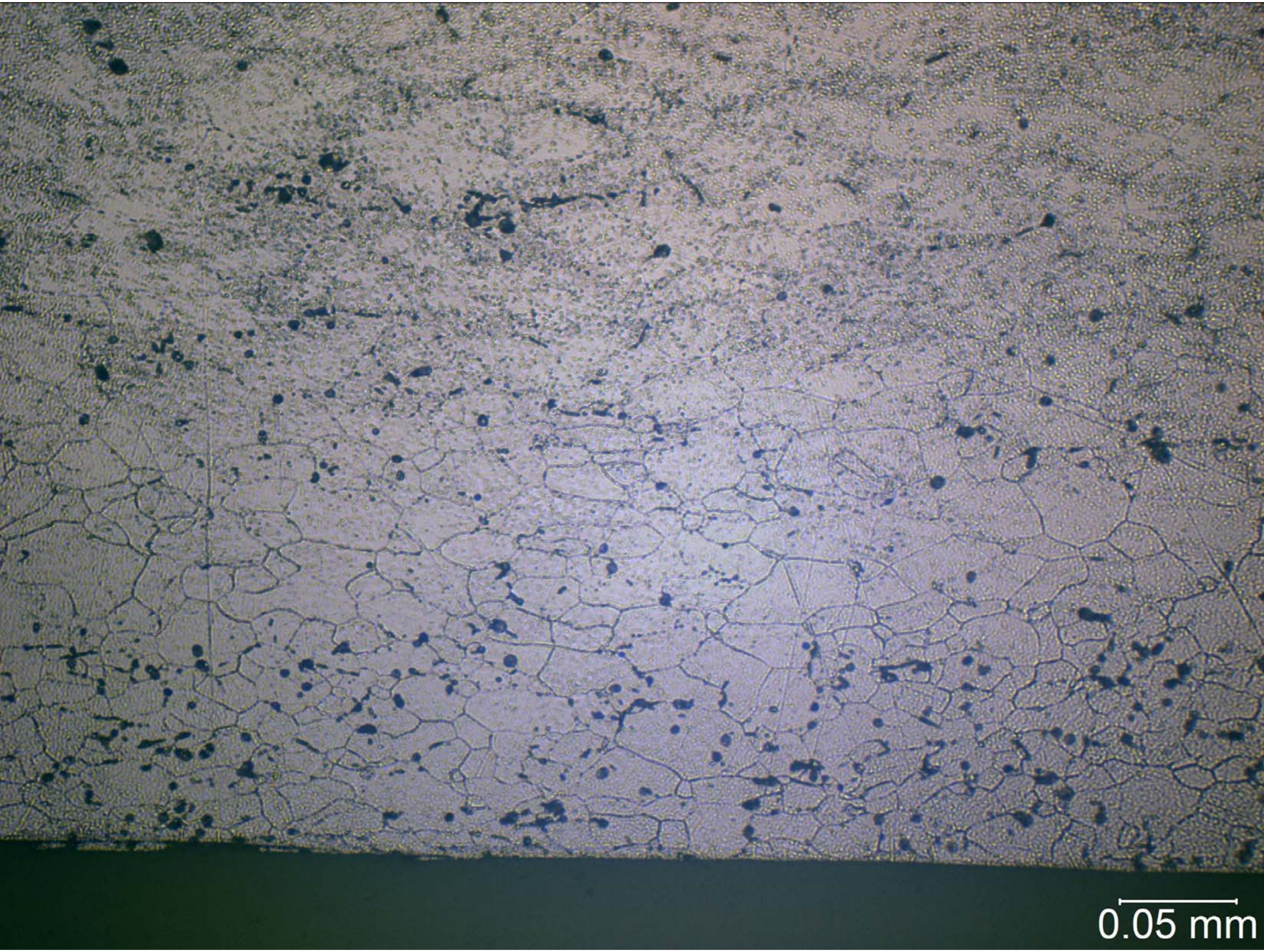

0.05 mm

ATTACHMENT 10

Microhardness Testing

Table 1
Knoop Microhardness Traverse and Converted Rockwell Hardness of **Sample A** from Tank Outside Surface to Tank Inside Surface

Distance (inch)	HK500	Converted HRB
0.000	Outside Surface	
0.010	93.7	25
0.030	99.9	33
0.050	99.2	32
0.070	101.9	36
0.090	99.6	33
0.110	104.0	38
0.130	106.2	41
0.150	101.0	35
0.170	89.0	18
0.177	82.7	8
0.184	Inside Surface	

Table 2
Knoop Microhardness Traverse and Converted Rockwell Hardness of **Sample A** from Tank Fracture Edge towards Tank Center

Distance (inch)	HK500	Converted HRB
0.000	Fracture Edge	
0.010	102.4	36
0.020	102.2	36
0.070	92.2	23
0.170	98.3	31
0.270	101.3	35
0.370	95.9	28
0.470	100.9	34
0.570	103.6	38
0.620	110.0	45
0.670	106.6	41

Table 3
Knoop Microhardness Traverse and Converted Rockwell Hardness of **Sample B** from Tank Outside Surface to Tank Inside Surface

Distance (inch)	HK500	Converted HRB
0.000	Outside Surface	
0.010	122.3	59
0.020	123.7	61
0.030	121.7	59
0.060	117.9	53
0.100	116.8	53
0.130	122.6	60
0.160	118.3	53
0.200	125.8	63
0.230	133.6	67
0.260	124.7	62
0.290	128.0	64
0.320	122.9	60
0.350	125.9	63
0.358	128.3	64
0.363	Inside Surface	

Table 4
Knoop Microhardness Traverse and Converted Rockwell Hardness of **Sample B** from Tank Fracture Edge towards Tank Center

Distance (inch)	HK500	Converted HRB
0.000	Fracture Edge	
0.010	128.5	64
0.020	131.7	66
0.030	133.0	66
0.080	130.7	65
0.130	121.0	58
0.180	127.5	64
0.230	128.0	64
0.280	128.8	64
0.330	125.3	62
0.380	120.8	58
0.430	129.8	65
0.480	119.3	56
0.530	117.3	53
0.580	122.7	60

Table 5
Knoop Microhardness Traverse and Converted Rockwell Hardness of **Sample C** from
Tank Outside Surface to Tank Inside Surface

Distance (inch)	HK500	Converted HRB
0.000	Outside Surface	
0.010	116.5	52
0.020	119.6	57
0.030	117.9	55
0.060	117.5	55
0.100	116.2	52
0.130	115.5	51
0.160	115.0	51
0.200	117.0	53
0.230	120.3	57
0.260	125.3	62
0.290	122.0	59
0.320	123.0	60
0.350	122.8	60
0.358	121.3	58
0.364	Inside Surface	

Table 6
Knoop Microhardness Traverse and Converted Rockwell Hardness of **Sample C** from
Tank Fracture Edge towards Tank Center

Distance (inch)	HK500	Converted HRB
0.000	Fracture Edge	
0.010	128.6	64
0.020	135.0	67
0.030	131.3	65
0.080	128.3	64
0.130	133.9	67
0.180	127.5	63
0.230	126.3	63
0.280	123.8	61
0.330	122.5	59
0.380	122.1	59
0.430	121.4	58
0.480	118.0	55
0.530	124.9	62
0.580	117.2	53

Table 7
Knoop Microhardness Traverse and Converted Rockwell Hardness of **Sample D** from Tank Outside Surface to Tank Inside Surface

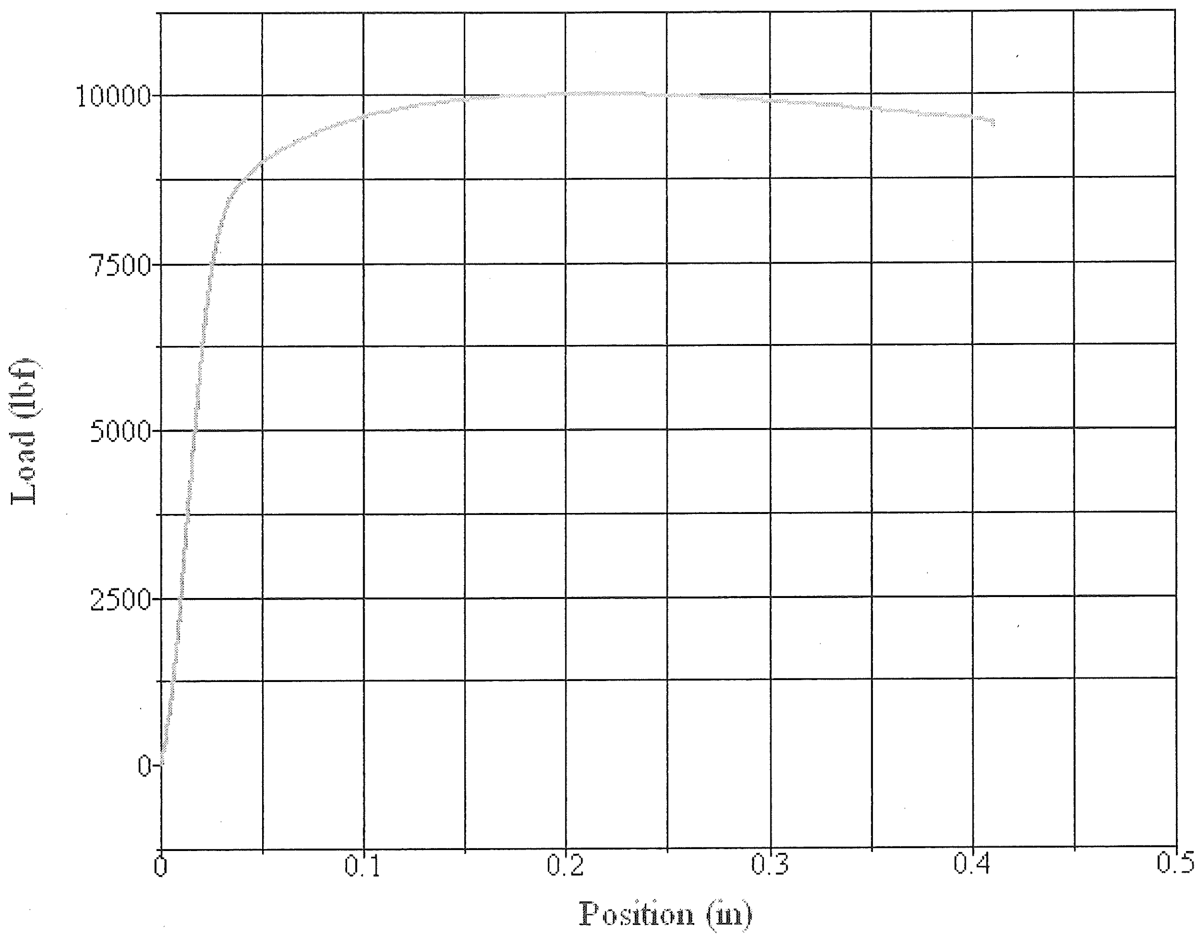
Distance (inch)	HK500	Converted HRB
0.000	Outside Surface	
0.010	121.3	58
0.020	130.3	65
0.030	123.4	60
0.060	126.4	63
0.100	126.0	63
0.130	120.1	57
0.160	122.8	60
0.200	125.7	63
0.230	121.0	58
0.260	126.1	63
0.290	121.1	58
0.320	125.4	62
0.350	128.2	64
0.357	Inside Surface	

Table 8
Knoop Microhardness Traverse and Converted Rockwell Hardness of **Sample D** from Tank Fracture Edge towards Tank Center

