Preventive Maintenance

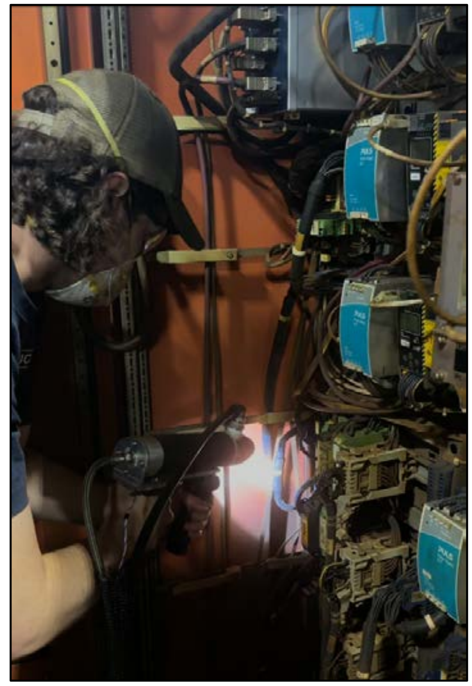
APP NOTE

- **Cleaning, Cleanliness, and Contamination Control (C4) Technology for Preventive Maintenance and Production Operations**
- **On-Demand CO_2 Blast Cleaning from a Cylinder, Use Anywhere in the Factory**
- **Broad-Spectrum CO_2 Cleaning Bridges the Gaps: Manufacturing Equipment-to-Manufactured Parts and Robust-to-Sensitive Surface Preparation Applications**
- **Safely Remove Particles, Carbon Residues, and Oily Insulating Films from Breakers, Contacts, Wire Terminals, and Heat Exchange Surfaces**
- **Micronized CO_2 Blasting has a Lower Cost-of-Operation and Superior Precision Spray Energy Control as Compared to CO_2 Pellet Blasting**
- **Simple Adjustment and Instant On/Off Spray Operation, Adaptable, Customizable, and 100% Dry**
- **PowerSno™ Micronized CO_2 Cleaning Systems, Micronizer™ CO_2 Blast Cleaning Guns, and Accessories**

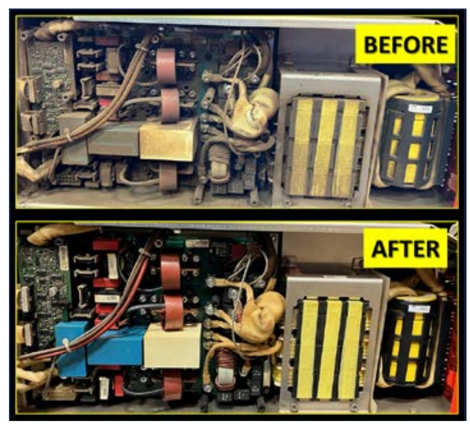
Uptime and reliability of manufacturing assets are vital to business profitability and sustainability. Owners and facility management teams need effective preventive maintenance strategies and technology to keep equipment working at peak performance.

These business stakeholders must manage many maintenance challenges, including extending equipment life cycles, improving efficiencies, decreasing unscheduled downtime, planning for unexpected failures - and all this while decreasing maintenance costs.

According to the National Fire Protection Association (NFPA), a comprehensive and well directed Electrical Preventive Maintenance program, *including safe and effective cleaning strategies*, reduces accidents, improves personnel safety and minimizes costly breakdowns and shutdowns of production equipment. Future troubles can be identified and corrected before they become major problems and require more expensive and time-consuming solutions.



Panels and Equipment



Reliability, Compliance, and Sustainability

NFPA 70B's electrical maintenance program includes scheduled visual inspection and cleaning for a broad range of facility power-distribution, control, backup-power, and electronic equipment. The cleaning, cleanliness, and contamination control (C4) plan, including interval, depend on the equipment category, its assessed condition, operating environment, criticality, and applicable manufacturer instructions. For a plant-oriented C4 scope, the highest-value targets are typically switchgear, MCCs, VFD/control cabinets, panelboards, UPS/battery cabinets, transformer enclosures, and any electrical enclosure exposed to conductive dust, moisture, oil mist, or corrosive process contamination.

