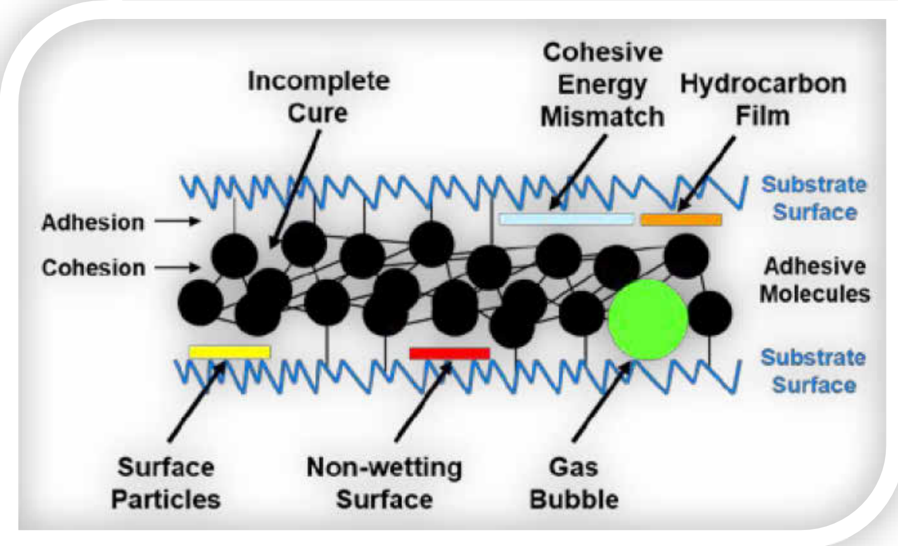
CO_2 Surface Preparation for Adhesive Bonding

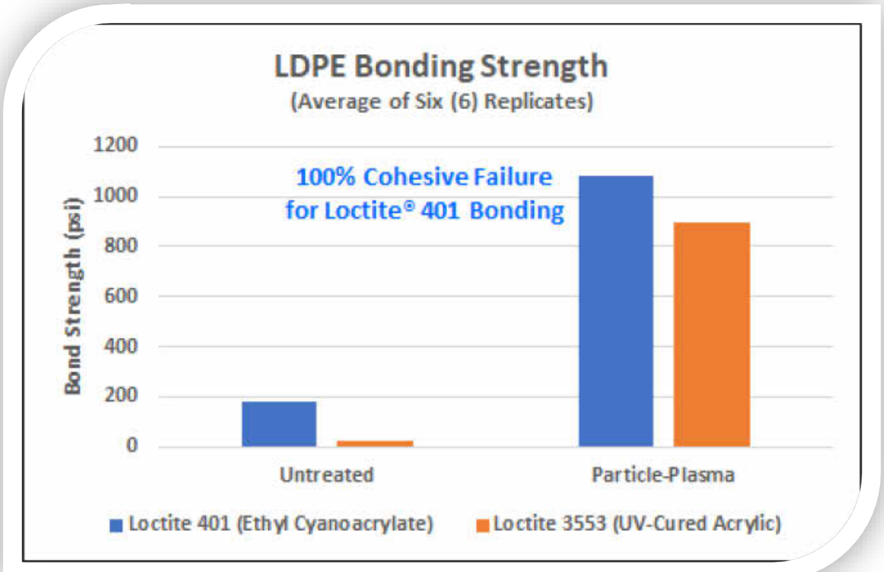
Case Study: Rivetless Fasteners

Clean Manufacturing, *Reimagined*.