Distance (inch)	HK500	Converted HRB
0.000	Fracture Edge	
0.010	121.6	59
0.020	127.3	63
0.030	132.9	66
0.080	142.8	71
0.114	141.9	71
0.164	133.9	67
0.214	132.0	66
0.264	124.8	62
0.314	125.9	63
0.364	125.2	62
0.414	126.1	63
0.464	129.0	64
0.514	126.7	63
0.564	127.5	64
0.614	130.9	65
0.654	125.6	63

ATTACHMENT 11

Tensile and Compression Testing



Test Summary

Counter:	13137
Elapsed Time:	00:01:05
Anamet Job Number:	5004.7104
Specimen Identification:	1
Operator:	eaf/bck
Comments:	Commpression Lenght 1.503"
Procedure Name:	Compression Load
Start Date:	3/14/2012
Start Time:	10:37:20 AM
End Date:	3/14/2012
End Time:	10:38:25 AM
Workstation:	MECH
Tested By:	Brian
Customer:	RTI

Test Results

Load at Peak Load:	10010.1900 lbf
Position at Peak Load:	0.2137 in
Halt of Force Yield:	10010.1900 lbf
Width:	0.5000 in
Length: (Thickness)	0.3480 in
Area:	0.1740 in²

Anamet, inc

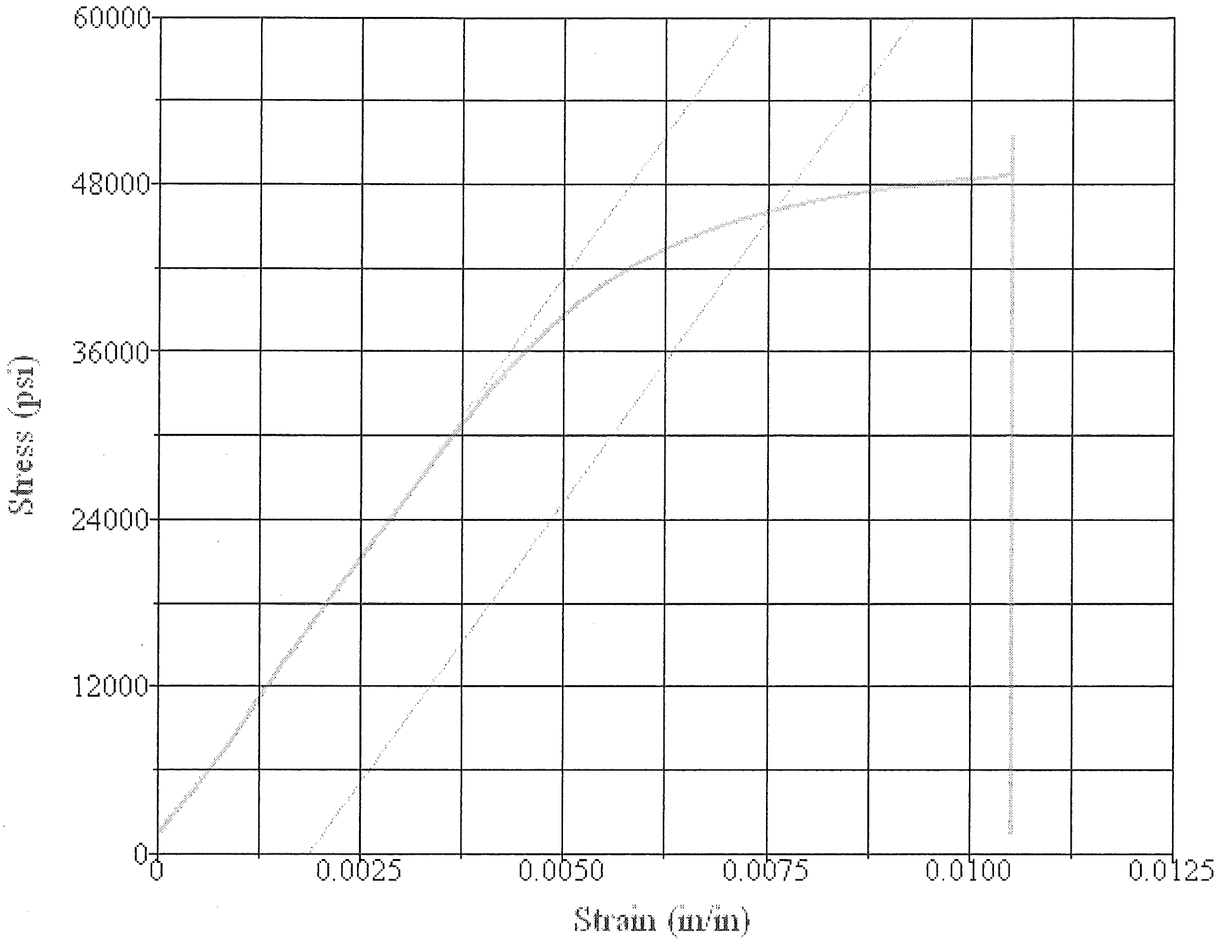
Anamet, inc Materials Engineering & Laboratory Testing

26102 EDEN LANDING ROAD, SUITE 3 • HAYWARD, CALIFORNIA 94545 •(510) 887-8811 • FAX (510) 887-8427

Table 1

Results of Tensile Test on a Specimen from the SCUBA Tank

Property		Tank	
Dimensions of Specimen	Width	0.509	inch
	Thickness	0.381	inch
Area		0.194	$inch^2$
Tensile Load		9965	lbs
Tensile Strength		51400	psi
Yield Load 0.2% Offset		8937	lbs
Yield Strength 0.2% Offset		46100	psi
Specimen Length	After		inch
	Before	5.187	inch
Elongation		0.30	inch
Elongation in 2.0” Gage		15	%



Test Summary

Counter:	13136
Elapsed Time:	00:03:15
Anamet Job Number:	5004.7109
Specimen Identification:	1
Operator:	eaf/bck
Procedure Name:	Tensile 2in. Ext.
Start Date:	3/14/2012
Start Time:	10:16:20 AM
End Date:	3/14/2012
End Time:	10:19:35 AM
Workstation:	MECH
Tested By:	Brian
Customer:	RTI
Comments:	

Test Results

Tensile Strength:	51392.4700 psi
Peak Load:	9965.0000 lbf
Young's Modulus:	8.07e+006 psi
Area:	0.1939 in²
Stress at Break:	2764.3120 psi
Load at Break:	536.0000 lbf
Halt of Force Yield:	9486.0000 lbf
Load at Offset:	8937.8910 lbf
Stress at Offset:	46095.3700 psi
Width:	0.5090 in
Thickness:	0.3810 in

ATTACHMENT 12

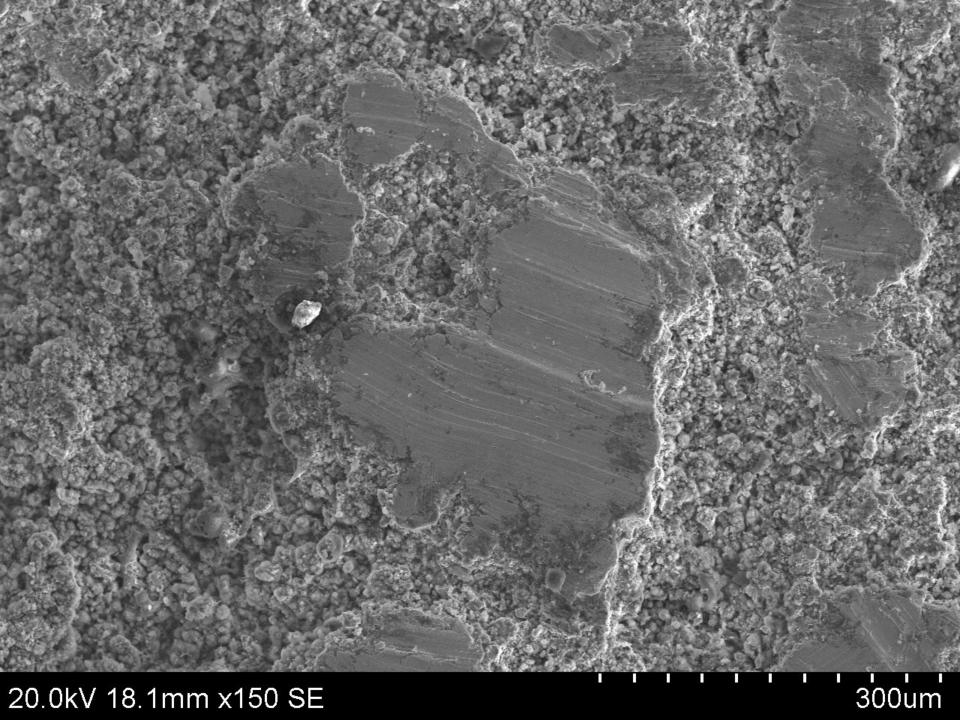
Scanning Electron Microscope Images
SEM images, in order of appearance

Pressure Regulator Adaptor 1 – 150x
Pressure Regulator Adaptor Air Cup 2 - 100x
Pressure Regulator Adaptor 1 – 25x
Pressure Regulator Adaptor 2 – 500x
Pressure Regulator Adaptor 3 – 27x
Pressure Regulator Adaptor 4 – 500x
Pressure Regulator Adaptor 5 – 27x
Pressure Regulator Adaptor 6 – 500x
Pressure Regulator Adaptor 7 – 27x
Pressure Regulator Adaptor 8 – 500x

Cylinder Inside Surface A 1 – 40x

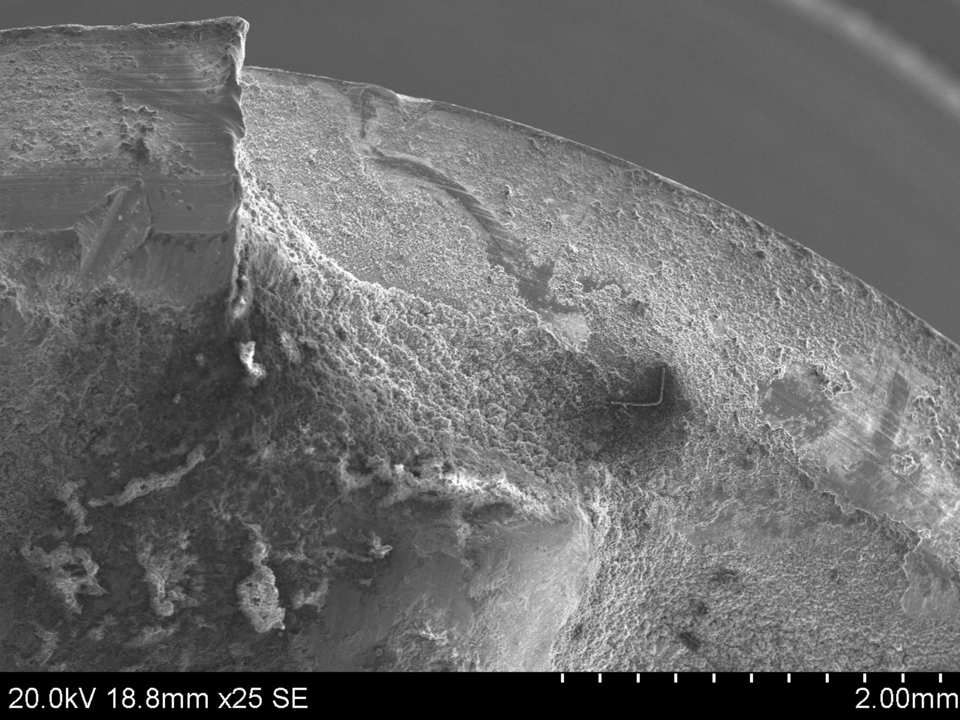
Valve Seat Body Exemplar 1 – 14x
Valve Seat Body Exemplar 2 – 14x
Valve Seat Body Subject 1 – 14x
Valve Seat Body Subject 2 – 14x