Micronized CO_2 Composite Spray vs. Pellet CO_2 Blast for Sensitive Electrical and Electronic Equipment

Overview

For facility electrical panels and equipment containing delicate wiring, wire markers, PCB assemblies, sensors, relays, drives, and similar sensitive components, a finely tuned CO_2 Composite Spray process presents lower damage risk than conventional pellet or shaved ice CO_2 blasting. The main reason is process controllability: composite spray uses much smaller, and more numerous hard CO_2 particles (miniaturized CO_2 pellets) and allows cleaning energy and temperature to be adjusted more precisely, while CO_2 pellet blasting uses larger preformed, and less numerous dry ice particles (or shaved ice fragments) with higher momentum that are better suited to heavier contamination on more robust surfaces.

Both methods are dry, non-conductive, and residue-free at the point of use, which makes each attractive for electrical maintenance environments. The important distinction is not whether either process can clean electrical equipment, but how much mechanical and thermal stress each process can impose on wires, labels, coatings, solder joints, connectors, and other fragile assemblies during cleaning.

CO_2 Cleaning Process Comparison

Attribute	Micronized CO_2 Composite Spray	Pellet-Shaved Ice CO_2 Blast
CO_2 media form	Microscopic CO_2 particles are generated in-situ from a liquid CO_2 supply and accelerated in an air stream.	Preformed dry ice pellets or solid CO_2 block ice fragments fed into and accelerated in an air stream.
Particle size and mass	Smaller, lower-mass particles intended for precision cleaning to general cleaning.	Larger, higher-mass particles intended for more aggressive contaminant removal.
Cleaning energy	More tunable for delicate surfaces and tight process control.	Higher impact energy, depending on pellet size, pressure, nozzle, and standoff.
Temperature management	Optional use of heated, clean dry air or nitrogen to avoid any potential atmospheric condensation.	More likely to create strong local cooling because the process relies on larger very cold dry ice particles.
Typical best-fit contamination	Dusts, particulates, thin films, fingerprints, light oils, and precision residues.	Heavy grease, tougher deposits, and contamination on robust industrial equipment.
Relative suitability for delicate electronics	Better suited when validated and tuned for sensitive assemblies.	More suitable for rugged equipment than for fragile electronics and labels.

Wires and Insulation

Micronized CO_2 Composite Spray is the safer starting point for wire bundles, fine-gauge leads, flex circuits, and polymer-insulated conductors because lower and more uniform particle mass reduces the likelihood of abrasion, nicking, embrittlement, or physical displacement during cleaning. The ability to control the cleaning spray (relative to pellet/shaved ice blasting) with warmer propellant gas-CO_2 particle mixtures reduce abrupt local chilling of polymer insulation, which matters for older or more brittle wire jackets.

CO_2 Pellet-shaved ice blasting can still be particularly useful on electrical equipment for thick or heavy oxides present on component surfaces, but its larger particles and higher momentum create a greater chance of damaging wire insulation or disturbing unsupported leads when pressure is high, standoff is too short, or dwell time is excessive. The Electric Power Research Institute (EPRI) specifically notes that the CO_2 blast cleaning process can become aggressive enough to cause insulation damage and coating removal if pellet size is too large or air pressure is too high. This distinction becomes more important for aged PVC insulation, thin fluoropolymer jackets, heat-shrink sleeves, cable-tie mounts, brittle legacy wiring, and fine instrumentation conductors, all of which are more vulnerable than robust power cables or metallic hardware. Selective vacuum brush pre-treatment, followed by Micronized CO_2 Composite Spray cleaning may also be considered in these applications.

Wire Markers and Labels

Wire markers, heat-shrink legends, adhesive identification labels, printed sleeves, and laminated tags are often more vulnerable than the metal conductors or panel structures beneath them. Micronized CO_2 Composite Spray offers a practical advantage because cleaning energy can be reduced and applied at glancing angles around labels and marker sleeves while still removing loose dust and light films.

CO_2 pellet blasting presents higher risk of lifting label edges, eroding printed legends, cracking brittle sleeves, or dislodging loosely attached identification markers because the cleaning mechanism depends more heavily on particle impact and rapid localized cooling. Even where pellet blasting is described as non-abrasive for many industrial tasks, that should not be taken to mean marker-safe for every label material, adhesive, ink system, or aged field condition.