Part 1

Surface Preparation for Reliable Adhesive Bonding



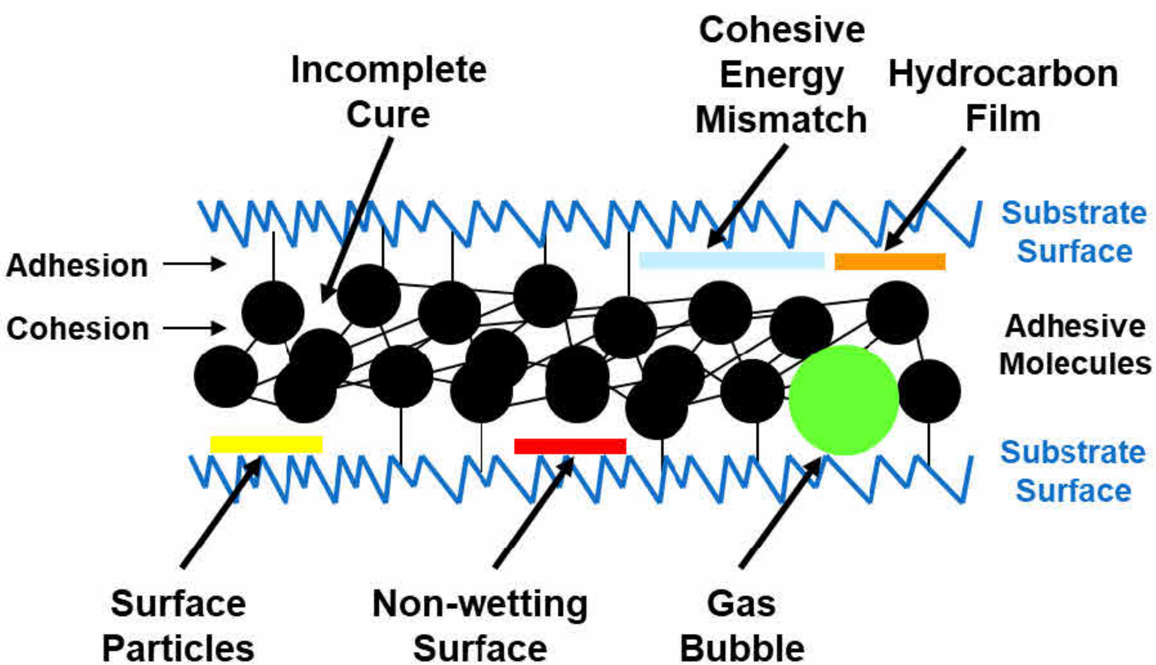


clean imagineering

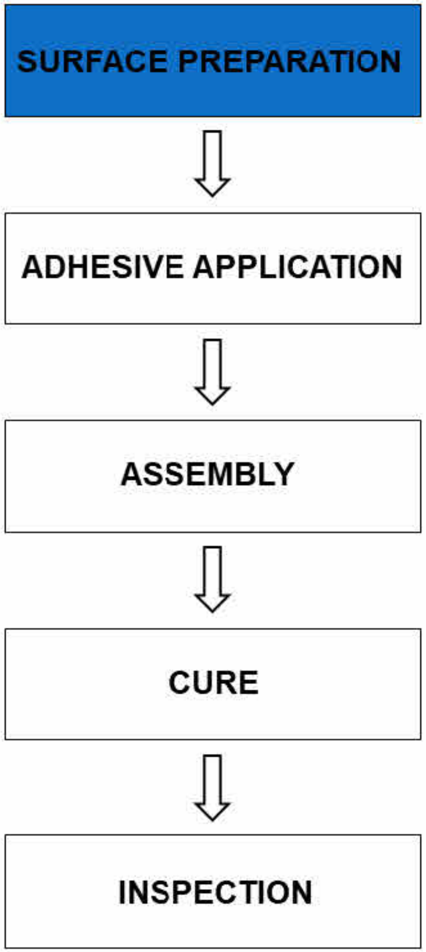
Reliable Adhesive Bonding

Basis for a reliable adhesive bond:

- Proper surface preparation
- Proper adhesive selection, preparation and application
- Proper curing
- Good joint design

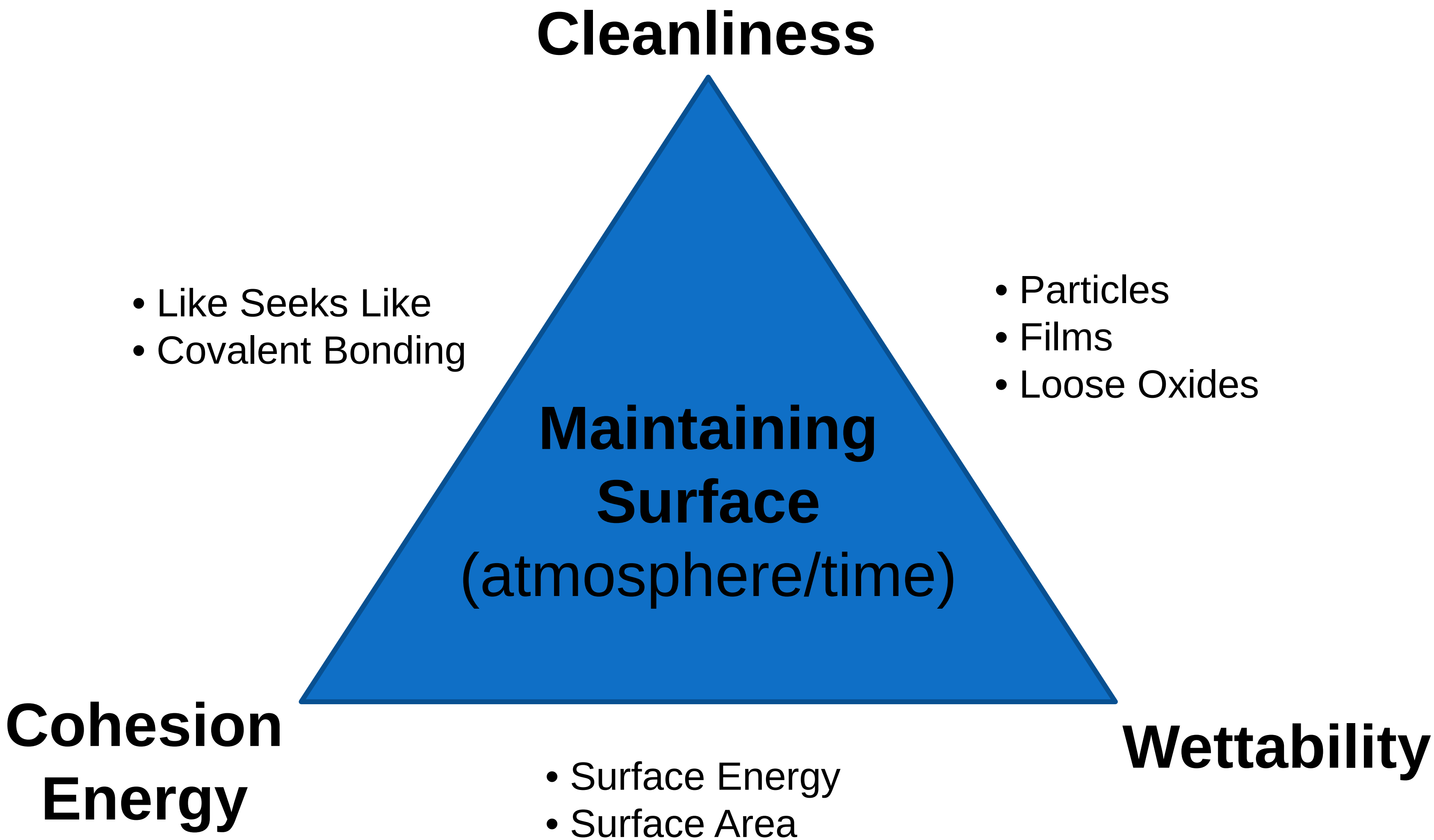


Adhesive Bonding Process Flowchart



clean imagineering

Proper Surface Preparation



Need for Reliable Surface Prep

- Surfaces are heterogeneous in terms of chemistry, surface energy, rugosity (roughness, surface area), and cleanliness.
- Most coating, **adhesive**, encapsulant, paint, and other adherent surfaces are polar.
- Hydrophobic polymer and metal substrate surfaces are generally non-polar.
- Cohesion chemistry of bonding surfaces should be similar for maximum adhesion.