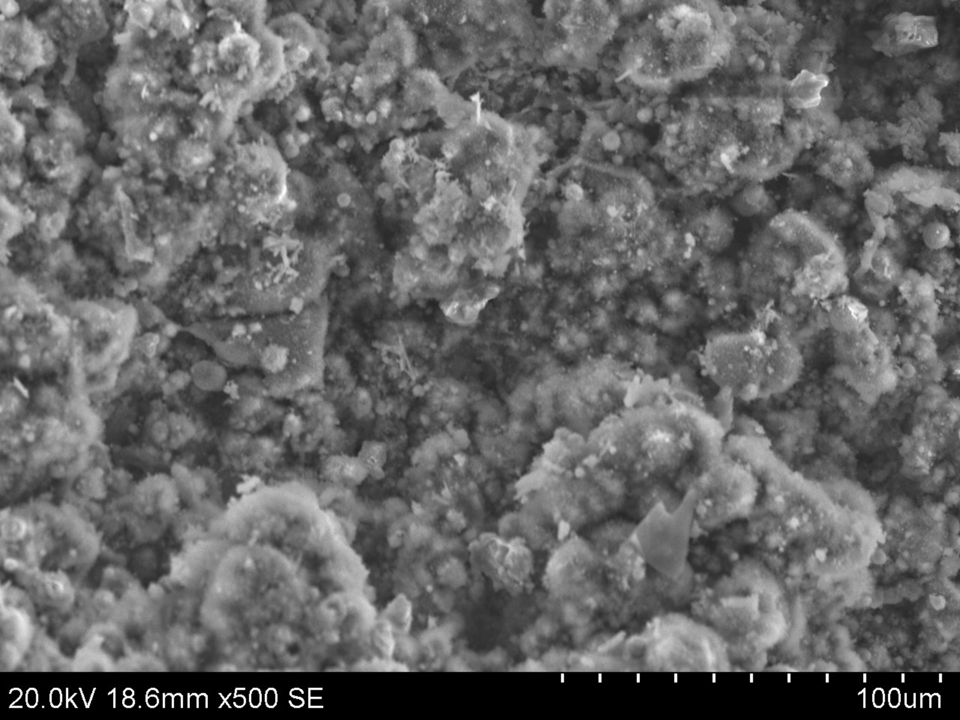
Valve Stem 1 – 40x
Valve Stem 2 – 40x
Valve Stem 3 – 40x
Valve Stem 4 – 40x
Valve Stem 5 – 40x
Valve Stem 6 – 500x
Valve Stem 7 – 1000x
Valve Stem 8 – 500x

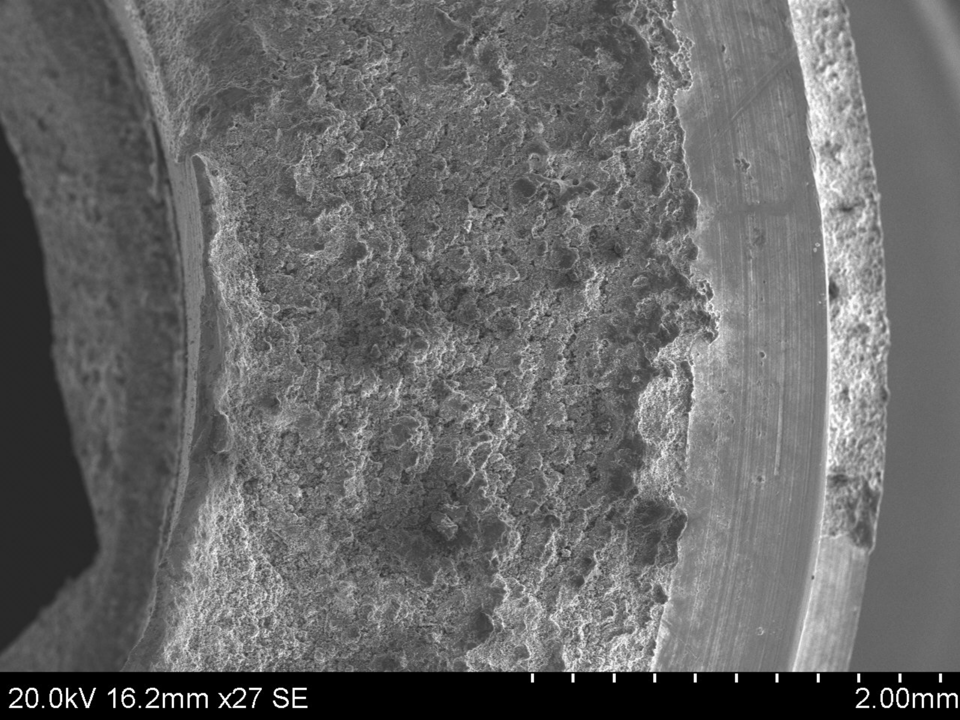


20.0kV 18.1mm x150 SE
300um


20.0kV 22.4mm x100 SE
500um


20.0kV 18.8mm x25 SE
2.00mm


20.0kV 18.6mm x500 SE
100um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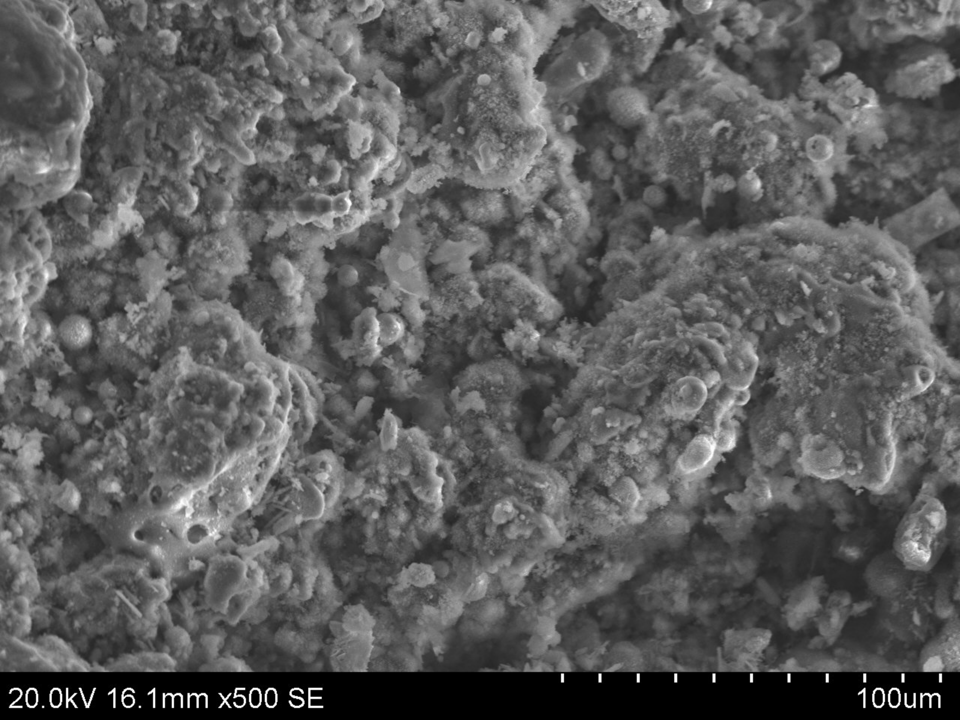
2.00mm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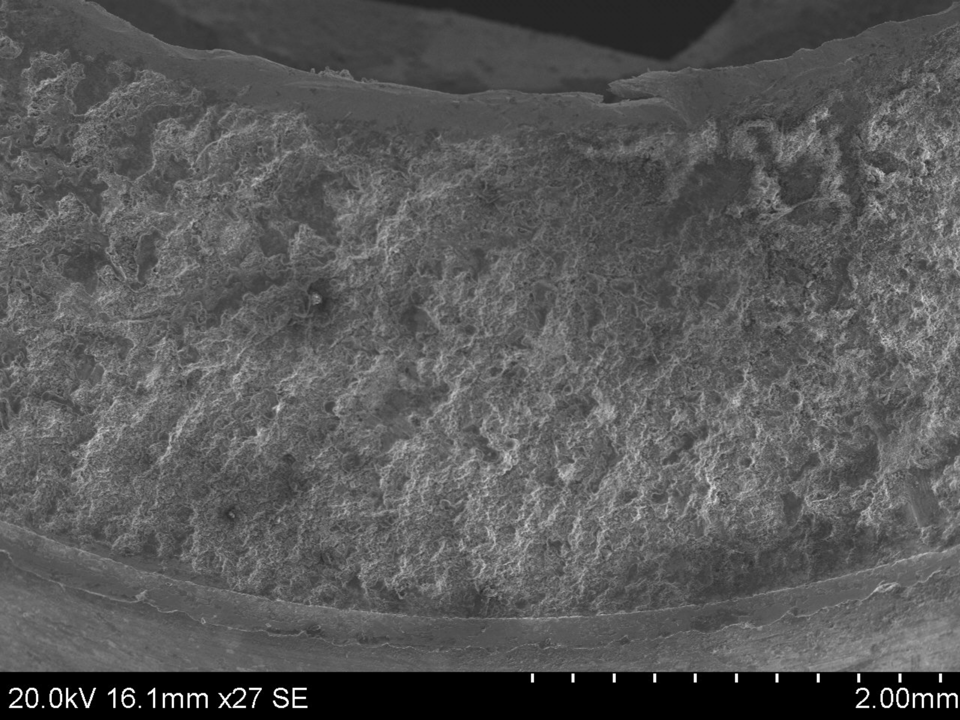
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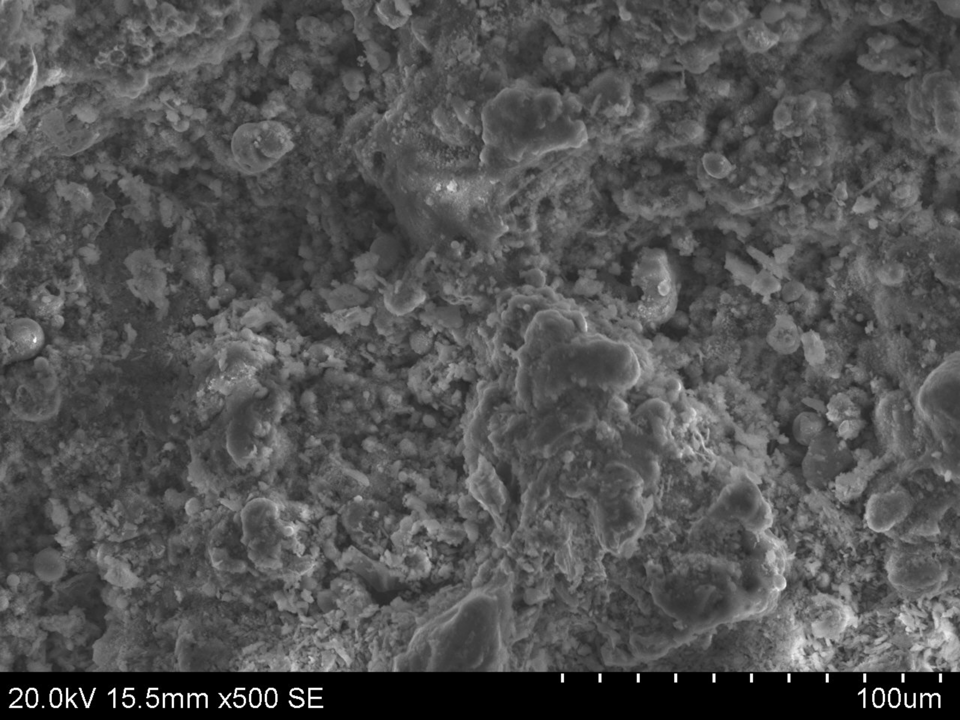
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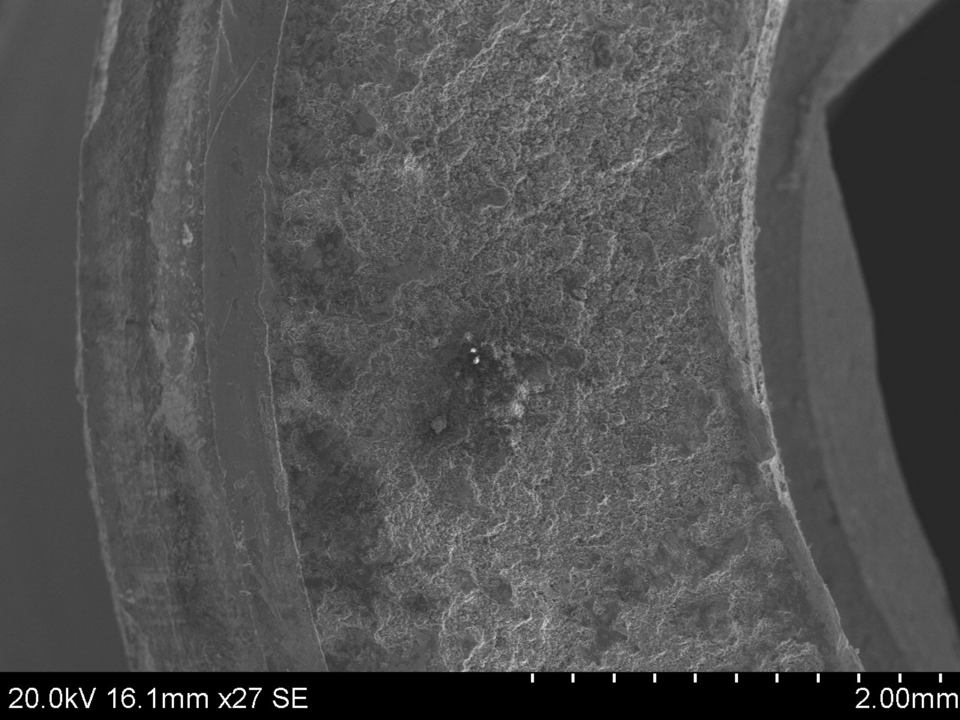
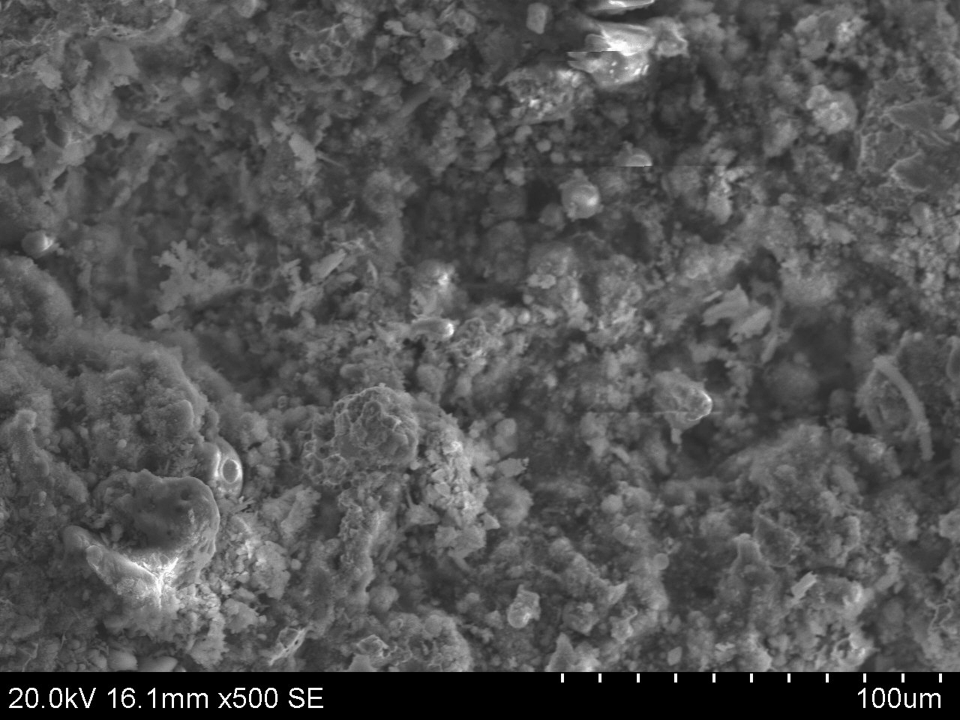
100um