Electronic Components

The main hazards to electronic assemblies are mechanical impact, thermal excursion, condensation, and debris redistribution rather than electrical conductivity, since both cleaning approaches are dry and avoid liquid water. Micronized CO_2 Composite Spray cleaning was developed for precision applications that include electronic components, sensors, optical assemblies, wire-bonded structures, and related high-value parts, which supports its use where process tuning and component preservation are critical.

CO_2 pellet blasting may be acceptable on robust electrical hardware, but it is a less conservative default for populated circuit boards, fine-pitch connectors, conformal coatings, small relays, displays, fans, and fragile sensor packages because larger particles can impart more mechanical shock and stronger cooling at the point of impact. That concern is especially relevant for aged solder joints, unsupported circuit boards, ceramic components, delicate connector systems, and any assemblies with uncertain adhesion of coatings or potting materials.

CO_2 Cleaning Damage Risk Comparison

Sensitive item	Micronized CO_2 Composite Spray	Pellet-Shaved Ice CO_2 Blast
PCB assemblies and solder joints	Lower-risk option when pressure, distance, and temperature are tightly controlled.	Higher risk of impact and thermal shock, especially on aged or unsupported assemblies.
Relays, terminals, and connectors	Better suited for dust and light films with targeted, low-energy application.	May drive debris into mechanisms or disturb weak connections if used aggressively.
PLC, VFD, and control cabinets	More appropriate for validated precision cleaning protocols.	Usually a less conservative choice for fragile electronics and densely populated cabinets.
Sensors, optics, optoelectronic devices, and precision parts	Better aligned with precision-cleaning applications.	Higher risk unless the component is known to tolerate the process.
Labels, coatings, and conformal films	Lower risk when exposure is brief and controlled.	Greater risk of cracking, delamination, or adhesion loss under aggressive settings.

Moisture and Thermal Considerations

A critical difference for panel interiors is condensation control. CO_2 pellet blasting uses larger, very cold dry ice media and can chill a surface enough to attract atmospheric moisture, which is undesirable around electronics, insulation systems, and connector interfaces. By comparison, a micronized CO_2 Composite Spray employs a uniform composition of dense microscopic particles dispersed in an equal volume of (clean dry) propellant gas (i.e., compressed air). This mitigates surface cooling effects, so it does not present a condensation risk in most applications. Heated, clean dry air or nitrogen can be used to add thermal capacity and help keep the work surface above the local dew point. In practice, that makes composite spray easier to tune for sensitive enclosures where moisture avoidance matters as much as soil removal.

Practical Application Guidance

Micronized CO_2 Composite Spray is the better fit for panel interiors containing wire bundles, marker sleeves, low-voltage controls, PLC hardware, relays, sensors, printed circuit boards, optics and optoelectronic devices, and similar components where cleaning energy must stay below a narrow damage threshold. CO_2 pellet blasting is better reserved for robust equipment, non-sensitive panel zones, exterior enclosures, or heavy deposits that require higher cleaning energy than a precision process normally provides.

Neither process should be assumed universally safe for all components without qualification testing. The most defensible practice is to validate nozzle type, pressure, standoff, angle, dwell time, gas dryness, and temperature on representative wires, labels, coatings, and electronic assemblies before routine field use.

The central tradeoff is precision versus aggressiveness. Pellet CO_2 blasting offers faster, higher-energy cleaning for durable contamination on rugged surfaces, while micronized CO_2 Composite Spray offers a broader safety margin for wires, wire markers, electronic components, and other sensitive assemblies commonly found in electrical equipment and panels.

Optical and Optoelectronic Cleaning Opportunities for Micronized CO_2 Composite Spray in Electrical Panels, Equipment, and AI Data Centers

Overview

Optical and optoelectronic cleaning opportunities are present both in conventional electrical/control equipment and in newer Artificial Intelligence (AI) data centers, but the most credible service scope is controlled, contamination-management cleaning around sensitive optical hardware rather than