CO_2 Particle-Atmospheric Plasma (**Particle-Plasma™**) hybrid cleaning-treatment processes provide simultaneous spray cleaning, micro-etching, and grafting polar carbon-, nitrogen-based oxygenated chemistries onto nonpolar surfaces to assure optimal wettability and adhesion.

clean imagineering

CO_2 Solvent Properties

	Carbon Dioxide			
	Solid	Liquid[/1]	SCF[/2]	Acetone
DENSITY g/cm^3	1.6	0.8	0.5	0.8
VISCOSITY mN-s/m^2	-	0.07	0.03	0.32
SURFACE TENSION dynes/cm	5-10	5	0	24
SOLUBILITY MPa$^{1/2}$	18	18	14	20

1. 20 C, 900 psi
Liquid CO_2 (LCO_2)

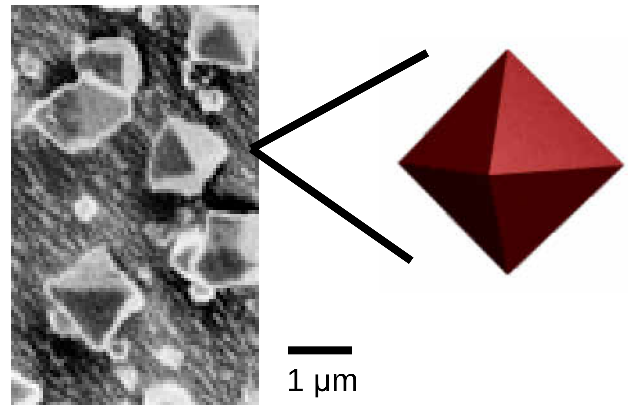
2. 35 C, 1500 psi
Supercritical Fluid CO_2 ($scCO_2$)

