# PLASMA CLEANING

LAUNCH

**NASA's Kennedy Space Center has developed a solvent-free precision cleaning process using plasma that has equal performance, cost parity, and no environmental liability, as compared to existing solvent cleaning methods.**

This technology impacts NASA's mission by reducing costs associated with waste treatment and environmental liability, while also reducing the risk that a particular solvent becomes regulated out of use during a program. Solvent free cleaning methods eliminate the liquid waste stream from the cleaning process, providing a radical change regardless of the nature of the solvent.

This technology is applicable to other NASA centers, government entities and other industries including biomedical, electronics, and recycling.

**Plasma technology has the following benefits:**

1. No long-term environmental pollution issues (ODS, GWP, ecotoxicity)
2. No long-term remediation costs
3. No solvent waste stream disposal costs
4. Greatly reduced consumable costs
5. Reduced risk of supply disruptions (e.g. due to regulatory issues)
6. Reduced toxicity exposure to workers

## CURRENT STATUS

Plasma cleaning has demonstrated the ability to meet the strictest level of nonvolatile residue (NVR) cleanliness (10mg/m2) in KCS's Specification for Surface Cleanliness of Ground Support Equipment Fluid Systems, KSC-C-123J. Cleaning tests were done with the following contaminants: two military specification hydraulic fluids, Mil-PRF-83282 and Mil-H-5606, two perfluorinated greases that also contain small PTFE particulates, Krytox 240AC and Braycote 601EF, and dioctyl sebacate, an oil used in gas regulator testing. This testing was done with laboratory scale equipment on small parts (1/4" Swagelok fittings). Verification of the cleaning ability on large parts is scheduled to be complete by September 2015.

## ADVANTAGES

- Essentially no hazardous waste stream
- No drying time
- Low cost consumables
- Cleaning time dependent on contamination level
- Demonstrated ability to sterilize surfaces
- Very simple operation

## DISADVANTAGES

- Plasma is not suitable for heavily contaminated parts
- Long tubes or extremely complex parts may not be cleaned.
- Polymers may be adversely affected by plasma

## HOW IT WORKS

Plasma cleaning is conducted in a low pressure chamber in which a gas is excited to the plasma state via exposure to an electrical field that causes electrons to dissociate from the nucleus (Figure 1). Depending on which process gas is used, the plasma will have different interactions with the surface contamination (Figure 2).

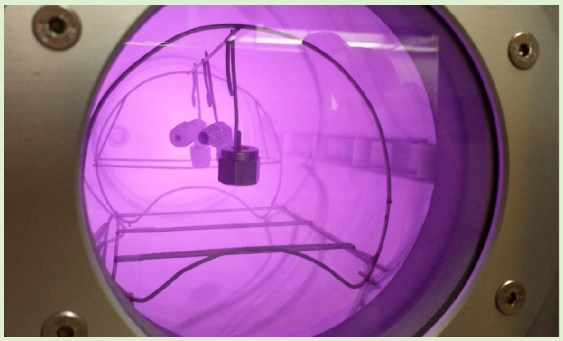

**FIGURE 1**
Sample parts on a rack during a plasma cleaning test

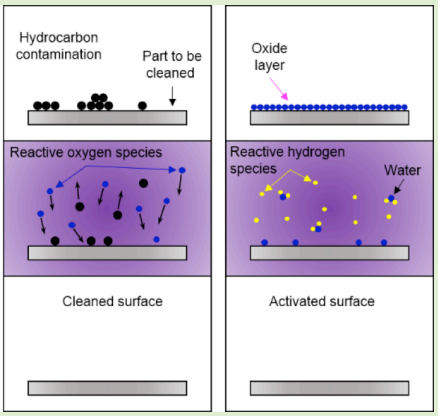


**FIGURE 2**
Illustration of the effects of plasma cleaning with oxygen (left) and hydrogen (right)

# SUPERCRITICAL $CO_2$ CLEANING

LAUNCH

**NASA's Kennedy Space Center has developed a solvent-free precision cleaning processes using supercritical carbon dioxide ($SCCO_2$) that has equal performance, cost parity, and no environmental liability, as compared to existing solvent cleaning methods.**

This technology impacts NASA's mission by reducing costs associated with waste treatment and environmental liability, while also reducing the risk that a particular solvent becomes regulated out of use during a program. Solvent free cleaning methods eliminate the liquid waste stream from the cleaning process, providing a radical change regardless of the nature of the solvent.