Optical and Optoelectronic Device Cleaning

Panel or Equipment	Optical / Electro-optical Device	Purpose	CO_2 Composite Spray Application
PLC, DCS, and SCADA cabinets	Industrial Ethernet fiber switches, SFP or SFP+ transceivers, media converters, fiber patch panels	Carries high-speed control, alarm, monitoring, and process data between controllers and field equipment.	Clean cabinet dust, fan and heat-sink areas, and enclosure surfaces while protecting exposed connectors and optical modules.
Substation protection-and-control panels	Fiber transceivers, relay communication ports, optical patch panels, Ethernet switches	Connects protective relays, communications processors, RTUs, and monitoring or control devices; fiber provides EMI immunity and electrical isolation.	Precision cleaning of surrounding dust and cabinet contamination with strict protection of fiber ports and end faces.
Medium-voltage switchgear and breaker-control cabinets	Arc-flash optical sensors, optical communications links, infrared viewing systems	Supports arc-flash detection, isolated communications, and inspection or condition monitoring.	Controlled low-energy cleaning around sensor windows, relay hardware, and panel contamination.
MCCs and VFD cabinets	Fiber-connected motor relays, industrial Ethernet links, optical encoders	Supports motor protection, isolated communications, and drive or motion feedback.	Suitable for light contamination removal from cabinet interiors if fiber ports, encoders, and connectors are protected.
UPS, battery, and energy-storage systems	Fiber communications modules, optical isolation devices, monitoring links	Supports monitoring, control, alarms, and communications in critical-power systems.	Clean enclosures and cooling paths after isolation; avoid direct exposure of optical interfaces unless specifically qualified.
Renewable-energy inverter and combiner systems	Fiber Ethernet switches, optical links, optical sensors	Connects distributed generation, storage, and plant controls across electrically noisy sites and long cable runs.	Dust removal in inverter and control cabinets, with optical faces and terminations protected.
Machine-vision and robotic cells	Cameras, laser sensors, photoelectric sensors, fiber-optic sensors, optical encoders	Provides object detection, alignment, inspection, measurement, and robot feedback.	Strong precision-cleaning opportunity for optics-adjacent contamination, subject to validation for lens, coating, and alignment protection.
Safety and perimeter-control panels	Photoelectric beams, optical safety devices, fiber sensors	Detects personnel, object position, access, or hazardous conditions.	Light contamination removal may restore reliability, but direct treatment of sensing optics must be validated.
Rail, traffic, and outdoor infrastructure cabinets	Fiber media converters, optical network terminals, cameras, lidar or laser sensors	Provides communications, signaling, video, and remote control in harsh or high-EMI environments.	Valuable where dust, insects, and environmental debris contaminate cabinets and electronics.

indiscriminate direct treatment of optical interfaces. Fiber-optic and electro-optical devices are used where equipment must communicate, sense, monitor, protect, or control in electrically noisy, long-distance, or high-voltage environments, and AI data centers intensify these opportunities because they contain dense optical interconnects, high-speed switching, critical cooling controls, and reliability-sensitive power infrastructure.

Select Optical and Optoelectronic Component Sensitivity to CO_2 Cleaning

Component	Acronym	Purpose	Sensitivity
Small form-factor pluggable transceiver	SFP / SFP+ / QSFP / OSFP	Plug-in optical module converting electrical network signals to and from light carried on fiber.	Extremely high; protect or remove before broader cabinet cleaning.
Fiber patch panel	FPP / ODF	Organizes, terminates, labels, and cross-connects fiber cables.	Extremely high; enclosure cleaning may be appropriate, but connector end faces require dedicated fiber-cleaning practices.
Fiber-optic connector	LC, SC, ST, MPO or MTP	Precision optical connector joining fiber links.	Extremely high; avoid direct generalized spray treatment on open or uncapped connector faces.
Media converter	N/A	Converts copper Ethernet to fiber Ethernet.	High; clean enclosure and surrounding surfaces conservatively.
Industrial Ethernet switch	IES	Hardened network switch often equipped with fiber ports or SFP slots.	High; suitable for surrounding cabinet and vent cleaning if optical interfaces are protected.
Optical encoder	Enc.	Uses light to report position, speed, or motion.	High; protect seals, disks, cables, and feedback connectors.
Photoelectric sensor	PE sensor	Uses light to detect presence, interruption, or object position.	High; excessive jet energy can affect lens condition, alignment, or seals.
Fiber-optic sensor	FOS	Uses fiber to convey light for measurement or detection.	High; protect sensing sections and terminations unless the application is specifically qualified.
Arc-flash optical sensor	AF sensor	Detects arc-flash light and signals rapid protective trip functions.	High; the sensing window can benefit from precision contamination removal but must remain undamaged and correctly positioned.
Optical isolator / optocoupler	Opto	Transfers a signal using light across an electrical isolation barrier.	Usually not directly accessible; the host PCB or module should be treated as a sensitive electronic assembly.
Electro-optic modulator	EOM	Uses an electric field to modulate light in specialized communications or sensing systems.	Extremely high; typically, a supplier-qualified or laboratory-level precision-cleaning application.