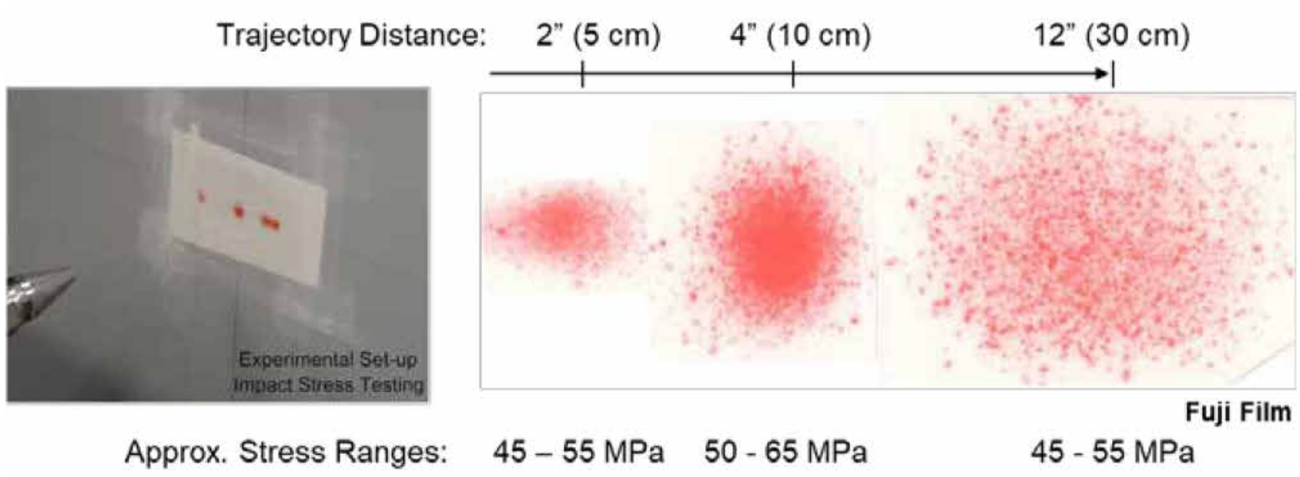
clean imagineering™

Micronized CO_2 Particle Power

Micronized Carbon Dioxide Particles

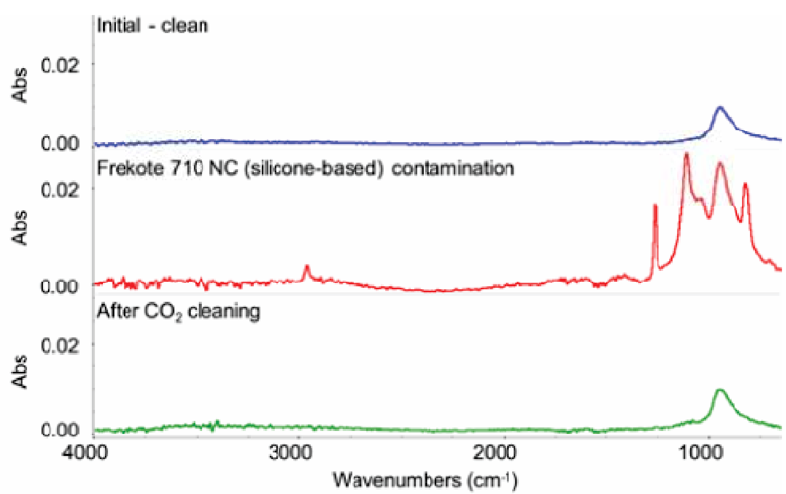
SEM Photomicrograph





Microscopic particle impact stresses as high as 8,000 psi from a 70-psi spray

CO_2 Removes Silicone Films

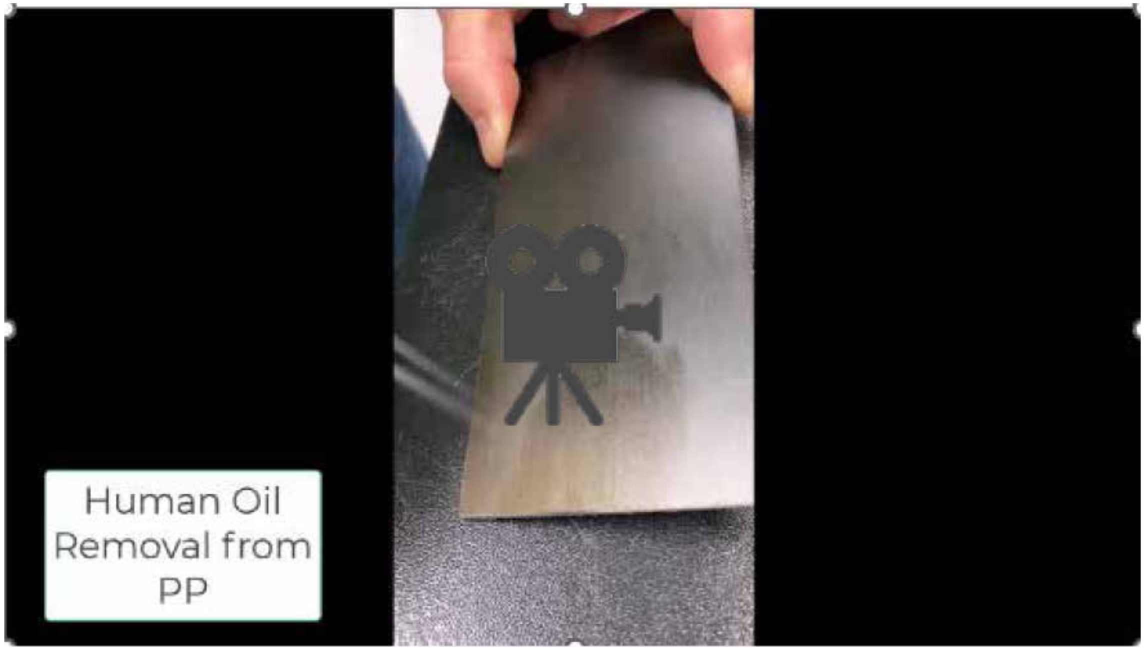


- Thick coating of Loctite® Frekote 710NC (Mold Release Agent) applied to a 7075 aluminum panel.
- Dry wiped with a cotton-based wiper to achieve a thin and somewhat uniform coating.
- IR data acquired using an Agilent 4100 handheld IR with a grazing angle attachment.
- 64 IR scans were averaged with a 4cm^{-1} resolution over 650-4000 cm^{-1} (2.5-15.5 um) spectral range.
- Peak around 900 cm^{-1} (11 um) present in both the clean and after CO2 composite spray cleaning spectra is due to aluminum oxide layer.

Hazardous Component(s)	CAS Number	Percentage*
Hydrocarbons, C9-C10, n-alkanes, isoalkanes, cyclics, <2% aromatics	64742-48-9	80 - 100
Dibutyl ether	142-96-1	10 - 30
Hydrocarbons, C7-C9, isoalkanes	1174921-67-5	1 - 5
Reaction product of tris(n-methylamino)methylsilane (TMAS) and silanol terminated polydimethylsiloxane (PDMS)	1432471-92-5	1 - 5

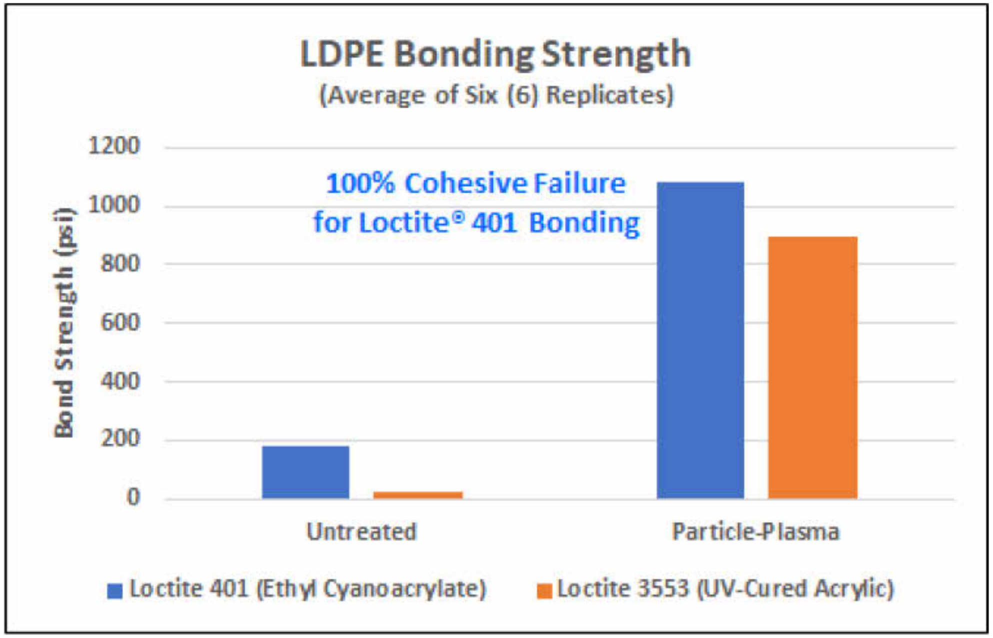
clean imagineering™

CO_2 Removes Fingerprints



Polypropylene (PP) Panel Cleaning

Bonding Performance



"Cleaned LDPE blocks bonded with 401 and 3553 showed enhanced surface profiles after failure testing of the bondlines. On these cleaned replicates, it appears that the adhesive penetrated into the surface of the LDPE and possibly contributed to the higher bond strengths."