20.0kV 16.1mm x27 SE
2.00mm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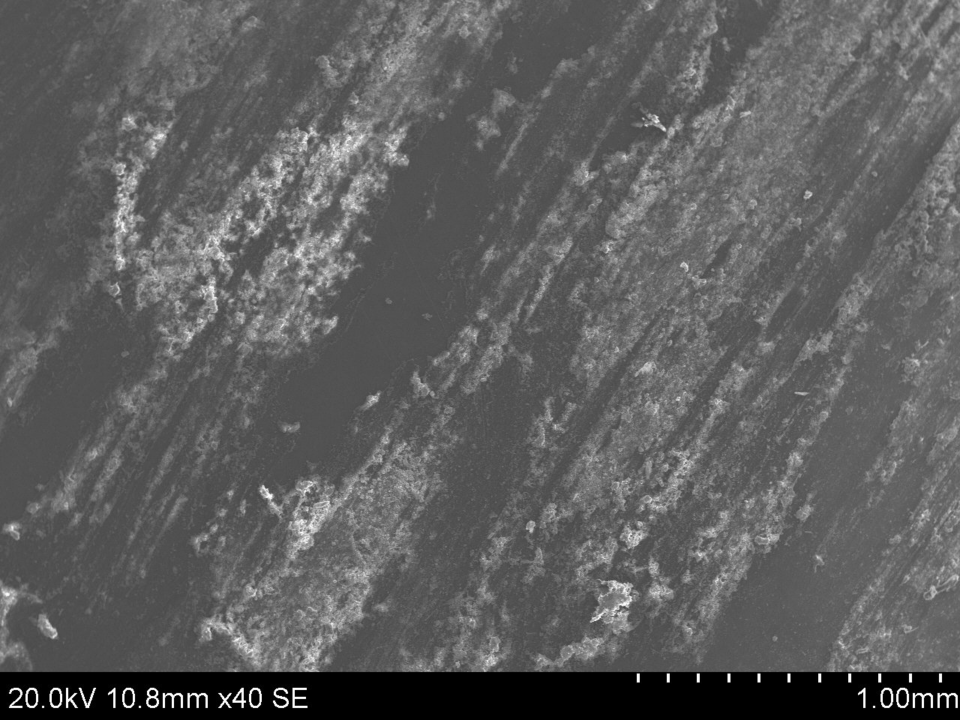
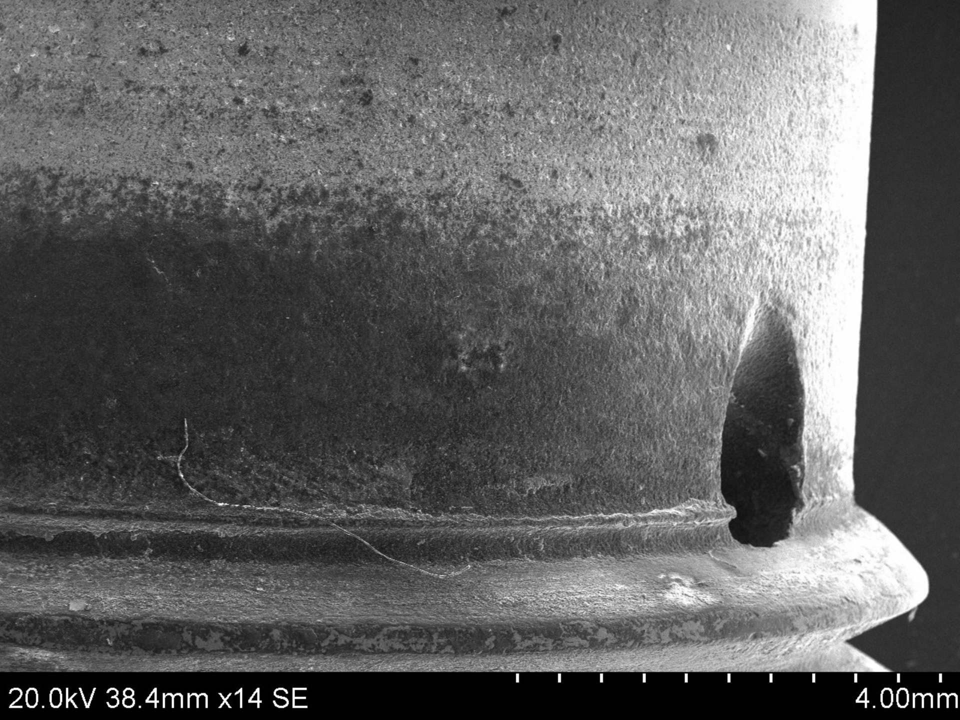
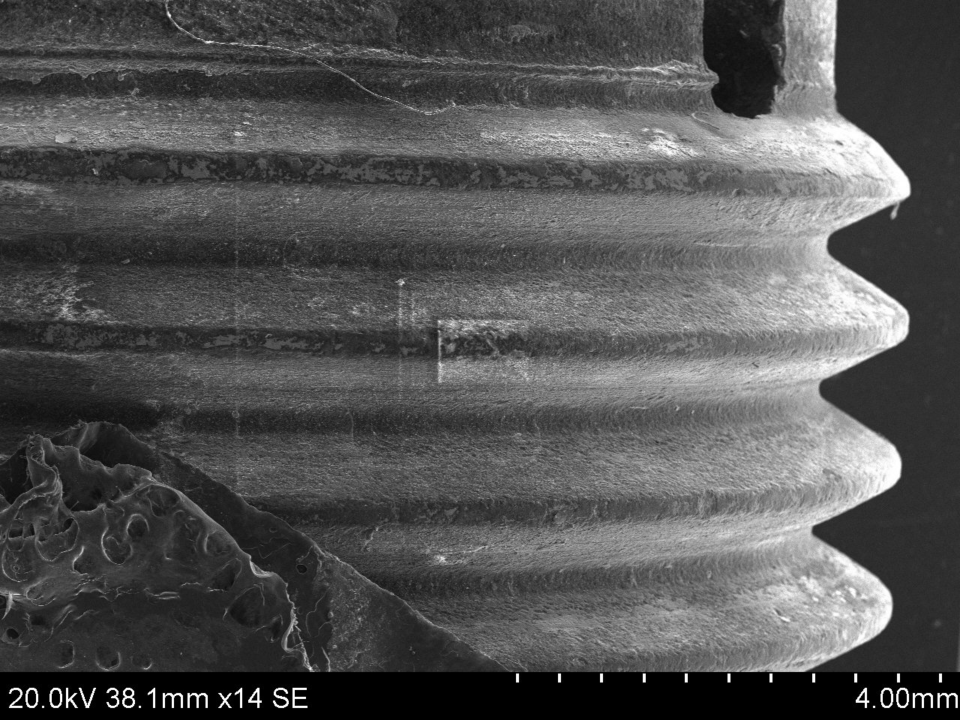
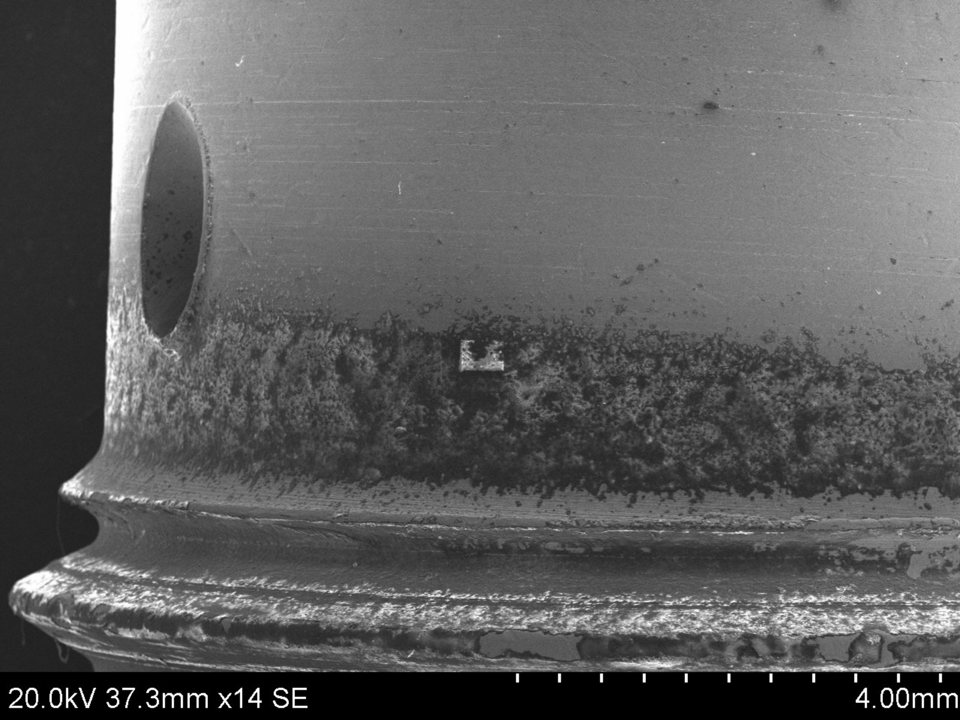