AI Data Center Opportunities

AI data centers contain substantial optoelectronic (precision) cleaning opportunities because they concentrate high-speed optical interconnects, dense switching, reliability-sensitive power systems, and advanced cooling infrastructure. The strongest precision CO_2 spray cleaning opportunity is a contained, low-residue, precision maintenance process for removing dust and light contamination from rack-adjacent infrastructure, power systems, cooling controls, cable-management zones, and electronics-adjacent surfaces while protecting optical interfaces.

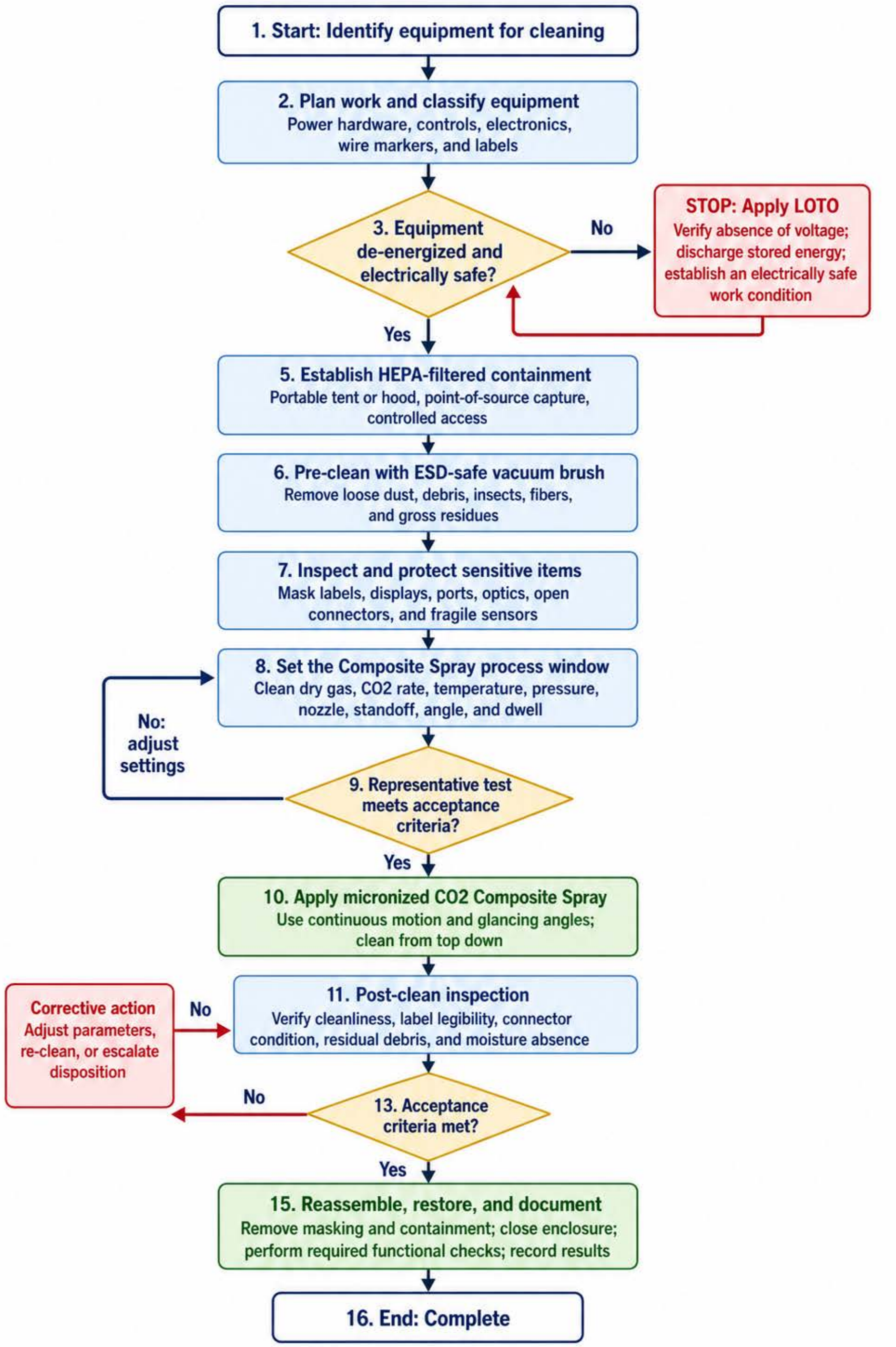
Cleaning Service Constraints

A credible service offering should distinguish between qualified infrastructure cleaning and direct optical-interface cleaning. Enclosures, control cabinets, power equipment, rack exteriors, cooling-control systems, and cable-management hardware are the best initial targets, while open fiber ports, connector end faces, transceiver optics, exposed PCBs, camera lenses, and sensitive optical sensors should normally be protected, removed, or handled under dedicated component-specific procedures. Our smaller CO_2 Composite Spray cleaning applicators (i.e., Micronizer SOLO) combined with lower spray pressures and the use of softer CO_2 particles can provide the precision bandwidth needed for sensitive optical device cleaning.

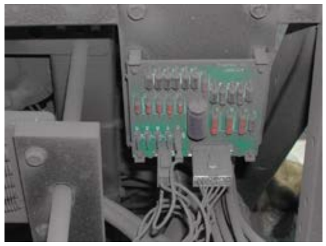
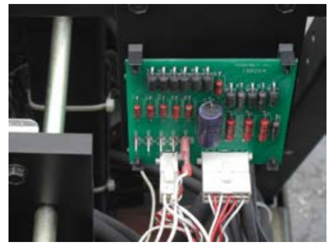
AI Data Center Component Cleaning Constraints

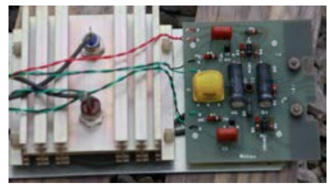
AI Data Center Asset	Optical/Electro-optical Components	Cleaning Opportunity	Important limitation
GPU server racks	High-speed optical transceivers, fiber jumpers, optical network interfaces, indicator and sensor optics	External dust removal from chassis surfaces, cable-management zones, and rack exteriors.	Do not spray directly into live servers, optical ports, or exposed fiber connectors without OEM approval and a validated procedure.