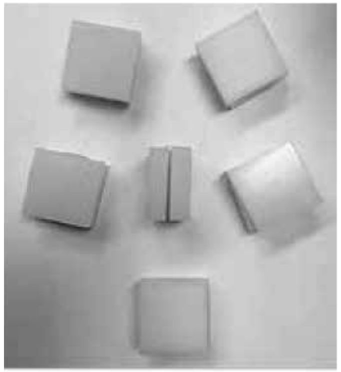
Test Methods:
ASTM D3163
Determining Strength of Adhesively Bonded Rigid Plastic Lap-Shear Joints in Shear by Tension Loading
ASTM D1002
Apparent Shear Strength of Single-Lap-Joint Adhesively Bonded Metal Specimens by Tension Loading (Metal-to-Metal)

Process Equipment:

Test Equipment:

- Dickson THDX hygrometer
- Instron 4400R Mechanical Properties Tester
- 30 kN load cell

Ambient Test Conditions:
Temperature: 70 ° F
Relative Humidity: 55 %



LDPE Bonding Test Pairs

clean imagineering™

Environmental, Health, and Safety

Setting the Record Straight:

CO_2 Technology is Part of the Solution

Carbon dioxide technology often is misunderstood, especially regarding the global warming controversy. The bottom line is that CO_2 technology is good for people, businesses and the environment.

BY DAVID JACKSON

Carbon dioxide (CO_2) technology is important in many commercial and industrial applications. For example, leading companies including Western Digital, Pentel, Gillette-PaperMate, Raytheon and Seagate have implemented CO_2-based cleaning technology because it has improved the productivity, worker safety and profitability of their precision cleaning operations. These same businesses have implemented CO_2 technology as a strategy for complying with stringent environmental regulations.

CO_2 is produced and captured as a byproduct of natural and industrial processes (aka recycled CO_2) and is a valuable resource for a number of commercial and industrial processes. Recycled CO_2 is a net benefit in terms of energy conservation, pollution reduction and other important societal benefits. No additional quantities of CO_2 are added to the atmosphere by using this valuable waste byproduct. Users of recycled CO_2 are not considered generators of CO_2. This is the position of the United States Environmental Protection Agency (EPA).[1]

Arguably the most important reason for using recycled CO_2

Unlike other manufacturing agents, CO_2 can be used as a spray agent (pictured), immersion cleaning agent, surface treatment agent, coolant, lubricant and extraction solvent.

EHSToday | AUGUST 2009 | WWW.EHSTODAY.COM 39

Environmental

Renewable Resource
No Water/Wastewater
No Air Pollution
No Environmental Permits
No VOCs
GWG Reporting Exempt

Facilities and Workers

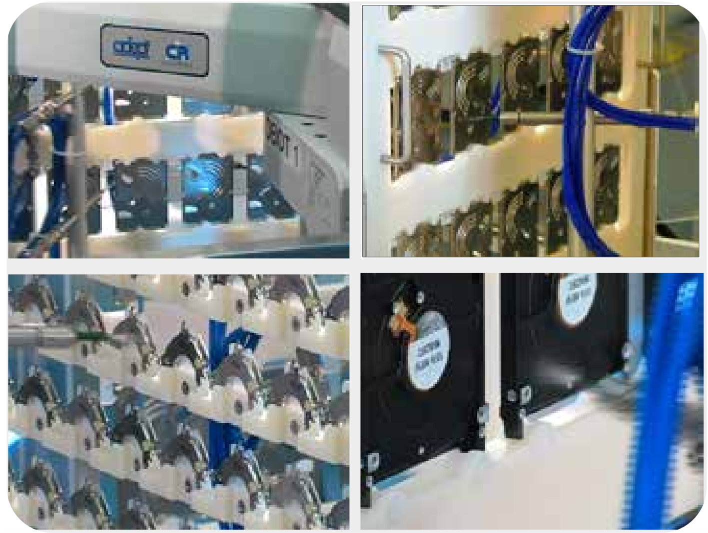
Non-Corrosive
Non-Toxic
Non-Flammable
Non-Contaminating

Reference:

1. "Setting the Record Straight: CO_2 Technology is Part of the Solution", D. Jackson, EHS Today, August 2009.

clean imagineering

Cost-Benefits



Cleaning Cost Comparison Between DI/US Immersion and CO_2 Composite Spray™ Cleaning

Deionized Water (Immersion/Drying)	**CO_2** (Dry Spray)
$0.12-$0.13/part	**$0.015-$0.06/part**