20.0kV 10.8mm x40 SE
1.00mm


20.0kV 38.4mm x14 SE
4.00mm


20.0kV 38.1mm x14 SE
4.00mm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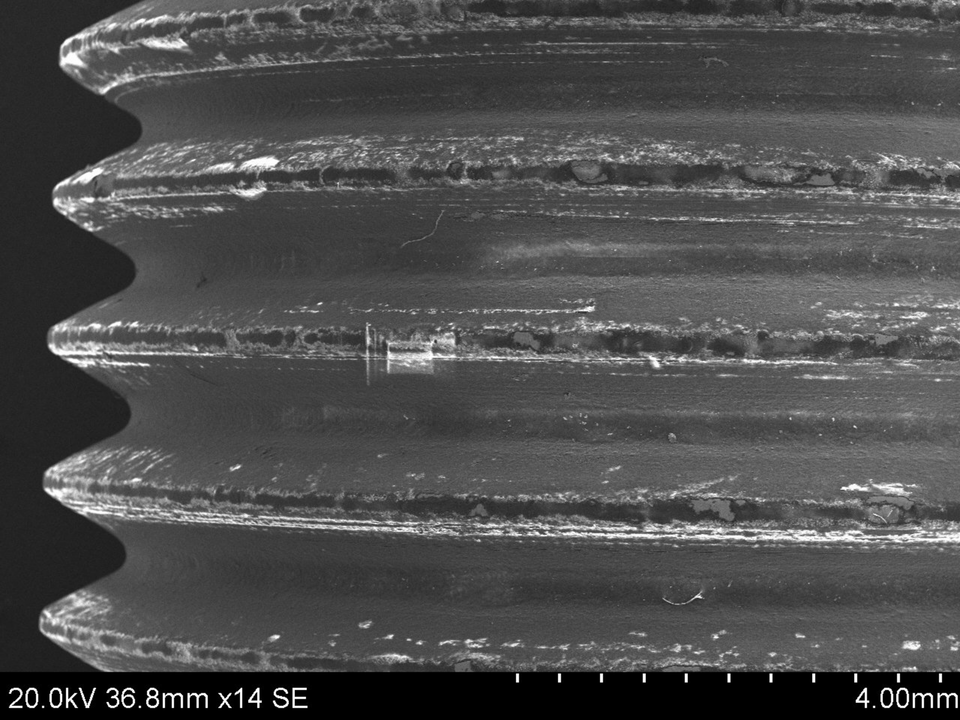
4.00mm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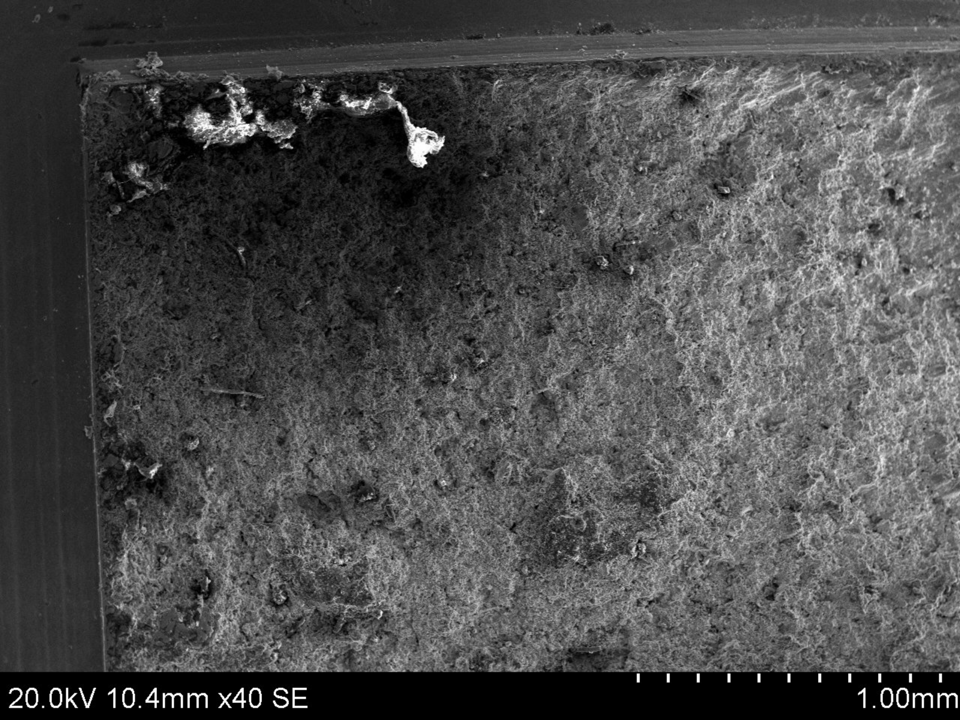
4.00mm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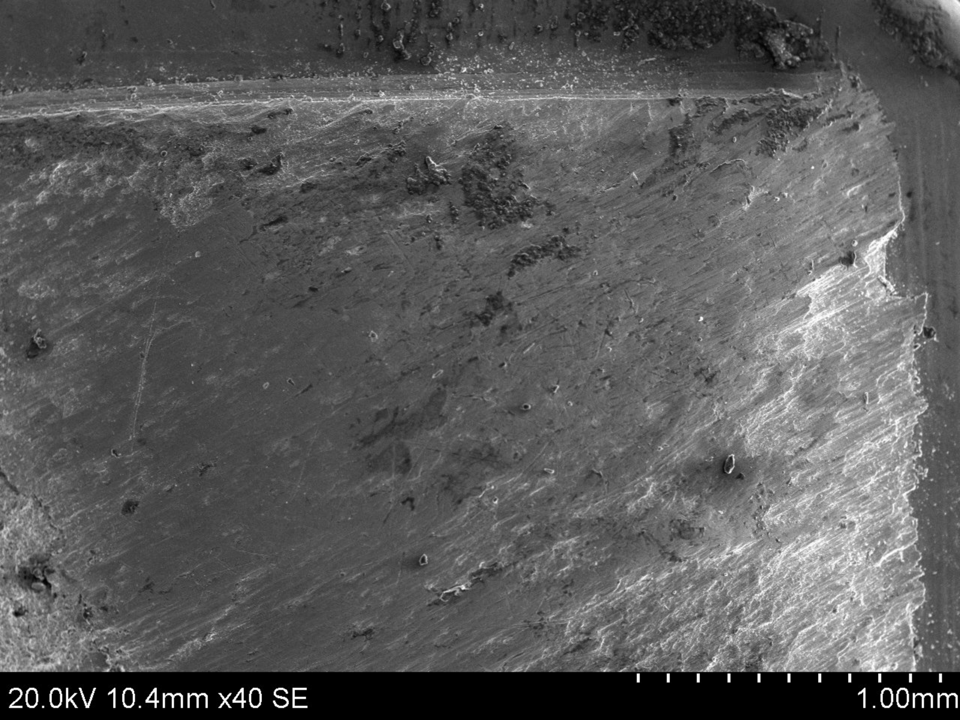
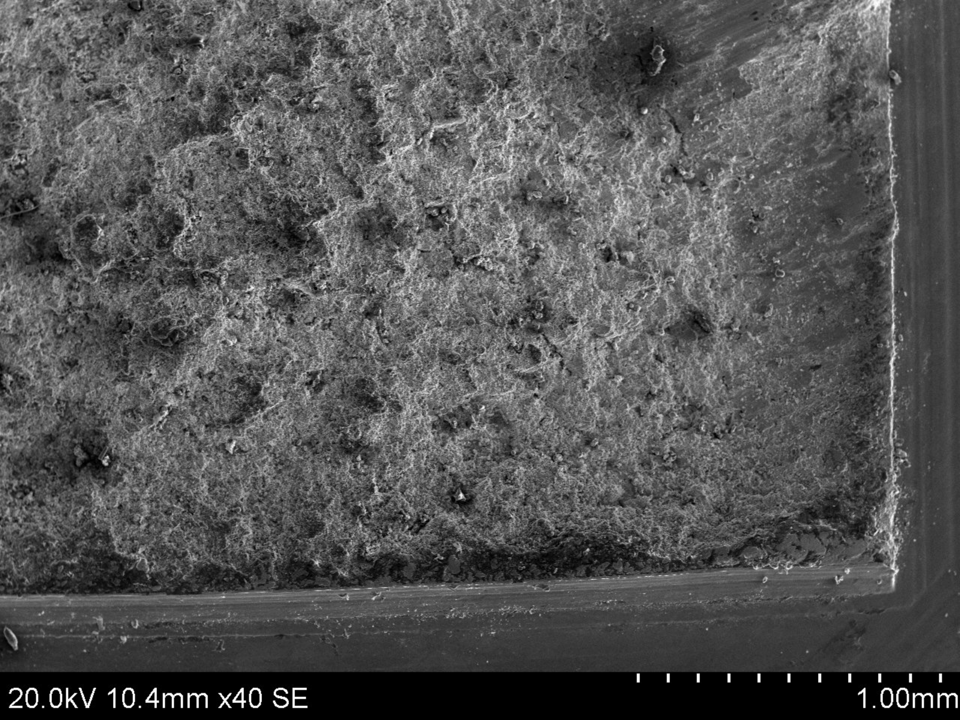
1.00mm