AI fabric switches	Dense SFP, QSFP, QSFP-DD, OSFP, and similar pluggable optical transceivers	Dust control on switch exteriors, port surroundings, and cooling paths during approved outage windows.	Optical ports, fans, and transceiver modules are extremely sensitive and should be protected or removed.
Fiber distribution frames and patch panels	LC, MPO or MTP, and other high-density fiber connectors	Containment and vacuum-brush precleaning of enclosure surfaces and surrounding debris.	Fiber end faces typically require dedicated inspection and connector-cleaning methods rather than a generalized cabinet-cleaning process.
Optical transceiver modules	SFP, QSFP, QSFP-DD, OSFP modules	Clean around installed modules and ports to manage loose dust before maintenance.	Usually protect or remove modules before broader cleaning; direct treatment is a component-specific precision application.
Optical circuit-switch or co-packaged-optics platforms	Optical engines, fiber arrays, micro-optics, photonic integrated circuits	High-value future niche for validated precision cleaning during manufacture, repair, or controlled service.	Not a routine field-cleaning target; direct cleaning needs supplier approval and optical-performance verification.
Liquid-cooling CDUs and control cabinets	PLCs, fiber-connected controls, pressure and flow sensors, HMIs, network gear	Dust and light-film removal from electrical controls, panel surfaces, heatsinks, and accessible cooling paths.	Avoid connectors, displays, open I O, and live circuitry unless specifically qualified.
Power systems	UPS, PDUs, switchgear, monitoring electronics, fiber-connected protection, and communications devices	Strong opportunity for contained de-energized cleaning of enclosure interiors, support zones, controls, and cooling paths.	Electrical safety, stored energy, arc-flash controls, and OEM instructions govern the work.
Environmental and telemetry systems	Cameras, laser or optical sensors, fiber temperature or condition sensing, leak-detection instrumentation	Precision cleaning of housings, windows, and nearby cabinet contamination.	Direct treatment of sensing faces or optical windows should be validated for coating, alignment, and calibration impact.