50% - 88% cost reduction - fully burdened

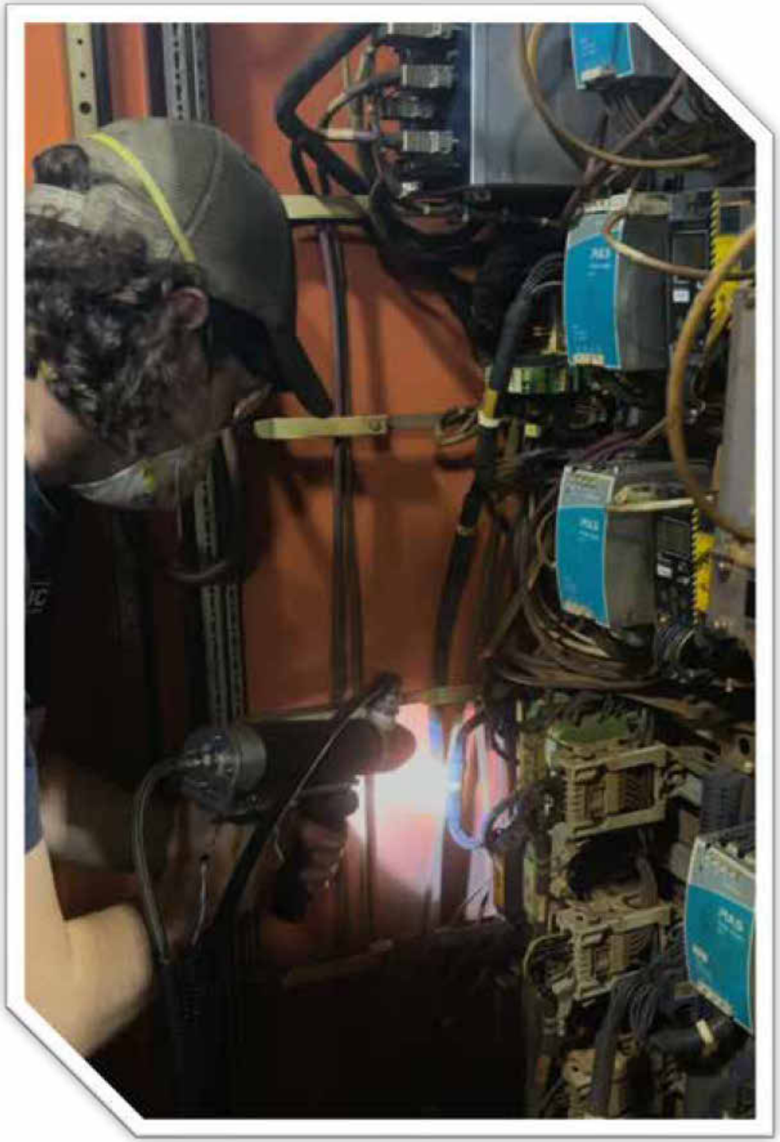
Economics

Low Cost of Operation
Less Space
Lower Energy
Lower Labor
No Waste Treatment
Faster Processing
Cash Flow Recovery

Reference:

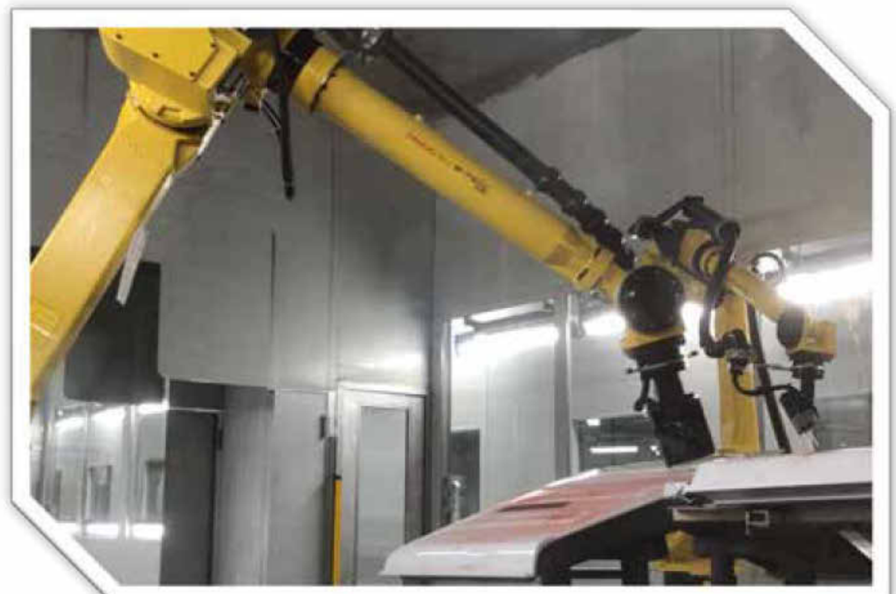
1. "Automated CO_2 Composite Spray Cleaning System for HDD Rework Parts", G.W. Knoth et al., Journal of the IEST, Volume 52, Number 1, April 2009.