This technology is applicable to other NASA centers, government entities and other industries including biomedical, electronics, and recycling.

**$SCCO_2$ technology has the following benefits:**

1. No long-term environmental pollution issues (ODS, GWP, ecotoxicity)
2. No long-term remediation costs
3. No solvent waste stream disposal costs
4. Greatly reduced consumable costs
5. Reduced risk of supply disruptions (e.g. due to regulatory issues)
6. Reduced toxicity exposure to workers
7. Turns a consumable into a reusable commodity (for $SCCO_2$)

## CURRENT STATUS

$SCCO_2$ cleaning has demonstrated the ability to meet the strictest level of nonvolatile residue (NVR) cleanliness (10mg/$m^2$) in KCS's Specification for Surface Cleanliness of Ground Support Equipment Fluid Systems, KSC-C-123J. Cleaning tests were performed using the following contaminants: two military specification hydraulic fluids, Mil-PRF-83282 and Mil-H-5606, two perfluorinated greases that also contain small PTFE particulates, Krytox 240AC and Braycote 601EF, and dioctyl sebacate, an oil used in gas regulator testing. This testing was done with laboratory scale equipment on small parts (1/4" Swagelok fittings). Verification of the cleaning ability on large parts is scheduled to be complete by September 2015.

## ADVANTAGES

- No drying time
- Can clean complex parts of any size, with hidden surfaces, such as those made by additive manufacture
- Low consumable cost
- Compatible with some polymers (additional testing required)
- $SCCO_2$ is a "tunable solvent" and can be used to remove a variety of contaminants by adjusting its temperature and pressure.
- Cleaning achieved in 5 minutes.

## DISADVANTAGES

- Requires a pressure vessel

## HOW IT WORKS

$SCCO_2$ cleaning takes advantage of the unique properties of a supercritical fluid. When carbon dioxide's critical pressure (1070 psi) and critical temperature (88 °F) it becomes a supercritical fluid which is neither a liquid nor a gas, but retains properties of both. $SCCO_2$ can dissolve substances like a liquid and can penetrate complex parts like a gas, making it ideal for cleaning (Figure 2).

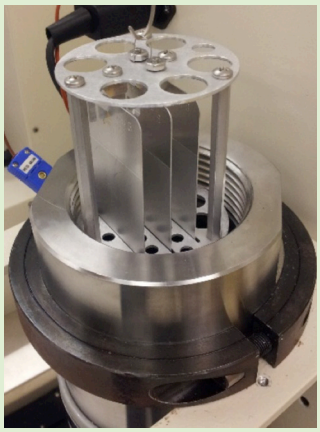

**FIGURE 1**
Test coupons being loaded for supercritical cleaning

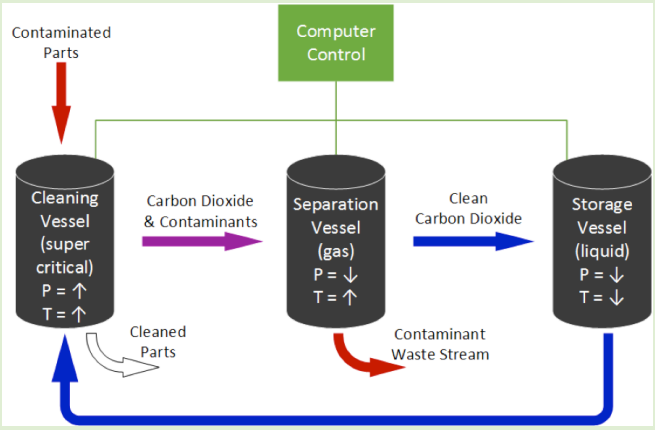


**FIGURE 2**
Basic schematic of the supercritical system. The separator and storage vessels enable a single charge of $CO_2$ to be used in multiple cleaning cycles (P = pressure, T= temperature)