Example C4 Best Practice
Electrical Equipment and Component Cleaning



Example Results
Electrical Equipment and Component Cleaning




MICRONIZED CO_2 BLAST CLEANING EQUIPMENT

The PowerSno™ Universal Surface Treatment System (PowerSno USTS), shown right, utilizes a patented micronized CO_2 Composite Spray technology, employing dense (adjustable) soft-to-hard microscopic CO_2 particles, produced on-demand, and entrained in an adjustable compressed air stream to sonically pulverize, dissolve, disperse, and blast away particles and residues from electronic and optoelectronic panels and equipment. The unique controllable nature of the PowerSno USTS system enables precision cleaning of complex surfaces, components, and features present in industrial power and control panels without risking damage. This fully portable system can be used in and around mezzanines, assembly lines, and maintenance shops. The PowerSno USTS system can be used for many different cleaning applications ranging from PLC control panel maintenance to welding equipment maintenance and weldment surface preparation.

**PowerSno™
Universal Spray Treatment System
Model PSVP-USTS-RENTAL**

Dense micronized CO_2 particles travelling at near-sonic velocity impact surfaces containing adhering particles and residues – producing thousands of discrete and energetic surface cavitations like ultrasonic cleaning. Quite different from the brute force delivered by CO_2 pellets, hard micronized CO_2 particle cleaning actions possess extremely high surface area and provide both micromechanical and chemical cleaning actions. The microscopic surface impact energy (shear stress) exerted by micronized CO_2 particles is adjustably controlled between 15 and 8,000 psi.

The PowerSno USTS system employs Micronizer™ CO_2 spray cleaning applicators, such as the Micronizer DECA cluster spray gun shown on the right. The DECA cleaning gun features an M-LOK® mounted lighted pistol foregrip and is actuated using a trigger finger switch mounted in a rear handle. (M-LOK is registered trademark of Magpul Industries)

**Micronizer™ DECA
Micronized CO_2 Blast Cleaning Gun
Model VPSA-DECA
(10 SPRAY CLUSTER)**

Portable Plug-and-Spray PowerSno System:

1. PowerSno™ USTS: All-in-one chassis equipped with main power on/off switch, adjustable compressed air regulator and gauge (0-200 psi), and adjustable liquid CO_2 injection pressure regulator and gauge (0-1500 psi).
2. Micronizer™ Blast Cleaning Gun: Barrel or Wide Spray gun with 24 VDC pistol grip finger switch for PowerSno™ spray actuation.
3. Liquid CO_2 Cylinder Supply Connection Kit: CGA 320-cylinder adaptor, hose, and 5-micron pre-filter for a high-pressure CO_2 cylinder (w/siphon tube), and supply hose(s) for one or more PowerSno spray generators.
4. Portability Features: Topside-mounted padded handle and bottom side-mounted full-swivel caster wheels.

SYSTEM REQUIREMENTS

System Power (Electric and Pneumatic)	110VAC 50/60 Hz (24VDC PS), Air, 75-120 psi
CO_2 Supply and Usage	Liquid CO_2, 830-950 psi, 10-25°C, 2-5 lbs/hr/nozzle
Propellant Gas Supply and Usage	CA, CDA or GN_2, 30-200 psi, 3-6 scfm/nozzle
Spray Actuation (Contact Closure)	Local PowerSno Panel, Application Gun Fingerswitch
Maximum Operating Temperature	28˚C (Liquid CO_2 Changes to $scCO_2$ above 31˚C)

Clean Manufacturing, *Reimagined.*

767 Hawthorne Avenue Units A and B
Ponderay, ID 83852 U.S.A.
https://www.cleanimagineering.com
info@cleanimagineering.com
+1 (661) 430-6767