clean imagineering



Part 2

CO_2 Surface Preparation Tools



clean imagineering™

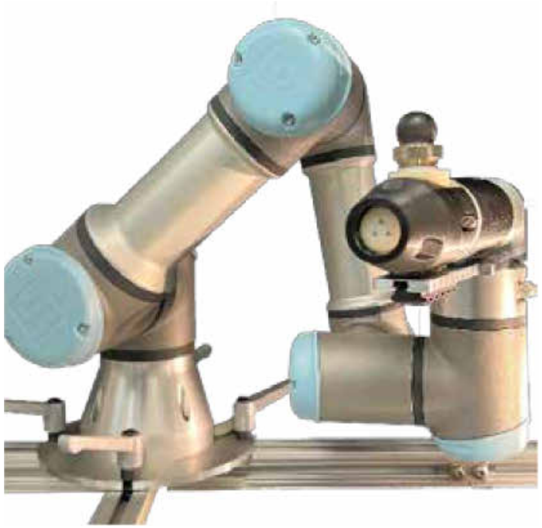
CO_2 Composite Spray Generators

PowerSno™
Vector Pro

clean
imagineering™

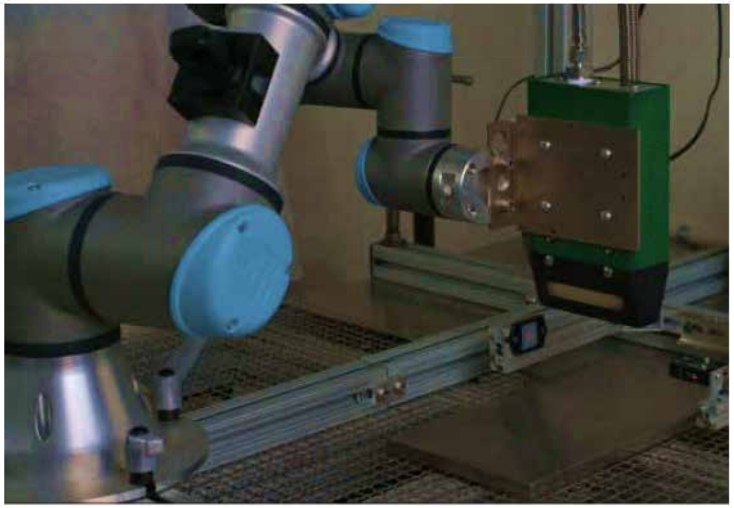
Spray Applicators

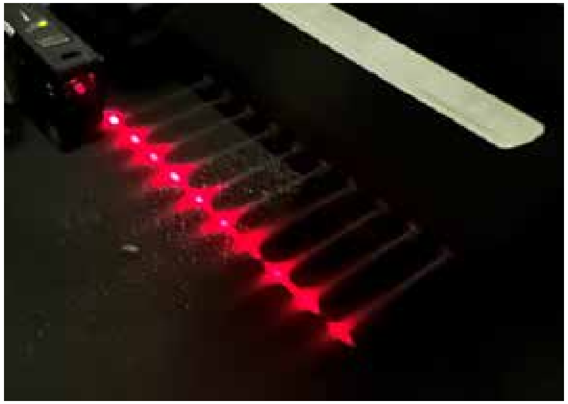
Micronizer™



clean imagineering™

Spray Automation and Control





LightSPEC

clean imagineering

Atmospheric Plasma

ParticlePlasma™

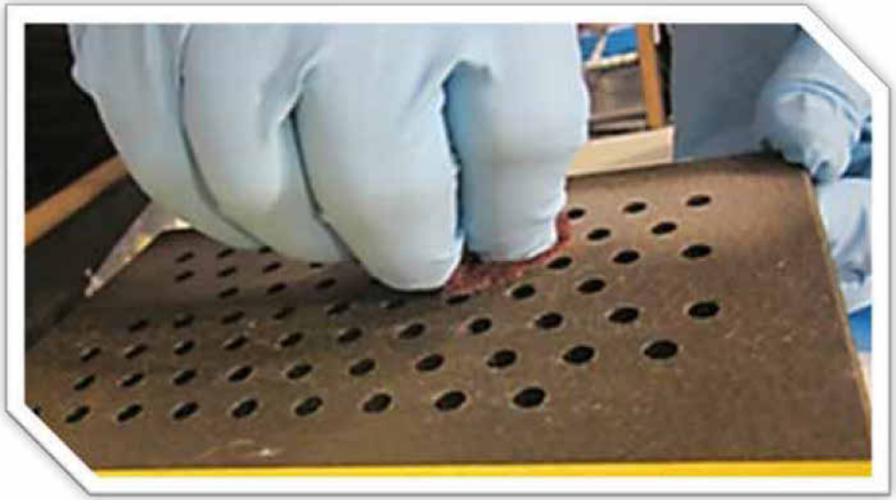
clean imagineering™

CO_2 Delivery Systems

PurCO2™

clean
imagineering

Part 3



Case Study

Surface Prep For Rivetless Fastener Bonding

clean imagineering

CO_2 Spray Cleaning Process

CO_2 Composite Spray Cleaning (Only)

clean imagineering

Conventional Surface Prep Processes

Wipe Clean à CO_2

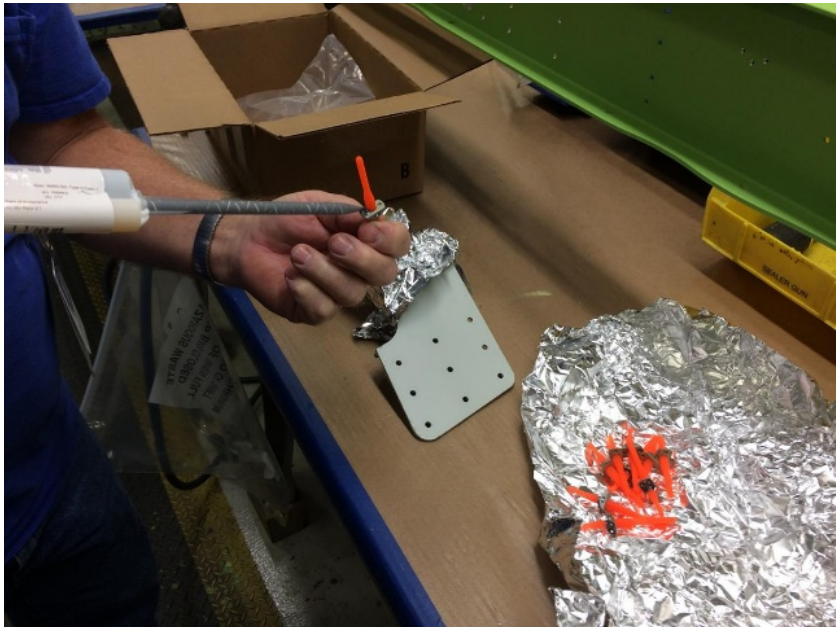
Abrade à Wipe Clean*
(Current Method)