20.0kV 10.4mm x40 SE
1.00mm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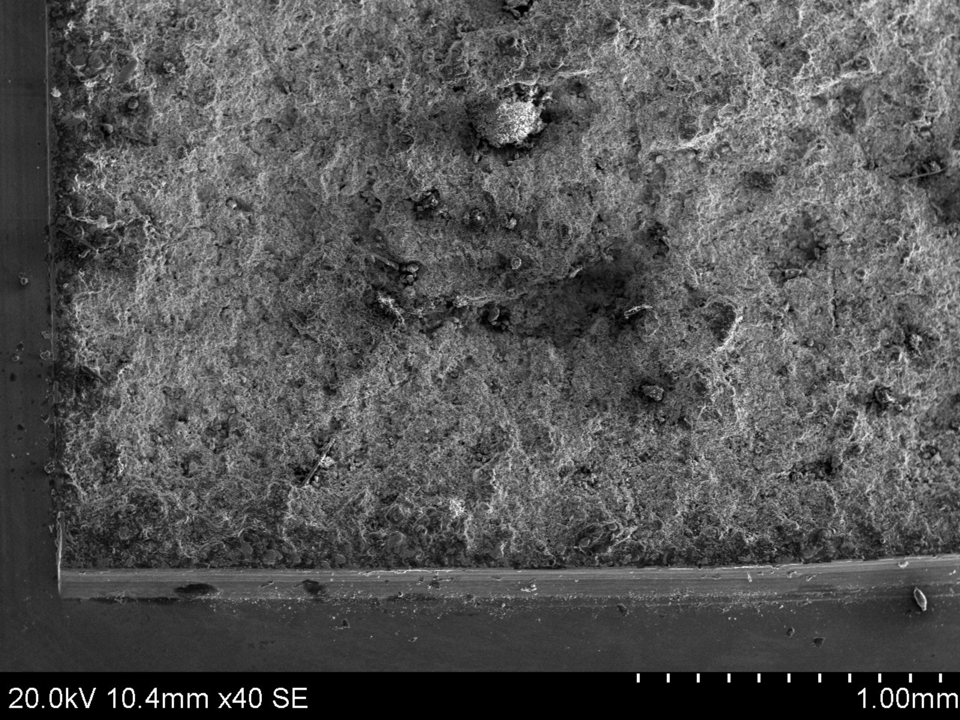
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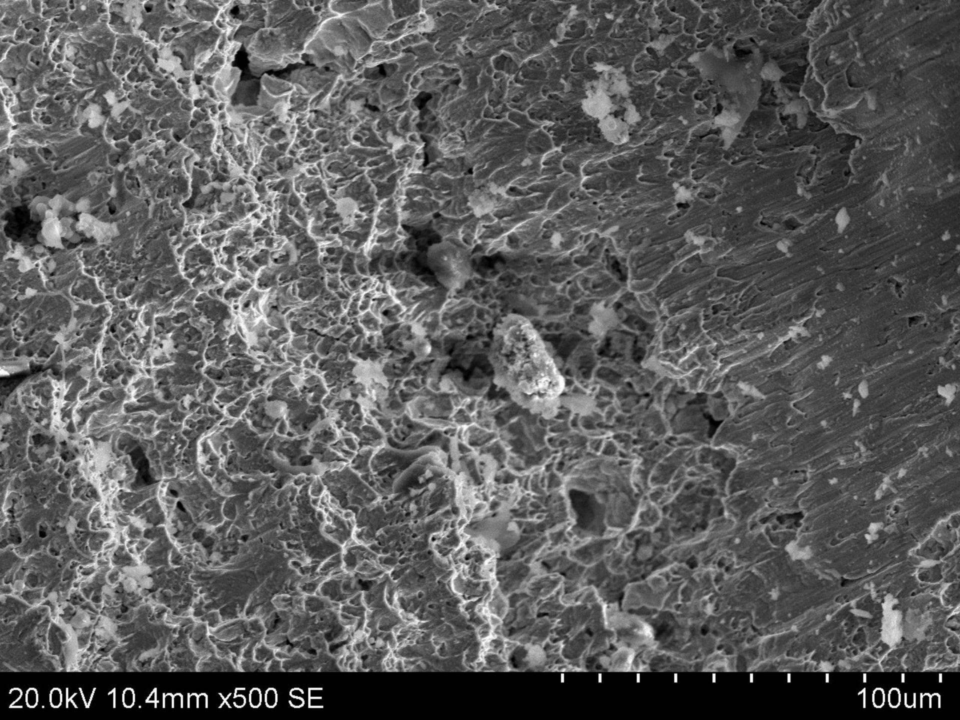
1.00mm


20.0kV 10.4mm x40 SE
1.00mm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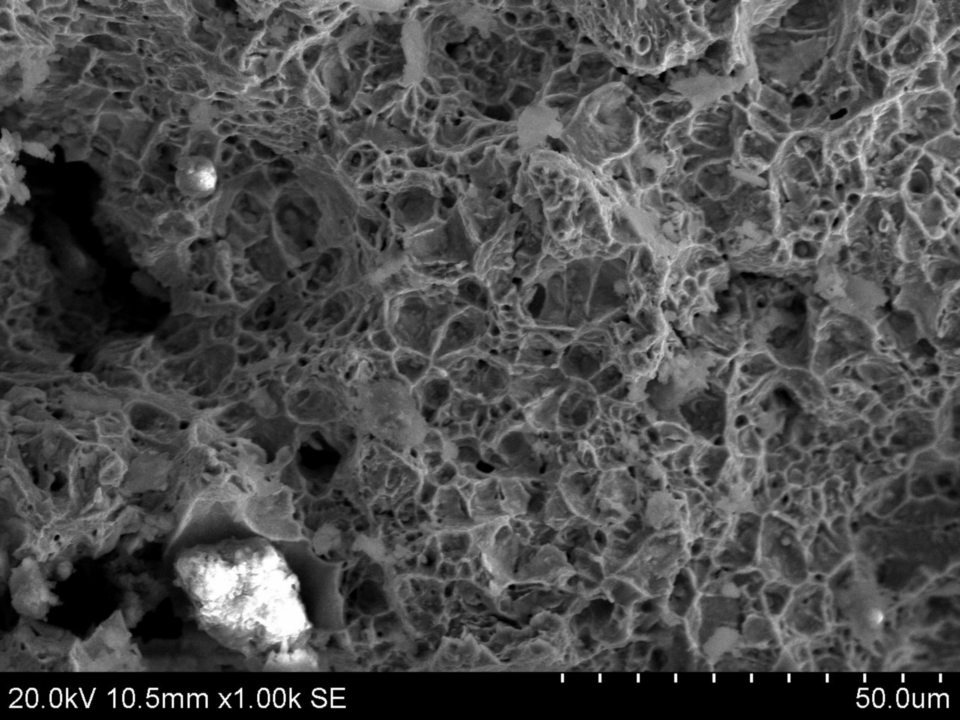
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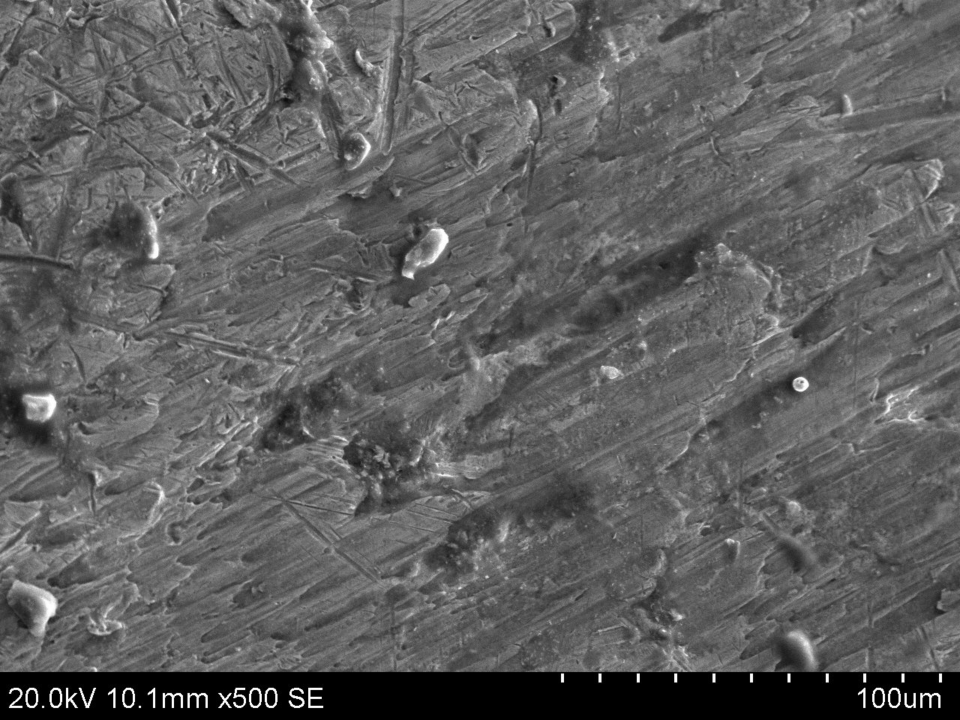
50.0um

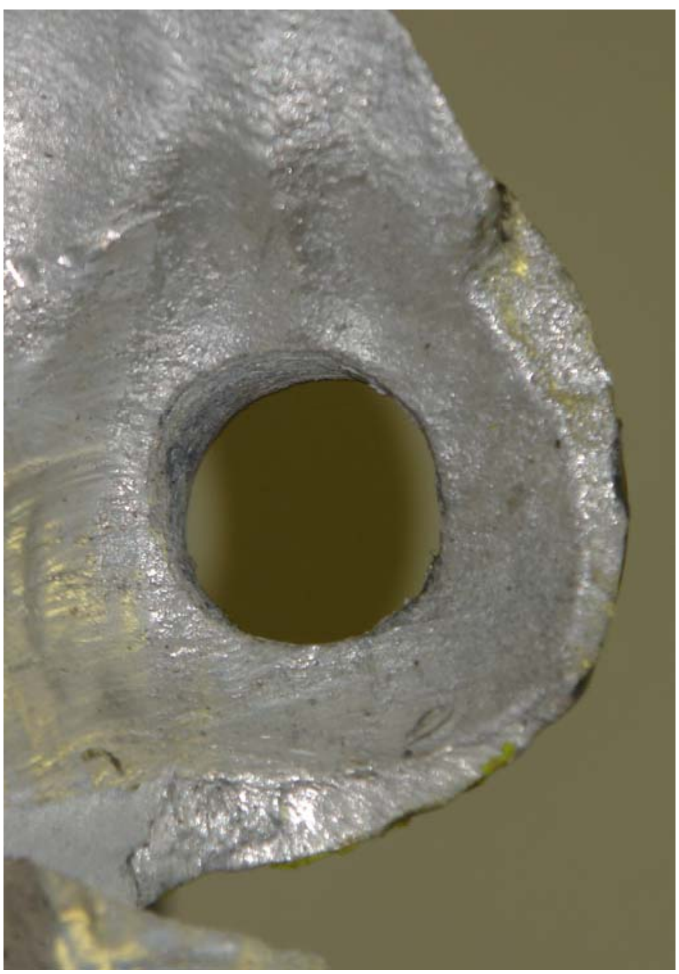
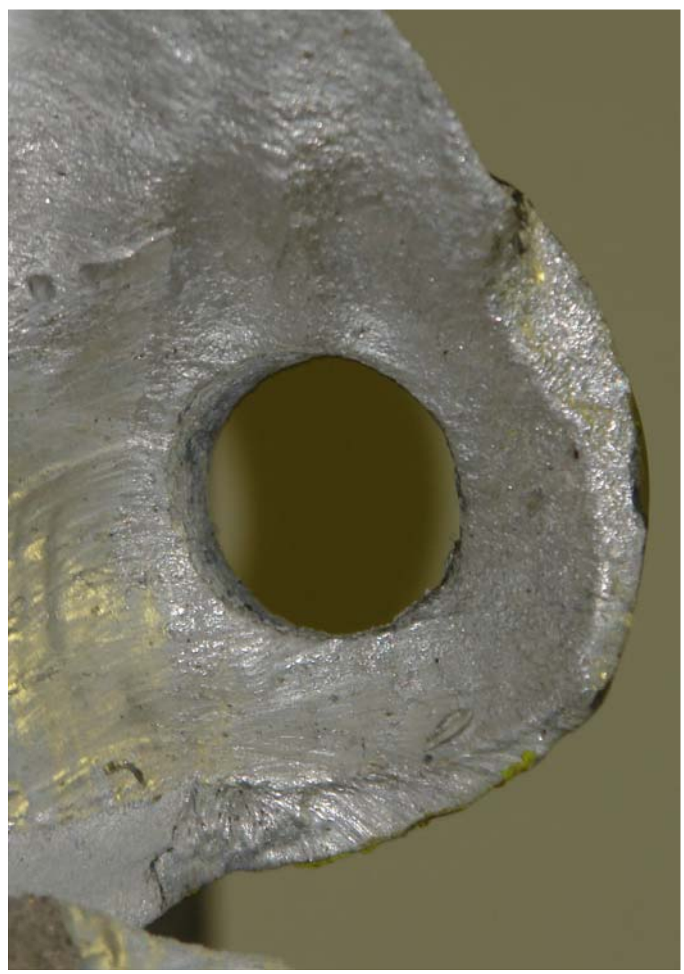