BMS 11-7 Wipe Cleaning Solvent

Scotch-Brite Scouring Pad

clean imagineering

Adhesive Bonding Nutplate



Apply Adhesive

3M Epoxy EC-3333

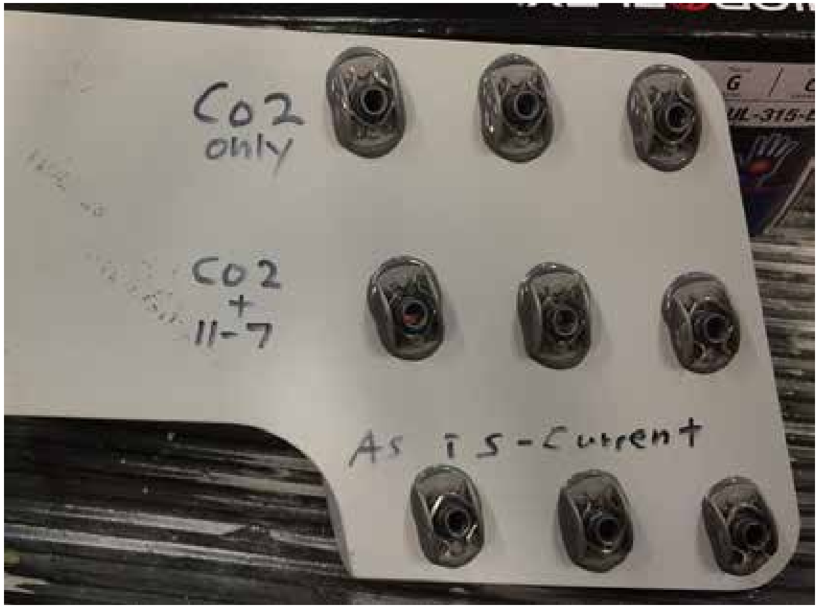
Apply Tension

clean imagineering

Pull Test Groups

Cured Nutplates
(with rubber nutplate tensioners in place)

Nutplate Pull Testing



Rubber Tensioners
Removed from Nutplates

Click Bond Pull Tester
Model CB602

clean imagineering

Results and Benefits

Pull Test Results:

- All three surface prep methods passed the 60 lbs. (minimum) pull test requirement.
- None of the nutplates failed at 90 lbs. pull test.

CO_2 Composite Spray Cleaning Benefits:

- CO_2 Composite Spray cleaning eliminates harsh cleaning solvents and wipe cleaning smears, and in most cases, requires only a single step.
- Cost reductions for conventional cleaning items such as BMS 11-7 wipe cleaning solvent, scouring pads, solvent wipers, hazardous waste bags, rubber gloves, etc.
- Reduction in hazardous waste disposal costs.
- CO_2 chemistry removes silicone residues (replaces fluorinated/chlorinated solvents).
- CO_2 Composite Spray cleaning can be easily automated or integrated directly into existing manufacturing and assembly processes and equipment (i.e., CNC machining).
- CO_2 Composite Spray cleaning can be hybridized with a rotary brush, atmospheric plasma, and/or surface analysis to provide a robust, selective, and smart surface preparation process for many different adhesive bonding applications.

clean imagineering™

Manual CO_2 Prep Solutions

Scotch-Brite

CO_2 Composite Spray

<u>Note 1</u>. Abrasives can grind surface contaminants deep into the surface. Surface contaminants must be removed prior to abrasive treatment.

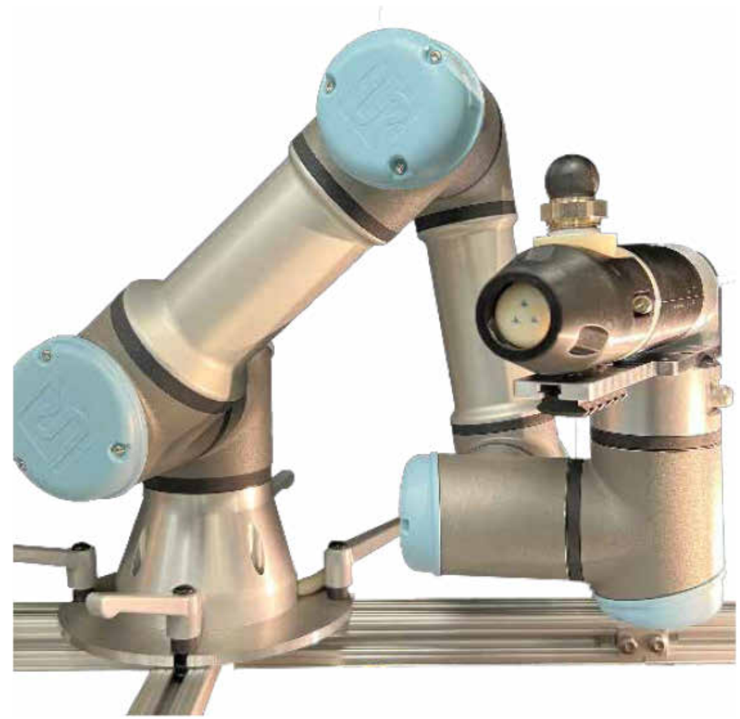
<u>Optimized Manual CO_2 Prep Methods</u>[1]

Spray Clean à Bond
or
Spray Clean à Abrade à Spray Clean à Bond

clean imagineering

Automated CO_2 Prep Solutions

https://www.andrewstool.com/surface-preparation-tool



Pneumatic Rotary Grinder

Robotic CO_2 Composite Spray

Contact Information

26074 Avenue Hall Unit 6
Santa Clarita, CA 91355 U.S.A.
info@cleanimagineering.com

Clean Manufacturing, *Reimagined*.

For more information, please visit http://www.cleanimagineering.com