20.0kV 10.1mm x500 SE
100um

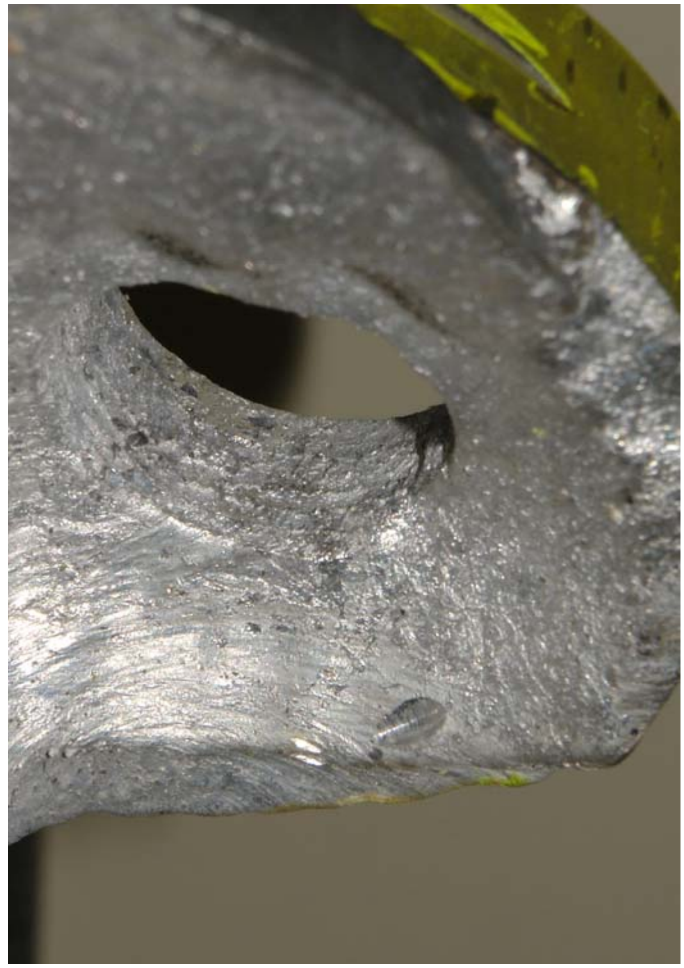
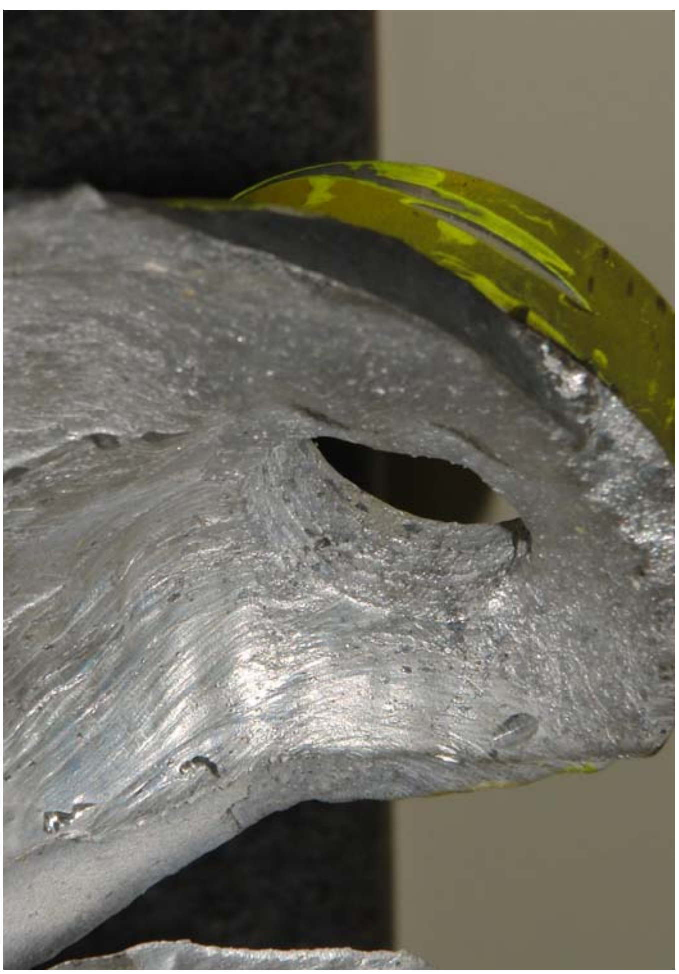
ATTACHMENT 13

Inspection Photos of Jun. 8, 2012

Images of interior surface combustion area





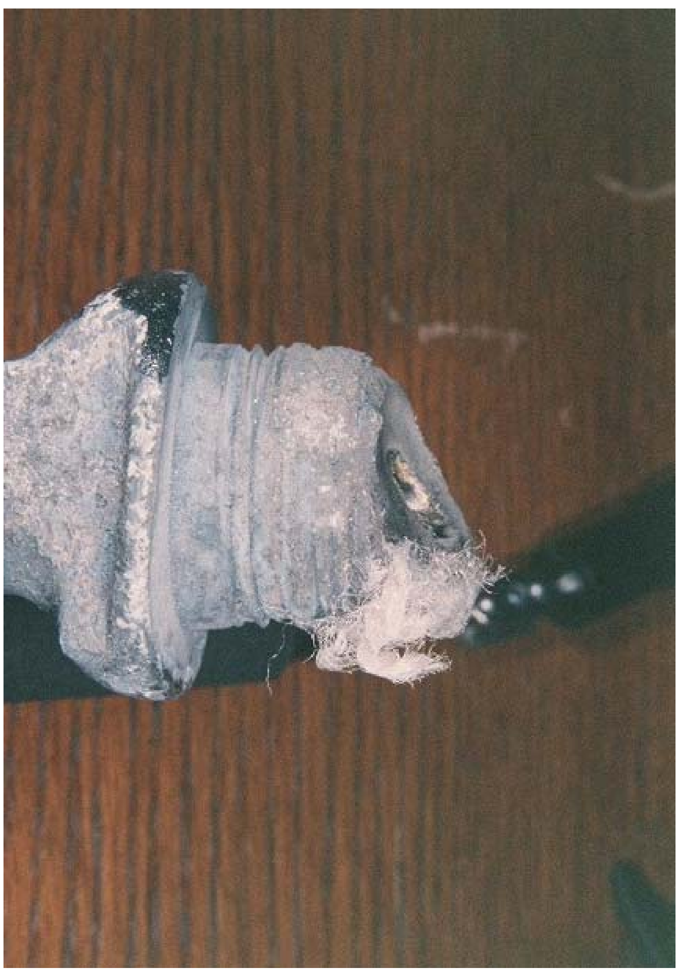


















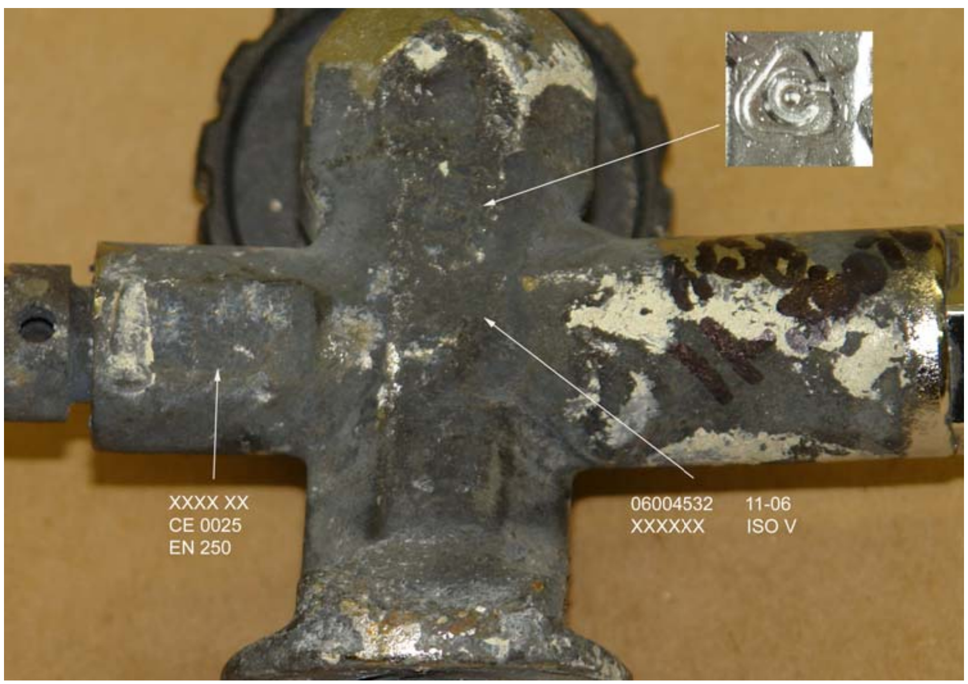
ATTACHMENT 14

Surface Curvature Measurements



ATTACHMENT 15

Cylinder Valve Markings


XXXX XX
CE 0025
EN 250
06004532 11-06
XXXXXX ISO V










ATTACHMENT 16

Chain of Custody

RTI Group, LLC
910 Bestgate Road, Suite E
Annapolis, MD 21401
ofc: +1 410 571 0712 | fax: +1 410 571 0713
www.rtiForensics.com
FORENSIC ENGINEERING SINCE 1975

CHANGE OF EVIDENCE CUSTODY RECORD

DATE: November 22, 2011

RTI File Name: DOT – Ruptured Scuba Cylinder

RTI File No.: 50151.ME002

The evidence herein described has been transferred on this date - -

To:	**Richard Loucks, PhD, PE**	**From:**	**U.S. Dept of Transportation Property Inventory Report**
Company:	**RTI Group, LLC**	**Company:**	

Description of Evidence (Note all markings):

1. **SEE ATTACHED LIST.**

Authorization of **Sending** Party:	Authorization of **Receiving** Party:
(Signature & Date)	(Signature & Date)
(Printed)	(Printed) Richard B. Loucks, PhD, PE

Matter: 50151ME002

Matter Name: DOT – Ruptured SCUBA Cylinder

Evidence Inventory

1) Yellow high pressure gas cylinder, Part 1

Smaller fragment from the cylinder, approximately 12 inch by 6 inch. Has the following marks at near the neck:

DOT-3AL 3000 HY-MARK

Cylinder has two decals

Decal 1: OXYGEN for decompression use only – MOD (Maximum Operating Depth) 20 FSW (20 feet submerged water), MOD 6 MSW (6 meters submerged water), International Association of Nitrox & Technical Divers, Inc.

Decal 2: "Tank & Valve Have Been Cleaned For Premix, Oxygen Content 22 to 40%" is not punched out. "Tank & Valve Have Been Cleaned In Accordance With O_2 Service" Is punched out at 2011. The month is uncertain.

2) Yellow high pressure gas cylinder, Part 2

Larger section, contains the bottom, neck and valve opening, measures about 24 inches by 14 inches. Has the following markings near the neck:

OU 0001 M5442 10 07 S40 TC-3AL 207

3) High Pressure Tank Valve, DIN Valve, manufactured by Genesis. 5000 psi, 30 lb/hr CG-1 type rupture disk. Oxygen (Fire Toxicity State and Corrosiveness FTSC Code 4160: 4 -highly oxidizing, 1-nontoxic, 6-nonliquified gas between 500 and 3000 psig, 0-noncorrosive, Class 2 Division 2.2 gas) use permits CG-1 (required in one end of the cylinder, regardless of length). A pressure regulator adaptor is present in the opening which has a fractured outlet. The metal particle filter is evident in the opening.

3) Regulator by Dive Rite, serial number 12008135, fitted with regulator fitting. The opening is occupied by the fractured end of the pressure regulator adaptor

Attached:

1. Black pressure line with dial gage on high pressure side of regulator. Dial gage face is heat affected and the gage is illegible.
2. Length of green pressure line stating "WARNING Do not exceed 250 psi (17 bar) high pressure may cause damage or personal injury" no manufacturer identified. Distal end terminates unattached. Low pressure side

U.S. DEPARTMENT OF TRANSPORTATION PROPERTY INVENTORY REPORT

DATE:	TIME:	LOCATION:	INSPECTION TYPE:	CASE Nº.
11/9/11				

COMPLAINANTS NAME: Vanhorn, Russell (deceased)	REASON FOR TAKING INTO D.O.T. CUSTODY: Ruptured cylinder examine for cause	SIGNATURE OF PROPERTY CUSTODIAN:
COMPLAINANTS ADDRESS: 5875 37th N. Apt 6 St. Petersburg FL 33710		DATE TAKEN INTO D.O.T. POSSESSION: 11/9/11
CONTACT NAME & PHONE NO.		

ITEM Nº	QUANTITY	DESCRIPTION OF PROPERTY
1	1	Scuba cylinder
2	1	Separated piece of scuba cylinder
3	1	valve, regulator and hose
		Nothing follows

ITEM Nº	DATE AND TIME RELEASED	DATE AND TIME ~~RETURNED~~ RECEIVED	SIGNATURE AUTHORIZING	SIGNATURE RECEIVING
1	11/10/11	11/15/11	[signature]	[signature]
2	11/10/11	11/15/11	[signature]	[signature]
3	11/10/11	11/15/11	[signature]	[signature]

PROPERTY.FRM

KEEP WITH PROPERTY

Anamet, inc Materials Engineering & Laboratory Testing, Since 1958

EVIDENCE CHANGE OF CUSTODY RECORD

Date Received/Shipped/Transferred: July 2, 2012

Anamet, Inc. File No: 5004.7532

Anamet, Inc. File Name: RTI Group RTI File 50151.ME002 RTI File Name: DOT Ruptured Scuba Cylinder

The evidence herein described has been transferred on this date to:

Matthew Wagenhofer
Name (Please Print)

Representing: RTI Group
Company Name (Please Print)

From: Norman Yuen
Name (Please Print)

Name Representing: Anamet
Company Name (Please Print)

Description of Evidence:

Two halves tensile specimen
One tank valve body

Signatures:

To: [signature] Date: 7/9/12

From: Norman Yuen

26102 Eden Landing Road, Suite 3, Hayward, California 94545-3811 • Phone: 510-887-8811 • Fax: 510-887-8427 • www.anametinc.com

RTI Group, LLC
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www.rtiForensics.com

FORENSIC ENGINEERING SINCE 1975

CHANGE OF CUSTODY RECORD

DATE:	**TBD**
RTI File Name:	**DOT – Ruptured Scuba Cylinder**
RTI File No.:	**50151.ME002**

The evidence herein described has been transferred on this date - -

To:	**TBD**	From:	**Richard B. Loucks, PhD, PE**
Company:	**U.S. Department of Transportation Pipeline and Hazardous Materials Safety Admin. 1200 New Jersey Ave., SE Room E21-338 Washington, DC 20590**	Company:	**RTI Group, LLC 910 Bestgate Rd., Suite E Annapolis, MD 21401**

Description of Evidence (Note all markings):

1. See attached description of evidence listing.
2.
3.
4.
5.
6.

Authorization:

Authorization of **Sending** Party:	Authorization of **Receiving** Party:
(Signature)	(Signature)
(Printed: name, company, address) **Richard B. Loucks, PhD, PE RTI Group, LLC 910 Bestgate Rd., Suite E Annapolis, MD 21401**	**(Printed: name, company, address)**

CHANGE OF EVIDENCE CUSTODY RECORD

RTI File Name: DOT-Ruptured Scuba Cylinder
RTI File No.: 50151.ME002

Description of Evidence Listing
Date____________

Contained in	Further contained in	Further contained in	Item	Part No.	Description
Bag "Tank Mounts A,B,C,D"			Sample A	1-a-i	Hardness tested sample
			Sample B	1-b-i	Hardness tested sample
			Sample C	1-c-i	Hardness tested sample
			Sample D	1-d-i	Hardness tested sample
Tupperware container 1			Fragment of the Scuba Tank	2	Approx. 6"x12". Two Decals.
Bag 2	Bag "Subject Valve - Relief Valve"		Relief Valve	3-a	Intact 5000psi burst disk in a hollow threaded bolt
	Bag "Subject Valve - Vave Seat Body"		Valve Seat Body	3-b	Threads coated green. Rectangular hollow.
	Bag "Subject Valve - Gand Nut"		Gland Nut	3-c	Threaded, hex head.
			O Ring	3-c-i	Back polymer, approx 1/2" diameter
	Bag "Subject Valve - Valve Stem"		Valve Stem	3-d	Steel stem, approx 1 1/8" in length
			O Ring	3-d-i	Brown Polymer, approx 3/8" diameter
			O Ring	3-d-ii	Brown Polymer, approx 3/8" diameter
			Washer	3-d-iii	White Polymer, approx 3/8" diameter
			Washer	3-d-iv	Brown Polymer, approx 1/2" diameter
	Bag "Subject Valve - Regulator Adapter"		Air Cup	3-f	Brass cup, approx 3/8" diameter 1/2" tall
			Handle	3-e-viii	Matte black, approx 1 3/4" diameter
			Adjuster	3-e	Black. Hollow. Threaded inside. Hex head.
			Adjuster Adapter	3-e-iv	Black. Hollow. Threaded outisde. Hex opening. Fractured
			O Ring	3-e-v	Black polymer, approx 3/4" diameter
			O Ring	3-e-vi	Black polymer, approx 1/2" diameter
			O Ring	3-e-vii	Black polymer, approx 3/8" diameter
Tupperware container 3	Bag 3-A		Pressure line	4-i	Green. Some yellow discoloration
	Bag 3-B		Regulator Handle	4-j	Black polymer, fire damaged
	Bag 3-C		Pressure Gauge	4-k	Atteched to an approx 6" black hose
	Bag "Regulator Body"	Bag "O Ring, Thrust Washer"	O Ring	4-g	Black polymer, approx 1" diameter
			Thrust Washer	4-h	White Polymer, approx 1" diameter
		Bag "Metal Diaphragm Retainer, Main Regulator Body, Valve Lifter"	Diaphragm Retainer	4-c-v	Metal, 1 5/8" diameter approx 3/4" tall
			Regulator Body	4	Metal, 1 5/8" diameter approx 1 1/2" tall
			Valve Lifter	4-a	Resembes a large thumbtack
		Bag "Turret"	Turret	4-b	Metal, 1 5/8" diameter approx 1" tall
			Gasket	4-b-i	Brown Polymer, approx 1 5/8" diameter
			O Ring	4-b-ii	Black polymer, approx 1 1/4" diameter
		Bag "High Pressure Diaphragm Spring, Adjustment Sleeve"	Diaphragm Spring	4-c-iii	approx 1/2" diameter, 3/4" tall, 5 turns
			Adjustment Sleeve	4-c-iv	approx 3/4" diameter, 3/8" tall, outside threaded
		Bag "Diaphragm, Retaining Ring, Spring Carrier"	Diaphragm	4-c	Grey Polymer approx 1 1/2" diameter
			Retaining Ring	4-c-i	Cllear Polymer Ring approx 1 1/2" diameter
			Spring Carrier	4-c-ii	Metallic button, approx 3/4" diameter. Center portion raised
		Bag "Mating Half Regulator Adjuster Adapter"	Adjuster	3-e-i	Remaining part of the adjuster
			O Ring	3-e-ii	Black Polyer approx 3/8" diameter
		Bag "Regulator Insert Low Pressure"	Regulator Insert	4-f	Piston Body with compression spring
			O Ring	4-f-i	Black Polymer approx 1/2" diameter
Bag 4	Bag 4-1		Tank Section	1-e	approx 2" in ength and 1/4" width
			Tank Section	1-f	approx 1 1/2" in length triangular section
	Bag 4-2		Tank Section	1-g	Main body approx 1" length and 1/2" width
	Bag 4-3		Tank Section	1-h	Triangular section approx 3/4" height
	Bag 4-4		Tank Section	1-c-ii	Approx 1 1/2" length and 3/4" width. Marked C
			Tank Section	1-c-iii	Approx 1 1/2" length and 1/4" width. Marked C
	Bag 4-5		Tank Section	1-i	Approx 3" length, 1" at one end and 1 1/2" at another
	Bag "Compression Specimen"		Tank Section	1-j	Approx 1 1/4" length and 5/8" width
	Bag 4-6		Tank Section	1-d-ii	Curved section of the tank. Marked D
	Bag 4-7		Tank Section	1-c-iv	Main body approx 4 1/2" x 6". Marked C
	Bag 4-8		Tank Section	1-k	Main body approx 8" length
Tupperware container 5			Tank Valve	3	Tank valve body. Fracturerd
Not Bagged			Scuba Cylinder	1	Ruptured. Specimens taken.
Bag 6			Tank Bottom	1-l	Bottom of the ruptured tank.
Bag "Tensile Specimens"	Envelope "Tensile Specimen A Fracture Surface"		Tank Section	1-m-ii	Part of the fractured specimen No. 1-m-i
	Envelope "Tensile"		Tank Section	1-m-i	Tensile testing specimen half
			Tank Section	1-m-iii	Tensile testing specimen half. Marked B.

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rti FORENSIC ENGINEERING SINCE 1975

CHANGE OF CUSTODY RECORD

DATE: June 12, 2012

RTI File Name: DOT-Ruptured Scuba Cylinder

RTI File No.: 50151.ME002

The evidence herein described has been transferred on this date - -

To: Norman Yuen	**From:** Matthew Wagenhofer
Company: Anamet, Inc.	**Company:** RTI

Description of Evidence (Note all markings):

1. Two (2) halves tensile specimen
2. One (1) tank valve body
3.
4.
5.
6.
7.
8.

Authorization of **Sending** Party:	Authorization of **Receiving** Party:
(Signature) [signature]	(Signature) [signature]
(Printed) Matthew Wagenhofer	(Printed) NORMAN YUEN

P:\CLIENT FOLDER\ Z – Change of Custody Form